# Saturn in 1996–'97

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*A report of the Saturn Section. Director: M. Foulkes*

BAA observations during the 1996–'97 apparition are reviewed. The planet's northern Equatorial Zone (EZ) had become quiescent late in 1995, and after the apparition reviewed here would be covered by the shadow of the rings. However, renewed white spot activity was apparent in the southern half of the EZ, and several relatively slow-moving spots were tracked, exhibiting the general slow current witnessed in the EZ since 1994–'95. The S. component of the Equatorial Band was wide and dark over long stretches, a development for which no historical precedent appears to exist. Dark spots were observed in the SEB, particularly in its S. component, but the NEB was inactive. Definite changes in belt latitudes had occurred since the previous opposition, particularly in the S. hemisphere, with a general poleward movement, which caused the STB to again be close to its historical average location. The rings were obliquely open upon the south face. The longstanding bicoloured ring observational programme continued, and two observers independently found that the *p.* ansa was brighter than the *f.* one on 1996 Sep 5. Shadow transits of Dione and Tethys were observed visually, and the transit of Tethys on 1996 Oct 30 was captured by a CCD camera.

## Introduction

Saturn was in opposition to the Sun on 1996 September 26, with the rings slightly open upon the southern face. The limiting solar conjunctions were on 1996 Mar 16 and 1997 Mar 30, and BAA data extended from 1996 Jun 21 (Gray) to 1997 Feb 15 (Bowyer). The value of the sub-Earth latitude ($D_e$) varied slightly, standing at –4° at opposition and varying from –3° to –6° during the period of observation. The planet was quite well placed for UK observers, its declination at opposition being –1°.

Interim analyses by D. L. Graham appeared in the BAA *Journal*[1–3] and *Circulars*.[4–5] A report was published by the ALPO.[6] An account by the UAI was also published,[7] but their data were not sent to the Section. A particularly good series of transit timings was again secured by Gray; measurements of bright spots in the EZ(S) from the CCD images of Asada, Miyazaki and Parker were also possible. A report from S. J. O'Meara accompanied an image secured with a large telescope on Hawaii. The total number of observations was lower than for the previous opposition when Saturn's rings had been edgewise.

This is the third in a series of Section Reports intended to narrow our publication gap, following on from 1995–'96[8] and 1994–'95.[9] Several professional papers[10–14] are relevant here.

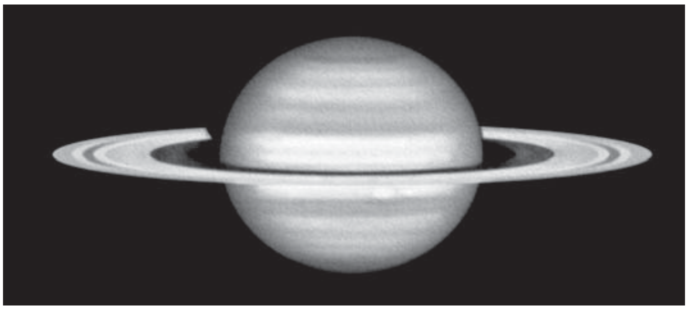

**Figure 1.** 1996 Jun 21d 02h 55m, $\omega_1$= 142°, $\omega_2$= 269°, 415mm DK Cass., ×262, *D. Gray*. The EZ(S)B is not yet dark; note the small EZ(N) white spot approaching the CM. The shadow of the rings on the globe is darkening the crepe ring crossing the globe. (Unless noted otherwise, all figures are drawings made by the observer. South is uppermost in all figures.)

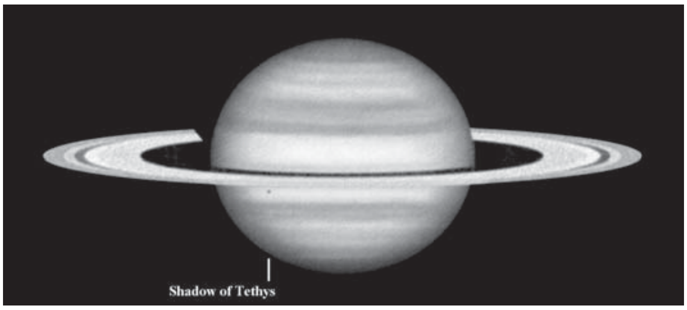


**Figure 2.** 1996 Aug 16d 03h 40m, $\omega_1$= 294°, $\omega_2$= 050°, 415mm DK Cass., ×348, *D. Gray*. Note the tiny shadow of Tethys in the EZ(N) between the p. limb and the CM, and the Encke complex in ring A.

## The globe

### *Global and ring colours*

At this opposition, any general difference in tint visually between the emerging S. and retreating N. hemispheres was at best marginal. Heath on 1996 Dec 13 and 28 found the N. hemisphere (NTropZ–NTeZ) grey compared with the slightly yellowish S. hemisphere (STropZ–STeZ). McKim found exactly the same effect on Nov 8 but otherwise did not notice any difference. Platt's single-shot colour image of Sep 15 (Figure 3) shows the NTeZ–NPR slightly bluish, compared with the southern hemisphere, but Miyazaki's colour composites (Figure 7) do not clearly show a more bluish N. hemisphere, and one from Sep 22 actually suggests the reverse. Parker's colour composites (Figure 8) also showed little difference, but we recall that perfectly satisfactory colour composite images were still not available in 1996, though they usefully revealed colour differences.

Miyazaki also made methane-band images (Figure 7) with a filter centred upon 893 nm.[15] These may be compared with Parker's work during 1995–'96.[8] The images showed that the region of the STeZ–STropZ was brighter than its N. counterpart, lending some support to the slightly colder tint reported in the north. The local reduction of aerosols and ammonia clouds in the north resulted in the underlying methane strongly absorbing in the near-infrared:

this results in a slight bluish or greenish tint, as constantly observed for Uranus and Neptune. At 893 nm, the EZ was the brightest part of the globe; the EZ(S) white spots (to be described below) looked brighter than the rest of the zone, but were still much fainter than the rings.

An obvious colour contrast between the hemispheres would become evident during the next apparition of 1997–'98.

There was nothing unusual to report during 1996–'97, although to Gray the planet's colours appeared more muted than usual. Visually the SEB and NEB were frequently reported to be brown or grey-brown: Weldrake's description of the SEB as 'rusty brown' on Sep 15 is typical. Gray found a slight difference between the SEB components on Jan 28: the SEB(N) had a strong ruddy hue and the SEB(S) was a very warm deep brown. Miyazaki's and Parker's best images show a brownish SEB and a reddish-brown NEB.

The EZ(S) was quite yellow or cream-yellow to all observers, and the EZ(N) only very slightly yellowish. The SPR, SPB and SSTB did not appear strongly tinted visually, and a cold grey or slightly bluish tint is indicated by the best CCD images. The SPR was particularly dark at 893 nm, supporting a cold tint. By contrast, Miyazaki's colour composite images suggest that the SSTeZ had a warmer tint than the STeZ or STropZ.

The rings appeared in shades of white and grey.

Heath (Oct 3–Dec 13) made a series of relative intensity estimates using the red (W25) and blue (W44A and W47) filters. These data confirmed that the EZ was the 'warmest' part of the disk with an average intensity that was considerably higher in blue than in red light.

**Table 1. Observers and observing groups**

| *Observer* | *Location(s)* | *Instrument(s)* |
|---|---|---|
| P. G. Abel | Burton on Trent, Staffs. | 114mm refl. |
| L. Aerts | Heist op den Berg, Belgium | 180mm OG |
| H. Asada | Kyoto, Japan | 310mm refl. |
| S.Beaumont | Windermere, Cumbria | 300mm refl. |
| N. D. Biver | Versailles, Paris, France | 256mm refl. |
| A. G. Bowyer | Epsom Downs, Surrey | 300mm refl. |
| T. R. Cave | Long Beach, CA, USA | 327mm refl. |
| J. S. Chapple | Bristol | 254mm SCT |
| E. Colombo | Milan, Italy | 152mm refl. |
| T. Dobbins | Coshocton, Ohio, USA | 254mm refl. |
| | Allegheny Obsy., Pittsburgh, USA | 330mm OG |
| M. Foulkes | Cleethorpes, S. Humbs. | 152mm refl. |
| | Hatfield, Herts. | 203mm SCT |
| | COAA, Portugal | 305mm & 500mm refls. |
| D. L. Graham | Richmond, N. Yorks. | 152mm OG & 406mm refl. |
| | Coshocton, Ohio, USA | 254mm refl. |
| | Allegheny Obsy., Pittsburgh, USA | 330mm OG |
| D. Gray | Spennymoor, Co. Durham | 415mm DK |
| A. W. Heath | Long Eaton, Notts. | 300mm refl. |
| L. T. Macdonald | Newbury, Berks. | 222mm refl. |
| R. J. McKim | Oundle, Northants. | 216mm refl. |
| C. E. Meredith | Manchester | 215mm refl. |
| M. Minami | Fukui City Obsy., Japan | 200mm OG |
| I. Miyazaki | Okinawa, Japan | 410mm refl. |
| S. L. Moore | Fleet, Hants. | 355mm refl. |
| D. Niechoy | Göttingen, Germany | 203mm SCT |
| S. J. O'Meara (with F.Rigaut & R.Arsenault) | CFHT, Mauna Kea, Hawaii, USA | 3.6 metre Cass. |
| D. C. Parker | Miami, Florida, USA | 410mm refl. |
| I. S. Phelps | Warrington, Cheshire | 114mm refl. |
| T. Platt | Binfield, Berks. | 318mm Tri-Schiefspiegler |
| J. H. Rogers | Linton, Cambs. | 254mm refl. |
| R. W. Schmude | Texas A&M Obsy., USA | 510mm refl. |
| D. Storey | Carterton, Oxon. | 254mm refl. |
| D.Weldrake | Stockton on Tees, Cleveland | 305mm refl. |

*Abbreviations*: OG= Refractor ('Object Glass'); refl.= Reflector; SCT= Schmidt–Cassegrain; DK = Dall–Kirkham Cassegrain.

**Figure 3.** 1996 Sep 15d 23h 42m, $\omega_1$= 050°, $\omega_2$= 251°, 318mm Tri-Schiefspiegler, Starlight Xpress CCD, *T. Platt.*

## Global features

### General

The overall appearance of the S. hemisphere was similar to that of the late 1960s or mid- to late 1970s with a dark SPR, a dark SSTB, fainter STB and broad, double SEB. Table 3 continues the historical record of latitudes and indicates that, unlike for the N. hemisphere belts, all those of the S. hemisphere were significantly more poleward of their positions in 1995–'96.[8]

### South Polar Region

As with 1995–'96, the cold grey SPR was dark, particularly in the CCD images. On four occasions (1996 Aug 4, Nov 7, Dec 4 and 1997 Feb 2) Gray considered he had resolved a small dark S. polar cap within the SPR, and the darker cap is very clearly shown in an infrared image by O'Meara on Sep 25.

The SPR was bordered by a dark S. Polar Belt (SPB). The SPB was not as dark as in the previous apparition.

### South South Temperate Zone

This was an obvious light zone at the edge of the SPR.

### South South Temperate Belt

The SSTB was relatively conspicuous and quite easy to see, and is shown in many of the drawings and images given here. On O'Meara's infrared image of Sep 25 it is quite weak, and fainter than the STB.

### South Temperate Zone

The STeZ was a featureless light zone.

### South Temperate Belt

The STB was fainter than the SSTB, being caught by the CCD cameras of Miyazaki and O'Meara, and by Biver, Graham (Figures 9, 14) and Gray (Figures 1–2, 12, 15) visually. Its visibility was helped by the relative lightness of the STeZ and STropZ. The belt was further from the equator than in 1995–'96, its average latitude once more in good accord with the historical norm.

### South Tropical Zone

Since 1995–'96, the STropZ had returned to normal, appearing light at all longitudes. It was featureless apart from faint light areas

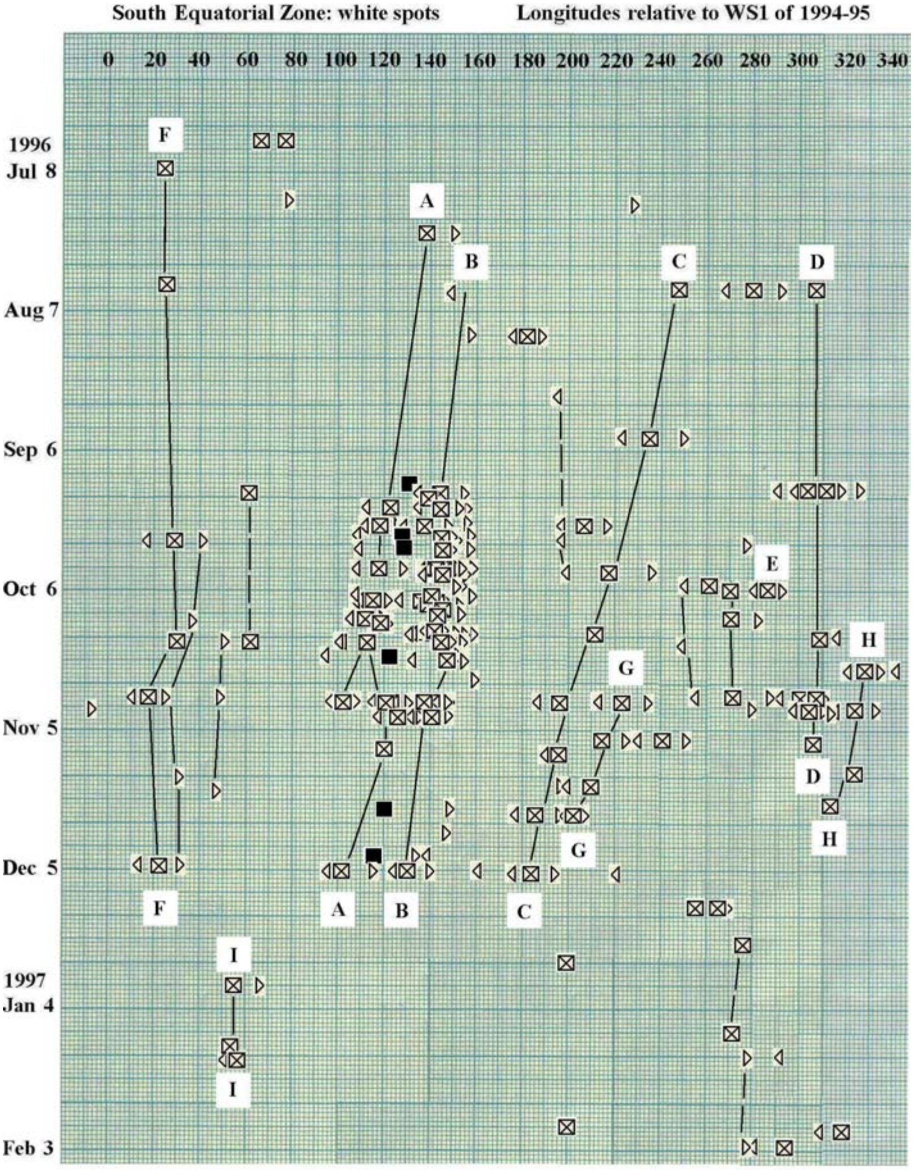


**Figure 4.** Chart of EZ(S) white spots, whose centres are plotted as crosses within white squares; *p.* and *f.* ends are also shown as open triangles. Longitudes are plotted in System I increasing by 10.65°/day, this being the average rate shown by the long-enduring feature 'WS1' of the 1994–'95 apparition and the first part of 1995–'96. The solid black squares are direct transits of the overall centre of the A/B complex: in the list of EZ(S) spots in the text, the motion of the centre of the complex was derived both from these plotted positions and from measurements of the centres of A and B on dates when both spots were individually transited.

centred near $\lambda_2$= 315° on 1996 Aug 4, at $\lambda_2$= 16° on Aug 12 (both illustrated in the *Journal*[1]), $\lambda_2$= 287° on 1996 Aug 31 and $\lambda_2$= 189° on Sep 26, all recorded by Gray. It is likely that the ovals seen on Aug 4 and 31 were the same feature: if so, a tentative period of 10h 37m 38s is indicated. The feature was adjacent to the S. edge of the SEB, and closely followed a dark SEB(S) spot on both dates.

| *Spot* | *Limiting dates* | *Limiting longitudes* | *No. obs.* | *$\Delta\lambda_2$ (°/day)* |
|---|---|---|---|---|
| WSc | 1996 Aug 4–31 | 315–287 | 2 | –1.01 |
| *STropZ period:* | | | | 10h 37m 38s |

Gray often saw a penumbral fringe to the south of the SEB(S).

## *South Equatorial Belt*

The SEB was broad and easily resolved into two roughly equal components. Both components lay a few degrees further south than in 1995–'96.

There were a number of obvious dark spots upon the SEB S. component (Figures 12, 14, 15). At the start of the apparition in 1996 June, Gray found the SEB(N) the darkest part of the SEB, but from mid-July the SEB(S) was sometimes the darker part. By August Gray generally found the SEB(S) darkest. The combined work of Graham and Gray showed this situation continued till the end of the apparition. Most of the dark spots seemed to move with negative drifts with respect to System II: there were several features and not enough transits close together in time, so no completely reliable rotation period could be derived.

The SEB(N) showed fewer dark spots than the SEB(S), and these rather seem to have been associated with the *p.* and *f.* parts of prominent EZ(S) white oval spots that sometimes overlapped or scalloped the belt's N. edge (see below, and Figures 11, 13). None was long-lived, and there were too few CM transits for identifications, though plotting the System I longitudes suggests slight negative drifts.

## *Equatorial Zone*

EZ(S): The EZ(S) was light and rather obviously yellowish, and the white spot activity observed during the apparition seems to have brightened it somewhat.

EZ(S) white spots were first seen on 1996 Jun 21 and 23 by Gray. The most conspicuous feature of the apparition was a close pair of bright spots in the EZ(S), denoted A and B, which were particularly well observed in Sep–Nov. (These are well shown in Figures 5, 6, 7 (upper part), 9–11, 13.) Spot A was seen for the first time on Jul 21 by Gray and Weldrake; the former found it faint, but the latter showed it conspicuously. Gray measured its centre at $\lambda_1$= 230°. (Weldrake's drawing was previously published.[1]) On Jul 20 Gray had observed the same longitudes somewhat following the CM without the spot having appeared yet. Spot B was first seen on Aug 3 by Gray, and it was 'very faint' then. Its *p.* end was not caught in transit but estimated at $\lambda_1$= 019°; neither were direct transits of the centre and *f.* end obtained. There were very few observations of the planet in Jun–Aug, and no others watched the longitudes of spots A and B. By September the 'A/B complex', as Graham described it,[1] was obviously bright. It was never as prominent, however, as the long-enduring white spot WS1 that had appeared in the *northern* part of the EZ during 1994–'95.[9]

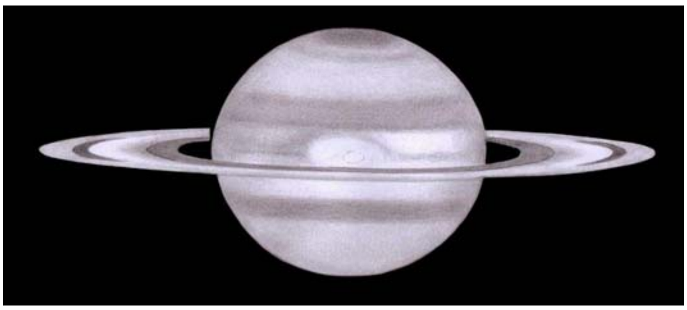

**Figure 5.** 1996 Sep 16d 22h 20m, $\omega_1$= 126°, $\omega_2$= 296°, 216mm refl., ×232, *R. J. McKim*. The EZ(S) A/B complex is at the CM and a bright nucleus is seen. The EZ(S)B/EB is deflected southwards by the complex. The SSTB is well seen.

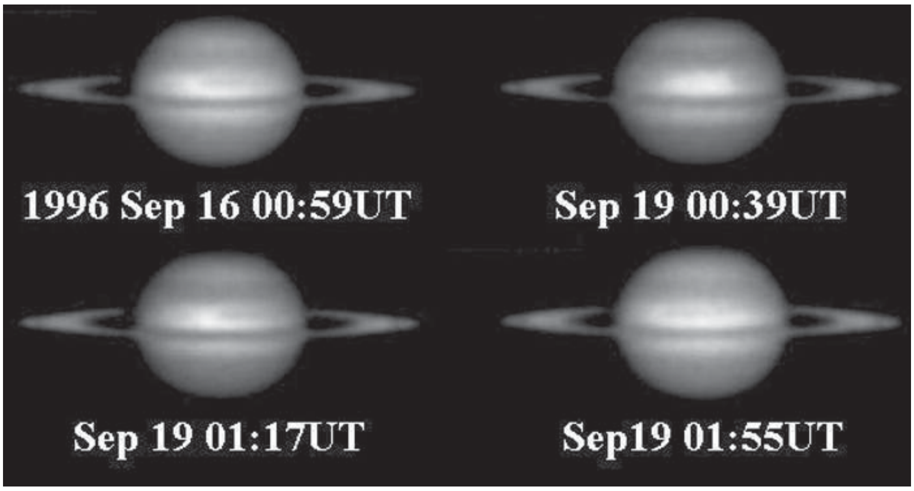


**Figure 6.** 1996 Sep16–19, 305mm refl., Mutoh CV-04 CCD, *H. Asada*. (Sep 15d 15h 59m, $\omega_1$= 139°, $\omega_2$= 349°; Sep 18d 15h 39m, $\omega_1$= 140°, $\omega_2$= 254°; Sep 18d 16h 17m, $\omega_1$= 162°, $\omega_2$= 276°; Sep 18d 16h 55m, $\omega_1$= 185°, $\omega_2$= 297°.) The EZ(S) A/B white spot complex is shown.

The lengths of spots A and B were most typically 15–30°, and their centres varied from about 20 to 30° apart: as separation was variable, there were fewer transits of A*f* and B*p* when the spots were relatively close. On Miyazaki’s Oct 30 images (Figure 10), the centres of A and B were only 17° apart but with another much fainter spot *p*. spot A. Spot A often appeared as a bright, slightly inclined teardrop, its long axis running N*p*. to S*f*, and this was particularly apparent to the writer on Nov 9 (Figure 13) and to Miyazaki’s camera on several dates. Spot B, originally at a similar southern latitude, as confirmed by the drawings of Graham on Oct 1 (Figure 9) and Aerts on Oct 2, was located more to the north by late October and early November: compare Miyazaki’s Sep 22, Oct 30 and Nov 2 images (Figures 7, 10). On Nov 2 Miyazaki’s images show that the *p*. end of spot B was at lower longitude than the *f*. end of A, so that they slightly overlapped on the chart. On Dec 5 Gray’s transits indicated a light area (spot B) between the EB and EZ(S)B in addition to another light area to the south, which lay between the EZ(S)B and the SEB(N).

The motions of the EZ(S) spots were dominated by the relatively slow-moving current recorded in the EZ(N) during 1994–’96, rather than by the faster current which seemed to be present in the southern part of the zone in 1995–’96. Longitude data from 14 observers (Figure 4) were again plotted against a reference point that increased by 10.65°/day in System I longitude.[8,9] Three other spots, C, D and F (Figure 4), were followed over several months, neither appearing as prominent as A or B. Spot C was indenting the N. edge of the EB, *e.g.*, to Miyazaki on Sep 22 (Figure 7, lower part). Graham’s account[2] also cites a white spot designated E (Figure 4), seen only once. The interactions of these spots with the belts in the surrounding zone are described later. A few other short-lived white spots could be identified with certainty, and these are denoted F–I in Figure 4. From Figure 4, the faster-moving spot G must have merged with C.

The rotation periods deduced are tabulated below.

| *Spot* | *Limiting dates* | *No. obs.* | *$\Delta\lambda_1$ (°/day)* |
|---|---|---|---|
| Ap | 1996 Sep 18–Dec 5 | 17 | +10.42 |
| Ac | 1996 Jul 21–Dec 5 | 14 | +10.39 |
| Bp | 1996 Aug 3–Dec 5 | 13 | +10.45 |

**Table 2. Visual intensity estimates, 1996–’97**

| *Feature* | *PA* | *SB* | *AB* | *MF* | *DGm* | *DGy* | *AH* | *RM* | *CM* | *SM* | *IP* | *RS* | *DS* | *DW* | *Ave.* | *No.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPC | – | – | – | – | – | 6.0 | – | – | – | – | – | – | – | – | 6.0 | 4 |
| SPR | 5.0 | 3.9 | 6.1 | – | 4.6 | 4.5 | – | 5.6 | 3.9 | – | 5.4 | 3.8 | – | 4.3 | 4.7 | 145 |
| SPB | – | – | – | – | – | 5.3 | – | – | – | – | – | – | – | – | 5.3 | 61 |
| SSTeZ | – | – | – | – | 3.7 | 3.4 | – | 4.5 | – | – | – | – | – | – | 3.9 | 70 |
| SSTB | – | – | – | – | 5.2 | 4.1 | – | 4.2 | – | – | – | – | – | – | 4.5 | 68 |
| STeZ | 3.5 | 2.6 | 3.2 | 3.2 | 3.0 | 3.1 | 3.0 | 3.3 | 3.4 | 4.8 | 3.0 | 2.8 | 3.4 | 3.8 | 3.3 | 199 |
| STB | – | – | – | – | – | 3.8 | – | – | – | – | – | – | – | – | 3.8 | 61 |
| STropZ | – | 2.0 | – | – | 2.6 | 2.6 | – | 3.4 | – | 4.8 | 3.0 | 2.8 | 3.4 | – | 3.1 | 108 |
| SEB(S) | – | 3.0 | 4.9 | – | 4.9 | 5.4 | – | 4.6 | 5.6 | – | 5.7 | 4.2 | – | 5.5 | 4.9 | 106 |
| SEBZ | – | – | 3.7 | – | 3.7 | 4.0 | – | 4.5 | 5.0 | – | – | – | – | – | 4.2 | 121 |
| SEB(N) | 5.0 | 4.1 | 4.9 | 4.9 | 4.6 | 5.3 | 5.0 | 4.9 | 5.6 | 6.6 | 5.7 | 4.3 | 4.3 | 5.7 | 5.1 | 169 |
| EZ(S) | 2.0 | 0.1 | 1.1 | 1.0 | 1.4 | 1.5 | 1.4 | 1.3 | 1.0 | 1.2 | 2.0 | 1.7 | 1.9 | 2.7 | 1.4 | 200 |
| EZ(S)B | – | – | – | – | – | 3.0 | – | – | – | – | – | – | – | – | 3.0 | 46 |
| EB | – | – | – | – | 2.8 | 2.5 | – | 2.8 | – | – | – | 3.0 | – | – | 2.8 | 50 |
| EZ(N) S.of rings | – | – | – | – | 1.9 | – | – | – | – | – | – | – | – | – | 1.9 | 7 |
| EZ(N) N.of rings | – | – | 2.0 | 1.9 | 2.1 | 2.0 | 1.9 | 1.6 | 1.6 | 4.0 | – | – | 2.9 | – | 2.2 | 161 |
| NEB(S) | 4.5 | 5.1 | 4.9 | 4.4 | 4.4 | 5.4 | 5.0 | 4.9 | 4.4 | 5.6 | 5.2 | 4.4 | 4.0 | 5.0 | 4.8 | 186 |
| NEBZ | – | – | – | – | 3.7 | 4.1 | – | 4.7 | – | – | – | – | – | – | 4.2 | 74 |
| NEB(N) | – | 4.5 | – | – | 4.4 | 5.2 | – | 4.9 | – | – | – | 4.3 | – | – | 4.7 | 87 |
| NTropZ | – | 2.2 | – | – | 2.8 | 3.2 | – | 3.5 | 3.6 | 4.1 | 3.0 | 2.7 | 3.3 | – | 3.2 | 151 |
| NTB | – | – | – | – | 3.5 | 4.0 | – | – | – | – | – | – | – | – | 3.8 | 60 |
| NTeZ | 3.0 | 3.3 | 3.8 | 3.1 | 3.2 | 2.9 | 3.3 | 3.5 | 3.6 | 4.1 | 3.0 | 2.7 | 3.3 | – | 3.3 | 194 |
| NNTB | – | – | – | – | – | 4.3 | – | – | – | – | – | – | – | – | 4.3 | 56 |
| NNTeZ | – | – | – | – | – | 3.5 | – | – | – | – | – | – | – | – | 3.5 | 56 |
| NPR | 5.0 | – | – | – | 3.7 | 4.8 | – | 3.5 | – | – | 6.3 | – | – | – | 4.7 | 78 |
| Ring A1 | 2.5 | 2.2 | 2.2 | 2.0 | 3.2 | 3.2 | 2.9 | 2.4 | 3.0 | 2.4 | 2.5 | 2.8 | 3.6 | 1.6 | 2.6 | 176 |
| Encke complex | – | – | – | – | – | 4.5 | – | – | – | – | – | – | – | – | 4.5 | 12 |
| Ring A2 | – | – | – | – | – | 2.5 | – | 2.4 | – | – | – | – | – | 1.5 | 2.1 | 73 |
| Cassini’s divn. | 9.0 | – | 7.9 | 8.6 | 8.1 | 5.8 | – | 5.3 | 4.0 | 3.0 | – | 7.0 | – | 6.3 | 6.5 | 98 |
| Ring B1 | – | 1.2 | 1.0 | 1.2 | 2.0 | 1.4 | 1.0 | 1.7 | 1.0 | 2.4 | 1.0 | 2.8 | 2.7 | 1.0 | 1.6 | 191 |
| Ring B2 | – | – | 1.9 | – | 2.5 | 2.9 | – | 1.9 | – | – | 2.5 | 2.8 | – | 1.5 | 2.3 | 90 |
| Ring C | – | – | – | – | 7.1 | 7.4 | – | 5.0 | – | – | – | – | – | 6.0 | 6.4 | 61 |
| Ring $C_m$ | – | – | – | – | 7.0 | 7.5 | – | 7.7 | – | – | 5.2 | 8.0 | – | 7.0 | 7.1 | 50 |
| ShRG | 9.5 | – | 7.7 | 9.9 | 9.4 | 9.2 | 9.0 | 10.0 | 8.6 | 7.4 | 9.5 | 7.7 | 7.8 | 9.0 | 8.8 | 172 |
| ShGR | – | – | 10.0 | 10.0 | 10.0 | – | – | 10.0 | 10.0 | – | – | 10.0 | 10.0 | 10.0 | 10.0 | 60 |
| Total used | 20 | 84 | 118 | 140 | 202 | 1,794 | 119 | 248 | 404 | 44 | 28 | 45 | 221 | 34 | – | 3,501 |

*Key to observers*: PA, Abel; SB, Beaumont; AB, Bowyer; MF, Foulkes; DGm, Graham; DGy, Gray; AH, Heath; RM, McKim; CM, Meredith; SM, S.L.Moore; IP, Phelps; RS, Schmude; DS, Storey; DW, Weldrake.

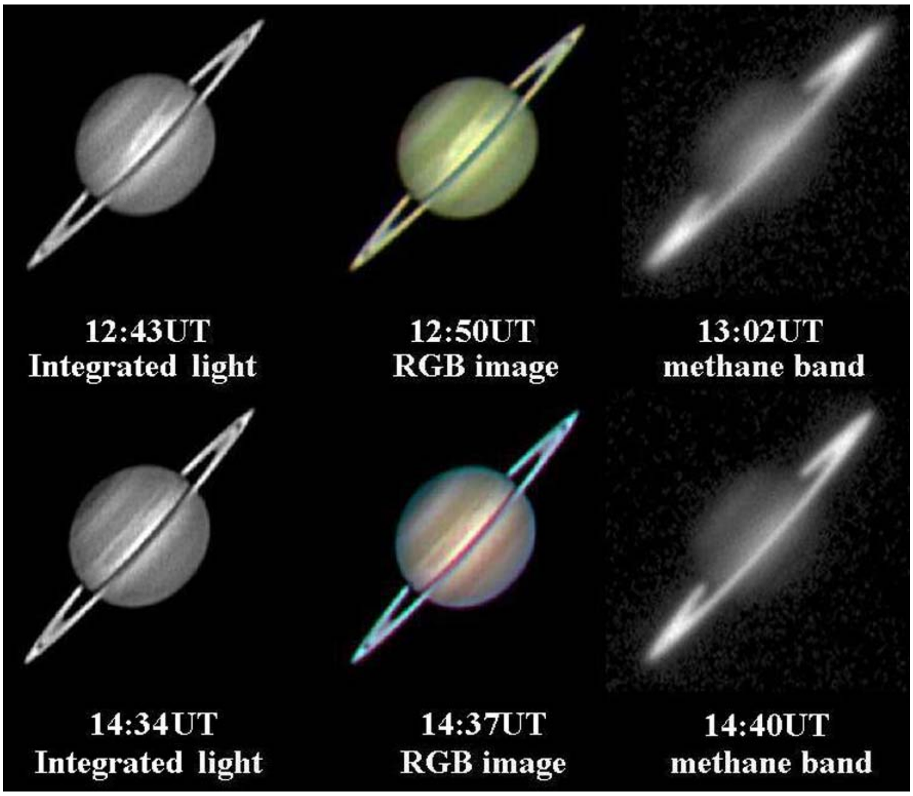


**Figure 7.** 1996 Sep 22, 410mm refl., Lynxx-PC CCD, *I. Miyazaki*. (12h 43m: white light image with NR400 filter (2s exposure), $\omega_1$= 175°, $\omega_2$= 164°; 12h 50m: tricolour composite image with NR400, red R60, green PO1 & blue B390 filters (3–20s), $\omega_1$= 178°, $\omega_2$= 167°; 13h 02m: methane band image with 893nm 893BP5 filter (90s), $\omega_1$= 186°, $\omega_2$= 174°; 14h 34m: white light image, $\omega_1$= 239°, $\omega_2$= 226°; 14h 37m: tricolour composite image, $\omega_1$= 242°, $\omega_2$= 228°; 14h 40m: methane band image, $\omega_1$= 243°, $\omega_2$= 229°.) The EZ(S) white spot complex A/B is shown near the CM in the top row, and in the lower row spot C indents the EB on its N. side *f.* the CM.

| | | | |
|---|---|---|---|
| Bc | 1996 Sep15–Dec 5 | 23 | +10.47 |
| Bf | 1996 Aug 12–Dec 5 | 36 | +10.50 |
| A/Bc (overall) | 1996 Sep 13–Dec 5 | 15 | +10.48 |
| Cc | 1996 Aug 2–Dec 6 | 8 | +10.15 |
| Dc | 1996 Aug 2–Nov 8 | 8 | +10.63 |
| Fc | 1996 Jul 7–Dec 4 | 6 | +10.65 |
| Ff | 1996 Sep 25–Dec 4 | 5 | +10.51 |
| Gc | 1996 Oct 30–Nov 23 | 4 | + 9.76 |
| Hc | 1996 Oct 23–Nov 21 | 4 | +10.13 |
| Ic | 1996 Dec 30–'97 Jan 15 | 3 | +10.77 |
| Average for A–D, F and I, omitting G and H: | | | +10.49 |
| *EZ(S) average period:* | | | 10h 21m 43s |

Graham[2] derived preliminary rotation periods for A, B and C over the shorter interval Oct 1–31, but during Sep–Oct spots A and B were nearly stationary in longitude (Figure 4); in particular, the longitude of the *f.* end of spot B was remarkably constant from Sep 15–Oct 26. However, the full dataset shows that a slight negative drift was apparent immediately before and after that epoch, and that the longitudes of both A and B individually, as well as their 'centre of gravity', showed a slight oscillatory motion.

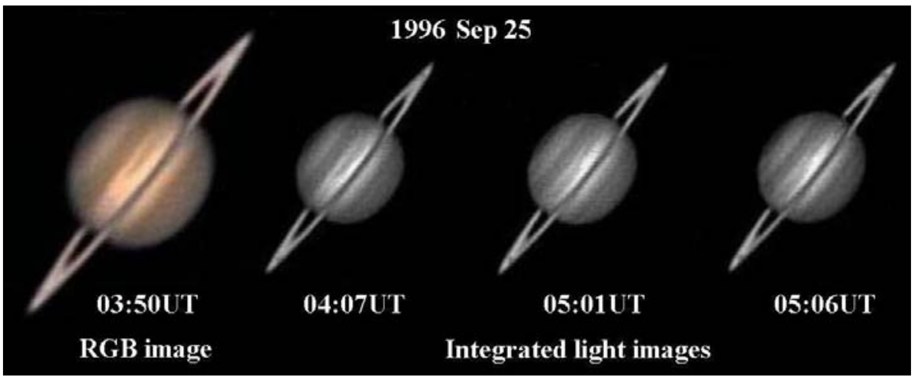


**Figure 8.** 1996 Sep 25d 03h 50m, $\omega_1$= 236°, $\omega_2$= 139°, 400mm refl., f/27, Lynxx-PC CCD, *D. C. Parker*. In this RGB collage together with other timed white light images, EZ(S) white spot activity precedes the darkened segment of EZ(S)B/EB.

The continuing slowness of the EZ current since 1994–'96[8,9] is interesting. Sanchez–Lavega *et al.*[13] wrote that their observations 'showed a strong increase of white cloud activity in the southern Equatorial Zone (latitude −13.5°) during 1996, declining later on during 1997', and that two prominent plumes and other features had velocities 'lower than those measured with the *Voyagers*. Altitude differences in the clouds and hence different zonal velocities, or real changes in the zonal jet as a consequence of Saturn's insolation cycle and ring-shadowing, can be the reason for such differences.' The latitude of the subsolar point lay within the EZ(S) throughout the period of observation.

The normal Equatorial Band (EB) was joined at its southern edge over long stretches of longitude by a wider and darker belt, which Graham denoted the EZ(S) Band, or EZ(S)B. At the last opposition we noted of the EB that: 'At high resolution ... the EZ(S) revealed a faint southern component of the Equatorial Band (EB).'[8] It was this southern component that darkened so considerably in the summer of 1996, and it became particularly wide and dark just preceding the A/B complex, at which point it veered south to join the SEB(N)n. Following spot B, it continued, widely separated from the normal EB, becoming darker south of spot C (a feature which indented the N. side of the EB and lay closer to the equator). Following C, it gradually faded, moved north towards the EB, and eventually merged with it. Variation in the EZ(B)S over time as well as the A/B complex was well shown in the fine series of Miyazaki images on 1996 Sep 22 and Oct 30 (Figures 7, 10),[2] and in Parker's of Sep 25 (Figure 8). A search of the historic literature showed the breadth and darkness of the transitory EZ(S) Band within the EZ to be quite unprecedented.

The EZ(S)B seems to have darkened in 1996 July. On Jun 21 it was not yet very conspicuous to Gray, but on Jul 1 he showed it broader and a little darker. On Jul 17 he found the EZ(B)S to be interacting with filaments from the SEB(N)n, and on Jul 20 wrote: 'Since 02:50 [UT] much of the *f.* SEB(N)n has appeared less defined and there is a duskiness/veil over the S. two-thirds of the EZ. By 03:30 this looks well *p.* the CM.' An estimated transit of 03:05 led to $\lambda_1$=154.7°, or 72.2° in the longitude system adopted for Figure 4, being some 50° ahead of where spot A was to be observed for the first time the following day. This longitude region was precisely the one where the EZ(S)B would continue to interact with the SEB(N)n. According to Weldrake's drawing on Jul 21, the EZ(S)B following spot A was not yet conspicuous. On Jul 15 Gray had not yet seen any sign of the feature in the longitudes that he was to observe again on Jul 20.

There were not so many observations of the planet before August, but by Aug 2 Asada's images showed that the EZ(S)B was already well-formed just preceding spot D. It was not yet conspicuous at all longitudes: Gray's drawing of Aug 4[1] does not show it in the region following spot B, but on Aug 12[1] he saw a short section of it close to the SEB(N)n immediately *f.* spot B.

Several times there were other, transitory gaps noted in the EB and in the EZ(S)B, and some of these

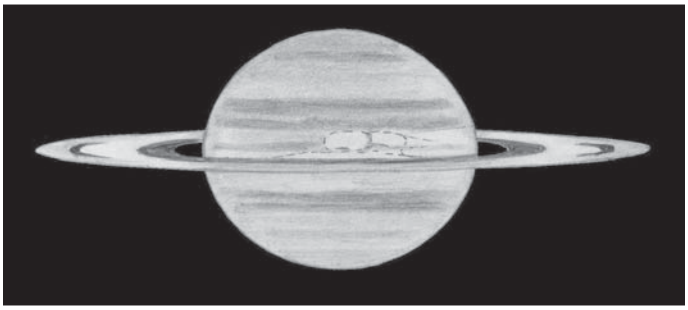

**Figure 9.** 1996 Oct 1d 03h 45m, $\omega_1$= 258°, $\omega_2$= 329°, 254mm refl., ×328, *D. L. Graham*. The EZ(S) A/B complex is at the CM.

were plotted on the chart as unlabelled features, though they were not brighter than the EZ(S). These gaps – which we can also regard as the *p.* and *f.* ends of dark strands of EZ(S)B – also shared in the general slow current.

On Oct 17 Dobbins considered the *p.* end of the A/B complex to be faded. As to the eventual decline in activity in the EZ(S), we can see that there were no sightings of the A/B complex nor of spot C after 1996 Dec 5, although continuing observations would record other, fresh white spots into 1997 Feb, so we must assume that spots A, B and C really had disappeared. According to Gray's notes, the EB and EZ(S)B remained visible at least until 1997 Feb 7: as there is no evidence to show their decline, any fading must have occurred during the following solar conjunction. By next opposition time, there would remain only a faint remnant of the EZ(S)B.

EZ(N): A tiny part of the EZ(N) was visible between the EB and the rings crossing the globe, but it was best seen to the N. of the rings, partly hidden by the rings and their shadow in that location. It showed only sporadic hints of white spot activity (Figure 1), and was always less bright than the EZ(S).

### North Equatorial Belt

The NEB was closely double, appearing less broad than the SEB with a rather dark intermediate zone (NEBZ) and more or less equal components. Its N. component lay closer to the equator than at the previous opposition, narrowing the belt overall. The NEB never showed any appreciable activity, though a dark spot on the NEB(S) was transited twice over a short period by Gray, and given the rarity of such spots, its identification is almost certain. A few other features could be tentatively identified, and also suggest very slight positive drifts with respect to System I.

| *Spot* | *Limiting dates* | *Limiting longitudes* | *No. obs.* | *$\Delta\lambda_1$ (°/day)* |
|---|---|---|---|---|
| DSf | Oct 29–Nov 10 | 043–048 | 2 | +0.43 |
| *NEB(S) period:* | | | | 10h 14m 19s |

There were also one or two transient condensations in the NEB(N), but no periods could be derived.

### North Tropical Zone

Light, like the STropZ, and without detail except for the thin NTropB that could be detected upon a few of Miyazaki's best images of Figure 10, looking like the NTB further north. It was also caught by O'Meara's Sep 25 image.

### North Temperate Belt

Rather thin and low in contrast against the dusky NTeZ. It was caught only by Biver, Graham (Figures 9, 14), Gray (Figures 1, 2, 12, 15), O'Meara, Miyazaki (Figure 10) and Parker.

### North Temperate Zone

The NTeZ was darker than the NTropZ.

### North North Temperate Belt

This was represented by Gray as a very thin belt. Miyazaki's best images confirmed its presence, and that it was darker than the NTB.

### North Polar Region

The S. edge of this dusky area fringed the extreme N. limb, and the latitudes derived from measurements look to be more typical of the NPBs than the NPRs.

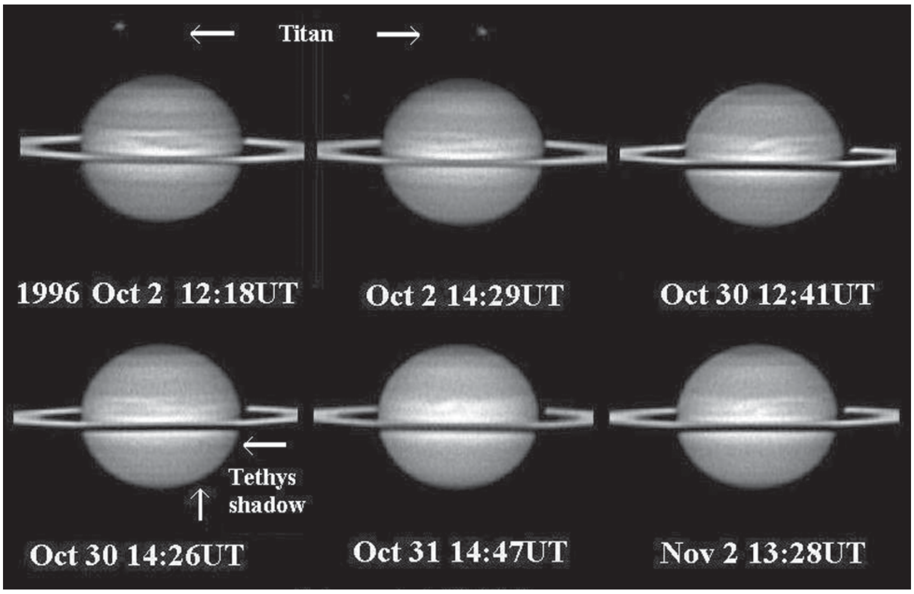


**Figure 10.** 1996 Oct 2–Nov 2, 410mm refl., Lynxx-PC CCD, white light images with no filter (exposure 1s), *I. Miyazaki*. (Oct 2d 12h 18m, $\omega_1$= 324°, $\omega_2$= 350°; Oct 2d 14h 29m, $\omega_1$= 040°, $\omega_2$= 064°; Oct 30d 12h 41m, $\omega_1$= 218°, $\omega_2$= 060°; Oct 30d 14h 26m, $\omega_1$= 280°, $\omega_2$= 119°; Oct 31d 14h 47m, $\omega_1$= 056°, $\omega_2$= 223°; Nov 2d 13h 28m, $\omega_1$= 259°, $\omega_2$= 002°.) Note Titan near superior conjunction south of the planet's S. pole on Oct 2, the shadow of Tethys on Oct 30, the interaction between several different EZ(S) white spots and the EZ(S)B and EB, and the interaction of the EZ(S)B with the SEBn.

## The rings

### General

The methane band images (Figure 7) showed the rings very bright compared to the brightest part of the globe.

### Ring A

It was possible to see that the outer part of ring A was a little darker than the inner. An image by O'Meara from Hawaii with the 3.6 metre telescope clearly shows the Encke Division towards the outer edge of the ring, as well as a shading marking the 'Encke complex'. Gray was also able to see the Encke complex at low resolution (see Figure 2 especially).

### Cassini's Division

Cassini's Division was hard to see at the ansae except in good seeing, and to most observers (including the UAI group[7]) it looked greyish rather than black. There was a large range in average intensity estimates (Table 2), but this was partly due to varia-

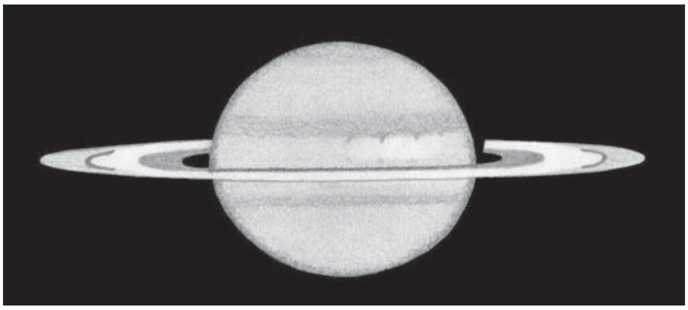

**Figure 11.** 1996 Oct 12d 19h 31m, $\omega_1$= 021°, $\omega_2$= 075°, 300mm refl., ×340, *D.Weldrake*. EZ(S) white spot activity is approaching the CM, interacting with the SEBn.

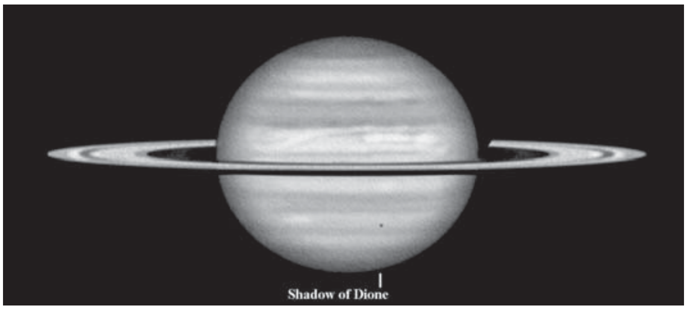


**Figure 12.** 1996 Oct 29d 21h 20m, $\omega_1$= 038°, $\omega_2$= 261°, 415mm DK Cass., ×348, *D.Gray*. Note the shadow of Dione against the NTropZ, *f.* the CM. The EZ(S) remains active with a tilted EZ(S)B.

tion in $D_e$.[16] With $D_e$ adequately large, the division appeared as a short arc.

### *Ring B*

Ring B was resolved into components B1 and B2. McKim specifically noted the contrast in brightness between rings A and B to be very small, and some others supported this view with their intensity estimates (Table 2). This small difference doubtless owed its origin to the narrow angle of opening of the rings.[16] Ring B1 appeared generally less bright than the standard value of 1.0, a point agreed upon by the UAI.[7] Observers more normally saw the EZ(S) as the brightest part of the telescopic image.

On Sep 25 O'Meara *et al.* obtained a superb CCD image with the 3.6 metre telescope on Hawaii that showed five 'spokes' very distinctly on the *f.* ansa of ring B. This image can be viewed online.[17] O'Meara commented that spokes had already been imaged by the Pic du Midi observers.

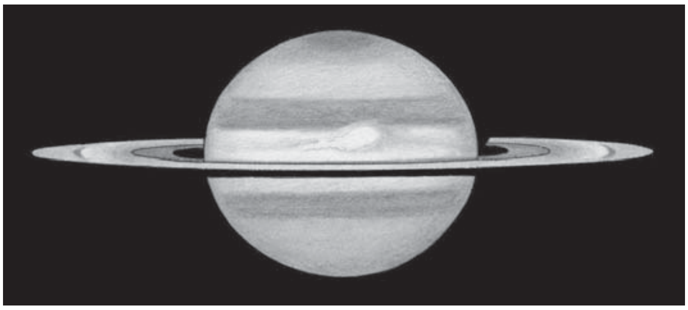

**Figure 13.** 1996 Nov 9d 21h 10m, $\omega_1$= 320°, $\omega_2$= 187°, 216mm refl., ×232, *R. J. McKim*. The bright EZ(S) white spot A, tilted slightly with respect to the equator, is approaching transit.

### *Ring C*

Ring C was sometimes hard to make out, but it was noted as being somewhat lighter than with the rings widely open:[16] it appears on Parker's 1996 Oct 29 image and Platt's Sep 15 image (Figure 3).

**Table 3. Saturnicentric latitudes, 1996–'97**

| *Feature* | *DGm* | *DGy* | *S'OM* | *RM* | *CM* | *IM* | *DP* | *Average* |
|---|---|---|---|---|---|---|---|---|
| SPCn | – | – | −69.6 | – | – | – | – | −69.6 |
| SPRn | −64.0 | −59.2 | −62.0 | −62.3 | −66.0 | −67.0 | – | −63.4 |
| SPBs | – | −59.2 | −62.0 | – | – | −67.0 | – | −62.7 |
| SPBc | – | −56.8 | −60.0 | – | – | −63.0 | – | −59.9 |
| SPBn | – | −54.3 | −58.1 | – | – | −58.9 | −59.4 | −57.7 |
| SSTBs | −56.2 | −50.5 | −54.6 | – | – | −48.9 | −48.8 | −51.8 |
| SSTBc | −52.8 | −48.4 | −53.3 | −52.7 | – | −46.6 | −46.8 | −50.1 |
| SSTBn | −49.4 | −46.3 | −52.0 | – | – | −44.2 | −44.8 | −47.3 |
| STBs | – | −41.1 | −43.3 | – | – | – | – | −42.2 |
| STBc | – | −38.6 | −41.4 | – | – | −37.5 | – | −39.2 |
| STBn | – | −36.1 | −39.3 | – | – | – | – | −37.7 |
| SEB(S)s | −27.6 | −29.5 | −31.6 | −28.3 | −28.6 | −31.0 | −32.2 | −29.8 |
| SEB(S)n | −23.3 | −24.8 | −24.6 | −24.6 | – | −27.6 | −28.7 | −25.6 |
| SEB(N)s | −18.4 | −19.6 | −21.5 | −19.0 | – | −19.8 | −22.1 | −20.1 |
| SEB(N)n | −13.7 | −15.1 | −15.9 | −13.4 | −15.0 | −16.0 | −17.7 | −15.2 |
| EZ(S)Bs | – | – | – | – | – | −12.2 | – | −12.2 |
| EZ(S)Bc | – | -8.7 | −12.6 | – | – | −10.8 | −11.9 | −11.0 |
| EZ(S)Bn | – | – | – | – | – | −9.3 | – | −9.3 |
| EBs | – | – | −4.8 | – | – | −6.0 | – | −5.4 |
| EBc | −4.0 | −1.8 | −3.8 | −3.5 | – | −4.2 | −6.9 | −4.0 |
| EBn | – | – | −2.7 | – | – | −2.4 | – | −2.6 |
| NEB(S)s | +17.1 | +13.2 | +16.2 | +12.9 | +12.5 | +12.7 | +15.6 | +14.3 |
| NEB(S)n | +19.0 | +16.3 | – | +16.6 | – | +15.8 | – | +16.9 |
| NEB(N)s | +21.9 | +19.2 | +20.5 | +19.9 | – | +19.7 | – | +20.2 |
| NEB(N)n | +25.6 | +22.2 | +26.9 | +24. 7 | +20.3 | +26.5 | +26.1 | +24.6 |
| NTropBc | – | – | +31.6 | – | – | +30.3 | – | +31.0 |
| NTBs | +35.6 | +29.9 | +37.2 | – | – | – | – | +34.2 |
| NTBc | +37.6 | +32.2 | +37.8 | – | – | +38.3 | +35.7 | +36.3 |
| NTBn | +39.6 | +34.5 | +38.4 | – | – | – | – | +37.5 |
| NNTBc | – | +42.6 | – | – | – | +47.6 | – | +45.1 |
| NPBs/NPRs | – | +51.8 | +55.8 | – | – | +58.3 | – | +55.3 |
| Total | 104 | 156 | 28 | 31 | 39 | 90 | 69 | 517 |

*Key to observers*: DGm, Graham; DGy, Gray; S'OM, O'Meara (image); RM, McKim; CM, Meredith; IM, Miyazaki (images); DP, Parker (images). Graham, Gray and Meredith reduced their own work; other data were reduced by McKim.

### *Ring C crossing the globe ($C_m$)*

Extremely foreshortened, but recorded in better seeing.

### *Shadow of rings on globe*

Early in the apparition ShRG darkened $C_m$ at the southern edge of the rings crossing the globe, being mostly hidden by the rings crossing the globe, but detectable till mid-September. After a short period of being hidden by the rings crossing the globe, it reappeared to their north in October (compare Figures 11 and 12), changing in width as the altitudes of the Sun and Earth above the illuminated rings changed in relation to each other.

### *Shadow of globe on rings*

ShGR was seen on the western side until Sep 19 (Niechoy); opposition was on Sep 26; it was again seen to the east from Oct 2 (Niechoy) onwards.

### *Bicoloured aspect of the rings*

The bicoloured aspect of the rings was reported by few observers. Bowyer saw ring B brighter in the *p.* ansa, 1997 Feb 15. Cave saw the ansae equal in white, red and blue light, 1996 Sep 15. Heath saw no difference between the ansae in white, red or blue light on any of his observing dates between 1996 Oct 3 and 1997 Jan 14.

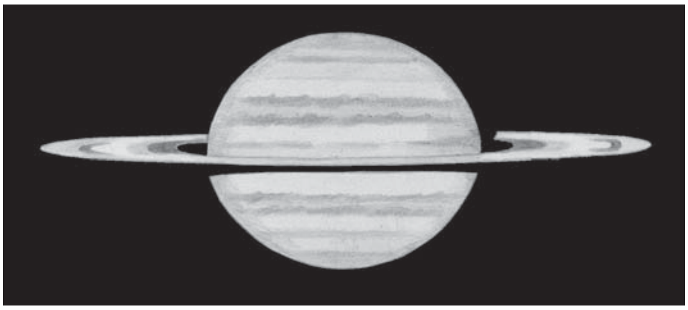

**Figure 14.** 1996 Nov 18d 20h 00m, $\omega_1$= 317°, $\omega_2$= 255°, 400mm refl., ×333, *D. L. Graham.* The SEB shows a good deal of structure, with both the STB and NTB shown.

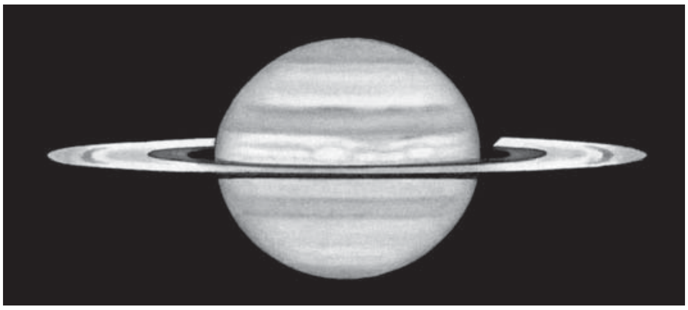

**Figure 15.** 1996 Dec 6d 18h 00m, $\omega_1$= 323°, $\omega_2$= 042°, 415mm DK Cass., ×348, *D.Gray*. The EZ(S)B/EB are still present, together with a number of EZ white spots.

There was unusual accordance between positive observations by two different observers on 1996 Sep 5: on that date, Macdonald saw the Cassini Division more easily in the *p*. ansa, and Meredith found the *f*. ansa darker than the *p*. one. These observations were made in white light. A greater brightness of ring B on the *p*. side would certainly have made the division easier to see by contrast. Two observations by S. Moore around this time also fit in: on Sep 21/22 the Cassini Division was easier to see on the *p*. side, while on Sep 27/28 the rings looked darker in the *f*. ansa.

Finally, Weldrake on Oct 12 found ring C marginally brighter in the *f*. ansa.

The ALPO[6] also recorded a few observations of an E–W brightness difference in the rings.

## The satellites

According to the 1997 BAA *Handbook*, the series of phenomena involving Titan came to an end on 1997 Apr 25, but no observations are to hand of these events. However, there were a few records of other satellite phenomena.

Gray caught the shadow of Tethys midway from the CM to the *p*. limb, against the EZ(N) north of the rings, on 1996 Aug 16 at 03h 40m. It appeared as a minute grey dot (Figure 2). Gray further recorded an eclipse disappearance of Rhea by the planet's shadow on Sep 1 at 00h 53m 39±5s, the 1996 BAA *Handbook* prediction being 00h 57m. Foulkes easily saw Enceladus at E. elongation with a 510 mm aperture on Sep 15. On Oct 29 at 21h 20m Gray caught the shadow of Dione as a tiny grey spot approaching the CM against the background of the NTropZ (Figure 12).

On Oct 30 Tethys was S*p*. its shadow while in transit. Miyazaki's CCD camera caught this event between 13:59 UT and 15:46 UT: the images (Figure 10) reveal a dark grey shadow against the southern NEB with certainty, moving at the correct rate from image to image: a few frames even suggest Tethys itself as a lighter dot against the EZ(N). This is likely to mark the first time such a Tethys event was imaged by a ground-based observer. (Miyazaki had already succeeded in taking images of transits and shadow transits of both Rhea and Titan in 1995–'96.[8]) Miyazaki's images of Oct 31 do not, however, record the transit of Enceladus that was scheduled for that date.

## Acknowledgment

David Graham collected the bulk of the observational records summarised in this report, and carried out a very useful preliminary analysis of the EZ(S) white spots.

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