The opposition of Mars, 2020: Part II

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

We report seasonal timings of the appearances and disappearances of the Equatorial Cloud Belt; the *Elysium Mons*, *Tharsis Montes* and *Olympus Mons* orographic clouds; and observations of the shadow cast by the *Arsia Mons* orographic cloud (or *Arsia Mons* Elongated Cloud). The sublimation of the south polar cap was followed in detail, and its recession was smooth and typical: after *Ls* ~218° the recession curves of 2003, 2018 and 2020 were indistinguishable, but before then the 2003 cap was systematically larger. The seasonal separation of *Novus Mons* from the cap was judged to be complete at *Ls* = 238°, which was seasonally normal. The south polar cap had first appeared beneath the polar hood in 2020 February at *Ls* = 151°, and it was last seen in 2021 January at *Ls* = 353°. The north polar cap was visible up till 2020 February (*Ls* = 154°), and reappeared in late 2020 at around *Ls* = 338°.

Introduction

Continuing from Part I,[27] we discuss seasonal cloud and polar phenomena in 2019–'21, during Martian Years (MY) 35 and 36, for comparison with the 2018 opposition and earlier.[21] We often quote *Ls* data for cloud phenomena, but seasonal comparisons with other years are most useful where they document cloud at the evening terminator: in other words, up till opposition. The most relevant comparisons are therefore with years having similar *Ls* at opposition: most recently, 2005 (opposition: Nov 7).[8] A selection of the Director's visual observations illustrating various phenomena is given in Figure 11.

White clouds

Equatorial Cloud Belt (ECB)

Phenomena in MY 35

We were last able to see the ECB commence in 2019 May at *Ls* = 020°. In 2020 we could observe its seasonal termination, though Mars was then distant. On Jan 15–23, to Foster the ECB was still causing the *Syrtis Major* to fade upon mid-disc. On Jan 31 – Feb 1 (*Ls* = 144°), Peach found the ECB still complete around CML = 250–260°, but it was no longer so effectively veiling the *Syrtis*. It looked very incomplete upon Foster's images of Feb 5–13 (CML = 030–114°, *Ls* = 146–150°; a typical seasonal date for termination). By Feb 14–15 (Casely, Foster, Peach), there was no longer any trace of it.

Phenomena in MY 36

By 2021 March, there were fresh signs of ECB; again, Mars was distant. Images by Maxson showed the *Syrtis Major* obvious in blue light up to *ca*. Mar 3 (implying weak or absent ECB). But from Mar 5 (*Ls* = 013°), the *Syrtis* was no longer distinct, and Ito's blue-light images showed veiling during Mar 14–23. The ECB was seen partially by the Director on Mar 17, under CM ~081°, and was quite clearly complete on Jun 9 (*Ls* = 057°) in Ito's blue image under CM = 223°. Hence the ECB had certainly commenced by *Ls* = 013°.

The *Tharsis Montes, Olympus Mons, Alba Patera & Elysium Mons*

We could not observe seasonal commencement of orographic clouds during the northern spring of MY 35, but later phenomena could be timed. *Arsia Mons* was the focus of attention, for we definitely detected the shadow of its banner cloud. The *Tharsis Montes*, *Olympus Mons*, *Elysium Mons* and *Hecates Tholus* showed a marked brightening for a week or so either side of the date of opposition.

In 2018, the orographics over the *Tharsis Montes* had all ceased on Jun 3 (*Ls* = 187°), as a global dust storm began. In 2020, the largest storms were regional.

Elysium Mons

Elysium Mons was bright in the evening from 2019 Nov 13 till 2020 Mar 25 (*Ls* = 172°), becoming faint by March. During 2018 it had persisted till May 7 (*Ls* = 171°). It was bright again on the morning side from 2021 Mar 2 (with morning cloud imaged as late as Jun 26 by Kidd (Part I, Figure 4), and bright on the evening side from Mar 22 – May 3 to several observers.

Olympus Mons

Olympus Mons, bright in the evening from 2019 Dec 31 till 2020 Apr 4 (till *Ls* = 178°), was fading in March. This was like 2018,

when the cloud was followed till May 13 (*Ls* = 175°). It then appeared as a dark circular marking in the absence of seasonal cloud, particularly when near the evening terminator in August–September, when a reddish tint was obvious. The orographic cloud reappeared, weakly at first, from 2020 Sep 27 (*Ls* = 286°), continuing till Nov 12.

As already mentioned, there was a marked brightening of *Olympus Mons* a week or so either side of opposition, but it was still possible to distinguish the presence of weak evening cloud even at that time. It was easy to record the opposition brightening near the CM, but on other occasions one or other flank of the volcano could be seen as a bright elongated area near the limb. For example, J. Sussenbach on Oct 11 recorded its W. slopes shining under evening illumination.

From 2021 Mar 2, late afternoon orographic cloud was again returning to *Olympus Mons*, but the evening terminator was not accessible. The Director saw it well on Apr 12, and Kidd imaged it clearly as late as Jun 26 (Part I, Figure 4) and Jul 29 (*Ls* = 064–079°, *D* = 3.9–3.7″). But by spring of 2021, the planet's disc had already become too small for critical work: a comment applicable to all white cloud statistics.

Arsia Mons

General

In professional literature, the banner cloud of *Arsia Mons* (which trails its summit on the west) is nowadays referred to as the *Arsia Mons* Elongated Cloud (AMEC). The long cloud of *Arsia* cast an observable ground shadow shortly before, at and shortly after opposition. See Figures 12–13.

Arsia Mons was clearly brightened in the evening by its orographic cloud, 2020 Feb 25 – May 31 (*Ls* = 157–211°), which became weaker after mid-May. (For comparison, in 2005 it was visible until Jun 1, or *Ls* = 222°.) The cloud appeared again from Aug 1 when Haigh (confirmed by della Vecchia on Aug 2) caught it at the evening terminator in blue light. It was well seen in September–October and persisted – fading after early November – till Nov 20, this second period spanning *Ls* = 250–318°. (The corresponding second period in 2005 was Jul 22 – Oct 25;[8] *Ls* = 254–312°.)

By 2020 late August, the banner cloud was sufficiently developed to cast a visible shadow (see below). As always, the orographic cloud was more prominent in the evening; by mid-September it had become conspicuous by early afternoon.

Gasparri on Sep 6–7 recorded how white cloud at *Arsia Mons* had appeared on both sides of the summit to give a 'butterfly' effect: an occasional phenomenon we have recognised in amateur images since 2005. See the images by Peach for Sep 12 (Figure 13C). The effect was visible for some weeks. The Oct 18 images by Pellier (Figure 13D) show the effectiveness of the UV waveband in recording orographic clouds.

Terminator projections & shadow of the AMEC

On 1988 Sep 30 – Oct 2 (*Ls* = 281–283°), I. Miyazaki had photographed a dark streak between the morning *Arsia Mons* and the terminator (Figure 12A). In the absence of higher-resolution work,

Figure 11 ***(Opposite page).*** Drawings in 2020–'21 with 410mm DK Cass., ×265, ×331 & ×410, white-light and W23A orange filter, by R. J. McKim.

(A) Jul 12, 02:15 UT, CM = 354°. The recent regional dust storm had greatly reduced the level of contrast. Note the SPC rift.

(B) Aug 12, 01:42 UT, CM = 049°. The 'deserts' around *Solis Lacus* were rather dark. Note *Phasis* and *Gallinaria Silva*.

(C) Sep 1, 02:25 UT, CM = 232°. *Syrtis Major* was dimmed by limb haze. *Nodus Alcyonius* and the *Aetheria* development were rather weak. *Gomer Sinus* was prominent. *Mare Chronium* was reddish, in contrast to the blue-grey *Mares Cimmerium* and *Tyrrhenum*.

(D) Sep 12, 22:20 UT, CM = 063°. Note the SPC rift, *Juventae Fons*, *Tharsis Montes* and the developing, bluish, NPH.

(E) Sep 14, 22:15 UT, CM = 044°. Small dark spots in S. *Chryse–Xanthe*; *Oxia Palus–Indus* development.

(F) Sep 20, 22:10 UT, CM = 348°. In excellent seeing, the third 'prong' of *Meridiani Sinus* (*Brangaena*) was glimpsed extending into *Aram*, and many fine details nearby were resolved. *Sinus Sabaeus – Meridiani Sinus* was slightly bluish, and *Hellas* slightly yellowish.

(G) Sep 29, 22:10 UT, CM = 268°. *Huygens* and other fine details in and around the bluish-grey *Syrtis Major* and *Mare Tyrrhenum*.

(H) Oct 8, 20:30 UT, CM = 164°. *Caralis Fons* is at the CM, south of *Mare Sirenum*. *Tharsis Montes* evening clouds.

(I) Oct 12, 20:50 UT, CM = 134°. *Olympus Mons* is seen at the CM. *Tharsis Montes* (*Arsia, Pavonis*) clouds.

(J) Oct 15, 20:35 UT, CM = 104°. *Mare Sirenum*, *Solis Lacus* and *Bosporos* were neutral grey, but *Aurorae Sinus – Mare Erythraeum* looked slightly bluish-grey. The 'desert' surroundings of *Solis Lacus* were intensely red.

(K) Oct 22, 20:20 UT, CM = 039°. Two bright spots within the NPH. Several a.m. and p.m. limb clouds. Very fine details were seen all over the disc; too many to draw.

(L) Nov 2, 19:40 UT, CM = 291°. *Yaonis Fretum – Nerei D.* and *Hellespontus* were dark at the W. border of *Hellas*, and there were fine details, including *Zea Lacus*, within *Hellas*. The equatorial and northern dark markings were bluish-grey, but those to the south were more reddish-grey.

(M) Nov 5, 19:15 UT, CM = 258°. Considerable morning cloud, which served to enhance the bluish tint of *Syrtis Major*.

(N) Nov 21, 17:00 UT, CM = 079°. Showing the western part of the regional dust storm. Bright nucleus in *Argyre*, dust along *Valles Marineris*, and slanting belt of dust south of *Solis Lacus*. (See also Part I, Figure 9.)

(O) Nov 26, 17:00 UT, CM = 033°. The eastern part of the regional storm was decaying but dust remained in *Hellas* and along part of *Valles Marineris*. (See also Part I, Figure 9.)

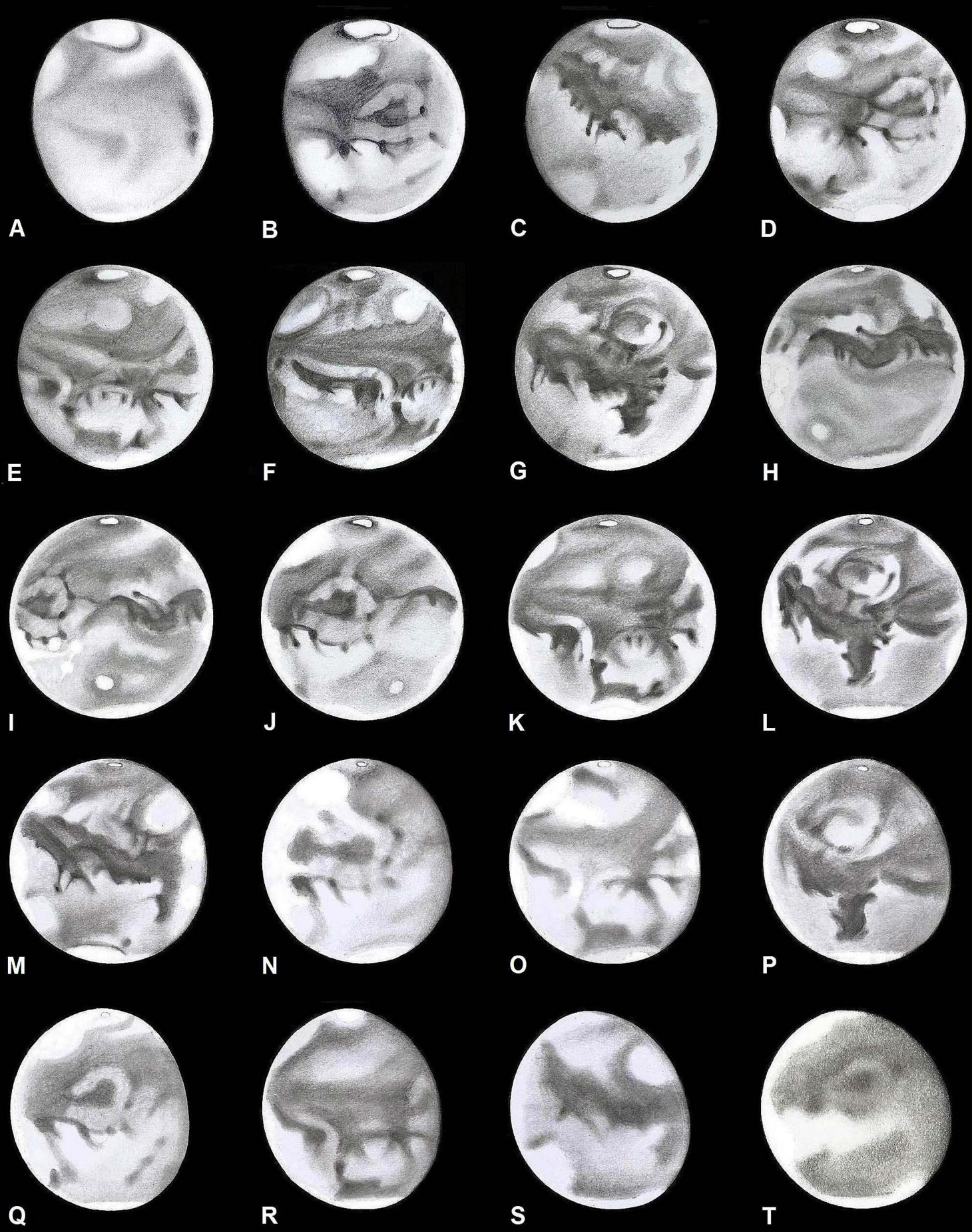
(P) Dec 6, 17:00 UT, CM = 299°. The dust storm had decayed in *Hellas*, though it and *Yaonis Regio* were yellowish. *Zea Lacus* appeared weaker.

(Q) Dec 27, 16:40 UT, CM = 095°. The SPC remnant was still visible. The *Tharsis Montes* were seen. Some yellowish dust fallout was seen in *Argyre*. On the S*f.* limb an E–W belt of white cloud was seen.

(R) Jan 5, 17:55 UT, CM = 027°. The SPR was light but no cap was visible. The N. limb was brilliantly white.

(S) Feb 25, 18:15 UT, CM = 260°. A good view for *D* = 6.5 arcseconds. The *Syrtis* was faded by morning cloud. NPC along the N. limb, with some NPH on the *f.* side.

(T) Mar 17, 19:16 UT, CM = 081°. *D* = 5.8 arcseconds. The ECB was visible, particularly on the evening side.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it was suggested at the time to have been the shadow of the volcano.[28] What must have been the same phenomenon was imaged again during 2003 Aug 29 – Sep 11 (*Ls* = 250–259°): see Figures 12B–C.[29] In 2018, BAA observers recorded the morning AMEC and its shadow from Sep 30 – Oct 29 (*Ls* = 260–279°).[21]

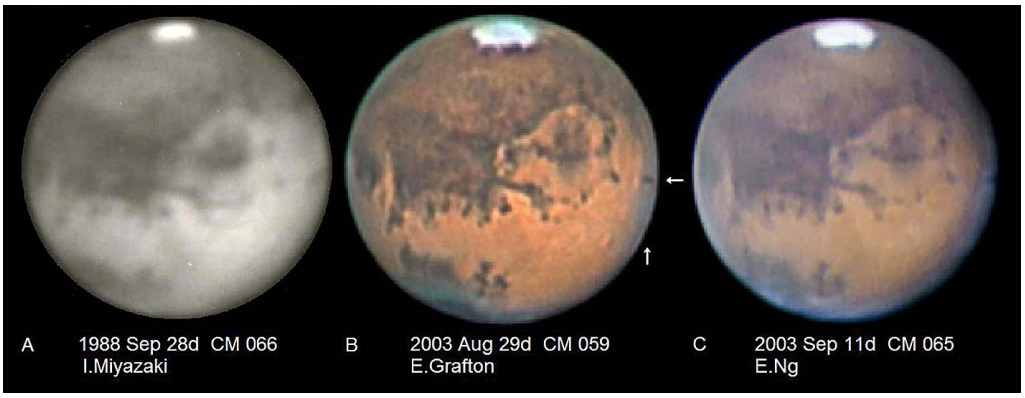

Figure 12. The *Arsia Mons* Extended Cloud (AMEC) shadow during 1988–2003.

(A) 1988 Sep 28, CM = 066°, by I. Miyazaki (Okinawa, Japan), 400mm refl. Two photographs on TP2415 film taken at 14:39–42 UT were combined in *Registax* by the Director and lightly sharpened. **(B)** 2003 Aug 29, CM = 059°, E. Grafton (Texas, USA), 355mm SCT, ST5 camera. The AMEC shadow is indicated. **(C)** 2003 Sep 11, CM = 065°, by E. Ng (Hong Kong), 310mm refl., ToUcam Pro.

Turning to 2020, the AMEC sometimes projected beyond the terminator. A visual sighting was the first that came to our attention, by Pozharov (50cm refl., ×216, Russian Federation) during Aug 30 (*Ls* = 268°) to Sep 3, from around CM = 171–176° (Figure 13A). The Aug 23 images by Kumamori and Yunoki (CM ~180°) are possible earlier records, but the effect is marginal. Next came an image by Arditti (UK) on Sep 7 around CM = 181° (Figure 13B). To him the projection was apparent upon both monitor-screen and processed images. From the USA, Ratcliffe reported the same effect on Sep 14 (CM = 189°). (For there to be a constant Martian time for the effect, as the terminator approaches the evening limb before opposition, there has to be a slow increase in the critical CM longitudes.) In Arditti's image, the presence of what appears to be a cloud shadow adjacent to the bright strip of cloud adds weight to the visual impression that the cloud projected beyond the terminator. Such a situation can even make a true shadow appear to be a surface depression.[30]

On Aug 31, Pozharov again saw the projecting cloud, and then also its shadow. He made sketches over 37 minutes, showing how the cloud first projected beyond the limb, and how the shadow then appeared: Figure 13A. These phenomena disappeared as the planet rotated. He repeated the observations on Sep 1 & 2/3, and although there were slight differences from night to night, the sequence of events was the same. Flanagan and Grafton (USA) on Sep 16 also caught the shadow of the AMEC cloud right at the terminator. J. Sussenbach apparently caught the shadow in the afternoon on the date of opposition (Oct 13).

From 2020 Oct 9–13, numerous Australasian observers caught the AMEC shadow in the morning: see Figure 13E for an Oct 12 example by Heffner. An image by Edwards on Oct 14 (Figure 13F) shows the shadow clearly again in mid-afternoon. Visibility in the afternoon or evening that day was confirmed by images from Radice, Rodriguez and E. Sussenbach. Foster caught the shadow on Oct 19 precisely upon the morning terminator, and Gasparri imaged it clearly next day. On Oct 22, della Vecchia (Figure 13G) recorded the shadow well off the terminator, and his animation showed how it first appeared and subsequently disappeared with rotation. On the same date, it was captured by Leatherbarrow and Pratt from the UK under less than perfect conditions, and by J. Sussenbach (Netherlands). In a very high-resolution Oct 27 Chilescope (1m Cass.) image, Peach (confirmed by E. Sussenbach) recorded it as a rather fine dark band (Figure 13H); this was repeated on Oct 30 when the shadow was partly lost in extensive morning cloud. Chappel, Flanagan, and Grafton (USA), on Nov 1–4 (till *Ls* = 309°), caught it in the morning. After that, the writer could find no more sightings.

It is obvious that a shadow can only be seen if (a) the time corresponds to the season of the banner cloud; (b) the disc diameter is adequately large; (c) the viewing geometry (*e.g.*, the position angle of the cloud) permits the shadow to be seen from Earth, so that it is not hidden by the cloud itself; (d) the Martian limb or terminator region can be clearly seen without too much dust haze; and (e) the local time is not so early as to lose the shadow among other morning clouds, but not so late that the banner cloud has disappeared. Obviously, the odds are against success. On the other hand, the phase defect apparently does not need to be large, and in 2020 the AMEC was visible even very close to opposition and sometimes well into the morning.

R. Konnai cites the work of M. Malaska in showing that this cloud had been monitored by ESA's *Mars Express* since 2007, and that it could be traced in ground-based observations back to 1971.[31,32] It was reported to occur every day during *Ls* = 230–305°. BAA sightings (which, in the absence of a more exhaustive search,[33] cover 1988–2020) add confirmation for *Ls* = 250–306°.

Arsia Mons was again bright upon the evening limb to Boudreau on 2020 Dec 27 (*Ls* = 338°) and to Ito on 2021 Jan 13 and Feb 19, ahead of the recommencement of orographic clouds over the other *Tharsis Montes*. The cloud persisted at least until April, being seen by the Director as late as Apr 15–16.

Pavonis Mons

Pavonis Mons was affected by orographic cloud in the evening, 2020 Feb 2 – May 23 (*Ls* = 145–206°), fading by mid-April. Often its orographic cloud merged with that over *Arsia*. It reappeared a little later than the *Arsia Mons* cloud did, being reasonably conspicuous but always smaller than the former, during Sep 6 – Nov 12 (*Ls* = 273° onwards). The cloud appeared again in the evening from 2021 Mar 2 onwards.

Ascraeus Mons

Ascraeus Mons was brightened by its orographic cloud in the evening, 2020 Feb 2 – Apr 17 (*Ls* = 145–185°). The cloud reappeared during Sep 29 – Nov 12 (*Ls* = 287–313°), and was always the

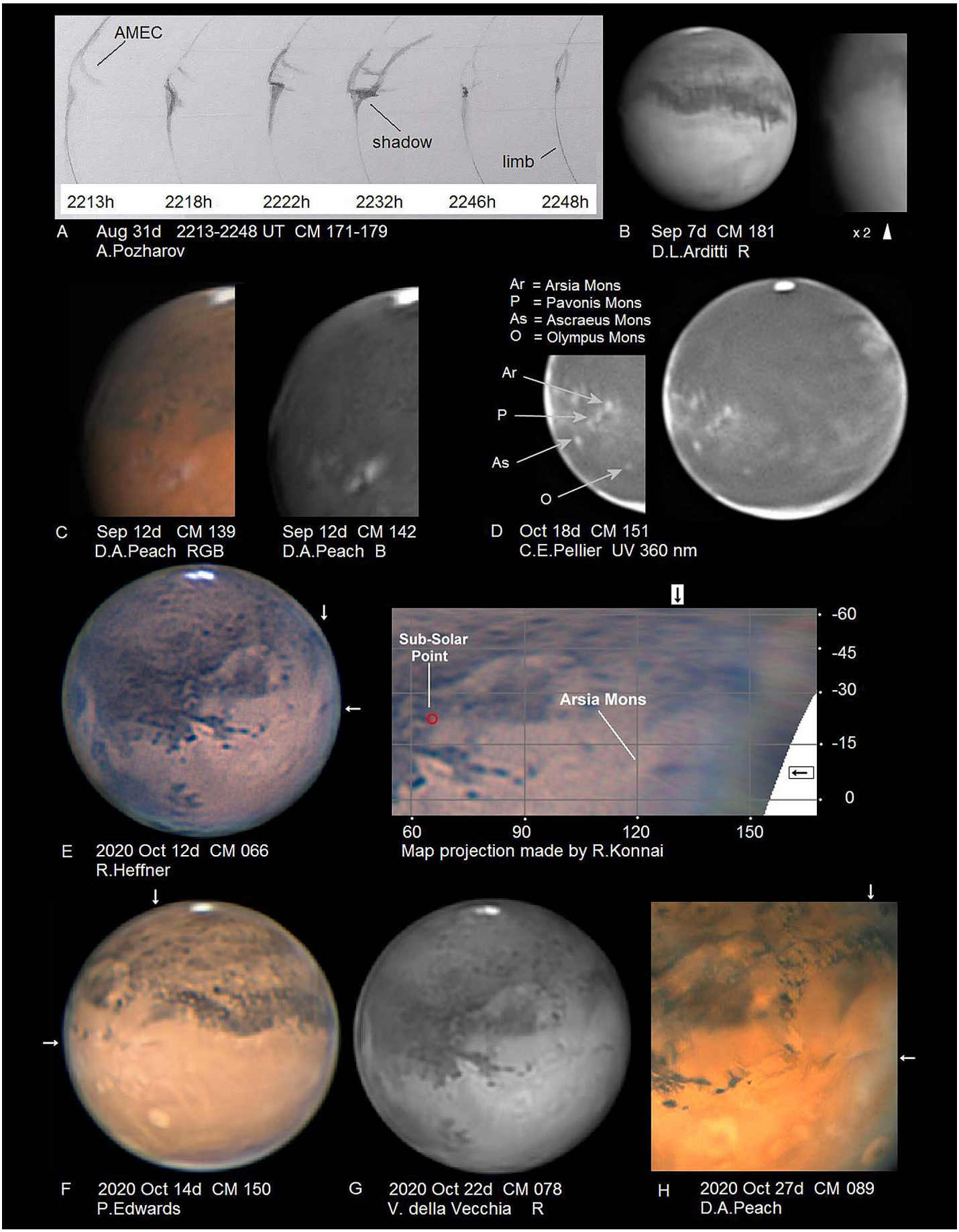

Figure 13. The *Arsia Mons* Extended Cloud and shadow in 2020. **(A)** A. Pozharov, drawings with 500mm refl., ×298. **(B)** D. L. Arditti, Flea 3 camera. **(C)** D. A. Peach, 250mm DK Cass., ASI 290MM. **(D)** C. E. Pellier, 620mm Cass., ASI 290MM. **(E)** R. Heffner, ASI 224MC (with *WinJUPOS* map projection made by R. Konnai).[31] **(F)** P. Edwards, ASI 224MC. **(G)** V. della Vecchia, ASI 290MM (red-light image). **(H)** D. A. Peach, 1m Cass., ASI 174MM (part of an image, not a map projection).

smallest and least conspicuous of the *Montes* at that time. The cloud was observed again in the following year when Haigh caught it upon the evening limb on 2021 Mar 6 & 8.

Alba Patera

The *Alba* (or *Alba Patera*) orographic cloud was sometimes light but never very conspicuous during 2020 Jan 31 – Apr 20 (*Ls* =144–187°), and it is indicated upon Hood's May 31 image right on the evening terminator. Afternoon cloud there was again revealed by Ito's 2021 May 13 image. In 2018, cloud had been observed during *Ls* = 137–176°, becoming very faint towards the end of that period.

The 'W' cloud

The 'W' cloud was not often seen, but with cloud present along *Ophir–Candor* and near *Phoenicus Lacus* as well as at the *Tharsis Montes*, it was visible upon the evening side during 2020 Apr 4–17 (*Ls* = 178–185°). The cloud was again seen near opposition, around Oct 8–18 (from *Ls* = 293°), but the evening terminator was becoming inaccessible. It was better seen in 2005 (from *Ls* = 299°), when opposition had fallen at a slightly higher value of *Ls*.

Terminator projections due to white cloud

It is possible that other near-terminator phenomena just prior to opposition represented shadow effects from other high white clouds, though the loss of the true limb *via* contrast enhancement, and/or the effect of derotation, can be highly misleading.

On 2020 Sep 1 (CM = 240°), the Director noticed a small, slightly projecting evening cloud over SE *Zephyria*.

Apart from the definite phenomena at *Arsia Mons* (see p.246), Peach on Sep 12 showed a projection under CM = 139–142°, located around the longitude of *Aurorae Sinus*. It was most apparent in blue light, implying white cloud. In his images of Sep 13 (CM = 115–135°), there is good evidence for the same phenomenon just east of *Aurorae Sinus*. The feature appeared as a long strip of white cloud, elongated north–south.

The contour of the terminator appeared slightly deformed at mid-southern latitudes to Melillo and Tatum on Oct 24–25, due to the presence of protruding higher-altitude clouds (CM = 120–141°).

Images by Yunoki on Oct 30 (CM = 208–215°) show a fingernail-shaded terminator projection south of *Hellas*; its *f.* end was still visible to Heffner under CM = 247°. A UV image of Yunoki's shows a bright cloud there, suggesting the projection was not dust-related. To Flanagan on Nov 1 (CM = 086°), another fingernail-shaped white cloud close to the south polar cap (SPC) projected beyond the terminator.

Small terminator projections at southern mid-latitudes were noted by Edwards and the Director on Nov 5 (CM = 264–279°).

Table 3. SPC latitude data, 2020–'21

Ls (°) range	*Ls* (°) mean	*Mean latitude of SPC N. edge* (°)	
151–155	153	52.1	(1)
156–160	158	50.3	(3)
161–165	163	53.5	(10)
166–170	168	54.0	(11)
171–175	173	55.5	(9)
176–180	178	56.4	(16)
181–185	183	58.9	(25)
186–190	188	59.4	(29)
191–195	193	59.6	(19)
196–200	198	61.2	(18)
201–205	203	61.0	(19)
206–210	208	63.2	(9)
211–215	213	64.6	(20)
216–220	218	64.7	(25)
221–225	223	67.9	(40)
226–230	228	68.0	(37)
231–235	233	70.2	(38)
236–240	238	71.4	(61)
241–245	243	74.8	(56)
246–250	248	77.5	(51)
251–255	253	79.6	(37)
256–260	258	80.0	(68)
261–265	263	80.6	(71)
266–270	268	81.6	(67)
271–275	273	82.1	(56)
276–280	278	83.1	(80)
281–285	283	83.1	(47)
286–290	288	84.6	(45)
291–295	293	85.1	(79)
296–300	298	85.8	(86)
301–305	303	86.3	(47)
306–310	308	86.6	(77)
311–215	313	86.5	(74)
316–320	318	87.3	(110)
321–325	323	87.4	(45)
326–330	328	87.4	(42)
331–335	333	87.6	(15)
336–340	338	87.7	(24)
341–345	343	87.8	(25)
346–350	348	87.3	(3)
351–355	353	87.6	(3)

For each *Ls* bin, the derived mean latitude is followed by the number of measurements in brackets.

These data, except the first point, are plotted in Figure 15.

Polar regions

North polar region

N. polar spiral clouds

Circumstances for observing these were very poor, but a small morning cloud at *Baltia*, probably of this type, was recorded by Foster within the correct *Ls* range, on 2020 Jan 15–16 (*Ls* = 136°, *D* = 4.5″).

The NPC–NPH transition, 2019–'20

The already small NPC was visible in the early observations of late 2019, while in 2020 January–February the polar hood gradually appeared, with the cap occasionally being resolved. For example, E. Sussenbach showed a tiny cap on Jan 9, but a hood on Jan 25. Foster showed a bright cap on Jan 15 which had become fainter and progressively more blurred during Jan 17 – Feb 17, while the hood is certainly visible in the Chilescope images of Peach on Jan 30 – Feb 1. The ground cap was seen until Feb 20 (*Ls* = 154°, *D* = 5.2″), after which the less bright polar hood persisted; details of the transition were frustrated by the tiny disc and the unfavourable value of D_e: one could make use only of the best observations. Bright points within the hood, offset from the pole, occasionally appeared (for example to Foster on Feb 26, CM = 265°).

The NPH–NPC transition, 2020–'21

Later in the year, as the SPC was shrinking to its summer limit, the north polar hood (NPH) became more prominent. In September the bluish, asymmetric hood had become quite prominent, extending to lower latitude around *Mare Acidalium*, and the 'Dawes slit' phenomenon was well seen at times, particularly in October.

The reappearance of the north polar cap (NPC) in 2020 late December was hard to time owing to the unfavourable value of D_e. Comparing its brightness and N–S depth in red and blue images suggests that the much-foreshortened ground cap may have

first appeared on Dec 27 (*Ls* = 338°) to Adachi in Japan and to M. R. Lewis and the Director in the UK, to whom it looked bright white. The Director noticed the slice of foreshortened polar region was even thinner and brighter on Dec 30. From the longitude of the Americas, the ground cap first appeared to Hood on Dec 23 and to Morales on Dec 26. Spacecraft images confirm that a ground cap was definitely already present by 2021 early January.

Especially around *Mare Acidalium,* and sometimes over *Utopia*, the hood was often present up till 2021 late February. (In a high-resolution late image, Enzmann (1m refl.) even showed the NPH covering the morning *Utopia* on Apr 4.) Indeed, the Dawes slit phenomenon continued to be recorded several times in these latter months at that longitude (*e.g.*, to Einaga, Dec 26),[34] and sometimes a similar phenomenon was seen slightly to the west (*e.g.*, to M. R. Lewis and Abel on Feb 10–12). A thin E–W band of white cloud from the mid-latitudes of *Mare Acidalium* to *Tempe* was sometimes imaged during 2021 mid-March to mid-April.

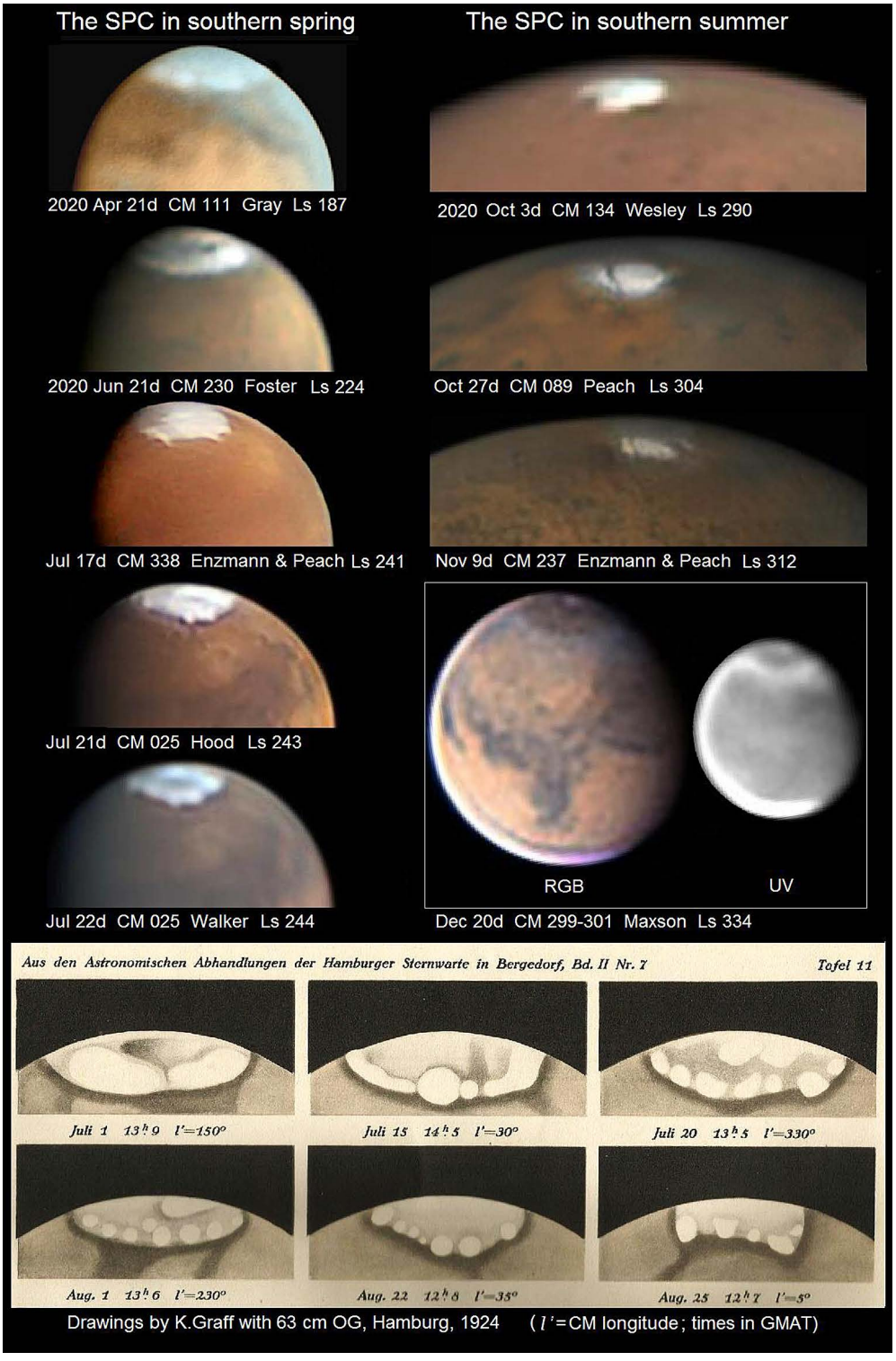

Figure 14. Images and a drawing (D. Gray, ×385) of the S. polar cap in spring and summer, compared with historical drawings by K. Graff (63cm OG, Hamburg Observatory).[35] Graff's drawing of Aug 25 shows the bright *Novus Mons* on the left and the bright *Argenteus Mons* on the right.

South polar region

The SPH–SPC transition, 2019–'20

We have described the SPC recession many times previously: our 2003 report offers a detailed scenario.[29] With increasing resolution, however, the final stages of the recession of the diminutive summer cap were recorded in greater detail during 2020–'21. Figure 14 offers some views.

In the first months of the apparition, *Hellas* was very bright and frost-covered. Gray showed it so on 2019 Nov 13 at *Ls* = 106°, but the beginning of the frost deposition was missed. On 2020 Jan 17–21 (*Ls* = 137–139°), the entire basin was still bright to Foster, even in red light. In the next weeks, the frost cleared, but there were few sufficiently good images to monitor it. By Feb 2 (*Ls* = 145°, Maxson), the frost had definitely gone. The polar hood continued to invade the south of the basin into March, during which there was some local dust activity (see Part I). Frost clearance in the previous Martian year had been achieved by 2018 Mar 16 (*Ls* = 144°).[21] *Argyre* was still frosted in 2020 March, appearing as a northward protrusion from the SPC, and the final sublimation of frost there was accompanied by local dust activity, as reported in Part I.

As usual, the initial sightings of the S. polar cap were highly dependent upon CM longitude. This time it was first seen on 2020 Feb 15 by Foster (CM = 016°, *Ls* = 151°), on Feb 23 by Adachi (CM ~190°), and on Feb 26 by Miles (CM = 338°); on Feb 15 & 26 the hood still invaded the morning *Argyre*. But on Feb 26, under CM = 126°, MacNeill showed only the hood. The SPH persisted for

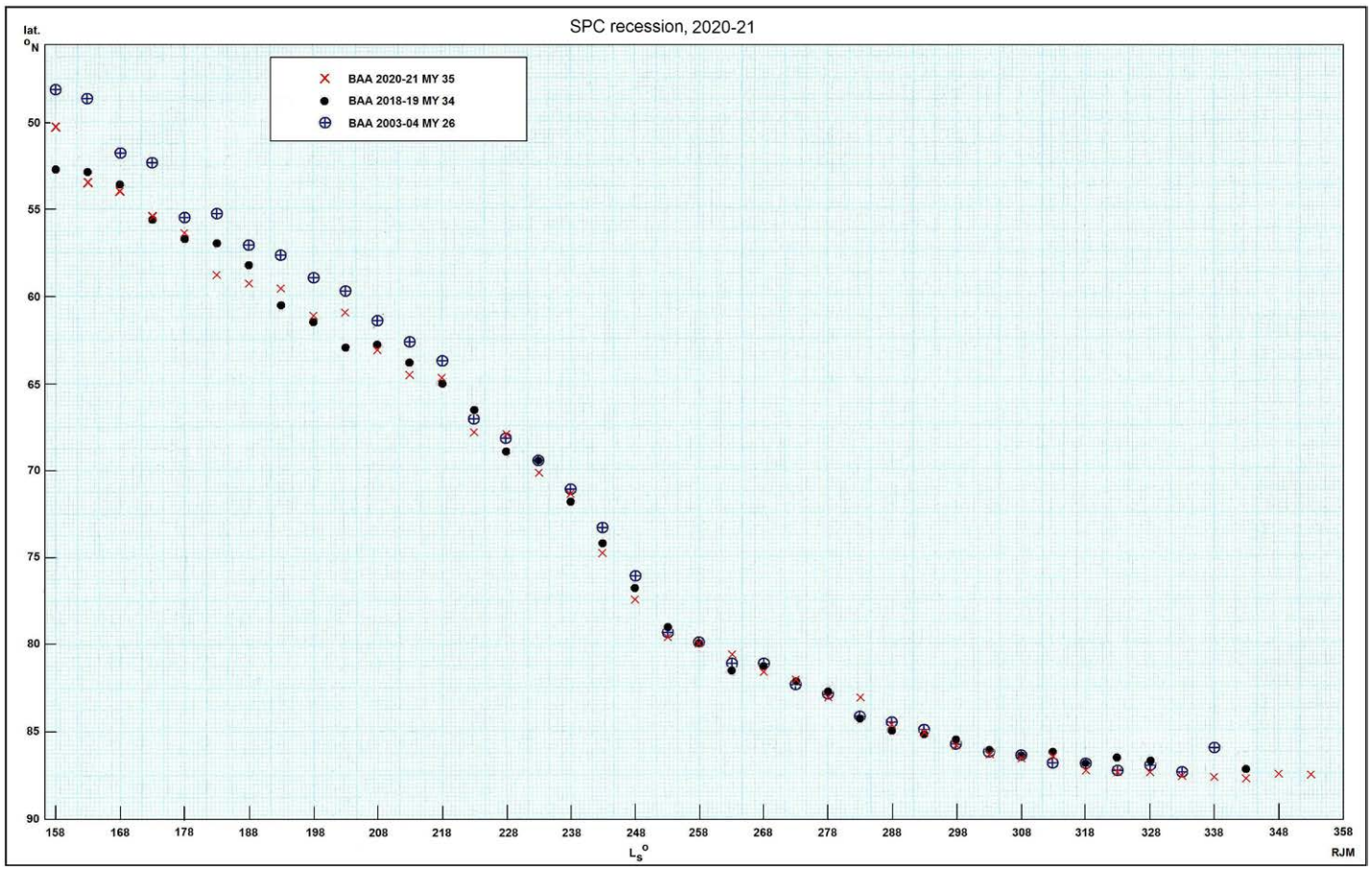

Figure 15. SPC recession curve, 2020–'21, compared with data for 2018 and 2003.[29] In early 2020, the SPH was sometimes still present until *Ls* ~168°.

weeks at some longitudes, but it was not noticed after Mar 17 (*Ls* = 168°), except for a tongue of cloud which protruded into S. *Hellas* (*e.g.*, to MacNeill, Mar 18–20).

SPC recession & fragmentation

Every S. hemisphere spring, or from 2020 early April this time, little bright patches have developed around the outer fringes of the recessing cap, which we assume are regions where recession is locally faster. In Figure 14, two images at almost the same time and longitude are shown with different processing styles: Walker's Jul 22 image strongly reminds the writer of the classical drawings made by K. Graff in 1924.[35] Dust activity at the centre of the spring cap and the various local storms around its edges were described in Part I.

In 2020, the seasonal separation of the 'Mountains of Mitchell' or *Novus Mons* was completed on Jul 13, at *Ls* = 238°, as described and illustrated in the second interim report.[12] (It is shown for example in Gray's Aug 23 drawing in Part I, Figure 2.) This is in line with the typical SPC recession this apparition; in 2003, another year without a global dust storm, separation was also completed at *Ls* = 238°. The fragmentation of *Novus Mons* was less well seen than in 2018, the last trace having disappeared prior to opposition. Following separation, it had split up into two parts, the *p*. one smaller than the *f*. one, by Jul 22. A faint 'tail' to the west of the *f*. fragment was seen by numerous observers during Jul 27 – Aug 3 and Aug 23 – Sep 3, as in previous perihelic oppositions like 2003. By Aug 24–29, the *p*. spot was at the limit of detection, while the *f*. one was now small. There were no records of the *p*. spot after Aug 29. The remaining fragment was just visible to the Director at the eyepiece on Sep 1 and was imaged until Sep 3 (Hood), the last date upon which it was sharp and white. After that, there remained a vaguely light, diffuse patch, suggesting that all the ice had evaporated to leave the bare ground which faintly marked its former location, such as in 2003. This location was still recognisable a month later.

The seasonal rift which commences at $\lambda \sim 60°$ was first seen as an indentation during 2020 July and was eventually seen to break through to the other side of the cap, splitting it into two asymmetric fragments (Figure 14). Complete splitting was achieved around Sep 16 according to Wesley, and on Sep 22 to Kidd and Peach & Enzmann. The smaller fragment of the two rapidly decreased in size but was still resolvable in late December.

The SPC was slightly dimmed by high-latitude dust from the 2020 November large regional dust storm.

The SPC–SPH transition, 2020–'21

From around 2020 Dec 1 onwards, there existed a high-latitude morning-terminator white cloud, which coincided in latitude with the S. perimeter of *Hellas*. From Dec 5 (CM = 098°), Maxson showed the belt had become extremely bright in the UV,

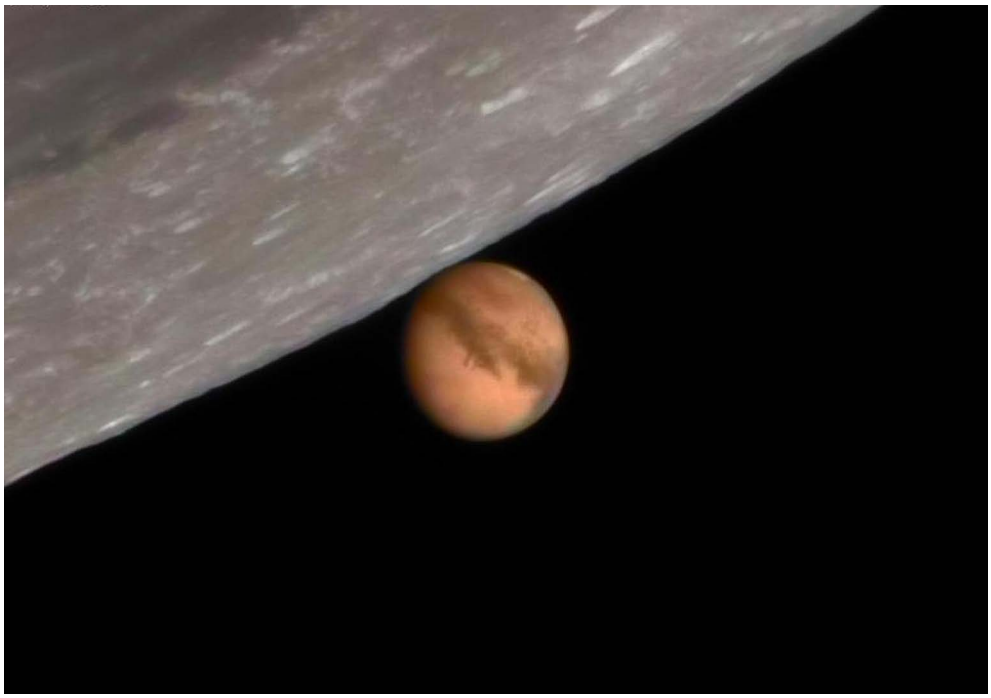

Figure 16. Lunar occultation, 2020 Sep 6 at 05:08:12 UT, imaged by D. A. Peach & E. Enzmann (760mm Cass. stopped to 500mm).

extending further onto the disc, and by Dec 9 it stretched across it from east to west. By then it was seen at all other longitudes, for example to Foster on Dec 9 under CM = 284°, and partly to the Director on Dec 11–15 under CM = 209–260°. It was less prominent in white light, but a blue filter made it brighter, and in the late-December UV images it was strikingly bright: see Figure 14 for Maxson's of Dec 20, upon which it extended south nearly to the edge of the SPC remnant. About 2021 mid-January the band faded, but it remained complete in longitude till late in the month, after which it was again limited to the morning side. Perhaps the final sightings were during Mar 22–25, upon images by Basey, Haigh and M. R. Lewis and drawings by the Director, which showed a wide southern belt over *Noachis–Argyre*. During the previous apparition, the belt of antarctic cloud had been well seen in 2019 February.[21]

By 2021 early January, cloud began to develop over the S. pole, alternating in visibility with the SPC summer remnant. Morning cloud was observed to affect western *Hellas* in 2021 January–February. Conspicuous white cloud that occupied the whole basin, and persisted throughout the day, was observed from Mar 2 until late April. *Argyre* too was filled by an isolated bright cloud, first imaged on Jan 31, and seen by the Director visually from early February till late March. This cloud had become larger and brighter by early March (appearing brilliant to Maxson, Mar 28–29), remained conspicuous during April, and was more condensed by early May.

As always, the final sightings of the summer SPC remnant depended upon CM longitude and hence upon the longitude of the observer: in the UK, visual observers lost it after Dec 31, though Haigh and M. R. Lewis imaged it till 2021 Jan 6. From Japan, Ito followed it till Jan 5, and despite good seeing conditions did not record it again till Jan 21. From Thailand, Olivetti had a similar experience, recording it until Jan 9, and then just once again on Jan 23 (*Ls* = 353°). From the USA, Maxson followed it till Jan 16.

SPC quantitative recession, 2020–'21

Figure 15 and Table 3 show SPC recession data for 2020–'21. 67 observers produced acceptably sharp images; 1,598 images were measured, and the latitude data grouped (as usual) into 5° 'bins' for *Ls* = 151–353° (2020 Feb 15 – 2021 Jan 23). Due to interference by the phase defect until July, latitudes initially had to be measured in the N–S direction at the CM, but thereafter we measured the cap's E–W angular diameter and hence the mean latitude of its N. edge. Red-light images were preferred over RGB composites.

Figure 15 shows that the 2020–'21 recession was regular and normal. In fact, the 2020–'21 data comprise the best set of BAA measures we have to date. Comparing 2018 to 2003, there had been evidence of a temporarily accelerated recession (beyond the seasonal norm) due to dust falling out upon the cap from the global storm.[21] For the three chosen years, the 2020 and 2018 data are in the closest accord, with the cap in both years being systematically smaller than in 2003 until *Ls* ~218°. After then, the recessions for the three chosen years do not differ significantly. The greatest differences always occur at the start of the recession, for it has been established that the new spring cap can show interannual variability: the amount of frost deposited may have been influenced by the levels of previous dust activity.

The Martian moons

For a BAA 'Observer's Challenge' the Director set the task of seeing Phobos and Deimos visually.[36] There was a good response, which the writer discussed on the Section website. Gray saw the moons visually on Aug 22. Venables viewed both moons on Sep 15 with a 450mm refl. at 00:30 UT, but had first reported glimpsing

Deimos by averted vision at 00:20 UT with only a 102mm OG, ×150 (a fluorite refractor with an occulting bar). The writer has not heard of other visual sightings with less than around 150mm aperture, but did not make a specific literature search. Biver saw the moons visually on Sep 22 and Oct 10. The Director noted any suspicion he had of a moon without first having checked the ephemeris, and on Oct 9 using a 410mm aperture, Deimos was correctly identified near W. elongation in this manner. Satellite images were received from Aerts, Biver, Go, James, M. R. Lewis, Maxson, Radice, J. Sussenbach, Tickner, Walton, and Wesley.

Lunar occultation

Enzmann & Peach secured a spectacular image of the lunar occultation of Mars on 2020 Sep 6: see Figure 16.

Conclusion

This was a closely followed opposition: a real achievement for all observers in the face of a world pandemic. It was also a remarkable moment in space exploration, with three countries succeeding with their Mars missions. This account has been completed well before the planet's solar conjunction, in order to bring the reports of the Section fully up to date.

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Notes & references

27 McKim R. J., 'The opposition of Mars, 2020: Part I', *J. Br. Astron. Assoc.*, **133**(3), 157–168 (2022)
28 McKim R. J., 'The opposition of Mars 1988', *ibid.*, **101**(5), 264–283 (1991)
29 McKim R. J., 'The Great Perihelic Opposition of Mars, 2003, Part 2', *ibid.*, **120**, 347–357 (2010)
30 The Director was very surprised by the anomalous evening terminator features portrayed by W. H. Pickering in 1894 (opposition date Aug 24, *Ls* = 267°) in a late edition of Sir Robert Ball's *The Story of the Heavens*, published by Cassell. (See for example the 1901 edition, p.217.) An original (and better) source is P. Lowell's *Mars* (Longmans, Green & Co., 1896, Plate 20, p.170f). Pickering's sketches show projections as well as apparent depressions. The projections were surely clouds, and it is just possible that some depression effects were caused by cloud shadows. The longitudes do not appear to correspond to that of *Arsia Mons*, but the observations were made at the same season.
31 See the note by R. Konnai and M. Murakami at the Oriental Astronomical Association's 'Communications in Mars Observations' (CMO) news page: **http://www.mars.dti.ne.jp/~cmo/2020News.html** (Accessed 2021 August)
32 **https://www.spaceweather.com/archive.php?view=1&day=24&month=10&year=2020** (Accessed 2023 July)
33 It is not expected that earlier observations will be forthcoming, for the successful detection of the AMEC shadow involves high-resolution imaging or critical visual inspection with a large aperture. A casual historical search by the Director yielded no other examples.
34 The 'Dawes slit' phenomenon is where an E–W strip of N. *Mare Acidalium* shows through the polar hood. For details and an historical illustration, see: McKim R. J., 'The opposition of Mars, 2005, Part 2', *J. Br. Astron. Assoc.*, **121**, 215–222 (2011).
35 Graff K., 'Beobachtungen und Zeichnungen des Planeten Mars während der Perihelopposition 1924', *Astron. Abhandlungen der Hamburger Sternwarte in Bergedorf*, **2**(7) (1926)
36 The BAA Observers' Challenge, 'Hunting the moons of Mars' (posted 2020 Sep 1) may be seen at: **https://www.britastro.org/node/24034** (Accessed 2021 August)

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