

their accompanying faculæ for all the Kew pictures available for this purpose.

From this it appeared that out of 1137 cases 584 have their faculæ entirely or mostly on the left side, 508 have it nearly equal on both sides, while only 45 have it mostly to the right. It would thus appear as if the luminous matter being thrown up into a region of greater absolute velocity of rotation fell behind to the left; and we have thus reason to suppose that the faculous matter which accompanies a spot is abstracted from that very portion of the sun's surface which contains the spot, and which has in this manner been robbed of its luminosity.

Again, there are a good many cases in which a spot breaks up in the following manner. A bridge of luminous matter of the same apparent luminosity as the surrounding photosphere appears to cross over the umbra of a spot unaccompanied by any penumbra. There is good reason to think that this bridge is above the spot; for were the umbra an opaque cloud and the penumbra a semi-opaque cloud, both being above the sun's photosphere, it is unlikely that the spot would break up in such a manner that the observer should not perceive some penumbra accompanying the luminous bridge. Finally, detached portions of luminous matter sometimes appear to move across a spot without producing any permanent alteration.

From all this it was inferred that the luminous photosphere is not to be viewed as composed of heavy solid, or liquid matter, but is rather of the nature either of a gas or cloud, and also that a spot is a phenomenon existing below the level of the sun's photosphere.

The paper concluded with theoretical considerations more or less probable. Since the central or bottom part of a spot is much less luminous than the sun's photosphere, it may perhaps be concluded that the spot is of a lower temperature than the photosphere; and if it be supposed that all the sun's mass at this level is of a lower temperature than the photosphere, then we must conclude that the heat of our luminary is derived from without.

## II. "On the Spectrum of the Great Nebula in the Sword-handle of Orion." By WILLIAM HUGGINS, F.R.A.S. Communicated by the Treasurer. Received January 11, 1865.

In a paper recently presented to the Royal Society\*, I gave the results of the application of prismatic analysis to some of the objects in the heavens known as nebulæ. Eight of the nebulæ examined gave a spectrum indicating gaseity, and, of these, six belong to the class of small and comparatively bright objects which it is convenient to distinguish still by the name of planetary. These nebulæ present little indication of probable resolvability into discrete points, even with the greatest optical power which has yet been brought to bear upon them.

The other two nebulæ which gave a spectrum indicative of matter in the

\* On the Spectra of some of the Nebulæ, Phil. Trans. 1864, p. 437.

gaseous form, are 57 M, the annular nebula in Lyra, and 27 M, the Dumb-bell nebula. The results of the examination of these nebulae with telescopes of great power must probably be regarded as in favour of their consisting of clustering stars. It was therefore of importance to determine, by the observation of other objects, whether any nebulae which have been *certainly resolved* into stars give a spectrum which shows the source of light to be glowing gas. With this purpose in view I submitted the light of the following easily resolved clusters to spectrum analysis.

"4670. 2120 h. 15 M. Very bright cluster; well resolved" \*.

"4678, 2125 h. 2 M. Bright cluster, well resolved."

Both these clusters gave a continuous spectrum.

I then examined the Great Nebula in the Sword-handle of Orion. The results of telescopic observation on this nebula † seem to show that it is suitable for observation as a crucial test of the correctness of the usually received opinion that the resolution of a nebula into bright stellar points is a certain and trustworthy indication that the nebula consists of discrete stars after the order of those which are bright to us. Would the brighter portions of the nebula adjacent to the trapezium, which have been resolved into stars, present the same spectrum as the fainter and outlying portions? In the brighter parts, would the existence of closely aggregated stars be revealed to us by a continuous spectrum, in addition to that of the true gaseous matter?

The telescope and spectrum apparatus employed were those of which a description was given in my paper already referred to.

The light from the brightest parts of the nebula near the trapezium was resolved by the prisms into three bright lines, in all respects similar to those of the gaseous nebulae, and which are described in my former paper.

These three lines, indicative of gas, appeared (when the slit of the apparatus was made narrow) very sharply defined and free from nebulousness; the intervals between the lines were quite dark.

When either of the four bright stars,  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$  Trapezii was brought upon the slit, a continuous spectrum of considerable brightness, and nearly linear (the cylindrical lens of the apparatus having been removed), was seen, together with the bright lines of the nebula, which were of considerable length, corresponding to the length of the opening of the slit. The

\* The numbers and descriptions are from Sir John Herschel's Catalogue, Phil. Trans. 1864, part 1.

† "The general aspect of the less luminous and cirrous portion is simply nebulous and irresolvable; but the brighter portion immediately adjacent to the trapezium forming the square front of the head, is shown with the 18-inch reflector broken up into masses, whose mottled and curdling light evidently indicates, by a sort of granular texture, its consisting of stars, and when examined under the great light of Lord Rosse's reflector, or the exquisite defining power of the great achromatic at Cambridge, U. S., is evidently perceived to consist of clustering stars. There can therefore be little doubt as to the whole consisting of stars too minute to be discerned individually even with these powerful aids, but which become visible as points of light when closely adjacent in the more crowded parts . . ."—Sir John Herschel, 'Outlines of Astronomy,' 7th edition, pp. 651, 652.

fifth star  $\gamma'$  and the sixth  $\alpha'$  are seen in the telescope, but the spectra of these are too faint for observation.

The positions in the spectra of  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$  Trapezii, which correspond to the positions in the spectrum of the three bright lines of the nebula, were carefully examined, but in no one of them were dark lines of absorption detected.

The part of the continuous spectra of the stars  $\alpha$ ,  $\beta$ ,  $\gamma$ , near the position in the spectrum of the brightest of the bright lines of the nebula, appeared on a simultaneous comparison to be more brilliant than the line of the nebula, but in the case of  $\gamma$  the difference in brightness was not great. The corresponding part of  $\delta$  was perhaps fainter. In consequence of this small difference of brilliancy, the bright lines of the adjacent nebula appeared to cross the continuous spectra of  $\gamma$  and  $\delta$  Trapezii.

Other portions of the nebula were then brought successively upon the slit; but throughout the whole of those portions of the nebula which are sufficiently bright for this method of observation the spectrum remained unchanged, and consisted of the three bright lines only. The whole of this Great Nebula, as far as it lies within the power of my instrument, emits light which is identical in its characters; the light from one part differs from the light of another in intensity alone.

The clustering stars of which, according to Lord Rosse and Professor Bond, the brighter portions of this nebula consist, cannot be supposed to be invisible in the spectrum apparatus because of their faintness, an opinion which is probably correct of the minute and widely separated stars seen in the Dumb-bell nebula, and to which reference was made in my former paper. The evidence afforded by the largest telescopes appears to be that the brighter parts of the nebula in Orion consist of a "mass of stars;" the whole, or the greater part of the light from this part of the nebula, must therefore be regarded as the united radiation of these numerous stellar points. Now it is this light which, when analyzed by the prism, reveals to us its gaseous source, and the bright lines indicative of gaseity are free from any trace of a continuous spectrum, such as that exhibited by all the brighter stars which we have examined.

The conclusion is obvious, that the detection in a nebula of minute closely associated points of light, which has hitherto been considered as a certain indication of a stellar constitution, can no longer be accepted as a trustworthy proof that the object consists of true stars. These luminous points, in some nebulae at least, must be regarded as themselves gaseous bodies, denser portions, probably, of the great nebulous mass, since they exhibit a constitution which is identical with the fainter and outlying parts which have not been resolved. These nebulae are shown by the prism to be enormous gaseous systems; and the conjecture appears probable that their apparent permanence of general form is maintained by the continual motions of these denser portions which the telescope reveals as lucid points.

The opinions which have been entertained of the enormous distances of the

nebulae, since these have been founded upon the supposed extent of remoteness at which stars of considerable brightness would cease to be separately visible in our telescope, must now be given up in reference at least to those of the nebulae the matter of which has been established to be gaseous.

It is much to be desired that *proper motion* should be sought for in those of the nebulae which are suitable for this purpose; indications of parallax might possibly be detected in some, if any nebulae could be found that would admit of this observation.

If this view of the greater nearness to us of the gaseous nebulae be accepted, the magnitudes of the separate luminous masses which the telescope reveals as minute points, and the actual intervals existing between them, would be far less enormous than we should have to suppose them to be on the ordinary hypothesis.

It is worthy of consideration that all the nebulae which present a gaseous spectrum exhibit the *same three bright lines*; in one case only, 18 H.IV., was a fourth line seen. If we suppose the gaseous substance of these objects to represent the "nebulous fluid" out of which, according to the hypothesis of Sir Wm. Herschel, stars are to be elaborated by subsidence and condensation, we should expect a gaseous spectrum in which the groups of bright lines were as numerous as the dark lines due to absorption which are found in the spectra of the stars. Moreover, if the improbable supposition be entertained, that the three bright lines indicate matter in its most elementary forms, still we should expect to find in some of the nebulae, or in some parts of them, a more advanced state towards the formation of a number of separate bodies, such as exist in our sun and in the stars; and such an advance in the process of formation into stars would have been indicated by a more complex spectrum.

My observations, as far as they extend at present, seem to be in favour of the opinion that the nebulae which give a gaseous spectrum, are systems possessing a structure, and a purpose in relation to the universe, altogether distinct and of another order from the great group of cosmical bodies to which our sun and the fixed stars belong.

The nebulous star  $\iota$  Orionis was examined, but no peculiarity could be detected in its continuous spectrum\*.

III. "Further Observations on the Planet Mars." By JOHN PHILLIPS, M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford. Received January 12, 1865.

The return of Mars to his periodical opposition with the sun has enabled me to offer a few observations on this planet, in addition to those which on a former occasion I had the honour to present to the Society †. Among

\* Admiral Smyth appears to have always maintained that the results of telescopic observation on the nebulae were insufficient to support the opinion that all these objects were probably of stellar constitution. See his 'Cycle of Celestial Objects,' vol. i. p. 316; and his 'Speculum Hartwellianum,' pp. 111-114.

† Proceedings of the Royal Society, 1863.