The eastern and western elongations of Venus, 1991–1998

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A report of the Mercury & Venus Section (Director: R. J. McKim)

This Report discusses ten successive morning and evening elongations. Data concerning phase anomaly, bright and dark atmospheric markings, cusp extensions and the Ashen Light are discussed. Systematic visual observations over days and weeks again provided definitive evidence for the 'four-day' retrograde 'weather' period, and measurements over a longer, eight-year epoch yielded a reliable average period of 3.99524 ±0.00027 days, closely comparable with the long-term average derived by C. Boyer and others. The phase anomaly was never very large, but 1994 E yielded a significantly higher anomaly than the other elongations. Occasional records were made of the blunting of the S cusp near dichotomy; the less commonly blunted N cusp was well observed at the 1995 W elongation. High resolution data for two elongations suggest that cusp-blunting may simply be due to the presence of high latitude dark bands at such times, or strong polar turbulence. Of the other discrete bright features (recorded mostly at the limb), there was a definite preponderance of the southern over the northern hemisphere. During 1991 to 1998 there were somewhat more records of the true Ashen Light (*i.e.*, when it appeared brighter than the surrounding sky) compared with the equivalent period from 1999 to 2006, with the 1991, 1993 and 1996 evening elongations yielding a significant number of independently confirmed sightings.

Introduction

The beauty and brilliance of Venus (Figure 1) both captivates and frustrates the visual observer. Nonetheless, the epoch 1956–1991 was marked by an unbroken series of BAA Venus elongation reports, showing the determination of successive generations of observers. Since 1991 few final reports have been published, dealing only with the elongations of 1991 E,[1,2] 2001 E[3] and 2004 E & W.[4] A number of short Section *Circulars* and *Newsletters*[5–7] and notes upon various elongations have also appeared in print.[8–17] Also of interest is the long-term Ashen Light report, covering the 1890s to 1990s.[18] Together with a similar recent Section Report for 1999–2006,[19] the present account (encompassing five pairs of morning and evening elongations) fills the remaining gap in publication.

In 1991–1998 almost all the observations were visual; there was some photographic work (Figure 2), pioneering early CCD work by Cook and others, and a handful of ultraviolet images. By 2000 the 'webcam revolution' was supplying many electronic images to the Section, from infrared to ultraviolet wavebands,[19] but for the period under review no observer was making fully systematic images, UV or otherwise.

No spacecraft visited Venus during 1991–1998, but NASA's *Pioneer Venus* (Figure 3A) encountered the planet a little earlier, in 1990 February.[20] The planet was subject only to limited observation by the Hubble Space Telescope (HST; Figure 3B) and there exist few other sources of data for useful comparison except for reports by similar groups such as the ALPO in the USA, the UAI in Italy[21] or the Japan-based JALPON.[22] It is hoped that, despite the delay in publication, this paper will be more valuable than ten individual elongation reports. In this respect we follow the lead given by former Director J. Hedley Robinson in his BAA *Memoir* covering the period 1956–1972.[23]

Figure 1. Venus in the evening, in conjunction with the crescent Moon (note the Earthshine). A digital photograph taken from Cyprus, 2007 March 21. *Jamie Cooper*.

Table 1. Observers of Venus, 1991–1998

Name	Location	Instrument(s)§	Elongations covered#
P. Abel	Burton-on-Trent	115mm refl.	FG
G. Adamoli	Verona, Italy	108mm OG	ABCE
	Padua, Italy	250mm refl.	
P. Barton*	Harrogate, N.Yorks.	220mm refl.	AC
R. M. Baum	Chester	115mm OG	ABC
(with Mrs A. Baum & Mr J. Baum)			
S. Beaumont	Windermere, Cumbria	75mm & 125mm OGs; 235mm & 305mm refls.	ABCDEFGIJ
N. D. Biver	Versailles, Paris, France	200mm refl.	EF
	Meudon Obs.	600mm Cass.	
K. W. Blaxall	Colchester, Essex	216mm refl.	A
M. Bosselaers	Berchem, Belgium	225mm & 250mm refls.	ABCDEF
M. Boulton	Redditch, Worcs.	157mm & 250mm refls.	AC
R. D. Bowen	Wakefield, W.Yorks.	300mm refl.	G
R. Braga	Corsico, Italy	102mm OG	I
C. E. R. Brook	Plymouth	60mm OG	GI
R. Buggenthien*	Lübeck, Germany	152mm OG	ABD
T. R. Cave	Long Beach, CA, USA	140mm OG & 320mm refl.	G
E. Colombo	Milan, Italy	152mm refl.	G
A. C. Cook**	Frimley, Surrey	200mm refl.	ABCD
W. Cuppens	Genk & Gruitrode, Belgium	203mm S–C & 200mm OG	CF
F. Daerden	Bilzen, Belgium	250mm refl.	AC
H. J. Davies	Swansea	75mm OG & 215mm refl.	BC
P. B. Doherty	Selsey, W. Sussex	390mm refl.	E
J. Dragesco	St Clément-de-Rivière, France	152mm M–C	H
E. L. Ellis	St Albans	90mm OG & 203mm S–C	ABCFGH
M. Falorni	Florence, Italy	205mm refl. & 360mm OG (Arcetri)	(A)
D. Fisher	Kemsley & Sittingbourne, Kent	215mm refl.	ABCDFGHJ
J. R. Fletcher	Tuffley, Gloucester	254mm refl.	A
M. Frassati	Crescentino, Italy	203mm S–C	J
M. V. Gavin**	Worcester Park, Surrey	300mm S–C	G
M. A. Gélinas	Ile-Perrot, Québec, Canada	152mm OG	ABCE
M. Genovese	Turin, Italy	200mm refl.	(A)
M. Giuntoli	Montecatini Terme, Pistoia, Italy	80mm OG	(A)BCDEFGJ
D. L. Graham	Brompton-on-Swale & Gilling West, N.Yorks.	152mm OG 406mm refl.	ABCDFG
D. Gray	Kirk Merrington, Co. Durham	415mm D–K	HIJ
D. Greenwood	Morecambe, Lancs.	470mm refl.	A
A. W. Heath*	Long Eaton, Notts.	203mm M–C & 254mm & 300mm refls.	ABCFGIJ
R. Hermans	Berchem, Belgium	250mm refl.	C
H. Hill	Wigan, Lancs.	210mm S–C	C
A. P. Johnson	Knaresborough, N.Yorks.	210mm refl.	ABC
J.–M. Leclére	Paris, France	153mm OG & 254mm refl.	A
S. Leonini	Sienna, Italy	400mm Cass.	(A)
T.W. Lohvinenko	Winnipeg, Canada	203mm S–C	A
D. H. Lorenzen	Bovenden, Germany	114mm refl.	A
L. T. Macdonald	Newbury, Berks.	222mm refl.	ACEI
R. Mackay	Havant, Hants.	203mm refl.	CG
R. J. McKim	Oundle & Upper Benefield, Northants.	76mm & 102mm OGs, 216mm & 300mm refls.	ACEFGIJ
	Colchester, Essex	152mm OG	
	Long Beach, CA, USA	320mm refl.	
G. Marabini	Castelguelfo, Italy	203mm S–C	(A)BC
J. C. D. Marsh*	Baldock, Herts.	203mm S–C	CDG
C. Meredith	Prestwich, Manchester	220mm refl.	ABCDEFGH
R. W. Middleton	Brightlingsea, Essex	127mm OG & 254mm refl.	DEFGHI
M. P. Mobberley*	Cockfield, Bury St. Edmunds	490mm refl.	G
P. A. Moore	Selsey, W. Sussex	127mm OG, 320mm & 390mm refls.	(A)BCDEF GHI
	SAAO, Sth Africa	457mm OG	
D. Niechoy**	Göttingen, Germany	102mm OG & 203mm S–C	all
	Carona, Switzerland	300mm refl.	
D. C. Parker**	Coral Gables, Miami, Florida, USA	400mm refl.	GI
I. S. Phelps	Warrington	150mm refl.	EGHI
(with L. Phelps)			
J. Polle	Salzgitter, Germany	130mm refl.	C
C. Raeburn	Alderney, Channel Islands	150mm M–C	A
D. Sarocchi	Florence, Italy	200mm S–C	(A)
R. W. Schmude*	Texas A&M Univ., Texas, USA	254mm refl. & 355mm S–C	ACDEFGHI
	Barnesville, & Villa Rica, Georgia, USA	102mm OG & 510mm refl.	
P. Smith	Darlington, Co. Durham	150mm refl.	AB
R. M. Steele	New Farnley, Leeds	80mm OG	IJ
(with M. L. Steele)			
M. Stübig	Salzgitter, Germany	114mm refl.	C
K. M. Sturdy	Helmsley, N.Yorks.	215mm refl.	ABCDEFGH
E. T. H. Teague	Chester	63mm OG & 215mm refl.	BCDG
L. Testa**	Parma, Italy	152mm OG & 200mm refl.	ABCEH
Unione Astrofili Italiani	various	various	(A)BCD
P. Vandenbulcke	Oostduinverve, Belgium	282mm S–C	E
J. Vantomme	Ekeren, Belgium	300mm refl.	C
E. Verwichte	Genk, Belgium	150mm refl. & 200mm OG	AC
J.–F. Viens	Charlesbourg, Québec, Canada	115mm & 254mm refls.	ABCDEF
A. Vincent*	Worthing, W.Sussex	203mm S–C	EGI
F. Vincent	St Andrews, Scotland	203mm S–C	B
F. Vitale	Saline Joniche, Italy	100mm OG	B
P. Wade	Morecambe, Lancs.	203mm S–C	EFGHIJ
J. Warell	Uppsala & Ulricehamn, Sweden	152mm refl. & 161mm OG	ABC
A. E. Warren	Northampton	130mm OG	A
D. C. Wright	Caterham, Old Coulsdon, & Sanderstead, Surrey	133mm OG	ACFG

§ S–C: Schmidt–Cassegrain; D–K: Dall–Kirkham Cass.; M–C: Maksutov–Cass.

A = 1991E; B = 1991W; C = 1993E; D = 1993W; E = 1994E; F = 1995W; G = 1996E; H = 1996W; I = 1997E; J = 1998W. ( ) denotes contributions received too late to be noticed in the previously published 1991 E Report.[1,2]

* denotes photographs; ** denotes CCD images.

Translated excerpts of observations by M. Stübig & J. Polle of the Verein. der Sternfreunde (Germany) were contributed by D. Fischer.

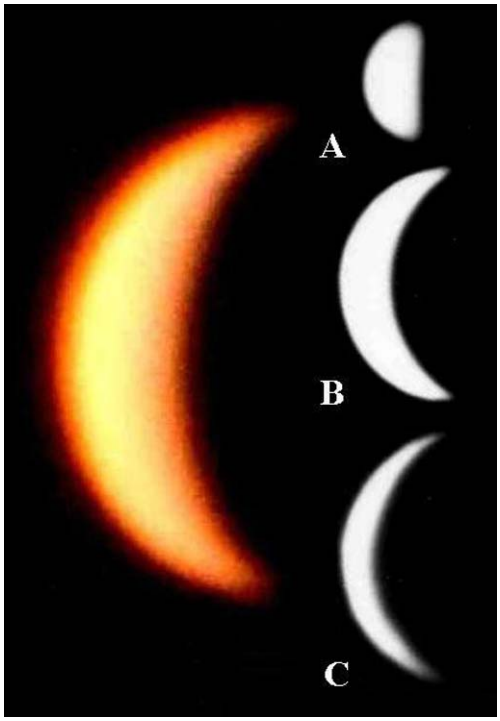

Figure 2. Photographs of Venus. Unless otherwise stated, south is uppermost in all figures.
Left: Venus photographed in colour on 1996 May 8d 18h 36m, with 490mm refl. at f/50, 1/30s on Fuji Provia slide film, *M. P. Mobberley*.
Right: Venus photographed with 203mm Schmidt–Cass. at f/80, 0.5s on Kodak TP 2415 film, *J. C. D. Marsh*.
A 1993 Feb 2d 18h 45m; **B** 1993 March 15d 19h 05m; **C** 1993 March 26d 18h 52m.

In the preparation of the present paper, computer analyses of a large amount of apparent dichotomy data (from 1991 E to1994 E inclusive) were performed by Blaxall, whilst Heath carried out preliminary descriptive analyses of 1995 W to 1998 W. The Director extended and completed this work and was responsible for the overall writing of the Report.

Observers and elongations

Table 1 lists the observers. We note the substantial contributions of Beaumont, Bosselaers, Ellis, Fisher, Giuntoli, Graham, Heath, McKim, Meredith, Middleton, Moore, Niechoy, Schmude, Sturdy, Testa, Viens and Wade, all of whom observed at five or more elongations. Gray produced exceptionally high resolution drawings at a few elongations. Of the observers listed herein, we especially regret the subsequent deaths of Tom Cave, Paul Doherty, Edward Ellis, Marco Falorni, Harold Hill, J. C. D. (Lou) Marsh and Keith Sturdy.

Table 2 summarises key dates for the period. Meeus[24] has tabulated the geocentric ecliptic latitude of Venus at inferior conjunction (IC), which effectively gives the angular separation between Venus and the Sun (Table 3). The 1996 IC was exceptionally favourable for observing the complete atmospheric ring, and indeed such observations were secured.

Table 2. Venus elongations, 1991–1998

*SC**	*GEE**	*IC**	*GEW**	*SC**
1990 Nov 1	1991 Jun 13	1991 Aug 22	1991 Nov 2	1992 Jun 13
1992 Jun 13	1993 Jan 19	1993 Apr 1	1993 Jun 10	1994 Jan 17
1994 Jan 17	1994 Aug 24	1994 Nov 2	1995 Jan 13	1995 Aug 21
1995 Aug 21	1996 Apr 1	1996 Jun 10	1996 Aug 20	1997 Apr 2
1997 Apr 2	1998 Nov 6	1998 Jan 16	1998 Mar 27	1998 Oct 30

* SC= Superior conjunction; GEE = Greatest elongation east; IC = Inferior conjunction; GEW =Greatest elongation west

Table 3. Venus inferior conjunctions, 1991–1998

Inferior conjunction	*Geocentric ecliptic latitude of Venus*
1991 Aug 22	–8° 14'
1993 Apr 1	+7° 52'
1994 Nov 2	–5° 24'
1996 Jun 10	–0° 30'
1998 Jan 16	+5° 49'

The observations

Although a Venus intensity scale has long existed,[25] together with a more recent scale of polar brightening,[1] it is not easy to compare the relative conspicuousness of Venusian markings from one elongation to the next. Observers differ considerably in portraying the dark markings that are often so elusive in integrated light, but there is generally much better accord with the bright features: cusp-caps, light spots, and cusp extensions. In this report we have tried to be objective, and to record only reasonably certain data and conclusions. The Section programme has been published in the *Journal*[26] as well as in the BAA *Observing Guide*.

Dark markings

1991 E

Except for mention of the polar collars, the 1991 E elongation

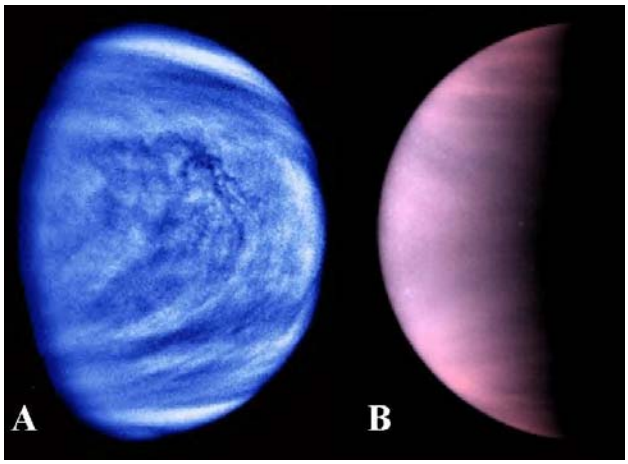

Figure 3. Venus viewed from space. North is uppermost.
A False-colour image of Venus by the *Pioneer Venus* spacecraft, 1990 Feb 14 *(NASA)*
B False-colour UV image of Venus by the HST Wide Field Planetary Camera-2 on 1995 Jan 24 *(L. Esposito/NASA (STScI-PRC1995-16))*.

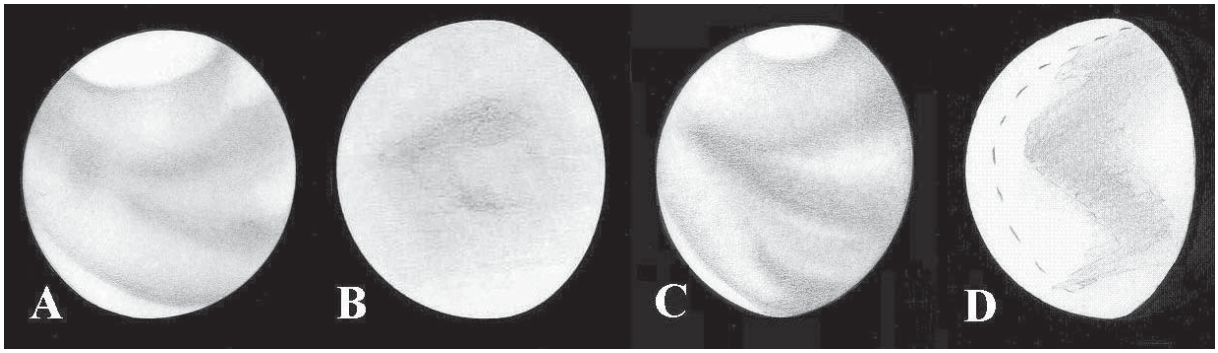

Figure 4. The long-enduring Y-marking at the 1991 E elongation, according to visual observations.
A 1991 Feb 11d 17h 15–35m, 115mm OG, ×186, *R. M. Baum*;
B 1991 Feb 19d 17h 40m, 127mm OG, ×250, *P. A. Moore*;
C 1991 Mar 11d 18h 30–50m, 115mm OG, ×186, *R. M. Baum*;
D 1991 Apr 12d 19h 51m–20h 07m, 152mm OG, ×261, *M. A. Gélinas*.

report[1,2] did not discuss dark markings, though there was brief mention in a Section publication,[5] and an atmospheric chart by Smith appeared in another *Newsletter*.[7]

The 1991 E drawing file was the largest of those archived for this period. A special search was made for records of the long-enduring Y (or Y and Ψ) features. A significant number of drawings clearly showed a Y feature upon the gibbous disk, and (as we shall presently see) these were useful in establishing an average rotation period. Thus Baum on Feb 11 (Figure 4A) was the first to observe it, Patrick Moore drew it on Feb 19 (Figure 4B), Bosselaers on March 3 (with partial confirmation by Beaumont and Moore), Baum again clearly described the Y feature in his notes on March 11 (Figure 4C), and other records by Macdonald (April 4), Gélinas (April 12, Figure 4D), Niechoy (April 12), Baum (May 2) and Barton (May 10, with W47 filter only) complete the record.

Other drawings showed the second long-enduring Y feature, which is separated by 90° in longitude – or one terrestrial day – from the former marking. These records however, were somewhat less frequent and included: Feb 18 (Moore), April 3 (Baum and Moore), April 15 (Baum), April 27 (Johnson).

The polar collars were normal in appearance and intensity. The S collar was generally the more conspicuous, and sometimes it was even noted as very evident: Baum[1] gave further details. The markings as a whole were of typical intensity. Patrick Moore several times noted especially conspicuous shadings in May and June.

1991 W

On Sep 7 with a W47 filter Johnson[7] sketched dark bands that apparently split the crescent into segments. To him, these markings were invisible in white light, though a number of similar features were drawn by Baum (without filter) later in Sep. Baum's drawings also reveal several good cases of a four-day periodicity in the dusky belted markings: for example, Oct 30 and Nov 3; Nov 1 and 5. Baum and Meredith are in excellent accord concerning diagonal banding on Nov 4.

Cusp-collars appeared normal; the S collar being better seen in Sep–Oct, and the N one from Nov through Jan. On Sep 30 Ellis recorded two dark streaks north of the S cusp collar, and reobserved by him on Oct 4, 8 (one and two rotations later); Baum's drawings also show these features (and others) on the same dates.

1993 E

The dark markings were unremarkable. On Jan 9 Macdonald and McKim drew the same broad, diffuse horizontal belts, and both Baum and Hill recorded three similar terminator patches on Feb 19. Occasionally the markings were especially well seen. For example, Ellis saw dark shadings in the S hemisphere on Dec 22 and again on Jan 8, and on Jan 3 Patrick Moore found the features reasonably distinct (on which date he and Johnson agreed upon a vertical shading and a dark N cusp-collar). Baum on Jan 20 found a N dusky area 'marbled' in texture, and Beaumont detected a general fine mottling on Feb 14.

Barton's sharp UV image (W18A glass filter) on March 6 (Figure 5A) did not show any of the markings detected visually, but the UV markings are always harder to image in the crescent phase.

The cusp-collars were typical in darkness and form, the N generally being the more apparent. Heath on Dec 24 (Fig. 5B) found the N collar especially obvious in white light.

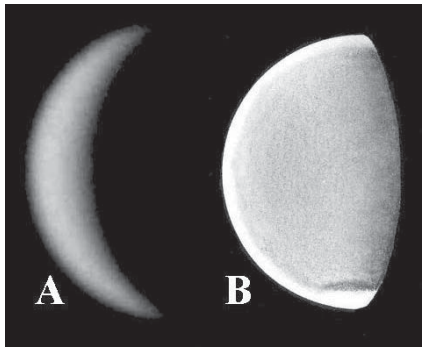

Figure 5. Aspects of the 1993 E elongation.
A 1993 Mar 6d 18h 30m, 220mm refl., W18A (UV) filter, 1s on Ilford HP5 film, *P. Barton*;
B 1992 Dec 24d 16h 30m, 300mm refl., ×318, W25 filter, *A. W. Heath*. Note dark N. cusp-collar.

1993 W

Markings were entirely typical, but there were too few good drawings for intercomparison. The cusp-collars were unremarkable: the N collar was much more often reported than the southern, though from July onwards the S collar was the better seen, mirroring the change observed in the visibility of the cusp-caps (see later).

Graham had a detailed view of the markings on the large gibbous disk of Oct 16, when the complex diagonal shadings

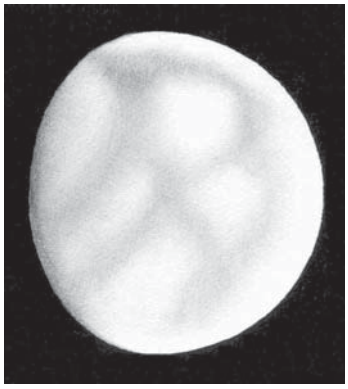

Figure 6. 1993 Jul 7d 08h 10m, 152mm OG, ×222, W12 filter, *D. L. Graham*. Complex markings seen; S. cusp-cap and collar more prominent than the northern.

were better seen in yellow light (W12) than in white (Figure 6). On the same date, Teague with a small refractor described an overall 'brushed texture' to the disk.

1994 E

The dark markings were entirely normal but there were too few good drawings for systematic studies. On July 4 Doherty and Patrick Moore independently agreed there were two low-contrast horizontal shadings present, and Macdonald's July 19 drawing was similar: very typical views. The cusp-collars were also normal, though Adamoli found them particularly dark on some dates in Aug (and, exceptionally, intensity 5 on Aug 22). The southern collar was sometimes the more conspicuous.

1995 W

This elongation did not yield many drawings suitable for intercomparisons. The HST UV image of 1995 Jan 24 (Figure 3) showed entirely typical diagonal markings, comparable with drawings by Section members (such as Ellis, Jan 30 or Fisher, Feb 28). Cusp-collars were seen throughout the elongation: the S one was often but not always the more conspicuous. (Figure 7A)

1996 E

Weak cusp collars were generally apparent from Nov through May. In Nov the N collar was the more obvious, but the S one was more generally the stronger (and sometimes fairly dark) during Dec to April. Other dark markings were visually elusive at this elongation, despite good observing conditions, though some well-marked features were seen occasionally. McKim (Figure 8A) drew a pair of diagonal bands on Feb 28. Very similar markings were seen by him on April 1 (Figure 8B), precisely eight atmospheric rotations later. On May 7 Ellis and Phelps were in general agreement about streaky markings in the S hemisphere. Patrick Moore saw particularly distinct shadings on Jan 17, Feb 28 and May 6 but otherwise he too found them elusive. Parker on Dec 2 imaged dark bands in the only UV image submitted (Figure 9).

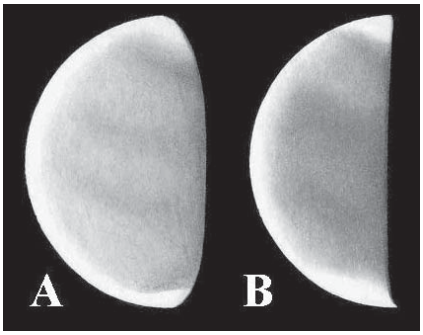

Figure 8. Drawings showing the same atmospheric longitudes of the planet at the 1996 E elongation, 216mm refl., ×232, *R. J. McKim*.
A 1996 Feb 28d 17h 40m (white light; similar views with filters including W47);
B 1996 Apr 1d 18h 40m.

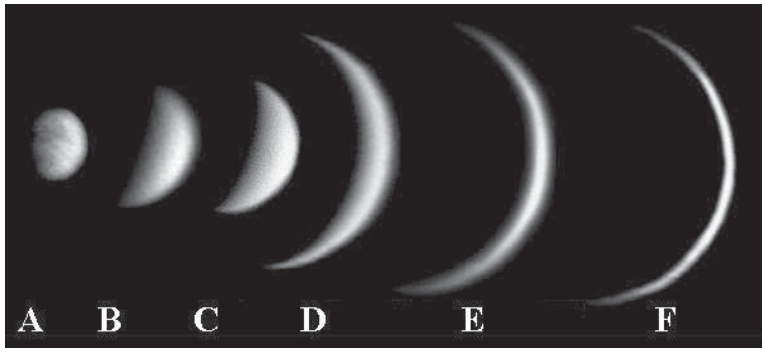

Figure 9. CCD images at the 1996 E elongation by *M. V. Gavin* (**B-F,** white light, Starlight Xpress camera and 300mm Schmidt–Cass. in daylight) and *D. C. Parker* (**A**, UG-1 UV filter, Lynxx camera and 400mm refl.).
A 1995 Dec 2d 22h 47m; **B** 1996 Apr 13; **C** 1996 Apr 25; **D** 1996 May 20; **E** 1996 May 21; **F** 1996 Jun 3.

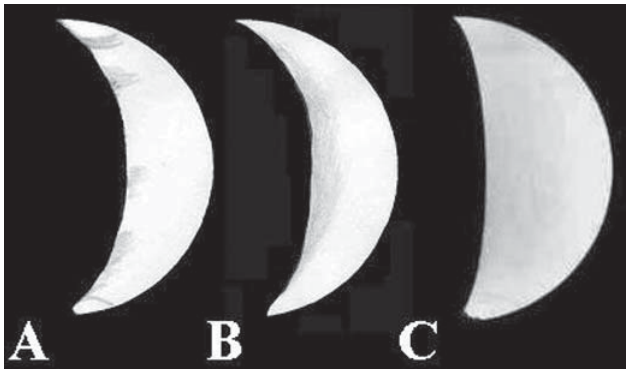

Figure 7. Selective blunting of the N. horn at the 1995 W. elongation.
A 1994 Dec 19d 09h 10m, 90mm OG, W58, *E. L. Ellis*. Bright cusp-caps, S. collar, blunt N. horn;
B 1994 Dec 19d 08h 45m, 125mm OG, violet filter, *S. Beaumont*. Blunt N. horn, as in **A**;
C 1995 Jan 6d 06h 00m, 320mm refl., ×330, *P. A. Moore*. Bright cusp-caps and blunt N. horn.

1996 W

Diagonal bands were recorded by most observers, with Fisher the first to see them well, on July 17. Cusp-collars were not especially prominent: in July the N one was reported more often, but from Aug onwards sightings of the S one (or reports of it being darker) were somewhat more common. Both are shown on Testa's blue light image, Oct 4 (Figure 10).

Gray made a number of high resolution drawings between July 25 and Nov 23. On July 25, exceptionally, he drew a small, isolated dark spot on the following side

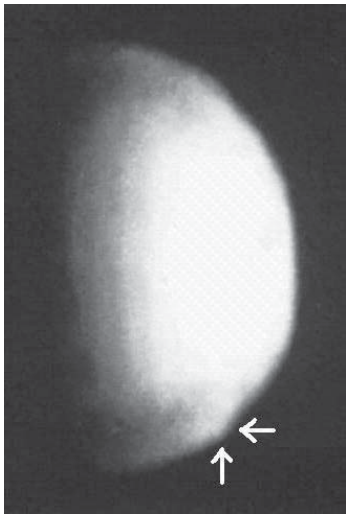

Figure 10. 1996 Oct 4d 04h 40m, 152mm OG, CCD image with W38 + IR blocking filters, *L. Testa*. Shows a bright NNW limb spot (as indicated).

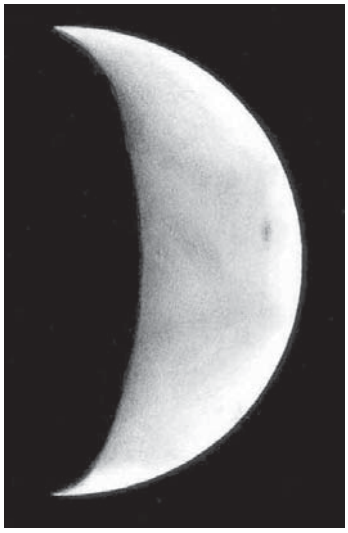

Figure 11. 1996 Jul 25d 06h 35m, 415mm Dall–Kirkham Cass., ×348, W47 filter, *D. Gray*. Shows unusual dark spot near the limb.

(Figure 11), which Baum[8] has already commented upon. Gray's other drawings (Figure 12) show complex, streaky dark markings. The features were generally better seen in blue-violet light (W47 filter), but on several dates most of the same features could be seen through a yellow filter (W15). On Oct 21, to his surprise, Gray found the horizontal banded markings better seen in red light (W25) than in blue-violet, but the banding was somewhat narrower and not quite the same. (Objective CCD images showing this difference in character between the red and blue-violet markings were finally obtained at the 2007 E elongation, outside the period of this report.) Some of Gray's drawings accord with the 4-day period, but exact configurations were never precisely repeated. Further comments were made by Baum.[9]

1997 E

Except at high gibbous phase most observations were done under fair or poor seeing. Early in the elongation Gray made high resolution drawings between July 7 and Aug 15 that showed complex banded markings and offer some evidence for the 4-day period (without precise repetition in detail). Baum has illustrated and described these drawings elsewhere.[10] To Gray the markings were very obvious with the W47 blue-violet filter; a combination of W15 yellow and W58 green also showed them well. Through the W15 alone the markings were less well defined and tended to appear patchy. Gray found a rather dusky feature following a light area in the S hemisphere on July 28 (Figure 13A). The cusp-collars were rarely conspicuous, the S one being slightly darker than the north. They continued to be weakly visible into

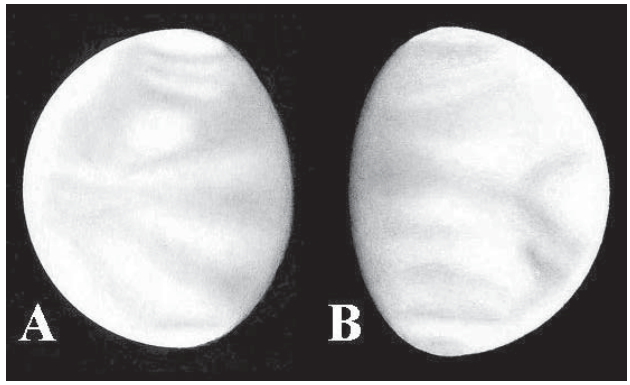

Figure 13. Aspects of the cusps and other atmospheric features, 1997–1998.

A 1997 Jul 28d 16h 20m-17h 16m, 415mm Dall–Kirkham Cass., ×262, ×348, W15 and W58 filters stacked (main details confirmed with W47), *D. Gray*. S cusp-cap especially conspicuous; S hemisphere light area; numerous dark belts.
B 1998 Jun 12d 05h 50m, 415mm Dall–Kirkham Cass., ×348, W15+W58+W80A, *D. Gray*. In Seeing I–II, a high latitude N. belt detected within the N. cuspidal area; also the Y feature at the W limb.

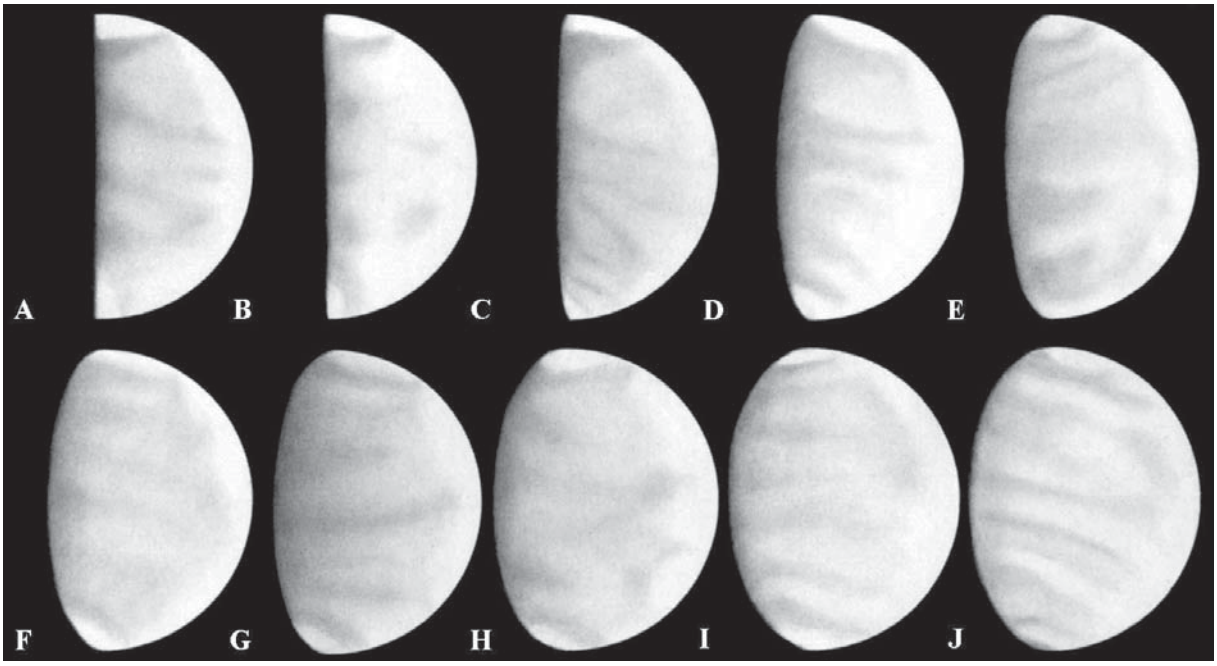

Figure 12. Drawings at the 1996 W elongation with 415mm Dall–Kirkham Cass., ×262, ×348, *D. Gray.* Observations made generally in very good or excellent seeing. Sketched at the same atmospheric longitudes at intervals of four (or integral multiples of four) days, some of the W47 filter views are very similar. Of the others, note the similarity between **A** and **B**, but **B** shows only part of the detail of **A**, and with less clarity. Oddly, **J** shows sharper bands in red light than in blue-violet (**I**).

Top row: **A** 1996 Aug 22d 05h 50m, W47; **B** 1996 Aug 22d 06h 10m, W15; **C** 1996 Aug 26d 05h 30m, W47;**D** 1996 Sep 15d 06h 10m, W47; **E** 1996 Sep 19d 06h 00m, W47.
Bottom row: **F** 1996 Oct 1d 06h 10m, W47; **G** 1996 Oct 5d 08h 10m, W47; **H** 1996 Oct 17d 08h 20m, W47; **I** 1996 Oct 21d 06h 50m, W47; **J** 1996 Oct 21d 07h 20m, W25.

Dec, and if there was any visible difference between them again the S was normally the darker.

1998 W

The planet was again in high S declination for part of the elongation. The cusp-collars were often seen, at least from April to August, but were rarely conspicuous. Of the two, the S collar was often the better seen and the more intense, though Frassati found the N collar darker on May 12. Few simultaneous observations are to hand, but (for instance) Frassati and McKim agree upon the presence of a dark marking in the N hemisphere on Feb 28. Gray again succeeded with some high resolution views in May–June. His experience was of complex diagonal banding, well seen with the W15/W58 combination. W38A and W47 filters showed similar but not identical banding, with differences in both form and intensity. The most interesting view is that of June 12 (Figure 13B) in which Gray observed the Y-shaped marking on the W side: this was also clearly seen with a 76mm OG. The same marking featured less strongly in his drawing of May 23, 06:40 UT, five rotations earlier, and of Aug 27, 06:30 UT, 19 rotations later.

Atmospheric rotation period

The 1991 E. elongation file contained the largest number of drawings for the period in question. It was found to contain a number of unambiguous representations of the long-enduring Y-shaped marking, as already noted. The clearest drawings of all (Figure 4) had the following dates and mid-times:

R. M. Baum (Fig.4A)	1991 Feb 11d 17h 25m	JD 2448299.2257
P. A. Moore (Fig.4B)	1991 Feb 19d 17h 40m	JD 2448307.2361
M. Bosselaers/ P. A. Moore	1991 Mar 03d 17h 45m	JD 2448319.2396
R. M. Baum (Fig.4C)	1991 Mar 11d 18h 40m	JD 2448327.2778
M. Gélinas (Fig.4D)	1991 Apr 12d 19h 59m	JD 2448359.3326

All these records are multiples of four days apart. An excellent average long-term period is obtained if we note that in each case the marking was situated centrally upon the disk in much the way it appears on a UV image by Sussenbach on 2006 July 12 (2006 W. elongation):

J. Sussenbach	2006 Jul 12d 05h 51m	JD 2453928.7438

The corresponding intervals between 1991 and 2006 are 5629.5153, 5621.5077, 5609.5014, 5601.4632 and 5569.4084d; 1409, 1407, 1404, 1402 and 1394 rotations, respectively, and the corresponding periods (with no correction for small angular displacements with respect to the CM, or light-times) are 3.99540, 3.99538, 3.99537, 3.99534 and 3.99527d.

Gray's 1998 June 12 drawing, already described (Figure 13), also shows the same characteristic Y marking:

D. Gray (Fig.13B)	1998 Jun 12d 05h 50m	JD 2450976.7430

The 1998 to 2006 interval is 2952.0008d; 739 rotations. The angular distance of the fork of the Y from the CM is *ca.* 8° closer to the CM on Sussenbach's image, implying more precisely 738.98 rotations: period = 3.99470d.

The average of all six determinations, 3.99524 ± 0.00027d, agrees extremely well with the BAA average result from 1999–2006, 3.99515 ± 0.0004d,[19] and with C. Boyer's long-term average result (from the 1890s to the 1970s), of 3.99525 days. (The relevant literature is fully cited in Ref. 19.) Although the Y marking varies in shape (and doubtless in longitude in the short term), and is subject to veiling by overlying cloud, its longevity and remarkably constant period (when followed over many years) is quite remarkable.

In the 1999–2006 Report[19] we used UV images of 2006 July 15 and 2004 Oct 29 to re-measure the rotation period more precisely. These latter relate to the other of the two Y (or Y and Ψ) markings.[19]

Dichotomy

White light and yellow (W15) filter observations between phases *ca.* 0.55 and 0.45 were plotted to establish the graphical date of apparent dichotomy. (The phase is always a little less in blue light, and substantially smaller in violet.) For the first five elongations the number of observations was sufficiently large to justify computer analysis.

1991 E

A straight terminator with phase 0.50 was most frequently reported during June 4–8.

1991 W

A consensus of observers (Baum, Beaumont, Ellis, Heath, Meredith, Sturdy and Fiona Vincent) indicates that a straight terminator was observable during Nov 5–8.

1993 E

A consensus gives Jan 14–17 for the period of dichotomy.

1993 W

A straight terminator was drawn by Bosselaers on June 15. On June 20 Sturdy also found the terminator straight, but Giuntoli saw it already slightly convex.

1994 E

A perfectly straight terminator was recorded by Giuntoli and Sturdy on Aug 14.

1995 W

A satisfactory number of phase estimations was available, and graphical interpolation gave a secure date of Jan 17.3. The terminator appeared straight to Beaumont, Ellis and Heath on Jan 17–18.

1996 E

A good number of observations was plotted to give a firm date of March 30.4. The terminator was often reported as being straight during March 29–April 1.

1996 W

Satisfactory data yielded a mean date of Aug 22.8. The phase also appeared precisely 50% to Ellis and Gray on the same day.

Table 4. Venus phase anomaly data, 1991–1998

Elongation	Date of dichotomy*		Anomaly*
	Predicted	Observed	
1991 E	Jun 13.19	Jun 8.0	5.2d early
1991 W	Nov 1.41	Nov 7.0	5.6d late
1993 E	Jan 21.94	Jan 15.9	6.0d early
1993 W	Jun 11.30	Jun 18.0	6.7d late
1994 E	Aug 22.47	Aug 13.3	9.2d early
1995 W	Jan 13.22	Jan 17.3	4.1d late
1996 E	Apr 2.93	Mar 30.4	3.5d early
1996 W	Aug 19.80	Aug 22.8	3.0d late
1997 E	Nov 5.22	Nov 1.5	3.7d early
1998 W	Mar 28.68	March 31.3	2.6d late

* Anomalies for 1991 E to 1994 E were deduced by computer least-squares analysis of the data (white light + W15 yellow filter) between apparent phase 0.55 and 0.45, and a probable error of ±0.5d seems appropriate. The remainder were analysed by simple graphical interpolation of the phase data, and for them a probable error of ±0.5d (E elongations) or ±1.0d (W elongations) was estimated.

1997 E

There were few observations around half-phase owing to the planet's extreme S declination, and none of a precisely dichotomised Venus. Drawings by McKim and Middleton yield a satisfactory but approximate interpolated date of Nov 1.5.

1998 W

There were few data near 50% phase (and none at precisely that phase), but an extrapolation gave March 31.3 as a fair result.

Dates of theoretical dichotomy were published by Meeus.[27] We summarise the phase anomaly at each elongation (Table 4).

The larger anomaly for 1994 E seems to be well-established, and stands out from the rest. Systematic estimates of dichotomy were also made by the UAI.[21]

Terminator irregularities

1991 E

Apparent depressions were often seen by Baum (May 5, 13, June 7, 20) to be associated with dark markings at the terminator. Eliminating other less certain sightings we are left with:

May 9: Slight terminator bulge to Baum (N hemisphere) and Beaumont ('definite', S hemisphere).

May 27: Beaumont, N and central hemisphere notches; Macdonald, N and S hemisphere notches.

June 1: Bosselaers and Smith showed a wavy terminator; partial support comes from Baum (N hemisphere notch) and Fletcher (S hemisphere notch).

June 3: Baum, central indentation; Fletcher, notch in S hemisphere.

June 15: Warell, two indentations in N and S.

July 6: Baum, depressions coincide with various dark markings; Gélinas, N hemisphere protrusion.

1991 W

Graham in good seeing on Sep 15 at 07:25 UT recorded a scalloped terminator, with marked indentations in three places (two south and one north of the equator), an impression precisely shared by Baum at 08:45 UT (Figures 14A–B). The irregularity had disappeared by the time Sturdy observed at 09:00 UT, and also Beaumont at 13:00 UT. On Sep 22 Beaumont and Baum also agreed upon a slightly irregular terminator. There were no other simultaneous records this elongation, but we cite Baum's observation of a bright S hemisphere cloud (see later) that projected over – and thereby distorted – the morning terminator on Nov 5 (Figure 14C).

1993 E

A particular inflexion at the S cusp will be discussed under 'Cusps'. There were several reports of irregularities from a dozen contributors. However, most were mere suspicions, dispelled by comparison with other work in better seeing. There is also an association with dark shadings. Beaumont on Feb 9 and Baum on Feb 26 described dark shadings associated with apparent terminator inflexions. Warell on Feb 12 (Figure 14D) shows dark shadings indenting the terminator. The following seem the most important remaining records:

Jan 3: Fisher and Johnson reported the same indentations near the S and N collars.

Jan 17: Baum and Hill reported a small inflexion in the latitude of the N cusp-collar, which Baum ascribed to the N cusp-cap's greater brightness; to Hill the effect was less pronounced on Jan 20.

Feb 2: Heath, Johnson and Patrick Moore. Heath reported straighter sections of terminator whose ends correspond with inflexions reported by Johnson. Moore saw a small indentation near the S cusp which the others did not record.

Feb 5: Heath again saw flattened sections of terminator (as well as on other dates) whilst McKim found the latter to be not a perfect ellipse, the S crescent broader than the north, an effect further reported by Teague on Feb 19–28 (an illusion arising from a shortening of the S horn, although not apparent as such).

Feb 6: Giuntoli and Johnson (not identical in place).

Feb 22: Beaumont and Cuppens (ditto).

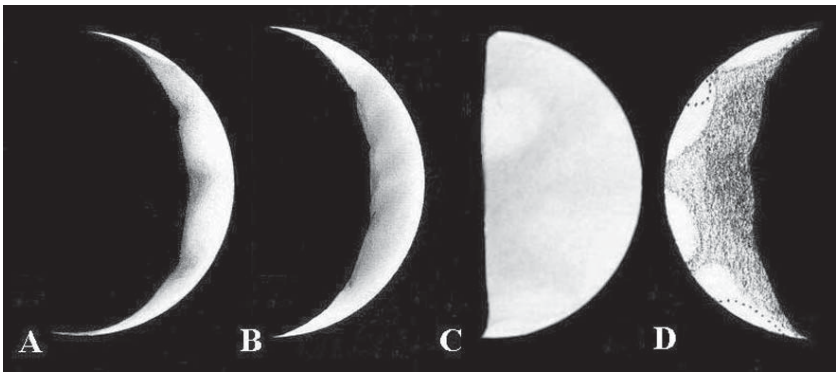

Figure 14. Terminator irregularities, 1991–1993.
A 1991 Sept 15d 08h 45m, 115mm OG, ×186, *R. M. Baum*. In Seeing I, three inflexions at terminator roots of dark shadings.
B 1991 Sept 15d 07h 25m, 152mm OG, ×222, in white light and with W12 yellow and W22 orange-red filters, *D. L. Graham*. Splendid agreement with **A**.
C 1991 Nov 5d 09h 15m, 115mm OG, ×186, *R. M. Baum*. A bright area causing a bulge as it crosses the terminator. (Note also blunt S cusp and pointed N one.)
D 1993 Feb 12d 18h 05–30m, 161mm OG, ×333, W38A filter, *J. Warell*. Three terminator depressions (or unusually dark shadings) plus several bright limb areas.

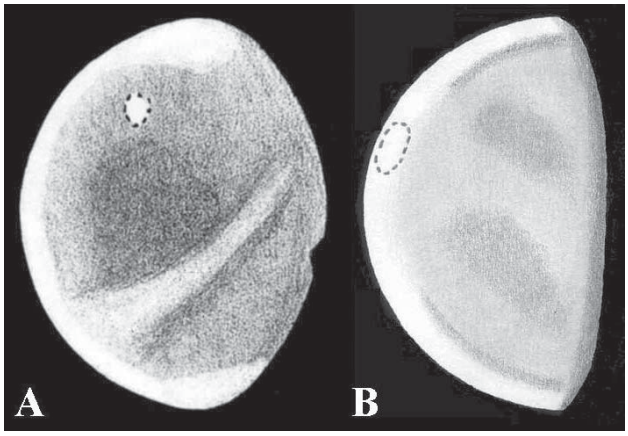

Figure 15. Bright spots (and terminator indent in **A**) observed at the 1996 E elongation.
A 1996 Jan 23d 20h 00m–21h 40m, 325mm refl., ×320 and 140mm OG, ×290, light blue filter, *T. R. Cave*.
B 1996 Feb 19d17h 49m, 114mm refl., ×150, *I. S. Phelps*.

Feb 28: Beaumont and Heath (a general impression).
Mar 8: Ellis and Hill reported a small indentation near the N cusp.

1994 E

On Aug 5 Sturdy recorded a small apparent indentation near the S horn. (But see also his record of July 27 under 'cusps', below.)

1996 E

On Jan 23 Cave (Figure 15A) found an indentation near the equator. Heath had several impressions of an uneven contour to the terminator on April 17, 26 and (especially) May 3. These were not confirmed, but on the day following the April 26 observation, at 19:00 UT Patrick Moore found a small indentation at the latitude of the S cusp-collar. Also on April 27, Beaumont (20:30 UT) described the terminator in general as 'ragged', lending some support to Moore's sighting. Finally, observing with a 510mm reflector at ×750 on May 19 at 01:11 UT, Schmude found the terminator 'bumpy' in outline.

1997 E

On Dec 4 Brook reported an indentation at the normal latitude of the S cusp-collar, but Heath saw nothing unusual. However, as Schmude reported a terminator notch at the same latitude on Dec 6 both observations may possibly be objective.

1998 W

Frassati on March 29 (08:00–08:20 UT) drew a remarkable diagonal dark rift crossing the terminator (Figure 16). Baum has discussed this and similar observations elsewhere.[11] An hour earlier Niechoy also reported possible small scale terminator irregularity; no other observations are to hand. On March 25 no irregularity had been reported; there was no record for April 2.

Figure 16. 1998 Mar 29d 08h 10m, 203mm Schmidt–Cass., ×222, W8 filter, *M. Frassati*. In Seeing I, a diagonal rift was seen across the terminator (the size of this feature is probably a little exaggerated here).

Cusps

1991 E

Bosselaers and Gélinas on May 28, and Baum next day found the S cusp blunted but the north a little extended, a typical situation around dichotomy. But on June 1 Baum and Fletcher (and on June 5 Sarocchi) reported the N cusp blunted and the S extended. On June 4 Baum and Patrick Moore found the N cusp more extended than the south, and again on June 7 (Baum) and 10 (Gélinas, Macdonald, McKim, Meredith and Raeburn) the S cusp was reported as blunt and the N one sharp and extended. Baum[2] has discussed these observations in greater detail.

1991 W

In a *Journal* note about the cusp-caps,[12] Baum reproduced his drawing of Nov 9, in which the S cusp was blunt and the N one straight. He had a similar impression on Nov 5, and Johnson shows the S cusp more blunted than the N on Nov 4. Patrick Moore found the S cusp blunted and the N sharp on Nov 6 and 15, and again on Dec 6 and 7, an impression Teague shared on Dec 7 and 8.

1993 E

Observations around dichotomy throw some new light upon the old problem of the blunting of the south cusp, and formed the subject of an Interim Report by Baum,[13] in which they were set in a historical context. Patrick Moore on Jan 13, and McKim and Teague next day found the S cusp blunted and the N already a little pointed. On Jan 17, at low resolution, the S cusp appeared blunt and the N pointed to several observers and confirmed by a photograph by Heath.[13] However, a high resolution drawing by Hill (Figure 17) showed a faint point emerging from the S cusp, extending the horn along the curve of the limb to where it would have been expected to terminate. To the present Director this implies that the dark notch to the north must have been a strong indentation of the terminator – perhaps a high latitude dark belt or (more likely) a lower cloud deck within a (presumably) highly turbulent part of the S polar region. On Jan 20 Hill still found the S cusp blunt but a less bright region (with W11 and 15 filters only) was seen to 'fill out' the cusp, although the indent was no longer seen.

1993 W

Just after IC, Fisher (April 2) and Sturdy (April 10 and 15) reported the N horn as blunted (and/or shortened). On May 18 Patrick Moore found the S cusp blunted. A few observers about dichotomy (Giuntoli, June 20; Beaumont, June 22) witnessed the well-known illusion of there being indentations near each cusp-cap with the terminator slightly convex. Sturdy (June 5, 20) found the terminator

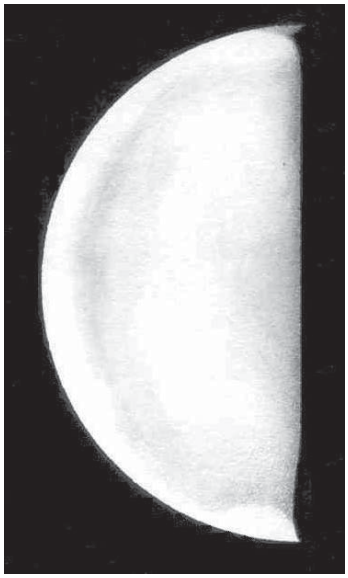

Figure 17. 1993 Jan 17d 15h 55m, 210mm Schmidt–Cass., ×245, *H. Hill*. Blunt S cusp drawn with dull extension.

shading very dark at this time, especially near the cusps, which would fully account for the illusion. On July 7 Graham recorded the same illusion, but suggested the slightly light equatorial patch at the terminator was the cause on that occasion.

1994 E

Sturdy on July 27 found the S horn a little extended (with the N rounded, as would be expected), which he attributed to an illusion caused by the dark shading just N of the S cusp-cap. Middleton confirmed this shading on July 29. Testa's CCD image of July 29 appears to show the N cusp more rounded or blunted than the south, though Adamoli did not find any difference visually on that date, nor did McKim when observing from the USA at 03:25 UT on July 30. However, Sturdy on July 28 recorded a similar effect.

At dichotomy on Aug 14 Giuntoli drew each horn slightly elongated. On Sep 19, observing from South Africa, Patrick Moore found the S cusp slightly blunt.

1995 W

The blunting of the N cusp (or N horn) is less common than that of the south, but several independent observations showed the effect during this elongation. On Dec 19 Ellis (09:10 UT) (Figure 7A) and Beaumont (08:25 UT) agreed upon the phenomenon (Figure 7B). It was short-lived because Patrick Moore (05:45 UT) and Bosselaers (11:05 UT) did not show the effect before or after that time, both drawing sharp cusps. All observers except the last one had good seeing. A blunted N cusp was again apparent to Ellis on Dec 20 and to Beaumont on Dec 22. McKim on Jan 3 found the N horn less tapered than the southern, and again on Jan 6 Patrick Moore (Figure 7C) commented upon a blunt N horn.

Just prior to dichotomy, Beaumont found the S cusp straight and the N pointed on Jan 12, while on Jan 23 and Feb 14 Moore found the S cusp blunt compared with the northern one.

1996 E

Around half-phase, Bowen found both cusps blunted on March 29. McKim found the S cusp blunt and the N pointed on April 1 (Figure 8B) and 3; Patrick Moore had the same impression on April 2, 3, 4 and 5.

1996 W

On Aug 22 with the phase at 50%, Ellis and Gray (Figures 12A–B) drew a straight terminator right up to and including the N and S horns.

1997 E

On Oct 28 McKim found the S horn more rounded than the north. On Nov 9 he found the N horn more pointed than the south, but any difference had disappeared two days later.

1998 W

Gray's June 12 observation of a N cuspidal dark area at the 1998 W elongation (see next section and Figure 13B) is suggestive in explaining the occasional blunting of the cusps.

Cusp-caps

1991 E

Baum's Section Report[1] discussed the cusp-caps in detail. The caps were not very conspicuous before March; they were generally equally visible in the latter month. The S cap was rather eccentrically placed before April. The S cap was often slightly brighter than the northern during April to May, whilst from June to July the N cap was the brighter of the two. Throughout this period the S cap was generally the more rounded and larger of the two, (Figures 18A–B) and also the more variable.[1] As usual, there were exceptions.

On April 14 Baum (Figure 18A) showed a bright patch at the pole within the S cuspidal area, whilst Baum's observation of May 2[1] (Figure 18B), indicated a spiral structure within the S polar region. These fine details were washed out of the image as the background sky darkened. Less conspicuous swirls were also reported by Baum on June 19, 21 and 23. Baum further reported bright spots within the S cap on April 3.

1991 W

Bright cusps were rather obvious at this elongation, with both visible from mid-Sep onwards. On most observing dates the S cap was the brighter and more conspicuous throughout Sep–Oct, and the N one was larger and brighter during Nov to Jan. In late Dec and through Jan the S cap was more rarely visible. Ellis on Sep 13 and 20 recorded an apparent doubling or bifurcation of the S cusp-cap. This change in visibility agrees perfectly with Baum's earlier analysis[1,2] of his personal data.

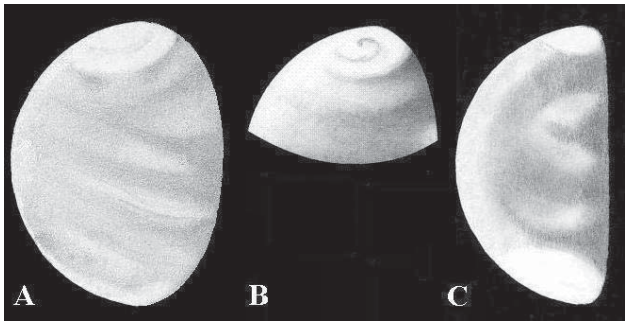

Figure 18. Aspects of the cusp-caps at the 1991 E and 1993 E elongations.

A 1991 Apr 14d 18h 55m, 115mm OG, ×186, *R. M. Baum*. Large bright S cusp with faint detail within.
B 1991 May 2d 19h 07–20m, 115mm OG, ×186, *R. M. Baum*. A spiral structure is evident within the large, S cusp-cap, whose central part near the pole appeared brightest.
C 1993 Jan 10d 16h 25m, 250mm refl., ×230, blue filter, *M. Boulton*. A typical view showing the N cusp-cap larger than the southern.

Baum on Sep 22 in superb seeing had the impression of tiny sparkling points upon the S cusp, an impression he had previously witnessed in the 1950s and which Trouvelot often recorded in the 19th century.[28] On Oct 19 Baum found two brighter spots upon both caps.

The cusp-collars were more prominent around whichever cusp was the brighter one that month.

1993 E

There were few observations before Nov, but the scanty Sep and Oct drawings all show at least the N cusp-cap. During 1992 Nov to 1993 March both caps were often well seen, with the N one almost always the larger, and more often than not the brighter of the two (Figure 18C). Occasionally the smaller S cap was the brightest. Baum on Feb 26 found two small bright patches within the S cap.

1993 W

The cusp-caps were never prominent and very rarely large. During May–June the N cap was the brighter and most obvious, with the S one rarely noticed at all. In July both were similar in appearance, and on July 7 Graham actually found the S one the brightest. In Aug–Oct the S cap became the brighter and more obvious cap, with few records of the N one.

1994 E

There were no features of special interest. Both caps were generally present, but the S one was less often seen before June. The N cusp was more often the brighter and slightly larger one when there was any difference, throughout April–Aug. In Sep the S cusp was generally smaller but brighter, but occasionally was the only one apparent. Thus Wade, Sep 2 noted: 'S cap distinct with collar strongly suspected. N cap indistinct...'

1995 W

In early Dec only the N cusp-cap was conspicuously bright, with Biver, Bosselaers, Middleton and Patrick Moore reporting that cap the more conspicuous during Dec 2–6. By mid-month the N and S caps seemed generally equal in prominence, and by dichotomy the planet sported a smallish bright cap at each pole. (Moore's Jan 3 comment is typical: 'bright and quite distinct.') This situation continued until at least 1995 May.

1996 E

In Oct and Nov several observers reported light cuspidal areas, the N appearing the more prominent. In Dec and Jan small bright caps were often seen at each pole, roughly equal in extent and brightness. In Feb both caps were seen but if there was a difference in visibility the S was generally the larger. On a few occasions to Meredith, notably Feb 1, the bright S cusp seemed to irradiate beyond the terminator. In March and April both cusps were roughly equal but there were some occasions when the S cusp was smaller but brighter than the north (an impression shared by Ellis, Fisher and Heath on April 17). Both horns could still be seen to be bright against the thin crescent throughout most of May. Sometimes the S was brighter, and sometimes the N one appeared brighter (*e.g.*, to Ellis, Phelps and Sturdy, May 7).

1996 W

The cusp-caps were small or very small, at least from July to Nov. Differences in size between S and N were small. If there was a difference the N cusp was a little larger and/or brighter than the south in a majority of cases, although in Aug the S one was more often reported as the larger of the two.

1997 E

In July–Sep Gray and Wade often saw the S cusp-cap a little larger and/or brighter than the north; neither was ever very large but the brightness was very evident. There are few drawings for the next month, but the pattern apparently continued, with Middleton finding the S cusp-cap extensive and very bright on Oct 19. In Nov the N cap may have been slightly the more conspicuous. The caps still brightened the horns of the thin crescent the next month, and on Dec 9–10 Parker's blue images showed the N limb considerably brighter than the southern.

1998 W

McKim found the N cuspidal area bright on Feb 28. Small caps at each cusp were subsequently reported between at least March and Aug, with little real difference between them. Gray saw bright caps at each cusp on March 19 and 20, with the north one 'striking' in W47 on the latter date and larger than the south. Heath on March 12 and Frassati on April 19 found only the N cap present. On May 23 Gray recorded a conspicuous S cap, but the N cuspidal area was only vaguely light. Both caps appeared small and light next day. On June 7 he found the N cap the more conspicuous.

On June 12 the S cap was small and bright, with a large but only vaguely light N cuspidal area. Within the latter area Gray drew a small dusky shading (no doubt a high latitude dark belt) right at the N cusp (Figure 13B). Would such a low-albedo feature, if visible near dichotomy and viewed with a small telescope, give the impression of a blunted cusp? Frassati on Aug 25 and Steele (confirmed by Gray) on Aug 27 found both caps to be very small.

Other bright areas

1991 E

In March the S cusp-cap was quite eccentrically placed, which some observers logged as a separate bright area. Other features were as follows:

April 8: Barton and Johnson, Sp. limb.

April 21: Baum, equatorial limb.

April 25: McKim, central terminator (previously published[1]), confirmed by Johnson.

May 1: Baum, N terminator.

May 2: Baum and Johnson, N and S terminator.

May 22: Johnson, two areas, Sp. limb.

May 24: Baum, Sp. limb.

May 26: Testa, Np. limb.

May 27: Leclère and Marabini, Sp. limb.

May 28: Adamoli, Leclère and Marabini, Sp. limb.

June 1: Baum and Bosselaers, Np. and Sp. limbs.

June 3, 4, 20, 21, 23, 28, 30 and July 3: Baum, Np. limb (sometimes merged with white N cuspidal area).

July 6: Gélinas, bright spot protruding over terminator.

1991 W

As reported earlier,[12] a bright patch at the Sf. (SW) limb was observed and drawn by Baum on Nov 9 (08:55 UT), and confirmed by Cook's near-IR CCD imaging (08:43–09:16 UT). To Cook the feature faded with time. Indeed, observing at 09:15 UT Sturdy did not record it. Other reports were as follows:

Sept 15 and 19: Baum, bright areas on NW limb.

Sept 16: Warell, bright area near S cusp.

Sept 20: Beaumont, SW and NW limbs (confirmed by Baum and Bosselaers).

Sept 21: Ellis, bright area N of S cusp-cap, best seen in W58 green.

Sept 22: Baum, ditto, as well as a small light circular patch S of the N cusp.

Oct 2: Beaumont, NW limb.

Oct 19: Baum, SSW, SW and NW limb.

Nov 5: Baum (Figure 14C), light spot projecting over the terminator, S hemisphere. Not apparent at 08:00 UT, but visible 08:28 UT till close of observation at 09:20 UT. (It was not visible to him on either Nov 1 or 9.)

Nov 16: Cook, SW limb, similar to Nov 9.

Nov 20: Johnson, several bright limb spots (SW, WSW, WNW) including repeat of Nov 16 feature.

Dec 9 and 10: Beaumont, SW limb.

Dec 27: Johnson and Sturdy, WSW limb.

Jan 11: Johnson, WNW limb.

1993 E

On Dec 4 and 8 Johnson drew what was apparently the same white patch at the ENE limb, one rotation apart. On Jan 14 Johnson and Patrick Moore show two bright patches in the NE quadrant which Bosselaers re-observed on Jan 18. Features on the SE and NE limbs both figure in Johnson's drawings of Feb 2 and 6. Warell also had excellent views of several bright limb clouds on Feb 12 (Figure 14D), 13 and March 2. He found them enhanced most with a W58 green filter/polaroid combination. Johnson's notes from March 6 indicate brighter limb patches alternating with terminator stubs or bands.

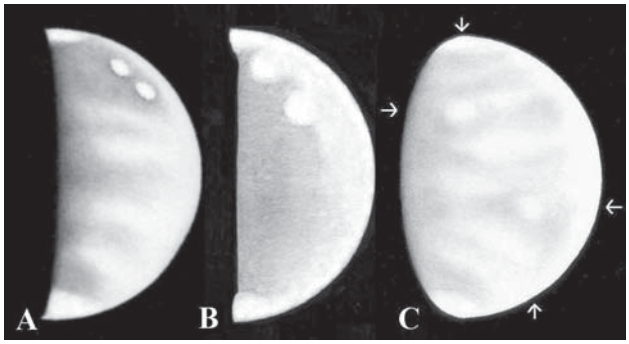

Figure 19. Bright areas observed at the 1998 W elongation.
A 1998 Mar 19d 07h 00m, 415mm Dall–Kirkham Cass., ×262, ×348, W15+W58 filters, *D. Gray*. Two light spots in SW quadrant.
B 1998 Mar 19d 09h 08m, 203mm Schmidt–Cass., ×80, W15, *P. Wade*. This also shows the light spots drawn in **A**.
C 1998 May 24d 06h 20m, 415mm Dall–Kirkham Cass., ×348, W15+W58 filters, *D. Gray*. One roundish light spot in each hemisphere.

1993 W

A near-equatorial bright patch appeared lighter than the limb band at the evening limb according to Beaumont on May 6–7 (which was relatively even brighter in violet light) and Sturdy on May 8. Also, as cited under 'terminator irregularities' above, Graham drew a light equatorial spot at the terminator on July 7.

1994 E

Middleton reported a bright area just off the N cusp on Aug 8 and 14. On several dates during Aug 14–29 Sturdy showed the N cusp-cap extended well along the limb – the same phenomenon at lower resolution?

1995 W

Ellis several times saw or suspected a small bright area close to the S cusp-cap (Dec 14, 20, 22, 31, Jan 6 and 10), and Fisher on Dec 14 suspected an equatorial bright patch near the terminator. None of these records were confirmed.

1996 E

Cave on Jan 23 saw a small bright spot in the planet's SE quadrant (Figure 15A), as Baum[14] has discussed elsewhere in a historical context. There were no simultaneous reports for comparison, but on Feb 19 Phelps (Figure 15B) drew a bright spot at the ESE limb at the same latitude, which would be consistent with just under seven atmospheric rotations elapsed. There were no sightings on intermediate dates: a resurgence of the same phenomenon? Phelps sketched another bright spot at the SE limb on April 28, and Wright reported a similar patch on the NE side on May 6.

1996 W

Ellis on Aug 27 drew a small bright spot following and apparently doubling the S cusp cap, but three other observers found the cap normal at that time. On Sep 27 Phelps recorded a small bright spot just N of the equator within the limb band. On Oct 4 Testa imaged a bright, irradiating spot on the NW limb (Figure 10), an observation previously discussed by Baum.[15] In both these latter cases nothing else was seen either earlier or later.

1997 E

On July 28 Gray (Figure 13A) drew a circular light area in the S hemisphere upon mid-disk with a dark area on the W side. His other drawings[10] indicate less striking lighter patches at the limb. Schmude (with 510mm aperture) on Aug 3 drew a light spot apparently projecting beyond the terminator. Phelps reported a small bright patch on the SE limb on Dec 14 (Figure 20E), and Middleton reported one in the NE, Dec 30.

1998 W

On March 19 Gray found two small, very bright spots in the SW quadrant (Figure 19A). Well seen with the W15/W58

combination at 07:00 UT, the area was simply covered by a light diagonal belt in W47, as Baum has already reported.[16] Remarkable confirmation is forthcoming from Wade's lower resolution W15 outline sketch (Figure 19B) at 09:08 UT. In his case the two light scallops blended in W25 and disappeared through W47. On March 20 at 07:10 UT Gray drew two other small light spots, also visible in a 76mm OG and closer to the SW limb: these were again effaced by a larger and paler streak in W47. Wade too had similar but less strong impressions of light areas in the SW quadrant on March 22 and 31.

On May 24 Gray (Figure 19C) recorded two small, round light spots in the S hemisphere and in the NW quadrant. Visible in the W15/W58 combination, they were invisible through a W47 filter.

Cusp extensions

1991 E and 1991 W

Baum[2] gave an early analysis of cusp extensions: here we concentrate upon the significant extensions seen close to IC. As early as June 30, Baum saw a small extension of the N horn which appeared knotted as if a string of tiny bright points, while on July 23 both extensions appeared knotted. In good conditions on July 11 Beaumont suspected points of light separated from the tips of the crescent's horns. Subsequent data show the complete 360° ring to have been elusive, but evening observations (especially those from Italy) proved the most successful.

Observer	*Date(s)*	*Maximum angular extension(°)*
Adamoli	Jul 11	N horn extended by 30°, S one by 15°
Adamoli	Jul 15,18	complete ring seen (evening observation)
Warell	Jul 17,18	crescent arc extended to 200°
Giuntoli	Jul 25	complete ring glimpsed (poor seeing but evening obs., excellent transparency)
Beaumont	Aug 2*	complete ring glimpsed (late afternoon)
Warell	Aug 2	arc to 200°
Buggenthien	Aug 4, 9	230° and 254° respectively
Niechoy	Aug 6	complete ring drawn
Viens	Aug 12	200°
Warell	Aug 13	220°
Buggenthien	Aug 16	complete ring drawn (mid-afternoon)
Viens	Aug 18	210°
Buggenthien	Aug 18,20	approx. 270°
Viens	Aug 20,22	220°

** Aug 2 only, not Aug 2 and 8 as stated elsewhere.*[2]

Following IC, Cook's Aug 24 near-IR CCD image (W87 filter) showed the horns extended to a full 360°. Observing visually, Buggenthien also recorded the complete ring on Aug 24. The phenomenon was recorded less certainly on Cook's other videotapes for Aug 25, 26, 31 and Sep 1.

Extension of the crescent arc to 210° was reported by Viens and Warell on Aug 29 and to 220° by Smith on Sep 1. Small extensions were variously reported during Sep[7] and through mid-Oct by several other observers. The degree of extension at each horn was not always the same; thus Beaumont on Sept 28 reported the N horn more tapering than the south, and Heath on Sept 30 found the S horn more 'hooked' (hence more extended) than the north.

1993 E and 1993 W

1993 E: Objective records of extensions cover March 4–28. Examples are:

Mar 4–19: Various. Small extensions of angular perimeter to *ca*. 190–200°.

Mar 21–25: Beaumont (mostly with 300mm aperture). Small extensions constantly visible; in flashes the entire 360° ring apparent. (On March 25, Baum, Graham (235° arc), McKim and Teague all recorded significant cusp extensions, but with smaller instruments than Beaumont's.)

1993 W: slight extensions were visible to Buggenthien and Fisher, April 2 and 5.

1994 E and 1995 W

Prior to IC, Niechoy found small cusp extensions in Oct, as did Viens on Oct 30. On Nov 1 Biver found the crescent irregular in brightness with the cusps extended full-circle. Adamoli, in full daylight, found apparent extensions of up to 45° at each cusp around dichotomy, on most of his observing dates from July 22–Aug 29. He recorded similar impressions at certain later elongations but the earlier sightings, made upon the gibbous disk, are at an exceptionally high phase.

After IC, Viens found the crescent arc extended to about 212° on Nov 3, whilst Giuntoli found small extensions on Nov 13.

1996 E and 1996 W

1996 E: This was a very favourable IC for seeing large cusp extensions. Prior to IC, small but growing cusp extensions were apparent to a large number of observers throughout May. To Phelps on May 27 and 31 the extended crescent differed significantly in brightness along its length. On May 31 Bowen and Meredith succeeded in glimpsing the complete atmospheric ring. Bowen: '... the image approached a complete but irregular annulus.' Gavin's CCD image of June 3 (Figure 9F) clearly shows faint extensions. We summarise selected visual data:

Observer	*Date(s)*	*Max. angular extension(°)*
Schmude	May 12, 19	small extensions
Phelps	May 17–24	ditto
Beaumont	May 27	small extensions
Phelps	May 27	crescent arc extended to 220°
Marsh	May 27, June 1	significant extensions
Giuntoli	May 28	arc to 217°
Phelps	May 31	227°
Bowen & Meredith	May 31	360°
Phelps	June 1	227°
Giuntoli	June 2	238°
Niechoy	June 8	240°

1996 W: Immediately after IC there were very few records, but Niechoy drew extended cusps on June 15 and 17.

1997 E and 1998 W

1997 E: Small cusp extensions were apparent from Dec 5 to Jan 14, but the later observations had to be made upon a bright sky. Niechoy on Jan 10 and 11 saw large extensions to about 250°.

1998 W: Small cusp extensions were reported by Frassati,

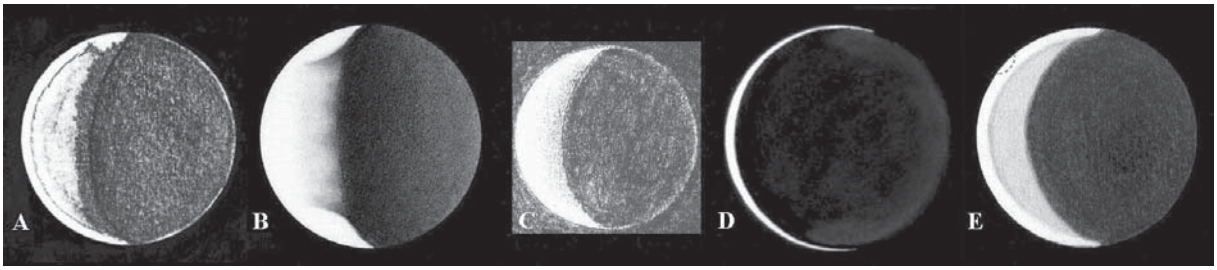

Figure 20. Aspects of the Ashen Light, 1991–1997.
A 1991 Jul 4d 20h 28m, 102mm OG, ×216, W15 filter, *D. Niechoy.*
B 1991 Jul 6d 21h 40m, 115mm OG, ×186, *R. M. Baum*. The nightside had a very low intensity, and appeared coppery.
C 1991 Jul 18d 19h 40m, 152mm refl., ×133, ×200, *J. Warell*. Note the lighter rim to the nightside.
D 1993 Mar 25d 19h 00m, 210mm refl., ×195, *A. P. Johnson*. The AL more apparent at the limb and cusps. (Most of the nightside appeared as dark as the background sky.)
E 1997 Dec 14d 16h 20m, 114mm refl., ×150, *I. S. Phelps* (also note bright Sp. limb spot).

Niechoy and Steele between Jan 17 and Feb 10, but the best view was had by Giuntoli on Jan 18 when the crescent arc extended to about 230°.

Ashen Light

In this section we have mostly excluded all daylight sightings, or impressions of the nightside appearing darker than the sky. Suspected sightings of the AL in its true form (lighter than the background sky) are mostly included only where they might support other data.

1991 E and 1991 W

1991 E: We should begin by stating that several additional AL reports came to hand after the original elongation report written by Baum,[2] from which we can now conclude that the AL was definitely visible in the first week of July. On July 2 Falorni (19:00 UT) reported: 'Sensazione di luce cinerea.' The AL was however not visible with a W58 green filter. Next day Baum (21:15 UT) reported: 'Dk. side visible, coppery?' On July 4 four observers independently had positive impressions: Baum (21:15 UT; warm tint), Beaumont (21:15 UT), Niechoy (at 20:28 UT a definite sighting: Figure 20A) and Testa (17:15 UT; 'visibile nel rosso': drawing with W25 red filter shows patchy visibility over the darkside). Baum repeated his impressions on July 6 (20:45–22:00 UT, Figure 20B). Despite concentrated observations no further positive reports emerge until the middle of the month.

Johann Warell (already quoted *in extenso* by Baum[2]) saw the AL with certainty against a darkening sky (19:30–20:00 UT) on July 17 and 18. The AL appeared grey, was lighter than the sky, showed a faintly glowing dark limb, and was best seen with a W80A blue filter or through a polarising filter. It was fainter with a W21 orange filter (17th) and invisible through a W25 red filter (both dates). The AL seemed more definite on the second date (Figure 20C) when Anders Warell further confirmed its presence. On July 17 Marabini (19:35–19:45 UT) partly supported Warell by recording the AL visible adjacent to the terminator of the bright crescent, gradually fading into the dark hemisphere. In summary, the presence of the AL was well established about July 2–6 and 17–18.

1991 W: For the morning elongation, on Aug 24 the extension of the horns to a complete circle gave Buggenthien (observing in full daylight) the illusion of the AL. Cook found a similar problem in analysing his CCD images around the same time. The following data seem most relevant:

Sept 1: Smith, AL 'strongly suspected', and drawn with uneven tone, brighter in SW.

Sept 6, 13 & 14: Niechoy had definite AL records around 04:15 UT on Sept 6 (no filter), 13 (no filter, W15 and W25) and 14 (no filter, W25). However, he could not see the AL at all on Sept 12 (contrast Johnson).

Sept 7 & 12: Johnson, AL with uneven tone (warm hue and brighter in S on 7th; even visible through W15 filter on 12th).

Sept 25: Marabini (03:40–05:00 UT) saw a weak AL in white light only, which was more apparent in the N. part of the nightside; Testa failed to see it at the same hour.

Sept 28: Beaumont (05:20–05:40 UT) definitely saw the AL 'in brief spells'.

Sept 30, Oct 2, 6, 15 & 18: Beaumont, suspected. On Sept 30 she reported fleeting glimpses of the true AL at 04:45 UT, but at 06:30 UT the 'nightside darker' illusion was noted. Observing on that date around 06:15 UT, neither Baum nor Heath could see the AL.

In summary, there was some evidence for the AL being occasionally visible for periods of a few days at a time only, in Sep. It was not a notable feature at this morning elongation.

1993 E and 1993 W

1993 E: There were a good number of positive reports. The first derive from two German observers (Polle and Stübig) who, with small telescopes (but independently) observed a limb brightening of the night side of the planet, on Feb 3.[29] These observations were not made against a dark sky and we suspect illusion as the cause. UK reports were negative for early Feb.

Baum has reviewed preliminary UK reports in much detail,[17] to which we have added data received subsequently. As with other elongations, it should be stated that negative observations are available for most of the dates not cited in the following lists. Early sightings were somewhat tentative: Feb 14 (Beaumont, suspected), 19 (Baum, glimpsed with occulting bar, especially along Sf. limb), 22 (Beaumont, glimpsed; Davies reported visibility in poor seeing), 26 (glimpsed by Beaumont, but invisible to Baum), 27 (Patrick Moore, strongly suspected), 28 (glimpsed by Beaumont, suspected by Patrick Moore and seen by Niechoy (with the bright crescent out of the field)), March 6 (Johnson, all around

dark limb at 19:00 UT; completely visible to Adamoli (and suspected by Giuntoli), 17:40 UT) and 7 (Niechoy; definite, and also visible through red W25 filter). More sightings followed but the AL seemed temporarily to decline: March 8 (Davies and Macdonald (suspected) – probably an illusion on a bright sky, and contradicted by negative reports by Ellis, Heath, McKim and Meredith), 9 (glimpsed by Beaumont and seen by Niechoy (reddish-brown)), and 13 (Davies, but with small OG in bad seeing).

There followed a resurgence of more definite AL sightings: March 14–15 (Niechoy), 18 (Baum, suspected,18:50–19:00 UT, but not seen by Beaumont, 18:45 UT), 19 (Niechoy) and 20 (Bosselaers, a possible sighting contradicted by a negative report from Patrick Moore). On March 21 (Beaumont, Johnson) and 22 (Davies, Johnson) the AL appeared warm-toned to Johnson, with Beaumont noting that the illusory form (darkside darker than background sky) was present prior to 19:10 UT. On March 23 Baum[17] saw a faint, reddish-grey AL at 19:45–20:00 UT, which Hill had also sketched between 19:17 and 19:22 UT (drawing reproduced by Baum[17]) and which Beaumont also glimpsed after 19:00 UT. (Before that hour Beaumont had again recorded the AL only in its illusory form, darker than the sky.) Niechoy could again see the AL on March 24. Next day, 18:50–19:25 UT, it was visible to Johnson (around the dark limb and especially near the cusps: Figure 20D).

To conclude, there was significant evidence for the true Ashen Light, sometimes confirmed by multiple records during (probably) two epochs, Feb 14–March 9 and March 14–25, representing the largest number of BAA sightings for many years. The partial visibility of the AL only in the region of the cusps is rare, and calls to mind a historic sighting by H. McEwen in 1948.[18]

1993 W: There were no positive reports apart from those by Buggenthien on April 2 and 5, in full daylight, which must be logged as illusory.

1994 E and 1995 W

1994 E: Prior to IC, Venus was poorly placed for European studies. Adamoli reported seeing the dark side on a bright sky around dichotomy during Aug 3–29, which must have been an illusion, perhaps created by the cusp extensions. (The dark hemisphere generally appeared darker than the sky: seeing was no better than poor to moderate, and no occulting bar was used.) Niechoy made no certain AL sighting, though he logged at least one unconfirmed suspicion (probably illusory) of a lighter spot on the dark hemisphere. We conclude there was no definite sighting.

1995 W: After IC, Giuntoli 'strongly suspected' the AL on Nov 13. A more secure record was made by Niechoy on Nov 29 when the AL was 'definitely present'. Just after 05:00 UT on Dec 2, Niechoy found the AL 'very pronounced' in white light or W25 red filter, but it was not visible through a W47 blue-violet filter. The same morning, Vandenbulcke thought the AL 'possibly present' at 06:00 UT. Biver did not see it at 06:55 UT with the Meudon 600mm Cassegrain, but by then it was daylight. Niechoy also reported the AL on Dec 5 ('very pronounced', brownish, definitely recorded in all visible wavelengths from about 06:00 UT onwards) with further views on Dec 7 (partially), 8, 16, 17 (partially) and 20.

1996 E and 1996 W

1996 E: This elongation witnessed several confirmed sightings of the AL: the Director regards those of April 27, 28, May 19, 21 and 27 as the most objective.

Having suspected the AL earlier in the evening, Niechoy reported it certainly visible and reddish-brown from 20:03 UT on April 27 (and it was also seen with W25 and W47 filters). Phelps reported his first view of the AL the same evening: to him it became visible as a greyish disk from 21:51 UT (note the longitude and therefore time difference between Germany and the UK). Next evening Phelps found the AL to be still more prominent, visible at an earlier hour (from 20:45 UT onwards). On May 2 both Niechoy and Phelps reported the AL, but the former considered it an illusion this time as it was only apparent against a lighter sky. Phelps again recorded the AL on May 7, becoming clearer as the sky darkened or with the bright crescent out of the field, and yet again on May 17 and 21. On the latter date Abel provided tentative confirmation. On May 19 Schmude (510mm Newtonian) found the AL faintly visible, and 'a faint glow encircling the planet' on the nightside. On May 27 both Beaumont and Marsh independently reported the AL.

On most of the nights of positive record, there were a few negative reports, but most were at an earlier hour than the positive AL reports. Not many observers employed an occulting bar, but by using an occulting eyepiece on May 20 under good conditions Patrick Moore was emphatic that the AL was not then visible.

1996 W: Niechoy considered that his few suspicions of the AL were not objective. Schmude suspected the AL on Aug 14, but this sighting is unconfirmed and we conclude the phenomenon was not definitely observed this elongation.

1997 E and 1998 W

1997 E: Phelps reported the AL on Dec 14 (Figure 20E). It still appeared when the bright crescent was placed outside the field, and his wife confirmed it. Niechoy recorded a partial appearance of the AL on Dec 26, but as the observation was in daylight it must have been illusory. To Niechoy on Dec 30, Jan 10 and 11 the (otherwise invisible) darkside appeared to be outlined by a diffuse brightening, which may be a manifestation of the partial AL.

1998 W: There were no reports of the AL, except in its illusory form.

There were more confirmed AL sightings in 1991–'98 compared with 1999–2006.[19] The 1991 E, 1993 E and 1996 E elongations produced the best records. Of the 1993 E data for 1993 March 23, the Director notes that the observed chronology depended upon aperture, which is a further argument for the objectivity of the AL. Beaumont had the largest instrument (305mm) and saw the AL earlier than Hill (210mm aperture); Baum with the smallest aperture (115mm) saw it last of all. It is extremely important that visual observers continue to watch for the Ashen Light, because long-term statistics yield interesting results, as McKim & Moore[18] have recently shown.

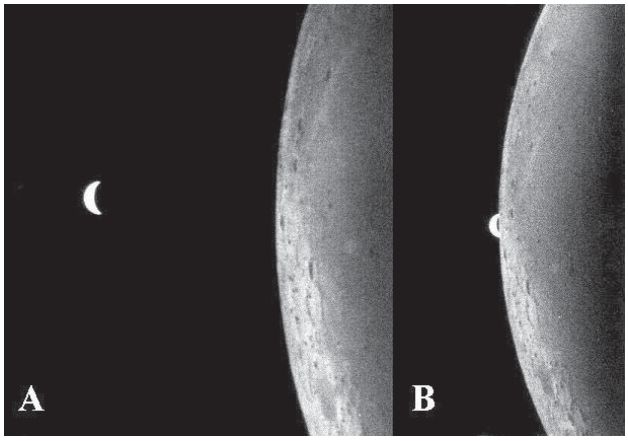

Figure 21. Lunar occultation, 1996 July 12, photographed with 152mm Mak–Cass., f/20, 0.25 sec., TP2415 film, W29 red filter, *J. Dragesco.* **A** 07h 15m; **B** 07h 36 m. North is uppermost.

Lunar occultation

Observing from the French Riviera, Professor Jean Dragesco obtained two excellent photographs of the lunar occultation of Venus on 1996 July 12 (Figure 21). The predicted Greenwich times were 07h 47.7m–08h 55.5m, but as viewed from southern France ingress was close to 07h 36m.

Acknowledgments

Apart from our obvious debt to the Section personnel, we note that nearly all the data listed in this Report were collected and chronologically filed by Richard Baum, at the time the Section Director. The 1991 E elongation apparent dichotomy date was strengthened by unpublished independent analyses by former Venus coordinators Drs John McCue and John Nichol. The Director thanks Detlev Niechoy for an in-depth analysis of his personal Ashen Light observations, Mr Robin Newman for help with software, Mr Mario Frassati for translation from Italian, and Mr Keith Hannis for translation from German.

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