Saturn in 1994–'95

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

BAA observations from 1994 April to 1995 January are reviewed. During this time the rings were obliquely illuminated on the north face and appeared dull, particularly after opposition and when the angle of inclination decreased. The planet's S. Temperate Zone exhibited a slightly bluish tint when compared with the warmer colour of the N. hemisphere. A slow-moving white spot in the planet's northern Equatorial Zone (with a drift-rate of +10.65°/day in System I, or a period 10h 21m 50.6s) was the most interesting feature of the apparition. It lasted for many months, and most other EZ white spots moved at a similar rate. The long-lived white spot exhibited a low-amplitude periodic oscillation in longitude.

Introduction

An unbroken series of reports of the BAA Saturn Section exists for the period 1952–1993. A new series of final Section Reports began in 2010 with the apparition of 2006–'07.[1] Although brief interim reports had appeared for the intervening apparitions, including the one covered here, by the then Director David Graham,[2,3] no final accounts had been written, so that this is the first in a series intended to bridge the gap.

Saturn was in opposition to the Sun on 1994 Sep 1, when the rings were open to the Earth at an angle of only +6.6° (the sub-Earth latitude, denoted by the value 'B' in the BAA *Handbook*), a smaller value than at the previous opposition. This value varied from a minimum of +4.9° in 1994 Jun to a maximum of +8.1° in 1994

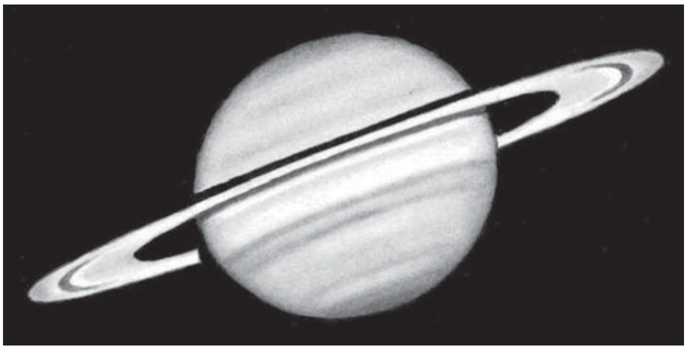

Figure 1. 1994 Jun 8d 03:40UT, ω_1= 231°, ω_2= 268°, 415mm DK Cass. ×415, W22 filter, *D. Gray*. ShRG very conspicuous to the S. of the rings. Note: South is uppermost in this and all other Figures.

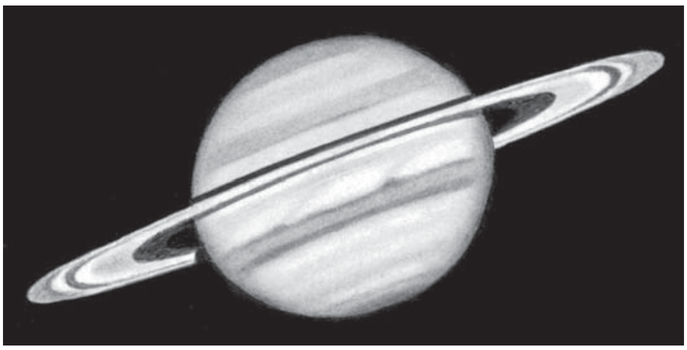

Figure 2. 1994 Jul 17d 01:30UT, ω_1= 326°, ω_2= 186°, 415mm DK Cass. ×415, ×663, INT+W15 filter, *D. Gray*. A division is shown in ring A.

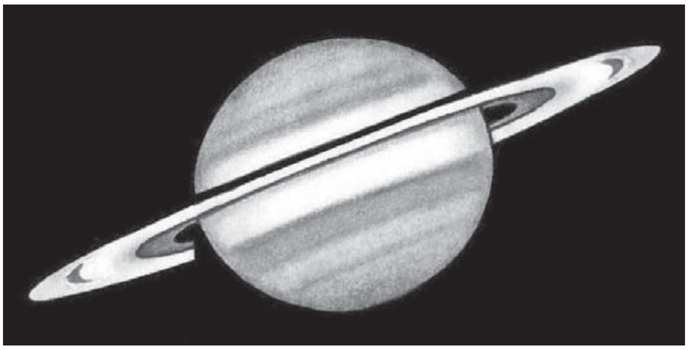

Figure 3. 1994 Jul 21d 07:00UT, ω_1= 297°, ω_2= 020°, 457mm refl. ×356, *R. J. McKim*. The NEB was noted as very regular at this longitude. SEB and NEB both have darker edges. NTB easily seen.

Oct–Nov. The planet's declination (–10.0°) had increased since 1993,[4] and a greater amount of observational material was received from 40 individuals or organisations: see Table 1. However, the planet was still fairly low in the UK skies.

Most observations were visual, although photography with fine-grained emulsions such as TP 2415 remained an important tool in 1994–'95. The CCD camera was not yet in widespread use among amateurs, and the 'webcam revolution' would not arrive until the start of the next decade. The images shown in this report are all therefore selected best single frames.

Several observers had the use of large instruments, including McKim during a summer trip to America (made primarily in order to observe the collision of comet Shoemaker–Levy 9 with Jupiter). Gray secured 232 Central Meridian transits (1994 Jun 8–1995 Jan 22) over 63 observing dates. Testa summarised the work of the Unione Astrofili Italiani (UAI). Good photographs came from Schmude[5] as well as Asada, the latter obtaining a long series of transits of a long-enduring white spot in the planet's equatorial zone as well as photos of that feature. Miyazaki and Parker submitted several CCD images, excellent for the standard of the time, and others were supplied by Dobbins, Mobberley, Platt, Strange and the UAI.

Visual intensity estimates are summarised in Table 2, apparent colours in the text and Saturnicentric belt latitudes in Table 3. This report, covering 1994 Apr 26 (Whitby) to 1995 Jan 30 (Biver), follows the style of earlier ones, in continuation to that of 1993.[4] It may be compared with one published by the Association of Lunar & Planetary Observers (ALPO, USA).[6] Online archiving of amateur Saturn images would not begin until the following opposition, under the auspices of the ALPO Japan (JALPON). The Hubble Space Telescope (HST) imaged the planet on Dec 1.[7] Finally, stud-

Table 1. Observers and observing groups

H. Asada	Kyoto, Japan	310mm refl.
S. Beaumont	Windermere, Cumbria	300mm refl.
N. D. Biver	Meudon Obs., France	600mm & 1m Cass.
A. G. Bowyer	Epsom Downs, Surrey	300mm refl.
J. N. Brown	Chesterfield, Derbyshire	254mm refl.
D. Bruton	Texas, USA	254mm refl.
R. Bullen	Bognor Regis, Sussex	216mm refl.
T. R. Cave	Long Beach, CA, USA	327mm refl.
J. S. Chapple	Bristol	203mm SCT
E. Colombo	Milan, Italy	152mm refl.
P. Devadas	Madras, India	355mm refl.
T. A. Dobbins	Coshocton, Ohio, USA	254mm refl.
P. B. Doherty	Keele University Obs.	300mm OG
D. Fisher	Sittingbourne, Kent	215mm refl.
M. Foulkes	Hatfield, Herts.	203mm SCT & 254mm refl.
M. Giuntoli	Montecatini Terme, Italy	80mm OG
D. L. Graham	Richmond, N. Yorks.	152mm OG & 406mm refl.
D. Gray	Spennymoor, Co. Durham	415mm DK
A. W. Heath	Long Eaton, Notts.,	300mm refl.
J. Lancashire	Cambridge Univ. Obs.	203mm & 310mm OGs
A. P. Lenham	Swindon, Wilts.	203mm refl.
C. Lintott	Paignton, Devon	152mm refl.
L. T. Macdonald	Newbury, Berks.	222mm refl.
R. J. McKim	Oundle, Northants.	216mm refl.
	Long Beach, CA, USA	327mm refl.
	Table Mntn Obs., CA, USA	457mm refl.
	Lowell Obs., Flagstaff, AZ, USA	610mm OG
C. E. Meredith	Manchester	215mm refl.
I. Miyazaki	Okinawa, Japan	400mm refl.
M. P. Mobberley	Chelmsford, Essex	490mm refl.
P. A. Moore	Selsey, Sussex	127mm OG
S. L. Moore	Fleet, Hants.	355mm refl.
D. Niechoy	Göttingen, Germany	203mm SCT
D. C. Parker	Minami, Florida, USA	410mm refl.
T. Platt	Binfield, Berks.	318mm Tri-Sch.
R. W. Schmude	Barnesville, Georgia, USA	90mm OG
	Texas A&M Obs., USA	355mm SCT
P. Stephens	Solihull, Birmingham	254mm SCT
D. A. Strange	Swanage, Dorset	500mm refl.
Unione Astrofili Italiani (UAI; 19 observers, communicated by L. Testa)	Italy	various
J.–F. Viens	Charlesbourg, Québec, Canada	254mm refl.
J. Warell	Uppsala Univ. Obs., Sweden	160mm OG
S. Whitby	Hopewell, Virginia, USA	152mm refl.
D. W. Wright	Caterham, Surrey	133mm OG

Observations by Asada were forwarded by M. Minami, Oriental Astronomical Association; one by Doherty by Heath; and one by Bruton by Lancashire.

Abbreviations: SCT= Schmidt–Cassegrain; DK= Dall–Kirkham Cassegrain; MKT= Maksutov–Cassegrain; Tri-Sch.= Tri-Schiefspiegler

ies of equatorial spot movements by A. Sanchez–Lavega *et al.* are pertinent to this paper.[8,9]

The globe

Global and ring colours

The EZ was the brightest zone, and appeared somewhat yellowish. The SEB looked greyish-fawn to Gray, but the NEB was more colourful, and to most observers showed a brown tint. Gray managed to see some colour variation with longitude within the NEB on Sep 27: the belt had a cool tone up to a NEBs projection, after which the normal brown tone prevailed. The projection itself was a distinct bluish-grey, as is often the case with Jupiter's NEBs plumes. Gray saw the EB as grey or fawn.

Figure 4. 1994 Aug 6d 07:56UT, ω_1= 160°, ω_2= 084°, 355mm SCT, f/200, 5s on Kodak 200ISO colour print film, *R. W. Schmude*.

There was little difference between the general hues of the N. and S. hemispheres. McKim found both hemispheres grey with a hint of yellow or other warm tone which was slightly deeper in the north. On some dates during Jul-Oct (for example on Jul 18 with a 457 mm refl.) he suspected an additional tint of green (but never blue) in the S. hemisphere. Any such tones were subtle to him, and on Jul 27 he saw both hemispheres merely greyish using the 610 mm OG at Lowell Observatory.

In making very careful colour estimates Gray always offset the planet in the field of a Ramsden eyepiece[10] to counter atmospheric dispersion, and a small difference between the two hemispheres then became apparent, with a slightly greater bluish tint in the S. Temperate region compared with the N. hemisphere. To the S. of the STeZ he found a cool grey tone; the STeZ itself was a pale blue-green. The STB was greenish-grey and the STropZ a slightly greenish-yellow. In the opposite hemisphere, the NTropZ was light ochre (though grey to the south), the NTB grey-brown or fawn. Further north, the NNTB was 'deep slate', the NNTeZ 'off-white', the NPR 'blue-grey', the NPB 'deep blue-grey' and the NPC 'deep slate'. Members of the UAI saw stronger tints in the main belts than their UK counterparts: to them, the SEB, NEB and NTB were all brown.

The narrowly open rings had a dull or leaden tone to several observers.

CCD images by Miyazaki and Parker provided good general confirmation of colour differences (Figure 9) in addition to showing the dull nature of the ring system (Figure 14). They show that the SPR was remarkably lighter in blue than in red light. The SEB appears to have been less warm than the NEB. The images also confirm the warm colour of the EZ. Finally, the NPR looked much darker in red than in blue light, confirming the cold tint reported above.

Global features

South Polar Region

The SPR formed a dusky edge to the S. limb. Biver, Gray and UAI members sometimes caught a well-marked SSTB (Figures 2 & 12). On Jul 10 Biver (600mm Cass.) showed the SSTB patchy.

A white spot appeared near the S. limb close to latitude −65° and System III longitude (λ_3) 305° on 1994 Aug 14, and was observed until Dec 1 according to Pic du Midi Observatory.[2,8,11,12] This spot expanded to the east,[2,13,14] its length increasing from 12° at discovery to 50° by Aug 28; it faded with time but maintained a lighter nucleus. By early October it had become very small. Section members did not record it. Its nucleus had a small drift in λ_3 of −3.5°/day similar to the rate for that latitude during the *Voyager* mission and for a small light spot of 1969–'71 followed by ground-based telescopes.

South Temperate Zone

The STeZ was light, without notable features.

South Temperate Belt

Gray found slight tonal variations with longitude.

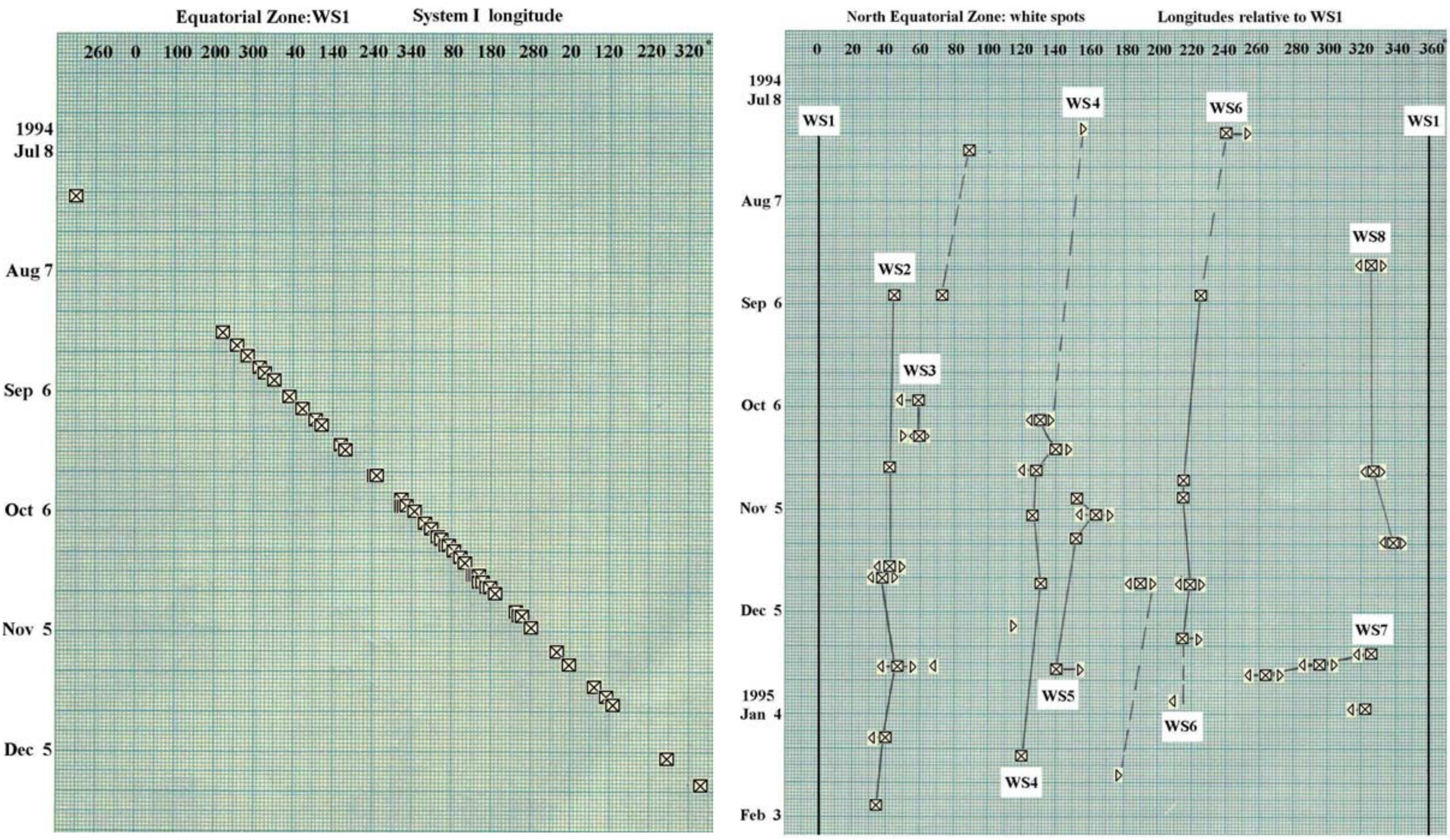

Figure 5. Longitude charts for the EZ, 1994–'95.
A *(left)*. Chart illustrating the rapid drift in increasing System I longitude of the centre of long-enduring white spot WS1.
B *(right)*. All EZ white spot data plotted on a longitude system increasing at 10.65°/day relative to System I. The average track of the long-enduring white spot (WS1) is represented by vertical columns at longitudes 0 and 360°. Tentative identifications are indicated by broken lines.

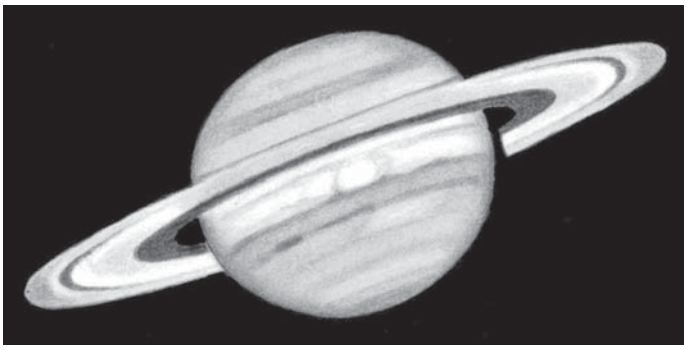

Figure 6. 1994 Sep 27d 20:55UT, ω_1= 244°, ω_2= 272°, 415mm DK Cass. ×262, *D. Gray*. The long-enduring EZ(N) white spot is near the CM, outlined by NEBs projections; the NEB(N) shows dark sections and the NTropZ lightens at the CM.

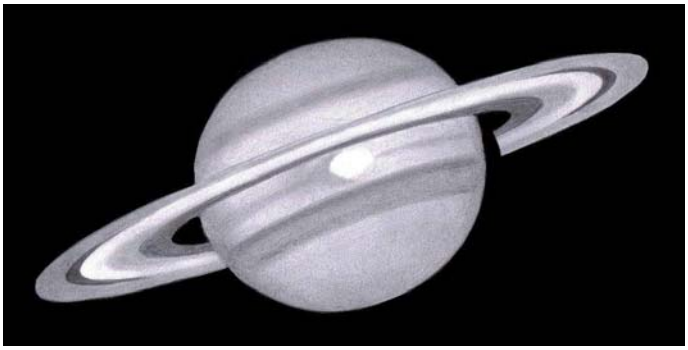

Figure 7. 1994 Oct 9d 23:05UT, ω_1= 012°, ω_2= 009°, 216mm refl. ×232, *R. J. McKim*. The long-enduring EZ white spot is at the CM, preceded by dark shading.

South Tropical Zone

The STropZ was like the STeZ, but its colour was sometimes different (see earlier).

South Equatorial Belt

The SEB was now easy to see, and a light zone (whose brightness strongly indicated it to be part of the southern half of the EZ) separated it from the rings crossing the globe. Biver and Gray saw a few darker sections within the belt, and some observers (Biver, Graham, Gray and McKim) occasionally reported it having darker edges (Figures 3, 6, 13). Latitude measurements[4] show that both edges of the 1993 SEB had been a little south of the average position according to BAA data from 1947–'76.[15] The average latitude for the SEB(S)n in 1993 was –25.8°; the 1994 SEB had a N. edge considerably further north at –18.4°, so it is likely that the whole SEB was observed in the present apparition, though not well resolved. The latitude of its S. edge was very similar to 1993.

Equatorial Zone

EZ(S): A narrow light strip of EZ, denoted EZ(S), lay between Cm and the EB, lighter than what was presumed to be another part of the same zone (separated by the shadow of the rings) to the S. of the rings crossing the globe (see above). On a few dates Biver (1995 Jan 15 (Figure 13)) and Gray (1994 Oct 7 & 8, Nov 21 and Dec 20 (Figure 12)) found a small white spot there: no rotation

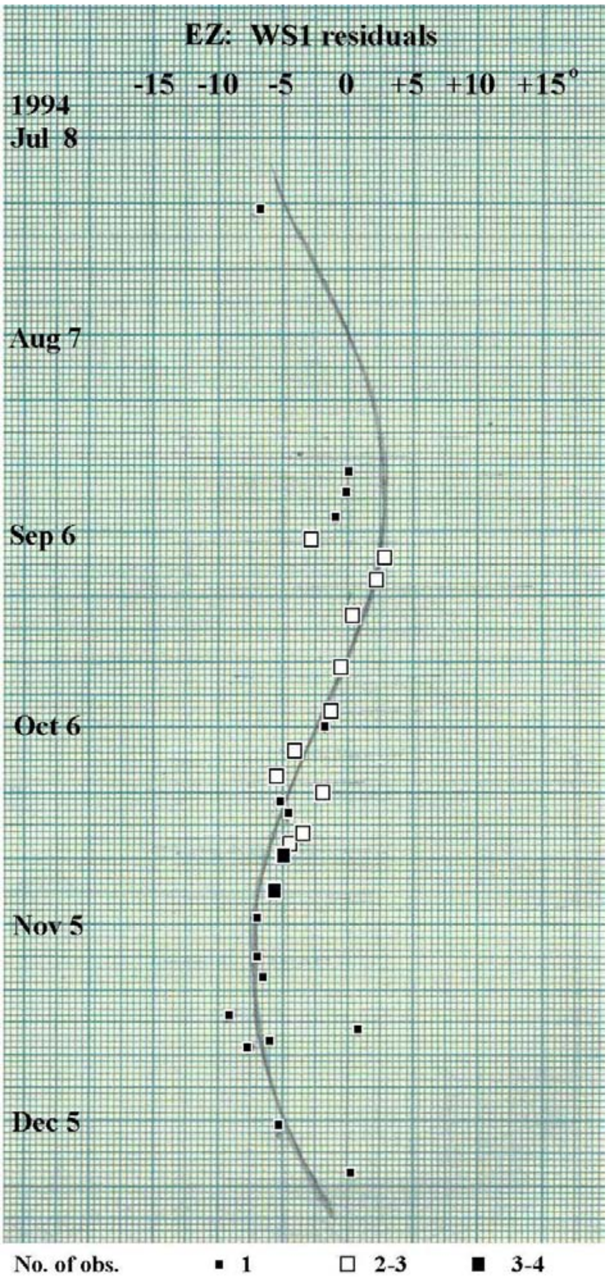

Figure 5C. Two-day means in the longitude residuals (O–C) for the centre of WS1 vs time against a drift rate of +10.65°/day relative to System I. The sinewave illustrated (P= 130 days, A= 5°) is intended roughly to model the longitudinal motion of the centre of the spot. An error in timing of 1 minute is equivalent to a longitude error of 0.6°, so some scatter in the data is to be expected.

period can be deduced but it is certain that there was more than one feature involved.

EB: According to Table 3, the EB lay north of the equator. Occasional darker sections and interruptions were quite marked, and were always associated with the white spots in the EZ(S) or EZ(N).

EZ(N): A number of small white oval spots have been seen at each opposition since the Great White Spot of 1990[16,17], but none were of long duration nor of comparable size. The small-scale activity of 1993[4] yielded drift-rates close to System I.

The northern EZ was the scene of the most interesting activity of the 1994–'95 apparition, when a bright white spot preceded by a dusky column was discovered on Jul 19 by observers at Pic du Midi,[8,14,18] when its centre was stated to be at latitude +9°; subsequently the writer measured it at +10° on Parker's Nov 10 image. Following its announcement in BAA *Circular* No. 742[14] the spot was well observed by our members, and was first confirmed by Gray (Figure 6), Heath and Stephens on Sep 27 when it obliterated

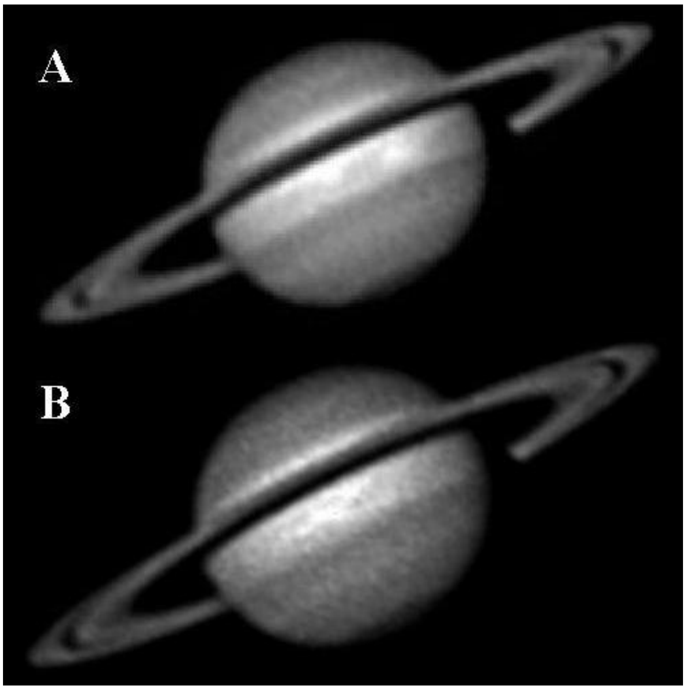

Figure 8. Post-opposition images with Lynxx-PC cooled CCD camera and 410mm refl., *D. C. Parker*.
A. 1994 Oct 25d 01:16UT, ω_1= 153°, ω_2= 023°. EZ white spot No. 8 is near the CM and the long-enduring white spot (EZ white spot No. 1) some 30° *f.* it.
B. 1994 Nov 2d 01:21UT, ω_1= 070°, ω_2= 041°. EZ white spot No. 5 is a little *p.* the CM.

the EB and appeared a little brighter than ring B1.[2,19] It was later observed on many occasions (Figures 7, 8A, 9) with modest apertures and upwards, and Wright could see it with his 133mm OG. Extrapolation of the BAA spot chart (Figure 5A) shows that Gray had observed the white spot (which we shall refer to as WS1) in transit on the discovery date (Jul 19), as an 'indefinite light area', more towards the southern EZ and centred at λ_1= 210°. It later transpired that Asada had taken transits of it from Aug 28, when there was a brighter core within the spot, and that Miyazaki (Figure 14) had imaged it on Aug 22, 25, Sep 7 and 20.

BAA data (mostly CM transits (16 observers)) demonstrate a drift relative to System I of +10.65°/day between the first and last visual transit observations. This translates to an exceptionally slow rotation period of 10h 21m 50.6s. Historically, EZ(N) and NEB(S) features have had periods close to System I (10h 14m 00s). Converting the observed drift to an equatorial wind velocity (adopting the equatorial circumference for Saturn from the 2010 BAA *Handbook*) results in 278 m/sec relative to System III (taken to be the core rotation period). This accords perfectly with 274 m/sec found by Sanchez–Lavega,[8] which is some 100–150 m/sec slower than the equatorial 'jet' measured by *Voyager*.

To Asada on Oct 15 the spot was still as bright as in August. Observers agreed well that the feature as a whole began to fade after October: Asada found it hard to identify by mid-Nov, Biver found it less obvious on Nov 30 than on Nov 1; Gray first described it as appearing diffuse on Nov 24 and it was 'rather indefinite' to him on Dec 13. Its *f.* end was often the least well defined (to Asada from Oct 15, and to Gray as early as Sep 27). Asada considered the EZ was brighter in November than in August, which Gray's monthly intensity averages tend to confirm.

Throughout its life the spot tended to generate a bay in the S. edge of the NEB, or a small NEBs projection on its *p.* or *f.* side. The

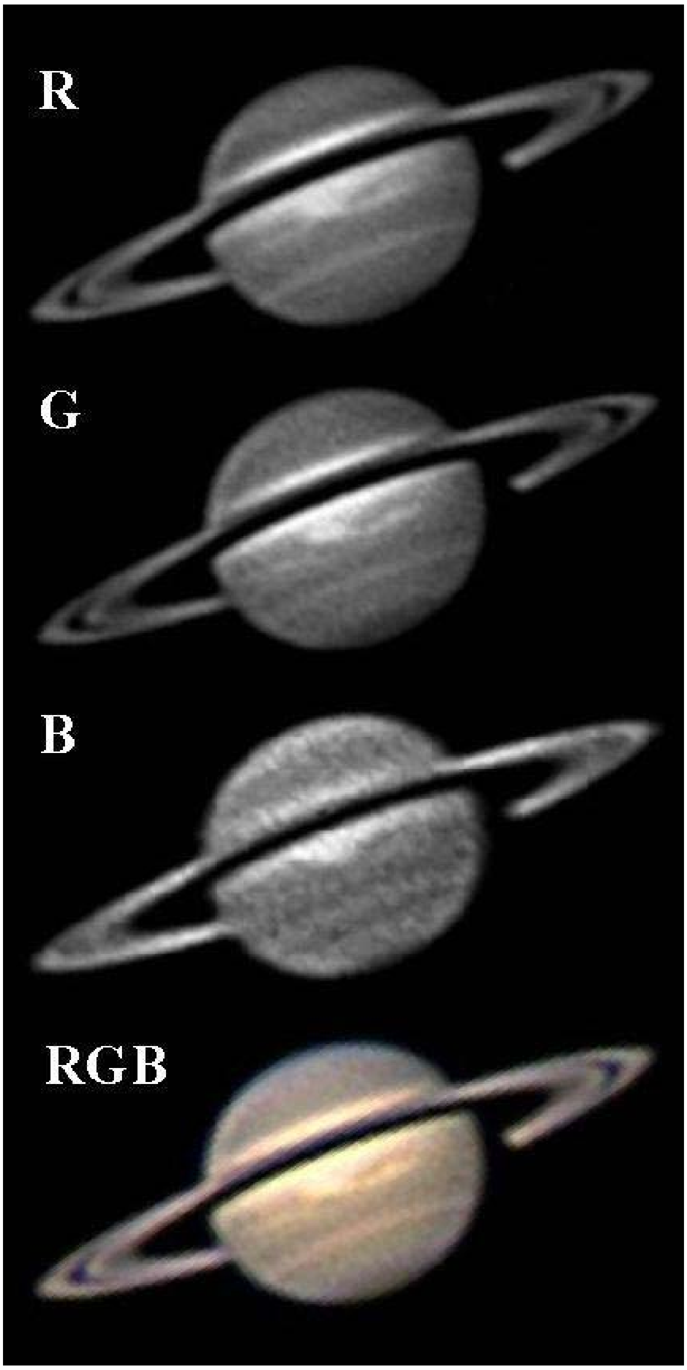

Figure 9. 1994 Nov 10d 01:33UT, ω_1= 350°, ω_2= 063°, 410mm refl., R, G, B and RGB composite images, Lynxx-PC cooled CCD camera, *D. C. Parker*. The long-enduring EZ white spot interrupts the EB and a stream of material follows it on the N*f.* side. Colour differences between the belts and zones are evident.

spot was imaged by Miyazaki, Parker and Strange, and Parker's images (Figure 9) showed its interaction with the EB and NEB in some detail.

The spot was imaged at the CM by the HST on Dec 1 (Figure 11), when it could be seen that the S*p.*, S*f.* and (particularly) the N*f.* sides were drawn out into white streaks parallel to the equator; the white streak in the N*f.* direction had also been well shown by Parker on Nov 10 (Figure 9). The HST image also shows a dark section developing in the EZ(N) close to the NEB S. edge, a feature also caught by Gray. In contrast to the EZ Great White Spots of 1933[17,20,21] and 1990,[16,17] however, it did not fill the entire EZ in terms of latitude, and its core never covered the same span in longitude.

The spot's length from images, complete transits, or reliable half-transits shown thus ( ), was as follows:

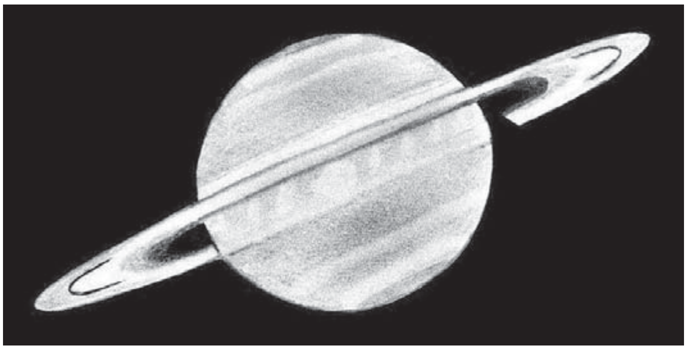

Figure 10. 1994 Nov 27d 01:39UT, ω_1= 306°, ω_2= 189°, 305mm refl. ×300–600, *T. R. Cave*. The EZ is active with WS6 in transit, and the NNTeZ rather light.

Date	*Length (°)*	*Observer*
Aug 22	22	Miyazaki
Aug 25	16	Miyazaki (Figure 14)
Aug 28	30	Asada
Sep 7	21	Miyazaki (Figure 14)
Sep 13	25	Asada
Sep 27	17	Gray (Figure 6)
Sep 27	(17)	Heath
Oct 3	15	Gray
Oct 6	(14)	McKim
Oct 9	(18)	Gray
Oct 9	21	McKim (Figure 7)
Oct 10	18	Gray
Oct 13	14	Gray
Oct 13	15	Lancashire
Oct 15	24	Asada
Oct 22	14	Lancashire
Oct 22	(22)	Whitby
Oct 23	(20)	Lancashire
Oct 24	18	Bruton
Oct 25	(15)	Lancashire
Oct 25	13	Parker (Figure 8A)
Oct 26	(17)	Bullen
Oct 31	(16)	Lancashire
Nov 1	(13)	Biver
Nov 1	17	Gray
Nov 1	15	McKim
Nov 10	13	Parker (Figure 9)
Nov 21	(18)	Gray
Dec 1	16	HST image (Figure 11)
Dec 13	(18)	Gray

With few exceptions the fluctuations are greater than the probable errors in measurement, and thus seem to be real.

We did not follow WS1 after 1994 Dec 13; the Pic du Midi observers rediscovered it again in 1995 May after the next solar conjunction,[8] which BAA data would confirm. Multispectral observations[8] revealed the spot to be considerably higher in the planet's atmosphere than the normal EZ features, doubtless accounting for its strong westward drift.

There were often darker condensations on the EB associated with WS1, and Sanchez–Lavega *et al.*[8] considered that five other long-lived features had moved at nearly the same $\Delta\lambda_1$: WS1 itself, a smaller white spot some 40° *p.* it, a dark condensation on the EB, another white spot *f.* it and a further white spot on the opposite side of the planet. BAA members often caught these other white spots too, and with two exceptions they were best represented by periods closely similar to the main white spot. Almost every transit observation can be perfectly represented by a small number of linear drift-lines. Gray considered that the region's activity in general peaked in September. Cave on Oct 27 drew the entire EZ patchy. As late as 1995 Jan 30 Biver (600mm Cass.) was still sketching complex EZ details.

The observations of all the EZ features are best examined by

Table 2. Visual intensity estimates, 1994–’95

Feature	*SB*	*AB*	*DF*	*MF*	*DGm*	*DGy*	*AH*	*AL*	*RM*	*CM*	*SM*	*RS*	*UAI*	*JW*	*Ave.*	*No.*
SPR						3.9			3.9						3.9	76
SSTB						4.7									4.7	50
STeZ	3.3	3.4		2.8	3.2	2.8	3.0	3.3	3.5	2.8	3.0	2.7		3.0	3.1	170
STB					4.0	3.7							4.6		4.3	72
STropZ	2.5				2.9	3.1			3.1				3.0		2.9	190
SEB	2.9	4.7	3.2	4.4	4.5	4.1	3.6	3.7	4.2	4.0		4.3	4.2	3.6	4.0	234
EZ(S) S. of rings					2.1	2.7		1.6	1.6	0.0	2.5	2.1	2.6	2.9	2.0	189
EZ(S) N. of rings						1.0							1.6		1.3	167
EB					2.5	2.9			2.8				2.9		2.8	93
EZ(N)	0.8	0.8	2.2	1.1	1.5	1.7	1.4	1.1	1.4	0.7	2.2	1.9	1.7	2.2	1.7	278
NEB(S)	4.9	4.7	4.0	4.8	5.0	5.0	5.0	4.4	4.3	4.3	4.8	4.6	4.5	3.9	4.6	281
NEBZ					3.5	3.9			4.1				4.0		3.9	115
NEB(N)					4.9	5.3			4.3				4.6		4.8	194
NTropZ	2.8			2.0	2.7	3.1		2.9	3.1			3.2	3.0	3.5	2.9	218
NTB					4.0	3.9		3.8	3.5			4.0	3.9		3.8	117
NTeZ	3.5	3.9		2.8	3.2	3.1	3.8	3.2	3.4	2.8	3.5	3.0	3.1	3.0	3.2	257
NNTB						4.2							3.6		3.9	65
NNTeZ						3.0									3.0	62
NPB						4.7						6.0			5.4	60
NPR					4.3	3.9		3.5	3.9			4.3	3.8		4.0	177
NPC						5.1							5.1		5.1	93
Ring A1	3.0	3.4	4.5	2.1	3.3	3.6	3.3	1.6	2.3	2.3		3.8	3.7	2.4	3.6	267
Encke’s divn.						4.9							8.6		6.8	27
Ring A2						2.6		1.5	2.3				2.4		2.2	95
Cassini’s divn.		8.0		10.0	6.6	7.1	8.5		5.9	4.2		8.4	8.0	9.6	7.6	225
Ring B1	1.0	1.0	1.0	1.0	2.0	1.9	1.5	1.1	1.7	1.5		2.2	2.3	1.0	1.5	259
Ring B2		2.3	3.2	2.8	2.5	3.0		1.2	2.2	2.0		4.1	3.0	1.9	2.6	216
Ring C				7.0	8.7	7.9			6.0			7.5	6.2	7.1	7.2	117
Ring C_m		8.8	9.0	7.1	7.4	7.4	8.6		7.7	4.8	7.8	7.0	7.4	5.5	7.0	193
ShRG	8.5				9.7	9.2		9.4	9.1			7.7	9.2	10.0	9.1	110
ShGR	9.7	10.0	10.0	10.0	9.7	10.0		10.0	10.0	10.0	10.0	9.6	9.6	10.0	9.9	220
Total used	187	123	16	231	138	1,838	103	53	293	27	13	73	1,737	55		4,887

Key to observers: SB, Beaumont; AB, Bowyer; DF, Fisher; MF, Foulkes; DGm, Graham; DGy, Gray; AH, Heath; AL, Lenham; RM, McKim; CM, Meredith; SM, S. L. Moore; RS, Schmude; UAI, Unione Astrofili Italiani; JW, Warell.

means of a longitude system which increases by 10.65°/day relative to System I. These data are shown in Figure 5B. Given their steady drifts and long endurance, rotation periods can be derived for several bright features in the EZ(N) despite the relatively small number of positions. WS2, WS3, WS4, WS5, WS6 and WS8 all moved with the WS1 drift-rate. On Dec 16.73, Dec 19.72 and Dec 22.70, the centre of WS7 was transited by Gray at nearly constant longitudes in System I of 346.0°, 347.9° and 347.8° respectively, corresponding to a normal drift rate for the EZ and suggesting that the equatorial ‘jet’ speed at that altitude at least was unchanged. This spot was closer to the NEB in latitude than some of the other spots:

Spot	*Limiting dates*	*No. obs.*	*$\Delta\lambda_1$ (°/day)*
WS1(c)	Aug 28–Dec 13	51	+10.65
WS2(c)	Sep 3–Jan 30	8	+10.59
WS3(c)	Oct 4–14	2	+10.59
WS4(c)	Oct 8–Jan 15	6	+10.55
	(probable limits Jul 17–Jan 15)		
WS5(c)	Nov 1–Dec 17	4	+10.40
WS6(c)	Sep 2–Dec 12	5	+10.57
	(probable limits Jul 18–Dec 31)		
WS7(c)	Dec 16–22	3	+ 0.30
WS8(c)	Aug 25–Nov 14	3	+10.80
	Average excluding WS7:		+10.59
	EZ(N) average period: 10h 21m 48s		

As noted earlier, WS1 was the long-enduring white spot. WS6, very roughly opposite the latter, was Sanchez–Lavega’s ‘antipodal’ white spot for which he obtained a velocity of 282 m/sec relative to System III. BAA data for WS6 yield the highly accordant figure of 279 m/sec. Further evidence of the slow EZ drift rate for large white spots would be obtained over the next few apparitions, and Sanchez–Lavega *et al*. have summarised those data elsewhere.[9]

A further investigation into the motion of WS1 was conducted by calculating the (O–C) residuals for its central longitude (and ends) against a constant drift of +10.65°/day. Data from the two main observers Asada (17 CMTs) and Gray (11 CMTs) independently agreed in showing a systematic (O–C) variation with time. Their results were combined with other observers’ work and 2-day means calculated to slightly smooth the data, and the results are shown in Figure 5C. The data clearly show a sinusoidal oscillation with a period of the order of 130 days and amplitude of *ca*. 5°. A sinewave of this description is plotted for comparison in Figure 5C. The more positive residuals towards the end of the observing period account for the marginally more positive overall drift rate than was measured

Figure 11. 1994 Dec 1d, HST image showing the long-enduring EZ(N) white spot WS1 at the CM (*R. Beebe (New Mexico State University), D. Gilmore, L. Bergeron (STScI), and NASA*). The rings look dull; Encke’s division (gap) is shown. The false colours (an amalgamation of red and blue images, with added green) only very roughly approximate to the visual appearance.

in the first months after discovery. This oscillation recalls the approximately 90-day period sometimes found for the Great Red Spot of Jupiter.[22,23]

North Equatorial Belt

The NEB was closely double and dark throughout 1994–95, with a dusky NEBZ between the components. Particularly following the appearance of white spot activity in the EZ(N), moderate to large apertures indicated slightly darker sections as well as southward projections: there was often some NEBs projection or EZ(N) column associated with the conspicuous long-lived EZ(N) white spot, as already described. These were probably temporary enhancements or disruptions in the belt caused by the spot. It is possible that there were a few other dark NEBs spots moving at the same rate as the white spot in other sectors of the EZ(N) but transit data are not sufficient to be sure.

Table 3. Saturnicentric latitudes, 1994–'95

Feature	*RB*	*DGm*	*DGy*	*AL*	*RM*	*IM+DP*	*RS*	*UAI*	*Average*
SSTBs			−48.8						48.8
SSTBc			−45.8					−43.1	−44.4
SSTBn			−42.9						−42.9
STBs			−37.8		−31.9				−34.8
STBc		−45.1	−33.4		−30.4			−34.0	−35.7
STBn			−29.0		−28.8				−28.9
SEBs	−25.3	−29.7	−24.6	−26.0	−26.4	−29.1	−31.6	−25.9	−27.4
SEBn	−15.1	−22.6	−15.9	−17.0	−18.7	−19.1	−16.4	−21.9	−18.4
EBs			+1.1		+5.1			+3.3	+3.2
EBc		+3.3	+2.8		+5.8	+5.4		+4.4	+4.3
EBn			+4.5		+6.4			+5.6	+5.5
NEB(S)s	+10.3	+14.3	+13.0	+11.0	+14.9	+16.1	+9.4	+15.8	+13.2
NEB(S)n		+17.3	+16.0		+16.4			+18.3	+17.0
NEB(N)s		+21.3	+20.4		+25.7			+21.8	+22.3
NEB(N)n	+22.3	+25.5	+23.4	+19.0	+28.0	+28.0	+20.6	+26.8	+24.2
NTropBc			+28.7						+28.7
NTBs		+36.8	+34.4		+41.6	+36.4	+39.3	+36.7	+37.5
NTBc		+39.7	+38.0		+44.4		+43.0	+38.5	+40.7
NTBn		+42.2	+41.7		+47.3		+46.8	+40.3	+43.7
NNTBs			+46.7						+46.7
NNTBc			+49.4						+49.4
NNTBn			+52.1						+52.1
NPBs			+57.5						+57.5
NPBc			+59.6						+59.6
NPBn			+61.8						+61.8
NPRs		+61.9	+61.8		+54.2	+61.8		+60.1	+60.0
NPCs			+67.1					+65.7	+66.4
Total	10	69	215	13	32	30	12	645	1,026

Key to observers: RB, Bullen; DGm, Graham; DGy, Gray; AL, Lenham; RM, McKim; IM+DP, Miyazaki+Parker; RS, Schmude; UAI, Unione Astrofili Italiani.
All observers reduced their own drawings, and McKim reduced Miyazaki's and Parker's CCD images which are amalgamated in one column. The UAI data arise primarily from measures off drawings.

The NEBZ was fairly dark and bland. Two transits of a diffuse darker spot (DS1) were made by Gray, and appear to have corresponded to the same feature (which on Oct 10 was immediately north of the long-enduring EZ(N) white spot), but the short time interval and its diffuse nature mean that the period should be treated with considerable reserve.

Spot	*Limiting dates*	*No. obs.*	*Limiting λ_2*	*$\Delta\lambda_2$ (°/day)*
DS1c	Oct 10–14	2	358–348	−2.67
	NEBZ period:	10h 36m 20s		

The NEB(N) was broader than the S. component. There were a number of darker spots or segments in this belt, accounting for its average intensity being marginally higher than the NEB(S) (Figures 6, 12). Numerous transits were made by Gray. Niechoy often drew the belt's N. edge as irregular. Positions were measured from drawings by Bullen (Aug 18, Sep 7) and McKim (Sep 27).

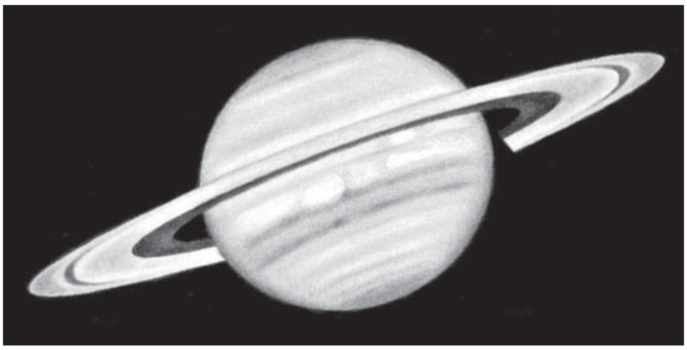

Figure 12. 1994 Dec 20d 17:30UT, ω_1= 119°, ω_2= 319°, 415mm DK Cass. ×262, *D. Gray*. White spot activity in the NEB and EZ(N) continues: the light patch between the NEBs plumes *p.* the CM is WS2. A small bright EZ(S) white spot is also seen south of the EB. The NTropB, NTB, NNTB and NPB are all seen.

A plot of these longitudes strongly suggests that all moved with similar small negative drifts with respect to System II. Some features could be identified with certainty over short intervals (though in each case there is evidence for a longer continuation) to yield drift rates. Given the short time intervals, periods for individual dark spots DS1–DS5 should again be treated with reserve, but the average looks to be typical:

Spot	*Limiting dates*	*No. obs.*	*Limiting λ_2*	*$\Delta\lambda_2$ (°/day)*
DS1c	Oct 4–24	2	186–177	−0.45
DS1f	Oct 28–Nov 21	2	186–173	−0.52
DS2c	Oct 28–Nov 21	2	190–178	−0.50
DS3f	Nov 6–26	2	275–262	−0.65
DS4f	Oct 14–18	2	338–333	−1.27
DS5p	Dec 16–20	2	309–307	−0.55
DS5c	Dec 16–20	2	312–309	−0.77
		Average:		−0.67
	NEB(N) average period:		10h 37m 54s	

North Tropical Zone

The NTropZ often appeared lightest in its northern two-thirds to Gray, who also witnessed (from 1994 mid-Oct onwards) a narrow NTropB between these N. and S. parts, and a lighter patch on two occasions. Biver confirmed the presence of the NTropB. Parker's CCD camera showed the NTropZ appearing much lighter than the NTeZ.

Gray recorded the *f.* end of the NTropB on Nov 6 and Nov 26; on the latter date it also corresponded to the end of a darker NTropZ section. The *f.* end of a NTropZ dark section (DS1) was drawn without a transit at the same longitude on Sep 27 (Figure 6). The tentative period was as follows:

Spot	*Limiting dates*	*No. obs.*	*Limiting λ_2*	*$\Delta\lambda_2$ (°/day)*
DS1f	Nov 6–26	2	273–276	+0.14
	NTropZ/NTropB period:		10h 38m 32s	

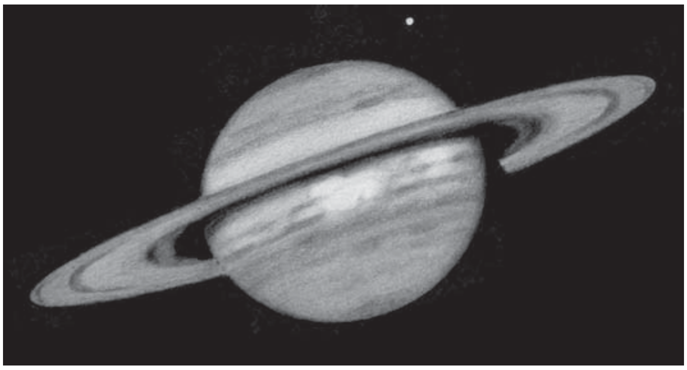

Figure 13. 1995 Jan 15d 17:18h UT, ω_1= 100°, ω_2= 180°, 1m Cass. ×735 (Meudon Obs.), *N. D. Biver*. EZ white spot WS4 at the CM, and another white spot S. of the irregular EB. The NTropB, NTB and NNTB are shown. The rings appeared very dull in comparison with the globe. Rhea is approaching inferior conjunction.

North Temperate Belt

The NTB was easy to witness with large instruments, given good seeing. Some tonal variations were noted. McKim saw the belt easily in July from the USA with a 457 mm reflector (Figure 3) and detected it through smaller ones, but it was never very obvious to him against the dusky neighbouring NTropZ and NTeZ through a modest instrument under UK skies.

North Temperate Zone

The NTeZ appeared very bland and darker than the NTropZ.

North North Temperate Belt

The NNTB was sharper and narrower than the NTB, according to Gray.

North North Temperate Zone

Not seen by most observers, the NNTeZ was observed by Gray to be a little lighter than the NTeZ, and was sometimes very light. Cave (Figure 10) observed the zone to be unusually light in Oct–Nov.

North Polar Region

The dusky NPR was edged by a thin dark NPB according to Gray and Schmude, and the former also reported a darker NPC within the NPR. Patrick Moore (Oct 4) and others found the NPR much darker than the part of the SPR visible at the extreme S. limb.

The rings

Ring A

The inner part was lighter as usual, and components A1 and A2 were sometimes seen to be separated either by a sharp division (which Biver saw more towards the outer edge of the rings (Figures 2, 13)), or more usually by a low-resolution view of the so-called 'Encke complex' at the centre of the ring which Foulkes[1] has described in detail for a later apparition. The UAI observers found a rather high intensity for Encke's division proper.

Cassini's Division

This obliquely presented division was visible only at the ansae. Bowyer, Graham, Gray and McKim all estimated it to be lighter than

in 1992, and the writer made particular note of the effect with the 610mm Clark refractor at Flagstaff on Jul 27, the appearance strongly reminding him of a 1948 Palomar photograph.[24] The reduction in intensity is more likely to be due to scattering of sunlight at low angles of incidence by the few ring particles within the division than the effect of irradiation, given that the effect was more noticeable with the larger apertures.

Ring B

Ring B1 (the bright reference standard) did not appear as bright as usual to most observers (Table 2) due to the narrow angle of opening of the rings. This was confirmed by several images, such as Mobberley's of Oct 11, where it appeared paler than the EZ. Ring B1 (and the rest of the ring system) was drawn particularly dull on Biver's sketches in Nov–Jan (Figure 13). B1 faded further after opposition due to the increasing phase angle and the decrease in latitude of the subsolar point. Ring B2 and imperfectly resolved B3 were progressively darker, inner components.

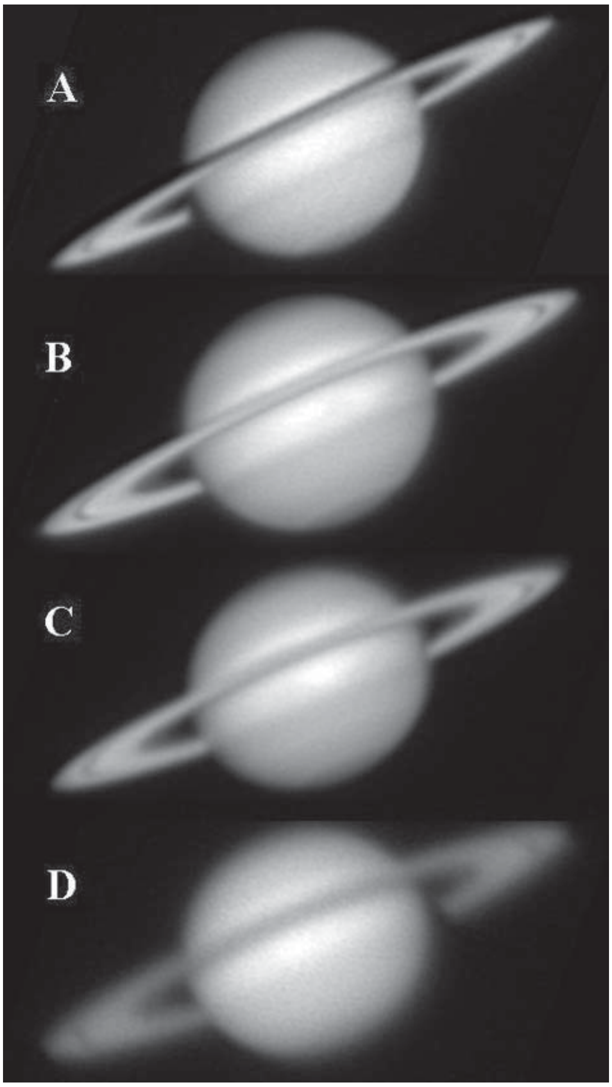

Figure 14. CCD images with a Lynxx PC camera and 400mm refl. illustrating the change in presentation of the rings during the apparition. *I. Miyazaki*.
A. 1994 Jul 1d 19:09UT, ω_1= 039°, ω_2= 032°. Note ShRG south of the rings.
B. 1994 Aug 25d 14:20UT, ω_1= 229°, ω_2= 251°. Ring C is clearly visible. The EZ shows two white spots.
C.1994 Sep 7d 13:46UT, ω_1= 026°, ω_2= 349°. EZ WS1 approaching the CM.
D. 1994 Nov 14d 13:50UT, ω_1= 200°, ω_2= 126°. The rings have opened since opposition and have darkened considerably.

Miyazaki's images from 1994 July to November clearly show the decrease in intensity of the rings generally during that period (Figure 14).

Ring C

Compared with its appearance when the rings are well open, ring C when seen was relatively light, a point often noted at low values of 'B'. It was well shown in some CCD images (Figure 14).

Ring C crossing the globe (C_m)

A normal dark band adjacent to the EZ(S); see also ShRG below. There had been reports of a mottled aspect to C_m from several observers in 1993,[4] but only Meredith reported it at the present opposition, and we must dismiss the 1994 impressions as illusory.

Shadow of rings on globe

ShRG was well visible to the S. of the rings crossing the globe until Aug 20 by Gray (Figures 1–4). On Aug 27 to Gray it was difficult, and it became invisible during Sep 2–17. After that, it was first seen to be darkening the S. part of ring C crossing the globe (C_m) to Beaumont and Gray on Sep 21. After that it remained visible in the same location.

Shadow of globe on rings

ShGR was visible up until Aug 27 (Gray) on the W. side and from Sep 6 (Platt) on the east. No-one could see it on Sep 2, one day after opposition. Adjacent to ShGR the contrast phenomenon called the Terby White Spot was distinctly visible to Warell before opposition on Jul 25, 29 and Aug 17, and to Whitby after opposition on Sep 20, 30 and Nov 12. On Sep 30 the latter saw it disappearing and reappearing as seeing fluctuated.

Bicoloured aspect of the rings

This effect has been described in previous reports and in a paper in the *Journal*.[25] Differences between the E. (IAU) (*p*.) and W. (*f*). ansae were noted as follows:

p. ansa brighter than f.		*f. ansa brighter than p.*	
Aug 4 (Schmude)	Note a		
Aug 18 (Bullen)	Note b		
Sep 7 (Bullen)	Note b		
		Sep 21 (Dobbins)	Note c
Oct 9 (Heath)	Note d		
Oct 22 (Whitby)	Note d		
Oct 25 (Parker)	Note d		
Jan 26 (McKim)	Note e		

Note a: Visual. For the entire ansae, in white light only.
Note b: Visual. For rings A and C, with W13 filter (Aug 18) and W8 (Sep 7).
Note c: For rings A and B from video stills with W12 yellow filter, and subsequently visually also, with W21 orange, W25 red, W56 green and W38A blue.
Note d: Visual. For the entire ansae, in blue light only. Equal in red and white.
Note e: Visual. The bright patch at ring B1 was easier to see in the *p.* ansa.

Negative reports were also logged by these observers during 1994 Jul–1995 Jan. (We have disregarded reports of differences with telescopes smaller than 15cm.)

The satellites

With the closing of the rings, transits and occultations of the inner satellites began to be observable, and running the *WinJUPOS* program readily confirmed that all moons from Rhea inward underwent eclipses, occultations and transits. No predictions were published in the BAA *Handbook* until the following apparition, but at the instigation of David Graham, Roy Delo of the Computing Section produced a set of predictions for observers. On 1994 Dec 19 at 17:00UT Gray was able to see the shadow of Rhea projected upon the globe at high southern latitude close to the CM: his drawing was previously published by Foulkes.[26]

Viens succeeded in resolving the disk of Titan on Aug 8.

Errata in 1993 report

In Table 3,[4] Gray's latitude for the NPBc should read +61.0° and not +73.2°; the published average latitude for that belt (+58.6°) is, however, correct.

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