Saturn in 1997–'98

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

Saturn during 1997–'98 exhibited a much lower degree of white spot activity in the Equatorial Zone, none of the features being long-lived. There was evidence of the continuation of the relatively slow equatorial current of 1994–'96, but the focus of spot activity upon the planet seems to have migrated southward to the latitudes of the South Equatorial Belt and the South Tropical Zone: periods were derived for a few SEB(S) dark spots and some small white oval spots in the STropZ. A distinct difference in colour was apparent between the warm-tinted S. hemisphere and the bluish-grey, retreating, N. hemisphere. Despite the rings' opening further towards the Earth and Sun, Tethys could still be recorded in transit, grazing the N. limb of the planet. Numerous fine divisions were observed upon the south face of the gradually opening rings.

Introduction

Saturn came to opposition on 1997 Oct 10. At declination +4°, the planet was 5° higher than at the previous opposition. The rings continued to open on the northern face: D_e at opposition was –10°. The limiting solar conjunctions occurred on 1997 Mar 30 and 1998 Apr 13, and BAA work covered 1997 Jul 6 to 1998 Feb 22.

Of the overseas observers, Nicolas Biver employed his 26cm reflector from his new home on Hawaii. In 1997 October, David Graham joined a group of American amateurs observing with large reflectors at the home of Tom Dobbins, while the writer had a profitable evening of perfect seeing at high altitude during a short visit to Arizona in the same month. From the UK, David Gray obtained a long list of valuable transit-timings: without his efforts no rotation periods at all could have been derived for the apparition. Several observers (Asada, Dijon, Meredith, Miyazaki, Mobberley, Parker and Platt[1]) took CCD images. During the apparition a BAA Saturn Section webpage was launched, and observational notes appeared in the *Journal*.[2,3] Apparition reports were published by the ALPO and UAI.[4]

The Hubble Space Telescope took a few high resolution images of the planet.[5] The year 1997 was historic, marking the launch of the *Cassini* spacecraft.[6]

This report continues from 1996–'97,[7] 1995–'96[8] and 1994–'95,[9] extending the new series that is intended to fill a long gap in the publications of the Section.

The globe

Colours

In 1997–'98 the whole N. hemisphere north of the NEB was found to have a bluish or azure colour, which contrasted strongly with the warm-tinted south. This effect was most strongly apparent to the group of observers using the telescopes of Tom Dobbins during 1997 Oct 14–20, when conditions were excellent, the effects being witnessed by Jeff Beish, Tom Cave, David Graham, Don Parker and others.[2,10] Historically, blue tints were thought to be confined to Saturn's polar regions.[11]

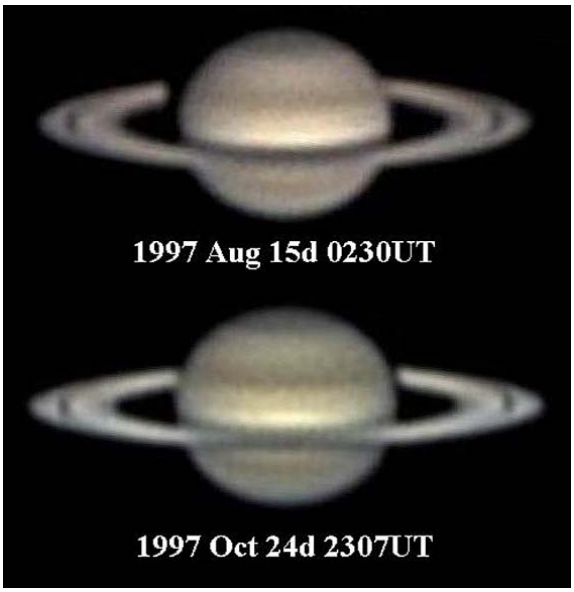

Figure 3. 1997 Aug 15d 02:30UT, ω_1= 125°, ω_2= 006°, and Oct 24d 23:07UT, ω_1= 197°, ω_2= 309°, 318mm Tri-Schiefspiegler, Starlight Xpress CCD, *T. Platt*.

Evidence for the hemispherical difference can be seen in some colour CCD images. Moreover, filter images by Parker on Oct 27 (Figure 11) showed the N. hemisphere lighter in blue than in red light, whereas the warm-tinted SEB and NEB were darkened in blue. On Oct 3 Miyazaki secured a methane band image (Figure 7) where the N. hemisphere was so dark as to be barely distinguishable from the background sky, demonstrating the depletion of aerosols and ammonia to the north, which would allow the underlying methane to absorb the longer wavelengths, resulting in a blue tone. Some colour composites suggest a colder tone in the north (Figures 3, 11). Further confirmation comes from a false-colour infrared HST image of Jan 4 (Figure 14), in which the false blue tint of the N. hemisphere represents a clear upper atmosphere.[12] In this image the SPC/SPR also looks to have a clear atmosphere above it. McKim and Blaxall have discussed how this north–south asymmetry was quite marked at similar past oppositions between 1947 and 1981,[13] while Sheehan (with large apertures) in 1992 and 1993[14] saw the reappearing S. hemisphere distinctly bluish compared with the warm-hued N. hemisphere that had been exposed to the Sun for years.

Of the other Section members, Gray unfortunately did not make systematic colour notes with his large aperture during the apparition (nor in 1996–'97), but a slight N–S difference in tint was confirmed by Foulkes, Heath and McKim with smaller reflectors. To Foulkes, the S. hemisphere (STeZ–STropZ) was yellowish-grey, whereas the N. hemisphere was simply grey, and somewhat darker than the S. hemisphere. On Oct 26 Heath found the N. hemisphere colder than the S, and the N. hemisphere was specifically described as slate-hued on Oct 18 and Nov 12. McKim found the S. hemisphere generally slightly yellowish, with the N. hemisphere grey, but on two occasions (Oct 4, Dec 26) the latter showed a distinct blue-grey tone.

Turning to the other features, Graham and Dobbins described the SPR as azure, slate grey or bluish-grey, the SSTB as slate-grey,

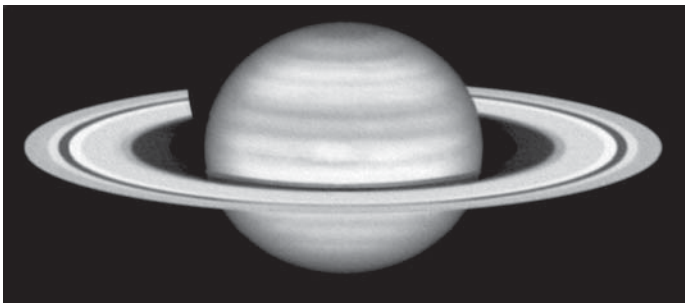

Figure 1. 1997 Jul 27d 04:00UT, ω_1= 335°, ω_2= 107°, 415mm DK, ×348, *D. Gray*. Shows a small white spot in the EZ(S). [Unless noted otherwise, all figures are drawings made by the observer. South is uppermost in all figures.]

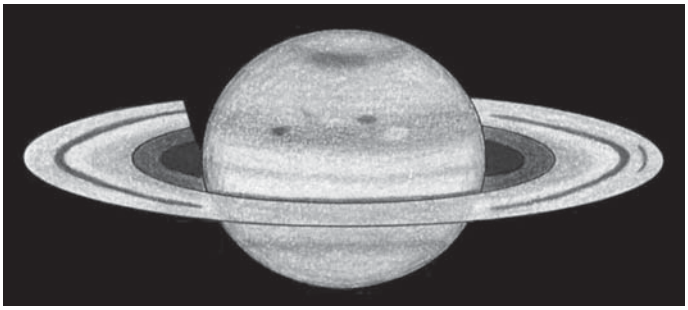

Figure 2. 1997 Aug 3d 08:39UT, ω_1= 289°, ω_2= 189°, 510mm refl., ×380, *R. W. Schmude*. Note dark spots or sections in the SPB, SEB(S) and SEB(N), and the lighter patch in the SEBZ.

Table 1. Observers and observing groups

Observer	*Location(s)*	*Instrument(s)*
P. G. Abel	Burton on Trent, Staffs.	114mm OG
H. Asada	Kyoto, Japan	310mm refl.
S. Beaumont	Windermere, Cumbria	300mm refl.
N. D. Biver	Versailles, Paris, France, & Honolulu, Hawaii, USA	256mm refl.
E. Y. Crandall	Winston-Salem, NC, USA	254mm refl.
J. Dijon	Champagnier, France	520mm refl.
T. A. Dobbins	Coshocton, Ohio, USA	254mm refl. & 355mm Cass.
M. Foulkes	Hatfield, Herts.	203mm SCT & 254mm refl.
(with D.Hatch)	Brampton, Northants.	152mm OG
M. Frassati	Crescentino (VC), Italy	320mm refl.
D. L. Graham	Richmond, N. Yorks.	152mm OG & 406mm refl.
	Coshocton, Ohio, USA	254mm refl. & 355mm Cass.
D. Gray	Spennymoor, Co. Durham	415mm DK
A. W. Heath	Long Eaton, Notts.	203mm SCT & 254mm refl.
R. J. McKim	Oundle and Upper Benefield, Northants.	216mm refl.
	Mills Observatory, Dundee	254mm OG
	Mt. Lemmon, Tucson, AZ, USA	254mm refl.
G. J. Martin	Easington, Co. Durham	203mm refl.
C. E. Meredith	Manchester	215mm refl.
I. Miyazaki	Okinawa, Japan	400mm refl.
M. P. Mobberley	Bury St Edmunds, Suffolk	355mm refl.
S. L. Moore	Fleet, Hants.	222mm refl.
D. Niechoy	Göttingen, Germany	203mm SCT
D. C. Parker	Miami, Florida, USA	410mm SCT
I. S. Phelps (with L.Phelps)	Warrington, Cheshire	114mm refl.
T. Platt	Binfield, Berks.	318mm Tri-Schief.
R. W. Schmude	Texas A&M Obsy., USA	510mm refl.
R. M. Steele	Leeds	80mm OG
D. Storey	Carterton, Oxon.	254mm refl.
D. Weldrake	Stockton on Tees, Cleveland	305mm refl.

Abbreviations: OG ('Object Glass')= refractor; refl.= reflector; SCT= Schmidt–Cassegrain; DK= Dall–Kirkham Cassegrain; Tri-Schief= Tri-Schiefspiegler

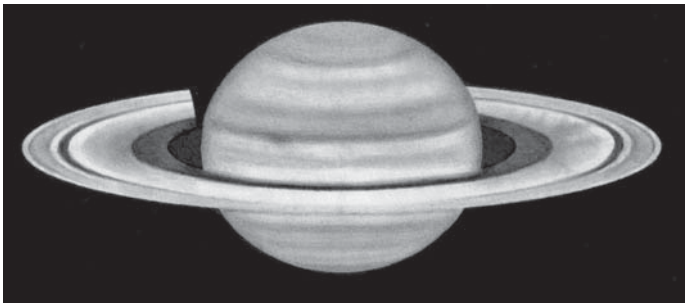

Figure 4. 1997 Aug 17d 00:50UT, ω_1= 079°, ω_2= 226°, 415mm DK, ×348, *D. Gray*. Note spokes on *f.* side of ring B, the Encke Division and the Encke complex, the SEB(N) dark spot, and the NEB, NTB and NNTB north of the rings. [Of Gray's drawings for this apparition, only this one was drawn by hand; the rest were drawn on a computer.]

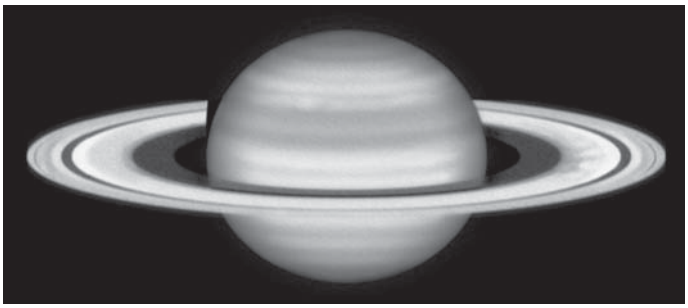

Figure 5. 1997 Sep 21d 23:05UT, 415mm DK, ×348, ω_1= 052°, ω_2= 150°, *D. Gray*. Showing the Encke Division, spokes on the *f.* side, and elusive STropZ details.

STeZ/STropZ creamy-yellow to yellow-grey, the SEB brown and the EZ(S) creamy-yellow. The NEB was grey. Beaumont found the SPR grey, the EZ strongly yellow, and the NEB grey. Foulkes also found the SEB brown. On three occasions (Oct 24, 25 and Jan 10) the latter described the SPR also as brown; otherwise it looked grey. Disagreement upon the colour of the dark polar regions is hardly surprising. Heath found the SEB brown, and there was a pink tint in the EZ(S) on Oct 18. McKim also saw the SEB as brown, with the EZ creamy-yellow. The SPR was neutral to him; the NEB grey.

The colour composite CCD images by Parker and Platt support the brown tone of the SEB, and the warm tint of the EZ. The blue filter images of Miyazaki and Parker show the EZ(S) slightly darker, but the EZ(N) north of the rings (which appeared light in red and green light, and visually) was greatly darkened. The filter images also showed differences in belt/zone contrasts within the S. polar region: see the collages of Miyazaki and Parker in Figures 7 and 11 for more details.

South Polar Region

This large dusky region showed a small and even darker cap within its boundaries to several observers. Gray and McKim saw the cap quite distinctly, and it is shown particularly well in a red light image by Miyazaki on Oct 3 and in Parker's red and infrared work, but it was not differentiated from the dusky SPR in green or blue light. To Gray, the S. polar cap's normally dark interior was occasionally light.

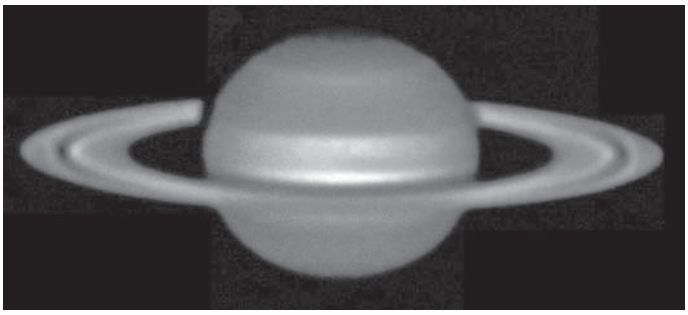

Figure 6. 1997 Sep 27d 22:15UT, ω_1= 173°, ω_2= 046°, 520mm refl., CCD image, *J. Dijon*. STeZ lighter than the neighbouring zones.

A dark and conspicuous S. polar belt (SPB) terminated the northern edge of the SPR. Its appearance between red and blue light varied, being less intense in blue. Schmude alone found a dark section upon the SPB on Aug 3 near λ_2= 185°. (Figure 2) This feature, whose drift in System II was likely to have been negligible, was not re-observed in 1998–'99, though darker sections were seen at other longitudes during the latter apparition.

A faint, narrow SSSTB was located between SPB and SSTB, according to Gray's visual work and Miyazaki's best images.

South South Temperate Zone

The SSTeZ was featureless.

South South Temperate Belt

The SSTB was a thin belt bordered by light zones.

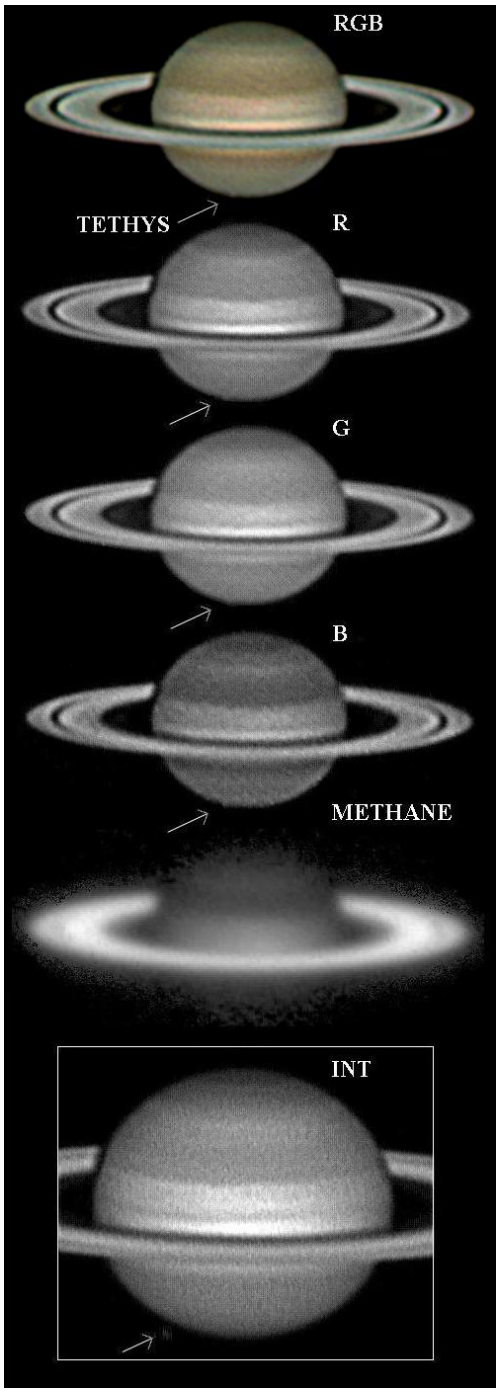

Figure 7. 1997 Oct 3d 14:55–14:57UT (ω_1= 178°, ω_2= 259°), 400mm refl., RGB image series with Lynxx-PC CCD camera, *I. Miyazaki*. From top to bottom, RGB composite (with R60, PO1, B390 and NR400 filters), red, green and blue filters. The methane band (893BP5 filter) image was taken at 12:19UT. The larger image at the bottom was taken at 15:20UT (ω_1= 192°, ω_2= 272°) with no filter. Tethys (arrowed) is completing its transit. Numerous belts are shown, and the EB is much more conspicuous than the EZ(S)B. (The RGB composite image given here was kindly made by Johan Warell.)

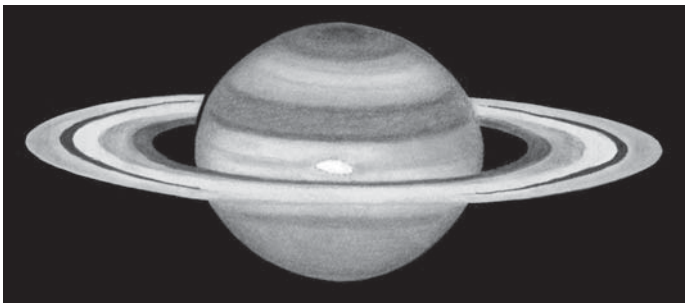

Figure 8. 1997 Oct 4d 07:30UT, ω_1= 041°, ω_2= 099°, 254mm refl., ×320, ×640, (Geology Vista Point, Mt Lemmon, AZ, alt. 2100m), *R. J. McKim*. Note the white spot in the central EZ interrupting the EB, many belts, dark SPC and ring details.

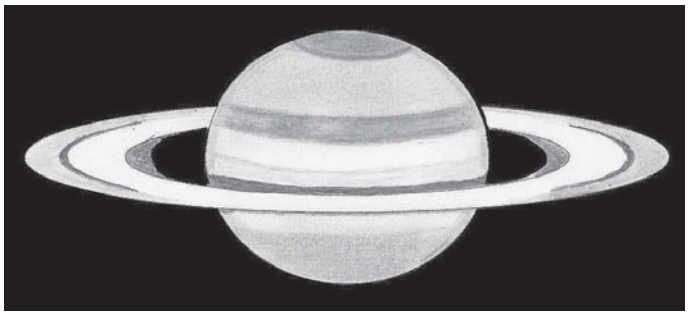

Figure 9. 1997 Oct 18d 22:40UT, ω_1= 155°, ω_2= 102°, 254mm refl., ×370, *M. Foulkes*. Note elusive markings in the SEB, and the SPB.

South Temperate Zone

The STeZ was another featureless zone, often lighter than either of the neighbouring zones according to Dijon's, Miyazaki's and Parker's images (Figures 6, 7, 11) and the eyepiece impressions of Gray and the writer (Figures 8, 15, 16).

South Temperate Belt

The STB was always narrow and featureless, like the STB.

South Tropical Zone

The STropZ was darkened more obviously with respect to the STeZ in blue light, then making it harder to separate from the SEB (Figures 9, 13).

Though the STropZ was generally featureless, a number of inconspicuous white oval spots was recorded by Gray (Figures 13, 15, 16). Despite numerous transit timings, a tentative period for just one spot can be quoted. This and four less well-observed objects drifted in decreasing System II longitude. On one date a white oval was found at the same longitude at which the STB was seen to fade. The best images we possess from 1997–'98, and the only ones likely to resolve these ovals – namely Miyazaki's of Oct 3 – cover longitudes where none had been reported.

Spot	*Limiting dates*	*No. obs.*	*Limiting* λ_2	$\Delta\lambda_2$ *(°/day)*
WS1p	1997 Oct 5–'98 Jan 27	3	355–216	–1.22
WS1c	1997 Aug 16–Oct 5	2	072–014	–1.14
			Average:	–1.18
STropZ average period:				10h 37m 29s

Table 2. Visual intensity estimates, 1997–'98

Feature	*PA*	*SB*	*MF*	*MFr*	*DGm*	*DGy*	*AH*	*RM*	*SM*	*IP*	*RS*	*RSt*	*DS*	*Ave.*	*No.*
SPC	–	–	–	–	5.0	5.1	–	5.9	–	–	–	–	–	5.3	72
SPR	4.0	3.8	3.8	4.0	4.4	4.3	–	5.0	4.5	6.0	2.8	5.0	4.6	4.4	148
SPB	–	–	5.5	–	6.0	5.6	–	5.6	–	–	3.8	–	–	5.3	83
SSTeZ	–	–	–	–	–	3.1	–	3.0	–	–	–	–		3.0	71
SSTB	–	–	–	–	–	4.2	–	4.0	–	–	–	–		4.1	63
STeZ	3.0	3.4	2.9	3.2	3.0	2.6	3.0	2.8	4.0	3.0	2.8	3.3	3.8	3.1	170
STB	–	–	–	–	3.7	3.8	–	4.0	–	–	–	–	–	3.8	75
STropZ	–	–	2.9	2.5	3.0	2.9	–	2.9	–	–	2.8	2.5	3.8	2.9	131
SEB(S)	–	–	5.2	4.8	4.9	5.9	–	5.4	–	6.3	5.0	–		5.4	120
SEBZ	–	–	–	4.4	4.3	4.3	–	3.8	–	–	3.0	–	–	4.0	85
SEB(N)	5.0	4.9	5.2	4.8	4.9	5.5	5.0	5.4	6.0	6.3	5.0	3.8	4.6	5.1	168
EZ(S)	2.0	0.5	1.0	1.5	1.6	1.6	1.5	1.3	3.5	2.0	1.8	2.0	0.8	1.6	170
EZ(S)B	–	–	–	–	2.5	–	–	–	–	–	–	–	–	2.5	1
EB	–	–	3.0	3.0	3.0	3.3	2.0	3.2	–	–	3.0	–	–	2.9	85
EZ(N) S. of rings	–	–	–	0.9	1.0	1.1	–	1.3	1.0	–	1.5	–	–	1.1	90
EZ(N) N. of rings	–	–	–	–	2.8	3.6	–	1.9	–	–	3.0	–	–	2.8	80
NEB(N)	4.0	5.9	–	4.1	4.6	5.0	4.9	4.5	4.5	5.0	3.5	–	–	4.6	113
NTropZ	3.0	2.0	3.2	2.5	3.3	3.6	–	3.3	–	3.5	2.8	–	3.8	3.1	134
NTB	–	5.0	–	–	4.4	4.4	–	–	–	–	–	–	–	4.6	73
NTeZ	4.0	3.1	3.3	3.2	3.6	2.9	4.0	3.3	4.0	3.5	2.8	4.0	3.8	3.5	170
NNTB	–	–	–	–	–	4.8	–	–	–	–	–	–	–	4.8	54
NNTeZ	–	–	–	–	–	3.9	–	–	–	–	–		–	3.9	54
NPR	–	3.4	3.3	–	4.1	5.5	–	3.8	–	4.5	–	–	3.8	4.0	132
Ring A1	3.0	2.5	2.4	3.2	2.9	3.3	3.0	2.3	3.0	2.8	2.8	3.0	2.8	2.8	172
Encke's divn.	–	–	–	–	4.0	–	–	–	–	–	–	–	–	4.0	1
Encke complex	–	–	–	–	3.9	4.6	–	3.5	–	–	–	–	–	4.0	67
Ring A2	–	–	–	–	2.1	2.4	–	2.3	–	–	2.8	–	–	2.4	88
Cassini's divn.	10.0	–	9.6	8.0	8.9	8.5	9.0	9.8	10.0	10.0	8.8	–	8.8	9.2	134
Ring B1	–	1.1	1.0	2.5	1.2	1.3	–	1.5	1.5	1.2	2.0	1.9	1.2	1.5	168
Ring B2	4.0	–	2.6	3.0	2.1	2.4	–	2.4	–	2.5	2.8	3.5	2.6	2.8	106
Ring B3	–	–	–	–	2.7	3.6	–	2.2	–	–	–	–	–	2.8	78
Ring C	5.0	–	7.3	6.0	8.3	7.5	8.5	6.6	–	–	9.0	–	9.2	7.5	162
Ring C_m	–	–	8.3	–	7.6	6.9	–	7.5	–	–	8.0	–	7.2	7.6	100
ShRG	–	7.5	9.6	9.0	9.6	9.2	–	9.8	–	8.5	6.5	–	9.0	8.7	122
ShGR	10.0	8.6	10.0	9.4	10.0	–	10.0	10.0	–	10.0	10.0	9.7	10.0	9.8	73
Total used	12	137	429	37	272	2,148	73	201	10	15	37	98	144	–	3,613

Key to observers: PA, Abel; SB, Beaumont; MF, Foulkes; MFr, Frassati; DGm, Graham; DGy, Gray; AH, Heath; RM, McKim; SM, Moore; IP, Phelps; RS, Schmude; RSt, Steele; DS, Storey.

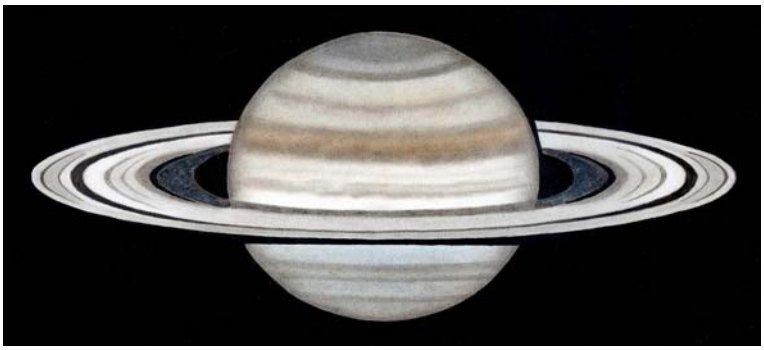

Figure 10. 1997 Oct 21d 04:10UT, ω_1= 238°, ω_2= 112°, 254mm refl., ×552, *D. L. Graham*. There are three belts in the EZ, many ring subdivisions including the one between rings B and C, while the N. hemisphere has a 'cold' tint in contrast to the 'warm' south.

In 1996-97 we obtained a tentative period of $\Delta\lambda_2$= –1.01°/day for a STropZ white spot, which is encouragingly close to the average for the present apparition. Such features have always been rare, and it is still more unusual for them to be detected with amateur telescopes.[15] None of the features survived with certainty into 1998–'99, though similar features would be observed then.

South Equatorial Belt

The SEB was wide and very obviously double. A considerable number of transits of darker spots in the SEB(S) were timed by Gray, while irregularities in the belt were confirmed by Graham (Figure 10) and Schmude (Figure 2). Tentative periods for three spots are given, and three other features appeared to have similar drift-rates. These spots all moved at similar speed, more slowly than the aforementioned STropZ white ovals. The dusky SEBZ was nearly featureless: Figures 2 and 9 indicate fleeting details.

Spot	*Limiting dates*	*No. obs.*	*Limiting* λ_2	$\Delta\lambda_2$ *(°/day)*
DS1p	1997 Dec 27–'98 Jan 16	3	272–268	–0.20
DS2p	1997 Jul 29–Aug 30	3	283–251	–1.02
DS2c	1997 Aug 14–Aug 30	2	275–260	–0.91
DS3p	1997 Aug 10–Aug 14	2	302–295	–1.73
DS3c	1997 Aug 10–Aug 14	2	312–309	–0.73
			Average:	–0.92
SEB(S) average period:				10h 37m 42s

The SEB north component showed a very few dark spots throughout the apparition, as indicated by the drawings of Graham, Gray and Schmude. The belt sometimes appeared mottled. As at the last opposition, no rotation periods could be established.

Equatorial Zone

The first observations of the apparition showed that the dark EZ(S)B of 1996–'97 had faded considerably during conjunction so that it was paler than the classical Equatorial Band (EB), but it was still complete in longitude. Its latitude was close to the SEB(N)n. Graham during his high resolution observations from the USA (1997 Oct; Figure 10) saw three thin belts in the EZ at some longitudes, due presumably to the EB being double.

The EZ was light on both sides of the EZ(S)B/EB. Some stretches of the southern part of the zone were quite shaded, so that it was less bright than the part between the EB and C_m. McKim on Oct 4 saw shading filling the S. part of the zone following a bright white spot that was embedded in the EZ(S)B/EB.

The EZ was much less active in 1997–'98: the white spots that appeared were almost all less conspicuous than the large spots such as the A/B complex that had been observed throughout 1996–'97, and none was long-lived. Little correlation was found between the System I longitudes of the spots observed, but plotting them against a system increasing at 10.65° per day (as we used during 1994–'96) again showed positive accordance, and a greater spread of velocities than for the last apparition.

A small, bright EZ(S) white oval close to the SEB N. edge was caught by Gray on Jul 27 and Weldrake on Aug 9 ('WS3' in our table below). It moved in increasing longitude in our slow longitude system. Parker on Aug 5 imaged a small, apparently double spot which was not seen subsequently. There was no activity in the zone for nearly the whole of September. The writer's strikingly bright oval spot interrupting the EZ(S)B/EB on Oct 4 (Figure 8, as confirmed by Don Parker and Dan Troiani who were observing visually with Dan Joyce's telescope) was clearly short-lived, and there is no further record. The only definite correlation in the same month was due to Gray's transits of a small light gap in the EB (labelled 'WS1', below), taken on Oct 4 and 10, which revealed a negative longitude drift against the slow system.

Parker's small light spot in the EZ(S) seen on Oct 27 (Figure 11) was only dubiously present in his images of Nov 2, again proving a rapid decline. The whole EZ looked tranquil in an HST October image,[16] and that was always Graham's impression throughout his high resolution work from the USA that month. November showed only marginal activity, but Gray's transit of a bright patch on Dec 27 agrees well with the larger of the two bright areas imaged by the HST on Jan 4 (Figure 14), in what may have been a resurgence in activity. A continuation of the latter feature (referred to as 'WS2' below) was probably recorded by Crandall on Jan 20. Finally, the smaller HST spot of Jan 4 was drawn by Biver on Jan 3. Both spots had negative drifts in the slow system.

Spot	*Limiting dates*	*No. obs.*	*Limiting* λ^*	$\Delta\lambda_1$ *(°/day)*
WS1c	1997 Oct 4–Oct 10	2	050–038	+8.69
WS2f	1997 Dec 27–'98 Jan 4	2	135–131	+10.13
WS3c	1997 Jul 27–Aug 9	2	240–257	+11.90
			Average:	+10.24
EZ(S) average period:				10h 21m 32s

* For a special system whereby longitudes increase at 10.65°/day in System I, the zero point being defined in terms of a large, long-enduring white spot observed during 1994–'96.[8,9]

The EZ slow current observed in recent years can now be summarised, and we add selected comparisons prior to 1997–'98 of slower

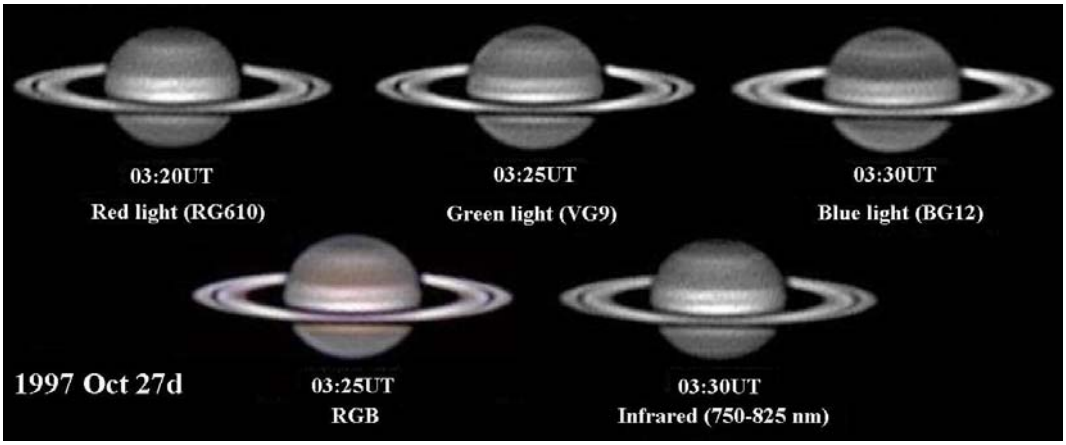

Figure 11. 1997 Oct 27d 03:20–03:33UT, ω_1= 238°, ω_2= 279° (03:25UT), 410mm SCT, Lynxx-PC CCD images at f/22, *D. C. Parker*. An elongated lighter patch in the EZ(S) just precedes the CM, and the rest of the EZ(S) is more shaded than the EZ(N). A small SPC is seen in red light.

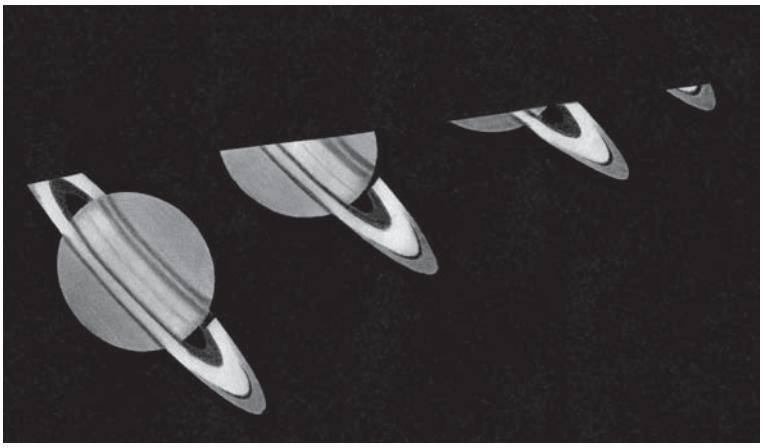

Figure 12. 1997 Nov 12d 01:28UT, 200mm MKT, ×200, *A. W. Heath*. Occultation disappearance sequence at the dark limb of the Moon.

drifts to System I (without having undertaken a full search):

Apparition	*Average period*
1997–'98 [this report]	10h 21.5m
1996–'97 [7]	10h 21.7m
1995–'96 [8]	10h 21.8m
1994–'95 [9]	10h 21.8m
1977–'78 [17]	10h 18.0m
1945–'46 [18]	10h 21.4m

The slow current would again be observed during the 1998–'99 apparition.

The EB and EZ(S)B also contained darker sections and patches. No definite periods could be derived from the transits, but the observations suggest drift-rates not dissimilar to the EZ(S) white ovals.

During 1997–'98 the part of the EZ(N) visible between the EB and the rings crossing the globe was often brighter than the EZ(S). In this part of the EZ(N), a long, yet brighter area was transited by Gray on Oct 10, by Graham on Oct 15, and drawn by Frassati four days later. This longitude remained very bright to Graham on Oct 21 and to Platt (Figure 3) on Oct 24, though no definite spot persisted. In contrast to the spots south of the EB, this one was near-stationary in System I. The *f.* end of another EZ(N) white spot was also nearly constant in System I according to Gray's Oct 24–27 data. The drifts are in good accord but must be regarded as tentative due to the very short intervals.

Spot	*Limiting dates*	*No. obs.*	*Limiting* λ_1	$\Delta\lambda_1$ *(°/day)*
WS1f	1997 Oct 24–Oct 27	2	121–116	−1.71
WS2c	1997 Oct 10–Oct 15	2	221–214	−1.60
			Average	−1.65
EZ(N) average period:				10h 12m 48s

No definite conclusions can be drawn from the Dec–Feb transit data except that there were at least another three EZ(N) white spots present.

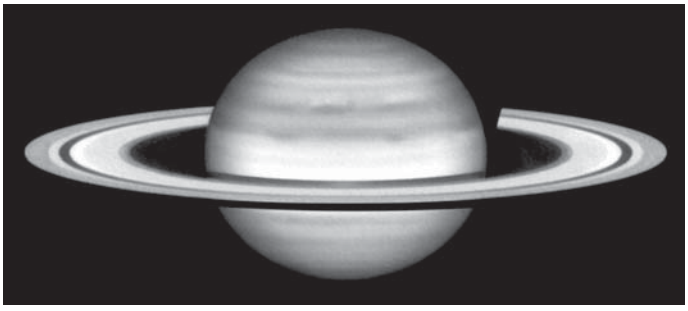

Figure 13. 1997 Dec 26d, 19:40UT, ω_1= 345°, ω_2= 227°, 415mm DK, ×348, *D. Gray*. Note the spots in the STropZ, SEB(S) and SEB(N).

North Equatorial Belt

The nearly featureless, foreshortened NEB appeared considerably narrower than the SEB, and latitude measurements reveal that only the N. component was visible. It sometimes had darker edges to Biver, Graham, Gray and Heath. A narrow light zone lay between it and the rings, and as it was too light to have been the NEBZ, it must have been part of the EZ(N). Thus the EZ had expanded to the north since the previous apparition: the zone was considerably darkened in blue-violet light, as the images of Miyazaki (Figure 7) and Parker (Figure 11) show.

North Tropical Zone

The NTropZ was dull and featureless.

North Temperate Belt

The NTB was always inconspicuous. Its latitude seems low, but perhaps not low enough to regard the feature as being the NTropB instead.

North Temperate Zone

The NTeZ appeared much like the NTropZ, except that during 1997 Oct 11–28 a lighter section, circa 70° long, was nearly stationary in

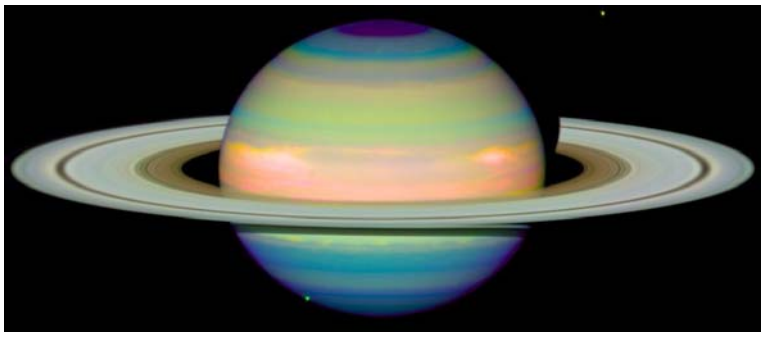

Figure 14. 1998 Jan 4d 03:04UT, ω_1= 159°, ω_2= 132°, Hubble Space Telescope image. (*E. Karkoschka (Univ. Arizona), & NASA.*) Images at three IR wavebands (1.0, 1.8, and 2.1μm, displayed as blue, green, and red respectively) were combined to make a false colour image, with the blue colours (N. hemisphere and SPR) indicating a clear atmosphere down to the main cloud layer. Note the two EZ(S) bright spots, and Tethys ending its transit at the N*p*. limb. The HST website[16] does not state a time, but the mid-egress of Tethys implies 03:04UT.

System II longitude according to Gray's transit data, although a precise period cannot be quoted.

North North Temperate Belt

A thin and difficult belt, close to the foreshortened NPR. Like the NTB, its latitude was lower than in some previous years, but it was closer to that of the NNTB than the NTB of the last two apparitions.

North Polar Region

Observers could make out the southernmost part of the NPR as a dark fringe to the N. limb.

The rings

General

An opposition brightening can be clearly discerned from Asada's images, rings A and B being notably brighter on 1997 Oct 13 (opposition: Oct 10) compared with his neighbouring dates of Sep 28 and Oct 17. Likewise with Platt's images of Figure 3.

Table 3. Saturnicentric latitudes, 1997–'98

Feature	*DGm*	*DGy*	*RM*	*IM*	*DP*	*TP*	*Average*
SPCn	–	−68.8	−64.8	−69.7	−71.9	–	−68.8
SPRn	−58.9	−60.9	−58.9	−64.5	−63.6	−64.9	−62.0
SPBs	−58.9	−60.9	−58.9	−64.5	−63.6	−64.9	−62.0
SPBc	−54.6	−58.2	−56.5	−63.0	−59.7	−61.0	−58.8
SPBn	−50.2	−55.6	−54.1	−61.5	−55.8	−57.2	−55.7
SSSTBs	–	–	–	−56.6	–	–	−56.6
SSSTBc	–	–	–	−55.6	–	–	−55.6
SSSTBn	–	–	–	−54.7	–	–	−54.7
SSTBs	–	−46.2	–	−47.6	–	–	−46.9
SSTBc	–	−44.4	−45.6	−46.8	–	–	−45.6
SSTBn	–	−42.5	–	−46.0	–	–	−44.2
STBs	–	−37.3	–	−40.9	–	–	−39.1
STBc	−37.5	−35.8	−37.6	−39.2	−39.9	–	−38.0
STBn	–	−34.4	–	−37.5	–	–	−36.0
SEB(S)s	−26.8	−27.9	−29.0	−31.6	−32.0	−31.0	−29.7
SEB(S)n	−21.3	−24.1	−25.1	−24.9	−26.8	–	−24.4
SEB(N)s	−18.2	−17.7	−17.9	−22.1	−20.8	–	−19.3
SEB(N)n	−14.0	−13.7	−12.9	−15.9	−16.1	−18.2	−15.1
EZ(S)Bs	–	–	–	−12.8	–	–	−12.8
EZ(S)Bc	–	–	–	−11.9	–	–	−11.9
EZ(S)Bn	–	–	–	−11.0	–	–	−11.0
EBs	–	–	–	−5.7	−7.0	–	−6.4
EBc	−6.9	−5.1	−5.1	−4.0	−5.3	–	−5.3
EBn	–	–	–	−2.3	−3.6	–	−3.0
NEB(N)s	+21.0	+19.8	+17.5	+18.3	+23.6	+21.4	+20.3
NEB(N)n	+26.0	+24.4	+24.6	+26.4	+32.1	+29.5	+27.2
NTBs	–	+30.6	–	+30.2	–	–	+30.4
NTBc	+35.0	+32.8	–	+31.4	–	–	+33.1
NTBn	–	+35.1	–	+32.5	–	–	+33.8
NNTBs	–	–	–	+40.2	–	–	+40.2
NNTBc	–	+42.7	–	+41.3	–	–	+42.0
NNTBn		–	–	+42.4	–	–	+42.4
Total obs.used	13	180	36	32	18	9	286

Key to observers: DGm, Graham; DGy, Gray; RM, McKim; IM, Miyazaki (images); DP, Parker (images); TP, Platt (images). Graham and Gray reduced their own work; other data were reduced by McKim.

Cassini's Division

This was much better seen than in 1996–'97, and Graham and McKim were able to follow it some way across the globe when ShRG lay behind the division. To them and to some others, the division was not completely black.

Ring B

Ring B1 was close to its usual intensity of 1.0 during 1997–'98.

There were three distinct 'steps' in brightness within the ring, noted by Graham & Dobbins, Gray and McKim: namely B1, a very slightly darker B2, and a dusky inner B3. Graham was able to detect a division between B1 and B2, and another halfway across B2. The inner third of ring B (B3) was described as beige or dusky tan in colour by Graham & Dobbins, and appeared to contain several further very narrow subdivisions.

Radial dark spokes across ring B were observed visually by Biver (1997 Nov 6 and Dec 18 upon both ansae, and 1998 Jan 3, when they were clearer on the *f.* side) and Gray as follows: 1997 Aug 17/*f.* side (Figure 4), Aug 30/*f.*, Sep 21/*f.* (Figure 5), Oct 27/*p.*, 1998 Jan 27/*p.* (Figure 15), Feb 2/*p.* and Feb 21/*p.* (Figure 16). The high resolution USA work of Graham & Dobbins did not detect these transitory features, but their high resolution work was quite close to opposition, when the brightness of the rings is known to make detection of their fine detail more difficult.

Graham & Dobbins saw a black division between ring B and ring C on Oct 20–21, one-third the width of Cassini's.

Ring A

Ring A had a blue-grey tint to Graham, and Foulkes several times reported a bluish-grey colour.

Graham, Dobbins and others had an exceptional view on the night of 1997 Oct 20–21 in perfect seeing, when there was a diffuse shading (the Encke complex) in the middle of ring A and the thin hairline division of Encke's Division outside it: Dobbins' drawing was previously published.[2] Ring A2 was brighter than the outer part, A1. Gray, Heath and McKim all reported the shaded Encke complex visually: Schmude, though using a 510mm aperture, could only record the latter in the *f.* ansa on Aug 3. The true Encke Division eluded all other observers except Biver and Gray, the latter catching it in superb conditions on Sep 21, Oct 27 and Feb 21 (Figures 5, 16).

Graham[3] has written an excellent account setting the modern observations of ring subdivisions in an appropriate historical context.

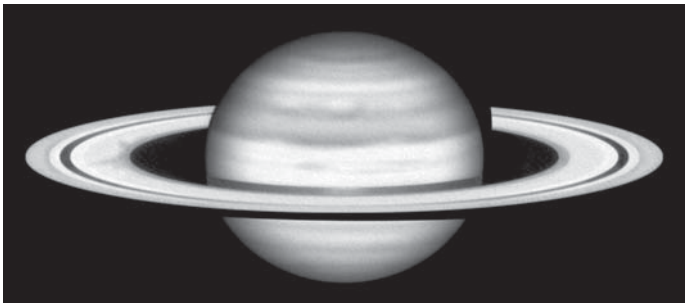

Figure 15. 1998 Jan 27d 18:00UT, ω_1= 301°, ω_2= 231°, 415mm DK, ×348, *D. Gray*. Shows ring spokes on the *p.* side, delicate EZ(S)B and EB details, and a white spot in the STropZ.

Ring C

Dobbins found the appearance of ring C to be 'reminiscent of the texture of coarse sandpaper'[2] and steel-grey in hue on Oct 20–21, under perfect seeing conditions. McKim considered the ring fairly light compared with its appearance when the system is fully open. Biver shows a division in the middle of ring C, but not the division between rings B and C. All other observers who remarked upon colour found ring C a dark grey. Ring C appears clearly in Miyazaki's methane band image (Figure 7).

Gray often found a marked difference in brightness – up to one scale point – between the ansae in white light. He found ring C brighter on the *p.* side on 19 occasions, and brighter on the *f.* side 38 times: during only 7 observations were the two ansae equal. On Sep 10 a short-term reversal was noticed: at 03:30UT the *f.* ansa was the brighter, but at 22:20UT the *p.* ansa was brightest. This phenomenon might be related to the patchiness observed in C_m during the 1993 apparition.[19] However, Gray did not report any obvious patchiness in the ansae, nor was it reported for C_m. The rotation period for the centre of the C ring was calculated by the writer to be 6.8 hours, so rapid brightness changes by rotation are plausible. (The periods of the outer edge and inner edge of ring C are, respectively 7.9h and 5.8h, according to Benton.[20])

Confirmatory evidence of variability was obtained by others. Graham on Oct 15 (white light) found it distinctly brighter on the *p.* side. On Oct 13, 24, Nov 3 and 13 (white light) Storey found ring C brighter or easier to see on the *f.* side: on Nov 30 it was equal in both ansae. Gray was observing significantly earlier than Storey on three of these evenings, and not surprisingly obtained different results: Oct 13 (*p.* = *f.*), 24 (*p.* side brighter) and Nov 30 (*f.* side brighter).

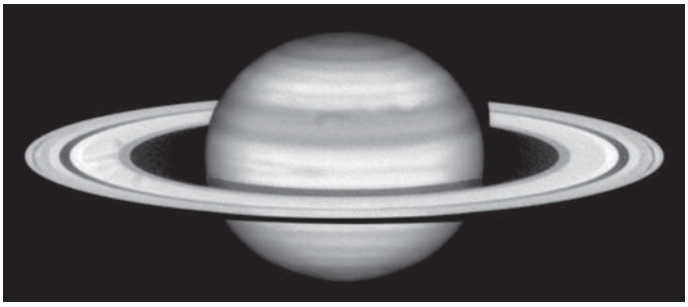

Figure 16. 1998 Feb 21d 17:50UT, ω_1= 159°, ω_2= 002°, 415mm DK, ×348, *D. Gray*. Showing the Encke Division, spokes on the p. side, the SSSTB as well as STB, SSTB and SPB, the STeZ lighter than the adjacent zones; a STropZ white oval is also seen.

Ring C crossing the globe

Observing from the Mills Observatory on 1997 Sep 12, McKim nicely saw the N. part of C_m intensified by the black shadow of the rings on the globe. This experience was typical: before opposition, ShRG was widely seen to be involved with C_m.

Shadow of globe on rings

The ShGR was last seen on the west on 1997 Oct 5 by Gray and Storey; opposition was on Oct 10; it was first seen on the east on Oct 18 by Foulkes.

Shadow of rings on globe

This fell behind the rings until opposition (see above); it was first observed to appear north of the rings on Oct 18 (Foulkes).

Bicoloured ring programme

We have commented on the white light fluctuations of ring C above.

Crandall found the bright parts of the ansae generally equally bright in red (W25), blue (W47) and no filter on 1998 Jan 20 and Feb 1, but on Jan 31 the *p*. ansa was brighter than the *f*. in red light only. Heath found them equal in red (W25), blue (W47) and no filter on 1997 Sep 20 and Oct 18, but on Oct 7 the *p*. ansa was considered slightly brighter with W25 and W47 but not with a light blue W44A filter. Schmude found both equal in W25 and no filter on Aug 3.

Benton's report[4] cites numerous positive ALPO observations of the bicoloured effect, but for different dates from ours.

The satellites

On 1997 Oct 3 near 14:52UT, Miyazaki's camera caught Tethys in transit, the satellite just running across the N. limb and appearing as a bright dot against the limb darkening (Figure 7). This was the only observation of a satellite transit by a Section member, but a similar transit of Tethys was also caught by the HST (Figure 14) on 1998 Jan 4.

Mimas and Enceladus were among those satellites caught by Platt's CCD camera on 1997 Aug 15.

Near opposition Foulkes was able to see Titan's distinct orange colour.

Occultations by the Moon

Three occultations of the planet by the Moon occurred during the apparition, and that of 1997 Nov 12 (disappearance at the dark limb) was observed by Mike Foulkes & Derek Hatch, Alan Heath, and Ian & Lydia Phelps. Graham was clouded out at the last moment, and McKim found local sky conditions too poor to continue beyond the previous evening.

Heath's sequence of drawings is reproduced here (Figure 12). To him, the event had occurred by 01:28UT, ingress being close to the latitude of the bright crater Aristarchus. Heath saw Titan occulted close to 01:31UT and significantly – found that it faded over 2 or 3 seconds. Phelps (latitude 53° 23' 55" N., longitude 2° 35' 57" W.) obtained more precise timings for the ingress of the *p*. ansa of the rings (01h 26m 06s) as well as the *f*. ansa (01h 27m 26s). He reminds us of the rarity of these events, and for him it 'brought back memories of 1974... Then, almost on cue, cloud rolled in completely.' No-one reported the egress. The 1974 Mar 2 occultation[21] had also been seen by the writer.

The *Journal* reproduced a sequence of images of the 1997 event taken by D. Briggs.[22]

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