Saturn in the 2008/2009 apparition: Part II

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Part I of this report[22] described the observations of Saturn made by Saturn Section members during the 2008/2009 apparition. Part II presents observations of a number of satellite and shadow transits and Titan eclipses that occurred during the apparition.

Introduction

During this apparition, the rings were edge-on to the Sun and Earth on 2009 Aug 11 and Sep 4 respectively. One benefit of the low ring inclination was that glare around the planet was reduced. This made the detection of the inner satellites by visual and imaging means much easier, particularly for Enceladus and Mimas.

The satellites from Titan inwards orbit the planet close to the plane of the rings. Consequently with the low ring inclination, the satellites appeared in approximate line with the rings during this apparition as shown in Figure 21. [Numbering of Figures, tables and references in this paper continues consecutively from Part I.] Sometimes the satellites were detected very close to the planet, either to the north or to the south of the rings (*e.g.* Figure 16(c), Part I).

On 2009 March 2, Gray observed both Titan and Ceres under very good conditions in an attempt to resolve their respective disks with his large aperture Dall–Kirkham Cassegrain. The disk of Ceres was approximately 0.8" on this date. Gray noted that he conditioned his eyes by initially observing the close double star 54 Leonis. Using a binocular viewer, the disks of both Ceres and Titan appeared non-stellar using ×365 and were unmistakable at ×535. At this magnification, he thought the disk of Titan looked soft-edged (see Figure 22).

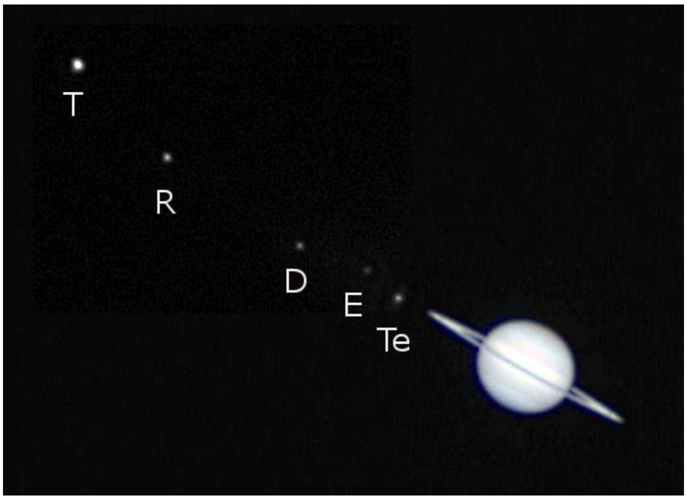

Figure 21. The satellites of Saturn, 2009 Mar 18, 23h 30m UT. CM1= 197.4; CM2= 123.8, CM3= 320.1. *(Image by Sampson).* Titan (T), Rhea (R), Dione (D), Enceladus (E) and Tethys (T). Image brightened to reveal Enceladus.

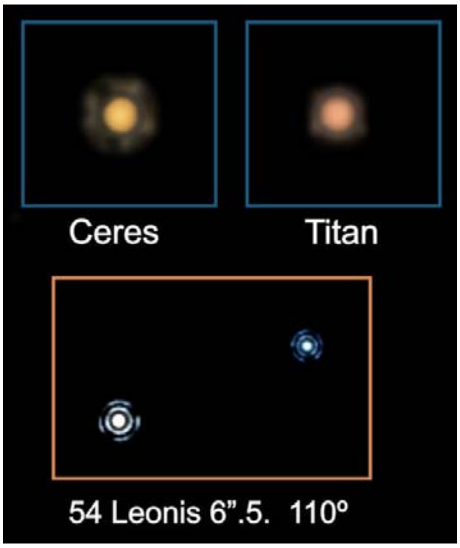

Figure 22. The disks of Titan and Ceres plus 54 Leonis. 2009 Mar 02, 01h 30m to 01h 55m UT. *(Drawing by Gray)*

Transits and eclipses

Satellite and shadow transits, occultations and eclipses of Titan inwards to Mimas occurred during this apparition. However with amateur instruments, transits were only observed for Titan, Rhea, Dione and Tethys and their respective shadows. A shadow transit of Enceladus and possibly Enceladus itself was also observed. Eclipse entry and re-appearance were only observed for Titan and no occultations were recorded.

Mimas and Enceladus

Due to their relatively short orbital periods, both Mimas and Enceladus were frequently in transit, sometimes concurrently with the transit of another satellite.

A small number of observations was made when these satellites and their shadows were in transit but the results were generally negative. For example on

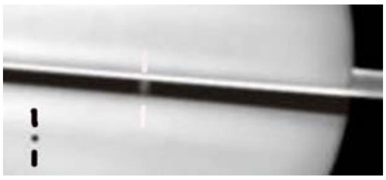

Figure 23. 2008 Nov 30. 07h 35m UT. CM1= 244.9, CM2= 81.4, CM3= 48.7. *(Drawing by Gray).* Shows the shadow of Enceladus in transit (dark tick marks) and possibly Enceladus itself (light tick marks) seen against the SH R on G.

Table 9. Summary of the observations of the transits of Enceladus

Date	*Time (UT)*	*Observer*	*Description*
2008 Nov 30	07:00–07:35	Gray	Drawings showing the shadow of Enceladus projected onto NEB(S) at 07:35UT. Enceladus itself was suspected *f.* the shadow where it was projected onto the SH R on G. (Figure 23).
2009 Mar 7	15:06–15:53	Go	See under Dione for this date.

Table 10. Summary of the observations of the transits of Tethys

Date	Time (UT)	Observer	Description
2008 Nov 12	06:50	Gray	Drawing showing the shadow of Tethys just *f.* the CM and projected onto the NEBs. Tethys was predicted to be projected onto the rings but was not detected (Figure 15(b), Part I).
2009 Jan 4 (see Figure 24)	03:26	Peach	Colour image showing the shadow of Tethys approaching the CM and projected onto the EZ(N), closeto the SH R on G. Tethys itself was in transit *f.* the CM and projected onto the EZ(S) but was not detected.
	03:41 & 04:18	Casquinha	Colour images showing the shadow of Tethys projected onto the EZ(N) close to the SH R on G and moving from the CM towards the *p.* limb. Tethys itself was detected, projected onto the EZ(S), initially *f.* the CM.
	04:02	Robertson	Drawing showing the shadow on Tethys just *p.* the CM and projected onto the EZ(N).
	04:40	Gray	Drawing showing the shadow of Tethys projected onto the EZ(N) and approaching the *p.* limb. Tethys itself was not detected.
2009 Feb 25/26	23:38–00:15	Castella	Possible observation of Tethys in transit on the EZ(S). Enceladus was also in transit but not detected.
2009 Mar 3	14:50	Go	Colour images and animation showing Tethys and its shadow in transit on S. edge of the northern EZ, just to the north of the projection of the rings onto the planet. Both satellite and shadow were projected onto the thin sliver of SH R on G which was just visible near each limb. The shadow of Tethys was slightly N*p.* of the satellite itself.
2009 Mar 5	14:31–14:56	Go	Colour images and animation faintly showing the shadow of Tethys approaching the *p.* limb just N of projection of the rings onto the planet. Tethys itself was suspected closely *f.* on a couple of images especially when close to the *p.* limb.
2009 Mar 16	21:19	Sharp	Colour and green images showing Tethys in transit on CM against the EZ(N). The shadow would have been projected onto the n edge of the projection of the rings onto the planet but was not detected.
2009 Mar 20	13:41–14:19	Go	Colour images and animation showing Tethys approaching transit N*f.* of the rings. It entered transit after 14:19. See details of the Titan eclipse re-appearance on the same date.
2009 Mar 22	13:21–14:17	Akutsu	Colour and IR images showing Tethys in transit and projected onto the EZ(N). It appeared as a bright spot. Its shadow was predicted to be projected onto the rings but not detected.
2009 Apr 2	21:15	Sharp	Colour and red channel images showing Tethys in transit projected against the EZ(N).
2009 Apr 8	12:22–13:19	Go	Colour images and animation showing Tethys in transit on the EZ(N). It appeared as a small bright spot. However its shadow was not detected.
2009 Apr 16	03:16	Friedman	Colour image showing Tethys in transit on the *f. l*imb projected onto NEB(S). The shadow of Tethys was projected against the ring and the SH R on G in the position predicted by *WinJUPOS*. (Figure 13(b), Part I)

Table 11. Summary of the observations of the transits of Dione

Date	Time (UT)	Observer	Description
2008 Nov 26	07:10	Gray	Drawing showing the shadow of Dione on disk approaching the CM and projected onto the S. edge of the NEB(N). Dione itself was in transit but wasn't detected. Enceledus was *p.* the planet, close to the *p.* limb and just N. of the rings.
2008 Dec 7	06:47	Peach	Colour image showing the shadow of Dione projected onto the northern NEBZ. Dione itself was in transit near the northern edge of the SH R on G but wasn't detected (Figure 16(a))
2008 Dec 7	07:16	Arditti	Red, green and colour images showing the shadow of Dione projected onto the northern NEBZ, approach ing the *p.* limb.
2008 Dec 23	17:39	Buda	Colour image showing the shadow of Dione projected onto the NEBZ and approaching the *p.* limb
2009 Jan 9	02:50	Gray	Drawing showing the shadow of Dione just *p.* the CM and projected just S. of the NEB(S). Dione and Enceledus were in transit projected onto the SH R on G but neither were detected. Rhea was *f.* the planet lying just S. of ring A
009 Jan 9	03:43–03:59	Casquinha	Colour images showing the shadow of Dione in transit, projected onto the NEB(Z). It was approaching the *p* limb. Dione itself was in transit projected onto the N edge of the SH R on G but wasn't detected.
2009 Feb 24	14:13	Wesley	See transit of Titan on this date. (Figure 30).
2009 Feb 27	08:24–08:36	Maxson	Colour images showing the shadow of Dione on the NEB(S). Dione itself was suspected on these images. Enceladus was in transit but not detected.
2009 Mar 2	02:30	Gray	Drawing showing the shadow of Dione approaching the CM and projected onto the NEB(S). Dione itself was in transit but wasn't detected. Enceladus and its shadow were also in transit but not detected.
2009 Mar 7	15:20	Akutsu	Colour image taken shortly before opposition. Shows Dione's shadow projected onto the NEBs. Dione possibly recorded N*f.* Enceladus and shadow in transit but not recorded.
2009 Mar 7	15:06–15:53	Go	Close to opposition. A series of colour images and an animation showing Dione and its shadow in transit. Dione was *f.* the shadow and slightly overlapping. Both were projected onto the NEBs. The observations covered Dione leaving transit on the *p.* limb. (Figures 17(f) & 25(a)). Enceladus was predicted to be in transit lying S*f.* of Dione and may have been shown in one image taken at 15:53 UT.
2009 Mar 18	13:57–13:50	Go	A series of colour images and an animation showing Dione and its shadow in transit. Dione was projected onto the NEBZ whereas its shadow lay S*f.* and was projected onto the NEBs /EZ(N) Enceladus was also predicted to be in transit but nothing obvious was detected in these images.
2009 Mar 29	11:48	Buda	Red light and colour images plus red light animation showing shadow of Dione close to the CM and projected onto the NEB(S). Dione itself and Enceladus were also in transit at the time but not detected.
2009 Apr 03	22:16	Abel	Drawing showing Dione and its shadow in transit near the *f.* limb. Dione was on the northern hemisphere with the shadow *f.* projected onto the EZ(N).
2009 Apr 23	02:41	Maxson	Colour image showing Dione's shadow projected onto the NEBs, *p.* the CM. Dione itself was not detected.
2009 Apr 25	20:50	McKim	Drawing showing Dione and its shadow in transit. Dione was just N. of the NEBn and appeared as a dark grey spot. The shadow was projected onto EZ(N) and was reported as small and not quite black. Mimas was predicted to be S. of Dione's shadow but was not detected.
2009 May 25	21:38	Casquinha	Colour image showing Dione projected onto the NEB(N)s

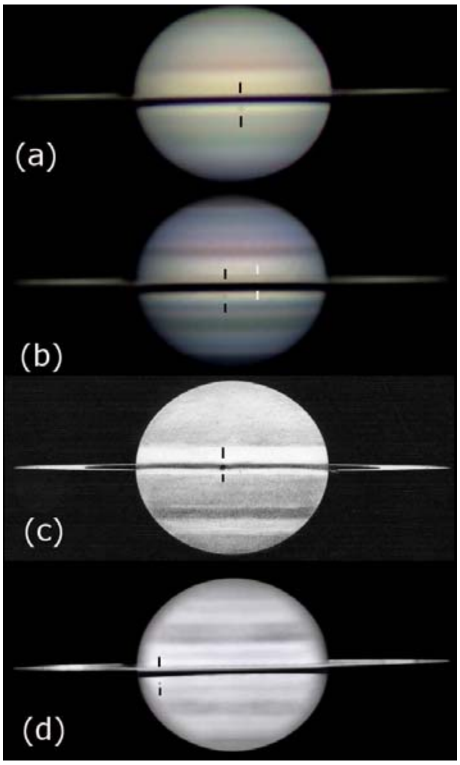

Figure 24. Transit of Tethys and its shadow on 2009 Jan 4. The shadow and satellite are respectively highlighted by dark and light tick marks.

24(a). 2009 Jan 4, 03h 26m UT. CM1= 131.3, CM2= 282.8, CM3= 208.1. *(Image by Peach).* The shadow of Tethys is on the EZN just *f.* the CM.

24(b). 2009 Jan 4, 03h 41m UT. CM1= 140.1, CM2= 291.2, CM3= 216.6. *(Image by Casquinha).* The shadow of Tethys is on the EZN just *p.* the CM. Tethys itself is on the EZS approaching the CM.

24(c). 2009 Jan 4, 04h 02m UT. CM1= 152.4, CM2= 303.1, CM3= 228.4. *(Drawing by Robertson).* The shadow of Tethys is on the EZN *p.* the CM.

24(d). 2009 Jan 4, 04h 40m UT. CM1= 174.7, CM2= 324.5, CM3= 249.8. *(Drawing by Gray).* The shadow of Tethys is on the EZN *p.* the CM.

Apr 23, McKim tried to observe Mimas and its shadow at the same time as Dione was in transit but Mimas and its shadow were not observed. Similar negative observations are listed in the tables below. The only exceptions to this are the observations of Enceladus shown in Table 9 and Figure 23.

Tethys

Table 10 lists the observations of the transits of Tethys and its shadow. A typical observation is shown in Figure 13(b) (Part I).

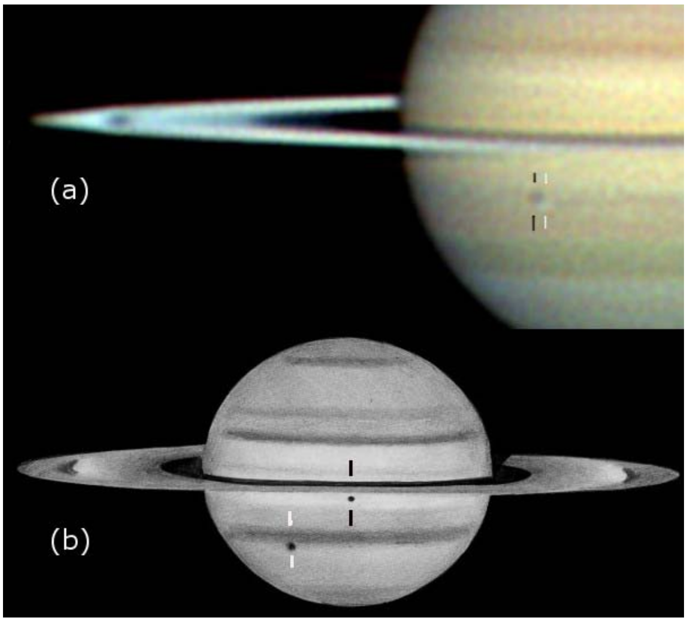

Figure 25. Transits of Dione.

25(a). 2009 Mar 7, 15h 06m UT. CM1= 333.9, CM2= 266.9, CM3= 116.9. *(Image by Go).* Dione transit. Enlarged from Figure 17(f) with Dione (light tick marks) overlapping its shadow (dark tick marks).

25(b). 2009 Apr 25, 20h 50m UT. CM1= 147.4, CM2= 290.2, CM3= 80.7. *(Drawing by McKim).* Dione (light tick marks) and its shadow (dark tick marks) are in transit. Dione was recorded as a dark grey spot and the shadow not quite black.

The transit on the night of 2009 Jan 4 was well observed, being viewed simultaneously by Casquinha, Gray, Peach and Robertson (Figure 24). The shadow was recorded by all four observers. However Tethys itself was only recorded by Casquinha and this was not prominent on the original image.

Robertson recorded a small dark spot in the correct position of the shadow at the time of his observation, without realising that a shadow transit was taking place.

Dione

Table 11 lists the observations of the transits of Dione and its shadow. See also Figure 25, and 15(b), 16(a) & 17(f) in Part I.

On April 25, McKim recorded Dione in transit as a dark grey spot and its shadow as not quite black. He also recorded similar results for Rhea and its shadow when in transit.

Akutsu and Go were able to observe Dione and its shadow in transit on March 7, one day before opposition. Both observations, in particular that of Go, show the shadow with the satellite N*f*, slightly overlapping the shadow (Figures 17(f) and 25(a)).

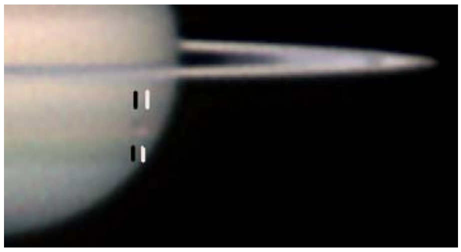

Figure 26. 2009 Mar 8, 13h 44m UT. CM1= 50.1, CM2= 312.7, CM3= 161.6. *(Image by Buda).* Shows the transit of Rhea (light tick marks) and its shadow (dark tick marks) close to opposition. The satellite overlapped its shadow.

Rhea

Observations of the transits of Rhea and its shadow are summarised in Table 12. Typical observations are shown in Figures 15(c) (Part I) and 26.

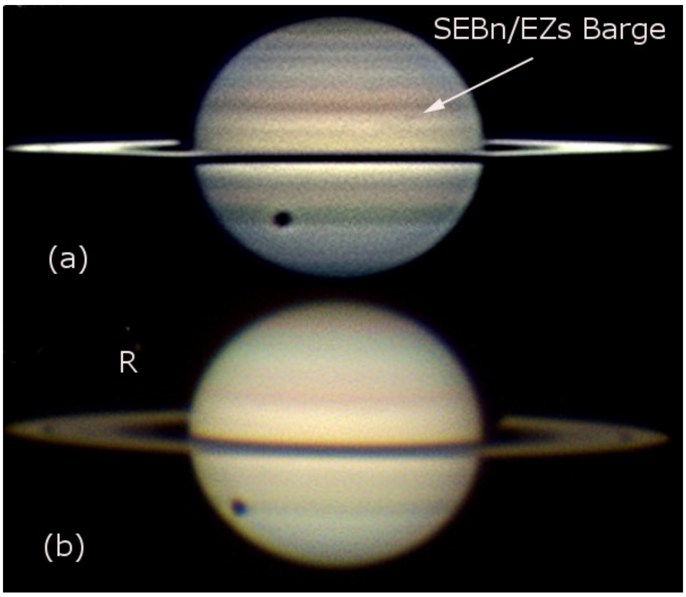

Figure 27. Transits of Titan and its shadow.

27(a). 2009 Feb 8, 16h 49m UT. CM1= 275.8, CM2= 358.7, CM3= 241.1. *(Image by Akutsu).* Titan in transit appears as a dark spot on the NEB(N). The SEBn/EZs barge is also shown.

27(b). 2009 Apr 29,10h 40m UT. CM1= 286.9, CM2= 314.1, CM3= 100.38. *(Image by Barry).* Titan's shadow in transit appears as a dark spot. Rhea (designated by R) was faintly visible *p.* the planet south of the rings.

Table 12. Summary of the observations of the transits of Rhea

Date	*Time (UT)*	*Observer*	*Description*
2008 Nov 20	04:00	Gray	Drawing showing the shadow of Rhea which was *f.* the CM and projected onto the planet just north of the NEBn. Rhea appeared just inside the *f.* limb, north of the SH R on G. (Figure 15(c)).
2009 Feb 13	23:30	McKim	Drawing showing the shadow of Rhea projected onto the NEBZ and near the *f.* limb. Rhea itself was *f.* the planet's *f.* limb.
2009 Feb 14	00:24–00:30	Arditti	Images taken with various filters showing Rhea and its shadow in transit. Rhea was projected onto the NEBs near the *f.* limb. The shadow lay *p.* and was projected onto the NEBZ.
2009 Feb 14	03:00–03:10	Casquinha	Colour images showing Rhea in transit projected onto the NEB(S) and approaching the *p.* limb.
2009 Feb 18	00:00	Go	Images and animation showing the shadow of Rhea near the *p.* limb and projected onto the NEBZ. The satellite itself was not detected.
2009 Mar 8	13:44	Buda	At opposition. Colour image showing Rhea and its shadow in transit. Rhea appeared as a bright spot projected onto the NEBZ and slightly overlapped its shadow which lay S*p.* (Figure 26).
2009 Mar 17	13:57–14:30	Go	A series of colour images and an animation showing Rhea and its shadow entering transit at the *f.* limb. The image taken at 14:15 UT shows Rhea on the *f.* limb; projected onto the NEB(N)s. By 14:30 UT, the shadow had entered the disk, lying S. *f.* of the satellite and was projected onto the NEB(S).
2009 Apr 22	20:24	McKim	Drawing showing the shadow of Rhea projected onto the NEBs. Rhea was on the *p.* limb, N of the NEB(N) having just left transit. Rhea's shadow was reported to be not quite black.
2009 Apr 22	20:41	Peach	Colour image showing Rhea *p.* the planet and its shadow projected onto the NEB(S).
2009 Apr 22	21:20	Sampson	Colour image showing the shadow of Rhea near the *f.* limb and projected onto the NEB(S). Rhea itself had left transit and was *p.* the planet.
2009 May 10	22:59	Abel	Drawing showing Rhea *p.* the planet with its shadow on the EZ(N) approaching the *p.* limb.
2009 May 19	21:56	Sussenbach	Red image showing the shadow of Rhea *p.* the CM and projected onto the southern EZ(N). Rhea itself was faintly recorded on the NEB(N), *f.* the CM.
2009 May 19	22:01–22:53	Abel	Drawings showing Rhea and shadow in transit. Rhea seen on northern hemisphere then later *p.* the planet. Shadow projected onto the EZ(N).
2009 May 19	20:47–21:30	McKim	Transit of Rhea and shadow observed. Rhea appeared as a grey spot projected onto the NEB(N). The shadow lay *f.* projected onto the EZ(N). Shadow appeared dark grey rather than black.
2009 May 28	21:42–21:52	Sussenbach	Two red light images showing Rhea in transit approaching the CM, projected onto the NEB(N). The shadow had just entered transit by the time of the 21:52 image and was faintly visible near the *f.* limb in the EZ(N).
2009 May 28	21:14–21:40	McKim	Transit of Rhea and shadow observed. Rhea projected onto the NEB(N) appearing grey and the shadow projected onto the EZ(N).

Table 13. Summary of the observations of the transits of Titan

Date	*Time (UT)*	*Observer*	*Description*
2009 Jan 7	19:50	Go	Colour images and animation showing Titan in transit. It appeared as a very dark, almost as a black spot, projected onto the NEB(S).
2009 Jan 23	17:32	Go	Colour images and animation showing Titan in transit. It appeared as a dark black spot and was projected onto the NEBZ.
2009 Jan 23	17:08–18:03	Akutsu	Images taken through a number of filters and colour images showing Titan in transit projected onto the NEBZ. Titan appeared as a dark spot. It appeared faint in the UV image and was not visible in the methane (893nm) image.
2009 Feb 8	16:33–16:48	Akutsu	Colour and IR images showing Titan in transit (appearing as a dark spot), projected onto the NEB(N). It lay *p.* the CM (Figure 27(a).
2009 Feb 08	18:00–18:22	Go	Series of colour images and animation showing Titan leaving transit at the *p.* limb of the planet. It was projected onto NEB(N) and appeared as a bright spot. It had cleared the *p.* limb by 18:22.
2009 Feb 24	14:13	Wesley	Colour image showing the shadow of Dione near the *f* limb projected onto the NEB(S). Dione was in transit *f.* but not detected. Titan was in transit *p.* the CM, projected onto the northern hemisphere, and appeared as a dark spot. Mimas and its shadow were also in transit near the *p.* limb but not detected (Figure 30).
2009 Mar 12	11:37–12:41	Akutsu	Colour images and red light image showing Titan's shadow in transit projected onto the NPR. Titan itself was initially projected onto the N*p.* limb and was leaving transit.
2009 Mar 12	10:11–10:19	Maxson	Colour images showing Titan and its shadow in transit. Titan itself spanned the N*f.* limb and appeared reasonably bright. The shadow was S*f.* on the northern hemisphere and appeared as a dark spot.
2009 Mar 12	11:51–13:08	Go	A series of images showing Titan and its shadow in transit. At 11:51 UT Titan was on the N*p.* limb near the N. pole and appeared dark. Its shadow was further S*f.* At 12:22 UT, Titan was clear of the planet and the *p.* edge of shadow was on the *p.* limb. The shadow had left by 13:08 UT. Mimas was predicted to be in transit but nothing obvious was detected on these images.
2009 Mar 12	12:19	Buda	Colour image showing Titan's shadow in transit. This was projected onto the Northern hemisphere near the *p.* limb. Titan itself lay N*p.* of the planet's northern limb.
2009 Mar 28	09:12	Maxson	Colour image showing Titan's shadow in transit. This was projected onto the Northern hemisphere near the *f.* limb. Titan itself lay N*p.* of the planet's northern limb.
2009 Mar 28	10:42	Akutsu	Colour image showing Titan's shadow projected onto the northern hemisphere just *p.* the CM. Titan itself was *p.* the planet.
2009 Apr 13	11:41–11:55	Go	Colour images showing shadow of Titan in transit and leaving the disk at the *p.* limb and projected onto the NTropZ.
2009 Apr 29	10:40	Barry	Colour image showing the shadow of Titan projected onto the NEB(N) and approaching the *p.* limb. Titan itself was *p.* the planet (Figure 27(b)).
2009 May 31	04:41–05:32	Hill	Series of colour images showing the shadow of Titan in transit (Figure 28).

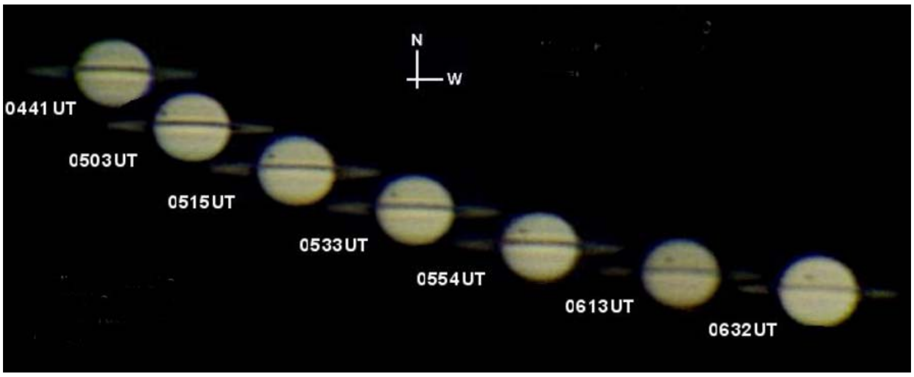

Figure 28. 2009 May 31, 04h 41m to 06h 32m UT. *(Images by Hill)*. Titan's shadow in transit appearing as a dark spot. Montage prepared by Hill with north upwards.

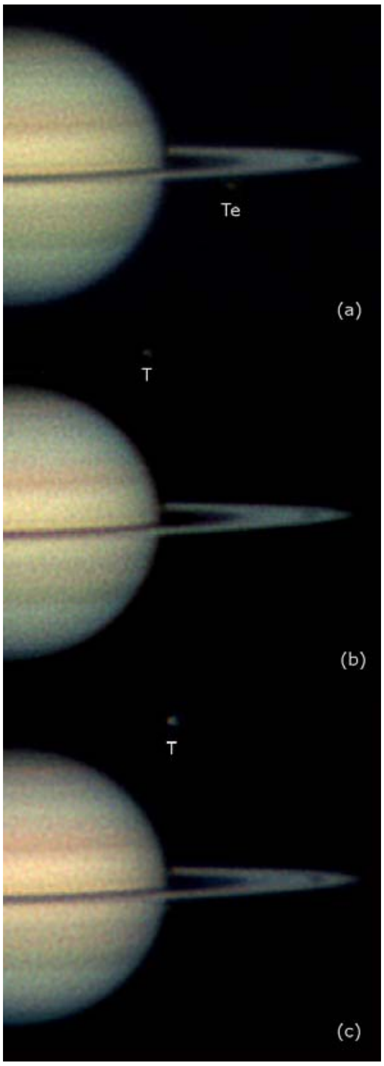

Figure 29. The re-appearance of Titan (designated T) from eclipse.
29(a). 2009 Mar 20, 13h 41m UT. CM1= 100.7, CM2= 335.8, CM3= 170.1. *(Image by Go)*. Also shows Tethys (designated Te).
29(b). 2009 Mar 20, 13h 52m UT. CM1= 107.2, CM2= 342.0, CM3= 176.3. *(Image by Go)*. Titan faint, as in partial eclipse
29(c). 2009 Mar 20, 14h 19m UT. CM1= 123.0, CM2= 357.2, CM3= 191.5. *(Image by Go)*. Titan brighter.

Buda was able to image the transit of Rhea and its shadow on the day of opposition (Figure 26). Although conditions were poor, the original image showed Rhea as a bright spot projected onto the NEBZ, which slightly overlapped its shadow which lay S*p*.

Titan

Transits, occultations and eclipses of Titan occurred during this apparition but only transits and eclipses were observed.

The observations of the transits of Titan and its shadow are shown in Table 13. Although transits were observable from parts of Europe, Asia, Australia and the Americas, none was visible from the UK. Typical observations are shown in Figures 27, 28 and 30.

During transit, Titan appeared dark (Figures 27(a) and 30) and only appeared bright when on the limb. Transits are visible with small telescopes and Hill was able to image the shadow of Titan in transit with only a 90mm aperture telescope (Figure 28).

On two nights (Table 14) Go was able to observe Titan re-emerging from eclipse. A typical observation sequence is shown in Figure 29.

Multiple transits

Several observations were made at the times when more than one satellite was predicted to be in transit. On Feb 24, Wesley observed a transit of Titan. At the same time Mimas and its shadow plus the shadow of Dione were also in transit but only Dione's shadow was recorded (Figure 30). This was the only multiple transit reliably observed.

Discussion

Transits, eclipses and occultations of the satellites from Titan inwards occur around the time when the rings are edge-on. These events occur over a longer period of time for the inner satellites than for the outer satellites.

A large number of satellite and shadow transit observations was received during this apparition. This in part was due to the number of observations made worldwide that were submitted to the Section. These allowed a greater coverage of these events than would have been possible from a limited number of geographical locations.

Readers interested in other observations of these events made since 1965 can consult references 5, and 10 to 17. A useful summary of observations made before 1965 is given in Ref 18.

During other edge-on phases, eclipses and occultations of Titan and other satellites have also been recorded (see for example references 10, 13 and 14). During this apparition, the only eclipses observed were those of Titan.

Some mutual satellite events have also been observed in other apparitions (see Refs 14 and 16). However to the author's knowledge, no such events were predicted for this apparition.

The majority of transit observations during this apparition were made using digital imaging. The first use of this technique in the BAA records to record transits was made during the 1995/1996 apparition.[16] Prior to 1995/1996, all observations of these events were made visually.

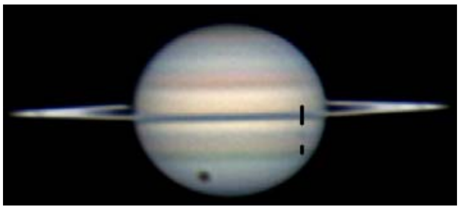

Figure 30. 2009 Feb 24, 14h 13m UT. CM1= 14.6, CM2= 304.2, CM3= 167.4. *(Image by Wesley)*. Titan in transit near the CM appearing as a dark spot. The shadow of Dione (dark tick marks) is near the *f.* limb.

All observations of Titan and its shadow made during this apparition were made by imaging techniques using medium to large aperture telescopes (See Table 13). This was the first apparition in the BAA records when Titan itself was imaged in transit, although the first image of a shadow transit was made during the 1995/1996 apparition.[16]

Historical observations have shown that Titan and its shadow can be seen visually with relatively small aperture telescopes. (For example see pages 298 and Plate XX1 of Ref 18). During this apparition, it was demonstrated that the shadow transit can be imaged by a 90mm aperture telescope as shown in Figure 28. Consequently, it should also be possible to image a Titan transit with a similarly sized telescope, as Titan appears dark in transit and appears only slightly smaller than its shadow.

Rhea, Dione and Tethys are much smaller than Titan, with Tethys being the smallest. As a result, transits of these satellites and their shadows are more difficult to observe than those for Titan. Such events have been recorded visually with medium to large amateur telescopes (see for example Refs 5, 10–17 and tables above).

The first image of a Rhea shadow transit in the BAA records occurred in the 1995/1996 apparition,[16] but imaging the satellite

Table 14. Summary of the observations of the eclipses of Titan

Date	*Time (UT)*	*Observer*	*Description*
2009 Mar 20	13:41–14:19	Go	Colour images and animation showing Titan emerging from eclipse *Sf.* the planet. (Figure 29). Tethys was approaching transit.
2009 Apr 5	13:27–13:45	Go	Colour images showing Titan emerging from eclipse *Sf.* the planet

itself in transit was only achieved during this apparition (see Table 12). This apparition also saw the first images of Dione and its shadow in transit (see Table 11) although a shadow transit was suspected in an image taken during the 2007/2008 apparition.[5] Tethys and its shadow were imaged in transit during the 1996/1997 apparition.[17]

Due to their small angular sizes, transits of Enceladus and Mimas are very difficult to observe. During this apparition, only one definite and one suspected observation of Enceladus in transit were made (Table 9). All other transit observations of both Enceladus and Mimas were negative and these were made with large amateur telescopes.

The first images in the BAA archive of Enceladus in transit were taken during the 2007/2008 apparition[5] although no shadow transits were recorded. When these observations were made, this satellite was projected against darker regions of the planet's northern hemisphere. Consequently, contrast effects may have aided detection.

No other transit observations of these two satellites have been reported in Refs 10 to 17. The only reports of such transits in Ref 18 (pp 237 and 238) and Ref 19 occurred in 1891 and 1892. Here shadow transits of these two satellites (and those including Titan, Rhea, Dione and Tethys) were recorded by the Revd A. Freeman and A. Stanley Williams using a 6.5-inch (166mm) refractor and 6.5-inch reflector respectively.

A typical observation by Williams of a Mimas shadow transit is reported in Ref 20. Here he reported that: 'The definition was very sharp and fairly steady. The shadow of Mimas was seen almost directly'. Magnifications of ×225, ×320 and ×420 were used.

These observations were criticised by Steavenson[21] who thought they were 'an incredible performance'. He also stated that a Rhea transit was a delicate object in a 510mm (20-inch) telescope. Certainly modern observations have shown that Rhea transits can be detected with telescopes much smaller than 510mm.

However the observations (both positive and negative) in the BAA archive made over the last two apparitions indicate that a telescope of aperture greater than approximately 280mm is required to detect Enceladus in transit. Further, modern observations have so far been unable to detect Mimas in transit.

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References

5 Mike Foulkes, 'Saturn during the 2007/2008 apparition', *J. Brit.Astron.Assoc.*, **123**(4), 209–220 (2013)
10 A. W. Heath, 'Saturn 1965–1966', *ibid.*, **76**(6), 422–432 (1966)
11 A. W. Heath, 'Saturn 1966', *ibid.*, **78**(4), 284–316, (1968)
12 A. W. Heath, 'Saturn 1967–1968', *ibid.*, **79**(1), 60–67 (1968)
13 A. W. Heath, 'Saturn 1978–1979', *ibid.*, **90**(5), 451–461 (1980)
14 A. W. Heath, 'Saturn 1979–1980', *ibid.*, **92**(1), 22–32 (1981)
15 R. J. McKim, 'Saturn in 1994–'95, *ibid.*, **124**(3), 142–150 (2014)
16 R. J. McKim, 'Saturn in 1995–'96, *ibid.*, **125**(4), 203–216 (2015)
17 R. J. McKim, 'Saturn in 1996–'97, *ibid.*, **125**(6), 350–357 (2015)
18 A. F. O'D. Alexander, *The Planet Saturn: A History of Observation, Theory and Discovery*, Faber & Faber, 1962
19 '*Memoir* of the Saturn Section', *Mem. Brit. Astron. Assoc.*, **2**(1), 9–17 (1891–1892)
20 A. Stanley Williams, 'Transit of the Shadow of Mimas', *The Observatory*, **15**, 191–192 (1892)
21 *J. Brit.Astron.Assoc*, **61**(4), 90 (1951)
22 *ibid.*, **128**(4), 206–217 (2018)

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