THE SHOEMAKER-LEVY 9 SPOTS ON JUPITER: THEIR PLACE IN HISTORY

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Abstract. Historical observations of Jupiter were studied in a search for descriptions or depictions of spots of a magnitude comparable to that produced by the impacts of comet Shoemaker-Levy 9 fragments with Jupiter in July 1994. No such record was found. With the possible exception of the Great Red Spot, the Shoemaker-Levy 9 "G" spot appears to be the most prominent jovian spot in history.

1. Introduction

Almost as soon as the first fragment of comet Shoemaker-Levy 9 struck Jupiter on 16 July 1994, reports of dark spots associated with the impact sites began to circulate among observers.[1] The appearance of these spots (seen in visible light) was described with adjectives such as "incredible," "startling," "amazing," and "awesome," even when viewed through telescopes as small as 10-centimeters in aperture. David Levy, co-discover of Shoemaker-Levy 9, called them "the most obvious features I have ever seen on Jupiter, and with the exception of Saturn's recent white spot, the most obvious feature on any planet."

The most spectacular spot, created by the impact of Shoemaker-Levy 9, fragment G, was "by far the most impressive feature."[1] It was comparable in size to the Great Red Spot and the darkest feature on the planet with the exception of satellite shadows. Well-known planetary observer Clark Chapman declared it, "the most visually prominent discrete spot ever observed on Jupiter."

These evocative descriptions are reminiscent of those used by visual observers during the golden age (pre-spacecraft) of ground-based planetary astronomy. To place the Shoemaker-Levy 9 spots in their proper historical context, it is necessary to examine the long record of visual observations of Jupiter in search of comparable spots. Are the spots that we are witnessing today unique in magnitude when compared to more-than three-hundred years of telescopic scrutiny?

Let us use as our hypothesis to test the following statement make by John Rogers of the British Astronomical Association: ". . . the big [Shoemaker-Levy 9] impact scars are the most prominent transient spots *ever* seen on Jupiter [my italics] . . ."[1] I will define "prominent" to mean a combination of physical size and albedo contrast with surrounding

[1] Quotes are taken from messages transmitted over the Internet via the SL9EXPLODER. These messages are posted in the "early_reports" directory of the FTP site pdssbn@astro.umd.edu. The SL9EXPLODER was coordinated by Anne Raugh, Department of Astronomy, University of Maryland.

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belts and zones.

Direct comparison of pre- and post-impact images of Jupiter does support the unique prominence of the Shoemaker-Levy 9 spots, at visible wavelengths. However, most of the historical record of planetary observations dates from the pre-photographic era. Here, I will use as my data base the published depictions and descriptions of Jupiter that make up the record prior to the 1880s.

I will begin with a general description of the observations of jovian spots made in the past. I will then consider specific examples of transient spots, considered prominent in their day, in a search for candidates of the magnitude of the Shoemaker-Levy 9 spots. (In addition to most of the published literature on the physical appearance of Jupiter published before 1880, I have examined more than two-hundred drawings and sketches of the planet from this time.)

2. Spots on Jupiter

I confine my examination to the depictions and descriptions of *spots* on Jupiter. (The Shoemaker-Levy 9 impact features on Jupiter have most often been called "spots.") While the observational literature is replete with reports of "streaks, " "plumes, " "festoons," "disturbances," "blobs," "loops," "wisps." "coves," "bays," "rings," and "whirlpools" on Jupiter, the term "spot" has been reserved for nearly circular and oval morphological features.

Into the twentieth century, spots were used foremost as jovian rotation-period indicators. These features were studied primarily so that they could be recognized repeatedly as unique markers and then timed during multiple surface transits. This procedure gives insight into the perceived physical nature of Jupiter at the time: The idea that there exists a single rotation period for the planet was an outgrowth of the belief that Jupiter, like other well-observed planets in the Solar System (e. g., the Earth, Moon and Mars), had a solid surface. If a feature were in some way anchored to this surface, its transit time would yield the planet's rotation. Variations in rotation timings by this method were often attributed to experimental error.

By the late 1700s, it was recognized that certain spots behaved like terrestrial atmospheric phenomena (again, an Earth-based analogy) and were imbedded in global cloud patterns such as the belts and zones. Thus, they were likely to be affected by the local wind-speed prevalent at a given latitude and not representative of the motion of the "surface" hidden below them.

It was believed that dark spots had more physical significance than bright ones, because they potentially represent holes in the clouds that might reveal the solid surface below. Bright spots were only of interest for wind-speed measurement, and even then there was a strong bias toward large, well-defined, equatorial features. More diffuse or lower-contrast temperate features might have been overlooked or simply ignored.

I have found no suggestion in the historical record that jovian spots could be formed by impact. With the exception of satellite shadows and the disks of satellites in transit, jovian spots have been considered to be endogenic.

3. Major Jovian Spots in History[2]

HOOKE'S SPOT OF 1664 AND CASSINI'S "PERMANENT SPOT" OF 1665

Priority for the earliest observation of an intrinsic spot on Jupiter goes to either Giovanni Cassini (1625-1712) or Robert Hooke (1635-1702). Hooke found "on the ninth of May, 1664. . .a small Spot in the biggest of the 3 obscurer Belts of Jupiter" (Hooke, 1665). The North Equatorial Belt was the most conspicuous jovian band during the 1660s (Chapman, 1968).

Cassini's sighting of the so-called "Permanent Spot" the next year was the more-important observation because its reoccurring passage across the disk not only offered proof of Jupiter's rotation but allowed Cassini to actually calculate the first reliable rotation time for the planet: $9^{h}\ 56^{m}$ (Oldenburg, 1665). The "Permanent Spot" was situated next to the South Tropical Belt (Chapman, 1968) and ". . .its diameter is about the tenth part of that of Jupiter. . ." (Cassini, 1672). It remained visible until 1672 vanished, and then reappeared for a time in1674 (Cassini, 1733).

In 1689, Cassini observed a spot in the South Equatorial Belt with an area that "autant à peu près qu'en occupe toute l'Affrique" (Cassini, 1733). This spot had a rotation period distinctly different from that of the "Permanent Spot": $9^{h}\ 51^{m}$. Two more spots, seen that same year, had periods of $9^{h}\ 51^{m}\ 30^{s}$.

HERSCHEL'S DARK SPOTS OF 1778

The foremost English astronomer of the 1700's was a prolific writer, but William Herschel (1738-1822) wrote only one paper about features on Jupiter (1781). Even this paper was principally about astronomical time-keeping. We would know very little about how Jupiter actually appeared in Herschel's day except for the fact that he included with his discourse on time portions of his observing log that dealt with his brief study of the planets.

Herschel also undertook the first series of jovian drawings. His thirteen illustrations for the Philosophical Transactions of the Royal Society (Herschel, 1781) were made in February, March, and April, 1778. The artistic style is extremely linear and impedes interpretation. It is clear that his motivation was principally to document equatorial features suitable for rotation-timing. Still, his drawings surpass any predecessor.

In two illustrations, three large dark spots can be seen in the northern component of the Equatorial Zone [EZ] (Herschel, 1781). They are arranged in a triangle.

Eighteenth century spots on Jupiter were also recorded by the first major German planetary astronomer, Johann Schröter (1745-1816). His first published examination of Jupiter (Schröter, 1788) took place in the winter of 1786. Schröter, too, was mainly concerned with rotation-timing, and we know little of the morphology or albedo of his spots, though we do know he was the first to refer to white spots.

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[2]Details about the instrumentation used by historical Jupiter observers may be found in Hockey, 1988.

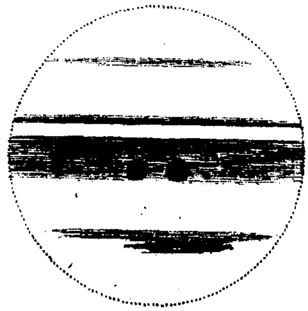

Fig. 1. Jupiter, April 7, 1778 (Herschel, 1781).

SPOTS OBSERVED BY MÄDLER, BEER, AND AIRY IN 1834-35

Johann Von Mädler (1794-1874) and his patron, a banker named Wilhelm Beer (1797-1850), described dark spots on Jupiter in the early nineteenth century (Beer and Mädler, 1835). In December 1834, they happened to observe Jupiter at the same time as George . Airy (1801-1892), just prior to his being named Astronomer Royal.

Airy wrote of "a remarkable spot seen on the apparent southern belt [North Tropical Zone], nearly four times as large as the shodow of the first satellite [Io], very well defined. About two-thirds of its breadth was apparently below the belt, and one-third upon the belt" (Airy, 1835). On the 13th, there were two spots "on the apparent lower belt, both well defined. The following spot is larger" (Airy, 1835).

DAWES' AND LASSELL'S SPOTS OF 1849

William Dawes (1799-1868) and William Lassell (1799-1880) independently tracked groups of South Temperate Zone [STZ] white spots, or "ovals," on Jupiter during the late 1840s and

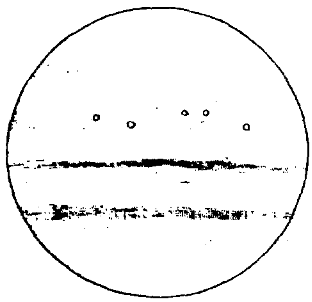

Fig. 2. Dawes/Lassell Spots on Jupiter, November 17, 1857 (Dawes, 1858a).

1850s. These spots were noteworthy in Dawes' and Lassell's time because of their multiplicity, not their size. The largest STZ spot was only two-thirds the size of Ganymede's shadow (Dawes, 1858b).

VARIOUS OBSERVERS IN THE 1870s

During the 1870s, telescopes with apertures large enough (> 12- inches) to incorporate multiple atmospheric seeing cells came into common use. The result was that resolution was no longer telescope-limited. Slow to realize this, astronomers increasingly attempted to document an overwhelming amount of minute and often spurious detail. The real information content of jovian images made during this time was often vastly exceeded by the number of "detectable features." Some examples appear in figure 3.

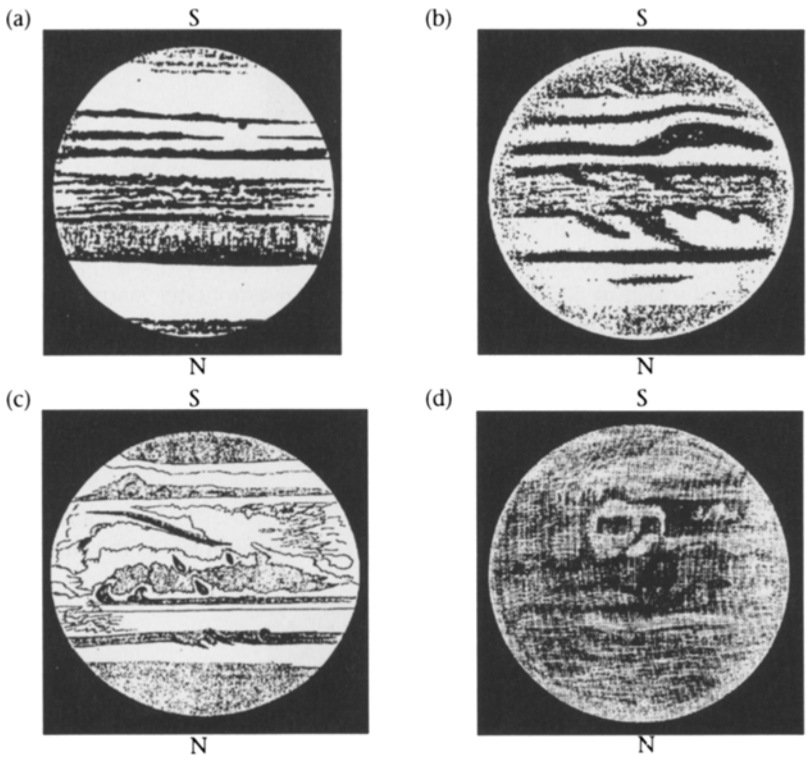

Fig. 3. Jupiter (a) December 30, 1871 (Lassell, 1872), (b) February 7, 1872 (Parsons, 1874), (c) January 28, 1873 (Tacchini, 1873), and (d) June 24, 1875 (Newcomb and Holden, 1880).

THE GREAT RED SPOT

In the new journal Observatory, Carr Pritchett (1837-1888) described the feature he first observed on Jupiter, beginning the night of July 6, 1878, as an "...elliptic cloud-like mass, separate from the general contour of the belts. This cloud was almost a perfect oval in shape, and was preeminently rose-tinted." (Pritchett, 1879) Pritchett had unequivocally seen what is now known as the Great Red Spot. The drawing that Pritchett included with his letter is conclusive. (See figure 4.) It is of no vague detail, but of a definite huge spot, disrupting the parallel jovian belt/zone pattern in the Southern Hemisphere.

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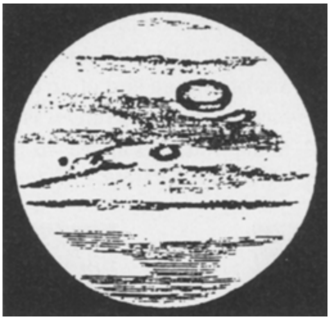

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Fig. 4. The Great Red Spot on Jupiter, July 9, 1878 (Pritchett, 1879).

While Pritchett's (1879) dated drawing gave him precedence, the "new" feature was almost simultaneously seen by observers among the planetary-astronomy community stationed all over the world. Those who did not see it, "recovered" it from their own drawings or observing notes made that summer or quickly spotted it when the first reports from others reached them. The feature known as the GRS has been more-or-less continuously monitored since.

THE WHITE OVALS

Peek (1958) well documents the appearance of large, White Oval features in the South

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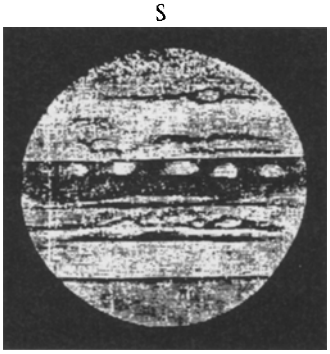

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Fig. 5. Jupiter as Drawn by O. Lohse, February 5, 1872 (Proctor and Ranyard, 1892).

Temperate Belt [STB] during 1939. Similar features had been recorded previously. In an 1872 drawing, made by Oswald Lohse (1845-1915) of the Potsdam Astrophysical Observatory, a single oval appears (Lohse, 1878). The spot is too far south to likely be the Great Red Spot. Instead, it is easier to imagine that it is akin to an STB White Oval or, perhaps, an isolated and large example of an STZ spot. Other observers drew Lohse's oval until 1874.

4. Discussion

Elongated features called "barges" are a common at 14-degrees north latitude on Jupiter. Cyclonic "barges" are easy to see because of their contrast with their surroundings and would have been particularly interesting to early observers who would have equated them with great depth. Spotting such a feature would have brought the observer closer to seeing the "real" Jupiter, so it was thought. Extremely dark, they might by nearly as easily resolved as satellite shadows, which had been observed on Jupiter as early as 1643 by Giambattista Riccioli (1598-1671). Both Hooke's spot and the spots observed by Mädler, Beer, and Airy were probably "barges." All were described as being smaller than the Shoemaker-Levy 9 spots.

Large-aperture telescopes today commonly resolve arcuate cloud structures in the northern component of the EZ. It takes little misleading of the eye to "complete" these curves into ellipsoids. Thus, these plumes can cause the lower-albedo regions between them to appear as large spots or "portholes," as they were called in the nineteenth century (Proctor and Ranyard, 1892). (See figure 5.) Because of their placement, the Equatorial spots of William Herschel can easily be interpreted in this way and therefore are not true "spots" at all.

Small, bright, anti-cyclonic spots can best be seen at the latitude of Dawes' and Lassell's spots in Voyager Spacecraft images from the 1970s. Both the Dawes/Lassell spots and their modern counterparts share the similar morphology of a dark annulus surrounding a brighter center. These were clearly small features that drew notice because they were bright spots rather than the more-common dark spots.

The Great Red Spot has been observed at various times throughout the history of telescopic observations of Jupiter. (See Hockey, 1991.) Indeed, a good argument has been made that Cassini's "Permanent Spot" and the GRS are one and the same (Chapman,1968). It must be remembered, though, that this feature was only a truly high- contrast feature for a relatively brief period from 1878-1882. At the time of the Shoemaker-Levy 9 impacts, for instance, the impact spots were clearly more prominent than the GRS.

Second only to the Great Red Spot in prominence are the White Ovals. However, these features achieve their contrast as *white* features on a low- albedo "background." They are also consistently rendered and described as being smaller in size than the GRS, while some Shoemaker-Levy 9 spots are equivalent in size to the GRS.

In conclusion, no other historic spot has matched the Great Red Spot in prominence. Yet, the GRS is most noteworthy because of its unique *chromophor*. Moreover, the GRS defies the definition of a "transient" spot.

There is no historical evidence for jovian spots of the size and darkness of the Shoemaker-Levy 9 "G" spot. The features that we are witnessing today on Jupiter would have been coveted by the great planetary observers of the seventeenth, eighteenth, and nineteenth centuries.

Acknowledgement

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