Night 2 Repeat Illumination Observations for *The 1963 Aristarchus Events*

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Introduction

In the online supplement Repeat Illumination Observations for The 1963 Aristarchus Events[1] Tony Cook and I provide background information and focus on future repeat illumination opportunities through 2017 for the transient lunar phenomena (TLP) R1, R2 and R3 observed by James Greenacre and Edward Barr at Lowell Observatory on Night 1, October 30, 1963 UT. Repeat illumination images are useful to produce simulations of atmospheric dispersion, optical aberrations and seeing blur which can then be evaluated to determine if such terrestrial influences can plausibly account for the limited, discrete and time-dependent effects reported by the observers. In this supplement we provide similar information and discussion for making repeat illumination observations for the Night 2, November 28, 1963 UT TLP R4, R4a and R5 seen by Lowell observers Greenacre, Barr, Fred Dungan and John Hall (See Figure 1). These efforts are directed at attempting to replicate and therefore explain what may have been inherently rare anomalous manifestations of spurious colors that brought a multi-year lunar charting program to a standstill on only two nights late in 1963.

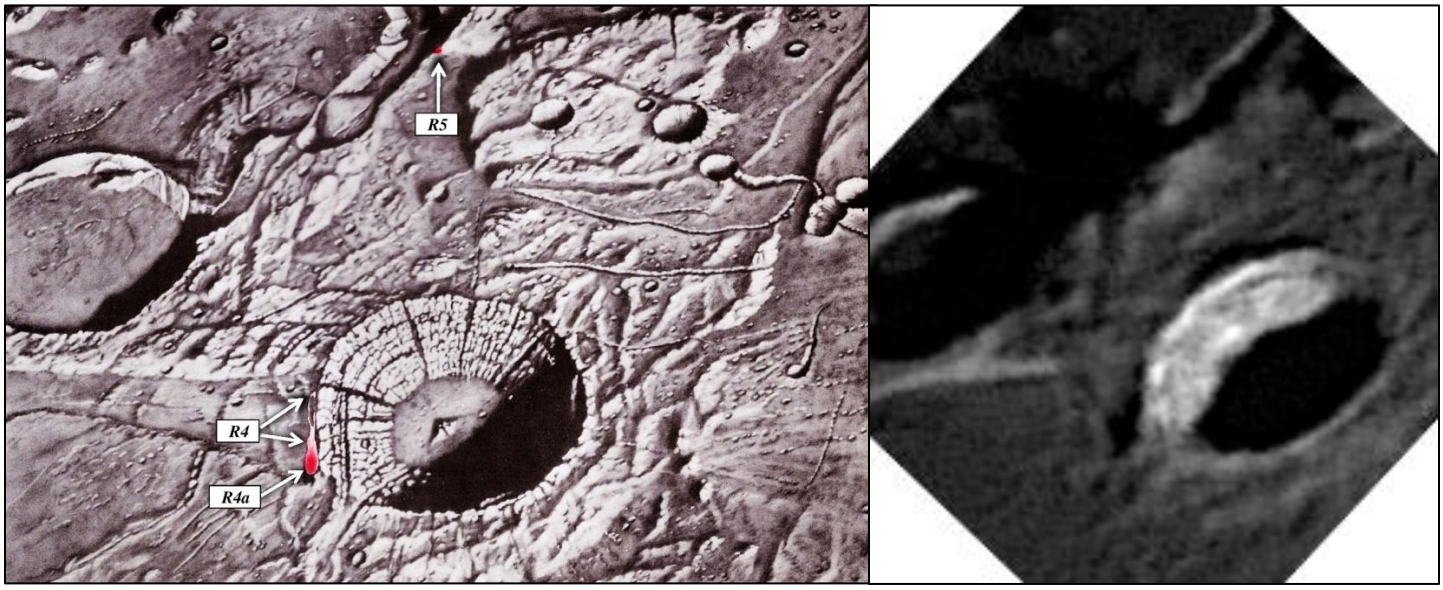

Figure 1. (*Left*) Patricia Bridges rendition of the TLP observed by four observers at the Lowell Observatory 24-inch Clark refractor on Night 2, November 28, 1963. Image originally published in 'Lunar Color Phenomena: Technical Report No. 12', USAF Aeronautical Chart and Information Center, St Louis, MO, 1964 May. (*Right*) Repeat illumination image by Brendan Shaw taken on 2012 Jan 05, 20:20-20:23 UT, corresponding to 1963 Nov 28 01:14 UT, when R4 and R4a were seen. This highly cropped similar illumination view shows the Aristarchus area as it would have appeared to the Lowell observers but is uncorrected for libration with IAU North to upper right. Shaw's image appeared as Figure 9 (*Left*) in our paper on page 202.

Note the following aspects of this report when attempting digital or visual observations under repeat illumination conditions:

1. The observation was made with the Lowell Observatory 24-inch f/16 Clark achromatic refractor with a zoom eyepiece providing a magnification range of ~430 to 1050X.
2. A 16-inch reflector or a 20-inch refractor were considered the minimum apertures required for visual detection.
3. No TLP were seen for the first 30 minutes of the observing run as the Moon rose in the eastern sky from 19 to 25 degrees.
4. These TLP were observed during a 75-minute period during which the Moon rose in altitude from 25 to 39 degrees.
5. Based on microdensitometer scans of images taken through the Clark, seeing had improved to mostly "*excellent*" during the last 30 minutes of the observations (01:09-01:39 UT).
6. It was a full 15 minutes after Barr first noted R4 forming that he and Dungan together observed R4a form, brighten and exceed R4 in intensity.

7. R4 and R4a formed over *shadowed* terrain just *outside* the crater rim, immediately adjacent to R3's location on October 30th (UT) that was just *inside* the crater rim over *sunlit* terrain.
8. TLP R5 was seen by Fred Dungan and John Hall with Jim Greenacre and Ed Barr unable to make a positive identification.

Also see the October 29, 2013 Lunar Photo of the Day (LPOD) for our comments on the November, Night 2 observation.

Repeat Illumination Observing Opportunities for Night 2 Reddish Phenomena

Table 1 lists dates and times though 2017 when repeat selenographic colongitude will occur for the R4 and R4a TLP.

Table 1: Repeat illumination opportunities (UT) for R4 and R4a TLP [1,2]

2013 Dec 14	12:14	2014 Jan 13	02:52	2015 Jan 02	10:58	2016 Jan 21	09:45	2017 Jan 09	17:50
		2014 Feb 11	17:21	2015 Feb 01	01:35	2016 Feb 20	00:06	2017 Feb 08	08:21
		2014 Mar 13	07:11	2015 Mar 02	15:41	2016 Mar 20	13:42	2017 Mar 09	22:16
		2014 Apr 11	20:06	2015 Apr 01	04:57	2016 Apr 19	02:22	2017 Apr 08	11:19
		2014 May 11	08:06	2015 Apr 30	17:16	2016 May 18	14:11	2017 May 07	23:27
		2014 Jun 09	19:24	2015 May 30	04:48	2016 Jun 17	01:21	2017 Jun 06	10:49
		2014 Jul 09	06:22	2015 Jun 28	15:51	2016 Jul 16	12:16	2017 Jul 05	21:46
		2014 Aug 07	17:23	2015 Jul 28	02:48	2016 Aug 14	23:21	2017 Aug 04	08:42
		2014 Sep 06	04:52	2015 Aug 26	14:03	2016 Sep 13	10:59	2017 Sep 02	20:05
		2014 Oct 05	17:07	2015 Sep 25	01:59	2016 Oct 12	23:28	2017 Oct 31	21:21
		2014 Nov 04	06:19	2015 Oct 24	14:49	2016 Nov 11	12:56	2017 Nov 30	11:21
		2014 Dec 03	20:23	2015 Nov 23	04:37	2016 Dec 11	03:11	2017 Dec 30	01:54
				2015 Dec 22	19:05				

1. All dates and times listed are for lunar selenographic colongitude 52.7º corresponding to the approximate time R4a began to appear and form at 00:45, November 28, 1963 UT.
2. Lunar librations for each observing opportunity will vary and therefore solar illumination conditions will not precisely match those for the original observation. Flagstaff topocentric lunar librations for the original observations were 4.1 deg. West and 7.3 deg North (IAU)
3. Observers should check that the Moon is visible from their geographic location before attempting to observe on these dates and UTs.

Discussion

Analysis of additional repeat illumination images can help to determine if any of the competing terrestrial hypotheses can adequately account for the reported discrete appearances of the Lowell reddish phenomena seen at only a few locations and for their curious idiosyncratic time-dependent behaviors. Phillips and Lena (2011), noting the reported limited areas of colors on both nights propose a *low-lighting-retinal-photoreceptor-rod-cone-brightness/color-sensitivity* hypothesis supported by their interpretation of repeat illumination spurious color simulations. See: 'GLR investigation: A plausible explanation for Transient Lunar Phenomena. Red Glow in Aristarchus', *Selenology Today*, **24**, (2011 May), pp. 1−11.

As we noted in our paper the experienced Lowell observers[2], familiar with quotidian ubiquitous atmospheric and optical spurious colors using the 24-inch Clark refractor under mostly poor seeing conditions, repeatedly scanned other bright, high-contrast areas looking for similar colors but found none. If these observations are to be attributed to deficits in human low-lighting color vision, why were not similar discreet and limited colors a nightly occurrence for observers routinely training the Clark refractor primarily along and near the lunar terminator during the multi-year USAF lunar charting program for NASA's *Project Apollo*?[3]

Similarly, if these colors were due to atmospheric prismatic dispersion, then why were they not initially present on both nights when the rising Moon was at its lowest observed altitude under comparable but unremarkable weather conditions and such atmospheric dispersions should have been most pronounced? A comparable problem arises in attributing these limited and time-dependent colors to chromatic aberrations in the Clark optical system which one would expect to always be ubiquitously present within the field of view once the Wratten 15 filter was removed[4].

Low-altitude poor seeing conditions have also been implicated in causing the limited and discrete appearances and behaviors of the October 30th TLP observed under moments of 3-4 seeing on a scale of 0-10.[5] Yet observers were very familiar with these conditions as the majority of the time lunar charting was routinely conducted under seeing conditions no better than 0-4.[6] As with spurious color hypotheses, given the observers' familiarity with prevailing poor seeing conditions, why were sightings of similarly limited and discrete colors not an almost nightly occurrence? It is also unclear how this explanation solves the Night 2 TLP observation as seeing conditions were distinctly better and the Moon's altitude was noticeably higher by the end of that observation.

Given what the observers reported, we find it frustratingly difficult to neatly apply terrestrial hypotheses especially when also considering the observers' combined experience and credibility, familiarity with both the Clark optical system and poor Lowell seeing conditions, their detailed documentation as well as the "*contention*" among the observers that the phenomena were not due to optical or atmospheric effects. This is not to suggest terrestrial effects cannot eventually explain the observations, but reaching this conclusion requires an objective assessment of the *entire observational record* based on analysis of additional repeat illumination observations. Finally we note there are other lines of research relating to TLP at Aristarchus which also do not require lunar geologic activity to explain anomalous observations and which require further investigation. See, for example: Cook, A. C., Grande, M. & Lane, J. A. 2011, 'Are Transient Lunar Phenomena in Aristarchus Crater Caused by Surface Optical Effects?', in *EPSC-DPS Joint Meeting 2011*, EPSC.

Conclusion

A number of historical TLP reports have now been disproven or their reliability weights downgraded based on careful studies of repeat illumination images and visual observations.[7] More work remains in this area for interested observers and specifically with regard to TLPs reported on or near the lunar terminator like those of 'The 1963 Aristarchus Events'. Phillips and Lena (2011) note *". . . a systematic investigation of a large set of observations during local lunar sunrise or sunset has not been undertaken so far and the nature and reality of TLPs is still an open problem for the professional lunar science community*." The authors further note "*The re-observations and recreations of TLPs can demonstrate their real nature*".

Ongoing analyses and discussions of just such repeat illumination observations are presented monthly by Tony Cook in both the A.L.P.O. Lunar Section newsletter *The Lunar Observer* and in the B.A.A. *Lunar Section Circulars*. Additional imaging of the Aristarchus Plateau under repeat illumination conditions for 'The 1963 Aristarchus Events' holds the promise of resolving these 50-year-old mysteries which are replete with a number of notable observational anomalies requiring further investigation.[8] TLP skeptic Thomas A. Dobbins wrote in 2007, "*And while I am skeptical of the reality of lunar transient phenomena or the ashen light of Venus, I would never dare to suggest that they do not merit further reporting. Such censorship would be contrary to the essence of the scientific method. It is the anomalies in the observational record that have often constituted the seeds of future discoveries*."[9] We agree the scientific method is preferred over preemptory dismissals of well-documented TLP reports regardless of how disquieting our fastidious empirical approach may appear to some in trying to resolve the TLP issue.

To determine if a particular repeat illumination opportunity in Table 1 will be visible from your location, see the online 'Project for the Verification/Elimination of past TLP Reports'. Observers interested in participating in repeat illumination observations are encouraged to contact Tony Cook at this email address: atc@aber.ac.uk

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1 A supplement to: O'Connell, R. & Cook, A., 'Revisiting The 1963 Aristarchus Events', *J. Brit. Astron. Assoc.*, **123**(4) pp. 197-208, (2013 August) available online at http://www.the1963aristarchusevents.com/

2 See our paper pp. 198-200 and online supplement "*A Short Biography of James Clarke Greenacre*" for background information on the observers.

3 According to William D. Cannell, first director of the USAF lunar mapping program at Lowell Observatory: "*Visual observations of the Moon are normally made along and up to approximately 30 degrees in front of the lunar terminator. In this illuminated portion, the shadows are optimum for detail interpretation. Along the terminator, the very low and gentle relief features, such as Maria Ridges and valleys, will show up prominently. Craters, small prominences, and rilles can easily be*

interpreted from 5 to 15 degrees in front of the terminator." See: Cannell W. D., 'Photogrammetric and Visual Compilation of Lunar Charts', Photogrammetric Engineering, **28**(4), (1962 September), p. 580. Cannell presented this paper at the 28th Annual Meeting of the Society of Photogrammetric Engineering held 1962 March 14−17, Washington, DC.

4 Hall noted with regard to the Clark optical system and the TLP observations, '*As for the equipment used, and the possibility that some unusual change may have influenced the observations, I think that it would be difficult to imagine a more stable telescopic setup. No changes in observational technique had been introduced during the entire period that this area has been under study*.' This is Hall's *complete* original *unedited* passage in his '*Supplementary Report*' sent to *Sky and Telescope* (1963 Nov 4) in Hall J. S. papers, Lowell Observatory Archives.

5 Note: Pickering seeing scale 1-10. USAF Lowell lunar seeing scale 0-10.

6 Cannell, (1962), p. 580, *op. cit*, ref. 3. For an interesting discussion of the seeing conditions at Lowell Observatory see: Sheehan, W. & Dobbins, T., 'Lowell and the Spokes of Venus' (Section - "The Myth of Flagstaff Seeing"), *Sky and Telescope Magazine*, (**104**)1 (July 2002), p. 100.

7 For example see Cook A. & Dobbins T., 'The Pseudo-Peak in Herodotus', *The Moon: Notes and Records of the Lunar Section of the British Astronomical Association*, **2** (2012 Dec.), pp. 22-35 (Accessed 2013-10-06)

8 For information relating to color imaging of the Moon see for example: Bailey, W., 'Color Imaging of the Moon', *The Journal of the Association of Lunar and Planetary Observers*. **52**(2) (Spring 2010), pp. 34-41 available for download at: : http://alpo-astronomy.org/

9 Dobbins, T. A. 2007, 'Letters and Correspondence', *Journal of the Association of Lunar and Planetary Observers*, (**49**)2, p. 6, available for download at: http://alpo-astronomy.org/