# Saturn during the 2009/2010 apparition

**Mike Foulkes**

*A report of the Saturn, Uranus & Neptune Section. Director: M. Foulkes*

This report describes observations of Saturn made during the 2009/2010 apparition. The evolution of a storm system that appeared in the South Tropical Zone is discussed, as well as observations of a long-lived white spot that was in the South Equatorial Belt Zone (SEBZ). Also presented is the appearance of the belts and zones; especially that of the North Equatorial Belt (NEB). At low resolution, the NEB often appeared as a single diffuse band. The NEB(N) was darker than the NEB(S) and the southern component of the NEB(N) was often the darkest. Observations of some satellite phenomena are also presented.

## Introduction

This apparition commenced at the solar conjunction on 2009 Sep 17,[1] and finished at the solar conjunction on 2010 Oct 1.[2]

Opposition was on 2010 Mar 22,[2] with the planet in the constellation of Virgo. It lay just north of the celestial equator, with a declination of just under two degrees. At this time, the planet's magnitude was 0.5, with an equatorial diameter of 19.5″ and the major axis of the rings at 44.7″.

The Sun and Earth passed through the ring plane on 2009 Aug 11 and Sep 4 respectively, after which the north face of the rings was presented to both the Sun and Earth.

The variation of the inclination of the pole and rings to Earth during this apparition can be found in the BAA *Handbooks* for 2009 and 2010,[1,2] or by using the *WinJUPOS* software.[3] The latter also allows the inclinations of the pole and rings to the Sun to be derived. The north pole and rings reached a maximum inclination of 4.9° during early January, and a minimum inclination of ~1.7° at the end of May. At opposition, their inclination was 3.1°. The inclination to the Sun and Earth became identical a few days before opposition.

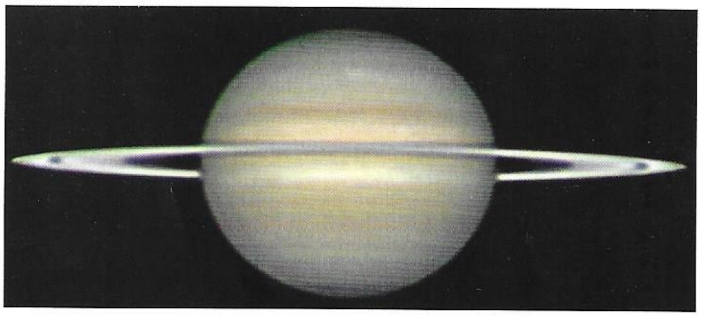


**Figure 1.** High-resolution image taken at opposition. 2010 Mar 22, 13:51 UT; CM1 = 351.9°, CM2 = 252.7°, CM3 = 4.4°. (By Wesley; 354mm Newt. with a PGR Dragonfly 2.) This shows the STropZ bright storm approaching the central meridian and the bright rings due to the opposition effect.

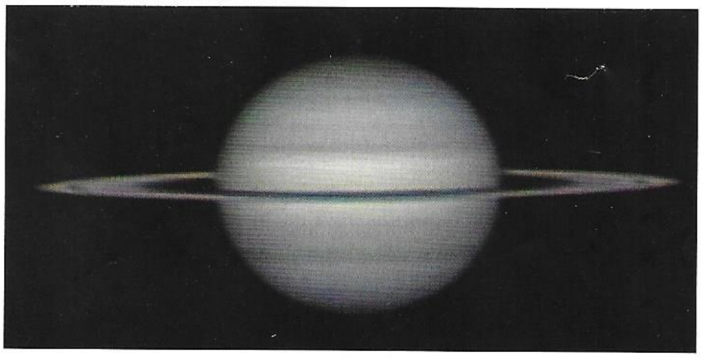


**Figure 2.** The appearance of Saturn during the 2008/2009 apparition. 2009 Mar 16, 16:40 UT; CM1 = 318.61°, CM2 = 309.3°, CM3 = 148.0°. (Image by Lawrence; 356mm SCT with a Lumenera SKYnyx 2.0M camera).

## Observations

Table 1 shows the observers who contributed observations for this apparition. A wide variety of instrumentation was used to observe the planet during this apparition. The majority of observations were made by digital imaging.

The first observation for this apparition was by Sussenbach on 2009 Oct 6 and the last was made by Colombo on 2010 Aug 7.

## Nomenclature & terminology

The belts and zones nomenclature used in this paper is that used in the previous apparition report.[4] Some observers used slightly different nomenclature. For example, the northern component of the South Equatorial Belt (SEB(N)) was sometimes described as the SEB by certain observers, although the measured latitudes matched that of the SEB(N) in recent apparition reports. In such cases, the belt and zone designations were adjusted to match those given in this report.

Terminology is as per Foulkes (2010).[5] All drawings and images are orientated with south at the top. All latitudes are planetographic unless otherwise stated.

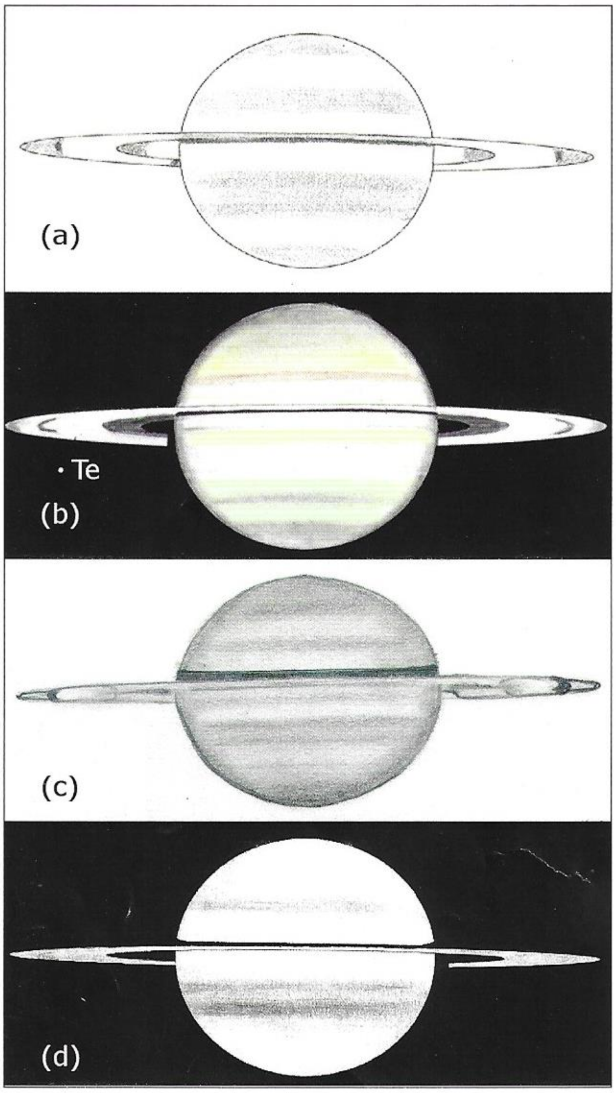



**Figure 3.** Visual observations of the belts and zones.

**(a)** 2010 Feb 13, 23:15 UT; CM1= 43.9°, CM2 = 47.0°, CM3 = 202.8°. (Drawing by Adamoli; 235mm SCT.)

**(b)** 2010 Mar 2, 00:46 UT; CM1 = 284.0°, CM2 = 128.4°, CM3 = 264.9°. (Drawing by Abel; 203mm Newt.) This drawing shows Tethys (labelled as 'Te') N*p*. of the planet.

**(c)** 2010 May 12, 20:30 UT; CM1 = 86.1°, CM2 = 130.7°, CM3 = 180.6°. (Drawing by Graham; 150mm OG.)

**(d)** 2010 May 27, 20:45 UT; CM1 = 158.6°, CM2 = 78.4°, CM3 = 110.2°. (Drawing by Giuntoli; 203mm SCT.)

**Table 1. List of observers, 2009/2010**

| *Observer* | *Location* | *Telescope** |
|---|---|---|
| Abel, Paul G. | Leicester<br>Selsey, West Sussex | 203mm & 381mm Newt. |
| Adamoli, Gianluigi | Verona, Italy | 235mm SCT & 125mm Mak. |
| Akutsu, Tomio | Cebu City, Philippines | 356mm SCT |
| Arditti, David | Edgware, Middlesex | 356mm SCT |
| Barry, Trevor | Broken Hill, Australia | 406mm Newt. |
| Buda, Stefan | Melbourne, Australia. | 405mm DK |
| Colombo, Emilio | Cambio, Italy | 150mm Newt. |
| Delcroix, Marc | Tournefeuille, France | 254mm SCT |
| Edwards, Peter | Horsham, West Sussex | 279mm SCT |
| Foulkes, Mike | Henlow, Bedfordshire | 203mm & 279mm SCT |
| Garbett, Peter J. | Shambrook | 356mm SCT |
| Giuntoli, Massimo | Montecatini Terme, Italy | – |
| Go, Chris | Cebu, Philippines | 279mm SCT |
| Graham, David | Catterick, Richmond, N Yorks. | 150mm OG & 230mm Mak. |
| Gray, David | Kirk Merrington, Spennymoor, Co. Durham | 415mm DK |
| Grego, Peter | St Dennis, Cornwall | 200mm SCT, 300mm Newt. & 445mm Newt. |
| Heath, Alan W. | Long Eaton, Nottingham | 203mm SCT & 250mm Newt. |
| Holt, Dale | Chipping, Buntingford, Hertfordshire | 150mm OG |
| Jaeschke, Wayne | West Chester, Pennsylvania, USA | 356mm SCT |
| Johnson, Simon | Plymouth, Devon | 200mm SCT |
| Kardasis, Manos | Glyfada, Athens, Greece | 254mm SCT |
| Lewis, Martin | St Albans, Hertfordshire | 222mm Newt. |
| Line, Ray | Wellingborough, Northants. | 212mm Newt. |
| Maxson, Paul | Surprise, Arizona, USA | 250mm Mak. |
| McKim, Richard | Upper Benefield, Northants.<br>Oundle school, Oundle | 410mm DK, 356mm SCT |
| Meredith, Cliff | Prestwich, Manchester | 70mm OG, 203mm SCT |
| Peach, Damian | Loudwater, Bucks. | 356mm SCT |
| Phillips, Jim | Charleston, South Carolina, USA | 203mm TMB OG, TEC 200mm OG, Zambuto 457mm Newt. |
| Porter, Malcolm | Petts Wood, Kent | SkyMax 180mm Mak. |
| Robertson, Andrew | Norwich, Norfolk | 300mm DK |
| Robinson, Andy | Dawlish, Devon | 279mm SCT |
| Sampson, Ed | Goring-by-Sea | 300mm Newt. |
| Sussenbach, John | Çamyuva,Turkey<br>Houten, the Netherlands | 127mm & 279mm SCT |
| Tyler, David | High Wycombe | 356mm SCT |
| Wesley, Anthony | Murrumbateman, Australia | 354mm Newt. |

The UK is the default location country.

*Cass. = Cassegrain; DK = Dall–Kirkham Cassegrain; Mak. = Maksutov; Newt. = Newtonian; OG = refractor; SCT = Schmidt–Cassegrain Telescope.

## Latitudes

Belt latitudes (Table 2) were derived from the belt colour images using *WinJUPOS*.[3]

A number of the belts appeared diffuse, as noted below. Consequently, in some cases, the measurement of best latitudes was more difficult. Given this, the uncertainty in the derived belt latitudes is likely higher than the measurement standard deviations shown in Table 2.

The latitudes derived for the belt edges during this apparition are comparable with those obtained during the previous apparition,[4] allowing for measurement error.

## Visual intensity & colour observations

A comparison in the belt and zone structure for this apparition compared to that of the previous apparition can be made by comparing Figures 1 & 2. Figure 2 has been taken from Figure 2 of Foulkes (2013).[4]

One of the most striking features of this apparition was the appearance of the belts and zones, particularly the NEB which often appeared diffuse. This is shown in the images contained in this report. Some visual observations of the belt structure are shown in Figure 3. Visually, Heath noted the weakness in intensity of the belts and zones on Mar 6.

The most obvious belt was the SEB(N), with its noticeable red colouration. The SEB(S) was fainter than the SEB(N), and indeed fainter than the STB.

In contrast, the NEB was often difficult to distinguish from the remainder of the northern hemisphere, particularly at low and medium resolution. The fading of the NEB may have started during the latter part of the previous apparition.[4]

Higher-resolution observations resolved some components in the NEB. McKim noted the faintness of the NEB, with the northern component darker than the southern, but recorded them to be closer in intensity later in the apparition. He also noted the SEB(N) to be fainter than the NEB on Mar 5. However, Gray's intensity observations (Table 3) showed the NEB(N) to be darker than the NEB(S). Further, some higher-resolution images sometimes showed the individual components of the NEB to be darker than the SEB(N). When resolved, the NTB appeared to be close to the intensity of the NEB.

Table 4 shows the visual colour estimates of the belts and zones, although only a limited number of such estimates were made. This table also gives the colour estimates by the author from the colour images received. There are some differences in the colours shown in images by different

## Table 2. Latitudes of the belts, 2009/2010

| *Belt* | *Measured planetographic latitudes* | | *Std. dev. (°)* | *Derived av. planetocentric latitudes (°)* |
|---|---|---|---|---|
| | *Average planetographic latitude (°)* | *No. of measurements* | | |
| SPR Band n | −64.4 | 15 | 1.5 | −59.5 |
| SSTBs | −56.8 | 15 | 1.0 | −53.1 |
| SSTBn | −53.0 | 15 | 1.0 | −47.2 |
| STB(S)s | −47.8 | 16 | 0.8 | −41.9 |
| STB(S)n | −44.4 | 6 | 1.3 | −38.5 |
| STB(N)s | −41.9 | 5 | 0.8 | −36.1 |
| STB(N)n | −41.8 | 18 | 1.2 | −36.9 |
| SEB(S) South Component s | −36.8 | 16 | 1.0 | −31.3 |
| SEB(S) South Component n | −34.7 | 7 | 0.6 | −29.4 |
| SEB(S) North Component s | −31.9 | 7 | 1.0 | −26.9 |
| SEB(S) North component n | −30.4 | 16 | 1.3 | −25.5 |
| SEB(N)s | −23.7 | 18 | 1.0 | −19.5 |
| SEB(N)n | −18.2 | 18 | 1.1 | −15.0 |
| C narrow belt in the S. EZ | −15.4 | 13 | 1.0 | −12.6 |
| C narrow EBS | −11.3 | 11 | 1.7 | −9.2 |
| EBNs | +2.8 | 5 | 0.8 | +2.3 |
| EBNn | +6.3 | 14 | 1.0 | +5.1 |
| NEB(S) South component s | +13.1 | 18 | 0.9 | +10.7 |
| NEB(S) South component n | +16.9 | 16 | 1.1 | +13.9 |
| NEB(S) Northern component s | +20.2 | 17 | 0.6 | +16.7 |
| NEB(S) Northern component n | +22.8 | 17 | 0.8 | +18.9 |
| NEB(N) South component s | +27.1 | 16 | 1.0 | +22.6 |
| NEB(N) South component n | +29.3 | 14 | 0.9 | +24.5 |
| NEB(N) North component s | +32.7 | 15 | 1.1 | +27.6 |
| NEB(N) North component n | +35.9 | 18 | 1.0 | +30.5 |
| NTBs | +41.1 | 18 | 0.8 | +35.4 |
| NTBn | +45.5 | 18 | 0.7 | +39.6 |
| NNTBs | +51.4 | 16 | 1.0 | +45.5 |
| NNTBn | +55.5 | 11 | 1.2 | +49.8 |
| NNNTBs | +58.9 | 13 | 1.3 | +53.4 |
| NNNTBn | +62.6 | 12 | 1.3 | +57.5 |
| S edge NPR | +67.8 | 14 | 1.4 | +63.4 |

*Notes:* Latitude measurements were made from images taken by Akutsu, Barry, Go, Jaeschke, Kardasis, Maxson, Peach, and Wesley over the period from 2010 February 26 until 2010 May 28. All values are given to one decimal place. Positive values are northern latitude. Negative values are southern latitude.

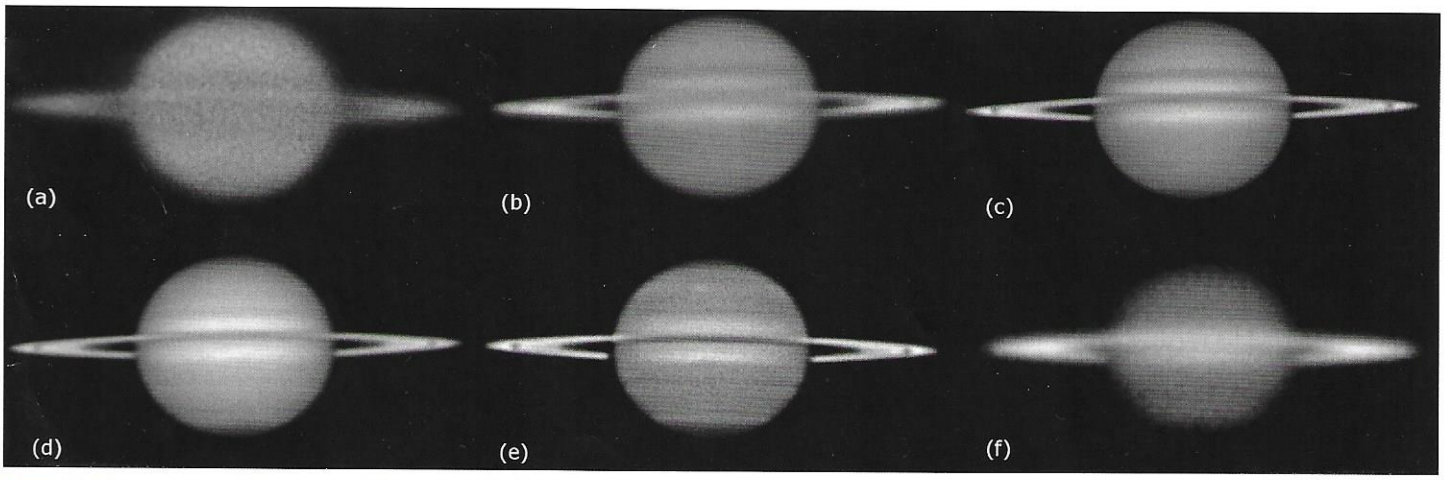



**Figure 4.** The appearance of the planet in different wavelengths.

**(a)** 2010 Mar 13, 17:34 UT; CM1= 83.3°, CM2 = 269.8°, CM3 = 32.2°. (UV image by Akutsu; 356mm SCT with a DMK 21AU04 camera.)

**(b)** 2010 Mar 21, 22:50 UT; CM1 = 183.6°, CM2 = 104.6°, CM3 = 217.1°. (Blue image by Tyler; 356mm SCT with a Lumenera 075 camera.)

**(c)** 2010 Mar 21, 22:32 UT; CM1= 173.1°, CM2 = 94.4°, CM3 = 206.9°. (Green image by Tyler; 356mm SCT with a Lumenera 075 camera.) SEBZ spot no. 1 is visible on the central meridian.

**(d)** 2010 Mar 21, 22:31 UT; CM1 = 172.5°, CM2 = 93.9°, CM3 = 206.4°. (Red image by Tyler; 356mm SCT with a Lumenera 075 camera.)

**(e)** 2010 Mar 13, 17:00 UT; CM1 = 63.4°, CM2 = 250.6°, CM3 = 13.0°. (Infrared (>800nm) image by Akutsu; 356mm SCT with a DMK 21AU04 camera.) The STropZ storm is just *p*. the central meridian.

**(f)** 2010 Mar 13, 17:28 UT; CM1 = 79.8°, CM2 = 266.4°, CM3 = 28.8°. (Methane band (890nm) image was taken by Akutsu; 356mm SCT with a DMK 21AU04 camera.)

observers. This may be due to the aperture, camera, filters and processing used.

Despite these differences, some consistent colours were recorded, such as for the SEB(N). Generally, all observations show this to have had a red colouration. The highest-resolution images show the NTZ to have had a distinct blue or turquoise colour and the NNTZ to have had an orange or reddish colour (see for example Figure 1). On some images, this reddish colour seems to extend into the NNNTZ. Such a colour has been recorded at similar latitudes of the southern hemisphere during previous apparitions. (See for example Foulkes (2013).[4])

The colour estimates of the NEB, its components and intermediate zones were however more diverse and ranged from cold through to warm colouration. For example, the individual NEB components shown in Figure 1 appeared a warm grey tone. In Figure 6(d), the belt appears red. In Figure 7(b), the individual components appear grey but with an overall green background. In Figure 8(c), the belt components appear warmer in tone.

**Table 3. Average visual intensity estimates, 2009/2010**

| *Observer* | *Abel* | | *Adamoli* | | *Colombo* | | *Giuntoli* | | *Gray* | | *Heath* | | *Johnson* | | *Line* | | *McKim* | | *Appn aver. (all obs.)* | *Tot. no. obs.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Dates* | Feb 21 – Jun 21 | | Feb 13 – Jul 9 | | Jun 18 – Aug 7 | | May 27 | | Oct 18* – May 28 | | Mar 6 – May 9 | | Mar 4 – May 23 | | Mar 21 – Jun 16 | | Mar 5 – May 27 | | | |
| | *Aver.* | *No. obs.* | *Aver.* | *No. obs.* | *Aver.* | *No. obs.* | *Aver.* | *No. obs.* | *Aver.* | *No. obs.* | *Aver.* | *No. obs.* | *Aver.* | *No. obs.* | *Aver.* | *No. obs.* | *Aver.* | *No. obs.* | | |
| ***The planet*** | | | | | | | | | | | | | | | | | | | | |
| SPC | | | | | | | | | 5.9 | 27 | | | | | | | | | 5.9 | 27 |
| SPR | 4.0 | 14 | 4.1 | 6 | 3.5 | 4 | 2.0 | 1 | 4.6 | 52 | 2.5 | 10 | 1.0 | 3 | 2.6 | 8 | 4.3 | 11 | 4.0 | 109 |
| SPB | | | | | | | | | 5.2 | 48 | | | | | | | | | | |
| SSTZ | | | | | | | | | 4.3 | 16 | | | | | | | | | 4.3 | 16 |
| SSTB | | | | | | | | | 4.9 | 15 | | | | | | | | | 4.9 | 15 |
| STZ | 2.6 | 14 | 3.0 | 1 | 3.0 | 4 | 2.0 | 1 | 4.0 | 52 | 2.5 | 10 | 0.7 | 3 | 2.3 | 8 | 3.4 | 11 | 3.3 | 104 |
| STB | 3.8 | 11 | 4.0 | 1 | | | | | 5.1 | 52 | | | | | 3.5 | 2 | 4.2 | 7 | 4.7 | 73 |
| STropZ | 1.7 | 14 | 2.7 | 6 | 3.3 | 4 | 2.0 | 1 | 3.3 | 52 | 2.5 | 10 | 0.7 | 3 | 2.3 | 8 | 3.0 | 11 | 2.8 | 109 |
| SEB(S) | 4.1 | 11 | | | | | | | 4.4 | 52 | | | | | | | | | 4.3 | 63 |
| SEBZ | 2.8 | 7 | | | | | | | 3.5 | 52 | | | | | | | | | 3.5 | 59 |
| SEB(N) | 4.8 | 14 | 4.3 | 6 | 3.0 | 1 | 2.5 | 1 | 5.5 | 52 | 3.0 | 10 | 2.3 | 2 | | | 4.8 | 11 | 4.9 | 97 |
| EZ(S) | 1.2 | 14 | 1.7 | 6 | 2.1 | 4 | 1.5 | 1 | 1.9 | 52 | 2.0 | 10 | 1.0 | 3 | | | 1.8 | 11 | 1.8 | 101 |
| EB | 3.8 | 4 | | | | | | | 3.2 | 51 | | | | | | | | | 3.2 | 55 |
| EZ(N) | 0.9 | 14 | 1.1 | 6 | 2.1 | 4 | | | 2.4 | 52 | 1.5 | 10 | 1.0 | 2 | 1.3 | 6 | 1.8 | 10 | 1.9 | 104 |
| NEB(S) | 5.5 | 14 | 4.1 | 6 | 3.1 | 4 | 2.5 | 1 | 4.9 | 52 | 4.0 | 10 | 2.3 | 3 | 3.8 | 2 | 4.4 | 11 | 4.6 | 103 |
| NEBZ | 3.7 | 12 | | | | | | | 4.1 | 52 | | | | | | | 3.7 | 10 | 3.9 | 74 |
| NEB(N) | 5.1 | 14 | 4.0 | 6 | | | 3.0 | 1 | 5.9 | 52 | | | | | | | 4.4 | 11 | 5.4 | 84 |
| NTropZ | 2.5 | 14 | 2.8 | 5 | 3.0 | 4 | 2.0 | 1 | 3.4 | 50 | 3.5 | 10 | 0.7 | 3 | 2.3 | 8 | 3.4 | 11 | 3.1 | 106 |
| NTB | 3.8 | 10 | 2.8 | 2 | | | | | 4.7 | 51 | | | | | | | 4.2 | 4 | 4.5 | 67 |
| NTZ | 2.5 | 10 | 3.0 | 1 | 3.0 | 4 | 2.0 | 1 | 3.2 | 52 | 3.5 | 10 | 0.7 | 3 | 2.3 | 8 | 3.6 | 9 | 3.0 | 98 |
| NNTB | | | | | | | | | 5.0 | 43 | | | | | | | 4.8 | 1 | 4.9 | 44 |
| NNTZ | | | | | | | | | 3.4 | 45 | | | | | | | | | 3.4 | 45 |
| NPB | | | | | | | | | 5.3 | 52 | | | | | | | | | 5.3 | 52 |
| NPR | 3.8 | 14 | 3.9 | 6 | 3.5 | 4 | 2.0 | 1 | 4.5 | 52 | 3.5 | 10 | 0.7 | 3 | 2.3 | 8 | 4.2 | 11 | 3.9 | 109 |
| NPC | | | | | | | | | 6.6 | 51 | | | | | | | | | 6.6 | 51 |
| ***The rings*** | | | | | | | | | | | | | | | | | | | | |
| Ring A1 | | | 5.0 | 6 | 4.1 | 4 | | | 4.9 | 52 | 3.0 | 10 | | | | | 2.8 | 11 | 4.4 | 83 |
| Ring A2 | | | 4.5 | 2 | | | | | 4.2 | 48 | | | | | | | 2.7 | 8 | 4.0 | 58 |
| Cassini Div. | | | 9.8 | 6 | 4.3 | 3 | | | 6.0 | 49 | | | | | 9 | 4 | 6.1 | 8 | 6.4 | 70 |
| Ring B1 | | | 2.1 | 6 | 4.0 | 4 | | | 2.9 | 52 | 1.0 | 10 | 0.7 | 3 | 2.5 | 7 | 1.6 | 11 | 2.4 | 93 |
| Ring B2 | | | | | | | | | 4.0 | 52 | | | | | | | 2.5 | 11 | 3.7 | 63 |
| Ring C | | | 6.0 | 2 | | | | | 6.2 | 50 | | | | | | | 3.9 | 10 | 5.8 | 62 |
| C(M) | | | 7.3 | 4 | | | | | 6.4 | 28 | | | | | | | 5.4 | 8 | 6.3 | 40 |
| ***The shadows*** | | | | | | | | | | | | | | | | | | | | |
| Sh GR | | | 10.0 | 3 | 8.5 | 4 | | | 10.0 | 52 | | | 10.0 | 3 | | | 10.0 | 10 | 9.9 | 72 |
| Sh RG | | | 9.8 | 2 | 8.8 | 4 | | | 8.6 | 37 | 8.5 | 10 | 10.0 | 3 | 9 | 7 | 9.8 | 10 | 8.9 | 73 |

*Notes*

All dates are 2010 except one, indicated (*).

Intensities are made on a scale where 0 = bright white, 10 = black.

Giuntoli, Heath and Line gave single intensities for the regions south of the SEB and north of the NEB. These have been allocated to the SPR/STZ/STropZ and NPR/NTZ/NTropZ, respectively.

Colombo, Heath, Johnson and Line gave intensities to a reported single SEB. These have been allocated to the SEB(N). Colombo, Heath and Line gave intensities for a reported single NEB. These have been allocated to the NEB(S).

All values are given to one decimal place.

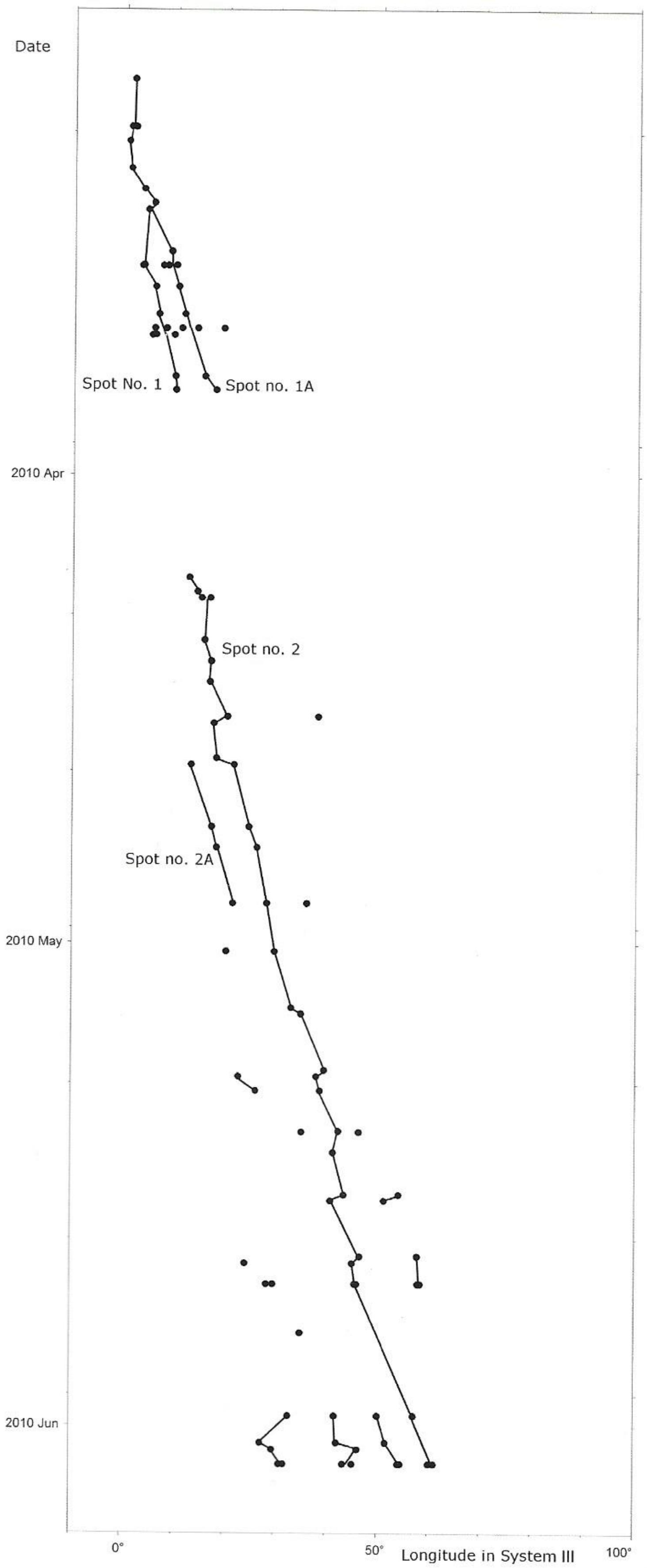



**Figure 5.** The System III longitudes of the STropZ light spots *vs.* time. These measurements were derived from images taken by Akutsu, Arditti, Barry, Delcroix, Edwards, Foulkes, Garbett, Go, Jaeschke, Kardasis, Maxson, Peach, Phillips, Tyler, and Wesley, plus drawings made by Abel. The solid lines shown in this Figure link the centres of what is believed to be the same spot, rather than showing System III drifts.

Lower-resolution visual observations recorded a grey colouration but McKim, using a large-aperture instrument, consistently recorded a reddish hue.

The reason for these variations in colour estimates is not clear and no obvious correlation of colour was found with date or longitude.

As in previous apparitions, a few observers imaged the planet using filters, with wavelengths ranging from the near ultraviolet (UV) up to the methane band (890nm). Some typical examples are shown in Figure 4.

In UV (Figure 4(a)), the rings appeared darker than at other wavelengths. Little was seen on the planet's disc at this wavelength, although the equatorial regions were dark.

The SEB(N) appeared slightly darker in the blue and green images (Figures 4(b) & 4(c), respectively) compared to the red image (Figure 4(d)), thus indicating the red colouration described above.

The NEB structure was more obvious at longer wavelengths, particularly in infrared (IR), compared to the appearance in the blue image, as did some other belts (Figure 4(e)).

As in previous apparitions, the equatorial regions appeared bright and the remainder of the planet dark in the methane band (Figure 4(f)). This indicates relative height of the equatorial regions.

## The planet

### South Polar Region (SPR)

The south pole was slightly tilted away from Earth. No detail was observed in this region, which appeared dark grey although Gray frequently reported a South Polar Cap (SPC). The northern edge of the SPR was marked by a dark belt whose latitude (Table 2) is consistent with the South Polar Band (SPB) observed in earlier apparitions.

### South South Temperate Belt (SSTB) & South South Temperate Zone (SSTZ)

A narrow and light SSTZ was sometimes observed south of the SSTB. The SSTB appeared as a narrow belt.

### South Temperate Belt (STB) & South Temperate Zone (STZ)

The STZ was light and narrow.

The STB was a dark belt. High-resolution observations showed this to be double, with the southern component the darker.

### South Tropical Zone (STropZ)

A major feature of the apparition was the bright storm system that appeared in this zone. This comprised one or more light or bright spots, which sometimes extended slightly into the northern edge of the STB.

One characteristic of a few of these spots was a rapid increase in brightness, followed by an expansion in longitude and then a fading. Another was the generation of a disturbed sector of the STropZ, which by Jun 3 extended just over 35° in longitude.

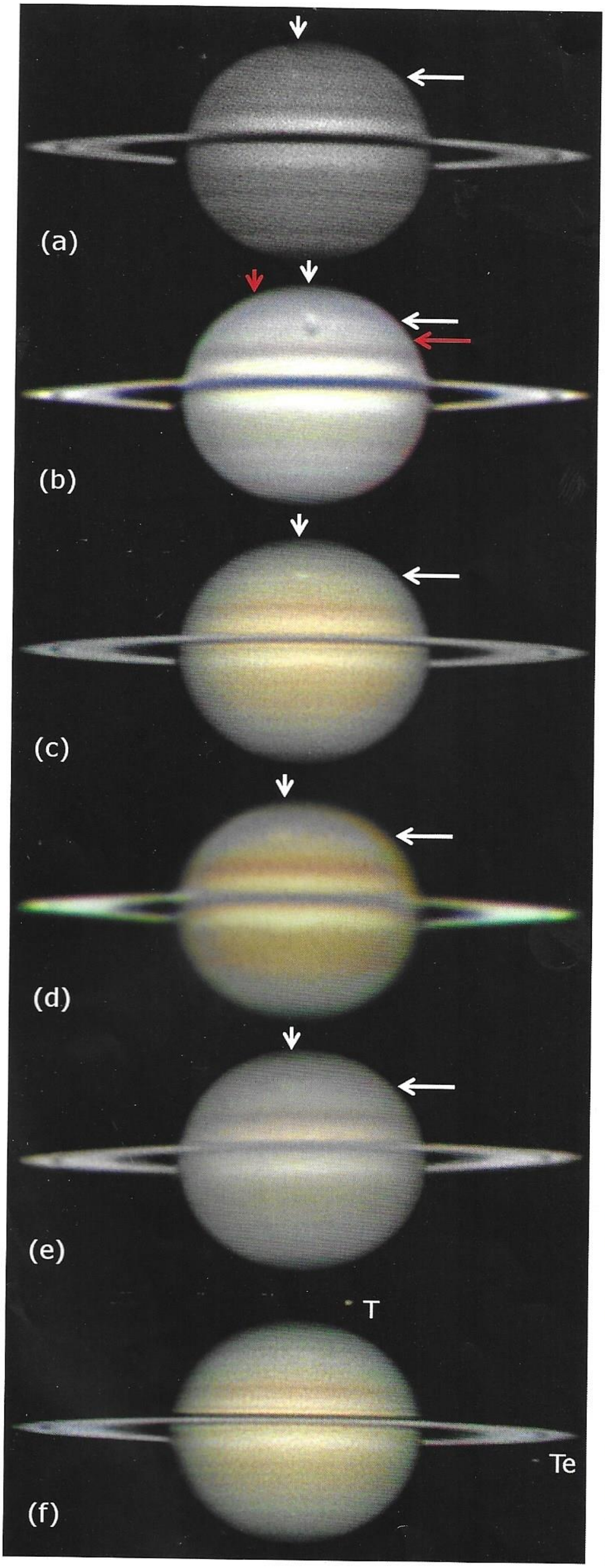
Figure 5 shows the measured System III longitudes, against time, of the centres of all light spots observed in this storm system. The solid lines shown in Figure 5 do not indicate the drifts of the individual spots, but rather link the centres of what are believed to be the same spots based on both the positional measurements and a review of all images. Some different interpretations of these data are possible, as there are some gaps in the coverage and some rapid changes were observed with timescales of a day.

**Table 4. Colour estimates, 2009/2010**

| *Observer* | *Abel* | *Adamoli* | *Colombo* | *Guintoli* | *Heath* | *Johnson* | *McKim* | *Colour from digital images assessed by the author* |
|---|---|---|---|---|---|---|---|---|
| *Dates* | Feb 21 – Jun 21 | Feb 13 – Jul 9 | Jun 18 – Aug 7 | May 27 | Mar 6 – May 9 | Mar 4 – May 23 | Mar 5 – May 27 | |
| ***The planet*** | | | | | | | | |
| SPR | Grey | Grey or brown | Grey or yellow | | | | S. hemisphere grey with greenish tint once recorded | Grey, dark grey |
| SPB | | | | | | | | Grey |
| SSTZ | | | | | | | | Light grey with sometimes a blue tinge |
| SSTB | | | | | | | | Grey or warm grey |
| STZ | Light grey or yellow | Yellow white or grey | Dull yellow | Yellowish white | | Yellowish white | | Light grey with sometimes a blue tinge |
| STB | Grey | | | | | | | Grey or warm grey |
| STropZ | Yellow | Yellow white or grey | Dull yellow | Yellowish white | | Yellowish white | | White or light grey |
| SEB(S) | Orange | | | | | Light brown | | Warm or red grey |
| SEBZ | | | | | | | | White, dull white, or light grey |
| SEB(N) | Brownish red, red | Brown or orange | Yellow or orange | Grey | | | Brown, orange brown | Red or red brown |
| EZ(S) | Yellow | Yellow white or yellow | Yellow | Creamy white | Cream | | Yellowish | White, cream, yellow, or sometimes a pink tone |
| EB | | | | | | | | Grey |
| EZ(N) | More yellow than EZ(S) | Yellow white or yellow | Yellow | Creamy white | Cream | | Yellowish cream | White, cream, or yellow |
| NEB(S) | | Grey | Grey | Grey | | | Brown or orange brown | Grey, warm grey, brown, or red |
| NEBZ | | Grey | | | | | | Light grey, blue or green tone |
| NEB(N) | Bluish grey or reddish | Grey | | Grey | | | Brown or orange brown | Grey, warm grey, brown or red |
| NTropZ | Light grey or yellow | Yellow white, white or grey | Yellow or grey | Yellowish white | Blue grey | Yellowish white | | Light grey, bluish or white |
| NTB | Grey | | | | | | | Warm grey |
| NTZ | | Yellow white, white or grey | Yellow or grey | Yellowish white | Blue grey | Yellowish white | | Distinct blue or turquoise |
| NNTB | Grey | | | | | | | Grey |
| NNTZ | | | | | | | | Red or orange tone |
| NPR | | Grey blue or grey | Grey | | Blue grey | | N. hemisphere grey, yellowish tint once recorded | Dark grey |
| ***The rings*** | | | | | | | | |
| Ring A1 | Grey | Grey | Yellow | | Grey | | Grey | Blue tone |
| Ring A2 | | | | | | | | Light blue |
| Cassini Div. | Black | Black | | | | | Dark grey | Black |
| Ring B1 | White | Yellow | Yellow | White | White | | White | White |
| Ring B2 | | | | | | | White | Light grey |
| Ring C | | Grey | | | | | | Grey |
| C(M) | | Brown | | | | | Grey | Grey |
| ***The shadows*** | | | | | | | | |
| Sh GR | Black | Black | Black | | | | Black | Black |
| Sh RG | Black | Black | Black or dark grey | | | | Black | Black |

*Notes*

Abel provided some colour estimates plus a few colour drawings. The colours shown in these drawings are also reflected in this table.




The appearance of this storm is shown in Figures 1, 6, 7, & 8. As well as being recorded in colour images, it was also recorded in red-light images and in IR on Mar 13 (Figure 5(e)). Throughout this apparition, it was only recorded in images, apart from two visual observations made by Abel on Mar 15 & 23. Table 5 gives the derived average drifts, latitudes and sizes for some of the spots observed in this storm system. The first observation was made on Mar 6 by Akutsu (Figure 6(a)), when it appeared as a small light spot at System III longitude 1.6°. This is designated as no.1 in Figure 5.

A faint object at a similar longitude was only suspected in an image taken by Maxson two days earlier on Mar 4. Nothing obvious was detected in this longitude region in observations made prior to that date, *i.e.*, by Wesley on Feb 26 and Mar 2.

Positional measurements of this spot from images taken during the first few days after its appearance indicate a small negative drift with respect to System III (Figure 5). However, this is uncertain given the limited time period of these measurements. After this time, a positive drift relative to System III was observed.

Over the next few days, the spot became brighter. It then began to expand in longitude, becoming more elliptical in shape but also beginning to fade (Figures 6(b)–(c)). This expansion may have been in the *f.* (following) direction, as the longitude of the centre of the spot seemed to move rapidly to *f.* in a few days; this is shown in Figure 5.

From Mar 18 (Figures 1 and 6(d) & (e)), higher-resolution observations showed it having a double structure. For the purposes of this report, the spot *f.* is designated no. 1A in Figure 5. Lower-resolution observations only revealed a single elongated object. If differing observations on the same night showed it both as single and double, only the observations that showed it to be double are shown in Figure 5 for clarity. However, all observations have been used in the overall analysis.

On Mar 22, the zone immediately *f.* these two spots appeared disturbed (Figure 1).

The storm was still visible on Mar 26, but Go's colour image taken on Mar 30 (Figure 6(f)) showed no feature at this

**Figure 6.** The appearance of the STropZ storm system during 2010 March. White arrows show the position of this storm on the planet's disc, whereas the red arrows show the position of the SEBZ spot no. 1.

**(a)** 2010 Mar 6, 14:26 UT; CM1= 182.8°, CM2 = 239.5°, CM3 = 10.5°. (Red image by Akutsu; 356mm SCT with a DMK 21AU04 camera.)

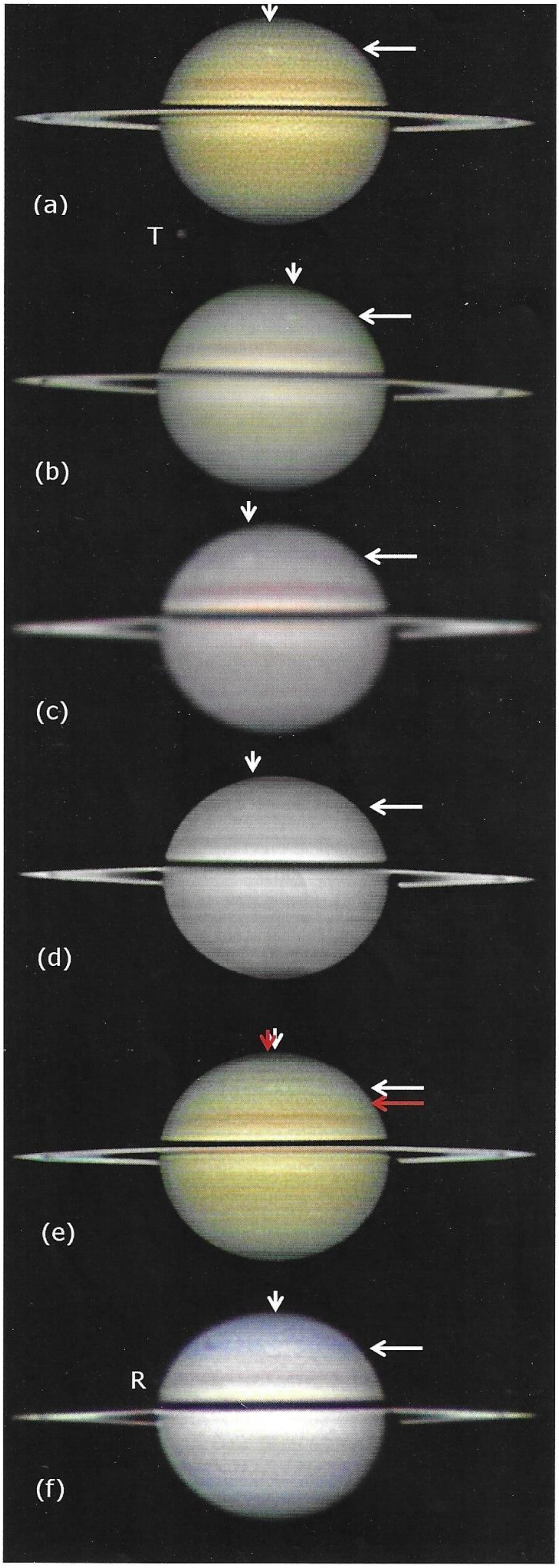
**(b)** 2010 Mar 9, 16:40 UT; CM1 = 274.1°, CM2 = 231.0°, CM3 = 358.3°. (Image by Barry; 406mm Newt. with a DMK 21AU04.AS camera.) This image shows Rhea and its shadow in transit, with Rhea *f.* the shadow. The STropZ storm system lies just south of Rhea's shadow. It also shows SEBZ spot no. 1.

**(c)** 2010 Mar 13, 16:48 UT; CM1 = 56.3°, CM2 = 243.9°, CM3 = 6.3°. (Image by Go; 279mm SCT with a DMK 21F04 camera.)

**(d)** 2010 Mar 19, 22:29 UT; CM1 = 278.5°, CM2 = 264.7°, CM3 = 19.6°. (Image by Kardasis; 254mm SCT with a TouCam Pro camera.)

**(e)** 2010 Mar 23, 00:48 UT; CM1 = 17.2°, CM2 = 263.2°, CM3 = 14.4°. (Image by Tyler; 356mm SCT with a Lumenera 075 camera.) The rings are brighter than normal due to the opposition effect.

**(f)** 2010 Mar 30, 13:40 UT; CM1 = 260.4°, CM2 = 263.0°, CM3 = 5.1°. (Image by Go; 279mm SCT with a DMK 21F04 camera.) The STropZ storm is not visible in this image, although it was taken at the correct System III longitude. It also shows Titan (labelled 'T') S*f.* of Saturn and Tethys (labelled 'Te') *f.* the planet, north of the rings.




System III longitude, although a brighter STropZ was suspected in the blue image taken almost at the same time. Nor was anything visible there in another image taken by Go on Apr 3.

However, on Apr 7, a bright spot was again observed in this longitude region (Figure 7(a)). This is designated no. 2 in Figure 5. In a similar manner to spot no. 1, this too began to brighten and expand in size, and began to appear more elliptical (Figures 7(b) & (c)).

By Apr 16 (Figure 7(d)), parts of the STropZ some 18° *f.* no. 2 had become slightly lighter. On Apr 17, McKim recorded the zone to be brighter (CM3 = 74–88°). Furthermore, on Apr 19 a small bright area had formed S*p.* of no. 2. This too brightened and over the next few days appeared brighter than no. 2 (Figure 7(e)), but subsequently they appeared of similar intensity and were in close contact on Apr 28 (Figure 7(f)). By May 1, both spots were only very faintly visible (Figure 8(a)).

On May 5, another spot had become bright. As its longitude lay on the extrapolated track of no. 2, this was assumed to be the latter undergoing another brightening; this is discussed further later. By May 9 & 10 (Figure 8(b) & (c)), this too had expanded, with the STropZ becoming more disturbed *p.* (Figure 8(d) & (e)).

By Jun 3, one small light spot was visible *p.* with two major bright spots further *p.* (Figure 8(f)), and as noted earlier, the storm system extended just over 35° in longitude.

Some other brighter areas were recorded in the STropZ by McKim on Mar 27 (CM3 = 309–314°) and on Apr 26 (CM3 = 174–185°).

Radio signatures associated with bright storms at this latitude have been detected by the *Cassini* spacecraft in orbit around Saturn. These have been shown to be caused by lightning activity, indicating that these storms are giant thunderstorms. The storm system observed during this apparition was also shown to be correlated with lightning activity.[6] The detection of this lightning started on Feb 7 (designated as 'storm I' in Fischer (2011),[6] but no storms were detected in the Section observations until Mar 6. The lightning was detected until Jul 14 but no Section observations recorded a storm after Jun 3.

Table 5 shows that the drifts derived for these spots did differ considerably. Spot nos. 1, 1A and especially 2A were observed over relatively short timescales and so their drifts may

**Figure 7.** The appearance of the STropZ storm system during 2010 April. White arrows show the position of this storm on the planet's disc, whereas red arrows show the position of the SEBZ spot no. 1.

**(a)** 2010 Apr 7, 13:48 UT; CM1= 179.9°, CM2 = 283.9°, CM3 = 16.3°. (Image by Go; 279mm SCT with a DMK 21F04 camera.) This image also shows Titan (labelled 'T') N*p.* the planet.

**(b)** 2010 Apr 8, 21:18 UT; CM1 = 208.1°, CM2 = 269.7°, CM3 = 0.5°. (Red image by Peach; 356mm SCT with a SKYnyx 2.0M camera.)

**(c)** 2010 Apr 12, 22:13 UT; CM1 = 17.6°, CM2 = 308.9°, CM3 = 34.8°. (Image by Garbett; 356mm SCT with a SKYnyx 2.0 camera.)

**(d)** 2010 Apr 16, 11:31 UT; CM1 = 137.9°, CM2 = 314.4°, CM3 = 36.0°. (Red light image by Wesley; 354mm Newt. with a PGR Dragonfly 2 PGR Flea 3 camera.)

**(e)** 2010 Apr 23, 13:30 UT; CM1 = 358.5°, CM2 = 306.2°, CM3 = 19.3°. (Image by Go, 279mm SCT with a DMK 21F04 camera.) This image also shows SEBZ spot no. 1.

**(f)** 2010 Apr 28, 10:48 UT; CM1 = 165.0°, CM2 = 314.8°, CM3 = 22.1°. (Image by Barry; 406mm Newt. with a DMK 21AU04.AS camera.) This also shows the shadow of Rhea approaching the *p.* limb, projected against the STBn. Rhea (labelled 'R') lies *p.* the planet.

be considered to be more uncertain. Figure 5 indicates that spot no. 1 may initially have had a small negative drift with respect to System III during its first days of existence, before assuming a more positive drift. However, Table 5 only gives the overall average drift for this spot. There were no observations of spot no. 2 at the end of May and so its track extending into June, shown in Figure 5, is also more uncertain.

It is possible that spots no. 1 and no. 2 may be the same object. Certainly, the later part of the track of spot no. 1 shown in Figure 5 extrapolates close to the initial position of spot no. 2. However, no activity was observed in this region in Go's images taken on Mar 30 (Figure 6(f)) and Apr 3, which could imply no. 1 had faded away and a new object then formed close to the same position. When first observed, no. 2 underwent a rapid brightening and subsequent expansion, which may imply a new object.

As described above, spot no. 2 faded at the beginning of May but a new brightening spot was observed on the same track on May 5. This has been assumed to be a resurgence of no. 2, but equally this could have been a new object forming in the same region.

An Internet search was made to see if there were any suitable whole-disc *Cassini* images of Saturn taken that covered this storm and the SEBZ spot described in the next subsection, but none were found.[7,8]

It is not clear if any of the other light spots observed in this region were also individual storms or, alternatively, the result of the local winds interacting with either spot no. 1 or no. 2 and producing turbulence in the zone.

A similar storm was observed during the previous apparition.[4] This system had a predicted System III longitude of approximately 106° for this apparition's opposition. Nothing was observed at this longitude, so the system must have disappeared before the start of the apparition.

## South Equatorial Belt (SEB)

The SEB appeared double and was separated by a light SEBZ. The southern component appeared much fainter than during the previous apparition, as shown by comparing Figures 1 & 2.

A white spot (SEBZ spot no. 1) was visible in the SEBZ. It was not easy to detect and was only shown in some images, *e.g.*, Figures 4(c), 6(b) & 7(e). Although only a few observations were made and there are some coverage gaps, the observations show a well-defined track (see Figure 9), with the drift given in Table 5.

Similar white spots have been observed in the SEBZ during the previous few apparitions and the details of these spots since the 2002/2003 apparition are summarised in Table 6. Reference is also made to the related apparition report.

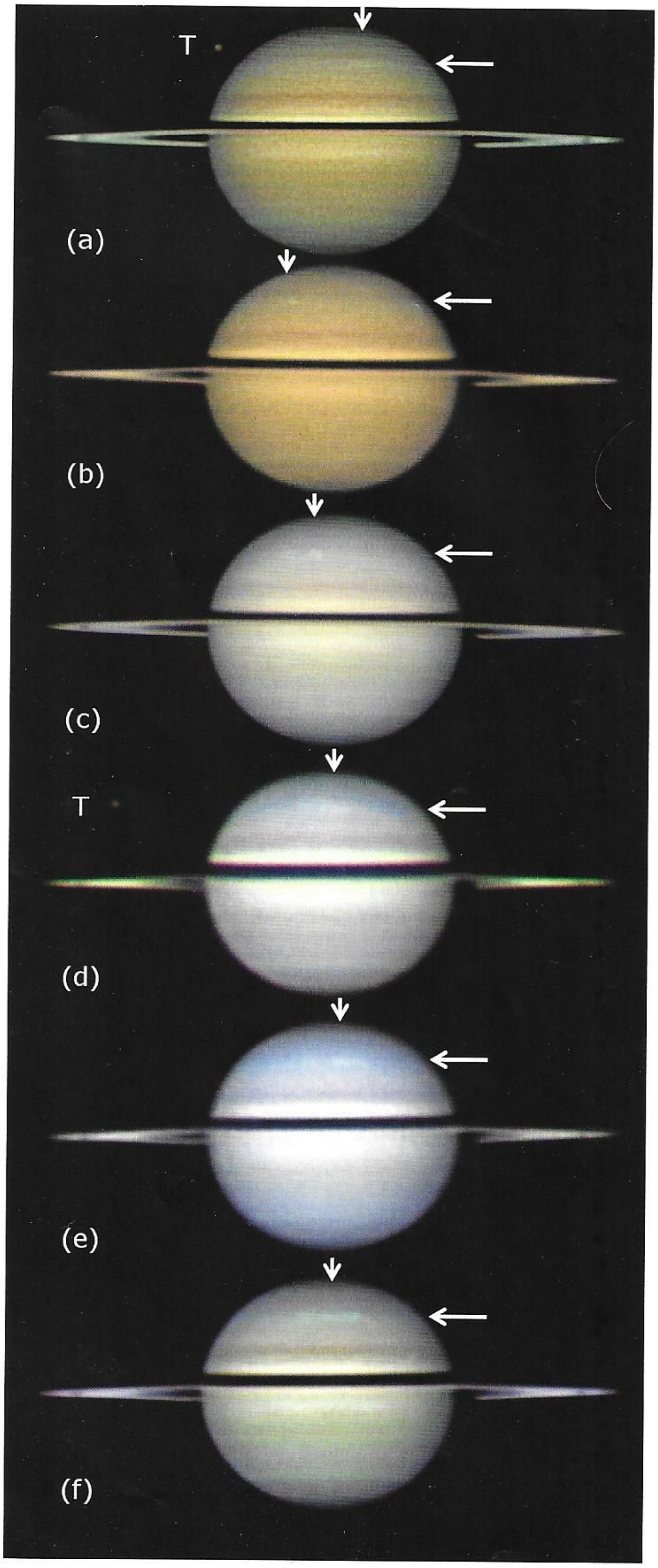



**Figure 8.** The appearance of the STropZ storm system during 2010 May/June. White arrows show the position of this storm on the planet's disc.

**(a)** 2010 May 1, 13:05 UT; CM1 = 258.2°, CM2 = 308.1°, CM3 = 11.6°. (Image by Go; 279mm SCT with a DMK 21F04 camera.) Titan (labelled 'T') is S*p*. the planet.

**(b)** 2010 May 9, 03:48 UT; CM1 = 205.9°, CM2 = 9.8°, CM3 = 64.1°. (Image by Maxson; 250mm Mak. with a Flea 3, SKYnyx2 camera.)

**(c)** 2010 May 10, 11:22 UT; CM1 = 236.3°, CM2 = 357.8°, CM3 = 50.5°. (Image by Wesley; 354mm Newt. with a PGR Dragonfly 2 PGR Flea 3 camera.)

**(d)** 2010 May 17, 13:35 UT; CM1 = 104.1°, CM2 = 356.5°, CM3 = 40.7°. (Image by Barry; 406mm Newt. with a DMK 21AU04.AS camera.) This image also shows Titan (labelled 'T') S*p*. the planet.

**(e)** 2010 May 22, 21:28 UT; CM1 = 282.7°, CM2 = 3.0°, CM3 = 40.7°. (Image by Edwards; 279mm SCT with a DMK 21AU04 camera.)

**(f)** 2010 Jun 3, 10:41 UT; CM1 = 314.1°, CM2 = 21.4°, CM3 = 45.2°. (Image by Wesley; 354mm Newt. with a PGR Dragonfly 2 PGR Flea 3 camera). This image also shows Rhea in transit, projected on the SEB(N) near the *f.* limb.

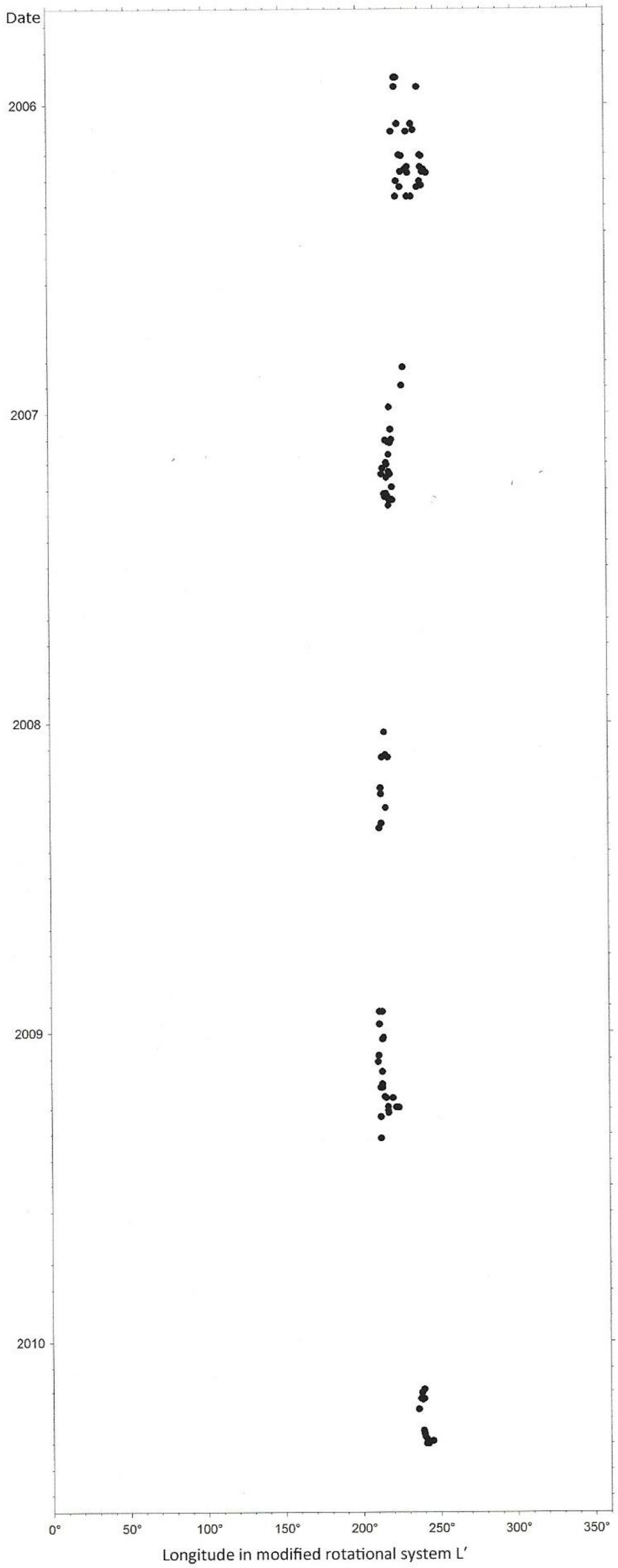



**Figure 9**. Drift chart of the white SEBZ spots observed from the 2006/2007 apparition until the 2009/2010 apparition. This uses a modified longitude system drifting at –7.05°/day relative to System III. The reference date is the opposition date of 2010 Mar 22. The positions for 2010 were derived from images taken by Akutsu, Barry, Go, Tyler, and Wesley.

The spots observed during the 2002/2003 apparition were followed over only a few days and are not considered further.

Seven spots were recorded during the 2003/2004 apparition, with drifts ranging from –9.84°/day to –6.89°/day relative to System III, although some were only observed over limited timescales.

Two spots were observed during the 2004/2005 and 2005/2006 apparitions and then only one was recorded subsequently. The observed drifts since the 2005/2006 apparition have all been close to approximately –7°/day with respect to System III and the measured latitudes have been consistent, allowing for measurement errors.

The 2008/2009 apparition report gave evidence that the single light spot observed in this zone during the 2006/2007, 2007/2008 and 2008/2009 apparitions were identical.[4] The following investigates whether any of the other spots shown in Table 6 were related to these.

Currently, positional data held in the Section's *WinJUPOS* database only starts from the 2005/2006 apparition. SEBZ spot data in the reports for the 2003/2004 and 2004/2005 apparitions were given in the form of drift rate (with respect to System III) and System III longitudes of the first and last observed date. This allows the spot positions to be extrapolated from the last observed position in one apparition to the first observed position of spots recorded in the following apparition. The results of this extrapolation of the spots from 2003/2004 to 2004/2005 are shown in Table 7.

One difficulty with these extrapolations is the timescale between the last and first observations, which in Table 7 ranges from 227 to 384 days. A difference in drift rate of only 0.1°/day could result in a positional change ranging from 22.7 to 38.4°.

This table indicates that either 2003/2004 WS1 or WS4 may be identical to 2004/2005 WS1 although, in both cases, the extrapolated longitude is not an exact match. 2003/2004 WS4 had only four observations and a more rapid drift compared to 2004/2005 WS1. Further, 2003/2004 WS7 looks the most likely candidate to be identical to 2004/2005 WS2.

The two SEBZ spots observed in 2004/2005 were slowly converging, so that when last observed, their separation in longitude was 13°. The two SEBZ spots observed during 2005/2006 had a mean separation in longitude of 12°, which could imply the spots observed during these two apparitions were identical. The motions of the 2004/2005 spots were extrapolated into the next apparition, as described above, and the results are shown in Table 8.

The spot 2004/2005 WS2 gives the best extrapolated match to the longitudes of both spots observed in 2005/2006, but a small change in drift rate could result in a better match.

The SEBZ spot data held in the *WinJUPOS* database were used to generate a drift chart (Figure 9) from the 2005/2006 apparition until the current one. The chart has been derived for a modified longitude system drifting at –7.05°/day relative to System III, with a reference date for the 2009/2010 opposition. The drift rate was chosen as giving the best overall fit.

This figure shows a well-defined locus of tracks which indicates that one spot could have lasted for five apparitions, assuming very small drift rate changes from apparition to apparition. Of the two spots observed in the 2005 apparition, the preceding (*p.*) spot (no. 1) is the most likely to be the one that survived into the next apparition. The long gaps between the observations do however prevent absolute certainty in this result.

**Table 5. Longitudes & drifts for spots**

| Spot | Description | Planetographic No. of obs. latitude (°) | L3 (O) (°) | DL3 per day | DL3 per 30d | Rotation period h m s | Dates (2010) | No. obs. | Average extent in long. (°) | No. obs. for aver. extent |
|---|---|---|---|---|---|---|---|---|---|---|
| ***On the STropZ*** | | | | | | | | | | |
| 1 | White spot STropZ | –41.8 ± 1.2 (1σ) | 6.6 ± 0.4 (1σ) | 0.4 ± 0.1 (1σ) | 12.41 ± 1.6 (1σ) | 10 39 41.99 ± 2.5 (1σ) | Mar 6 – Mar 26 | 18 | 5.5 ± 1.48 (1σ) | 13 |
| 1A | White spot STropZ | –41.0 ± 0.8 (1σ) | 12.2 ± 0.5 (1σ) | 0.9 ± 0.2 (1σ) | 28.3 ± 5.1 (1σ) | 10 40 7.1 ± 08.05 (1σ) | Mar 13 – Mar 26 | 11 | 6.2 ± 2.26 (1σ) | 10 |
| 2 | White spot STropZ | –41.4 ± 1.3 (1σ) | 359.9 ± 1.0 (1σ) | 0.8 ± 0.02 (1σ) | 23.32 ± 0.7 (1σ) | 10 39 59.2 ± 1.0 (1σ) | Apr 7 – Jun 3 | 30 | 6.9 ± 2.26 (1σ) | 20 |
| 2A | White spot STropZ | –40.9 ± 1.4 (1σ) | 347.4 ± 1.2 (1σ) | 0.9 ± 0.04 (1σ) | 27.6 ± 1.1 (1σ) | 10 40 06.0 ± 1.7 (1σ) | Apr 19 – Apr 28 | 4 | 5.4 ±0.7 (1σ) | 2 |
| ***On the SEBZ*** | | | | | | | | | | |
| 1 | White spot SEBZ | –28.9 ±1.0 (1σ) | 239.0 ± 0.5 (1σ) | –7.0 ± 0.02 (1σ) | –210.0 ± 0.6 (1σ) | 10 33 54.4 ± 0.9 (1σ) | Feb 26 – May 1 | 13 | 6.2s ± 2.2 (1σ) | 5 |

*Notes:* L3(O) is the System III longitude at opposition on 2010 March 22. () indicate the estimated opposition longitude for any spot not observed at opposition. DL3 per day is the drift relative to System III in degrees of longitude per day. DL3 per 30 days is the drift relative to System III in degrees of longitude per 30 days. All values rounded to one decimal place.

In conclusion, it is likely that one SEBZ spot has lasted for five apparitions. This and a second one could have initially appeared during the 2003/2004 apparition, but that is much less certain.

As noted earlier, the SEB(N) was the most distinctive belt visible during this apparition.

Higher-resolution images revealed a narrow, warm-grey belt, just to the north of the SEB(N) and designated as a S. EZ belt in Table 2. Its latitude was very similar to that recorded during the 2008/2009 and earlier apparitions, where it generally appeared distinct from the SEB(N) as shown in Figure 2.[4] During this apparition, the distinction was sometimes less obvious, and it occasionally appeared as a northern component to the SEB(N). Sometimes the region between this and the SEB(N) appeared shaded. Vague lighter regions were sometimes suspected between this belt and the SEB(N) in some high-resolution images. In particular, two vague, elongated lighter regions were shown on Wesley's images taken on Mar 22 (Figure 1) & 25, although the System I longitudes were different. Some vague darker sections were also suspected on this belt.

A dark elongated feature was observed on this belt during the previous apparition,[4] and is shown in Figure 2. This was not detected during this apparition.

## Equatorial Zone (EZ)

This zone was bisected by the projection of the rings onto the planet and the shadow of the rings on the globe (Sh RG). The southerly half of this zone (EZ(S)) was generally brighter than the northerly half (EZ(N)). The EZ(S) was in turn bisected by a narrow band (designated as the EBS) and the zone appeared of equal intensity either side of this band. After opposition, the northern half of the EZ(S) was partially hidden by the Sh RG.

The EZ(N) too was bisected by a belt (designated the EBN), but this was broader than the EBS.

McKim suspected a light spot in the EZ(N) on Mar 5 & 15, with approximate System I longitudes of 355 and 115°, respectively.

**Table 6. Summary of white spots in the SEBZ observed since the 2002/2003 apparition**

| Apparition | No. of white spots | Spot designation plus drift rate with respect to System III (°/d) | Average planetographic latitude (°) |
|---|---|---|---|
| 2002/2003[9] | 2 (Limited number of observations over a short time span) | WS1: –7.53<br>WS2: –8.37<br>Average: –7.95 | No latitudes measured |
| 2003/2004[10] | 7 (although spot WS6 is omitted, as only observed on two dates) | WS1: –6.92<br>WS2: –7.48<br>WS3: –6.89<br>WS4: –9.84<br>WS5: –8.0<br>WS7: –7.13<br>Average: –7.71 | The apparition report quotes –29.6 from professional measurements (Sanchez–Lavega). Section images subsequently measured gave –28.5 ± 0.6 (1σ). |
| 2004/2005[11] | 2 (one dark spot also recorded but not included here). | WS1: –7.0<br>WS2: –6.83<br>Average: –6.92 | –24 (planetocentric);<br>–28.7 (planetographic) |
| 2005/2006[12] | 2 | No. 1: –7.02 ± 0.0.017 (1σ)<br>No. 2: –7.03 ±0.03 (1σ)<br>Average: –7.025 | –28.9 ±0.6 (1σ) |
| 2006/2007[5] | 1 | No 1: –7.1 ± 0.02 (1σ) | –28.0 ±0.5 (1σ) |
| 2007/2008[13] | 1 | No 1: –7.08 ± 0.02 (1σ) | –28.4 ±0.5 (1σ) |
| 2008/2009[4] | 1 | No 1: –7.01 ± 0.17 (1σ) | –28.1 ±1.12(1σ) |
| 2009/2010 | 1 | No 1: –7 ± 0.02 (1σ) | –28.9 ± 1.0 (1σ) |

## North Equatorial Belt (NEB)

At low resolution, the NEB often appeared as one diffuse band. However, higher-resolution observations revealed it to be divided into two major components: the NEB(S) and the NEB(N).

The NEB(S) was further divided into two components, with the

**Table 7. Extrapolation of the positions of light SEBZ spots from the 2003/2004 apparition into the 2004/2005 apparition**

| *SEBZ spot identifier, 2003/2004 apparition* | *Extrapolated long. for 2004/2005 WS1 on 2004 Sep 17** | *Actual long. for 2004/2005 WS1 on 2004 Sep 17* | *Extrapolated long. for 2004/2005 WS2 on 2004 Nov 6** | *Actual long. for 2004/2005 WS2 on 2004 Nov 6* |
|---|---|---|---|---|
| WS1 | 297.8 | 314 | 311.8 | 277 |
| WS2 | 150.7 | 314 | 136.7 | 277 |
| WS3 | 233.7 | 314 | 249.3 | 277 |
| WS4 | 301.5 | 314 | 187.5 | 277 |
| WS5 | 91 | 314 | 51.0 | 277 |
| WS7 | 270.5 | 314 | 274.0 | 277 |

*Notes:* Longitudes are given in System III (degrees). *Initial observed date.

southern generally appearing fainter than the northern. Vague segments of this component, or small projections, were sometimes recorded extending south into the EZ(N) in images taken by Barry and Wesley. Some of these were easier to see in the animations made by Barry, where they moved with the rotation of the planet. A small projection was also recorded by McKim on Mar 27. Unfortunately, there are far too few observations of these projections to derive any drift rates.

The NEB(N) appeared double but closely so and sometimes appeared as only one single band. The southern component of the NEB(N) was the darker and often the darkest NEB component. On Dec 4, Gray recorded a darker streak on this belt. On Apr 16, McKim recorded a dark condensation on the NEBn at an approximate System III longitude of 350°, and on Apr 17 at approximate System III longitudes of 65 and 105°.

### North Tropical Zone (NTropZ)

This was a featureless zone.

### North Temperate Belt (NTB)

This was a single belt and often appeared almost as dark as the NEB(N).

### North Temperate Zone (NTZ)

The distinctive blue colour of this zone was mentioned earlier in this report. A lighter area was recorded by Gray on Dec 4.

### North North Temperate Belt (NNTB) to North North North Temperate Zone (NNNTZ)

An NNTB and NNNTB were sometimes recorded, as were the NNTZ and NNNTZ. The colours of these zones have been described earlier.

### North Polar Region (NPR)

This region appeared dark grey.

The North Polar Hexagon was discovered by the *Voyager 2* spacecraft and subsequently imaged by *Cassini*. On 2013 Jan 26, Australian amateurs Darryl Milika and Pat Nicholas were able to image the hexagon plus its vertices. This will be discussed later in the associated apparition report.

Although the north pole was only tilted by a few degrees towards Earth during this apparition, a number of the highest-resolution images were examined to see if the hexagon could be resolved. This was achieved by generating stereographic polar projections of the images using the *WinJUPOS* software. No hexagon was identified, probably due to the low polar tilt to Earth. However, this projection shows the blue colour of the NTZ very well.

## The rings

The appearance of the rings throughout this apparition is shown in the Figures that illustrate this report, and a series in chronological order is presented in Figure 10.

The first observation of the rings, post solar conjunction, was made by Sussenbach on 2009 Oct 6, using only a 127mm aperture telescope. The rings were imaged, although they appeared faint. The ring inclination at the time with respect to Earth and the Sun was 1.8 and 0.9°, respectively. They were also faintly visible in Akutsu's image on Oct 10, but easily seen in his subsequent image on Oct 15 (Figure 10(a)).

No further observations were made until early December. Over this period, the ring inclination to Earth increased to reach a maximum value of 4.9° during early January, before decreasing again, as shown in Figure 10.

Depending on the telescope aperture used, more detail became visible in the rings. The Cassini Division was detected in the extremities of each ansa. Sometimes Ring A was resolved into Rings A1 and A2. Ring C and C(M) were also difficult.

However, all images taken up to shortly before opposition showed the rings to be less bright than after opposition, as shown in Figure 10. This dullness was also reported visually by Adamoli and Graham. It may have been due to the low ring inclination to the Sun over this period.

The ring inclination with respect to Earth and the Sun became identical shortly before opposition. With this geometry, the projection of the rings onto the planet appeared to bisect the Sh RG, as shown in Figures 1, 4(b), (c) & (d); 6(c), (d) & (e); and 10(d).

The rings became brighter for a few days either side of opposition, due to the opposition effect. This was recorded by a number of observers and is shown in Figures 1, 4(b), (c) & (d); and 10(d).

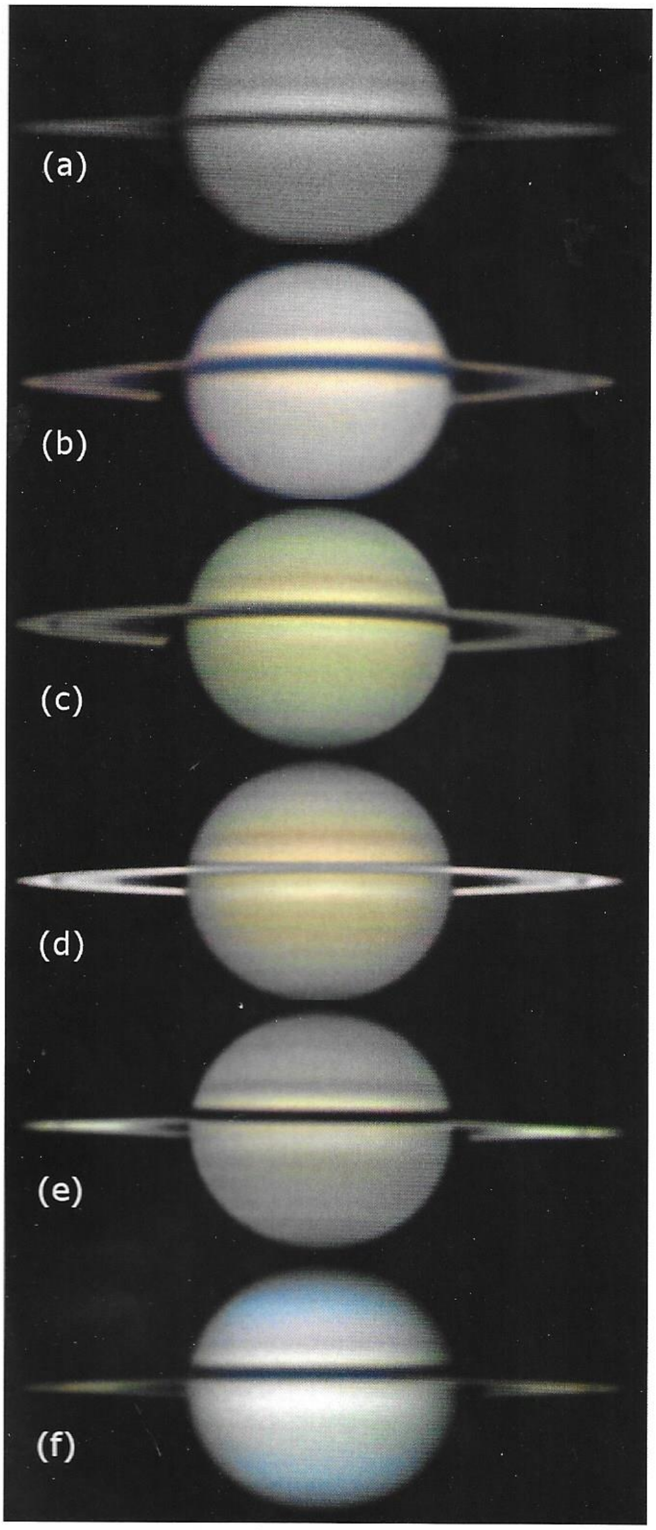



**Figure 10.** The varying appearance of the rings during this apparition.

**(a)** 2009 Oct 15, 21:11 UT; CM1 = 44.2°, CM2 = 358.9°, CM3 = 300.8°. (Red image by Akutsu; 356mm SCT with a DMK 21AU04 camera.)

**(b)** 2010 Jan 6, 12:01 UT; CM1 = 318.5°, CM2 = 124.4°, CM3 = 326.6°. (Image by Maxson; 250mm Mak. with a Flea 3, SKYnyx2 camera.)

**(c)** 2010 Jan 25, 17:00 UT; CM1 = 337.0°, CM2 = 242.4°, CM3 = 61.5°. (Image by Buda; 405mm DK with a DMK 21AU04 camera.)

**(d)** 2010 Mar 24, 14:10 UT; CM1 = 258.1°, CM2 = 87.6°, CM3 = 196.8°. (Image by Buda; 405mm DK with a DMK 21AU04 camera.) This shows the opposition effect.

**(e)** 2010 May 4, 20:45 UT; CM1 = 180.8°, CM2 = 123.4°, CM3 = 182.9°. (Image by Lewis; 222mm Newt. with a DMK 21AF04AS camera.)

**(f)** 2010 Jun 15, 01:20 UT; CM1 = 35.7°, CM2 = 88.0°, CM3 = 97.8°. (Image by Jaeschke; 356mm SCT with a Flea 3 camera.)

After opposition, the rings faded slightly but were brighter than pre-opposition. Although the inclination of the rings with respect to the Sun increased over this period, the inclination with respect to Earth decreased. This resulted in them appearing very narrow and ring detail became more difficult to detect, including the Cassini Division.

## The shadows

The shadow of the globe onto the rings (Sh GR) was projected onto the N*p*. side of the rings before opposition and onto the N*f*. side after opposition. The shadow of the rings onto the globe (Sh RG) was visible north of the projection of the rings onto the planet before opposition, and to the south after opposition (see for example Figure 10).

## The satellites

The satellites from Titan inwards to Mimas were recorded by several observers. Rhea was imaged on May 14 by Wesley using a methane filter. The faint satellite Hyperion was successfully imaged by Maxson and Sussenbach, as shown in Figures 11 & 12.

During this apparition, eclipses, occultations and transits were predicted to occur for all satellites from Mimas outwards to Titan. Such events for Mimas and Enceladus were not resolved.

Some transits and shadow transits were recorded for Tethys and Dione, as shown in Tables 9 & 10, respectively. These observations show that the satellites were more difficult to detect in

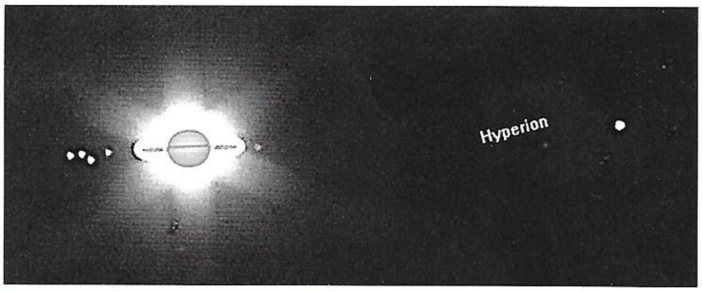



**Figure 11.** 2010 Apr 12, 04:15 UT. (Image by Maxson; 250mm Mak. with a Flea 3, SKYnyx2 camera.) This image shows the following satellites, left to right: Dione, Tethys, Rhea, Enceladus, Mimas, Hyperion (labelled) and Titan.

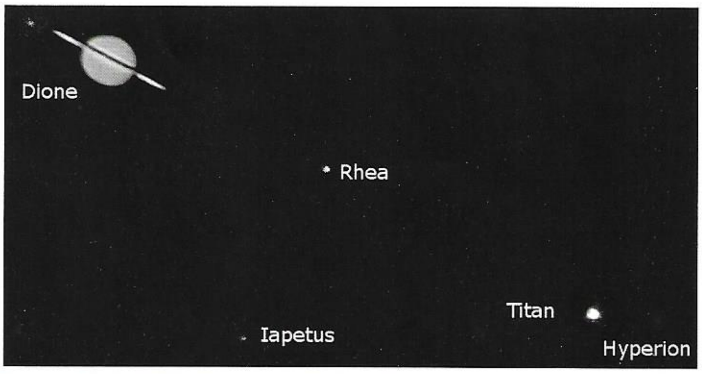



**Figure 12.** 2010 May 28, 22:15 UT. (Red filter image by Sussenbach; 279mm SCT with a DMK 21AU04 camera.) This image shows several satellites, including Hyperion.

transit than their respective shadows. The most interesting event observed, by Delcroix (see Table 9), was the double transit of Tethys and Dione.

The transits of Rhea and its shadow are summarised in Table 11.

Eclipses, occultations and transits of Titan also occurred. Tables 12 & 13, respectively, summarise the transit and occultation observations made for this satellite. Titan and its shadow were predicted to be in transit on Oct 6 and this was observed by Sussenbach (Table 12). This was the only Titan shadow transit observed during this apparition. *WinJUPOS* simulations showed that only shadow transits and occultations occurred after this date up to mid-January. No further events took place until Apr 15, when Titan was predicted to be in transit, lying very close to the southern limb. After this date, only satellite transits and occultations took place.

The only observation of a Titan occultation (a reappearance at the *p.* limb) was made by Go on May 9 (see Figure 14). The sequence of images taken at this time also shows Rhea approaching occultation at the *f.* limb, but this event was not observed. Details are given in Table 13.

**Table 8. Extrapolation of the positions of light SEBZ spots from the 2004/2005 apparition into the 2005/2006 apparition**

| *SEBZ spot identifier, 2004/2005 apparition* | *Extrapolated long. for 2005/2006 No. 1 on 2005 Nov 11** | *Actual long. for 2005/2006 No. 1 on 2004 Sep 17* | *Extrapolated long. for 2005/2006 No. 2 on 2005 Dec 11** | *Actual long. for 2004/2005 WS2 on 2004 Nov 6* |
|---|---|---|---|---|
| WS1 | 114 | 157.5 | 37 | 79.6 |
| WS2 | 137.9 | 157.5 | 62.8 | 79.6 |

*Notes:* Longitudes are given in System III (degrees). *Initial observed date.

**Table 9. Summary of observations of the transits of Tethys & its shadow**

| *Date* | *UT* | *Observer* | *Observation type* | *Notes* |
|---|---|---|---|---|
| 2009 Nov 17 | 07:20 | Gray | Visual | The shadow of Tethys was seen in transit. |
| 2009 Dec 04 | 07:40 | Gray | Visual | Tethys and its shadow were seen in transit, projected respectively against the SEBZ and the southern EZ(S). |
| 2010 Mar 25 | 16:05–16:53 | Akutsu | Imaging with various filters | The shadow of Tethys was detected in transit. The satellite was in transit but not detected. |
| | 16:35 | Wesley | Colour image | The shadow of Tethys was detected in transit. The satellite was in transit but not detected. |
| 2010 Apr 7 | 21:50 | Heath | Visual | The shadow of Tethys in transit was suspected near to the *f.* limb. |
| 2010 Apr 21 | 03:55 | Maxson | Colour image | The shadow of Tethys was detected in transit. The satellite was in transit but not detected. |
| 2010 Apr 24 | 21:02–22:18 | Delcroix | Images with R, G, B, L, IR>742nm filters | Double transit of Tethys and Dione, which were detected in transit at the *f.* limb at 21:02 and 20:56, respectively. They were subsequently not detected. The shadow of Tethys was detected on the *f.* limb at 21:23, followed by Dione's shadow at 21:44, and they were subsequently tracked. |
| 2010 May 8 | 03:44–03:51 | Maxson | Colour images | The shadow of Tethys was detected in transit near the central meridian. The satellite itself was in transit but not detected. |
| 2010 May 14 | 03:27 | Maxson | Colour image | The shadow of Tethys was detected in transit. The satellite itself was in transit but it was not detected. |
| 2010 May 25 | 03:38 | Maxson | Colour image | The shadow of Tethys was detected in transit. The satellite itself was in transit but it was not detected. |
| 2010 Jun 11 | 03:42 | Maxson | Colour image | The shadow of Tethys was detected in transit. The satellite itself was in transit but it was not detected. |

**Table 10. Summary of observations of the transits of Dione & its shadow**

| *Date* | *UT* | *Observer* | *Observation type* | *Notes* |
|---|---|---|---|---|
| 2010 Jan 19 | 05:50 | Gray | Visual | Dione was seen leaving transit at the S*p.* limb. |
| 2010 Feb 21 | 00:31 | Abel | Visual | Dione and its shadow were seen in transit. |
| | 00:52 | Peach | Red-light image | The shadow of Dione was detected in transit. The satellite itself was in transit but it was not detected. |
| 2010 Mar 6 | 15:22 | Akutsu | Colour image | Dione and its shadow were detected in transit near to the *f.* limb, with the shadow lying N*p.* |
| | 15:32–16:39 | Go | Colour image. | Observation similar to that of Akutsu. |
| 2010 Mar 17 | 15:45–16:39 | Akutsu | Colour and IR images | The shadow of Dione was detected in transit. The satellite itself was in transit but it was not detected. |
| 2010 Apr 24 | 21:02–22:30 | Delcroix | See Table 9 | See Table 9 for description. |
| 2010 Apr 30 | 10:44 | Buda | Red-light image | The shadow of Dione was detected in transit. The satellite itself was in transit but it was not detected. |

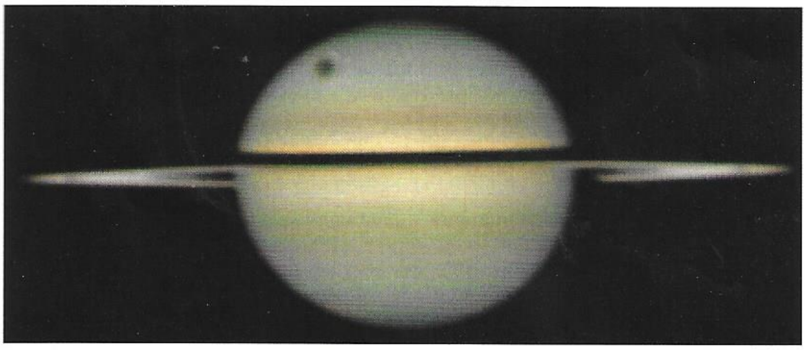


**Figure 13.** 2010 May 17, 10:01 UT; CM1 = 339.2°, CM2 = 236.4°, CM3 = 280.7°. (Image by Buda; 405mm DK with a DMK21AU04 camera.) This image shows Titan in transit.

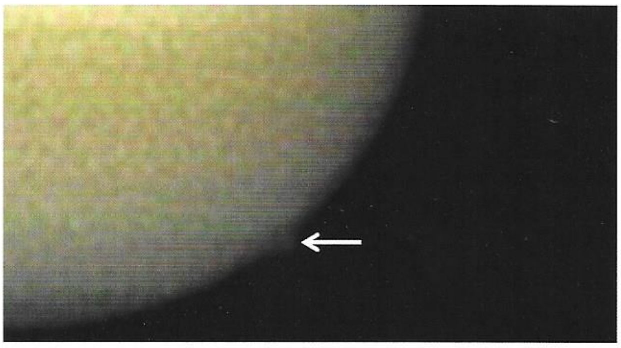


**Figure 14.** 2010 May 9, 03:44 UT. (Image by Go; 279mm SCT with a DMK 21F04 camera.) This is an enlargement of a section of the original image and shows Titan (labelled with a white arrow) re-emerging from occultation at the N*f.* limb of Saturn.

## Table 11. Summary of observations of the transits of Rhea & its shadow

| *Date* | *UT* | *Observer* | *Observation type* | *Notes* |
|---|---|---|---|---|
| 2009 Nov 21 | 05:50 | Gray | Visual | Rhea and its shadow were seen in transit. |
| 2010 Feb 19 | 15:54 | Wesley | Colour image | Rhea and its shadow were detected in transit with the shadow projected against the SEB(S) and Rhea faintly visible, projected against the STB(N). |
| 2010 Mar 9 | 15:31–15:46 | Go | Colour image | Rhea and its shadow were detected entering transit near Saturn's *f.* limb. |
| | 15:20–16:40 | Barry | Colour image | Rhea and its shadow were detected in transit near the central meridian (see Figure 6(b)). |
| 2010 Apr 28 | 09:40–11:24 | Barry | Colour images | Rhea's shadow was detected in transit. Rhea was in transit but not detected until after transit egress at 10:48 UT (see Figure 7(f)). |
| 2010 May 21 | 00:04 | Abel | Visual | Rhea's shadow was seen in transit. The satellite itself was in transit but not seen. |
| 2010 Jun 3 | 09:57–11:13 | Barry | Colour images | Rhea was detected in transit. It was only suspected in the image taken at 10:33, but it was definitely detected after 10:50. |
| | 10:41 | Wesley | Colour image | Observation similar to that of Barry; see Figure 8(f). |
| 2010 Jun 8 | 02:15 | Phillips | Colour image | Rhea's shadow detected in transit. The satellite itself was in transit but not detected. |

## Table 12. Summary of observations of the transits of Titan & its shadow

| *Date* | *UT* | *Observer* | *Observation type* | *Notes* |
|---|---|---|---|---|
| 2009 Oct 6 | 03:28–03:37 | Sussenbach (from Çamyuva, Turkey) | IR images | The image taken at 03:36:37, with a 127mm SCT, was heavily processed by the late Willem Kivits. Although noisy, it shows two separate dark spots in the southern hemisphere at the predicted positions of Titan and its shadow in transit. |
| 2010 May 1 | 10:54 | Wesley | Colour image | Titan was detected in transit, appearing as a dark spot projected against the southern hemisphere. |
| | 11:00–13:05 | Go | Colour images | Titan was detected in transit, appearing as a dark spot. It was imaged at transit egress at 12:10. The part of the satellite projecting from the *p.* limb appeared as a bright spot, whereas the part projected onto the planet appeared as a dark spot. It is not clear whether this dark appearance is real or a processing artefact. |
| 2010 May 17 | 09:01–10:01 | Buda | Red and colour images | Titan was detected in transit, appearing as a dark spot (see Figure 13). |
| | 10:09 | Wesley | Methane image | Titan was detected in transit, appearing as a bright spot. |
| 2010 Jun 2 | 04:46–05:58 | Maxson | Colour images | Titan was detected at transit ingress, and then appeared as a dark spot from 05:08. |

## Table 13. Summary of observations of the occultations of Rhea & Titan

| *Date* | *UT* | *Observer* | *Observation type* | *Notes* |
|---|---|---|---|---|
| 2010 May 9 | 13:05–14:04 | Go | Colour images | Rhea was detected approaching occultation disappearance at the *p.* limb, but the actual occultation was not imaged. Titan was imaged reappearing from occultation (see Figure 14). |

## Other observations

During this apparition, Saturn was projected against the constellation of Virgo which is well known for its deep-sky objects; the planet was observed close to a couple of such objects.

On Mar 7, Robertson observed Saturn in the same field of view as NGC 4179 with a ×135, 0.5-degree field-of-view eyepiece. This conjunction was also observed by Grego using a 300mm Newtonian with a ×35 eyepiece. He also recorded NGC 4073, NGC 4116 and NGC 4126 nearby.

On Apr 11, Grego recorded the planet close to NGC 4046 and NGC 4073, using a 445mm Newtonian with a ×77 eyepiece (Figure 15).

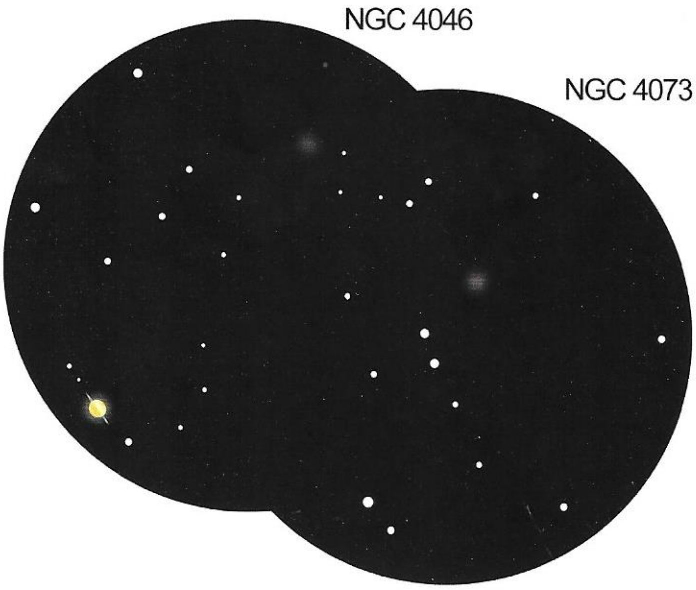



**Figure 15.** 2010 Apr 11, 23:50 UT. (Drawing by Grego; 445mm Newt.) This drawing shows Saturn near to NGC 4046 and NGC 4073.

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**Address:** 2 The Hawthorns, Henlow, Bedfordshire SG16 6BW [mike.foulkes@btinternet.com]

## References

1 *The Handbook of the British Astronomical Association 2009*, BAA, London, 2008
2 *The Handbook of the British Astronomical Association 2010*, BAA, London, 2009
3 *WinJUPOS*, free software available to download from: **jupos.privat.t-online.de/index.htm** (accessed 2021 March)
4 Foulkes M., 'Saturn during the 2008/2009 apparition, Part I', *J. Br. Astron. Assoc.*, **123**(4), 209–220 (2013)
5 Foulkes M., 'Saturn during the 2006/2007 apparition', *ibid.*, **120**(4), 206–218 (2010)
6 Fischer G., Barry T., Delcroix M., Go C., Peach D., Wesley A. *et al.*, 'Overview of Saturn Lightning Observations', pp. 134–144 of *Proceedings of the 7th International Workshop on Planetary, Solar and Heliospheric Radio Emissions held at Graj, Austria, September 15–17, 2010* (ed. Rucher H. O., Kurth W. S., Louam P. & Fischer G.), Austrian Academy of Sciences Press, Vienna (2011)
7 **https://Ciclops.org/ir_index/130/Cassini_In_Orbit** (accessed 2021 March)
8 **https://photojournal.jpl.nasa.gov/mission/Cassini** (accessed 2021 March)
9 McKim R., 'Saturn in 2002–2003', *J. Br. Astron. Assoc.*, **127**(2), 101–108 (2017)
10 McKim R., 'Saturn in 2003–'04', *ibid.*, **127**(6), 329–337 (2017)
11 McKim R., 'Saturn in 2004–'05', *ibid.*, **128**(2), 94–102 (2018)
12 Foulkes M., 'Saturn during the 2005/2006 apparition', **130**(2) 95–106 (2020)
13 Foulkes M., 'Saturn during the 2007/2008 apparition', **123**(4) 209–220 (2013)

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