## LUNAR SECTION CIRCULAR

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## FROM THE DIRECTOR



Gassendi and Gassendi B, 23 April 2021, C14 (Leo Aerts)

In the May issue of this Circular Paul Abel reported an observation he made of what he described as a 'rille-like' feature entering the crater Gassendi B via its southern rim
and crossing the floor in a northerly direction. Paul's observation was made visually on the evening of 24 March 2021 using a 12-inch reflector and the feature was also imaged by the Director on the same evening. A feature described as a rille-crater chain is also shown in that location on the USGS geological map of the area. However, as Paul pointed out, the feature does not appear to be a rille on QuickMap/LROC imagery, but rather a raised ridge that appears to originate alongside a sunken feature outside the south wall of Gassendi B before crossing over the rim and continuing as a raised ridge across the crater floor.

This feature has elicited considerable interest among readers and we have received comments and images from Brendan Shaw, Dave Rothery, Richard Edmonds and Leo Aerts. The feature is well shown on Leo's fine image on the frontispiece of this issue (Gassendi B is the crater towards the top-left corner of the image).

Barry Fitz-Gerald has taken a particular interest in trying to establish the nature of this feature and he has worked up his thoughts into the thorough and elegant analysis featured later in the present issue. It remains to be seen whether his ideas turn out to be correct, but they are persuasive. Meanwhile, Paul invites observers to continue to submit images and drawings of Gassendi B under all possible angles of illumination.

## Bill Leatherbarrow

## OBSERVATIONS RECEIVED

A busy month has seen many images and sketches received from the following observers:

Leo Aerts (Belgium), Paul Abel, Massimo Bianchi (Italy - submitted by Franco Taccogna), Maurice Collins (New Zealand), Richard Edmonds, Dave Finnigan, Mike Harvey, Rik Hill (USA), Nick James, Martin Lewis, Rod Lyon, Mark Radice, Dave Scanlan, Trevor Smith, Alexander Vandenbohede, and the Director.

Pressure on space is particularly acute this month, so apologies to those who work is not featured in this issue. As ever, I have prioritised submissions devoted to a particular observational aim or accompanying report, along with a selection of gallery images.

Trevor Smith has reported an observation of Proclus on 17 May 2021 that showed bright spoke-like lines on the inner eastern slopes of the crater. Trevor commented that he had not seen such an appearance before over many years of observing, and neither had I. However, on setting the invaluable 'Dial-a-Moon: Moon Phase and Libration 2021' website to the time and date of Trevor's observation the features were clearly visible, suggesting they are of normal appearance under such illumination. Trevor's sketch and a screenshot from 'Dial-a-Moon' appear on the following page.


Franco Taccogna of the UAI has submitted the following two sketches of behalf of his colleague Massimo Bianchi. It is good to establish further relations with our Italian colleagues.

## Osservazione cratere Aristarchus



| Bianchi Massimo Alessandro | Tecnosky D: 125 mm f: 975 mm |
| :--- | :--- |
| Milano, $45,50^{\circ} \mathrm{N} 9,20 \mathrm{E}$ | Ingrandimenti: 325 x |
| 24/04/2021, ora (T.U.): da 19:23 a 19:49 | Filtri: lunare |
| Seeing (Scala Antoniadi):2 Trasp: 4 |  |

Osservazione cratere Gassendi


| Bianchi Massimo Alessandro | Tecnosky D: 125 mm f: 975 mm |
| :--- | :--- |
| Milano, $45,50^{\circ} \mathrm{N}$ 9,20E | Ingrandimenti: 325 x |
| 23/04/2021, ora (T.U.): da 19:03 a 19:25 | Filtri: nessuno |
| Seeing (Scala Antoniadi):2 Trasp: 4 |  |

## ARISTARCHUS AND HERODOTUS

In a previous Lunar Section Circular (April 2021), I reported on the results of my observations of Aristarchus and Herodotus using filters. I reported that the bands of Aristarchus (and indeed the whole of the interior of the crater) looked much darker in a W21 filter.

On 2021 April 24, I was able to repeat the observation and I obtained similar results. This observation yielded two new points of interest. I was expecting the darkening of the bands to be even more pronounced in the W25A red filter- this was not the case and I was under the strong opinion that the effect was more visible and better defined in the W21 filter. The second drawing here shows the effect in the W21 compared with integrated light

The second point was the observation of Aristarchus in the violet W47 filter. The effect was quite pronounced in that the whole crater seemed to be incredibly brilliant and appeared to be 'glowing' in this light. I removed the filter and observed and confirmed that in white light the formation looked completely normal, and on returning the W 47 the glow effect was repeated. I do not propose that this was a TLP, nor that the crater was really glowing, rather I think that the crater is perhaps most brilliant in shorter wavelengths.

The table below gives the full details of the observation as recorded in my $3{ }^{\text {rd }}$ Lunar log book:

2021 April 24, 305mm Newtonian Reflector, x300. Seeing: AII

| UT | Filter | Remarks |
| :---: | :---: | :--- |
| 2324 | W15 <br> (yellow) | Bands in Aristarchus are a little easier to see (in IL they are very hard <br> to spot tonight). The Schroter valley rille seems to be a little brighter <br> also in this light? |
| 2326 | W21 <br> (orange) | Striking difference- the bands are much darker and better defined. <br> Indeed all of the crater interior is fairly well defined, this includes <br> the wall and the central peak. |
| 2328 | W25A <br> (red) | The bands and crater interior are still easier to see, but interestingly <br> the effect is not as pronounced as in the W21. I was expecting the <br> bands to be darker (or as dark) but this is not the case. |
| 2332 | W47 <br> (violet) | Interesting view! The bands and the interior of Aristarchus are much <br> less distinct, but the whole crater seems to be glowing in this filter. <br> On returning to IL the effect vanished, I replaced the W47 filter and <br> the effect returned. |

I think it would be interesting to repeat this observation with other banded craters, and I am currently putting together a short paper for the Journal about this project.


When I give talks on lunar imaging I frequently get the question: 'Why the Moon? Nothing changes there. It's all been seen!' Well things change with slight changes in lighting. Most spacecraft have orbited and imaged the Moon do so to maintain a specific distance from the terminator in their pole to pole orbits, as a compromise lighting condition. As a result, you will not see a spacecraft image of the Blanchinus ' X ' shown in the left image, a feature that only lasts a few hours before the rising sun hides it. The circular shadow filled crater below and to the right is Werner ( 71 km dia.) with Blanchinus ( 70 km ) itself lost in the pool of darkness above immediately right of the ' X '. In fact the walls of Blanchinus make up the right side of the ' X '. On the right edge of this image is a nicely shown flat floored crater Apianus ( 65 km ) with Playfair $(49 \mathrm{~km})$ above it half in shadow.


The right hand image is at a colongitude equivalent to a day later (though actually 355 days later). The large crater at the top of the image is Arzachel ( 100 km ) with Werner being the very circular crater at bottom. Blanchinus is just above it, a shallow oval crater and above that is La Caille ( 70 km ). The large crater on the terminator to the left of Blanchinus is Purbach ( 121 km ). Can you see the ' $X$ '? It takes a bit of work but I've given you lots of clues. One feature I used as a landmark for myself is the odd crater to the upper right of La Caille that looks like a deer footprint, Delaunay ( 48 km ). In the left image it is in full shadow but is identifiable with the small crater below. This is pretty much how the ' X ' looks in most spacecraft images. This is one reason 'Why the Moon?' To look for transient features like this ' X ' and watch them change with different sun angles.

## HIGH-SUN VIEWS OF THE MOON

Most lunar observers concentrate on features near the terminator, where long shadows reveal formations at their most dramatic. Maurice Collins has submitted a series of images taken under high solar illumination and these show familiar features in - quite literally - a different light. We feature one of the area around the Ariadaeus rille. This emphasises just how bright the crater Dionysius is around full moon. It is located just to the left of Sabine and Ritter in the image below.


Dionysius, 28 April 2021, 10-15 UT, 110mm OG (Maurice Collins)

## IMAGES GALLERY

The following is just a small selection of other images submitted this month.


Eratosthenes \& Montes Apenninus with Stadius to south-west. 2021.04.21-19.59 UT.

300mm Meade LX90, ASI 224MC Camera with Pro Planet 742nm I-R Pass Filter. 1,000/4,000 Frames. Seeing: 7/10. with troublesome wind.

Mark Radice has marked the recent passing of Apollo 11 astronaut Michael Collins with this fine image of the historic landing site and adjacent craters named in honour of the Apollo 11 crew.


Apollo 11 Landing Site
18 April 2021 2030Z
C11 f20 ASI224MC 610nm Red filter


Montes Caucasus (Alexander Vandenbohede)


Mare Frigoris, 23 April 2021, C14 (Leo Aerts)


Plato, 20 April 2021, 20-11UT, 444mm Dobsonian (Martin Lewis)


Cassini 2021.03.22 20:47 UT, S Col. $21.0^{\circ}$, seeing 6/10, transparency very good
Libration: latitude $-03^{\circ} 06^{\prime}$, longitude $-07^{\circ} 00^{\prime}$
305 mm Meade LX200 ACF, f 25, ZWO ASI 120MMS camera, Baader IR pass filter: 685 nm . 640 frames processed in Registax 6 and Paintshop Pro 8.
Dave Finnigan, Halesowen

## AN ANALYSIS OF THE TOPOGRAPHY OF GASSENDI B

Barry Fitz-Gerald

In the May 2021 LSC Paul Abel describes a rille-like feature that he spotted visually near to the crater Gassendi B [1] and which appeared split into eastern and western branches to the south-west of the crater. The eastern branch cut the south-western rim of Gassendi B and continued down on to the crater floor, whilst the western branch ran up the western side of the crater (Fig. 1). He commented that spacecraft images of the crater do not show any rilles, but an image that accompanied Paul's article and taken by Bill Leatherbarrow at the same time as the observations were made confirms the presence of a rille-like feature crossing the south-western rim.


Fig. 1 Drawing by Paul Abel of the rille-like feature associated with Gassendi B
Paul's comments regarding the spacecraft images are indeed correct; in fact the LRO and SELENE images which provide the best resolution only make any interpretation of what is actually present more confusing!

Fig. 2 is a SELENE morning image of Gassendi B showing some of the features that may be connected with Paul's observations - with emphasis on the may! A 30km long line of 4 to 5 small elongate troughs can be seen running from the south-west of the crater up to the western rim. Some of them may be secondary craters of some form, others simply elongate troughs but they do not appear to be related to each other in
any way, and their alignment is probably fortuitous. What they may do in combination and under grazing morning illumination, however, is to contribute to the appearance of an apparently linear feature running up towards the western rim of Gassendi B. This might account for the western branch of the rille seen in the visual observation. These craters are visible in Bill Leatherbarrow's and other amateur images of the area available on the internet.


Fig. 2 SELENE/JAXA evening image of Gassendi B showing a series of craters and troughs (outlined in blue) running from the south-west up to the western rim. A further two elongate troughs apparently cut the southern rim. Note the NE-SW trending graben Gr (outlined in yellow).

There are a number of graben in the area which trend in a NE-SW direction, and one of these, which is relevant to this account, can be seen in some amateur images to run down from the crater Letronne A, southwards and to apparently cut the north-eastern rim of Gassendi B. The spacecraft images show the graben is heavily obscured, presumably by later deposits of crater ejecta, and it becomes quite indistinct as it approaches the crater rim. It is not visible on the floor of Gassendi B, though it is undoubtedly present beneath the material that now fills the crater floor. Images captured by observers and available on the internet do however show an apparent alignment between the graben and a low ridge that crosses Gassendi B and lines up with the apparent notches in the southern rim, suggesting some form of continuation of the graben across the crater floor. Fig. 3 is a 3D viewer rendition of Gassendi B viewed from the north, showing the graben approaching the crater's north-eastern rim, which it cuts as shown by the notch in the rim at this location. On the crater floor the
low ridge that follows the line of the graben can be seen heading towards the notches in the southern rim. This certainly suggests that the graben continues in some form beneath the crater or its presence has played some part in forming the topography within the crater. One rather baffling aspect of this model however is that the ridge not only appears to head towards the southern rim, but seems to climb up and over the southern rim and continue onto the plains surface beyond! Of course what appears to be happening in these images may just be an artefact of the reconstruction, and the ridge in question may perform no such acrobatics in reality.

Of relevance to the observation that started this article is a US Geological Survey map (Fig. 4) of the Letronne Region produced in 1963 [2], and prepared following telescopic observations of the area. Unfortunately we don't know whether these observations occurred at a particular lunar phase or whether the map is a composite based on numerous observations under varying illumination.


Fig. 3 3D viewer model of Gassendi B viewed from the north along the line of the graben that cuts the north eastern rim. The low ridge that follows the graben alignment can be seen on the crater floor (yellow arrows) and it appears to head towards the notches in the southern rim. Note that in this model the ridge appears to climb up and over the southern rim and onto the plains beyond.


Fig. 4 Section of USGS Geological map of the Moon Letronne Region I-385, showing Gassendi B. Note the graben approaching the crater from the north (dashed line) transforms into a feature marked 'rc' which is 'Rill and crater chain material'.

This map shows that the observers who contributed to it saw the feature crossing the floor of Gassendi B as a rille or alignment of craters and not a ridge. This seems to tally with what Paul saw, showing that what is seen in the eyepiece is clearly rillelike.The spacecraft data, however, shows nothing resembling a rille crossing the crater floor and so an alternative explanation is required.


Fig. 5 Geological sketch of Gassendi B showing Hummocky crater floor-Hcf, hilly ridge-Hr, grabenGr, prominent ridge-R, slumps off the rim of the crater-S and troughs-T.

The geological sketch map Fig. 5 shows some of the key features in and around Gassendi B. Firstly, and to state the obvious, Gassendi B is clearly older than Gassendi A. This is relevant because the floor of Gassendi B is covered in hummocky material that is likely to be ejecta from its younger neighbour. This ejecta is broken up into numerous small hills separated in places by curving grooves, which give the deposits something of a structured appearance. Of relevance to the current subject is the presence of a couple of lines of hills which form a boomerang-shaped complex with one arm sub-parallel to the northern rim and the other running across the crater floor on the same alignment as the graben mentioned earlier (Hr in Fig. 5). This particular alignment crossing the floor is extremely subdued, and in the spacecraft images is extremely difficult to distinguish from the surrounding hummocks. However, it must, under very low angle illumination, become visible possibly as a result of shadows cast to the west by the individual hills. Fig. 6 shows the floor in a
little more detail, and even though the white line is laid along this alignment, it is remarkably difficult to see, especially to the south. But if you flick back to Fig. 3 it appears to be conspicuous, and telescopically gives the impression of a rille or crater chain!


Fig. 6 SELENE evening view of Gassendi $B$ with white line indicating the eastern edge of a line of hills which are aligned with the graben cutting the north eastern rim. Note the hummocky nature of the crater floor deposits which are cut by curving grooves in many places.

A possible explanation for the alignment is that prior to the deposition of the hummocky ejecta, the graben cutting the northern rim was exposed on the crater floor and that the deposition of the ejecta reflects this underlying topography. In this model the line of hills would be perched on and bury the western side of the graben, with the trough of the graben lying to the east as a slight depression orientated along the same direction. Alternatively, the graben may have become active after the ejecta was deposited and produced the alignment in the hills by faulting - but this seems unlikely with such an apparently ancient graben.

So in conclusion, as to the rille crossing the crater floor, we are not really very much further forwards, other than to say that there is no rille in the strict sense of the word and that the impression of a rille or crater chain when viewed telescopically may be down to the eye joining up the shadows cast by the individual hills to form a continuous line, a phenomenon not unusual when viewing at the limit of resolution. This impression clearly influenced the USGS map makers in 1963.

Returning to Fig. 5 we can see that a much more prominent ridge snakes across the eastern crater floor, and appears to climb up and over the southern crater rim (Fig. 3). Fig. 6 shows that it is this more prominent ridge that crosses the crater rim, and the impression that the line of hills crosses the rim seen in Fig. 3 is just that - an impression, as the southern end of this line of hills corresponds to the 'kink' in the prominent ridge where it turns south up the crater wall. This ridge is a ridge proper and not an alignment of hills, but it is scored in many places by grooves which cut it at $90^{\circ}$ to its long axis. When it climbs up and over the crater rim it is flanked on each side by irregular troughs which are visible in Bill Leatherbarrow's and other high-res photos cutting the rim. Slumping off the crater rim is also visible between the ridge and the rim, particularly the eastern rim.

A fairly obvious interpretation of this ridge is that it is just the result of more rim slumping, rather as if Gassendi B had aspirations towards being a concentric crater but failed as only the eastern part of the rim collapsed. This ridge is still buried in shadow in Bill Leatherbarrow's image and Paul's drawing, but is clearly shown in other amateur images available on the internet. Curiously it is also labeled 'Rill and crater chain material' in the USGS map (Fig. 4) but is clearly a ridge, and even more so than the hilly ridge discussed above which was quite vague in comparison.

Whilst a rim slump is probably the least contentious explanation for this ridge, there are one or two aspects of its morphology that suggest this is not the whole answer.


Fig. 7 LRO topographic profile along the line shown in the left panel showing the position of the prominent ridge in relation to the crater rim. The slope of the red arrow is approximately $7^{\circ}$.

Fig. 7 shows a topographic profile across one section of the ridge, and as can be seen it is not at the base of the inner crater wall but some distance from it. In fact if this was a slump it would have travelled some 2 kms down a slope of $7^{\circ}$ and still retained its integrity as an approximately 100 m high ridge. In comparison the annulus of Hesiodus A, another rim slump, has not travelled further than the base of the inner wall which is much steeper at some $26^{\circ}$. Also there is the little problem of it taking a detour off the crater floor and up and over the southern rim - not easy to explain using the slump scenario.

An alternative explanation may be connected with the impact that created Gassendi A, which appears circular in outline, but is I suspect the result of an oblique impact. Evidence for this can be seen in the ejecta pattern of Gassendi A shown in Fig. 8 which shows the crater with two different Quickmap overlays enabled. Fig. 8a shows the iron abundance in the deposits surrounding the crater with blue representing low iron and green high iron content. The blue colour reflects the presence of plagioclase rich highland rocks (which are poor in iron), and as can be seen the distribution is asymmetric, with most to the east and north but less to the south and west. This reflects the geology of the impact site, with the northern part being composed of plagioclase rich highland rocks and the southern part less so. This might have something to do with the southern part of Gassendi A having excavated the glacis of Gassendi and the iron rich impact melt rocks within it.

The most significant component of this ejecta pattern is the long ray that extends from the crater's western rim up towards Letronne A. This northern, plagioclase-rich ray is visible in Fig. 8b as a curving lighter coloured feature, visible in this reflectance image but otherwise indistinct. Meanwhile, to the west of Gassendi A there is no bright ray, but instead a darker more iron-rich ray that appears to hug the northwestern rim of Gassendi. So, what appears to be shown in the mineral data is a bright curving ray to the north and a dark curving ray to the south, with both emerging from the western side of Gassendi A and each passing very close to the eastern rim of Gassendi B.


Fig. 8a JAXA SELENE/Kaguya Mineral Mapper abundance of FeO (wt\%) with the ejecta to the north of Gassendi A highlighted by its low iron content (blue) and 86 Chandrayaan-1 M3 Apparent Reflectance Mosaic @1489nm showing a light ray with a slight curve within this area of ejecta. Note the ray has a slight curve to the east. Also note the dark iron-rich ray emerging from the western rim of the crater. Northern ray indicated by yellow arrows.


Fig. 9 The crater Harding (left) has one bright cardioid ray to the south, but no corresponding ray to the north. The Clementine UVVIS FeO abundance overlay (right) shows that the bright ray (white arrow) is relatively low in iron content but that a darker more iron rich ray also also present to the north (black arrow).

This asymmetric distribution of ejecta appears to define a 'Cardioid' ray pattern which is characteristic of some oblique impact craters, where the up-range ejecta blanket is dominated by two prominent rays which are convex in the up-range direction [3]. Good examples can be seen in the far-side craters Jackson and Ohm, but a lesser known example is Copernicus, which has prominent cardioid rays in its southern ejecta blanket [4].

These rays indicate the trajectory of the impactor as they form symmetrically either side of it and in the up-range direction, which in the case of Gassendi A was from the north-west, with the approach being directly over Gassendi B! It could be argued that as only one ray, the northern one is clearly visible in the imagery, that this is not a Cardioid ray system at all, and therefore cast doubt the whole oblique impact scenario, but the oblique impact crater Harding (Fig. 9) provides another example where one Cardioid ray is bright and the other dark and essentially invisible due to the diverse nature of the lunar surface at the impact site.

The area between two cardioid rays is termed the Zone of Avoidance or ZoA, because ejecta is normally sparse or absent in this wedge-shaped zone. The crater Cauchy is a super example of this, with a ZoA to the west of the crater apparently devoid of any ejecta. But not all craters with these rays have a ZoA with no ejecta, with Copernicus being an example of a crater with these rays but where ejecta and secondary craters cover the surface between [4]. Another unusual feature that can be found in the uprange ejecta of some craters is ridges, some vaguely chevron-shaped and some rather sinuous [5].


Fig. 10 Left. SELENE/JAXA image of Dawes showing Rima Dawes to the east which is the up-range direction. Right Clementine UVVIS colour-ratio image showing early ejecta in the downrange direction to the west (red arrows) and the later ejecta distributed in a more symmetrical halo (white arrows). Area shown in yellow box is shown in more detail in Fig. 11.

The crater Dawes is probably the best example of this type of crater, with Rima Dawes to the east being an example of a complex up-range ridge pattern. Fig. 10 shows Dawes and Rima Dawes which takes the form of a ridge running almost tangential to the eastern rim with a trough running parallel down the eastern (uprange) edge. A gap in the 'rima' can be seen dividing it into northern and southern halves - this gap corresponds to the impactor's trajectory. The impact that produced Dawes was a low angle one from the east, which is clearly shown by the distribution ejecta visible in the Clementine UVVIS colour-ratio image. The first ejecta to leave the crater did so preferentially downrange along the trajectory of the impactor - this shows up as a yellow fan to the west in Fig. 10. As the impact process proceeded the ejecta left the crater more symmetrically, producing a fainter circular halo as can be seen. There is no ZoA, but the ridges are arranged symmetrically either side of the uprange to down-range axis indicating that they are features of the ejecta blanket.

A more detailed view of the northern element of Rima Dawes (Fig. 11) shows it to have a somewhat sinuous nature, not unlike the ridge in Gassendi B. It is likely that the ridge and the adjacent trough formed simultaneously in a process that is probably related to secondary cratering.


Fig. 11 SELENE/JAXA view of the northern component or Rima Dawes. Note the trough immediately to the east which probably formed simultaneously.

Another fine example of an up-range ridge is shown in Fig. 12 which is a SELENE image of the crater Horrocks, which is another low-angle impact crater, with the impactor this time having arrived from the south. Here a chevron or 'V' shaped ridge can be seen in the up-range direction to the south. This ridge may have formed in association with pair of now invisible cardioid rays, and whilst they suggest a ZoA within the ' V ', a thin layer of ejecta exists to the south of the ridge and within the arms of the ' V '. As with many of these ridges (such as those in Dawes) the chevron ridge comes with an associated trough on its up-range side, in this case it is most clearly seen to the south of the V's vertex (Fig. 13).

Returning to the ridge in Gassendi B we can see that it shares a lot of features with the up-range ridges discussed, it is in the up-range zone of an oblique impact crater, it has a somewhat sinuous morphology that lies on top of the pre-impact surface and as in the case of Horrocks, it has a (roughly) chevron shape with the vertex pointing back towards the parent crater.


Fig. 12 Horrocks as imaged by SELENE showing a V or chevron shaped ridge to the south which is the up-range direction in this oblique angle impact crater.


Fig. 13 SELENE view of the chevron or V shaped ridge to the south of Horrocks. Note the slight sinuosity to the ridge and the trough running parallel to it on the up-range side.


Fig. 14 SELENE image showing the ridge (orange dashed line and $R$ ) climbing up and over the southern rim of Gassendi B and onto the adjacent plains.

The fact that the Gassendi B ridge appears draped over the topography such as the southern rim (Fig. 14) is an additional factor suggesting that it is a depositional feature within the up-range ejecta of Gassendi A and not a slump off the rim of Gassendi B. The troughs either side of the ridge and the notches they create in the southern rim may also have formed at the same time as the ridge and are analogous to the troughs seen in association with the ridges in Dawes and Horrocks. I think the evidence is reasonably persuasive, but then again I am an unapologetic lowangleophile, and tend to see evidence for oblique impacts everywhere.

So, Paul's observation has revealed a potentially rather complicated story concerning this rather unassuming crater. His drawing clearly reflects the strong impression of a rille on the crater floor, an impression shared with the telescopic observers who prepared the USGS map and provided the geological interpretation and labelling. The spacecraft data whilst limited in some senses allows an explanation to be proposed for the observations - showing that both sources of information, visual observations and photography are complementary with each telling a different but equally valid story.

## Appendix.

The below image, kindly supplied by Mark Radice shows the graben approaching and cutting the northern rim of Gassendi B (red arrow) the low ridge of hills which may define the western edge of this graben as it passes underneath the crater floor (white arrow) and the notch in the southern rim (yellow arrows). The alignment of all these features is clear in this image, as are the numerous troughs outlined in Fig.2.


## Acknowledgements:

Many thanks to Bill Leatherbarrow and Paul Abel for their useful discussion and input on the subject contained in this article.

Fig. 1 reproduced courtesy of Dr P. Abel.
Fig. 4 reproduced courtesy of the United States Geological Service and Lunar and Planetary Institute.
LROC images reproduced by courtesy of the LROC Website at http://lroc.sese.asu.edu/index.html, School of Earth and Space Exploration, University of Arizona.

Selene images courtesy of Japan Aerospace Exploration Agency (JAXA) at: http://l2db.selene.darts.isas.jaxa.jp

## References

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4. Fitz-Gerald, B. (2017) 'Pytheas and Copernicus'. BAA. Lunar Section Circular, Vol. 54, Nos 8-9
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## LUNAR OCCULTATIONS <br> June 2021 <br> Tim Haymes

## Time capsule: $\mathbf{5 0}$ years ago

[ With thanks to Stuart Morris for the LSC archives. https://britastro.org/downloads/10167]

- Report of the LS meeting at Chester, June $5^{\text {th }}$.
- W. Leatherbarrow: Drawing Lunar features.
- R. Browning (while studying O-level): three occultations timed during the Lunar Eclipse of August $6^{\text {th }}$ with 10 cm reflector $\times 31$.


## Occultations with the 'SPALAKH' Television System

Steve Harvey (Director, BAA Computing Section) sends a PDF of a paper authored by V.V. Kleshchonok and M.L. Buromsky (University of Ukraine, Kiev) of 'television' observations of lunar occultations recorded at the Astronomical Observatory of Kyiv University made in 2003-2004.

Timings were made as AVI $25 \mathrm{fps}(40 \mathrm{~ms})$ using the SPALAKH TV system. The stars reported are the double gamma Virginis (SAO 138917) and eleven other SAO stars. Gamma produced a step light curve.

I subsequently found some details of the equipment in another reference. The camera was a SANYO CCD TV camera VCB-35741RP mounted on the Repsold refractor ( $\mathrm{D}=20 \mathrm{~cm}$ ), captured with an ASUS VideoSuite videocard and VideoCap software. The Computer system had NTP time synchronised with 'AboutTime' once a minute. The UT of the gamma Vir step event was 2003 Aug 06, 1850h 11.00s and 1850h 11.47s.

A Google search on the camera indicates its primary use was as a sensitive security camera. I also found this picture:
https://www.researchgate.net/figure/Main-photosensitive-component-CCD-TV-camera-SANYO-VCB-3574IRP fig2_252772929

## Observations of gamma Virginis - a bit of a surprise?

Searching the Occult4 archive (AD 1623-2017), I was surprised to note the most 'recent' UK observations were by the late Ernest Beet at Pangbourne on 1948 Feb 26 at 2331UT, and by Mr P. Eade (Wallington Green) on the same evening. They both observed a disappearance at the bright limb (DB) at $93 \%$ phase. An un-named observer at Haywards Heath observed an RD of gamma on 1980 Feb $5^{\text {th }}$ just after moonrise at an altitude of 9 degrees. Since then there have been no UK reports.

Why not?

## Predictions for Gamma Vir:

Occult-4 was used to display all events from 1948 to 2022. One hundred ninety-eight (198) events were listed. Twenty-six occurred for the UK, of which only 3 were observable in darkness or reasonable elevation. For the majority the events were in daylight or too close to the horizon. Only three observable events remain. These are:

Date / UT Observed by:
1948 Feb 27.0
1980 Feb 6.0
Beet, Eade
1998 Nov 15.2 anon. unobserved in the UK.

## Next events:

It appears we don't have to wait long for another opportunity. Next year (2022) there is a favourable situation across Europe and West Africa on May $13^{\text {th }}$ just after midnight when gamma Vir will be occulted (DD) with the Moon at $87 \%$ illumination and at 20 degrees elevation from the UK. A second event occurs on July $6^{\text {th }}$ at 18 hr .

## Occultation of 1821 SF0, 2.8, on 2022 May 13



Above: Global map for the prediction of gamma Vir on 2022 May 13.1 The white line is a graze in darkness and the Eastern lobe contains events at night for UK, France, Spain, Germany etc.

My thanks to Steve which prompted this look at gamma Vir, a well observed double star, and a good example.

## Reports Received:

Double Star SAO-99202:

Observers in the UK occultation group recorded the DD of SAO 99202 on April 22nd (2309UT) - a suspect double brought to our attention by Alex Pratt in Leeds, UK. The response was good, and five light curves were obtained. None indicated a double though.

Two observations were recorded at higher frame rates (as SER files), the others were at 25 fps . Our provisional conclusion is that there was no double resolved at this Cusp Angle, or the companion was too faint.

Video recording of lunar occultations aim to find new double stars and to investigate previous visual observations reported as possibly double. For known doubles we can determine the position angle and separation of the components if the observing stations are far apart (...at least 1000 km )

Observer Details: P Denyer (London), T Haymes (Oxford), S Kidd (Stevenage), M O'Connell (Dublin), A R Pratt (Leeds), P Tickner (Reading).


S Kidd at 148 fps, USB3 CMOS


A R Pratt at 25fps, WAT-910HX video

Epsilon Gem on 2021 May 15:
The writer set up a 300 mm F5.6 telephoto lens to time the DD. The Moon was visible through a double-glazed window at low elevation of 10 degrees, and he used a QHY174m CMOS camera with the GPS time module. He found the limiting magnitude was about 7.5 using 40 ms exposure ( 25 fps ). Magnitude v3.0 Epsilon was also recordable at $100 \mathrm{fps}(10 \mathrm{~ms})$. Unfortunately the Moon was covered by cloud 20 min before the ingress, so no timing was obtained.

The image quality is quite usable for brighter occultations at this illumination despite double glazing. The maria are illuminated by Earthshine but I don't believe any further data could be gleaned with this small aperture (53mm). The camera has $5.9 \times 5.9 \mathrm{u}$ pixels ( $8 \mathrm{arcsec} / \mathrm{pix}$ binned).

The software was SharpCap 3.2.6482 as SER (bin $2 \times 2$ ) and a frame taken from TANGRA (Below)


Above: epsilon Gem and the Moon on May $15^{\text {th }}$ with Canon 70-300mm F4-5.6 $L$ lens and image stabilisation turned off. Focus was manual at 300 mm focal length. A number of fainter stars are recorded.

## Occultation predictions for North Oxfordshire in 2021 June

E. Longitude - 11800 , Latitude 515500 , Alt. 119m; Moon Alt $>5$ degrees Some fainter predictions are omitted near Full Moon.


| 1 Jul | 2 | 2 | 44 | 41.8 | R | 129029 | K4 | 7.9 | 7.2 | 48- | 87 | -8 | 21 | 120 | 3 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 Jul | 3 | 0 | 54 | 37.7 | R | 109997 | K0 | 8. | 8.2 | 39- | 77 |  | 4 | 86 | 80 N |
| 21 Jul | 4 | 1 | 35 | 20. | R | 344 | G5 | 8.4 | 7. | 29- | 66 |  | 7 | 83 | 82 S |
| 21 Jul | 5 | 1 | 59 | 31.1 | R | 93279 | F5 | 8.8 | 8.6 | 21- | 54 | -12 | 9 | 77 | 48 N |

Notes on the Double Star selection:

Doubles are selected from Occult4, where the fainter companion is brighter than mag 9.0, and the time difference(dT) is between 0.1 and 10 seconds. Please report double star phenomena. Additional prediction are available from OccultWatcher software.

Key:
$\mathrm{P}=$ Phase ( R or D ), $\mathbf{R}=$ reappearance $\mathbf{D}=$ disappearance
$\mathrm{M}=$ Miss at this station, $\mathrm{Gr}=$ graze nearby (possible miss)
CA = Cusp angle measured from the North or South Cusp. (-ve indicates bright limb)
$\mathrm{Dbl}^{*}=\mathrm{A}$ double star worth monitoring. Details are given for selected stars.
$\operatorname{Mag}(\mathrm{v})^{*}=$ asterisk indicates a light curve is available in Occult-4
Star No:
1/2/3/4 digits = Zodiacal catalogue (ZC) referred to as the Robertson catalogue (R)
5/6 digits = Smithsonian Astrophysical Observatory catalogue (SAO)
X denotes a star in the eXtended ZC/XC catalogue.
The $\mathrm{ZC} / \mathrm{XC} / \mathrm{SAO}$ nomenclature is used for Lunar work. The positions and proper motions of the stars in these catalogues are updated by Gaia

Detailed predictions at your location for 1 year are available upon request.
Occultation Subsection Coordinator: tvh dot observatory at btinternet dot com

## LUNAR DOMES (part XLVIII): Domes near Maskelyne region

Raffaello Lena and Barry Fitz-Gerald

## Introduction

In this note we examine two suspect lunar domes located near the craters Maskelyne $G$ and $X$ in Mare Tranquillitatis, near the Apollo 11 landing site (Fig. 1).

The image shown in Fig. 1 displays the examined region under a moderate-high solar illumination angle and indicates the boundary of some units including sinuous rilles, wrinkle ridges and a series of elongated pits which likely are secondary impact craters from Theophilus.


Figure 1: Image of the examined lunar region made by M. Wirths using a Starmaster driven Dobsonian 40 cm . In this image the examined domes are labeled as 1 and 2.

The domes were imaged under lower solar illumination angle by Viladrich on July 17, 2014 at 02:16 UT using a 35.5 cm Schmidt Cassegrain telescope (Fig. 2).

Note the small dome ( 3 km in diameter), named Maskelyne 2, which is well detected in the image taken by Viladrich.

On the contrary Maskelyne1 is not prominent demonstrating that the slope of this suspected dome is extremely shallow.


Figure 2: Image of the examined lunar region made by C. Viladrich on July 17, 2014 at 02:16 UT using a 355 mm Schmidt Cassegrain telescope. Crop of the original image with contrast enhancement. The domes are marked with white lines.

## General overview and historical report

On the $15 t^{\text {h }}$ July 1964 C.M. Pither observed and drew a dome-like feature which he believed to be previously unreported to the east of the crater Maskelyne [1]. His drawing of the feature is reproduced in Fig. 3 which shows an oval feature with its major axis running north-south.


Figure 3: Drawing made by C.M. Pither of a dome-like feature to the east of Maskelyne. The image is orientated with south upwards. The small crater at the northern end of the dome is Maskelyne $G$. Reproduced from The Moon, Vol.13, No. 1 courtesy of the BAA Lunar Section.

Following his observations with a 7inch reflector Pither consulted his copy of the Kuiper Photographic Lunar Atlas, and noted the presence of the dome in images B4-a and B4-e [2]. The same area is shown in Photo Number C2201 (Fig. 4) of the Consolidated Lunar Atlas [3] which shows the incredibly uneven appearance of the surface of Mare Tranquillitatis under low angle illumination.

What this image also shows is that the suspected dome lies immediately east of a wrinkle ridge complex that extends southwards from Lamont. Bearing this in mind it would be reasonable to ask whether this feature is really a dome, and not simply part of the broad surface swelling we see associated with many wrinkle ridges? Pither's drawing seems to suggest this structure is a discrete dome as opposed to an extension of the wrinkle ridge complex and he reported it as such.

## Morphology

The flank slopes of Maskelynel are extremely shallow so it is only visible under very low angle illumination, and as a consequence it is very poorly shown in modern spacecraft images.

Fig. 5 is a SELENE evening image of the area, showing the location of the dome, though LRO topographic data suggests that the surface swelling extends much further to the east and west. No obvious signs of dome-like structures are visible in this image, with no lava flows or pyroclastic deposits to suggest any form of effusive volcanism. There is a small $(\sim 1 \mathrm{~km}$ diameter) crater located at the 'summit' of the dome, but this has morphology more in keeping with being a secondary crater from Theophilus.

It has slightly raised rims to the east and west, a depressed rim to the south and no rim to the north, which would be consistent with being formed by a low angle impact from the south.


Figure 4: Photo Number C2201 from the Consolidated Lunar Atlas showing the southern portion of Mare Tranquillitatis and the location of the dome observed by C.M. Pither. It can be discerned to the south of Maskelyne $G$ and between a wrinkle ridge to the west and Diamondback rille to the east (see Fig. 5). Image courtesy of Lunar and Planetary Institute.

There are a number of other depressions in the summit area, but they show no compelling evidence for being anything other than old impact craters. The absence of an obvious vent makes identification of this as being a dome as opposed to a tectonic crustal up-warping slightly problematic, but the LRONAC imagery provides some other support for this interpretation. This takes the form of a number of small impact craters on the dome (black circles in Fig. 5) and in the surrounding area that have unusual patches of lighter material visible, particularly around their rims and the inner walls.

These patches are difficult to spot in LRO images taken with high incidence illumination and only become conspicuous under low or medium incidence illumination. They are also easily confused with the patches of loose rocks and boulders which erode from the crater rims to form scree-type deposits.


Figure 5: SELENE evening image of Maskelynel to the south of crater Maskelyne G. The location is indicated by the large yellow dashed oval. A smaller dome like feature to the south-west is indicated by a yellow dashed circle. Black circles indicate the location of small craters with bright patches and the orange circle a Ring Moat Dome. Craters numbered 1-3 shown in more detail below.

Fig. 6 shows two typical examples where these light patches can be seen around the carter rims and walls. Unlike scree-type deposits which tend to form patches and streaks down slope, these particular patches are irregular in shape but in many places have quite sharp edges. Unfortunately the size of many of these patches means that they are at the limit of resolution in even LRO NAC images, but it is still possible to see that the general lighter background consists of a rocky substrate with the occasional superimposed larger boulder which probably originates from bedrock around the crater rim. The beneath the rocky component a much smoother light surface can be seen, so the patches consist of a fine grained base, with an irregular rocky layer above and then the odd larger boulder superimposed. In all probability the fine-grained base is composed of smaller rocks below the resolution of the images available.

Due to its larger size, the 2 km diameter crater 3 in Fig. 5 immediately to the west of Maskelyne G provides a much better illustration of the morphology of these light patches, and though not strictly part of Maskelynel, the morphology displayed is the same, albeit on a larger scale.


Figure 6: Examples of two small impact craters (craters 1 and 2 in Fig. 5) showing unusual light patches on their rims and inner walls. Note the irregular shapes but relatively sharp margins to some of the patches.

## Irregular Mare Patches (IMPs)

With reference to Fig. 7 which shows a portion of the north-western rim of crater 3 in Fig. 5, two light patches can be seen, labeled A and B. Patch A shows the irregular shape with the sharp margins often seen in these features, as well as the fine grained base with an overlying but irregular rocky layer and finally one or two isolated larger boulders. Patch B shows an intriguing morphology with just the fine grained base visible but arranged in a weird irregular 'wormy' pattern. This 'wormy' pattern is shown to better effect on the rim of a nearby small crater (inset Fig. 7) and it is clear that this and patches A and B are not conventional boulder fields but represent some other feature.

One possible explanation for these patches is that they are produced by removal of dark fine grained mature surface regolith by the vigorous release of volcanically derived gasses from within the crust, exposing brighter optically immature subsurface material. This type of process has been suggested as a mechanism in the formation of Irregular Mare Patches (IMPs) [4] and as such it would mean that these features are IMPs of some form.


Figure 7: A small section of the north-western rim of Crater 3 in Fig. 5, showing larger examples of the light patches seen within some small craters on the dome to the south. Patch $A$ has a rockier and more continuous floor whilst patch B is more irregular and has a finer grained, less rocky floor. The inset shows a nearby smaller patch at the same scale - note the sinuous pattern which covers a $100 \mathrm{~m} x$ 20 m patch on the rim of a small crater.

Numerous IMPs have been identified in Mare Tranquillitatis in the past and new IMPs continue to be catalogued [5-6] and whilst their origin continues to be debated the outgassing hypothesis is, in the opinion of the current author (Fitz-Gerald) the most parsimonious and consistent with the evidence. In the examples discussed above it appears (if this is the correct mode of origin) that the amount of outgassing and removal of mature regolith has been insufficient to produce the high albedo, deeply etched structures commonly associated with IMPs. As such these might be considered to be relatively immature examples, where maturity relates to the stage of development reached before the formation processes stopped.

These structures will therefore be referred to as Immature Irregular Mare Patches or iIMPs to distinguish them from their more visible relatives. These structures may therefore represent the earliest stages of IMP formation where gas release has removed some of the mature surface regolith, but not to a depth sufficient to expose the very optically immature subsurface or produce depressions typical of regular IMPs. The examples noted above such as patch B in Fig. 7 may represent an early phase where the upper regolith layers only are removed, whilst the rockier patch A would represent a more advanced stage where the more coarse grained deeper subsurface becomes exposed. In all of these cases that fact that the iIMPs are difficult to see under high incidence illumination suggests that the amount of immature and therefore bright material exposed is much less than that seen in more mature IMPs.

The arrested development of iIMPs may be related to the low volume and rate of gas released or the exhaustion of the gas reservoir at an early stage. Other structures that fall in to the iIMP category are located on the flanks of the dome Yal in Mare Vaporum and have been described in a previous LSC [13]. In this case the iIMPs were similarly inconspicuous, and only become apparent under low incidence illumination. The fact that these iIMPs are of such low visibility could suggest that many are unreported, and that as a result the processes that give rise to these structures and the more conspicuous IMPs are more widespread than currently thought.

The presence of these features which are characteristic of volcanic areas suggest that the feature to the south of Maskelyne G is of volcanic origin, or at least to have been affected by subsurface volcanic activity. This would support Pither's belief that this feature is a dome, likely formed by intrusive activity, with little to nothing in the way of surface effusive activity such as lava flows or the eruption of pyroclastic material. Alternatively many effusive lunar domes do not display a summit vents these become plugged by the ascending lava [10] due to their high eruption rate.

A smaller dome-like feature (named Maskelyne2) with a summit crater nestled closely to the west of the wrinkle ridge is visible to the south of the main dome discussed above (Fig. 5). This small dome has no obvious volcanic features on its surface. The dome appears from topographic data to be located on the western 'flank' of the wrinkle ridge, an observation that might hint at a link between the formation of the dome and the presence of the ridge.

## Age estimation

Both domes lie in a region mapped as $\operatorname{Im} 2$ unit in the rasterized version of the 2013 renovation of the I-0703 Wilhelms Geologic Map of the near side, mapped at a scale of 1:5,000,000 and ranging from -64 to 64 degrees latitude and -70 to 70 degrees longitude [7], which denotes Upper Imbrian mare material (3.2-3.75 billion years ago).

We have also used the ACT-REACT Quick Map tool to access to the mare age units. In the corresponding map of Maskelyne region each polygon includes the unit name and crater size-frequency distributions model age [8]. For both two examined features the model ages indicates an age of 3.70 billion years ago.

## Spectral data

The Lunar Reconnaissance Orbiter's (LRO) Diviner Lunar Radiometer Experiment (spatial resolution of $950 \mathrm{~m} / \mathrm{pixel}$ ) produces thermal emissivity data, and provides compositional information from three wavelengths centered around $8 \mu \mathrm{~m}$ that are used to characterize the Christiansen Feature (CF), which is directly sensitive to silicate mineralogy and the bulk $\mathrm{SiO}_{2}$ content. These spectral bandpass filters are centered at $7.00,8.25$, and $8.55 \mu \mathrm{~m}$. The major minerals of lunar soils - plagioclase, pyroxene, and olivine - have different ranges of CF values [9]. The feldspar a high silicic material, including quartz, silica-rich glass, and alkali and ternary feldspars, are characterized by CF values of 7.8-7.3 $\mu \mathrm{m}$. In the case of olivine abundances the CF values is $>8.7 \mu \mathrm{~m}$ [9]. The average CF position of Maskelyne1 and 2 domes is $8.35 \pm$
$0.05 \mu \mathrm{~m}$; this value is not different from the average CF position of the typical basaltic maria, which is $8.30-8.40 \mu \mathrm{~m}$.

Chandrayaan-1 Moon Mineralogy Mapper ( $\mathrm{M}^{3}$ ), an imaging reflectance spectrometer that can detect 85 channels between 460 to $3,000 \mathrm{~nm}$, was used to identify the composition of the Maskelyne1, the central crater on the summit and nearby mare unit where the second dome (Maskelyne2) is situated.

The spectra (Fig. 8) display a narrow trough around $1,000 \mathrm{~nm}$ with a minimum wavelength at $975-989 \mathrm{~nm}$ and an absorption band at $2,200-2,300 \mathrm{~nm}$ for the examined features indicating for both features a basaltic composition.


Figure 8: Chandrayaan-1 Moon Mineralogy Mapper, spectral analysis.

## Morphometric properties

The ACT-REACT Quick Map tool was used to access to the LOLA DEM dataset, obtaining the cross-sectional profiles for the examined domes.

## Maskelyne1 dome

The first examined dome (termed Maskelyne1) is located at $26.70^{\circ} \mathrm{E}$ and $1.70^{\circ} \mathrm{N}$, with an estimated diameter of $18 \mathrm{~km} \pm 0.5 \mathrm{~km}$. The height amounts to $85 \pm 10 \mathrm{~m}$, yielding an average flank slope of $0.6^{\circ} \pm 0.1^{\circ}$ (Fig. 9a). The dome edifice volume is determined to $10.8 \mathrm{~km}^{3}$ assuming a parabolic shape.


Figure 9a: Cross sectional profile of Maskelyne1 in E-W direction.

However, based on the data reported by LOLA DEM and Figures 1-2, the dimensions of Maskelynel are smaller than those reported in the drawing of Figure 3. A 3D reconstruction obtained using LOLA DEM and GLD100 data set is shown in Fig. 9b.


Figure 9b: 3D reconstruction of Maskelyne1.
$\mathrm{TiO}_{2}$ and FeO contents are estimated utilizing the Multiband Imager (MI) data. MI is a high-resolution multispectral imaging instrument on board of Selene [11]. It has five visible (VIS) bands ( $415 \mathrm{~nm}, 750 \mathrm{~nm}, 900 \mathrm{~nm}, 950 \mathrm{~nm}$, and $1,000 \mathrm{~nm}$ ) and four nearinfrared bands ( $1,000 \mathrm{~nm}, 1,050 \mathrm{~nm}, 1,250 \mathrm{~nm}$, and $1,550 \mathrm{~nm}$ ). The VIS bands of MI have the same center wavelengths as those of the Clementine UV/VIS camera but have much higher spatial resolution ( $20 \mathrm{~m} /$ pixel) [12].

The $\mathrm{TiO}_{2}$ content of Maskelyne 1 is determined to about $8 \mathrm{wt} \%$. The FeO content amounts to $17.0 \mathrm{wt} \%$. Similar values for $\mathrm{TiO}_{2}$ and FeO content are obtained in nearby mare units.

Regarding the mode of formation we can consider an effusive origin or alternatively an intrusive origin.
a) Considering the effusive origin rheologic model yields a high effusion rate of $970 \mathrm{~m}^{3} \mathrm{~s}^{-1}$ and a lava viscosity of $2.8 \times 10^{4} \mathrm{~Pa} \mathrm{s}$. years. In this scenario Maskelynel belongs to class $\mathrm{C}_{2}$ in its morphometric and rheologic properties. It was formed from lava ascending at speed of $3.9 \times 10^{-3} \mathrm{~m} \mathrm{~s}^{-1}$ through a dike 8 m width and 33 km length, corresponding to domes belonging to rheologic group $R_{1}$. The first group $R_{1}$, is characterised by lava viscosities of $10^{4}-10^{6}$ Pa s , magma rise speeds of $10^{-5}-10^{-3} \mathrm{~m} \mathrm{~s}^{-1}$, dike widths around $10-30 \mathrm{~m}$, and dike lengths between about 30 and 200 km . Rheologic group $\mathrm{R}_{2}$ is characterised by low lava viscosities between $10^{2}$ and $10^{4} \mathrm{~Pa} \mathrm{~s}$, fast magma ascent $\left(\mathrm{U}>10^{-3} \mathrm{~m} \mathrm{~s}^{-1}\right)$, narrow ( $\mathrm{W}=1-4 \mathrm{~m}$ ) and short ( $\mathrm{L}=7-20 \mathrm{~km}$ ) feeder dikes. The third group, $\mathrm{R}_{3}$, is made up of domes which formed from highly viscous lavas of $10^{6}-10^{8} \mathrm{~Pa} \mathrm{~s}$, ascending at very low speeds of $10^{-6}-10^{-5} \mathrm{~m} \mathrm{~s}^{-1}$ through broad dikes of several tens to 200 m width and $100-$ 200 km length.
b) Another possible explanation is an intrusive origin. The candidate intrusive domes regarded in previous studies are all of strongly elongated shape (with circularity $<0.8^{\circ}$ ) [10].

The first class, In1, comprises large domes with diameters above 25 km , flank slopes of $0.2^{\circ}-0.7^{\circ}$ and characterized by the presence of linear rilles crossing the surface, class In2 is made up by smaller and slightly steeper domes with diameters of $10-15$ km and flank slopes between $0.4^{\circ}$ and $0.9^{\circ}$, and domes of class In3 have diameters of $13-20 \mathrm{~km}$ and flank slopes below $0.3^{\circ}$.

In this scenario, due to its diameter and edifice volume, the dome would match the properties derived for putative intrusive domes belonging to group In2 but the circularity is estimated to be $>0.8(\mathrm{c}=0.89)$.

Thus based on our data both two possible mode of formation cannot be ruled out.

## Maskelyne2 dome

The second examined dome (termed Maskelyne2) is located at $26.19^{\circ} \mathrm{E}$ and $1.12^{\circ} \mathrm{N}$, with a diameter estimated of $3.0 \mathrm{~km} \pm 0.3 \mathrm{~km}$. The height amounts to $45 \pm 5 \mathrm{~m}$, yielding an average flank slope of $1.2^{\circ} \pm 0.1^{\circ}$. Thus it is more prominent and has higher slope angle than Maskelyne1. It is connected on the margin of a wrinkle ridge.

A similar configuration is shown by other lunar domes, such as the small dome termed A1 located near the Arago alpha and beta domes (http://aragodomes.blogspot.com).

A 3D reconstruction, obtained with LOLA DEM and GLD100 dataset, is shown in Fig. 10.

The dome edifice volume is determined to $0.16 \mathrm{~km}^{3}$ assuming a parabolic shape. The rheologic model yields an effusion rate of $40 \mathrm{~m}^{3} \mathrm{~s}^{-1}$ and a lava viscosity of $2.8 \times 10^{4} \mathrm{~Pa}$ s. It formed over a period of time of 0.12 years.


Figure 10: 3D reconstruction of Maskelyne2.

The $\mathrm{TiO}_{2}$ content of Maskelyne 2 is $6 \mathrm{wt} \%$. The FeO content amounts to $17.2 \mathrm{wt} \%$. According to the classification scheme for lunar domes Maskelyne2 belongs to class $\mathrm{E}_{2}$ in its morphometric and rheologic properties.

Maskelyne2 was formed from lava ascending at speed of $1.0 \times 10^{-4} \mathrm{~m} \mathrm{~s}^{-1}$ through a dike 10 m width and 43 km length. Thus it belongs to rheologic group $\mathrm{R}_{1}$ and is classified as an effusive lunar dome.

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## LUNAR GEOLOGICAL CHANGE DETECTION PROGRAMME

Tony Cook
Introduction: The set of observations received in the past month has been divided into three sections: Level 1 is a confirmation of observations received for the month in question. Every observer will have all the features observed listed here in one paragraph. Level 2 will be the display of the most relevant image/sketch, or a quote from a report, from each observer, but only if the date/UT corresponds to: similar illumination $\left( \pm 0.5^{\circ}\right)$, similar illumination and topocentric libration report $\left( \pm 1.0^{\circ}\right)$ for a past TLP report, or a Lunar Schedule website request. A brief description will be given of why the observation was made, but no assessment done - that will be up to the reader. Level 3 will highlight reports, using in-depth analysis, which specifically help to explain a past TLP, and may (when time permits) utilize archive repeat illumination material.

News: David Teske, ALPO Lunar Section director has made a start on digitizing the Cameron TLP cards that were very kindly sent in by David Darling. An example can be seen in Fig. 1, and it is an interesting example as it states that this particular TLP was not confirmed by Cameron when she observed using a scope in Tucson, whilst attending an ALPO conference.


Figure 1. An index card that was used to compile the Cameron TLP catalog for NASA. This one is from a TLP in Alphonsus on 1966 Aug 28.

Nigel Longshaw (BAA) has been in touch with me over an earlier report/write-up of mine on Eudoxus. With the information Nigel has given me, I have updated dates/colongitudes for the Lunar Schedule programme, to see if we can capture the 'thread effect' that Trouvelot originally reported.

It was sad news that I learned of Eugene Cross' passing. Gene was a very active TLP observer during the 1960s and early 1970s and was involved in a lot of the Ross C TLP observations, including one using a Mt Wilson telescope. He once told me that he had a NASA Trident electronic Moon Blink device in his basement.

TLP reports: No TLP reports were received in April - the Riccioli report from 2021 Apr 25 UT 19:42-20:32 by Franco Taccogna (UAI) was concluded by Franco and myself to probably be due atmospheric spectral dispersion, and so was not a TLP. Thanks to the other observers who followed this alert up.

Level 1 - All Reports received for April: Jay Albert (Lake Worth, FL, USA ALPO) observed: Cichus, Plato and Torricelli B. Alberto Anunziato (Argentina SLA/ALPO) observed: Alphonsus, Aristarchus, Bullialdus, Eimmart, Gassendi, Promontorium Laplace, Schickard and Vallis Schröteri. Massimo Alessandro Bianchi (Italy - UAI) observed: Aristarchus and Gassendi. Maurice Collins (New Zealand ALPO/BAA/RASNZ) imaged: Airy, Alphonsus, Aristarchus, Boussingault, Bullialdus, Clavius, Copernicus, Descartes, Dionysius, Langrenus, Mare Crisium, Moretus, Petavius, Plato, Posidonius, Proclus, Reiner Gamma, Rupes Altai, Theophilus, Tycho and imaged the whole lunar disk. Anthony Cook (Newtown, UK ALPO/BAA) obtained video of earthshine in monochrome, the illuminated side in colour, and the lunar surface in thermal IR. Marco Di Francesco (Italy - UAI) imaged Eratosthenes. Walter Elias (Argentina - AEA) imaged: Aristarchus, Birt, Gassendi, Lichtenberg, Mare Humboldtianum, Plato, Riccioli, and obtained a whole Moon
image. Les Fry (West Wales, UK - NAS) imaged: Alphonsus, Clavius, earthshine, Guericke, Longomontanus, Montes Recti, Montes Riphaeus, Moretus, Palus Epidemiarum, and Rupes Recta. Rik Hill (Tucson, AZ, USA - ALPO/BAA) imaged: Archimedes, Barrow, and Blanchinus. Bill Leatherbarrow (Sheffield, UK - BAA) imaged: Ptolemaeus. Jean Marc Lechopier (France - UAI) imaged: Mutus F and Ptolemaeus. Leandro Sid (Argentina - AEA) imaged: Eratosthenes, Tycho and several features. Trevor Smith (Codnor, UK - BAA) observed: Promontorium Agarum, Alphonsus, Aristrachus, Atlas, Bullialdus, Copernicus, earthshine, Eratosthenes, Gassendi, Littrow, Mare Crisium, Mersenius (\& C), Mons Piton, Plato, the SE limb, Sinus Iridum, Taruntius, Vallis Schröteri, the W limb, and several features. Thierry Speth (France - BAA) imaged Aristarchus and observed: Arago_B, Linne, Moltke and Torricelli B. Franco Taccogna (Italy - UAI) imaged: Riccioli. Aldo Tonon (Italy - UAI) imaged: Ptolemeaus. Ivan Walton (Cranbrook, UK - BAA) imaged Eratosthenes. Paul Zellor (Indianapolis, IN, USA - ALPO) imaged: Riccioli.

## Level 2 - Example Observations Received:

Ptolemaeus: On Apr 19 UT19:41-21:24 Jean Marc Lechopier (UAI) and Bill Leatherbarrow (BAA) obtained image coverage for this crater, at high resolution, under similar illumination to the TLP report below. In addition, Aldo Tonon (UAI) obtained images that covered an earlier Lunar Schedule request for the same event:

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Ptolemaeus 2020 Feb 01 UT 19:40-19:50 P. Sheperdson (York, UK, 102mm Mak -
BAA) saw an "ashen" sliver of bright light across the floor. Images taken.
This maybe normal appearance - though observer re-observed in May and found
the effect different in that there was no "ashen" like effect. Visual
sketches and time lapse image sequences welcome. If doing visual work - try
using a polaroid filter and rotate it to see if that makes any difference.
For imaging work, please over-expose slightly to bring out detail on the
floor; you could also try colour imaging of the floor as an interesting
experiment - though for comparison purposes image other terminator features
exhibiting shadow spires. ALPO/BAA weight=1.
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Figure 2. Intentionally contrast stretched images of Ptolemaeus, taken on 2021 Apr 19 and orientated with north towards the top. (Far Left) Image by Aldo Tonon at 18:25 UT. (Left) Image by Jean Marc Lechopier (UAI) at 19:36UT. (Right) Image by Jean Marc Lechopier (UAI) at 20:04UT. (Far Right) image by Bill Leatherbarrow (BAA) at 21:24 UT.

Aldo's image (Fig. 2 - Far Left) was outside the $\pm 0.5^{\circ}$ similar illumination window, but was within a requested longitude range window from the Lunar Schedule web site. It is a good check for any ashen light effect, but as you can see, none is visible here. Fig. 2 (Left and Right) show the centre of the floor emerging from shadow and the needle-like shadow spires. Fig 2 (Far Right) shows some of the underlying topography that the needle like shadows moved across. Whether this counts as ashen light (perhaps if seen under poorer seeing conditions) remains in question. What is interesting is the brightness in between the dark shadow spires. There could be five
reasons for these: 1) it is simply small scale topographic sunward facing slopes catching the sunlight, 2) it could be an image processing/sharpening artefact, 3) it might normally be bright, but elsewhere there are micro-shadow spires cast from the eastern rim, that are not fully resolved, but darken sunlit areas of the floor, giving the impression that the areas where there are no micro-shadow spires, are brighter, 4) it might be diffraction effects off of the gaps in the crater rim on the east, 5) saving the least likely option till last - could this be light scattered off electrostatically charged levitated dust particles moving from shadowed into sunlit areas? The Occam's Razor principle suggests the least exotic explanation(s) are the most likely. But anyway, it's a very good reason to observe flat-floored craters at sunrise/set and study the appearance of shadow spires. It is even more revealing when a time lapse movie is made - I have done this already, but cannot show it in this PDF! I may put it on-line some time, but need to work a bit more on image registration and normalisation, as it's currently a wobbly to watch.

Interestingly we also have a visual report from Trevor Smith (BAA) who noted the appearance of Ptolemaeus, whilst he was observing Alphonsus from 21:03-21:24UT: 'Ptolemaeus was a fine sight tonight with much detail on it's floor. The eastern ramparts cast needle-like shadows across the eastern floor. The floor looked like pumice. The extreme western floor was also in a lighter shadow for approx. one quarter of the crater's width. This gave a distinct impression that the floor must be slightly dome-like and/or the floor to the east maybe higher and sloping downwards to the west! No other craters showed this effect tonight!' Actually, checking the LROC Quickmap website, it looks like the floor is a depression and not a dome, about 80 m deeper at the centre than at the edges, though there is a gradient to the floor, with its western side sloping to the eastern side. A slightly raised area can be found near the crater centre.

Eratosthenes: On 2021 Apr 20 UT Marco Di Francesco (Italy - UAI), Ivan Walton (BAA), and Leandro Sid (AEA) imaged this crater under similar illumination and/or ALPO/BAA schedule request to the following reports:

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Figure 3. Eratosthenes as imaged on 2021 Apr 20 and, orientated with north art the top. The top images have not been contrast stretched. The bottom images have had a non-linear contrast stretch applied to see if there is any detail in the shadow. (Left) Monochrome image by Ivan Walton (BAA) taken at 21:10UT. (Centre) Colour image by Marco Di Francesco (UAI) taken at 21:35, with colour saturation increased to $65 \%$. (Right) Colour image by Leandro Sid (AEA) after colour normalization and colour saturation increased to $65 \%$.

Fig. 3 (Left and Centre) are similar colongitudes to the Abel TLP report. Marco's image is in colour and shows two central peaks, as did the original sketch by Abel, however there is no obvious orange/brown colour on the terraces on the western rim. Fig. 3 (Right) does show some colour, but not in the same locations as in the original Abel sketch. Fig. 3 (Centre and Right) correspond to similar illumination to the Hill report to within $\pm 0.5^{\circ}$, however a lot can happen within the space of $\pm 0.5^{\circ}$ at sunrise. Although it's interesting in Fig. 3 (Lower Right) that there is a not completely black area to the west of the central peak and up until the illuminated western rim/floor.

Cichus: On 2021 Apr 22 UT01:15-01:26 Jay Albert observed the crater under similar illumination to the following report:

```
Cichus 1975 Sep 15 UT 11:15-11:30 G.Ryder (Corinda, Australia, 25cm
reflector, x250 & x380, seeing good but with some cloud). The interior W.
wall of this crater (on the lip) appeared hazy - difficult to bring detail
into focus. Neighbouring craters/detail were sharp. Details in the crater
wall interior were starting to become visible as time went on, but it had
clouded over by 11:30. A Moon Blink was used but no colour was detected.
ALPO/BAA weight=1.
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Jay, using an 8 " SCT (x226) with transparency at magnitude 1 and seeing varying from 2-3 to $6 / 10$, found: 'The crater's $W$ wall was bright and detailed with a prominent, very bright strip along the $W$ rim. The craterlet Cichus $C$ was also bright and detailed with its interior in shadow. There was no haziness on the interior $W$ wall. The E wall shadow covered at least half of Cichus' floor. No color was seen'. So, quite a marked difference in the description of the western wall, between these two reports. There is a possibility that Ryder got the date wrong by one day - this will need to be checked. In the meantime we shall leave the weight at 1 for now.

Gassendi: On 2021 Apr 23 UT 19:03-19:25 Massimo Alessandro Bianchi (UAI) sketched and from 20:00-20:20 Trevor Smith observed this crater under similar illumination and topocentric libration to the following TLP report from Northern Ireland. Bianchi's sketch is reproduced on page 4 of this issue.

Gassendi 1967 Mar 22 UT 19:39-19:43 Observed by Mosely (Armagh, N. Ireland, 10" refractor, x360) "Red color \& blink strongly suspected in small area centred on junction of 3 clefts $1 / 2$ way from c.p. \& ESE wall. Well-defined \& did not note change during obs. period. Clouds terminated obs. till 2120 when it was not seen." NASA catalog weight=3. NASA catalog ID \#1018.

So, Bianchi's sketch shows what Mosely should have seen if all had been normal in 1967 - so is quite a useful context sketch. We also have Trevor Smith's visual description: 'No ink black spot was seen on ramparts of the crater. No red colour was seen in interior of crater. All looked normal'. There is a chance that the 'ink black spot' might have referred to the triangular shaded/shadow area to the SW of Gassendi A - though it definitely is not ink black in Massimo's sketch. We shall leave the weight as it is.

Promontorium Laplace: On 2021 Apr 25 UT 01:20-01:30 Alberto Anunziato 9ALPO?SLA) observed this area under similar illumination to the following report:

On 1978 Nov 20 Peter Foley observed a tiny yellow-brown region close to the tip of the cape, north east of the precipitous west edge, in the face of the north facing slope. The area concerned was diffuse and varied in density despite the surroundings not varying. Foley noticed no colour elsewhere on the Moon, though Amery thought that he saw some in Aristarchus, but Foley thinks this was spurious. Cameron 2006 catalog extension $I D=27$ and weight=5. ALPO/BAA weight=3.


Figure 4. The location of dark shadows in Promontorium Laplace, as depicted by Alberto Anunziato against a background map, on 2021 Apr 25 UT 01:20-01:30.

Alberto, using a 105 mm . Maksutov-Cassegrain (Meade EX 105), at a magnification of x154, saw no colour, and the areas in shadow were to the NW of the promontorium and on the east rim of Laplace D (see Fig. 4).

Riccioli: On 2021 Apr 25 Anthony Cook (ALPO/BAA), Franco Taccogna (UAI), and Walter Elias (AEA) imaged this crater under similar illumination and topocentric libration to the following report and also for a lunar schedule request:

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On 1979 Aug 06 at 22:24-22:54 P.Madej (Huddersfield, UK, 6" reflector.
Purple Wratten 35, and Yellow Wratten 15 filters used) Orange glow seen (at
x73) on west side of crater, near the central peak. The central peak was
coloured too at x110. At 22:32 (x75) the central peak was brighter than the
rest of the area through the yellow filter. At 22:34UT at x73 everything
looked OK through the purple filter. The TLP was still visible at 22:54.
ALPO/BAA weight=1.
ALPO Request: Either visually observe or obtain a colour image of this
crater shortly after it has emerged from the sunrise terminator. Minimum
sized aperture scope needed: 5". Any observations or images should be
emailed to: a t c @ a b er.a c . uk
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Figure 5. Images of Riccioli captured on 2021 Apr 26/26 and orientated with north towards the top. (Far Left) A Colour image by Franco Taccogna (UAI), taken at 20:00UT with colour saturation increased to $70 \%$. An image by Anthony Cook (ALPO/BAA) taken at 20:26 UT with colour saturation increased to 70\%. (Right) A monochrome image taken by Walter Elias (AEA). (Far Right) A cell phone colour image taken by Paul Zellor (ALPO) with colour saturation increased to $70 \%$.

The images in Fig. 5 do not really show much of what the Madej observation describes, through there is some evidence of atmospheric spectral dispersion, especially in Fig. 5 (Left) which was taken when the Moon was low in the sky. Concerning the Lunar Schedule request - this refers to an earlier image taken a few months ago, when a green/brown cast was visible on the floor of Riccioli. There is perhaps a hint of colour on Fig 5 (far Left and Left), on the floor, but it is by no means certain.

Although not part of the above repeat illumination/lunar schedule requests, in response to Franco Taccogna detecting colour (see last month's newsletter), an alert was put out via Twitter and Paul Zeller made a visual observation a few hours later on 2021 Apr 26 UT 02:03-02:09 and obtained some images. He was using a Meade 8" LX10 SCT (f/10) x77 magnification, seeing: 2, transparency: magnitude 3.5. He found that 'Riccioli stood out clearly near the lunar limb. The rim of the walled plain near the limb was bright while the limb closest to Grimaldi still showed a very thin shadow. The darker northern floor of the walled plain was in sharp contrast to the brighter floor to the south. There were occasional ripples and shimmering when the seeing was troublesome. However, the view was usually sharp and still' He saw no noticeable unusual colour on either limb of Riccioli or any of the surrounding craters, and this is borne out in Fig. 5 (Far Right).

## Level 3 - In Depth Analysis:

Aristarchus: On 2021 Apr 27 UT 22:32-23:30 Thierry Speth (BAA) imaged the carter under similar illumination to the following report:

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Aristarchus: On 1983 May 28 at UT 01:50-03:00 K. Marshall (Medellin,
Columbia) observed the whole region of Aristarchus, Herodotus and Schroter's
Valley all to have a brightness of }3\mathrm{ and all blue and impossible to focus on
(he had never seen it like this before). Also, the interior of Aristarchus
was invisible. Brightness measurement taken and a sketch was made. The
Cameron 2006 catalog ID=222 and the weight=3. The ALPO/BAA weight=3.
```



Figure 6. Aristarchus as imaged in colour by Thierry Speth on 2021 Apr 27 - orientated with north towards the top. (Far Left) UT22:54. (Left) 22:59UT. (Right) 23:01UT. (Far Right) 23:03UT.

Thierry was using a Maksutov Cassegrain 127 ETX, under seeing 5 conditions. He noticed that the crater appeared very bright with no visible detail inside at 22:32UT, but by 23:00UT some detail was visible and the crater was less bright and slightly blue/violet. Re-reading the Marshall report, I note that his seeing was Antoniadi III-IV (moderate-poor). Thierry's images (Fig. 6) also show mostly no detail inside the crater under the atmospheric conditions present. So, in reality the TLP that Marshall saw (under poor observing conditions) is really dependent upon the CED (Crater Extinction Device) brightness value he gave of 3.2 - which may or may not be normal - this remains to be investigated. I will lower the ALPO/BAA weight from 3 to 2.

Aristarchus: On 2021 Apr 28 UT 10:01 Maurice Collins (ALPO/BAA/RASNZ) imaged this area in colour under similar illumination to the following report:

```
On 1992 Jul 16 at UT 03:32-09:31 D. Louderback (South Bend, WA, USA, 3"
refractor, x134) detected yellow on the southern rim of Aristarchus, and the
colour looked "darker" through a yellow filter and the region was "duller"
than normal. The region was 1 intensity step brighter on the 2nd
measurement, "on all points in it". The comet tail-like ray had 3 sections
and was "mottled" in appearance. Finally, the Cobra Head region had possible
variations in brightness. The Cameron 2006 catalog ID=451 and the weight=3.
The ALPO/BAA weight=2.
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Figure 7. Aristarchus as imaged by Maurice Collins in colour on 2021 Apr 28 UT 10:10 and orientated with north towards the top. The image has had its colour saturation increased to $65 \%$.

As you can see from the colour enhanced image that Maurice took, (Fig. 7) the southern rim is certainly not yellow. It is blue and just outside there is a pink or mauve coloured ejecta. The SW ray, which Louderback describes as comet-like, does indeed have components to it, possibly three (depending upon how closely you look at it), and I suppose it could be described as mottled, though not as mottled as the famous 'Wood's Spot' brown rectangular plateau to the NW. We cannot comment on the variations in brightness that Louderback reported as we only have one image here to study, but the crater looks bright. We shall leave the weight at 2 for now.

General Information: For repeat illumination (and a few repeat libration) observations for the coming month - these can be found on the following web site: http://users.aber.ac.uk/atc/lunar_schedule.htm . Only by re-observing and submitting your observations can we fully resolve past observational puzzles. To keep yourself busy on cloudy nights, why not try 'Spot the Difference' between spacecraft imagery taken on different dates? This can be found on: http://users.aber.ac.uk/atc/tlp/spot the difference.htm . If in the unlikely event you do ever see a TLP, firstly read the TLP checklist on http://users.aber.ac.uk/atc/alpo/ltp.htm , and if this does not explain what you are seeing, please give me a call on my cell phone: +44 (0)798 5055681 and I will alert other observers. Note when telephoning from outside the UK you must not use the (0). When phoning from within the UK please do not use the +44 ! Twitter TLP alerts can be accessed on https://twitter.com/lunarnaut .

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[^0]:    Eratosthenes 1947 Jan 30 Mean Col. 16deg. Observed by Hill (UK) "Main peak of massive central mountain group appeared to be in a shadowless condition, having regard to its claimed height of $6,600 \mathrm{ft}$. The whole of the floor to the west should have still been in darkness. Instead, immediately to the west was a dark (intensity $1.5-2$ ) region extending almost to the foot of the bright inner wall and very diffuse in outline. The observation could not be followed through due to increasing cloud, but on the following night all was normal.

    On 2009 Nov 25 UT18:42-21:03 P.Abel, T.Little and C.North (Selsey, UK, 15" reflector, seeing II-III, transparency very good), all saw visually a brownish tinge on the north west rim of Eratosthenes crater. P.Abel made a sketch and T.Little took some high resolution CCD images, some of which were through coloured filters. Checks were made for spurious colour, but none was seen elsewhere on the Moon. The eyepiece was changed but this made no difference. M.C.Cook (Mundesley) was observing with a smaller scope at the same time, but saw no colour, however observing conditions were worse. W. Leatherbarrow (Sheffield, UK) was observing with an instrument mid-way in size, and saw a brownish tinge in the NW rim area, but saw a similar colour elsewhere and put this down to spurious colour. Normally multiple observers seeing the same thing would result in a weight of 4 , however as this was only observers at selsey and some of the evidence contradicts, I am allocating an ALPO/BAA weight=3.

