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OF

THE ASTRONOMICAL OBSERVATORY OF HARVARD COLLEGE.

VOL. XIX.—PART I.

METEOROLOGICAL OBSERVATIONS

MADE DURING THE YEARS 1840 TO 1888 INCLUSIVE,

UNDER THE DIRECTION OF

WILLIAM CRANCH BOND, GEORGE PHILLIPS BOND, JOSEPH WINLOCK, AND  
EDWARD C. PICKERING,

SUCCESSIVE DIRECTORS OF THE OBSERVATORY.

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### CHAPTER III.

#### OBSERVATIONS OF AURORA BOREALIS.

THE original records of the following observations occur chiefly in the meteorological memoranda of the Observatory; but some of them have been found in the astronomical records. It is not known that any regular watch for aurora was kept before 1877. The auroras observed before that year are probably only such as happened to attract attention enough to secure a record, and it is likely that the amount of attention paid to auroral phenomena varied considerably at different periods. During the years 1877-1879, aurora was regularly looked for at 8<sup>h</sup> P.M., except during the months of June and July. In the years 1880-1888, it was regularly looked for at some time during every clear evening. To print the observations of the absence of aurora for the years following 1876 seems, therefore, to be superfluous; but such observations have been copied out for the previous years in the comparatively few cases in which they occur.

The names of the observers are not in all cases known. For the period 1840-1858, it is probable that most of the observations were made by Professor W. C. Bond; for the period 1859-1864, Professor G. P. Bond is most likely to have been the observer, in the absence of any indication to the contrary. During 1865, Professor T. H. Safford was in charge of the Observatory. For the period 1866-1868, the observations were made in part by Professor J. Winlock, and in part by Messrs. E. P. Austin, S. P. Langley, C. S. Peirce, and G. M. Searle. After 1868, the meteorological record was usually kept by Mr. Arthur Searle, but other observers have often made records of auroras. Mr. E. L. Trouvelot was connected with the Observatory during the years 1872-1874, and for this period his observations of aurora were very frequent. Many of his observations made at Medford (near Cambridge) in 1870 and 1871 are also comprised in the list below, but in all cases specially designated, to distinguish them from the Cambridge observations. The notes of different observers have frequently been used to form a description of a given aurora; but in such cases care has been taken not to combine two accounts of the same phenomenon.

When the observers are mentioned, it is frequently by their full names. The initials R. F. B. (for Richard F. Bond) occur in addition to those of the gentlemen already named.

#### OBSERVATIONS OF AURORA BOREALIS.

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- September 19. Aurora at 10<sup>h</sup> P.M.
- September 21. Aurora.
- September 22. Aurora.
- September 23. Aurora at midnight.
- September 25. Aurora at 11<sup>h</sup> P.M.; bright and flashing at 12<sup>h</sup> P.M.
- September 28. Aurora.
- September 29. Auroral arch at 8<sup>h</sup> 30<sup>m</sup> P.M.
- October 2. Aurora.
- October 3. Aurora through clouds.
- October 8. Aurora in northeast at 2<sup>h</sup> A.M.
- October 24. Faint aurora all the evening.
- November 26. Faint aurora at midnight.

1868.

- March 19. Aurora.
- March 22. Aurora.
- April 13. Aurora at 9<sup>h</sup> P.M.
- April 18. Fine aurora; no vertical lines; at 12<sup>h</sup> P.M., vertical lines detached from the bright cloud.
- April 26. Aurora, not very bright.
- April 28. Aurora, faint.
- July 10. Very bright and remarkable white aurora. At 10<sup>h</sup> 55<sup>m</sup> P.M., very rapid vibrations toward zenith at intervals of  $\frac{3}{4}$  second. Pretty faint at 11<sup>h</sup> 15<sup>m</sup> P.M. Had been visible since dark. One bright line observed with spectroscope at  $\lambda$  5550  $\pm$  (J. W.), 5650  $\pm$  (C. S. P.).
- September 5. Brilliant aurora at 8<sup>h</sup> 35<sup>m</sup> P.M.
- November 19. Aurora at 9<sup>h</sup> P.M., with steady streamers and upward waves of white light.

1869.

- January 6. Brilliant aurora from 8<sup>h</sup> 30<sup>m</sup> to 9<sup>h</sup> 30<sup>m</sup> P.M.
- January 7. Aurora about 10<sup>h</sup> P.M.
- February 5. Fine aurora, with streamers, last midnight.
- March 9. Very brilliant aurora indeed. Spectrum of one remarkably bright line,  $\lambda$  5700  $\pm$  (J. W.), 5650  $\pm$  (C. S. P.); this line as bright as the brightest in the spectrum of the nebula in *Orion*, and quite narrow when the slit is closed.

up. J. W. also saw a very faint continuous spectrum crossed by dark bands or stripes more refrangible than the bright line; some continuous light far up in the violet; the continuous spectrum was not nearly as bright as that of the nebula in *Orion*.

April 5. Fine aurora. Single line in spectrum at  $\lambda 5600 \pm$  (C. S. P.); seen also by J. W.

April 9. Fine aurora at 10<sup>h</sup> P.M., with strong vertical streamers and very dark sky under the arch. Some auroral light has appeared on several evenings lately.

April 10. Aurora; not very fine; not perceptible in spectroscope at first. One line seen on a new trial; another very doubtful.

April 15. Aurora covering larger part of the sky, first noticed about 7<sup>h</sup> 30<sup>m</sup> P.M., by C. S. P. Part of it was then rose-colored, part of the usual yellowish-green. Rose-color disappeared before telescope could be turned on it. At 10<sup>h</sup> sidereal time [8<sup>h</sup> 25<sup>m</sup> P.M.], streamers converging spirally from all quarters to a point near  $\zeta$  *Leonis*; spiral from west to north, north to east, east to south, south to west; clouds partly cut off the view toward midnight.

The spectrum was observed by C. S. P. with the large telescope. The red color having then disappeared, no red line was seen in the spectrum. The places of seven lines were determined and reduced to the scale of Mr. Huggins. The results were printed in the "American Journal of Science," XCVIII. 404, and in Volume VIII. of these Annals, p. 50. Reducing the measurements to wave-lengths by means of the data given by Dr. Gibbs in the "American Journal of Science," XCVII. 203, we shall have the following approximate values:

No.	Huggins.	$\lambda$ .	Remarks.
1	1280	5570	Brightest line.
2	1400	5446	.....
3	1550	5320	.....
4	1680	5210	.....
5	....	....	Near F.
6	2640	4650	.....
7	....	....	Near G.

April 16. Moderate aurora about 9<sup>h</sup> P.M.

May 7. Moderate aurora about 9<sup>h</sup> P.M.; one bright line seen with spectroscope.

June 6. Aurora. Bright arch at 10<sup>h</sup> P.M., with little appearance of streamers at 10<sup>h</sup> 15<sup>m</sup>. At 11<sup>h</sup> 20<sup>m</sup> aurora much more brilliant, streamers extending to zenith. At 2<sup>h</sup> 20<sup>m</sup> A.M. (June 7) renewed activity of aurora, streamers extending to and beyond the zenith. At 2<sup>h</sup> 30<sup>m</sup> overcast to the south.

The spectrum at about 10<sup>h</sup> 15<sup>m</sup> P.M. (June 6) showed only the usual line in the green. At 11<sup>h</sup> 20<sup>m</sup> P.M. this line was well seen in a direct-vision spectro-

scope used without a telescope in the dark sky below the aurora light as well as in the light itself; and there also appeared several broad faint bands more refrangible than the green line. A comparison with the spectrum of air from sparks passing between platinum electrodes showed that the green line was not coincident with any line of the spectrum of air. With a chemical spectroscope having one prism, five lines or bands were seen in the spectrum of the aurora, the green line being the least refrangible. At 2<sup>h</sup> 30<sup>m</sup> A.M. (June 7) the green line could be perceived in the spectrum of the southeastern sky, 30° beyond the apparent termination of the auroral light.

June 29. Brilliant aurora about 9<sup>h</sup> P.M., with usual streamers in the north, also a high arch beyond them extending from the east to the west point. This arch was very white and was the brightest part of the aurora; it moved slowly to the south, and later streamers appeared in the south. At 16<sup>h</sup> 28<sup>m</sup>, chronometer A 424 [10<sup>h</sup> P.M.],  $\alpha$  *Aquilæ* was in the middle of the arch; at 16<sup>h</sup> 31<sup>m</sup> [10<sup>h</sup> 3<sup>m</sup>] *Arcturus* was in the middle of the arch; chronometer A 424 compared with south clock and found to be two minutes slow. The spectrum of the streamers showed the usual green line; that of the arch from east to west was continuous.

June 30. Some auroral light 9<sup>h</sup> to 10<sup>h</sup> P.M.

August 6. Aurora this evening.

August 24. Aurora; also a narrow band of light in a great circle from horizon to horizon nearly. This showed a continuous bright spectrum with telescope and with chemical spectroscope. Passed through the moon at 20<sup>h</sup> 23<sup>m</sup> sidereal time [10<sup>h</sup> 11<sup>m</sup> P.M.]. At 20<sup>h</sup> 25<sup>m</sup> [10<sup>h</sup> 13<sup>m</sup> P.M.] set little telescope out of doors so that the band was on a circle of declination all the way (J. W. and C. S. P.). Mr. Langley got place of band by stars as follows: At 8<sup>h</sup> 20<sup>m</sup> (Arnold) [apparently mean time] the band covered  $\delta$  and  $\mu$  *Herculis*, and its middle line was inclined so as to be about 30' south of  $\mu$  while it crossed  $\delta$ . The other extremity touched the moon. The band was sinuous. It was roughly estimated as 2.5 wide and as moving southward (keeping nearly parallel to its first place) at the rate of 3° a minute. At 8<sup>h</sup> 23<sup>m</sup> the band was growing faint and appeared about 4° south of  $\mu$ . (These estimates of its motion do not agree.) At 8<sup>h</sup> 37<sup>m</sup> it was south of  $\alpha$  *Ophiuchi* and very diffuse. From this it returned to a position between  $\alpha$  *Herculis* and  $\alpha$  *Ophiuchi*, where it remained till it disappeared (S. P. L.).

Bars crossed this band or formed another south of it, obliquely pointing toward the zenith. They moved slowly from east to west, continuing to point to the zenith.

One line very distinct, four other lines or bands seen by C. S. P., also two of them by J. W. and A. G. Clark, very faint but indubitable. Seen with chemical spectroscope without telescope.

September 3. Auroral arch at 22<sup>h</sup> [11<sup>h</sup> 9<sup>m</sup> P.M.], extending from eastern horizon to western between  $\alpha$  *Andromedæ* and  $\gamma$  *Pegasi*, over  $\beta$  *Pegasi* and  $\beta$  *Cygni* and so on to western horizon; drifted slowly to southward; had a continuous spectrum with some signs of the bright line. (E. P. A.)

This arch showed continuous spectrum with the auroral line faintly but decidedly. (C. S. P.)

September 5. Much auroral light in the early part of the evening. An uncommonly bright streamer appeared about 8<sup>h</sup> 45<sup>m</sup> P.M. It was high in the sky (Vega being about in its centre) and detached from the auroral arch; it was not straight, but of a sinuous form. Detached clouds of auroral light (like cirro-strati) also appeared, remaining stationary longer than common.

September 11. Aurora in the evening, lasting till after midnight.

September 13. Aurora in the evening, lasting till after midnight.

September 14. Auroral arch visible at midnight, September 14-15; not bright.

September 15. Some faint auroral light in the evening.

September 27. Aurora through the evening; fine and very bright; extended to zenith; very brilliant white streamers about 9<sup>h</sup> P.M.

September 28. Aurora in the evening.

September 29. Some aurora in the evening.

October 1. Some aurora behind clouds.

October 2. Some aurora behind clouds.

October 6. Pretty bright aurora this evening; arch distinct; not much appearance of streamers.

October 25. Auroral arch formed early in the evening. At 9<sup>h</sup> P.M., light unusually green, with some appearance of streamers. At 11<sup>h</sup> P.M., faint, a little yellow; a few streamers.

October 27. Some aurora all the evening.

October 31. Aurora; double and sometimes triple arch. - Some appearance of streamers at 9<sup>h</sup> P.M. Later, the streamers extended at times nearly to the zenith and showed rose-color.

November 8. Aurora behind clouds during evening.

November 9. Aurora; streamers and arch.

November 11. Appearance of some aurora behind clouds in the evening.

November 25. Aurora at 7<sup>h</sup> 20<sup>m</sup> P.M.; pretty bright.

red light, reaching beyond the zenith; it soon faded again. C. S. Peirce noticed a bright arch at 9<sup>h</sup> P.M.; very bright about 9<sup>h</sup> 15<sup>m</sup> P.M. He thought the red light which appeared about 10<sup>h</sup> 30<sup>m</sup> P.M. much redder than that of any previous aurora. It appeared to A. Searle not redder, perhaps even paler than that of the aurora of October 14, 1870. With the spectroscope C. S. Peirce found no trace of light less refrangible than the usual green line; but there were lines more refrangible, which, with the continuous light between them, looked red in the sky. The red and green were mingled in the sky in irregular bands. Trouvelot at Medford saw red light at 6<sup>h</sup> P.M., particularly, in the west, where it formed a pyramid with its base almost on the horizon, rising much higher than elsewhere. There was a similar pyramid at Cambridge, smaller and fainter. At 6<sup>h</sup> [? perhaps 9<sup>h</sup>] P.M. the red light was gone, and only a pale light remained over a dark segment in the north. Toward 11<sup>h</sup> P.M. there were bright streamers. Between midnight and 1<sup>h</sup> A.M. (November 10) there were still streamers, but pale and colorless, colors not having appeared since 6<sup>h</sup> [in marked contrast to the observations at Cambridge]. No undulatory or pulsating movement was noticed, nor even any such lateral movement of streamers from east to west as is often seen.

November 10. Aurora by nightfall seen by E. L. Trouvelot at Medford.

November 12. Faint aurora most of the night seen by E. L. Trouvelot at Medford.

November 14. Some auroral light from 2<sup>h</sup> 30<sup>m</sup> to 5<sup>h</sup> A.M. seen over bank of clouds; no distinct arch or streamers.

November 17. Clear night; no light seen by E. L. Trouvelot at Medford.

November 19. Faint aurora, without streamers, seen by E. L. Trouvelot at Medford; suspected at Cambridge.

November 23. Faint aurora, with dark segment, but no streamers, between 6<sup>h</sup> and 9<sup>h</sup> P.M.; observation by E. L. Trouvelot at Medford.

December 8. Rather fine aurora seen by E. L. Trouvelot at Medford, with long dark segment and fine light above; all not over 45° altitude; no streamers; auroral arch observed at Cambridge at times from 7<sup>h</sup> P.M. to midnight; few streamers; arch quiet, narrow at first, afterward rather wide.

December 9. Low auroral arch at 7<sup>h</sup> 30<sup>m</sup> P.M. At 9<sup>h</sup> P.M. another below the first, on the horizon; aurora seen by E. L. Trouvelot at Medford; began at 8<sup>h</sup> 30<sup>m</sup> P.M.; streamers ten minutes later of an unusual kind, being short and not anywhere higher than 25° or 30°; no traces of aurora left at 10<sup>h</sup> P.M.; the streamers began to appear in the northeast.

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December 9. Low auroral arch at 7<sup>h</sup> 30<sup>m</sup> P.M. At 9<sup>h</sup> P.M. another below the first, on the horizon; aurora seen by E. L. Trouvelot at Medford; began at 8<sup>h</sup> 30<sup>m</sup> P.M.; streamers ten minutes later of an unusual kind, being short and not anywhere higher than 25° or 30°; no traces of aurora left at 10<sup>h</sup> P.M.; the streamers began to appear in the northeast.



the pale tint peculiar to periods of aurora showed itself; then mists slowly gathered in the north horizon, and at the end of half an hour formed a very high and not well-defined segment. At 8<sup>h</sup> 40<sup>m</sup> P.M. two short streamers issued from the red light in the south-southeast; toward 9<sup>h</sup> P.M. two or three undefined streamers appeared above the northeastern mists. At 10<sup>h</sup> P.M. rather fine streamers issued from the segment, but not well-defined nor rising above 65° to 70°. At 10<sup>h</sup> 50<sup>m</sup> P.M. the reddish light in the south exactly resembled in form and position the whitish light in the north, and seemed like a copy of it; was it the northern auroral light refracted over to the southern mists? At 11<sup>h</sup> 15<sup>m</sup> P.M. the aurora was much diminished; the red tint was nearly gone, and so was the whitish light in the north.

The bright red light in the south was observed with the spectroscope by J. W. and C. S. P.; no line seen in red, though five other lines were seen in fainter aurora (green) at north.

February 5. Faint aurora in the north at 9<sup>h</sup> 40<sup>m</sup> P.M., without streamers; sky below remarkably dark; aurora seen also at 10<sup>h</sup> 20<sup>m</sup> P.M.

February 7. Aurora at 7<sup>h</sup> 45<sup>m</sup> P.M.; some pale auroral light behind a dark segment only a few degrees in altitude; not conspicuous, but clearly recognized. At 8<sup>h</sup> 45<sup>m</sup> P.M. no trace of it could be seen; none seen at 9<sup>h</sup> 30<sup>m</sup> P.M.

February 15. A faint aurora seen toward midnight by J. W.

February 18. Auroral light toward 10<sup>h</sup> P.M.; faint, with a dark segment.

February 19. Aurora at 9<sup>h</sup> P.M., without streamers; it was a light above a dark segment well seen in spite of moonlight.

February 20. Aurora toward 10<sup>h</sup> P.M.; faint; undefined light in the north.

February 27. Aurora visible at 7<sup>h</sup> 50<sup>m</sup> P.M.; only a rather strong light; no streamers; a little auroral light low in the north from 8<sup>h</sup> 30<sup>m</sup> to 9<sup>h</sup> P.M.; no traces to be seen of it at 9<sup>h</sup> 45<sup>m</sup> P.M., the moon then rising.

March 1. A pretty bright aurora at 9<sup>h</sup> P.M., without streamers, and with a low and very dark segment. At 9<sup>h</sup> 25<sup>m</sup> P.M. aurora more extensive and brighter; segment higher; wind none at nightfall, pretty strong upon the appearance of the aurora; the arched appearance peculiar to this aurora was soon lost and a greenish mist rose nearly to the upper limit of the light, forming an immense segment bordered by a pale and much diffused light. At 10<sup>h</sup> 45<sup>m</sup> P.M. arch and some streamers, both undefined.

March 5. Aurora at 9<sup>h</sup> P.M.; no streamers, but pretty bright light over dark segment.

March 6. Aurora at 10<sup>h</sup> P.M.; faint; no streamers; with dark segment; calm; at 10<sup>h</sup> 30<sup>m</sup> P.M. still visible.

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