JOHN COUCH ADAMS
AND THE
DISCOVERY OF NEPTUNE

On the night of 13 March 1781 William Herschel, musician by profession but assiduous observer of the heavens in his leisure time, made a discovery that was to bring him fame. He had for some time been engaged upon a systematic and detailed survey of the whole heavens, using a 7 in. telescope of his own construction; he carefully noted everything that appeared in any way remarkable. On the night in question, in his own words:

'In examining the small stars in the neighbourhood of H Geminorum I perceived one that appeared visibly larger than the rest; being struck with its uncommon appearance I compared it to H Geminorum and the small star in the quartile between Auriga and Gemini, and finding it so much larger than either of them, I suspected it to be a comet.'

Most observers would have passed the object by without noticing anything unusual about it, for the minute disk was only about 4 sec. in diameter. The discovery was made possible by the excellent quality of Herschel's telescope, and by the great care with which his observations were made.

The discovery proved to be of greater importance than Herschel suspected, for the object he had found was not a comet, but a new planet, which revolved round the Sun in a nearly circular path at a mean distance almost exactly double that of Saturn; it was unique, because no planet had ever before been discovered; the known planets, easily visible to the naked eye, did not need to be discovered.

After the discovery of Uranus, as the new planet was called, it was ascertained that it had been observed as a star and its position recorded on a score of previous occasions. The earliest of these observations was made by Flamsteed at Greenwich in 1690. Lemonnier in 1769 had observed its transit six times in the course of 9 days and, had he compared the observations with one another, he could not have failed to anticipate Herschel in the discovery. As Uranus takes 84 years to make a complete revolution round the Sun, these earlier observations were of special value for the investigation of its orbit.

The positions of the planet computed from tables constructed by Delambre soon began to show discordances with observation, which became greater as time went on. As there might have been error or incompleteness in Delambre's theory and tables, the task of revision was undertaken by Bouvard, whose tables of the planet appeared in 1821. Bouvard found that, when every correction for the perturbations in the motion of Uranus by the other planets was taken into account, it was not possible to reconcile the old observations of Flamsteed, Lemonnier, Bradley, and Mayer with the observations made subsequently to the discovery of the planet in 1781.

'The construction of the tables, then,' said Bouvard, 'involves this alternative: if we combine the ancient observations with the modern, the former will be sufficiently well represented, but the latter will not be so, with all the precision which their superior accuracy demands; on the other hand, if we reject the ancient observations altogether, and retain only the modern, the resulting tables will faithfully conform to the modern observations, but will very inadequately represent the more ancient. As it was necessary to decide between these two courses, I have adopted the latter, on the ground that it unites the greatest number of probabilities in favour of the truth, and I leave to the future the task of discovering whether the difficulty of reconciling the two systems is connected with the ancient observations, or whether it depends on some foreign and unperceived cause which may have been acting upon the planet.'

Further observations of Uranus were for a time found to be pretty well represented by Bouvard's Tables, but systematic discordances between observations and the tables gradually began to show up. As time went on, observations continued to deviate more and more from the tables. It began to be suspected that there might exist an unknown distant planet, whose gravitational attraction was disturbing the motion of Uranus. An alternative suggestion was that the inverse square law of gravitation might not be exact at distances as great as the distance of Uranus from the Sun.

The problem of computing the perturbations in the motion of one planet by another moving planet, when the undisturbed orbits and the masses of the planets are known is fairly straightforward, though of some mathematical complexity. The inverse problem, of analysing the perturbations in the motion of one planet in order to deduce the position, path and mass of the planet which is producing these perturbations, is of much greater complexity and difficulty. A little consideration will, I think, show that this must be so. If a planet were exposed solely to the attractive influence of the Sun, its orbit would be an ellipse. The attractions of the other planets perturb its motion and cause it to deviate now on the one side and now on the other side of this ellipse. To determine the elements of the elliptic orbit from the positions of the planet as assigned by observation, it is necessary first to compute the perturbations produced by the other planets and to subtract them from the observed positions.

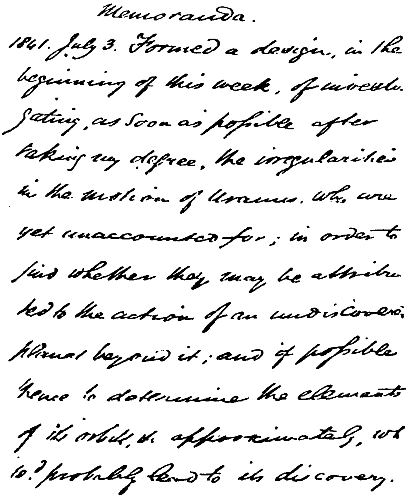
The position of the planet in this orbit at any time, arising from its undisturbed motion, can be calculated; if the perturbations of the other planets are then computed and added, the true position of the planet is obtained. The whole procedure is, in practice, reduced to a set of tables. But if Uranus is perturbed by a distant *unknown* planet, the observed positions when corrected by the subtraction of the perturbations caused by the *known* planets are not the positions in the true elliptic orbit; the perturbations of the unknown planet have not been allowed for. Hence when the corrected positions are analysed in order to determine the elements of the elliptic orbit, the derived elements will be falsified. The positions of Uranus computed from tables such as Bouvard's would be in error for two reasons; in the first place, because they are based upon incorrect elements of the elliptic orbit; in the second place, because the perturbations produced by the unknown planet have not been applied. The two causes of error have a common origin and are inextricably entangled in each other, so that neither can be investigated independently of the other. Thus though many astronomers thought it probable that Uranus was perturbed by an undiscovered planet, they could not prove it. No occasion had arisen for the solution of the extremely complicated problem of what is termed inverse perturbations, starting with the perturbed positions and deducing from them the position and motion of the perturbing body.

The first solution of this intricate problem was made by a young Cambridge mathematician, John Couch Adams. As a boy at school Adams had shown conspicuous mathematical ability, an interest in astronomy, and skill and accuracy in numerical computation. At the age of 16 he had computed the circumstances of an annular eclipse of the Sun, as visible from Lidcot, near Launceston, where his brother lived. He entered St John's College in October, 1839, at the age of 20, and in 1843 graduated Senior Wrangler, being reputed to have obtained more than double the marks awarded to

Cambridge University Press
978-1-107-69189-6 - John Couch Adams: And the Discovery of Neptune
Sir Harold Spencer Jones
Excerpt
More information

the Second Wrangler. In the same year he became first Smith's Prizeman and was elected Fellow of his College.

Whilst still an undergraduate his attention had been drawn to the irregularities in the motion of Uranus. After his death there was found among his papers this memorandum, written at the beginning of his second long vacation:


Memoranda.
1841. July 3. Formed a design, in the beginning of this week, of investigating, as soon as possible after taking my degree, the irregularities in the motion of Uranus, wh. are yet unaccounted for; in order to find whether they may be attributed to the action of an undiscovered planet beyond it; and if possible thence to determine the elements of its orbit, &c. approximately, wh. wd. probably lead to its discovery.

'1841, July 3. Formed a design in the beginning of this week, of investigating, as soon as possible after taking my degree, the irregularities in the motion of Uranus, which are yet unaccounted for; in order to find whether they may be attributed to the action of an undiscovered planet beyond it; and if possible thence to determine the elements of its orbit, etc. approximately, which would probably lead to its discovery.'

As soon as Adams had taken his degree he attempted a first rough solution of the problem, with the simplifying assumptions that the unknown planet moved in a circular orbit, in the plane of the orbit of Uranus, and that its distance from the Sun was twice the mean distance of Uranus, this being the distance to be expected according to the empirical law of Bode. This preliminary solution gave a sufficient improvement in the agreement between the corrected theory of Uranus and observation to encourage him to pursue the investigation further. In order to make the observational data more complete application was made in February 1844 by Challis, the Plumian Professor of Astronomy, to Airy, the Astronomer Royal, for the errors of longitude of Uranus for the years 1818–26. Challis explained that he required them for a young friend, Mr Adams of St John's College, who was working at the theory of Uranus. By return of post, Airy sent the Greenwich data not merely for the years 1818–26 but for the years 1754–1830.

Cambridge University Press
978-1-107-69189-6 - John Couch Adams: And the Discovery of Neptune
Sir Harold Spencer Jones
Excerpt
More information

Adams now undertook a new solution of the problem, still with the assumption that the mean distance of the unknown planet was twice that of Uranus but without assuming the orbit to be circular. During term-time he had little opportunity to pursue his investigations and most of the work was undertaken in the vacations. By September 1845, he had completed the solution of the problem, and gave to Challis a paper with the elements of the orbit of the planet, as well as its mass and its position for 1 October 1845. The position indicated by Adams was actually within 2° of the position of Neptune at that time. A careful search in the vicinity of this position should have led to the discovery of Neptune. The comparison between observation and theory was satisfactory and Adams, confident in the validity of the law of gravitation and in his own mathematics, referred to the 'new planet'.

Challis gave Adams a letter of introduction to Airy, in which he said that 'from his character as a mathematician, and his practice in calculation, I should consider the deductions from his premises to be made in a trustworthy manner'. But the Astronomer Royal was in France when Adams called at Greenwich. Airy, immediately on his return, wrote to Challis saying: 'would you mention to Mr Adams that I am very much interested with the subject of his investigations, and that I should be delighted to hear of them by letter from him?'

Towards the end of October Adams called at Greenwich, on his way from Devonshire to Cambridge, on the chance of seeing the Astronomer Royal. At about that time Airy was occupied almost every day with meetings of the Railway Gauge Commission and he was in London when Adams called. Adams left his card and said that he would call again. The card was taken to Mrs Airy, but she was not told of the intention of Adams to call later. When Adams made his second call, he was informed that the Astronomer Royal was at dinner; there was no message for him and he went away feeling mortified. Airy, unfortunately, did not know of this second visit at the time. Adams left a paper summarizing the results which he had obtained and giving a list of the residual errors of the mean longitude of Uranus, after taking account of the disturbing action of the new planet. These errors were satisfactorily small, except for the first observation by Flamsteed in 1690. A few days later Airy wrote to Adams acknowledging the paper and enquiring whether the perturbations would explain