The eastern and western elongations of Venus, 1999–2006

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

This Report discusses ten successive morning and evening elongations of Venus. BAA data concerning phase anomaly, atmospheric markings, cusp extensions and the Ashen Light are presented and compared with historical data. The observational data include infrared imaging of the thermal emission from the planet's nightside, and extensive ultraviolet imaging. An improved BAA estimate for the UV rotation period has been determined from our data as 3.99515 ± 0.0004 days.

Introduction

From the 1956 E elongation up to the 1991 E elongation the Section published an uninterrupted series of Venus reports. Numerous notes and a few formal reports punctuated the ensuing years. The present account, dealing with five morning and five evening elongations of Venus, bridges half the gap in the Section's publications between 1991 and 2006. A further report will cover the years 1991–'98.[1] Formal reports of the 2001 E elongation[2] and for those of 2004 E and W[3] have already appeared. In 2006 the Section was asked to coordinate ground-based imaging in support of the *Venus Express* mission. A short account of the observations secured was published at the time.[4] Very brief published notes upon some of the other elongations should also be cited.[4]

There is a cycle of eight years during which Venus undergoes ten successive elongations and then returns to almost precisely the same place in the sky. Thus the recent 2007 E elongation greatly resembles other highly favourable elongations such as those of 1895, 1903, 1911, 1919, 1927, 1935, 1943, 1951, 1959, 1967, 1975, 1983, 1991 and 1999, every one of which was studied by Section members.

The data for 1991–1998 are almost entirely visual, but the 1999–2006 epoch witnessed a slow decline in the amount of visual observing, although the later elongations were still being reasonably well observed. Almost no traditional photography was being submitted by the end of the period, but many observers had acquired digital cameras and/or CCD equipment. Unfiltered CCD images are actually of relatively little value except to support visual estimates of dichotomy. More useful are those secured with the appropriate ultraviolet or infrared filters. The UV images agree well with the best visual drawings, and especially with those made in blue or violet light, so there is no doubt that quality visual data are still highly valuable. Indeed, the Section will continue to welcome new visual observers.

Observers and elongations

Table 1 lists the observers. We note the steady visual work of Adamoli, Crandall, Ellis, Fisher, Frassati, Haas, Heath, McKim, Middleton, Niechoy and Wade, all of whom contributed reports at five or more elongations. Patrick Moore's final drawings of the planet were made in 1999, completing an extraordinary series begun in 1935. CCD work by Ikemura, Melillo, David Moore, Olivetti, Parker, Peach and Pellier is also especially praiseworthy.

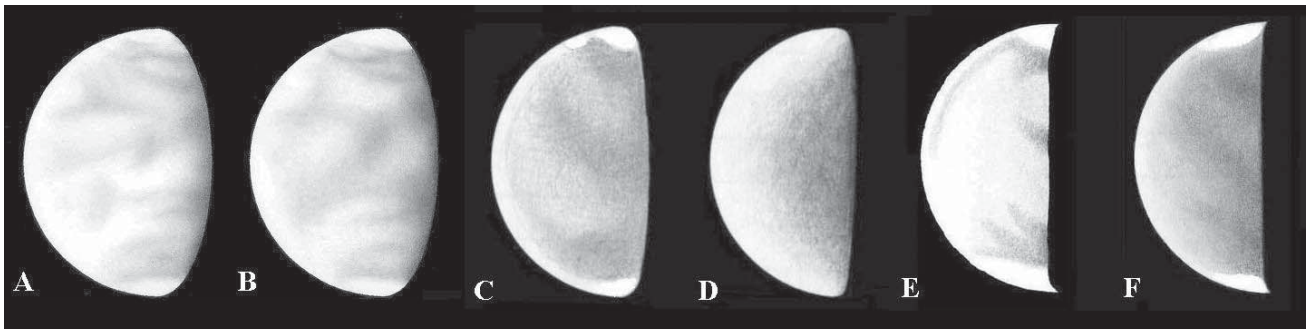

Figure 1. In this and all other Figures, except for Figures 13A–B, south is uppermost.
A 1999 April 27d 16h 40m, 415mm Dall–Kirkham Cass., ×348, W15+W58, *D. Gray*.
B 1999 April 27d 17h 00m, 415mm Dall–Kirkham Cass., ×348, W47B, *D. Gray*. Complex markings, similar in **A** and **B**.
C 1999 May 20d 19h 15m, 216mm refl., ×130, Int, W15, W25, *R. J. McKim*. Diagonal bands.
D 1999 May 20d 19h 30m, 216mm refl. ×130, W47 blue-violet filter, *R. J. McKim*. Wider limb brightening and heavier terminator shading than in **C**.
E 1999 June 9d 18h 35m, 203mm Schmidt–Cass., ×250, W8, *M. Frassati*.
F 1999 June 9d 20h 20m, 216mm refl., ×180, *R. J. McKim*. Diagonal bands match those in **E**.

Tables 2 and 3 summarise key dates. Meeus[5] has tabulated the geocentric ecliptic latitude of Venus at inferior conjunction (IC). This effectively gives the angular separation between the centres of Venus and the Sun (to within ± 0°.1). Refer to Table 3.

The observations

Dark markings

These were entirely typical, consisting mostly of horizontal or diagonal bands. The collars at the N and S cusps were rarely prominent, though very often noted as being present. Reports of exceptionally dark collars come from 2002 E only. We refer to the dark markings in the following only if there were some definite trends established, if there was clear evidence of the 4-day period, if there was good accord between observers or if markings were especially prominent. We regard the terminator shading as a constant (and therefore unremarkable) feature. Technical data for UV filters have been published elsewhere.[3]

1999 E

On April 3 Heath remarked upon the dark collars visible around each cuspidal area. Gray surely had the best view of any observer on April 27, when the complex markings visible (Figures 1A–B) were similar in both yellow and blue-violet light. McKim saw the inclined belts well on May 20 in yellow light (Figures 1C–D), but on this occasion the view seemed different at shorter wavelengths. He made a similar W15 drawing on June 6. Frassati and McKim made similar sketches of inclined belts on June 9 (Figures 1E–F), resembling the latter's May 20 view five rotations later.

Melillo contributed UV images that showed the belts well.

1999 W

On Sept 18 Heath and Steele recorded three identical horizontal bands (which Heath's larger aperture and brighter image reduced to apparent terminator stubs). Both these observers recorded the same dusky equatorial patch on the *f.* side on Oct 26 (Figures 2A–B). (Other accordances have been discussed by

Table 1. Observers of Venus, 1999–2006

The list excludes those who only contributed work relating to the Venus transit of 2004. These observers have already been acknowledged in the appropriate elongation report.[3]

Name	*Location*	*Instrument(s)*[§]	*Elongations covered*[#]
G. Adamoli	Verona, Italy	108mm OG, 125mm M–C & 235mm S–C	EGHIJ
T. Akutsu**	Tochigi, Japan	320mm refl.	H
D. L. Arditti**	Edgware, Middlesex	254mm D–K	IJ
A. Ayiomamitis**	Athens, Greece	355mm S–C	G
P. Barker	Christchurch, New Zealand	127mm OG	A
R. M. Baum	Chester	152mm M–C	I
S. Beaumont	Kendal, Cumbria	203mm S–C	CDEF
R. Bosman**	Enschede, Holland	279mm S–C	J
R. D. Bowen	Wakefield, W. Yorks.	300mm refl.	C
R. Braga (with R. de Manzano*)	Corsico, Italy	102mm OG, 127mm M–C	C
C. E. R. Brook	Plymouth	60mm OG	ABC
M. Brown*	York	370mm refl.	C
N. D. Bryant**	Lesmahagow, Scotland	300mm S–C	J
A. Carbognani	Parma, Italy	110mm OG, 203mm refl.	E
J. A. Clark**	Gravesend, Kent	203mm S–C	GH
E. Colombo	Cambio and Gambarana, Italy	80mm OG, 150mm M–C & 152mm refl.	CDGI
J. A. Cooper**	Northampton	178mm Mak–Newt.	G
E. Y. Crandall*	Winston-Salem, North Carolina, USA	76mm OG & 254mm refl.	BCDFH
D. H. DeKarske	Colorado Springs, USA	254mm refl.	F
D. Del Valle**	Aguadilla, Puerto Rico	203mm S–C	CDH
E. L. Ellis	St. Albans	90mm OG & 203mm S–C	BCEFGI
L. H. Field	Christchurch, New Zealand	178mm M–C	A
D. Fisher	Sittingbourne, Kent	215mm refl.	ACDEFGHIJ
M. Foulkes	Hatfield, Herts.	300mm telephoto lens	I
M. Frassati	Crescentino, Italy	203mm S–C	ABCDEFG
M. H. Gaiger	Kingston on Thames, Surrey	220mm refl.	FG
M. Giuntoli	Pistoia, Italy	90mm OG & 203mm S–C	CFIJ
D. L. Graham	Truro, Cornwall	80mm OG	A
D. Gray	Kirk Merrington, Co. Durham	415mm D–K	AB
P. T. Grego	Rednal, Brimingham	127mm M–C	J
W. H. Haas	Las Cruces, New Mexico, USA	152mm, 203mm & 320mm refls.	ABEFG
J. P. Hatton**	Mill Valley, California, USA & Noordwijk, Holland	235mm S–C	GHJ
A. W. Heath*	Long Eaton, Notts.	76mm OG, 203mm M–C & 254mm refl.	ABCEFGHIJ
M. J. Hendrie	Colchester, Essex	152mm OG	G
T. Ikemura*/**	Nagoya City, Japan	310mm refl.	CDGHIJ
J. Jefferson**	Ruislip, Middlesex	127mm S–C	IJ
G. F. Johnstone	Birdingbury, Warwicks.	200mm S–C	A
B. A. Kingsley	Maidenhead, Berks.; Barbados, W. Indies	279mm S–C	J
W. Kivits**	Siebengewald, Holland	305mm S–C	J
P. Lawrence	Selsey, W. Sussex	102mm OG	G
P. R. Lazzarotti** (with P. Guidoni)	Massa and Rocchetta, Italy	252mm refl.	GH
H–G. Lindberg**	Skultana, Sweden	254mm Schmidt–Newt.	J
E. Lomeli**	Sacramento, California, USA	235mm S–C	J
N. Longshaw	Oldham, Lancs.	102mm S–C	I
J. C. McConnell	Moira, Co. Down, Northern Ireland	90mm S–C	A
L. T. Macdonald	Newbury, Berks.	222mm refl.	CD
R. J. McKim	Oundle and Upper Benefield, Northants.	70mm, 76mm & 102mm OGs; 216mm refl. & 410mm D–K	ABCDEFGHI
	Colchester, Essex	152mm OG	
G. McLeod	Reay, Caithness, Scotland	152mm OG	DEFH
F. J. Melillo**	Holtsville, NY, USA	203mm S–C	all
C. Meredith**	Prestwich, Manchester	203mm S–C & 215mm refl.	ACEG
R. W. Middleton	Brightlingsea, Essex	127mm OG & 254mm refl.	ABCFGH
D. M. Moore**	Phoenix, Arizona, USA	250mm refl. & 362mm Cass.	C

Table 1. ***(continued)***

Name	*Location*	*Instrument(s)*§	*Elongations covered*#
P. A. Moore	Selsey, W. Sussex	125mm OG, 320mm & 390mm refls.	AB
D. Niechoy**	Göttingen, Germany	102mm OG, 203mm S–C	all
R. Nunes**	Lisbon, Portugal	203mm S–C	E
T. Olivetti**	Bangkok, Thailand	180mm M–C	HIJ
R. W. Panther	Walgrave, Northants.	60mm, 77mm & 90mm OGs	FGH
D. C. Parker**	Miami, Florida, USA	400mm refl.	BCE
D. A. Peach*/**	King's Lynn, Norfolk Rochester, Kent Tenerife, Spain Loudwater, Bucks. Barbados, W. Indies	279mm & 305mm S–C	CEFGHJ
C. Pellier**	Bruz and Paris, France	180mm & 400mm refls., 210mm D–K	GHI
I. S. Phelps	Truro, Cornwall	80mm OG	A
R. W. Schmude*	Barnesville, and Villa Rica, Georgia, USA	102mm OG & 510mm refl.	ABCD
B. Shaw**	Oakley, Hants.	127mm OG	H
R. M. Steele	New Farnley, Leeds	80mm OG, 300mm refl.	ABC
I. Stellas	Athens, Greece	130mm OG	E
D. Storey	Douglas, Isle of Man	150mm OG	CDE
J. Sussenbach**	Houten, Holland	279mm S–C	J
M. M. Taylor**	Glenfield, Leicester	203mm refl. & 355mm S–C	GH
E. T. H. Teague	Chester	63mm OG	C
L. Testa**	Parma, Italy	152mm OG	AB
D. B. V. Tyler**	Flackwell Heath, Bucks.	279mm S–C	HJ
A. van Kranenberg**	Vlaardingen, Holland	235mm S–C	J
J. Vetterlein*	Rousay, Orkney	175mm M–C	GI
A. Vincent*	Worthing, W. Sussex	203mm S–C	AC
P. Wade	Morecambe, Lancs.	203mm S–C	ABCDEF
T. Wilson	Jefferson City, Minnesota, USA	90mm OG	E
D. C. Wright	Caterham, Surrey	133mm OG	A
K. Yunoki**	Sakai City, Japan	200mm refl. & 600mm Cass.	G

§ S–C: Schmidt–Cassegrain; D–K: Dall–Kirkham Cass.; M–C: Maksutov–Cass.
# A = 1999E; B = 1999W; C = 2001E; D = 2001W; E = 2002E; F = 2003W; G = 2004E; H = 2004W; I = 2005E; J = 2006W. ( ) denotes contributions received too late to be noted in earlier Reports.
* denotes photographs (silver halide or digital); ** denotes CCD images

Steele and Heath elsewhere.[15]) On Dec 9, Patrick Moore drew a horizontal streak from the terminator attached to an 'exceptionally dark' vertical dark marking on the *f.* side. On the nearly full disk of 2000 May 14 Frassati had an excellent view of the complex markings (Figure 3A).

The collars were not pronounced. The S one was generally darker than the N one.

2001 E

In the summer of 2000 Frassati made a number of fine drawings at high gibbous phase. His views of July 8, 12 and 16 show clear evidence of the 4-day periodicity in the markings (Figures 3B–D). The observations of the dark markings were entirely typical at this elongation. Under good conditions, drawings by observers compared favourably: for example, on 2001 Jan 14 Fisher and McKim agreed upon the two diagonal bands present; on Jan 17 McKim and Middleton showed a central dark terminator feature, from which a band ran in the S*p.* direction.

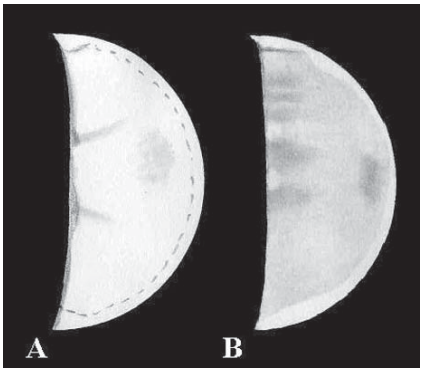

Figure 2. Drawings.
A 1999 Oct 26d 06h 45m, 203mm Schmidt–Cass., ×200, Int, W44A, *A. W. Heath*.
B 1999 Oct 26d 07h 24m, 80mm OG, ×225, Int, W15, W25, W58, *R. M. Steele*.

David Moore's fine UV images (Figures 4A–D) showed the markings in detail. Note in particular the exceptionally strong horizontal bands on Dec 3, and the C-shaped shading partly visible at the limb on Dec 22. Steele[2] has further reproduced and compared UV images by Moore and Melillo with the Section's drawings.

The cusp collars were often present, but weak, visually. Ellis paid special attention to them. On 2000 Dec 15 he found the S collar clearly visible; on Dec 28 both collars showed up well. The S collar was more prominent than the N to him during Jan 6–Feb 5. During Feb the S collar became fainter. On Jan 29 (Ellis) and 31 (Schmude) both collars showed up equally well. In UV light the collars were much darker, with the N one appearing very dark on Dec 22 (Moore; Figure 4B) and again six rotations later on Jan 15 (Parker).

2001 W

On some dates the markings were especially well seen, but there is no special feature to record here. Frassati found the S*f.* limb of the thin crescent partly shaded on April 8. Diagonal dark markings were very well seen by McKim on May 22 and 23 (Figures 5A–B), the latter drawing according well with one by Fisher. Fisher and Del Valle also agreed in portraying complex (mostly horizontal) bands on Sept 16.

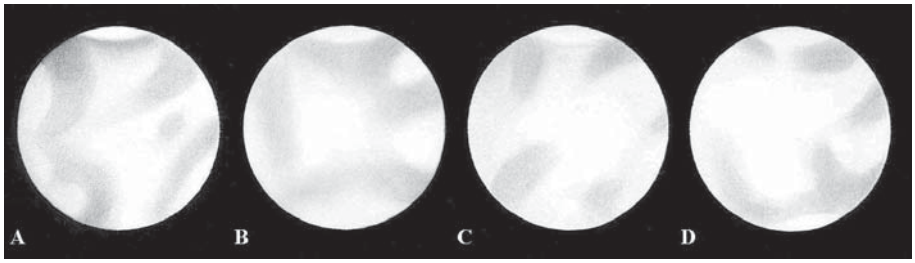

Figure 3. Drawings by M. Frassati with 203mm Schmidt–Cass. Note bright S cusp-cap and evidence of 4-day period in **B–D**.
A 2000 May 14d 09h 58m, ×200, W56. Seeing I!; **B** 2000 July 8d 12h 40m, ×250, W80A; **C** 2000 July 12d 14h 50m, ditto; **D** 2000 July 16d 11h 30m, ditto.

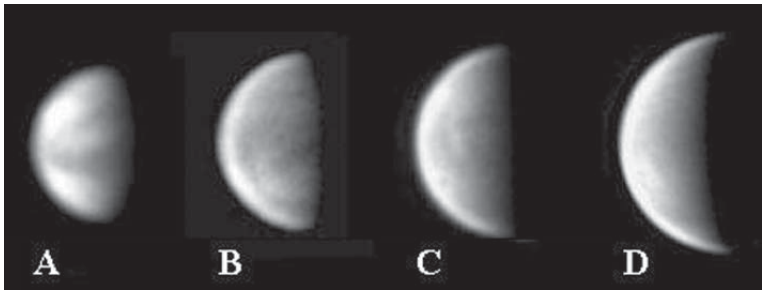

Figure 4. CCD images by D. M. Moore with 250mm refl. (**C, D**) or 360mm Cass. (**A, B**) and 365nm Schuler UV filter.
A 2000 Dec 3d 17h 49m; **B** 2000 Dec 22 00h 09m; **C** 2001 Jan 14d 00h 34m; **D** 2001 Feb 5d 00h 56m

Frassati's Sept 3 and 15 drawings of the gibbous disk agree well with each other, corresponding to the same longitudes of the upper atmosphere. Frassati's drawing of Nov 1 also agrees well with Fisher's of Nov 5.

2002 E

Visual data call for few special remarks. Dusky bands were recorded from May 15 onwards. Fisher recorded three horizontal bands on May 15 and again (three atmospheric rotations later) on May 27. Haas drew complex banded markings on July 24.

Parker (July 17–Sept 14) secured especially fine images of the typical diagonal banding in UV light, but too few in number for further analysis (Figures 6A–D). Melillo's small but systematic images showed many examples of the 4-day rotation of the dark markings. On July 16 Melillo experimented with different filters and found that the UV markings were also recorded through a blue-violet W47 filter combined with an IR-blocker. (This fact would later be utilised by other CCD observers.) The W80A light blue filter did not record the UV markings.

Collars to the cusps were often seen but rarely prominent. In June the S collar was the more prominent. Adamoli found the S collar very dark (intensity 4+) on June 29 and 30, and the N collar even more so on Aug 30 (intensity 5, quite exceptional for any Venusian feature). Haas also drew the S collar clearly, and more prominently than the northern, on July 24.

Table 2. Venus elongations, 1999–2006

*SC**	*GEE**	*IC**	*GEW**	*SC**
1998 Oct 30	1999 Jun 11	1999 Aug 20	1999 Oct 30	2000 Jun 11
2000 Jun 11	2001 Jan 17	2001 Mar 30	2001 Jun 8	2002 Jan 14
2002 Jan 14	2002 Aug 22	2002 Oct 31	2003 Aug 18	2003 Aug 18
2003 Aug 18	2004 Mar 29	2004 Jun 8	2004 Aug 17	2005 Mar 31
2005 Mar 31	2005 Nov 3	2006 Jan 13	2006 Mar 25	2006 Oct 27

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

Table 3. Venus inferior conjunctions, 1999–2006

Inferior conjunction	*Geocentric ecliptic latitude of Venus*
1999 Aug 20	–8° 07'
2001 Mar 30	+8° 01'
2002 Oct 31	-5° 42'
2004 Jun 8	-0° 11' (transit)
2006 Jan 13	+5° 30'

2003 W

On Dec 1 a rather dark terminator projection was apparent in the S hemisphere to Frassati (Figure 7A) and Middleton. On Jan 7 McKim (Figure 7B) and Panther agreed upon a similar feature. The same markings recurred to McKim one atmospheric rotation later on Jan 11 (Figure 7C), and were largely confirmed by Gaiger (Figure 7D). Streaky, mostly horizontally banded markings were apparent on the nearly full disk to Fisher in 2003 May and Aug, and Niechoy also made many records of them.

2004 E

These data have been described at length elsewhere.[3] Both diagonal and horizontal bands were seen. The UV images revealed a number of C- and Y- shaped shadings exhibiting the 4-day period.

Polar collars were not conspicuous, but the southern one was the more prominent.

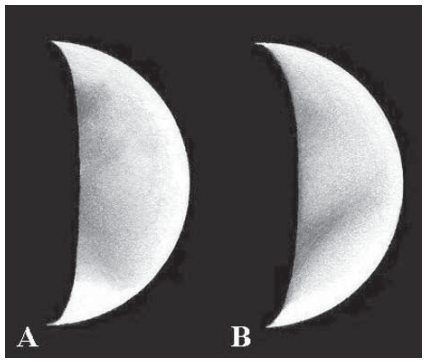

Figure 5. Drawings by R. J. McKim with 102mm OG ×120, showing diagonal bands.
A 2001 May 22d 09h 00m
B 2001 May 23d 11h 15m

2004 W

These data have also been described elsewhere.[3] Markings were typical. We take the opportunity of reproducing a series of previously unpublished blue-violet images by Olivetti that show the same – but nonetheless variable – markings at successive atmospheric rotations (Figures 8A–D).

The S collar was more prominent than the N in the UV images, and from Sept 19 to Nov 6 these images revealed a higher latitude circumpolar belt within the S cuspidal area.

2005 E

Most of the visual data were due to Adamoli, who succeeded in observing horizontal or diagonal banding on several occasions. McKim glimpsed a diagonal band on June 27. Adamoli's drawings of Aug 8 and 24 portray the same southern horizontal band (confirmed by Olivetti's violet image on the same date), four atmospheric rotations apart. A pair of horizontal bands was drawn by Fisher on June 19 and Panther on June 27, two rotations apart, and again by Panther on Aug 1 and Adamoli on Aug 5, one rotation apart.

McKim did not see polar collars on June 27. The N collar was seen as a dark feature from July 19 onwards (appearing especially dark to Adamoli [intensity 4.5] on July 27), but it faded considerably from Aug 29 and was not conspicuous after dichotomy; the S collar was recorded from July 24 onwards, initially faint, then darkening (especially on Aug 12, 19, 24). It was more conspicuous than the N collar in Sept, and was not very obvious after dichotomy.

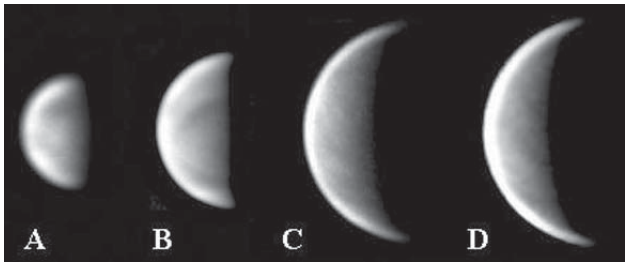

Figure 6. CCD images by D. C. Parker with 410mm refl. and 355nm UV filter.

A 2002 July 17d 00h 39m; **B** 2002 Aug 19d 00h14m; **C** 2002 Sept 14d 23h 32m; **D** 2002 Sept 17d 23h 01m

Pellier's UV image of June 18 shows strong horizontal features including a dark N collar. Horizontal banding is very apparent in the violet or UV images by Arditti, Melillo and Olivetti from Aug until Dec 10, but the collars never appeared strong during this later period.

2006 W

For this elongation there were far more UV images than visual drawings. In the UV, broad horizontal dark markings surrounded the cusp-caps at many longitudes and the classic Y- or Ψ-shaped markings were much in evidence (Figures 9, 10A–C). Sussenbach produced an ultraviolet atmospheric chart for July 12–17 (Figure 10D). More than once van Kranenburg simultaneously recorded a Y-shaped marking in both blue light and in the UV. The 4-day period was sufficiently obvious (in the images of April 13 and 21, for example (Figure 9)).

Atmospheric rotation period

Given the large number of ultraviolet images available for 1999–2006, it was possible to make several measurements of the rotation period of the atmosphere. In particular, it was possible reliably to identify the characteristic UV markings over a number of months or years, and thus to improve upon the 2004 results.[3]

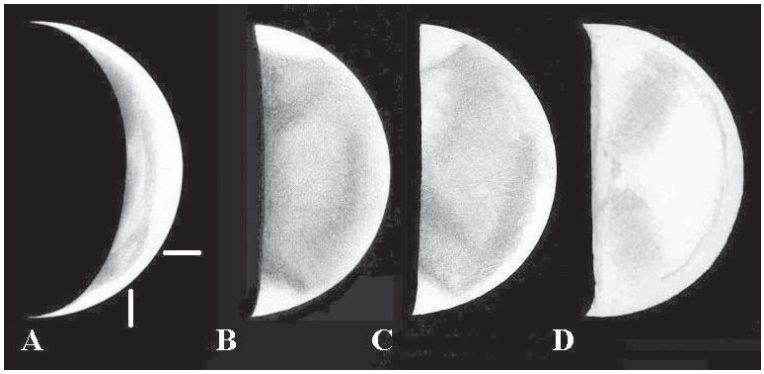

Figure 7. Drawings.
A 2002 Dec 1d 07h 30m, 203mm Schmidt–Cass., ×250, W80A, *M. Frassati*. The location of a small light patch is indicated.
B 2003 Jan 7d 07h 50m, 410mm Dall–Kirkham Cass., ×256, *R. J. McKim*. S cusp blunted. The shading at the *f.* limb was seen one rotation later in **C**.
C 2003 Jan 11d 07h 10m, 410mm Dall–Kirkham Cass., ×256, *R. J. McKim*. Bright cusps and diagonal bands.
D 2003 Jan 11d 08h 00m, 220mm refl., ×224, *M. H. Gaiger.* Compare with **C**.

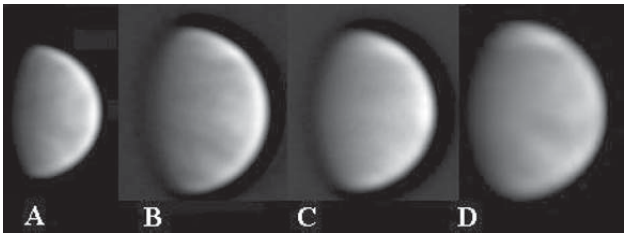

Figure 8. Blue-violet images that show the same region at intervals of two (**A–C**) or three (**D**) atmospheric rotations. Parts of the chevron pattern, seen diverging from the terminator, are sometimes veiled by higher cloud. Also note the growth of the S cusp-cap between **A** and **B**. Images by T. Olivetti with 180mm Mak–Cass., Astromeccanica KC381 CCD camera, with W47 (blue-violet) and IR-blocking filters combined.

A 2004 Oct 7d 22h 38m; **B** 2004 Oct 15d 23h 29m; **C** 2004 Oct 23d 23h 36m; **D** 2004 Nov 4d 23h 21m

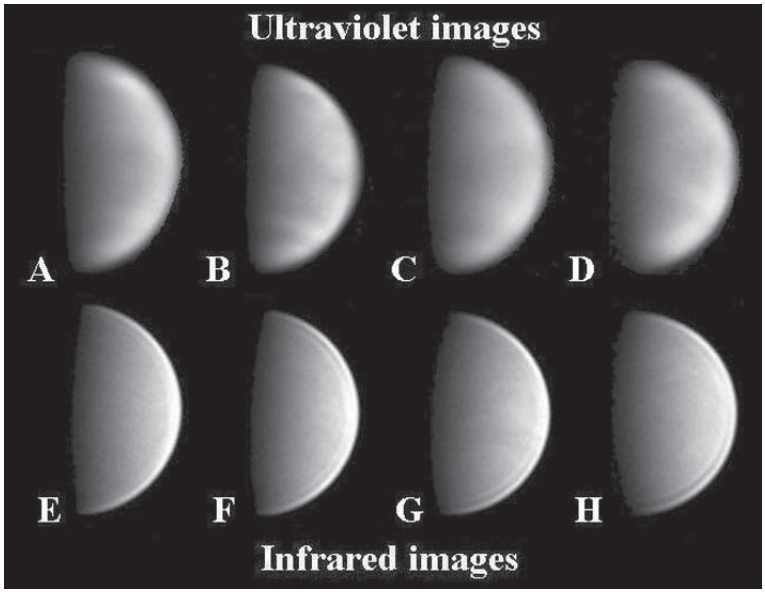

Figure 9. CCD images by D. A. Peach in 2006 April with 235mm Schmidt–Cass. Top row (**A–D**): 365nm Schuler UV filter images. Bottom row (**E–H**): 1-micron IR images.

A April 13d 09h 42m; **B** April 15d 09h 40m; **C** April 20d 09h 39m; **D** April 21d 10h 00m; **E** April 13d 09h 28m; **F** April 15d 09h 20m; **G** April 20d 09h 53m; **H** April 21d 09h 49m

One simply picks an image with highly characteristic dark features, if possible of the type allowing of longitude measurement, and then tries to match it with another image, either earlier or later. The first images showing enough detail for such measures date from 2001 E. However, the best success was obtained by comparing the most characteristic UV marking (one of the permanent Y-shaped features) from 2004 W with 2006 W:

A: T. Olivetti 2004 Oct 29d 23h 17m
JD 2453283.4701 (Figure 6F, Ref. 3)

B: A. van Kranenburg 2006 Jul 15d 04h 44m
JD 2453931.6972 (Figure 10A, this paper)

C: J.Sussenbach 2006 Jul 15d 05h 45m
JD 2453931.7396 (Figure 10B, this paper)

A to **B** interval 623.2271d; 156 rotations; period = 3.9950d

A to **C** interval 623.2695d; 156 rotations; period = 3.9953d

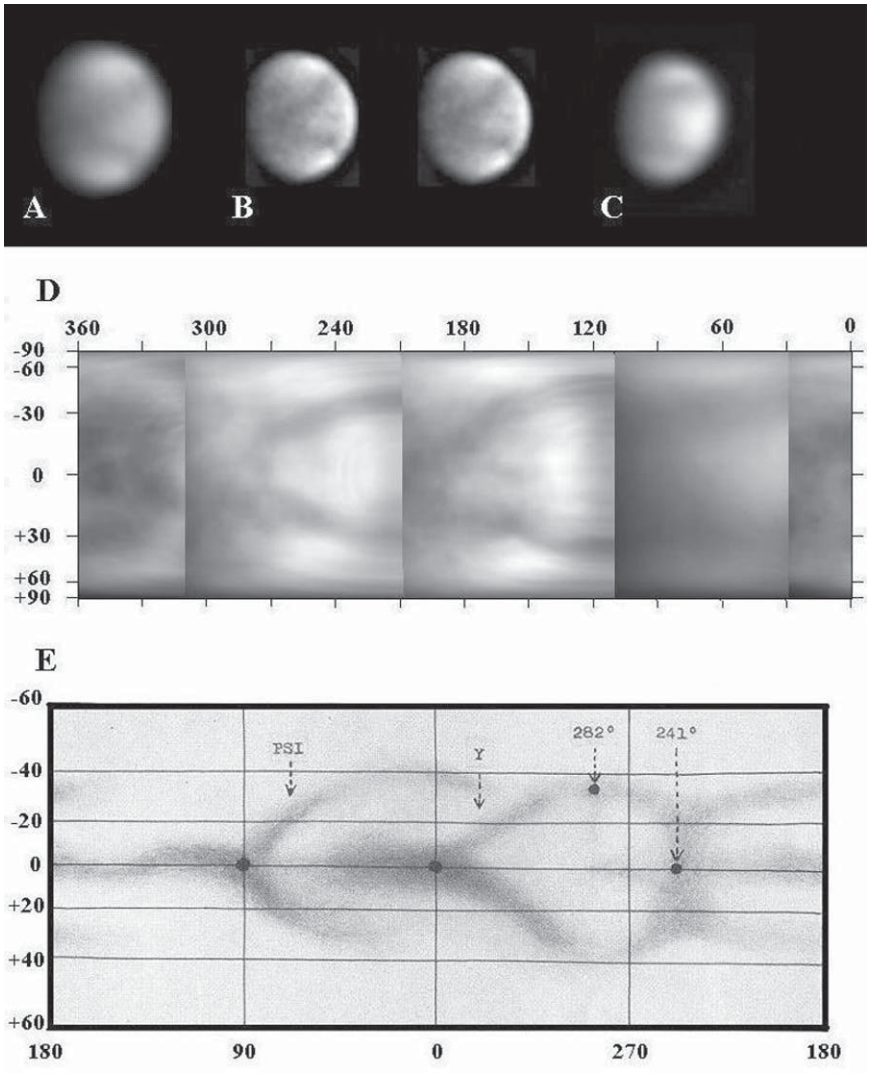

Figure 10. UV images and maps.
A 2006 July 15d 04h 44m, 235mm Schmidt–Cass., Lumenera CCD camera, 355nm Baader UV filter, *A. van Kranenburg*. Note the prominent Y marking.
B 2006 July 15d 05h 45m, 279mm Schmidt–Cass., ATK 2HS CCD camera, 365nm Schuler UV filter (two images), *J. Sussenbach*. Compare with **A**.
C 2006 July 14d 06h 22m, 356mm Schmidt–Cass., 355nm Baader UV filter, *D. B. V. Tyler*. The Y and Ψ markings are absent: instead, dark collars border the light cuspidal areas.
D A partial UV map compiled by J. Sussenbach from his own UV images of 2006 July 12, 13 and 15 and from R. Bosman's image of July 14. The longitudes adopted are purely arbitrary but based on a precise 4-day period. Latitudes are planetocentric.
E General Venus atmosphere chart reproduced from the paper by Boyer & Guérin,[7] in which longitude zero is formally defined as the intersection of the three branches of the Y marking.

The displacement of the marking in longitude between these images is very small, and can be ignored. (The same marking was recorded in a number of other images from 2006 W, but none were as sharp as the ones chosen; some success was also had by measuring drawings, but the results are not given here.) Adding an estimate of the probable error we have 3.99515±0.0004d for the average period. This is an improvement over the 2004 BAA figure of 3.996±0.001d,[3] and may also be favourably compared with the final result of Boyer *et al.,* which was 3.99525±0.00001d.[6]

It is interesting to compare the 2006 chart (Figure10D) with Boyer & Guérin's general chart[7] showing the permanent UV markings (Figure10E).

There are pitfalls with the process of identification. On the face of it, images by Peach and Pellier dated 2004 Sept 16 (Ref. 3, Figure 6B) look identical to another by Peach dated 2006 April 21 (this paper, Figure 9D). Calculation shows that these images differ in longitude by some 90°, so each has imaged one of the two (very similar) Y- or Ψ-shaped markings. Despite a number of other initially promising pairs, no other truly satisfactory match could be obtained.

Dichotomy

Although observers used a variety of filters, most visual records of phase were in white light. The discrepancy in phase was, as always, larger at shorter wavelengths. The following data refer to white light or yellow filter (W15) observations, except where stated.

1999 E

The consensus was that the terminator was convex on June 1, straight on June 3 and concave next day. Therefore dichotomy occurred on June 3.

1999 W

Heath recorded a 50% phase on Nov 2, and this date for apparent dichotomy was confirmed by graphical interpolation of available data (especially Heath and Steele[15]) for a few weeks either side.

2001 E

The most consistent visual observers agreed that the terminator appeared straight, with phase 50%, on Jan 13–16, giving a median date of Jan 15. (This was also Steele's conclusion.[2]) Parker's processed UV image of Jan 15 showed a crescent phase.

2001 W

Visual observers agreed that dichotomy occurred after June 8. Both Del Valle and Fisher recorded a dichotomised disk on June 9, although there is then a gap in the daily record until June 26.

2002 E

According to Adamoli, Ellis and Heath, apparent dichotomy occurred on Aug 12–16, with a median date of August 14.

2003 W

The relevant observations are not numerous, but Ellis and Heath both recorded a phase of precisely 50% on Jan 16.

Table 4. Venus phase anomaly data, 1999–2006

Elongation	*Date of dichotomy**		*Anomaly**
	Predicted	*Observed*	
1999 E	Jun 10.92	Jun 3	7d early
1999 W	Oct 30.03	Nov 2	3d late
2001 E	Jan 19.48	Jan 15	4d early
2001 W	Jun 8.95	Jun 9	1d late
2002 E	Aug 20.06	Aug 14	5d early
2003 W	Jan 10.74	Jan 16	6d late
2004 E	Mar 31.63	Mar 28	3d early
2004 W	Aug 17.49	Aug 23	6d late
2005 E	Nov 2.69	Oct 27	6d early
2006 W	Mar 26.21	Mar 29	3d late

* The observed dichotomy date for 2004 E was based upon least-squares analysis of the observations from apparent phase 0.55 to 0.45 and was quoted as Mar 28.9±0.5d, yielding an anomaly of 2.7d.[3] The date for 2004 W was quoted as Aug 23.0, yielding an anomaly of 5.5d.[3] The rest have an uncertainty±1d and are based on estimation of the median date for phase 0.50.

2004 E and 2004 W

The data have been extensively discussed elsewhere.[3]

2005 E

Few data were available, but Panther found the planet exactly dichotomised on Oct 27 and this is confirmed by Olivetti's Oct 28 images.

2006 W

As noted elsewhere[4] the planet was dichotomised to Heath (white light) on March 29 and upon Olivetti's image (violet light) of April 1, giving a larger anomaly at shorter wavelength.

We summarise these data in Table 4. Predicted dates (correct to ±0.01 days) are due to Meeus.[8] There is no obvious correlation of the magnitude of the anomaly with factors such as declination.

Terminator irregularities

Objective features were probably recorded only on a few occasions. There is a tendency to mistake the root of a dark marking at the terminator for an indentation. The Director has ruthlessly eliminated dubious records from the following account. The observations of 2001 Feb 23 seem to represent the most objective and well-confirmed features.

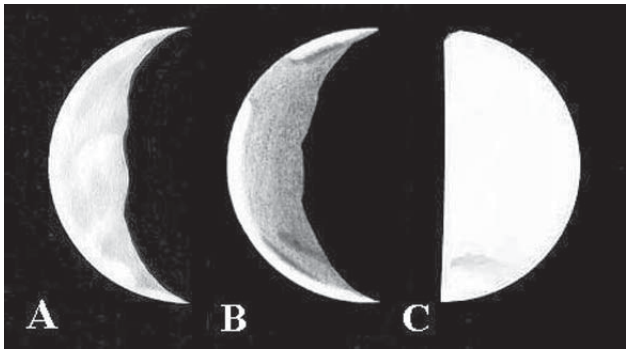

Figure 11. Drawings.
A 2001 Feb 23d 18h 05m, 215mm refl., ×230, Int, W25, *D. Fisher*. Terminator indentations both N and S of equator.
B 2001 Feb 23d 21h 29m, 102mm OG, ×230, *R. W. Schmude*. Compare with **A**.
C 1999 Nov 17d 07h15m, 320mm refl., ×360, *P. A. Moore*. Blunted S cusp.

1999 E

A number of reports by lone observers were not confirmed. For instance on June 9 Frassati (Figure 1E) found slight inflexions near the N and S cusps, but Heath and McKim did not see them.

1999 W

Heath found an apparent indentation on the S*p*. side on Sept 17; on the same date Ellis drew a dark collar to the S cusp cap at the same latitude. A similar feature was drawn by Heath on Oct 5, so probably both were just markings with rather dark roots at the terminator.

2001 E

In good seeing there were several records of terminator notches. On 2000 Dec 28 Frassati reported one N of the S cusp. However, the most interesting case was on 2001 Feb 23, when four observers agreed upon an irregular terminator. Heath at 1730 UT found the terminator was not a smooth curve. Middleton at 1700–1745 UT saw an indentation in the S hemisphere. At 1805–1900 UT Fisher (1805–1905 UT) and Schmude (2129–2159 UT) confirmed this feature as well as two more northerly indents and the associated slight bulges between them. (Figures 11A–B) To Schmude the central indentation was the largest and about 1 arcsec in depth. To Fisher the indents were seen in red and white light but were not evident in blue. In an earlier observation at 1530 UT upon a daylight sky McKim (102mm OG) failed to see any terminator irregularities but he did see atmospheric bands meeting the terminator closely similar to those in Figure 9A. By 2218 UT Del Valle's drawing (reproduced elsewhere[2]) merely hinted at the terminator irregularities, so that these features had not been long-lived.

On March 7 Heath again found the terminator was not quite smooth. (This was exactly three atmospheric rotations later, but no irregularities had been reported on Feb 27 or March 3.)

Steele in his Section Report for the 2001 E elongation[2] listed a number of possible terminator indentations, each reported by only one observer.

Cusps

The following will show that the same pattern emerges around dichotomy in E elongations concerning the variable behaviour of the N and S cusps, and that the time-course of events repeats in reverse at W elongations.

1999 E

The horns of the planet were always rounded on the gibbous disk and pointed in the crescent. Some north–south difference was apparent around dichotomy. With a straight terminator on June 3 McKim found the S cusp rounded or blunted while the N was sharp and slightly pointed.

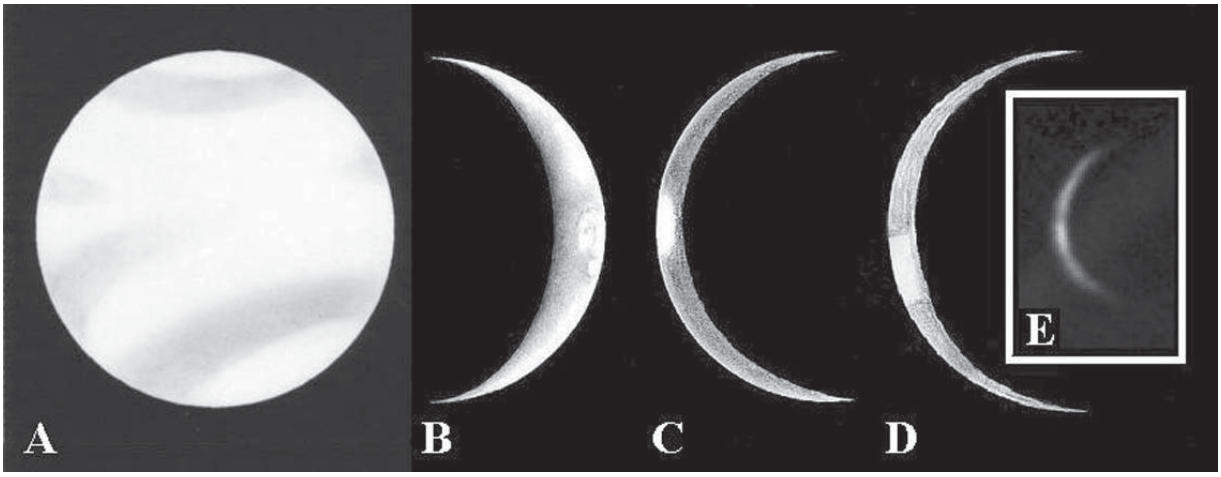

Figure 12. **A** 2002 Jan 1d 10h 00m, 203mm Schmidt–Cass., ×222, W80A, *M. Frassati*. Small S cusp and larger eccentric N one.
B 1999 Sept 10d 05h 50m, 415mm Dall–Kirkham Cass., ×348, Int, W15, W58, *D. Gray*. Bright area on the *f.* limb with cyclonic structure.
C 2001 March 19d 18h 20m, 75mm OG, ×90, *A. W. Heath*. In **C–E** note the equatorial bright patch in the narrow crescent.
D 2001 March 19d 17h 40m, 203mm Schmidt–Cass., ×119, *C. Meredith*.
E 2001 March 19d 18h 36m, 203mm Schmidt–Cass., SX MX5-C CCD camera, *C. Meredith*.

1999 W

On Nov 9 Frassati found the S horn blunted and the N projecting slightly. Brook had a similar view on Nov 12. On Nov 17 Patrick Moore recorded the S cusp as 'exceptionally blunt' and the N one sharp (Figure 11C). He also suspected a threadlike projection from the N cusp.

2001 E

Around dichotomy, during Jan 11–17, Bowen, McKim and Meredith agreed that the S cusp was more blunted than the north (the latter becoming pointed by Jan 14). However, Macdonald recorded an extended S cusp on Jan 14. All observers agreed both cusps to be pointed from Jan 18.

On Feb 23 Heath suspected a thread-like extension of the pointed N horn, but only with a W47 filter. Note the similarity with Moore's observation at the1999 W elongation.

2001 W

At dichotomy on June 9 Fisher saw the N cusp slightly extended and pointed, with the terminator straight.

2002 E

On Aug 2 the S cusp was more rounded than the N to McKim; to Beaumont on Aug 5 the S cusp was blunted and the N slightly extended.

2004 E

As described already elsewhere,[3] the S cusp was more rounded than the N a few days prior to dichotomy. After dichotomy the N horn for a few days was sharper than the S one.

Cusp-caps

In summarising this period, we particularly note the exceptional size of the S cusp-cap during part of the 2004 W elongation.

1999 E

Cusp-caps were conspicuous enough, but never large nor exceptionally bright. If there was a difference between them, the N cuspidal area was more often brighter and/or larger than the S from March to June. On April 27 hints of structure in the S cusp-cap were indicated by Fisher and Gray independently. In May and June Patrick Moore found the outline of the south cap more rounded than the north (Figure 12A). On June 18 Fisher found a small brighter area within the N cap.

1999 W

Small light cusp-caps were often observed. The first sighting, of the S one only, was by Ellis on Sept 9. Both cusp-caps were visible by the end of the month. It was often found that the S one was brighter but often smaller than the N one in Oct to early Nov. During Nov the N cusp increased in size (Ellis). During 2000 Jan–May our data (mostly by Crandall and Frassati) show the S cusp to have been brighter and better defined than the N, but never large.

2001 E

Small light cuspidal areas were often present, but never very conspicuous. In 2000 June–Sept Fisher and Frassati found the S cusp cap smaller and brighter than the north. This impression was confirmed by others in the succeeding months. In Dec–Feb the S cap continued often to be the brighter and more conspicuous one, but from Dec onwards the N cap was sometimes equally prominent.

On Feb 7 Middleton found a small brilliant tip to the S cuspidal area (further details were given by Steele[2]), on Feb 23 Fisher[2] had the same impression at each cusp, and on March 10 Heath[2] found a bright point within the N cap.

Small bright areas feature at the cusps on some of the UV images (Figure 4), with N and S mostly of equal prominence. However, the N limb was much the brighter on Jan 3 and Feb 5.

2001 W

Small light cusps were often observed, the first record being by Del Valle, May 18. On May 22 and 23 (Figures 5A–B) McKim saw brightness only at the N cusp, but Fisher found both cusps bright on May 23 and 24. Only small differences in visibility were recorded during the elongation, so that the cusps seemed more or less equal during June to Sept.

During 2001 Dec 22–2002 Jan 6, Frassati (Figure 12A) was still recording a bright area centred upon the S cusp and another eccentrically located near the N cusp.

2002 E

Immediately after SC, Frassati on 2002 Jan 26 was still drawing a small bright S cusp-cap and an eccentric, larger but less bright N cuspidal area. From early May onwards, several observers agreed that small light cusp caps were present. The N and S cusp-caps remained inconspicuous and roughly equal through June–July, though on July 24 Haas found the south one clearly the brighter. The N cusp was the brighter of the two in Aug–Sept. The cusp-caps were not very evident in the UV work.

2003 W

The cusp caps were never large this elongation. A bright S cusp cap was recorded from late Nov. Both caps were seen equally well in Dec and early Jan. From Jan 9 the S cusp was generally the brighter. They seemed equal in Feb and in the scant April data.

2004 E

The S cusp-cap was more often the larger and more prominent from 2003 Sept till 2004 May. In the UV images there was little difference between the cusp-caps. However, the S limb was often brighter than the north.[3]

2004 W

Cuspidal light areas were noted visually during Aug–Nov. In Aug the S was almost always larger and brighter, and only on two dates were both caps reported equal. Sept–Nov: too few visual records exist for generalisations.

In the ultraviolet images (Aug–Sept), the S cusp-cap was often the larger, though sometimes the N was brighter. The S cap grew during Sept, becoming enormous in the second half of the month. During this period a horizontal dark belt cut across the large cusp-cap: see earlier. This situation mostly prevailed till late Nov when the cusps became equal. The Dec and Jan images showed the N cap as the larger.[3] Figures 8A–D illustrate the variable bright caps as they appeared in the UV.

2005 E

The cusp-caps were not very conspicuous visually. Early in the elongation only the S cusp was seen as a slightly lighter area (Fisher May 27, Panther June 8, and Adamoli June 26). The N cusp was not seen as a discrete area until July 19 visually, though it seems to be present on Pellier's June 18 UV image. Around dichotomy there were small, inconspicuous cusp-caps. In Nov and Dec the N cuspidal area was mostly the brighter of the two, though McKim found the S cusp brighter on Dec 15.

In UV light the cuspidal areas were a bit brighter, but there were very few images obtained of the gibbous phases.

2006 W

In UV light the caps were quite large, and they were widely imaged in both hemispheres. They seem to have been roughly equal during April to Sept, though occasionally the N cap seemed a little larger or brighter (Figures 9, 10). Visually Grego found the N cusp-cap large, and brighter than the southern one, on July 12.

Other bright areas

We regard the limb brightening or 'limb band' as a constant phenomenon. The following data show that discrete light spots on the disk or at the limb show a slightly higher incidence in the southern hemisphere. Only the more prominently described features are cited here.

1999 E

Fisher found part of the S*p*. limb brighter on April 15. A similar feature was seen three atmospheric rotations later on April 27 by Heath (and perhaps Gray). McKim found a small bright area adjacent to (and apparently doubling) the S cusp cap, May 20 (Figure 1C). Frassati found a light spot at the SSE limb of the thin crescent on Aug 10.

1999 W

On Sept 10 Gray drew a bright area on the *f*. limb at the equator, within which an apparent cyclonic structure was well seen in yellow-green light but proved elusive in blue or violet (Figure 12B). A bright spot adjoined this feature's N edge. A bright patch in the S hemisphere was visible to Frassati in blue light on Sept 29. Steele recorded an apparent doubling of the S cusp on Nov 2. A bright equatorial patch on the f. limb was recorded by Heath on Nov 27. Crandall on Dec 1 and 15 found the N cusp cap apparently extended towards the equator along the f. limb. There was no sign of the feature to him on Nov 27 or Dec 5, one rotation either side of Dec 1.

2001 E

There were quite a number reported: 2000 Aug 20 (Frassati, N*p*. limb), Aug 25 (Fisher, ditto) and Sept 1 (Frassati, N*f*. limb), 2001 Jan 27 and Feb 14–17 (Heath, near S cusp[2]), Feb 13, 20 and March 4 (Ellis, S*p*. limb), March 5 (Middleton, *p*. limb at equator) and March 7 (Heath, N*f*. terminator). Some of these features were better seen in blue or green light. The Feb 20 limb feature was very probably a view of the Feb 17 spot at its next rotation.

All the above were unconfirmed individual impressions, but on March 19 Heath and Meredith (1740–1850 UT) both observed a large bright equatorial bright patch apparently filling the width of the narrow crescent (Figures 12C–D),

which Meredith confirmed in a CCD image (Figure 12E). Frassati had not drawn the patch in good seeing at 1610 UT; contemporary observers experienced bad seeing and did not confirm the feature. Steele[2,9] has discussed this marking further in a historical context.

Bright areas on mid-disk are also apparent upon David Moore's UV images of Jan 14 and Feb 5 (Figures 4C–D).

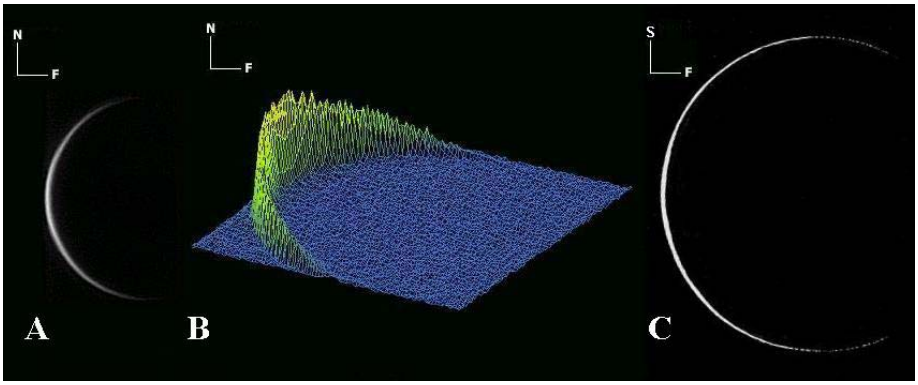

Figure 13. (Note: **A–B** have north uppermost.)
A–B D. A. Peach's enhanced red light (720nm) image of 2003 Nov 10d 08h 01m.
A The highly contrast-enhanced CCD image. Cusps extended to *ca.* 200° in length.
B The 3D colour-coded intensity tracing from the image. No trace of the Ashen Light.
C 2006 Jan 8d 13h 15m, 203mm Schmidt–Cass., ×203, *M. Giuntoli*. Cusp extensions.

2001 W

A bright area on the S*f.* limb was reported by Del Valle on May 18, and again two atmospheric rotations later on May 26. The same observer also reported bright areas at the *f.* limb at the equator on July 6, and at the S*f.* limb on July 13.

2002 E

Frassati, Jan 26: large elliptical bright patch in S hemisphere of the gibbous disk.
Adamoli, June 24: equatorial bright spot at *p*. limb.
Melillo, July 11 (UV image): ditto.
Haas, July 24: equatorial whitish oval near terminator.
Frassati, Sept 11: N*p*. limb brighter than usual limb brightening.

2003 W

A very small light spot was seen in the N hemisphere by Frassati, 2002 Dec 1 (Figure 7A). On Jan 6 Middleton and Wade agreed upon a discrete south equatorial bright patch.

2004 E

A very bright area was imaged in the UV by Pellier and Melillo on Feb 8; their images 5 hours apart show it rotating. On Cooper's Feb 28 image it was no longer bright. Pellier's UV images of Feb 9 and 13, and Feb 10 and 14 also show changing bright areas at the *p*. limb; Peach's Feb 19 image is similar; Pellier's March 16 image shows two near-equatorial bright areas near the *p*. limb; traces of them remained on March 28.

McKim on Feb 28 recorded a lighter halftone near the central terminator, and on April 19 in orange and white light he recorded a bright patch at the NNE limb close to the N cusp-cap which in blue light seemed engulfed by the cap. Ellis saw bright patches at the limb, on March 25 and 29 (SE; these may represent later sightings of a feature seen by Colombo, March 9), April 2 (ENE), and April 16, 23 (SE, SSE), May 6 (SSE), whilst on May 13 (six rotations after April 19) Frassati saw a light spot near the NE limb. Heath on March 30 drew a lighter patch at the terminator S of the disk centre.[3]

2004 W

A bright patch at the NW limb was captured by Akutsu's UV image of Aug 31, and again by Melillo on Sept 12 three rotations later. It had disappeared by Sept 20. Lighter patches on mid-disk are shown on Olivetti's violet images of Nov 19.[3]

2005 E

Pellier's June 18 UV image shows a large bright area at the SE (*p.*) limb. Violet images by Olivetti on Sept 17 and Oct 28 show a light patch just N of the equator and towards the p. limb. Adamoli reported a small bright limb patch at the SSE limb visible only with the W25 red filter, on Nov 11. On Dec 11 Longshaw drew a light patch at the terminator in the S hemisphere.

2006 W

Lindberg's May 4 UV image showed a bright patch at the WSW (*f.*) limb, and this reappeared at the next rotation on May 8. On several images the N cuspidal area appeared to extend southward along the *f.* limb, for instance to Kivits on June 10, Lindberg on July 3 and Sussenbach on July 12, 15 (Figure 10B) and 19.

Cusp extensions

Apart from the comparative notes on cusp blunting or extension around dichotomy, here and in the next section we analyse five inferior conjunctions (IC). Data in Table 3 give an indication of the relative chance of observing highly extended cusps, or the complete atmospheric ring.

1999 E and 1999 W

Venus was over 8° from the Sun at IC, so nothing more than small cusp extensions was to be anticipated. Before IC small extensions were seen by Field on July 6, Frassati on Aug 10 and by Graham, Phelps and Steele on Aug 12, all the August observations being against a bright sky. However, under transparent New Mexico skies (and much to his own surprise), Haas was able to see the complete ring from Aug 16–20 (the latter the day of IC). The observations by Haas either side of IC have been quoted *in extenso* by Baum.[4] Throughout the series, Haas found that the illuminated arc was not always uniform in brightness; for example on Aug 16 he wrote of '...brighter and darker segments in the very dim cusp prolongations.' Filters had little effect on the appearances.

After IC, slight cusp extensions were recorded by Steele on Aug 21 and 22, Parker's Aug 24 image and by Frassati, Aug 30. Haas again saw the entire 360° ring on Aug 20–25, but by Aug 27 the extension was probably incomplete as his data below show. He again found the extensions of uneven brightness and (later) of unequal length at each cusp.

Date(s)	*maximum angular extension (°)*
Aug 20–25	360
Aug 27, 30	290
Aug 28	260
Aug 29, 31	240
Sept 2–6	230–235
Sept 7, 9	220
Sept 10–18	205–210
Sept 25, 30	190–195

2001 E and 2001 W

Before IC, small cusp extensions of 10° or more at either cusp were reported from Feb 23 onwards. Schmude found 18–20° extensions at each cusp on March 22 and 25. Melillo also imaged small extensions on March 25.

Few observations were made immediately after IC: Giuntoli found slight cusp extensions on April 1. Schmude on April 19 found a 10° extension at each cusp, and over the next few weeks reported progressively smaller extensions.

2002 E and 2003 W

Due to close proximity to the Sun at IC, this was a favourable opportunity to see long cusp extensions and the complete atmospheric ring. Prior to IC, Frassati recorded small extensions on Oct 26, but given the unfavourable declination around IC, the best views were by Haas from New Mexico. Haas recorded the angular length of the crescent:

Date(s)	*maximum angular extension (°)*
Oct 19	250
Oct 25	300 (360 suspected)
Oct 28, 29	360

Following IC, Frassati recorded extensions on Nov 5, and Peach's enhanced red light image of Nov 10 (Figures 13A–B) shows the crescent extended to *ca*. 200° in length, but the following series by Haas was obtained at higher altitude upon more transparent skies:

Date(s)	*maximum angular extension (°)*
Nov 5	360
Nov 6	290
Nov 7	270
Nov 8, 9	250
Nov 11–13	225–230
Nov 14–19	215–220
Nov 21, 23	195–200

The complete ring was best seen at very low power and with a red filter. On Nov 14 the extensions were visible through a 320mm reflector but not with a small refractor. Apparent mottling of the unilluminated hemisphere *and* of the surrounding sky was often reported by Haas.

2004 E and 2004 W

Prior to IC, Haas again made the most systematic records: for him, greatest extension to about 270° was seen on June 2.

Observer	*Date(s)*	*max. angular extension (°)*
Haas	Apr 15–May 1	182–185
Haas	May 2–14	185–195
Haas	May 17–28	205–220
Fisher	May 19	185
Fisher	May 22	225
Fisher	May 23	215
Frassati	May 24–25	205
Haas	May 30–Jun 4	225–270
Frassati	Jun 3	230
Ikemura (CCD)	Jun 5	240
Pellier (CCD)	Jun 5	250
Lawrence (CCD)	Jun 6	250
Lazzarotti (CCD)	Jun 6	255

Hendrie also observed on June 5: 'Crescent very thin... at moments of best seeing is a complete ring.' And many observers would see a fringe of light around Venus' dark limb as she neared (or ended) her transit across the Sun's disk on June 8.[3]

Following IC, a number of significant cusp extensions feature on Niechoy's drawings, June 12–26. The crescent was *ca.* 210° long on Pellier's June 12 image.[3]

2005 E and 2006 W

Although the angular separation at IC was again favourable, the declination was not. Prior to IC, slight cusp extensions were drawn by Longshaw on Dec 27 and by Ellis and McKim on Dec 31 (with the S cusp the more extended on both dates), by McKim on Jan 1 and Giuntoli on Jan 8 (Figure 13C). Adamoli observed from Italy with the planet higher in the sky, and on Nov 11, 17, 18, 21, Dec 1, 22 and Jan 9 he suspected very faint cusp extensions of 20–30 at each cusp which may have been traced much further round the dark limb. This series began at unusually high (nearly half) phase, but such observations are not unprecedented.[11] On Jan 12, Adamoli found that the crescent extended to 315°, and next day (IC) at very low power (×40) he could persistently glimpse the entire circle in white light or through W15, 25 or 44A filters.

After IC, some of Niechoy's drawings showed cusp extensions.

Ashen Light

Again we report five IC periods. The 'darker than sky' aspect of the dark side during the crescent phase is regarded as purely illusory, but we shall need to mention it sometimes. Gray's 1999 W observations of Oct 3 were the most detailed records of the true Ashen Light (AL), though other sightings from 1999 E, 1999 W, 2003 W, 2004 E and W, 2005 E and 2006 W also seem objective. All these sightings were made upon a twilight or dark sky. Unless otherwise stated the whole of the night side was illuminated. Mere suspicions of the AL are almost entirely excluded from the following discussion.

Niechoy made the most complete searches for this phenomenon. The Director has not included any of Niechoy's reports of the AL apparently being visible in daylight, nor where it was reported only by the use of filters but not in white light. Niechoy made more positive sightings of the AL during the period 1991–1998 than during 1999–2006. Of his positive sightings, the AL mostly appeared grey or brown.

1999 E and 1999 W

A pre-IC report by Brook on June 18 (60mm OG) was negated by the work of three others with larger apertures

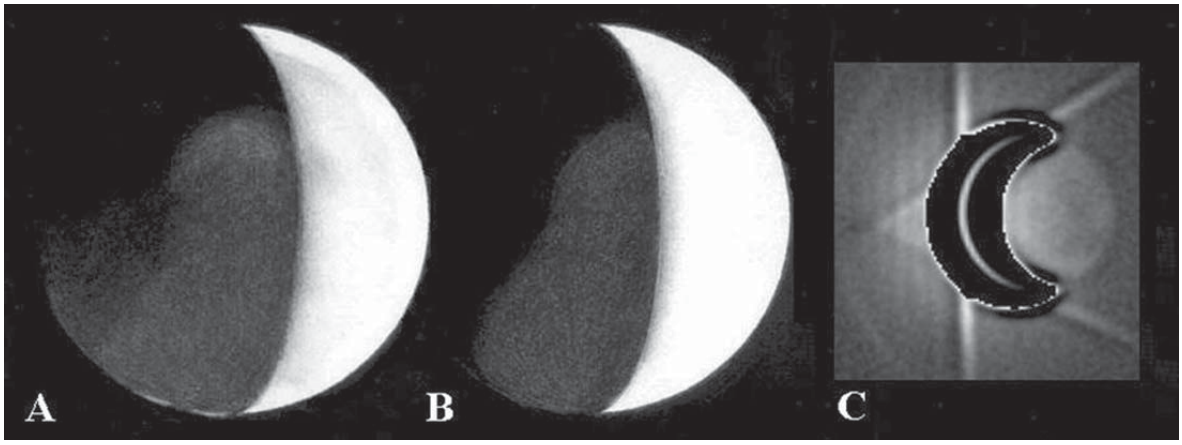

Figure 14.

A 1999 Oct 3d 05h 40m, 415mm Dall–Kirkham Cass., ×348, W22, *D. Gray*.
B 1999 Oct 3d 05h 50m, 415mm Dall–Kirkham Cass., ×348, W23A, *D. Gray*. In **A** & **B** Gray observed the AL to be clearly brighter than the sky, irregular in brightness and tawny-grey in tone.
C 2006 Jan 2d 08h 30m, 310mm refl. & ATK-2HS SC990 CCD camera with 1000nm filter, *T. Ikemura*. Nightside bright in the infrared.

(Heath, McKim and Steele). In an Ashen Light paper[10] Baum described in more detail how Field (confirmed by Barker) reported the AL on July 6. In support of the latter, Niechoy found the AL definitely present and warm-tinted on July 2.

The series of cusp extensions reported by Haas either side of IC has already been described; Baum[4] has also quoted some of Haas' dark side observations. Haas found the dark side apparently darker than the sky during Aug 16–20, and again after IC up till Sept 18, an effect which must have been illusory (at least at this IC, with Venus too far from the Sun to have been silhouetted against the brighter, inner part of the solar corona). It is interesting that Haas also found the dark side mottled on many dates, an impression perhaps enhanced through a W25 red filter. However, his later work for the 2002 IC (see below) would point to the mottling as being another illusion, when the observer found the surrounding sky similarly affected.

Of the other post-IC data, Gray observed the AL without doubt on Oct 3, and found it brighter than the sky and tawny-grey in tone, although it was not seen by Heath with a smaller aperture at that time. Gray found that part of the dark hemisphere was brighter than the rest, as illustrated here (Figures 14A–B). Further details were given by Baum.[10] On Oct 12 Niechoy also was definite about having observed the grey-coloured AL; Heath (mediocre seeing) and Steele (smaller aperture) on the same date did not report it.

2001 E and 2001 W

Prior to IC, Frassati suspected the AL brighter than the sky on Feb 12 with the planet out of the field but concluded the effect was due to eyepiece reflection. McKim saw nothing on the same evening against a dark sky. Steele carried out a systematic search during Feb–March using an occulting bar, with equally negative results. Melillo made long exposures by CCD in an attempt to record the AL on Feb 17, 22 and 27, and March 10, 18 and 25 in red light (W25), and in IR on Feb 22 and 27: all results were negative.

No definite reports following IC are to hand, though Del Valle reported a suspicion of the AL on June 2.

2002 E and 2003 W

During his pre-IC observations Haas often recorded the well-known illusion whereby the dark side of the planet appears darker than the sky. As noted in the foregoing section on several dates he found the dark side apparently mottled. However, he always had the impression that the surrounding sky was equally mottled. This latter impression continued post-IC. Niechoy also recorded the dark side apparently darker than the sky. Therefore there were no objective records of the AL pre-IC.

Post-IC, there were several positive reports of the dark side appearing lighter than the sky. Middleton found the AL present on Dec 1 (with a brighter area in its Sp. quadrant), but it was not seen at all by Frassati at the same hour. Niechoy had suspicions of the AL on Dec 11, 12 and 20, and described it as definitely present and brownish on Dec 10 and Jan 8. Haas did not record the true AL. Peach made a search for the AL by CCD on Nov 10, with a negative result (Figures 13A–B).

2004 E and 2004 W

Reports of the AL in early April do not seem objective. On May 18 Niechoy reported the AL as slightly lighter than the sky, and grey, whilst on May 19 Haas reported having seen a faint outline of the dark limb. These sightings may therefore have been real; also, they coincide with Pellier's records of nightside IR emission.

After IC, Adamoli reported the AL on June 28, as did Niechoy on July 23.[3]

2005 E and 2006 W

Prior to IC, on Nov 11, 17, 18, 21, Dec 9 and 22, Adamoli (125mm Mak–Cass.) had repeated suspicions of a faint grey AL. This was reported on dates where faint cusp extensions (see earlier) that had partly outlined the dark limb had also been suspected. It was best seen with a W25 red filter, and was not seen at all in blue light. No occulting bar was used, and Adamoli is not certain the AL was recorded. Longshaw on Dec 11, 17 and 27 also suspected a fleeting coppery glow

on the nightside. McKim failed to see the AL visually on Nov 16, 20, Dec 3, 8, 12, 15 or 31. Arditti attempted to image the AL or IR emission at a variety of wavelengths (excluding1000nm) but did not succeed.

Post-IC, the AL was reported only by Niechoy, and he found it visible only near the terminator, on March 8 ('yellowish') and 13 ('grey-brown').

Nightside thermal infrared emission

Another highlight of the 1999–2006 epoch was the imaging of the nightside thermal IR emission from the planet, and even an indication of coarse surface topography in the same images. To avoid excessive irradiation, such data can only be obtained with a narrow crescent, but the solar elongation must not be too small.

2004 E

By overexposing and stacking multiple images of the bright crescent, Pellier was able to record infrared emission from the dark hemisphere at $\lambda = 1$ micron (1000nm) at all six attempts during May 12–21. The images showed albedo features, stable over several days, corresponding to actual topography. The dark patches (illustrated in Figure 7, Ref. 3) may correspond with elevated (and cooler) terrain about *Phoebe Regio* and *Beta Regio*.

2005 E

Pellier was again able to image the nightside thermal emission (at $\lambda = 1$ micron) on Dec 18. Between Dec 24 and Jan 2, Ikemura (Figure 14C) succeeded on five dates, and Melillo was also successful (though more troubled by glare) on Dec 23 and 30. Ikemura's images of Dec 29, Jan 1 and 2 (Figure 14C) show signs of surface topography.

2006 W

Following IC, Ikemura (Jan 28) again secured 1-micron infrared images showing the nightside thermal emission.

Infrared observations of the sunlit disk

Infrared CCD observations prior to 2004 were obtained (in particular by Melillo), but lacked the necessary resolution to have revealed the typical, very low contrast features.

2004 E

Observations were mostly obtained at $\lambda = 1$ micron. The following extract describes the general appearance of all such images: 'Observations with infrared filters revealed a dusky terminator and a bright limb that sometimes extended to the cusps. The latter were no brighter than the limb, and tended to appear dark in IR. Any albedo markings imaged rarely corresponded with the UV features; most characteristic were extremely diffuse dusky shadings near the cusps and faint horizontal bands.'[3]

2004 W

No bright areas upon mid-disk were recorded by any of the IR images, except Akutsu's of 2004 Nov 9 and Olivetti's of Nov 6, 19, 20 and 26. Analysis of two near-equatorial bright patches (latitude 0–14°N) suggested a rotation period of 4.99±0.01d.[3] Other images (using 780–1000nm filters) occasionally revealed fugitive horizontal dusky bands including cusp-collars.

2005 E

The general comments from 2004 E would again apply, with only the slightest hints of banding on a couple of the best images. No bright spots were seen.

2006 W

Arditti, Ikemura and Peach occasionally imaged cloud structures in the form of vague low-contrast lighter and darker areas. Peach's best images of April 20 portray several thin dusky bands slightly inclined to the equator. The polar areas were never bright in the infrared, and were sometimes rather shaded. The markings in the IR, when visible, were clearly different (but not in inverse relation) to those imaged simultaneously in the UV (Figure 9).

Solar transit

Venus was in transit across the face of the Sun on 2004 June 8. Very full accounts were published at the time, so we shall not give further details here.[3,12,13]

Lunar occultation

Venus was occulted by the Moon on 2004 May 21. A note was included in the 2004 Report.[3]

Figure 15. 2005 June 27d 18h 53m, 175mm Mak–Cass., ×120 with digital camera, *J. C. Vetterlein*. Conjunction of Mercury (lower left) with Venus (upper right).

Conjunction with Mercury

On 2005 June 27 at 1900 UT Venus was 0.07°N of Mercury. This conjunction was well observed by Baum, Foulkes, McKim, Niechoy[14] and Vetterlein (Figure 15). Baum (21:30 UT) wrote: 'Interesting to compare the relative lustre just as Nasmyth did all those years ago. Conditions were actually very good. Not a trace of cloud, sky an opalescent green-yellow and a hint of coppery pink closer to horizon. Venus bright and silvery, Mercury dull and leaden in hue.' The Director had a similar impression at 15:00 UT, viewing the planets in daylight with a 102mm OG.

Conjunction with σ Sgr

On 2005 Nov 18 Adamoli found the bright star σ Sgr to be some 10 arcmin due N of Venus, forming a spectacular telescopic and binocular sight.

Miscellaneous studies

We also note some observational papers by individual Section members that were published during 1999–2006. These include visual investigations by Steele & Heath,[15] long-term comparisons by Heath & Ellis,[16] studies of the terminator by Wade,[17] an analysis of cusp extension *vs* angular distance from the Sun by Haas[18] and a discussion of Italian observations of the 2001 IC by Braga.[19]

Acknowledgments

All observers are thanked for their efforts, the results of which have significant scientific value. Apart from the elongations from 2004 W to 2006 W, for which the writer was alone responsible, the observations in this report were collected by successive past Mercury & Venus Section Directors (R. M. Baum for 1999–2000, R. M. Steele for 2000–2003, the late E. L. Ellis (Acting) for 2003, and M. Frassati for 2003–2004). The encouragement of Richard Baum during the preparation of the present paper has been much appreciated. Detlev Niechoy is thanked for an in-depth analysis of all his Ashen Light data, specially prepared at the Director's request.

The Section's observational programme[20] has recently been brought up to date by the present Director with regard to ground-based support for the *Venus Express* mission.[21]

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