Chasing Shadows

Measuring Faint Asteroids with a DSLR

My first successful asteroid occultation observation was a "miss" earlier this year. In August, I had my first successful positive observation. That occultation was the asteroid (1197) Rhodesia passing in front of a 10th magnitude star. You can see in this image from my DSLR the one star trail with a gap in it, revealing when the asteroid passed between my telescope and the star.

Outline

- Introduction
- Observing with a DSLR and a Dobsonian telescope
- Resources: Prediction and Planning
  - Lunar Occultations (example: Aldebaran, Oct. 2)
  - Asteroid Occultations (example: Rhodesia success, Aug. 14)
- Conclusion: Other upcoming events
- Addendum: A brief Kepler update

- What they are and what can be learned from observing them
- Example of how to observe one
- Sources of information and tools for observing occultations, especially the International Occultation Timing Association (IOTA)
- Sum up with my results and opportunities coming up in next few weeks
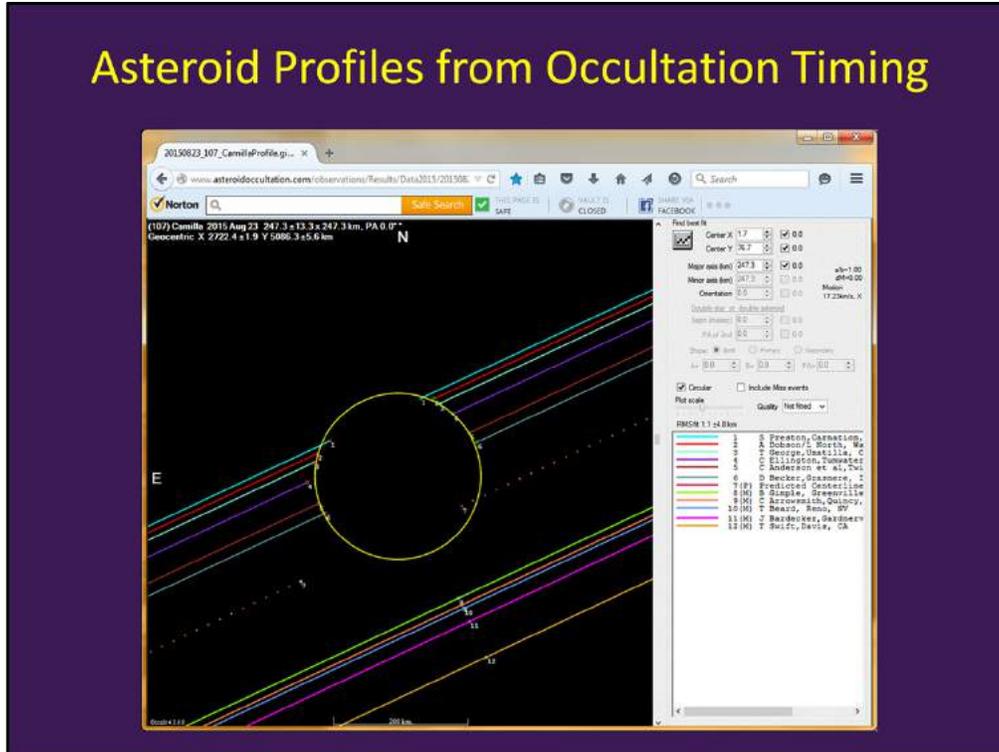
This is from the online results page for a recent observation with 11 participants. Each station's result shown as a star trail parallel to the predicted centerline of the predicted shadow path. They are adjusted so they appear as though the stations were all lined up perpendicular to the path, resulting in the blank area showing the apparent shape of the shadow:

- consistent with a circular shadow of a 247.3-km diameter asteroid
- Prediction was off a little more than half the radius
- Some constraint on the one edge (not elongated enough to show up at the 8th station)
- No satellites showed up ahead or behind the asteroid, nor in the band to the southwest

Two pieces from Stardate:

Asteroids are always getting in the way. Every night, several of them pass in front of stars, briefly blocking the stars from view. Astronomers don't mind, though. In fact, each of these occultations offers a chance to learn about the asteroids themselves.

Occultations are visible across a narrow path — usually just a few miles wide. To be of greatest value, that path needs to cross over several telescopes. They don't have to be at major observatories, though — many amateur astronomers contribute valuable measurements as well.

By comparing the length of an occultation at different sites along the path, and adding observations close to the path that show no occultation, astronomers can learn quite a bit.

A couple of years ago, for example, telescopes across the United States watched an

occultation of two asteroids that form a binary. Several telescopes saw the occultation, while the rest saw nothing. From those observations, astronomers measured the size and shape of both asteroids with an accuracy of a few miles.

A few months earlier, an occultation by an asteroid named Chariklo revealed that it was encircled by rings — the only rings yet seen around any asteroid. Observations of later occultations showed that there are four rings, which form two close pairs. A small moon could orbit outside the rings, with an even smaller one between them. Future observations may confirm them — when Chariklo gets in the way of another star.

An eclipse is the result of the total or partial masking of a celestial body by another along an observer's line of sight. Solar eclipses result from the Moon blocking the Sun relative to the Earth; thus Earth, Moon, and Sun all lie on a line. Lunar eclipses work the same way in a different order: Moon, Earth, and Sun all on a line. In this case, the Earth's shadow hides the Moon from view. An occultation occurs when a celestial object is eclipsed by the Moon or another solar system body. A transit is either the act of one celestial body passing in front of another or the time at which a celestial object is highest in the sky. The time at which a celestial object crosses the meridian is called the transit time.
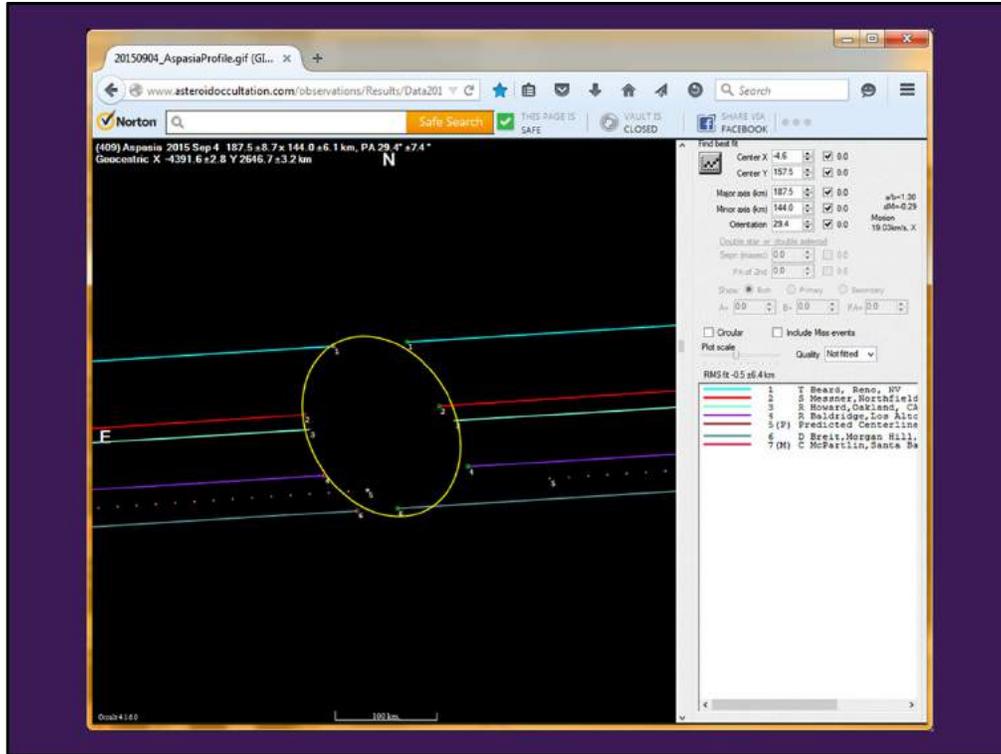
My first look at one of these charts was in a presentation by Ted Blank at the Northeast Astro-Imaging Conference in 2014. I thought it was a cute coincidence that the "blank" area shows the asteroid shape.

Observing with a DSLR: Adapters

As a sort of "how-to," I'll talk about my first successful recording of an occultation using a DSLR camera. I have some of the recommended equipment for video observation, but took a break and changed methods after having difficulties getting the video recording working. Video is currently the standard way of getting good timing data, but newcomers might already have a DSLR to try out observing occultations before shopping for a low-light video camera, a camcorder, and a video time insertion device (VTI).

I found a low-profile adapter for Nikon DSLRs with 42-mm filter threads. To reach focus, I had to "correct for nearsightedness," which a Barlow facilitated. This one has a removable lens cell that fits the adapter's filter threads. The lens cell then also acted as the nosepiece to fit in the 2-inch focuser. The compact arrangement avoided more Barlow magnification than needed to move the focal plane out a reasonable distance. You could also add a light-pollution filter to darken the sky background.

Calibrating the DSLR Clock

F6 00:46:03		8362	644342	F6 00:46:27		8597	645782
F6 00:46:05		8382	644462	F6 00:46:29		8617	645902
F6 00:46:07	8235	8401	644581	F6 00:46:31	8469	8630	646022
F6 00:46:09	8254		644701	F6 00:46:33		7988	646138
F6 00:46:11	8274		644821	F6 00:46:35		8008	646258
F6 00:46:13	8293		644941	F6 00:46:37		8028	646378
F6 00:46:17	8666		645183	F6 00:46:39		8047	646498
F6 00:46:19	8686		645303	F6 00:46:41	7900		646617
F6 00:46:21	8705		645423	F6 00:46:43	7919		646737
F6 00:46:23	8725	8558	645542	F6 00:46:45	7939		646857
F6 00:46:25		8577	645662	F6 00:46:47	7958		646977

For timing precision and accuracy with analog video observations, insertion of time annotation is the preferred technique. IOTA licenses a video time inserter (VTI) that derives its time from the GPS. You connect it between the video camera and a recorder, and it adds a time stamp to the video it passes through.

I found the camera rounded the internal time from its clock when timestamping the images taken by clicking the shutter manually. However, it had a way of scheduling shots to start on any even minute and repeat after a programmable number of seconds. I connected the video time inserter to a TV and had the camera snap a picture every 2 seconds. This is a composite of the bottom of the TV display for 22 of the resulting pictures. I did the same test after the observation and used the comparison of time according to the camera and time according to the VTI to find that the Universal Time was the camera time plus 4 hours and 3.93 seconds.

If anyone is interested in observing an occultation this way, we could meet somewhere with our cameras and use my VTI to calibrate them. Doing a practice run prior to the night of the event is a very good idea and would be an opportunity for such a meet-up.

This event was predicted for 05:45:04 UT (about 1:45:00 a.m. camera time) and gave me all evening to set up and get ready to record the occultation. By trial and error, I found I could schedule 30-second exposures every 33 seconds. The camera apparently actually exposed for about 32 seconds and needed 33 seconds to be ready for the next exposure "interval."

Among the resources I'll discuss are ways of getting a list of "pre-point" stars. They give you a choice of times you can get a fixed telescope pointed at the right place in the sky to see the occultation occur as the target star drifts through the center of the field at the predicted time. I used them to practice and get my telescope pointed with the camera turned so the trails would be horizontal. This 6.7 magnitude star was the last on the list, with a lead time of 1:57. The camera was scheduled to take nine images starting at 1:42 a.m. on its clock. The sixth image would start at 1:44:45 and go to 1:45:17.

The pre-point list indicates the target trails will be 1.9 arc-min south of these trails.
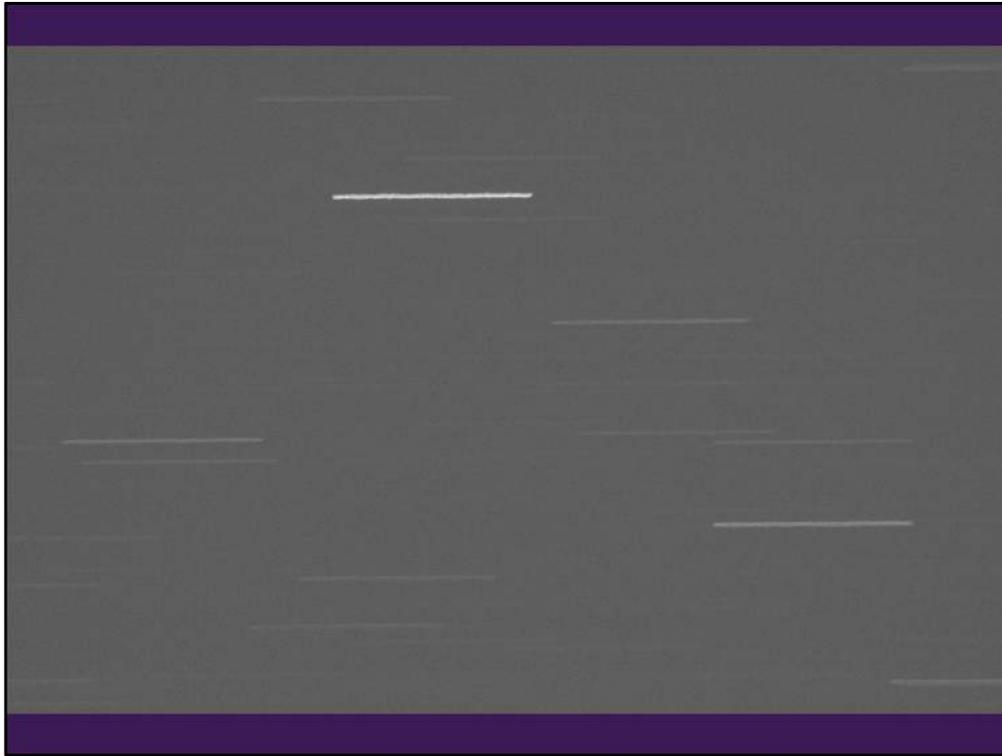
This trail of the pre-point star in the third exposure starts about 2 minutes before the predicted occultation. The target trail covering the predicted occultation time will be centered a little below the start of this one.
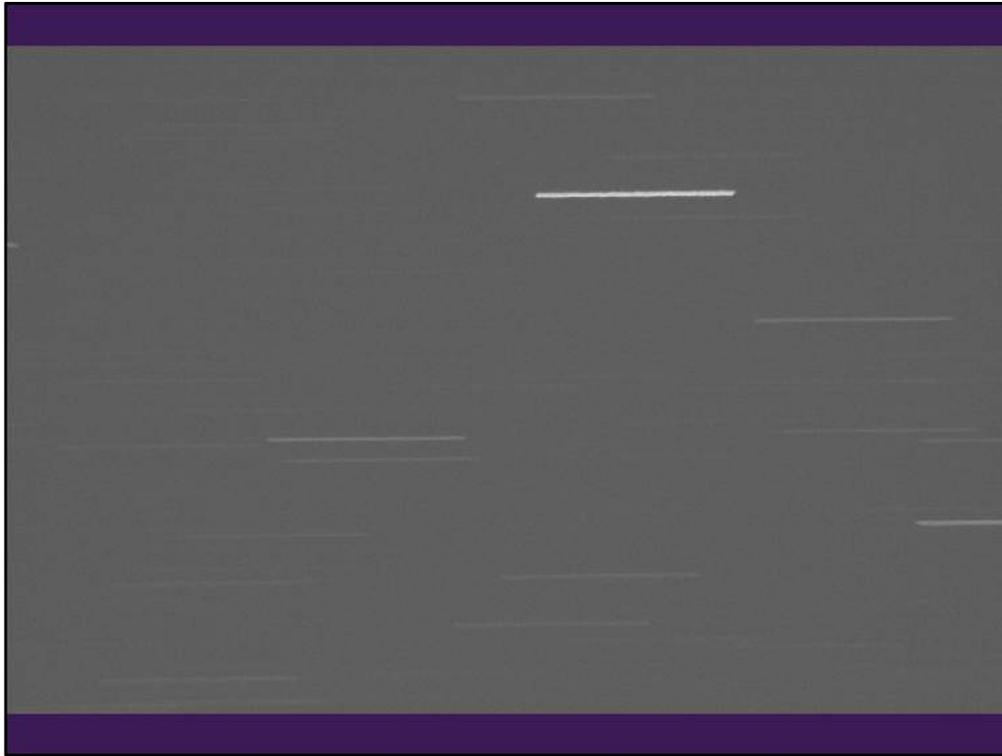
The target star trail just barely shows up in this fourth image.

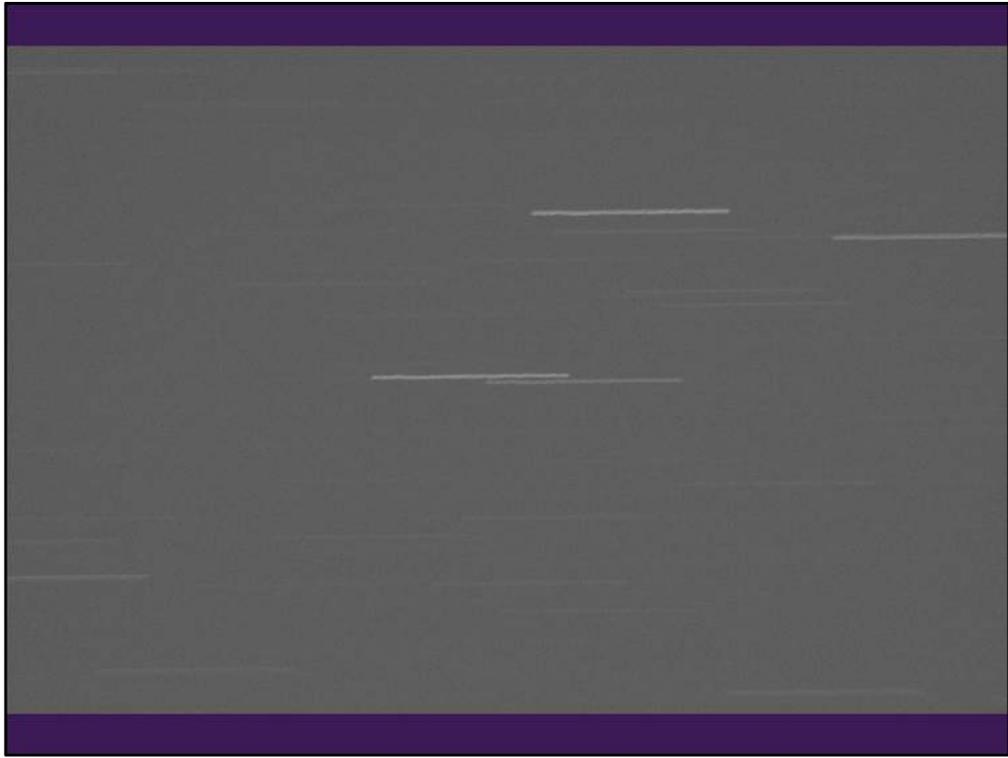I got a full trail of the target star on the image before the predicted occultation.

Here is the occultation image with the pre-point star trail leaving on the western edge. I was able to see this faintly in the camera display right after all nine images were taken.

Notice no other star trails have a gap.

14
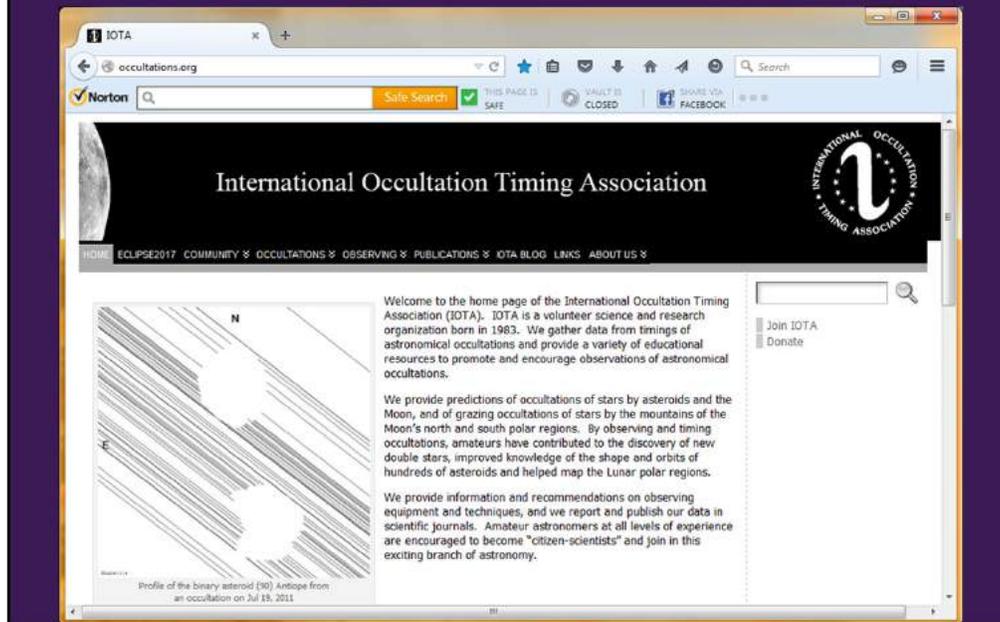
Many of the resources I'll discuss can be found from the IOTA website: occultations.org
You can find many resources I'll discuss and more via the observing menu.
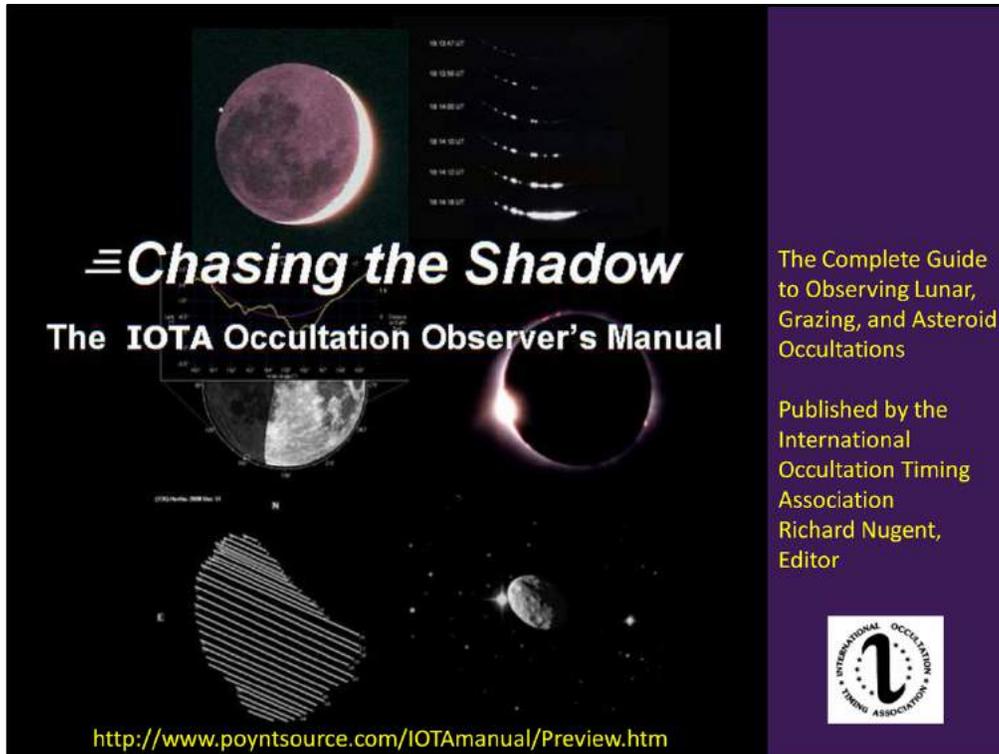
The Observer's Handbook link is in the publications menu.
This is a free observer's manual. You can download it in PDF format.
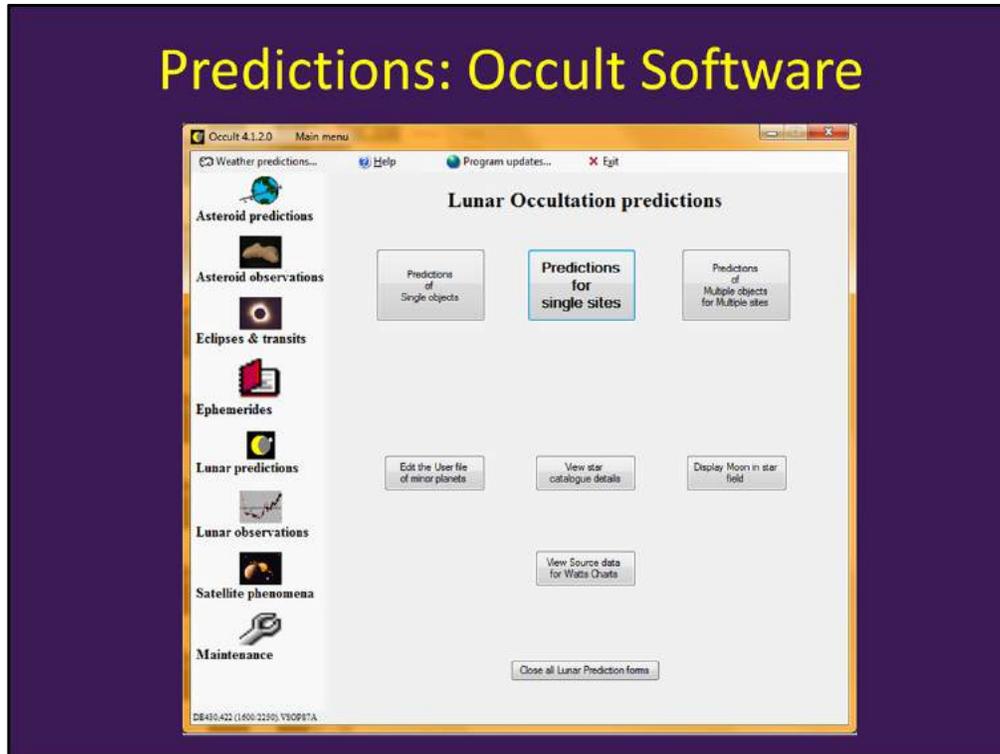
Occult is free software available through the IOTA website (observing link: software). It does lunar and asteroid predictions, but I leave the asteroid predictions to the experts who know how to find the most up-to-date information on star positions and asteroid orbits. Lunar predictions are tailored to your location and telescope size, which helps weed out events that happen elsewhere or might be too faint to observe.
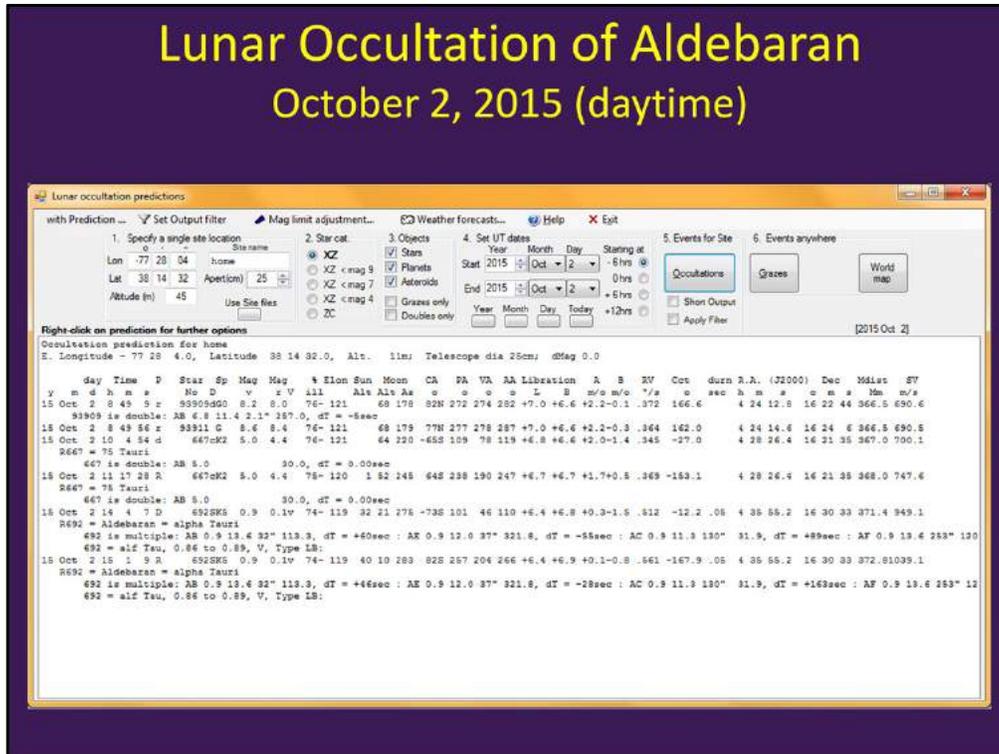
Occult did this prediction for my 10-inch telescope and indicates that even though it is a daytime event, I might see up to three other stars besides Aldebaran. I think Aldebaran is bright enough to see with a small telescope or perhaps binoculars. It could be worthwhile trying to catch this event just to see Aldebaran in the daytime.

Following the time is a letter for whether the event is a disappearance or a reappearance: lowercase means it would be harder to see. The 8.2 and 8.6 magnitude pair would be a challenge, and the magnitude 5 star reappearance would be easier than its disappearance on the sunlit limb of the Moon. Note that the Moon altitude prediction is 21 degrees for the disappearance and 10 degrees for the reappearance. It would help to be farther west on October 2.

Right clicking on the first entry brings up a map of the Moon on which you can have all these events marked.
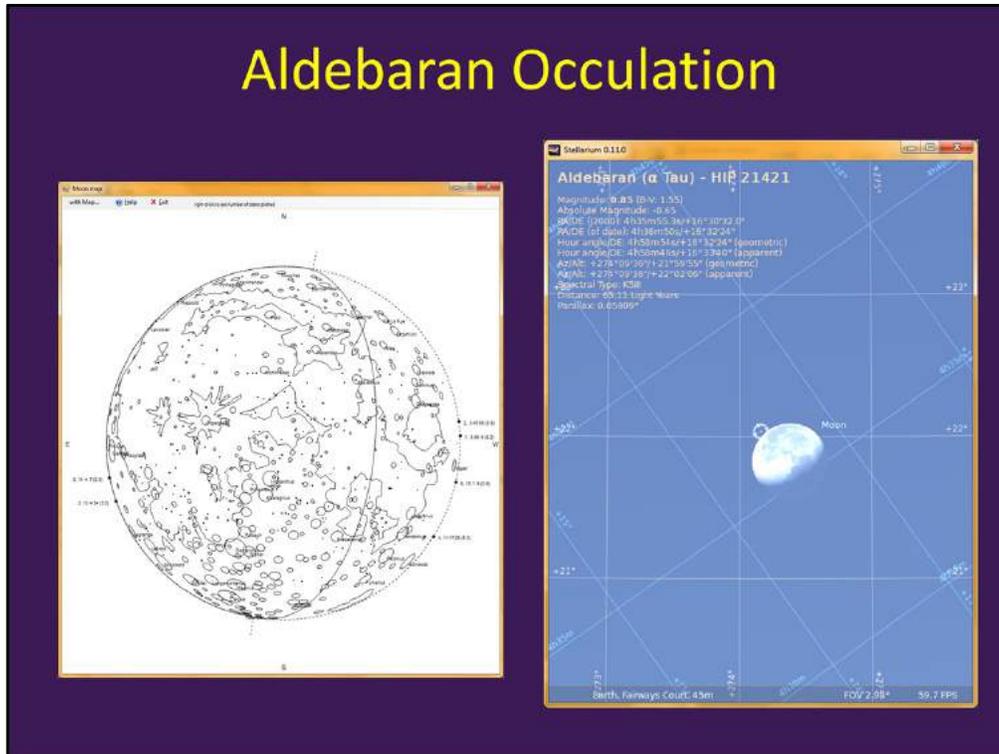
The map shows where to look for the disappearance and reappearance events. You bring it up from the menu brought up by right-clicking on one of the stars. Then right clicking on the map gives an option to add stars and show 5 or 10 stars total. I set Stellarium to a short time before the disappearance, and it agrees Aldebaran could be visible
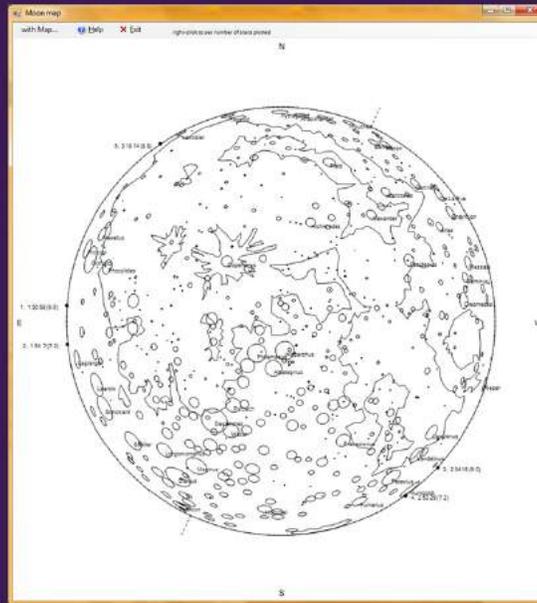
I also ran predictions for September 27 because some of us are likely to be out observing the lunar eclipse then. The first 2 are disappearance events after that part of the Moon is in the umbra. One is a pretty faint star. The next two are their reappearances. The fifth is another disappearance before that part of the Moon leaves the umbra. No reappearance is shown for it.

This is one of the web pages with asteroid positions. (use the observing: occultation predictions link and select Dereck's Current Global Asteroid Events Page).

The first columns show the date and time. Universal Time is 4 hours ahead of us during Daylight Savings Time and 5 hours ahead of Eastern Standard time. Next you see asteroid identification and maximum duration, star identification, and information about the magnitude. If the magnitude is too dim to observe, you can move on to another event. A small magnitude drop also means a more difficult observation. The magnitude includes the combined magnitude of the asteroid and star, and the drop is the difference between the asteroid magnitude and combined magnitude.

The mapping info provides various pictures of where the shadow path is predicted to go. You have to check one of these to weed out events happening too far away. When you find a suitable event, the observing info columns can help with planning your observation. I'll show some of what is available later.

This website is a little more convenient for narrowing the list to events closer to you because you can see some information about the path in the visibility column. It's the Worldwide Asteroid Occultation Predictions link above Dereck's. It also has a details link that combines some of the mapping and observing information available from the other website. I'll show an example of the details page shortly. It also has links to finder charts, but not the pre-point list available on the other website.
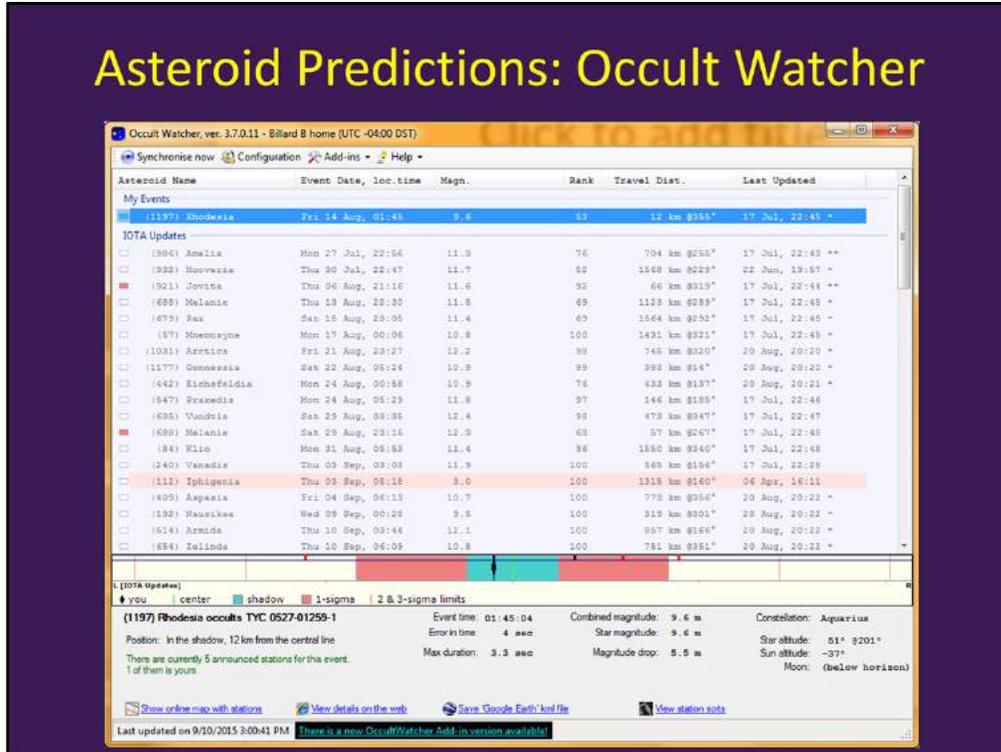
Occult Watcher is another free download available through IOTA that searches the online predictions like the ones I showed you. It also filters predictions according to criteria you can set up to avoid searching through events happening far away or ones too faint for your equipment. Thus it is my usual starting point.

When you select a prediction, you get more details at the bottom, and the links at the bottom go to some of the resources for the selected event I mentioned in the previous slides.

Here I have selected the Rhodesia event of August 14. Because of the relatively large uncertainty, I had a less than 1-in-3 chance of actually being in the shadow path. That is indicated by the relative size of the 1-sigma area compared with the shadow area.
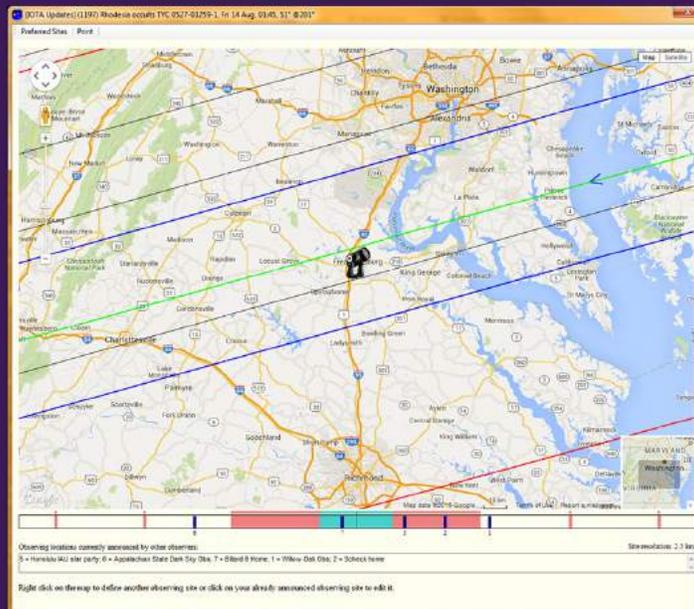
Clicking on "show online maps with stations" brings up this window. It is also available with the GoogleMap link in the table of the first prediction website I showed, but here it is zoomed in on my location. I used it to announce my plan to observe this event.
The green line shows the predicted center of the shadow path, and the blue lines show the edges. You can also see red lines marking the 1-sigma uncertainty limits, and three of the announced observers' station positions relative to the predicted shadow path center line.

The view details on the web link brings up a page like this for the asteroid event you select in Occult Watcher. It is also available from the link in the Details column of the Asteroid Occultation Predictions website. From here, you can choose a finder chart and bring up details of the event, including a table showing the shadow path coordinates with apparent position in the sky, where the Sun and Moon are at the time, and more.
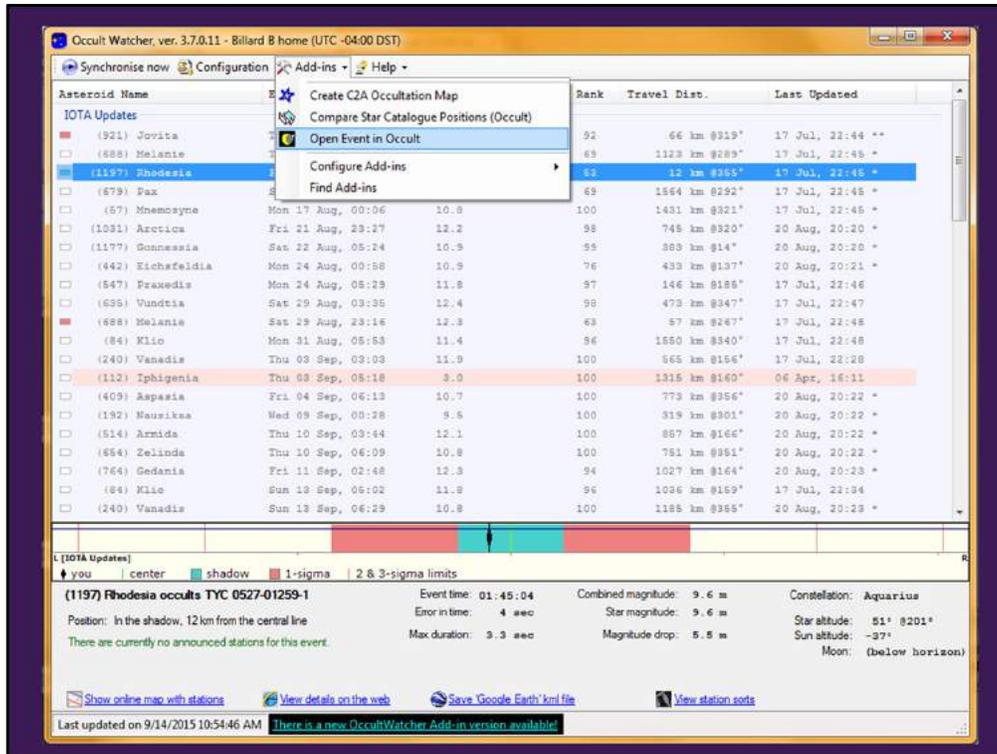
You can configure Occult as an add-in for Occult Watcher. Then you can open Occult with the selected event by clicking the highlighted Add-ins menu item.
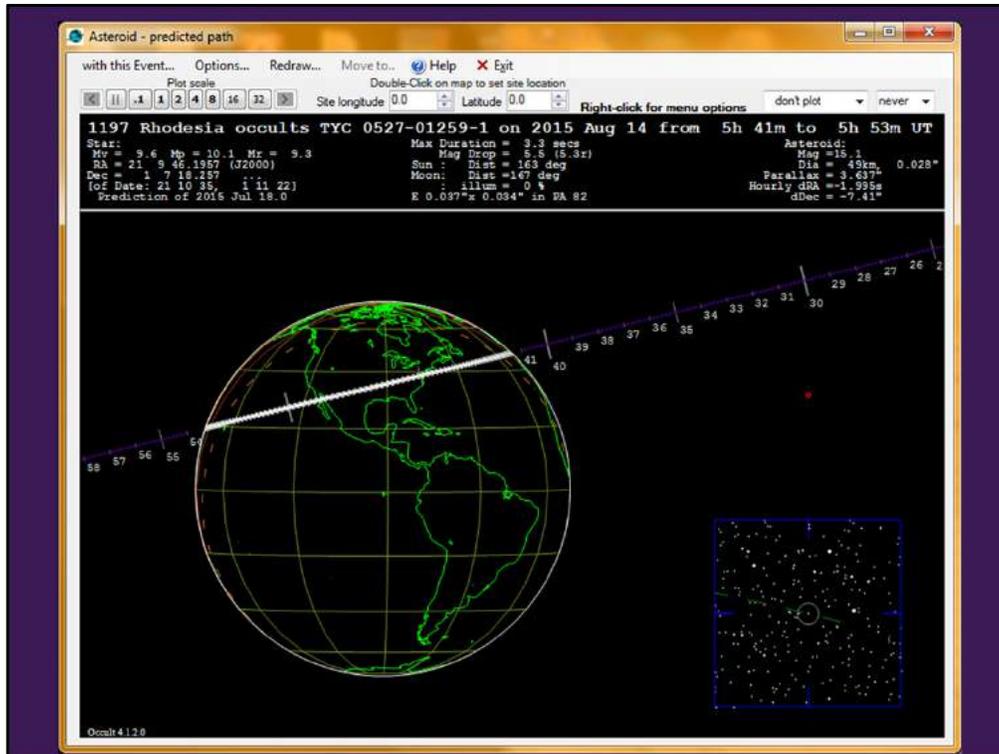
Occult opens with the event showing the predicted path of the shadow across the Earth and some information at the top of the image. It uses the online prediction information rather than what I might have generated by running my own prediction. More information is available from the top left menu…
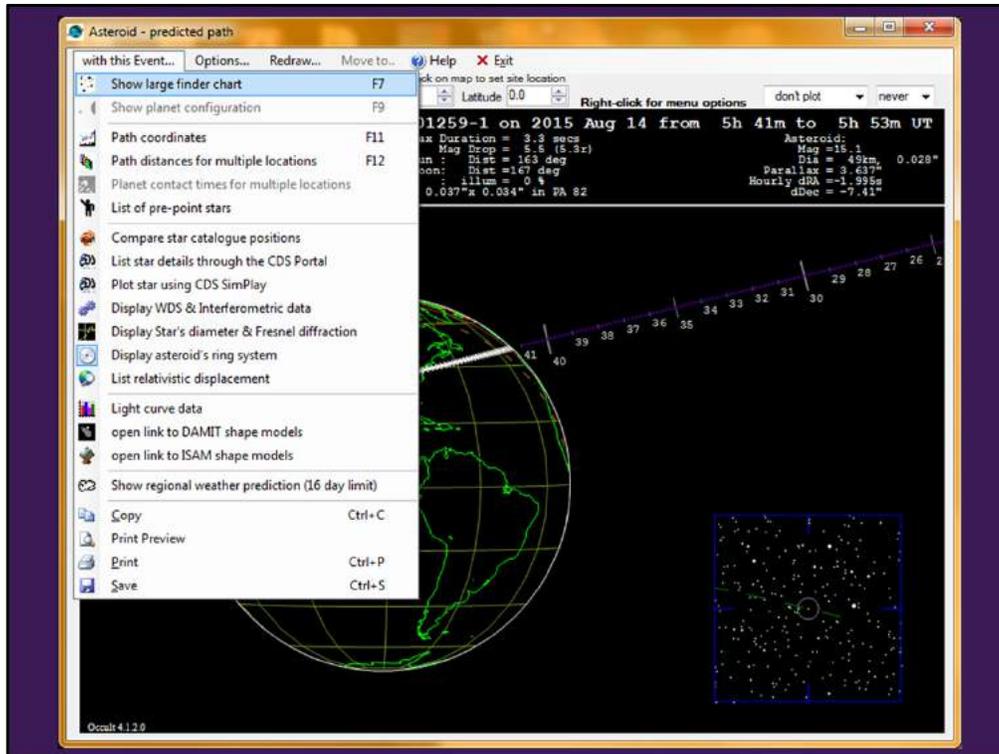
I mentioned a link from one of the asteroid predictions websites that offer finder charts and lists of path coordinates. With the Occult add-in, you can make your own, starting from this menu. The path distances for multiple locations can show your location's distance, and it also gives the chance of seeing the event from your location based on the prediction uncertainties. I'll show the finder chart and also the pre-point star list offered here.
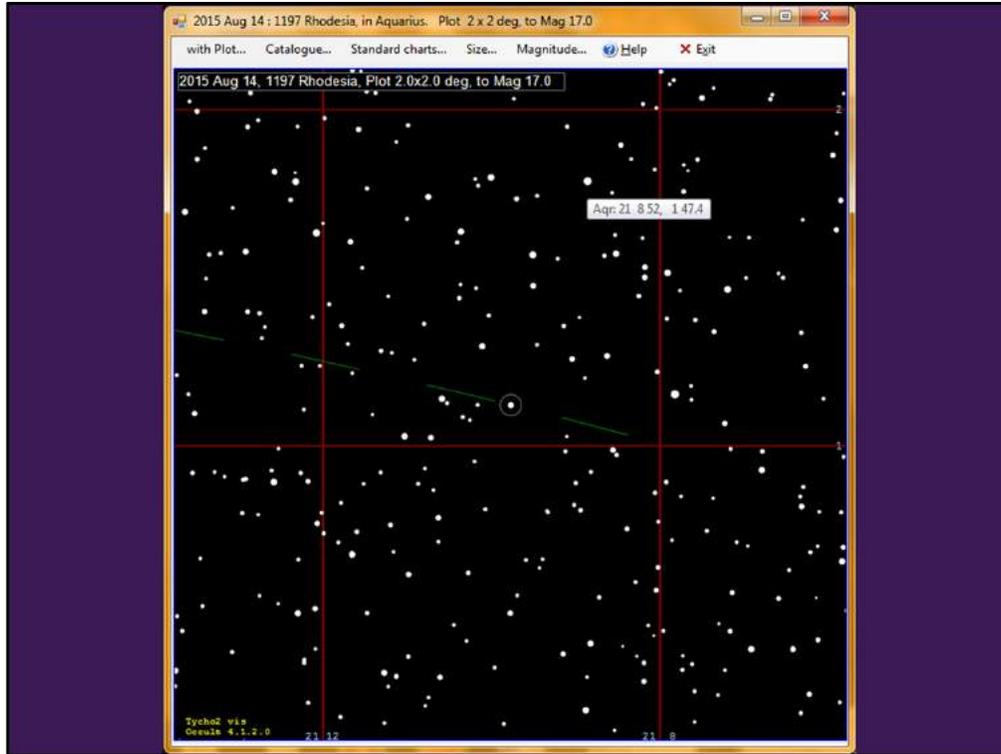
Moving the cursor around in the finder chart reads out the coordinates. The screenshot did not show the arrow, which I had pointed at the star above the top left corner of the screen tip box.
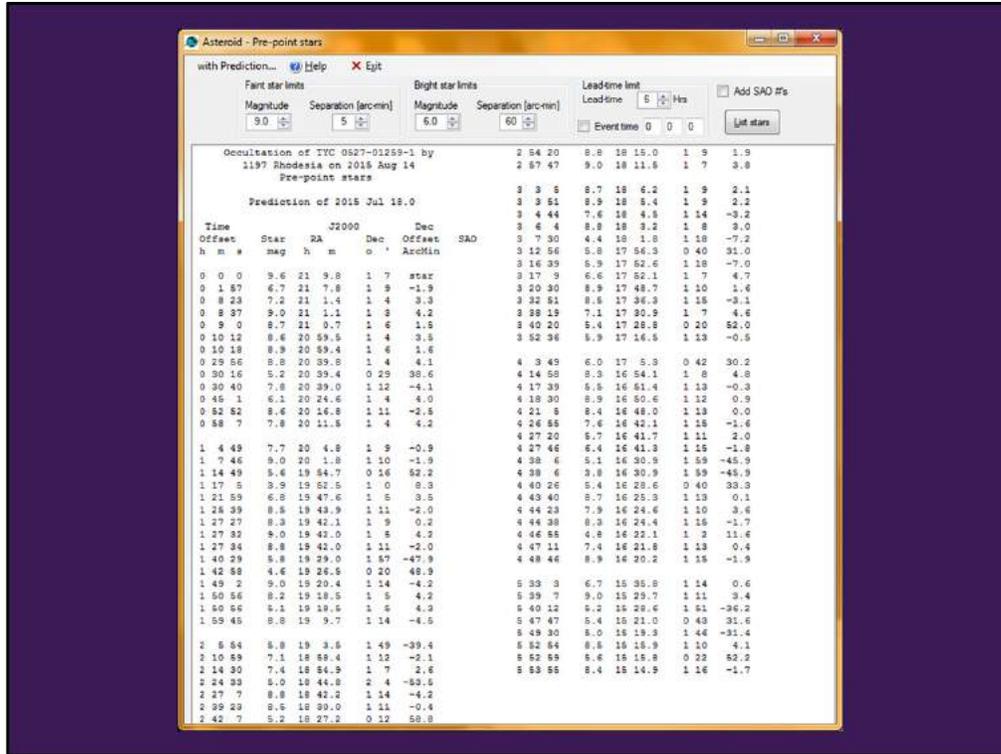
Selecting the list of pre-point stars brings up this window. It can calculate stars to pre-point your telescope ahead of time. You find the star and get it centered (east to west) in your field at the appropriate time before the event. Then you turn off tracking, if you are using it, and the target star will reach the middle of your field of view when the event time arrives. If you want to allow a larger declination offset in order to select a brighter pre-point star, you need to offset your pre-point star north to south by the amount shown to get the target star centered in that direction.

The pre-point technique was just the thing for my Dobsonian scope, and was an easy first step in the learning process.

The other predictions website I showed includes a link to a list of pre-point stars like this, but here you can type in the event time and it does the pre-point time calculations for you.

Note the target star and the pre-point star at the west edge. Also note the pair between them at the bottom right.

I set Stellarium to show essentially what my camera got at the beginning of the occultation exposure. It only shows one of the bottom pair of stars.

Here is my image. [flip back and forth to previous slide]

DRIFT-SCAN TIMING OF ASTEROID OCCULTATIONS

John Broughton (Updated 2014-11-13)

Occultations present the opportunity to remotely investigate shape and dimensions of planetary objects with orders of magnitude gain in resolution over direct imaging. I have in the past observed visually a spectacular Jupiter occultation of 2.6-magnitude Beta SCO and measured brief disappearances of a fifth magnitude star by ringlets of Saturn but until 2003 I had never observed the more common variety of occultation by an asteroid. Following on from the development of Dave Herald's Occult software, the turning point came with the advent of Steve Preston's updated predictions, the accuracy of which made viable a CCD imaging and timing technique I had under consideration many years earlier. The original inspiration was a trailed photograph of a Metis occultation taken by Paul Maley in 1979.

CCD
Due to their slow image transfer rate, most astronomical CCD cameras cannot record short-term variability on consecutive frames without missing out on most of the action; hence an occultation is best recorded on a single frame. One technique that has been particularly useful in recording rapid changes during lunar occultations is called TDI (time delay integration) where the CCD array is read out line by line to produce a trailed image. Not many cameras including my own have operating software supporting this electronic option but any integrating camera attached to a stationary telescope can take trailed images as a consequence of Earth's extremely regular rotation, which just happens to provide a rate of motion well suited to recording asteroid occultations.

With the advantage of noise reduction, a cooled CCD camera provides a substantial magnitude gain over non-integrating video cameras. From a moderately light-polluted location under otherwise favourable circumstances, sidereal-rate star trails as faint as magnitude 14 can be acquired with a telescope of 25cm aperture. A single image provides a convenient record for analysis, producing in most cases an unambiguously positive or negative result. Although cloud induced disappearances can mar an observation, they equally affect all nearby trails, making them easy to differentiate from the real thing.

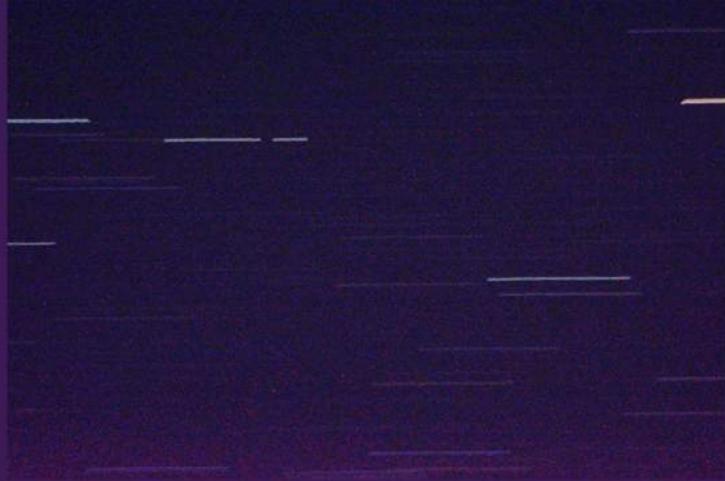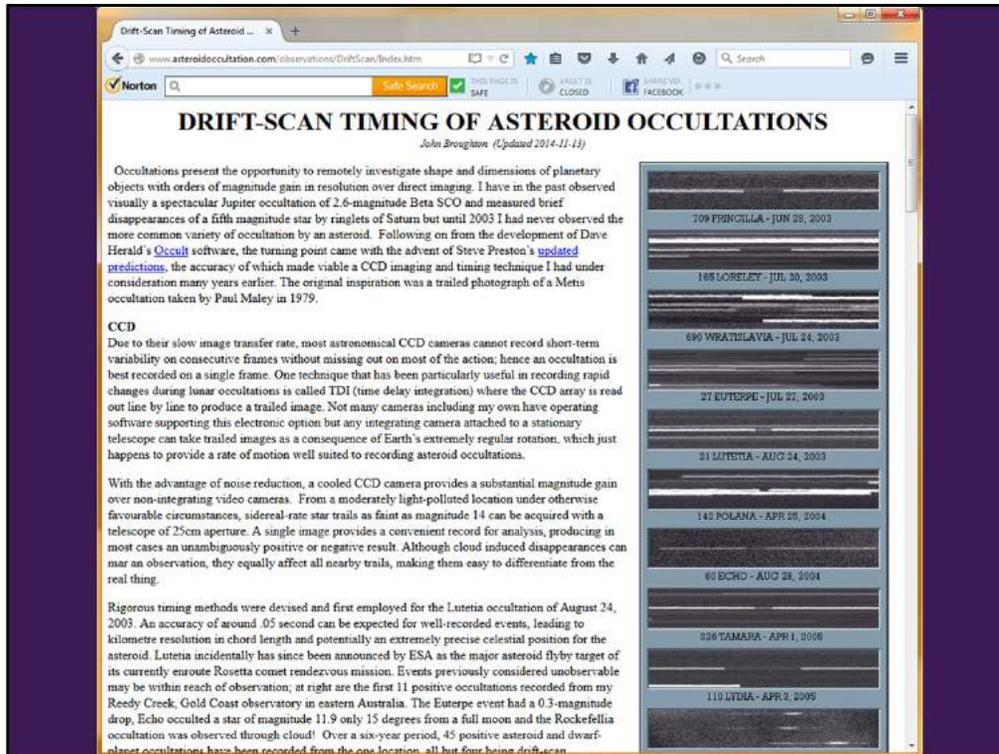Rigorous timing methods were devised and first employed for the Lutetia occultation of August 24, 2003. An accuracy of around .05 second can be expected for well-recorded events, leading to kilometre resolution in chord length and potentially an extremely precise celestial position for the asteroid. Lutetia incidentally has since been announced by ESA as the major asteroid flyby target of its currently enroute Rosetta comet rendezvous mission. Events previously considered unobservable may be within reach of observation; at right are the first 11 positive occultations recorded from my Reedy Creek, Gold Coast observatory in eastern Australia. The Euterpe event had a 0.3-magnitude drop, Echo occulted a star of magnitude 11.9 only 15 degrees from a full moon and the Rockefellia occultation was observed through cloud! Over a six-year period, 45 positive asteroid and dwarf-planet occultations have been recorded from the one location, all but four being drift-scan.

709 FRINGILLA - JUN 28, 2003
165 LORELEY - JUL 30, 2003
690 WRATISLAVIA - JUL 24, 2003
27 EUTERPE - JUL 27, 2003
21 LUTETIA - AUG 24, 2003
142 POLANA - APR 25, 2004
60 ECHO - AUG 28, 2004
326 TAMARA - APR 1, 2005
110 LYDIA - APR 2, 2005

I'm not going to get into details on analyzing the results of the observation, but I hope to be able to do an article in the next *Stargazer*. I am indebted to John Broughton for the analysis of my images. His website is an excellent resource for using CCD cameras for drift-scan observations and has links to freely available software to aid observation and analysis. The down side is I did not know how to get an image without star trails and use Astrometrica to measure the distortion of my telescope and did not try recording the sound of the camera shutter along with the WWV shortwave time signal to help with converting positions in the image of star trails' starts and stops into times. John was able to use the extra star trail images to come up with distortion and the end time of the trail. The upside is he congratulated me on recording the event and pioneering a potentially accurate timing method for DSLRs.
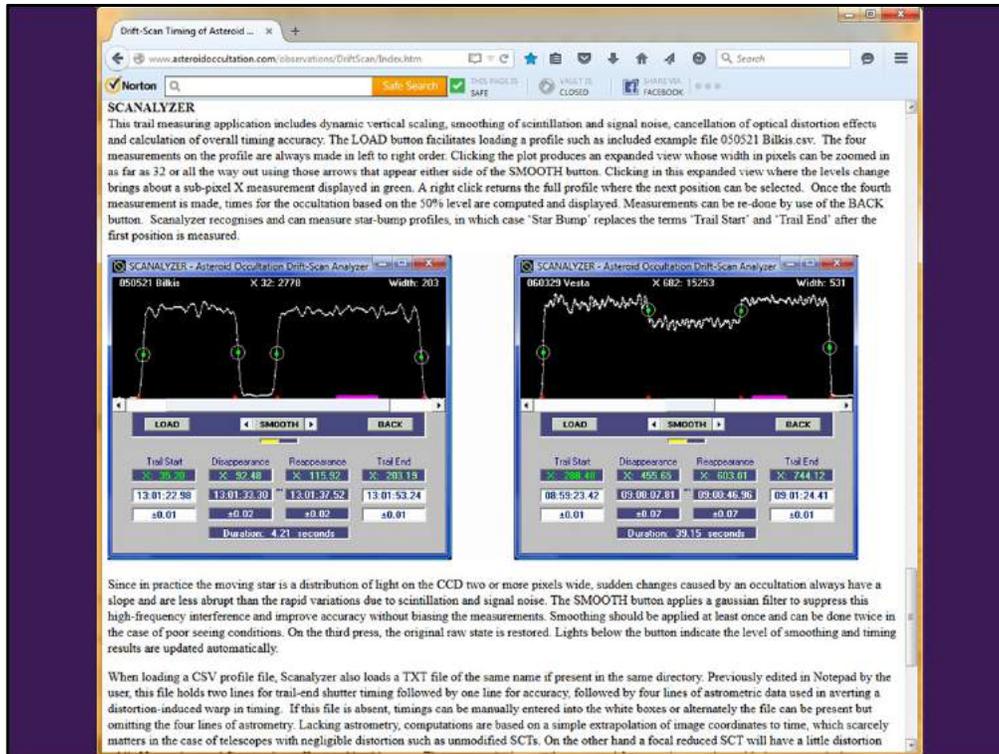
This is a sample light curve analysis with Scanalyzer, one of the software tools available via John Broughton's website. The light in the star trail is computed with a separate program for each column in the image and saved as a csv file. Scanalyzer reads this file along with a text file with start and stop times and results of the telescope distortion measurement. The positions where the light curve starts and stops are marked with green dots. These positions can be interpolated to a precision of a fraction of a column. Scanalyzer then computes the times of disappearance and reappearance of the star. The Vesta example on the right shows what happens when the star and asteroid are similar in magnitude.
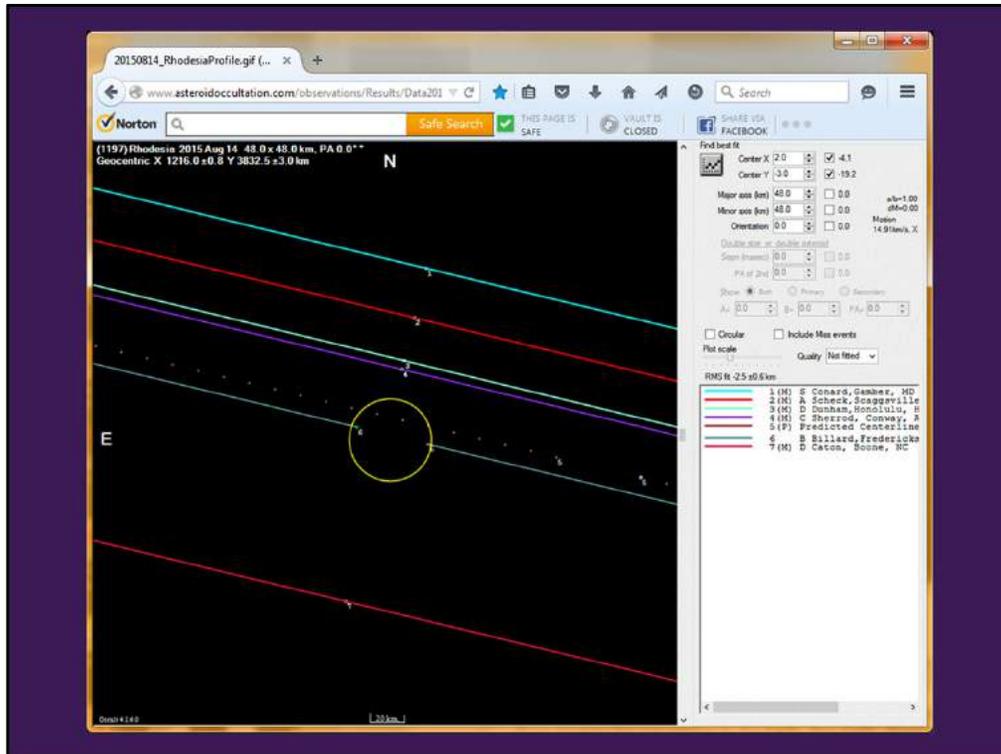
This is the profile resulting from the reported observations of the Rhodesia occultation.
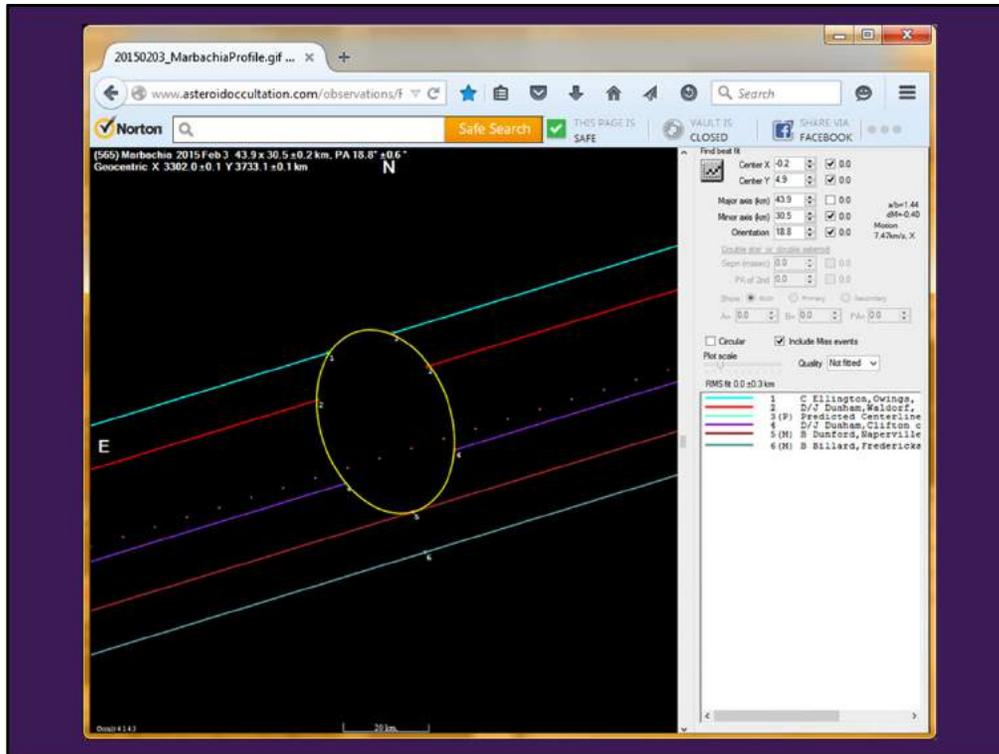
I also reported my miss observation earlier this year. The other observations are consistent with my position being outside the actual shadow path. For this event, four out of five observations provided constraints on the possible asteroid profile.

Some possible events in the next few weeks:
September 27 Lunar Eclipse   Disappearance 01:30:56 UT (21:30:56 EDT)   Reappearance 02:34:18 UT (11:01:09 EDT)

9.0 magnitude, in umbra (UT is 9/28)
Disappearance 01:54:07 UT (21:54:07 EDT)
Reappearance 02:53:29 UT (11:01:09 EDT)

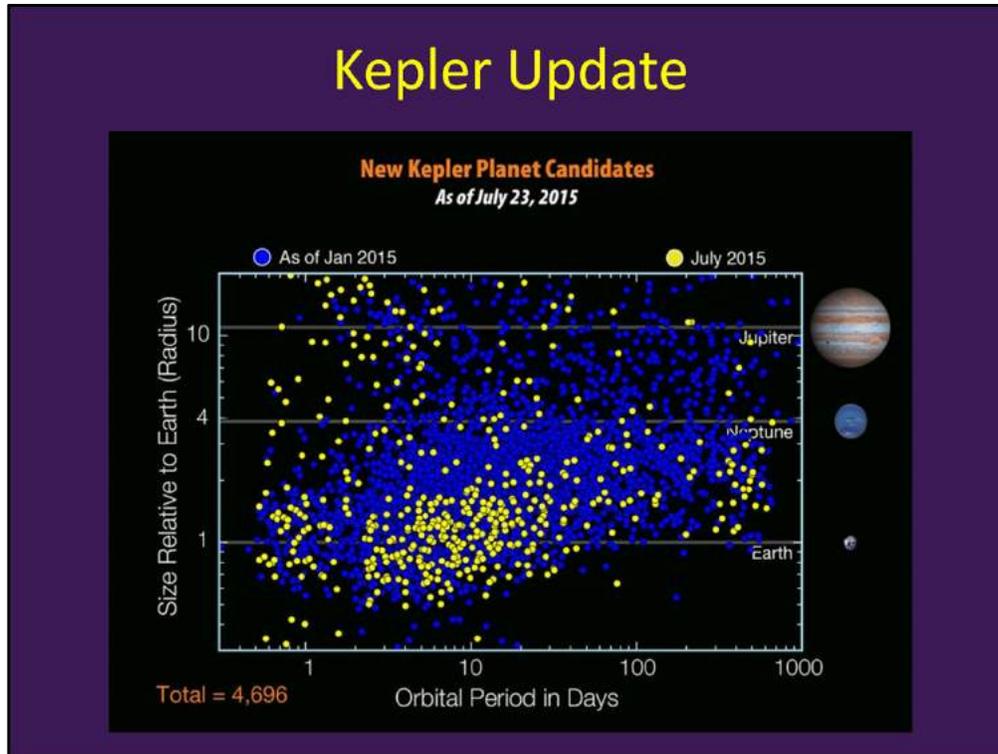7.2 magnitude, in umbra

Disappearance 03:18:14 UT (23:18:14 EDT)
8.6 magnitude, in umbra

Moon Occults Aldebaran October 2   Disappearance 14:04:07 UT (10:04:07 EDT)
Reappearance 15:01:09 UT (11:01:09 EDT)
Daytime event visible with telescope, maybe binoculars

I learned about detecting extrasolar planets by the transit method several years ago and was interested to learn amateurs could measure some transits with a moderate-sized telescope. When the Kepler mission launched in 2009, I began following it and did a program once a year at club meetings. This time I'll just give a brief update.

Kepler successfully collected more than 4 years of data before the failure of a second reaction wheel needed for precision pointing of the telescope ended the primary mission. Data analysis is still ongoing, and this graph shows how the increasing length of observing time now analyzed is improving the detection of smaller exoplanets. As of the last report from NASA, Kepler had discovered 4,696 candidate exoplanets, of which 1,030 have been confirmed. Twelve of the confirmed planets are small planets in the habitable zone of their stars.

Last year, a new mission called K2 was approved. Kepler now spends about 80 days at a time in observing campaigns targeting fields along the ecliptic. These campaigns allow it to maintain sufficient pointing precision with the two remaining reaction wheels and the help of balanced sunlight pressure on its solar panels. The confirmed planet count for K2 is 22.
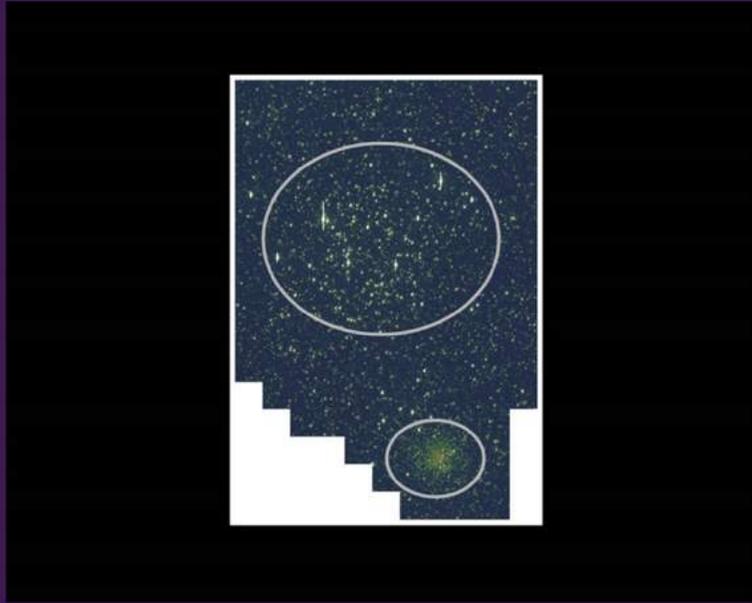
Observing Campaign 6 started July 14 and will end at the end of September. Targets have been selected for Campaign 7, and field positions for the next 3.
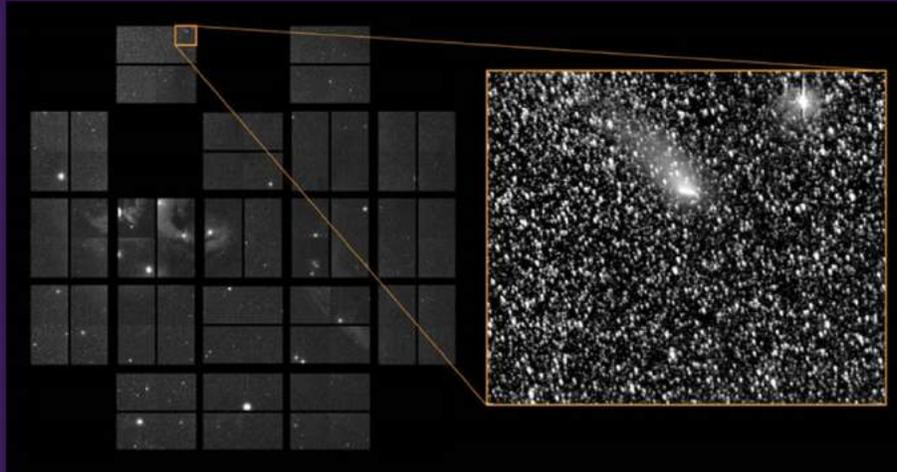
The K2 Campaign 2 field of view had a visit from Comet Siding Spring in October.

The K2 Campaign 0 was an engineering test run of the new mission concept. This image is a mosaic of "postage stamp" images from the Kepler field of view. The highlighted regions show two open clusters, Messier 35 (top) and NGC 2158. Kepler started out with nearly 100 megapixels, and consequently provisions were made for only returning "postage stamp" rectangular regions for targets of interest, or groupings of rectangular regions for larger targets like these.
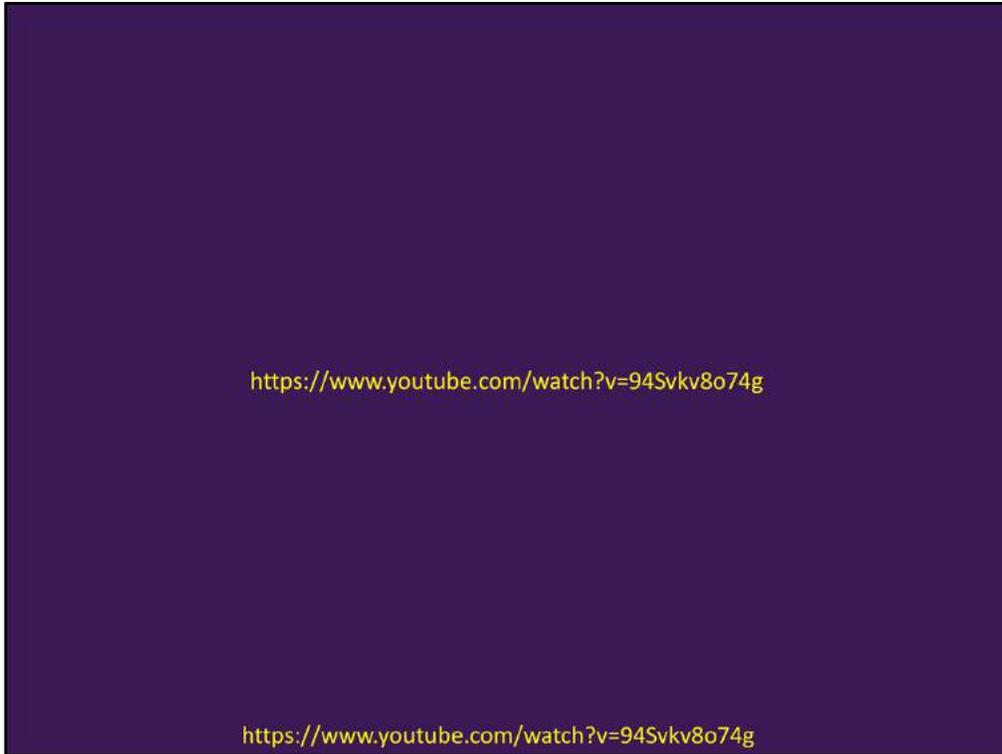
Backup? YouTube video of Antares occultation?