The opposition of Mars, 2010: Part II

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A Report of the Mars Section. Director: R. J. McKim

In Part II we discuss white clouds and the polar regions. The equatorial cloud band (ECB) was well observed from Ls= 001° onward. The behaviour of the orographic clouds over the great volcanoes was seasonally normal, in the absence of any large dust disturbance. We saw the *Tharsis* orographics from Ls= 011°, and the *Olympus Mons* orographic from Ls= 019°. As with the ECB, observations did not continue late enough to establish their seasonal decline. The 2009–'10 N. polar cap recession was followed in detail nearly as far as the summer remnant stage. The recession curve closely agreed with aphelic oppositions from recent decades, but a small increase in size compared with 2007–'08 was suggested during Ls ~45–70°, in the period immediately after a significant polar dust storm. At most seasonal dates the 2010 cap was either exactly the same size or marginally larger than in 2008. The seasonal separation of *Olympia* was complete at Ls= 74°, which was slightly later than usual (including recent aphelic oppositions), which is in accordance with a marginally retarded recession.

White clouds and blue-violet light phenomena

Part I of this report[35] described atmospheric dust activity and its effects upon surface features and the N. polar cap. (Numbering of figures, references and tables runs on consecutively from Part I.) As in 2005 and 2007, we only attempt to discuss those aspects of the white crystal clouds that enable us to check well-established seasonal patterns. Figure 11 shows the planet near opposition and indicates the positions of the volcanoes referred to in this part.

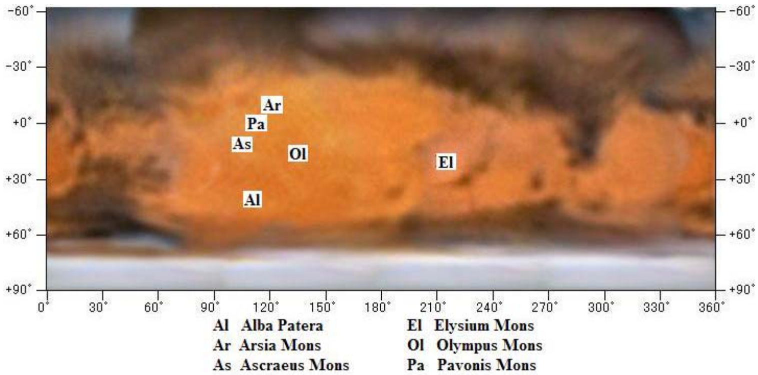

Figure 11. Map of Mars from his best near-opposition images with 203mm DK Cass. and DM21AF04 camera, 2010 Jan 5–Feb 13, *Teruaki Kumamori*. Simple cylindrical projection, with latitude and longitude indicated. The positions of the volcanoes referred to in the text are marked.

White: Visual measurement of the proper motions of stars using an undriven 250mm telescope (conclusion)

Milky Way, albeit in an apparent plane that is oblique to the plane of the Galaxy.

For Groombridge 1830 however, converting its proper motion to Galactic co-ordinates shows that its galactic longitude is decreasing with time and its galactic latitude is increasing with time. This is because Groombridge 1830 is a star belonging to the galactic halo, and is moving in the general direction out of the galactic plane. Moreover, the Sun is passing it by on an orbit that is closer in to the galactic centre than that of Groombridge 1830, therefore the latter displays a kind of retrograde motion when viewed from our vantage point. In other words, a significant component of its proper motion is the result of the motion of the Sun around the centre of the Galaxy.

A small number of other stars, such as μ Cas and o^2 Eri, are bright enough and have large enough proper motions that amateur astronomers can measure them visually over a reasonably short period of time. Measuring the proper motion of such stars is straightforward and requires only a few hours of effort, a few times per year, over one or two years. Results can be rewarding in the sense that they provide a 'direct experience' of solar and stellar motion around the centre of the Galaxy, and because they provide an insight into the observing skill of those early observers of proper motion.

Table 4. Proper motion data for 61 Cygni & Groombridge 1830

Professional data shown in Table 1 compared with the measurements

Target star	Δ(RA) per year (arcsec) Table 1	Δ(RA) per year (arcsec) Measured	Δ(Dec) per year (arcsec) Table 1	Δ(Dec) per year (arcsec) Measured
61 Cygni	4.133	4.2±1.4	3.202	3.7±3.7
Groombridge 1830	4.004	4.8±1.0	−5.814	−4.9±3.2

Acknowledgments

The author is grateful to the referees for their useful and constructive comments during the production of this article.

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References

1 E. Halley, *Phil. Trans. R. Soc.* Vol. **30**, p.736 (1717)
2 G. Piazzi, *Libro sesto del Reale Osserv. di Palermo*, p.30 (1806)
3 F. W. Argelander, *Astron. Nachr.* Nr. **475**, p.314 (1843)

Received 2017 August 27; accepted 2017 October 25

Equatorial Cloud Band (ECB)

The first sign of an incomplete ECB, when the *Xanthe* white evening cloud became drawn out in the *f.* direction, was due to Minami on 2009 Oct 28 (Ls= 001°) and 29, *etc*. In the longitude of *Chryse* (Oct–Dec) Minami found that the ECB developed each Sol from around CM= 55°. This commencement accords perfectly with spacecraft data, which established that the ECB begins to be visible from Ls~ 0°, but is never complete or conspicuous before Ls~ 50°. ECB continued sporadically and incompletely in the above manner for some months, particularly across *Chryse–Xanthe* and from *Elysium* through *Aethiopis* to *Isidis Regio–Libya*. In Figure 12 we have shown the progressive development of the ECB over two selected regions of longitude. ECB can also be seen in some other Figures (Parts 1 and 2).

Figure 13. The *Syrtis* Blue Cloud according to RGB images by Delcroix (Lumenera SkyNyx 2-0M camera), D. C. Parker (410mm refl., SkyNyx 2-0M) and Peach (SkyNyx 2-0M). (For other telescope details see Part I, Table 2.)

Under CM= 169° on 2010 Jan 23, Parker saw the ECB very nearly complete in UV light. On 2010 Jan 25, at Ls= 43° according to Lawrence's RGB images, the *Xanthe* evening cloud was extended along the equator to the morning *Tharsis*, so this was the first real sign of complete ECB, albeit faintly. Likewise in the blue images by Peach on Jan 26/27. Macsymowicz on Jan 29 (Part I, Figure 3) also saw the ECB complete, as did Flanagan on Feb 7 (CM ~50°), and there were other confirmations. The ECB looked complete even in a RGB composite image by M. R. Lewis on Feb 9 (CM= 284°), as it seemed to faintly cross *Syrtis Major*. Minami on Feb 13 found the *Xanthe* evening cloud part of the ECB now as bright as the NPC.

However, upon mid-disk during Feb–Mar the ECB was still not fully complete at all CML. McKim saw the ECB complete at CM= 96–104° on Feb 26 and at CM= 52° on Mar 1, but on Mar 4–7 noticed it only on the morning side under CML= 13–18°, while it remained weak or incomplete to him under CML= 300–312° on Mar 11–15. D. C. Parker's March data show it was seen at some longitudes but not others: on Mar 1 (CM= 225°) he showed it largely complete, but incomplete on Mar 15–25 (CM= 286–017°), and complete again on Mar 28 (CM= 258–264°). Minami felt that the ECB had become fully developed during Mar 30 (Ls= 71°) to Apr 3, and D. C. Parker's images from Apr 3 onwards do not disagree.

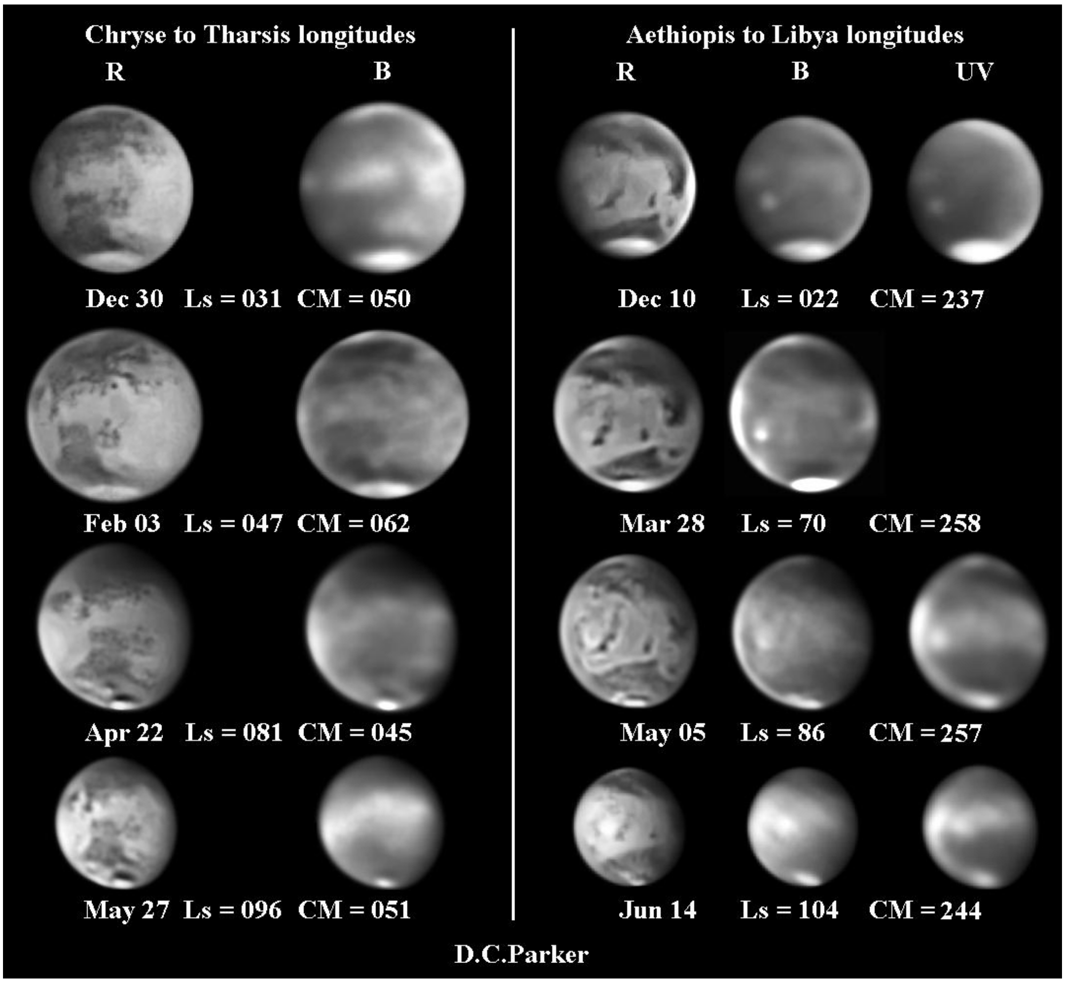

Figure 12. The development of the Equatorial Cloud Belt over two selected regions of longitude, 2009–'10, according to comparative images by D. C. Parker (410mm refl., Lumenera SkyNyx 2-0M camera) with 625nm red (125nm BWHM), 480nm blue (135nm BWHM) and 365mm ultraviolet (60nm BWHM) *Astrodon* filters. *Note*: All illustrations have south uppermost unless otherwise stated.

Thus the first sign of complete ECB was at Ls= 43°, in precise accord with our result for 2007.[27]

Delcroix on Apr 24 (Ls= 82°) noticed that a faint ECB ran across and dimmed the obviously bluish *Syrtis Major* at the CM, and Abel also recorded this several times. (Coincidentally, equatorial cloud crossing and veiling the *Syrtis* was first noticed in the Mars Section on 1901 Mar 28 (Ls= 83°) by Dr W. A. Kibbler and at the next opposition on 1903 May 23 (Ls= 128°) by W. F. Denning, and a later example from the pre-CCD age is from 1967 Jun 3–7 (Ls= 144–146°), due to J. H. Botham and M. J. Gainsford.)[36]

The ECB was still being detected as late as May. McKim saw it complete on May 12–21, as did D. C. Parker on May 27: the ECB was particularly conspicuous in the near-UV images which Parker secured with the *Astrodon* λ= 480nm filter. Others confirmed these records, and Minami could still see it complete on Jun 11 (CM= 68°), as could Parker on Jun 14 (CM= 244°). We can say that it persisted at least as late as Jul 21 (Morita, Ls= 121°), but its eventual seasonal demise could not be followed.

The Syrtis Blue Cloud

See Figure 13. The morning version of the so-called *Syrtis* Blue Cloud was first apparent to Akutsu and Morita, 2009 Oct 15 and to Arditti, Nov 2, when the rising *Syrtis Major* looked bluish or greenish. (This effect is due to the scattering of shorter wavelengths by the presence of light a.m. clouds extending over the *Syrtis* and the neighbouring regions *Isidis Regio–Libya* and/or *Aeria*.)

The effect was long-enduring upon the morning side, obviously being related to the presence of the ECB, and it continued through opposition. To the writer on 2010 Jan 3 the *Syrtis* was very blue at the morning limb. Minami saw it 'sky blue' as it moved clear of morning cloud, Jan 26–31. Akutsu and Peach saw the same effect on Jan 31–Feb 2, as did the writer on Feb 9. It continued longer, but there were odd occasions where the cloud was *not* observed. On Apr 24 the phenomenon was obvious to Delcroix even at the CM, when the *Syrtis* was dimmed slightly (see the previous section and Figure 13). D. C. Parker still showed it on May 5 and Jun 14, as did Morita as late as Aug 1, by which time the disk was tiny.

On 2010 Jan 2 Pellier saw evening cloud over *Libya* invading the *Syrtis Major*, as Phillips confirmed on Jan 9. This gave rise to the *Syrtis* Blue Cloud on the evening side, which McKim, Peach and others confirmed on Jan 29–31. This was the period when the ECB was becoming complete. The evening *Syrtis* Blue Cloud continued to be well seen in February and March, when the evening cloud was thick enough to hide the *Syrtis* close to the limb. The Director saw the effect extremely well again on the evening side on Mar 11, and could still see it on Apr 26.

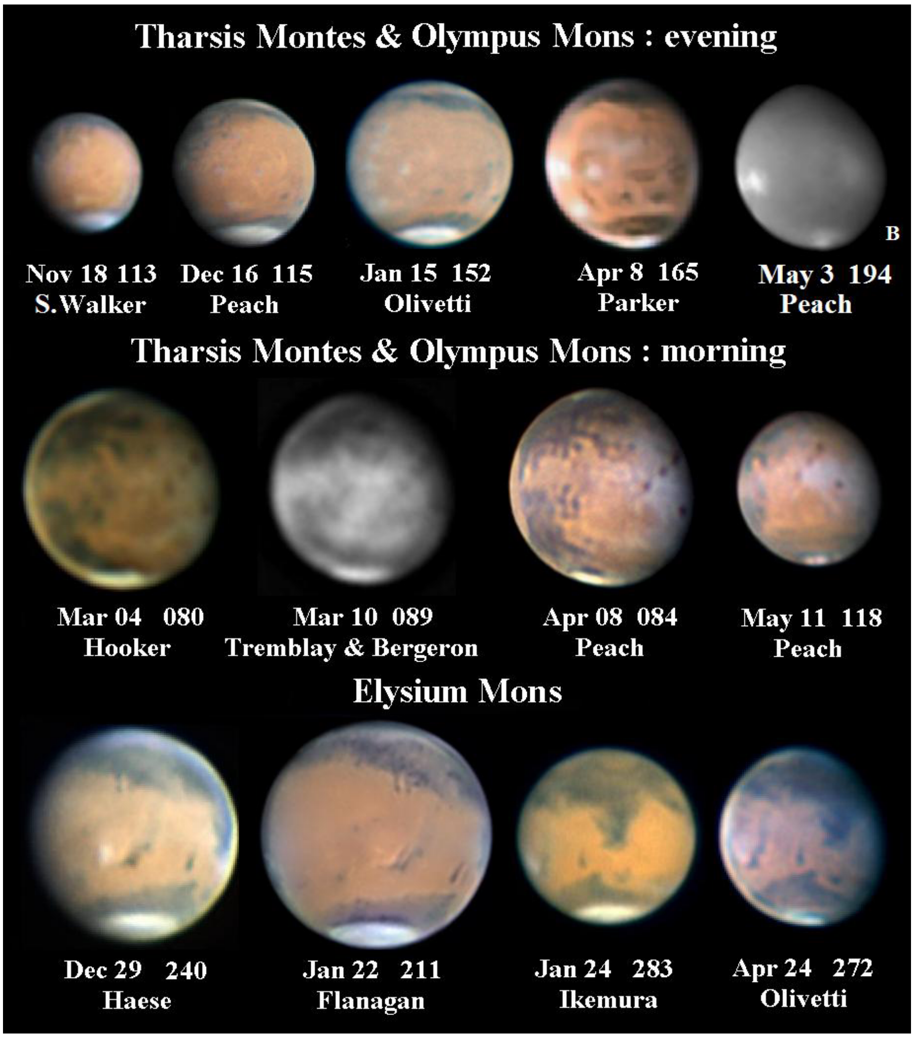

Figure 14. Aspects of the martian volcanoes according to images by Flanagan (Lumenera LU-075M camera), Haese (Lumenera SkyNyx 2-0), Hooker (DMK 21AU04.AS), Ikemura (ToUcam-Pro), Olivetti (Lumenera LU075M), D. C. Parker (254mm DK Cass., SkyNyx 2-0), Peach (RGB or B filter, SkyNyx 2-0), Tremblay & Bergeron (SkyNyx 2.1 monochrome) and S. Walker (DMK21AU04.AS).

Orographic clouds

The evening Tharsis Montes, Olympus Mons, Alba Patera and Elysium Mons

See Figure 11 for a location chart. See Figure 14, and Part I Figures 2, 4 and 5, for typical views. Orographic clouds associated with these features can be observed in the evening (and sometimes afternoon) depending upon the time of the martian year. The seasonal beginning of evening cloud over *Arsia Mons* was first observed for certain by Poupeau on Aug 23 (Ls= 326°). In 2007 the seasonal commencement was at Ls= 333°.[27]

Orographic clouds over the other two *Tharsis Montes* (*Ascraeus* and *Pavonis Montes*) begin seasonally later on account of their lower latitude, being first detected by S. Walker on 2009 Nov 18 (Ls= 011°), when orographic cloud over the evening *Alba Patera* was also seen. At the last apparition the corresponding date was 2007 Dec 1 for *Ascraeus* and *Pavonis Montes* (or Ls= 356°). In 2007 the *Alba Patera* orographic had arrived a trifle earlier (at Ls= 355°): it was seen at the CM by D. C. Parker on 2010 Jan 31, and remained bright in the evenings till April.

Evening cloud over *Olympus Mons* appeared slightly later, first sighted by Akutsu on 2009 Dec 3 (Ls= 19°). (In 2007: Ls= 354°.) The cloud would not reach its peak seasonal intensity for many months, and it can never be well observed long after opposition (see below), so it was not as prominent as in some past oppositions.

Evening cloud over *Elysium Mons* was active according to Poupeau from 2009 Dec 7 (Ls= 20°), and it was visible from early afternoon by 2010 January. In contrast, the whole of *Elysium* was light, covered by morning cloud upon the limb in Sep–Dec. The *Elysium Mons* orographic continued to be visible in February and March but only right at the evening limb, and it was not exceptionally bright. On Apr 26 Peach showed it very weak, but it was brighter in early June to him, and to D. C. Parker on May 5.

By opposition time all of the orographic clouds were excellently placed for observation, and they were very conspicuous on account of the release of water vapour from the shrinking NPC. Many images portrayed intricate details, such as those recorded by Peach on Dec 16 (Figure 14, and Part I, Figure 8).

After opposition the situation was less favourable from an observational viewpoint, as the sunset terminator vanished behind the evening limb and we could only catch the clouds brightening in early afternoon. Minami could still see the *Olympus Mons* orographic on 2010 Apr 24–25, but now sightings were difficult. Caught at the right moment, the cloud was still *very* conspicuous, as in Peach's images of May 3–4 (Figure 14) at Ls= 86°. According to Smith & Smith,[37] *Olympus Mons* reaches its most active state during Ls= 90–130°. Morita caught it upon the limb (local early afternoon) as late as May 31 (Ls= 98°), as did Morales Rivera on Jun 17 (Ls= 106°).

On Apr 8 D. C. Parker's images still showed the afternoon clouds over *Alba Patera* and *Ascraeus Mons* (alone of the *Tharsis Montes*). Peach was again able to catch the *Ascraeus Mons* orographic right on the limb on May 3–4. The *Alba* evening cloud had last been observed by Morita on Apr 25. *Elysium Mons* was still being imaged in the evening by Peach on Jun 2–3, though it was past its seasonal maximum brightness by then.

Difficulties with comparative meteorology: a résumé

The Central Meridian only corresponds to local noon for the longitude at the centre of the disk at opposition. If we want to compare the meteorological situation at say *Olympus Mons* (λ= 133°) over the course of the apparition *at the same time of the martian day*, we must allow for the variation in the phase angle, *i*. The phase angle and fractional phase are related:

$$\text{Phase} = 0.5\,(1 + \cos i)$$

Suppose we consider two dates either side of opposition (2010 Jan 29) when *i*= 15° and the corresponding fractional phase is 0.983. The condition is met on 2010 Jan 13 and Feb 15. Seen from Earth on the first date the actual noon meridian lies 15° to the *west* of the CM, while on the second, 15° to the *east*. To compare the volcano's cloud coverage at 1 p.m. local martian time on each Sol, images taken at CM= 118, 133 and 148° will be needed on Jan 13, Jan 29 (opposition) and Feb 15 respectively.

The post-opposition approach of the noon meridian towards the evening terminator frustrates any campaign to follow the orographic clouds into the late afternoon and evening. On 2010 May 14 the phase reaches a minimum of 0.897, for which *i*= 37.4°, so to examine the situation at 1 p.m. local martian time we need to find an image taken at CML= 170°. As D= 6.4" on this date, any orographic cloud will be challenging to record even in the early afternoon, and will be close to the *p*. limb. To witness the cloud's behaviour much later in the day is impossible. Pre-opposition, a minimum phase of 0.884 was reached on 2009 Oct 6, with *i*= 39.8°, corresponding to a required image taken at CML= 93°. Recalling that sin 30°= 0.5, on this image the volcano will actually be over halfway towards the *following* limb.

Thus the extreme range in required CML varies (in 2009–'10) from 93 to 170°, which is much larger than would have been estimated without calculation. The foregoing provides further evidence of why a picture of annual activity on Mars can be built up only over years of ground-based study.

Opposition brightening of the volcanoes

An 'opposition brightening' should be observable for the calderas of these volcanoes (which would be nearly cloud-free near the CM), about a week either side of opposition (Jan 29). For *Olympus Mons* the Americas would be best-placed for observation, and although in practice extreme weather conditions reduced the number of suitable records, on Jan 29 Hernandez visually recorded its unclouded caldera looking bright near the CM. Peach had found it brightened on the a.m. side even in red light on Jan 27 under CM= 68–73°, but not yet on Jan 23, even at CM= 84°. Kivits found it rather bright in the morning (RGB) on Jan 27; Lawrence on Jan 25 and 26, Tyler on Jan 26, while Phillips and G. Walker on Jan 28 found it only slight whitish in the morning. Melillo (Part I, Figure 5) and Morales Rivera on Jan 27, and Maxson on Jan 30 show it whitish near the CM. Variable morning cloud must have weakened the opposition effect in some images, including those of Friedman, Morales Rivera and D. C. Parker, Jan 29–31. Thus there was only a slight opposition effect in 2010.

Elysium Mons was better placed from Japan at opposition, but this smaller feature demands top quality images, and the most satisfactory view of the effect was by Flanagan on Jan 22 with the feature near the CM, while the volcano just shows up as a lighter dot in Barry's best red images of Jan 28 and Feb 5, and Peach's of Jan 20–21.

The morning Montes post-opposition

As in 2007–'08, the morning *Tharsis Montes* (*Ascraeus*, *Pavonis* & *Arsia Mons*) and *Olympus Mons* appeared as dark reddish or brownish patches amidst widespread white morning cloud which lay thickly at the morning terminator, this aspect being visible first (at low contrast) with the *Montes* on 2010 Feb 19 to Morita and on Feb 26 to McKim (Part I, Figure 2I) and – together with *Olympus Mons* – to Peach.

In the following weeks there would be many such observations, and by early March the dark spots were very well contrasted. Thus on Mar 5 (Part I, Figure 2J) and May 12 McKim clearly saw *Ascraeus Mons* dusky in the morning, and as late as May 11–16 he could still see the dusky belt of the *Tharsis Montes* amidst white a.m. cloud; Abel had a similar view on May 15. From March through May the planetary imagers had the best views: see in particular Figure 14. The *Montes* were at least equally contrasty in the blue light images, and definite records of them continued till about Jun 5 (Morita), after which the disk diameter was too small.

'Violet holes'

Unusually dark areas in the violet images are referred to as violet holes and must represent areas of lower water vapour content than the surroundings. Visually they can show up as strongly reddish enhancements of a surface feature. We have catalogued any obvious such areas in past reports.

In 2009–'10 there were few relevant records, but on 2010 Jan 23 Peach drew attention to the wine-red colour of the northern tail of *Mare Acidalium*, contrasting in tint with the rest of the marking, just prior to the dust activity in and north of the region. The effect was apparent to Akutsu and Garbett on Jan 17, Morita on Jan 19, Sanchez on Jan 21 and Morales Rivera on Jan 31.

Martian 'flares'

D_e and D_s (the latitudes of the sub-Earth and subsolar points) coincided three times during the apparition, but only once when the disk exceeded 6", on 2010 Jan 20–21, at +15.8°, the latitude of the south flank of *Olympus Mons*. We are not aware of any systematic 'flare' or 'flash' patrol, and reviewing the best images reveals nothing unusual just prior to the few observations of opposition brightening of volcanoes (see earlier). Moreover, this latitude did not coincide with any feature which previously showed the effect. See for example the high resolution Jan 20 image by Casquinha in Part I, Figure 5 at CM= 136° showing *Olympus Mons* at the CM: there is nothing abnormal. Past experience shows that only for specific features is there much chance of success, *e.g.*, *Edom* in 2001.[38]

T. A. Dobbins[39] has commented that highly aligned mineral grains in areas such as *Edom* and *Tithonius Lacus* might produce specular reflections. The Director was always uncomfortable with the requirement for the presence of extended ice sheets or frosted dunes to produce a flash at *Edom*, which is nearly upon the martian equator.

North polar region

Activity in the NPH and the NPH/NPC transition

The behaviour of N. polar dust storms crossing the cap was reported in Part I.[35]

Figure 15 presents some aspects of the NPR in 2009–'10. As early as 2009 Jul 20 Pellier caught a N. polar hood along the limb; D_e became positive after Aug 15, enabling a better view of the area, but in contrast to the same season during 2007, the tiny disk diameter did not favour close scrutiny. Nonetheless, on Aug 9 (Ls= 318°, D= 5.4") Peach was the first to image the ground cap. His image of Aug 19 (Ls= 324°) revealed the N. part of the NPR to be dark, with the NPC certainly visible in red light accompanied by a larger overlying hood in blue. Maxson (Aug 15–30) also recorded early sightings of the ground cap.

By Sep 9 (Ls= 335°), as D_e became more northward, Peach was able to separate the dark annular rift within the cap from the N. limb, an observation confirmed by Ikemura on Sep 24, Maxson on Oct 4 and Flanagan on Oct 18. As in 2007, the NPC south of the rift was not very bright at first, but nonetheless represented the ground cap. (It is also likely that fresh snowfalls caused the annular rift to fade somewhat with time, as has been witnessed in the past.) The hood was generally visible in blue light and considerably larger than the cap, for example in the Oct 18 image sets of Flanagan.

Sometimes the hood was thickly visible even in red light, particularly around the longitudes of *Mare Acidalium*, in the a.m. and p.m., but on Aug 22 according to Morita the hood invaded the space between *Acidalium* and *Nilokeras* resulting in a dust storm, as described in Part I. On Sep 17 & 19 and Oct 13 a thick hood obscured the cap even in red light to Peach; likewise to Poupeau, Sep 8. Latitude measures of the NPC S. edge before September were further frustrated by the tiny disk and unfavourable tilt.

Circumstances also did not favour viewing the so-called 'Dawes' slit' effect over *Mare Acidalium*, but it was seen a few times. On Sep 8 Poupeau showed the N. part veiled even in red light, apart from a dark patch in the NW. This was repeated by Peach on Sep 17, Maxson on Sep 20 and Ghomidazeh (Figure 15) on Oct 12. On Oct 15 the invasion of the hood left a dark north-south 'slit' over *Acidalium* to Poupeau.

The hood was often active around *Mare Acidalium* and N. *Utopia* in Sep–Nov, but as in 2007 was quite stable at λ ~180°. By Ls ~20° the activity of the hood had greatly declined. The slightest trace can be seen only over the S. edge of the cap (towards E. *Mare Acidalium*) on the morning limb, such as imaged by D. C. Parker on Dec 8 (Ls= 21°). After that epoch, any morning cloud adjacent to the cap was no longer part of the hood.

Images of a frost patch at *Lomonosov* crater (+60°, 008°) were taken by Pellier (Nov 1), Casquinha (Nov 4), Peach (Nov 5 and Jan 31) and Grafton (Nov 14).

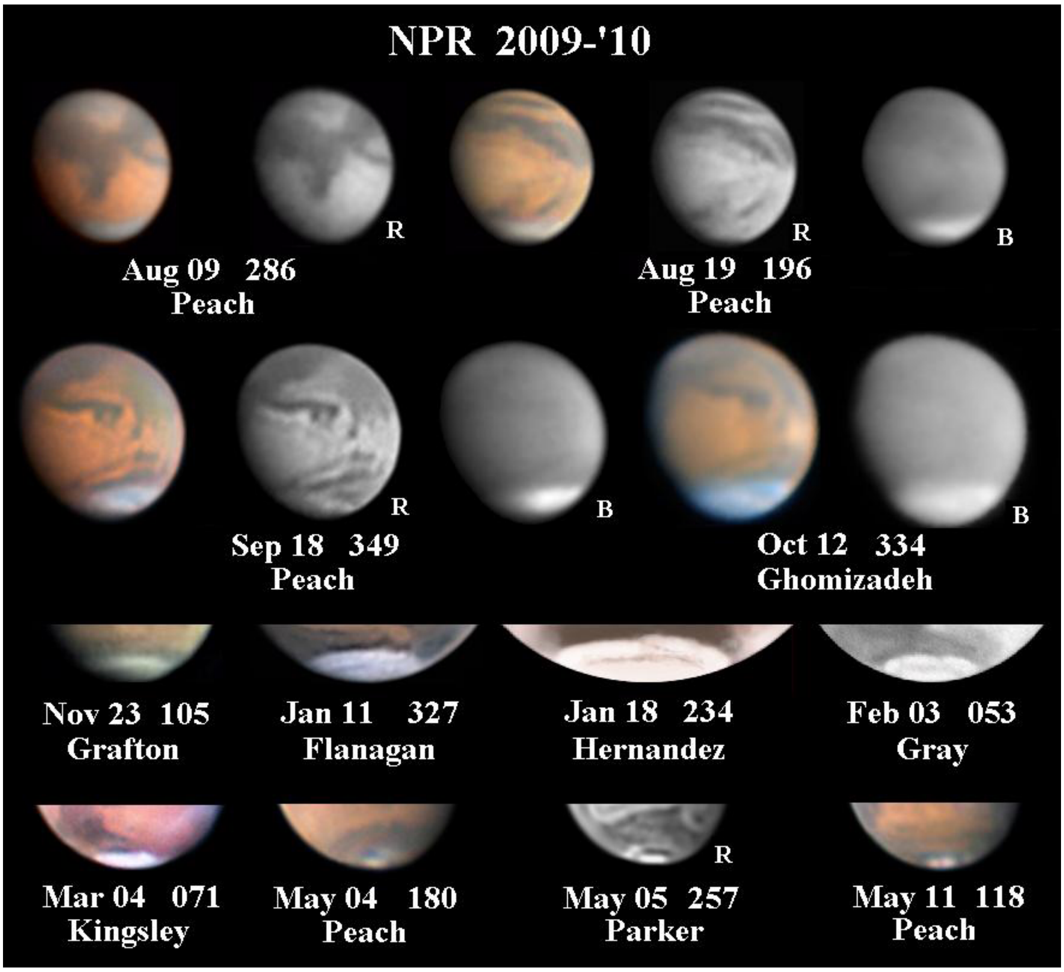

Figure 15. The north polar region according to images by Flanagan (Lumenera LU-075M camera), Ghomizadeh (DMK 21AU04), Grafton (ST402 CCD), Kingsley (Lumenera SkyNyx 2-0), D. C. Parker (410mm refl., SkyNyx 2-0) and Peach (Lumenera SkyNyx 2-0), and drawings by Gray (×365) and Hernandez (×443). Note *Olympia* on 2010 May 4–5 and *Chasma Boreale* on May 11.

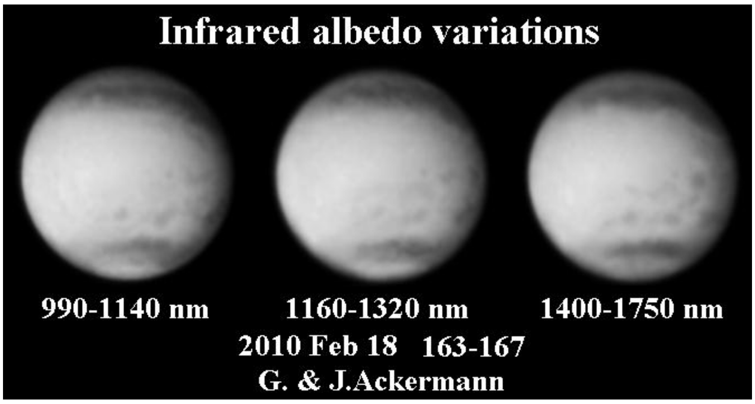

Figure 16. Comparative IR and near-IR NPC images, 2010 Feb 18, by G. & J. Ackermann (VDS NIR300FPGE camera). Note the decrease in the cap's albedo beyond λ= 1400nm.

North polar fronts ('cascades')

In earlier reports we described how fronts blowing off the SPC were detected as small bright projections from the cap edge. In 2009–'10 these events were detected in connection with the NPC.

On 2009 Dec 2, Jolly imaged several streamers of cloud over *Mare Acidalium*. At Ls= 18°, this was probably a high resolution view of some NPH remnants.

On 2010 Jan16 & 17, Akutsu, Kumamori and Morita imaged a bright southward projection from the cap at *Baltia*, this being another front blowing off the cap.

On Jan 26 and later, a small bright spot at the NPC edge E. of *Mare Acidalium* was likely to have been a polar front; if so, it may have been responsible for initiating the largest of the polar dust storms of the apparition: see Part I.

On Feb 17 (Ls= 53°), Kidd, Peach and others imaged a 'banner cloud' near CM= 180–190°, which Clitherow and Lawrence caught on Feb 19 (Part I, Figure 5) in slightly altered form. On Feb 20 only a trace of the cloud remained. Only the advent of such high resolution work has made imaging these phenomena possible, though historical examples in visual work could be cited.

NPC fragmentation

There were often small irregularities in the S. edge of the NPC. For instance, on 2009 Dec 24 Minami found irregularities under CML= 220–250°, and Bailey saw several indentations near CM= 329° on Dec 27. Pellier's Jan 2 image showed a bright spot and indentation in the NPC near *Mare Acidalium*. In mid-February the cap was also irregular *f. Mare Acidalium*.

Sanchez on Jan 21 at 23:07–:26UT showed a small dark spot *within* the NPC close to its southern edge, on the morning side under CML= 95°. Nothing was present on Jan 19/20 according to excellent images by Casquinha, but on Jan 20/21 Morales Rivera imaged the same spot, now smaller. On Jan 22 00:21UT Mancini (UAI) caught the same anomalous dark patch in the cap, which to D. C. Parker next day had faded nearly to invisibility. Lawrence, Maxson, Phillips and G. Walker on Jan 24–30 all showed an unchanging notch at the cap edge at the same longitude. Although we do not rule out a dust storm, we believe the dark patch was a local thinning of the cap reached by the retreating snowline days later, causing a notch, for the absence of movement argues against dust.

With D_e reaching a minimum value of only +12.1° by late Feb, the annular rift became harder to observe, and McKim's last visual sighting was on Feb 19. But it was still detected by Flanagan's imaging on Mar 30: it would later form the border of the summer cap.

Olympia is the major fragment which detaches from the cap in late spring, but in 2010 this seasonal event fell long after opposition. On Kumamori's images of 2009 Dec 21–29 the location of *Olympia* was already indicated as an ill-defined brightening of the cap S. of the circumpolar rift. McKim also saw this on Feb 5. On Mar 30 (Ls= 71°) Flanagan showed *Olympia* as a brighter continuous area S. of

Table 3. NPC latitude measurements, 2009–'10

Mean L_s (°)	*Latitude of S. edge of cap on images (°)*	*No. of measures*
333 (*e.g.*, 331–335°)	53.2	4
338	53.5	5
343	54.9	11
348	53.3	2
353	57.4	10
358	57.8	24
003	59.8	35
008	59.3	37
013	61.6	21
018	61.4	29
023	63.6	46
028	63.3	37
033	64.1	65
038	64.4	67
043	66.0	114
048	67.0	70
053	67.1	97
058	68.9	88
063	69.9	37
068	71.1	24
073	75.3	21
078	77.5	23
083	77.6	14
088	79.8	11
093	81.0	12
098	80.8	8
	Total	912

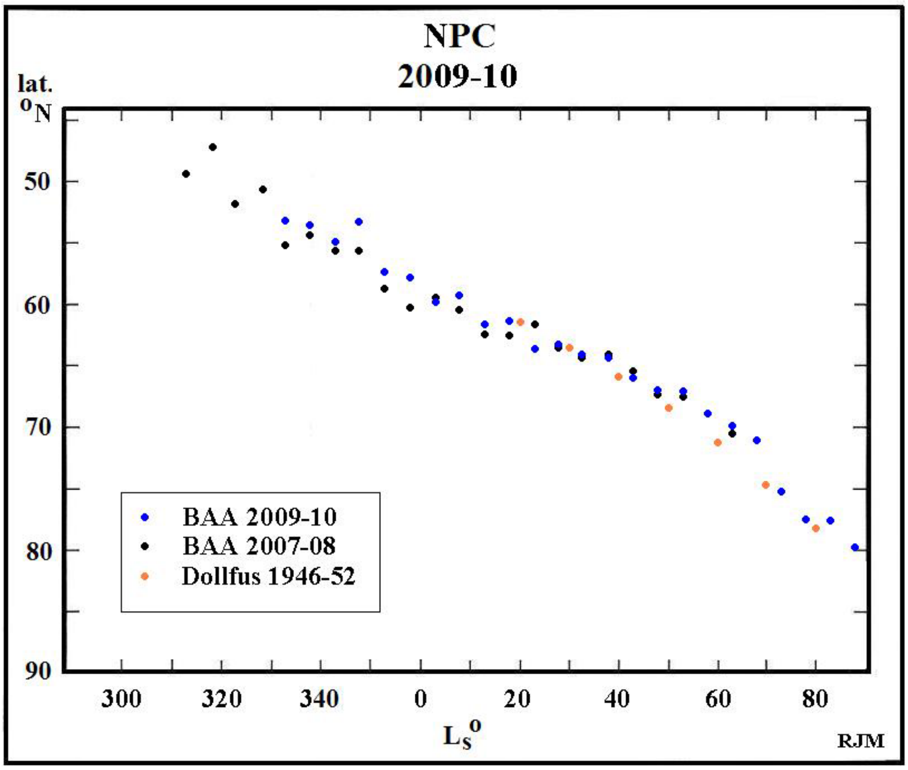

Figure 17. Recession curve for the N. polar cap, 2009–'10, latitudes being 5° means in Ls. Comparisons are made with the result for 2007–'08[27] and with the average recession curve of Dollfus.[41]

the annular rift, with a dusky border, with the part of the cap following beginning to fade and evaporate. Yunoki was perhaps first to catch its complete separation on Apr 6 (Ls= 74°), followed by Ikemura on Apr 8, G. Walker from Apr 12, Peach from Apr 16, Olivetti from Apr 18, McKim on Apr 26 (Part I, Figure 2K), *etc*. *Olympia* is also shown in Figure 13.

Olympia's separation was therefore marginally late, for in 1995[40] we caught it already at Ls= 70°, and even upon the tiny post-opposition disk in 2008[27] its separation was judged complete at Ls= 72°. In 2010 it was definitely not yet detached at Ls= 71°. But as we shall shortly see, the NPC in 2010 was if anything marginally larger than 2008 at the same seasonal date, so this result would accord with a very slightly delayed recession. *Olympia* remained visible till the end of the observing period whenever seeing was good enough. Thus D. C. Parker could still see it on Jun 14, by which time it had shrunk considerably. On several occasions the contours of the evaporating *Olympia* looked hazy in blue light, especially to Peach on Apr 2, 4 and May 4, and to Parker on Apr 28 and Jun 14. *Olympia* features in Figures 9–12.

Ierne was not well observed as an outlier or projection in 2010 as the smallness of the disk at the right time frustrated observation. A small protrusion from the cap edge at the correct longitude at Ls= 72° was caught by Peach, Apr 2–4, and Gray on Apr 3.

Hyperboreus Lacus: noticed as a dark patch upon the retreating snow line of the NPC by McKim on Mar 5 and later; it had become conspicuous by April and continued so into June, after which the disk became too small.

Chasma Boreale was resolved by Peach on Apr 5–8 and again and more distinctly on May 11–12 (Figure 12): under CM ~110–120° on the latter dates, it appeared to cut the cap nearly in half.

Figure 19. Mars near Praesepe (Messier 44), according to James (2010 Apr 16, 21h 30m, 4×300s stacked exposures, 72mm OG + EOS-10D DSLR camera) and Hudson (Apr 17, 21h 50m, 30s exposure, 102mm OG + Canon EOS-350 DSLR camera). North is uppermost.

NPC albedo variation with wavelength

In 2010 Feb–Mar the Ackermanns carried out comparative red and near-IR observations at three wavebands: in the 1400–1750nm waveband the NPC was considerably less bright than at 990–1140nm or 1160–1320nm, demonstrating the lower albedo of water ice compared to carbon dioxide ice beyond λ= 1400nm. See Figure 16.

Figure 18. RGB images showing the SPC upon the tiny disk (D= 4.3–4.9") from 2009 Mar–Jun, and its recession, according to Akutsu (DMK21AU04 camera) and Buda (DMK21AF04).

NPC recession

The 2009–'10 NPC recession was studied in the usual way: the Director made 912 measurements (2009 Sep 9–2010 Jun 3) of the latitude of the S. edge of the cap at the CM upon images by 53 observers. The data were grouped in intervals of 5° in Ls and averaged. The data showed nearly precise seasonal accord with 2007–'08 (Table 3 and Figure 17) and with the standard double-image micrometrical curve of Dollfus[41] from the 1940s and '50s epoch. It is clear that any deposition of dust upon the cap during the present apparition (see Part I) cannot have accelerated recession: perhaps lingering suspended dust rather retarded the recession following the Regional polar dust storm which began at Ls= 45°. Figure 17 shows that the cap diameter at several points of the graph was marginally larger than in 2007–'08, and in particular there may have been a small but systematic deviation (corresponding to a slower recession) during Ls ~45–70°. Thus the slightly delayed seasonal separation of *Olympia* (see earlier) is explained. More detailed comparisons of the NPC recessions during the 1980s and 1990s aphelic apparitions are available elsewhere.[42]

Macsymowicz made the final definite record of the summer cap visually on Aug 31 upon a very tiny disk.

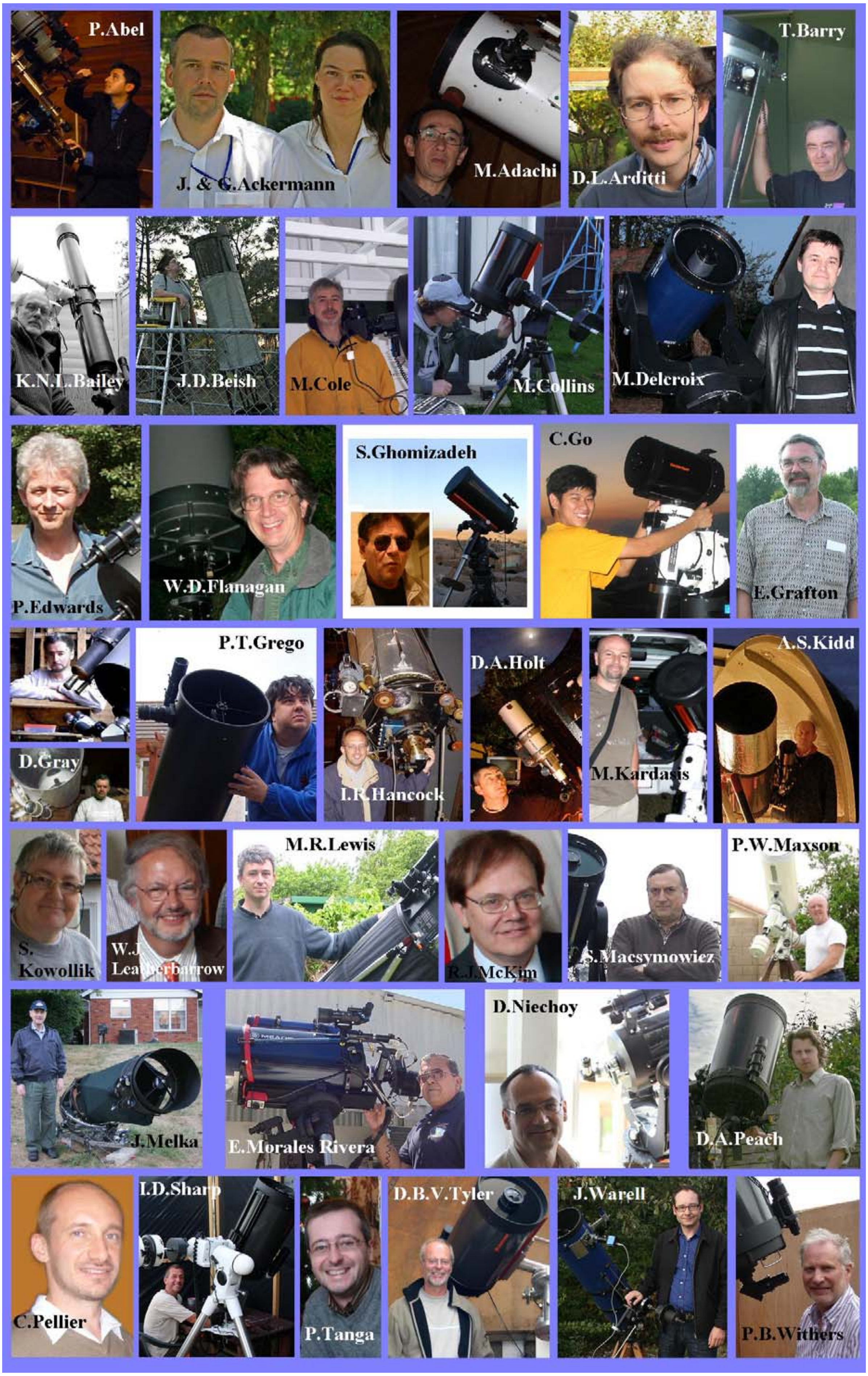

Figure 20. A collage of some of the 2009–'10 Mars Section observers and their instruments.

South polar region

The S. polar cap had already greatly recessed prior to the first observations. Akutsu and Buda imaged the cap at very low resolution in 2009 Mar–Jun (Figure 18), and after that it became a difficult feature. Its presence was still registered by Pellier on Jul 20 and 26, Poupeau on Jul 27 and Maxson on Aug 3. It was impossible to watch the separation of *Novus Mons* or other outliers.

Minami found the S. limb white on 2009 Aug 19 after the SPC was no longer visible. (D_e had become positive after Aug 15, so that the transition to SPH was not visible from Earth.) The N. part of the SPH visible at the S. limb was distinctly separated from *Hellas* and *Argyre* at first, as noted by S. Walker, Sep 21 and Morita, Sep 26. Then the SPH appeared to be merged with the southern basins, *e.g.*, to Akutsu and Morita, Oct 9–10. By late October the SPH was very bright at the S. limb, continuing thus through 2010 January. *Argyre* remained bright at the limb, Jan–Mar, and even near local noon, Feb onwards.

On Apr 16 *Argyre* was still white to McKim, but on Apr 22 D. C. Parker found that it was not visible. McKim however saw it light again on May 21, and on May 27 together with *Noachis* it was light at the CM. The S. limb was light at other CML from time to time at least as late as June.

Early in the apparition in 2009 Mar–Sep, *Hellas* looked cloud-free and showed its ground colouration as well as some floor detail. Later it showed diurnal cloud, and first looked whitish on the morning limb in 2009 Sep–Oct, and light on the evening side from Oct onwards, but it did not show more than very thin cloud upon mid-disk. It was not bright in the morning or near local noon around opposition or in 2010 Feb, though the extreme S. limb was bright at that longitude and at others. Upon the CM to Wesley on Mar 2 *Hellas* was still not bright, but the S. limb remained so. *Hellas* appeared slightly whitish due to thin cloud at local noon (though fainter than the NPC) to Colombo on Mar 13, Heath and Peach on Mar 14, the Director on Mar 15, Abel on Mar 17, Graham on Mar 20, D. C. Parker on Mar 25, *etc*.

On Apr 17 Minami found *Hellas* very bright in the south at the CM, while Peach on Apr 20, Delcroix on Apr 24 and Parker on Apr 28 found a brighter white spot in the eastern part of the basin which later in the martian day merged into more widespread evening cloud.

The whole *Hellas* basin soon became bright even at local noon: Abel and McKim on Apr 26 saw it rather bright, while Minami on May 14–17 (Ls= 91–92°) considered it had then reached its maximum brightness. Now several observers, such as Adamoli on May 26, Olivetti on May 29, McKim on Jun 3 and Jaeschke on Jul 12, *etc*., showed it rivalling the NPC. *Hellas* now appeared bright most of the day, though in the mornings in May–Jun it was still covered by weak diurnal cloud which was fainter than the frosted ground. The surface of *Hellas* by Ls ~90° is taken to be frosted (such as observed by the Section in 1997).[42]

Conjunctions

Salway submitted a beautiful image of the dawn conjunction of Mars with Jupiter, Mercury and the Moon on 2009 Feb 23.[43] Another digital photograph showing Mars, Jupiter and the Moon on 2009 Mar 24 was sent by Akutsu.

Alerted by the Deep Sky Section Director's *e-Bulletin*,[44] several observers watched Mars as it passed just north of the stars of Messier 44 (Praesepe, 'The Beehive') in Cancer. Hudson and James submitted telephoto images for 2010 Apr 15–16: see Figure 19. Mars had passed through the same open cluster in 2009, as observed by Arditti and others on Nov 3.

A BAA Mars Section Centenary: 2009

The scientific foundations of the BAA Mars Section were laid during the Directorship of Eugène–Michel Antoniadi (1896–1917). In 2009 September a conference in Paris[45] marked the 100th anniversary of the start of Antoniadi's groundbreaking studies with the Meudon 830mm OG (which had begun on 1909 Sep 20). In 2009 the 'Grande Lunette' was still under repair: it was last used for Mars, by the present Director, in 1988 and 1990. Fortunately, conference organiser and Section member Nicolas Biver was able to make use of another telescope that Antoniadi had often employed: the 380mm Arago refractor of the Paris Observatory (see Part I, Figure 4).

Acknowledgments

Damian Peach is thanked for kindly making the excellent N. polar projections of a dust storm that appeared in Part I, Figure 9B.

All observers made extraordinary efforts under Earth meteorological circumstances which – particularly near opposition – were often very trying. To acknowledge their work,[46] we again present a collage of some of our observers and their telescopes (Figure 20).

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References

35 R. J. McKim, *J. Brit. Astron. Assoc.*, **128**(3), 157–167 (2018)
36 For the 1901 observation see E–M. Antoniadi, *Mem. Brit. Astron. Assoc.*, **11**(3), 86 (1903); for 1903 see E. W. Maunder, *J. Brit. Astron. Assoc.*, **13**(8), 313 (1903); for 1967 see E. H. Collinson, *ibid.*, **79**(1), 53–59 (1968). Prior to 1901, the effect was recorded by Gledhill (1871).
37 S. A. Smith & B. A. Smith, *Icarus*, **16**, 509–521 (1972)
38 R. J. McKim, *J. Brit. Astron. Assoc.*, **119**(4) 205–211 (2009)
39 T. M. Dobbins, OAA *Communications in Mars Observations*, Nos. 374 & 375 (2010)
40 R. J. McKim, *J. Brit. Astron. Assoc.*, **115**(6), 313–333 (2005)
41 A. Dollfus, *Icarus*, **18**, 142–155 (1973)
42 See the BAA Mars reports for 1995 (ref.40) and 1997: R. J. McKim, *J. Brit. Astron. Assoc.*, **116**(4), 169–186 (2006)
43 R. J. McKim, *ibid.*, **120**(2), 67 (2010)
44 S. Moore, BAA *e-Bulletin* No.490 (2010 Apr 18)
45 D. L. Arditti, *J. Brit. Astron. Assoc.*, **120**(2), 108–109 (2010). Many of the talks at The International Workshop on one Century of Mars Observations are available here: **http://www.kwasan.kyoto-u.ac.jp/~cmo/cmomn5/2009Paris_Meudon_Index.htm**. For the writer's talk about Antoniadi's life, see: **http://www.kwasan.kyoto-u.ac.jp/~cmo/cmomn5/ 2009Paris_Meudon_Talks_RMk.htm**
46 In the 1920–'24 BAA Variable Star Section *Memoir*, (*Mem. Brit. Astron. Assoc*., **28** (1929)), H. H. Turner complained that, unlike the AAVSO, the BAA didn't publish pictures of its contributors: 'Why should not the BAA Section have a picture every five years?' This one and our 2003 collage (R. J. McKim, *J. Brit. Astron. Assoc.*,**120**(6), 357 (2010)) constitute a somewhat delayed response.

Received 2016 September 1; accepted 2016 October 26