# The opposition of Mars, 2014: Part I

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

During this aphelic opposition we received over 6,000 observations from 102 contributors. Small-scale dust activity was evident in the north polar region on several occasions, some events coinciding with the seasonal detachment of *Olympia*. Later dust activity in the region was associated with the development of the polar hood. At *Ls* = 154° a Regional storm commenced in *Libya–Isidis Regio*. The most frequently active site until the 1960s, it remained almost completely inactive – at telescopic resolution – for years. This event occurred seasonally early, but a second Regional event that simultaneously broke out there and in *Hellas* at *Ls* = 216° in 2014 October showed typical timing: dust spread west across *Noachis* and led to a darkening of *Pandorae Fretum*, as well as a broadening of *Mare Serpentis*. Short-lived local equatorial storms were recorded over *Valles Marineris* and *Chryse–Xanthe*. The entire *Ls* period over which planet-encircling storms are known to emerge was checked, a full terrestrial year after opposition, but we found no such event during Martian Year 32 (2013–'15). Unlike in 2012, no extraordinary high-altitude terminator phenomena were seen. Part II will describe meteorological phenomena, in particular the spiral clouds that formed from *Ls* = 117° at the edge of the summer N. polar cap, and the transition from the cap to the N. polar hood. A nearly complete recession curve for the N. polar cap was obtained, and compared with previous years. The post-opposition observations document the S. polar hood and later the S. polar cap recession.

## Introduction

This report describes BAA observations of Mars during the period 2013 July to 2015 April, covering the very end of Martian Year (MY) 31 and most of MY 32.[1]

Mars came to opposition in Virgo on 2014 Apr 8 at 21h UT (at areocentric longitude (*Ls*) 114°, in early northern summer) at declination –5° and with a diameter (*D*) of 15.1 arcseconds (″), a little larger than in 2012. Closest approach (*D* = 15.2″) occurred on Apr 14, and for UK observers the higher diameter did not compensate for the much reduced altitude. The planet's diameter was 6″ or greater between 2013 Dec 12 and 2014 Oct 6. The latitude of the centre of the disc at opposition ($D_e$) equalled +21.4°, favouring observation of the northern hemisphere; it remained positive until 2014 late October. Key dates are listed in Table 1.

The Director received 6,317 observations (5,759 images and 558 drawings) from 102 observers (Table 2). Excellent coverage from 2013 Jul 27 (*D* = 3.9″) until 2015 Apr 15 (*D* = 3.9″) corresponded to *Ls* = 358° through 0° to 326°, or 91% of a continuous span in *Ls*. Images spanned 2013 Jul 27 (Kardasis) to 2015 Apr 13 (Foster), and visual records 2013 Aug 13 (Gray) to 2015 Apr 15 (Adamoli). The distribution by month (days observed/days possible) was: 2013 Jul 1/31, Aug 5/31, Sep 20/30, Oct 29/31, Nov 22/30, Dec 22/31, 2014 Jan 23/31, Feb 27/28, Mar 31/31, Apr 30/30, May 31/31, Jun 30/30, Jul 30/31, Aug 29/31, Sep 25/30, Oct 21/31, Nov 12/30, Dec 7/31, 2015 Jan 11/31, Feb 11/28, Mar 9/31, Apr 4/30.

We were well-supported by observers in Australia and (for the first time in many years) South Africa. From the latter country, Clyde Foster made full use of advantages conferred by low latitude (25.8°S) and high altitude (1,475m) to study the planet in the evening twilight for many months after opposition. Supported by the visual work of Gianluigi Adamoli, Foster's images proved the absence of an encircling dust storm. Paul Maxson again obtained the largest number of images (871) on 178 dates, with much valuable early morning work. Yukio Morita and Maurice Valimberti each supplied over 500 images. In the UK, despite the lower altitude, high resolution was achieved by our observers, in particular by Martin Lewis and David Tyler. Damian Peach made another successful expedition to Barbados in April. The Director secured 55 drawings. This was the final Mars apparition observed by Don Parker,[2] and Masatsugu Minami.

The following are seasonally comparable oppositions covered by the BAA: 1903 (*Ls* = 103° at opposition),[3] 1920 (127°),[4] 1935 (111°),[5] 1950 (097°),[6] 1952 (136°),[7] 1967 (121°),[8] 1982 (105°),[9] and 1999 (129°).[10]

Short interim reports were produced,[11–13] together with a preview of what might be observed.[14] Other organisations maintained online image galleries,[1] but none produced final analyses. Schmude has discussed some of the *Mars Reconnaissance Orbiter* images.[15]

Throughout the apparition NASA's *Mars Odyssey* (arrived 2001) and *Mars Reconnaissance Orbiter* (MRO, 2006) remained active in orbit, as did ESA's *Mars Express* (2003) probe. The NASA rovers *Opportunity* (2004) and *Curiosity* (2012) were still at work on the surface. This select group of spacecraft at Mars was enlarged by the post-opposition arrival of NASA's MAVEN *(Mars Atmosphere and Volatile EvolutioN)* spacecraft on 2014 Sep 21,[16] and India's *Mars Orbiter Mission*

**Table 1. Physical details of the 2014 apparition**

| | *Ls* (°) | *Date* |
|---|---|---|
| Solar conjunction | 303 | 2013 Apr 18 |
| N. spring equinox/ S. autumn equinox (MY 32 commences) | 0 | 2013 Jul 31 |
| Aphelion | 70 | 2014 Jan 1 |
| N. summer solstice/ S. winter solstice | 90 | 2014 Feb 15 |
| Opposition | 114 | 2014 Apr 8 |
| N. autumn equinox/ S. spring equinox | 180 | 2014 Aug 17 |
| Perihelion | 250 | 2014 Dec 10 |
| N. winter solstice/ S. summer solstice | 270 | 2015 Jan 11 |
| Solar conjunction | 358 | 2015 Jun 14 |

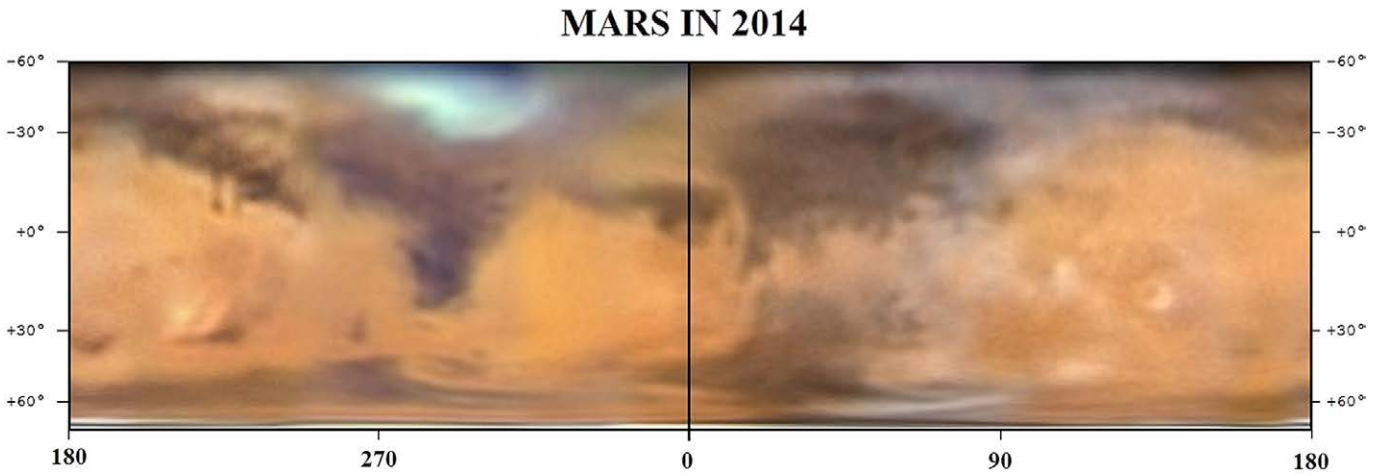


**Figure 1.** Map of Mars, from images taken with a 279mm SCT and ASI120MC camera during 2014 Apr 9– May 21. *Note:* south is uppermost in this and other figures. *T. Kumamori*

(MOM) spacecraft *Mangalyaan* on Sep 24.[17] China also had a Mars mission at the planning stage.

## Surface features

### General

The albedo features were mapped by T. Kumamori (Figure 1) and M. R. Lewis. Though Figure 1 is less detailed than our 2012 chart, it confirms that there were no major changes since then. D. A. Peach created an impressive 'animated globe' video, covering a wide longitude range. The 2010 and 2012 oppositions also showed hardly any albedo feature variations (the last planet-encircling dust storm having occurred in 2007). We again refer mostly to telescopic names from Ebisawa's general map, readily available at the Section's website.

### Region I: long. 250–010°

See Figures 1 & 2. *Syrtis Major* continued to be broad, and blunted to the north, with *Nepenthes* invisible. The dark spot in *Huygens* was well visible. At the start of the apparition *Nodus Alcyonius* was distorted by a local dust storm (described later), but soon

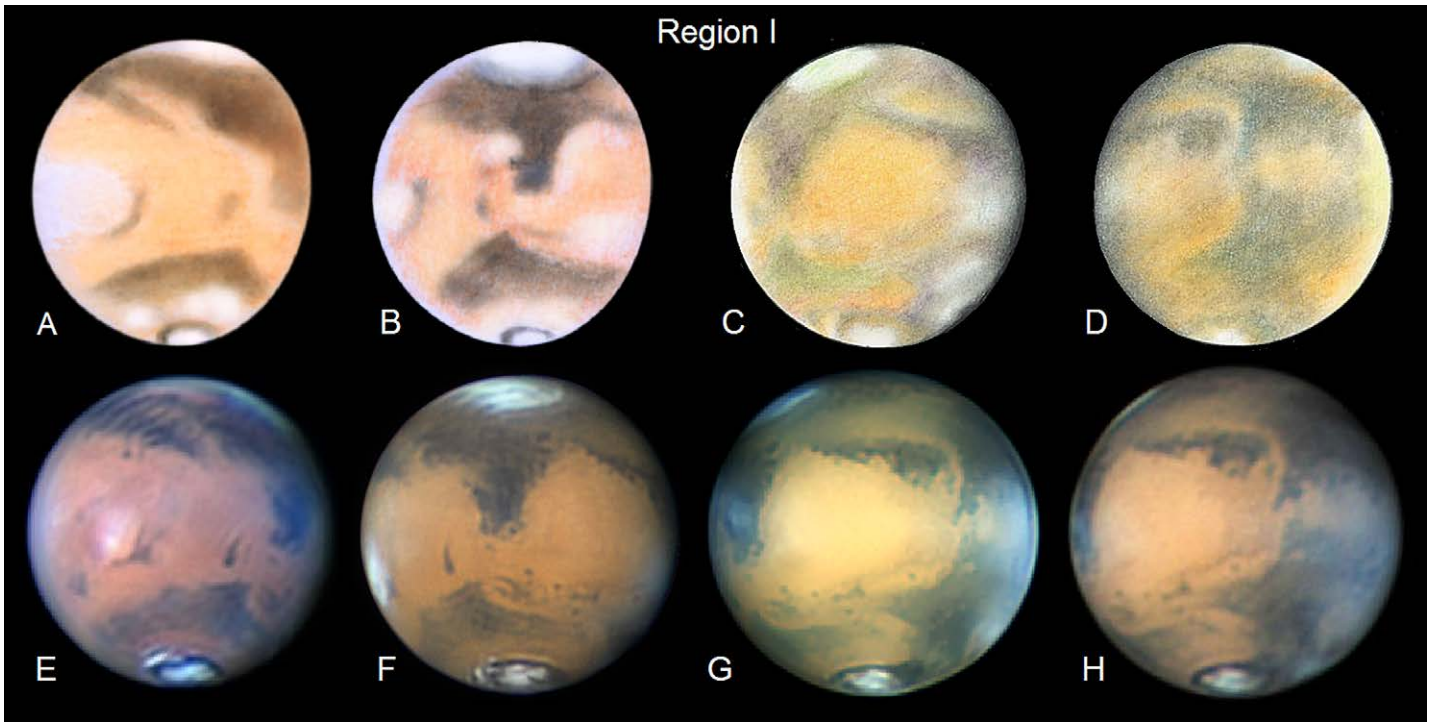


**Figure 2.** Drawings (top row) and images of Region I, λ ~ 250–010°. See Table 2 for observer details and definitions of abbreviations.

**(A)** 2014 Jun 5, 22:28 UT, CM = 248°, 203mm refl., ×250. N. polar cloud over *Utopia*. *(P. G. Abel)*
**(B)** 2014 May 31, 22:03 UT, CM = 288°, 508mm DK Cass., ×356. Frosted *Hellas*. *(P. G. Abel)*
**(C)** 2014 May 11, 12:25 UT, CM = 330°, 305mm SCT, ×600. N. polar spiral cloud with dark nucleus at terminator. *(R. Konnai)*
**(D)** 2014 Feb 23, 17:40 UT, CM = 010°, 305mm SCT, ×600. *(R. Konnai)*
**(E)** 2014 May 6, 03:34 UT, CM = 245°, 355mm SCT with Flea 3 camera. NPC with *Olympia*; *Syrtis* Blue Cloud. *(W. D. Flanagan)*
**(F)** 2014 Apr 26, 01:03 UT, CM = 297°, 355mm SCT with SKYnyx 2-0M camera. Frosted *Hellas*; *Chasma Boreale*; detached *Olympia*. *(D. A. Peach)*
**(G)** 2014 Apr 2, 14:26 UT, CM = 343°, 369mm refl. with Grasshopper3 camera. Evening clouds over *Syrtis Major*; *Chasma Boreale*. *(A. Wesley)*
**(H)** 2014 Apr 22, 02:59 UT, CM = 001°, 355mm SCT with Flea 3 camera. As (G), with extensive a.m. clouds. *(W. Jaeschke)*

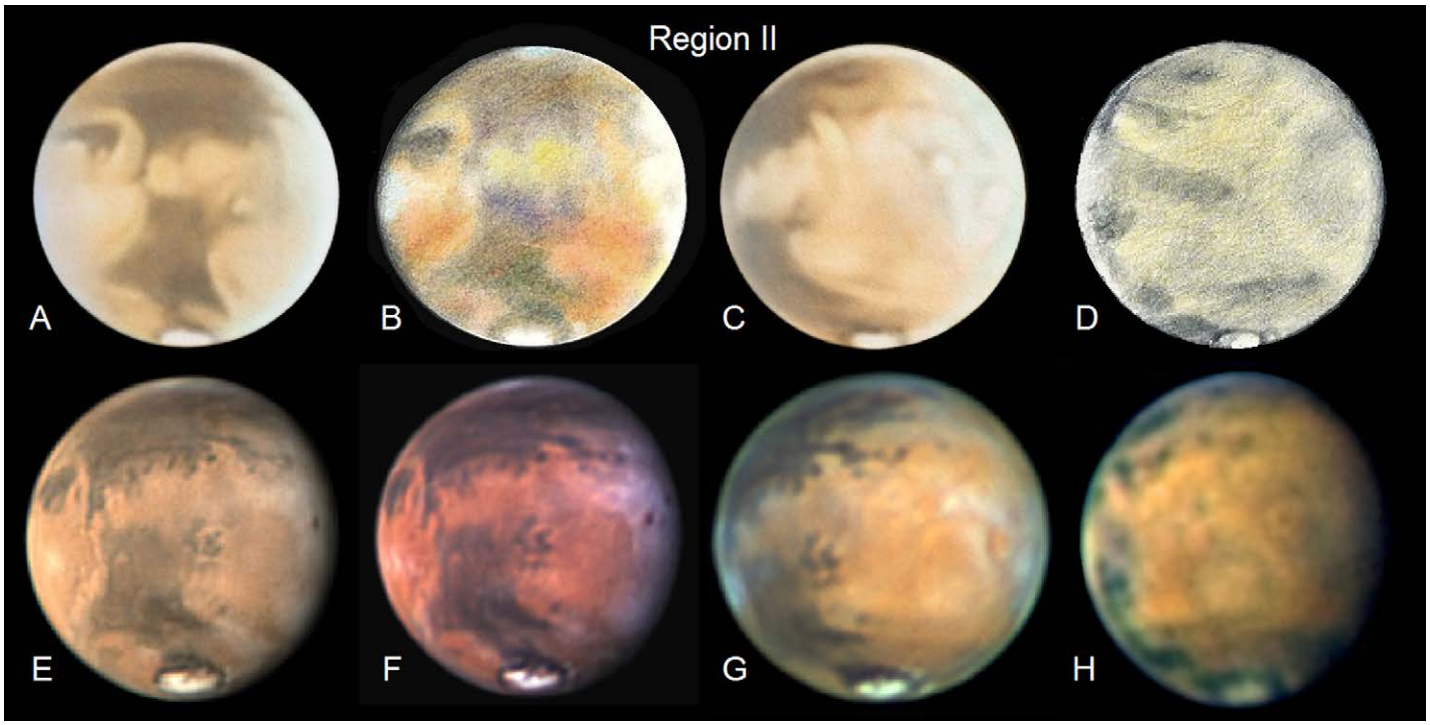


**Figure 3.** Drawings (top row) and images of Region II, λ ~ 010–130°.

**(A)** 2014 Apr 8, 21:10 UT, CM = 029°, 415mm DK Cass., ×365. *(D. Gray)*
**(B)** 2014 Mar 27, 14:45 UT, CM = 040°, 305mm SCT, ×600. Whiteness in *Argyre*. *(R. Konnai)*
**(C)** 2014 Apr 8, 00:30 UT, CM = 087°, 415mm DK Cass., ×365. Note N. and S. components of *Solis Lacus*. *(D. Gray)*
**(D)** 2014 Apr 27, 12:50 UT, CM = 101°, 310mm refl., ×400. Some *Tharsis Montes* as dark spots amidst a.m. clouds; *Ierne* at *f.* side of NPC. *(M. Adachi)*
**(E)** 2014 May 16, 21:16 UT, CM = 054°, 444mm refl. with ASI 120MC camera. Exceptional resolution. Note the frosted *Argyre* at the south. The detached *Ierne* and the *Tharsis Montes* are well shown on the a.m. side in (E)–(G). *(M. R. Lewis)*
**(F)** 2014 May 15, 21:07 UT, CM = 061°, 355mm SCT with Flea 3 camera. *Ierne* on the *f.* side is broken into fragments (also (E) and (G)). *(D. B. V. Tyler)*
**(G)** 2014 Apr 9, 00:56 UT, CM = 084°, 250mm Gregorian with PLA Mx camera. *(C. E. Pellier.)* In (G) and (H), the lighter streak dividing *Solis Lacus* horizontally is clearly shown.
**(H)** 2014 May 31, 10:44 UT, CM = 123°, 260mm refl. with DMK21AU618 camera. The *Phasis* streak runs N. from *Aonius Sinus*; it is too early in the day for orographic clouds. *(K. Yunoki)*

recovered.[11] A fragment of *Nepenthes* also may have temporarily appeared, but the disc was too tiny to be sure.

*Pandorae Fretum* was pale, incomplete and hardly visible for much of the apparition, though *Deucalionis Regio* was lighter than southern *Noachis*. After the 2014 October *Hellas* Regional storm, *Pandorae Fretum* darkened the following month in response to dust excavation where that event had propagated west towards *Argyre*. *Mare Serpentis* was also broadened by the event. To the north, *Ismenius Lacus* remained very small; it is hardly visible in Figure 1.

### Region II: long. 010–130°

See Figures 1 & 3. Images by Peach and Parker as early as 2013 Oct 6 and Nov 18, respectively, showed that *Nectar* had darkened and broadened since 2012, and was now in its usual configuration. Observations close to opposition however showed that as in 2012, the SW part of *Solis Lacus* remained fainter than its pre-2007 configuration, and that a light streak still bisected the N. and S. halves of the 'Eye of Mars'.

The diminutive dark spot *Juventae Fons* was routinely imaged by many observers, and was seen visually by Biver, Gray, Konnai and McKim. The *Phasis* streak was still visible between *Aonius Sinus* and the little 'oasis' *Gallinaria Silva* (Figure 3H).

### Region III: long. 130–250°

See Figures 1 & 4. The *Aetheria* secular dark marking was somewhat reduced in area and intensity this apparition, and the streaky markings that had formerly crossed *Aethiopis* had faded somewhat. Dust fallout has resulted in a net accumulation at *Cerberus–Trivium Charontis* on the opposite flank of *Elysium* since the late 1980s, while in similar fashion an explicit, bright yellowish patch of dust fallout was still present (from the last opposition) at the NW corner of *Elysium.*

*Propontis* and *Castorius Lacus* remained small – and the latter hard to see or to image clearly – as at the last opposition. Since 1986, *Mare Sirenum* on its W. side has continued to end some 20° east of its classical position on the IAU and Ebisawa maps.

## Dust storms

### Introduction

There was less intense polar dust activity in 2014. Among the various dust storms, there were two small events in *Libya–Isidis Regio*. Although the most active region for the emergence of storms until the 1960s,[18,19] this location later became most uncommon for telescopic-scale events, due to long-term changes in dust deposition.

The following analysis was made completely independently of ongoing spacecraft imagery. We sometimes seek confirmation of our data in such images, but not the other way round.

### Local activity at *Utopia*, 2013 September

Very early observations showed low resolution. A meaningful search for dust activity was possible only from 2013 September.

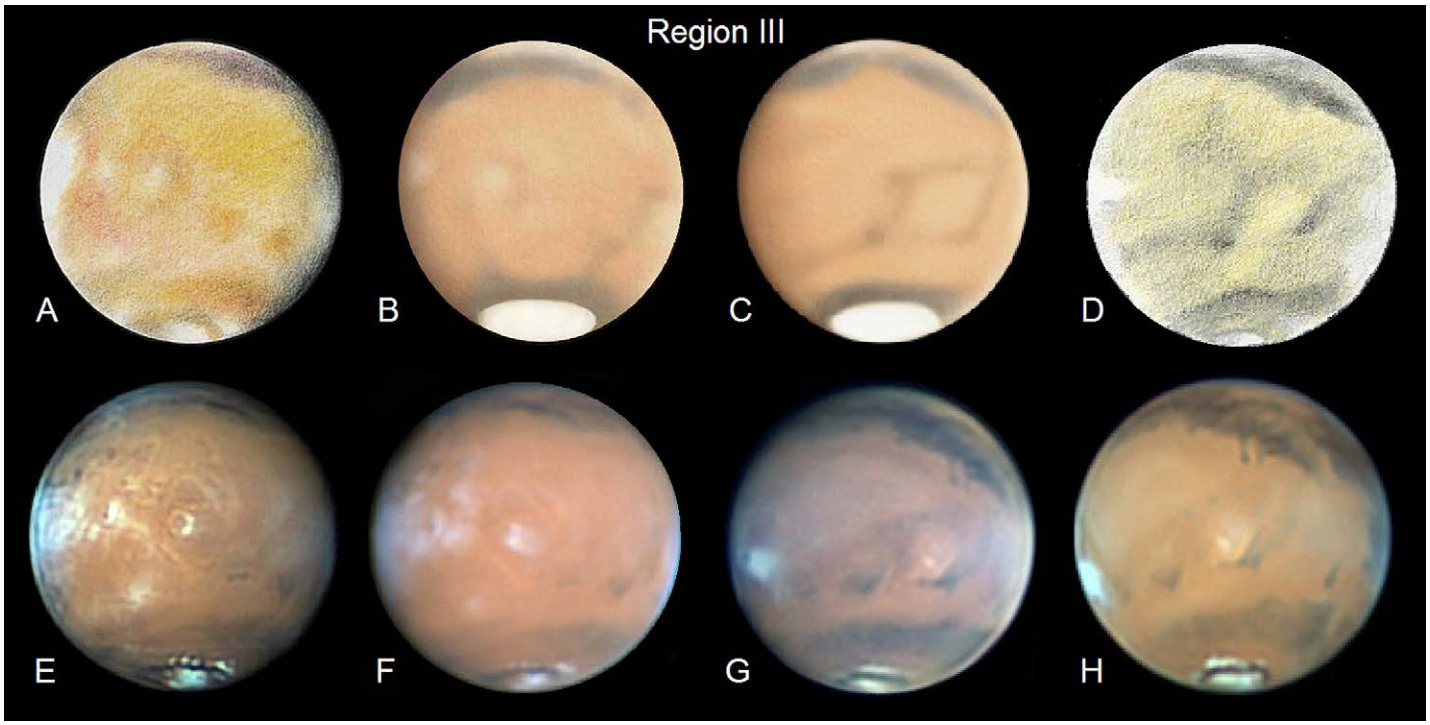


**Figure 4.** Drawings (top row) and images of Region III, λ ~ 130–250°.

**(A)** 2014 Apr 23, 13:45 UT, CM = 150°, 305mm SCT, ×600. Orographics; *Olympia* on the *f.* side of the NPC in (A) and (B). *(R. Konnai)*
**(B)** 2013 Sep 30, 05:35 UT, CM = 152°, 415mm DK Cass., ×535. An early view with weak orographic clouds at *Ascraeus Mons* and *Olympus Mons*. *(D. Gray)*
**(C)** 2013 Sep 26, 05:25 UT, CM = 188°, 415mm DK Cass., ×665. Another early view with the NPC still quite large. *(D. Gray)*
**(D)** 2014 Apr 16, 12:50 UT, CM = 215°, 200mm OG, ×400. *Olympus Mons* orographic cloud. *(M. Adachi)*
**(E)** 2014 Apr 24, 13:25 UT, CM = 136°, 355mm SCT with Flea 3 camera. *Ierne* fragmented (see also (F), with *Olympia* following in (E)–(F)). Orographic clouds, with *Alba* brighter than in (F). *(C. Go)*
**(F)** 2014 Mar 19, 16:45 UT, CM = 140°, 405mm DK Cass. with DMK21AU04 camera. The orographic cloud over *Arsia Mons* is barely visible in (F), and invisible in (E). *(S. Buda)*
**(G)** 2014 Mar 13, 16:40 UT, CM = 192°, 355mm SCT with ASI120MM camera. Very bright evening cloud over *Olympus Mons*, orographic cloud at *Elysium Mons*, and *Olympia* near the CM in (G) and (H). *(P. Miles)*
**(H)** 2014 Apr 15, 13:37 UT, CM = 218°, 305mm refl. with DMK21AU618 camera. *Syrtis* Blue Cloud; W. end of *Olympia* is breaking up. *(M. Justice)*

On 2013 Sep 20 (*Ls* = 024°) Peach imaged a light, round spot over S. *Utopia–Umbra* and just north of *Boreosyrtis* (Ebisawa nomenclature), bright in red and green light: clearly a local dust storm. See Figure 5. (On 2010 Nov 4 (*Ls* = 004°), a similar event had commenced here.[20]) *Nodus Alcyonius* was pale, and was extended to the NE. Two days earlier, Gray showed *Utopia* faded and *Nodus Alcyonius* invisible. On Sep 23–24 the faintness of these features continued, though the light spot had vanished or become diffuse, and *Nodus Alcyonius* remained faint or invisible to Morales. Parker on Sep 26, Hood on Sep 27 and Maxson on Sep 30 caught *Nodus Alcyonius* weakly again, and on Parker's larger image it was still extended to the NE, while *Utopia–Umbra* now looked nearly normal (Figure 5).

On Oct 12–13, Morita produced very good images that revealed *Nodus Alcyonius* too had returned to its pre-storm shape and intensity.

*Nodus Alcyonius* has appeared dark and strongly contrasted at each apparition since 1982, but in 1980 and for a few oppositions immediately beforehand it was faint: it acts as a useful 'litmus test' for dust deposition in the area.

## Activity at *Olympia*, 2014 January–March

The detachment of *Olympia* from the N. polar cap in 2012 was accompanied by local dust activity.[1] This happened again in 2014. First, Hood, Maxson, Morales and Parker showed in January a yellowish streak running SW from the W. end of *Olympia* during Jan 14–20: see Figure 6A. At this time there was a tapering W. 'tail' to the freshly-detached *Olympia*, which would evaporate in due course, not to be confused with a dust streak. The cloud was almost equally well seen in red, green and blue light, so a mixture of dust and white cloud is suggested. The area west of *Olympia* looked quite ill-defined at this time, as though a certain amount of diffuse dust had spread into the atmosphere.

February data reveal a longer and even more obvious dust streak at *Olympia*, first traceable upon the a.m. limb in RGB and infrared images by Wesley on Feb 8. Buda on Feb 9–10 imaged a

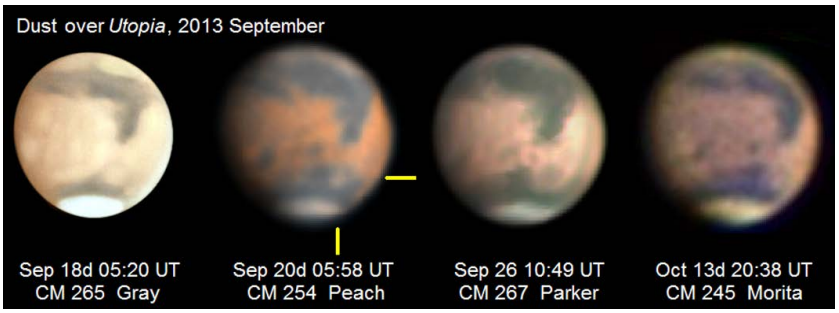


**Figure 5.** A dust storm over *Utopia*, 2013 September, according to D. Gray (415mm DK Cass., ×665), Morita (355mm SCT with Flea 3 camera), D. C. Parker (410mm refl. with ASI120MM camera) and D. A. Peach (355mm SCT with SKYnyx 2-0M camera). Note the bright dust storm (indicated) in S. *Utopia–Umbra* on Sep 20. *Nodus Alcyonius* is weak and distorted Sep 20–26, and fragments of *Nepenthes* may be visible. By Oct 13, the area looks normal again.

narrow but well-defined streak running far to the SW from *Olympia's* E. end. Justice and Valimberti confirmed it on Feb 9 & 11. Again the feature was almost equally well seen in red, green and blue light, and a mixture of dust and white cloud is indicated: see Figure 6B. Arditti and Morales still recorded yellowness and a general loss of contrast on Feb 15–21.

A striking dark-orange storm, obscuring more than one-third of the main body of the N. polar cap's area in the longitudes west of *Olympia*, was obvious upon Buda's Mar 3 images. Under a central meridian (CM) longitude of 305°, it covered the S*p*. part of the cap and the dark band (NPCB) at its edge, with its *f*. (following) end a little west of the CM: see Figure 6C. 'Normal' images for nearly the same *Ls* and CM for 2012 April and 2014 April are provided for comparison in Figure 6C. The beginning of the activity could be traced back to lower-resolution images from about Feb 27. For some days, this part of the cap looked dull, and at low resolution the entire NPC looked anomalous in shape: with *Sinus Sabaeus* crossing the CM the cap appeared to be skewed. Wesley imaged the dusty area with its E. end located at $\lambda \sim 270°$ on Mar 6, when it appeared less dark. Images by Buda and Wesley confirm its fading on Mar 8–9, but Kardasis and Pellier could still trace it on Mar 14 as a coloured patch obscuring the NPCB, and Boudreau on Mar 19 showed it faintly, confined within the cap.

It is worth noting that the area of the cap affected by the March dust activity was the part that was cut off from the main body by a minor rift in April, and which decayed faster than the rest of the cap: see Part II.

Images at the corresponding season in 1999 would have been too low in resolution to easily capture such events.[10]

## A storm over *Valles Marineris*, 2014 June

On Jun 6 (*Ls* = 142°), Milika & Nicholas saw a bright yellow streak running the whole length of *Valles Marineris*: see Figure 7. On the west side, the dust cloud branched around *Aurorae Sinus*, with the north branch obliterating the *Coprates* (IAU)/*Agathodaemon* (Ebisawa) part of *Valles Marineris* and terminating inside *Tithonius Lacus*, with the south branch crossing *Thaumasia* as far as central *Solis Lacus*. Miles and Valimberti had found everything normal on Jun 4 & 5, though on the latter date there was a thin E–W belt of what we take to have been white cloud detached from the S. polar hood, south of *Solis Lacus* (Figure 7). Einaga confirmed the Jun 6 observation, and provided images that showed rapid decay of the event on Jun 7 & 8 (Figure 7). On Jun 7 the dust storm was spilling out of the NE end of the canyon and fading, while immediately to its south there was a remarkably intense E–W dark streak (already partially visible on Jun 6), suggesting a local reduction in atmospheric water vapour. On Jun 8 the storm and the dark E–W streak had faded considerably, but there was more diffuse dust obscuring the markings around its E. limit at *Margaritifer Sinus*.

Around May 31 – Jun 2, as the daily images of Maxson show particularly well, there was a tremendous southward surge of activity from the N. polar region, with a large frontal system of white cloud travelling south and reaching the latitude of *Valles Marineris* at the morning terminator. This front seems to have been the trigger for the dust storm. We have seen past examples of a N. polar front causing a storm, and a *Chryse Planitia* event from 1986 August is a good example.[21]

**Table 2. Observers of Mars, 2014**

| *Name* | *Location* | *Instrument(s)* |
|---|---|---|
| P. G. Abel **V** | Leicester | 203mm refl. |
| | Leicester University Obsy. | 508mm DK Cass. |
| M. Adachi **V** | Otsu, Japan | 310mm refl. |
| | Dynic Obsy., Shiga, Japan | 200mm OG |
| | Kwasan Obsy., Kyoto, Japan | 450mm OG |
| G. Adamoli | Verona, Italy | 235mm SCT |
| L. Aerts | Heist-op-den-Berg, Belgium | 355mm SCT |
| T. Akutsu | Cebu, Philippines | 320mm refl. & 355 mm SCT |
| J. Albert **V** | Lake Worth, FL, USA | 279mm SCT |
| M. Andrews | Laindon, Essex | 279mm SCT |
| D. L. Arditti | Edgware, Middlesex | 355mm SCT |
| K. N. L. Bailey | Swindon, Wilts. | 222mm Cass. |
| T. Barry | Broken Hill, Australia | 406mm refl. |
| D. R. Bates | Houston, TX, USA | 254mm refl. |
| N. D. Biver | Versailles, France | 407mm refl. |
| R. Bosman | Enschede, Netherlands | 355mm SCT |
| J. Boudreau | Saugus, MA, USA | 368mm DK Cass. |
| S. Buda | Melbourne, Australia | 405mm DK Cass. |
| M. Cole | Keighley, Yorks. | 279mm SCT |
| E. Colombo **V** | Gambarana, Italy | 150mm refl. |
| B. Curcic | Melbourne, Australia | 279mm SCT |
| D. G. Daniels **V** | Hampstead Obsy., London | 152mm OG |
| J. Dawson | Nottingham | 279mm SCT |
| P. Edwards | Horsham, W. Sussex | 279mm SCT |
| H. Einaga | Kasai, Hyogo, Japan | 300mm refl. |
| C. Fattinnanzi | Montecassiano, Italy | 250mm refl. |
| W. D. Flanagan | Houston, TX, USA | 355mm SCT |
| C. Foster | Centurion, Gauteng, South Africa | 355mm SCT |
| S. Gale **V** | Landing, NJ, USA | 254mm & 310mm refls. |
| S. Ghomizadeh | Roudehen, Iran | 279mm & 355mm SCT |
| J. Gionis | Breckland AS, Norfolk | 254mm refl. |
| M. Giuntoli **V** | Montecatini Terme, Italy | 80mm & 102mm OGs |
| C. Go | Cebu, Philippines | 355mm SCT |
| E. Grafton | Houston, TX, USA | 355mm SCT |
| D. L. Graham **V** | Barton, Richmond, N. Yorks. | 152mm OG |
| D. Gray **V** | Kirk Merrington, Co. Durham | 415mm DK Cass. |
| R. Haddon **V** | Coventry, Warwicks. | 152mm OG |
| N. J. Haigh | Southampton | 305mm refl. |
| F. Hay | Leamington Spa | 200mm refl. |
| A. W. Heath **V** | Long Eaton, Notts. | 203mm SCT & 254mm refl. |
| C. E. Hernandez **V** | Miami, FL, USA | 229mm MKT |
| R. Hill | Tucson, AZ, USA | 203mm MKT |
| M. Högberg | Örebro, Sweden | 254mm refl. |
| D. A. Holt **V** | Chipping, Herts., | 254mm refl. |
| M. Hood | Kathleen, GA, USA | 200mm OG & 355mm SCT |
| K. C. Howlett | Cwmbran, Gwent & Wroughton, Wilts. | 203mm & 235mm SCT |
| T. Ikemura | Nagoya, Japan | 380mm refl. |
| R. Iwamasa | Yokohama, Japan | 355mm SCT |
| W. Jaeschke | West Chester, PA, USA | 355mm SCT |
| G. Jolly | Gilbert, AZ, USA | 355mm SCT |
| M. Justice | Melbourne, Australia | 305mm refl. |
| M. Kardasis | Athens, Greece | 279mm SCT |
| J. Kazanas | Melbourne, Australia | 318mm refl. |
| A. S. Kidd | Cottered, Herts. | 355mm SCT |
| R. Konnai **V** | Fukushima, Japan | 305mm SCT |
| T. Kumamori | Osaka, Japan | 279mm SCT |
| P. R. Lawrence | Selsey, W. Sussex | 355mm SCT |
| W. J. Leatherbarrow | Sheffield | 300mm MKT |
| M. R. Lewis | St.Albans, Herts. | 444mm refl. |
| R. N. B. Lewis | Cardiff | 254mm SCT |
| P. Lyon **V** | Birmingham | 82mm OG |
| T. McCague **V** | Chicago, IL, USA | 333mm refl. |
| R. J. McKim **V** | Upper Benefield, Northants. | 410mm DK Cass. |
| | Mnichovo Hradiště, Czech Republic | 70mm OG |
| S. Macsymowicz | Ecquevilly, France | 100mm OG & 254mm Cass. |

*Table continuation and explanatory notes on p.49*

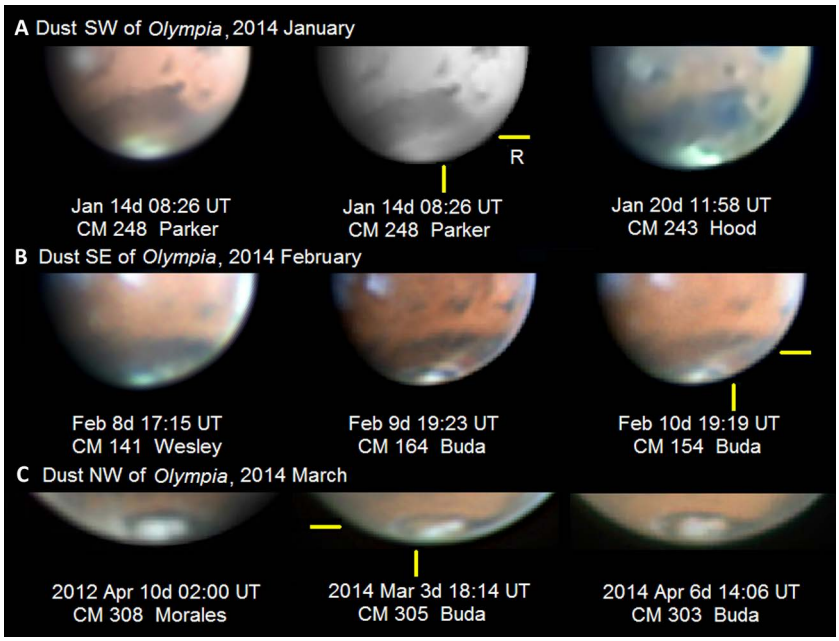


**Figure 6.** Dust activity following the separation of *Olympia* from the N. polar cap.

**(A)** A dust streak (indicated) SW of *Olympia*, 2014 January, according to M. Hood (355mm SCT and ASI120MM camera) and D. C. Parker (410mm refl. and ASI120MM camera).

**(B)** Dust streak (indicated) SE of *Olympia*, 2014 February, according to S. Buda (405mm DK Cass. and DMK21AU04 camera) and A. Wesley (369mm refl. with Grasshopper3 camera).

**(C)** Dust over the cap NW of *Olympia*, 2014 March, according to S. Buda (405mm DK Cass. and DMK21AU04 camera). Normal images from 2012 April and 2014 April are added for comparison.

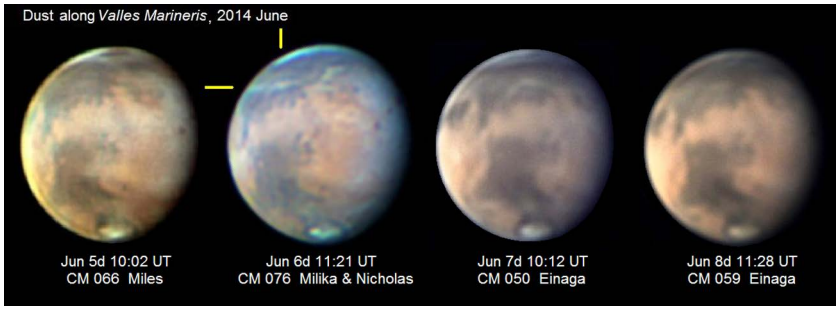


**Figure 7.** A dust storm along *Valles Marineris*, 2014 June, according to H. Einaga (300mm refl. with ASI120MM & MC cameras), P. Miles (355mm SCT and ASI120MM camera) and D. P. Milika & P. Nicholas (355mm SCT and ASI120MM-S camera). On Jun 5 the area looked normal, though there was a bright streak separated from the SPH lying just S. of *Solis Lacus*. Next day a streak of bright dust (indicated) was seen, and on Jun 7 dust was spilling out of the NE end of the canyon, but was already fading. On Jun 8, dust was more diffuse at the E. end of the storm, which was fading further.

## Activity at *Libya–Isidis Regio*, 2014 July

On 2014 Jul 1 (*Ls* = 154°), Foster imaged a yellowish cloud with a sharply-defined eastern boundary over *Libya–Isidis Regio* (*Isidis Planitia*) that had not been present the previous day. The bright, complex nucleus on the E. side was a prominent feature. The Director on Jul 1 could catch the area only upon the *p.* (preceding) limb, when the W. limit was not distinguished from the bright limb. The event was announced in an *e-Bulletin*,[22] as well as an interim report.[13] See Figure 8.

On Jul 2, Foster showed some expansion to the east, but the original nucleus had faded. Olivetti could image the E. end at higher resolution, where the E–W streak of dust was patchy and ended south of *Elysium*, in *Aethiopis*. On Jul 3, the storm looked thinner and very faint when imaged at the CM by Foster. On the same date, Haigh, Macsymowicz and Mercer found the cloud more noticeable towards the evening limb, when the optical density was greater. On Jul 4 Olivetti caught small fingers of dust near the CM at λ ~ 198° in W. and NW *Zephyria*, marking the E. limit. On Jul 5 the original nucleus appeared as a large, ill-defined light orange patch to Abel; Adamoli could see its E. extent, but it was no longer conspicuous. On Jul 6, Foster and Mercer found the storm to have faded out.

Thus the E. limit of the storm moved from λ ~ 249° on Jul 1.722d to λ ~ 198° on Jul 4.552d at latitude ~0°, yielding a typical propagation rate of about 44km/h. (A similar result was obtained for the interval Jul 1–2.)

## Activity in the N. polar hood, 2014 August

There is often dust activity associated with the development of the N. polar hood, as discussed in some past reports. On Aug 9 (*Ls* = 175°) Maxson caught what appear to have been two bright cores of a storm, NE and NW of *Mare Acidalium*: these clouds were seen well in the near-infrared, red and green, but less well in blue light; dust must therefore have been the main component. See Figure 9A. The W. storm nucleus was considerably brighter on Aug 10, but no trace of activity was seen in the following days.

## Activity in NW *Hellas*, 2014 August

A short-lived dust cloud appeared close to the NW corner of the *Hellas* basin on 2014 Aug 27, its W. limit being marginally outside the basin. This event was discovered and systematically pursued solely by Valimberti up till Aug 30, by which time it was diffused and dying out.[13] Starting at *Ls* = 185°, this corresponds to early spring in the southern hemisphere. See Figure 9B.

## Activity at *Chryse Planitia*, 2014 October

On Oct 6 (*Ls* = 209°) Foster captured the start of a dust storm in *Chryse Planitia*.[13] This striking bright yellow cloud had not been present on Oct 5: see Figure 10.

On Oct 7–8 the original cloud was hardly visible, but dust was seen to have moved south to become a Regional event obscuring the central part of *Valles Marineris*, and north to obscure parts of *Mare Acidalium*.

## Activity at *Libya–Isidis Regio* and *Hellas* to *Argyre*, 2014 October–November

Foster imaged a second event commencing in *Libya–Isidis Regio* on Oct 17 (*Ls* = 216°),[13] which was much brighter the following day when it showed two nuclei. His images show that at the same time dust broke out from *Hellas* in a NW direction across *Iapigia*, and across *Mare Hadriacum* into *Ausonia*; on the same date Adamoli remarked upon the loss of the boundary between *Hellas* and *Ausonia*.[13] The secondary activity in *Hellas* made this into a Regional event: see Figure 11. On Oct 20 Foster's images showed a patchy structure to the *Hellas* dust, and activity propagating east, northwest and west. After a short gap in the observations,

Foster on Oct 25–27 recorded dust – now pale – from near the CM (λ ~ 214°) to the morning terminator, over *Eridania–Ausonia–Hellas*. Dust did not spread any further east.

Foster could not watch the dust spreading west from *Hellas* as the area was becoming lost at the morning terminator; there were few other observers now. However, on Nov 10, Milika & Nicholas clearly imaged a darkened *Pandorae Fretum* (which until then had been thin and almost invisible); *Mare Serpentis* looked broader and darker, while *Hellas* still looked bright dusty yellow. Foster confirmed these aspects on Nov 14–20; the images show a little dust near the S. polar cap south of *Noachis*. To Foster on Nov 26 *Hellas* had become dull, comparable to the equatorial deserts, with all activity finished. *Pandorae Fretum* was quite obvious in December, and was still detectable as late as 2015 Mar 8.

The activity had reached as far west as *Argyre*: upon the evening limb on Oct 28 Barry found this area brighter and strongly yellow. As soon as he could observe that longitude from Nov 7 onwards, Foster too found the basin bright and yellowish, an appearance remaining till Nov 18 by which time it had greatly faded. Previous events demonstrate that *Argyre* often develops a secondary dust core during *Hellas* events: for example in 1988 June.[23] The darkening of *Pandorae Fretum* during *Hellas* Regional storms is now well established.

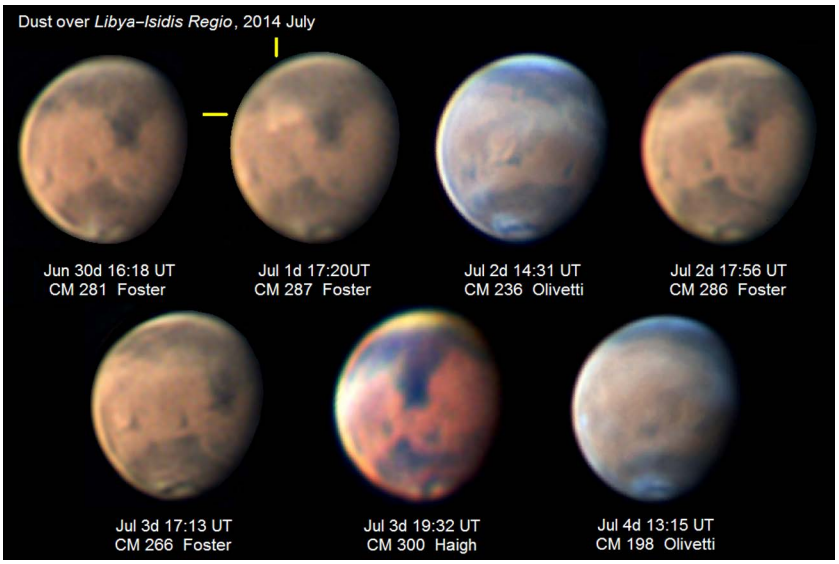


**Figure 8.** A dust storm starting in *Libya/Isidis Regio*, 2014 July, according to C. Foster (355mm SCT and ASI120MC camera), N. Haigh (305mm refl. and ASI120MM camera) and T. Olivetti (410mm DK Cass. and Flea3 ICX618 camera). The bright core of Jul 1 extended rapidly to the east, but quickly faded on Jul 2 and later. On Jul 4, traces of dust had reached W. and NW *Zephyria*, but the bluish-white area towards the morning terminator on that date is white cloud, not dust.

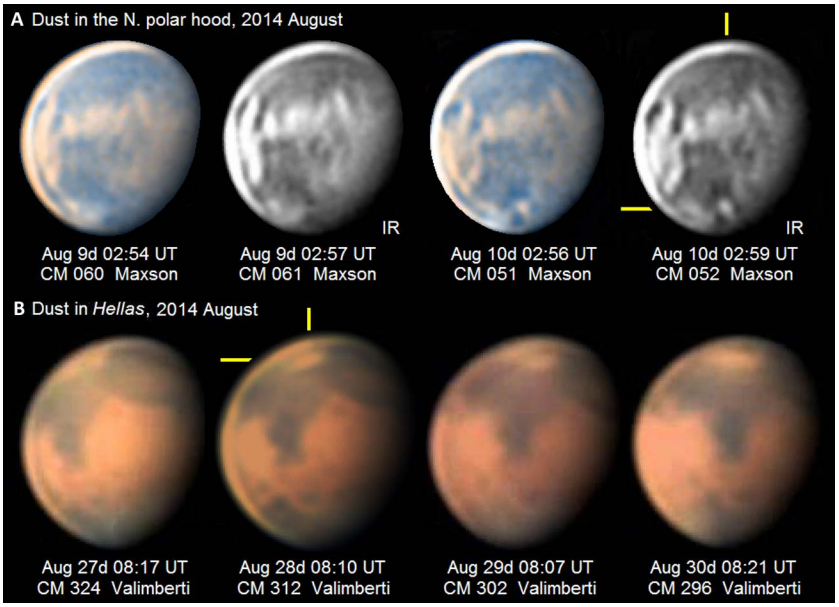


**Figure 9.** Dust activity in 2014 August. The dust is indicated. **(A)** Dust in the N. polar hood, according to P. W. Maxson (355mm SCT with ASI120MM-S camera). **(B)** A post-opposition dust storm in NW *Hellas*, according to M. P. Valimberti (355mm SCT with ASI120MM camera).

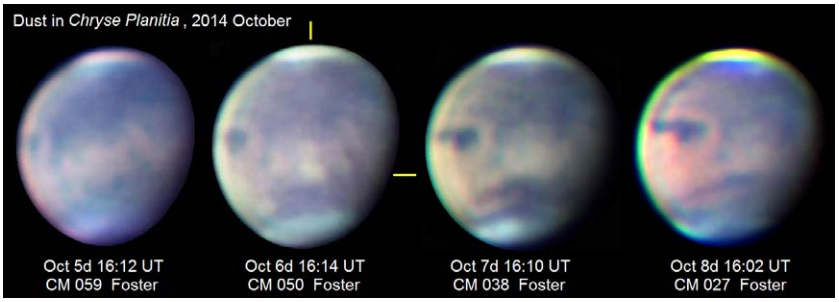


**Figure 10.** Post-opposition dust storm in *Chryse*, 2014 October, according to C. Foster (355mm SCT with ASI120MC camera). The dust outburst in *Chryse* on Oct 6 is indicated. On Oct 7–8 the original source had faded, but dust moved south over the central part of *Valles Marineris*, and north to obscure parts of *Mare Acidalium*.

## Dust storm patrol, 2014 November – 2015 April

Perihelion was reached on 2014 Dec 10, and the start of southern summer on 2015 Jan 11. The seasonally latest-known encircling dust storm had begun (during 1924–'25) at *Ls* = 311° in southern midsummer.[24] This seasonal point was reached on 2015 Mar 19, nearly an entire terrestrial year beyond the date of opposition.

A number of observers were able to frequently monitor the planet's shrinking sub-6″ disc for many months. That the unlikely goal of checking the planet up to and slightly beyond *Ls* = 311° was achieved – even getting fairly good coverage until 2015 Apr 15 – was largely due to the imaging efforts of Foster and the visual work of Adamoli (with Milika & Nicholas and Morita being the only others still observing in November). There was definitely no encircling event during 2014–'15 (MY 32), for during this late epoch our observers recorded only the finale of the 2014 November Regional *Hellas* event detailed above: the albedo markings continued to stand out clearly. The planet's disc diameter had fallen to only 3.9″ at the end of the apparition, and a Regional event could probably not have been detected. On Apr 15, Adamoli had a surprisingly sharp eyepiece view of *Sinus Sabaeus–Meridiani Sinus*. Some of the very late images are illustrated in Part II, Figure 16.

It was interesting to look at spacecraft weather reports to see what low resolution may have prevented us seeing. During 2015 March, MRO and *Mars Express* data revealed a southern Regional storm that affected the longitudes from *Hellas* through

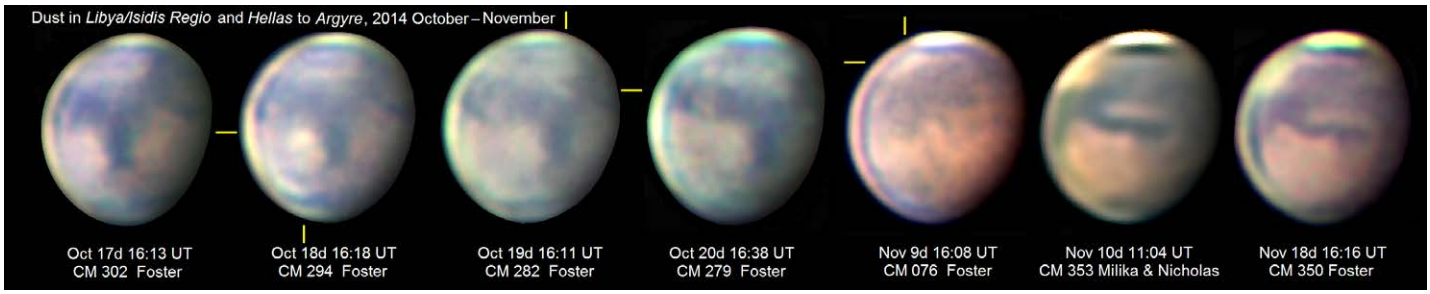


**Figure 11.** Post-opposition dust storm phenomena, 2014 October–November, in *Libya/Isidis Regio* and *Hellas*, according to C. Foster (355mm SCT and ASI120MC camera) and D. Milika & P. Nicholas (355mm SCT and ASI120MM-S camera). Dust in *Libya/Isidis Regio* arose on Oct 17 and its location is indicated for Oct 18. Dust spilled out of NW *Hellas* (indicated on Oct 19) into *Iapigia* and across *Mare Hadriacum*. The Nov 9 image shows bright yellow dust over *Argyre*; that for Nov 18 shows dust at high southern latitude near the SPC and those for Nov 10 & 18 feature the darkening of *Pandorae Fretum*. (The Nov 9 & 18 images show a processing artefact at the limb, but at $D = 5.4''$ represent remarkable technical achievements.)

*Ausonia* during Mar 13 ($Ls$ = 307° ) to 15, with dust propagating eastward into *Phaethontis–Electris* by Mar 21.[25] Dust-lifting south of *Hellas* continued for a few days into the following week, with typical dusty haze at high southern latitudes. There were also a number of local storms moving south from *Mare Acidalium* into *Chryse* and E. *Valles Marineris* in that week. *Solis Lacus*, *Argyre* and *Margaritifer Sinus* were affected by the latter activity as it became Regional.[26]

We can interpret Foster's images more clearly with the benefit of hindsight. At the time they looked more or less normal for the disc diameter and seeing, but it is now evident that his red and infrared images of Mar 15–16 show *Ausonia* lighter than *Hellas*, even though there was no physical connection or anomaly. *Mare Sirenum* could be identified on Mar 26, but on Apr 6 under CM = 042°, *Margaritifer Sinus* is not resolved while *Thaumasia* looks bland; *Sinus Meridiani* may be normal. On Apr 13 under CM = 333° the southern hemisphere looks blurred in general, but *Syrtis Major* is clear enough and *Hellespontus* faint; significantly, *Sinus Sabaeus* is dark only in the E. part and *Mare Serpentis* looks to be further broadened. However, it is clear from the spacecraft data that this activity was seasonally too late in starting to have attained 'encircling' status.

## General discussion

Increased resolution has shown that dust activity was coincident with the separation of the outlier *Olympia* from the N. polar cap in both 2012 and 2014.

Historically, in a review of all observations of dust storms up to 1993,[27] the author found that the *Libya–Isidis Regio* emergence site was active between $Ls$ = 171–034°, so the 2014 October event ($Ls$ = 216°) fits the pattern well. However, the 2014 July storm ($Ls$ = 154°) was seasonally early. We have already written that this emergence site was the most frequently active of all sites until the 1960s,[18,19] and then became inactive for a long time.

During 2014 there were a number of events at the NW side of *Hellas*, at $Ls$ = 185 & 217°. History shows that *Hellas* is typically active (counting only Regional or larger events) between $Ls$ = 163–331°.[28]

No encircling storm was seen to arise during southern spring or summer during 2014–'15 (MY 32). However, a large Regional event did begin on 2015 Mar 13 at $Ls$ = 307°, of which a few confirmatory indications were noticed upon our ground-based images. The previous encircling event occurred as long ago as 2007 (MY 28).

## Table 2. Observers of Mars, 2014 (Cont'd from p.46)

| *Name* | *Location* | *Instrument(s)* |
|---|---|---|
| S. Massey | Hervey Bay, Queensland, Australia | 305mm refl. |
| P. W. Maxson | Surprise, AZ, USA | 250mm DK Cass. & 355mm SCT |
| F. J. Melillo | Holtsville, NY, USA | 254mm SCT |
| J. Melka | Chesterfield, MO, USA | 457mm refl. |
| L. E. Mercer | Malta | 279mm SCT |
| P. Miles | Rubyvale, Queensland, Australia | 355mm SCT |
| D. P. Milika & P. Nicholas | Adelaide, Australia | 355mm SCT |
| M. Minami **V** | Fukui City Obsy., Japan | 200mm OG |
| M. P. Mobberley | Bury St. Edmunds, Suffolk | 300mm refl. |
| E. Morales | Aguadilla, Puerto Rico | 310mm SCT |
| Y. Morita | Hiroshima, Japan | 355mm SCT |
| P. U. Neville **V** | Maidenhead, Berks. | 102mm & 152mm OGs |
| D. Niechoy **V** | Göttingen, Germany | 203mm SCT |
| G. Okša **V** | Nitra, Slovak Republic | 180mm MKT |
| T. Olivetti | Bangkok, Thailand | 410mm DK Cass. |
| D. C. Parker | Miami, FL, USA | 355mm SCT & 410mm refl. |
| D. A. Peach | Selsey, W. Sussex | 355mm SCT |
| C. E. Pellier (with M. Delcroix & F. Colas) | Paris, France<br>Pic du Midi Obsy. | 250mm Gregorian<br>1.06m Cass. |
| J. H. Phillips | Charleston, SC, USA | 254mm MKT |
| J-J. Poupeau | Pecqueuse, France | 350mm Cass. |
| A. R. Pratt | Leeds | 203mm MKT |
| Z. Pujic | Brisbane, Australia | 310mm refl. |
| J. R. Sánchez | Córdoba, Spain | 279mm SCT |
| D. Scanlan | Romsey, Hants. | 203mm SCT |
| R. W. Schmude | Barnesville, GA, USA | 90mm MKT |
| K. Smet **V** | Bornem, Belgium | 305mm refl. |
| J. Sussenbach | Houten, Netherlands | 279mm SCT |
| R. Tatum | Henrico, VA, USA | 305mm SCT |
| D. B. V. Tyler | Flackwell Heath, Bucks. | 355mm SCT |
| M. P. Valimberti | Melbourne, Australia | 355mm SCT |
| D. Vidican **V** | Bacau, Romania | 150mm refl. |
| G. Walker | Macon, GA, USA | 254mm OG |
| J. Warell | Skivarp, Sweden | 220mm refl. |
| D. Weldrake | Bungendore, NSW, Australia | 130mm OG |
| A. Wesley | Murrumbateman, NSW, Australia | 369mm refl. |
| F. Willems | Saint Johns, FL, USA | 355mm SCT |
| J. Willinghan | Elkridge, Maryland, USA | 305mm SCT |
| K. Yunoki | Osaka, Japan | 260mm refl. |

*Abbreviations*: OG = object glass (refractor); refl. = reflector; Cass. = Cassegrain; DK = Dall–Kirkham; MKT = Maksutov–Cassegrain and SCT = Schmidt–Cassegrain (Telescope).

All observers sent images except those marked **V** (for visual observations *only*).

## Terminator projections

Observers carefully scrutinised the SW part of the post-opposition morning terminator. Nothing was seen of the remarkable events seen in 2012.[1,29] In 2015 March, NASA announced that one of the MAVEN instruments had detected the presence of dust at altitudes of 150–300 km,[27] that it had been present 'the whole time MAVEN has been in operation' and that 'no known process on Mars can explain the appearance of dust in the observed locations'. Dust at altitudes of up to 260 ± 50km was associated with the terminator projections of 2012.[1,29] The spacecraft also made important discoveries concerning the martian ultraviolet aurorae.[30]

A small, bright projection was imaged over the *p*. limb on Apr 7, 8 (opposition) & 9 by Pellier, located against the NE tip of *Margaritifer Sinus* in *Aram*/S. *Thymiamata*. It was brightest in green and blue light and lay at the S. edge of the latitude range of the Equatorial Cloud Band, so we assume it was a high-altitude white cloud: see Part II. The projection effect was most notable on Apr 8, around 00:16 UT (CM = 083°).

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### Erratum

In the 2012 Mars report, Part 1,[1] an incorrect caption for Figure 1 was substituted [by editorial error] at the proof stage. However, the published map is the correct one for the 2012 opposition.

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15 Schmude R. W., 'Some recent studies of Mars: the North Polar Cap, *Cecropia* and *Hellas*', *Georgia Journal of Science*, **72**(2), 109–119 (2014)
16 MAVEN was launched on 2013 Nov 18 and reached Mars orbit on 2014 Sep 21. Its aim is to explore the planet's upper atmosphere, ionosphere and interactions with the Sun and solar wind, as well as to determine the rate of loss of its atmosphere. The NASA MAVEN website is found at: **https://www.nasa.gov/mission_pages/maven/main/index.html**.
17 The Indian Space Research Organisation's craft – *Mangalyaan*, launched on 2013 Nov 5 and reaching Mars orbit on 2014 Sep 24 – has so far been the cheapest successful mission to fly. *Mangalyaan* has a methane detector and other instruments on board and was expected to function for at least six months, but the mission was later extended. For a short overview see: **https://www.space.com/30633-india-mars-orbiter-mission-anniversary.html**. A downloadable atlas of the first year's results may be found at: **http://www.isro.gov.in/pslv-c25-mars-orbiter-mission/celebrating-one-year-of-mars-orbiter-mission-orbit-release-of-mars**.
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