BAA Jupiter Section: 2018 Report no.5 (2018 May):

Historical records of the Great S. Tropical Disturbance (STropD) passing the Great Red Spot (GRS)

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In 2018, we are watching a STropD passing the GRS, a phenomenon that has never before been observed at such high resolution. This encounter was keenly awaited because of the remarkable behaviour of the great STropD over a century ago. The great STropD appeared in 1901 [refs.1-3]. It always moved faster (eastward) than the GRS, so it caught up and overtook the GRS six times from 1902 to 1913. (Usually the GRS itself was very faint so the observations mainly refer to the Red Spot Hollow [RSH].) Whenever it caught up with the GRS, the preceding (east) end of the STropD (p-STropD) was reported to stream rapidly round the south side of the GRS and to re-form p. the GRS within days or weeks [ref.1: Fig.1]. However in 2018, although dark material and intense turbulence from the STropD has been streaming round the S side of the GRS for 3.5 months, it has still not re-formed a p-STropD.

Therefore, I have reviewed the accounts of 1902-1913 in the original BAA Journals and Memoirs. To summarise the conclusions: the observations (all visual) were often incomplete, and very few good drawings were published. On the first passage of the p-STropD past the GRS, in 1902, it was reported to have re-formed rapidly but this does not seem to be well established. The second passage (1904) was not observable, but the next 4 passages (1906, 1908, 1910, 1913) all occurred in a more subtle and prolonged manner. The p-STropD was not actually observed for some weeks after it arrived at the RSH, then it only formed indistinctly, via vague ill-defined shadings. Although it did eventually reappear in its classic curved dark form on each occasion, the idea that it had passed the GRS rapidly (taking only days or weeks) was only inferred by extrapolating its subsequent motion back to the RSH.

In 1902, Jupiter was in the southern sky; the passage occurred in June and opposition was on Aug.5. The p-STropD is said to have arrived at the RSH in May [ref.3] or June [BAA Memoir] but the planet would have been low in the morning sky from the UK so it may not have been well observed; I have not found any recorded observation of the event. Whereas British observations of the f. end in 1901 showed a steady drift [ref.3], Molesworth's observations of the p. end showed more variable drift. It was rapid (eastward) from 1901 July to Nov. [ref.2], suggesting that it would reach the RSH as early as 1902 Feb.-Mar; but in fact it had still not reached the GRS by 1902 April [Fig.2]. The p-STropD must have accelerated again in order to reach the RSH in 1902 May or June, on unknown date. The main account of its passage past the GRS was by Phillips [ref.4]. On June 19, Phillips found the dark STropD stretching from the f. edge of the RSH for over 35º longitude, and thickening and darkening of the STB south of the GRS; on June 21, Denning found it quite similar; but on June 26 Phillips saw "a very conspicuous dark mass on the p. side of the RSH" spanning the STropZ. Peek [ref.1 & Fig.1] said the passage was observed by Molesworth (in Ceylon, now Sri Lanka) but this appears to be wrong. I have inspected Molesworth's hand-drawn strip-maps in the BAA archives, and on April 8, the p-STropD was still ~25º f. the RSH; then there are none between April 9 (no.24) and July 12 (no.25, when the p-STropD had already re-formed p. the RSH) [Fig.2]. He may have been prevented from observing due to other commitments or the monsoon. There are no published drawings of the passage and I have not found any unpublished ones. Therefore, the account of the rapid passage does not seem to be very secure, and it may actually have taken a month or even more before the p-STropD re-formed.

In 1906 [BAA Memoir, text adapted in ref.1] the p-STropD arrived at the RSH on Feb.25. Some darkening was seen in the STropZ during April but the p-STropD had not definitely completed its re-formation two months after the passage started, when the apparition ended. Two fine original drawings by Denning [Fig.3] showed the rest of the STropD still f. the GRS.

In 1908, the BAA Memoir gave only a brief mention and few illustrations of the passage, so its duration is not clear, which is unfortunate as it occurred during a very favourable opposition.

In 1910, the BAA Memoir gave the most detailed account so far of such a passage, and included some illustrations [Figs.4 & 5]. It started in early January; ill-defined shading was seen in the STropZ p. the RSH in Feb. & March, but the p-STropD did not definitely re-form until late April, over 3 months since it had arrived at the RSH.

In 1913 [BAA Memoir] the passage started during solar conjunction, and the p-STropD was seen re-forming gradually at the start of the apparition [Fig.6].

In 2018, the p-STropD reached the RSH on Feb.4, and hi-res images from amateur observers and from JunoCam [ref.5] showed that extensive, intense turbulence streamed round the S side of the GRS and spread out in the latitudes of the STB and southern STropZ p. the GRS, with both cyclonic and anticyclonic eddies. We could say that vague ill-defined disturbance was appearing p. the GRS since Feb., though by late May it still has not re-formed the p-STropD. So, apart from the fact that this disturbance is not obviously dark, it is not yet inconsistent with what used to happen a century ago.

I suggest that during the encounters of the Great STropD with the GRS, the same process happened, and the p-STropD re-formed in a stochastic manner from the extensive turbulence that accumulated p. the GRS, when eddies there sooner or later captured the SEBs retrograde jet to produce the recirculation that constitutes the p-STropD.

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References:

1. Peek BM (1958) *The Planet Jupiter* (Faber & Faber)

2. McKim R (1997) JBAA 197 (no.5), 239-245. 'P.B. Molesworth's discovery of the great South Tropical Disturbance on Jupiter, 1901.'

3. Denning WF (1902) JBAA 12,121-125. 'Dark Spot in Jupiter's South Temperate Region, 1901.'

4. Phillips TER (1902) JBAA 12, 354-355. Meeting report.

5. Rogers J (2018) 'JunoCam at Perijove-12 (2018 April 1): What the images show.' https://www.britastro.org/node/13011

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Figure 1: See separate file.

Figures 2-5: On following pages.

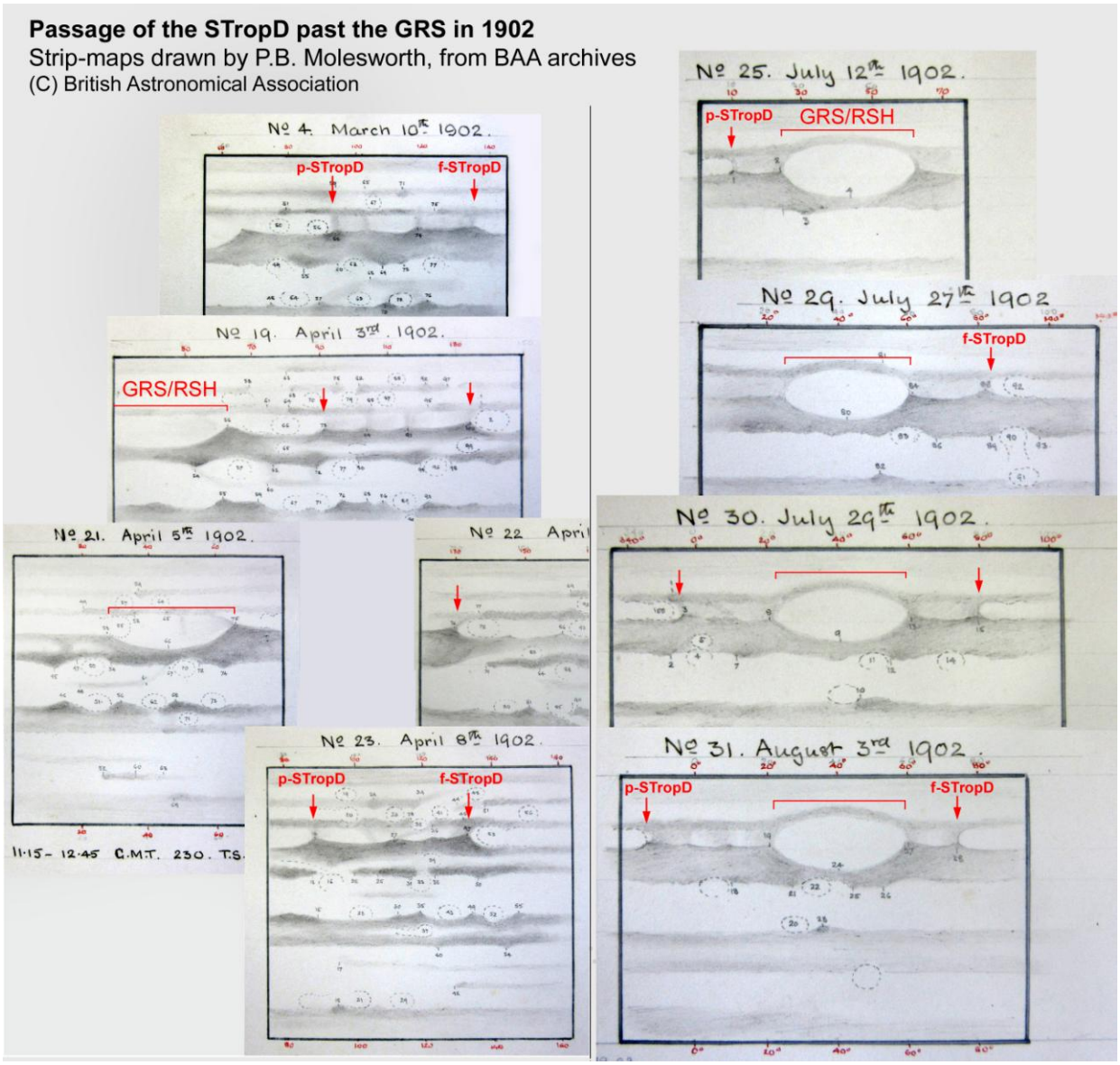
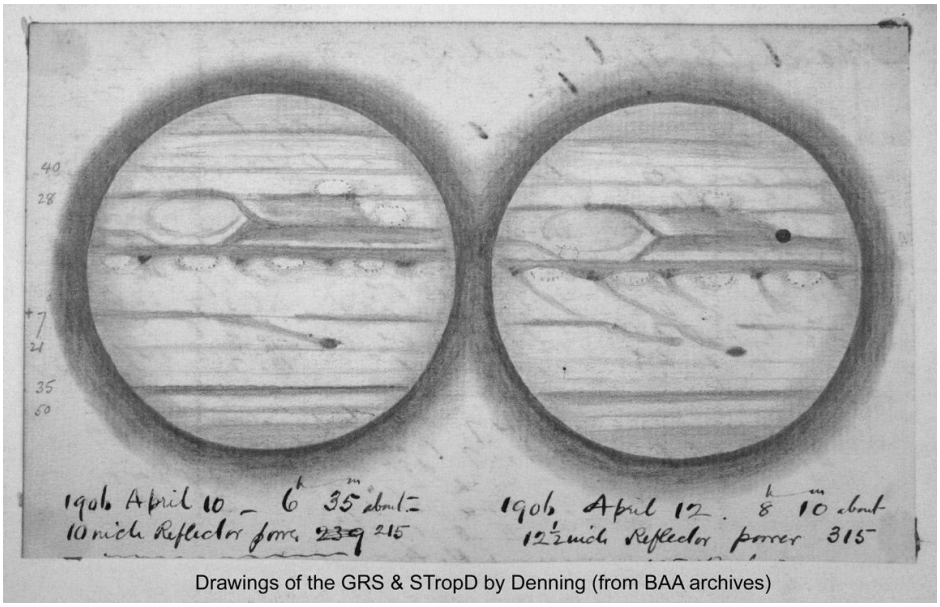


Figure 2.



Drawings of the GRS & STropD by Denning (from BAA archives)

Figure 3.

The great S. tropical disturbance was again a prominent feature of the disc, exceeding in length anything it had previously attained. The *p.* end of the disturbance overtook the *f.* shoulder of the Red Spot hollow for the fifth time during the first week in January 1910. Now, at the conjunctions in 1902 and 1904 the appearance of dark matter on the *p.* side of the hollow occurred very rapidly—so rapidly as to give considerable support [to Major Molesworth's theory that the material]

of the S. temperate belt, through which the disturbance was supposed to pass, behaved almost like an incompressible fluid, material near the *p.* end of the Red Spot being displaced from the belt as soon as the disturbance reached the *f.* shoulder of the bay. But, as Mr. Bolton points out, at more recent conjunctions the apparent transference of dark matter from one side to the other of the bay has been much less rapid, and it must be admitted that it is not yet clear how the transference takes place, whether by passing round, or over, or even under the Red Spot. Mr. Bolton believes he has traced wispy material in transit over the Red Spot; other observers, including M. Antoniadi, Messrs Hawks, Newbegin, O'Hara, and the Director, have all found irregular dusky patches and bright spots lying over the Red Spot hollow.

A difficulty in the study of the behaviour of the dark area during the last three conjunctions has arisen from the circumstance that though the arrival of the *p.* end of the disturbance at the *f.* shoulder is an easily observable phenomenon, given suitable weather conditions, it is otherwise with the reappearance of the disturbance on the other side of the bay. In 1906, 1908, and again at the last apparition, an ill-defined dusky shading could be discerned hanging over the region of the S. tropical zone in the neighbourhood of the *p.* shoulder for some time before anything distinct enough to be certainly described as the *p.* end of the disturbance could be made out. In fact, the latter has seemed to grow and develop gradually *in situ* before beginning to move down the zone (Plate I., Figs. 2 and 3). Thus Mr. Bolton says, "dark matter hovered intermittently about the *p.* shoulder of the hollow for many weeks prior to the reappearance of the *p.* end of the S. tropical dark area in March 1910." This is in accordance with the observations of the Director, though on February 23 he recorded the *p.* end of the disturbance as in $\omega_2 = 345°$. It is very doubtful, however, whether this was really the *p.* end of the disturbance, as the observed longitude was exactly the same at the beginning of March. In fact, it does not seem possible to say when the disturbance did appear on this side of the Red Spot. The Director found the *p.* end still vague and difficult to determine on April 2 ($\omega_2 = 333°$), though towards the end of the month it was perfectly definite, with a very dark spot indeed where it was united with the S. equatorial belt (Plate III., Fig. 2).

In general appearance and structure the disturbance has not varied much during recent apparitions. It still shows marked irregularities of density and much detail in the shape of dark and white spots. Mr. O'Hara describes it on more than one occasion as striated. The dark spot at the *p.* end of the disturbance which developed in April 1910 became an exceedingly prominent and interesting object, and the details which subsequently appeared in the region following the Red Spot are well shown on several of the drawings which have been received (Plate I., Fig. 6; Plate II., Figs. 3 and 4; Plate IV., Fig. 1).

As already remarked, the S. temperate belt in this longitude was greatly swollen and "humped" and exceptionally dark (Plate I., Figs. 2 and 3), while its outline throughout the entire

FIFTEENTH REPORT OF THE SECTION.

APPARITION OF 1909-10.

length of the disturbance was very irregular. This is especially well shown in M. Antoniadi's drawing (Plate III., Fig. 1).

In the region following the Red Spot hollow the white and dark markings in the disturbance were clearly associated with similar, though more intense markings in the S. equatorial belt (Plate II., Figs. 3 and 4).

Since its first appearance in 1901, the length of the disturbance has shown large variations. The changes, however, have not been irregular, but periodic in about two years, maxima being attained at the times of conjunction of the disturbance with the Red Spot, while in the intervals the dark area has shrunk to much smaller proportions. During the apparition under review, the length (as above stated) exceeded anything previously recorded, though on this occasion it is not certain that there was any very marked increase during the time of conjunction with the Red Spot as compared with its length a few weeks previously. Thus in the middle of December, according to the Director's observations, the length of the disturbance was 108° ±, and he found the length exactly the same during the months of April and May while the conjunction was in progress. On February 23, March 4, and April 2, the length seemed to be 131°, 120°, and 114° respectively, but it is by no means certain that the faint, vague shading seen on these occasions near the *p.* shoulder was really part of the disturbance at all. Mr. Bolton's early observations before conjunction with the *f.* shoulder show that the *p.* end of the disturbance was much slower in overtaking the Red Spot than usual. On former occasions the motion as conjunction approached became greatly accelerated, and this, together with the quick appearance on the other side of the bay, caused the marked increase in length observed. In 1910 both the approach of the *p.* end to the *f.* shoulder and its reappearance on the other side were apparently delayed, so that the failure of the disturbance to exhibit any marked increase in length at the conjunction is readily accounted for.

The following note gives the main variations in length exhibited by the disturbance since its appearance in 1901.

Apparition.	Remarks.
1901	Disturbance first seen as a hump at S. edge of S.E.B. by Major Molesworth on February 21. It subsequently spread across the zone to join S.T.B.
1902	First conjunction with Red Spot. Max. length, 90° ±.
1903	Min. length, 35°.
1904	Second conjunction. Max. length, 80°; at end of year, 30°.
1905–6	Third conjunction (1906). Planet too near Sun about third conjunction, but length about 65° when disturbance reached *f.* shoulder.
1906–7	Length, 57°–45°.
1907–8	Fourth conjunction (1908). Length, 95°–100°.
1908–9	Length, 57°–70°.
1909–10	Fifth conjunction. Length, 108°.

Figure 4.

P. end of STropD passing GRS, 1910

(from BAA Memoir)

GRS GRS

FIG. 2.—1910, Mar. 14d 12h 45m G.M.T.
λ1 = 337°·0, λ2 = 12°·5.
T. E. R. PHILLIPS. 12¼-in. spec.

FIG. 6.—1910, April 8d 9h 25m G.M.T.
λ1 = 204°·8, λ2 = 51°·6.
H. THOMSON. 8½-in. spec.

FIG. 3.—1910, Mar. 26d 12h 15m G.M.T.
λ1 = 54°·2, λ2 = 359°·2.
E. HAWKS. 18¼-in. spec.

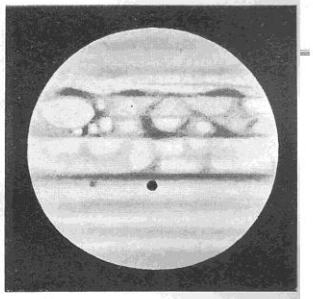


FIG 3.—1910, April 27d 10h 0m G.M.T.
λ1 = 347°·8, λ2 = 49°·4.
T. E. R. PHILLIPS. 9-in. O.G.

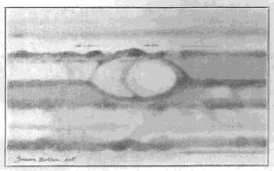


FIG. 2.—1910, March 28. (BOLTON.)

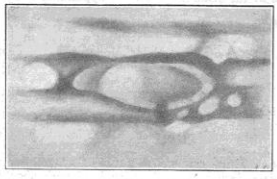


FIG. 1.—1910, May 9. (PHILLIPS.)

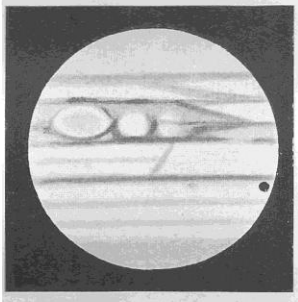


FIG. 4.—1910, May 4d 10h 30m G.M.T.
λ1 = 131°·7. λ2 = 39°·7.
A. M. NEWBEGIN. 9-in. O.G.

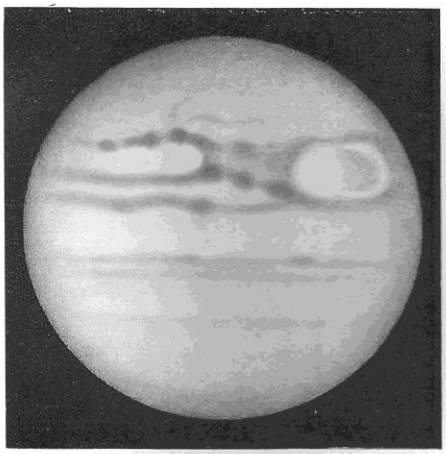


FIG. 2.—1910, June 18d 10h 9m G.M.T.
λ1 = 281°·8, λ2 = 306°·6. Image iv.
E. M. ANTONIADI. 32·7-in. O.G.

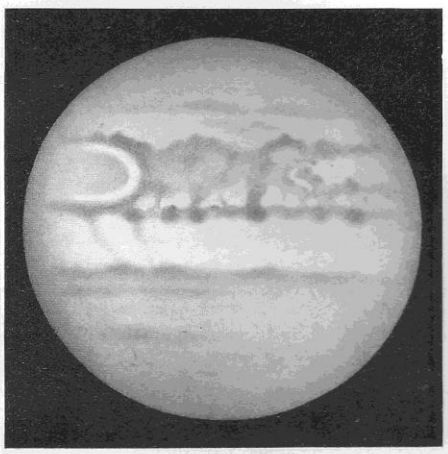


FIG. 1.—1910, May 21d 9h 51m G.M.T.
λ1 = 172°·1, λ2 = 50°·6. Image iii.
E. M. ANTONIADI. 32·7-in. O.G.

Figure 5.

APPARITION OF 1913.

Date of "Opposition," 1913, July 5^{d} 3^{h}.

THE S. TROPICAL DISTURBANCE.

As above stated, the S. tropical disturbance had already appeared beyond the *p.* shoulder of the bay at the beginning of the apparition. Attention has been drawn in former memoirs to the difficulty at recent conjunctions of determining either the time of the first appearance of dark matter W. of the hollow or the exact longitude of its *p.* edge. There has been usually a vague impression of a dusky appearance on the zone, which has seemed gradually to grow and intensify *in situ* rather than arrive there as a distinct marking. The same thing appears to have happened at the last conjunction. Mr. Newton writes :—"On March 25th the dark matter preceded the Red Spot hollow for many degrees, but appeared to fade gradually into the brightness of the S. tropical zone, no definite end being visible with 3-in. O.G. When this region was next observed, on April 18, the *p.* end was quite definite and of the usual curved (concave to *p.* limb) form."

As at other times of conjunction, the length of the disturbance attained a maximum value in 1913 ; indeed, it easily surpassed all previous figures. In 1912 it had been about 65°, but early observations by Mr. Newton made the length at the end of March (including the Red Spot bay) at least 140°. Observations by Mr. Apple and the Director, in May and June, support Mr. Newton's figures, but the disturbance was slowly diminishing in consequence of the retarded motion of the *p.* end, and at the end of October its length was only about 124°.

The intensity of the disturbance was not uniform, the portion preceding the Red Spot being decidedly darker than that following it. Towards the close of the apparition the latter became very faint indeed, and at times little more appeared than a dark wisp at its *f.* end connecting the S. equatorial and S. temperate belts.

Figure 6.