The opposition of Mars, 1997

Richard McKim

A report of the Mars Section (Director: R. J. McKim)

The opposition marked the successful return to Mars of lander-type spacecraft, the first since Project *Viking* two decades earlier. In 1997 the BAA Mars Section helped to provide ground-based coverage for the *Mars Pathfinder* and *Mars Global Surveyor (MGS)* missions. Only small-scale surface changes were evident since 1995, of which the continuing pallor of *Cerberus–Trivium Charontis* was especially notable. Several dust storms were detected by the BAA, the *Hubble Space Telescope (HST)* and the spacecraft in martian orbit: these included a large regional event in 1997 November which began in *Noachis*. The Equatorial Cloud Band (ECB) effect was rather evident around opposition, and its gradual decline was traced. The seasonal behaviour of the NPC was typical, excepting small differences in the timing of the disappearance and reappearance of the polar hood. The recession of the cap was followed in detail.

Introduction

NASA's *Mars Pathfinder* landed on 1997 July 4 at the confluence of the *Ares* and *Tiu Valles* outflow channels (lat. +19°, long. 33°), and *MGS* underwent orbital insertion on September 11. A timetable of BAA and spacecraft imaging of Mars between 1993 and 2003 was given in the Section Report for 1995.[1]

Mars came to opposition on 1997 March 17, right at the start of northern summer. The planet's N. pole was tilted towards the Earth throughout the apparition, increasing from +6° in early 1996 August to + 24° by mid-November, decreasing a few degrees in early 1997, then rising again to +26° by June, decreasing steadily to 0° by November and subsequently reaching –23° by the close of the apparition. Other physical data are listed below:

Physical data for the 1997 opposition

Solar conjunction	1996 Mar 4	
Spring equinox N. hemisphere/ Autumn equinox S. hemisphere	1996 Aug 26	Ls= 0°
Aphelion	1997 Jan 27	Ls= 70°
Summer solstice N. hemisphere/ Winter solstice S. hemisphere	1997 Mar 13	Ls= 90°
Opposition	1997 Mar 17	Ls= 92°
Autumn Equinox N. hemisphere/ Spring Equinox S. hemisphere	1997 Sep 12	Ls= 180°
Perihelion	1998 Jan 5	Ls= 250°
Solar conjunction	1998 May 12	

Mars was closest to the Earth on 1997 March 20, when the disk diameter was just 14".2, and the distance 98.6 million km. Opposition occurred at declination +4° 40' in the constellation of Virgo, when the latitude of the apparent disk centre was +23°. Although the disk diameter was fractionally larger than in 1995, the planet's considerably lower N. declination diminished the number of observations and marginally reduced the quality of the CCD images. Observers were also distracted by the simultaneous apparition of the great Comet Hale–Bopp in the spring of 1997. Nevertheless, the planet was very well observed, and UK observers enjoyed periods of excellent seeing in 1997 March–April. Due to the very high volume of CCD images the overall number of observations exceeded that for 1995.

In addition to publishing observational hints,[2] the Director produced a large number of Section *Circulars*,[3] achieving a real-time meteorological summary as the Association's contribution to the ground-based *Marswatch* effort[2,4] organised by Dr J. F. Bell (Cornell University) to monitor the planet during the *Pathfinder* mission. These circulars were distributed as paper copies and by email (the first use of the latter medium within the Section), whilst a new website offered an online archive.[5] Six Interim Reports were published in the *Journal*,[6–11] as well as one BAA *Circular*.[12] Other amateur organisations have produced both preliminary (OAA,[13] ALPO[14]) and final (ALPO[15]) reports on this apparition, and others (UAI[16]) were active. Accounts of personal work by Nakajima & Minami[17] and by Schmude[18] have also been published. Dr S. Ebisawa made several reports of his observations from Tokyo.[19–20]

MGS data continued beyond the period reviewed, and *HST* data spanned 1996 September 18–1997 October 9. BAA observations covered the extreme range 1996 August 4 (Ls= 349°, Warell) to 1998 January 21 (Ls= 259°, Parker), and therefore spanned late winter, all of spring, summer, and most of autumn, in the martian N. hemisphere. 84 observers (Table 1) in 14 countries contributed 2,391 observations: 1,316 drawings, 13 photos and 1,062 CCD images. The number of days observed per month by original observations was as follows: 1996 Aug 4(actual)/31(possible), Sep 5/30, Oct 10/31, Nov 9/30, Dec 13/31, 1997 Jan 27/31, Feb 28/28, Mar 31/31, Apr 30/30, May 30/31, Jun 28/30, Jul 21/31, Aug 15/31, Sep 0/30, Oct 6/31, Nov 1/30, Dec 2/31, 1998 Jan 1/31. In addition there were very useful summaries by members of the OAA.[13]

Particular mention should be made of the fine European CCD work by Dijon,[9] Platt,[21] Quarra and colleagues,[8] and Warell, as well as that by Parker in the USA (Figure 1), and the images of Higa and Miyazaki from Japan. Dr Akabane contributed CCD images from his professional programme at the Kwasan and Hida Observatories. Especially good series of visual records were made by Devadas, Gaskell, Gray, Heath, Mettig, P. A. Moore, Schmude, Shirreff, Teichert, Troiani, Warell, the Director, and by the late Tom Cave and the late Dr Rowland Topping. Biver and Tanga made good use of large apertures, whilst Adamoli did sterling work with a small refractor in 1997 July–August when most contributors had ceased observing. Butler reported naked eye magnitudes of Mars. As usual the Director was glad to receive copies of the work of members of other organisations.

The *HST* had a very extensive program of Mars observations,[9] concentrating upon the meteorological conditions of the *Pathfinder* landing site. Many images were uploaded to the internet.[22] Both academic and popular magazines gave much coverage to the space missions as well as to the claimed discovery of 'life-forms' in a martian meteorite.[23] Some authors reviewed the *HST* and ground-based work accomplished.[24] A second *International Mars Telescopic Observations* workshop[25] was held in Arizona in 1997 whilst *Pathfinder* was active on the martian surface; the Director attended and presented BAA data.[26] Many papers appeared concerning the *Pathfinder*[27] and *Mars Global Surveyor*[28] results.

The present report is a continuation of that for 1995.[1] Seasonally comparable apparitions during BAA history have been: 1982,[29] 1965,[30] 1950, 1933,[31] 1918,[32] and 1903.[33]

Observations

Figure 1 presents a selection of composite CCD images by Parker. Figure 2 is an apparition map, and Figure 4 gives some of the Director's drawings. These illustrate the chief features of the apparition. Of special interest here, Bell *et al.*[34] have reviewed 1995–'97 *HST* near-infrared images to chart albedo variations since the *Viking* era.

Surface features

Apparition map

Figure 2 was drawn by the Director from the Section's best CCD and visual work at opposition. In the following account E. and W. are used areographically (E.= *p*., W.= *f*.), and the nomenclature is again after Ebisawa.[35]

Generalities

The albedo variations from 1995 noticed during the present apparition were all on a very small scale, so it is not proposed to give the same degree of detail as in the last Section Report.[1]

The most obvious changes – impersonally documented by the CCD images – occurred to the north of *Hellas* and in the far north. The dark band that was so conspicuous to the north of *Hellas* in 1995 was considerably paler in 1997. In 1995 the regions adjacent to the spring NPC had appeared uniformly dark and bland, but in 1997 the far northern maria were lightened in several areas (due to dust deposition during the previous martian N. winter). This fading of the northern maria with the onset of summer was recognised a century ago by Antoniadi,[36] in connection with *Mare Acidalium* and its environs.

Another feature of the apparition was the rather striking difference in apparent colour between the northern and southern maria. Such differences have been seen at many previous aphelic oppositions. The Director easily spotted the difference around opposition. On March 21 (CML= 286°) *Syrtis Major–Mare Tyrrhenum* was distinctly blue-grey to him, whilst *Casius–Utopia* looked reddish-brown. On March 10 and April 15 (CML= 21–26°) *Sabaeus Sinus–Margaritifer Sinus–Mare Erythraeum–Aurorae Sinus* appeared blue-grey, contrasting with the brownish *Mare Acidalium* in the north. CCD images showed that the central part of *Syrtis Major* was visibly bluer than any other albedo feature. Colour differences seem to be related to recent mineralogical analyses that reveal hemispherical differences in iron-bearing minerals. The apparent blueness of the *Syrtis* – at least towards the edge of the disk – must have been enhanced by

Figure 1. *(opposite)*
Colour CCD images of Mars (to correct relative scale) by D. C. Parker. Tricolour filter work with Schott glass filters (original images: red with RG610; green with VG9 + IR rejection filter; blue with BG12 + IR rejection filter), 410mm refl., F/43, and Spectrasource Lynxx camera.

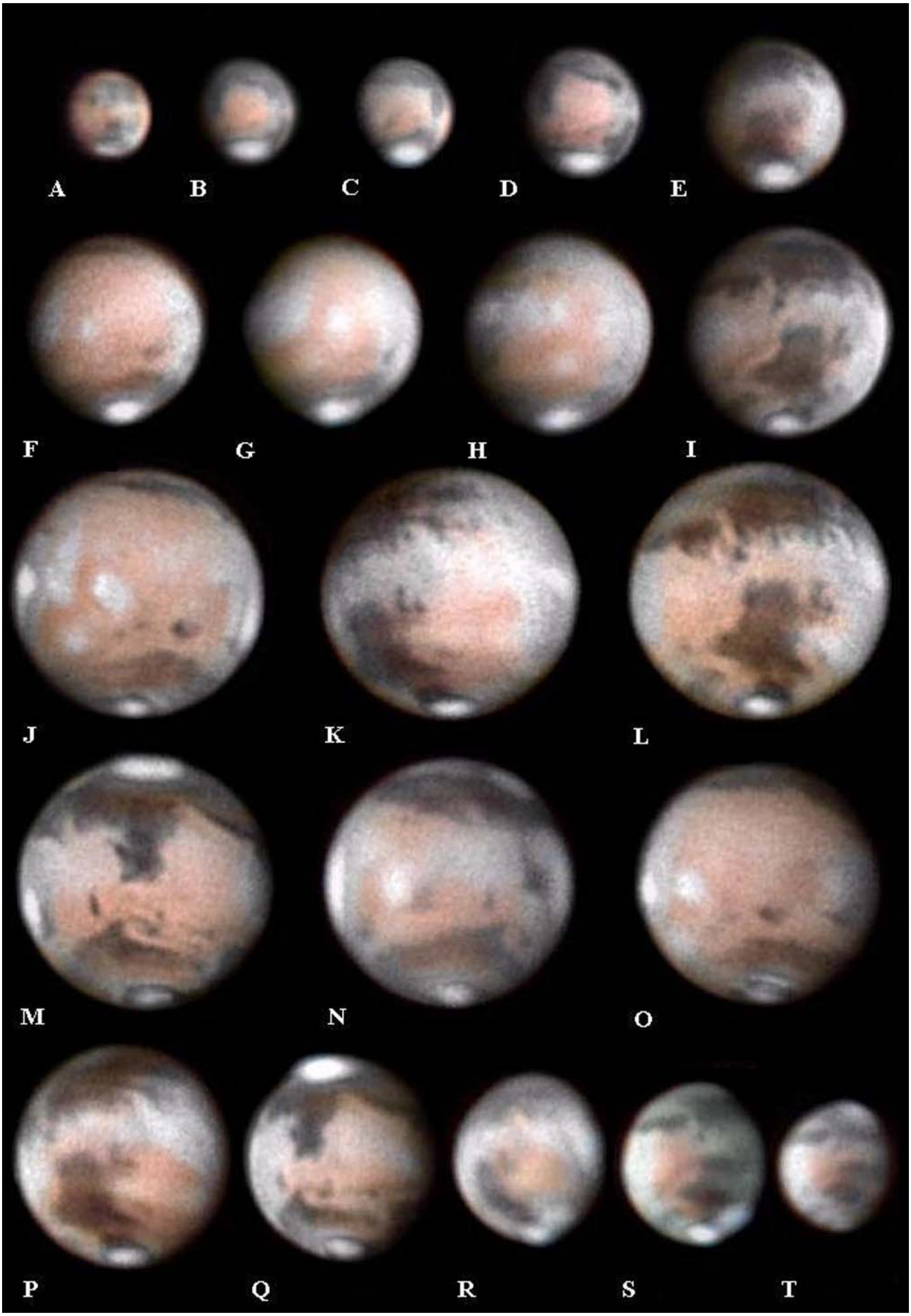
Top row, left to right:
(A) 1996 September 18d 10h 20m, CML= 17°. NPH present.
(B) 1996 October 31d 10h 34m, CML= 324°. NPC with dark border.
(C) 1996 November 8d 10h 04m, CML= 239°.
(D) 1996 December 7d 10h 03m, CML= 319°.
(E) 1997 January 4d 08h 52m, CML= 36°.

2nd row:
(F) 1997 January 29d 07h 53m, CML= 148°. Early images of the evening orographic clouds.
(G) 1997 February 1d 08h 14m, CML= 117°. As (F); *Nix Olympica* at the CM.
(H) 1997 February 4d 08h 38m, CML= 104°. Orographic clouds.
(I) 1997 February 10d 06h 30m, CML= 19°.

3rd row:
(J) 1997 March 7d 06h 13m, CML= 153°. Orographic clouds (compare Figure 8A); small 'oases' west of *Propontis I*; *Ierne p.* the CM and *Olympia f.* it
(K) 1997 March 13d 04h 42m, CML= 78°. ECB. Structures in *Tithonius Lacus* and *Nilokeras*.
(L) 1997 March 19d 04h 42m, CML= 26°. Fine detail in S. *Chryse–Xanthe*.

4th row:
(M) 1997 March 29d 04h 20m, CML= 294°. Brilliant white *Hellas*; *Huygens*; structure in *Boreosyrtis*.
(N) 1997 April 3d 03h 59m, CML= 245°. *Syrtis* blue cloud at a.m. terminator.
(O) 1997 April 8d 02h 27m, CML= 179°. Orographic clouds; *Olympia*.

5th row:
(P) 1997 April 21d 02h 33m, CML= 64°. ECB. Shows at least one volcano caldera as halftone spot on a.m. side, surrounded by white cloud.
(Q) 1997 May 4d 03h 20m, CML= 317°.
(R) 1997 May 28d 02h 44m, CML= 84°. ECB. Bright a.m. cloud at S. edge of NPC.
(S) 1997 June 3d 02h 19m, CML= 21°. *Baltia* brilliant bluish-white bordering NPC.
(T) 1997 July 9d 01h 38m, CML= 25°. Large a.m. cloud at S. limb covering *Argyre* and *Mare Erythraeum*; NPH obscures *Hyperboreus Lacus*.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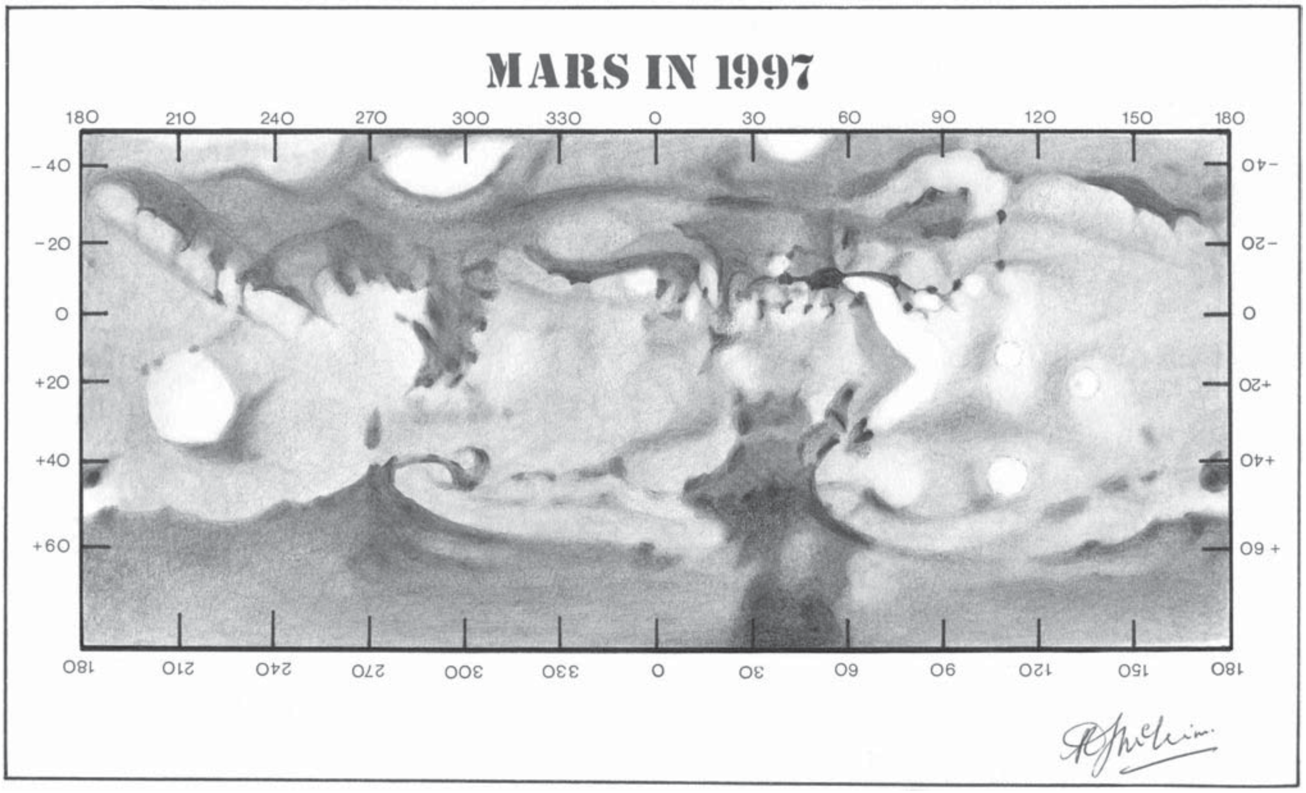


Figure 2. Martian albedo features at opposition, 1997. Ground-based CCD images and selected visual drawings were used in this compilation. (*HST* images were not used.) *R. J. McKim.*

its being overlain by the equatorial cloud belt in northern spring and summer. Minami often described the *Syrtis Major* as bluish (or blue-green) between November and May, the blueness more vivid near the edge of the disk, contrasting with the brown *Utopia*. Minami and Topping (March) noted that the other southern maria were generally bluish, though Minami found a chocolate tint to *Sinus Sabaeus* (February). Minami found *Phlegra* was brownish, and *Mare Acidalium* bluish when near the morning limb (February).

The dark markings bordering southern *Arcadia* were often seen to be strongly red. The OAA (March–May)[13] drew attention to the intense redness of the halftone lying between *Mareotis Lacus* and *Ascraeus Lacus (Mons)* (*e.g.*, southern *Ceraunius*), and the halftone belt roughly comprising *Uranius–Ascraeus Lacus–Ulysses*. This redness was confirmed by the CCD images. Gaskell (April) found the redness of (southern) *Arcadia* to strongly contrast with the pale tint of the belt of equatorial cloud to its south. The OAA wrote that *Cerberus, Deuteronilus*, and *Panchaïa* north of *Propontis* also appeared densely reddish, whilst the deserts immediately west of *Thaumasia* were more red than the latter.

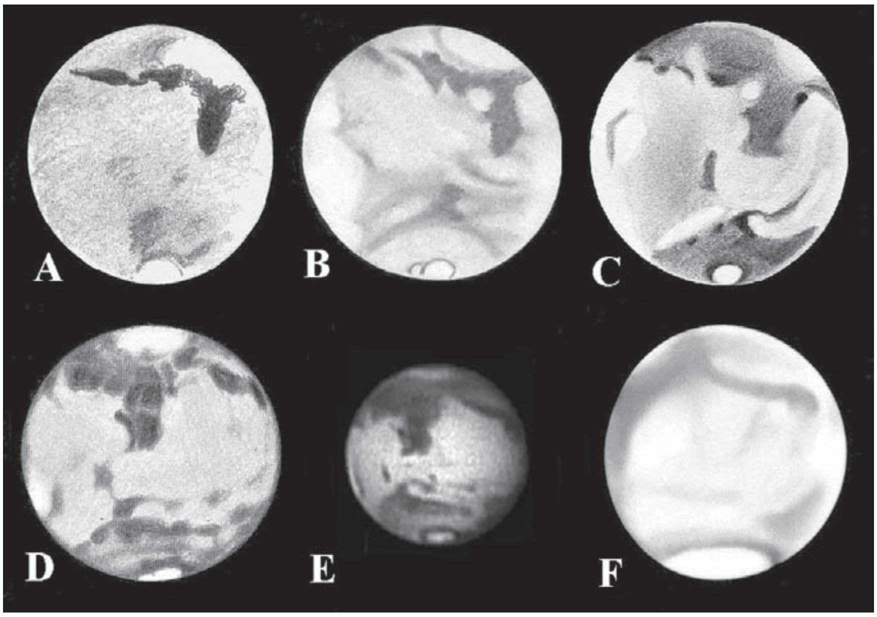


Figure 3. ***Region I, long. 250–010°.***
(A) 1997 May 1d 22h 12m, CML= 260°, 390mm refl. ×330, *P. A. Moore.*
(B) 1997 March 21d 22h 00m, CML= 263°, 215mm refl. ×343, *D. Fisher*. *Olympia*.
(C) 1997 May 9d 03h 15m, CML= 271°, 325mm refl. ×400–×780, *T. R. Cave*. *Nodus Alcyonius; Huygens*.
(D) 1997 March 17d 21h 45m, CML= 294°, 256mm refl. ×507, *N. D. Biver*. As (C).
(E) 1997 March 30d 05h 47m, CML= 306°, 410mm refl., CCD image, red (RG610) filter, *Parker*. *Olympia* at *p.* limb. *Chasma Boreale* enters cap from N*f.* limb.
(F) 1996 September 14d 03h 50m, CML= 322°, 415mm Dall–Kirkham Cass. ×415, ×663,W15, *D. Gray*. Large NPC at the start of spring.

Region I: long. 250–010°

Figure 3 illustrates this part of the planet. In the south, the complex of markings around *Syrtis Major*, *Mare Tyrrhenum*

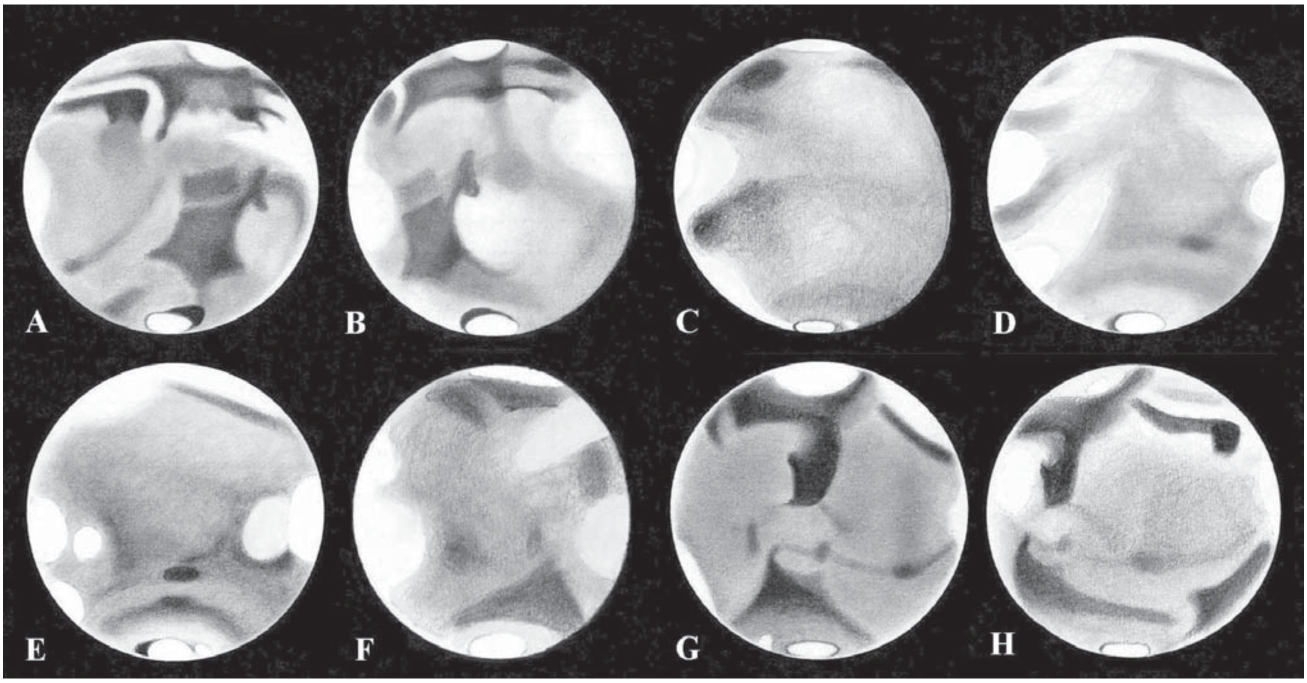


Figure 4. Drawings by the Director with 216mm refl.
Top row, left to right:
(A) 1997 March 10d 23h 35m, ×464, W15, W44A, CML= 21°. Brightness in *Argyre*, and N. of *Aurorae Sinus* and environs; *Baetis*; *Hyperboreus Lacus*.
(B) 1997 April 15d 22h 45m, ×464, CML= 54°. Large a.m. cloud over *Tharsis–Amazonis*; bright *Argyre*; details on *Nilokeras*; *Lunae Lacus* large and faint.
(C) 1997 May 14d 20h 50m, ×464, CML= 119°. Brilliant S. limb; *Olympia*; p.m. clouds.
(D) 1997 March 31d 20h 45m, ×232, W15, W44A, CML= 157°. Bright p.m. clouds; *Elysium* a.m. cloud.
Bottom row, left to right:
(E) 1997 March 29d 20h 50m, ×232, CML= 176°. Evening orographic clouds; morning clouds over *Elysium–Aetheria–Aethiopis*; *Olympia*.
(F) 1997 April 29d 20h 52m, ×232, CML= 259°. NPH surrounds NPC; a.m. cloud partly covers *Syrtis Major*; bright *Elysium*.
(G) 1997 March 21d 23h 45m, ×232, CML= 288°. Bright *Hellas*; *Nodus Alcyonius*; *Protonilus–Ismenius Lacus–Deuteronilus*; *Olympia*.
(H) 1997 March 22d 01h 45m, ×232, CML= 317°. *Hellas* brightest in NW corner; *Libya–Isidis* evening cloud.

and *Hellas* had not materially altered since 1995 (or indeed since the early 1980s). The *Huygens* area in *Iapigia* could again be recognised (Figures 1M, Q, 3C–E). *Hellas* was conspicuously bright near opposition, and its meteorological activity is described elsewhere. The halftone crossing it from east to west was recorded in some observations. The blue *Syrtis* cloud (Figures 1N, 4F, 6 (middle)) was seen for several consecutive months at the morning or evening side, and the *Syrtis* was faded by cloud crossing it between *Aeria* and *Libya–Isidis Regio*. (This latter cloud formed part of the ECB for part of the apparition.) *Nepenthes* again remained invisible.[37] *Sinus Sabaeus*, *Mare Serpentis*, *Pandorae Fretum* and *Noachis* were as in 1995, with *Pandorae Fretum* dusky and again running somewhat south of its classical course.

To the north of Region I, *Utopia–Boreosyrtis–Nodus Alcyonius* looked much the same as earlier. To the north of *Utopia*, *Copais Palus* (Ebisawa's nomenclature) appeared as a darker condensation. The terrain W. and N. of here appeared more structured than

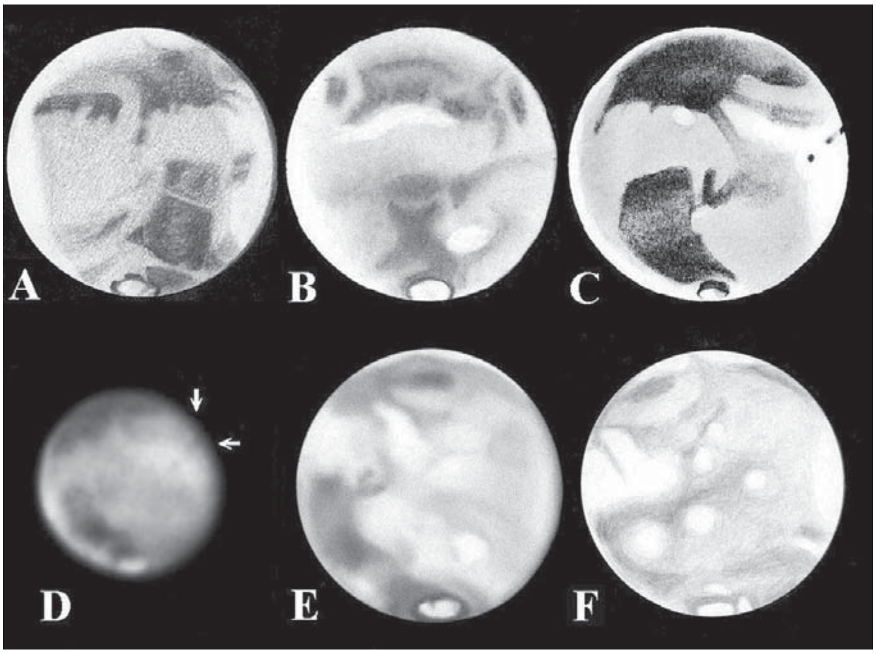


Figure 5. ***Region II, long. 010–130°.***
(A) 1997 April 12d 18h 30m, CML= 27°, 160mm OG ×400, *J. Warell*. *Baetis*; *Oxia Palus*; *Chasma Boreale*.
(B) 1997 April 15d 22h 30m, CML= 50°, 152mm OG ×286, *D. L. Graham*. S. *Chryse–Xanthe* light.
(C) 1997 April 13d 22h 10m, CML= 63°, 420mm OG ×417–×670, *P. Tanga*. Three cloud-free volcano calderas appear as dark spots at morning terminator.
(D) 1997 April 12d 22h 35m, CML= 78°, 320mm refl., CCD image (original in colour), *T. Platt.* Compare (C): the dark caldera are indicated.
(E) 1997 April 10d 21h 40m, CML= 83°, 415mm Dall–Kirkham Cass. ×348, W25, *D. Gray*. *Achilles* and *Idaeus Fons*; *Baetis*.
(F) 1997 March 27d 15h 30m, CML= 115°, 200mm OG ×400–×600, *M. Minami*. *Ierne*, *Olympia* detached; orographic clouds on western side of *Tharsis Montes*.

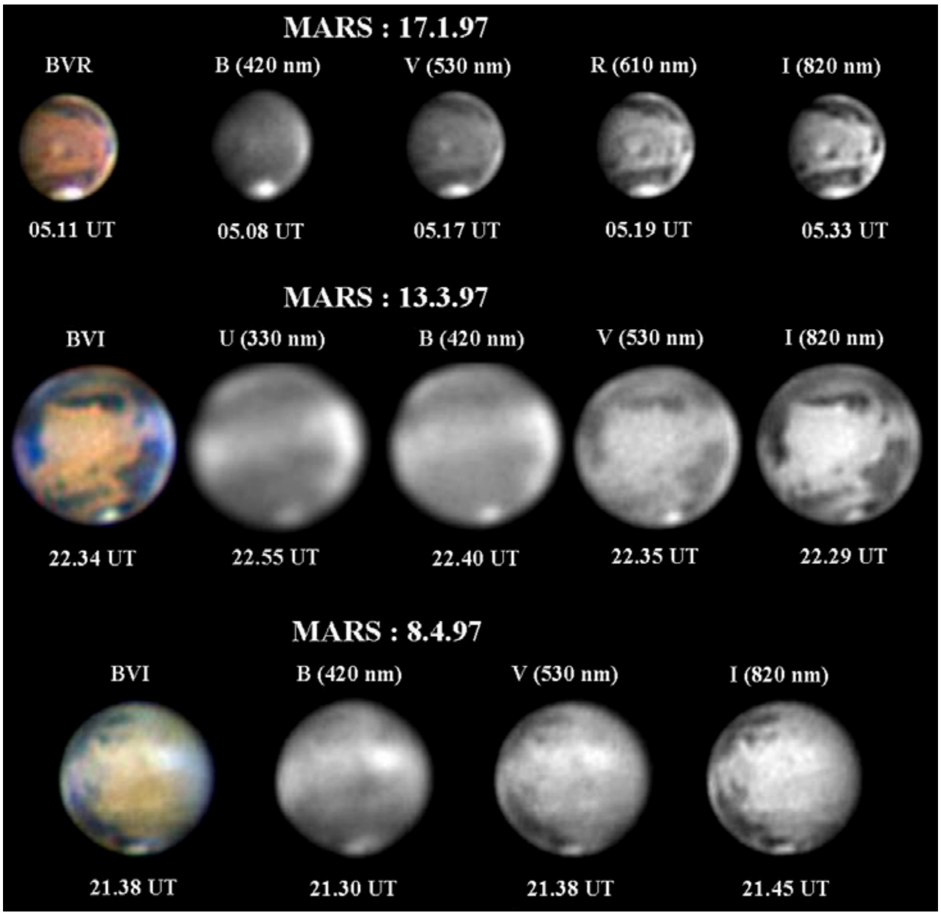
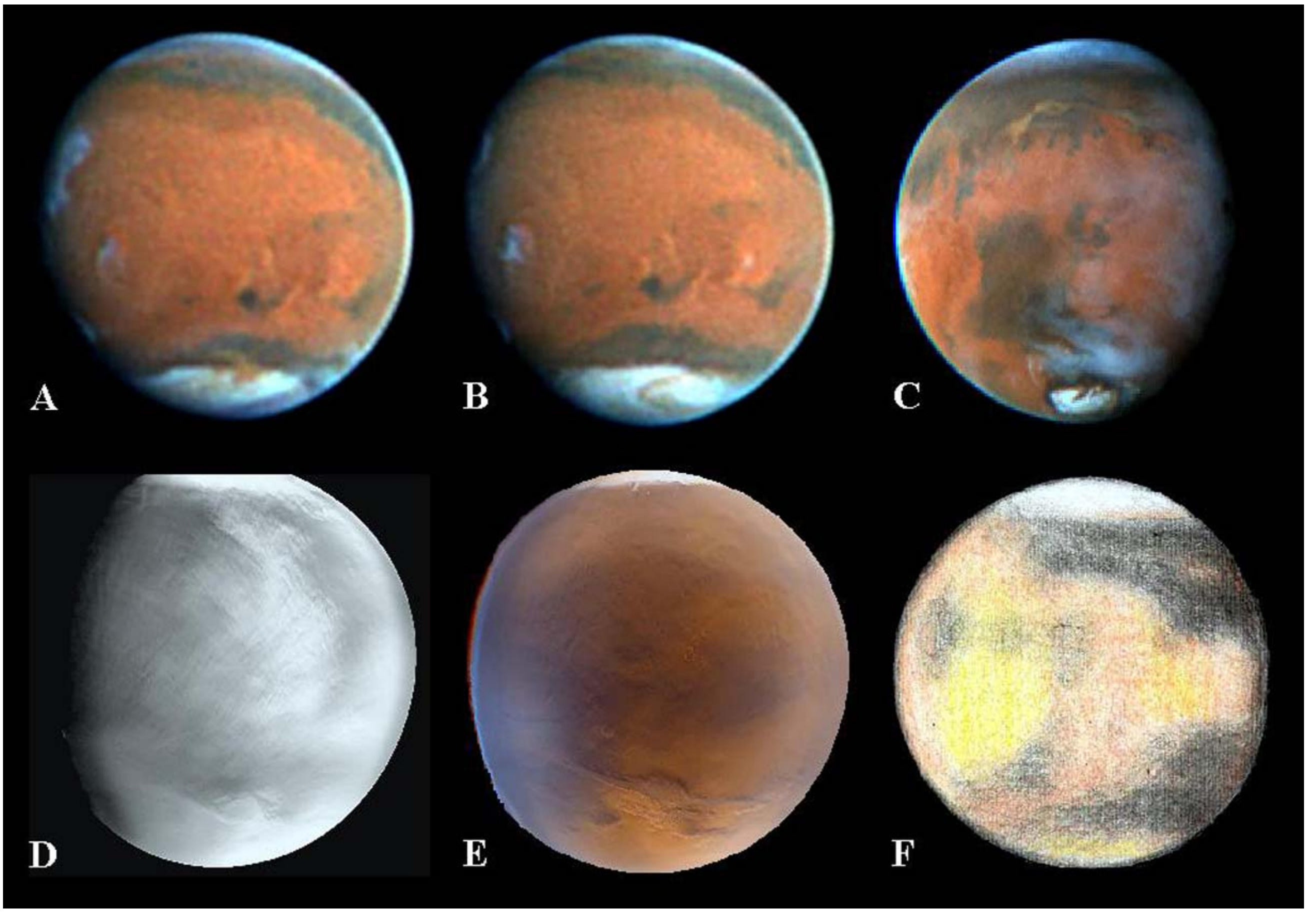


Figure 6 *(left)*. The wavelength-dependence of martian albedo features and clouds, 1996–97.
Filter series by G. Quarra, A. Leo & D. Sarocchi (300mm refl., F/24, ISIS CCD-800 camera) to show the variable transparency of the martian atmosphere. Rows 2 and 3 show the ECB, and row 3 shows a strong general 'Blue Clearing', revealing even small surface features clearly. Filter peak transmission indicated (U= ultraviolet, B= violet, V= green, R= red, I= infrared.) Time and CML given for (BVR) colour composites.
Top row: 1997 Jan 17d 05h 11m, CML= 220°.
Middle row: 1997 March 13d 22h 34m, CML= 340°.
Bott*om row:* 1997 April 8d 21h 38m, CML= 99°.



in 1995, the monotonous landscape being broken by some streaky (unnamed) E–W features. A lightening of N. *Cecropia* was also seen. *Protonilus* continued to be faint, and *Ismenius Lacus* again looked faded in the eastern part.

The equatorial desert areas showed small tonal differences, best illustrated by the apparition map (Figure 2).

Region II: long. 010–130°

See in particular Figure 5. To the north, the *Mare Boreum* region north of *Mare Acidalium* was lightened by the presence of *Baltia*, and looked more structured than in 1995. *Hyperboreus Lacus* was very prominent for the greater part of the apparition. *Mare Acidalium* was very prominent, and showed much fine detail. It was darkest in the NE and NW parts (Figures 1I, K, L, P, 4A, B, 5A, C, D). The markings *Nilokeras*, *Achilles Fons* and *Idaeus Fons* (Figures 1I, K, L, P, 4A, B, 5B–E) showed tiny differences in shape and intensity from 1995. *Lunae Lacus* was rather large but pale, as noted especially by Heath and the Director. *Chryse* and *Xanthe* showed complex albedo features in the far south and were often affected by a.m. or p.m. cloud. *Juventae Fons* was recorded in the best CCD images (Figures 1K, L, P) and visually by Cave in March as a tiny black spot, and *Baetis* (connecting it to *Aurorae Sinus*) was glimpsed by Gray, McKim and Warell (Figures 4A, 5A, E). The excessive redness of markings in southern *Arcadia* has already been mentioned.

To the south, *Solis Lacus* was still large and dark (Figures 1K, 4B–C, 5C–F, 6 (bottom)). The slight fading of the NW part detected in the 1995 images had not persisted, and the feature had returned to its typical 1990s appearance. (It was originally thought that *HST* on March 20 had confirmed the 1995 fading,[9] but later examination showed this impression to have been due to partial veiling by white cloud.) The centre was again divided in the E–W direction by a slightly lighter tract. *Phasis* seemed even fainter than in 1995, near the limit of visibility on the ground-based CCD images. With a large aperture, Ebisawa sketched *Phasis* running from *Aonius Sinus* as far north as the small dark spot *Gallinaria Silva*. A pale streak again ran west from the latter feature. *Argyre* was often light at the S. limb. The regions *Mare Erythraeum–Margaritifer Sinus–Aurorae Sinus* were nearly identical to 1995.

The orographic clouds (Figures 1F–H, J, O, 4E, 5F, 8A–D) over the *Tharsis* volcanoes and over *Olympus Mons* were well seen, with the ‘W’ cloud partly visible for a portion of the apparition. The OAA called attention to the fact that the dusky albedo streak running from *Olympus Mons* to the *Tharsis Montes* was better seen in the martian afternoon: this feature was better seen in blue light (Figures 1J, 5F, 8A)). In March and April there were some remarkable Section observations that showed the dark summits of the volcanoes on the morning side of the disk, surrounded by bright cloud. Minami on March 27 (CML= 54°) saw *Ascraeus Mons*. (Near local noon in March *Ascraeus Mons* was nearly invisible as an albedo feature.) Tanga on April 13 (Figure 5C) drew three very small dark spots: *Ascraeus Lacus* (*Ascraeus Mons*), *Pavonis Lacus* (*Pavonis Mons*) and *Arsia Silva* (*Arsia Mons*), the latter two united by the *Ulysses* halftone. The *HST* on March 20 and other CCD work by Parker and Platt for April

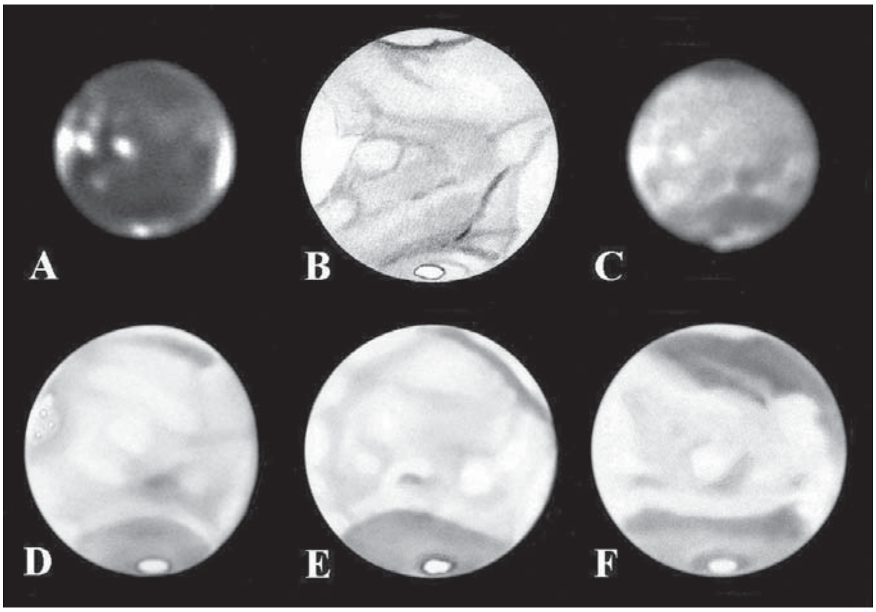


Figure 8. ***Region III, long. 130–250°***
(A) 1997 March 7d 06h 11m, CML= 152°, 410mm refl., CCD image, blue (BG12) filter, *D. C. Parker*. Orographic clouds partly coalescing to form ‘W’ cloud on evening side (compare Figure 1J).
(B) 1997 April 1d 21h 50m, CML= 164°, 215mm refl., ×343, *D. Fisher.* Orographic clouds.
(C) 1997 April 1d 21h 54m, CML= 165°, 310mm refl., CCD image, *J. Dijon.* Orographic clouds; *Olympia*.
(D) 1997 May 10d 21h 50m, CML= 172°, 415mm Dall–Kirkham Cass., ×415, W58, *D. Gray*. Tiny white spots within the evening *Nix Olympica*.
(E) 1997 March 30d 22h 20m, CML= 189°, 415mm Dall–Kirkham Cass., ×415, W15, W58, *D. Gray*.
(F) 1997 March 24d 21h 30m, CML= 229°, 415mm Dall–Kirkham Cass., ×415, W22, *D. Gray. Aetheria* secular darkening.

Figure 7 *(opposite)*. Dust storms, 1996–’97 viewed by the *HST* (A–C), *MGS* (D–E) and from the ground (F).

HST colour images (synthesised from red (673nm), blue (410nm) and green (502nm) images) of a N. polar dust storm (A–B) and the later *Valles Marineris* event (C). *(NASA/STScI)*
(A) 1996 Sept 18, CML= 167°. Dust at NPC S. edge.
(B) 1996 Oct 15, CML= 173°. Spiralling dust dispersing over cap.
(C) 1997 June 27. Bright yellow dust along *Valles Marineris*.

MGS images of the *Noachis* regional storm of 1997 November. (*Malin Space Science Systems/NASA)*
(D) 1997 Nov 26. *MGS* orbit 50 red filter montage, with greatly distorted viewing geometry due to the low orbit. Bright dust over *Noachis* in the upper part of the image; *Edom* (*Schiaparelli* basin) near the northern limb. (S. limb not completely imaged.)
(E) 1997 Dec 12. *MGS* R(G)B montage from 2700km high orbit; distorted viewing geometry. Dusty haze lingers during storm decay phase, especially to the S. (*Argyre* to *Dia*, etc.) and in the evening. *Valles Marineris–Tithonius Lacus* can be seen below the centre.
(F) 1997 Dec 14d 04h 25m, CML= 322°, 256mm refl., ×507, *N. D. Biver*. SPC visible, but *Syrtis Major (left)* and *Sinus Sabaeus* largely effaced by S. hemisphere dust storm.

Table 1. Observers of the 1996–’97 apparition

Name	*Location*	*Instrument(s)*
G. Adamoli	Verona, Italy	108mm OG
T. Akabane**	Kwasan & Hida Obs., Kyoto, Japan	650mm OG
P. G. Barbero	Pino Torinese Obs., Turin, Italy	420mm OG
S. Beaumont	Windermere, Cumbria	305mm refl.
N. D. Biver	Meudon Obs., France	600mm Cass.
	Honolulu, Hawaii, USA	256mm refl.
M. Bosselaers	Berchem, Belgium	254mm refl.
A. G. Bowyer	Epsom Downs, Surrey	300mm refl.
R. Buggenthien	Lübeck, Germany	180mm OG
F. C. Butler	London	–
P. Cannaerts	Westerlo, Belgium	250mm Schmidt–Cass.
G. Canonaco	Genk, Belgium	200mm OG
T. R. Cave & V. Cave	Long Beach, California, USA	325mm refl.
E. Colombo	Milan, Italy	254mm refl.
W. Cuppens	Gruitrode, Belgium	355mm refl.
I. Dal Prete	Pescantina, Italy	200mm refl.
P. Devadas & K. Murugesh	Madras, India	355mm refl.
J. Dijon**	Champagnier, France	310mm refl.
A. Farr	Garforth, Leeds	102mm OG
D. Favaro	Padua, Italy	200mm refl.
F. Feys	Izegem, Belgium	300mm refl.
D. Fisher	Sittingbourne, Kent	215mm refl.
M. Foulkes	Hatfield, Herts.	203mm Schmidt–Cass.
M. Frassati	Crescentino, Italy	203mm Schmidt–Cass.
C. M. Gaskell	Lincoln, Nebraska, USA	152 & 510mm refls.
M. V. Gavin**	Worcester Park, Surrey	305mm Schmidt–Cass.
M. Giuntoli	Montecatini Terne, Italy	80mm OG
H. Goertz	Beek, Holland	100mm OG
D. L. Graham	Brompton-on-Swale, N.Yorks.	152mm OG
	Gilling West, N.Yorks.	406mm refl.
D. Gray	Spennymoor, Co. Durham	415mm Dall–Kirkham Cass.
H. Gross	Hagen, Germany	250mm OG
A. W. Heath	Long Eaton, Notts.	203mm Schmidt–Cass. & 300mm refl.
M. J. Hendrie	Colchester, Essex	152mm OG
C.E.Hernandez	Miami, Florida, USA	203mm refl.
Y. Higa**	Okinawa, Japan	250mm refl.
R. E. Hill	Tucson, Arizona, USA	254mm Cass.
K. Huebner	Wilhelm–Foerster Obs., Berlin, Germany	203mm OG
J. Knott	Liverpool	216mm refl.
P. Lyon*	Birmingham	203mm Schmidt–Cass.
L.T. Macdonald	Newbury, Berks.	222mm refl.
R. J. McKim	Oundle, Northants.	216mm refl.
	Tucson, Arizona, USA	254mm refl.
K. J. Medway	Southampton, Hants.	102mm OG
F. J. Melillo*	Holtsville, New York, USA	203mm Schmidt–Cass.
C. Meredith	Manchester	216mm refl.
H.–J.Mettig	Dresden, Germany	150mm OG
M. Minami	Fukui City Obs., Fukui, Japan	200mm OG
I. Miyazaki**	Okinawa, Japan	400mm refl.
P. A. Moore	Selsey, W. Sussex	320 & 390mm refls.
S. L. Moore	Fleet, Hants.	222mm refl.
H. Munsterman**	Meppel, Holland	356mm Schmidt–Cass.
D. Niechoy	Goettingen, Germany	203mm Schmidt–Cass.
A. Nikolai	Berlin, Germany	100mm OG
D. C. Parker**	Coral Gables, Miami, Florida,USA	410mm Schmidt–Cass. & 410mm refl.
I. S. Phelps	Warrington, Cheshire	150mm refl.
T. C. Platt**	Binfield, Berks.	320mm refl.
C. J. Proctor	Torquay, Devon	203 & 500mm refls.
G. Quarra, A.Leo & D.Sarocchi**	Florence, Italy / Pino Torinese Obs., Turin, Italy	300mm Cass. / 420mm OG
T. J. Richards	Eltham, Victoria, Australia	180mm OG
J. H. Rogers	Linton, Cambs.	254mm refl.
F. Salvaggio	Catania, Italy	200mm refl.
R. W. Schmude*	Barnesville, Georgia, USA	152mm refl.
	Villa Rica, Georgia, USA	510mm refl.
J. D. Shanklin	Cambridge University Obs.	300mm OG
D. Shirreff	Marlborough College, Wilts.	254mm OG
E. Siegel	Malling, Denmark	203mm Schmidt–Cass.
R. M. Steele	Leeds	80mm OG
I. Stellas	Athens, Greece	102mm OG
D. Storey	Carterton, Oxon.	254mm refl.
D. Strange**	Worth Matravers, Dorset	508mm refl.
K. M. Sturdy	Helmsley, N. Yorks.	216mm refl.
P. Tanga	Pino Torinese Obs., Turin, Italy	420mm OG
G. Teichert	Hattstatt, France	279mm Schmidt–Cass.
R. Topping	Tredegar, Gwent	300mm refl.
D. M. Troiani	Schaumberg, Illinois, USA	444mm refl.
A. Van der Jeugt	Gent, Belgium	127mm OG
D. Vidican	Bucharest, Romania	150mm OG
P. Völker	Berlin, Germany	110mm OG
P. Wade	Morecambe, Lancs.	203mm Schmidt–Cass.
J. Warell**	Uppsala, Sweden	160mm & 360mm OGs
	Sandvreten Obs., Sweden	
	Tenerife, Spain	450mm refl.
	La Palma Obs., Spain	500mm OG§
D. Weldrake	Stockton-on-Tees, Cleveland	203mm OG & 300mm refl.
S. Whitby	Hopewell, Virginia, USA	152mm refl.
A. W. Wilkinson	Worcester	203mm Schmidt–Cass. & 229mm refl.

* denotes the submission of photographs; **CCD images;
§ the Swedish solar vacuum telescope

Observations by members of the VvS (Cannaerts, Canonaco, Cuppens, Feys, Goertz and Munsterman) were sent by their Coordinator, Marc Bosselaers. Observations by members of the VdS (Buggenthien, Gross, Huebner, Nikolai and Völker) were likewise contributed by Wolfgang Meyer. Observations by UAI members (Barbero, Dal Prete, Favaro and Salvaggio) were sent by Coordinator Paolo Tanga. Higa’s videocassette was contributed by Alan Heath.

11–21 also clearly showed the effect (Figures 1P, 5D). *HST* images as late as August also exhibit the effect.

Region III: long. 130–250°

Refer to Figure 8. *Scandia* and *Panchaïa* were both lighter than the *Herculis Pons* region. The continuing faintness of the *Trivium Charontis–Cerberus* complex is of special note: it consisted of only two diminutive ‘oases’ together with the tiny *Pambotis Lacus* at the SW end. Compared with 1995, *Propontis I* had a slightly different shape at its E. end. To the east lay several small ‘oases’, as in 1995. *Elysium* as a whole was often lightened by diurnal cloud, and the *Elysium Mons* volcano was sometimes further brightened by a small orographic cloud. The *Aetheria* secular darkening was again conspicuous (Figures 1N, O, 4F, 8F).

The markings to the south such as *Mare Cimmerium* showed no special features of interest and were very similar in shape to 1995, with the fading of the NW end of *Mare Sirenum* (first noticed in 1986) persisting for the sixth successive apparition. The small dark spot *Caralis Fons* was again visible with difficulty south of *Mare Sirenum*.

Intensity estimates

White light intensity data on the usual scale[1] provided by six observers are summarised and averaged in Table 2.

The martian atmosphere

White clouds

General

As in 1995 the seasonal increase in white cloud activity with the NPC recession could be followed. At the end of the observing period activity was declining again as the SPC formed. The observations showed the orographic clouds well. The Equatorial Cloud Band phenomenon (ECB) was first noted in 1996 December, though it *might* have been seen earlier had the disk been larger. It was well observed around opposition, always enhanced in blue light: the 1997 March *HST* whole-planet map (Figure 9) confirms that the belt of cloud was continuous in longitude, but complex. This aspect remained till early July. *HST* images on September 12 (Ls= 180°) do not show it.

In a review paper,[38] Sprague *et al*. have described the 1996–'97 seasonal rise and fall of atmospheric water abundance during the period Ls= 18–146°. The seasonal variability of *Elysium*, *Hellas* and *Nix Olympica* noted in the present report may be compared with the research of Smith & Smith.[39]

The martian disk diameter exceeded 6 arcsec from 1996 November till 1997 August. Outside the period December to July the observations cannot be considered to be complete in longitudinal coverage, nor are they adequate for resolving small atmospheric features. For notes on the conventions adopted in this subsection, see the last Report.[1] Recall that before opposition the actual morning terminator is never observable, nor is the evening one thereafter.

Figure 6 illustrates the wavelength-dependence of the planet's appearance.

1996 August to October

August: *Elysium* was bright at the a.m. limb (Niechoy, Aug 26).

September: Morning haze was seen over *Cebrenia–Elysium* and *Tempe*. Evening haze was seen over *Amazonis*, *Chryse, Hellas, Memnonia* and *Tharsis*. *Hellas* was light at the CM. *Argyre* was light at the S. limb, as was the S. limb in the longitude of *Thaumasia*. The *HST* September 18 image at Ls= 11° (Figure 7A) was the earliest to reveal the orographic clouds over the martian volcanoes at the evening terminator, three months before the ground-based observations could resolve them.

October: *Chryse–Xanthe, Claritas, Elysium, Memnonia* and *Tharsis* were bright in the morning. Evening haze was seen over *Chryse–Xanthe* and *Nox Lux* (near *Phoenicus Lacus* (Schmude, Oct 12)). *Hellas* was white at the CM. As in September, *Elysium* was not bright on the CM or in the early afternoon. *Argyre, Electris* and *Eridania* were light at the S. limb. On October 15 the *HST* again imaged the orographic clouds (Figure 7B).

1996 November

A.m. limb: *Aeria, Argyre, Candor–Ophir, Chryse–Xanthe, Isidis Regio–Libya, Meroe, Neith Regio, Tempe, Tharsis*.

p.m. terminator: *Argyre, Chryse–Xanthe, Hellas* (slightly white [hereafter abbreviated 'sw'] only), *Thymiamata*.

mid-disk: *Argyre* was light near the CM. *Hellas* was not very bright near the CM. *Elysium* was dull.

1996 December

A.m. limb: *Aeria, Argyre, W. Cebrenia* (sw), *Chryse–Xanthe, Elysium, Isidis Regio–Libya, Meroe, Neith Regio*, *Tempe, Tharsis, Thymiamata*.

p.m. terminator: *Cebrenia, Chryse–Xanthe, Elysium* (sw on Akabane's images), *Hellas* (sw), N. border of *Sinus Sabaeus, Thymiamata*.

mid-disk: *Argyre* (sw), *Hellas* (sw). The orographic cloud over *Alba* was vaguely light at the CM to Gray (Dec 22) but the other orographic clouds were not observed. *Elysium* was dull. The limb was light S. of *Thaumasia* (*e.g.*, over *Dia*) to Gray (Dec 22).

Nakajima and Minami[13,17] observed the ECB effect to be visible from 1996 December 13 (Ls= 51°) from the evening *Thymiamata* to the morning *Tharsis*.

1997 January

A.m. limb: *Aeolis, Aeria, Arabia, Candor–Ophir, Cebrenia, Chryse–Xanthe, Elysium, Hellas* (sw), *Isidis Regio–Libya* (giving rise to the '*Syrtis* blue cloud' (Parker, Jan 20–23)), *Meroe, Neith Regio, Tempe* (sw), *Tharsis, Thaumasia, Thymiamata*. (*Hellas* was still not bright.)

p.m. terminator: *Aeria, Candor–Ophir, Chryse–Xanthe* (with *Xanthe* brilliant and projecting beyond the terminator to Sturdy, Jan 26), *Elysium, Hellas* (sw), *Isidis Regio–Libya* (whose cloud crossed *Syrtis Major* to join the *Aeria* cloud at the evening terminator), *Tharsis, Thaumasia, Thymiamata*. Orographic clouds (Figure 1F) were observed from local noon onwards over *Alba* (brightening further at terminator), *Ascraeus Mons* (large, and extended southwards by a bright cloud streak) and *Olympus Mons*. (These orographics were observed by the OAA members from January 10 onwards, and by European observers a few days later, though Gray's earlier observation of *Alba* in December has already been cited. Akabane's images of January 12 show the orographics well, including the southward bright extension from the *Ascraeus Mons* cloud.)

mid-disk: *Candor–Ophir, Elysium* (sw), *Hellas* (sw). Ebisawa[20] noted a pre-polar hood over *Dia* at the S. limb, Jan 10.

ECB was again reported from *Thymiamata* to *Tharsis*.

1997 February

A.m. limb: *Aeria, Arabia, Argyre, Candor–Ophir, Cebrenia, Chryse–Xanthe, Eden, Edom*

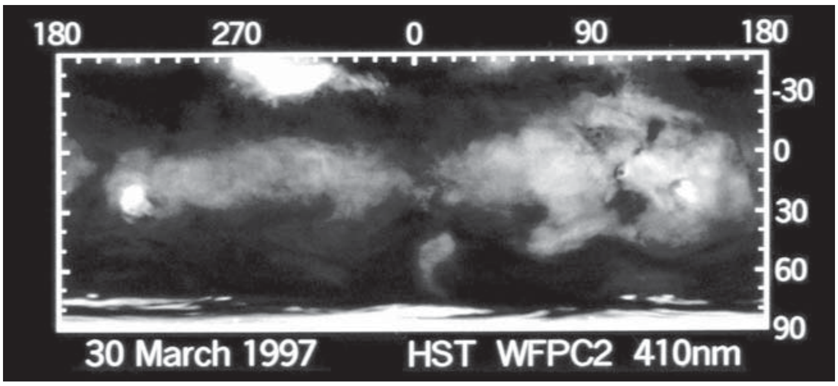


Figure 9. *HST* violet light (410nm) mosaic for 1997 March 30 showing continuous but complex ECB, as well as partial transparency of the martian atmosphere. South is uppermost. *(NASA/STScI)*

(and north border of *Sinus Sabaeus*), *Elysium, Hellas* (sw), *Isidis Regio–Libya* (giving rise to the '*Syrtis* blue cloud' (Parker, February 24)), *Tempe, Tharsis, Thaumasia* (especially NE), *Thymiamata*. Quarra's images showed that the blue light cloud over *Syrtis Major* was also visible in the UV, and rotated with the planet. The *Nix Olympica* orographic cloud was visible in the morning. (*Alba* was light in the morning too, but Minami's phase angle calculations rather suggest sunlit ground.)

p.m. terminator: *Aeria,* S. *Aetheria, Aethiopis, Amenthes, Arabia, Candor–Ophir, Chryse–Xanthe, Eden, Edom* (and north border of *Sinus Sabaeus*), *Elysium* (with a still brighter area, *Elysium Mons*), *Hellas* (sw), *Isidis Regio–Libya (*with *Syrtis* blue cloud[8]*), Neith Regio, Tempe, Tharsis, Thymiamata* (continuous with the *Edom–N. Sinus Sabaeus* haze). The same orographic clouds remained visible as in January (Figures 1G, H), with that over *Ascraeus Mons* spread considerably in area both E. and S. The latter cloud merged with evening cloud over *Chryse–Xanthe* to partly form an ECB. *Alba* and *Nix Olympica* were very bright; both were also seen in red light. (This was later confirmed by Parker's March 7 image, but they remained much brighter in green or blue light.)

mid-disk: *Aeria, Argyre, Cebrenia* (sw), S. *Chryse–Xanthe* (sw), *Edom, Elysium* (sw), *Hellas, Isidis Regio–Libya.* The orographics were visible at the CM. The limb S. of *Thaumasia* was again light.

The ECB effect continued. It was not quite complete in longitude, for in the best images the evening cloud over *Aeria–Arabia* did not merge with morning cloud over *Eden*. At other longitudes the ECB was apparently continuous: thus Parker's February 22 images reveal extensive cloud from limb to limb with *Syrtis Major* central. The cloud over *S. Aetheria, Aethiopis* and *Amenthes* was also weakly visible with those areas at the CM. Minami noted that the evening *Thymiamata–Chryse–Xanthe* cloud crossed *Ganges* to join with the morning cloud over *Tharsis*.

1997 March

A.m. limb: *Aeolis, Aeria, Aetheria, Aethiopis, Amazonis* (in part), *Ara-*

Table 2. Martian intensity estimates

Feature	*Adamoli*	*Foulkes*	*Heath*	*McKim*	*Meredith*	*Schmude*	*Ave.*	*s.d.(+)*	*No.*
	----	----	----	*Observer*	----	----			
Achillis F.	–	–	–	4.9	–	–	4.9	0.0	4
Achillis P.	–	6.2	–	3.5	–	–	4.8	1.4	5
Acidalium, M.	5.8	7.4	5.6	5.2	4.4	4.5	5.5	1.1	35
Aeolis	1.7	2.5	–	1.8	2.0	–	2.0	0.4	11
Aeria	1.8	2.5	1.0	1.3	1.8	1.5	1.6	0.5	26
Aetheria	–	–	–	2.0	1.9	–	2.0	0.1	13
Aethiopis	2.0	2.5	–	2.7	1.8	2.0	2.2	0.4	17
Amazonis	2.0	–	–	1.8	1.8	2.0	1.9	0.1	19
Amenthes	2.5	–	–	1.7	1.7	1.5	1.8	0.4	11
Arabia	1.8	1.5	–	1.8	2.0	2.0	1.8	0.2	29
Arcadia	2.0	–	–	1.7	2.0	2.0	1.9	0.2	14
Argyre	1.5	2.5	–	0.9	–	–	1.6	0.8	8
Ascraeus L.	–	–	–	4.0	–	4.0	4.0	0.0	4
Astaboras	–	–	–	3.0	–	–	3.0	0.0	2
Aurorae F.	–	–	–	5.5	–	–	5.5	0.0	1
Aurorae S.	–	7.0	–	6.0	4.2	5.0	5.6	1.2	11
Ausonia	2.0	2.5	–	0.2	1.9	1.0	1.5	0.9	11
Baltia	–	–	–	3.8	–	–	3.8	0.0	4
Boreosyrtis	6.0	–	–	4.0	–	–	5.0	1.0	3
Boreum, M.	5.2	–	4.0	3.8	3.4	4.0	4.1	0.7	16
Callirrhoes S.	–	–	–	5.5	–	–	5.5	0.0	1
Candor	–	–	–	1.2	–	–	1.2	0.0	3
Casius	–	–	4.0	5.3	–	–	4.6	0.6	4
Cebrenia	–	–	–	1.4	–	–	1.4	0.0	2
Cecropia	–	–	–	3.0	–	3.0	3.0	0.0	6
Ceraunius	–	–	–	3.2	–	3.0	3.1	0.1	4
Cerberus	–	–	–	3.8	2.5	2.5	2.9	0.8	4
Chaos	–	–	–	4.0	–	–	4.0	0.0	1
Chryse	2.0	2.0	0.0	1.9	2.0	1.5	1.6	0.8	25
Cimmerium, M.	6.4	7.5	6.0	6.3	4.3	5.0	5.9	1.1	22
Claritas	–	–	–	0.0	–	–	0.0	0.0	1
Cydonia	2.0	–	–	2.3	–	–	2.2	0.2	6
Daedalia	–	–	–	1.8	–	–	1.8	0.0	1
Deucalionis R.	–	3.0	–	1.3	–	2.0	2.1	0.8	6
Deuteronilus	4.0	–	–	3.7	–	–	3.8	0.2	7
Diacria	–	–	–	2.0	–	–	2.0	0.0	1
Dioscuria	–	–	–	2.5	–	–	2.5	0.0	2
Eden	1.0	–	–	1.6	2.0	2.0	1.6	0.5	23
Edom	–	–	–	1.0	–	–	1.0	0.0	2
Electris	1.0	2.2	1.0	1.0	1.5	1.5	1.4	0.5	8
Elysium	–	–	–	1.0	2.0	1.5	1.5	0.5	8
Eridania	1.5	2.5	1.0	0.8	1.9	–	1.5	0.7	11
Erythraeum, M.	6.0	6.5	6.0	5.6	–	4.8	5.8	0.6	14
Ganges	4.0	–	–	3.2	–	–	3.6	0.4	5
Gehon	–	–	–	2.9	–	–	2.9	0.0	4
Hellas	0.8	1.0	0.0	0.3	0.8	0.5	0.6	0.4	27
Hesperia	–	–	–	3.0	–	–	3.0	0.0	1
Hyblaeus	–	–	–	4.0	–	3.0	3.5	0.5	3
Hyperboreus L.	–	–	–	6.5	–	–	6.5	0.0	4
Iapigia	6.6	7.0	5.6	6.3	4.8	4.1	5.7	1.1	19
Idaeus F.	–	–	–	4.9	–	–	4.9	0.0	4
Isidis R.	2.8	–	1.0	1.4	1.9	2.0	1.8	0.7	25
Ismenius L.	–	–	–	3.8	–	–	3.8	0.0	2
Libya	2.8	–	1.0	1.2	1.9	1.3	1.6	0.7	25
Lunae L.	–	6.5	3.6	4.5	–	–	4.9	1.5	9
Margaritifer S.	5.5	6.5	5.0	5.5	4.4	5.5	5.4	0.7	23
Memnonia	–	–	–	1.8	2.0	2.0	1.9	0.1	10
Meridiani S.	6.8	7.0	6.0	6.0	3.9	5.2	5.8	1.1	26
Meroe	–	–	–	2.0	2.0	2.0	2.0	0.0	12
Nectar	5.8	–	–	5.8	–	–	5.8	0.0	4
Neith R.	2.8	–	–	2.0	1.9	2.0	2.2	0.4	22
Niliacus L.	–	7.3	6.0	4.8	–	–	6.0	1.2	11
Nilokeras	5.0	5.3	–	4.2	3.5	–	4.5	0.8	11
Noachis	2.0	1.5	–	1.5	–	–	1.7	0.3	8
Nodus Alcyonius	–	–	–	5.0	–	–	5.0	0.0	1
Ophir	–	–	–	1.2	–	–	1.2	0.0	3
Ortygia	–	–	–	2.7	–	–	2.7	0.0	6
Panchaïa	6.2	6.0	4.0	4.2	3.4	4.9	4.8	1.1	23
Pandorae F.	–	4.8	–	4.1	–	–	4.4	0.4	6
Phaethontis	1.0	2.0	–	0.5	–	1.5	1.2	0.6	5
Phlegra	–	–	–	3.8	–	–	3.8	0.0	2
Propontis (I)	–	–	–	4.8	–	3.5	4.2	0.6	3
Protonilus	–	–	–	3.0	–	–	3.0	0.0	3

Table 2. ***(continued)***

	------ Observer ------								
Feature	*Adamoli*	*Foulkes*	*Heath*	*McKim*	*Meredith*	*Schmude*	*Ave.*	*s.d.(+)*	*No.*
Pyrrhae R.	–	–	–	4.6	–	–	4.6	0.0	4
Sabaeus S.	6.2	7.0	6.0	5.4	4.1	4.8	5.6	1.0	26
Scandia	5.6	–	–	3.8	3.2	3.8	4.1	1.0	14
Sirenum, M.	6.2	7.0	6.0	4.5	3.0	4.0	5.1	1.5	14
Solis L.	6.2	7.0	4.0	5.8	3.3	4.0	5.0	1.5	19
Syrtis Major	6.1	7.5	6.8	5.8	5.7	4.9	6.1	0.9	31
Syrtis Minor	–	–	–	6.6	–	–	6.6	0.0	6
Tanais	–	–	–	5.1	–	–	5.1	0.0	4
Tempe	–	2.0	0.0	1.8	1.8	0.5	1.2	0.9	17
Tharsis	2.0	–	–	1.0	1.7	1.7	1.6	0.4	24
Thaumasia	1.5	–	–	1.9	2.0	–	1.8	0.3	12
Thymiamata	–	–	–	1.2	–	–	1.2	0.0	1
Tithonius L.	–	–	–	4.3	–	–	4.3	0.0	3
Trivium Charontis	–	–	–	4.2	–	–	4.2	0.0	2
Tyrrhenum, M.	6.7	8.0	6.0	6.6	4.8	4.8	6.2	1.2	26
Uranius	–	–	–	3.8	–	–	3.8	0.0	3
Utopia	5.8	8.0	5.0	5.2	3.8	4.5	5.4	1.4	32
Xanthe	1.2	2.0	1.0	1.7	1.8	1.2	1.5	0.4	23
Yaonis F.	–	–	–	6.3	–	4.0	5.2	1.2	5
Zephyria	1.8	2.5	–	1.5	2.0	2.0	2.0	0.4	14
No. of useful estimates	133	65	71	333	293	98		*Total:*	993
Period of observation	Jul 9 –Aug 31	Mar 12 –Apr 22	Mar 1 –Apr 30	Feb 7 –Jun 4	Dec 6 –Jun 1	Dec 20 –Jun 14			

bia, Argyre (Figure 4A), *Azania, Candor–Ophir*, *Cebrenia, Chryse–Xanthe* (also affecting *Niliacus Lacus*), *Eden, Edom* (and north border of *Sinus Sabaeus*), *Elysium* (sometimes united with cloud over *Aetheria–Aethiopis* (Figure 4E)), *Eridania, Hellas* (sw), *Isidis Regio–Libya* (giving rise to the *Syrtis* blue cloud), *Memnonia,* W. *Ortygia, Tempe* (also affecting northern *Mare Acidalium*), *Thymiamata, Tharsis, Zephyria*. *Nix Olympica* was seen bright even near the morning limb, Knott visually confirming its better visibility in blue than in red light. Minami considered that the slight lightness of *Alba* in the morning was simply sunlit ground. Morning cloud was also seen west of *Ascraeus Mons*. In March and April the cloud-free summits of the volcanoes were occasionally visible as dark spots in the morning: see under 'Surface features'.

p.m. limb: *Aeria,* S. *Aetheria, Aethiopis, Alba* (bright only at the limb), *Amenthes, Arabia, Ascraeus Mons* orographic (still extended to the S., merging with *Candor–Ophir* at the limb), *Candor–Ophir, Chryse–Xanthe*, *Cydonia, Eden, Edom, Electris, Elysium* (with *Elysium Mons*), *Hellas, Isidis Regio–Libya* (giving rise to the *Syrtis* blue cloud, and crossing and partly effacing *Syrtis Major* to join *Aeria*), *Neith Regio, Nix Olympica* (its N*f.* trail less visible), *Pavonis Mons* orographic, *Phaethontis, Tempe, Tharsis, Thaumasia*. The orographics again appeared as in February (Figures 4E, 5F), and were imaged in detail by *HST*.[9] This month there were indications of the 'W' cloud uniting the orographics, especially in blue light, but not all the 'downstrokes' of the W were complete: *e.g.*, Parker March 7 (Figures 1J, 8A).

mid-disk: *Aeria, Amenthes, Arabia, Argyre, Chryse, Edom, Electris, Elysium* (not bright but containing the light *Elysium Mons* which brightened in the early afternoon, merging later with general evening haze), *Eridania, Hellas* (lighter than in February, very bright at the CM (Figures 1M, 3D, 4G, H), and brighter still in its NW corner, CM and p.m.), *Isidis Regio–Libya, Phaethontis,* S. *Thaumasia* (sw). The increased activity of *Hellas* was a notable feature. The orographic clouds were again visible at the CM.

With *Syrtis Major* central there was again the impression of a continuous ECB from limb to limb, though it was weaker than in February. The cloud crossed the *Syrtis*, thus enhancing its blue tint. ECB appeared to run all the way from *Elysium* to *Chryse–Xanthe*.

1997 April

A.m. terminator: *Aeria, Aetheria, Aethiopis, Alba* (sw), *Amazonis, Amenthes, Argyre, Candor–Ophir, Cebrenia*, *Chryse–Xanthe* (partly covering *Niliacus Lacus*), *Elysium* (united with bright cloud over *Aetheria–Aethiopis*), *Hellas* (dull in the morning generally, but very bright at the terminator), *Isidis Regio–Libya* (again with the *Syrtis* blue cloud effect, together with partial obscuration of the *Syrtis* (Figures 1N, 4F)), *Memnonia, Meroe, Neith Regio*, *Nix Olympica* (within the bright region of *Amazonis–Tharsis*), *Ortygia, Tempe, Tharsis* (Figure 4B), *Thymiamata*. The *Memnonia–Tharsis* cloud was strikingly blue to Gaskell on April 18 (51cm refl.). The bright clouds over *Ortygia*, adjacent to the NPC, lasted all month. They are described in more detail in the 'Polar Regions' section.

p.m. limb: *Aeolis, Aeria, Alba* (sw), *Amazonis, Arabia, Argyre, Ascraeus Lacus* orographic cloud, *Candor–Ophir*, *Cebrenia, Chryse–Xanthe, Cydonia, Eden, Edom, Elysium* (sw from early afternoon, bright at limb, with *Elysium Mons* a still brighter patch), *Hellas* (very bright), *Isidis Regio–Libya* (again with the *Syrtis* blue cloud effect, and the central *Syrtis* hidden at the limb by this cloud and that over *Aeria*), *Meroe, Nix Olympica* (Figures 1O, 8B, C; very bright, but due to changing phase angle, now only really bright close to the limb), *Noachis, Tempe, Tharsis*, *Zephyria*.

mid-disk: *Aethiopis, Amenthes, Argyre* (Figure 4B), *Ausonia, Candor–Ophir,* S. *Chryse–Xanthe* (Figure 5B; including a small bright patch in *Electra* (*e.g.*, Tanga, April 13 (Figure 5C)), *Edom, Elysium* (sw), *Eridania, Hellas* (brightest in blue but now also significantly bright in green and red light; Patrick Moore (April 24) found it as bright as he had ever seen it), *Isidis Regio–Libya, Ortygia, Tharsis, Thaumasia*.

The ECB effect was visible as in March between *Elysium* and *Xanthe*, but it also seemed to extend across *Tharsis* to *Elysium* (Figure 1P) in a continuous (though not always equally bright) manner, thus encircling the planet.

1997 May

A.m. terminator: *Aeria, Aethiopis, Amazonis,* N. *Arcadia*–W. *Mare Boreum, Argyre, Baltia*–N. *Mare Acidalium, Candor–Ophir, Cebrenia, Chryse–Xanthe, Diacria, Eden, Elysium* (sw, but with the whiter *Elysium Mons*), *Hellas* (bright at the terminator), *Isidis Regio–Libya* (again with the *Syrtis* blue cloud effect), *Meroe, Neith Regio, Nix Olympica* (within the bright *Amazonis–Tharsis*), *Tempe, Tharsis*. The very bright clouds in the far north over *Arcadia–Mare Boreum* (Figure 1R) and *Baltia–Mare Acidalium*, presaging the onset of the N. polar hood, are described further later in the 'Polar Regions' section.

p.m. limb (now corresponding to early afternoon only): *Aeria, Aeolis, Alba* (weak), *Amazonis, Amenthes, Argyre, Ascraeus Mons* orographic, *Candor–Ophir, Chryse–Xanthe, Cydonia, Deucalionis Regio, Eden, Elysium* (as April, with *Elysium Mons* a brighter patch), *Hellas* (brighter than the NPC, brighter still in NW corner, and irradiating over the *p.* limb to Warell, May 31), *Isidis Regio–Libya* (with haze from here and *Aeria* weakening the evening *Syrtis Major*), *Neith Regio, Nix Olympica* (complex, with tiny brilliant spots to Gray (May 10; Figure 8D)), *Noachis, Tempe* (sw), *Tharsis, Zephyria*. With the exception of the more generally visible *Nix Olympica*, the other orographics could only be seen near the evening limb.

mid-disk: *Aeolis* (sw), *Aeria, Amenthes* (sw), *Arabia* (weak), *Argyre, Ausonia* (sw), *Candor–Ophir, Chryse–Xanthe* (sw), *Claritas, Eden* (weak), *Elysium* (sw), *Hellas, Isidis Regio–Libya, Noachis, Phaethontis, Tharsis, Thaumasia*.

The observations still show faint but apparently continuous cloud from *Libya* across *Syrtis Major* via *Aeria–Arabia–Eden* to link up with *Chryse–Xanthe*. Also from *Elysium* across *Aethiopis–Amenthes* to *Libya*, and from *Chryse–Xanthe* across *Tharsis* (Figure 1R). Overall, nearly complete ECB.

1997 June

A.m. terminator: *Aeria, Ausonia, Baltia*–E. *Mare Boreum* (bright bluish-white (Figures 1S, 7C)), *Chryse–Xanthe*, *Elysium, Hellas* (sw), *Hyperboreus Lacus, Isidis Regio–Libya* (again – together with *Aeria* – obscuring *Syrtis Major*), *Meroe,* W. *Scandia, Tempe* (sw, also partly veiling W. *Mare Acidalium*), *Tharsis*. Thus the bright far northern clouds (*Baltia–Mare Boreum, Scandia*) continued.

p.m. limb: *Aeria, Alba* (as May: see also *Nix Olympica*), *Amazonis, Arabia, Ascraeus Lacus* orographic cloud, *Chryse–Xanthe, Elysium, Hellas* (still very bright, and irradiating over the *p.* limb to Warell, June 1), *Isidis Regio–Libya* (which together with the *Aeria* cloud obscured central *Syrtis Major*), *Neith Regio, Nix Olympica* (seen right at the limb only, due to phase angle), *Tempe* (sw), *Tharsis* (visible only at the limb).

mid-disk: *Aeria* (sw), *Argyre, Ausonia, Hellas, Noachis, Phaethontis*. *Claritas–Dia–Mare Australe* was a bright strip along the S. limb, the polar hood becoming more continuous in longitude. Ebisawa[20] found by polarimetry that the transition to a single polar hood occurred at Ls= 140° (late 1997 June), the same seasonal date as in 1994–'95.

Hellas was again bright throughout the martian day. It was brilliant from March through June (Ls≈ 90 to 140°), implying a frosted floor.

The ECB was weakened and fragmented in CCD images, especially later in the month, but was still imaged by *HST* at the longitude of the *Pathfinder* landing site. With *Syrtis Major* central there was still obvious ECB from limb to limb, apparent even in white light. This ECB traversed and faded the *Syrtis*, *e.g.*, to the Director, June 24. Historically this obscuration has been mistaken for dust activity: examples have been given by the writer elsewhere.[3,10]

1997 July

A.m. terminator: *Argyre* (merged with large a.m. cloud to cover *Mare Erythraeum*, July 9 (Parker; Figure 1T)), *Chryse–Xanthe, Isidis Regio–Libya* (again extending over and obscuring *Syrtis Major*), *Tempe* (sw, again covering part of W. *Mare Acidalium*), *Tharsis*. *HST* images on July 9–11 showed bright a.m. cloud in the far north over *Baltia*.

p.m. limb: *Aeolis, Aeria, Amazonis, Arabia, Argyre, Chryse–Xanthe, Eden, Elysium, Hellas* (whitish, not bright), *Isidis Regio–Libya, Tempe, Tharsis, Zephyria*.

mid-disk: *Argyre* was conspicuous but *Hellas* was less bright than before. McKim on July 6 saw *Hellas* and *Noachis* merged into an SPH. The SPH was strong (and becoming continuous in longitude) over *Ausonia–Electris–Eridania*, and *Claritas–Dia–Mare Australe–Phaethontis*.

HST images showed the ECB to be weaker; according to Mars Section data it was also fragmentary. On July 1 (Ls= 141°) Dal Prete (UAI) under CML= 15° wrote [trans.]: 'The equatorial 'band' [ECB] is not uniform, on the contrary it seems like a chain of discrete cloudy patches in close contact.'

1997 August

A.m. terminator: *Aeria, Chryse–Xanthe, Tharsis*. Morning haze was often seen near the NPR.

p.m. limb: *Chryse–Xanthe, Tempe, Tharsis, Thymiamata*.

mid-disk: *Hellas* was generally no longer conspicuous at the CM, but was still obvious to Adamoli, Aug 13. There was a strong, continuous belt of SPH over *Claritas–Dia–Mare Australe–Phaethontis–Electris* and over *Eridania–Ausonia–Hellas*. *Argyre* was white throughout the martian day. On Aug 4 Warell re-observed on the CM a large S. limb cloud similar to that of July 9, over *Argyre* and *M. Erythraeum*.

The ECB was not seen.

1997 September to October

September: *Chryse* was bright in the morning. *Libya, Tharsis* and *Xanthe* were light in the evening. *Hellas* was dull in the morning and at midday; sw in the evening. Ishadoh (OAA) on Sept 7 and *HST* on Sept 12 recorded the dull ochre ground colour of *Hellas*. The basin had decayed in brightness from July till September (Ls≈ 140–180°). A light SPH, including *Argyre* and *Eridania*, covered the S. limb.

October: Parker's tiny images no longer showed any cloud detail. Visually, *Chryse* and *Tharsis* were bright in the morning, and *Libya* showed evening cloud. *Hellas* was quite dull at the CM (and sw in the evening). *Argyre* was bright. (The SPC was now visible.)

No useful post-October analysis of BAA data is possible, but we note that all white cloud activity ceased while the *Noachis* regional dust storm (see below) existed.

Yellow clouds (dust storms)

The greatest activity during the apparition was a large regional storm which began in 1997 November over *Noachis*. There were no events that could be really well observed by ground-based observers.

1996 September to December

On Sept 18 (Ls= 11°) *HST* (Figure 7A) imaged a broad comma-shaped tendril of dark salmon-coloured dust (*ca.* 1000km long) overlapping the NPC S. edge near λ= 160–200° in the longitude of *Propontis*, and extending from about 55–70°N. Its next image of the same longitudes, on Oct 15 (Figure 7B), showed this local dust storm dispersing in a spiral pattern over the cap.[6,40] On the Nov 29 *HST* image dust was still present over the cap.[40,45] These events were too early for fine ground-based scrutiny: Minami could not see the dust storm on Sept 18, although a small projection of the cap edge in the same longitude was noted by Ebisawa.[20] Remarkably, Ishadoh (OAA) reported a slight brownish tint to the NPC from November or even earlier,[13] which was still present on

Dec 16 but gone by Dec 24, and Schmude independently found the cap orange-white on Dec 20 (the final ground-based evidence of the event).

These polar dust storms in early N. spring have been described and modelled by James *et al.*,[40] who concluded the dust was swept off the CO_2 seasonal cap surface by a front. Polar projection maps by Cantor *et al.*[45] are also of interest. The writer has listed a handful of historical records which may represent the same phenomenon, rarely visible in ground-based observations.[35]

A more localised suspected yellow cloud was reported by Gray when he found two separate bright patches over *Candor* and *Ophir* on 1996 Nov 22 and 23,[6] which were as bright as the NPC in red light under CML= 37°. Poorer but similar views were had on Nov 24, 27 and 29, but unfortunately Gray did not observe in blue light. Gavin's Nov 24 CCD red images show no obvious dust storm, and Parker's filter work on Nov 27 demonstrates that only a little white cloud existed in and around the region. Later, Gray too considered he had seen white cloud (which could have been bright in all colours at the high phase angle involved), and the Director agrees.

1997 January to June

On Jan 17 Quarra *et al*. (Figure 6 top) imaged a small light spot in the NW corner of *Elysium*, brightest in violet and in infrared. This must have been a small dust storm over the flanks of *Elysium Mons*, even if white cloud was also involved. Parker's images of Jan 21 and 23 also show marginal brightness in *Elysium* in red light. On April 30 Biver drew a small yellow patch in N. *Elysium*: a resurgence of this very minor local activity?

On Jan 29 Hernandez reported that *Thaumasia* was very bright in red light and possibly dusty. However, this was a 'false alarm':[24] images by Parker on the same date and by Quarra *et al.* on Jan 31 did not show any sign of dust there. European visual data in the last week of January indicate likewise.

As in 1994–'95, Ebisawa[19,20] found a long-enduring negative polarisation anomaly for certain desert areas: this was detectable from 1997 mid-January till April (Ls≈ 65–99°) for *Chryse–Xanthe–Tharsis* and *Tempe–Arcadia*. This implies that the bright white diurnal clouds already described over these regions had a dusty component for at least part of the apparition. To Ebisawa they betrayed a slight yellowish tint when seen at the disk edge. However, *Tempe* cannot have been dusty on Feb 16 and 17, when outstandingly high resolution 2.331 micron images with NASA's IRTF facility on Hawaii by J. F. Bell and the late L. J. Martin showed the *Mare Acidalium* hemisphere (including the *Pathfinder* landing site) to be entirely dust-free.[24] (Dr Martin had suspected some dust in *Tempe* on Feb 14 and 15, but this was negated by the later IRTF data.)

To Gaskell on June 26 under CML= 175°, a *p*. limb cloud located over *Ascraeus Mons/Ceraunius* was bright in all filters but especially so in red. The Director in reply commented upon similar activity in that area during N. spring in 1935 and 1978,[35] and this preliminary remark was duly communicated by Gaskell to the IAU, appearing in *Circular* 6693.[12] Gaskell subsequently made similar filter observations of evening limb cloud as far east as *Chryse* during June 28–July 3 over a range of CML, suggesting that – as these regions looked normal at the CM – white cloud was primarily involved. However, traces of dust from the *Valles Marineris* storm (see below) may have reached *Chryse*, so accounting for some of the observations.

1997 July to December

Excitement over the landing of *Mars Pathfinder* was heightened by the emergence of a dust storm over the eastern *Valles Marineris*,[10–12,41] according to June 27 *HST* images and July 2 *MGS* images (Figure 7C). Most dust remained in the valley, but some diffused NW over southern *Chryse* and east over *Mare Erythraeum* to reach *Thaumasia*. Recognising that the event would follow a pattern similar to previous storms charted in that region,[35] none of which lasted more than a week or so and none of which spread far to the north, the Director emailed the *Pathfinder* team[10] to allay fears that the atmospheric entry of the craft might be affected. The W. storm limit had been poorly seen at the a.m. terminator: an *HST* image of Aug 12 indicates considerable albedo anomalies (and a general darkening) in E. *Thaumasia*, suggesting that the event had also affected *Solis Lacus* and environs. The latter image also displays weak continuing dust activity along the E. *Valles Marineris*, as do others on Aug 29 and Sept 1. However a final *HST* image of Sept 18 shows *Thaumasia* near-normal and the dust abated.

None of the few BAA observations near this longitude or time (D≈ 7") showed the event: thus Dal Prete did not resolve it on July 1, nor could the Director on July 1 or 6. On July 9 Parker's CCD images did not show the storm; indeed, only traces of dust could be seen even on *HST* images of the same date.

HST images of July 9 (Ls= 145°) also show a thin tendril of dust (*ca*. 1200km long) sweeping south from the S. edge of the NPR to just reach NE *Mare Acidalium*.[40,41] The appearance of this N. polar local dust storm (illustrated in several publications[27,41]) coincided with the white cloud activity in the far north presaging the arrival of the polar hood. The dust streamer became diffuse during July 9–11. Lee *et al.*[41] also note that more N. polar dust activity was seen on *HST* images in late August and September. *HST* images of Sept 12 show an ochre colour to *Hellas*, but this seems to the writer to be the cloud-free basin floor rather than airborne dust.

The largest-scale phenomenon of the apparition was the large regional storm that began over *Noachis* in 1997 November, and which was imaged by *MGS*,[42,43] as briefly described in a BAA *Interim Report*.[11] The following summary of initial expansion is taken from Pearl & Smith.[23] On the *MGS* images of Nov 25 (Ls= 224°), a small bright patch of dust some 300km across lay over *Noachis*, as did the initial cloud of the 1971 global storm. Next day (Figure 7D) it had expanded, and its position was 15 to 50°S, λ= 325–005°; on Nov 29 the W. boundary lay near 015°, dust reached 60°S near the zero meridian, and further activity was recorded north of *Argyre* near longitude 050° and as far west as 070°. By Nov 30 it spanned λ= 290 to 030°, from *Hellas* to *Argyre*, and was spreading onto the SPC along a broad front. Evidence of an increase in dust activity in the N. hemisphere to latitude +35° was also registered.

In 1997 October, Christensen *et al.*[43] had inferred an almost constant atmospheric dust opacity from *MGS* Thermal Emission Spectrometer (TES) data. Then, prior to the *Noachis* regional event, small dust storms were detected at the edge of the shrinking SPC by the TES. On Nov 25 TES data showed a warming of the lower atmosphere and an increase in dust opacity; five days later a further area of dust activity was located near –20°, 290° (*Iapigia*), and expansion of the main storm to the east created further activity centred near –60°, 240°. The storm's enhancement of upper atmospheric density could be recognised during the aerobraking manoeuvres of *MGS*. An *MGS* image of early December (Figure 7E) shows very washed-out features in the vicinity of *Solis Lacus* and traces of remaining dust. After Dec 10, activity equatorward of 65°S began to cease, and background dustiness began to fall so that by 1998 Jan 10 dust opacity generally had returned to pre-storm values, and only transient small-scale activity at the edge of the SPC was being recorded.

Visible white crystal cloud activity (including the *Tharsis* orographics) had ceased by Nov 30, as the storm significantly warmed the martian upper atmosphere, a fact corroborated by ground-based CO microwave work.[11,44] White cloud activity resumed a month later.

A few ground-based records actually confirmed this final activity of the apparition. On Dec 10 Schmude recorded *Mare Tyrrhenum* normally, but not *Syrtis Major* (which should have appeared on the *f.* side), while on Dec 14 Biver (Figure 7F) found the *p.* side of the disk very yellowish, *Syrtis Major* very faint on the afternoon side and *Sinus Sabaeus* invisible. Parker (with J. D. Beish) on 1998 Jan 21 (D= 4".3), after the event had subsided, recorded *Syrtis Major* together with the SPC.

This large event can best be compared with the past regional storms of similar origin and seasonal date: 1971 July (Ls= 213°–), 1973 July–August (Ls= 244°–) and 1988 June–July (Ls= 212°–),[35] but the 1997 November event (Ls= 224°–) seems to have extended somewhat further west, to about λ= 160°.

Smith *et al.*[43] described a further regional dust event witnessed by *MGS* from Ls= 309° (1998 April): it began at low southerly latitudes over λ≈ 20–120°, and spread south and east.

Table 3. Blue-violet filter data

Observer	*Filter***	*Wavelength (nm) of peak transmission*	*BWHM** (nm)*
Visual			
(all)	Wratten 47	440	70
CCD			
Akabane	–	436	–
Parker	Schott BG12	405	150
Quarra *et al.****	–	420	120
HST	F410M	410	15

* bandwidth at half maximum data from Parker *et al.*, *Icarus*, **138**, 3–19 (1999)
** with CCDs,W47 and Schott BG12 filters require an infrared rejection filter.
***Quarra *et al.* also made ultraviolet exposures with a filter centred upon 330nm.

Blue clearings

Although the term 'Blue Clearing' (hereafter 'BC') is misleading, we retain it for historical comparisons. As in the past, CCD and visual investigation into the transparency of the martian atmosphere in blue–violet light was undertaken with filters whose transmission characteristics are given in Table 3.

Visual data

Most visual data were due to Colombo, Heath, McKim, Siegel, Storey, Topping and Troiani. Records of partial to full BC span the following periods: order 1, 1996 Oct 11–1997 May 22; order 2 or greater, 1997 March 10–May 14. For BC order 2, and especially order 3, the sightings were discontinuous. Almost all instances of BC order 3 were in March–April. As ever, BC within the longitudes of *Syrtis Major* or *Mare Acidalium* was easier to detect visually (with a dim image) than elsewhere. In most observations in blue–violet light the *Syrtis* (and sometimes southern *Acidalium*) was veiled by the ECB, although Troiani saw *Syrtis Major* clearly at the CM on May 5.

CCD data

The 'densely reddish' markings around the *Ascraeus Mons* area (and the band between the *Tharsis Montes*) described under 'Albedo features' showed up darker in blue light (*e.g.*, to Akabane, Jan 12; Parker and Quarra *et al.*, March–April (Figure 6, bottom)), implying a local absence of both dust and crystal clouds.

Most of the CCD data were due to Akabane, Parker and Quarra *et al*. They reveal hints of vaguely defined northern albedo markings (*e.g.*, BC1) from 1996 October 24. From 1997 January the weak BC continued, with occasional hints of southern markings. Feb 9 was the first record of BC2 both north and south, in the *Mare Acidalium* longitude. BC1–2 continued through the month, but not all features were equally well seen: the ECB hid the northern part of *Syrtis Major*, and the deserts E. and W. of *Utopia* were dark making it hard to define. The complete *Syrtis Major* was faintly seen on Feb 24.

Throughout March and up to and including April 25 the BC generally remained as 2, often verging upon 3 during March 19–April 8. Quarra *et al.* obtained remarkable images on April 8 with *Solis Lacus* sharply defined at 420nm, with a strong general BC (order 3) and more or less complete ECB. From about April 30, through May and June, the BC varied from 1 to 2, with the last record of BC2 about May 28. After July 9 the images show no albedo markings in blue light, only white clouds.

Summary

Taking all the data together, the extreme limits of the different orders of BC were: BC1, 1996 Oct 11–1997 July 9; BC2 (or higher) 1997 Feb 9–May 28. These periods were again asymmetric with respect to the date of opposition (March 17).

North polar region

NPH dispersal

In 1996 August the N. polar hood was a diffuse bright area over the N. limb, especially conspicuous in blue light (Warell (Aug 4), Schmude (Aug 14), Niechoy (Aug 19–26)). Ls reached 0° on Aug 26. The first indication of a sharply defined NPC was due to Ebisawa[20] (49cm Cass.) on Sept 3 (CML= 297°, Ls= 4°), Schmude (51cm refl.) on Sept 6 (CML= 128–142°) and Gray on Sept 14 (Figure 3F). Parker on Sept 18 imaged the cap in red light, but a larger hood showed up in blue, reaching down to lower latitude on the morning side – a well-known phenomenon – thus partly covering *Mare Acidalium* and *Tempe*. By Oct 5 at the same longitude OAA members witnessed only the ground cap. Quarra's blue and UV images as late as 1997 Feb 8 and 9 still revealed an overlying hood. (Other blue images also apparently revealed the hood, but caution is needed: blue CCD images need significantly longer exposures, and in poor seeing the image excursion can create a large 'hood'.)

Summarising, the ground cap first appeared about Ls= 4°, but a hood could still be detected in blue light for longer.

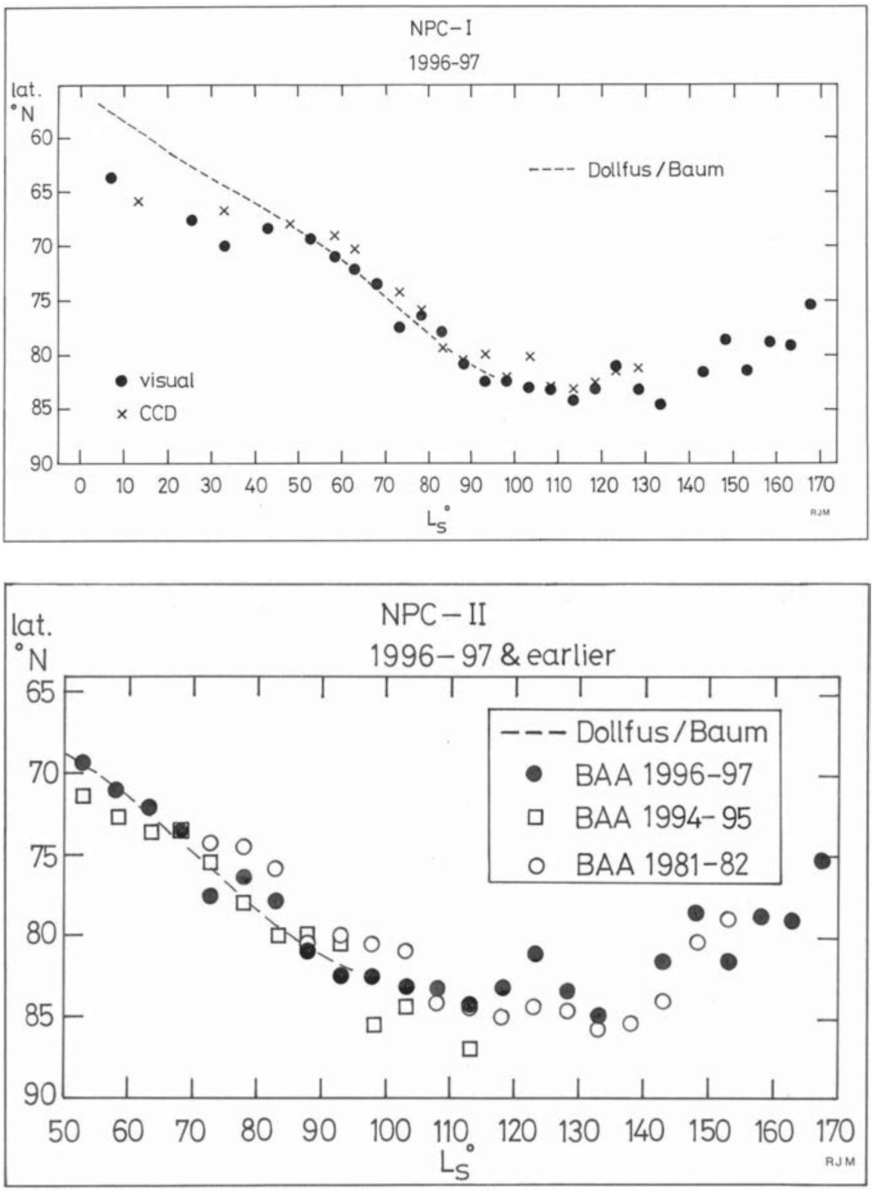


Figure 10. (A) *(top)*. Recession curve for the NPC – I: BAA 1996–'97 visual and CCD data compared. Data averaged in 5° intervals in Ls. *R. J. McKim*
(B) *(bottom)*. Recession curve for the NPC – II: BAA 1996–'97 visual data from (A) compared with the historical mean curve of Dollfus and Baum, and with BAA 1981–'82 and 1994–'95 data. *R. J. McKim*

NPC retreat

The Director measured the latitude of the S. edge of the cap upon 546 drawings by 36 observers, and derived means in 5° intervals in Ls (Table 4; Figure 10(A)). Useful data covered the exceptionally long interval Ls= 1–170° (1996 late August to 1997 late August). Red-light CCD images (mostly by Parker, with some from Dijon, Miyazaki, and Warell, supported by frame captures from Higa's white light CCD videotape) could also be profitably measured for Ls= 11–130°. As shown in Figure 10(A), these data (plotted for N= 3 or more measurements per point) agreed closely with the visual recession. We received no micrometrical data. Cantor *et al.* have reviewed *HST* NPC data for 1990–'97,[45] and the ALPO also published results.[15] Iwasaki *et al.* independently measured Parker's 1996–'97 CCD work, and compared it with *HST* data.[46]

Data before Ls= 50° were not plentiful, but adequately establish a slow recession till then, with a systematically smaller cap than the classic results of A. Dollfus[47] and W. A. Baum.[48] The rapid retreat phase after about Ls= 50° agrees closely with BAA data from 1994–'95 and 1981–'82 (Figure 10(B)). In 1994–'95 the BAA curve[1] had joined the Dollfus–Baum curve a little *after* Ls= 50°, indicating a small interannual difference. Was suspended dust from the N. polar dust storm (that commenced at Ls= 11° on 1996 Sept 18, as discussed earlier) responsible for this difference?

A near-static summer remnant was reached after Ls≈ 100°, as in 1982 BAA data.[29] The mean cap diameter for Ls= 101–135° was 14°. After Ls≈ 140° the (initially irregular) presence of the NPH enlarged the NPR and softened its outline (as in 1982 and other years).

NPC internal structure

In 1994–'95[1] much attention was given to the annular dark rift observed within the new spring cap. This rift had also been seen during the earlier part of the 1992–'93 apparition.

Table 4. NPC latitude measurements 1996–'97

	Visual drawings		CCD images	
Mean Ls (°)	*Latitude of S. edge of cap (°)*	*No. of measures*	*Latitude of S. edge of cap (°)*	*No. of measures*
008*	63.8	5	–	–
013	–	–	66.0	3
018	–	–	–	–
023	–	–	–	–
026**	67.6	3	–	–
028	–	–	–	–
033	70.0	4	66.8	8
038	–	–	–	–
043	68.3	3	–	–
048	–	–	68.0	3
053	69.4	5	–	–
058	71.0	3	69.2	10
063	72.1	17	70.3	7
068	73.5	10	–	–
073	77.5	21	74.2	10
078	76.4	17	75.9	9
083	77.9	35	79.3	15
088	80.8	61	80.4	17
093	82.5	60	80.0	14
098	82.5	62	82.2	17
103	83.1	74	80.1	18
108	83.2	41	82.2	10
113	84.2	37	83.1	7
118	83.3	16	82.5	4
123	81.1	20	81.3	3
128	83.2	18	81.2	5
133	84.7	7	–	–
138	–	–	–	–
143	81.6	5	–	–
148	78.5	4	–	–
153	81.3	3	–	–
158	78.7	3	–	–
163	79.0	3	–	–
168	75.3	3	–	–
Totals *used*		540		160
available		546		167

*averaged over Ls= 1–15°
**averaged over Ls= 21–30°

It was not present in the Section's data for 1996–'97, doubtless because of the tiny disk diameter during the corresponding period. *HST* NPC polar projection maps[45] do show a low contrast annular feature in the same position for the same epoch, but it was paler and less contrasty this apparition, as if the overlying polar deposit was thicker. Figure 11 offers some comparisons for 1992–'96. Ebisawa[20] has also commented upon this question.

The seasonal indentation in the cap, *Chasma Boreale* (or *Rima Hyperborea*) was first seen by Gray on 1996 Nov 22. At that time it was a short, broad notch. From 1997 February through May it was more obviously and widely visible (and cut further into the snows) as the cap dwindled (Figures 5A, E). After then, the resolution of the ground-based work was too low, but *HST* on June 27 (Figure7C) confirmed that it continued as a permanent feature of the N. summer.

As we explained in last apparition's report,[1] a certain configuration of *Chasma Boreale* may account for reports of the *Rima Tenuis* rift apparently bisecting the cap along a great circle. On Parker's images of March 29 and 30 (Figure 3E) and May 2 and 4 (CML range 289–317°), *Chasma Boreale* begins to cut into the cap at the N or N*f.* limb, then bends round to the east and curves south to *approach* the S. edge of the cap. If there is an existing rift or notch at the edge of the NPC near λ= 330°, an impression may arise of an apparent N–S rift right across the cap. (*Rima Tenuis* has often been reported to commence near λ= 330°.) This effect is also suggested by *HST* work.[9] Evidently any rift indenting the opposite side of the cap is a physically unconnected feature. In 1995 *Rima Tenuis* was observed as a notch on the 330° side, but in 1996–'97 no indentation was seen there.

NPC surroundings and outliers

A thin dark fringe bordering the cap was seen by Schmude on 1996 Sept 6, and it appeared darker to Minami and Nakajima on Sept 27. This NPCB was well seen from 1996 Oct 31 (Parker) onwards. Also, the inky-black peripheral patch *Hyperboreus Lacus* had been fully exposed by about Jan 9. Several reports exist of a coarsely serrated cap edge (*e.g.*, Cave in March). As always the NPCB was visible until the cap was hidden by the returning hood. About the summer cap it was darkest and broadest in the longitudes around *Hyperboreus Lacus*. A dark band, *Iaxartes*, connected the latter to *Mare Acidalium*.

Olympia was very well seen: see Figures 1O, 3B, E, 4C, E, G, 5F and 8C. The rift which would later separate it from the NPC – *Rima Borealis* – was reported by Minami and Nakajima (OAA) on 1996 Dec 28, but it would have been visible earlier upon a larger disk. Hernandez on 1997 Jan 23 saw *Olympia* protruding but not yet detached. Parker's Jan 21 and 23 CCD images suggest *Olympia* had detached (Ls= 68°), and his Feb 1 and 2 images definitely show it thus. Under CML≈ 200° on Feb 10, Minami and Nakajima found the following quarter of the cap dull and ochre-coloured, due to the rapid decay of the cap in the longitude of *Olympia* there. Minami's transits of *Olympia* placed its *p.* end near λ= 170° on March 20–22, and the *HST* montage of March 30 (Figures 9 and 12) places its limits at λ= 164–266°.

Throughout February to May there were many sightings of *Olympia* by different observers. Quarra's images of Feb 8–9[8] showed it clearly separated from the NPC by the dark *Rima Borealis*, a circumstance Tanga and Warell soon confirmed visually. *Olympia* shrank slowly with time on its S. perimeter and in longitudinal extent. Visual data record it up till June 24, but after then it could no longer be resolved. *HST* on June 27 showed it more fragmented than in Figure 12: at the time, it was the only obvious outlier remaining (*HST* imaging the whole cap well within the limb). *Mars Global Surveyor* imaged *Olympia* on Aug 20 (Ls= 167°) as an icy sliver.

Ierne, a smaller outlier (located at λ= 104–152° in Figure 12) was imaged by Parker (March 7, 11; Figure 1J) and drawn by Minami (March 20–27 (Figure 5F) and April 25). Earlier it had appeared as a small cap projection (Biver, Jan 30).

The outlier shown in northern *Ortygia* on some classic maps was neither seen nor imaged in 1997. There were several conspicuous bright clouds in that area from April onwards, being precursors of the N. polar hood, and the writer considers that some cartographers have mistaken these persistent features for surface deposits. The *HST* map of 1997 March 30 (Figure 12) shows only the *Ierne* and *Olympia* outliers.

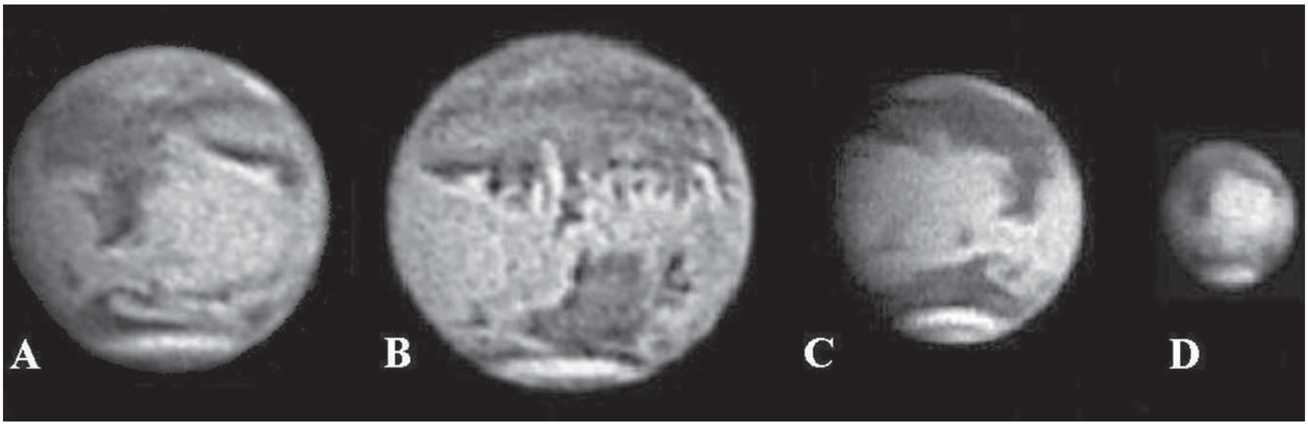


Figure 11. The NPC annular rift, 1992-1996.
Red light CCD images by D. C. Parker, 410mm refl. (with technical details given in Figure 1). Images are shown to the correct relative scale.
(A) 1992 December 8, D= 13".4, Ls= 8°, tilt= +12°.
(B) 1993 January 6, D= 14".8, Ls= 22°, tilt= +7°.
(C) 1994 December 27, D= 10".5, Ls= 37°, tilt= +22°.
(D) 1996 November 2, D= 5".5, Ls= 32°, tilt= +23°.
An annular rift is clearly seen in (C), and less obviously in (A) and (B). In 1996–'97 the disk diameter was too small for critical inspection in early N. spring: in any case, *HST* images reveal the rift to have been very faint in the apparition under review.

The return of the NPH

UV images by Quarra and colleagues on 1997 Feb 8–9 showed haze over the cap. From late March onwards some visual observations indicated a slight haze surrounding the summer cap, but no trace of the overlying hood was noticed before June. Activity suddenly increased in April, when there was a remarkable plethora of bright clouds visible off the morning terminator adjacent to the cap, some of which could still be seen at local noon. On April 1, 9 and 10 (the intervening days being cloudy) Minami sketched a large white cloud, slightly variable in shape, located over northern *Ortygia* (λ *approx*. 340 to 10°) which was visible at least up till CML= 10°. (Possibly the same feature had been reported by Devadas and Niechoy on March 7, Graham on March 10 and by Schmude on March 27.) Graham, Mettig and Teichert provided further sightings on most dates between April 13 and 21, during which time the longitude of the feature did not change much, but it continued to vary in shape, size and brightness. It is probable that the cloud reformed each morning up till about April 30, when Cave last sighted it as a very small patch on the a.m. side. On May 7–8 Hill sketched two small clouds N. of *Mare Acidalium* over *Baltia*, and Shanklin and Topping saw cloud at the same location on May 28–30; Parker on May 28 (Figure 1R) imaged cloud over N. *Arcadia*–W. *Mare Boreum*, which Warell's May 21–22 drawings confirm.

On June 27 *HST* imaged a complex bluish-white a.m. cloud over *Hyperboreus Lacus*–*Baltia*–E. *Mare Boreum* and part of NW *Mare Acidalium* (Figure 7C), which Parker had already imaged on June 3 (Figure 1S). Hill, June 30, CML= 136°, recorded bright clouds irradiating beyond the morning terminator over W. *Scandia*.

On July 6, McKim saw polar haze obscuring the cap's S. edge, as did Biver next day. On July 9 Parker's images (Figure 1T) showed NPH covering *Hyperboreus Lacus* and blurring the cap edge. *HST* images of July 9–11 showed bright a.m. cloud over *Baltia* which had an easterly motion from day to day,[41] and complex, swirling structure to the NPH. On July 14 Ishadoh (OAA, Japan) apparently saw the ground cap, but on July 20 the cap was again obscure on Higa's images in the longitude of *Mare Acidalium*, and on July 22 Minami found *Hyperboreus Lacus* obscure. NPH was seen on July 25–26 (Parker), but a ground cap was definitely seen by Minami on Aug 2 (and indeed on *MGS* red images throughout the month). The NPH was dull on Parker's images of Aug 5 and 18, on Schmude's Aug 6 sketch and to Adamoli visually on Aug 25. Thus a variable hood predominated through August.

In summary, the hood began to develop about July 6 (Ls= 143°), and to more or less permanently cover the cap after Aug 2 (Ls= 157°). (Compare 1981–'82,[29] where the corresponding BAA figures were Ls= 144° and 152°.) The decreasing northward tilt of the martian axis made the hood impossible to see after early November: thus on Nov 16 Biver did not find any brightness along the N. limb.

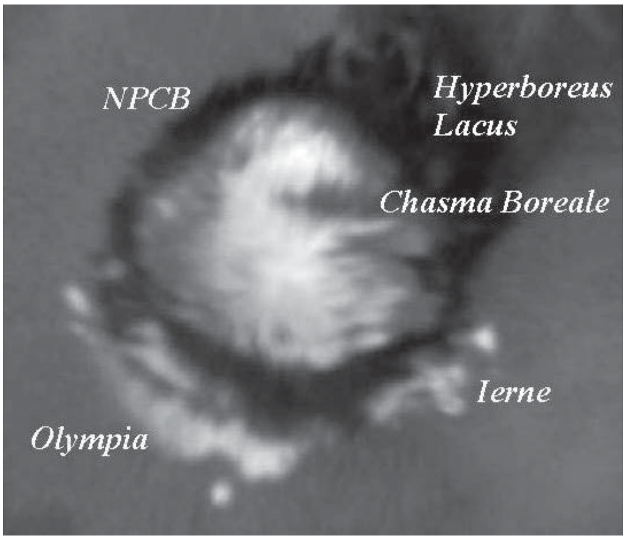


Figure 12. Polar projection map for the summer NPC from *HST* images of 1997 March 30 (Ls= 97°). λ= 0° is at the top, 90° is to the right, 180° at the bottom and 270° to the left. Selectively labelled by the Director. *(NASA/STScI)*

South polar region

The emergence of the SPC

The gradual growth of the S. polar hood during the apparition has been chronicled earlier. Occupying particular regions such as *Hellas* and *Argyre*, these bright frosted areas gradually merged during the apparition. A northward expansion of the nascent SPH was imaged by Parker on July 9 (CML= 25°, Figure 1T), when a large bright cloud on the a.m. side (seen in blue light but not in red) was seen to cover *Argyre* and part of *Mare Erythraeum*. *HST* images during July 9–11 show a progressive thickening of the SPH.[41] The critical phase of SPC formation could not be well observed from northern Europe: by August the planet was low in the evening twilight. To Warell on Aug 4 from Tenerife (CML= 61°), and to Iwasaki (OAA) on Aug 31 from Japan (CML= 3°), the S. limb had become brighter than the N. polar region.

In September the S. limb appeared as a near-continuous foreshortened bright arc, impossible to see well due to the unfavourable tilt. However, the *HST* on Sept 12 resolved a thin silvery slice of the polar region (ground cap plus some patchy SPH at its N. boundary); the cap did not merge with the dull ochre *Hellas*. McKim on Oct 3 (D= 5", CML= 266°) observed from Arizona with Parker, Troiani and D. Joyce: a bright S. polar region was seen; Biver from Hawaii on Oct 5 apparently saw a polar hood over *Ausonia–Hellas*. On Oct 10 the ground cap was probably seen by Murakami (OAA) to the south of (and again distinct from) *Hellas*. Schmude on Dec 10, Biver on Nov 16 and Dec 14 (Figure 7F), and Parker on 1998 Jan 21 also reported the SPC.

To conclude, the SPC was visible at least from Sept 12 (Ls= 179°) onwards, and no polar hood was recorded after Oct 5. Such behaviour is typical. Christensen *et al.*[43] used *MGS* TES data to map the SPC regression, finding it comparable with *Viking* data. James *et al*. were able to more precisely describe the cap's recession phase from *MGS* images.[49]

Address: Cherry Tree Cottage, 16 Upper Main Street, Upper Benefield, Peterborough PE8 5AN. [rmckim5374@aol.com]

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