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WILLIAM LASSELL AND THE RING OF NEPTUNE: A CASE STUDY IN INSTRUMENTAL FAILURE

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William Lassell (1799–1880) was one of the foremost British amateur astronomers of the nineteenth century (see Figure 1). Self-taught and highly motivated, he belonged in the words of John Herschel "to that class of observers who have created their own instrumental means—who have felt their own wants, and supplied them in their own way".[1] William Huggins even went so far as to compare his achievements, especially as a telescope maker, with those of the elder Herschel and Lord Rosse.[2] Today, Lassell is remembered for his bold and determined construction of two large-aperture reflecting telescopes, a 24-inch (61-cm) completed in 1846 and a 48-inch (122-cm) erected at Valetta, Malta, in 1861, and for the discoveries of numerous nebulae and galaxies and of faint satellites of Saturn, Uranus and Neptune.

Lassell rose to fame during the months after the finding of Neptune. On 10 October 1846, using the 24-inch telescope, he had a tentative initial sight of Triton, chief moon of the planet. Confirmation of his discovery took place in July the following year. But another feature had aroused his suspicions too; the telescopic image of Neptune suggested to his eye the presence of a ring system. This time Lassell was wrong. The hypothesis withered, and the strange fancy from which it sprang disappeared into the ranks of what have been listed as "the astronomical myths of an uncritical age".[3]

Since it was recalled in 1973,[4] the observations of the ring have attracted renewed interest from historians, and figured, albeit briefly, in some contemporary planetological speculation.[5] However, none of the accounts so far published has exploited the Lassell manuscripts held by the Royal Astronomical Society. Accordingly, through these and other unused archive materials, we revisit what is now seen as a failure in the astronomical career of William Lassell, and hypothesize that the ring originated in flexure of the speculum metal mirrors of the 24-inch telescope with which he observed Neptune. We further argue that the history of Neptune's 'ring system' is an exceptionally well-documented example of instrument failure that provides rich insights into astronomical practice during the nineteenth century.

Discovery and Confirmation

Neptune was discovered on 23 September 1846 by J. G. Galle and H. d'Arrest at the Berlin Observatory. News reached London on 30 September, and a letter from J. R. Hind announcing the event appeared in *The Times* of 1 October.[6] Lassell inserted a cutting of Hind's letter in his current observing diary,[7] determined no doubt to observe the new planet at the earliest opportunity. That same day, 1 October, John Herschel penned a short note to Lassell. Herschel knew that Lassell had recently built a 24-inch reflector, effectively the most powerful telescope in England, and had installed it at Starfield, his aptly-named private observatory near Liverpool. He also knew that Lassell had

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FIG. 1. William Lassell *c.* 1850 (from a print at the Royal Society, London, and reproduced with the Society's permission).

overcome some teething troubles in the telescope's mounting, and had moreover recently observed the satellites of Saturn. It is thus not surprising that after informing Lassell of the find and giving a position, Herschel should urge Lassell to look for "satellites with all possible expedition!!".[8] The imperative could not be ignored. Attracted by novelty and the strong probability of discovery, Lassell swung his great telescope to the appointed spot and on 2 October logged his first observation of 'Le Verrier's planet'. It was found easily, and its disk seen without any difficulty. Yet, as he confided in his diary

the next night, what he saw was not a disk alone:

> I observed the planet last night the 2nd and suspected a ring . . . but could not verify it. I showed the planet to all my family and certainly tonight have the impression of a ring. . . .[9]

Several days elapsed before Lassell again examined Neptune. Whether inclement weather or his heavy business commitments—he was in trade as a brewer—occasioned this hiatus is not clear, but his next observation was not made until 10 October. Now he noted: "I see a satellite or a suspicious looking star . . . and a ring. I see the [satellite] and suspect the ring with various powers 316 to 367 . . . ."[10] Lassell next viewed Neptune on 26 October, but although he was "pretty well assured of the close satellite", his drawing omits the ring.[11] Three days later he observed in the company of John Hartnup, Director of the Liverpool Observatory, and William Simms, the well-known London instrument maker. Unfortunately the conditions were too poor to see the planet well.[12] A more significant set of observations followed on 10 November (see Figure 2). Once more with company, Lassell aimed the 24-inch at Neptune:

> Mr. Hartnup, Mr. Ice [?] and Mr. A. King and Mrs. Kearsley observed [Neptune] tonight—power 316—Mr. H. and Mr. A. King drew independent diagrams of the position of the supposed ring which were quite accordant without any previous prejudice or information. There is therefore no doubt whatever that the telescope *shews* an appendage. Whether it really exists in the planet remains to be confirmed.[13]

"The sky in a most tremulous and muddy state", Lassell wrote the day after, but "Le Verrier [Neptune] still gave to me the impression of a ring though less distinctly than before—as might be expected from the unfavourable circumstances. This may moreover be said to be a new telescope as both mirrors

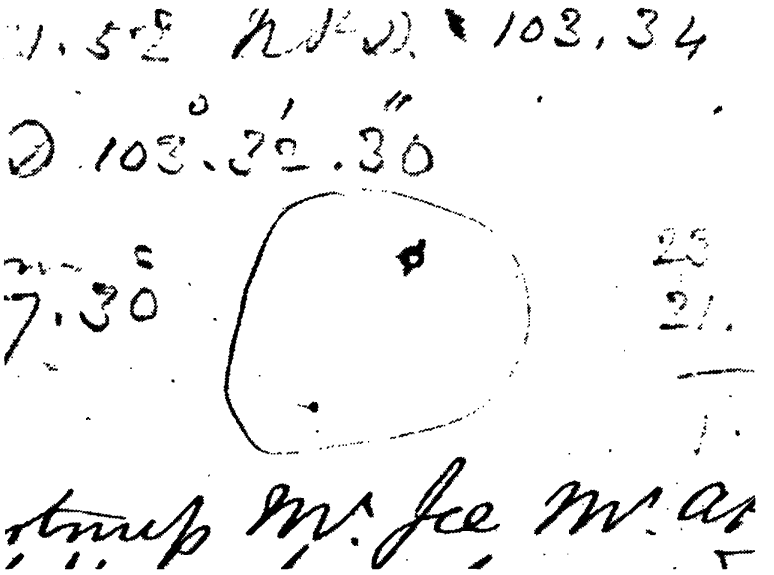

FIG. 2. Lassell's drawing of the ring, 10 November 1846 (from Lassell papers 9.7, Archives of the Royal Astronomical Society, and reproduced by permission of the Society).

are . . . different. My daughter Maria not having seen the planet with any suspicion of a ring drew a diagram of it tonight having the same aspect as the previous [diagram]. The supposed satellite is in the same situation tonight".[14] Further inspections on 29 and 30 November, and 3 and 15 December, did nothing to shake his near conviction that a satellite accompanied Neptune, and his very strong suspicion of a ring. Bad weather and the rapidly diminishing distance of the planet from the Sun brought the 1846 Neptune season for him to an end on 15 December, and it was the following July before Lassell could again inspect the planet.

So far we have examined only the notebook record. Lassell had in fact quickly made public what he had seen around Neptune. Thus on 12 October he had staked his claims to the satellite and the ring by writing to *The Times* (a common method of the period to establish priority). Here, if anything, he was rather more certain of the ring than he had admitted in his private record:

> With respect to the existence of the ring, I am not able absolutely to declare it, but I received so many impressions of it, always in the same form and direction, and with all the different magnifying powers, that I feel a very strong persuasion that nothing but a finer state of atmosphere is necessary to enable me to verify the discovery. Of the existence of the star, having every aspect of a satellite, there is not the shadow of a doubt.[15]

Another account was sent to the Royal Astronomical Society and reported in the Society's *Monthly notices* for November 1846. The writer noted that Lassell had seen "something like a ring crossing [Neptune's] disc", and that while atmospheric conditions had not been favourable, the streak was seen in the same direction using two different mirrors and by several observers, so its existence "seems very probable. The appearance may possibly be caused by some distortion or flexure in the mirror, but can scarcely be the effect of imagination".[16] In the following issue Lassell related that the planet appeared like a fainter version of Saturn as seen through a small telescope with a low power. Further, "several persons saw the supposed ring, and all in the same direction, as shown by independent diagrams".[17] Lassell's status as a good observer (although little experienced with large telescopes), and the fact that his telescope had the greatest light grasp of any in England, imbued these statements with authority, and to other astronomers they made convincing reading.

Support was soon forthcoming. Two English astronomers, J. R. Hind and James Challis, both of whom had made unsuccessful searches for Neptune in the summer of 1846,[18] made observations that went a considerable way to confirming Lassell's findings. Hind had first seen the disk of the planet on 30 September, the very day on which he had received news of the discovery. He had then proceeded to observe it whenever conditions allowed. Hind, once an assistant in the Magnetic and Meteorological Department of the Royal Observatory at Greenwich but at this time director of a private observatory in London, used a 7-inch (18-cm) Dollond refractor in his examinations. Nevertheless, it was December 1846 before he noticed anything peculiar about Neptune's disk. As he then described it: "The existence of a ring appears to be as yet undecided, though most probable. [Neptune] presents an oblong appearance in Mr. Bishop's refractor."[19]

Challis, director of the Cambridge Observatory, began a regular series of observations of Neptune on 3 October, but not until 12 January 1847 did he receive a first impression of a ring. Viewed through the 11¾-inch (30-cm) Northumberland refractor the image assumed an appearance "such as would be presented by a ring like that of Saturn, situated with its plane very oblique to the direction of vision".

> I felt convinced that the observed elongation could not be attributed to atmospheric refraction, or to any irregular action on the pencils of light, because when the object was seen most steadily I distinctly perceived a symmetrical form. My assistant, Mr. Morgan, being requested to pay particular attention to the appearance of the Planet, gave the same direction of the axis of elongation as that in which it appeared to me.[20]

Two days later, Challis saw that the "ring is very apparent with a power of 215, in a field considerably illumined by a lamp-light. Its brightness seems equal to that of the Planet itself".[21] Lassell was excited by his news. On 19 January he told Challis that this observation "puts beyond reasonable doubt the reality of mine; especially as even your measured angle of position agrees with my estimation within four degrees".[22] Challis also announced in the *Monthly notices of the Royal Astronomical Society* and the *Astronomische Nachrichten* that he had verified Lassell's suspicions about a ring.[23] In fact, Challis was to tell Lassell that the ring "is not difficult to discern with the Northumberland telescope with powers of 215 and 200, and once on taking a transit with the former power, and with a field pretty well illumined the Ring appearance so forced itself upon me that I was diverted from my transit".[24]

Challis and Hind were not alone in their observations. W. C. Bond, M. F. Maury and F. de Vico each thought they had detected something odd about the telescopic image of Neptune, but as these reports have been treated elsewhere, we merely observe that the elongation effect Bond saw when using the 15-inch (38-cm) Harvard refractor can be rejected since, as he noted, it vanished if the planet was viewed at high magnification. The supposed evidence of de Vico and Maury is so vague that it too can be disregarded.[25] Nevertheless, the standing of Lassell, Challis and Hind as observers meant that by early 1847 opinion in Britain at least had shifted in favour of the ring's existence. As a result the Annual Report of the Royal Astronomical Society, dated 12 February 1847, contained the claim that the reality of the "ring seems almost certain".[26]

The Fading Vision

Within months of this confident assertion, however, the ring's existence was being seriously questioned. Ironically, it was a close friend of Lassell, the well-known double-star observer the Reverend W. R. Dawes, who first expressed doubt. Writing to Challis on 7 April 1847, Dawes regretted that he could not

> quite comprehend about the *ring*. Mr. Lassell has not I think distinctly mentioned in any of his published statements . . . *in what direction the ring lies*. He merely says that it is "about 70° from the parallel of declination": but whether from north following to south preceding, or from south following to north preceding he does not state. In private letters to myself

> however he has given me several diagrams from time to time, in which the inclination of the ring has always been drawn from *south* following to *north* preceding . . . or in double star phraseology, the angle of position is given [as] 160° and 340°. If this is what Mr. Lassell has observed it is at variance with your observation.[27]

Challis was soon confiding to Dawes that he doubted the existence of the ring, blaming the atmosphere for the illusion.[28] In the meantime, Lassell himself had cleared up the mystery about the ring's orientation, as Dawes related to Herschel:

> Lassell informs me that when he drew the position of the ring . . . in his letters to me, the diagram was taken from its appearance in the telescope without respect to the direction of the parallel;—that of the direction being rather refered to. At first he contented himself with noting that it was *nearly at right angles* to the diurnal motion: but in his later observations he has expressly depicted it [south preceding to north following]. So that he and Challis agree—Hind draws it [south following to north preceding]; but this of course is of little weight, as well as my own seeing no elongation at all.[29]

Yet his disagreement with Lassell still troubled Challis, and on 3 May he again wrote that the ring's existence was not certain.[30] Adopting the same reasoning as Dawes, Challis was concerned that initially Lassell had stated the ring's axis to be nearly coincident with a right angle to a parallel of declination, but had later placed it 20° from this position, then about 25° distant. It had struck Challis that so "good an observer as Lassell could not be so much mistaken as to position in his first observation, and that what we see is something due to the refraction of the atmosphere and consequently changeable in position. It seems nevertheless to be an appearance peculiar to this planet".[31] The most urgent need, Challis judged, was for more observations, and he was anxious to get after them.

Lassell was similarly disposed. His first chance in 1847 to reobserve Neptune under reasonable conditions came on 7 July. He received "just the same impression of a ring very nearly at right angles to the parallel [of declination] . . . the south end of the ring a little preceding".[32] As usual, the state of the atmosphere at Starfield prevented any immediate follow-up. Even so, in August Lassell told Herschel he had not "thrown overboard the ring of Neptune—on the other hand I have the same impression of its existence as last year".[33] About this time, Lassell lamented to J. P. Nichol, Professor of Astronomy at Glasgow University, that he had been "invariably foiled" by the Liverpool climate in his battle to observe Neptune. He was very anxious to publish any "*facts*" respecting Neptune, but he was equally determined not to deceive himself or others.[34] To a correspondent on 8 September, Lassell again complained that "the sky this year has never been such as to give reasonable hope of a position and absolute settlement of the question [of the ring]. For myself I can only say that some glimpses I have had tend to strengthen my conviction of its existence".[35]

That very same day, Lassell viewed Neptune in the company of Dawes, who was in the middle of one of his frequent visits to Starfield. Now, for the first time, Dawes too saw the ring. In Lassell's observing diary is a drawing of the

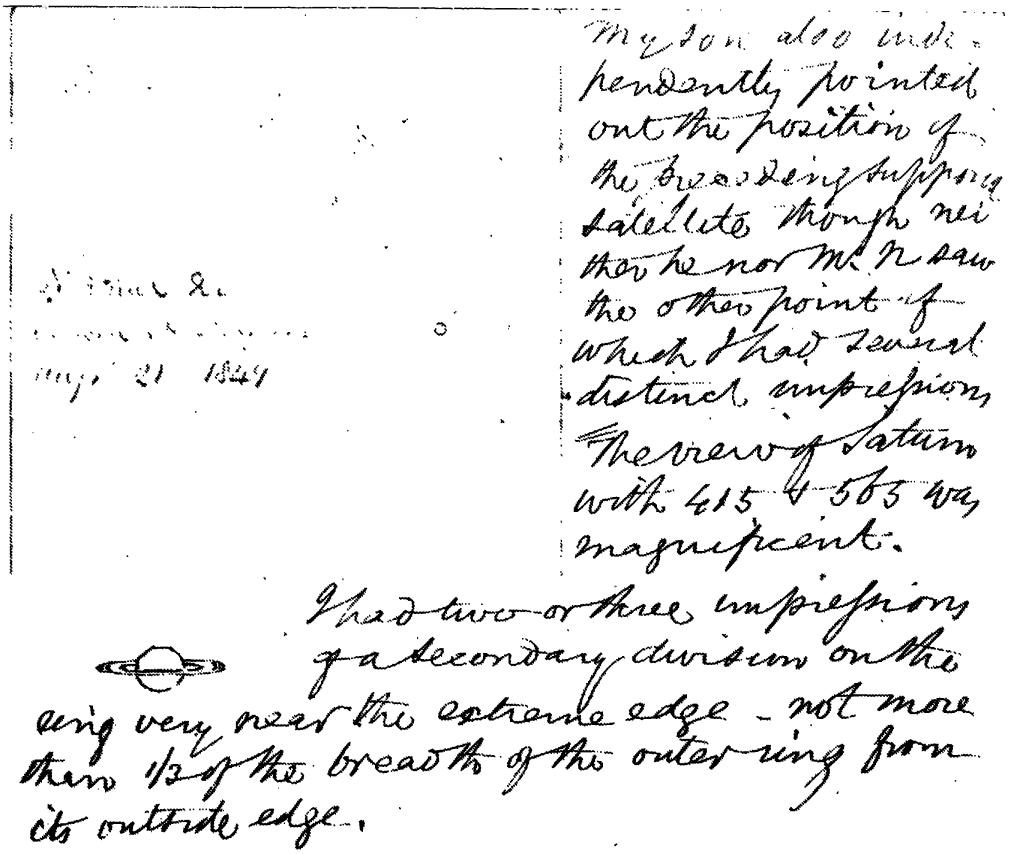

FIG. 3. The drawing in the upper left was made by James Nasmyth at Starfield on 21 August 1849 and shows Neptune and its attendant ring. The drawing at bottom left was made by Lassell and shows Saturn (from Lassell papers 9.11, Archives of the Royal Astronomical Society, and reproduced by permission of the Society).

planet showing a ring and it is initialled "W. R. D." for William Rutter Dawes. Alongside is to be found the comment "south preceding or [north following] perhaps by 10°".[36] More light is shed on these observations by Dawes's own observing book. His entry for 8 September reads: "The planet considered by W. R. D. to be elongated. A measure of the direction of the elongation 73° . . . but considered too large an angle by 10°. Clouded before measures [could] be completed."[37] Five days later Dawes measured the position of what he termed a ring or observed elongation as 81°·82, south preceding, and on the next night, 14 September, he valued it at 87°·9 south preceding. To check that the elongation was not the product of an instrumental defect, the telescope was rotated 30° on its axis and the measurement repeated. Now the answer was 88°·6 south preceding, a figure highly consistent with his earlier result and thus indicative of the ring's reality. Lassell, his own beliefs reinforced by what Dawes had seen, wrote to *The Times* that he had several times noticed the same appearance as he had in 1846. He had repeatedly measured the projections or supposed anse of the ring to form an angle with the parallel of declination of about 70° south preceding. Further, he was now satisfied that the ring did not result from anything in the telescope. However, the planet's low altitude and the poor quality of the atmosphere had hitherto prevented him ascertaining the appearance's precise nature and form.[38]

Still the matter was not settled. Challis gave it a further twist in 1848 when he reported another observation of the ring, although he was now searching for an instrumental explanation:

> . . . in the autumn of 1847 I several times saw the appearance which I suppose to be a Ring of Neptune, both before and after opposition, and when the Planet was not far from the meridian; and the axis of elongation constantly had the same position relatively to a parallel of declination as when noticed at the beginning of the year. In the present year (1848) I have had occasion to take out the object-glass from its cell, and re-adjust the two lenses: so that at the next opposition of the Planet, I shall be able to ascertain whether the appearance noticed is dependent on the relative positions of the lenses, one of which is now turned about the axis of the Telescope into an entirely different position relatively to the other.[39]

Lassell too sought in 1848 to repeat his earlier observations. But he was oppressed by uncertainty, and the year passed without a decision being made, in part because in September, independently of Bond at Harvard, he discovered Hyperion, a moon of Saturn. As a result it was Saturn that occupied his energies and thoughts throughout the autumn of 1848, the best time to observe Neptune.

The next year Lassell seriously renewed his campaign on Neptune. In August he was observing in the company of James Nasmyth, a brilliant practical engineer closely involved in the building of the 24-inch, a skilled draughtsman, a fine artist and a most capable astronomer. On this occasion Lassell "received as strong an impression of the ring as at any previous view".[40] Nasmyth too saw a ring and his independent drawing appears in Lassell's notebook (see Figure 3). Furthermore, the inclination of the ring drawn by Nasmyth agrees well with that indicated by Lassell. A few days later Lassell spent an unproductive half-hour studying Neptune. The very next night, 4 September, he observed the planet as soon as it became visible, and again no ring was to be seen. Obviously the capricious manifestation had begun to haunt him, bringing a hint of desperation into his proceedings. Fifteen other observations of Neptune are entered in Lassell's notebook for the autumn and winter of 1849. In none is the ring mentioned. As most were made in poor conditions this is perhaps not surprising. For example, on 27 November he complained that the sky was "excessively muddy and [the] planet a mass of indistinct confusion—nothing could be done with it".[41]

Nor did anything concrete emerge from the 1850 observing season. The following year, Lassell referred to the ring in his public report of "Observations of Neptune and his satellites", but here it is clear that he no longer believed it to be real. Thus he described what he had seen on 26 August as "an evident appendage, *such as I used to take for a ring,* but more evident on the south side, nearly at right angles with the parallel of motion. The same appearance remained with 366, but scarcely so striking, and it vanished with 614. . . . The sky, however, was very variable, and clouds and haze coming on prevented my obtaining any measures, even of the known satellite" (emphasis added). Three nights later he "received again an impression of a ring-like appendage, but it is principally on the south side, and is nearly at right angles to a parallel of declination".[42] On 12 September, Lassell took advantage of a spell of

exceedingly fine observing weather (four nights in a row!) to again examine the planet, and his drawing hints at an appendage. More observations followed, but, from the evidence of his notebooks, none disclosed a ring.

The deterioration of Starfield as a site from which to conduct astronomical observations, caused throughout the encroachment of buildings and the indifferent seeing generally encountered, persuaded Lassell to seek out a better place for an observatory. Accordingly in the autumn of 1852 his telescope was transported to Malta. Here he met conditions better than he had ever experienced, and his first excited reports gave Nasmyth reason to expect a definite pronouncement about the ring.[43]

It was not to be. Lassell, as he remarked in *Monthly notices*, found Neptune generally spherical and well defined even with his highest power, although he did record on 4 November 1852 "a decided impression of ellipticity in the direction of the greatest elongation of the satellite", and, more significantly, "an impression of an extremely flattened ring in the direction of the transverse axis. I think I have never seen *Neptune* so well before".[44] But he refrained from judging this as evidence for the ring. Instead he confessed "yet I suspect some illusion", a far cry indeed from the confident claims of 1846 and 1847.

This, however, is not the whole story. Lassell's notebooks reveal how on the very first night of observing in Malta, 5 October 1852, he saw Neptune accompanied by a ring. A little more than a month later "the indication of the supposed ring immediately struck" Lassell. Its inclination was about 65°, south preceding. The next evening it was "remarkably strong" with a power of 219; the inclination was 80° south preceding, a shift of 15° from the previous night. However, with a power of 1018 "there was the smallest possible suspicion of the ring together with some elliptic form of the planet—both in the direction of the planet's satellite—query whether not both due to the telescope". In a further inspection that night Lassell "found the position of the supposed ring was south preceding and north following".[45] He also suspected that Uranus too appeared elliptical.

Lassell's uncertainties were now quickly dispersing and on 15 December he finally rejected the ring, for he then measured the ring's position "to ascertain whether it depended at all upon the telescope". This he did by rotating the telescope tube and repeating his measurements. His results were 60°·49, 46°·19 and 76°·45:

> It is thus evident that the phenomenon keeps a constant angle with the direction of the telescope and not at all with the parallel [of declination], proving that whatever may be the cause it is more intimately related to the telescope than the object.[46]

Lassell had spent over six years trying to verify beyond doubt the reality of the ring, but in the end he was compelled to admit that the most likely cause was his own telescope. Despite the numerous observations of Neptune he was still to make, Lassell never again indicated or even suggested the planet was encircled by a ring system analogous to that of Saturn.

Analysis

Shortly after his discovery of Uranus, William Herschel believed he had evidence to suggest that the planet was surrounded by rings.[47] It is now

generally accepted he was mistaken (as he himself came to believe), and that the defect was a product of his adoption of the front-view arrangement for his ocular. Such an explanation, even if correct, does not apply to what was allegedly seen about Neptune. It fails to account for the reports of Challis and Hind since both used refractors; nor did Lassell employ the front-view system in his telescope.

Of late there has been some debate about the possible existence of rings around Neptune. But given the present state of knowledge, it seems impossible that Lassell did indeed detect an objective feature. How then do we make sense of the ring observations?

It has been proposed that Lassell's observations could have sprung solely from a predisposition to see a ring.[48] Certainly it is today recognized that prior beliefs and commitments can have a very deep influence on observations and observational practice, and that directly observed experience may be transformed in the mind of the observer by consciously or unconsciously held preconceptions. But what might have persuaded Lassell to 'see' a ring in the first instance? Saturn possesses rings, so *a priori* it was not unreasonable to suppose that Neptune might have a system. More importantly, Lassell may have confused John Herschel's urging to search for satellites with one to examine the planet for satellites *and* rings. We thus discover Lassell writing to Herschel on 12 October that "I am obliged by your note directing my attention to the possible ring and satellites of Le Verrier's planet".[49] Herschel's letter pressing Lassell to look for satellites was written on 1 October, and given the speed of the British postal system of the period, it perhaps arrived before Lassell made his first observation of the new planet on 2 October. Nevertheless, it is clear that sometime between the arrival of Herschel's letter and 12 October, when Lassell replied, Lassell transmuted Herschel's remarks about satellites to include satellites and rings, and was thereby given additional justification for his suspicion of the ring's existence. Unfortunately there is no definite evidence about whether Lassell made this shift before going to the telescope on 2 October. Hence we are in no position to state with certainty how much he was predisposed to 'see' a ring. Yet Lassell was aware of the danger of preconceptions. For example, we find him in 1847 writing to a correspondent about examining Neptune in the company of Dawes: ". . . Mr. Dawes I believe may have a word to say upon the subject [of Neptune's ring] but I fancy would rather not say it until he has had the chance of better circumstances— indeed we have scarcely spoken upon the subject being desirous that all observations should be quite independent and free from all bias."[50] Naturally, awareness of the possible influence of preconception is hardly a guarantee that observations will be unaffected. Furthermore, as Dawes already knew of the ring and of what had been seen previously by Lassell and other users of the 24-inch as well as by Challis and Hind, Lassell's remarks seem a little naïve. It is thus not entirely beyond belief that preconception alone could have caused Lassell to 'see' a ring, and that, in the manner of a string of falling dominoes, several other observers fell into line after Lassell's initial 'push'.

There is, however, overwhelming evidence that Lassell's telescopes suffered from troublesome optical defects. Indeed, we shall argue that a much more

satisfactory explanation of Lassell's ring observations is to be found in a combination of optical defects and preconceptions.

Lassell himself eventually concluded that faults in his telescope most probably were to blame. He was an experienced observer and knew from the first the danger of mistaking telescope defects for a real feature. But his doubts had been allayed because he was able to see the ring using a wide range of oculars, two different specula (each of the same dimensions), besides various flats. He was also fond of substituting the flat by a flint-glass prism by Merz. For instance, on 11 November 1846 he changed both the primary speculum and the flat. He had seen the ring the previous night, but even with the "new telescope" it was still visible.[51] The ring had also been seen by other users of Lassell's telescopes. Amongst these was John Hartnup, a trained astronomer and director of the Liverpool Observatory, in addition to the renowned "eagle-eyed" Dawes. Moreover, had not Hind and Challis reported sightings akin to what the 24-inch had so often shown? Lassell was thus strongly encouraged to believe that something other than optical defects was at work; that, in short, he was observing an objective feature.

As we have seen, his confidence did not last, and by 1851 Lassell was writing of that "evident appendage, such as I used to take for a ring". His mounting doubts were evident in Malta a year later when the 'ring' pressed itself upon him once again. This time he adopted a more critical stance, exhibiting a scepticism derived of experience, and marking, if our argument is correct, a decided step in his development as an observer. For, while Lassell was a respected observer of many years standing by 1846, he (like nearly all of his contemporaries) had had little opportunity to use a telescope the size of the 24-inch, a giant instrument for the time. Certainly his early hopes for and reports of the excellence of his telescope were somewhat exaggerated, and its performance, as is evident from his notebook entries, was less impressive than one might believe on the basis of the published papers, the product one must remember of a proud and very enthusiastic owner and builder. So while the 24-inch was a fine telescope, it possessed flaws. We shall now turn to what Lassell regarded as the most annoying of these.

In 1850, Lassell reported that despite the use of lever systems he had continued to have problems supporting the primary speculum of the 24-inch without its flexing under its own weight:

> One of the greatest difficulties I have encountered in supporting the [24-inch] speculum equably, in its various positions, is to avoid the effects of the friction of its edge under considerable changes of altitude of the telescope.
>
> It is obvious that when the altitude is low the principal part of the weight of the speculum must be borne upon its edge, and the plates in this position being in a great measure relieved from the pressure of the speculum, must, by their elasticity, tend to distort the metal by pressure at its back; and when the telescope is moved towards the zenith, the plates yield again by the weight of the speculum, while the lower edge, still in hard contact at the points of support, is unduly borne up there, and the equilibrium is destroyed. To remedy this evil, I have slung the speculum in a hoop of thin iron, equal in length to half of its circumference, the ends of the hoop being

> attached to swivels fixed in each of the two horizontal brackets, and the lower part of the hoop being thus quite at liberty to rise and fall with the plates.
>
> This has nearly, if not entirely, removed all perceptible distortion, yet in some positions and under some circumstances vestiges of it are to be perceived.[52]

Neptune was at declination −13° in 1846, and from Liverpool, even when on the meridian, was only 22° above the horizon. This situation changed little throughout the late 1840s and early 1850s. Lassell therefore had to observe the planet with the telescope tube far from the zenith, and from his words above we might reasonably infer, even without the copious evidence of his notebooks, that his examinations of Neptune were affected by his method of mounting the primary speculum. His introduction of a hoop to support his specula did not satisfy him for long and, again in 1850, he devised a new system of gravity-operated levers to prevent his 24-inch mirrors flexing. This, he judged happily, "totally removes the indications of flexure formerly discernible", and on 14 May 1851 he used a new speculum with this lever system attached for the first time:

> I have no doubt from the vision I have of stars and Jupiter that the evil of the bending is entirely removed and therefore the object in view has been completely gained. . . . The penumbra of stars becomes perfectly round on both sides [of the focus] and the oval at right angles deformity has totally disappeared without any of the devices I have been accustomed to practise such as turning the telescope to the zenith.[53]

His optimism was to prove badly founded. On October 1852, for example, we find him observing Saturn but again annoyed by what he termed 'crossing', that is, the slightly-out-of-focus images appearing elongated and at right angles to each other, thereby indicating an astigmatized image. To improve matters he had to resort to tricks learnt from experience such as turning "the eyepiece very much up so as to throw the weight of the speculum in a great measure upon the western bracket and afterwards bring [the telescope] down slowly to a horizontal position [as a result of which] the annoyance nearly if not quite disappeared and the vision became remarkably fine".[54]

It is, in fact, unlikely that any maker of a large speculum metal telescope ever fully mastered the problem of equably supporting the telescope's mirrors despite the use of various systems of levers and hoops. For example, in 1848 the Astronomer Royal, G. B. Airy, described some observations he had made with Lord Rosse's 72-inch (183-cm) reflector, the "Leviathan of Parsonstown":

> Upon directing the telescope to an object very near the zenith, it was seen very well-defined; or, at least, with no discoverable fault. It must be remembered that the image of a star never assumes the neat spherical form to which the eye of an observer with a fine refractor is so much accustomed. This arises evidently from the circumstances that (from the great aperture of the mirror) the diffraction image and the diffraction rings are invisibly small, and the form of the blurred image is probably determined by the irregular sensibility of the nervous membranes of the eye. The same effect exactly is produced by a large refractor when a power is employed too low to exhibit the rings [of Saturn].

> But when the telescope was directed to a star as low as the equator its image was very defective. The defect, however, followed that simple law which [William Whewell] has described by the word *astigmatism*. When the eyepiece was thrust in, the image of the star was a well-defined straight line, 20 seconds long, in a certain direction; when the eyepiece was drawn out a certain distance (about half an inch from the former position) the image of the star was a well-defined straight line, 20 seconds long, in a direction at right angles to the former. Between these two positions the image was elliptical, or, at the middle position, a circle of 10 seconds diameter. The image of *Saturn* (then without a ring) was, in the two positions above mentioned, an oval (not an ellipse), whose length was about double its breadth; or, in the middle position, it was a confused circle, whose diameter was about 30 seconds instead of 20. The position of the astigmatic lines had no distinct relation to the vertical plane; and this circumstance, as well as the magnitude of the astigmatism, proved that it was not produced by a tilt of the mirror.[55]

Here is an excellent description of the difficulties facing Lassell, although his were on a smaller scale. In addition, speculum metal mirrors were subject to distortion because of the imperfect temperature equilibrium between themselves and their surroundings. Also, the figures of Lassell's specula were often a source of irritation to him. Indeed, when he first observed the ring neither of the 24-inch specula available to him in 1846, Speculum A and Speculum B, had a good parabolic figure.

From the outset Lassell had realized that a distortion or flexure in his mirrors was capable of inducing a feature akin to a ring. Yet it is not clear if he made many tests for such effects. Dawes's observing diary for 14 September 1847 refers to two sets of measurements of Neptune's elongation. In between the two sets of readings the 24-inch tube was turned 30° on its axis (as we noted above).[56] There is no similar record in Lassell's notebook. Such comparisons may have been made on numerous occasions but went unnoted. On the other hand, the fact that Lassell detailed in full the decisive test of 15 December 1852 perhaps indicates he did not normally make such checks. Anyway, the 30° spread of the measurements of the inclination on that night finally convinced him the ring was "more intimately related to the telescope than the object". Further, if the feature was due to the telescope, then we have a ready explanation of why others who observed with the 24-inch likewise saw the ring.

If image defects help to explain the observations of Lassell, how are we to account for those of Challis and Hind, two observers of considerable repute? A crucial point is that they both noticed some peculiarity in the image of Neptune only *after* they were aware of Lassell's ring observations, although they had both examined the planet on several occasions very soon after its discovery.[57] Nor should we forget that Challis and Hind had been beaten by Galle and d'Arrest in the hunt for Neptune in 1846. They knew too that Lassell's telescope was more powerful than their own and that his observations had been endorsed by other users of the 24-inch. It is therefore likely that Challis and Hind were disposed by their preconceptions to see Neptune as elliptical or oblong, and in Challis's case to 'see' a ring, although even here image defects might well have played some part. Lassell and the other observers who saw the

ring with the 24-inch were also subject to preconceptions. For, if our argument about the effects of astigmatism is correct, Lassell and his colleagues interpreted elongated images as a ring almost edge-on. For them to have made such an identification must have been due in part to the prior knowledge that Saturn has rings, and, in the case of Lassell, his belief that John Herschel had asked him to look for rings and satellites.[58]

Conclusions

It has been contended that for most of the nineteenth century the British amateur undertook research without pressure from a "professional network and devoid of the hunger for professional recognition".[59] While it is true that there was no strong professional network in British astronomy during the 1840s and 1850s, Lassell, a provincial brewer by trade, did very much desire recognition, particularly from the influential members of the Royal Astronomical Society. He was ever anxious to demonstrate the excellence of the 24-inch telescope that he had built through his own initiative, skills and energy.[60] His rather exaggerated public reports of the 24-inch's performance meant that faults in his creation were not emphasized—at least, faults of such a magnitude as to produce a ring-like appearance. Certainly Lassell made but brief and tangential public reference to his fears that optical illusions had given rise to the supposed ring. As so often happens in science, once the ring became suspect it was generally ignored, and only a few contemporary writers mentioned its likely spurious origin. One who did was W. H. Smyth. In 1859, he noted that the "case of a ring must probably remain undecided for a few years, until the planet occupies a better situation in the ecliptic, by rising in declination to a good-working altitude: but as we happen to know personally that its existence is now doubted by Mr Lassell himself, 'tis as well to say so".[61]

Nevertheless, the most important conclusion to emerge from the story of Neptune's ring concerns the effects of preconception and how these are currently regarded. It has lately become common to use such effects to explain why scientists perceive phenomena in a manner that appears inexplicable to others. We have suggested that both Challis and Hind were strongly influenced by the reports of Lassell's observations. Further, it is tempting to argue that Lassell himself was a 'victim' of preconceptions. But we have indicated that it is highly likely that mirror flexure played a significant rôle throughout, and a study of the telescope used by Lassell has thus been shown to be just as necessary as the inquiry into the conceptual framework within which Lassell and his contemporaries sought to interpret their observations. We therefore wish to emphasize that a full account of Lassell's observations requires an analysis of both his instruments and his expectations, and that, in general, it is essential to pay full attention to the instrument employed by a scientist in cases where preconception is, or might be, invoked to help explain a set of observations or experimental results.

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3. A. von Humboldt, *Cosmos: A sketch of a physical description of the universe* (English transl., London, 1852), iv, 476, footnote 16.
4. R. Baum, *The planets: Some myths and realities* (Newton Abbot, 1973), chap. 6.
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6. J. R. Hind, "Discovery of Le Verrier's planet", letter to the editor, *The Times*, 1 October 1846, 8. Neptune was often referred to as "Le Verrier" for some time after its discovery.
7. The cutting is located between the entries for 2 and 3 October 1846 in one of Lassell's notebooks: Lassell papers 9.7, Royal Astronomical Society Archives (hereafter cited as RASA). The references to Lassell's notebooks follow those given in J. A. Bennett's "Catalogue of the archives and manuscripts of the Royal Astronomical Society", *Memoirs of the Royal Astronomical Society*, lxxxv (1978).
8. J. Herschel to W. Lassell, 1 October 1846, Royal Society Herschel papers (H.S.22.285).
9. Entry for 3 October 1846 in Lassell papers 9.7, RASA.
10. Entry for 10 October 1846 in Lassell papers 9.7, RASA. The satellite was Triton, Neptune's largest moon.
11. Entry for 26 October 1846 in Lassell papers 9.7, RASA.
12. Entry for 29 October 1846 in Lassell papers 9.7, RASA.
13. Entry for 10 November 1846 in Lassell papers 9.7, RASA.
14. Entry for 11 November 1846 in Lassell papers 9.7, RASA.
15. W. Lassell, letter to the editor, *The Times*, 14 October 1846, 7. The letter is dated 12 October.
16. W. Lassell in the collection of various "Observations of Le Verrier's Planet", *Monthly notices of the Royal Astronomical Society*, vii (1846), 154–7, p. 157.
17. Reported in "Observations of Le Verrier's Planet", *ibid.*, 165–8, p. 167.
18. Hind's search for Neptune is discussed in Robert W. Smith's "The discovery of Neptune", in preparation.
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22. W. Lassell to J. Challis, 19 January 1847, Cambridge Observatory Archives. See also W. Lassell to R. Sheepshanks, 9 February 1847, Sheepshanks papers, RASA.
23. J. Challis, "Schreiben des Herrn Professor Challis, Direktor der Cambridge Sternwarte, an den Herausgeber; 'Observations of Le Verrier's planet taken at Cambridge Observatory'", *Astronomische Nachrichten*, xxv (1847), 229–32. Lassell reported this to Sheepshanks: see W. Lassell to R. Sheepshanks, 9 February 1847, Sheepshanks papers, RASA.

24. W. Lassell to R. Sheepshanks, 9 February 1847, Sheepshanks papers, RASA.
25. See Baum, *The planets*, 134–9.
26. Reported in "Report of the Council to the twenty-seventh Annual General Meeting", *Monthly notices of the Royal Astronomical Society*, vii (1847), 193–231, p. 217.
27. W. Dawes to J. Challis, 7 April 1847, Cambridge Observatory Archives.
28. W. Dawes to J. Herschel, 21 April 1847, Royal Society Herschel papers (H.S.6.81).
29. *Ibid.* This letter solves the problem raised by Hetherington (*op. cit.* (ref. 5)) of the apparent disagreement between the inclination measurements of Lassell and Challis.
30. Draft of letter by J. Challis, 3 May 1847, Cambridge Observatory Archives.
31. *Ibid.*
32. Entry for 7 July 1847 in Lassell papers 9.8, RASA.
33. W. Lassell to J. Herschel, 14 August 1847, Royal Society Herschel papers (H.S.11.134). A few days earlier Lassell had written to the *Astronomische Nachrichten* and commented that he had noticed on two or three occasions the same appearance of the ring as in 1846, "but nothing more strongly confirmatory, and I wait to see the planet more nearly on the meridian, and for a state of atmosphere that will bear the application of higher powers than are necessary to see the satellite" (W. Lassell, "Schreiben des Herrn Lassell an den Herausgeber", *Astronomische Nachrichten*, xxvi (1848), 165–8, p. 168).
34. W. Lassell to J. P. Nichol, 17 August (?) 1847. Copy in Lassell papers 8.2, RASA.
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36. Entry for 8 September 1847 in Lassell papers 9.8, RASA.
37. Entry for 8 September 1847 in Dawes papers 3 (Observing journal 1847–1858), RASA.
38. W. Lassell, "The planet Neptune and his satellite", letter to the editor, *The Times*, 24 September 1847, 7.
39. J. Challis, *Astronomical observations made at the observatory of Cambridge*, xv (1848), Appendix 1, 20.
40. Entry for 21 August 1849 in Lassell papers 9.11, RASA.
41. Entry for 27 November 1849 in Lassell papers 16.1, RASA.
42. W. Lassell, "Observations of Neptune and his satellite", *Monthly notices of the Royal Astronomical Society*, xii (1851), 155.
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44. W. Lassell, "Extract of a letter from Mr. Lassell", *Monthly notices of the Royal Astronomical Society*, xiii (1853), 36–39, p. 38.
45. Entry for 11 November 1852 in Lassell papers 16.3, RASA.
46. Entry for 15 December 1852 in Lassell papers 16.4, RASA.
47. These observations are discussed by Baum, *op. cit.* (ref. 4), chap. 5.
48. See Hetherington, *op. cit.* (ref. 5), 27.
49. W. Lassell to J. Herschel, 12 October 1846, Royal Society Herschel papers (H.S.11.130).
50. W. Lassell to R. Sheepshanks, 8 September 1847, Sheepshanks papers, RASA.
51. Entry for 11 November 1846 in Lassell papers 9.7, RASA.
52. W. Lassell, "Description of a machine for polishing specula etc., with a description for its use . . . ", *Memoirs of the Royal Astronomical Society*, xviii (1850), 1–20, p. 17.
53. Entry for 14 May 1851 in Lassell papers 16.2, RASA.
54. Entry for 29 October 1852 in Lassell papers 16.3, RASA.
55. G. B. Airy, "Substance of the lecture delivered by the Astronomer Royal on the large reflecting telescopes of the Earl of Rosse and Mr. Lassell, at the last November meeting", *Monthly notices of the Royal Astronomical Society*, ix (1848), 110–21, p. 118. Airy's observations were of course made at an early time in the career of Rosse's giant telescope, and Rosse was later to devise various other systems to combat flexure, some of which Airy describes in the same paper. The question of flexure problems in large speculum metal reflectors is taken up by Robert W. Smith in "The telescopes of William Lassell", in preparation.
56. However, it is likely that such measures were not attempted until Lassell began his observations of Neptune in 1847, and then he employed his "excellent" parallel wire micrometer by Dollond for position and distance determinations of Neptune's satellite as well as for measures of the projections of the supposed anse of the ring: see W. Lassell, "The planet Neptune and his satellite", letter to the editor, *The Times*, 24 September 1847, 7. Lassell's behaviour is here worth comparing with that of the professional Challis. In particular, Lassell apparently made no attempts to measure the ring's position until Challis had done so. Challis indeed took his first measures but three days after his initial sighting of the ring. We

are thus given a view of Lassell's determined but, in 1846, essentially amateurish approach to the problem of the ring's existence.

57. On 30 September 1846, Hind told Challis that he had observed Neptune's "distinctly perceptible" disk and that it is "bright". No mention was made of any irregularity of form: J. Hind to J. Challis, 30 September 1846, Cambridge Observatory Archives.
58. It is not clear if Lassell knew of William Herschel's spurious detection of rings around Uranus. Preconception played a central rôle in Herschel's observations of the newly discovered planet for at first he thought he had found a comet and, moreover, measured it to be increasing in size just as he had anticipated a comet would do, this despite the fact that Uranus was then decreasing its size as seen from the Earth: see R. H. Austin, "Uranus observed", *British journal for the history of science*, iii (1967), 275–84, and S. Schaffer, "Uranus and the establishment of Herschel's astronomy", *Journal for the history of astronomy*, xii (1981), 11–26.
59. M. Berman, "'Hegemony' and the amateur tradition in British science", *Journal of social history*, viii (1975), 30–50, p. 40. On amateurs in late nineteenth-century astronomy see J. Lankford, "Amateurs and astrophysics: A neglected aspect in the development of a scientific speciality", *Social studies of science*, xi (1981), 275–303.
60. This is taken up in more detail in Robert W. Smith's "The telescopes of William Lassell", in preparation.
61. W. H. Smyth, *The cycle of celestial objects continued at the Hartwell Observatory to 1859. With a notice of recent discoveries, including details from Aedes Hartwellianae* (London, 1860), 417. However, the idea that Neptune has a ring took many years to disappear completely. For example, a set of ten English mechanical astronomical slides dated *c.* 1865 includes one of Neptune with a ring: *Tesseract: Early scientific instruments Catalogue C, Winter 1983* (Hastings-on-Hudson, N.Y., 1983), lot number 2.