effects of precession for every particular star. He was not aware till that evening that a globe of a similar character was in the possession of the Society.

Mr. Christie. We have also a similar globe at the Greenwich Observatory which the Astronomer Royal had made some thirty or forty years ago; and we have often found it useful when we are troubled with questions on Babylonian and Egyptian astronomy, as to the heliacal rising and setting of stars, and so on. Now that Mr. Bosanquet has made this globe, we may hope that these questions will be addressed to him, as he has entered so fully into the subject, and is so much more competent to answer inquiries.

The President. I ought not to leave the Chair without mentioning the most serious loss which the Royal Astronomical Society has sustained in the death of Prof. Peters, the Director of the Royal Observatory of Kiel, and for so long a time the editor of the 'Astronomische Nachrichten.' He died, after a long illness, on Saturday last; and it is only right that from this Chair some expression of regret should be made to the Fellows of the Society at the loss to Astronomy from his death.

Lord Lindsay. Would it be in order for the Meeting to request the Council to express their sympathy with his widow?

The President. If it is the pleasure of the Meeting, the Council will send an expression of regret and condolence to Prof. Peters's widow.

Lord Lindsay. Might I ask if any reliable information has come from the Cape about the great Southern Comet?

The President. There have been some observations from Melbourne, but the best series of observations are those made by Dr. Gould. We must rely mainly upon his observations for elements in the present year.

The following gentlemen were balloted for and duly elected Fellows of the Society:—T. Buckney, L. A. Eddie, T. Gullon, and N. Perini.

The Meeting adjourned at ten o'clock.

On Comets and Ultra-Neptunian Planets.*

The object of the present communication is, first, to show reasons for a belief in the existence of two planets whose orbits are greater than that of Neptune; and, secondly, to indicate the probable positions of these planets.

The whole of this research is founded upon the theory of the introduction of comets as permanent members of the solar system, which is now generally held. According to this theory, comets are bodies of size, composition, and character, which we need not at present discuss, but which move through interstellar space subject to the laws of gravitation. Every time that such a comet becomes

* Abstract of a Memoir read before the Royal Society of Edinburgh, by Prof. George Forbes. From an advance copy.

sensibly attracted by any star, such as we have reason to suppose our Sun to be, it is attracted towards it, and tends to describe about it an orbit sensibly parabolic.

Let us call the distance of the Earth from the Sun one Earth's radius. The orbits of comets thus attracted into the Sun's neighbourhood, though on the numerical average parabolic, may have these orbits transformed, by planetary perturbation, either into ellipses or hyperbolæ. If the comet approach a planet in such a manner that its velocity is increased, it then will describe a hyperbolic orbit in future, and will never again return to the Sun. But if the action of the planet be such as to reduce the velocity of the comet, it will then for the future revolve in an elliptic orbit round the Sun, which may have its elements altered by planetary perturbations, and which may eventually be actually in this way driven out of the solar system altogether, but which, in default of these accidental occurrences, must become a permanent member of the solar system.

It has long been known that the aphelion-distances of comets are grouped in classes at definite distances from the Sun. Thus we know that there is a large group of comets whose aphelion-distance is about the same as the distance of Jupiter from the Sun. Jupiter's distance is 5 Earth's radii, and there are 11 periodic comets whose aphelion-distance is between 4 and 6 Earth's radii. Neptune's distance is 30 Earth's radii, and there are six comets whose aphelion-distances vary from 32 to 35 Earth's radii.

Aphelion distances of all the Comets revolving in elliptic orbits.

Comet.	Aph. Dist.	Comet.	Aph. Dist.	Comet.	Aph. Dist.
Encke's ..	4·1	1852 iv ..	32·0	1811 ii ..	181·4
Pons'	4·8	1812	33·4	1807	285·2
1844 i	5·0	1815	34·0	1858 vi ..	303·8
1743 i	5·3	1846 iv ..	34·5	1769	322·8
1766 ii....	5·5	1847 v ..	35·0	1840 ii ..	359·3
1819 iii ..	5·5	Halley's .	35·4	1827 iii ..	377·4
Brorsen's ..	5·6	1862 iii .	48·6	1846 i ..	388·2
Lexell's ..	5·7	1683	65·5	1811 i ..	420·7
1846 iii ..	5·7	1857 iv ..	74·9	1825 iv ..	533·6
D'Arrest's .	5·7	1845 iii ..	78·9	1822 iv ..	617·0
Faye's	6·0	1840 iv ..	96·7	1680	620·0
Biela's	6·2	1843 i ..	100·0	1851 iii ..	624·0
1783 i	7·8	1846 vii .	108·2	1763	754·3
1846 vi ..	9·4	1861 i ..	110·3 *	1849 iii ..	823·6
1858 i	11·0	1793 ii ..	111·0	1830 i ..	2971·3
1866 i	16·8	1861 ii ..	111·2	1780 i ..	3209·9
1863 v....	27·6	1855 ii ..	124·2	1844 ii ..	4275·6

* [With regard to this group of seven comets, it is to be remarked that for the Comet of 1843 Prof. Hubbard deduced an aphelion-distance 173 from *all* the observations, and 131·4 from the micrometer measures alone (period 533 years), and not 100 (period 376 years) as stated here and elsewhere. If, as

On tabulating the aphelion-distances of all the known elliptic orbits of comets*, it was found that in no case was there any grouping of aphelion comet distances which did not agree with the distances of planets, except that beyond the distance of Neptune there were two groupings of comet aphelion-distances, one at 100 Earth's radii, the other at 300 Earth's radii, approximately.

Taking Prof. H. A. Newton's theory with respect to the introduction of comets into the solar system, it would follow that the disturbing planet must, at the time when a comet was so introduced, have been somewhere near the position of the comet's aphelion. Two hypotheses then present themselves :—(1) We may suppose that the planet must have been extremely close to the comet when it influenced it, in which case it would be necessary to prove that the aphelion-positions of a fair proportion of these comets lay in one plane which passes through the Sun. In this case we could determine the date when the planet was in some definite positions, and so might predict its present position. (2) We may suppose that the planet revolved in some orbit close to the ecliptic, and assume that it attracted the comet into the solar system, when it was most near to the comet's aphelion-position.

From the elements of the seven comets ranging from Aph. Dist. 96·7 to 124·2, the longitudes (measured along the ecliptic) and latitudes of the aphelion-positions were calculated (see Table, p. 443).

These points were marked by wafers upon a celestial globe, and it was immediately evident that the four Comets, I., II., IV., and VII., have their aphelion-positions almost exactly on one great circle. The exactness of the coincidence is so remarkable that there were strong reasons for believing that the planet must have been close to each comet at the time when it deflected it from a parabolic orbit. Consequently this plane was examined on the supposition that it is the plane of the planet's orbit. The longitude of its ascending node is at 250°, and it cuts the ecliptic at an angle of 53°. This is a high inclination; but when we think of the satellites of Uranus and Neptune, which have high inclinations and retrograde motion, and of the divergence of Neptune from Bode's law, we lose confidence in a belief of the maintenance of all the general features characteristic of the nearer planets in those orbits which are near the limits of the solar system. In fact, if, as we may suppose, there are at least two planets beyond Neptune,

---

appears probable, this comet be identical with the great southern comet of this year, its period must be 37 years instead of 533 years. Also for Comet 1793 ii D'Arrest found that the observations (extending over 2½ months) were equally well satisfied by a parabola. For Comet 1855 ii Schulze deduced an ellipse with an aphelion-distance of 57 instead of 124·2 as found by Donati. As regards the other four comets, the aphelion-distances deduced by other calculators agree pretty closely with those here given.—Ed.]

* Those in G. F. Chambers's 'Astronomy' have been adopted, as his catalogue is an impartial selection of the best orbits computed.

it is quite a possibility that there may be a special plane in which they move, and which in those vast orbits supplants the ecliptic.

We now have to see whether the motion of a planet about 100 Earth's radii from the Sun with a period of about 1000 years could bring it into the position of these aphelia at the dates when the comets were there, either in the last revolution of the planet, or at least the last but one. [If the comet was caused to move in an elliptic orbit earlier than the last revolution but one, it would have returned so often to the neighbourhood of other planets that probably it would have met with planetary perturbations which would have altered its orbit entirely, and might have reduced the orbit to one like those of Comets III., V., and VI., which have their aphelion-positions not in the plane of those of the Comets I., II., IV., and VII.]

Such a planet would come into juxtaposition with the four aphelia in the course of *two* revolutions, arriving at each one at the time when the corresponding comet may have been expected to have been in aphelion, as is shown in the following Table:—

Comet.	Period in years.	Aphelion date. A.D.	Aphelion long. °	Planet's long. °	Difference. °
IV. 1861 i ..	415	409	29	19	−10
I. 1840 iv..	493	968	203	218	+15
VII. 1855 ii ..	376	1608	82	87	+ 3
II. 1843 i ..	344±8	1655	115	105	−10

The period of revolution of the planet is taken as 1006 years.

According to this hypothesis, Comets VII. and II. were affected by the planet when it was last in these positions, Comets IV. and I. in a previous revolution of the planet. We have to suppose, then, that Comets VII. and II. have only once appeared in the neighbourhood of the Sun, that Comet I. has appeared three times altogether, and Comet IV. so many as four times. Comet I. has been supposed to be identical with Comet 1490 A.D., and it ought to have appeared before in the year 1140 A.D.—giving a period of 350 years, and dates of aphelion-passage in the years 1668, 1318, 968 A.D. Comet IV. has a calculated period of 415 years, which gives for the dates of aphelion-passage the years 1654, 1239, 824, 409 A.D.

As to Comet IV. it was visible to the naked eye in 1861, and ought to have been seen in the years 1446, 1031, 616 A.D. As a matter of fact, we find from historical accounts that comets were seen in the years 1444, 1032, and 617 A.D. All these comets were seen at about the same time of the year (midsummer), *i. e.* when the Earth was in the same position, and they were all seen to pass near to the star β Leonis. It is then shown that in the July position of the Earth we should see the Comet 1861 i pass close to the star β Leonis, and the identity of the four comets is thence concluded.

The present position of the planet is thus determined. The mean of the four dates of aphelion disturbance by the hypothetical planet is the year 1160 A.D., and the mean longitude of the planet at these four times is 287°. From the year 1160 to 1880 it must have passed over 258°, thence its present position in its orbit is in longitude 185°.

Fairly good results have been obtained from the hypothesis which was first chosen, viz. that the planet moves in a plane inclined to the ecliptic. But even from general reasoning it is probable that if the dates fit in for an orbit inclined 53° to the ecliptic, they will do so equally well for other orbits. It is right, therefore, to see what would be the present position of the planet if it was on the ecliptic, and if it attracted each comet at the time when it came nearest to the aphelion-position of the comet. Thus we deduce a motion of 1° in 2·96 years, and get the following dates and longitudes of the planet. The latitudes of aphelia are also given, as those nearest to the ecliptic are likely to give the surest indications as to the position of the planet; the period is also given.

	Comet.	Period in years.	Aphel. date. A.D.	Aphel. lat. °	Aphel. long. °	Planet's long. °	Diff. °
I.	1840 iv ..	350	968	−38	220	225	− 5
II.	1843 i ..	376	1655	−36	100	98	+ 2
III.	1846 vii..	400	1248	+29	340	320	+20
IV.	1861 i ..	415	409	+32	37	37	0
V.	1793 ii ..	422	1582	−47	241	..	..
VI.	1861 ii ..	419	1651	+30	96	97	− 1
VII.	1855 ii ..	493	1609	− 9	79	82	− 3

The only comets which do not fit in fairly are Comets III. and V., of which the latter has a very great latitude. It is really a bad argument, unless, indeed, we suppose it to have been influenced by the planet about 700 B.C. It seems better to reject this comet. We are certain that Comet IV. dates as far back as 409, and this gives us an excellent means of determining the rate of motion of the planet.

If, then, at the mean date of the three Comets II., VI., and VII., 1638 A.D., the planet was in the longitude there determined, viz. 92°, and if it has since travelled at the rate of 1° in 2·96 years, it must now (1880) be in the position—

Long. 174°, R.A. $11^h\ 40^m$, N.P.D. 87°.

Having now examined the two hypotheses, both of which have wonderful coincidences, and considering the strong evidence in favour of each, Prof. Forbes proceeds to test them by examining which, if either of them, agreed with facts in the case of such a planet as Neptune, which has six comets associated with it.

Comet.	Aphel. dist.	Ω.	*i.*	π.	μ.	Date.	Period in years.	Date of Aphel.
		°	°	°				
I.....	32	346	41	43	+	1852 iv	70	1817
II.....	33	253	74	92	+	1812	71	1777
III.....	34	83	44	149	+	1815	70	1780
IV.....	34	78	85	70	+	1846 iv	72	1810
V.....	35	310	19	79	+	1847 v	75	1810
VI.....	35	55	18	305	−	1835	75	1798 Halley'

Omitting Halley's comet, which has returned so often that it cannot be included in the present research, we have the following Table :—

Comet.	Period in years.	Aphel. date.	Aphel. lat.	Aphel. long.	Planet's long.	Diff.
			°	°	°	°
I. 1852 iv ..	70	1817	−33	215	..	..
III. 1815	70	1500	−39	321	329	+8
II. 1812	71	1635	+ 9	256	256	0
IV. 1846 iv ..	72	1810	−12	260	259	−1
V. 1847 v....	75	1810	−15	260	260	0

No plane passing through the Sun includes many of these positions, hence the first hypothesis must be given up.

Comets IV. and V. have about the same longitudes and dates of last aphelion. They were probably affected by Neptune on the last possible occasion; and although this is not certain, it is the best hypothesis to start from. Now from the aphelion-distances we would assume Neptune to be about 30 Earth's radii from the Sun, which gives a yearly motion of about 2°·2.

Comet II. must have been in aphelion in the years 1706 and 1635. But if in 1810 the planet was in longitude 260°, and moved over about 2°·2 a year, it would in 1635 have been in longitude 235°, which is not very far from the longitude of aphelion, viz. 256°. By assuming the planet to have a yearly motion of 2°·08, it would have been at the right spot in 1635 to influence Comet II. Comet III. was in aphelion at the dates 1780, 1710, 1640, 1570, 1500 In 1500, according to hypothesis, the planet was in longitude 329°, and the comet's aphelion longitude is 321°. Comet I. does not seem to fit in.

From 1810 to 1880 is 70 years, which, with a yearly motion of 2°·08, gives the longitude of Neptune in 1880 equal to 45°. Its longitude, deduced from the 'Nautical Almanac,' is 48°.

This remarkable agreement makes it probable that the second hypothesis (the one which assumes the planet to move in the plane of the ecliptic) is the correct one, and that the present longitude of the new planet is about 174°.

It was impossible to test the method by means of the Jupiter-group of comets, because they are not generally visible to the naked eye, and in consequence we cannot guess when they were first affected; but the behaviour of Lexell's comet would certainly have indicated the whereabouts of Jupiter.

Prof. Forbes has also, to a certain extent, studied the conditions of the more distant planet (about 300 Earth's radii). But the investigation cannot be looked upon as likely to be very accurate, since the elements of these comets of long period are not known with sufficient accuracy. There is an orbit which would embrace four of these aphelion-positions out of six, while a fifth is not far from it. This orbit has the longitude of ascending node=265°, and the inclination of its orbit=45°. This is nearly the same plane as found on the first hypothesis for the other planet; and had it not been seen from the analogy of the Neptunian comets that the second hypothesis was the correct one, this would have been taken as evidence that for these external planets a new plane supplants the ecliptic. The present position which is deduced for this external planet is:—R.A. $22^h\ 0^m$, Dec. 39° N.; but this is not at all likely to be an accurate determination, and it is only with respect to the other planet that Prof. Forbes feels confident as to the present position.

He has searched through a number of star-catalogues to see whether any star has been observed in the position of the nearer of these two planets, and which has not since been observed. The only star as yet found fulfilling these conditions is No. 894 of the 'Greenwich Seven Year Catalogue,' 1860. Two observations were made both of R.A. and N.P.D., from which its position was—R.A. $11^h\ 19^m\ 14^s{\cdot}35$, N.P.D. 85° 3′ 23″·57, whilst from the cometary calculations the hypothetical planet would have been in R.A. $11^h\ 8^m$, N.P.D. 85°. If, then, the star above mentioned be the planet, the cometary calculations are in error to the extent of 11^m, or nearly three degrees, which is quite possible.

Prof. Forbes concludes:—"I think that, even although we may not be absolutely certain that the position of the nearest planet is at present in R.A.=$11^h\ 40^m$ and N.P.D.=87°, still we may feel very confident that these two planets do exist; and this consideration in itself is of great interest. The light of the Sun must take 15 hours to reach the nearest of the two planets, and 45 to reach the outer one; and α Centauri is only 750 times further from the Sun than the furthest planet, and 2240 times further than the nearest one. Considering the probably enormous mass of the stars, it is nearly certain that they must influence the motion of these two planets; and if we have the good fortune to observe either of them, a new field wherein to test the extent to which the law of gravitation holds good will be immediately opened to astronomers. Our ideas of time are in the same way extended when we think of these two planets revolving in periods, the one of 1000 and the other of 5000 years; and when we consider that some of the comets introduced by the most distant planet were influenced by that planet tens of thousands of years ago.

"In conclusion I have to say a few words about the principles of the method which has been adopted. There are two principles involved:—First, we assume that when a comet is influenced by a planet, so as to cause it to move in an ellipse, the planet tends to destroy that part of the comet's motion which is towards or from the Sun, thus causing this position to be its aphelion-position. Even were the investigation of Prof. H. A. Newton, which supports this view, found to be defective, however, we should still have the analogy of the Jupiter groups of comets, of the Neptune group, and one comet and several meteor-streams connected in the same way with Uranus. I admit, however, that the theory of the influence of planets on comets is well worthy of further investigation.

"The second principle relates to the relative position of planet and comet at the time of influence. The hypothesis to which I have given greatest weight is that which supposes the planet to be in that part of its orbit which is nearest to the aphelion-position, or the position occupied by the comet when it was so influenced. Other hypotheses might have been adopted; and considering the great distances, in some cases, between the aphelion-positions and any point in the planet's orbit, it is difficult to understand how this hypothesis agrees so exactly as it undoubtedly does with the motions of a planet at that distance from the Sun. Here again, however, in default of a complete theory of planetary influence on comets, I have felt justified in working on the hypothesis stated, because of the analogy of Neptune. By working out this hypothesis with the Neptune group, I immediately deduced the true position of Neptune to within 3°, or almost with the same precision as Adams deduced it by his splendid research on Uranus. I think it only right here to say, that when making the computations I was ignorant of the position of Neptune, or, rather, I had a notion that the planet was in quite a different part of the heavens; and I was disappointed with my work, because I thought it gave an erroneous result, until I consulted the 'Nautical Almanac,' and then I found my result correct within 3°."

On the Origin of Planets.*

If Laplace's hypothesis of the formation of planets and satellites from nebulous *rings* cannot be sustained †, we may conclude that each planet, at its origin, was separated from a very limited arc of the equatoreal protuberance; or, in other words, that instead of the separation of a ring, the centrifugal force produced a rupture at the point of least resistance in the equatoreal belt. From the chasm thus formed a nebulous mass was thrown out, which in process of time was transformed into the outermost planet‡. The

* Read before the American Philosophical Society, April 2, 1880. Communicated by the Author.

† Proc. Amer. Phil. Soc. vol. xviii. p. 324. 'Observatory,' No. 37, p. 409.

‡ It is now believed by astronomers that the phenomena of temporary stars, such as those of 1572, 1866, and 1876, are produced by enormous outbursts of incandescent matter.

tendency to separation around the equator would thus be relieved, and the ellipticity of the spheroid temporarily diminished. Further condensation, however, would again increase the centrifugal force until another rupture or outrush similar to the first would necessarily result. The formation of planets from these nebulous masses may thus be explained without the necessity of supposing such matter to have been slowly collected from continuous rings.

The origin of satellites is also very obviously accounted for. In short, where the ring hypothesis is encumbered with difficulties well nigh insuperable, the theory here proposed seems less open to objection. Not improbably, however, the ancient orbits of the secondary system, and perhaps also of some of the primary planets, may have differed to a considerable extent from their present dimensions, as is shown by Mr. G. H. Darwin in his "Tidal Theory of the Evolution of Satellites"*. DANIEL KIRKWOOD.

Double Stars for June.

FOR the most important pairs see the 'Observatory,' Vol. iii. p. 53.

Σ 3123. R.A. $12^h\ 0^m{\cdot}0$, Dec. $+69°\ 22'$. Mag. 7, 7.

Elongated by Σ and Mädler; single to De in 1862 and to OΣ in 1867. In 1832·20 Σ found it thus:—289°·7, 0″·3, elongated.

Σ 1602. R.A. $12^h\ 1^m{\cdot}1$, Dec. $+69°\ 44'$. Mag. 7·5, 9.

179°·1	14″·49	1867·5	De.
178 ·8	15 ·13	79·3	Cincinnati Obs.

Angle unchanged; distance increasing.

Σ 1608. R.A. $12^h\ 5^m{\cdot}5$, Dec. $+54°\ 5'$. Mag. 7·5, 7·7.

223°·0	11″·36	1869·1	De.

Angle unchanged since 1830; slight increase in distance.

Σ 1659. R.A. $12^h\ 29^m{\cdot}5$, Dec. $-11°\ 23'$. Mag. 8, 8·1.

AB	351°·6	27″·24	1867·6	De.
	350 ·1	27 ·39	79·3	Cincinnati Obs.
AC	69 ·2	34 ·31	67·6	De.
	69 ·8	35 ·07	79·3	Cincinnati Obs.
BC	113 ·2	39 ·01	67·6	De.
	111 ·3	40 ·08	79·2	Cincinnati Obs.

AB probably unchanged. In AC the angle has not changed, but the distance has increased about 5″ since 1832. In BC slight decrease in angle and increase of 4″ in distance since 1832.

* 'Observatory,' No. 27, p. 79.