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PUBLICATIONS

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OF THE PACIFIC.

(Founded February 7, 1889.)

VOLUME I.

1889.

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1889.

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Transcriber's notes: the following corrigenda provided in the original volume have been implemented in this text. Other minor corrections are detailed in the source code.

CORRIGENDA.

Page 39; Insert a star (*) to signify life-membership after the following names, viz: Charles Goodall, Horace L. Hill, D. O. Mills.

Page 44; *for* 5 × 7 *read* 4 × 5.

Page 59; Column "Star"; *for* W. H. Z. *read* W. M. Z.

Page 71; *add* to Mr. Boulton's address, (Box 2015, New York City).

Page 71; *for* Centreville *read* Warm Springs.

Page 71; *for* Terry *read* Torrey.

TABLE OF CONTENTS.

Publications No. 1. (February 7, 1889).

List of Officers *pro tem.* 1
Circular 1
List of Members 2
By-Laws 3

Publications No. 2. (March 30, 1889).

The Work of an Astronomical Society. Address by EDWARD S. HOLDEN 7
Minutes of the First Annual Meeting, March 30, 1889 16
List of Corresponding Observatories, Academies of Science, etc. 16
Officers of the Society 17
Notice to Members 18

Publications No. 3. (July 27, 1889).

Plate of the Helical Nebulæ 19
On the Helical Nebulæ. By EDWARD S. HOLDEN 20
On the Orbit of Comet Barnard (1889, June 23). By A. O. LEUSCHNER 25
On the Occultations of Jupiter (visible in 1889) and on the Eclipses of Satellite IV. By CHARLES B. HILL 25
On Photographing the Corona in full Sunshine and on Photographs of the Moon in the Daytime. By JAMES E. KEELER 26
Notices from the Lick Observatory 27
Photographs of the Davidson Comet. By E. S. HOLDEN 27
Spectrum of Davidson's Comet. By JAMES E. KEELER 28
New Double Stars. By S. W. BURNHAM 29
Meridian Circle Observations of Victoria and Comparison Stars. By J. E. SCHAEBERLE 30
New Double Stars. By E. E. BARNARD 30
List of the Articles, etc., contributed to Scientific and other Journals by the Astronomers of the Lick Observatory since June 1, 1888. Compiled by CHARLES B. HILL 31

Minutes of the Meeting of the Board of Directors, held July 27, 1889 35
List of Corresponding Observatories, Academies of Science, etc. 35
Action regarding the Comet Medal 36
Amendment to Article VII of the By-Laws 37
Minutes of the Meeting of the Society, July 27, 1889 38
List of Members 38
Note regarding Professor TACCHINI'S Work on the Solar Eclipses of 1870, 1882, 1883, 1886 and 1887 40
Telegram of Congratulation to Director OTTO V. STRUVE 40
The Comet Medal of the Astronomical Society of the Pacific founded by Hon. JOSEPH A. DONOHOE 40
Rules governing its bestowal 41
Formal Acceptance of the gift of Mr. DONOHOE 41
The Lick Observatory Eclipse Expedition (December 21, 1889), sent at the cost of Hon. C. F. CROCKER 42
List of Officers, etc. 42

Publications No. 4. (September 28, 1889).

On the Photographic Brightness of the Fixed Stars. By J. M. SCHAEBERLE 44
On the Establishment of a Standard Meridian Line for Santa Clara County, California. By J. E. KEELER 55
Table of Azimuths and Elongations of *Polaris* for 1889 and 1890 57
Occultations of Stars by the Moon. Observed by A. O. LEUSCHNER 59
Conjunction of Mars and Saturn (September 20, 1889). By W. E. DOWNS. 60
A very remarkable Comet (BROOKS, July 7, 1889). By E. E. BARNARD 61
Notices from the Lick Observatory 63
Photographing the Milky Way. By E. S. HOLDEN 63
Occultation of Jupiter, 1889, September 3 63
Examination of Stellar Photographs. By E. S. HOLDEN 64
Review of the early numbers of the Publications of the Astronomical Society of the Pacific [by Professor E. SCHOENFELD] 64
Note on the Corona of January 1, 1889 [by Professor P. TACCHINI] 64
Zenographical Fragments [by A. STANLEY WILLIAMS, F. R. A. S.]. Notice by E. S. HOLDEN 65
Accommodation for Visitors to the Observatory 65
American Equatorial Mountings in Berlin 66
Notes on Double Stars. By S. W. BURNHAM 66
Notes on Stellar Spectra. By J. E. KEELER 67
"An Improved Astronomical Mirror" 68
Observations of the near approach of Mars and Saturn, September 19 1889. By E. E. BARNARD 68
The Uses of Trails of Stars in Measurements of Position or of Brightness. By E. S. HOLDEN 69
Minutes of the Meeting of the Board of Directors, September 28, 1889 71
Minutes of the Meeting of the Astronomical Society of the Pacific, September 28, 1889 . 71

List of Members elected 71
Report of the Committee on the Diploma 72
Designs for the Comet Medal by M. Alphée Dubois 72
Expeditions to Observe the Eclipse of December 21, 1889 72
Papers presented 73
List of Officers 73

Publications No. 5. (November 30, 1889).

Observations of Jupiter with a 5-inch Refractor during the years 1879 to 1886. By E. E. Barnard. (Plates I, II, III, IV accompany) 75
Drawings of Jupiter made with the 26-inch Equatorial at Washington during 1875. By E. S. Holden. (Plate V accompanies) 93
Notices from the Lick Observatory 94
On the Determination of the Brightness of Stars by means of Photography. [Containing a Review of Charlier; *Publ. Astr. Gesell.*, No. XIX, 1889.] By Edward S. Holden 94
Variations of the Surface of Mars [from a note by M. C. Flammarion] 100
Stability of the Great Equatorial 101
Mountain Observatories [from the *Opticks* of Sir Isaac Newton] 101
Rainfall at Mount Hamilton 102
Great Telescope for Los Angeles 102
Force of Gravity at Mount Hamilton and San Francisco, as determined by E. D. Preston of the U. S. Coast and Geodetic Survey 103
Lick Observatory Photographs of the Moon 103
American Eclipse Expedition to Africa (December 21, 1889) 103
Eclipse of *Japetus*, the VIII satellite of *Saturn*. By E. E. Barnard 104
Five full-page plates of drawings of *Jupiter* to follow 105
Parabolic Elements of Comet Swift (Nov. 16). By A. O. Leuschner 105
Minutes of the Meeting of the Board of Directors, November 30, 1889 106
Minutes of the Meeting of the Society held in San Francisco, November 30, 1889 106

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 1. San Francisco, California, February 7, 1889.

The Society was organized at a meeting held February 7, 1889, and the distribution of the following Circular was ordered. The list of present members is given on page 2. The following officers *pro tem.* were chosen to serve till the annual election on March 30th, next:

EDWARD S. HOLDEN (Lick Observatory), ... President
J. M. SCHAEBERLE (Lick Observatory), ... Secretary
C. BURCKHALTER (Chabot Observatory, Oakland), ... Secretary
E. J. MOLERA (850 Van Ness Ave., San Francisco), ... Treasurer

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CIRCULAR.

San Francisco, February 7, 1889.

My Dear Sir:—The cordial co-operation of many amateur and professional astronomers in the very successful observations of the Solar Eclipse of January 1, 1889, has again brought forward the desirability of organizing an Astronomical Society of the Pacific, in order that this pleasant and close association may not be lost, either as a scientific or as a social force. You are respectfully invited to become a member of this organization, and to do your part towards making it useful in our community.

The new Society is designed to be popular in the best sense of the word. We wish to count in our membership every person on the Pacific Coast who takes a genuine interest in Astronomy, whether he has made special studies in this direction or not, and we believe that every such person will get, and feel that he gets, a full return from the Society, either from its publications or from its meetings.

You will observe that the seat of the Society (the place of deposit of its library, collections, etc.) is in San Francisco, where rooms can doubtless be found. Half of the meetings of the Society are to be held there (including the annual meeting). The other half are proposed to be held at the Lick Observatory, on certain Saturdays of the summer months when clear weather is to be expected. It will be easy for the members to organize a trip (at excursion rates) from San Francisco to the Lick Observatory, leaving San Francisco at 8:30 a. m., and arriving at the Lick Observatory at 4 p. m. A business meeting can be held before 7 p. m.

At 7 p. m. on Saturdays the telescopes of the Observatory are put at the disposition of all visitors, and thus actual demonstrations from the heavens can be made of subjects of discussion.

It would seem that, in this way, a vivid interest in our science can be created and maintained, and that a Society possessing such exceptional advantages ought to grow and prosper, and be of real weight in the advancement and in the diffusion of knowledge. We should look forward to the establishment of an astronomical journal of high class, to the formation of a special astronomical library, and especially to the organization of such scientific work as requires co-operation and mutual assistance.

Invitations to join the Society have been sent and are hereby extended to each member of the California Academy of Sciences, Technical Society, Microscopical Society, Pacific Coast Amateur Photographic Association, Geographical Society of the Pacific, San Diego Society of Natural History, California Historical Society; to each person who is known to have made observations of the Solar Eclipse of January 1, 1889; to the President and Faculties of the Colleges, Normal and High Schools of California; and to the officers of the Government Surveys in California.

Very faithfully yours,

E. J. Molera,	San Francisco.	Wm. Irelan,	San Francisco.
A. P. Redington,	"	C. Burckhalter,	"
Geo. W. Reed,	"	Ed. Gray,	"
C. L. Goddard,	"	W. C. Gibbs,	"
O. V. Lange,	"	C. P. Grimwood,	Fruitvale,
F. H. McConnell,	"	E. S. Holden,	Lick Observatory,
S. C. Partridge,	"	S. W. Burnham,	"
W. H. Lowden,	"	J. M. Schaeberle,	"
E. W. Runyon,	"	J. E. Keeler,	"
Wm. Boericke,	"	E. E. Barnard,	"
W. A. Dewey,	"	C. B. Hill,	"
F. R. Ziel,	"	J. R. Jarboe,	San Francisco.
Wm. M. Pierson,	"	P. R. Jarboe,	"
Chase Gitchell,	"	John Le Conte,	Berkeley.
George Tasheira,	"	I. Stringham,	"
V. J. A. Rey,	"	F. Soulé,	"
A. J. Treat,	"	T. Guy Phelps,	Belmont.
J. H. Johnson,	"	Arthur Rodgers,	San Francisco.
S. C. Passavant,	"	Wm. Norris,	"
W. B. Tyler,	"	C. Webb Howard,	"

BY-LAWS
OF THE
ASTRONOMICAL SOCIETY OF THE PACIFIC.

(Adopted February 7, 1889.)

ARTICLE I.

This Society shall be styled the ASTRONOMICAL SOCIETY OF THE PACIFIC. Its object shall be to advance the Science of Astronomy, and to diffuse information concerning it.

ARTICLE II.

This Society shall consist of Active, Life, Corresponding and Honorary members.

1. Active members shall consist of persons who shall have been elected to membership, and shall have paid their dues as hereinafter provided.

2. Life members shall consist of persons who shall have been elected to life membership and shall have paid $50 (fifty dollars) to the Treasurer of the Society.

3. Corresponding members shall consist of persons not residing on the Pacific Coast, who shall have been elected by the Society as such.

4. Honorary members shall consist of persons specially distinguished for their attainments in Astronomy, who shall have been elected to honorary membership.

Corresponding and Honorary members shall pay no dues, shall not be eligible to office, and shall have no votes.

ARTICLE III.

At each annual election there shall be elected a Board of eleven Directors, and a Committee on Publication consisting of three members. The officers of this Society shall be a President, three Vice-Presidents, two Secretaries and a Treasurer. The Directors shall organize immediately after their election and elect from their number the officers of the Society. They may also appoint a Librarian, and such other assistants as may be required.

The Library of the Society shall be kept in San Francisco, and shall be open to the use of all the members.

ARTICLE IV.

The President, or, in his absence, one of the three Vice-Presidents, or, in the absence of both the President and the Vice-Presidents, any member whom the Society may appoint shall preside at the meetings of the Society. It shall be the duty of the President to preserve order, to regulate the proceedings of the meetings, and to have a general supervision of the affairs of the Society.

ARTICLE V.

The Secretaries shall keep and have the custody of the records; they shall have the custody of all other property of the Society, excepting the money thereof; they shall give timely notice of the time and place of meetings; they shall keep in books a neat and accurate record of all orders and proceedings of the Society, and properly index them; they shall conduct the correspondence of the Society; they shall preserve and index the originals of all communications addressed to the Society; and keep a copy of all their letters, properly indexed; and they shall prepare for publication an accurate summary of the transactions of the Society at each of its meetings.

ARTICLE VI.

The Treasurer shall receive and deposit in such bank as may be designated by the Directors, to the credit of the Society, all donations and bequests of money and all other sums belonging to the Society. He shall keep an account of all money received and paid by him, and at the annual meeting render a particular statement of the same to the Society. Money shall be paid by him only on the written order of the Finance Committee of the Board of Directors.

ARTICLE VII.

Candidates for membership may be proposed at any meeting, and voted for at any subsequent meeting. The vote shall be by ballot, and a majority of the members present shall be required for an election.

ARTICLE VIII.

Each active member shall pay an annual subscription of five dollars, due on the first of January of each year, in advance. Each active member shall, on his election, pay into the Treasury of this Society the sum of five dollars, which shall be in lieu of the annual subscription to the first of January following his election. No one shall be deemed an active member, or receive a diploma, until he has signed the register of members, or accepted his election to membership in writing, and paid his dues for the current year. Any member may be released from annual dues by the payment of fifty dollars at one time, and placed on the roll of life members by the vote of the Board of Directors. Any failure on the part of a member to pay his dues within six months after the time the same shall have become payable, shall be considered equivalent to a resignation.

ARTICLE IX.

The annual meeting of this Society shall be held on the last Saturday in March at eight o'clock P. M., at the rooms of the Society in San Francisco; and bi-monthly meetings shall be held on the last Saturday of each alternate month, for the ordinary transactions and purposes of the Society, as follows:

The meetings for the months of May, July and September shall be held in the Library of the Lick Observatory, Mount Hamilton, at a suitable hour; and the meetings for January, March and November shall be held in the rooms of the Society, in San Francisco, at eight o'clock P. M.

A special meeting may be called by the President, or, in his absence or disability, by one of the Vice-Presidents; or, in the absence or disability of both the President and the Vice-

Presidents, by the Secretary, on the written requisition of ten active members; and the object of such meeting shall be stated in the notice by which it is called.

The annual election shall be held on the day of the annual meeting, during such hours as the Directors may appoint.

Only active and life members shall be permitted to vote at any meeting of the Society, and no one shall vote who has not paid all his dues for past and current years.

ARTICLE X.

Ten active or life members shall be a quorum for the transaction of business.

ARTICLE XI.

No papers or manuscripts shall be published by the Society without the consent of the Directors. Any motion to print an address, or other paper read before the Society, or any other matter belonging to the Society, shall be referred to the Committee on Publication, who shall report to the Directors. The Committee on Publication may make suggestions to the Directors, from time to time, with reference to the publication of such papers as in their judgment should be published by the Society; and this committee shall have the care, direction and supervision of the publication of all papers which the Directors may authorize to have published.

Members of the Society shall receive all the publications of the Society free of charge.

ARTICLE XII.

This Society may, by a vote of the majority of all its active and life members, become a branch of an American Astronomical Society, should one be formed.

ARTICLE XIII.

It shall be the duty of the Directors, in case any circumstances shall arise likely to endanger the harmony, welfare or good order of the Society, to call a special meeting of the Society; and if, at such meeting, after an examination of the charges, and hearing the accused, who shall have personal notice of such proceedings, it shall be proposed that the offending member or members shall be expelled, a vote by ballot shall be taken, and if two-thirds of the members present vote in favor thereof, the offending member or members shall be expelled.

ARTICLE XIV.

The Directors shall meet one hour before the stated time of each bi-monthly meeting, and at such other times as they may appoint. The President, or in his absence, any one of the Vice-Presidents, may call special meetings of the Board of Directors at any time. Notice of the time and place of such meeting shall be given by the Secretaries, by depositing in the postoffice at San Francisco, a notice of the time and place, addressed to each Director personally, at his last known place of residence, with the postage thereon prepaid, six days before the time of meeting.

ARTICLE XV.

The By-Laws may be amended at any time by a consenting vote of nine members of the Board of Directors at any regular meeting thereof.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

No. 2. San Francisco, California, March 30, 1889.

THE WORK OF AN ASTRONOMICAL SOCIETY.

Address delivered before the Astronomical Society of the Pacific, March 30, 1889, by Edward S. Holden, LL. D., *Director of the Lick Observatory.*

In the year 1820 the state of Astronomy in England was somewhat as follows: The Royal Observatory at Greenwich was pursuing its regular routine observations of the positions of the sun, moon and stars under the direction of the Astronomer Royal, Pond, whose chief service to Astronomy consisted in the minute accuracy of his observations and in the faithfulness with which they were amassed and discussed. His controversy with Brinkley (Astronomer of the Dublin Observatory) on the latter's determination of stellar parallaxes, cleared the way for the great researches of Bessel and Struve on the same subject, which followed a dozen years later. The Radcliffe Observatory at Oxford was in operation, but no observations were published. The Cambridge Observatory was just founded. The Observatory at Edinburgh was barely built, and was not yet a public institution. The Armagh Observatory had no instruments of importance and was doing no work. Groombridge's private observatory at Blackheath was busy with his catalogue of 4243 circumpolar stars. Sir William Herschel, the greatest of practical astronomers and the glory of England (then 82 years old), was resting from his labors. His son, Sir John Herschel, had not yet begun that long series of observations which has made his name illustrious.

On the Continent, the magnificent labors of Bessel, Gauss, Olbers and Struve were laying the foundations of the science of to-day. The spirit of their methods made itself known in England and deeply affected some of the younger men at the universities—notably Babbage, Dean Peacock, and Sir John Herschel. These three entered into a compact, which was most fruitfully carried out, "to leave the world wiser than they found it." One of the most important results of this resolution was the founding of the Royal Astronomical Society of London—an institution which has done incalculable good in fostering the science of Astronomy, not only in England, but throughout the whole civilized world. It is not part of my purpose to trace the influence of this society, nor to show in detail what its work has been. I rather wish to quote here a few paragraphs from the "Address of the Society, Explanatory of their Views and Objects," which was circulated in the year 1820, at the time of its foundation. And I wish to do this for two reasons: because, first, the need of such an association in our own midst is much the same as that felt by Herschel and Babbage in England sixty years ago; and, secondly, because the programme of this society may point out to us along what lines we should proceed to make our own newly formed Astronomical Society equally useful in its own sphere.

The times have changed since then, no doubt. The immediate problems of Astronomy are different; but the spirit of the methods by which they are to be attacked and solved is eternally the same; and the need for co-operation and concentration of forces is more and more pressing as the complexity of processes becomes greater and greater.

I ask you, then, to listen to a few brief extracts from the first printed paper of the Royal Astronomical Society, and to imagine to yourself the state of English Astronomy of that day, when the elder Herschel had finished his work, and when the host of English amateurs of to-day was represented by Groombridge, toiling at the observations and the reductions of his polar catalogue:

> "In a country like Great Britain, in which the sciences in general are diligently cultivated, and *Astronomy* in particular has made extensive progress and attracted a large share of attention, it must seem strange that no society should exist peculiarly devoted to the cultivation of this science; and that Astronomy, the sublimest branch of human knowledge, has remained up to the present time unassisted by that most powerful aid; and has relied for its advancement on the labors of insulated and independent individuals.
>
> "It may be conceived by some that Astronomy stands less in need of assistance of this kind than any other of the sciences; and that, in the state of perfection which its physical theory has already reached, its ulterior progress may safely be intrusted to individual zeal and to the great national establishment exclusively appropriated to celestial observations; or, at all events, to those public institutions and academies in all civilized nations whose object is the general cultivation of the mathematical and physical sciences. It may therefore be necessary to state the useful objects which may be accomplished, and the impediments which may be removed, by the formation of a society devoted solely to the encouragement and promotion of Astronomy.
>
> "Owing to the great perfection which the construction of optical instruments has attained in England, and the taste for scientific research universally prevalent, there have arisen in various parts of the kingdom a number of private and public observatories, in which the celestial phenomena are watched, and registered with assiduity and accuracy, by men whose leisure and talents peculiarly adapt them for such pursuits; while others, with a less splendid establishment, but by the sacrifice of more valuable time, pursue the same end with equal zeal and perseverance. Considerable collections of valuable observations have thus originated; by far the greater part of which, however, owing to the expense and difficulty of publication and various other causes, must inevitably perish, or at least remain buried in obscurity, and be lost to all useful purposes, unless collected and brought together by the establishment of a common center of communication and classification, to which they may respectively be imparted.
>
> "This great desideratum, it is presumed, will be attained by a society founded on the model of other scientific institutions, having for one of its objects the formation of a collection or deposit of manuscript observations, etc., open at all times for inspection, to which the industrious observer may consign the results of his labors, with the certainty of their finding a place, among the material of knowledge so amassed, exactly proportioned to their intrinsic value. At the same time it will thus be rendered practicable to form a connected series from a mass of detached and incomplete fragments; and the society will render a valuable service to science by publishing from time to time from this collection such communications or digests as seem calculated by their nature and accuracy either to supply deficiencies or to afford useful materials to the theoretical astronomer.
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> * * * * * * *
>
> "It is almost unnecessary to enumerate the advantages likely to accrue from the encouragement which an Astronomical Society may hold out; but among others may be mentioned the perfecting of our knowledge of the latitudes and longitudes of places in every region of the globe; the improvement of

the lunar theory, and that of the figure of the earth, by occultations, appulses, and eclipses simultaneously observed in different situations; the advancement of our knowledge of the laws of atmospherical refraction in different climates, by corresponding observations of the fixed stars; the means of determining more correctly the orbits of comets, by observations made in the most distant parts of the world; and, in general, the frequent opportunities, afforded to a society holding extensive correspondence, of amassing materials which (though, separately of small importance) may by their union become not only interesting at the present time, but also valuable as subjects of reference in future.

"By means of corresponding members, or associates, in distant countries, the society may hope to unite the labors of foreign observers with their own; and by thus establishing communication with eminent astronomers and institutions in all parts of the world, to obtain the earliest intelligence of new discoveries and improvements, which it may, perhaps, be desirable to circulate among such of its members as may profess themselves anxious to receive it, without loss of time.

"The circulation also of notices of remarkable celestial phenomena about to happen (with a view to drawing the attention of observers to points which may serve important purposes in the determination of elements or coefficients) may form another, and perhaps not the least interesting object of the society. To have the same phenomena watched for by many observers is the only sure way of having them observed by some; and moreover, the attention of an astronomer may frequently be aroused by a formal notice, especially when accompanied with directions for observing the phenomenon in the most effective way, when probably the mere ordinary mention of it in an ephemeris might fail to attract his observation.

"One of the collateral advantages of a society including many practical astronomers among its members (but which will appear of no small importance to those who possess good instruments) will be the mutual understandings which will be propagated among amateur astronomers, by frequent meetings and discussion, as to the relative merits of their instruments; and as to the talents and ingenuity of the various artists, both of our own and of foreign nations; not to mention the emulation which this must naturally excite to possess the best instruments; and the consequent tendency of such discussion towards a further improvement in their construction, or to the discovery of new ones.

"As the extent of the funds of the society must depend on the number of its members, it is impossible to conjecture at present how far its views respecting their application may extend. Besides the ordinary expenses attending an institution of this nature, the annual or occasional publication of communicated observations; the payment of computers employed in the reduction and arrangement of observations, or in computing the orbits of new planets, comets or other interesting bodies; the formation of an extensive astronomical library, not only of manuscripts, but also of printed books; and perhaps, at some future period, the proposals of prizes for the encouragement of particular departments of the science, either theoretical or practical, or for the improvement of astronomical instruments or tables, may be mentioned as worthy objects on which they may be bestowed.

"Such are the principal considerations which have actuated a number of individuals to form themselves into a society, under the name of the *Astronomical Society of London*, and to give this publicity to their determination, with a view of inviting others to unite in the prosecution of their plans. They have at the very commencement met with the most flattering success, which induces them to hope that, in a short time, every assiduous cultivator of the science will be found to have added his name to the list of members.

"The objects of the original members may be sufficiently gathered from what has been already said, and may be thus summed up in a few words, viz: to encourage and promote their peculiar science by every means in their power, but especially, by collecting, reducing and publishing useful observations and tables, by setting on foot a minute and systematic observation of the heavens, by encouraging a general spirit of inquiry in practical Astronomy, by establishing communications with foreign observers, by circulating notices of all remarkable phenomena about to happen and of discoveries as they arise, by comparing the merits of different artists eminent in the construction of astronomical instruments, by proposing prizes for the improvement of particular departments, and bestowing medals or rewards on successful research in all; and, finally, by acting as far as possible in concert with every institution, both in England and abroad, whose objects have anything in common with their own; but avoiding all interference with the objects and interests of established scientific bodies."

In our own case, we must remember how various are the opportunities and attainments of our different members, and try to lay the foundations of our efforts so broadly that every class will find a sphere of action in our programme, a stimulus in our proceedings, and a support in our friendly association. The few professional astronomers in our midst will here lose that sense of intellectual and professional isolation which is a drawback and a danger. Nothing that is clearly conceived is too technical to be placed before an assemblage of intelligent men, and the very effort to explain gives a lucidity to the original conception which it might otherwise lack. There is a moral force, too, in knowing that one does not need to wait for sympathetic appreciation, but that it is to be found every day and all around one. The opportunity to communicate the results of one's work readily and quickly is of the highest value; and "the end of all observation is communication."

By far the greater number of our members will be amateurs, and here again we must recognize the fact that there are many classes with many differing opportunities and means for work and study. Some among us already possess telescopes of no inconsiderable power. In 1820, there was no refractor in Europe more powerful than the 5-inch telescope with which HERSCHEL and SOUTH observed their double stars. It should be the aim of the society to point out the directions in which such instruments can be used, so that either some useful result will be attained for the science, or so that, at least, the maximum amount of pleasure and personal profit can be had by the owners. I presume there are few amateurs who have not experienced a sense of disappointment in the use of their telescopes. It is not that the heavens are less glorious, nor that the observer is less devoted and enthusiastic, but it is because he often comes to feel that there is an aimlessness in his work which he finds to be disheartening. If at this moment some word or hint can be given to him which will show him how to employ his time and energies to some real advantage, either to science or to himself, the old enthusiasm will return and the labor will again become delightful. It is precisely such words and such hints that he may expect to find here among his colleagues.

There is an important class of our amateur members whose photographic experience and skill can bear the most useful fruits if they are directed toward certain astronomical ends. We also have professional astronomers among us, whose photographic knowledge is second to none. The association which this society makes easy and puts into an organized form, has already led to important results in the observations of the Solar Eclipse of last January by photographic means, and will, no doubt, continue to be fruitful. There are many other fields of research open to this method of observation. We have other members, also, who have no apparatus for observation, but who have the ability, the leisure and the desire to forward Astronomy by computing the observations of others. There is a boundless field for such amateurs, and I am not sure that their efforts, if rightly directed, might not be of more real importance than any others. The Lick Observatory alone could provide the observations to keep a score of computers busy, and this work could be so selected as to be of all grades of difficulty and to employ every variety of talent.

Finally, we have among us those who have joined as learners; who are here to listen, to observe, to read and to study. They, in turn, should find in our meetings what they seek for and require. Their reading and their study can be guided, and it is among them that we may look for our workers after the next few years. Every class of talent and opportunity ought to find its profit either in our meetings or in our publications.

One word with regard to the conduct of our meetings. My own experience in scientific societies has led me to think that their meetings should never consist of mere lectures, no matter how interesting. There should be discussion, questions, remarks, interchange of ideas, contact of active minds. Let each member feel that he has a part to bear, both in the actual meetings and outside of them, among his associates. In one word, let our society be a live one—active, intelligent, modest, competent. It has a doubled interest in its two-fold place of meeting. The astronomers of the Lick Observatory can promise that the meetings held at Mount Hamilton shall be interesting and fruitful. The meetings held in San Francisco will also be full of interest.

One of the chief uses of the society will be to make an astronomical library available to the amateur observer. We have already made a beginning in this direction. It is not necessary that our collection should be very extensive. A complete astronomical library would contain, perhaps, 20,000 volumes. But it is desirable that we should own a full set of the most important astronomical journals. The progress of the science can be traced in their pages from day to day, and their past volumes give its history.

I have thought it worth while to give in a list which follows the titles of the more important astronomical periodicals, and I have ventured to add the names of some twenty or thirty books which our members would do well to own personally. It is not necessary to buy all of them at once, but the possession of one will lead to the desire for another, as the scope of observation or of reading is enlarged. The society library should begin by owning these volumes. It will grow subsequently as our wants develop, both by purchase and by exchange with other scientific institutions:

Astronomical Journals.

Astronomische Nachrichten (established 1821); 2 vols. a year. Kiel; price, $8.00.
Astronomical Journal (established 1851). Cambridge, Mass.; $5.00.
Bulletin Astronomique (established 1884). Paris; $4.75.
L'Astronomie (established 1882). Paris; about $3.75.
The Observatory (established 1877). London; $3.50.
Ciel et Terre (established 1880). Brussels; $2.60.
Himmel und Erde (established 1888). Berlin; $5.00.
Sirius (established 1868). Leipzig; $2.60.
Wochenschrift für Astronomie (established 1847). Halle; $2.70.
The Sidereal Messenger (established 1882). Northfield, Minn.; $2.00.
Nature. London; $6.00.
La Nature. Paris; $6.00.
The Companion to the Observatory. London; published annually; 1s. 6d. [This latter work will take the place to the amateur observer which the *Nautical Almanac* holds to the professional.]

Publications of Astronomical Societies.

Publicationen der Astronomischen Gesellschaft. Leipzig; 4to (at irregular intervals).
Vierteljahrsschrift der Ast. Gesell. Leipzig; quarterly.

Memoirs and Monthly Notices of the Royal Astronomical Society. London; yearly and monthly.
Journal of the Liverpool Astronomical Society. Liverpool; monthly.
Bulletin de la Société Astronomique de France. Paris; yearly (?).
Publications of the Astronomical Society of the Pacific. San Francisco.

List of Some Books of Reference in Astronomy.

Houzeau: Vade Mecum de l'Astronome; 8vo.
Wolf: Geschichte der Astronomie; 8vo.
Delaunay: Cours Elémentaire de l'Astronomie; 12mo.
Loomis: Treatise on Astronomy; 8vo.
Chauvenet: Spherical and Practical Astronomy; 8vo; 2 vols.
Ball: Elements of Astronomy; 12mo.
Young: General Astronomy; 8vo.
Herschel: Outlines of Astronomy; 8vo.
Arago: Astronomie Populaire; 8vo; 4 vols.
Flammarion: Astronomie Populaire; 8vo.
Newcomb: Popular Astronomy; 8vo.
Webb: Celestial Objects for Common Telescopes; 12mo.
Oliver: Astronomy for Amateurs; 12mo.
Proctor: The Sun; 8vo.
Proctor: The Moon; 8vo.
Proctor: Saturn and His System; 8vo.
Ledger: The Sun, Its Planets and Their Satellites; 8vo.
Watson: A Popular Treatise on Comets, etc.; 12mo.
Smyth: Celestial Cycle; 2d ed.; revised by Chambers, 8vo.
Klein: Star-Atlas (translation by McClure.)
Gledhill: Handbook of Double Stars; 8vo.
Chambers: Descriptive Astronomy; 8vo.
Grant: History of Physical Astronomy; 8vo.
Clerke: History of Astronomy in the XIX Century; 2d ed.; 8vo.
Delambre: Histoire de l'Astronomie; 4to; 6 vols.

If our own publications are valuable and worthy, they will bring to us through exchanges many works of permanent value. This brings me naturally to the question of what and how much we ought to publish. On this I shall give my own opinion freely, from my personal point of view. It may easily be that my ideas on this question, which are rather positive, require correction. If they do, the experience of the society will be sure to show it.

It seems to me, then, that we should be extremely careful to make our publications fully worthy of the society. Any observation faithfully made and properly recorded well deserves a permanent place. Our very constitution, as a society of amateurs, will usually prevent us from presenting these long series of observations which can be amassed by professional observers in fixed observatories. But we should be careful not to make our publications a vehicle for the expression of mere unsupported opinion. A theory should always be accompanied by its vouchers. I would give more for one careful measure of a double-star, for one faithful observation of a comet, than for pages of speculation regarding the origin of the solar system. Such speculations have their place in science, no doubt, but to be valuable they must follow after years of work. We should make our papers a record of actual work accomplished. There is room, too, for *résumés* of the work of other observers and for papers relating to the best methods of making our own observations. Important papers in other periodicals may well be translated and printed here. The pages of our journal should be truly representative of the work and thought of the society in general. It would be easy for the Lick Observatory staff to contribute enough material to completely fill such a journal; but it appears to me that, in general, the work of our observatory should appear in abstract only, and that the observations and communications from the amateur members of the society should always constitute the greater part of the publication. At the same time the observatory can serve a very useful end by furnishing a series of abstracts of work done and in progress and by printing notes on work proposed, especially if it is such that our members can co-operate in it. It will be a source of pride to us, if after many years we can look back over what has been printed by the society, and see that every part of it is the record of useful work faithfully done, and possesses a permanent value.

It is for this reason that it seems to me we should not attempt to print at any regular intervals, as monthly or quarterly. Let us keep our papers until we have enough material to form a number of 8, 16, 24 pages, and then issue and distribute this to our members and to our correspondents.

It is tolerably certain that the time has not yet come for us to perform another function of an astronomical society. I refer to the foundation and to the bestowal of the medal of the society as a reward for astronomical work of the highest class. It is certain, however, that in the future, if such a medal were founded, and if it were bestowed only for work of the highest class, as I have said, and never, under any circumstances, to one of our own members, that the responsibility of the award would constitute an important stimulus to the society itself, which would have to judge of the merits of the various works proposed to be rewarded; and that such awards, if always bestowed with judgment and discretion, would soon make the voice of our society respected everywhere. In fact, there is probably no way in which the society could do more good, and in which it could be more quickly influential, than by the bestowal of its medal upon those astronomers whose works fully deserve it. And there is probably no way in which a mistake of judgment would so quickly discredit us, as in the bestowal of our highest award upon insufficient scientific grounds, or for personal reasons.

It is probably quite time that I should leave these general considerations and come to the more special questions of the work which our members may reasonably expect to do. In any particular case this depends very largely upon the time available for such occupation, upon the instrumental equipment at hand, and upon the individual aptitude and ability. I have already said that for those of us who are willing to calculate the observations made by others, there is an endless variety of work to do, of all grades of importance and difficulty. For those who have only the leisure to interest and divert themselves with observing, there is a rational and useful method to follow, instead of a random one, which will inevitably lead to disappointment. For those who are willing to spend a very little time and money, there are many fields, both old and new, needing cultivation. Let me mention a few of these fields—speaking very briefly of each one:

A very cheap telescope will serve to photograph the sun, provided it be of tolerably long focus. It is highly desirable to obtain enlarged pictures of the solar spots, and to repeat in this country the solar photographs of Janssen, which are taken with extremely short exposures—say, from one one-thousandth to one two-thousandth of a second of time. A series of careful counts of the number of new groups and new spots can be made with a very small telescope, and will be very useful. If any one of the society will charge himself with the necessary measurements, we, at Mt. Hamilton, will undertake to furnish daily photographs of the Sun on a scale of $4\frac{1}{2}$ inches to the solar diameter for the purpose.

I believe that much can be done by studying the moon's surface with comparatively small telescopes. In such studies I think it desirable to confine the attention to very limited areas, and to study and draw these over and over again, under every possible variety of illumination, until the telescope and the observer can do no more. In this way it may be that only small areas will be covered, but it is certain that our knowledge can be materially increased. The observation of the occultations of stars is most useful, provided the position of the observing station and the local time are accurately known. The Lick Observatory time-signals can be readily made available for this purpose. Probably little can be added to our knowledge of the surface features of the planets by observations with the smaller telescopes. It is, however, well worth the labor for several of our members to maintain a series of observations of the eclipses of the satellites of *Jupiter*. There is nowhere in America, I believe, such a series maintained. The results of this work will be directly comparable with the observations on which the present tables are founded, and constants of reduction can be determined by which these observations can be employed in conjunction with long series already obtained elsewhere. In this case, as in so many others, our great distance in longitude from the centers of observation, will give to our work a peculiar value. We are eight hours west of Greenwich and three hours west of Washington, and there is no astronomical establishment between us and Japan, and no active observatory between California and Australia. There is a whole field of photometric work (both visual and photographic) which is open to amateurs, and which needs cultivation. I refer especially to the photometry of different portions of the sky under illumination by the sun or by the moon.

Photographs of the planets and neighboring stars of about the same brilliancy on the same plate may very likely be of use in comparing their relative brightness. Should a bright comet appear, no chance should be lost to photograph it, to study the changes in its head, and to map the position of its tail among the stars.

The observations of Gothard, on nebulæ, by means of long-exposure photographs have proved that even comparatively small telescopes (provided with driving clocks), properly used, are capable of giving the most brilliant and important results. It is at least possible that the Zodiacal Light, the Milky Way, the Twilight Arch, the Aurora, can be photographed. I know of no direction where the skill of amateur photographers could be better spent than in experiments upon these subjects. The problem is of the same nature as the photography of the faint outlying streamers of the Solar Corona, in which our California amateurs have been so successful.

The field in which amateurs can render the greatest service, however, is in the observation of the variable stars. If these are to be observed by the eye, the use of a mere opera-glass or of a very small telescope is usually sufficient to fix the time of maximum or minimum light with accuracy, by comparisons with neighboring stars which do not vary. Professor Pickering has already presented to the Society a set of printed instructions for making such observations. If the observer has a photographic telescope or camera, the most elegant and accurate method might be to allow the star's image to *trail* over the plate. When the trail is weakest the Star has reached its minimum. A scale of time can be put upon the plate by capping or uncapping the lens at known instants. If the star is too faint to trail on the plate while the latter remains at rest, a very simple clock-work motion can be devised which will cause the telescope to follow the star towards the west at a slow rate. This rate can be so chosen by experiment as to make the *trail* of suitable brightness for measurement.

There are scores of other researches of interest and importance which I have not time to mention and which are well within the reach of amateurs. One competent sextant observer, acting in concert with the Lick Observatory, could render a real service to the geography of the State, with very little expenditure of time and money, by determining the latitudes and longitudes of important points. If such an observer were to fix the positions of the eclipse stations occupied by the various parties on the 1st of last January, he could thus make a positive contribution to science. Mr. Keeler, of the Lick Observatory, has just completed a determination of the position of Norman, for this purpose, as a beginning.

I believe the radiant points of the brighter and more slowly moving meteors can be accurately fixed by photography, and at any rate the experiment is worth a trial. Statistics of the number of telescopic meteors in different parts of the sky and at different hours are very much needed and are extremely easy to obtain.

I have thus hastily gone over the principal lines along which we, as a society, may hope to work with success. If we undertake all or any of the work thus indicated, and if we carry it on with faithfulness and industry, we may be sure that our efforts will be a veritable aid to science. Whatever we do, let us do thoroughly. Whatever we say, let it be well considered. Let us clearly understand the objects for which we are organized, and let us pursue these with entire confidence. The scope and membership of this society are such that it can have no antagonisms and rivalries with any other. But we may look forward to a career of real usefulness, not only to our members, but to the science of Astronomy. In our own time and way we may hope to make advances in this path, and we may be sure that we can diffuse information in its regard, and help to increase the intelligence, the activity and the pleasure of all our members.

Edward S. Holden.

Lick Observatory, February 15, 1889.

Extract from the Minutes of the Annual Meeting of the Astronomical Society of the Pacific, held at 8 p. m., March 30, 1889, at 605 Merchant Street, San Francisco.

(Prepared by the Secretaries for publication.)

The minutes of the meeting of February 7, 1889, were read and approved.

The following named persons (proposed February 7th) were elected to membership: Messrs. William Alvord, J. M. Selfridge, A. O. Leuschner, William F. Herrick, E. M. Bixby, H. T. Compton, C. F. Montealegre, W. Letts Oliver, E. B. Jordan, James G. Jones, Eugene Frost, C. Mitchell Grant, J. T. Wallace, T. P. Andrews, and Miss Rosa O'Halloran.

A Board of eleven Directors and a Publication Committee of three members were elected.

An address on "The Work of an Astronomical Society" was read by Mr. Holden. This is printed in the present number. A paper on "The Solar Corona," by Mr. Pierson, was received and its reading postponed to the next meeting.

After hearing the reports of the officers *pro tem.*, the Society adjourned to meet at Mount Hamilton, May 25th.

The following resolution was adopted:

Resolved. That the Publications of the Astronomical Society of the Pacific be regularly sent to the following Observatories, etc., and that the Secretaries of the Society be instructed to notify them of this resolution, and to request that they exchange their publications with our own; and that the list of these Corresponding Societies and Observatories be printed in the Publications of the Astronomical Society of the Pacific:

1. Dudley Observatory, Albany, New York.
2. Detroit Observatory, Ann Arbor, Michigan.
3. Royal Observatory, Berlin, Germany.
4. University Observatory, Bonn, Germany.
5. Royal Observatory, Brussels, Belgium.
6. University Observatory, Cambridge, England.
7. Harvard College Observatory, Cambridge, Massachusetts.
8. Royal Observatory, Capetown, Africa.
9. University Observatory, Cincinnati, Ohio.
10. University Observatory, Dorpat, Russia.
11. Royal Observatory, Greenwich, England.
12. Ducal Observatory, Karlsrühe, Germany.
13. University Observatory, Kasan, Russia.
14. University Observatory, Koenigsberg, Prussia.
15. Royal Observatory, Kopenhagen, Denmark.
16. University Observatory, Leiden, Holland.
17. University Observatory, Leipzig, Germany.
18. Royal Observatory, Milan, Italy.
19. Observatory, Melbourne, Australia.
20. University Observatory, Moscow, Russia.
21. Lick Observatory, Mount Hamilton, California.
22. Royal Observatory, Munich, Germany.
23. Carleton College Observatory, Northfield, Minnesota.
24. Radcliffe Observatory, Oxford, England.
25. Savilian Observatory, Oxford, England.

26. National Observatory, Paris, France.
27. Astrophysikalishes Institut, Potsdam, Germany.
28. Imperial Observatory, Pulkowa, Russia.
29. Observatory of the Roman College, Rome, Italy.
30. University Observatory, Stockholm, Sweden.
31. University Observatory, Strassburg, Germany.
32. McCormick Observatory, University of Virginia, Virginia.
33. Naval Observatory, Washington, District of Columbia.
34. Imperial Observatory, Vienna, Austro-Hungary.
35. Royal Astronomical Society, London, England.
36. Liverpool Astronomical Society, Liverpool, England.
37. Astronomical Society of France, Paris, France.
38. Astronomical Society, Chicago, Illinois.
39. Astronomical Society of Germany, Leipzig, Germany.
40. Gesellschaft Urania, Berlin, Germany.
41. National Academy of Sciences, Washington, District of Columbia.
42. Smithsonian Institution, Washington, District of Columbia.
43. California Academy of Sciences, San Francisco, California.
44. Bureau des Longitudes, Paris, France.
45. The Nautical Almanac, London, England.
46. The American Ephemeris, Washington, District of Columbia.
47. Berliner Jahrbuch, Berlin, Germany.

At a meeting of the Board of Directors held immediately after the meeting of the Society, the officers of the Society for the ensuing year were elected. (For list of officers see below.) Mr. William Alvord was elected to life membership. The Secretaries were instructed to correspond with the members of the Society, with a view to ascertain what instruments were in their possession, etc.

OFFICERS OF THE SOCIETY.

EDWARD S. HOLDEN (Lick Observatory),	President
WM. M. PIERSON (76 Nevada Block, S. F.), W. H. LOWDEN (213 Sansome Street, S. F.) FRANK SOULÉ (Students' Observatory, Berkeley),	Vice-Presidents
CHAS. BURCKHALTER (Chabot Observatory, Oakland), J. M. SCHAEBERLE (Lick Observatory),	Secretaries
E. J. MOLERA (850 Van Ness Avenue, S. F.),	Treasurer

Finance Committee—W. C. Gibbs, Wm. M. Pierson, E. J. Molera.

Board of Directors—Messrs. Alvord, Boericke, Burckhalter, Gibbs, Grant, Holden, Lowden, Molera, Pierson, Schaeberle, Soulé.

Committee on Publication—Messrs. Dewey, Treat, Ziel.

NOTICE.

Members are requested to preserve the copies of the *Publications* of the Society as sent to them. At certain intervals a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with Mr. Burckhalter without delay, in order that arrangements may be made for transportation, lodging, etc.

Plate I

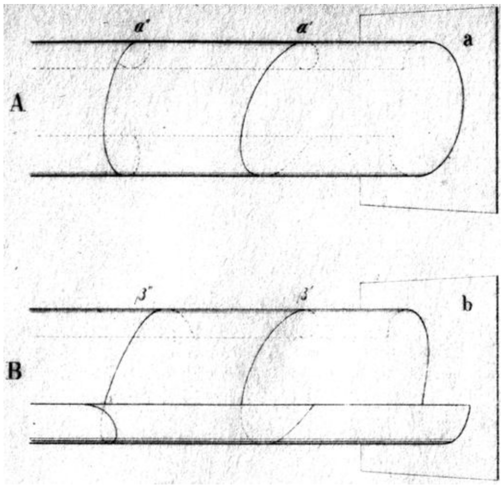

Fig. 1.

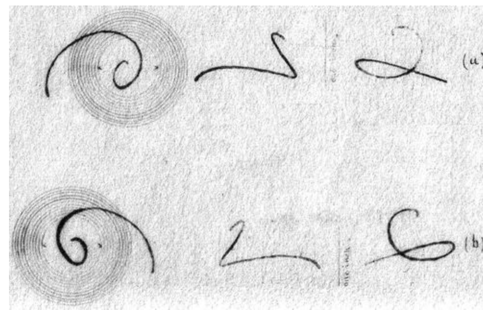

Fig. 2. The Type-Helix,
(a) direct; (b) reversed.

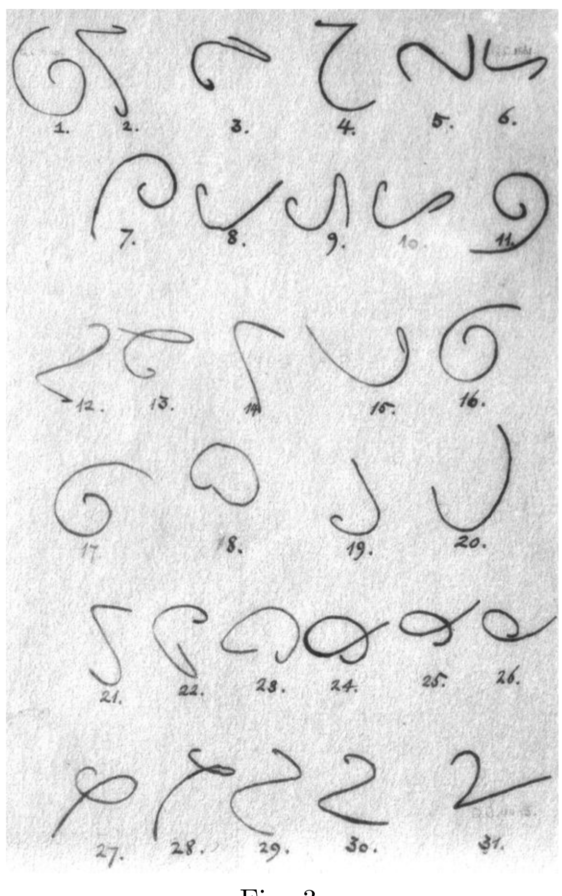

Fig. 3.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 3. San Francisco, California, July 27, 1889.

ON THE HELICAL NEBULÆ.

By Edward S. Holden.

The discovery of the helical appearance of the planetary nebula H. iv. 37 (G. C. 4373) at this Observatory in 1888[1] naturally led to the search for a method which might enable one, in some cases at least, to determine the actual situation of the different branches of a nebula in space of three dimensions from the data afforded by the projection of these branches upon the background of the sky. In general, this problem is hopelessly insoluble by our present means.

I have, however, obtained some interesting results for one class of nebulæ at least, and perhaps the method employed is capable of wider application.

To understand the method, let us consider how it is that we see a nebula (Plate I, Figure 1). The only data that we have are the outlines a of a drawing of the nebula as it is seen projected against the sky. We must conceive the curve a to be the base of a cylinder, A, whose elements are straight lines (rays of light) extending from the projection a to the eye at A. If the curve a is complicated and involved, so will also be the surface of the cylinder A. Any curve whatever which is drawn on the surface of the cylinder (as α', α'',) will be projected into the same curve a on the sky; so that the real nebula in space may be any one of the infinite number of curves which can be drawn on the surface of this particular cylinder; for any such curve will be projected into the curve a. This is true for any and every nebula, as β, b; γ, c; δ, d, etc., etc. The only thing we really know about the form of a nebula, in general, is that it is projected into a certain shape, as a, or b, or c, or d. The problem is to find the true curves, α, β, γ, δ, in space, knowing only the projected curves a, b, c, d.

In order to fix the ideas, let us think of the elongated strings of nebulosity which form the spiral nebulæ.

Before going further, it is necessary to remark that the data (the curves a, b, c, d) are at present to be obtained only from drawings, and hence they are affected by various classes of errors, due to imperfect telescopic, visual and artistic powers. Photographs of nebulæ are subject to a different and less hurtful class of errors, and they are free from personality. When the great telescope is again in a position to photograph the nebulæ, I shall hope to resume this research with better data. For the present I shall take the drawings of Lord Rosse, of Lassell, and others, as the best available, and shall not concern myself with any errors remaining in them, but shall treat them as correct, since they are the best we have.

[1] *See Monthly Notices* R. A. S. vol. 48, p. 388.

To resume consideration of the special problem in hand, let us again examine Figure 1. The only thing we know about the nebula in space is that its projection on the sky is a. Any curve on the cylinder A *may be* the true shape of the nebula itself. It is the same for another nebula, b, whose curve b is usually different from that of a. *Any* curve on the surface of B will be projected into b. In general, the shapes of the two cylinders are so utterly different that no two identical curves, α', β', can be drawn on their surfaces.

Now, if we should find a pair of curves, a, b, whose cylinders, A, B, are of such a shape that the same curve *can* be drawn on their surfaces, then there is a certain probability that this identical curve is, in fact, the true shape of each nebula in space. If, again, we can find another nebula, c, whose cylinder, C, is so similar to that of a that like curves can be drawn on the three surfaces, A, B, C, then there is a still greater probability that the identical curve on the three surfaces, A, B, C, is, in fact, the true shape of these three nebulæ, a, b, c, in space. If we find another nebula, d, whose cylinder, D, is of such a shape that we can also draw the same curve on *its* surface, there is a much higher probability that this one curve really represents the true shape of all four nebulæ, a, b, c, d, in space.

As we get more and more examples, all fulfilling the same condition, the probability that we have obtained the true shape of the nebulous form in space is very rapidly increased; and by finding enough examples we may increase the probability to essential certainty; and still more so, if one curve, and only one, can be found which is common to all the projecting cylinders.

We may attack this problem practically, by seeking through trails for a single curve, Φ, which by projection at various angles and in various positions will give all the differing curves, a, b, c, d, e, $\dots z$. If such a curve can be found (by trial), and if only one such curve can be found, it will become more and more probable that Φ is, in fact, the true curve of each nebula, α, β, γ, δ, $\dots\omega$, in proportion as more and more curves, a, b, c, d,$\dots$ accurately correspond to the different projections of this type curve, Φ. The idea of such types has been suggested to me by observations of nebulæ with the great telescope, and I have partially discussed it in *Himmel und Erde*, for June, 1889, page 503 *et seq.*

I proceed to give what seems to be the type curve of a certain family of spiral nebulæ. The accompanying Figure 2 shows several representations of a helix of wire, which I have found by trial to be capable of being projected into the shape of each one of the following nebulæ. Figure 2 also gives a scale photographed at the same time as the wire model. The diameter of the smallest circle of the scale is one inch, and the circles are successively $\frac{1}{10}$ of an inch greater in diameter. One inch is also marked near each of the vertical projections.

I give in Figure 3 a selection from projections of the type-helix of Figure 2, which were made by placing the wire model in a beam of parallel rays and tracing its shadow on a plane. Most of the comparisons of drawings of nebulæ with the type-helix have been made by placing the eye vertically over the plane of the paper and by moving the wire helix (its origin nearly always touching the paper in the nucleus of the nebula) until the projection of the helix accurately covered the drawing of the nebula. Usually the model must be applied n different times for a nebula with n branches. I have found no case in which this helix will fit one branch of a nebula without fitting every other branch also.

I give in what follows a few comparisons of this type-helix with drawings of nebulæ, and I begin with the admirable series of drawings given by Mr. Lassell in *Mem.* R. A. S., vol. 36:

Lassell's Figure	G. C. No.	Remarks.
2	600	The outlines of this nebula have been exactly reproduced (in our Fig. 3, No. 1). [The axis of the type-helix is in position angle 280°, and altitude above paper 70° to 75°.]
3	604	Ditto (when Lassell's figure is reversed).
9	1511	Ditto. (Compare our Fig. 3, No. 3.)
12 (a)	1861	Ditto (in our Fig. 3, No. 6); (b) compare the last drawing of Fig. 2. The nucleus of the nebula is probably due to a crossing of two loops of the helix.
12 (b)	1861	The outlines can be reproduced. (Compare our Fig. 3, Nos. 13, 24, 25.)
15	2373	The loop and the following edge of Lassell's drawing can be exactly reproduced. (Compare our Fig. 3, Nos. 15, 19.)
16	2838	The axis of the main curve of the drawing has been exactly reproduced. (Compare our Fig. 3, No. 20.)
17	2890	Both these figures have been accurately reproduced. Each branch is a projection of the type-helix. (Compare our Fig. 3, Nos. 11, 16, 17.) Inner spiral, position angle 120°, altitude of axis 80° to 85°; outer spiral, position angle 120°, altitude 80°. If we match the inner spiral and then revolve the type-helix, keeping its axis in the same plane, about 90° in the direction S W N E the outer spiral will be matched.
27	3572 M 15	All the principal branches have been accurately reproduced, one application of the type-helix for each branch. (Compare our Fig. 3, Nos. 1, 7, 11, 16, 17.) Inner spiral, P = 150°, Alt. = 85° to 90°; outer spiral, P = 150°, Alt. = about 80°. Revolve type-helix nearly 180° from the position where it matches the outer spiral in the direction N W S E, and it will match the inner spiral.
28	3606	When this drawing is reversed the three branches can be exactly reproduced by three applications of the type-helix. (Compare our Fig. 3, Nos. 8, 14, 15, 19, 20.) Is the nucleus due to the crossing of two branches of the helix?
29	3614	When this is reversed its two branches can be reproduced by two applications of the type. (Compare our Fig. 3, Nos. 5, 6, etc.)
33	4403	(The Omega nebula.) The axes of the loop and of the straight following part can be exactly reproduced. (Compare our Fig. 3, No. 31.)

N. B.—Note that the position angle of the axis of the type-helix is the same for both spirals of G. C. 2890; and for both spirals of G. C. 3572.

Comparisons with Lord Rosse's Drawings in the Philosophical Transactions, 1861.

Fig.	G. C.	Remarks.
9	888	*h.* 327. (Compare our No. 1. etc.)
10	532	*h.* 131. This can be accurately reproduced when it is reversed and its scale changed suitably.
13	2053	*h.* 689. Ditto.
15	2216–17	*h.* 765–6. (Compare our Nos. 2, 3, 4, 12, 13, 28, 31.)
16	2377	*h.* 857. (Compare our Nos. 1, 7, 11, 16, 17, etc.)
18	2670–1	*h.* 1052–3. (Compare our Nos. 2, 3, 12, etc.)
19	2680	*h.* 1061. Can be reproduced.
21	2870	*h.* 1196. (Compare our Nos. 3, 9 (reversed), 12, 29, 30, etc.)
23	3341–2	*h.* 1306–8. (Compare our Nos. 5, 6, 21, etc., and 11, etc.)
24	3085	*h.* 1337. (Compare Nos. 2, 14, twice applied.)
25	3151	*h.* 1385. (Compare our Nos. 23, 24; and notice the opening on the lower side of the figure (as in Fig. 23) and the brightening of the nebula just above this (as in Fig. 23) where the right-hand hook bends back.)
26	3189–90	*h.* 1414–15. (Compare our Nos. 5, 6, 21, 29, 30.)
28	3511	*h.* 1589. (Compare our Nos. 5, 6, etc.)
29	3615	*h.* 1650. (Compare our No. 11, reversed.)
32	4160	*h.* 1946. (Compare our No. 1, etc.)
36	4594	*h.* 2084. If this drawing be reversed, each of the four branches can be accurately represented by projections of the type-helix. I have made a wire model of this nebula.*
41	4971	*h.* 2245. (Compare our No. 1, etc., reversed.)

* Before the present investigation was begun I succeeded in making a model of this nebula of four branches, starting on the assumption that each of the four branches was produced by the projection (at four different angles) of one and the same curve in space. I finally succeeded in bending a wire so that when it was held in four different positions (the origin of the helix always touching the nucleus), the four projections accurately covered the four branches as they are laid down in the drawing. I then laid this model to one side and constructed a type curve from the nebulæ G. C. 600, the great Nebula G. C. 3572 (M. 51) and others. This second type curve was then applied (reversed) to the nebula 4594, and it was found to accurately represent it, and to be the same curve as the one first constructed. Probably in this case, as in others, the conviction that the real type of the nebula has been discovered is more strongly brought home to the person who has actually constructed the models and found them to exactly represent the pictures, than to one who merely reads an account of how the experiment was conducted. The only ambiguity in my model of this nebula is due to the fact that it is impossible to decide on which side of the plane of projection any or all of the branches are situated. We know the real shape of each branch, but we do not know whether it lies on the hither or on the farther side of the plane of projection.

Comparison with Lord Rosse's Drawings in the Scientific Transactions Royal Dublin Society, Vol. II.

Plates.	G. C.	Remarks.
I.	1202	(Compare our Figs. 24, 25)??
I.	1267	(Compare our Figs. 14, 15, 19, etc., reversed.)
I.	1519	This can be accurately reproduced.
II.	1520	Ditto.
III.	1861–3	The principal curves in these nebulæ, ditto.
IV.	3572	Ditto.
V.	4561	(Compare our Figs. 9, 10, the middle parts only.)
VI.	4403	The axes of this can be accurately reproduced. (See our Fig. 31.)

It is unnecessary to give more examples. Indeed, the cases already given include nearly all the spiral nebulæ. Those just referred to are sufficient to exhibit the whole evidence to any one who will construct for himself a type curve from the data in Figure 2, and who will go over the comparisons with the plates as above outlined. The spirals of *Nebula Orionis* are probably of the type just given, also. The case of the *Omega* nebula (G. C. 4403) is very striking. I have also found remarkable analogies in various spiral streams of stars.

It may be objected to the suggestions given above that the forms of the nebulæ are so indefinite that a very great latitude is allowed in matching the drawings with the projections of any particular type curve. This is undoubtedly true. The only remedy for it is to obtain better representations of the nebulæ themselves by photographic means.

A second objection is that Figure 3 shows that a particular spiral, once assumed, may be projected into many forms, and that these might be sufficiently varied to be fitted to a comparatively small number of objects out of the many thousands of known nebulæ. To this it may be said that it is undoubtedly true that the projection of many different curves can be made to fit a certain number of the drawings referred to. Still, it appears to me, after trials, that the helix of Figure 2 comes nearer to being the type curve of the nebulæ in question than any other that I can now construct. It certainly will need to be corrected, but it seems to be a good first approximation. The difficulty of improving it can be best appreciated by making the trial.

Again, it must be remembered that while there are many thousands of nebulæ, there are only comparatively few spiral nebulæ, and that the type curve fits a very great percentage of these, while it cannot be tortured into a resemblance to other nebulæ not spiral.

If the helix given in Figure 2 is indeed the type of a certain class of nebulæ, many interesting questions may receive a solution. For example, what are the directions in space of the *axes* of these different nebulæ? Is there anything systematic in these directions? What is the law of the force by which particles of matter are expelled from (or attracted to?) the central nucleus? Have we here in the nebulæ different types of spirals somewhat analogous to the different types of comets' tails so ably discussed by Professor Bredichin?

Some of the parts of these nebulæ must be approaching the earth, some receding from it.

Can we by the spectroscope discriminate between such motions?

A suggestion which holds out even the hope of successfully attacking such problems is not without its value, and I have, therefore, no hesitation in presenting the foregoing paper in its present incomplete form.

EDWARD S. HOLDEN.

LICK OBSERVATORY, July 12, 1889.

ON THE ORBIT OF COMET BARNARD (1889, JUNE 23).

BY A. O. LEUSCHNER.

From Mr. BARNARD'S observations of June 23, 24, 25, I have deduced the following elements:

$$
\begin{aligned}
T &= 1889,\ \text{June 20. 1480 G. m. t.} \\
\left.\begin{aligned}\Omega &= 271^\circ\ \ 4'.1 \\ \omega &= \ \ 59^\circ\, 20'.7 \\ i &= \ \ 31^\circ\, 14'.6\end{aligned}\right\} & \ 1889.0 \\
\log q &= 0.04236
\end{aligned}
$$

Obsd.—Computed; $\Delta\lambda \cos\beta = -0'.3, \Delta\beta = 0'.0.$

[ABSTRACT.]

ON THE OCCULTATIONS OF JUPITER (VISIBLE IN 1889); AND ON THE ECLIPSES OF SATELLITE IV.

BY CHARLES B. HILL.

Mr. HILL spoke of the various phenomena of *Jupiter's* satellites, etc., of special interest, and called the attention of members especially to

The Eclipse (reappearance) of Satellite IV:

1889, August 18, at 8h. 37m., P. s. t.; and to

The Occultation of Jupiter by the Moon:

1889, Sept. 3—*Immersion*,	I	contact,	5h. 32.5m.,	P. s. t.
	II	“	5h. 34.5m.,	“
Emersion,	III	“	6h. 26.0m.,	“
	IV	“	6h. 28.0m.,	“

Angle from North Point, Imm. = 149°
“ “ “ “ Emer. = 234°

The above prediction is based on an approximate (graphical) computation for the position of Mt. Hamilton. The occultation will be visible in the United States generally. In California it will take place shortly before sunset, the moon being one day past *First Quarter*.

[Abstract.]

ON PHOTOGRAPHING THE CORONA IN FULL SUNSHINE; AND ON PHOTOGRAPHS OF THE MOON IN THE DAYTIME.

By J. E. Keeler.

Mr. Keeler gave a brief account of the attempts that had been made to see and to photograph the corona in full sunshine, and spoke of the evidence of the eclipse photographs on the practicability of the latter experiment. It had been shown by Professor Holden in the Eclipse Report of 1889 that if the intrinsic brilliancy of the daylight near the sun was 1000, the intrinsic brilliancy of the daylight *plus* corona was not above 1002. Hence, to photograph the corona in full sunshine, we must be able to record a difference of brilliancy, a contrast, of $\frac{1}{500}$. The eye could detect a contrast of $\frac{1}{60}$ only, and hence the attempt seemed hopeless, as the rays and streamers of the corona had a continuous spectrum like that of diffused daylight. He also exhibited some photographs of the moon taken in the daytime by Mr. Burnham, with a lens of aperture = $^3/_4$ inch, focus = 9 inches, stop $f/_{44}$, time $\frac{1}{60}$ to $\frac{1}{100}$ of a second. The moon was more than 120° from the sun at the time.

Experiments on this matter were recommended to the amateur photographers of the Society, and it was asked that successful trials might be communicated to the Lick Observatory. Photographs of the dark side of the moon before first quarter might be included in the plan. Each plate exposed should be marked with the observer's name; the aperture, stop, and plate employed; the hour and minute of exposure; the length of exposure.

Mr. Keeler exhibited some prints made on ordinary dry plates and on ortho-chromatic plates, and recommended the attention of the members of the Society to the excellent results attained by the use of the latter plates, and suggested a trial of them for pictures of the moon in the daytime, as the moon was relatively rich in light of greater wave length than F.

NOTICES FROM THE LICK OBSERVATORY.

Prepared by Members of the Staff.

The desire is expressed, on many sides, that the Publications of the Society should contain brief notices of the work current at the Lick Observatory, because much of this work is necessarily published in Eastern and foreign journals and therefore may escape the attention of our members.

Such notices must evidently be of the briefest and most popular character, and very often can be nothing more than a reference to the title and place of publication of a paper. Even such references as these may serve, it is said, to call the attention of our members to the existence of a paper which may be of interest to several of them.

It is therefore proposed, as an experiment merely, to include in each of our Publications a few pages of items relating to the work of the Lick Observatory. Should these meet the want which has been expressed, it will be easy to continue them in the future. In this way an acquaintance with the work of the Observatory can be maintained, without taking too much space in the pages of our Publications, which should be reserved for longer articles by the members of the Society in general.

As the Observatory commenced active operations not long before the foundation of the Society, the present number of the *Notices* may well be devoted to a list of the mere titles of the different papers, etc., which have been sent to various scientific journals and magazines since June 1, 1888, by the members of the Observatory staff. Articles printed in newspapers, etc., are not included, as these are generally of transient interest only. This list, then, will bring the history of the astronomical activity of the Observatory up to the present time, and leave a clear field for the subsequent numbers of these *Notices*. E. S. H.

Photograph of the Davidson Comet.

The comet discovered by Mr. Davidson at Queensland, on July 21, was photographed at the Observatory by Mr. Barnard, with the new Willard lens (about 5 inches aperture, 30 inches focus) on July 30. A Seed 26 plate was used, and an exposure of ninety minutes was given. The camera was mounted on the top of the twelve-inch equatorial, and the camera was kept directed at the comet by moving the slow motion screws in R. A. and in Dec. As the comet had a rapid motion in reference to the stars, the latter appeared as *trails* about 13′ to 14′ long. This was the comet's motion in ninety minutes of time. The head of the comet shows as a neat round mass. The tail is fan-shaped, with its borders convex to the axis, and very narrow at the root. It can easily be traced 20′ and it is evident for about 53′. Mr. Barnard could trace it no further than 50′ or so, with the telescope. After the picture of the comet was taken, the negative was exposed to the light of our standard lamp for 1, 5, 10, 15, 20, 25 and 30 seconds, making a series of squares of standard intensity. (See Lick Observatory Eclipse Report, page 12.) The night-sky was less intense than the square exposed one second. The brightest part of the tail of the comet 2′ or so from the head matched the standard square exposed ten seconds. Hence the comet is about nine and one-half times as bright as its background. Omitting any consideration of the absorption of the atmosphere, and of the absorption of the lens (as yet undetermined), I find that the intrinsic brilliancy of this portion of the comet was 0.000,000,15 units of the standard lamp. The full moon has an intrinsic brilliancy of 1.66 units (PICKERING) and the brightest parts of the corona of January 1, 1889, had an intrinsic brilliancy of 0.08 units. Hence the comet is 10,000,000 times fainter than the full moon, area for area; and 500,000 times fainter than the brightest parts of the corona of last January. According to Mr. PICKERING'S measures, the intrinsic brilliancy (actinic) of the sky within 5° from the full moon is 0.000,064 units; and thus the sky near the moon is 400 times brighter than the comet, and more than 4000 times as bright as the night-sky. These measures relate only to the photographic brilliancy of the comet. The visual brilliancy would be much higher relatively, as the observations of Mr. KEELER show the most refrangible end of its spectrum to be very weak.

The results just given are interesting and important in themselves, and they also have an historical value; since this is the first occasion on which the light of a comet has been actually measured with accuracy.[2]

The preceding experiment also suggests various applications. For example: we may measure the total amount of a comet's light on various dates, and compare this measured light with the amount of light reflected to us by the comet from the sun, which latter quantity can be accurately calculated. Thus, we might find

	JAN. 1.	JAN. 2.	JAN. 3, ETC.
Measured light from the comet	= L,	= M,	= N, etc.
Calculated light from the comet	= A,	= B,	= C, etc.
∴ Native light of the comet	= L − A,	= M − B,	= N − C, etc.

It has long been known that the brilliancy of comets increases beyond the theoretical amount as they approach the sun, owing to native light emitted by them under the influence of the sun. It appears that there is now some hope of tracing such changes of brilliancy from day to day, by photographic means, and of obtaining in this way some clue to the energy of the forces which produce these observed changes. E. S. H.

1889, July 31.

SPECTRUM OF DAVIDSON'S COMET.

The spectrum of Davidson's comet was observed here with the twelve-inch equatorial, on July 31st, and with the thirty-six-inch equatorial, on August 1st. The *coma* showed a spectrum consisting of three somewhat diffuse bright bands, which were found to be identical in position with the carbon fluting given by the blue flame of a spirit lamp. A faint luminosity connected the bands, so that the spaces between them were not perfectly dark.

The nucleus gave a continuous spectrum not extending below the D line, with slight brightenings at the positions of the carbon flutings. Such a spectrum would probably be given by the material of the *coma* at an increased pressure. Although the comet is now

[2]Since the above was written, I have seen a reference to a measure of the light of the comet of 1881 (?) by JANSSEN (*Ann. Bureau Long.* 1882, p. 781), which is stated as 300,000 times fainter than the full moon. This book is not accessible to me, and I do not know if the brilliancy was measured, or only inferred from the time of exposure compared with that of the moon.

rated at about the sixth magnitude, its spectrum is much fainter than that of a star of this brightness, on account of the diffusion of its light over a large area. J. E. K.

Aug. 2, 1889.

New Double Stars.

One of the more recent double-star discoveries with the thirty-six-inch telescope is a seventh-magnitude star (D. M. 30°, 4809) near η Pegasi. The measures on three nights give:

1889.55	335°.3	0″.23	7.2	8.2

The 4–5 m. star, ψ *Cassiopeiæ*, has been known since the first Herschel as a triple star, from a small double companion at a distance of 28″ from the large star. The Lick telescope shows a small star of about 13–15 m. at a distance of 3″.2 in the direction of 41°.2.

A careful set of measures of the close pair, κ *Pegasi* (β 989) has been made with the thirty-six-inch telescope. The change in both angle and distance has been very great since its discovery with the Chicago telescope in 1880. As the distance now is only 0″.14, it could hardly be seen, or measured, with any instrument much smaller than the Lick telescope. The components differ by only about half a magnitude, and there is a possibility of the wrong quadrant having been given in my first measures made in 1880, although at the time this was carefully looked after. Taking the early measures as they stand, the motion (direct) would be 235° in nine years. If the first angle should be reversed, the change would be only 56°.

There is a small star 11″ distant, which makes the double, Σ2824. This is fixed with reference to the bright star.

28 *Andromedæ* is also a new double star. The following is the mean of three nights' measures with the thirty-six-inch refractor:

1889.51	360°.1	2″.42	5.5	13.3

Herschel, at the Cape of Good Hope, noted a small double star in the fine cluster and nebula, Messier 8, and entered it as No. 5009 of the Cape Catalogue. The Lick telescope shows that the principal star of Herschel's pair is a close pair. The mean of four measures is:—

1889.40	55°.6	0″.63	8.7	9.5

There is probably no change in Herschel's more distant star.

	°	″			
1837.70	20.8	2.	10.	12.	1n H
1880.58	19.9	3.86	9.0	9.5	1n Cin
1889.40	23.3	4.05	8.7	9.6	4n β

For many years Σ 2438 has been found to be single with all telescopes. A recent set of measures with the large refractor of the Lick Observatory gives for the distance 0″.24, and the position angle 46°.2. The angle when measured by Struve in 1832 was 340°.6.

With powers up to 2000, the thirty-six-inch shows the large star of Σ 3130 as single. It has not been seen double during the last thirty years. S. W. B.

Meridian Circle Observations of *Victoria* and Comparison Stars.

In connection with astronomers in the northern hemisphere, the Astronomer Royal at the Cape of Good Hope, Dr. David Gill, is observing the planet *Victoria*, for the determination of its parallax (and hence of the Solar Parallax). He has requested various observatories to determine, by meridian observations, the positions of the planet and of thirty-seven comparison stars. This work has been done at the Lick Observatory by eighteen nights of observations, between June 8 and July 8, and the results will soon be ready for publication. From a series of experiments, it was found that (thanks to the designer of the large pivots, nearly four inches in diameter) much better results could be obtained when the observations were made without clamping the instrument. The clamp was accordingly removed (some months ago), so that all of the observations referred to above were made with the nearly counterpoised instrument hanging freely in the wyes. That this variation from the usual method is to be approved, when the proper precautions are taken, seems to be shown by the smallness of the probable errors of observation, which, for a single observation in R. A. and Dec., are about $0^s.020$ and $0''.25$ respectively. These figures also show that the Repsold meridian circle is capable of first-class work, and that the refraction as given in Vol. 1, *Publications Lick Observatory*, is not very far out of the way. J. M. S.

New Double Stars.

I have found the stars, 2 *Piscium* and W xxiii.803 to be double with the twelve-inch equatorial. Mr. Burnham has kindly measured these stars with the thirty-six-inch and supplied me with his results for publication. From the inequality of the components, 2 *Piscium* is a difficult object with the twelve-inch.

Following are Mr. Burnham's measures. E. E. B.

1889, August 5.

2 Piscium.

22h. 53m. 18s.
0° 19′

	°	″		
1889.553	96.0	3.87	6	14.
.556	91.8	3.88	6	13.5
.589	93.1	3.68	6	13.5
1889.57	93.6	3.81	6	13.7

W xxiii.803.

23h. 40m. 53s.
4° 35′

	°	″		
1889.553	166.2	0.49	8.7	8.7
.556	166.5	0.59	8.6	8.6
.589	166.0	0.53	8.5	8.5
1889.57	166.2	0.54	8.6	8.6

List of the Articles, Etc., Contributed to Scientific and other Journals by the Astronomers of the Lick Observatory since June 1, 1888.

[Compiled by Mr. C. B. Hill.]

Writings of Edward S. Holden.

Hand-Book of the Lick Observatory. San Francisco, June, 1888. 32°, pp. 135.

Stellar Photography.—*Overland Monthly*, June, 1888.

Note on Earthquake Intensity in San Francisco, 1808–1888.—*American Journal of Science*, June, 1888.

The Total Solar Eclipse of 1889, January 1st, in California.—*Monthly Notices Royal Astronomical Society*, vol. 48.

Occultation of 47 Libræ by Jupiter, June 9, 1888.—*Astronomical Journal*, vol. 8, p. 64.

The Ring Nebula in Lyra.—*Monthly Notices Royal Astronomical Society*, vol. 48, p. 383.

Regarding Sir W. Herschel's observations of Volcanoes in the Moon. *The Observatory*, 1888, p. 334.

Earthquakes in California, Washington and Oregon, 1769–1888. Communicated to the *California Academy of Sciences* in July, 1888.

Sidereal Astronomy, Old and New. 2 papers.—*The Century* for August and September, 1888.

Occultation of a Star (11th magnitude) by Mars.—*Astronomical Journal*, vol. 8, p. 102.

Observations of the Lunar Eclipse of July 22, 1888, at the Lick Observatory of the University of California. Communicated to the *National Academy of Sciences*. [By all the astronomers].

Suggestions for Observing the Total Eclipse of the Sun on January 1, 1889. (Printed by Authority of the Regents of the University of California). State Printing Office, Sacramento, 1888. 8vo, pamphlet.

Hypothetical Parallax of Binary Pairs.—*Sidereal Messenger*, October, 1888, p. 356.

Physical Observations of Mars during the Opposition of 1888, at the Lick Observatory. (With a plate).—*Astronomical Journal*, vol. 8, p. 97.

The Same.—*Journal of Liverpool Astronomical Society*, vol. 7, November, 1888, p. 7, with plates.

Saturn and his Satellites.—*Sidereal Messenger*, January, 1889.

Observations of Nebulæ at the Lick Observatory (by E. S. Holden and J. M. Schaeberle).—*Monthly Notices Royal Astronomical Society*, vol. 48 (1888) p. 388.

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Earthquakes in California (1888).—*American Journal of Science*, May, 1889, p. 392.

On the Solar Eclipse of January 1, 1889.—*Observatory*, March, 1889, page 130; May, p. 221.

The Lick Observatory.—*Himmel und Erde* (Berlin; illustrated), May and June, 1889.

On the Photographs of the Corona at the Solar Eclipse of January, 1, 1889.—*Monthly Notices Royal Astronomical Society*, vol. 49, p. 343.

Reported Changes in the Rings of Saturn. (Observations by E. S. Holden, J. M. Schaeberle, J. E. Keeler, E. E. Barnard.)—*Astronomical Journal*, vol. 8, p. 180.

Occultation of the Planet Jupiter, as observed at the Lick Observatory, March 23, 1889. (Observations by J. E. Keeler, E. E. Barnard, C. B. Hill, A. O. Leuschner.)—*Sidereal Messenger*, May, 1889, p. 221.

Address before the Astronomical Society of the Pacific "On the Work of an Astronomical Society."—*Publications Astronomical Society of the Pacific*, No. 2, March 30, 1889.

Reports on the Observations of the Total Solar Eclipse of January 1, 1889. Published by the Lick Observatory, 8vo.

Great Telescopes and their Work.—*Observatory*, March, 1889, p. 138.

Recent Discoveries in the Nebulæ by means of Photography.—*Scientific American*, July 27, 1889.

On the Helical Nebulæ.—*Publications Astronomical Society of the Pacific*, No. 3, July 27, 1889. Die Helikalischen Nebel.—*Himmel und Erde.*

Astronomical Photography.—*The Pacific Review*, September, 1889.

Writings of S. W. Burnham.

Double Star Observations made at the Lick Observatory.—*Astronomische Nachrichten*, No. 2875.

New Double Stars Discovered at the Lick Observatory.—*Astronomical Journal*, vol. 8, p. 141.

Companion to Sirius.—*Astronomische Nachrichten*, No. 2884.

The Trapezium of Orion.—*Monthly Notices Royal Astronomical Society*, 1889, vol. 49, p. 352.

The Double Star, ϵ Hydræ.—*Sidereal Messenger*, May, 1889.

New Double Star, α Ursæ Majoris.—*Astronomische Nachrichten*, No. 2891.

Seventeen Comæ Berenices.—*Observatory*, May, 1889, p. 227.

Double Star Observations made with the 36-inch refractor of the Lick Observatory.—*Astronomische Nachrichten*, No. —.

η Ophiuchi, θ Cygni.—*Astronomische Nachrichten*, No. 2912.

Writings of J. M. Schaeberle.

Elements and Ephemeris of Barnard's Comet (e), 1888.—*Astronomical Journal*, vol. 8, p. 102; *Sidereal Messenger*, October, 1888, p. 357. Communicated to the *California Academy of*

Sciences.

Orbit and Proper Motion of 85 Pegasi (β 733).—*Astronomical Journal*, vol. 8, p. 129. Communicated to the *California Academy of Sciences.*

Elements and Ephemeris of Barnard's Comet (f), 1888.—*Astronomical Journal*, vol. 8, p. 144; *Sidereal Messenger*, December, 1888. Communicated to the *California Academy of Sciences.*

Observations of Nebulæ at the Lick Observatory (by E. S. Holden and J. M. Schaeberle).—*Monthly Notices Royal Astronomical Society*, vol. 48 (1888), p. 388.

Meridian Observations of Polyhymnia and Harmonia.—*Astronomische Nachrichten*, No. 2877.

Corrections to the Lick Observatory Time Signals for December 30.0, December 31.0, January 1.0, and January 2.0.—*Astronomical Journal*, vol. 8, p. 168.

Elements and Ephemeris of Barnard's Comet (March 31). Communicated to the *California Academy of Sciences*; telegraphed to *Astronomical Journal*, and printed in vol. 8, pp. 183 and 191; *Astronomische Nachrichten*, No. 2839. See also *Astronomische Nachrichten*, No. 2903.

Reports on the Solar Eclipse of January 1, 1889.—In *Lick Observatory Reports*, p. 23.

Writings of J. E. Keeler.

The 36-inch Equatorial of the Lick Observatory.—*Scientific American*, June 16, 1888.

Recent Astronomical Work at the Lick Observatory.—*Scientific American*, November 10, 1888.

Observations of the Satellites of Mars.—*Astronomical Journal*, No. 178, pp. 73–78.

The Appearance of Saturn in the 36-inch Equatorial of the Lick Observatory.—*Ciel et Terre*, No. 21, January, 1889, p. 514.

The Outer Ring of Saturn.—*Ciel et Terre*, No. 3, April, 1889. *Astronomical Journal*, vol. 8, p. 175.

Report on the Total Solar Eclipse of January 1, 1889.—In the *Lick Observatory Report*, p. 31.

On the Spectra of Saturn and Uranus.—*Astronomische Nachrichten*, No. —.

Writings of E. E. Barnard.

Discovery and Observations of a Comet (e 1888).—*Astronomical Journal*, vol. 8, p. 102; *Astronomische Nachrichten*, No. 2862.

Drawings of Comet, 1888, I.—*Astronomische Nachrichten*, No. 2859. (With a plate.)

Discovery of a Comet (f, 1888).—*Astronomical Journal*, vol. 8, p. 128. Communicated to *California Academy of Sciences.*

Observations of Olbers' Comet (1887, V).—*Astronomische Nachrichten*, No. 2861.

Discovery and Observations of a Comet (f, 1888).—*Astronomische Nachrichten*, No. 2871, p. 237; *Astronomical Journal*, vol. 8, p. 134.

Note on the Orbit of Comet (e), 1888.—*Astronomical Journal*, vol. 8, p. 120.

On a Search for the Comet reported January 15, 1889, by Mr. Brooks.—*Astronomical Journal*, vol. 8, p. 168.

Partial Eclipse of the Moon, January 16, 1889.—*Sidereal Messenger*, March 1889, p. 137.

Discovery and Observations of Comet Barnard (March 31).—*Astronomical Journal*, vol. 8, p. 183; *Astronomische Nachrichten*, No. 2894; *Astronomical Journal*, vol. 9, p. 5; *Astronomische Nachrichten*, No. 2899; *Astronomische Nachrichten*, No. 2901.

Report on the Total Eclipse of January 1, 1889.—In the *Lick Observatory Report*, p. 56.

Observations of Faye's Comet.—*Astronomische Nachrichten*, No. —; *Astronomical Journal*, vol. 9, p. 29.

Anomalous Tail of Comet I, 1889.—*Astronomical Journal*, vol. 9, p. 32; *Astronomische Nachrichten*, No. 2906.

The Nebula G. C. 2091.—*Monthly Notices Royal Astronomical Society*, vol. 49, p. 418.

The Cluster G. C. 1420, and the Nebula N. G. C. 2237. *Astronomische Nachrichten*, No. —.

Discovery and Observations of a Comet (June 23).—*Astronomische Nachrichten*, No. 2906; *Astronomical Journal*, vol. 9, p. 47.

Writings of C. B. Hill.

Observations of Comet, 1888, I.—*Astronomische Nachrichten*, No. 2877.

Report on the Total Solar Eclipse of January 1, 1889.—In *Lick Observatory Report*, p. 74.

Writings of A. O. Leuschner.

Bahn des Cometen Barnard (Marz 31) aus Beobachtungen mit eintaegigen Zwischenzeiten nach v. Oppolzer's Methode.—*Astronomische Nachrichten*, No. 2907.

Reports on the Total Eclipse of January 1, 1889—In the *Lick Observatory Report*, p. 81.

Orbit of Comet Barnard (1889, June 23).—*Astronomische Nachrichten*, No. 2909; *Astronomical Journal*, vol. 9, p. 40; *Publications of the Astronomical Society of the Pacific*, No. 3.

Minutes of the Meeting of the Board of Directors, held July 27, 1889, at the Lick Observatory.

A quorum was present.

The Committee on the Diploma was authorized to expend not to exceed $50.

It was *Resolved*, That the Publications of the Astronomical Society of the Pacific be regularly sent to the following Observatories, etc., and that the Secretaries of the Society be instructed to notify them of this resolution, and to request that they exchange their publications with our own; and that the list of these Corresponding Societies and Observatories be printed in the Publications of the Astronomical Society of the Pacific:

Dudley Observatory, Albany, New York.
Detroit Observatory, Ann Arbor, Michigan.
Royal Observatory, Berlin, Germany.
University Observatory, Bonn, Germany.
Royal Observatory, Brussels, Belgium.
University Observatory, Cambridge, England.
Harvard College Observatory, Cambridge, Massachusetts.
Royal Observatory, Capetown, Africa.
University Observatory, Cincinnati, Ohio.
University Observatory, Dorpat, Russia.
Royal Observatory, Greenwich, England.
Ducal Observatory, Karlsrühe, Germany.
University Observatory, Kasan, Russia.
University Observatory, Koenigsberg, Prussia.
Royal Observatory, Kopenhagen, Denmark.
University Observatory, Leiden, Holland.
University Observatory, Leipzig, Germany.
Royal Observatory, Milan, Italy.
Observatory, Melbourne, Australia.
University Observatory, Moscow, Russia.
Lick Observatory, Mount Hamilton, California.
Royal Observatory, Munich, Germany.
Carleton College Observatory, Northfield, Minnesota.
Radcliffe Observatory, Oxford, England.
Savilian Observatory, Oxford, England.
National Observatory, Paris, France.
Astrophysikalishes Institut, Potsdam, Germany.
Imperial Observatory, Pulkowa, Russia.
Observatory of the Roman College, Rome, Italy.
University Observatory, Stockholm, Sweden.
University Observatory, Strassburg, Germany.
McCormick Observatory, University of Virginia, Virginia.
Naval Observatory, Washington, District of Columbia.
Imperial Observatory, Vienna, Austro-Hungary.
Royal Astronomical Society, London, England.
Liverpool Astronomical Society, Liverpool, England.
Astronomical Society of France, Paris, France.
Astronomical Society, Chicago, Illinois.
Astronomical Society of Germany, Leipzig, Germany.
Gesellschaft Urania, Berlin, Germany.
National Academy of Sciences, Washington, District of Columbia.

Smithsonian Institution, Washington, District of Columbia.
California Academy of Sciences, San Francisco, California.
Bureau des Longitudes, Paris, France.
The Nautical Almanac, London, England.
The American Ephemeris, Washington, District of Columbia.
Berliner Jahrbuch, Berlin, Germany.
Library of the Mechanics Institute, San Francisco, California.
Library of Congress, Washington, District of Columbia.
Mercantile Library, San Francisco, California.
Library of the University of California, Berkeley, California.
Chabot Observatory, Oakland, California.
Royal Observatory, Edinburgh, Scotland.
University Observatory, Cambridge, England.
Observatory, Nice, France.
Observatory, Marseilles, France.
Observatory, Bordeaux, France.
Observatory, Lyons, France.
Observatory, Toulouse, France.
Observatory, Kiel, Germany.
Observatory, Gotha, Germany.
Observatory, Hamburg, Germany.
Observatory of Geneva, Switzerland.
Observatory of Zurich, Switzerland.
Observatory of Berne, Switzerland.
Observatory of Neuchâtel, Switzerland.
Observatory of Madrid, Spain.
Observatory of Lisbon, Portugal.
Observatory of Naples, Italy.
Observatory of Palermo, Italy.
Observatory of Upsala, Sweden.
Observatory of Lund, Sweden.
Observatory of Christiania, Sweden.
Observatory of Helsingfors, Russia.
Observatory of Tacubaya, Mexico.
Observatory of Cordoba, Argentine Republic.
Observatory of Rio Janeiro, Brazil.
Observatory of Santiago, Chile.
Observatory of Madras, India.
Observatory of Sydney, New South Wales.
Observatory of Amherst College, Massachusetts.
Observatory of Clinton, New York.
Observatory of Georgetown, District of Columbia.
Observatory of Glasgow, Missouri.
Observatory of Hanover, New Hampshire.
Washburn Observatory, Madison, Wisconsin.
Winchester Observatory, New Haven, Connecticut.
Halstead Observatory, Princeton, New Jersey.
La Plata Observatory, La Plata, Argentine Republic.
Williams College Observatory, Williamstown, Massachusetts.
University Observatory, Tokio, Japan.

Mr. HOLDEN presented to the Board of Directors a communication from Hon. JOSEPH A. DONOHOE, of Menlo Park, relating to the establishment of a comet medal, and it was

Resolved, That the Board of Directors recommends to the Society the acceptance of Mr. DONOHOE'S generous gift.

Resolved, That on the acceptance of the gift by the Society, Mr. DONOHOE'S name be placed on the roll of Life-Members; that the *Donohoe Fund for the maintenance of the Comet Medal of the Astronomical Society of the Pacific* be placed under the immediate charge of the Finance Committee; and that the Committee on the Comet Medal shall, until the next annual meeting, or until their successors are appointed, be composed as follows:

The Director of the Lick Observatory, *ex officio*, and of Messrs. SCHAEBERLE and BURCKHALTER on the part of the Society.

It was *Resolved*, That Article VII of the By-Laws of the Astronomical Society of the Pacific be amended so as to read as follows:

"ARTICLE VII.

"Candidates for membership may be proposed at any meeting of the Society and may be elected at the same meeting by unanimous consent of those present. In case of dissent of any one member, candidates so proposed shall be voted for at the next succeeding meeting. The vote shall be by ballot, and a majority of the members present shall be required for an election."

This was adopted by the consenting votes of nine members of the Board of Directors, namely: Messrs. ALVORD, BURCKHALTER, GIBBS, GRANT, HOLDEN, LOWDEN, MOLERA, PIERSON, SCHAEBERLE, and therefore takes the place of Article VII in the By-Laws as printed in Publications No. 1.

The printing of Publications No. 3 and the preparation of photo-lithographic plates to illustrate it and Publications No. 4, was ordered.

The life-members whose names are marked with a star (*) in the list of members given in full in the minutes of the meeting of the Society July 27, were duly elected by the Board of Directors. Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific, held July 27, 1889, at the Lick Observatory

[Prepared by the Secretaries for Publication.]

The minutes of the meeting of May 25, 1889, were read and approved.

Sixty-five persons were elected to membership under the provisions of the newly adopted Article VII of the By-Laws. For the convenience of the Society a full list of its present members is given below. This list includes the members elected at the present meeting. All are active members, except those whose names are marked with a star (*), to signify that they have been elected to life-membership.

LIST OF MEMBERS, JULY 27, 1889.

NAME.	ADDRESS.
T. P. Andrews,	529 Commercial Street, San Francisco, Cal.
Hon. Henry B. Alvord,*	San Jose, Cal.
Hon. Wm. Alvord,*	Bank of California, San Francisco, Cal.
Mrs. Wm. Alvord,*	Palace Hotel, San Francisco, Cal.
Director Angel Anguiano,	National Observatory, Tacubaya, Mexico.
Dr. Wm. Boericke,	834 Sutter Street, San Francisco, Cal.
S. W. Burnham,	Lick Observatory, Mt. Hamilton, Cal.
E. E. Barnard,	Lick Observatory, Mt. Hamilton, Cal.
Chas. Burckhalter,	Chabot Observatory, Oakland, Cal.
E. M. Bixley,	317 California Street, San Francisco, Cal.
John C. Bullock,	1626 Twelfth Street, Oakland, Cal.
D. P. Belknap,	604 Merchant Street, San Francisco, Cal.
Hon. John H. Boalt,	332 Haight Street, San Francisco, Cal.
H. F. Compton,	966 Chester Street, Oakland, Cal.
Col. C. F. Crocker,	4th & Townsend Streets, San Francisco, Cal.
J. C. Cebrian,	Pine & Octavia Streets, San Francisco, Cal.
J. Costa,	406 Montgomery Street, San Francisco, Cal.
E. Bentley Church,	1036 Valencia Street, San Francisco, Cal.
Chas. S. Cushing,	1669 Thirteenth Street, Oakland, Cal.
Dr. J. Callandreau,	1307 Stockton Street, San Francisco, Cal.
C. H. Clement,	Livermore, Cal.
Dr. W. A. Dewey,	834 Sutter Street, San Francisco, Cal.
L. L. Dunbar, D. D. S.,	500 Sutter Street, San Francisco, Cal.
Hon. Joseph A. Donohoe,*	Menlo Park, Cal.
Eugene Frost,	Alameda, Cal.
Arthur W. Foster,*	322 Pine Street, San Francisco, Cal.
Hon. James G. Fair,*	230 Montgomery Street, San Francisco, Cal.
T. W. Fenn,	319 California Street, San Francisco, Cal.
Andrew B. Forbes,*	401 California Street, San Francisco, Cal.
Robert D. Fry,*	1812 Jackson Street, San Francisco, Cal.
Chas. W. Friend,	Carson City, Nevada.
Edmund Gray,	2925 Jackson Street, San Francisco, Cal.
Dr. C. L. Goddard,	131 Post Street, San Francisco, Cal.
Chase Gitchell,	609 Sacramento Street, San Francisco, Cal.
C. P. Grimwood,	Fruitvale, Cal.
W. C. Gibbs,	303 California Street, San Francisco, Cal.
C. Mitchell Grant,	331 Kearny Street, San Francisco, Cal.

Adam Grant,* .... Bush & Sansome Streets, San Francisco, Cal.
Joseph D. Grant,*................ Bush & Sansome Streets, San Francisco, Cal.
Capt. Charles Goodall,*......... McAllister & Pierce Sts., San Francisco, Cal.
Camilo Gonzalez, ... National Observatory, Tacubaya, Mexico.
Hon. J. M. Gitchell, ... 609 Sacramento Street, San Francisco, Cal.
C. Webb Howard,*................ Pacific Union Club, San Francisco, Cal.
Prof. E. S. Holden, ... Lick Observatory, Mt. Hamilton, Cal.
C. B. Hill, ... Lick Observatory, Mt. Hamilton, Cal.
Wm. F. Herrick,.................. 439 California Street, San Francisco, Cal.
Dr. H. W. Harkness,............... California Academy of Sciences,
cor. California & Dupont Sts., San Francisco, Cal.
F. H. Hausman,..................... 328 Montgomery Street, San Francisco, Cal.
Judge S. G. Hillborn, ... 401 California Street, San Francisco, Cal.
Horace L. Hill,*.................. 314 California Street, San Francisco, Cal.
Wm. Ireland, ... 301 California Street, San Francisco, Cal.
J. R. Jarboe, ... 917 Pine Street, San Francisco, Cal.
P. R. Jarboe, ... 917 Pine Street, San Francisco, Cal.
E. B. Jordan, ... 581 Market Street, San Francisco, Cal.
J. H. Johnson, ... 414 Buchanan Street, San Francisco, Cal.
James G. Jones,*.................. Room 61, Flood Building, San Francisco, Cal.
Hon. John P. Jones,* .... Gold Hill, Nevada.
Miss Fidelia Jewett, ... San Francisco High School, San Francisco, Cal.
J. E. Keeler, ... Lick Observatory, Mt. Hamilton, Cal.
Henry Kahn, ... 212 Kearny Street, San Francisco, Cal.
O. V. Lange, ... 1025 Market Street, San Francisco, Cal.
W. H. Lowden, ... 213 Sansome Street, San Francisco, Cal.
Prof. John Le Conte, ... Berkeley, Cal.
A. O. Leuschner,.................. Lick Observatory, Mt. Hamilton, Cal.
W. B. Lewitt, M. D., ... Cor. Hayes & Laguna Streets, San Francisco, Cal.
Joseph G. Lavery, ... 410 California Street, San Francisco, Cal.
Miss L. J. Martin, ... San Francisco High School, San Francisco, Cal.
F. H. McConnell, ... 618 Market Street, San Francisco, Cal.
E. J. Molera, ... 850 Van Ness Avenue, San Francisco, Cal.
C. F. Montealegre, ... 230 California Street, San Francisco, Cal.
Alexander Montgomery,*....... N. W. cor. Leavenworth & Vallejo Streets, San Francisco, Cal.
Mrs. Alexander Montgomery,* . N. W. cor. Leavenworth & Vallejo Streets, San Francisco, Cal.
Hon. J. W. McClymonds,.......... City Hall, Oakland, Cal.
Hon. D. O. Mills,*................. 224 Montgomery Street, San Francisco, Cal.
Rev. Robert Mackenzie,.......... First Presbyterian Church, San Francisco, Cal.
Hon. Wm. Norris, ... 927 Bush Street, San Francisco, Cal.
Miss Rosa O'Halloran,........... 1511 Clay Street, San Francisco, Cal.
W. Letts Oliver, ... 1110 Twelfth Street, Oakland, Cal.
Sam. C. Partridge, ... 529 Commercial Street, San Francisco, Cal.
Wm. M. Pierson,.................. 76 Nevada Block, San Francisco, Cal.
Hon. T. Guy Phelps, ... Belmont, Cal.
Dr. S. C. Passavant, ... 306 Guerrero Street, San Francisco, Cal.
Hon. Geo. C. Perkins,* .... Oakland, Cal.
John Perry, Jr.................... Occidental Hotel, San Francisco, Cal.
John Partridge, ... 214 California Street, San Francisco, Cal.
Dr. Geo. C. Pardee, ... 526 Montgomery Street, San Francisco, Cal.
Señor Manuel G. Prieto,......... Tacubaya, Mexico.
Lawrence H. Pierson,............ Pacific Pine Lumber Co., San Francisco, Cal.

FEODORO QUINTANO, ... National Observatory, Tacubaya, Mexico.
ALFRED P. REDINGTON, ... 53 Stevenson Street, San Francisco, Cal.
GEO. W. REED, ... 506 Battery Street, care W. B. Tyler, San Francisco, Cal.
E. W. RUNYON, ... 53 Stevenson Street, San Francisco, Cal.
V. J. A. REY, ... 829 Union Street, San Francisco, Cal.
A. W. ROSS, JR., ... 224 California Street, San Francisco, Cal.
Hon. ARTHUR RODGERS, ... Nevada Block, San Francisco, Cal.
Rev. J. L. RICARD, ... Santa Clara, Cal.
LESTER L. ROBINSON,* .... 320 Sansome Street, San Francisco, Cal.
FRANCISCO RODRIGUEZ REY, ... National Observatory, Tacubaya, Mexico.
ALBERT RAYMOND, ... 76 Nevada Block, San Francisco, Cal.
J. M. SCHAEBERLE, ... Lick Observatory, Mt. Hamilton, Cal.
Prof. I. STRINGHAM, ... Berkeley, Cal.
Prof. F. SOULÉ, ... Berkeley, Cal.
J. M. SELFRIDGE, ... Oakland (Box 37), Cal.
JOHN R. SPRING,* .... 328 Montgomery Street, San Francisco, Cal.
GEORGE H. STRONG, ... 220 Market Street, San Francisco, Cal.
M. J. SULLIVAN, D. D. S., ... 30 Post Street, San Francisco, Cal.
A. J. TREAT, ... 224 McAllister Street, San Francisco, Cal.
W. B. TYLER, ... 506 Battery Street, San Francisco, Cal.
EDWARD G. THOMAS, ... 234 Montgomery Street, San Francisco, Cal.
C. W. TIEDEMAN, ... 312 Sixth Street, San Francisco, Cal.
Hon. ALFRED L. TUBBS,* .... 611 Front Street, San Francisco, Cal.
CHARLES R. TISDALE, ... Alameda, Cal.
JACOB VOORSANGER, ... 2316 California Street, San Francisco, Cal.
RUDOLPH E. VOIGHT, ... 207 California Street, San Francisco, Cal.
Señor FELIPE VALLE, ... National Observatory, Tacubaya, Mexico.
Prof. J. T. WALLACE, ... Highland Park, Oakland, Cal.
R. H. WHITE, ... 1216 Haight Street, San Francisco, Cal.
J. C. L. WADSWORTH, ... Pacific-Union Club, San Francisco, Cal.
CHARLES G. YALE, ... 220 Market Street, San Francisco, Cal.
F. R. ZIEL, ... 410 California Street, San Francisco, Cal.

The list of presents received was read by the Secretary, and the thanks of the Society were voted to the donors. It was reported from the Committee on the Diploma that a design was now preparing and would soon be ready for examination. Also that designs for the comet medal had been sought for.

The attention of the members of the Society was called to the volume recently published by Professor TACCHINI, in which he gives an account of his expeditions to observe the total solar eclipses of 1870, 1882, 1883, 1886 and 1887, together with many plates and illustrations. This volume has been prepared by Professor TACCHINI, in order that the proceeds of its sale might be devoted to the erection of a suitable monument to the noted Italian astronomer, Padre SECCHI. The work can be had through B. WESTERMANN & Co. (Box 2306, New York City), at a cost of about $2.

It was also *Resolved*, That the Astronomical Society of the Pacific will join with the Astronomers of the Lick Observatory in sending a telegram of greeting and congratulation to Director OTTO v. STRUVE, on August 19, 1889, the fiftieth anniversary of the founding of the Pulkowa Observatory and of Director STRUVE'S official connection with it.

A communication from the Hon. JOSEPH A. DONOHOE, of Menlo Park, was presented to the Society by Mr. HOLDEN. In this communication Mr. DONOHOE offers to establish a perpetual fund to provide for the bestowal of a medal of bronze upon the actual discoverer of each new comet according to the provisions hereafter given.

Mr. DONOHOE will provide the necessary dies for the medal, and will present to the Society ten finished medals, and also an invested fund of $500 to be known as the *Donohoe Fund for the*

Maintenance of the Comet Medal of the Astronomical Society of the Pacific. The conditions of the gift follow:

Comet Medal of the Astronomical Society of the Pacific.

I. A medal of bronze is established as a perpetual foundation to be given for the discovery of comets as follows:

The medal is to bear on the obverse the effigy of a bright comet among stars, with the legend "*Astronomical Society of the Pacific*" around the border; and on the reverse the inscription "*This medal, founded in 1890 by Joseph A. Donohoe, is presented to* ——— [the name of the discoverer] *to commemorate the discovery of a comet* ——— [the date]."

It is to be understood that this medal is intended solely as a recognition of merit, and not as a reward.

II. The medal will be given to the actual discoverer of any unexpected comet, when the discovery is made in the course of regular astronomical occupations; and to that observer of any telescopic periodic comet who obtains and promptly publishes the first precise determination of its position at any one of its expected returns.

III. The discoverer is to make his discovery known in the usual way; and he must also address a letter, giving his first observation, to the Director of the Lick Observatory, by the first mail after the discovery. This letter must state the exact time of the discovery, the position of the comet, the direction of its motion (when this can be determined), and the physical appearance of the object.

If the observations of one night are not sufficient to settle all these points, the discovery must nevertheless be communicated as prescribed, and a second letter can be sent, giving the missing items of information, when they are obtained. The expectation of obtaining a second observation will never be received as a reason for postponing the communication of the first one. No application for the bestowal of the medal is required. The letters received from discoverers of comets will be preserved in the records of the Lick Observatory. Cable telegrams to the Lick Observatory are to be addressed to "Astronomer, San Francisco."

IV. All such communications will be referred to a committee consisting of the Director of the Lick Observatory, *ex officio*, and of two other persons, members of the Astronomical Society of the Pacific, who are to be annually appointed by the Board of Directors. The decisions of this committee are to be final upon all points relating to the award of the medal. The committee will print an annual statement of its operations in the Publications of the Society.

Under ordinary circumstances the medal for the discovery of a comet will be awarded within two months after the receipt of the letter of the discoverer which contains the record of his first observation. In cases of doubt a longer period may elapse. The medal will not be awarded (unless under the most exceptional circumstances) for the discovery of a comet until enough observations are secured (by the discoverer or by others) to permit the calculation and the verification of its orbit.

V. This medal is to be a perpetual foundation from and after January 1, 1890.

It was, on the recommendation of Board of Directors,

Resolved, That the Astronomical Society of the Pacific accepts the generous gift of Mr. Donohoe under the conditions named by him, and

Resolved, That the Secretaries of the Society be instructed to notify Mr. DONOHOE of the acceptance of the Society, and to assure him that his gift is certain to promote and encourage the discovery and observation of comets, not only now, but always.

By a vote of the Directors Mr. DONOHOE'S name has been placed on the roll of life-members.

It was also announced to the Society that Hon. C. F. CROCKER, a member of the Society, had generously offered to bear the expense of sending an expedition from the Lick Observatory to Cayenne, South America, to observe the total solar eclipse of December 21, 1889. The Regents of the University have authorized Messrs. BURNHAM and SCHAEBERLE to take part in this work, and to use such instruments of the Lick Observatory as may be useful. Mr. F. G. BLINN, of Oakland, and Captain R. L. PHYTHIAN, U. S. Navy, Superintendent of the U. S. Naval Observatory at Washington, have also materially aided the expedition by the loan of instruments and apparatus. Messrs. BURNHAM and SCHAEBERLE will probably leave California about November 1st, and arrive at Cayenne about December 1st, 1889. The eclipse will be observed at Cayenne by an English party under Rev. S. J. PERRY, F. R. S., Director of the Stonyhurst College Observatory, and in Africa by two parties, one under Professor D. P. TODD, of Amherst College, the other under Mr. TAYLOR, F. R. A. S., Assistant in the Private Observatory of Mr. A. A. COMMON, F. R. S., of London.

Papers were then read to the Society by Mr. KEELER, on the photography of the Corona in full sunshine, etc.; by Mr. LEUSCHNER, on the orbit of comet Barnard (June 23); by Mr. HILL, on occultations of *Jupiter* during 1889; by Mr. HOLDEN, on the Helical Nebulæ. These papers are printed in full or in abstract in the preceding pages.

Mr. BARNARD exhibited a beautiful negative of a portion of the Milky Way (R. A. 18h. 11m., Dec., 20° S.) near *Jupiter*, which he took on July 24, with the Willard photographic lens of the Lick Observatory,[3] giving an exposure of 1h. 48m.

The Society then adjourned to meet at the Lick Observatory September 28, 1889.

OFFICERS OF THE SOCIETY

[3]Bought by Hon. C. F. CROCKER for the expedition to observe the eclipse of December 21, 1889.

NOTICE.

Members are requested to preserve the copies of the Publications of the Society as sent to them. At certain intervals a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with Mr. Burckhalter, at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 4. San Francisco, California, September 28, 1889.

ON THE PHOTOGRAPHIC BRIGHTNESS OF THE FIXED STARS.

By J. M. Schaeberle, Astronomer of the Lick Observatory.

The investigations relating to the photographic brightness of the fixed stars contained in this paper were made with the aid of an equatorially mounted Dallmeyer portrait-lens of $6^{in}.05$ aperture, loaned to this Observatory by the U. S. N. Observatory for the purpose of photographing the next total solar eclipse at Cayenne, South America.

Professor Holden placed this instrument in my charge, and requested me to make a series of experiments on atmospheric absorption of the light, and on the photographic brightness, of the fixed stars, so that the extended work of the same character which it is intended to execute in South America could be more intelligently and profitably performed.

The photographic focus was carefully determined by making several series of short exposures, and trails, of bright stars both inside and outside of the adopted position of the plate. The position of the plate for each setting was read off on a scale which I cut on the tube. All the exposures were made on 4×5 Seed 26 plates.

Leaving the work relating to atmospheric absorption to a future paper, let us consider the subject of the photographic brightness of stars as determined by the dimensions of their circular images on the sensitive plate. (As the dimensions—widths—of the trails could only be accurately determined for the brighter stars, I finally avoided examining trails for this special investigation.)

As the whole subject was comparatively new to me, several weeks were spent in work of an experimental character. A careful study of the data given on the exposed plate was made with the aid of our excellent measuring engine. I finally came to the conclusion that the diameter of the image of an "over-exposed" star could be used to determine the star's brightness with accuracy. To find the law of variation of the diameter of the photographic image for a variation of both the aperture of the objective and the time of exposure, seven different stops, varying in diameter from 5.41 inches to 1.91 inches, were used, and exposures of 1^s, 2^s, 4^s, 8^s, 16^s, 32^s, 64^s, and 128^s duration made for each stop. In order to be sure of the effective aperture of the stops, they were placed centrally in front of the objective, and not in the usual place between the lenses. The diameters of these stops, which we will number 1, 2, 3, etc., are as follows:

No.	1	2	3	4	5	6	7
	in.	in.	in.	in.	in.	in.	in.
Diameter ...	5.41	4.59	3.81	3.31	2.72	2.31	1.91

The figures in the following table give the diameters of the images of *Polaris*, in inches, as measured on one of the plates:

POLARIS

EXPOSURE	DIAMETERS OF IMAGE FOR DIFFERENT STOPS AND TIMES.						
TIMES.	1	2	3	4	5	6	7
	in.	in.	in.	in.	in.	in.	in.
1^s	0.0048	0.0049	0.0049	0.0048	0.0045	0.0041	0.0036
2	58	57	59	52	47	45	37
4	68	66	58	59	57	55	40
8	78	74	70	72	40	—	48
16	81	—	72	64	56	52	50
32	92	72	74	76	65	61	53
64	116	90	91	86	78	68	59
128	139	117	102	96	84	78	67

I tried to represent these numbers by various equations of the second and third degrees as functions of the aperture and time, but finally concluded that they could only be represented by an equation of the n^{th} degree, or, in other words, that the logarithms of the variables enter into the equation. I then made a similar set of exposures, using α *Lyræ* (discussed further on), and found that the function which represented the diameters was of precisely the same form. I have deduced the following general expression for the diameter of the photographic image of a star:

$$d = \alpha + \beta \,.\, \log D + \gamma \,.\, D \,.\, \log t \tag{1}$$

In which, for a given star,

$d =$ the measured diameter of the photographic image;
$\alpha =$ a constant depending only on the sensitive plate and the atmospheric state;
$\beta =$ " " " " " " " "
$\gamma =$ " " " " " " " "
$D =$ the effective diameter of the objective (stop);
$t =$ the time of exposure expressed in seconds.

In order to determine the most probable values of α, β, and γ for a particular case it will be more convenient to place

$$\alpha + \beta \log D = a \tag{2}$$
$$\gamma D = b \tag{3}$$

Equation (1) then becomes

$$d = a + b \log t \tag{4}$$

In selecting the unit for D it must be remembered that with a small stop the images, for comparatively short exposures, are small and faint. Greater accuracy may therefore be expected from large apertures. I have accordingly chosen six inches (6^{in}) as the unit of D. The diameters of the stops in terms of this unit are therefore as given below:

STOP.	1	2	3	4	5	6	7
Diameter ...	0.902	0.765	0.635	0.552	0.453	0.385	0.318
Log. of Diam.	-0.045	-0.116	-0.197	-0.258	-0.344	-0.415	-0.498

Equation (1) shows that when $t = 1^{\text{s}}$ and $D = 6^{\text{in}}$, we have $d = \alpha$; in other words, α is the diameter of the photographic image of the star for an aperture of six inches and an exposure time of one second.

Taking *Polaris* for the standard star, the above-measured diameters give the following values for a and b as found by the method of least squares; each equation of condition being of the form:

$$d = a + b \log t$$

STOP.	a	b
	in.	in.
1	0.0051	0.0032
2	53	22
3	51	19
4	46	22
5	43	15
6	43	13
7	36	12

To find the value of α and β we have the following equations of condition

$$\begin{aligned}
\alpha - 0^{\text{in}}.045\,\beta &= 0^{\text{in}}.0051 \\
\alpha - .116\,\beta &= .0053 \\
\alpha - .197\,\beta &= .0051 \\
\alpha - .258\,\beta &= .0046 \\
\alpha - .344\,\beta &= .0043 \\
\alpha - .415\,\beta &= .0043 \\
\alpha - .498\,\beta &= .0036
\end{aligned}$$

The solution of which by the method of least squares gives for values of α and β

$$\alpha = 0^{\text{in}}.0055 \qquad \beta = 0^{\text{in}}.0033$$

The diameter of the photographic image of *Polaris* for six inches aperture and one second exposure is therefore, for this particular case, $0^{\text{in}}.0055$.

The independent values of γ given by the expression $\gamma = \dfrac{b}{D}$ are

b	D	γ
in.		in.
0.0032	0.902	0.0035 from 8 different exposures with Stop 1
22	.765	0029 " 7 ditto 2
19	.635	0030 " 8 ditto 3
22	.552	0040 " 8 ditto 4
15	.453	0033 " 8 ditto 5
13	.385	0034 " 7 ditto 6
12	.318	0038 " 8 ditto 7

Taking the mean of the values of γ, we have for the images of *Polaris* the equation

$$d = 0^{\text{in}}.0055 + 0.0033 \log D + 0.0034 D \log t \tag{5}$$

The residuals obtained by subtracting the diameters computed by the above formula from the measured diameters are as follows:

Polaris.

Exposure Time.	Observation—Computation.						
	1	2	3	4	5	6	7
	in.	in.	in.	in.	in.	in.	in.
1^s	− 0.0005	− 0.0002	0.0000	+ 0.0001	+ 0.0001	0.0000	− 0.0003
2	− .0005	− .0002	+ .0004	.0000	− .0001	.0000	− .0004
4	− .0004	− .0001	− .0004	+ .0001	+ .0004	+ .0006	− .0005
8	− .0003	− .0001	+ .0002	+ .0008	——	——	.0000
16	− .0009	——	− .0003	− .0005	− .0004	− .0005	− .0002
32	− .0008	(0018)	− .0007	+ .0001	.0000	.0000	− .0001
64	− .0007	− .0008	+ .0003	+ .0006	+ .0008	+ .0003	+ .0001
128	− .0020	− .0011	+ .0008	+ .0010	+ .0010	+ .0009	+ .0006

The diameters of the images of α *Lyræ* on a plate exposed Sept. 2, are as follows:

α Lyræ.

Exposure Time.	Diameters of Images for different Stops and Times.						
	1	2	3	4	5	6	7
1^s	0.0093	0.0088	0.0073	0.0061	0.0055	0.0046	0.0045
2	114	91	—	70	63	55	48
4	123	96	—	80	70	—	57
8	148	107	102	109	80	71	66
16	* —	125	114	114	88	—	72
32	* —	146	133	122	104	—	83
64	* —	169	151	145	119	—	—

* In this table, as in the one for *Polaris*, the missing figures belong to cases in which the images, on account of imperfect pointing, are not circular but elongated; while for stop 1 the images are so close together that the larger ones overlap, and, consequently, were not used.

The equation which fairly represents these diameters is:

$$d = 0^{\text{in}}.0070 + 0^{\text{in}}.0050 \log D + 0.0074 D \log t \tag{6}$$

the individual values of γ, found by dividing each b by the corresponding D, are:

b	$\div$	D	$=$	γ
0.0067	$\div$	.902	$=$	0.0074
46		.765		.0060
42		.635		.0066
46		.552		.0083
34		.453		.0075
30		.385		.0078
27		.318		.0085

The observed values of d, minus the values computed by equation (6), are as given below:

α Lyræ .

Exposure Time.	Observation—Computation.						
	1	2	3	4	5	6	7
1^{s}	+0.0005	(+0.0024)	+0.0013	+0.0004	+0.0002	−0.0002	0.0000
2	+ .0006	.0010	——	+ .0001	.0000	− .0001	− .0004
4	− .0005	− .0002	——	− .0001	− .0003	——	− .0002
8	——	− .0008	.0000	+ .0015	− .0003	− .0002	.0000
16	——	− .0007	− .0002	+ .0008	− .0005	——	− .0001
32	——	− .0003	− .0001	− .0004	+ .0001	——	+ .0003
64	——	+ .0003	+ .0006	− .0009	+ .0006	——	——

From equation (6) we infer that, for six inches aperture and one second exposure time, the diameter of α *Lyræ's* image on this particular plate is $0^{\text{in}}.0070$. Comparing equation (6) with equation (5) we learn that the increase in the diameter of the image of α *Lyræ* on this plate for any t is 2.2 times as rapid as it is in the case of *Polaris* for the same t on the plate first described; so that, if other things were equal, the difference between the photographic energy of two stars could be more accurately determined from comparatively long exposures than from short ones. (The *rate* of increase, of course, varies inversely as t.)

Now, let

$$d = \alpha_0 + \beta_0 \log D + \gamma_0 D \log t \tag{7}$$

be the equation giving the diameters for a particular star taken as a standard, and let

$$d' = \alpha + \beta \log D_0 + \gamma D_0 \log t \tag{8}$$

be the equation which gives the diameter of the image of *any* star for the *constant aperture* D_0 (unity $= 6^{\text{in}}$); then if Q represents the particular aperture in equation (7) which, for the same value of t makes $d = d'$, the reciprocal of this quantity, or $\frac{1}{Q}$, substituted in place of D_0 must, for all values of t, satisfy equation (8) for $d' = d$ if the assumed law[4] is theoretically

[4]The law expressed in equations (1) and (7).

exact. Q, then, becomes a measure of the square root of the relative brightness of the two stars, since, if we assume that the amount of energy required to produce a given impression on a given plate is always the same, whatever the unit of energy (intensity) may be, the total amount of energy for the same telescope can be considered as varying directly with the area of the aperture, or with D^2. Hence, if B_0 and B denote respectively the brightness of the standard and comparison stars, we can at once write:

$$\left(\frac{Q}{D_0}\right)^2 = \frac{B}{B_0} \tag{10}$$

Q being that value of D which when substituted in the equation for the standard star (equation 7) will make $d = d'$. In other words, Q *is the diameter of the aperture which the standard star would require to produce, in the time* t*, an image having the same diameter as that of any other star photographed with an aperture* D_0 (= six inches) *in the same time* t. Equation (7) can therefore be written:

$$d' = \alpha_0 + \beta_0 \log Q + \gamma_0 Q \log t \tag{11}$$

Let us now take the equations deduced from the measured diameters of the images of *Polaris* and *α Lyræ*, and see to what degree of accuracy the necessary theoretical relations between Q and D_0 will represent the observed data. For $d = d'$ we have the equation:

$$0.0055 + 0.0033 \log Q + 0.0034 Q \log t = 0.0070 + 0.0050 \log D_0 + 0.0074 D_0 \log t$$

After a few trials, for different values of t, we obtain the approximate value $D_0 = 0.48$ when $Q = 1$, and, according to the above considerations, we should also have $Q = 2.10$ when $D_0 = 1$. Both of these conditions should be fulfilled for all values of t.

As the images of the two stars are on different plates I have not thought it worth while to derive a more accurate relation between Q and D_0 for this particular case.

The approximate relation will, however, serve to show the agreement between our theory and the data derived from actual observations.

The accompanying table contains the computed values of d and d' for each t, for reciprocal values of Q and D_0:

Exposure Time.	D_0= 1.00, Q = 2.10		D= 0.48, Q= 1.00	
	Polaris d	*α Lyræ* d'	*Polaris* d	*α Lyræ* d'
1^s	0.0070	0.0066	0.0055	0.0054
2	.0087	.0092	.0065	.0065
4	.0109	.0114	.0075	.0075
8	.0130	.0140	.0086	.0086
16	.0151	.0159	.0096	.0097
32	.0173	.0181	.0106	.0107
64	.0195	.0204	.0117	.0118

If the two sets of star images had been impressed upon the same plate, we would have inferred the photographic brightness of *α Lyræ* to be about 4.4 times that of *Polaris*.[5] As,

[5]Neglecting atmospheric absorption.

however, the diameters of the star images on different plates taken from the same box are not always the same for equal exposures, it became necessary to make a separate investigation covering this particular phenomenon.

I found that if we express the diameters of the image of *Polaris* on any plate in terms of the diameters given on the plate for which equation (5) holds good (which we will call the standard plate), we have only to multiply the second member of equation (5) by such a number x that for a given t the measured d will be satisfied. From a series of comparisons I find that x is practically constant for the different values of t. The general equation for any No. 26 Seed plate exposed in the stellar focus of the particular telescope used in these investigations I therefore assume to be

$$\frac{d}{x} = 0^{\text{in}}.0055 + 0^{\text{in}}.0033(\log Q + Q \log t) \tag{12}$$

since, for all practical purposes, β_0 and γ_0 in equation (5) are the same.

To find the value of Q from this equation we can write:

$$\log Q + Q \log t = \log \left(Qt^Q\right) = \frac{d}{0.0033 \centerdot x} - 1.67 \quad . \tag{13}$$

In order, however, to facilitate the determination of Q for certain observed values of d and t, I have computed the following table, by means of which Q can be obtained by simple interpolation.

The horizontal argument is Q, the vertical argument is t, and the tabular function corresponding to these arguments is the measured d of equation (13) for $x = 1.00$.

Exposure Time.	Q.									
	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00
2^s	0.0046	0.0060	0.0070	0.0078	0.0085	0.0091	0.0098	0.0103	0.0109	0.0114
4	.0050	.0068	.0081	.0093	.0105	.0115	.0125	.0135	.0145	.0154
8	.0054	.0078	.0093	.0109	.0125	.0139	.0153	.0167	.0181	.0194

If for a particular plate any measured diameter is d, the argument for entering the above table is $x \centerdot d$, and x is to be taken as a constant for the same plate.

We will now give a few examples illustrating the application of the formulas for determining the brightness of the fixed stars:

Example I. On September 5th, 1889, *Polaris*, α *Aurigæ*, γ *Cephei* and α *Tauri* were photographed on the same plate with exposures of 2^s, 4^s and 8^s. The measured diameters are:

Exposure Time.	Measured Diameters ($= d$).			
	Polaris.	α *Aurigæ.*	γ *Cephei.*	α *Tauri.*
2^s	0.0064	0.0081	0.0042	0.0060
4	.0074	.0090	.0052	.0061
8	.0080	.0109	.0056	.0072

The aperture being six inches for all the exposures, we first assume the plate to be a standard one, and find d with the argument $Q = 1$, either by means of equation (5) or, by interpolation, from the table:

Polaris.

Exposure Time.	Computed d.	O − C.
2^s	0.0065	−0.0001
4^s	.0074	0.0000
8^s	.0085	−0.0005

As the measured values are slightly smaller than those given by our assumed standard plate, we give x such a value that the (O − C) quantities will nearly balance each other. Placing $x = 1.03$ and multiplying the observed values of d by 1.03, the residuals (O − C) become respectively +0.0001, +0.0001, and −0.0003.

To obtain the value of Q by direct computation, for any star whose image is on this particular plate, we would therefore use the equation

$$\log Q + Q \log t = \frac{d}{0.0034} - 1.67 \tag{15}$$

in which d is the measured diameter corresponding to the time t.

The tabular values at once give the desired quantities by interpolation, first multiplying each measured d by 1.03 for the argument:

Exposure Time.	Values of $Q - \sqrt{B}$			
	Polaris.	*αUrigæ.*	*γ Cephei.*	*α Tauri.*
2^s	1.04	1.89	0.32	0.84
4^s	1.05	1.60	0.32	0.69
8^s†	0.90	1.68	0.47	0.73
Mean	1.00	1.72	0.42	0.75

† Transcriber's note: Original text reads 5^s

Using the mean values of Q, we obtain the following residuals:

Exposure Time.	Observation − Computation			
2^s	0.0000	+0.0003	−0.0003	+0.0003
4	+ .0002	− .0004	+ .0002	− .0003
8	− .0003	− .0002	+ .0003	− .0001

If we use the familiar expression for the light-ratio of visual magnitudes,

$$B = (0.4)^{m-1}$$

(in which B and m are respectively the visual brightness and visual magnitude of any star) for expressing also the light-ratio for the photographic magnitudes m', we can write

$$m' = 1 - \frac{\log.(\kappa \cdot Q^2)}{\log. 0.4} \tag{17}$$

in which κ is a constant depending upon the photographic magnitude of the standard star. For the purpose of comparing the photographic with the visual magnitudes, let us take *Polaris* as the standard star, and assume its photographic magnitude to be 2.00; equation (17) becomes

$$m' = 2 - \frac{\log Q^2}{0.4}$$

The values of m', for certain values of Q, can be taken from the accompanying table, which I have computed for illustration:

Q	0.00	0.20	0.40	0.60	0.80
0.00		5.49	3.99	3.11	2.48
1.00	2.00	1.60	1.27	0.98	0.72
2.00	0.50	0.29	0.10	−0.07	−0.24
3.00	−0.39	−0.53	−0.66	−0.78	−0.90

From an inspection of the table and the values of Q given in the next example, we see at once that if we wish to avoid negative numbers for expressing some observed magnitudes we must either represent the magnitude of *Polaris* by a greater number or change the light-ratio.

I have tabulated the photographic magnitudes of the four stars, together with the probable errors. The visual magnitudes as given in Volume XIV, *Harvard College Observatory Annals*, and the differences between the photographic and visual magnitudes, are also added:

Star.	Photog. Mag.	Probable Error.	Visual Mag.	Vis. − Photog.
Polaris	2.02	±0.11	2.2	+0.2
α *Aurigæ*	0.82	0.11	0.2	−0.6
γ *Cephei*	4.20	0.28	3.4	−0.8
α *Tauri*	2.62	0.13	1.0	−1.6

Example II. During the night of September 6, in bright moonlight, I made exposures of 2^s, 4^s and 8^s on *Polaris*, α *Lyræ*, α *Cygni*, α *Aquilæ*, and four hours later the same plate was exposed on α *Pisces Australis*, β *Ceti*, α *Aurigæ*, α *Arietis* and α *Andromedæ*. The measured diameters are tabulated below. For this plate we see at once that the differences between the observed and computed values of d are such that the $(C - O)$ values (+0.0001, -0.0003 and +0.0003) practically balance each other; hence we place $x = 1.00$ and use equation (13) (or the table) to obtain the values of Q given below. For the $(O - C)$ values the computed quantities are obtained by substituting the mean values of Q in equation (12):

Exposure Time.	Measured Values of d								
	Polaris.	α *Lyræ.*	α *Cygni.*	α *Aquilæ.*	α *Pis. Aust.*	β *Ceti.*	α *Aurigæ.*	α *Arietis.*	α *Androm.*
2^s	0.0066	0.0103	0.0092	0.0090	0.0077	0.0049	0.0075	0.0053	0.0079
4	.0072	.0134	.0116	.0106	.0087	.0054	.0094	.0063	.0090
8	.0088	.0169	.0136	.0129	.0099	.0060	.0106	.0066	.0116
Exposure Time.	**Resulting Values of $Q = \sqrt{B}$.**								
2^s	1.04	3.20	2.46	2.33	1.55	0.49	1.45	0.60	1.66
4	0.92	3.16	2.44	2.04	1.40	0.49	1.63	0.69	1.50
8	1.07	3.26	2.31	2.11	1.35	0.50	1.52	0.60	1.77
	1.01	3.21	2.30	2.15	1.43	0.49	1.53	0.63	1.64
Exposure Time.	**The Mean Values of Q, give the Residuals.**								
2^s	+0.0000	0.0000	+0.0002	+0.0003	+0.0002	0.0000	−0.0002	−0.0001	0.0000
4	+ .0001	− .0001	+ .0003	− .0002	.0000	.0000	+ .0003	+ .0003	− .0004
8	− .0003	+ .0002	.0000	− .0001	− .0003	+ .0001	+ .0001	− .0001	+ .0005

The numbers expressing the photographic brightness of each star in terms of that of *Polaris* are therefore, in the above order, 10.3, 5.3, 4.6, 2.0, 0.2, 2.3, 0.4 and 2.7. The only star of the list which was near to the zenith at the time its image was formed on the photographic plate is α *Lyræ*; the effect of moonlight, atmospheric absorption and haze would therefore be at a minimum for this star, and its relative brightness would apparently be near a maximum. The same remarks apply to the results given in the next table as in the last example:

Star.	Photog. Mag.	Probable Error.	Visual Mag.	Vis. − Photog.
Polaris	+1.95	±0.05	+2.2	+0.2
α *Lyræ*	−0.53	±0.02	+0.2	+0.7
α *Cygni*	+0.10	±0.03	+1.5	+1.4
α *Aquilæ*	+0.34	±0.06	+1.0	+0.7
α *Pis. Aust.*	+1.22	±0.05	+1.3	+0.1
β *Ceti*	+3.53	±0.01	+2.1	−1.4
α *Aurigæ*	+1.08	±0.05	+0.2	−0.9
α *Arietis*	+3.01	±0.07	+2.0	−1.0
α *Androm.*	+0.93	±0.07	+2.1	+1.2

No corrections for absorption, etc., have as yet been applied to the above results, which consequently refer to the apparent magnitude at the instant of exposure. The last column of the above table plainly shows that we can make no definite *a priori* estimate as to what the photographic magnitude of a star is if we simply know its visual magnitude. There is therefore no advantage (as Professor Holden has pointed out in his "Memorandum" to the Paris Photographic Conference) in following the methods used for visual magnitudes.

It is evident that we must first know the law of atmospheric absorption of the photographic rays before we can determine the true relative brightness of the stars; since each observed brightness requires a certain plus correction, depending directly upon the zenith distance, to reduce it to the brightness which would have been obtained at the zenith. Or each observed brightness could be reduced to what it would be at a certain zenith distance, as, for instance, that of the celestial pole at a given place. The photographs already taken show that this correction is quite sensible, even at small zenith distances. From some preliminary reductions I find that for this Observatory (altitude 4209 feet) the absorption of stellar photographic brightness at 80° zenith distance is considerably more than fifty per cent. of the brightness reduced to 0° zenith distance. After a complete series of observations bearing upon this subject has been obtained at sea-level near the earth's equator, I hope to give, in a more or less complete state, the photographic magnitudes of a large number of the brighter stars in both hemispheres. Just how far down the scale of magnitudes the formulæ will hold good I am, as yet, unable to say.

In photographing faint stars the exposure time should evidently be so long as to make the diameters of the disks as great or greater than the faint penumbral image which, in the telescope used, surrounds the primitive umbral image in short exposures on faint stars; when this precaution is taken, it seems that the formulæ give consistent results, judging from a few experimental exposures. This form of image for short exposures on faint stars may, of course, be peculiar to this particular telescope. Too much stress cannot be laid upon the statement, *that if reliable results are to be obtained*, the objective must be of the first order of excellence and *the plate must be kept exactly in the stellar focus*.

Throughout this whole discussion I have purposely avoided bringing in any relation between aperture and focal length, as it seems probable that different telescopes must be compared before any definite conclusions can be drawn.

The results contained in the present paper are only to be considered as preliminary to a much more extended investigation to be undertaken in South America under the auspices of this Observatory, made possible through the generosity of Col. Crocker.

In conclusion, I wish to express my obligations to Professor Holden, Director of this Observatory, for his readiness in placing at my disposal everything which could in any way aid me in past and future investigations; for his practical help and advice relating to a subject which has claimed his attention for some time past, and which is destined to become the most important method of investigation in our science, viz: *Astronomical Photography*.

I also wish to thank Mr. Burnham for his kind and willing assistance in the photographic work.

J. M. Schaeberle.

Lick Observatory, September 21, 1889.

ON THE ESTABLISHMENT OF A STANDARD MERIDIAN LINE FOR SANTA CLARA COUNTY, CALIFORNIA.

By James E. Keeler.

A few months ago, at the suggestion of Professor Holden, Mr. Chas. Herrmann, County Surveyor of Santa Clara county, and Mr. A. T. Herrmann, Surveyor and Civil Engineer, obtained the permission of the County Supervisors to establish a standard meridian line in San José, for the benefit of surveyors, with a sufficient sum of money to provide suitable monuments.

It was agreed that the astronomical staff of the Observatory should make the necessary observations without expense to the county, and I was appointed to carry out the work.

Absolute directions on the earth can only be determined by reference to the heavenly bodies. The magnetic needle has been and still is extensively used as a secondary means of determining directions, but the angle which the magnetic needle makes with the true meridian is constantly changing, and is, moreover, subject to sudden and irregular variations, so that, even with the greatest precautions, the compass is an unsafe guide. Ignorance of these facts, or of the amount of necessary allowance from lack of a suitable standard of reference, has given rise to an endless amount of litigation in this country. It is safe to say, that if each county in the Union had legally established a standard meridian in the early days of its settlement, the gain to the country would have to be estimated by hundreds of thousands of dollars.

The remedy for the evils resulting from the secular change of the magnetic declination has been repeatedly pointed out, ever since the days of Rittenhouse. Prof. Gillespie, in his well-known work on Land Surveying, says (p. 210): "The only complete remedy for the disputes, and the uncertainty of bounds, resulting from the continued change in the variation, is this: Let a meridian, *i. e.*, a true north and south line, be established in every town or county, by the authority of the State; monuments, such as stones set deep in the ground, being placed at each end of it. Let every surveyor be obliged by law to test his compass by this line, at least once in each year. . . . . Let the variation thus ascertained be inserted in the notes of the survey and recorded in the deed. Another surveyor, years or centuries afterward, could test his compass by taking the bearing of the same monuments, and the difference between this and the former bearing would be the change of variation. He could thus determine, with entire certainty, the proper allowance to be made in order to retrace the original line, no matter how much, or how irregularly, the variation may have changed, or how badly adjusted was the compass of the original survey."

But although these evils have been thus forcibly stated, even in the text-books of every school, and the remedy so clearly pointed out, very little interest has been taken in the matter by State authorities. Professor Holden, while Director of the Washburn Observatory, once proposed to establish a standard meridian in every county-seat in the State of Wisconsin, for the bare personal and traveling expenses of an observer, an offer which was declined without thanks.

There is no doubt that the Lick Observatory would assist in such a plan for California, by every means in its power, should the proper authorities be willing to pay the bare expense of the undertaking.

It may be noted that the value of a standard line of reference is particularly great in a newly settled country, where the compass is more relied upon than it is in older communities with well-established boundaries and landmarks.

The scene of our operations in San José was what is known as the "Meridian Road," because it is supposed to be in the line of the Mt. Diablo meridian. It has been the practice of surveyors to test their instruments by sighting up and down this road, which, however, contains no marks sufficiently definite to admit of a precise determination by this method. The north end of the road terminates at a high board fence which forms the southern boundary of the Fair Ground, and on a shelf secured to this fence a mark was put up, consisting of a hole one-half inch in diameter in a thin plate, illuminated from behind by a bull's-eye lantern. Two thousand feet south of the mark a substantial pier of brick and cement was built for the support of the instrument. The mark was as nearly in the meridian of the pier as could be determined with the aid of a compass. At the pier it subtended an angle of 4″, and to the naked eye appeared as a star of about the first magnitude.

The instrument employed was the Repsold altazimuth briefly described in Vol. I, Publications of the Lick Observatory, and more completely in my report on the geographical position of Norman, California, in the Reports on Observations of the Total Eclipse of January 1, 1889, published by the Lick Observatory. It has vertical and horizontal circles ten inches in diameter, read to 2″ by micrometer microscopes, or by estimation to 0″.2. All necessary attachments are provided for exact astronomical work. The time-piece used was a sidereal chronometer, Negus 1720.

Preliminary observations were made on the night of August 5th, and more accurate ones on August 6th and 7th. The azimuth of the mark was determined by alternate readings on the mark and on *Polaris* near eastern elongation, the instrument being reversed during the measurements to eliminate the error of collimation. The latitude of the pier was determined, with sufficient accuracy, by measuring the zenith distances of four stars with the vertical circle, and the local sidereal time by using the altazimuth as a transit instrument. No elaborate time observations were made, as a knowledge of the time to within one second is amply sufficient for computing the small reductions to elongation. The horizontal circle was turned one-third round on August 7th, in order to bring different divisions under the microscopes.

Ten observations of the mark and ten of *Polaris*, on August 6th, made the mark 1° 22′ 48″.0 west of the vertical circle passing through the point of elongation. The computed azimuth of the star corrected for diurnal aberration, was 1° 37′ 7″.2, hence the azimuth of the mark was +0° 14′ 19″.2.

From six observations of the star and six of the mark, on August 7th the mark was west of the star 1° 22′ 50″.6. The computed azimuth of the star was 1° 37′ 6″.8, and hence the azimuth of the mark was +0° 14′ 16″.2. The adopted azimuth of the mark was 14′ 17″.7 east, which, at a distance of 2000 feet, corresponds to 8 feet 3.8 inches, and the mark was moved this distance to the west to bring it into the meridian of the centre mark on the pier. The estimated probable error of the meridian is 2″ or about one-quarter of an inch at a distance of 2000 feet, a quantity thirty times smaller than the smallest angle which is measured with ordinary surveying instruments. From the above data permanent monuments will be established by the Messrs. Herrmann.

For the convenience of those who cannot avail themselves of this meridian line, I have computed the following table of azimuths and times of elongation of *Polaris* for the latitude and longitude of San José. The azimuths are given to the nearest 10″; the times of elongation in *Standard Pacific Time* to the nearest minute. For San Francisco the azimuths must be increased by 40″, and the times of elongation will be about two minutes later. An error of thirteen minutes in the time of elongation will produce an error of only 10″ in the azimuth. The formulæ from which this table was computed may be found in DOOLITTLE'S Practical Astronomy (p. 527).

If the meridian is determined from observations of *Polaris* near elongation by a surveyor's transit, the line of collimation must be adjusted with especial care, so as to travel on a truly vertical line. As there are several minutes near elongation during which the azimuth of the star does not differ appreciably from the tabulated value, it is better to make two observations of the star, one with reversed position of the telescope, and take the mean of the readings of the horizontal circle. It must be remembered that the reading of the compass needle, when the sight line of the instrument is in the meridian, is not necessarily the magnetic declination, since the line of zeros of the compass circle may not be in the same plane with the line of collimation (as, of course, it should be). The reading of the needle will, however, be the declination *for that particular instrument*, and true bearings can be taken just as well as if the adjustment were perfect.

TABLE OF AZIMUTHS AND TIMES OF ELONGATION OF *Polaris*.
(Computed for the latitude and longitude of San José, Cal., by J. E. KEELER.)

DATE.			W. ELONGATION.			E. ELONGATION.			AZIMUTH.		
			h.	*m.*		*h.*	*m.*		°	′	″
1889.	Sept.	6…	8	19	A.M.	8	25	P.M.	1	37	00
	"	16…	7	39	"	7	46	"	1	36	50
	"	26…	7	00	"	7	06	"	1	36	50
	Oct.	6…	6	21	"	6	27	"	1	36	40
	"	16…	5	42	"	5	48	"	1	36	40
	"	26…	5	03	"	5	08	"	1	36	30
	Nov.	5…	4	23	"	4	29	"	1	36	30
	"	15…	3	44	"	3	50	"	1	36	20
	"	25…	3	05	"	3	11	"	1	36	20
	Dec.	5…	2	25	"	2	31	"	1	36	20
	"	15…	1	46	"	1	52	"	1	36	10
	"	25…	1	06	"	1	12	"	1	36	10
1890	Jan.	4…	12	27	"	12	33	"	1	36	10
	"	14…	11	43	P.M.	11	53	A.M.	1	36	10
	"	24…	11	04	"	11	14	"	1	36	10
	Feb.	3…	10	24	"	10	34	"	1	36	10
	"	13…	9	45	"	9	55	"	1	36	10
	"	23…	9	06	"	9	16	"	1	36	10
	Mar.	5…	8	26	P.M.	8	36	A.M.	1	36	20
	"	15…	7	47	"	7	57	"	1	36	20
	"	25…	7	07	"	7	17	"	1	36	20
	April	4…	6	28	"	6	38	"	1	36	30
	"	14…	5	48	"	5	58	"	1	36	30
	"	24…	5	09	"	5	19	"	1	36	40
	May	4…	4	30	"	4	40	"	1	36	40
	"	14…	3	50	"	4	00	"	1	36	40
	"	24…	3	11	"	3	21	"	1	36	50

Date.			W. Elongation.			E. Elongation.			Azimuth.		
			h.	*m.*		*h.*	*m.*		°	′	″
	June	3...	2	32	"	2	42	"	1	36	50
	"	13...	1	53	"	2	03	"	1	36	50
	"	23...	1	14	"	1	23	"	1	36	50
	July	3...	12	35	"	12	44	"	1	36	50
	"	13...	11	55	A.M.	12	04	"	1	36	50
	"	23...	11	16	"	11	22	P.M.	1	36	50
	Aug.	2...	10	37	"	10	43	"	1	36	40
	"	12...	9	58	"	10	04	"	1	36	40
	"	22...	9	19	"	9	25	"	1	36	40
	Sept.	1...	8	40	"	8	46	"	1	36	30
	"	11...	8	00	"	8	06	"	1	36	30
	"	21...	7	21	"	7	27	"	1	36	30
	Oct.	1...	6	42	"	6	48	"	1	36	20
	"	11...	6	02	"	6	08	"	1	36	20
	"	21...	5	23	"	5	29	"	1	36	10
	"	31...	4	44	"	4	50	"	1	36	00
	Nov.	10...	4	05	"	4	10	"	1	36	00
	"	20...	3	25	"	3	31	"	1	36	00
	"	30...	2	46	"	2	52	"	1	35	50
	Dec.	10...	2	07	"	2	12	"	1	35	50
	"	20...	1	27	"	1	33	"	1	35	50
	"	30...	12	48	"	12	54	"	1	35	50
1891	Jan.	9...	12	09	"	12	14	"	1	35	40

OCCULTATIONS OF STARS BY THE MOON.

Observed by A. O. Leuschner.

Date.	Star.	Mt. H. M. T. of Disappearance.			Telescope.	Power.	Remarks.
1889.		h.	m.	s.			
Aug. 29	S D. (− 3°) 3459	7	26	31.9	12-in.	80	Good.
" 29	S D. (− 3°) 3468	8	5	26.6	"	"	
" 29	S D. (− 3°) 3469	8	[10]	2.3	"	"	Minute probably 10.
" 29	S D. (− 3°) 3470	8	13	40.1	"	"	Good.
" 30	S D. (− 8°) 3733	7	27	22.5	"	"	"
" 30	S D. (− 8°) 3736	7	39	51.1	"	"	"
" 30	S D. (− 9°) 3896	7	58	51.5	"	"	"
" 30	S D. (− 8°) 3739	8	17	24.7	"	"	"
" 30	S D. (− 9°) 3898	8	19	24.0	"	"	"
Sept. 2	S D. (− 21°) 4494	7	48	45.1	6-in.	75	"
" 2	S D. (− 21°) 4496	7	50	32.9	"	"	"
" 2	S D. (− 21°) 4512	9	10	59.9	12-in.	80	"
" 3	C Z. XVII h. 3871	7	54	10.9	"	"	
" 3	C Z. XVII h. 3960	8	13	50.7	"	"	
" 3	C Z. XVII h. 3978	8	22	40.4	"	"	"
" 3	Anonymous 9.0						
	*17h. 58m. 26s.; −23° 16′.0	9	12	46.4	"	"	"
" 3	Anonymous 9.0						
	*17h. 58m. 37s.; −23° 18′.7	9	15	28.9	"	"	"
" 3	Anonymous 9.0						
	*17h. 58m. 12s.; −23° 27′.3	9	34	24.5	"	"	"
" 3	W M Z. 175	9	50	8.6	"	"	"
" 3	Anonymous 8.0						
	*18h. 0m. 1s.; −23° 27′.0	10	0	0.2	"	"	"
" 3	Anonymous 8.5						
	*18h. 0m. 41s.; −23° 26′.4	10	21	8.4	"	"	"
" 3	C Z. XVII h. 133	10	23	24.4	"	"	"

* These positions are for 1850.0.

CONJUNCTION OF MARS AND SATURN (Sept. 20, 1889).

By W. E. Downs.

The observations were made with the four-inch broken-tube comet-seeker. The times were noted on a watch running on P.S.T. A magnifying power of about thirty diameters was used.

4^h 00^m. First sight of *Saturn* and *Mars* in the telescope, through a very dense haze. *Mars* appeared as a very red, ill-defined spot of light. *Saturn* was very red, but less so than *Mars. Regulus* was also visible in the same field, to the south, and eight or ten times more distant from the planets than the space between them, and was of a lighter red color and fainter than either planet.

4^h 15^m. Both planets were visible to the naked eye, and easily separated as soon as seen.

4^h 25^m. *Saturn*, in the telescope, was of an orange color, and *Mars* of a light red.

4^h 45^m. To the eye *Saturn* was about as bright as *Polaris*, and *Mars* a little fainter.

5^h 15^m. Broad daylight approached fast. *θ Tauri* was still easily visible to the naked eye, and *c Orionis*, fifth magnitude, was barely visible and disappeared at 5^h 20^m. *θ Orionis* disappeared at 5^h 23^m, and *Saturn* and *Mars* at 5^h 30^m.

5^h 40^m. *Saturn* and *Mars* were of a very light yellow color in the telescope; *Mars* being very slightly tinged with red. *Regulus* was white.

5^h 50^m. *Venus* was still easily visible to the eye. The clouds were getting ruddy in the east. *Saturn* and *Mars* were growing very rapidly fainter. After this *Regulus* was not kept in the field of the telescope.

5^h 55^m. *Mars* was easier to see than *Saturn*, the light from it being more vivid.

6^h 00^m. *Saturn* and *Mars* last seen in the telescope, and the sun's disc about two-thirds up. As the sun rose, its disc was round and red, and was crossed by horizontal cloud-belts.

6^h 05^m. *Venus* was still visible to the eye.

6^h 10^m. Lost sight of *Venus*, and did not again recover it. The sun was too far up to look at comfortably.

Regulus, Saturn and *Mars* formed an interesting triangular group, the angle at *Saturn* being slightly obtuse. This angle remained sensibly the same throughout the observations, although the planets were separating.

W. E. Downs.

Mt. Hamilton, 1889, Sept. 22.

A VERY REMARKABLE COMET.

By Edward E. Barnard.

On the morning of July 7th, a small comet was discovered by Mr. Brooks in the constellation Cetus. The moon coming into the morning sky blotted the comet out before any observations (except three at the Lick Observatory) could be made of it. When a sufficiently long interval was obtained the orbit was computed, and from the small inclination of its path to that of the earth it was at once suspected to be periodic; the suspicion has since been verified, the comet having a period of about seven or eight years. This was sufficient of itself to make it of more than ordinary interest. While observing this object in the first part of August I discovered that it was attended by at least four companions, which were moving through space in advance of the main comet. Two of these companions were discovered with the twelve-inch on August 1st, and the other two on August 4th with the great telescope. These last two were seen several times, but always remained too faint to be measured, and finally disappeared.

The two brighter companions were perfect miniatures of the larger comet, each having a small, fairly well-defined head and nucleus, with a faint, hazy tail, the more distant one being the larger and less-developed. The three comets were in a straight line, nearly east and west, their tails lying along this line. There was no connecting nebulosity between these objects, the tails of the two smaller not reaching each other or the large comet. To all appearance they were absolutely independent comets. The four which were discovered here I have named B, C, D, E, in the order of increasing right ascension, A being the original comet discovered by Mr. Brooks. As D and E disappeared after a few observations, they will not be again referred to; they were both north following C and in a line with it.

Since discovery I have measured these objects on every available occasion, using the micrometer of the thirty-six-inch equatorial. It was found that these two were separating from the main comet quite rapidly; the more distant one moving the fastest. Towards the latter half of August the nearer companion B ceased to recede, and then underwent a remarkable change. It enlarged rapidly, becoming extremely diffused, and losing all appearance of central condensation. It could be measured only with the utmost difficulty. Throughout its visibility its position angle remained almost constant; towards the last, however, this angle began slowly but sensibly to increase as if the companion were in orbital motion. Unfortunately, at this most important point in the observations, the companion faded rapidly and totally from view, being last seen on the 5th of September. It disappeared as absolutely from the face of the heavens as did Biela's comet, which doubtless underwent a similar dissolution.

In the meantime the more distant companion continued to recede, and increased very much in brightness and size, until on August 31st it was perceptibly brighter than the larger comet! In the latter half of September it, too, became stationary with reference to the principal comet; remaining thus for some days, it began slowly to lessen its distance, having attained a maximum distance of 356″. This object has also undergone a change in appearance similar to that in the lost companion. Its tail has disappeared, and the head has become large and much diffused, its brightness in the meantime having diminished very greatly. The position angle of this object has remained remarkably constant for the past two months; it attained a maximum of about 62° in the middle of September; since then it has been slowly decreasing, until it is now the same as when first observed.

Measures of the companion B on twenty-two nights were obtained, and up to the present date measures of C have been made on forty nights.

The following, selected from the observations, will give an idea of the relative positions of this group:

			°		″
Aug. 1.	Position angle	A and B,	59.4;	distance A and B,	64.1.
Sept. 4.	" "	" " "	65.0	" " " "	71.5.
Aug. 4.	" "	A and C,	61.5	" A and C,	267.6.
Sept. 15.	" "	" " "	62.1	" " " "	356.4.
Sept. 30.	" "	" " "	61.4	" " " "	352.1.

It is hoped that through measures of the relative positions of these bodies we shall be enabled to detect orbital motion of the smaller ones about the larger. If this were shown to exist, we should at once have the means of determining the mass of this cometary system. These changes may, however, be due to perspective.

So far as we know, the phenomenon presented by this comet is extremely rare. It is needless to repeat the story of Biela's comet. In 1845 it separated into two distinct comets, which traveled side by side, and returning at the appointed time, they were seen to be widely separated—indeed, moving in distinctly separate paths; they then disappeared, to be seen no more in the heavens. One of the comets of 1861 was seen double for a few days. Some companions were seen moving with the Great Comet of 1882, but no measurements were made. This covers our knowledge of multiple comets, or comets with companions, unless, indeed, we accept the evidence of the Chinese records, which possibly describe comets that consisted of two or more parts.

Mt. Hamilton, September 30, 1889.

Note.—In order not to delay the publication of the present number, the printing of two papers on Drawings of *Jupiter* in the years 1875–1883, by Messrs. Holden and Barnard, is postponed to the next number.

NOTICES FROM THE LICK OBSERVATORY.

Prepared by Members of the Staff.

Photographing the Milky Way.

The great success obtained by Mr. Barnard in his preliminary experiments with the Willard portrait lens ($a = 5.9$, $f = 30.7$) has led to the determination to employ it in making a systematic study of the Milky Way by photography. For this purpose it has been mounted at the object-glass end of the tube of the great telescope, and arrangements made by which the lens can be capped and uncapped from the eye end. The driving clock of the great telescope (with a control) will keep the camera directed at the star-group chosen during an exposure of two hours. An independent equatorial stand for this instrument is very desirable, but cannot be had at present. Plates 8×10 are used, which correspond to about 16 by 20 degrees. The definition is good over the central 10 or 11 degrees. E. S. H.

Occultation of *Jupiter*, 1889, September 3.

Phenomenon Observed.	Initials of the Observer. Lick Observatory Mean Time.			
	J. E. K.	E. E. B.	C. B. H.	A. O. L.
	h. m. s.	*m. s.*	*m. s.*	*m. s.*
First Contact of *Jupiter*	5 25 39.1	25 41.3	25 43.5*	25 41.6
Second Contact of *Jupiter*	5 27 50.7	27 47.3	27 47.8	27 43.9
Reappearance of Satellite II	6 11 33±	......	......	......
Reappearance of Satellite IV.	6 16 46.2	......	......	......
Third Contact of *Jupiter*	6 19 17.2	......	......	19 26.2
Fourth Contact of *Jupiter*	6 21 39±	21 38.3::	21 39.5::	21 32.2
Reappearance of Satellite I	6 23 12.8	23 15.7::	23 16.0†	......
(Instrument employed)	*36-inch Tel.*	*12-inch Tel.*	*6½-in. Tel.*	*Comet seeker.*

Observers' Notes.—* 3–5 secs. late; † 2–3 secs. late.

Mr. Schaeberle obtained several photographs of the Moon and *Jupiter* after IVth Contact.

Observers: Mr. Keeler = J. E. K.; Mr. Barnard = E. E. B.; Mr. Hill = C. B. H.; Mr. Leuschner = A. O. L.

These observations have been printed *in extenso* in the *Astronomical Journal*, Vol. 9, page 84 *et seq.*

Examination of Stellar Photographs.

If it is desired to obtain *all* the information which can be had from a given negative, it is necessary to make a positive copy of it on glass, and to examine both negative and positive independently. Each presents a different set of contrasts. The negative will show the empty spaces and lanes between stars; the positive will show the arrangement of the stars themselves. It is only by examining both that *all* the information can be had from a given exposure. This is certainly true for stellar photographs, and it is even more important in regard to photographs of surfaces,—as nebulæ, the corona, etc. It should also be remembered that no single negative can establish the existence of a new nebula. At least two are required.

Experiments by Mr. Barnard have shown that many features may be brought out by the simple device of copying the whole of an 8×10 plate on a plate of $3\frac{1}{4} \times 4\frac{1}{4}$ inches. This process is analogous to the automatic one by which a person places a picture to be viewed at an appropriate distance for seeing the particular details he wishes to examine. Enlargements of negatives are sometimes serviceable, also. These simple precautions are worth mentioning, as they help to emphasize a fundamental point, namely,—that it is far more important to extract all possible information from a few photographs, than to make large collections of negatives without sufficiently examining each of them. E. S. H.

Review of the Early Numbers of the *Publications of the Astronomical Society of the Pacific*.

The *Vierteljahrsschrift* of the German Astronomical Society (Vol. 24, 1889, p. 210) has a very friendly review of the Nos. 1 and 2 of our own *Publications*, written by Professor E. Schoenfeld, Director of the Observatory of Bonn. The last paragraph is: "The Reviewer has no right to speak in this place in the name of the *Astronomische Gesellschaft*; but, in his own name and in that of other members, he expresses a hearty greeting to the new Society which has been founded on the Coast of the Pacific Ocean and wishes for it all success and prosperity."

It will be gratifying to our members to know of this early and courteous recognition of our modest beginnings. E. S. H.

Note on the Corona of January 1, 1889.

Professor Tacchini has a note in the *Atti della R. Accademia dei Lincei* 1889, page 472, on the corona as shown in a positive-copy on glass of one of Mr. Barnard's negatives. The corona extends, he says, from +64° to −68° on the west limb of the Sun, and from +53° to −68° on the east limb. These are about the limits of the zone of the maximum frequency of protuberances defined by Professor Tacchini's own observations. Two of the protuberances of the photograph were observed at Rome and at Palermo. The other protuberances shown on the photograph were not seen by the spectroscope, and Professor Tacchini surmises that they belong to the class of *white* protuberances discovered by him at the eclipses of 1883 and 1886. This surmise is completely corroborated by the observations of Professor Swift (L. O. Eclipse Report, 1889, Page 203). E. S. H.

Zenographical Fragments.

The Motions and Changes of the Markings on Jupiter, during 1886–7.

Under this title Mr. A. Stanley Williams, F.R.A.S., has printed a handsome octavo volume, of 118 pages and nine carefully executed plates, which gives the results of his own observations during 1886–7 with a $6\frac{1}{2}$ inch reflecting telescope (power 170). The work consists of seven sections, as follows: Section I treats of the instrument and the methods of observation (usually transits over the central meridian, 312 of which were observed); II treats of the construction of the chart of the markings on *Jupiter* (which gives the relative positions of all the spots from all the observations, reduced to the positions which they would have occupied had every observation been made April 21, 1887, the date of opposition); III speaks of the general arrangement of the belts, and gives an excellent system of nomenclature for the various separate features; IV, by far the longest section, presents the observations of the different spots in a most convenient form; V gives a summary of rotation periods in different Jovian latitudes; VI relates to the different altitudes (in *Jupiter's* atmosphere) of the different features; while VII treats of the repellant influence apparently exercised by the Red Spot on markings in its neighborhood.

This work deserves an extended notice, which cannot be given here; but it should not be allowed to pass without remark, since it affords an admirable example of just the kind of work which amateur observers can prosecute with great success. Its author (a professional man, constantly occupied) has chosen a definite problem, suitable to his instrumental equipment, and by dint of clear conceptions of the nature of the problem to be solved and of persevering observations in his leisure moments, has produced a work of lasting value. It appears that this volume is to be followed by others on the same subject from the same hand. It can be obtained from Mitchell & Hughes, publishers, 140 Wardour street, London. The price is not stated.

E. S. H.

Accommodation for Visitors to the Observatory.

In order to accommodate visitors to the Observatory on the public evenings, a continuous bench, long enough to seat one hundred persons, has been built on the east, south and west sides of the upper gallery of the large dome. As we sometimes have as many as two hundred and fifty visitors to the Observatory during one of our public nights, this addition has become necessary.

The Gundlach Optical Co., of Rochester, N. Y., is making a low-power eye-piece with a large field—something like half a degree—for the use of visitors who come to see the Moon. Such an eye-piece will show enough of the lunar surface to make a *picture* with a background of sky, which is what is really needed to convey the effect. The eye-pieces used in the regular astronomical observations have fields of view of hardly more than $10'$ of arc, and, hence, only serve to show a limited portion of the Moon's surface—less than one-tenth, usually. As the image of the Moon in the large telescope is 6.51 inches in diameter, it follows that the field lens of the new eye-piece must be of about the same dimensions. It will be useful in real work also, for objects like nebulæ and comets, where a large field and full contrast are required.

E. S. H.

American Equatorial Mountings on Sale in Berlin.

The Observatory has lately received the price-list of Th. Wegener of Berlin. So far as I have examined it, the instruments appear to be well-designed. It is not for this reason that it is mentioned, but because, on page 6, there is given a full-page wood-cut of the equatorial telescope and mounting of the Observatory of Beloit College, Wisconsin. This admirable mounting was made by Warner & Swasey, of Cleveland, from their own designs, and it is an excellent model to follow. It would have been more straightforward for Herr Wegener to have made some acknowledgment of the source from which he derived his model. His wood-cut has no title, and conveys the impression that the design was made by him. Messrs. Warner & Swasey have, however, no cause to complain. Imitation is the sincerest flattery. I can heartily recommend the design of the mounting which Herr Wegener proposes to make.

E. S. H.

Notes on Double Stars.

The Herschel companion to ϕ^1 *Aquarii* is shown in the 36-inch telescope to be a very close double star. From a single measure the distance appears to be less than 0″.15, and, of course, it is a different object, even in a large refractor. This companion has the same proper motion as the large star, and the relative change is practically nothing since the measures of Struve, in 1836, when the distance was 49″.63 in the position-angle of 312°.2.

Prof. Hough found the neighboring star ϕ^3(95) *Aquarii* double, with the Chicago $18\frac{1}{2}$-inch refractor, in 1884, the companion being eleventh magnitude, at a distance of a little more than 1″. Last year this was noted independently here with the 12-inch, and measured on three nights, the result being substantially the same as the single measure by Hough in 1884. In the course of the observations given above, this star was looked at with the 36-inch on two or three nights, but there was not the faintest trace of the companion. I am wholly unable to account for this failure, as there was apparently no change in the preceding four years. It should be carefully watched hereafter.

The sixth magnitude star, 44 *Cassiopeiæ*, has a minute attendant, hitherto unseen, at a distance of 1″.7 from the principal star.

Several new pairs have been found in the *Pleiades*, one of them following *Alcyone* 64^s and about 4′ north. This is a difficult pair, as the distance is only 0″.3, and the components below the ninth magnitude. Another new pair, still more difficult, is 55^s following *Pleione* (28 *Tauri*). The distance of this pair is about 0″.4, but the components are only $11\frac{1}{2}$ magnitude.

Since the time of Herschel, 67 *Ophiuchi* has been known as a wide double star (54″). The large telescope shows a very faint star at a distance of 6″.8.

The star D. M. 63°, 1618, has a very small companion at a distance of 4″.3. The principal star is brighter than sixth magnitude, but is strangely wanting in nearly all of the star catalogues covering this part of the heavens. It is not in the B. A. C., Radcliffe (1 and 2), Lalande, Argelander U. N., Heis, Piazzi, Bradley, Romberg, AOe, Grant, D'Agelet, Armagh, Yarnall, Bonn observations. In fact, it is found only in the D. M. and Rumker (No. 8289), the magnitudes being 5.9 and 5.6, respectively. In the Harvard Photometry the magnitude is 5.82. In observing it here as a double star the magnitude was estimated 5.8. It does not appear to be variable, and is probably a rare example of star catalogue omissions. The attention of meridian observers is called to this object.[6]

The double star, Σ2816, consists of a sixth magnitude primary, and two $7\frac{1}{2}$ m. companions with distances from the larger star of about 12″ and 20″, respectively. These stars have remained relatively fixed since 1832. The large telescope shows a minute companion within 1″.5 of the large star.

The fifth magnitude star, 2 *Andromedæ*, is a very close and difficult pair, the distance being only 0″.8, and the components quite unequal. This was suspected with the 12-inch, and verified and measured with the 36-inch.

HERSCHEL noted a ninth magnitude companion to α *Cassiopeiæ* at a distance of 63″. The large telescope shows a very faint star at a distance of 17″.5.

The distance of the close pair in γ *Andromedæ* (0Σ38) is now less than 0″.1. It is very difficult, and the best conditions are necessary to see the elongation at all with the large telescope.

The binary star, 7 *Tauri*, has been rapidly changing. The distance now is 0″.30.

The large refractor fails to show any third star in the system of 70 *Ophiuchi*, and both components are single with all powers. At one time 72 *Ophiuchi* was thought to be double (0Σ342), but no companion can be seen here. S. W. B.

NOTES ON STELLAR SPECTRA.

The spectra of the following stars (among many others) have been examined here during the past summer with a small spectroscope attached to the 36-inch equatorial, and in response to inquiries which have been made, I give below a preliminary statement of the results. The spectroscope which was used has no measuring apparatus, and the positions of lines are merely eye estimates.

γ *Cassiopeiæ*. This star is the most conspicuous example of VOGEL'S class I*c*, and remarkable changes in the bright lines in its spectrum have been observed by VON KONKOLY, VON GOTHARD and others. I have therefore examined it frequently, but, so far, no changes have been seen. The C and F lines are brilliant, narrow and sharp; Hγ, in the violet, is seen with some difficulty. The green is full of very fine, delicate dark lines, seen only under good atmospheric conditions, the *b* group being somewhat more prominent than the others. There is also an appearance of faint bright lines in the green, which may be due to the actual existence of bright lines, or, perhaps, to spaces between the fine dark lines just mentioned, seeming bright by contrast. It is difficult to decide on this point. There are in all eight or ten such places. Somewhat nearer to C than to the estimated position of D is a fairly prominent dark band, or, more probably, group of fine lines. Not the slightest trace of either dark or bright lines can be seen in the vicinity of D. The continuous spectrum close to the bright hydrogen lines appears somewhat darker than it does elsewhere, but this I have considered to be the effect of contrast.

U Cygni. This is a very red star, with a spectrum described by DUNÉR as III*b*. When examined with the 36-inch refractor it was of about the tenth magnitude, and the spectrum was dim, but the zones in the lower part could be distinguished. The blue was excessively faint. There was no appearance of bright lines.

[6]This star will be observed by Professor SCHAEBERLE with the L. O. meridian circle.—E. S. H.

V Cygni is also a very red star, and when examined with the spectroscope was of about the same brightness as *U Cygni*. Its spectrum is described by DUNÉR as III*b*! The sky was remarkably smoky when observations were made here, and the spectrum was dim, but at three places in the yellow and green shone with such comparative brightness that these places appeared like bright lines. The brightest was the more refrangible yellow line. It is possible that these lines may be the edges of the usual zones of class III*b*, as DUNÉR says the yellow and green zones are very bright, but the appearance was more like that of bright lines.

D. M. 43°, No. 3571. This is a star recently found by Prof. PICKERING, by the aid of photography (A. N. 2912), to belong to class II*b*. It is much like the other stars of this class found by Prof. PICKERING and by WOLF and RAYET. The faint spectrum connecting the principal bright lines in the spectra of these stars appears to be continuous with a small instrument, but with the 36-inch refractor is seen to be an extremely complicated range of absorption bands and faint bright lines. The above star differs from others that I have examined in the unusual broadness and diffuseness of these faint bands. J. E. K.

"AN IMPROVED ASTRONOMICAL MIRROR."

A device for constructing large telescope mirrors, which has recently been patented (at an expense of $60), is described under the above title in the *Scientific American* for September 7, 1889. The mirror is a flat, circular disc of metal, supported around its circumference by a flange or shoulder on the cell. Through a hole in its centre passes a bolt, and by turning a nut on the outside of the cell, the mirror is "buckled" into shape. The inventor has omitted to mention that by carrying the motion of the nut to a convenient position near the eye-piece a ready adjustment of the focus will be obtained. This method has the great advantages of simplicity and cheapness; its defects will be ascertained by the inventor when he comes to try it. J. E. K.

OBSERVATIONS ON THE NEAR APPROACH OF MARS AND SATURN ON SEPTEMBER 19, 1889.

The eastern sky was thick with haze when the two planets rose, and they were not visible until a considerable altitude was attained. At about 4 A. M. they could be seen dimly with the naked eye; *Mars*, small and insignificant, slightly east of *Saturn*. As soon as the images were at all measurable, I made a series of micrometrical observations of the two for position angle and distance, and for differences of right ascension and declination, using the 12-inch equatorial.

Following are the measures which are corrected for refraction in distance and in the $\Delta\delta$ and $\Delta\alpha$; the times being Mt. Hamilton mean time:

		d.	*h.*	*m.*	*s.*	
1889.	Sept.	19	16	16	39.	Position angle of *Mars*, 101°.0 (3).
"	"	19	16	24	24.	Dist. betw'n outer limbs of *Mars* and *Saturn*, 356″.1 (3).
"	"	19	16	29	14.	" " nearer " " " " 342″.3 (3).
"	"	19	16	34	19.	" " center and center, 358″.8 (3).
"	"	19	16	39	49.	Position angle of *Mars*, 101°.8 (4).
"	"	19	17	36	$29.^7$	$\Delta\,\delta$ ♂ − ♄ $-1'\ 39''.2$ (5) apparent.
"	"	19	17	45	$49.^7$	$\Delta\,\alpha$ ♂ − ♄ $-0^{m}29^{s}.91$ (11) apparent.

The most striking feature was when the two planets were fading from the advent of daylight. At the approach of day *Saturn* assumed a pale, ashy hue, with a slight tinge of yellow, while *Mars* retained its lustre in a surprising manner, being of a strong orange yellow in color; its north polar cap stood out strikingly towards the close of the observations, a dark marking being also visible near the middle of the disc. *Saturn* ceased to be visible in the telescope at 18h. 6m., the last glimpse being had a few seconds earlier. At this time *Mars* was easily conspicuous, the sun being 5° or 6° high and the sky pretty thick. At 18h. 10m. *Mars* began to grow pale. At 18h. 25m. it was still visible but very pale and easily lost in the field, though it could have been followed for some time longer. By the time the planets were high enough to observe with the large telescope they had separated too far to be brought into the field of view of the largest eye-piece. E. E. B.

Mt. Hamilton, Sept. 20th, 1889.

The Uses of Trails of Stars in Measurements of Position or of Brightness.

Photographs of star groups may be made for either one of three important objects. They may serve—(*a*) to give a picture merely; (*b*) for measurement of the relative positions of the stars of the group; or, (*c*) for measurement of the photographic magnitudes of the stars of the group. For the first purpose the stars must be photographed as points or *dots*. Such dots may also be used for the purposes *b* and *c*. For the purposes *b* and *c* it will often be very advantageous to employ *trails* instead of *dots*. The difference of declination of two stars, A and B, can be more accurately determined from measures made of the distance apart of their *trails* than from measures of the distance of the corresponding *dots*; just as a star can be more accurately bisected in declination by a Z. D. micrometer than in R. A. by a fixed thread. Hence the use of trails in R. A. If now we can produce trails in declination, a corresponding advantage can be had for measures of differences of R. A. The negative plate of the great equatorial is to be mounted on a compound slide-rest. The upper slide-rest which carries the plate has a motion in any desired direction (usually in R. A.), and the lower slide-rest, which carries both plate and upper rest, has a motion at right angles to the direction for the upper slide.

If a clock-work motion is attached to the lower slide, this slide can be moved in declination (say) for a certain distance (only). It will finally come to the end of its run. Suppose the telescope at rest, the objective covered and the lower slide-rest moving in declination. If an exposure is now made, we shall have trails suitable for measuring differences of R. A. After a few minutes, the lower slide comes to the end of its run. Trails in R. A. are now produced, which are suitable for measures of differences of declination.

The direction of motion of the lower slide may be ordered in *any* desired position angle. Thus we may choose the direction of the first set of trails so as to be most advantageous for the subsequent measures. The second set of trails will always be in R. A. The angle between the first and second directions will define the position angle of the first trails. It is believed that this simple method will have important bearings on the determination of stellar parallax by photography, a research for which the great equatorial is especially fitted.

Trails may also be used to determine the magnitudes of the stars. The blackening of

[7] These times are for the bisection of *Mars*.

the plate is proportional to the photographic magnitude of the star and to the star's rate of motion on the plate (and to other things, also).

Two stars at different declinations will move at different rates on the plate and hence will produce trails of different intensity. A (theoretical) correction for the different rates of motion can be made and the measures of the relative intensities of the trails can be taken as measures of the relative magnitudes of the stars. This method has been extensively used by the Harvard College Observatory.

I will not here discuss the objections to the method, but will simply show how all objections can be overcome by adopting an ingenious proposal made by Professor SCHAEBERLE. His suggestion is to photograph the trails of all stars on a plate moving in declination at the same rate that an equatorial star moves in R. A. All trails will then have the same exposure. The rate of the clock which drives the plate in declination can be tested at any time by photographing *both* trails (R. A. and Dec.) of the same equatorial star.

It appears to me that a photometry of all stars sufficiently bright to give such trails should be made by this method. For fainter stars the method described by Professor SCHAEBERLE *(Publ. Ast. Soc. Pacific*, No. 4) should be employed. E. S. H.

LICK OBSERVATORY, July 15, 1889.

Minutes of the Meeting of the Board of Directors, held September 28, 1889, at the Lick Observatory.

A quorum was present.

The report of the Treasurer was received and ordered on file.

The printing of a circular of information was authorized.

Hon. R. W. Waterman, Governor of California; Henry Lord Boulton, Esq., Caracas, Venezuela; Mrs. Anna Palmer Draper, New York City, were duly elected as life members of the Society.

It was *Resolved*, That the design for the Society's diploma recommended by the Committee be adopted, and that 500 copies of it be printed by Messrs. Button & Rey.

Mr. Pierson reported that the Society had been incorporated on August 28, 1889.

The thanks of the Board of Directors were offered to Mr. Pierson for his kind services in the matter of incorporating the Society, and also to Mr. Knox, notary. The fees to State officers were ordered paid.

It was ordered that the Secretary in San Francisco be furnished with a revolving fund of $10 for the payment of petty bills. Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific, held September 28, 1889, at the Lick Observatory.

[Prepared by the Secretaries for Publication.]

The minutes of the meeting of July 27 were read and approved.

A list of presents to the Society was read, and thanks were returned to the donors.

The following persons were elected to membership (the names of life-members, duly elected by the Board of Directors, are marked with a star (*):

Henry Lord Boulton, F.R.A.S.,*	Caracas, Venezuela. (Box 2015, New York City)
Rev. A. L. Brewer,	San Mateo, Cal.
George W. Beaver,	418 California Street, San Francisco, Cal.
Hon. John L. Beard,	Warm Springs, Alameda Co., Cal.
A. J. Burnham,	Lick Observatory, Cal.
Mrs. Anna Palmer Draper,*	271 Madison Avenue, New York City.
W. E. Downs,	Berkeley, Cal.
S. J. Cunningham,	Swarthmore College, Delaware Co., Penn.
Prof. Geo. C. Edwards,	Berkeley, Cal.
Prof. T. C. George,	University of the Pacific, San José, Cal.
Prof. Alfred Higbie,	University of the Pacific, San José, Cal.
Dr. J. C. Hawyer,	Auburn, Cal.
Hon. W. H. Jordan,	328 Montgomery Street, San Francisco, Cal.
Prof. Josiah Keep,	Mills College, Alameda Co., Cal.
Miss Laura Kimber,	Occidental Hotel, San Francisco, Cal.
Dr. A. Liliencrantz,	1459 Telegraph Avenue, Oakland, Cal.
F. G. Montealegre,	230 California Street, San Francisco, Cal.
President C. C. Stratton,	Mills College, Alameda Co., Cal.
Frederick C. Torrey,	529 Commercial Street, San Francisco, Cal.

Otto Von Geldern,	1905 Polk Street, San Francisco, Cal.
Rev. J. H. Wyeth,	Oakland, Cal.
Hon. R. W. Waterman,*	Sacramento, Cal.
E. C. Winchell,	1214 Grove Street, Oakland, Cal.
Edward B. Young,	430 Montgomery Street, San Francisco, Cal.

The design for the Society's diploma, which was recommended by the Committee and has been adopted by the Board of Directors, was exhibited to the meeting.

(Extract from the Report of the Committee on the Diploma.)

"A design for this diploma was prepared by the Committee and sent to Mr. P. R. Calvert of Nashville, who has made the finished drawing.

"As the Astronomical Society of the Pacific owes its origin to the association of amateur and professional astronomers in the observation of the Total Solar Eclipse of January 1, 1889, it was thought appropriate to give a chief position in the diploma of the Society to the Sun's Corona as then displayed. Accordingly, the centre of the upper panel contains the Sun, the Moon and the Corona of January, 1889. To the left and right of this are the symbols of the eight major planets. The twelve medallions of the lower panel include the twelve Zodiacal signs, copied from the beautiful designs of Mr. Vedder. The right hand panels represent first, the great comet of 1858, and second, the configuration of the Constellation of Orion. The stars of this constellation may stand for the stellar universe; while they also remind us that the central star of the sword-handle is the nucleus of the grandest of all the nebulæ. The drawing of the Muse of Astronomy—*Urania*—in the left-hand panel is copied from the antique statue of the Vatican. The national coat of arms in the upper left-hand panel designates the country in which the Society has its seat, and to which the work of our members should bring increasing honor as time goes on."

E. S. Holden, E. E. Barnard, W. B. Tyler, *Committee.*

It was announced that Mr. Donohoe had secured very satisfactory designs for the Comet Medal from M. Dubois in Paris, and that the dies were now making.

The Society was also notified that Messrs. Burnham and Schaeberle were to leave California September 29th or 30th for South America, on the expedition to observe the Total Eclipse of December 21st. Thanks to the generosity of Mr. Crocker, the expedition is completely equipped, and, barring bad weather, is sure of success.

The U. S. Government will send an expedition in the U. S. S. *Pensacola*. Five thousand dollars has been appropriated to cover the expenses. The expedition is under Professor Todd. The vessel will touch at St. Paul de Loanda and from thence two parties will, it is said, separate and go to points on the Coanza River.

The English expedition to South America under Rev. Father S. J. Perry, F. R. S., will take station at Salute I., near Cayenne. Mr. Taylor, F. R. A. S., goes to St. Paul de Loanda. Each of these expeditions has the same programme and twin instruments, viz: an Abney 4-inch photographic lens and a 20-inch reflector of 45 inches focus. It is hoped to get sixteen pictures at each station. No spectroscopic work is to be attempted. Miss Brown and Miss Jefferys, who observed the eclipse of 1887 in Russia, expect to observe that of next

December in Trinidad. H. M. S. *Comus* is placed at the disposal of the English expeditions by the British Admiralty.

It is to be regretted that the Lick Observatory Expedition is (apparently) the only one provided with a lens of more than 45-inch focus. The experience of last January seems to have shown that the solar images from lenses of less than 60 or 70 inches focus are too small to show much detail in the *inner* corona.

The papers presented were:

On the Companions to Brooks' Comet (July 23, 1889) discovered at the Lick Observatory, by E. E. Barnard.

Drawings of *Jupiter* made with the 26-inch Equatorial at Washington during 1875, by E. S. Holden.

Drawings of *Jupiter* made with a 5-inch Equatorial at Nashville during the years 1879–1883, by E. E. Barnard.

(The drawings of *Jupiter* made by Mr. Keeler with the 36-inch Equatorial during the present opposition were not exhibited for lack of time.)

On the Establishment of a Standard Meridian Line for Santa Clara County, California, by James E. Keeler.

Occultations of Stars by the Moon, by A. O. Leuschner.

Conjunction of *Mars* and *Saturn*, September 20, 1889, by W. E. Downs.

On the Photographic Brightness of the Fixed Stars, by J. M. Schaeberle.

These papers will be printed in full or in abstract in numbers 4 and 5 of the Publications.

The Society then adjourned to meet at its rooms, 408 California Street, San Francisco, on November 30, 1889.

OFFICERS OF THE SOCIETY.

NOTICE

Members are requested to preserve the copies of the Publications of the Society as sent to them. At certain intervals a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with Mr. Burckhalter, at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 5. San Francisco, California, November 30, 1889.

OBSERVATIONS OF *JUPITER* WITH A FIVE-INCH REFRACTOR, DURING THE YEARS 1879–1886.

By E. E. Barnard.

During the years 1879 and 1880 I was constantly employed in the daytime with my business duties; but every possible opportunity was used in astronomical observations at night. The latter part of 1879 and the major part of 1880 were devoted to an extended series of observations and drawings of *Jupiter.*

These observations were made at Nashville, Tennessee, ($\lambda = +0^{\mathrm{h}}39^{\mathrm{m}}.0; \phi = +36°10'$), and before I was connected with the Vanderbilt University Observatory.

The telescope was a five-inch refractor, mounted on a portable tripod, without a driving clock. A magnifying power of 173 diameters was nearly always employed—the instability of the mounting preventing the use of a much higher power. A right-angled prism was used with the eye-piece. This shows the planet reversed, but not inverted. In sketching, a small wooden box or desk was used, with a glass in the top, on which the paper was laid. A faint illumination from below, through the sketching paper, was obtained from the reflected light of a candle. By this means I could sit with the desk on my knees and compare the telescopic image directly with the drawing.

The drawings were very carefully made, and faithfully show the markings as they appeared upon the planet at the time of observation. Professor Holden has lately seen these drawings, and suggested that I collect them together and prepare them for reproduction by photo-lithography. I have, therefore, selected forty-five of them as fairly representing the phenomena of *Jupiter* during the period of observation, and they are reproduced in Plates I, II, III, IV, following. Constant reference should be made to the plates by the reader. In these plates the top of each drawing is north; the bottom is south; the right-hand side is east, or following; the left-hand side is west, or preceding.

During the observations the usual appearance of the planet was about as follows: Around the equatorial regions was a broad band or belt, which could really be said to be two belts; for it was always divided longitudinally by a sinuous, lighter portion, which was sometimes much broken by diffusions from the belts and by cloud-like forms. In the observations, I have considered this great belt as two, and have called the parts, respectively, the north and the south equatorial belts, or, collectively, the equatorial belt. Considered as one, the belt was about one-fifth the polar diameter of the planet in width.

Just south of the equatorial belt was situated the Great Red Spot, covering an area of over two hundred million square miles—greater than the entire surface of our earth.

On the inner part of the south equatorial belt was frequently seen a brilliant white spot, which had a very strong proper motion with reference to the Red Spot.

To the north of the equator were situated three narrow lines or belts. I have designated these as the first, second and third linear belts. The third was usually the border of the north polar cap, while the first became the scene of remarkable changes about the 1st of November, 1880.

What principally attracted my attention to the planet was the appearance of the Great Red Spot. The early history of this object seems to be rather obscure, but it was certainly seen as early as July, 1878, by Professor PRITCHETT, at Glasgow, Missouri, and was probably seen at intervals as early as 1870.

It was first seen by me in the early morning of August 3, 1879. I had heard nothing of it; and while observing and sketching *Jupiter* it came into view around the following limb, and was so remarkable in form and color that I was at once struck with its appearance. On this date the form of the spot was different from what it was at any of my subsequent observations. While the south edge of the spot was nearly straight and the following end blunt, the north edge tapered towards the preceding end, strikingly like the drawing by TROUVELOT in the *Observatory* for April, 1879 (p. 411).

It will be seen that my drawings nearly all show some phase of the Red Spot. I have so selected them because it was the principal object of interest with a small telescope, and therefore received the most attention. Though the Red Spot was watched carefully, I never saw any details on its surface until the latter part of the observations, when a whitish cloud formed upon it. Changes were sometimes seen, however, in the form of the spot. These were confined to the ends, which occasionally appeared rounded, and, again, were very much pointed, or cigar-shaped. Faint trails were frequently seen running from one end or the other of the spot, and sometimes from both ends at the same time; the most persistent of these was the trail from the preceding end.

One of the most interesting features of the Great Spot was the repulsion it seemed to exert upon adjacent markings on the planet. For a time it was surrounded by a sea of light that completely encircled it for a distance of three or four thousand miles (see drawing of October 3, 1879), and which appeared as a visible barrier against the approach of any spot or marking. So manifest was this repellant force that, as early in the observations as 1879, I called attention to it in the *English Mechanic* (Vol. 30, p. 166).

There was, however, one striking exception to this general rule: In July, 1880, a dense, smoky shading was seen apparently attached to the south side of the Red Spot, extending to the south preceding, and covering an area but little less than the Great Spot itself. This eventually passed the Red Spot, and, having a shorter period, soon left it far behind, and finally became squeezed out into a short longitudinal belt or spot, some twenty-five or thirty thousand miles long. Two white belts, one on each side, seemed to compress it into a definite form, that now extended east and west, instead of southwest and northeast, its primitive direction.

During the observations, a great number of estimates were made of the instant that the Great Spot was in transit across the central meridian of the disc of *Jupiter*. In discussing his micrometer measures of such transits from June to December, 1880, on thirty-one days, Prof. HOUGH says that his observations "gave for the mean error of a single pair of measures $\pm 0^{m}.9$, and for the average mean probable error for any day, $\pm 0^{m}.4$, on the observed transit of the Red Spot over the central meridian," and further remarks: "It may be inferred from these results that the use of a micrometer is infinitely preferable to any method of estimation." Among the observations of the Red Spot I have forty-four complete and carefully estimated transits—that is, observations of the preceding end, middle, and following end of the spot. Twenty-one of these are from a single but careful estimate of each phase. These give the probable error of a transit of the center from the mean of the three observations = $\pm 1^{m}.0$. In twenty-three of these transits three estimations were made of each phase; from these I get for the transit of the middle from the mean of the nine observations the error of the transit, = $\pm 0^{m}.7$. These values are comparable with the best micrometer measures. It is evident that they should be so. The Red Spot moves through an angle of about $0^{\circ}.6$ in 1^{m}. At transit this amounts to a change of distance from the limb of about $0''.2$. It is clear, that with a five-inch telescope the position of the spot could not have been fixed more closely with a micrometer (even if I had been provided with one, which was not the case) than it was by the method of transits. I think the sole advantage of micrometer measures in a case of this kind is that they can be made *near* the transit, thus saving time by not having to wait for special phases, and that they can be repeated until the accidental error of the result is reduced to a small quantity.

I have inserted the above comparisons to show what accuracy may be obtained by carefully made estimates, and as an encouragement to those who have not all the accurate appliances of an observatory to work with.

During the observations, which frequently extended over an interval before the appearance of the Red Spot at the following limb and until after it had disappeared at the preceding limb, I several times noted the moment when the first trace of the Red Spot could be seen at the *f.* limb. The mean of seven such observations, compared with the observed transit of the center of the spot, gave the interval $2^{h}1^{m}$ from the first trace of the *p.* end of the Red Spot at the *f.* limb, until the center of the spot was in transit. This gives $1^{h}36^{m}$ as the time that a mark of the same distinctness as the Red Spot, and at the same distance from the equator, could be seen before its transit; $3^{h}12^{m}$ is, therefore, the total duration of visibility of *any* point of the Red Spot during a rotation. Thus the spot could never be altogether invisible through rotation for a greater interval than $5^{h}53^{m}$ from the time the *f.* end disappeared at the *p.* limb until the *p.* end reappeared at the *f.* limb. The mean of two estimates gave $1^{h}9^{m}$ as the interval between the time when the spot was clearly seen free within the *f.* limb and the time of transit of its center. Slight variations in the tint and depth of color of the spot were noticed, and it was frequently contrasted with some portion of the equatorial belt; but as the belt itself was probably subject to a far greater change in depth and color than the Red Spot, such a comparison would not be very conclusive proof of change.

It would take up too much space to give the observations, even in an abbreviated form, so I shall briefly summarize the most important points:

The Color of the Red Spot.

1879. Aug. 2, it is described as of the color of red-hot iron.

1880. July 11, a clear, darkish Indian red, brighter in color than equatorial belt; July 24, a clearer red than equatorial belt; July 29, a light Indian red, the belts a duller red;

Aug. 16, a brick-dust color—same tint as north equatorial belt; Sept. 14, a lighter red, very much lighter than north belt; Sept. 16, a brick red, more strongly marked than the north band; Sept. 25, a deep brick-dust color; Sept. 30, a distinct red, the equatorial bands a heavier red; Oct. 7, a redder color than the belts; Oct. 13, a heavy red, clear and sharp; Oct. 20, a light, clear red; Nov. 1, a pale red; Nov. 3, a deep brick-dust color; Nov. 11, a solid red, well outlined; Nov. 20, a little less deep in color, but very much redder than the belts.

1881. Jan. 7, not so well defined at edges, but a deeper tint at the middle; July 2, a pale light red; July 9, the spot is even of a deeper tint than last year; Oct. 31, lightish red.

1882. Jan. 23, faintish red, very pale.

1885. April 25, it is very faint—quite difficult to observe—a very pale red; April 28, it is very well seen, and is clearly outlined all round; May 12, very faint; May 15, fairly distinct, probably a white mass superposed on it.

1886. April 8, a long white cloud clearly seen on the Red Spot; April 22, very faint, a whitish strip of cloud on it, north of middle.

Trails from the Ends of the Red Spot.

Faint reddish trails were recorded on the following dates:

1879. Oct. 3, faint trail from following end.

1880. July 11, faint trail from preceding end; July 18, faint trail from each end; Aug. 16, faint trail from each end; Aug. 30, faint trail from each end; Sept. 16, faint trail from each end; Nov. 18, faint trail from preceding end; Nov. 20, faint trail from preceding end.

1886. Nov. 5, faint trail from preceding end.

These usually were about $2''$ or $3''$ long.

Size of the Red Spot.

Frequent estimations were made, at the telescope, of the relative size of the Red Spot, on dates extending from July, 1880, to December 14, 1880. Following are the estimations:

***Breadth*:** From twelve estimates of its breadth north and south, it was just perceptibly less than one-half the breadth of the equatorial band = estimate I; while eight estimates made it exactly one-half = estimate II. One estimate placed it perceptibly greater than one-half = estimate III.

***Length*:** Sixteen estimates made the length very slightly less than one-third the length of the same parallel of the disc of *Jupiter* = estimate I; while the mean of six other estimates made it 0.32 that distance in length = estimate II.

***Distance of North Edge of Spot from South Edge of Belt*:** Twenty-four estimates of the distance between the north edge of the spot and the south edge of the equatorial belt gave it 0.40 of the width of the spot, with decided and considerable variability (which never, however, exceeded one-half).

Adopting from the *Report* of the Dearborn Observatory for 1882 Professor HOUGH's micrometer measures of the breadth of the equatorial bands (for a period exactly covering my estimation) as $= 7''.04$, and his value for the radius of the parallel of the center of the Red Spot $= 17''.94$, we have the above estimations expressed in seconds of arc at the distance unity.

BREADTH OF SPOT:	Estimate	I	= very slightly less than $3''.5$.
	Estimate	II	= $3''.5$.
	Estimate	III	greater than $3''.5$.
LENGTH OF SPOT:	Estimate	I	= very slightly less than $12''.0$.
	Estimate	II	= $11''.5$.

DISTANCE NORTH EDGE OF SPOT FROM SOUTH EDGE OF BELT: Assuming, with the above estimates, the breadth of spot to equal $3''.5$, the estimates give the distance above as $1''.4$.

THE BAY AT THE RED SPOT FORMED BY THE SOUTH EQUATORIAL BELT.

This singular recurring feature of the south equatorial belt is worthy of particular attention. As it seems intimately connected with the Red Spot, it had best be mentioned here. In a drawing published in the *Observatory* for April, 1879 (p. 411), TROUVELOT shows a sharp curvature of the south side of the equatorial belt around the preceding end of the Great Spot, forming, as it were, a bay. He says it had disappeared and reappeared no less than three times in a little over a year, always reappearing at the same place with reference to the Red Spot. This bay, or a similar one, is shown in my drawing of October 3, 1879. It then curved south, following the Red Spot, the southern limit diffusing very greatly, but sharply terminated where it curved down following the spot. It is shown thus also in a drawing of September 14, 1879. It was wholly absent throughout 1880, the south edge of the equatorial band being perfectly straight all around the planet. The first indication I have of its return is February 4, 1882, (the observations had, however, ceased to be continuous after 1880), when I recorded that the south equatorial band "appeared to blend southwards, following the Red Spot." In 1885, this feature was distinctly marked—the appearance being the same as in 1879, except that its extreme south edge did not blend so much as in that year. Its presence was marked on April 25, May 12, May 15, and, 1866, April 22, when the planet was examined. The absence of other dates indicates only that the region of the Red Spot was not examined, and not that the bay existed only on these dates. At the Lick Observatory I have seen it frequently at the present opposition just as it was in 1879. That this is intimately connected with the forces that produce the Red Spot there is no doubt. In connection with this feature and the Red Spot, I would mention a singular thin red line that sprung out from the south edge of the equatorial band like a spur, and, curving backwards, ran along parallel to the south edge of the equatorial belt for some distance. This is shown in the drawings of 1880, September 18, 28, 30, and October 10. Prof. HOUGH has figured this singular object in a drawing made September 9, 1880, with the $18\frac{1}{2}$-inch refractor, just as I have seen it, except that he does not show it of a red color. (See *Report Dearborn Observatory*, 1882.) It occupied a place near the preceding curve of the bay. Though this spur-line joined the south edge of the equatorial belt, to which it seemed attached, it did not partake of its motion; for throughout its visibility it retained the same position with reference to the Red Spot, showing that its period was the same as that of the spot, while the period of the belt is about $5\frac{1}{2}^{\mathrm{m}}$ shorter.

I have already mentioned the smoky shading which, in July, 1880, seemed to be attached to the Red Spot, and which finally passed by it through a more rapid rotation. It is shown on a great many of the drawings. I would specially call attention to those of Pl. I (July 24, 29, August, 16, 17, September 9, 11); Pl. II (September 30, October 7, 10, November 1). The drawing of July 24, 1880, shows a very small spot near transit in the southern hemisphere. This small spot was usually quite hard to see, but was clearly defined and dusky when best seen; it was probably about 4000 miles long and some 2000 miles wide. The remarkable features were its permanency and its slow rotation period. Its period being somewhat less than the Red Spot, it slowly drifted westward from that object, and probably, in course of time, completed a circuit of the planet, which it would do in a little over two years, when it would again be in the region of the Red Spot. It is shown in several of the drawings.

The Equatorial White Spot.

Throughout the entire period of my observations, there was present on the planet a very remarkable White Spot, situated on, or generally imbedded in, the north edge of the south equatorial band. This object was subject to remarkable changes of form and brightness. It required but a few observations to show that it was in rapid motion with reference to the Red Spot. Its period was nearly five and a-half minutes shorter than that of the Great Spot. Its westward drift with reference to that object was about 8° of longitude per day, or about 2430 miles, at every rotation of the planet. This rapid relative motion with reference to the Red Spot would therefore carry it completely around the planet in forty-five days, and a number of such revolutions were actually observed. It required but four days for this swiftly moving body to completely pass the Red Spot, which it soon left far behind, and in twenty-two and one-half days it would be on the opposite side of the planet. I would refer to the drawings of Plate III (November 18, 20, 22 and 23), where one of these passages of the Red Spot is shown. The motion of this object was not perfectly uniform. At times it seemed to slacken its speed, and then to spurt forward again. Among the surprising things about this spot were its great changes, both of form and brightness. At times it became so bright as to glisten like a star. When in this condition it was by far the brightest object on the planet. For a while it would appear as a rather small, inconspicuous, light, oval spot, imbedded in the dark matter of the north edge of the south equatorial band. In this state it would scarcely attract attention. It would next be seen brilliantly white, burying its head in the dusky matter of the belt, with a vast, luminous train streaming backwards along the equatorial regions, like the tail of a comet. Sometimes this train was composed of white, cloud-like balls, that streamed eastward on the planet. After continuing thus for some time, it would seem to have wasted its energies, and would then assume the quiescent state. I have tried to connect these changes of brightness with the changes of motion, but have not been able to do so, though there is doubtless a relation between them. When at its brightest it seemed to burrow in the south band and plow the matter before it. A long, sinuous rift in the northern part of the north equatorial band had constantly the same relative position to the White Spot, and was perhaps in the same layer of the planet's atmosphere. Probably all the objects in the equatorial regions had the same motion as the White Spot, or were stationary, relative to it. Indeed, the entire belt is revolving around the planet once in forty-five days, relatively to the Red Spot.

I will select a few of the many notes I have on this object and those connected with it:

1880. Aug. 13 ($13^h 33^m$), a brilliant white spot appearing at the *f.* limb; Aug. 16 (11^h), very white; Aug. 18, bright spot n. f. Red Spot, followed by light, cloudy masses; Aug. 23, the bright spot of the 18th has toned down; Aug. 30, bright; Sept. 10 ($10^h 30^m$), brilliant, with train; Sept. 15 ($9^h 30^m$), very bright, with train of white, cloudy masses; Sept. 24 (about 9^h), a bright head, with long, curved stream of white matter following; Sept. 28 ($11^h 30^m$), bright; Sept. 31 ($7^h 33^m$), two large white spots about midway the disc, a smaller one between them—they all shine with a very white luster; Nov. 11, a great number of white balls seen near 10^h; Nov. 18, white; Nov. 20, it is more isolated from the other matter—pale white, diffused at edges; Nov. 22, smaller and pale, about the size of Satellite I, but much paler; Nov. 23, it is smaller and paler; Nov. 24 ($9^h 20^m$), light; Nov. 29, white. When best seen, it is roundish. It seems to push a dark mass in front of it; it is as large as a satellite.

1881. Jan. 7, very bright and well-defined—it keeps the mass of matter pushed up in front of it as before; Aug. 3, a small white spot; Oct. 29, a very bright spot, with luminous and clouded train; Nov. 1, bright, and plowing its way along the equatorial regions; Nov. 12, white and distinct, about the size of a satellite, a clouded train following.

1882. Feb. 4, white—fainter, luminous train.

1886. May 13, white, luminous train.

The above times do not necessarily refer to its transit. These apparitions were doubtless the same object, as they refer to a bright body imbedded in the inner edge of the south band, and just south of the equator. From the comparisons of its size to the satellites, it was probably about two or three thousand miles in diameter. It is shown on the drawings for (Pl. I) Aug. 13, 16, Sept. 10; (Pl. II) Sept. 24, 28, 30, Nov. 7; (Pl. III) Nov. 18, 22, 23, and (Pl. IV) Nov. 5, 1881.

The Equatorial Belts.

The equatorial belts were subject to many internal changes. These changes, though frequent, are not so great as one would be led to think from examining, say, that region just north of the Great Spot. Part of the changes are due to the continual drift of the belt past the Red Spot; thus every few days presenting an entirely different part of the belt to view from any one standpoint. As an illustration of this, we have only to follow the White Spot in its journey around the planet. I would also refer to (Pl. II) the drawings of September 30 and October 7, where a decided drift of the dusky masses is shown. These belts changed in strength and depth of color. When I first examined the belts, in 1879, the northern one was reddish, while the southern was bluish; the two being separated by a whitish, serpentine division. Though my notes contain frequent reference to the colors of these belts, it will probably be best, considering the limited space, to very briefly state a few of the observations in a general form.

Colors of the Equatorial Belts.

North of the narrow, light rift in the northern part of the north belt, the color was frequently of a deep, rich vermilion, while the rest of the belt towards the equator was of a much lighter red, though at times it became a very deep, darkish red. The south belt remained bluish for a long time, and I first began to call it reddish about the middle of August, 1880. Even in September I have called it a drab color. On September 9, 1880, when the Red Spot was in transit, the north band was a warm purple, while the south one was a cold purple. On October 10, 1880, at 10^{h}, part of the north band, north of rift, was a dark, heavy red, while the south band was a bluish-gray, mixed with red; while on October 13, at 8^{h}–9^{h}, they were both a deep red. On October 10, 1881, both sides of the belt were reddish, while the inside was bluish.

Forms in the Equatorial Bands, etc.

The belts were usually clearly and sharply defined at their polar edges and perfectly straight. The peculiar disturbances to which they were subject were confined to their inner edges or to parts near the equator. Besides the famous White Spot that has been mentioned, there were sometimes the most exquisitely beautiful forms at the equator. These came and went—at times filling the interior of the great belt with dusky, cloud-like forms and softly delicate plumes that were very transitory. At times the belts appeared as one, being completely filled in with one solid tint. Such was the case, 1880, September 25, when the part visible (with the Great Spot central) was dusky and evenly filled in, and the belt in every respect was one solid, unbroken shade. I have never seen it, before or since, so absolutely uniform in tint. A few days after this (September 28) faint forms began to appear in the equatorial regions near the Red Spot. The south band was usually well-defined at both edges, and rather narrow, the inner edge being more or less undulating. At other times, there were large, soft, dusky, feathery projections from it, spreading out to the equator; in almost every case, these streamed backward, towards the east limb, as if the south belt were moving faster than the equatorial region. The north band was markedly different from this. It was always much diffused towards the equator. The edges were sometimes festooned with dusky, cloud-like forms. I would refer to the drawings of Pl. III (November 10, 22); Pl. II (October 7, 10, etc.), as showing the differences in the two belts. A long light rift was frequently visible near the extreme north edge of the north band. From the fact that this always bore the same relative position to the bright spot in the south band, I infer that the north component of the equatorial band rotated in the same time as the south component; but from the retarded appearance of the dusky masses projected from the inner edge of the south band, and frequently from the north band, one might also infer a somewhat slower rotation at the equator. This, however, is a mere conjecture, with no other warrant than appearances.

In reference to this retardation of the masses projected from the south band toward the equator, I quote an observation of mine on April 1, 1886, respecting one of the most remarkable appearances that I have seen on *Jupiter*: "At $12^{h}\,45^{m}$, three of the dark projections ranged along the inner edge of the belt and just south of the equator. I noticed that from the summit of each there extended for a short distance in a following direction, a dusky streak, looking like smoke. I was strongly impressed with the resemblance to what might be called a silhouette view of three volcanic peaks, ranged in a line and vomiting smoke, which a strong wind was carrying eastward!" (*Sid. Mess.*, May, 1886, p. 156.)

The History of the Formation of a New Belt.

In all the drawings previous to the 1st of November, 1880, a very thin line or belt is shown, just north of the north equatorial belt. In the first observation, in 1879, this narrow line was reddish, and formed a neat border to the north side of a delicate band or space that lay between it and the equatorial band. It was also the south edge or border to a delicate broad white band that encircled the northern hemisphere. Finally, the delicate band south of it faded, and became of the same tint as the light band to the north, thus leaving the border occupying the position of a distinct linear belt around the planet. This is what I have called the first north linear belt, or, simply, the first linear belt. It continued thus perfectly linear, without a mark on it, until the latter part of October, when it rapidly underwent a change so remarkable that I have thought it worth describing in detail. On the night of October 21, 1880, at $9^h\,30^m$, this belt appeared a little swollen, or thicker than usual. On the 23d, the entire planet seemed to be undergoing a great change, so much so that I wrote in my note book: "*Jupiter* is undergoing some remarkable changes now; there are a great many degrees of shade, somewhat like ill-defined spots and light spaces, appearing in the southern hemisphere near the Great Spot. The space between the north edge of the north equatorial band and the first linear belt is deepening in tint, as it was last year—a grayish green. At 8^h the first linear belt near the following limb is knobbed in appearance, as if several little dark beads were strung on it, and at 9^h it was seen to have two pretty distinct, dusky spots on it, close to each other."

On account of the remarkable character of these changes I feel that it is proper, strictly as a matter of record, to give my notes in full:

1880. Nov. 1. *Jupiter* has been undergoing some remarkable changes. From the time the Red Spot began to appear until after its transit, the first linear belt was composed of a string of large dusky spots. I counted five, each as large as the shadow of a satellite. Under the best definition, they appeared as black as the shadows of the two satellites (I and II, shown in the drawing), and the belt elsewhere appeared thicker than usual.

Nov. 2. At $6^h\,30^m$ the affected belt observed last night appeared very heavily marked.

Nov. 3. $7^h\,45^m$. The disturbed portion of the belt just appearing. At $8^h\,25^m$, the affected part reaches from the following limb to near midway the disc. It is heavy, broad and uneven. 8^h40^m. The first portion of this is in transit; a number of roundish, cloudy masses on it clear to the following limb.

Nov. 4. It is heavily marked, and its following portion transited at 6^h9^m.

Nov. 7. 8^h. The belt faint and undecided; no trace of the affected part.

Nov. 8. Near 7^h. The belt now is heavily marked all the way across the disc, and dark, with remarkably large, distinct, knotty lumps, in places quite broad with them. The disturbed region plainly visible; almost the most conspicuous part of the planet. Near 9^h, that portion of the belt visible is not affected at all, but was faint and ill-defined.

Nov. 10. From 7^h30^m until 11^h, the belt was very heavy and dark. It consisted of a strip of "veiling," pretty even at its northern edge, but undulating southwards; it was heavily nucleated at several points by heavy, blackish spots, and at these points the "veiling" was pressed outwards towards the equator. Later, that portion opposite the Red Spot, which was so heavily affected on November 1, was seen to be slightly wavy, but faint and ill-defined.

Nov. 11. Before the Red Spot had appeared the belt was affected as before. That portion opposite the Red Spot at transit was diffused and slightly wavy. Near 10^h, after the spot had disappeared, the belt was a pale blue, broader than usual.

Nov. 18. 7^h to 8^h. Opposite the Red Spot, the belt was very diffused and broad, and appeared slightly wavy where the spots of November 1 appeared.

Nov. 20. 9^h49^m. The belt is very diffused and faint, with no spots on it.

Nov. 23. 8^h35^m. Three large and intensely *black spots* nearing transit. The spots are as black as the shadows of the satellites.

Dec. 1. 7^h. The belt is broad, heavy and distinct across the entire disc. It is dotted with black spots. 7^h20^m. It is now heavier to the preceding side of the disc, and is faded and diffused following. 8^h45^m. The belt is now faint and diffused across the entire disc.

Dec. 2. 6^h51^m. It is faint and diffused, and no dark spots on it. At 7^h37^m, it is heavy with separate "blocks" or oblong spots. These are probably the ones seen on November 1, which have gone completely around the planet, and have now arrived at the point where they where first seen. They are about as conspicuous as the equatorial belts, and are moving around the planet with great velocity.

Dec. 5. The large spots have drifted past the Red Spot, and appear as at last observation—broken—forming a disjointed belt. At 8^h, the belt is composed of a number of dusky spots that stretch from limb to limb.

Dec. 7. 7^h19^m. The belt is heavy and broken.

Dec. 9. 8^h to 10^h. The belt is heavy and uneven. The south edge has a light rim or border.

Dec. 10. The northern hemisphere is delicately beautiful. The south side of the new belt consists of beautiful curves, their inner (south) edge bordered with a light line. I notice that the equatorial edge of the north equatorial band has the same or corresponding curves to those in the new belt.

Dec. 14. 6^h35^m. The new belt consists of several large dusky spots.

Dec. 29. 7^h40^m. The new belt faint, the scolloped edge seen with difficulty.

Dec. 30. About 9^h, it is heavy and undulating.

Dec. 31. 8^h. The new belt is faint.

1881. Jan. 7. 8^h to 9^h. The new belt is deeply scolloped—long and regular sweeps; it fades northwards. There is no white rim to the scollops. The belt diffuses north as a grayish shade all over the northern hemisphere. The second and third linear belts that crossed the northern hemisphere in 1880 cannot be seen.

March 6. 7^h30^m. The new belt is much scolloped.

July 2. 15^h. There is a heavy diffused belt north of the equatorial belts, where, in 1880, existed the first linear belt. This is the final result of the spots that broke out on it November 1, 1880.

July 9. 14^h30^m. The new belt is broad and diffused, and of a brick-dust red.

Oct. 3. The new belt is very diffused. There is a dark line running through it a little north of the middle of the belt. [Is this the first linear belt?] A small, white spot, like a satellite, on its south edge, transited at 10^h15^m.

Oct. 14. 10^h. The new, diffused, reddish belt is double.

This is the complete history of the formation of at least *one* of the belts of *Jupiter*; and probably no more remarkable outburst has been witnessed.

During the time these striking changes were taking place the weather was very bad, and only occasional glimpses of the planet could be had. These glimpses, though, gave sufficient evidence of the rapid changes that were taking place. These changes were so rapid and peculiar, and the weather so unpropitious, that no transits that could be positively identified as belonging to the same portion of the affected belt could be obtained, and therefore the motions of these spots could only be estimated. But it was clearly evident that they were extremely rapid. If the sketches refer to identical objects, the period, with reference to the Red Spot, would not be far from thirty days, or two-thirds of the period of the White Spot, with reference to the Great Spot.

Let us briefly review what the notes tell us about this disturbance. For, at least, over one year, a thin, uniformly even stripe around *Jupiter* existed north of his equatorial belt. About the last of October, 1880, both hemispheres of the planet were greatly affected by a disturbance that finally culminated in a great outbreak on this thin stripe, just mentioned. First, it became swollen in places; then, lumpy spaces appeared on it; next, small black spots were formed, each with a penumbra—not unlike a sun-spot; these had a very rapid motion westward on the planet, and enlarged and increased in longitudinal extent, becoming large, oblong, dusky spots, without a black nucleus. They then diffused into a "veiling," with condensations in it. This "veiling" became beautifully scolloped, its southern side consisting of graceful, light-rimmed curves, which decreased in sweep as they extended eastwards. Finally, these encircled the planet completely, diffusing northwards quite to the pole. The energies that produced the disturbance finally died out, and the beautiful curve-bordered belt lost its characteristic features and toned down to a broad, diffused, red belt, surrounding the planet; and this finally became double, and was apparently a fixed feature of the surface when I ceased to observe it.

The Polar Caps.

The north polar cap was variable in its color and in the distance to which it extended. It was frequently noted to be of a delicate wine tint; at other times it was pale gray. Its usual limit was the third linear belt, though on several occasions it extended nearer the equator. At these times the third belt was seen crossing it.

The edges of the south cap were seldom well-defined. I have never seen it of a warm tint. These caps have never been very deeply marked. One striking fact was noted on several occasions. When dawn had whitened the sky the poles appeared to grow darker and more dusky in color. There was usually a marked difference in the appearance of the northern and southern hemispheres of the planet. The northern was free of spots, except several tiny *black* ones, which were visible for a long time on the third linear belt, and which did not have a greatly different period from that of the Red Spot. Graceful, narrow linear belts crossed this hemisphere, and light bands were often seen. In the southern hemisphere there was no such symmetry. The Great Red Spot, dusky shadings, strips or fragments of belts, were the characteristic features of the southern hemisphere.

It is a very difficult question as to which portion of the surface of the planet is the highest—whether the belts are at a lower depth than the whiter surface or otherwise. During these observations I was frequently impressed with the idea that the general matter of the equatorial belts was at a lower altitude. I was particularly struck with this on several occasions. A peculiar brushing-out or smearing of the bright surface adjacent to the south band, which was recorded on several dates, had every appearance of a blending of the light surface over and above the belt. Several times in 1886 a luminous spot was seen close to the northern edge of the north equatorial band that seemed to push the white surface over and above the belt The more rapid rotation of the belt is also consistent with its being at a lower altitude.

At a number of occultations of the satellites I watched carefully for any evidences of their being seen through the edges of the planet, but saw nothing of the kind. Professor Holden informs me, however, that, with the thirty-six-inch equatorial, the whole disc of a satellite has been visible within the planet's atmosphere, at every occultation he has observed. (See, also, the observations of 47 *Libræ* by *Jupiter*, as observed by Professor Holden and myself, June 9, 1888. *A. J.*, vol. 8, p. 64.)

I would call special attention to the second drawing of 1880, November 1 (Plate II). There is a large lithograph of *Jupiter* published by the Scribners, from a drawing by Trouvelot. This was made in Cambridge, Mass., November 1, 1880, ($9^h 30^m$, Cambridge mean time). The difference of longitude between Nashville and Cambridge is $1^h 3^m$. My drawing was made at $8^h 30^m$, Nashville mean time, adding the difference of longitude, and we have $9^h 33^m$, Cambridge mean time, for my drawing, or within three minutes of the time of the drawing by Trouvelot. That is to say, that while my pencil, in Nashville, was marking on the paper, Trouvelot, at Cambridge, Mass., was, at that identical instant, drawing the same thing. The two drawings are exactly similar in the main features. His telescope was larger than mine, and he, therefore, saw more details. To the left below the belt, on this drawing, are the first and second satellites; the first nearer the belt. On the Red Spot is the shadow of the second satellite, while near the equatorial belt is the shadow of the first moon.

I have collected nearly all the observations of transits of spots over the central meridian of *Jupiter's* disc, and present them in the following table. I would state, in reference to these observations, that the first ones to the latter part of September may be affected by an error in the times of as much as two or three minutes outside of the error of observation. I had no means of determining my time, and depended upon the tower clock of the University, which, I afterwards found, had not been carefully looked after during the vacation season. I therefore give them with the above caution. I regret this; for I believe the observations themselves were made with much accuracy for simple eye-estimates. Some that were obviously far out, from the above cause, I have rejected altogether.

In conclusion, I would express my indebtedness to Professor Holden, without whose interest and encouragement these observations and drawings would never have been published.

Descriptions of the Drawings.

Plate I.

1879. Oct. 3. Shows the Red Spot and the area of light surrounding it, and the peculiar diffusion of the south band towards the south, which forms a bay around the following end of the spot. North of the equatorial bands is shown the narrow linear belt, which later on plays an important part in the drawings. This we have designated the first linear belt north.

1880. July 24. A very small dusky spot is seen between the equatorial belts and the south pole. The Red Spot is appearing at the following limb.

July 30. The peculiar mass of shading, referred to in the notes, is seen attached to the south preceding portion of the Red Spot.

Aug. 13. This shows the famous White Spot in the south part of the equatorial bands, near the following limb.

Aug. 16. The White Spot is nearer the Red Spot.

Aug. 17. Shows a group of small spots, and the mass of shading and the Red Spot just coming into view around the following limb. The left-hand one of the three small spots is the same as that shown in the drawings of July 24 and August 1.

Sept. 10. The White Spot is shown in one of its brightest phases, with a luminous train following it near the equator. It has passed the Red Spot and left it far behind.

Sept. 16. Shows the shading now separated from the Red Spot, which it is leaving slowly behind.

Plate II.

1880. Sept. 18. This shows the thin red line springing from the south side of the equatorial belt and streaming backwards parallel to the equator, near the following end of the Red Spot. Two very small, very black spots are seen. One of these was visible for a great length of time on the second linear belt north. Though the Red Spot is shown in this drawing, the white one is invisible, being indeed on the other side of the planet at this time.

Sept. 24. The Red Spot is disappearing at the preceding limb, while the White Spot, with its train of light, is near the middle of the disc.

Sept. 28. The Red Spot is just past the middle of the disc, and the White Spot is fully within the following limb.

Sept. 30. (I) Satellite I is seen on the Red Spot, while its shadow is on the edge of the spot. The shading and two of the small spots in the southern hemisphere are also seen. (II) Satellite I and its shadow have now left the Red Spot. On this occasion I transited most of the disc as a dusky brown spot, south following its shadow. The White Spot is appearing at the following limb.

Oct. 7. Satellites I and II are in transit, partially hiding their shadows, which are close north following them.

Oct. 23. (I) The Red Spot is disappearing, and some dusky lumps are coming into view on the first linear belt north. These are the first indication of the great outbreak on that belt. (II) These swollen places in the belt are shown in transit.

Nov. 1. (I) The Red Spot is appearing, while the shadow of I is just skirting its north preceding end, and the shadow of II is on the spot. Near the middle of the disc, south of the equator, satellite I itself is shown as a dusky spot near transit, while satellite II is lost in the brightness of the disc. Near the north following limb a string of dark spots is coming into view on the first linear belt. (II) Both satellites now appear as small pale discs, relieved by the slight duskiness of the planet near the preceding limb. The shadows have changed their places with respect to the Red Spot. The row of dark spots on the first linear belt is now in transit. These look like sun-spots—a black umbra surrounded by a penumbra. These are, doubtless, the same spots that are shown in an incipient stage of development in the sketches of October 23. They are, therefore, in rapid motion around the planet. (Compare their relative position to the Red Spot in the first drawing of October 23 with that of the second drawing of November 1.)

Nov. 7. We have the White Spot in this drawing on the opposite side of the planet to the Red Spot. Two other bright spots are just ahead of it.

Plate III.

1880. Nov. 8. The second satellite is seen as a white spot on the south following end of the Red Spot, while I is partially on the north preceding end as a dusky spot, and its shadow is shown to the right of the center below the equatorial belt. That portion of the first linear belt north now visible with the Red Spot has not as yet been affected by the eruptive spots.

Nov. 10. (I) The shadow of III is seen at a high southern latitude, and a mass of dusky shading is north following it. Another phase of the new spots on the first linear belt is shown. (II) The Red Spot is now visible, and the affected part of the belt has been carried off the disc by rotation. That portion now seen is faint and wavy.

Nov. 18. The White Spot is in one of its brilliant phases, just above the following end of the Red Spot.

Nov. 20. The White Spot has now moved to a point near the preceding end of the Red Spot, and is in one of its quieter phases.

Nov. 22. (I) Another phase of the northern spots is shown. The two small spots in the southern hemisphere have been shown in previous sketches. The Red Spot is not in sight. (II) The Red Spot and the White Spot are both visible—the White Spot having left the Red Spot far behind.

Nov. 23. (I) The distance between the White and Red Spots has sensibly increased since the drawing of last night. (II) The Red Spot is disappearing, and the first portion of the affected belt is coming into view at the north following limb.

Dec. 2. (I), (II), (III) show further phases of the disturbance.

Plate IV.

1880. Dec. 9. Shows the spots becoming connected by long loops bordered with a brilliant line on the equatorial side.

Dec. 10. (I) Another portion of the new belt visible when the Great Spot is leaving the disc—the shadow of a satellite on it. (II) This drawing was made after the Red Spot had disappeared.

1881. Aug. 29. In the place of the first linear belt north there is now a broad diffused reddish belt that completely encircles the planet. The remarkable spots and the beautiful light-rimmed curves have disappeared, and all the other singular transformations that the first linear belt north underwent have finally ended in the formation of this now persistent diffused red belt.

Nov. 5. The Red and the White Spots are again near each other. The diffused red belt, the scene of the great disturbance of 1880, remains unchanged. Two of the small black spots previously seen are shown on the second linear belt north—which, suffering almost total obliteration during the changes of 1880, is now as marked as ever.

1885. May 12. The Great Spot is now very faint. The south equatorial band diffuses southwards around the following end of the Red Spot, as in 1879.

1886. April 22. A white cloud has formed over the middle of the great Red Spot, almost obliterating it. The peculiar bay formed around the following end of the spot by the south band is now very persistent.

I have observed a few abnormal transits of Satellites I, III and IV, which are given here, so that they may be available for a study of the causes of these dark and black transits.

Satellite I.

1880. Sept. 30, occasionally seen during transit as a brownish spot; Nov. 1, seen in mid-transit as a dusky spot; Nov. 8, seen in mid-transit as a dusky, brownish spot; Dec. 1, seen in mid-transit quite plainly as a dark spot—quite dark.

Satellite III.

1879. Aug. 2, very black nearly all the way across—mistaken for shadow; Sept. 14, black during transit.

1880. Sept. 28, carefully watched throughout transit, not visible except near limbs—not a black transit; Dec. 30, at $8^{h}\,30^{m}$, seen in a high south latitude as a small, black spot; continued visible as black spot until near *p.* limb, and only lost its blackness at $9^{h}\,4^{m}$. Ten minutes after emergence it was certainly as bright as that part of disc on which it appeared as black as a shadow.

1880. Nov. 10, the shadow of III appeared fuzzy and not black. It seemed to be affected by penumbra.

1881. Oct. 13, at inferior conjunction it passed the south pole with only three-quarters of its disc on the planet—carefully estimated.

1883. Feb. 12 ($9^{h}\,40^{m}$), small, black.

1885. May 9 ($7^{h}\,15^{m}$), on north edge of belt very black, and remained dark until close to limb.

Satellite IV.

1885. Feb. 27, at $6^{h}\,15^{m}$, it is as black as its shadow, and about half as large—it remained dark up to nearly the moment of emergence.

1886. May 8 ($9^{h}\,20^{m}$), IV near north pole, very black.

Observed Transits of Spots on *Jupiter*.

(nashville mean time.)

Date.	red spot.			white spot.	*a*	*b*	*c*	*d*
	P. End.	*Middle.*	*F. End.*					
1880.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
July 10.	14 40	15 22	15 47	...	...	...	...	...
" 17.	15 20	15 44	16 04	...	...	...	...	...
" 24.	16 12	16 40	16 57	...	...	...	...	...
" 29.	15 17	15 43	16 11	...	14 00	...	...	...
Aug. 1.	16 52	17 18	17 42		15 18	...	...	...
" 7.	...	...	...	...	16 09	...	...	...
" 11.	...	11 32	12 01	...	...	...	...	...
" 13.	12 36	13 04.5	13 32	...	...	...	...	...
" 16.	10 16.5	10 35	10 56	...	...	10 36	...	...
" 17.	15 55	16 19	16 41	...	14 14	...	...	...
" 23.	10 54.5	11 19	11 40.5	...	...	...	...	...
" 28.	...	10 24.5	10 48.5	...	...	...	...	...
" 30.	11 34.7	11 58.2	12 24.2	...	...	...	...	...
Sept. 9.	9 51.7	10 15.2	10 39.2	...	...	...	...	...

Date.	Red spot.			White spot.	a	b	c	d
	P. End.	*Middle.*	*F. End.*					
	h. m.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
“ 14.	…	9 27±	…	…	…	10 21	…	…
“ 15.	…	…	…	…	…	9 47	…	…
“ 16.	10 32	11 02	11 24	…	…	…	…	…
“ 18.	12 14	12 37.7	13 03	…	…	12 22	…	…
“ 25.	12 58	13 24	13 45	…	10 46	…	…	…
“ 28.	10 28	10 53	11 17	…	…	10 38	11 40	…
“ 30.	12 01.5	12 29.5	12 54	…	9 48	12 11	…	…
Oct. 1.	7 57	8 25	8 52	…	…	…	…	7 28
“ 6.	7 01.5	7 29.5	7 57.5	…	…	…	8 18	…
“ 7.	12 45	13 13	13 40	…	10 24	…	…	…
“ 10.	10 13.5	10 39.5	11 08.5	…	…	10 26.5	…	…
“ 13.	7 44	8 10	8 36	…	…	…	…	…
“ 20.	8 29	8 53	9 17	…	…	…	…	…
“ 22.	…	10 30	…	…	…	…	…	…
Nov. 1.	8 19	8 48	9 10.5	…	…	…	…	…
“ 4.	…	6 15	6 39	…	…	…	…	…
“ 7.	…	…	…	7 59	…	…	…	…
“ 8.	9 06	9 31	9 57	…	…	…	…	…
“ 10.	10 44	11 09	11 33	…	…	…	…	…
“ 11.	6 34	6 57	7 25	…	…	…	…	…
“ 18.	7 17	7 42	8 09	…	…	…	…	…
“ 20.	8 58	9 22	9 48	…	…	…	…	…
“ 22.	10 40	11 01	11 29	10 18	7 46	…	…	9 07
“ 23.	6 32	6 53	7 20	…	…	…	…	…
Dec. 2.	8 56	9 15	9 41	6 27	…	…	7 33	7 23
“ 5.	6 28	6 46	7 11	…	…	…	…	…
“ 6.	…	…	…	8 53±	…	…	…	…
“ 7.	7 59	8 23	…	…	…	…	…	…
“ 9.	9 37	10 01	10 24	…	…	…	…	…
“ 14.	8 46	9 09	9 34	9 20	…	…	…	7 05
“ 29.	…	…	…	7 41	…	…	…	…
“ 31.	7 45	8 08.5	8 33	…	…	…	…	…
1881.								
Jan. 7.	8 39	9 01	9 24	8 02.5	…	…	…	…
Mar. 6.	6 52	7 14	7 36	…	…	…	…	…
July 2.	…	…	15 21	…	…	…	…	…
“ 9.	15 12	15 34	15 57	…	…	…	…	…
“ 11.	16 47	…	…	…	…	…	…	…
“ 21.	15 04.5	15 27	15 50	…	…	…	…	…
“ 28.	15 53	16 12	16 36	…	…	…	…	…
Aug. 3.	…	…	…	14 42.5	…	…	…	…
“ 5.	…	…	…	15 46	16 06	…	…	…
“ 29.	…	…	…	…	15 39.5	…	…	…
Oct. 10.	…	…	17 32	…	…	…	…	…
“ 29.	…	…	…	10 25	…	10 15±	…	…
Nov. 3.	…	6 50±	…	8 24	…	…	…	…
“ 5.	8 09	8 30	8 54	9 34	…	9 20	…	…

Date.	Red Spot.			White Spot.	*a*	*b*	*c*	*d*
	P. End.	*Middle.*	*F. End.*					
	h. m.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
" 12.	9 52	9 14	9 42	8 44	...	...	...	...
" 15.		6 45	7 08	...	...	...	...	...
" 26.	...	...	7 27	...	...	...	...	...
" 29.	8 54	8 15	8 37	...	8 30±	...	...	...
1882.								
Jan. 23.	8 19	8 40	9 03	...	...	...	...	...
Feb. 4.	8 08	8 28	8 49	9 07	...	...	...	...
April 27.	...	...	6 50±	...	...	...	...	...
1885.								
April 25.	...	10 41.5	...	7 56.5	...	...	...	...
May 12.	...	9 43	...	...	...	...	...	...
May 13.	...	...	...	8 48	...	...	...	...
1886.								
April 22.	...	10 18.6	...	...	...	...	...	...
1888.								
*July 24.	11 51.9	12 08.4	12 29.8	...	...	...	...	...
1889.								
*May 31.	...	...	15 09.3	...	...	...	...	...
*June 9.	...	...	17 48.4	...	...	...	...	...
" 17.	...	13 53.0	...	...	...	...	...	...
*July 2.	...	11 19.1	...	...	...	...	...	...

* With twelve inch at Lick Observatory. Like the others, in Nashville mean time.

The transits of a few objects were observed with the six-inch, at the Vanderbilt University Observatory, as follows:

Date.	*e*	*f*	*g*
	h. m.	*h. m.*	*h. m.*
1885. April 21.....	8 02.5	....	....
" " 22.....	....	7 05.5	6 55.7
" " 25.....	7 08.2	....	....
" " 29.....	....	7 54.5	7 46.5
" May 9.....	8 42.5	....	....

Note (explanatory of the table of transits).—*a* is the small spot mentioned as having been seen 1880, July 24, and subsequently; *b* is a small black spot, the *p.* of two shown on the second linear belt north in the drawing of 1880, September 28, and subsequently; *c* is the second of these two black spots; *d* is the shading spoken of in connection with the Red Spot; *e* is a luminous spot, sometimes recorded as a notch in the north edge of the north equatorial band, probably not all the same object; *f* is a very small, intensely black spot *on* the south part of the equatorial belt—round, and like a satellite's shadow, but smaller; *g* is a luminous spot or notch in the north edge of north equatorial band.

DRAWINGS OF *JUPITER* MADE WITH THE 26-INCH EQUATORIAL, AT WASHINGTON, DURING 1875.

By Edward S. Holden.

During June and July, 1875, I made drawings of *Mars* and *Jupiter*, in colored crayons, for the purpose of comparing the tints on those two planets. The drawings were all made with the twenty-six-inch equatorial of the United States Naval Observatory, usually with a magnifying power of 400, and no pains were spared to make correct delineations, both as to forms and colors. From one cause and another, these drawings have not been published.

I beg to present a photograph of the sketches of *Jupiter* to the Society.

The original colored drawings [exhibited to the meeting] will be deposited in the library of the Lick Observatory, where they will always be available for comparison with more recent work. Below, I give the few notes which should accompany the drawings, which are reproduced in Plate V. It will be interesting to compare these drawings with the admirable series by Mr. Barnard, which are given in Plates I to IV.

There are three general remarks to be made on these drawings. In the first place, while the general features of the planet's surface have remained about the same from 1875 to 1889, there has been an entire change as to the form and disposition of the details. In the second place, the disposition of color on the surface of the planet has entirely changed, also. In 1889 there is very little of the red color to be seen, except in the great central belt, while in 1875 red belts were seen almost to the poles. Thirdly, the characteristic red color itself has changed in a surprising manner since 1875.

The color of the red markings in 1875 was most carefully matched in crayons, and I was finally satisfied with the tint of the drawings. In 1881 I found that the same crayons (pieces of which I had preserved) would no longer match the red belts. In 1889 the color of the red belts is entirely different from that previously drawn. All the observations were made with Clark objectives (of 26, $15\frac{1}{2}$ and 36 inches aperture), which had their color-corrections very much alike. Unfortunately, it is not practicable to reproduce these colors in Plate V. The notes follow:

The top of the drawing is south; the right-hand side is east, or following.

1875. June 16, seeing not good; June 18, hazy; June 24, the columnar structure in the southernmost belt is somewhat too coarse; July 13, the position of the shadow of the satellite is for 8^{h} 40^{m}; July 16, planet unsteady.

NOTICES FROM THE LICK OBSERVATORY.

Prepared by Members of the Staff.

On the Determination of the Brightness of Stars by Means of Photography.

Dr. Charlier, assistant in the Observatory at Stockholm, has prepared a memoir[7] on the use of photography in determinations of the brightness of stars, which has been published by the Astronomical Society of Germany, and dedicated to the Pulkowa Observatory, on the occasion of the fiftieth anniversary of its foundation, August 19, 1889.

The subject treated is so new and so important that it will not be out of place to give a brief review of Dr. Charlier's excellent treatise here, and to add some general considerations on the same question. The importance of this subject will be obvious, when we consider that within the next decade we may expect to have at least two sets of photographic maps, covering the whole sky from pole to pole, and including millions of stars down to the fourteenth magnitude.

Besides these systematic maps, hundreds of charts of special regions will be made. Each star on each of these maps will have impressed its image on a negative plate as a disc of measurable size. Hence the magnitude of each and every star *can* be determined if necessary, and when the catalogue of the stars to the eleventh magnitude, also proposed by the Congress, is constructed, the magnitude of each one of these two million stars *must* be given.

There are two imperative questions to be settled before the principles on which this great work is to be done can be considered to be established. The first and more special question is, What is the relation between the diameter of the photographic image of a star (d) the aperture and focus of the telescope employed (a, f) and the exposure time (t), and what is the relation between the (photographic) brightness of a star and the diameter of its image? Having satisfactorily determined the relations just named, the second and more general question presents itself, namely: On what fundamental principles ought the photographic magnitudes of the stars to be assigned?

These two questions are not treated separately in the work before us. Its second paragraph states the problem of the photographic photometry of stars as follows: It is "to determine the function which gives the relation between the size of the photographic image and the photographic brightness of the star, and to determine the constant quantities in this function *in such a manner that the resulting photographic brilliancies shall correspond accurately throughout with the brilliancies determined visually.*"

In my judgment, this is by no means the problem of stellar photographic photometry. It is impossible, in general, to fulfill that portion of the above statement which I have printed in italics. The difference between the photographic and the photometric magnitudes of *Aldebaran*, for example, is more than one and one-half magnitudes, and so with other stars. We may leave this part of the question for the moment, and proceed to give a brief analysis of Dr. Charlier's memoir, laying stress principally on the novel portions of his work.

[7] *Ueber die Anwendung der Sternphotographie zu Helligkeitsmessungen der Sterne*, von C.V.L. Charlier. *Publication der Astronomischen Gesellschaft*, XIX. Leipzig 1889. 4to. (pp. viii, 31).

The observations which he discusses were made with a photographic lens by STEINHEIL of 3.19 inches aperture and 39.37 inches focus ($\frac{f}{a} = 13$). The plates took in an area of twenty square degrees. The images were satisfactory over a field of about three degrees in diameter. Stars to eighth magnitude, inclusive, left trails. The plates employed were made in Lyons, by LUMIÈRE. Four plates are discussed. All were exposed on the *Pleiades*, as follows: No. 2, $t = 13^{\text{m}}$; No. 4, $t = 2^{\text{h}}$; No. 24, $t = 1^{\text{h}}30^{\text{m}}$; No. 26, $t = 3^{\text{h}}$. The plates were exposed at very different altitudes, and no account is taken of absorption of light by the atmosphere.

Dr. CHARLIER finds two defects in the plates: first, bright rings round the larger stars, which he proves to be due to reflections from the back of the plate (the well-known halation images); and, again, false stars. He finds no less than fifty-six such false stars on his plate No. 26. They were probably due to defects in the manufacture of the plate itself.

As subjects for experiments he chose the *Pleiades*, because their photometric magnitudes are accurately determined, and also because they afford a variety of magnitudes within a comparatively small area.

Although he does not expressly mention the fact, the *Pleiades* have the special advantage for his purpose of being all of the same spectral type. A region containing many very red or many very blue stars would have given a corresponding number of anomalous results, which are avoided by choosing a group of stars of one type. The diameter of each star on each of the four plates was measured. Calling H the brightness of a star, and m its magnitude, and 0.4 the light ratio, Dr. CHARLIER starts with the formula

$$H = (0.4)^m \tag{1}$$

That is, he assumes that the brightness of a first magnitude star ($m = 1$) is 0.4. It is better to write this formula, I think,

$$H_m = (0.4)^{m-1} \tag{2}$$

which for $m = 1$ gives $H_1 = 1$. Assuming the equation (1), however, and further assuming that when d is zero, H must be zero, he finds

$$m = a - b \log d \tag{3}$$

Here it may be remarked that, in fact, H is not necessarily zero for $d = 0$, because all stars below a certain brightness will fail to produce an image on the plate, no matter how long the exposure may be—for any practical exposure-time. The brightness of a star must be above a certain finite limit in order to produce any impression at all. The assumption is sufficiently accurate, however, for the purpose in hand. The relation between exposure-time and diameter of star image is next determined from a series of exposures on *Polaris*, assuming the form

$$d = d_0 \cdot t^k \tag{4}$$

That is, that the diameter of the star-image varies as the k^{th} power of the time. From *Polaris* (two plates) the values of k are 0.243 and 0.249; from a star 5th mag. k results 0.243,—hence, the numerical value of the diameter of the star-image varies as the fourth root of the time or

$$d = d_0 \cdot \sqrt[4]{t} \tag{5}$$

This formula shows that the diameter d will be doubled when the exposure t is increased sixteen-fold.

If there are no limits to the formula it also shows that, for the telescope and plates employed, an exposure of $\frac{1}{16}$ second would give a perceptible image. Without considering the question of the *range of sensitiveness* of plates I may state it as my opinion that the formulæ of Dr. CHARLIER and those of Professor SCHAEBERLE (*Publ. Ast. Soc. Pacific*, No. 4) can (at present) be applied safely only to *over-exposed* stars, and that there is a superior limit also beyond which they are no longer applicable. Both Dr. CHARLIER and Professor SCHAEBERLE have found that the stars with the longest exposure are best fitted for the determination of magnitude.

We may now quote, without further remark, the final formula to which Dr. CHARLIER is led, which gives the relation between m (star's magnitude), d (diameter of star-image on plate), and t (exposure time). It is

$$m = A + B \log d + C \log t \tag{6}$$

In the particular plates in question the constants A, B and C are

$$A = +17.2 \quad B = -6.75 \quad C = +1.69$$

A, B and C are proved to be constant on the four plates in question; t is expressed in minutes.

From the formula (6) the photographic magnitudes of fifty-two of the brighter stars in the *Pleiades* were computed, and compared with the photometric magnitudes of the same stars as determined by Dr. LINDEMANN, at Pulkowa. (Table III.)

The mean difference between the photographic and photometric magnitudes is ± 0.22 mag. The differences occur 0.6 mag. (twice), 0.5 (twice), 0.4 (4 times), 0.3 (12 times), 0.2 (12 times), 0.1 (10 times), 0.0 (7 times). Two stars are either variable or red. The individual results for the photographic magnitudes from the four plates agree well. The mean difference is 0.10 mag. The largest difference is 0.4 (occurring twice).

Dr. CHARLIER makes the important remark that the red stars, etc., which are thus discovered in the group of the *Pleiades*, are very suitable for a determination of its parallax, since they differ in spectral type, and are therefore *presumably* not members of the group. A few moments' examination with a small spectroscope will, however, be a surer indication in similar cases.

Section III of the memoir is devoted to a comparison of the results of the Stockholm photographs with those obtained by Professor PICKERING, at Harvard College, and by Dr. SCHEINER, at Potsdam. The linear formula deduced by the latter is shown to be inferior to the logarithmic form adopted by Dr. CHARLIER; and in Table IX it is shown that the systematic differences between the results at Harvard College and at Stockholm are likely to be due to constant errors in the H. C. O. results. In all this discussion, as has been said, the effect of atmospheric absorption is omitted, as it has been in all previous publications of the kind. It is of considerable amount, however.

Section IV of the memoir is chiefly concerned with a comparison between the photometric magnitudes given by WOLF, of Paris, for 571 of the *Pleiades* stars and the photographic magnitudes of the same stars derived from one plate (only) taken at Stockholm. Twenty-eight of WOLF'S stars do not appear on this plate; *en revanche*, it contains more than 100 stars not in WOLF'S catalogue. In passing, we may remark that the single Stockholm plate made in three hours has a value at least comparable with the chart of M. WOLF, which was the result of many months of labor. It is worth while to remark here that it is highly desirable for the present to make every result derived by photography depend on two negatives at the very least. A comparison of the scales of WOLF and CHARLIER closes this section and concludes the important work.

We may now say that the present memoir and that of Professor SCHAEBERLE, previously cited, have fixed the form under which discussions of this character must be made in future. For every telescope a relation between the diameter of a star image and the corresponding exposure must be deduced in the form $d = \Phi(\log t)$.

The constants of this formula will vary with the aperture, focus, plate, site, and with the spectral type of the star, and will probably be applicable only within certain limits of absolute brightness and within certain limits of exposure time.

The memoir of M. CHARLIER is an excellent example of the method of discussion which must be adopted to determine this function for all cases where the prime object is to make the photographic magnitudes harmonize as nearly as possible with the photometric. The real fundamental question is, however, Should any endeavor be made to harmonize them? I proceed to discuss this point as briefly as possible, in the light of our present knowledge, since it is the most important question remaining open for settlement.

Establishment of the Present System of Visual Magnitudes.

Let us consider, very briefly, the history of the introduction of the present system of visual magnitudes. The main epochs in this history are very few. The first is that of PTOLEMY (A. D. 150,) who arbitrarily assumed the brightest stars to be of the *first*, the faintest which he could see, to be of the *sixth* magnitude. The other stars were divided into classes of 2d, 3d, 4th, 5th, etc., magnitudes. The second great event in this history is the publication of the *Uranometria Nova* by ARGELANDER, in 1843. He adopted the general rules laid down by PTOLEMY, and followed by SUFI, TYCHO and BAYER. The brightest stars were called first magnitude, the faintest visible to the naked eye were called sixth magnitude. Stars of the classes 2, 3, 4, 5, etc., were intermediate. By FECHNER'S law, it necessarily followed that equal differences of sensation corresponded to equal *ratios* of light; or that the light of a star of m^{th} magnitude must be $\frac{1}{\delta}$th part of the light of a star one magnitude brighter $(m - 1)$. Measures of this *light-ratio* δ show its numerical value to be 0.4 very nearly, omitting all questions of small variations, etc.

The *Durchmusterungen* of ARGELANDER, KRUEGER, SCHOENFELD and THOME will determine the visual magnitude of every star in both hemispheres as bright as the tenth magnitude by this same scale. That is, if the brightness of a star of the first magnitude is unity, the brightness of a star of the m^{th} magnitude is

$$H_m = (\delta)^{m-1} \quad \text{where } \delta = 0.4 \tag{7}$$

The universal practice of modern observers has extended this scale from the tenth down to the sixteenth or seventeenth magnitude (the faintest stars now visible in the largest telescopes). Thus the *accidental* choice of the sixth magnitude as the limit of the naked-eye stars by PTOLEMY has fixed the light-ratio and the practice of all astronomers with regard to visual magnitudes for all time to come. It is to be noted that if PTOLEMY'S work on visual magnitudes were to be done again *de novo*, and absolutely independently, the method chosen would be essentially the following: *One* standard star would be chosen (*Polaris*, in our hemisphere). This star would be compared with a selected group of stars, and the fact of the constancy (or the law of the variation) of its light during the course of the observations would be established. Every other star would be compared with *Polaris*, either directly or indirectly, and its relative light determined. Some convenient magnitude would be *arbitrarily* assigned to *Polaris*, and some convenient light-ratio would be *arbitrarily* assumed. The magnitude of any and every star would then be deduced from the measured ratio of its brightness to that of *Polaris* by a formula like our (7) in which the numerical value of δ would be assigned on grounds of convenience alone. It is very likely that the value $\delta = 0.4$ would be again chosen, because the tenth part of a magnitude (easily written with one place of decimals), thus defined, is about the limit of perception of the most highly trained human eye.

Such, I conceive, would be the process adopted if the whole question of visual magnitudes was entirely open, and if a Congress of Astronomers were called in 1890 to decide on the proper methods to be followed in fixing the visual magnitudes of the stars anew, or for the first time. The process is simple, it is complete, it is logical, it is sufficiently accurate for all conceivable uses to which visual magnitudes are to be put. The use of a visual magnitude assigned to a star is chiefly to determine its brightness at one epoch, so that observations at other epochs will determine whether there have or have not been changes in its light. It is from celestial bodies which are subject to change, and chiefly from these, that we can hope to learn anything of the nature of celestial bodies in general. A secondary convenience in having a magnitude assigned to a star is to aid in identifying, classifying and describing it.

Establishment of a System for Determining Photographic Magnitudes.

The International Congress of Astronomers will have to decide the question as to how to define the photographic magnitude of a star. They will soon be in possession of plates on which millions and millions of stars have impressed themselves. The diameter of each one of these stars can be measured. The photographic brightness of each one of these stars relative to the photographic brightness of *Polaris* (for example) can be readily determined. What *magnitude* shall be assigned to each one of these stars? Dr. Charlier's answer to this question has already been given. He would assign to each one of a group of stars a photographic magnitude, deduced on the principle that the mean deviation of their photographic magnitudes from their visual magnitudes should be as small as possible. If the same star occurs in two or more different groups, it will certainly have different magnitudes assigned to it, according as one or the other set of standards is employed. The same method has been followed by Mr. Espin and by the Harvard College Observatory in all of its many important publications on this question, notwithstanding the fact that (owing to the color of a star) the photographic and visual magnitudes not infrequently differ by at least *two whole magnitudes.* That is, if the visual brightness be expressed by 1.00, the photographic brightness of the same star may be no more than 0.16, or only one-sixth part. Such anomalies must in the nature of things constantly appear for a considerable percentage of the stars. A tolerable agreement is possible for perhaps eighty per cent. of the larger stars, and even here there will be small persistent differences. For those remaining, the disagreement will be more or less marked, according as the spectral type of the star in question varies more or less from the average type. The reason of this is well known. The eye is sensitive to rays which fall between the Fraunhofer lines B and G (approximately) of the solar spectrum. The maximum brilliancy to the eye is somewhere near the line *b*. The photographic plate is sensitive to rays falling between F and N of the solar spectrum (approximately). The plates now in use are sensitive in the highest degree to rays of about the wave length of the line G.

Whenever we have a group of say five hundred stars, whose spectra are nearly all of the same type (as the *Pleiades*, for example,) we can measure for each star the relative energy of the light in the portion of its spectrum between B and G (by the eye), in that between F and N (by the photographic plate), and, *as the energy is distributed according to the same law in the spectrum of each star of the group*, we can determine constants of reduction which *will* make the photographic magnitudes of the various stars agree well with their visual magnitudes. If, however, two hundred of the stars are very red, one hundred very blue and two hundred of the ordinary type, it is, in the nature of things, impossible to bring the photographic and the visual magnitudes to a good agreement. The very red stars will always appear brighter to the eye than they do on the plate, and the very blue stars will always appear fainter to the eye than on the plate, and there is no process of reduction which will smooth away a difference in their magnitudes which is inherent in their nature. If there were such a process, it would be most unwise to employ it. When I see that a star is of the visual magnitude 1 and the photographic magnitude 2.5, I at once learn something of the nature of this star's spectrum, and so in like cases.

It therefore seems to be a rational and a useful plan to leave out all consideration of the visual magnitudes of stars in determining their photographic magnitudes. A simple and most satisfactory method of procedure would be to assume *Polaris* as the standard star of the whole sky, and to fix its magnitude (when in the zenith of a station at sea level) at 2.00, once for all; to select a set of secondary standards, distributed round the equator, and to determine the brightness of each one of these stars in terms of that of *Polaris* (a proof of the constancy of the light of *Polaris* being thus attained). Important groups like the *Pleiades*, etc., would also have their brightness determined in terms of that of the standard. The brightness of the principal Southern stars should also be fixed in terms of *Polaris* indirectly through the *Pleiades*, etc. A light-ratio should be selected on grounds of convenience alone and the photographic magnitude of every star should be determined by an equation like our equation (7) in terms of a single standard star with a definite light ratio.

If this programme were to be followed, we should simply have to add to our star-catalogues another column headed "Photographic Magnitude," which would immediately follow the column "Visual Magnitude." The agreement or disagreement of the two numbers would tell us something of the nature of the spectrum of each star. In order to have the work exact, it would be necessary that all the stars should be photographed on one kind of plates, as is now done by the Harvard College Observatory, and as will be done by the International Photographic Congress. The photographic Southern *Durchmusterung* might for convenience have its magnitudes expressed in visual units, though the DM of the Cordoba Observatory will make this unnecessary, and will, in fact, make it distinctly to the advantage of science if the photographic DM is made *entirely* photographic. The International map of two million stars to the eleventh magnitude should, in my judgment, give photographic magnitudes *alone*. I can conceive of no advantage to be gained by determining the approximate visual magnitude of these millions of stars at all comparable with the labor involved. In any event, it would seem that the photographic magnitudes should be given whether the visual magnitudes are or are not.

Such, it appears to me, are the general principles which should govern in the determination of star magnitudes by photography. I have set them forth because no amount of discussion at this stage can be called superfluous. After the International Congress has once settled its methods of procedure, it will be the duty of all co-operating observatories to conform to the spirit and to the letter of the methods finally adopted. As long as they are not yet adopted any suggestions, however simple, cannot fail to be of use.

The Lick Observatory is endeavoring to make a modest contribution to the general subject of which we have spoken. Professor SCHAEBERLE has made observations at Mount Hamilton (4209 feet above sea), and will make observations at Cayenne, South America, (nearly at sea-level), to determine the photographic atmospheric absorption at zenith distances between 0° and 70° or 75°. He has already compared the *Pleiades* and other stars with *Polaris*, and will compare the principal Southern stars with the *Pleiades*, etc. In this way, his observations, if successful, will enable us to transfer the standards of the Northern Hemisphere into the Southern.

The immense work now in progress in both hemispheres under the auspices of the Harvard College Observatory will afford material for a thorough discussion of the whole subject. The contributions of Dr. CHARLIER and Professor SCHAEBERLE have established the final form under which special discussions of this kind must be made. The only part of the subject remaining for settlement is that which relates to the establishment of the fundamental principles on which the final methods of reductions are to be based. I have endeavored, in what precedes, to set forth what seems to me to be a satisfactory system, at once simple and comprehensive. E. S. H.

Variations of the Surface of Mars.

In the second volume (1888) of the *Bulletin de la Société Astronomique de France*, M. FLAMMARION has two long and studied articles on the *markings* of the planet *Mars*. He is careful to present a great number of *fac-simile* drawings of the planet, which date from 1659 to 1888, so that the evidence which he has used is before the eyes of the reader. After showing that drawings of *Mars* may differ greatly from each other on account of differences of eyes, methods, interpretation, instruments, atmospheric influences both on *Mars* and the earth, and on variations of the inclination of the planet's axis, he goes on to show that there still remain variations which are (probably) not due to any of these causes, and which therefore are to be attributed to real variations in the surface of the planet itself.

Most of the paper is devoted to an examination of the evidence of the drawings. (In this connection it is well to refer to a set of articles by Professor SCHIAPARELLI, in *Himmel und Erde* for October, November and December, 1888, where the same questions are treated also in a masterly manner.) At the close of this examination M. FLAMMARION feels authorized to draw the following conclusions as established facts—leaving all speculation to one side:

I. "There are permanent markings on the surface of *Mars,* which in all probability represent *('doivent représenter')* seas, lakes, regions of water of various kinds, etc. (It has long been known that on this planet there are polar snows which melt in summer, clouds, and the vapor of water shown by spectroscopic observations.)

II. "These markings are permanent; they are seen to-day in the same regions where they were observed in the seventeenth and eighteenth centuries. They are not atmospheric products, then, such as are shown, for example, on *Jupiter*.

III. "However, while they are permanent they are not invariable. They change both in extent and in depth of tone, in different years and without doubt during different seasons [seasons of *Mars*].

IV. "There are some regions which are specially variable. These appear to hold a middle place between continents and seas, and to be marshy lands, which are in turn elevated above and submerged below a thin layer of water.

V. "The continents of *Mars* appear to be flat; and subject to inundations in nearly all their extent.

VI. "The northern hemisphere is more elevated than the southern; the seas are chiefly in the southern hemisphere, and they do not appear to be deep.

VII. "The evaporation on *Mars* is, without doubt, rapid and considerable. Millions of cubic yards of water pass readily from the state of vapor to the state of liquid, and millions of acres pass from the continental to the maritime aspect.

VIII. "Water is perhaps not the only agent concerned in these changes. The general order of things is very different on *Mars* and on the earth."

This is not the place to examine the conclusions critically. In a general way, they all depend upon the assumption that the darker markings on *Mars* represent bodies of water. As this is quite probable (though by no means proved as yet) the eight theorems given above may serve as points of departure in the further working out of this plausible hypothesis.

E. S. H.

Stability of the Great Equatorial.

Observations for the position of the great telescope have been made by Messrs. Schaeberle and Keeler, as below:

1888,	July 27,	azimuth	=	+36″;	level	=	8″	too low.
1889,	May 18,	"	=	——	"	=	36″	" "
	Sept. 16,	"	=	+83″	"	=	58″	" "

There appears to be a slight progressive change in level and probably in azimuth.

Mountain Observatories.

Telescopes … "cannot be formed so as to take away that confusion of rays which arises from the tremors of the atmosphere. The only remedy is a most serene and quiet air, such as may perhaps be found on the tops of the highest mountains above the grosser clouds."—Sir Isaac Newton, in his *Opticks*, a. d. 1730.

Rainfall on Mount Hamilton.

Meteorological observations have been kept at Mount Hamilton since 1880. The following table of rainfall on the summit is the best available summary. This rainfall is considerably more than that in the Santa Clara Valley near San José (about 13.4 inches) and it is probably considerably less than the fall in some of the cañons and valleys immediately surrounding the mountain. The great variations in the annual amount of rainfall are interesting from a meteorological point of view, and decidedly inconvenient from a practical one, especially as our reservoir capacity is not quite adequate. E. S. H.

Rainfall at Mount Hamilton in the Years 1880–89.

Month.	1880–81	1881–82	1882–83	1883–84	1884–85	1885–86	1886–87	1887–88	1888–89
	in.	in.	in.	in.	in.	in.	in.	in.	in.
July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
August	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.02
September	0.00	0.10	0.00	0.65	0.65	0.15	0.00	0.33	0.49
October	0.00	0.33	6.16	2.15	3.71	0.05	0.60	0.09	0.03
November*	0.50	0.91	3.45	1.48	0.01	——	2.82	0.90	3.27
December	9.68	9.72	1.93	2.05	33.84	——	2.34	11.25	4.23
January	3.51	3.55	3.10	5.60	1.99	——	2.83	10.04	1.04
February	5.99	2.90	3.75	12.76	0.57	1.80	7.80	1.38	1.42
March	1.13	5.40	8.66	16.35	1.15	5.77	1.39	3.40	6.17
April	0.98	4.70	2.66	11.96	2.08	6.79	5.75	0.68	1.92
May	0.09	0.48	7.55	1.24	0.16	0.70	0.25	1.25	3.21
June	0.33	1.06	0.00	3.85	0.36	0.00	0.30	0.67	0.00
Sums	22.21	29.15	37.26	58.09	44.67	——	24.08	30.03	21.80

* November, 1880—One shower, amount assumed to be $0^{in}.50$. N. B. December, 1884.

Mean annual rainfall (8 years), *July to July* = 33.41 in.

Great Telescope for Los Angeles.

Authentic information regarding the proposed forty-inch refractor for Wilson's Peak is difficult to obtain. A newspaper report of an interview with Mr. A. G. Clark on September 28, recites that one of the discs (now on exhibition at Paris) will probably arrive in Boston in October. The other disc is not yet cast, and M. Mantois is, apparently, not willing to undertake the work without a contract, which is not yet executed. The Trustees of the Fund have, so it is said, authorized Mr. Clark to pay $10,000 for two satisfactory forty-inch discs, which is not an unreasonable price by any means. Mr. Clark offered to make the objective and the mounting for $100,000, during his visit to California in the winter of 1888–9. So far as is now known, the fund available for the telescope does not yet exceed $150,000. Probably $300,000 to $400,000 would build and equip the observatory. E. S. H.

Force of Gravity at Mt. Hamilton and San Francisco.

Mr. E. D. Preston of the U. S. Coast and Geodetic Survey has published his report on gravity determinations in the Pacific Ocean (*Bulletin* No. 11, U. S. C. and G. S., 1889). The force of gravity at Washington being 1.000000, that at San Francisco (Professor Davidson's Observatory) is 0.999854 and at the Lick Observatory it is 0.999544. Determinations of g at four stations in the Hawaiian Islands and for a station at Caroline Island are also given.

E. S. H.

Lick Observatory Photographs of the Moon.

Knowledge for October 1, 1889, contains an article by the editor (Mr. Ranyard), on the Moon as seen in the Lick Telescope. Excellent reproductions of five silver prints made by the Direct Photo-Engraving Company of London, accompany the article. Mr. Ranyard's remarks upon the temperature of the moon and upon the possibility of the existence of snow-fields on its surface, are well worth close attention. E. S. H.

American Eclipse Expedition to Africa (December 21, 1889).

The New York *Sun*, for October 17, has an account of the sailing of the U. S. S. *Pensacola* with the American Eclipse Expedition to Africa. The expedition is under Professor D. P. Todd, of Amherst College, as chief astronomer. His astronomical assistants are Messrs. Bigelow, Davis and Jacobi. Mr. Carbutt goes as photographer, with Mr. Wright as his assistant; Mr. E. J. Loomis as naturalist; Professor Abbe as meteorologist, with G. E. Van Guysling as assistant; Mr. Preston as the observer of magnetics and for determinations of gravity; Mr. W. H. Brown as osteologist and naturalist, with his brother as assistant; Mr. Orr as ethnologist and ornithologist; H. Chatelaine as interpreter; G. T. Flint as stenographer, and Dr. Bartlett as apothecary! Add to these names that of Professor Alex. Agassiz, who may join the vessel at Cape Town to engage in deep-sea dredging. This is carrying the war into Africa, indeed. The newspaper account of the astronomical outfit is somewhat meagre. It appears that the expedition is provided with a photoheliograph, giving an image of the sun four inches in diameter. With this the partial phases will be photographed on *ortho-chromatic* plates (No. 16) and the total phase on *ortho-chromatic* plates (No. 27). A large mirror, belonging to Professor Langley, an equatorial belonging to the Harvard College Observatory, and *twenty* cameras are also provided for photography.

It is to be hoped that the expedition will meet with fine weather, in order to utilize its unusually large force of observers and instruments. Sir Isaac Newton said at the death of his pupil Cotes, "If Cotes had lived, we should have known something." If the four minutes of totality are clear at St. Paul de Loanda we shall certainly learn something from these many skilled observers with their large equipment.

It now appears that with two expeditions in Africa, and with two at least, in America, the observation of this eclipse is thoroughly well provided for. It should be a source of gratification to Californians, and especially to this Society, that the generosity of one of our members has allowed the Lick Observatory to put a strong expedition in the field. E. S. H.

October 26, 1889.

Eclipse of *Japetus*, the VIII Satellite of *Saturn*, on November 1, 1889.

The eclipse of *Japetus* was observed here on November 1 with the twelve-inch equatorial. Only a part of this very rare phenomenon was visible at this point, the interval between the rising of *Saturn* and daylight covering only a small portion of the time occupied by the eclipse, or, rather, series of eclipses; for the satellite passed through the shadow of the entire ring system as well as that of the globe of *Saturn*. The satellite would first pass into the outer edge of the shadow of the ring, and would next appear in the sunlight, shining through the Cassini division, being visible for probably eighteen minutes. It would then pass into the shadow of the inner bright ring; from this it would emerge in the semi-shadow of the Crape Ring, from which it would pass into the sunlight again between the shadow of the Crape Ring and that of the ball. It would next enter the shadow of the ball, and, from this point on, a reversal of all the first phenomena would happen. The entire series of eclipses covered a period of approximately nineteen hours. That portion of the eclipse which could be seen from the Lick Observatory was the reappearance from the shadow of the globe and passage through the semi-shadow of the Crape Ring into the shadow of the inner bright ring.

The important questions in connection with this phenomenon were: Would the satellite become visible when it came to the projection of the Cassini division? What would be the effect of the Crape Ring upon the appearance of the satellite?

The last question only could be answered from this point, as the satellite would rise eclipsed in the shadow of the ball, and not reach the second part of the Cassini division until long after sun-up.

Carefully watching the point of reappearance of the satellite, it was faintly caught at $14^h\ 38^m$ Mt. H. m. t. It reappeared quite close to the satellites *Tethys* and *Enceladus*. It grew pretty rapidly brighter, and attained its full brightness at about $14^h\ 50^m$. It was then about 0.1 magnitude less than *Tethys*. The proximity to these two satellites gave an excellent means of detecting changes in its brightness by comparison with their light. Eighty such comparisons were made, and from these I have constructed a curve, which very clearly shows what effect the Crape Ring had upon the appearance of the satellite. *Japetus* required a little over ten minutes to become wholly free from the shadow of the ball. After remaining at its full brightness for fifteen minutes, it began very slowly to decrease in light; however, changing less than 0.1 magnitude in forty minutes' time. At $15^h\ 54^m$ the light began to decrease more rapidly, and in sixty-five minutes it passed through 0.7 of a magnitude. It then approached the shadow of the inner bright ring, and in fifteen minutes its light diminished 0.66 of a magnitude, when it totally disappeared, at $17^h\ 11^m\ 1/2$.

These observations show us that, after striking the sunlight shining through between the ball and the rings, the satellite then passed into the shadow of the Crape Ring, which sensibly affected its brightness. Passing deeper into this *shade*, the absorption of the sunlight became more and more pronounced, until finally the satellite struck the shadow of the inner bright ring, which it rapidly entered and within which it disappeared.

These observations, therefore, tell us that the Crape Ring is truly transparent—the sunlight sifting through it; that the particles composing the Crape Ring cut off an appreciable quantity of sunlight; that these particles cluster more and more thickly—or, in other words, the Crape Ring is denser as it approaches the bright rings.

Observations made elsewhere will tell us whether the satellite was seen when it entered the projection of the CASSINI division. The observations will be published in full in the *Monthly Notices* of the Royal Astronomical Society. E. E. B.

MT. HAMILTON, Nov. 6th, 1889.

PARABOLIC ELEMENTS OF COMET SWIFT (NOV. 16).

By A. O. LEUSCHNER.

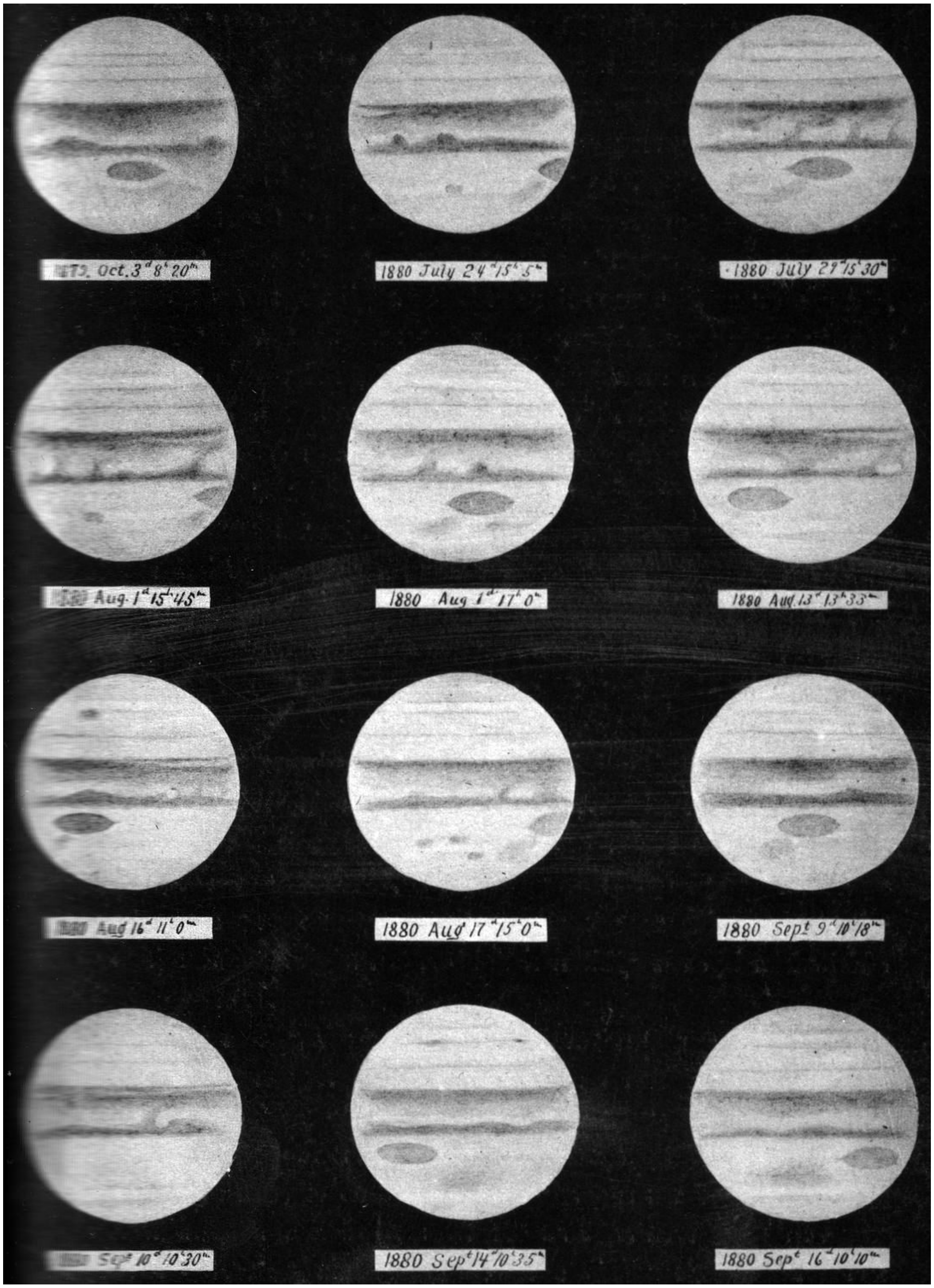
From the three successive observations at Lick Observatory, November 20, 21, 22, which were kindly communicated to me by Professor E. E. BARNARD, I have deduced the following parabolic elements by OPPOLZER'S method:

$$\begin{aligned} T &= 1889\text{, Dec. 11, 8493 G. M. T.} \\ \Omega &= 306^\circ\ 25' \\ \omega &= 116^\circ\ 24' \\ i &= 6^\circ\ 47' \\ \log q &= 0.0633 \end{aligned} \qquad \text{O} - \text{C} \begin{cases} \text{d}\,\lambda,\ \cos\beta = +1'.2 \\ \text{d}\,\beta \qquad\quad = \pm 0.0 \end{cases}$$

The small geocentric arc and the error of $1'.2$ remaining in λ render these elements extremely uncertain. The comet is very likely periodic.

BERKELEY, CAL., November 27, 1889.

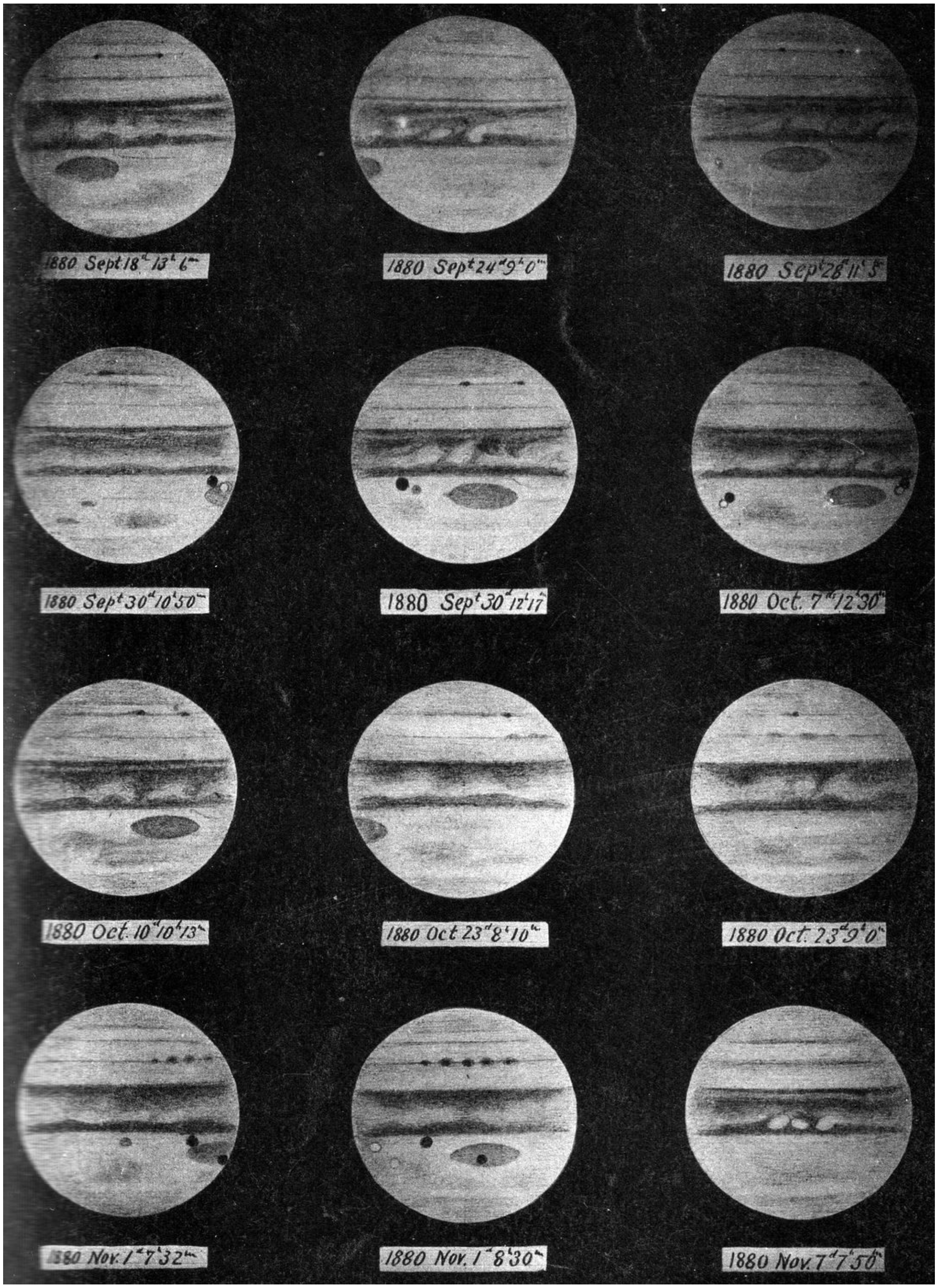
Plate I



E.E.B. Delt

Jupiter.

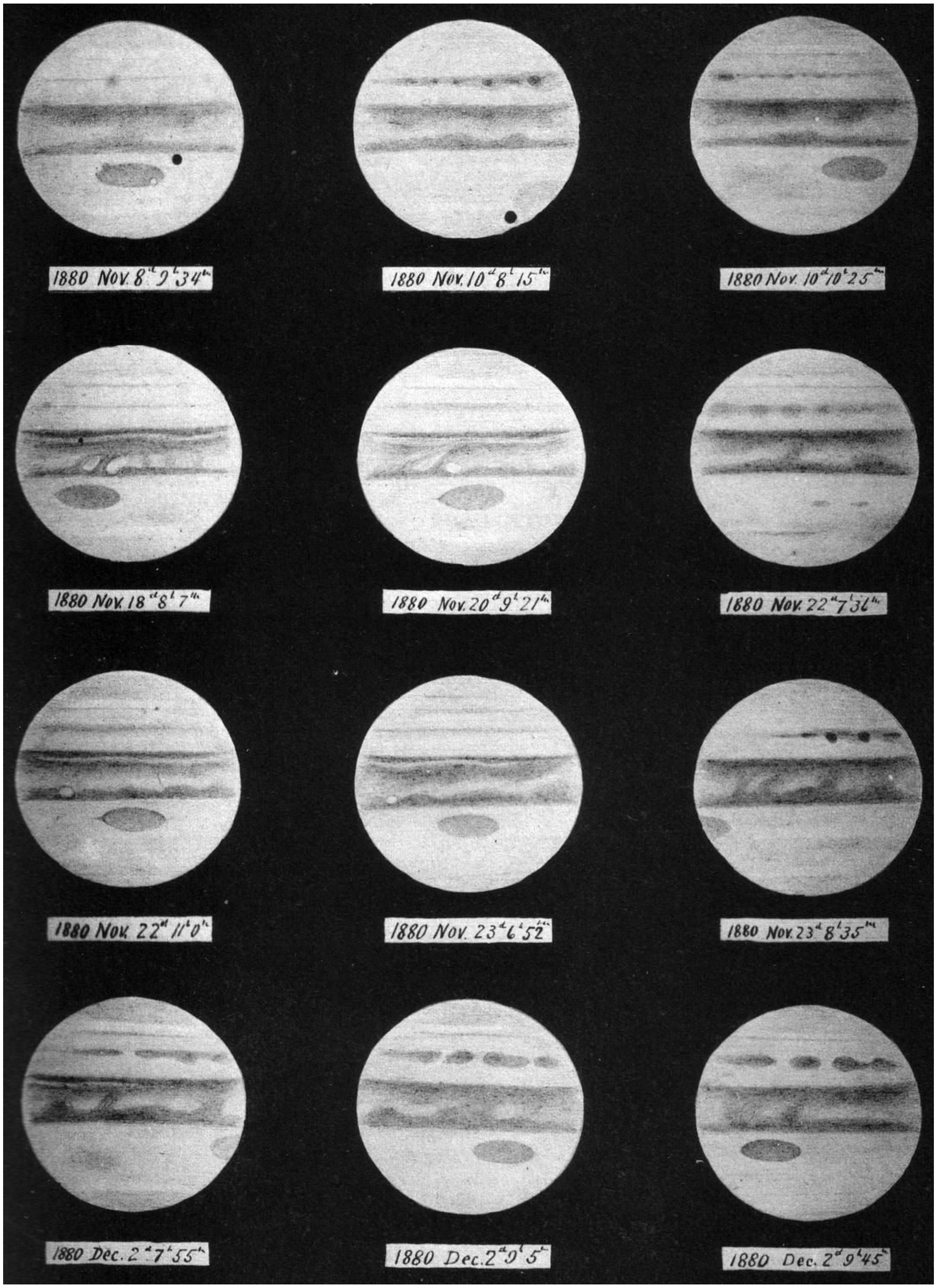
Plate II



E.E.B. Del^{t}

Jupiter.

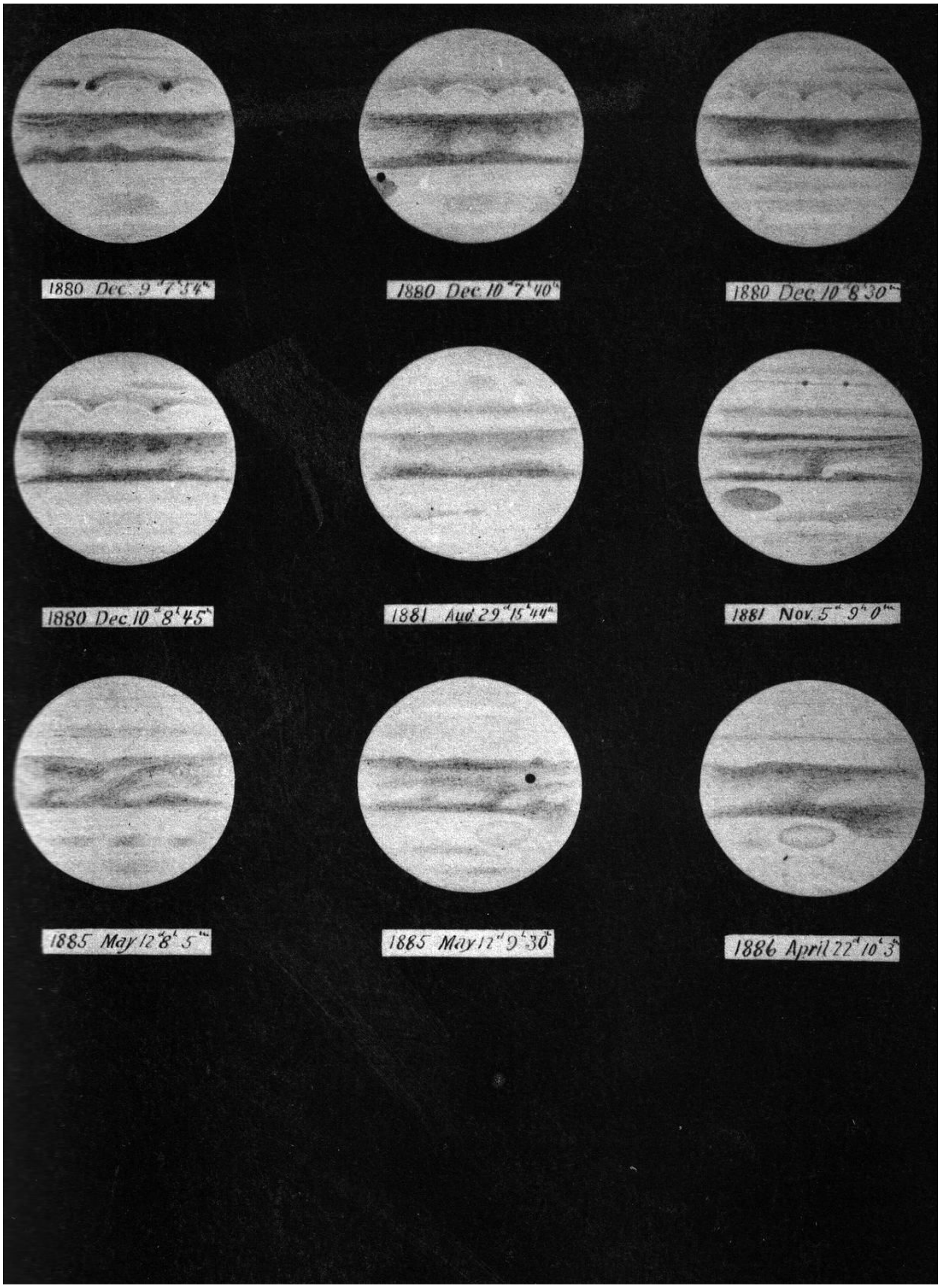
Plate III



E.E.B. Delt

Jupiter.

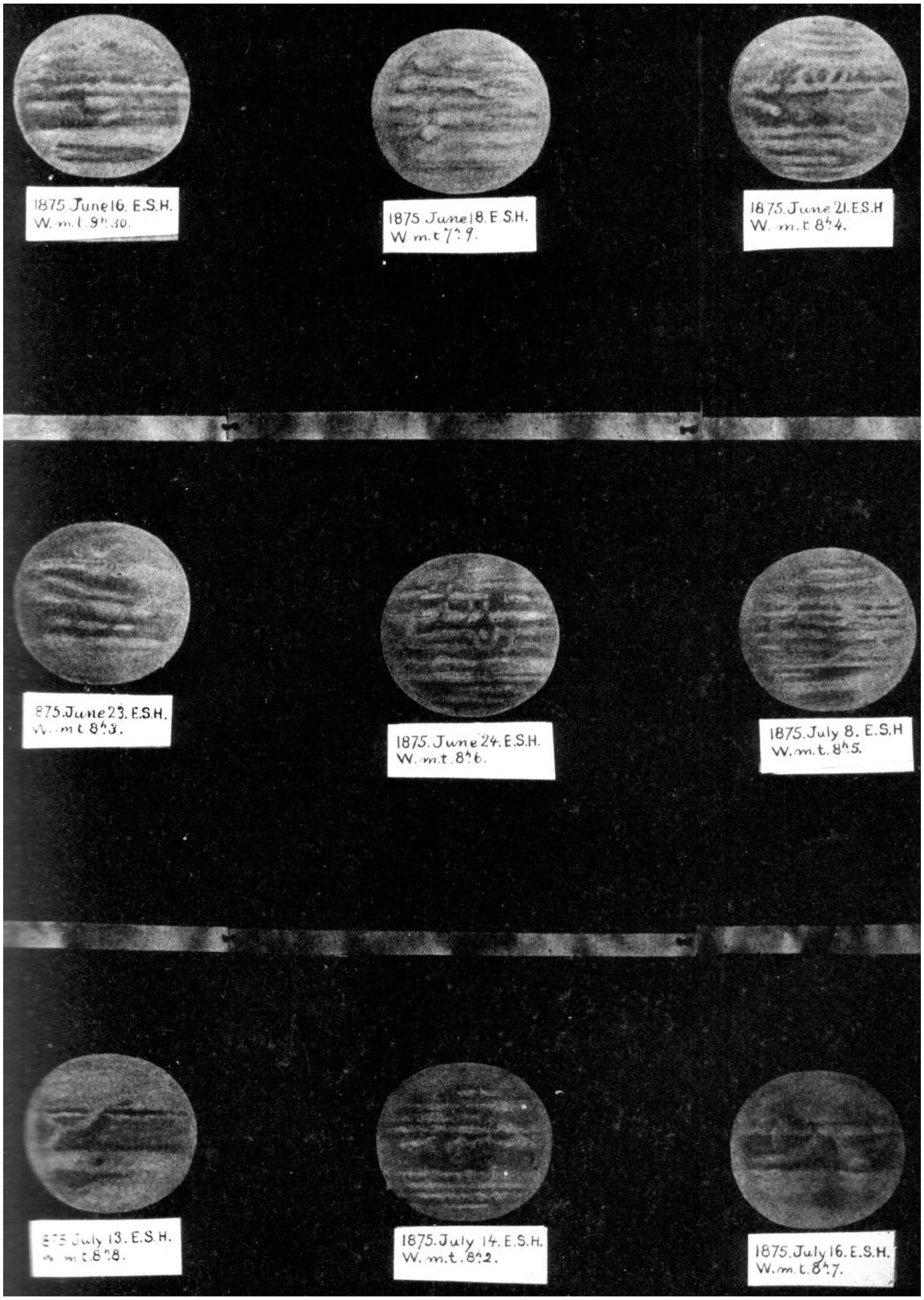
Plate IV



E.E.B. Del^{t}

Jupiter.

Plate V


1875. June 16. E.S.H.
W. m. t. 9h. 30.
1875. June 18. E.S.H.
W m.t 7h.9.
1875. June 21. E.S.H
W. m.t 8h.4.
875. June 23. E.S.H.
m.t 8h.3.
1875. June 24. E.S.H.
W. m.t. 8h.6.
1875. July 8. E.S.H
W. m.t. 8h.5.
875 July 13. E.S.H.
m.t. 8h.8.
1875. July 14. E.S.H.
W. m.t. 8h.2.
1875. July 16. E.S.H.
W. m.t. 8h.7.

Minutes of the Meeting of the Board of Directors, Held November 30, 1889, at 408 California Street, San Francisco.

A quorum was present.

The minutes of the last meeting were read and approved.

Bills presented by the Secretary and Treasurer were approved.

Miss C. W. Bruce, of New York City, was duly elected a life member, subject to the action of the Society.

Adjourned.

Minutes of the Meeting of the Astronomical Society Of the Pacific, Held November 30, 1889 (by Invitation), in the Rooms of the California Academy of Sciences, San Francisco.

[Prepared by the Secretaries for Publication.]

Owing to the absence of the President, Vice-President Pierson took the chair.

The thanks of the Society were tendered to the California Academy of Sciences for the use of their rooms.

The minutes of the last meeting were read and approved.

A list of gifts to the Society was read, and thanks were returned to the donors.

The following members were then elected; the names of life-members, duly elected by the Board of Directors, being marked with a star (*):

Charles S. Aiken,	Berkeley, Cal.
J. H. C. Bonté, D. D.	Berkeley, Cal.
Miss C. W. Bruce,*	39 East Twenty-third Street, N. Y. City.
N. E. Beckwith,	Los Gatos, Cal.
J. A. Brashear,	Allegheny City, Penn.
Charles M. Bakewell,	Berkeley, Cal.
Miss Agnes M. Clerke,	68 Redcliffe Square, London, England.
Hon. Horace Davis,	1011 Bush Street, San Francisco, Cal.
A. B. Depuy,	216 North Sixth Street, Camden, N. J.
Warren B. Ewer,	220 Market Street, San Francisco, Cal.
Mrs. Martha McC. Ewer,	220 Market Street, San Francisco, Cal.
John Gamble,	Laurel Hall, San Mateo, Cal.
Henry Harrison,	South Bergen, N. J.
Charles F. Hart,	N. Temescal, Alameda County, Cal.
O. C. Hastings,	Box 166, Victoria, B. C.
John J. Herr,	438 California Street, San Francisco, Cal.
Whitney Herr,	438 California Street, San Francisco, Cal.
Frank Jaynes,	W. U. Telegraph Co., San Francisco, Cal.
Rev. George W. James, F. R. A. S.,	Oleander, Fresno County, Cal.
Augustus F. Knudsen,	Box 2139, Boston, Mass.
Professor Joseph Le Conte,	Berkeley, Cal.
Miss Margaret Lepper,	Box 490, Benecia, Cal.
Warren Olney,	481 Prospect Avenue, Oakland, Cal.
James N. Pemberton,	Downey, Cal.
C. D. Perrine,	211 Clay Street, San Francisco, Cal.

J. E. Richards,	Los Gatos, Cal.
F. B. Rodolph,	969 Washington Street, Oakland, Cal.
Wm. G. Raymond,	Berkeley, Cal.
Professor J. K. Rees,	Observatory of Columbia College, New York City.
Wm. F. Smith,	2515 Broadway Street, San Francisco, Cal.
Garrett P. Serviss	8 Middagh Street, Brooklyn, N. Y.
J. A. Sladky,	Berkeley, Cal.
Irving M. Scott,	507 Harrison Street, San Francisco, Cal.
John H. Yoell,	San José, Cal.

The Secretary's books show that the Society now consists of 156 active and 22 life members, or 178 in all. Mr. Pierson announced to the Society that Hon. Alexander Montgomery, a member of the Society, offers the sum of $2500 to the Astronomical Society of the Pacific, for the purpose of establishing a gold medal to be awarded annually to the writer of the best paper on the subject of Astronomy presented to the Society during the year; the gift to be without conditions, and the Society to have the privilege of using this gift for other purposes. The Society accepted this generous gift by a rising vote.

A paper "On the Determination of the Relation between the Exposure Time and the consequent Blackening of a Photographic Film" was then read by Mr. Leuschner. This was followed by a paper "On Photographs of the Milky Way," by Mr. Barnard. The latter paper was illustrated by lantern slides prepared by Mr. Barnard from some of his own negatives. The other papers announced for the evening were not read.

The Society then adjourned to meet at its rooms, 408 California Street, on January 25, 1890.

OFFICERS OF THE SOCIETY.

Edward S. Holden (Lick Observatory),	*President*
Wm. M. Pierson (76 Nevada Block, S. F.), W. H. Lowden (213 Sansome Street, S. F.) Frank Soulé (Students' Observatory, Berkeley),	*Vice-Presidents*
Chas. Burckhalter (Chabot Observatory, Oakland), J. M. Schaeberle (Lick Observatory),	*Secretaries*
E. J. Molera (850 Van Ness Avenue, S. F.),	*Treasurer*

Board of Directors—Messrs. Alvord, Boericke, Burckhalter, Gibbs, Grant, Holden, Lowden, Molera, Pierson, Schaeberle, Soulé.

Finance Committee—Messrs. Gibbs, Pierson, Molera.

Committee on Publication—Messrs. Dewey, Treat, Ziel.

Committee on the Comet Medal—Messrs. Holden (*ex officio*), Schaeberle, Burckhalter.

NOTICE.

Members are requested to preserve the copies of the Publications of the Society as sent to them. Once each year a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

It is intended that each member of the Society shall receive a copy of each one of the Publications for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied.

Complete volumes for past years (preceding the calendar year in which any member was elected) will also be supplied to members, so far as the stock in hand is sufficient, on the payment of one dollar to either of the Secretaries.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.