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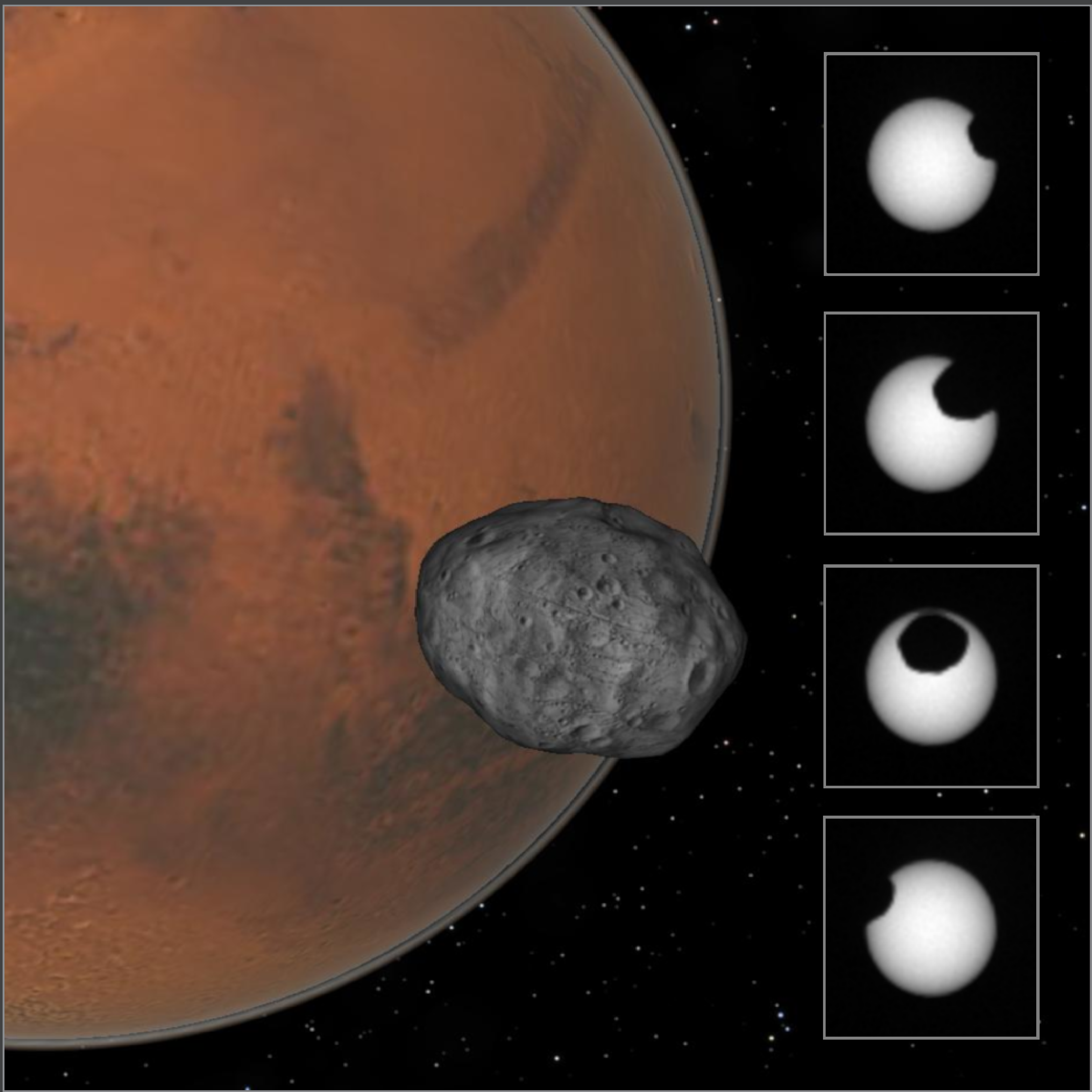

The Final Transit by Phobos

Dear reader,

In this issue...

We mark the passing of Belgian amateur astronomer Pierre Vingerhoets, who as well as being a key figure in his own country was instrumental in creating Planoccult and other group mailing lists, essential resources for our international occultation community.

In our 'Beyond Jupiter' series we take you to the dwarf planet Haumea. Most occultations by such distant objects involve faint stars; they are priority events but often beyond the reach of amateur equipment. Could we contact public and private observatories that house large 'scopes and team up with them? Read the very informative and detailed article on how to undertake collaborative observing to obtain quality data and maximise the outcomes for all concerned.

Not many observers employ an alternative to video recording: the drift scan method using a CCD imaging camera. Read how this technique recorded an intriguing double positive chord by (814) Tauris.

The transit of Mercury on 2019 November 11 will be the last one until 2032. Take part in the project to measure the solar diameter.

Clear skies,

Alex Pratt
IOTA/ES, JOA Editorial Team

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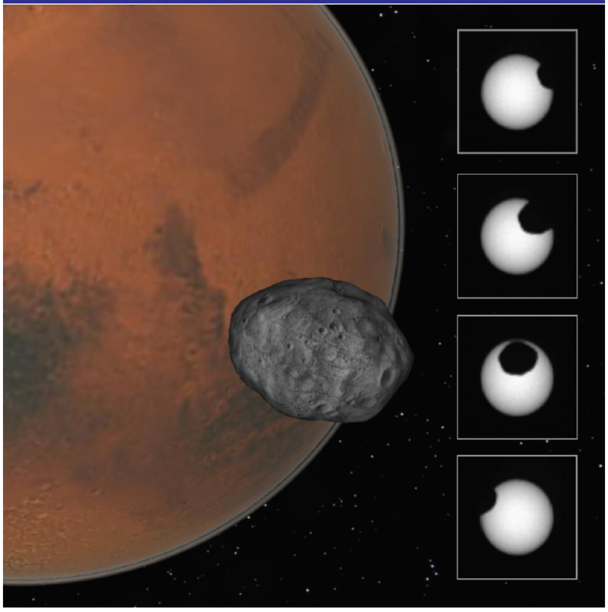
In this Issue:

COVER



NASA's Mars rover *Curiosity* made a final recording of a transit by Phobos in front of the Sun on 2019 March 27 at 03:45 UT. The transit lasted about 35 seconds. To date, there have been eight observations of Deimos transiting the Sun from either *Spirit*, *Opportunity* or *Curiosity*; 40 observations of transits by Phobos were observed. These images help to track down changes in the orbits of the Martian moons. The graphic is an artist's impression of Phobos seen at a distance of 120 km from the direction of the Sun at the time of the final transit recording.

Image credit: NASA/JPL-Caltech/MSSS Graphic: O. Klös, Celestia 1.6.1.

Copyright Transfer

Rules for Authors

In order to optimize the publishing process, certain rules for authors have been set up how to write an article for *JOA*. They can be found in "How to Write an Article for *JOA*" published in this *JOA* issue (2018-3) on page 13. They also can be found on our webpage at http://www.iota-es.de/howtowrite.html .

Journal for
Occultation Astronomy

CCD Photometry of the Occultation of Star TYC 2521-00170-1 (UCAC4 631-047700) by Asteroid (814) Tauris on March 19, 2018 UT

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ABSTRACT: We present a double positive CCD observation and data reduction results of the occultation of star TYC 2521-00170-1 (Vmag = 9.04) by asteroid (814) Tauris (Vmag = 14.4) on March 19, 2018 UT. The observation was made at Elgin, Oregon, USA. A miss observation occurred in Rexburg, Idaho, USA. Possible interpretations of the double positive are: separated binary asteroid; contact binary asteroid with observation chord over gap, or asteroid with large-deep crater. The complete disappearance of the star during both positive occultations precludes possibility that a double star was occulted. Further observation of this asteroid is recommended to determine the source of the double positive.

Introduction

In observing asteroidal occultations, the most common method is to capture the event by video using sensitive low-light video cameras. However, there are two methods of recording an asteroid occultation event using an astronomical grade CCD camera. The first is using a high cadence series of images analogous to a video recording. The second method is known as a drift scan, wherein, just prior to the predicted event, the telescope tracking is stopped, and the CCD camera shutter is opened. The field stars and the target star are thus recorded as streak trails as they cross the field of view at the sidereal rate due to the Earth's rotation. The timing for opening the shutter and closing the shutter are precisely measured. The shutter timing and the sidereal rate of stars drifting across the field provides the information needed to calculate the occultation parameters. This observation of the March 19, 2018 occultation by (814) Tauris as presented here was by the drift scan method.

Predictions of Occultation by (814) Tauris

The prediction data we used for the observation was published by Steve Preston [1]. The occultation was predicted to occur on March 19, 2018 with a local time predicted at 07:19:08 UT. The star, TYC 2521-00170-1, V magnitude at 9.04, and the asteroid (814) Tauris, V magnitude of 14.4 gave a predicted combined V magnitude of 9.03. The predicted V magnitude drop was 5.37. The event sky elevation was at 80 degrees and the azimuth was 195 degrees, very favourable for measuring this occultation. The probability of the event occurring at the observer's location was 74.9%, with a maximum occultation duration of 8.1 seconds. A map of the occultation path for this event generated by *Occult4* [2] and the location of the observing stations is presented in Figure 1.

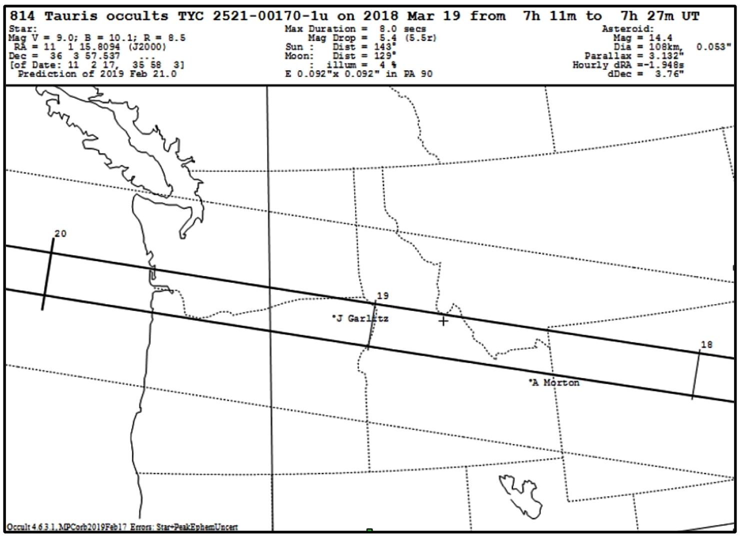

Figure 1. A map for the occultation path generated by Occult4 [1].

Location and Equipment

The double positive observation of the Tauris event was made by Joe Garlitz at Elgin, Oregon, USA located at latitude 45:34:22.33 North and -117:55:15.7 longitude at an elevation of 810 metres. The telescope was a standard Newtonian with an aperture of 30.5 cm and a focal length of 152 cm. The CCD camera used was an SBIG ST402 which uses a Kodak KAF-0402ME chip having a 756 x 510 array of 9.0-micron pixels.

Method of Observation

The drift scan procedure for recording this occultation was straight forward. The target star was acquired before the event and set to the East edge of the image frame. With the camera shutter closed and knowing the time it takes for the target star to drift halfway across the image field, the telescope tracking was stopped at a time just prior to this amount (32 seconds before the predicted centre of the event). Immediately after stopping the tracking the shutter was opened for a timed 60 second exposure. Finally, at a time just before the star would drift out of the camera frame, the shutter was closed. The CCD image recorded the trail of the target and field stars as they drifted across the camera field of view. The beginning of the trail was marked by the timing of the shutter opening and the end of the trail was marked by the closing of the shutter.

Timing

Timing of the shutter operation was made using a Garmin 18xusb GPS unit through an add-in feature for the SBIG *CCDOps5* camera software. The camera software used the GPS timing signal to precisely mark the shutter opening and closing. The shutter operation times were recorded in the image FITS header. Measuring the length of the drift trail in pixels and dividing this length by the time between the shutter opening and closing calibrates the drift trail in pixels per second and conversely seconds per pixel. The time at which the shutter opened marks the absolute UT time of the start of the drift trail. This provided the timing reference for the measurement of the occulted star drift scan trail.

Data Processing and Reduction

The event data consisted of a single CCD image; see Figure 2.
The image was dark and flat field calibrated and the precise times of the camera shutter opening and closing were read from the FITS header of the image.

The length of the star's drift trail was then measured in pixels and the brightness of the trail along its length was measured using the spectroscopy tool in *AIP4Win* [3]. A drift trail and a star's spectrum are analogous linear light traces. As a result the *AIP4Win* tool works as well for measuring the brightness variations of the drift trail as it does for measuring a spectrum. The measured "spectrum" file was saved as a .csv file for analysis (Figure 3).

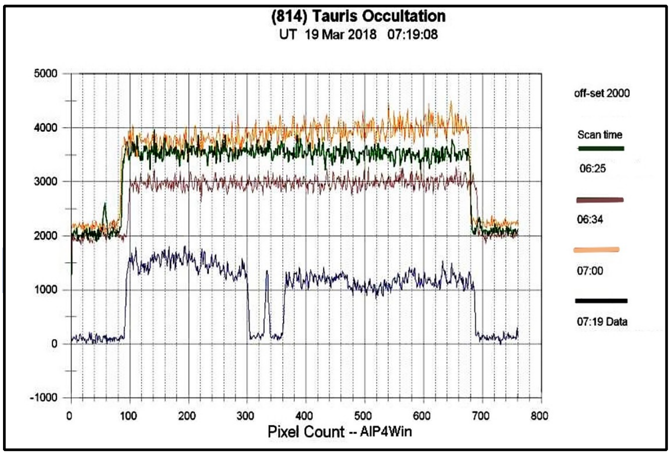

Figure 3. The photometric measurement the drift-scan trail intensity.

The original .csv file was not in a format that could be analyzed with occultation timing analysis tools, so the data was transcribed into a .csv format normally produced by *Limovie* [4]. The Limovie format .csv file was then analyzed using *R-OTE* [5]. *R-OTE* is only capable of analyzing one 'event' at a time. So the light curve was split into two segments, with one 'event' in each segment. The *AIP4Win* analysis of the drift trail creates multiple data points in the disappearance (D) and reappearance (R). This is normal for a drift scan analysis. For each segment, *R-OTE* fitted a square wave to the light curve using maximum likelihood statistics. The D and R times reported conform to the point in the transition that represents the 50% brightness level. Error bars were generated using a Monte Carlo analysis of a synthetic square wave, with

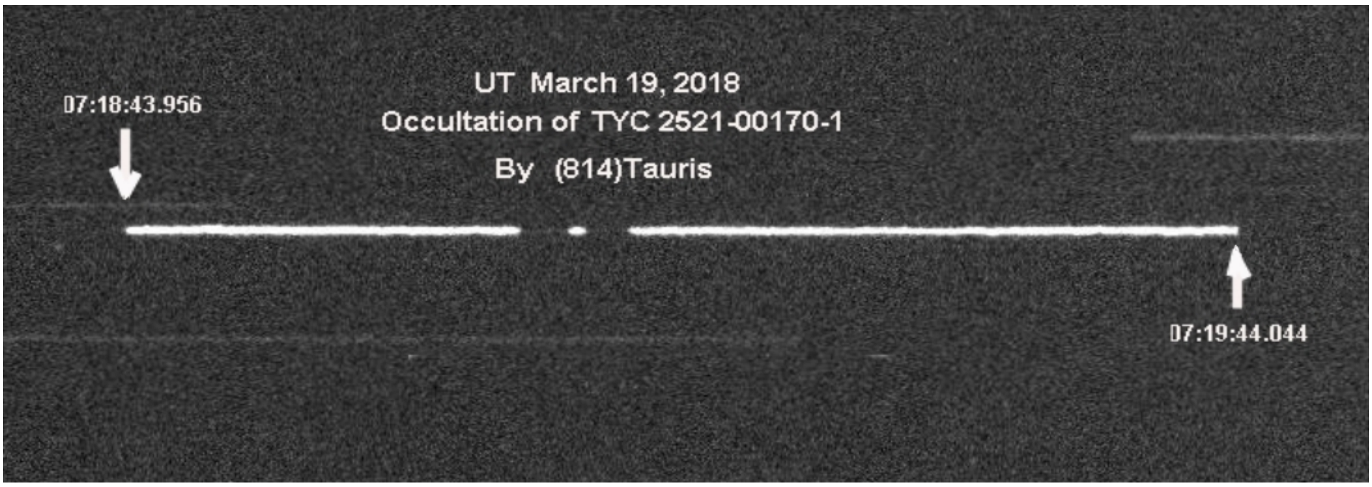

Figure 2. CCD image of the drift-scan trail of the occultation event.

noise equivalent to the event added. The light curves analysed on *R-OTE* are shown in Figure 4 and Figure 5.

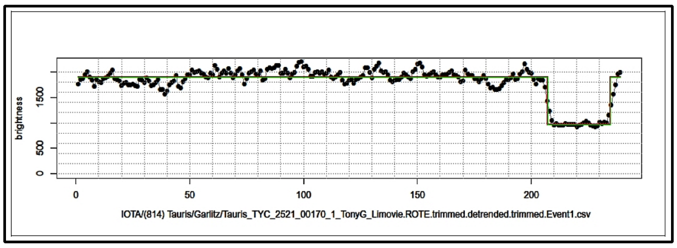

Figure 4. The beginning half of the light curve analysed on R-OTE.

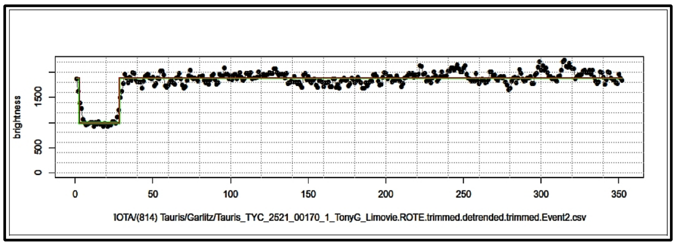

Figure 5. The ending half of the light curve analysed on R-OTE.

Results

The analysis of the event timing was made by Tony George using *R-OTE* as described. From the time stamp in the header of the FIT file, the UT times for the event, was as follows:

Time UT = 07:18:43.956 [start of exposure, no flux drop]
Time UT = 07:19:44.044 [end of exposure, no flux drop]
The data point rate = 0.1011804 s per data point.

Based on the above timing, the resulting D and R times for both events were:

First event:
D = 07:19:05.065
R = 07:19:07.849 +/- 0.02 s (0.95 confidence level)
Measured magnitude drop = 0.73

Second event:
D = 07:19:08.545
R = 07:19:11.193 +/- 0.02 s (0.95 confidence level)
Measured magnitude drop = 0.70

Note: Measured magnitude drop is for comparison of the two events and not for evaluation against the predicted magnitude drop. The measured magnitude drop depends on the subtraction of the background brightness from the light curve, which does not appear to be done in *AIP4Win*.
When these observations are plotted in *Occult4* on the fundamental plane defined by the apparent position of the star on the equinox of date, and the events are compared to the nominal predicted 108 km diameter of a single asteroid, we get the plot as shown in Figure 6.

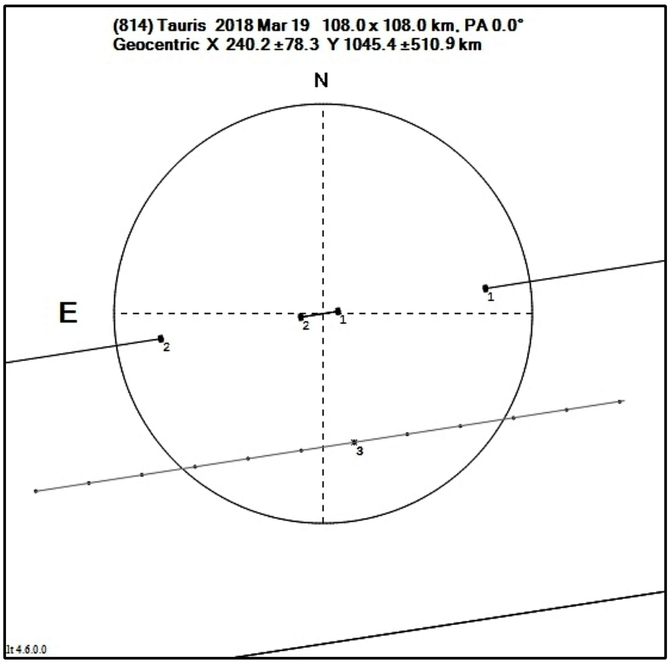

Figure 6. A plot of the nominal predicted 108 km diameter of single asteroid against the measured and predicted asteroid path.

Clearly, neither of the double events on the Garlitz chord characterize the proper size of the asteroid. Also, the 'miss' chord of Allan Morton to the south of the Garlitz chord constrains positioning of any grazing event.
The double event can also be characterized by a two-body double asteroid, with one body behind the other in the line of sight. For two bodies to be large enough to create the same surface area as one single asteroid with 108 km diameter, they would have to be 76.36 km in diameter. The resulting two 76 km bodies, when fitted to the Garlitz observation would appear as shown in Figure 7.

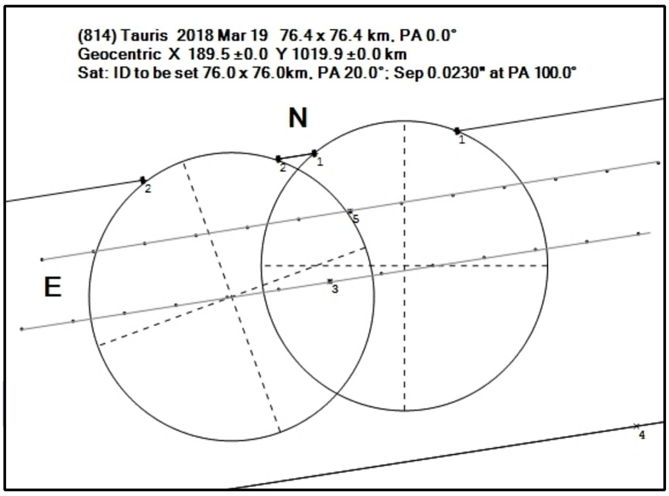

Figure 7. A plot of two 76 km bodies fit to the observation and predicted paths.

Note that in the two-body solution with one body behind the other, the resulting brightness of the asteroid would be reduced and the measured magnitude drop would be greater than predicted. It is also interesting to note that the area centroid of the two-body system is very close to the original path centreline (Chord 3) as well as an updated path centreline using Gaia star coordinates and updated MPCorb elements (Chord 5).

Another alternative could be a 'contact binary'. A contact binary would have a shape similar to that shown in Figure 8.

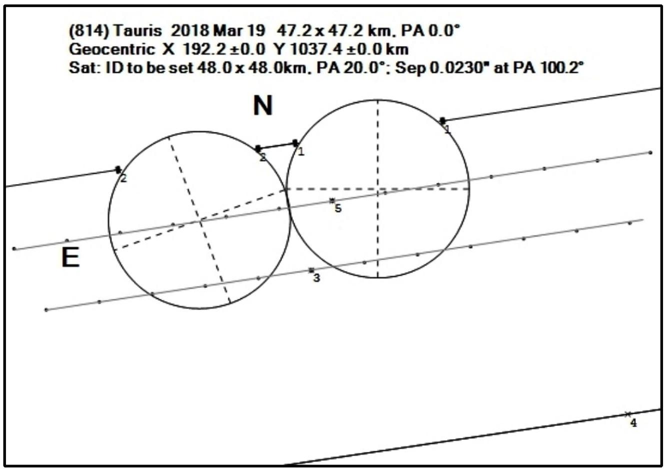

Figure 8. A plot of a 'contact binary' fit to the observation and predicted path.

The contact binary solution is unlikely as both objects have a diameter of 47 km. The combined surface area of the contact binary system is 1/2.64 the surface area of a 108 km diameter object. The brightness of this system would be much lower than the 108 km diameter derived from brightness measurements.

The fourth possible explanation for the observed double event is an asteroid with a crater on one side. The plot would look similar to that shown in Figure 9.

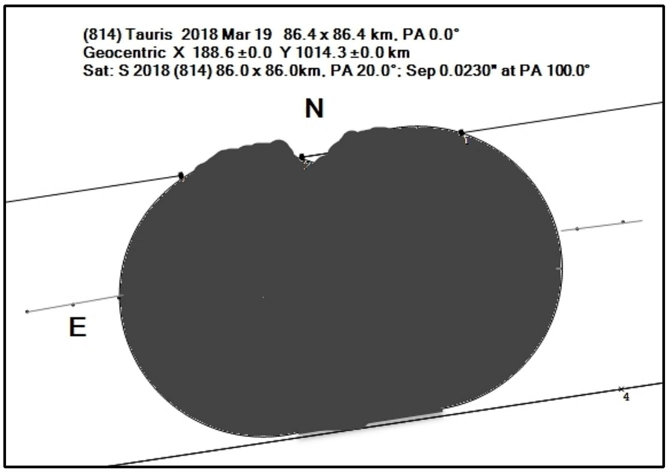

Figure 9. A plot of an asteroid with a crater on one side fit to the observation and predicted paths.

The last possible explanation for a double positive event is for a double star to have been occulted. The double components would have to be nearly equal in brightness for the events to have similar measured magnitude drops. However, because the drift scan light trace shows the complete disappearance of the star during both events, this precludes the possibility that a double star was occulted.

A review of the *Occult4* occultation database archive shows that (814) Tauris was observed occulting stars on four other occasions:

Date	No. of Chords	Positive Chords
1999 Dec 15	2	2
2005 Sep 8	2	1
2015 Jul 26	1	1
2015 Jul 29	1	1
2018 Mar 19	3	2

Of the four other occultation observations in the IOTA archive, none show any sign of duplicity. Only two of the other observations have multiple chords. One recorded by T. Satou and F. Kanno on September 8, 2005, with a positive chord and a miss, shows indications that the asteroid is elongated (Figure 10).

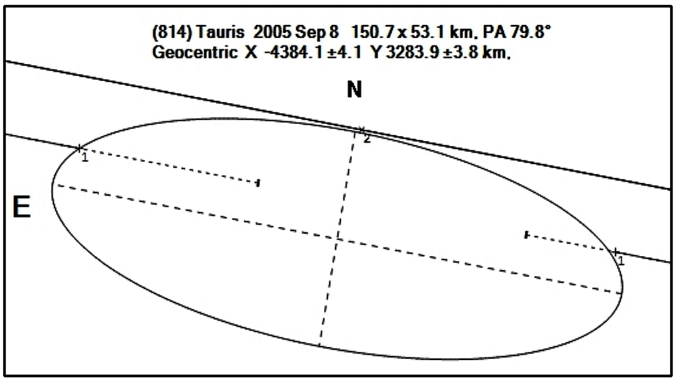

Figure 10. A plot of an occultation of (814) Tauris recorded by .T Satou and F. Kanno on September 8, 2005, with a positive chord and a miss, this shows an indication that the asteroid is elongated.

The other multi-chord event by R. Casas and N. Kedzierski on December 15, 1999 has disparate timing results and possible geographic coordinate issues and cannot be used. The other two observations are single-chord events and do not show any sign of double events.

Conclusions

The double event observed by Garlitz coupled with the miss observed by Morton indicates that (814) Tauris is perhaps a double asteroid, contact binary, or asteroid with a large crater in the side. It is not possible to determine which of these alternatives is correct from this single observation. The double positive event was not due to the occultation of a double star.

It is recommended that (814) Tauris be flagged for future occultation observations (Figures 11 - 14) as a possible double asteroid or contact binary.

Also, it is recommended that (814) Tauris be flagged for lightcurve analysis and the development of a shape model. The lightcurve inversion technique used to find an object's rotation period, its period, its shape and spin-axis orientation requires the availability of multi-epoch and multi-apparition lightcurve measurements in sufficient quality [6]. At present the available lightcurve for (814) Tauris is incomplete [7].

Acknowledgments

We would like to thank;
Steve Preston for his valuable work in providing timely analysis and prediction of asteroid occultations;
Dave Herald who maintains the *Occult4* Occultation Prediction Software;
Bob Anderson who maintains the *R-OTE* light curve analysis software;
Brad Timerson (posthumously) for his initial work on this observation as well as the many years he devoted during his life serving as the regional coordinator for IOTA;
John Broughton for his clear instructions on using the drift-scan method of timing asteroid occultations and the software tools he has provided to facilitate obtaining and measure asteroid occultations.

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[4] *LIMOVIE*, Light Measurement Tool for Occultation Observation using Movie Recorded written by Kazuhisa Miyashita of Japan. It is available for download from:
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[7] Minor Planet Bulletin 40 (2013), 215

Upcoming (814) Tauris occultation events in 2020 calculated by Oliver Klös, IOTA/ES, using *Occult4* software:

Figure 11. 2020 Jan 23 - Middle East, Southeast Europe

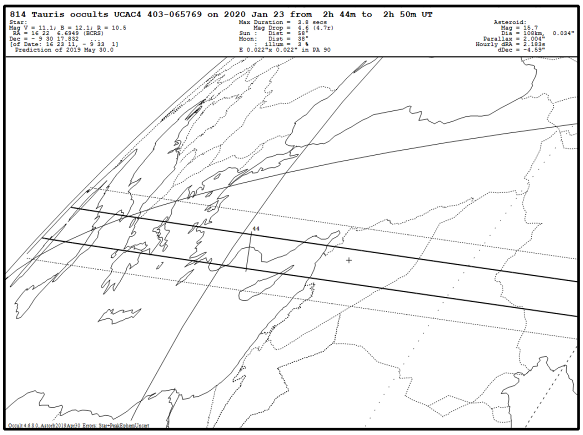


Figure 12. 2020 Jan 26 - Europe

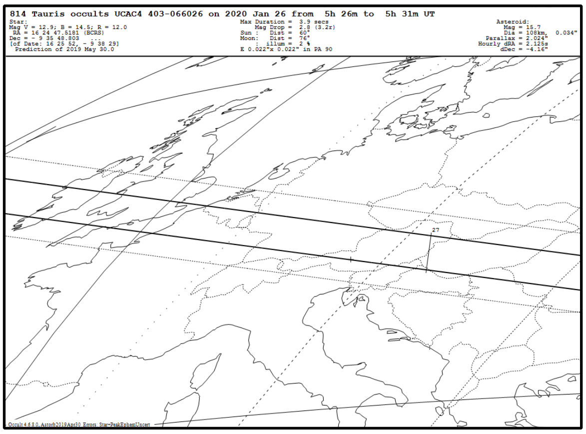


Figure 13. 2020 Jun 15 - Southern Africa

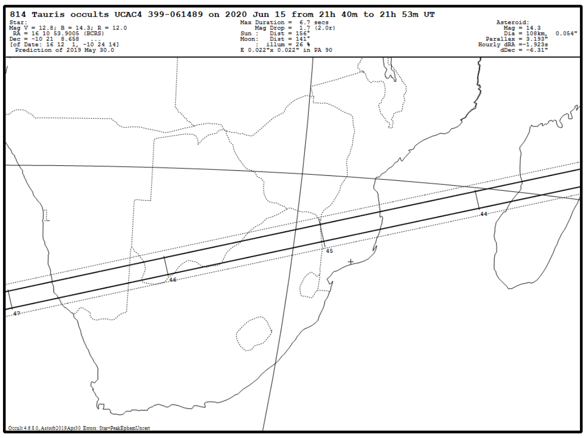
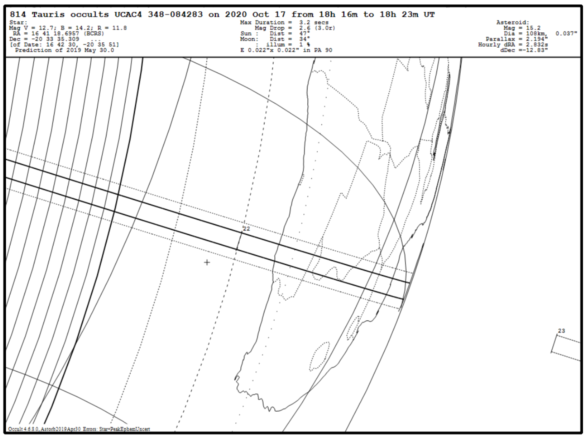


Figure 14. 2020 Oct 17 - Southern Africa



Transit of Mercury and General Relativity from Observations, and the 2019 November 11 Transit

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ABSTRACT: The transit of Mercury of November 11 2019, provides the opportunity to test a method of measuring the solar diameter and shape (due to the oblateness) better than 0.1", or 70 km of resolution on the Sun. Beyond the General Relativity implications of Mercury itself, we exploit the most precise ephemerides to achieve 0.1" with ground-based instruments of the solar diameter, of which monitoring the secular variations (related to our climate), as well as transient variations as potential proxies of major flares and Coronal Mass Ejections (to predict space weather).

Introduction

The theory of General Relativity of Albert Einstein solved the problem of the anomalous precession of the perihelion of Mercury of 43" per century. From observations this value was known since the second half of 1800 and it was the aim of research of Urbain Joseph Le Verrier [11] after finding Neptune in 1846 using calculus. Here we start from the simple fact that in November transits Mercury is 10" in diameter, while in May it is 12" wide as seen from the Earth; since the duration of the ingress/egress phases of a transit last about 2 to 3 minutes and are symmetrical, 43" would correspond to about 10 minutes of time in the transits.

Since the perihelion position is a calculated point, we concentrate on the observational uncertainties achievable from ground-based observations of the transit phenomenon, connecting to the measurements of the solar diameter through the historical transits of Mercury made by I. I. Shapiro in 1980 and repeated with satellite observations by J. Pasachoff with TRACE and M. Emilio with SOHO. Some attempts made from the ground are also reviewed in view of preparing the strategy of the observations of the next transit of November 11, 2019. The sphericity of the Sun versus its oblateness is also a matter of relativistic relevance, discussed by R. Dicke at Princeton in 1967, though the oblateness reported by Dicke et al. turned out to be intensity oblateness linked to the distribution of faculae. The oblateness is detectable with high precision measurements and in the Mercury transits.

Mercury Transits & Solar Radius

The transits of Mercury have been used by Shapiro [1] to evaluate the variations of the solar radius since the first observations at the telescope in 1631, after the claiming by J. Eddy [2] of the smaller diameter of the Sun during the annular eclipse of 9 May 1567 observed in Rome by Clavius. This controversial theme continued in the "SOLE" paper for the ballon-borne Solar Disk Sektant [3,4]. Further investigations carried out by M. Emilio [5] on the SOHO data of the Mercury transits of 2003 and 2006 pointed again towards a constant Sun. Sigismondi reviewed classical and recent results [6].

Relationship between Mercury Transit and General Relativity

Mercury appears as a disc of 12" for May transits and 10" for the November ones. The amount of shift in perihelion precession per century is 43", corresponding to 4 diameters of Mercury. The ingress and the egress of the transits of Mercury on the solar disk are two occasions for measuring accurately its position or the solar diameter and shape. With Gaussian methods the perihelion is found, but here we want to stress the other connections between Mercury transit and General Relativity.

Mercury contact timings with the solar limb are potentially the best positioning observing methods for the planet, by using the solar disk as a standard. Conversely, Mercury can be used to test the length of a solar chord, assuming the Sun is perfectly circular. Furthermore, assuming a perfect knowledge by the ephemerides of the position of Mercury the shape (oblateness) of the Sun can be assessed, as showed in papers of Dicke [7] and Rozelot [8]. The position of the Sun and of Mercury are now well known because of a very high statistics in the modern ephemerides. Moreover the problem of the "black drop" [9] has to be overcome by an extrapolation.

Observational Strategies

The amount of daily seeing in normal ground-based environments is around 2", except for some specialized telescopes, specific sites, and solar telescopes in orbit, where it is not better than 0.5". The success in timing the transit of Mercury for the purpose of

assessing the solar diameter is by achieving an absolute time resolution better than 0.1s.
The planet scans 10" in 100s. Therefore each second of time corresponds to 0.1". A space resolution of 1" for the lucky images is associated to their time resolution which can be at the level of 0.01 s. Both resolutions should allow a better identification of the external and internal contacts times of Mercury with the solar limb.
This can be obtained only statistically, by a sequence of "lucky images" of 1" resolution. Space Instruments SOHO and SDO will be ready to observe the transit. But a higher cadence should be set of the ingress and egress. Provisional Ground Network: Pawel Rudawy at Bialkow Coronograph; Michele Bianda at Locarno IRSOL Gregorian telescope; Cyril Bazin and Serge Koutchmy at the Carte du Ciel of Paris; C. Sigismondi applies to use the solar tower of Monte Mario of 26 cm f/100. Other stations of the network are: Rio de Janeiro Heliometer; IBIS at Dunn Solar Telescope at Sacramento Peak, New Mexico; Williams College Telescope in Massachusetts; SPSO South Pole MOTH; H. Altafi in Tehran, Iran, and X. Wang in Hauirou, China.

Simulations with Real Observations

The observation of the big sunspot AR2740 allowed us to test the lucky imaging in the worst case: telescope indoors and big turbulence through a window. Some details of the umbra are visible, as well as two or three pores at 14:50 UT on May 7, 2019. A practical resolution of 1.5" for the second pore is attained. The spot is 40" wide, particularly big. Same size for the AR2741. Telescope: SC 8"/f10 with full aperture glass filter (once belonging to the Science Museum of Virginia) at 270x with eyepiece Plössl 7.5mm eyepiece (Taiwan), afocal video with Samsung J5 smartphone at 4x digital zoom. Crisper images have been seen using the Plössl 25 mm Meade Series 3000, but the video with more detail was the one at larger magnification. This video shows less detail than the eye, but it is possible that the lucky imaging will give accurate timing and allow us to do an accurate extrapolated fit to the zero chord.

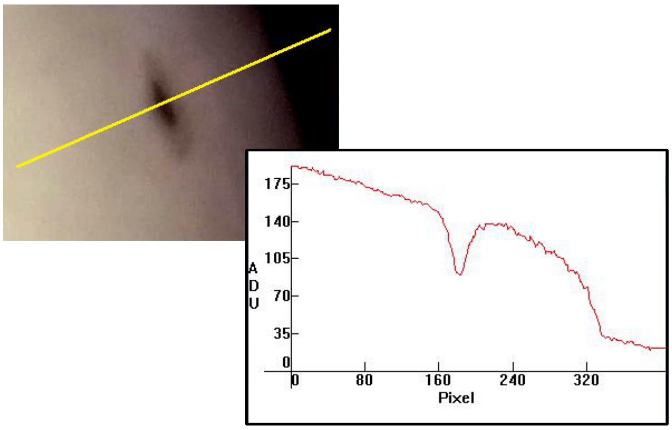

Figure 1 & 2. The intensity of the AR2741 spot and the solar limb profile are seen on the graph. The inflexion point for determining the solar limb is detectable within 1 pixel (0.6"), as well as the texture of the faculae between the spot and the solar limb.

There is a lucky image (like Figure 1, 3) about each second. This makes possible the 0.1" final resolution on the solar limb positioning through Mercury's contact.
The darkness of Mercury is much deeper than the umbra of the sunspot - as Angelo Secchi [10] said for Venus - even if its surface will be brightened by the light of the solar limb, with a strong radial derivative.

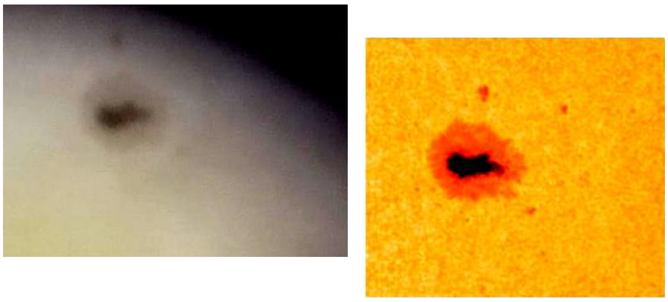

Figure 3 & 4. AR2740 region with the three pores detectable. The curved area on the upper right is due to unwanted vignetting. Comparison image 4096x4096 px by SDO.

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The Use of Fixed Observatories for Faint High Value Occultations

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ABSTRACT: The International Occultation Timing Association (IOTA) has supported the science community by taking part in high value occultation campaigns for many years. Until recently, most of these campaigns involved relatively bright target stars, and were most efficiently observed by deploying many small telescopes across the predicted path. A single ambitious observer could deploy ten or more stations, and the cost of each station was in the range of hundreds of dollars. In addition, small private or club observatories were occasionally utilized in providing single location chords. More recently, the most scientifically sought-after observations have tended to be faint stars being occulted by Jupiter Trojans, Centaurs, and distant Trans-Neptunian Objects (TNOs).
The 15 August 2018 occultation of a 12.9 magnitude star by Pluto offered one of the best opportunities for observing the properties of Pluto's atmosphere since the New Horizons encounter. Data from this event was sought by several groups of scientists from both the US and Europe. The authors, rather than either observe from our home areas or deploy a single large portable telescope, obtained observing time and operational support from four university and museum observatories. These observatories were very close to the centreline of the event, and were in good position to possibly observe the scientifically important central flash. Our team of five contacted these observatories and were enthusiastically welcomed to use their facilities. Despite weather risks, all four sites successfully participated in collecting data.
We describe our planning of these observations, outreach to the observatories, operations, and results from this campaign. We further discuss the advantages to IOTA produced by pursuing the use of similar observatories in the future. Advantages include ease of logistics, high data quality, public outreach, and recruiting new long-term observers.

Team History of Using Fixed Site Observatories

Several International Occultation Timing Association (IOTA) [1] members have made use of fixed observatories over the years. In the past 10 years, one of our team (Conard) has had good success in obtaining observing time at various college and university observatories in the mid-Atlantic region of the United States. While several of these attempts were in support of other occultations by Pluto, others were for typical high probability main belt asteroid events. Steve Conard has used observatories at Alfred University, University of Maryland Baltimore County, Towson University, Kutztown State University, and Randolph College for these purposes.

We have also found that the astronomy club observatories are very interested in supporting these observations. Past examples include Astronomical Society of Harrisburg's Naylor Observatory and Southern Maryland Astronomical Society's Nanjamoy Creek Observatory.

The primary advantage to the observer in pursuing fixed facilities is not only access to relatively large aperture telescopes, but also minimizing the required hardware to just a camera and timing equipment. When travelling for other reasons, one can search for events on *OccultWatcher* [2] within your travel area , then determine if there is a public or private observatory suitable for potential use. A secondary advantage is the possibility of recruiting new observers for future events.

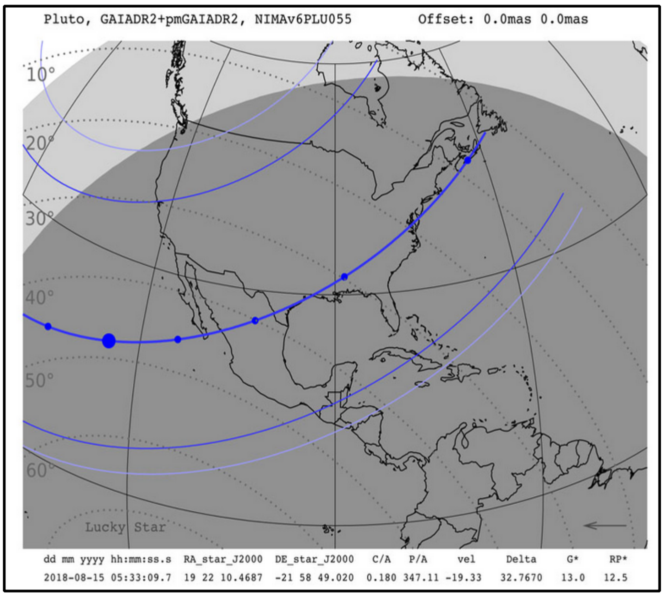

Figure 1. Occultation path of Pluto over Canada, the USA and Mexico. [3]

Finding Fixed Site Observatories

Locating and choosing fixed site observatories that fit the event criteria regarding optimal location for the event, aperture/resolving capabilities, typical local weather patterns and staffing resources is the key challenge.
Unfortunately, there is not one centralized listing of astronomical observatories that is very complete, although the ClearDarkSky and http://www.go-astronomy.com/observatories.htm websites offer good starting points. In addition, Google searches for astronomy clubs in a given locale are helpful in providing e-mail contacts along with talking to local astronomy-based merchants for insight into fixed site observatories.

The listing compiled by the authors eventually had almost 50 observatories within 200 km of the central line for the Pluto event. Over half of these had at least one telescope larger than 0.5 m, and the vast majority had apertures at least 0.35 m in size. Most were affiliated with colleges and universities, while others were generally operated by local astronomy clubs or other public institutions. It was surprising to find some less well-known schools and other institutions had very respectable sized telescopes. Examples include Three College Observatory in Greensboro, NC with a 0.8 m and Buice Observatory in Atlanta with a 0.9 m. Three College Observatory is operated jointly by The University of North Carolina at Greensboro, North Carolina A&T State University, and Guilford College, and Buice Observatory is operated by Fernbank Science Center.

The listing we compiled was shared with the teams from L'Observatoire de Paris and Southwest Research Institute. The Paris team reached out to several of the observatories, with some successes.

Contacting and Obtaining Permission to Use the Observatories

Establishing initial contact with an observatory was another key challenge. We found that some observatories did not maintain their websites and contact information often was not current. Generally relying upon e-mail for initial contact, and when routed to the proper person, typically resulted in a positive response.
Key to establishing first contact was to be brief and to the point. Introduce yourself as a member of IOTA, and say you are collecting science data in support of an astronomical event. Clearly state what support is being requested and when. Offer the opportunity for a limited number of staff and students to observe the data collection. In later communications, make sure that the observatory staff understands the risk of unsuccessful observations, in our predictive ability, weather, and possible technical failures.

IOTA members need to express our goals and the event project in a way the observatory staff can envision as being useful to them. For example, once contacted, the observatory directors were welcoming not only in the hands-on scientific use of the site, but in the potential exposure and recognition the scholastic institution would gain from the observation activity.

Planning the Observations

It is essential that IOTA members communicate with the observatory staff with clear direction and limited use of jargon. While we can easily translate 01:15 UT to local time and date, the same might not be said for a student or staff member juggling class work with a late night/early morning event session. Note that the actual date of any observation happening after local midnight has been a cause of confusion for multiple fixed site observatories (FSOs) over the years, including this Pluto observation. One way to clarify the post-midnight time is to list both days (e.g. the night of Tuesday/Wednesday, August 13).

Make it easy for the observatory team. If available, provide a whitepaper highlighting the scientific reason for the event and explain how the observatory can contribute to the data collection efforts and how the data will be used (current and future, or reusable baseline data). Prepare and leave a short written schedule – so everyone is onboard with the start and end times, including allowed time for issue recovery and for potential meet and greet with any school alumni or observatory benefactor. Exchange cell phone numbers, find out who has the keys to the gate and to the observatory.

Schedule a pre-run date to physically use the observatory, meet the staff and to hopefully work out any issues (e.g. power availability/accessibility, site security) beforehand. Work with the scope docent to practice slewing the scope. Check your charts, confirm the scope's Goto accuracy. This is where having a well-documented step by step guide (a defined repeatable process) was very helpful.

Challenges of Using Long Focal Length Optics

One commonly overlooked factor in using a large, fixed observat ory telescope is the small field of view (FOV) that will be obtained with standard IOTA cameras. While most modern observatories are equipped with Ritchey-Chretien (R-C) telescopes that are typically f/8 or f/9, many older observatories have classical Cassegrains that often times are f/12. Table 1 shows some example FOVs.

			Field of View (arcminutes)		
Aperture	f/#	EFL	1/3" Sensor	1/2" Sensor	QHY 174M GPS
0.2 m (8")	5	1 m	16 x 12	22 x 16	39 x 24
0.5 m (20")	8	4 m	4.1 x 3.1	5.5 x 4.1	9.8 x 6.1
0.6 m (24")	12	7.2 m	2.3 x 1.7	3.1 x 2.3	5.4 x 3.4

Table 1. Example Telescope/Camera Field of View

Often, the telescope operator will not have experience slewing the telescope to such a small field. It is essential to have field maps showing the field area, and also knowing the orientation of the field. Older telescopes, which tend to have longer effective focal lengths, often have mounts that are either not "go-to" or have lower accuracy slews. Knowing the field, and practicing finding the field becomes more critical in this situation.

Focal reducers usually can be employed to widen the field, and shrink the telescope's point spread function, often resulting in increased signal to noise ratio. However, several times we have found that these larger telescopes do not have the back focal distance required to support a focal reducer. Be especially careful in situations where there is an instrument selector (90 degree mirror with rotation to allow multiple instruments to be mounted to the telescope at once) – as these configurations often do not support the use of a focal reducer. We had a case several years ago where a secondary mirror ran off its translation screw while trying to reach focus with a reducer.

Also be aware that Ritchey-Chrétien telescopes are designed for a specific back focal distance. Their imaging performance will slowly degrade as you go "off prescription" by moving the focus away from the primary mirror. Note that most classical Cassegrain and Ritchey-Chrétien telescopes do not have a flat focal plane, and your focus may be compromised over part of your field.

Instructions

Our team believes strongly in having an instruction sheet for data collection. These instructions include a checklist of required hardware. For the Pluto event, we were all planning to use QHY 174M-GPS cameras. As a starting point, we used Dr Marc Buie's (Southwest Research Institute) instructions for set-up of the portable systems used for the 2014MU69 occultation campaigns. These were edited for a generic fixed telescope system, and went through several rounds of revisions by the team (see Appendix).

Rehearsal Night

Based on past experience, having a practice session well in advance of the actual data collection is extremely beneficial. As mentioned previously, making sure that you can get to focus is critical. The practice session can allow you to determine if any additional hardware is required to make the observation, with time enough to get it to the observation location.

Consider a checklist and look for other issues such as missing hardware. In the past, we've found we were short on electrical cables (AC extension cords, power strips, USB extensions, etc.), tables, and chairs.

Focusing is best done with a bright target initially – if a Bahtinov mask is available, we recommend its use. After a bright target has been roughly focused, switching to an unsaturated star is advised. When good focus is obtained, record the focus position:

- Record the camera, scope, cable configuration (aka stack-up) of hardware in your notebook
- Photograph the stack-up
- Record focal position if the system has a focus counter (mechanical or digital)
- If there is no counter, try to measure the focus simply with a ruler, allowing you to quickly get back near focus on "game day"
- Make sure that the camera is oriented in a way that is repeatable and is matched to the finder maps

Practice finding the field, and if possible record data for both the occulted star and the asteroid. These data are sometimes useful for later data analyses. Make sure the finder maps are adequate, and mark them for expected field size and orientation.

Take the time to discuss with the observatory team what will happen on event night. Include who will be in attendance, when the team will arrive, and what will be done in the event of either bad weather predictions or unexpected poor weather.

Data Collection

On the event night, we suggest you arrive much earlier than the time you feel you need. This conservatism has paid off in the past, and we haven't found the observatory staffing resistant to such an early arrival – several in fact suggested it. Arriving 4 or more hours early is actually quite reasonable. Since you will be there a relatively long time, dress comfortably. Bringing along food, liquids and possibly a jacket and gloves is a good idea.

In general we started with a premeasurement briefing, and went over the plan for the night's measurement activities. Then the camera was installed and wired up. The telescope was then started, and slewed to a bright target (Moon or bright planet typically). Focus was checked and adjusted. The telescope was generally slewed to the target field as soon as it was available, and held on the field until event time. Be aware of meridian flip for German equatorial mounts, and consider that extended slew with possible target recentreing in the timing for the night.

Take photos to record your experience and the observatory team and copy down all names and titles. These photos often will be used by your hosts to show others their involvement in the measurement.

Near event time, make sure everyone is seated or knows not to be moving around the observatory. Minimize the temptation of making last minute adjustments – follow the rule that if the issue won't cause you to lose the data, don't try to correct for it. Often, something as simple as recentreing the target in the field results in a fast slew out of the field, with little time to recover.

Once the data is collected, including any additional data such as dark exposures, make a copy of the data set on a back-up drive or a large volume USB stick. Getting a backup as early as possible mitigates a lot of risk, but even copying the data isn't without risk. Pack up your hardware – using a hardware inventory list can help prevent leaving equipment behind. Make sure to help clean up the observatory when you finish. Thank your hosts, and make sure they eventually get a copy of the data set.

Pluto Measurements Results

All four locations produced usable data. Two were moderately compromised. Highland Road Observatory had some thin clouds, but the resulting data was corrected by use of other stars in the field (Figure 2). Belk Observatory had a failure of the telescope mount. After several hours of trouble-shooting without success, one of the cameras was moved to one of their nearby 20 cm student telescopes, which quickly was put on field and collected data.

Our data sets were shared and readily made available to the professional scientists that requested them. Due to their size, network transfer of the data files proved troublesome with significant time spent in the monitoring and upload retries. Allow ample time when transmitting your files to the various researchers. We expect that journal papers will be forthcoming from these science teams over the coming year.

Plans for Future Fixed Observatory Campaigns and Outreach

It would be beneficial to both IOTA and to scholastic observatories to work together on future event campaigns. The use of these observatories can help to show a stronger return on investment (ROI) on observatory assets and strengthen the school's position on the observatory's use in external / off campus / real world scientific studies.

Long-term, an outreach project could be to make cameras and timing kits available to observatories with instructions on how to collect data for IOTA .

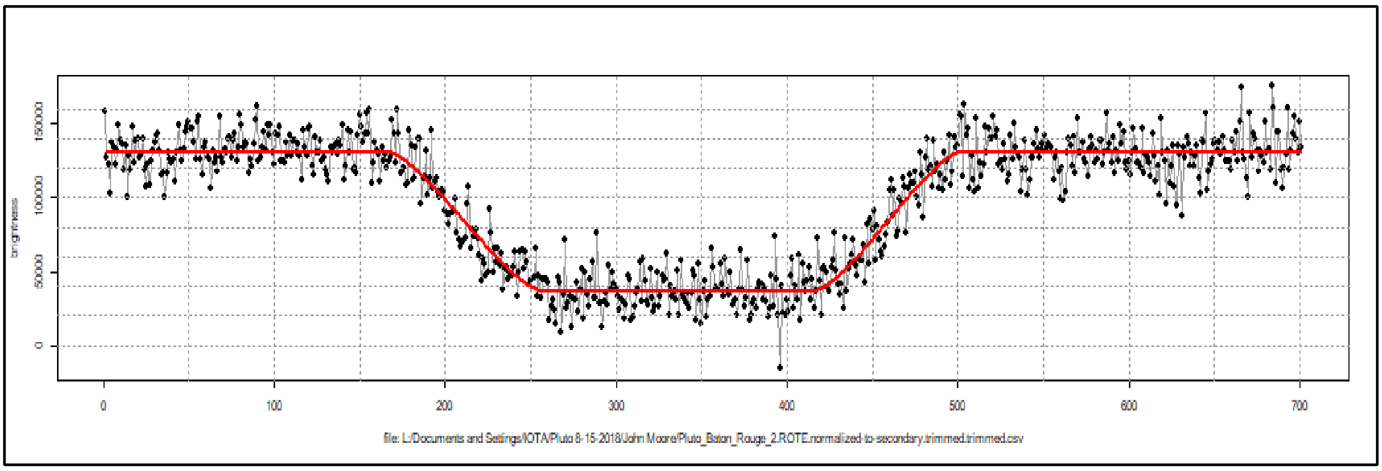

Figure 2. Example Light Curve from Highland Road Observatory. Note that there was no indication of a central flash from this location.

Figure 3. George Observatory

Experiences from the Pluto Campaign

GEORGE OBSERVATORY

John Moore made two pre-event planning trips from Oklahoma to Houston. This was critical in ensuring a successful occultation night observation.

Ted Blank arrived at the George Observatory at 6:00 PM on August 14 and was met by Docent Tracy Knauss who ably operated the 0.9 m scope. They spent the remaining daylight hours preparing the camera and computer connections and testing everything possible. Once the sky darkened, Tracy slewed the scope to a pre-point star, omicron Sagittarii, and proceeded to work across the appropriate line of declination until reaching the target star. This took approximately 30 minutes. Once the target star was reached Pluto was easily visible, and the scope's tracking was perfect, easily keeping the target star and Pluto in the FOV of the camera.

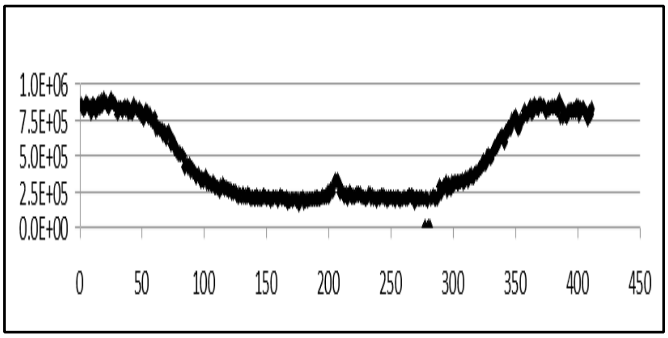

Figure 4. Example Light Curve from George Observatory. Note that there is a strong indication of a central flash from this location.

Dark, flat and bias frames were obtained before and after the event. The occultation was recorded at an exposure time of 500 msec which afforded an excellent signal to noise ratio. The central flash was successfully observed and recorded.

Paul Maley (IOTA) and David Haviland also obtained data from a C14 in another dome at the George Observatory.

Figure 5. Observer Ted Blank at George Observatory.

HIGHLAND ROAD OBSERVATORY

IOTA member John Moore accessed websites for the Baton Rouge Astronomical Society (BRAS) and the Highland Road Park Observatory (HRPO) to obtain contact information for this facility. Observatory manager and lead operator Merrill Hess responded positively to our proposal to partner with the observatory for the upcoming Pluto occultation. Plans were made for a preliminary visit to test camera compatibility and to perform a practice session that simulated the event night activities including acquiring the target and recording images at the same time as the actual event. The telescope at HRPO is a 0.5 m RC and included an instrument selector that had an available position to attach the occultation camera. Fortunately attaching the camera was uneventful, focus was quickly obtained, and the slewing accuracy of the telescope proved to be very accurate. During the practice session both Pluto and the target star were quickly acquired and multiple test exposures were taken to determine what the best camera settings would be for the actual event. After the successful test of the equipment a plan was agreed to for the actual event that was to take place a week later.

When John returned to Baton Rouge for the actual Pluto occultation he was invited to speak at the monthly meeting of the Baton Rouge Astronomical Society that was to meet the night before the event at the observatory. John gave an overview of occultation activities and described the Pluto occultation and what the overall goals were. A lively Q&A session followed with about 25 of the BRAS members at the meeting. Once the meeting ended, a final practice session was conducted and everyone was well prepared for the occultation the following night. Calibration images were recorded of both Pluto and the target star.

Typical afternoon thunderstorms gave way to clear skies as the Sun set on event night and the seeing was fair. High humidity required an exposure of 500 ms and a successful recording of the occultation was obtained. Flat, dark and bias frames were also collected.

Merrill Hess and the entire staff at HRPO were very supportive of this effort and seemed to genuinely enjoy participating in this activity. An invitation to use these facilities for future events was offered by the HRPO staff.

LIBERTY UNIVERSITY

On June 23 Steve Conard sent Jack Gross, President of the Lynchburg astronomy club, an e-mail asking him to make personal contact with Lynchburg University's Belk Observatory and Liberty University's Observatory to see if they would be interested participating in the Pluto Occultation. Both observatories were key to the occultation observations, as both fixed sites were located close to the estimated centre line. The goal of our team was to capture the data supporting the "central flash". This flash is

Figure 6. Highland Road Observatory Telescope and Observer John Moore

caused by the star's light being bent through Pluto's atmosphere as Pluto passes (continue tense as prior paragraph) in front of the target star. The size and shape of the flash will help to determine the obliqueness of Pluto's atmosphere. Dr. Scott Long, Chair and Associate Professor, Department of Mathematics at Liberty University was willing to assist. Steve provided Jack with event information along with a detailed write-up noting the scientific highlights that the Pluto event would provide to the global astronomical community.

Jack then met with Dr. Long at the observatory on June 28 and explained what would be involved. The 0.6 metre telescope, a custom-built fork-mounted DFM Engineering Ritchey-Chrétien (DFM RCT), is located on Liberty Mountain approximately five miles from the main campus. The dome building housing the state of the art scope along with a separate well-appointed educational building are located on the outskirts of the Liberty University Equestrian Center. The site offers a Bortle class 6 sky. The facility and the welcome were impressive. Dr. Long invited several students to attend and participate in the initial meeting.

A second visit to the observatory was made on August 4th. Steve Conard and experienced IOTA volunteer, Roxanne Kamin, drove

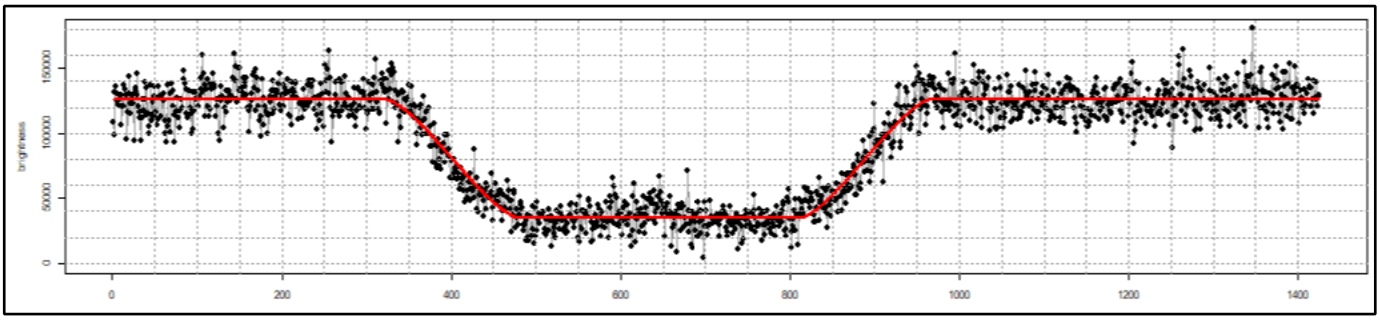

Figure 7. Light Curve from Liberty University Observatory. Note that there may be a slight indication of a central flash from this location.

to Lynchburg to check the interface of their equipment with the telescope, make preliminary calibrations, and to confirm focus along with field of view (FOV) measurements. They also identified the star field and recorded all camera settings. Roxanne used her personal QHY 174M-GPS camera that has a built in GPS timing. Dr. Long again had several university students present to observe. A rising senior, Steve Dutkus managed the scope operations. Weather that night was 21° C with less than 45% cloud cover.

With high expectations of a successful event, Roxanne returned solo to Lynchburg and the Liberty University Observatory to record the occultation on the night of 14/15 August. A long line of cars greeted her at the observatory gate, as the Liberty staff once again hosted a warm welcome and refreshments. Dr. Long as well as the scope benefactor, several students and other university visitors were present for the big occasion. Initial equipment setup began at 9 PM under clear skies and a temperature of 17° C.

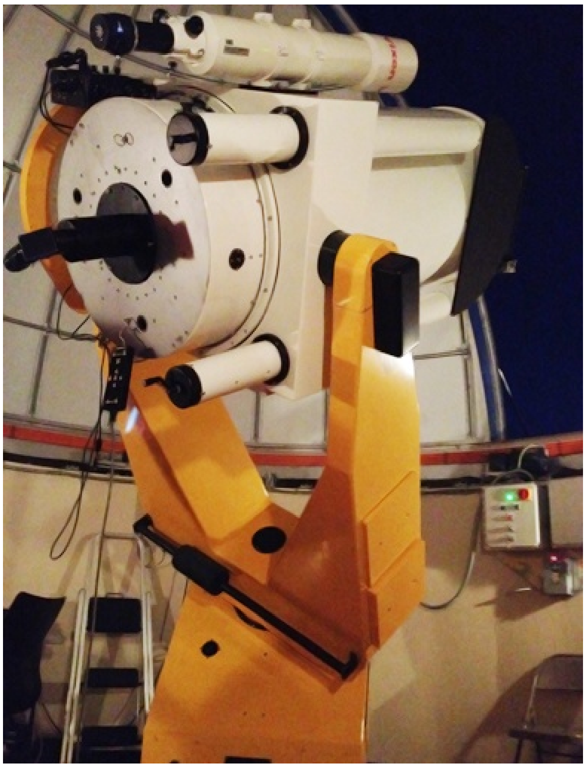

Figure 8. Liberty University Observatory Telescope

Figure 9. Observer Roxanne Kamin at Liberty University Observatory.

The stack-up proceeded according to the team's well documented plan with minor adjustments. Exposure was at 250 ms. Manning the telescope with skill, Steve Dutkus maintained excellent positioning and tracking of Liberty's DFM R-C during the 30 minute event window. The students enjoyed periodically watching Pluto's path progress towards the target star with the occultation event obvious on the imaging laptop screen. Results confirmed the team's success in that Roxanne's data recorded and captured the central flash. After collecting darks, flats and bias data, the tired but happy participants shook hands and departed with the acknowledgement of a long successful night.

LYNCHBURG UNIVERSITY

Lynchburg University's Belk Astronomical Observatory is located at the Claytor Nature Study Center, a short distance north of the Town of Bedford and a half-hour drive from the main campus in Lynchburg, Virginia. The dome houses a 0.6 m Paramount German equatorial mounted-Ritchey-Chrétien telescope. The facility also has 12 piers with eight mounted 0.2 m Celestron Schmidt-Cassegrain Telescopes housed in an adjacent roll-off roof structure. This would prove to be important on the night of the actual occultation.

This location was intended to have an experimental set-up using a dichroic beamsplitter, Johnson filters, and two cameras. The dichroic assembly is a Innovations Foresight On-Axis Guider (ONAG), on loan from Bruce Holenstein of Gravic, Inc. A Johnson V filter was placed in the visible light output of the ONAG, and an I filter in the Near Infrared (NIR) output. The goal was to obtain atmospheric transmission curves from two bands simultaneously, to better characterize Pluto's atmosphere.

Finding someone in order to gain permission to use the telescope for the Pluto occultation proved problematic at first. Dr. Crystal Moorman the facility overseer was on maternity leave and Danielle Racke, Education Coordinator at the Claytor Nature Center was on vacation until shortly before the occultation. Jack Gross then contacted Dr. Greg Eaton who is the director of the Claytor Nature Study Center, owned by the University of Lynchburg. He also teaches in the Environmental Science, Environmental Studies, and the Biology programs. The initial request via e-mail contained an explanation of the proposed project and its importance and attached Steve's information. Fortunately, Dr. Eaton was familiar with the operation of the telescope and enthusiastically agreed to assist in the occultation in an e-mail to Jack on July 22. However, the e-mail included a caveat concerning the telescope, "The Gilbert scope has been up-again, down-again for several years"

Figure 10. Belk Observatory

Further e-mails from Jack detailed a timeline and explained exactly what was required of the observatory staff, which in this case was Dr. Eaton, and what the IOTA volunteers would be responsible for. We also asked if a visit ahead of the actual occultation could be arranged to check out Steve's QHY 174M-GPS camera and the dichroic assembly. Next, the checkout visit was coordinated with all involved. The 4th and 5th of August were agreed to. This allowed back-to-back visits at both the Liberty and Lynchburg observatories. After successful tests at the Liberty observatory on the 4th, the team met in Bedford to visit the Lynchburg University's Belk Observatory. The Bortle class 5 sky was clear and all equipment interfaces were successful. Focus was obtained and with Dr. Eaton manning the telescope controls, the starfield was found and all instrument settings were recorded. Both check visits had been successful. The dichroic assembly was tested, although it was found that the NIR leg had very poor signal to noise ratio even with long exposures (~1 second). Future use may require a more sensitive NIR camera.

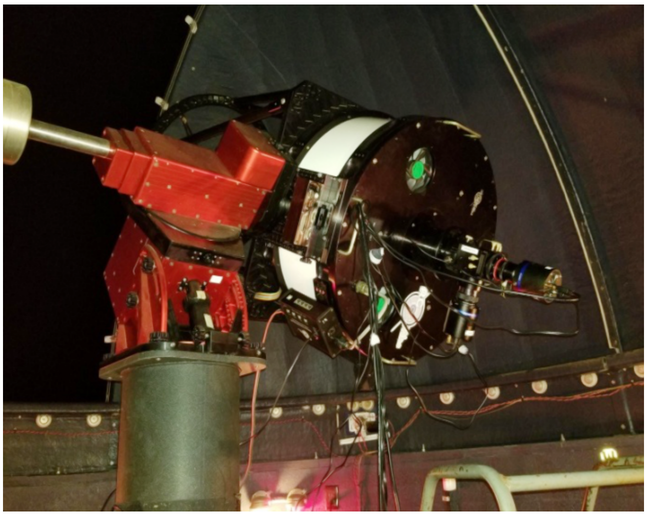

Figure 11. Telescope at Belk Observatory. Note the dichroic and paired cameras.

On the actual occultation night of August 14/15, operations at Belk were problematic. As Steve, Jack and Roger Yeager, another amateur astronomer assisting Steve, reached the Nature Center they found the gate locked. The problem was solved with a few cellphone calls, it was; however, a portent of things to come.

The sky was clear when the team arrived at the observatory shortly after 10 PM and remained clear throughout the night. The temperature was 21° C with a humidity of 93% when as the equipment was unpacked and set up it soon became evident that the telescope was losing communication with the laptop that controlled it. Once slewed to the target area, it would rapidly drift off. Next began several hours of trouble shooting including checking all connections, commanding the telescope back to its home position, shutting down the system and restarting it, rebooting the control laptop, and various permutations of these procedures, to no avail. Although the team arrived early with plenty of time to set up, time was quickly running out.

Used to unexpected problems and determined to record the occultation, Steve suggested using the 0.2 m Schmidt-Cassegrain Telescopes. The roll-off roof was quickly deployed, and one of the 0.2 m telescopes was aligned. Steve set up a Watec 910HX camera and IOTA VTI time inserter. The target field was identified, and tracking was verified. A new problem quickly arose. The high humidity was causing dew to form on the one working 0.2 m telescope. Amateur astronomers are good at improvising and Roger found a shop vacuum and reversed the hose so that it was connected to the vacuum's fan output side causing warm air to flow out of the hose. This was used to clear the dew from the telescope's objective lens with just minutes to spare before the occultation timing was to begin. The team was able to collect good data and the night was pronounced a qualified success since the dichroic assembly could not be used with this telescope.

Summary

The observations made by the IOTA team were highly successful. We were extremely lucky with weather, all four observatories were able to collect data, and only one was somewhat affected by clouds. While one large telescope failed due to a mount issue, a student telescope available on site allowed scientifically useful data to be collected.

We have learned much from this experience beyond the scientific data that was collected. Using fixed observatories by IOTA volunteers for occultations requires good communication skills. Keeping everyone in the loop is critical. A personal visit to the observatory to discuss the project can help facilitate the request. Preplanning should include a detailed written plan delineating the responsibilities of the IOTA volunteer(s) and the observatory staff. An event timeline indicating who will do what at every stage of the event, from the initial request to the final thank you correspondence will avoid confusion and frustration. Finally, be prepared for the unexpected.

For faint, high value observations, we highly recommend this approach. However, we would like to suggest that this approach not be used for observations with a low likelihood of success. While observatory personnel will understand failures due to weather and event technical failures, the nuances and complexity of events that result in a negative may be lost and cast a disappointment with the observatory team and observatory benefactors. Be upfront about the possibility for success, but realize that it only takes a miss or two before the observatory will lose interest in cooperating in the future.

We hope that this insight into the positive use of existing observatories will encourage other members of IOTA and the worldwide occultation community to do the same and engage with their local school and university observatories to participate in future occultation events..

The authors would like to thank the Baton Rouge Astronomical Society, the Houston Museum of Natural Science, Liberty University, and Lynchburg University for generously sharing their facilities with us.

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Appendix

<u>Event Night Steps</u>
Version: Pluto_20180729a
Last updated July 29, 2018

Edited from Marc Buie's documents supporting the MU69 occultations. SharpCap instructions from Rodrigo Leiva's Capture Software document (edited).

This version is intended for observers supporting the August 15, 2018 Pluto occultation observing from "large" fixed observatories.

These steps are for setting up the camera and taking occultation data on practice and event nights.

Required Hardware

a. QHY 174M-GPS camera (including GPS antenna)
b. 9-10' USB 3.0 cable
c. 12 vdc power supply
d. 12 vdc power cable
e. Laptop with power supply (must have a USB 3.0 port)
f. M42 male to 2" male adapter (ScopeStuff #TA2P)
g. Antares 2" 0.5x reducer (other 2" reducers may also work, test them first)
h. Power strip
i. Memory stick

Optional Hardware

a. Johnson band filter (B, V, or I as directed)
b. Blue Fireball T/T2 male & 1.25" filter female to T/T2 female thread adapter (#T-10)

SharpCap Loading Instructions

a. Download drivers from http://www.qhyccd.com/QHY174.html At the end of the site "Windows Driver and Software" Download Camera Driver -> Latest Version currently is 3.1.5.193.0
b. Go to www.sharpcap.co.uk/sharpcap/downloads and download "SharpCap Pre-Requisites Installer ".
c. Download SharpCap from www.sharpcap.co.uk/sharpcap/downloads and install version 3.1
d. To install a license, go to top menu "Help -> SharpCap Pro License". License to copy text in the white box. These instructions assume you have the Pro license.
e. Ensure have at least 100 GB available disk space of the computer.
f. Be sure to disable option to turn off Windows screen or hibernate due to lack of activity. The computer must be active all the time during capture to avoid data loss.
g. Once you have a well-tested, stable version of SharpCap, stop allowing it to update unless you have a problem that needs to be corrected. Keep the same version through the event. The current working version is:

SharpCap General File Settings

General Settings SharpCap, top menu "File -> SharpCap Setting".

a. In general"
   1. Enable "Automatically connect to camera When SharpCap start"
   2. Activate "Save Setting Capture alongside each capture file"
   3. Activate "Log all QHY GPS data to file ()"
b. In "Filenames"
   1. Activate "Organize files into subfolders captured"
   2. First select by "Date" Then by "None"
   3. Enable "Use UTC times in file and folder names"
   4. Enable "Use sortable date format YYYY'MM'DD"
   5. Activate "Create subfolder for each sequence"
c. Press OK to save.
d. It may be convenient to "pin" the Camera Control Panel in place so it isn't always shifting off screen. The pin is upper right next to the "Camera Control Panel" wording.

SharpCap Pluto Occultation Settings

Configuration parameters capture settings. Important--these will be changed for the event. DO NOT USE THIS VERSION FOR THE ACTUAL OCCULTATION. In the "Camera Control Panel" on the right:

a. Capture Profiles
   Save your profile when necessary by using the Save button and naming it.
   Load a profile by pulling down the list, selecting one, and pressing the Load button.
b. Capture Format and Area
   1. Color space: MONO16
   2. Capture Area: 1920x1200
   3. Binning: (to be determined)
   4. Output format: deselecting Auto and choose "FITS files (* .fits)"
c. Camera Controls
   1. Exposure: 100 ms (FAST_Pluto), 250 ms (MED_Pluto), or 500 ms (SLOW_Pluto)
   2. LX Mode: Off
   3. Auto Exposure: Off
   4. Quick picks and slider not used
   5. Gain: 300
   6. Frame Rate Limit: Maximum
   7. Offset: 100 (likely to change to 50 if we bin 2x2)
   8. USB Traffic: 50
   9. Enable Live Broadcast: Off
   10. Force Still Mode: Off (Important--if on in 16-bit mode, GPS will not work!)
d. GPS Controls
   1. IMPORTANT: Make sure your profile has GPS set to off. After you load your profile, turn the GPS on manually. *This was the standard procedure last year--perhaps it has been fixed?*
   2. GPS: On (manually)
   3. GPS Show Data: On (hide the window if it is in the way)
   4. GPS Calibration Data: OFF
   5. Calibration Start: N/A if calibration Data is OFF
   6. Calibration End: N/A if Calibration Data is OFF

e. Image Controls
IMPORTANT NOTE: Adjusting the image controls changes the saved data--do not change anything except turning the timestamp on.

1. Gamma: 1.0
2. Brightness: 0.0
3. Contrast: 0.0
4. Timestamp Frames: On

f. Thermal Controls

1. Cooler Power: Auto
2. Target Temperature: 0 (TBC)

g. Preprocessing

1. Subtract Dark: none
2. Apply Flat: none

h. Display Histogram Stretch

1. Press Auto button (looks like a lightning bolt)
2. Grab and slide the dashed line left (to brighten) or right (to darken)
3. Note that these adjustments do no impact the saved data

i. Top Row

1. Don't use live stack
2. Target Name: Pluto or Practice
3. FX: none
4. Reticule Styles: Off
5. Zoom: Auto (will always show the entire image)
6. Histogram: Generally off
7. Focus Assistant: Can enable for focus, turn back off when done. Most useful ones in the past have been FWHM Measure, Multi-Star FWHM, and Bahtinov Mask.

j. Once all set to go Capture Profiles

1. Save As, type OCC and press OK.

Every time you start SharpCap go to Capture Profiles, select the proper profile, and press "Load"

Step 1: Assemble theCamera Unit to the Telescope

a. Power on the computer. Put in username/password if required, allow to boot.
b. Attach the 2" adapter (M42 male to 2" male) to the camera by screwing it onto the front of the camera.
c. Attach the Antares 0.5x focal reducer to the other end of the 2" eyepiece adapter.
d. Slide the assembly into the telescope's drawtube, as far as it will go.
e. To aid in data reductions, we have a standard orientation for the camera (to be supplied). Rotate the camera in the drawtube to this configuration.
f. Connect the camera's GPS antenna and magnetically affix the antenna to somewhere near the center of the dome (maximize its skyview).
g. Connect the camera to a 12vdc power supply, using supplied cables. Plug into the camera first, then plug into the power supply. Listen for the camera's fan; if this is not running then the camera is not receiving power. Use of the short power extension cable is optional.
h. Connect the camera's USB cable to one of the laptops **USB3** ports a long (9-10') USB cable--do not extend longer than this. Listen for the computer's tone to indicate a connection.
i. Strain relieve the cables if possible.

Step 2: Initialize SharpCap

a. Do not start this step until the computer and camera have been powered on.
b. Start SharpCap, the default profile "OCC" is loaded at the start.
c. Adjust settings for telescope and finderscope alignment.
d. Make sure display zoom is on "auto" to show full frame.
e. The GPS antenna must be connected and turned on "GPS Controls" "GPS: On".
f. The bottom status bar should show **GPS: *** *** Locked.** This can also be confirmed in "GPS Controls" GPS and press Show Data. The first line of the window that opens should say "Status: Locked". GPS can take several minutes to move to the Locked state so you must connect everything in advance.

Step 3: Align Finderscope Boresight to the Camera

a. Have the operator move the telescope around until any bright object (recommend Jupiter or Saturn) is centered on the computer screen.
b. With the operator's permission, adjust the finder scope boresight screws until the finder crosshairs are on the same object that is on the computer screen. There is no need to be accurate in centering on this step. You will improve this later. Be absolutely sure you are on the same object!

Step 4: Align telescope

a. Recenter on the same object.

b. If possible, have telescope operator "resync" (or the equivalent) to this object. Alternatively, calculate and record the RA and Dec offset to this object--be sure you understand your sign convention!

Step 5: Slew to Pluto and Occultation Star

a. Have telescope operator slew to the occultation star. Ensure that the RA and DEC of the occultation star matches the following (apply offsets if necessary):

August 15 Occultation Star:
RA: 19h 22m 10s **DEC:** -21° 58' 49"

b. After the slew is finished your FOV should be near the target field. If not, don't panic, and try spiraling the telescope around a little bit to find the target field. If the target field cannot be found, try slewing the telescope back to the star Nunki. If the telescope centers directly on Nunki, you should be close when you go back to your field. If not, recalculate your offsets.

c. Once the target field is found, center the target star.

Star Fields

We'll put the star maps here.

Step 6: Acquire Data

1. Load the appropriate SharpCap profile as directed by Marc. The "FAST_Pluto" profile is the preferred profile (200 msec exposure, 5 frames/sec). If clouds make it difficult or impossible to see the star using the FAST_Pluto profile you may switch to the slower SLOW_Pluto profile (500 msec exposure, 2 frames/ sec). **Always initiate your SharpCap captures using frame count, never by elapsed time.**
2. Using "Start Capture" take the appropriate amount of data, depending on whether this is a **short practice night**, a **full practice night**, or the **event night**. Monitor the start and stop times and insure that your capture does in fact take the expected number of elapsed minutes. Also monitor for dropped frames and report all of this information on the log sheet.
   a. On any practice night other than full, take 10 minutes of data of field, record everything in your notebook.
   b. On **full practice night**, take 30 minutes of data from **05:15** UT to 16 JUL **05:45** UT. Alternatively, take data just after astronomical twilight ends (if unable to work late). This will be **TBD frames** if using the FASTOCC profile, or **TBD frames** if using the slower OCC profile.
   c. On **EVENT night** of August 14/15, take 30 minutes of data from **05:15** UT to 16 JUL **05:45** UT. This will be **TBD frames** if using the FASTOCC profile, or **TBD frames** if using the slower OCC profile.
3. Maintain logsheet
   a. Use the provided logsheet to document each image capture sequence (one line per capture).
   b. Use the UT time (HH_MM_SS) as shown on the screen at the end of the capture as the label in the left-most column on the logsheet. Don't use an approximate time from some other means. This is used for finding the files, not documenting the time.
   c. Make sure to write down the observing location (lat/lon/alt) of your site on the logsheet.
   d. Do not use a logsheet on more than one night, start a fresh one each night.
4. During exposures:
   a. DO
      i. Control lighting - laptop screen or flashlights should not shine down into the tube.
      ii. Keep target star near the center. Use the lowest rate possible for guiding. It should be very slow so that there is minimal to no smearing of the image during an exposure.
      iii. Vigilance is required while collecting data. You will have to determine a safe interval between checks if constant supervision is not possible but an upper limit is probably 5 minutes.
   b. DO NOT
      i. Walk around (static or tripping hazard)
      ii. Shine flashlights around
      iii. Fully close the lid on the laptop (you need to see the screen to guide, right?)
      iv. Over-guide. Some drifting is ok.

   c. For the 2-3 minutes around the predicted mid-time, do not guide at all unless it is really, really necessary. Your sensitivity is reduced when you are moving.
5. After data collection is over, tear down and pack up system. While you are doing this you can set up the laptop to copy the data to your memory stick and get this done during tear down and the drive back.
6. Upon returning back to the base hotel, make sure you and your team **check in and turn in your memory stick and logsheet for the night.**

Beyond Jupiter

The World of Distant Minor Planets

Since the downgrading of Pluto in 2006 by the IAU, the planet Neptune marks the end of the zone of planets. Beyond Neptune, the world of icy large and small bodies, with and without an atmosphere (called Trans Neptunian Objects or TNOs) starts. This zone between Jupiter and Neptune is also host to mysterious objects, namely the Centaurs and the Neptune Trojans. All of these groups are summarized as "distant minor planets". Occultation observers investigate these members of our solar system, without ever using a spacecraft. The sheer number of these minor planets is huge. As of June 2019, the *Minor Planet Center* listed 951 Centaurs and 2553 TNOs.

In the coming years, JOA wants to portray a member of this world in every issue; needless to say not all of them will get an article here. The table shows you where to find the objects presented in former JOA issues. (KG).

No.	Name	Author	Link to Issue
944	Hidalgo	Oliver Klös	JOA 1 2019
5145	Pholus	Konrad Guhl	JOA 2 2016
8405	Asbolus	Oliver Klös	JOA 3 2016
10199	Chariklo	Mike Kretlow	JOA 1 2017
20000	Varuna	André Knöfel	JOA 2 2017
28728	Ixion	Nikolai Wünsche	JOA 2 2018
54598	Bienor	Konrad Guhl	JOA 3 2018
60558	Echeclus	Oliver Klös	JOA 4 2017
90482	Orcus	Konrad Guhl	JOA 3 2017
120347	Salacia	Andrea Guhl	JOA 4 2016
134340	Pluto	André Knöfel	JOA 2 2019
136199	Eris	André Knöfel	JOA 1 2018
136472	Makemake	Christoph Bittner	JOA 4 2018

In this Issue:

(136108) Haumea

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ABSTRACT: Haumea is one of the four currently known dwarf planets beyond Neptune. Haumea's mass was estimated to be about 1/3rd of Pluto's mass. Two moons were discovered so far. Due to the short rotation period (~ 4h) the dwarf planet is distorted into a triaxial Jacobi ellipsoid. A stellar occultation in 2017 revealed a ring, the first discovery for a TNO and the second discovery for an object not being a (giant) planet, after the discovery of a ring system around the Centaur (10199) Chariklo in 2013, also by a stellar occultation. From these 2017 occultation observations the physical dimensions (2322 x 1704 x 1026) km were modelled for a triaxial ellipsoid, placing Haumea among the largest trans-Neptunian objects discovered so far (after Pluto and Eris).

Discovery and Name

Haumea was discovered on 7 March 2003 at the Sierra Nevada Observatory in Spain (MPC station code J86)[1]. But in fact two different research teams (J. L. Ortiz et al. and M. Brown et al.) have claimed discovery credit, leading into a controversy about that [1]. On 29 July 2005 the Minor Planet Center assigned the provisional designation 2003 EL61 to the object, based on the Spanish discovery images. On 7 September 2006, Haumea was numbered and admitted into the official minor planet catalogue as (136108) 2003 EL61. Precovery images of Haumea have been identified back to 22 March 1955.

On 17 September 2008, the IAU announced that Haumea has been accepted as a dwarf planet [2]. The name "Haumea" was proposed by the Caltech team led by Mike Brown. The Spanish team led by Jose Luis Ortiz had proposed "Ataecina", named for the ancient Iberian goddess of Spring, but this name did not meet the IAU requirements, because the names of chthonic deities are reserved for plutinos that resonate 3:2 with Neptune, which was not the case for Haumea, which is believed to be in a weak 7:12 resonance.

In the Hawaiian mythology, Haumea is the goddess of childbirth and fertility. Haumea is the matron goddess of the island of Hawai'i.

Orbit and Classification

Haumea orbits the Sun in an elliptical orbit with a perihelion distance q ≈ 35 AU, an aphelion distance Q ≈ 52 AU and an orbital inclination of about 28°. The orbital period is 285 years. Last aphelion was in 1992, the next perihelion will be in the year 2132. The current (mid 2019) distance from the Sun is r ≈ 50.4 AU.

Haumea is classified as a dwarf planet because it is presumed to be massive enough to have been rounded by its own gravity into a shape in hydrostatic equilibrium (though having a highly non-spherical shape due to its fast rotation), but not massive enough to have cleared its neighbourhood of similarly sized objects.

Haumea is in a weak 7:12 resonance with Neptune [3] and it is hypothesized to be the parent body of a TNO collisional family [4], which is probably rare, because the formation of such a family is a highly improbable event in today's Edgeworth-Kuiper Belt [5]. Besides Haumea itself and its two moons, a further 10 objects were identified as family members with similar orbital parameters and common physical characteristics like albedo, colour and spectra (nearly pure water-ice) [6,7,8]. Collisional formation of the family requires a progenitor body with radius of about 830 km and a density of ~2.0 g/cm^3 (similar to Pluto and Eris) [4].

[1] At the Minor Plane Center and the NASA JPL website (small body database) no discoverer names are given, just the discovery location (observatory) is mentioned. See also [1].

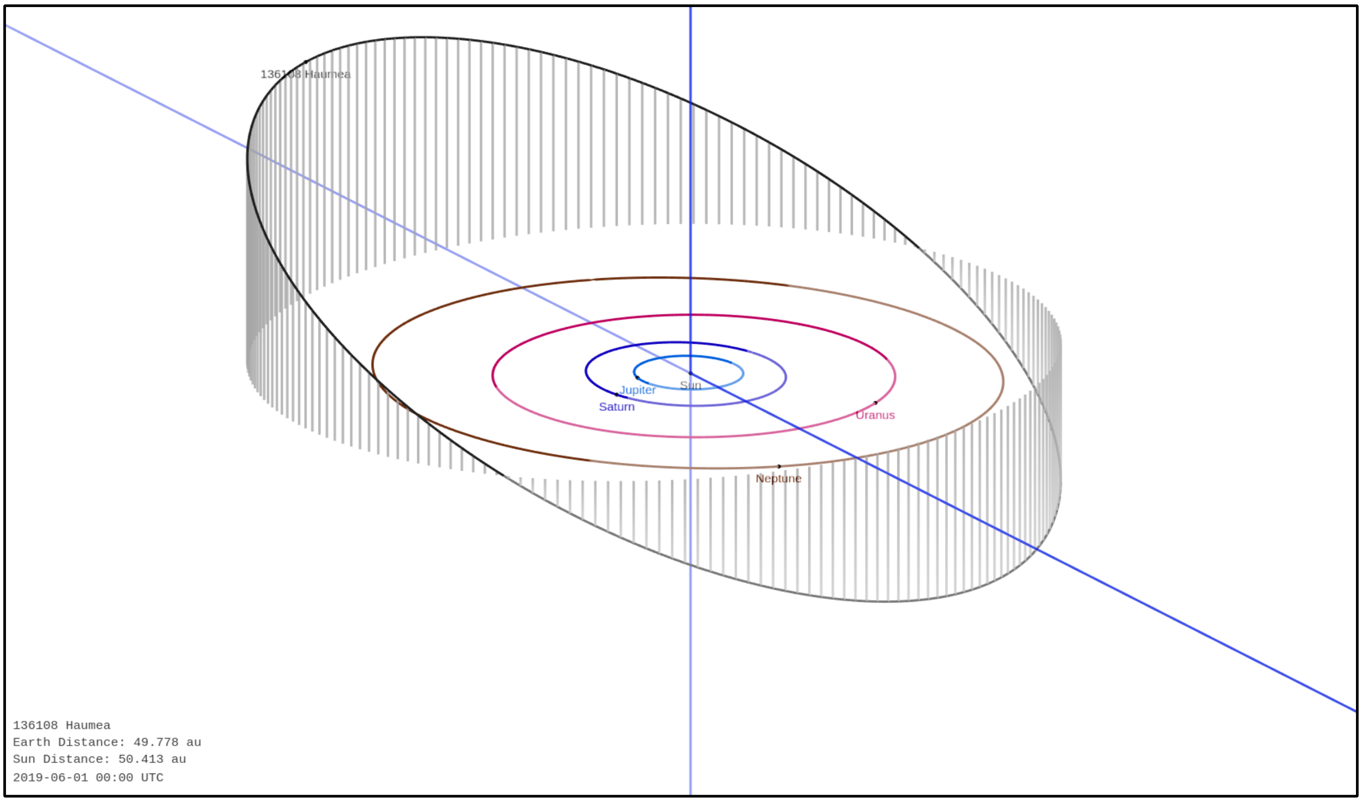

Figure 1. Orbit diagram of Haumea and the outer planets. Credit: JPL Small-Body Database Browser.

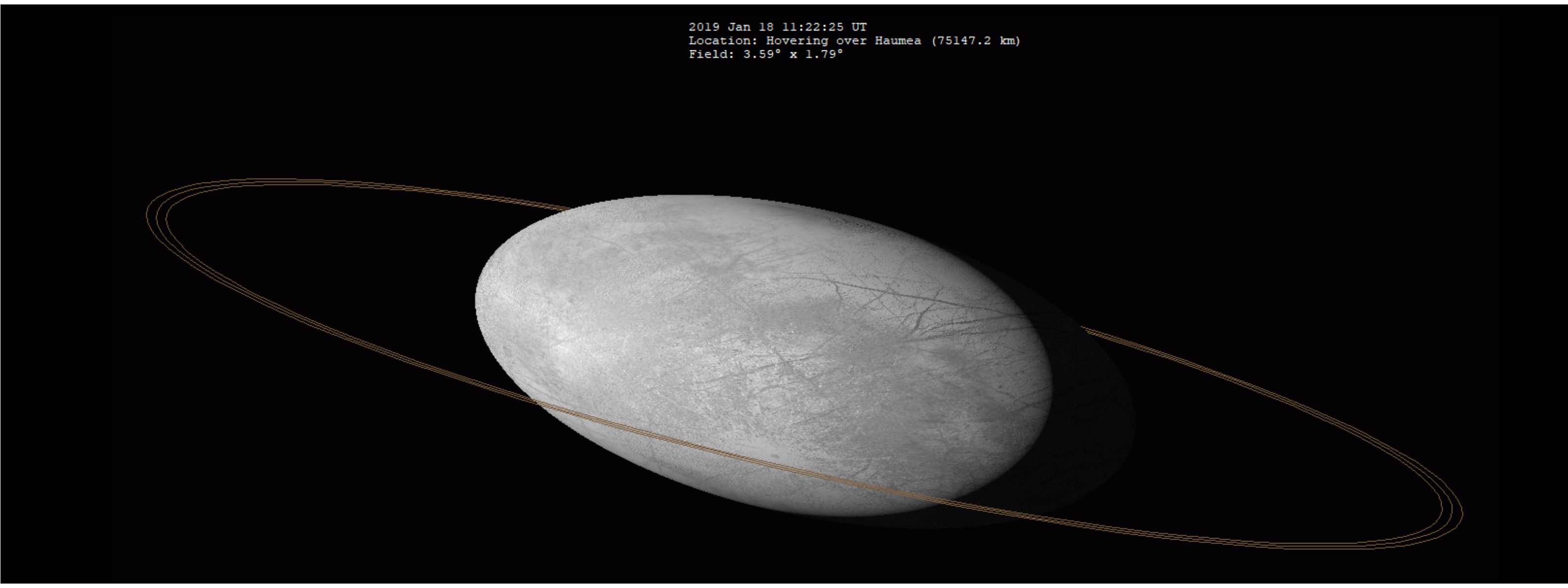

Figure 2. Screenshot of a simulation (artist's concept) of Haumea's rotation inside the ring. Credit: Tom Ruen and Wikipedia [18].

Moons and Rings

In 2005 two moons were discovered by Brown et al. on images taken with the large telescopes of the W. M. Keck observatory on Mauna Kea, Hawaii. The two moons are named after two of Haumea's daughters, Hi'iaka und Namaka. In the Hawaiian mythology they were formed from the body of their mother Haumea. This naming reflects the assumption that these moons were formed during the collisional formation of Haumea itself instead of being captured satellites. This was concluded by Brown et al. from spectral observations of Hi'iaka, the outer and larger of the two moons, which shows a strong similarity to the spectrum of Haumea (crystalline water-ice absorption features in the infrared spectrum). Assuming a density of water ice, the estimated diameter of Hi'iaka and Namaka are ~320 km and ~160 km, respectively [9].

The observation of a multi-chord stellar occultation on 21 January 2017, with secondary events around the main body, revealed a ring around Haumea with an opacity of 0.5, a width of 70 km and a radius of about 2287^{+76}_{-40} km [10]. The ring is coplanar with both Haumea's equator and the orbit of its larger, outer moon Hi'iaka. The ring is located close to the 1:3 resonance (which is at r = 2285 ±8 km) between the orbital mean motion of the ring particles and the spin period of Haumea (~4 h), but recent simulations showed, that this would be dynamically unstable and the ring particles are rather in a stable region associated with a so-called first kind periodic orbit[2] instead of the 1:3 resonance [11]. This was the first discovery of a ring around a TNO. In 2013 a ring system was detected around the Centaur (10199) Chariklo by a stellar occultation, the first body other than a giant planet known to have a ring. Something similar is also proposed for the Centaur (2060) Chiron [12, 13], based on observations of a stellar occultation on 29 November 2011.

Physical Properties

Different size estimates (using different instruments and methods) have been published since Haumea's discovery. Data from the 2017 multi-chord stellar occultation, combined with light curves, constrained the triaxial ellipsoid shape, with values a = 1161 ± 30 km, b = 852 ± 4 km and c = 513 ± 16 km [10]. The volume-equivalent diameter is 1 595 ± 11 km. Haumea is larger than

Figure 3. Image of Haumea with its moons. Hi'iaka is above Haumea (centre), and Namaka is directly below. Credit: Keck telescope, Caltech, Mike Brown et al.

[2] Poincaré periodic orbits of the first kind in the planar circular restricted problem of three bodies are those originated from particles initially in circular orbits.

estimated previously, approximately the diameter of Pluto along its longest axis. This size implies an upper limit of its density of 1.885 g/cm³ and a geometric albedo of 0.51, both smaller than previous estimates (e.g. 2.6 g/cm³ for the density [14]). A density value of 1.885 g/cm³ is closer to the mean value of 1.96 g/cm³ for TNOs with diameter > 900 km [15]. Pluto for example has a mean density of 1.85 g/cm³.

This diameter (and density) is determined under the assumption that the ring does not contribute to the total brightness. For an upper limit of 5% contribution by the ring, the light curve amplitude of the main body increases (and thus the semi-major axis), the volume-equivalent diameter is 1632 km and the density is 1.757 g/cm³.

From the Keplerian orbit of Hi'iaka, the outer and larger of the two moons, a value of $4.006 \pm 0.04 \cdot 10^{21}$ kg was derived for the mass of Haumea [16]. This is ~31% of the mass of Pluto.

Haumea is a fast rotator, a spin period of 3.9155 h was derived from the light curve. This rapid rotation is explained by its collisional formation (of two dwarf planets / TNOs). No other large object in the Solar System spins as fast as Haumea. This rapid spin deforms Haumea into an elongated ellipsoid whose shape balances gravitational and rotational accelerations.

Spectral observations with the Gemini and Keck telescopes showed strong crystalline water ice features similar to the surface of Pluto's moon Charon. Haumea is covered mostly with almost pure crystalline water ice.

Though the main part of the amplitude of Haumea's light curve is due to the highly elongated shape (and thus colour independent), smaller colour variations show a region on the surface that differs both in colour and in albedo ("dark red spot" [17]).

So far no atmosphere has been detected around Haumea.

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Pierre Vingerhoets

1939 – 2019

(Image: Hugo Riemis)

On May 18th, the VVS[1] and the occultation community lost with the passing of Pierre Vingerhoets one of their very active members and observers of the past decades.

He had just turned 80 in January.

At the beginning of the 1970s, Pierre was already active as an amateur at the recently opened public observatory Urania (Hove) and soon he would also become a familiar face within the VVS.

In 1982 he took over the Star Occultation working group from Roger Laureys, a position he held for more than 30 years. Pierre took care of disseminating the predictions, collecting and processing the observations and organizing numerous expeditions for grazing occultations, sometimes far beyond the national borders (France, Spain). In the many heroic stories linked to some of those expeditions, Pierre's figure will undoubtedly live on for a long time.

But it was not only his own working group, he was also one of the driving forces behind the bi-monthly umbrella magazine "Werkgroepeninfo" / WGI. He also took care of the manual dispatching of Heelal[2], the Hemelkalender[3] and WGI, a task that took a lot of time. He was awarded a silver Galilei prize for his contributions.

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Pierre was also a welcome participant at the ESOP symposia of the International Occultation Timing Association. Pierre Vingerhoets was a key figure for many European amateurs, from Scandinavia to Spain and from Portugal to Russia. Together with Jan Van Gestel, he created the Planoccult, Moonoccult, and Graze mailing lists for the international community. These are currently available on http:// vps.vvs.be/mailman/listinfo. Planoccult has almost 500 subscribers.

But above all Pierre was a true observer. He enjoyed not only the solar eclipse trips he made, but certainly his countless observation trips to France with his group of friends "AstroDuvels"[4]. First to Provence and then for many years to the observatory at an altitude of 3000 metres in Saint Véran. He was not only one of the most experienced observers who always advised and assisted the others, but also served as the esteemed chef.

At home, Pierre always had the support of his understanding and loving partner Lizette in his many activities. Also in recent years, when his health deteriorated, she was his support.

Pierre realized that the inevitable was coming (he said "I'm buying time" a year ago), but he remained interested in astronomy. A few weeks before his death, he attentively watched from his hospital bed the demo of the automatic observatory built by his AstroDuvel friends.

We had to say goodbye to a fantastic amateur and a fascinating man, but we look back on many beautiful memories. Pierre, we keep you in mind.

Jef Van Camp, VVS

Adopted for JOA by Chris Steyaert, VVS

VVS[1] Vereniging voor Sterrenkunde, Astronomical Association, Flanders, Belgium
Heelal[2] The Universe, the monthly magazine of the VVS, coverage 2000
Hemelkalender[3] The Sky Calendar, the yearly handbook of the VVS, edited by Jean Meeus
AstroDuvels[4] Duvel = devil, a strong Belgian beer

"Chef" Pierre Vingerhoets at work in Saint Véran. (Image: Hugo Riemis)

Pierre takes a first look at the Moon during sunset in Saint Véran. (Image: Hugo Riemis)

Journal for Occultation Astronomy

IOTA's Mission

The International Occultation Timing Association, Inc was established to encourage and facilitate the observation of occultations and eclipses It provides predictions for grazing occultations of stars by the Moon and predictions for occultations of stars by asteroids and planets, information on observing equipment and techniques, and reports to the members of observations made.

The Journal for Occultation Astronomy (JOA) is published on behalf of IOTA, IOTA/ES and RASNZ and for the worldwide occultation astronomy community.

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www.occultations.org
www.iota-es.de
www.occultations.org.nz

These sites contain information about the organisation known as IOTA and provide information about joining.

The main page of occultations.org provides links to IOTA's major technical sites, as well as to the major IOTA sections, including those in Europe, Middle East, Australia/New Zealand, and South America.

The technical sites hold definitions and information about all issues of occultation methods. It contains also results for all different phenomena. Occultations by the Moon, by planets, asteroids and TNOs are presented. Solar eclipses as a special kind of occultation can be found there as well results of other timely phenomena such as mutual events of satellites and lunar meteor impact flashes.

IOTA and IOTA/ES have an on-line archive of all issues of Occultation Newsletter, IOTA'S predecessor to JOA.

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