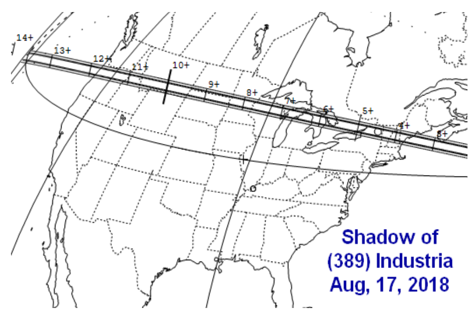
OCCULTATION OBSERVING and RECORDING PRIMER

Most amateur astronomers look forward to observing eclipses – a nice lunar eclipse, and the all-too-rare solar variety. Some travel for hundreds of miles to “catch the shadow”. ...But did you know there are potential eclipses to observe nearly every clear night? There are ---- Asteroid Occultations.

What's an asteroid occultation?

Assuming you know what an asteroid is... There are now well over 1 MILLION asteroids that have published orbits. Over 600,000 of them have orbits that are established well enough that they have been “numbered” (and in general, the lower the number, the more refined the orbit). There are also billions of stars visible through a telescope in the night sky. It's only inevitable that at times the alignment will be just right for these chunks of rock in space to pass in front of the absolute pinpoint light from stars. If you are in just the right place on Earth, the asteroid will “eclipse” the star, blocking its light for anywhere from a fraction of a second, to up to 10's of seconds. As the star is essentially infinitely far away – as compared to the distance to the asteroid – the “shadow” the asteroid casts on Earth is basically the size of the asteroid. This shadow moves across the surface of the Earth in a narrow band (the width of which is the diameter of the asteroid), often crossing thousands of miles of the Earth's surface. If you are located somewhere in this narrow band, and it's clear out, you can see the star “blink out”, and then back - an asteroid occultation. As an example, the image to the right shows the shadow path of the asteroid (389) Industria crossing the northern United States.



Shadow of (389) Industria Aug, 17, 2018

Of course in order to predict the shadow path, it is also important to know the positions of the stars in the sky to a very high precision. In 2013, the European Space Agency launched a satellite named Gaia. Its mission is to very precisely measure the positions of a couple billion stars in the sky – to an angular accuracy of the diameter of a quarter on the Moon as seen from the Earth. It can measure stars to about magnitude 20 - FAR dimmer than what can be seen with the eye, or even with a moderately size telescope. As Gaia continues to remeasure the same stars over many years, it builds a catalog of the actual individual motions of these stars (in 3D!) - allowing astronomers to know precisely where a star is now, and for many years to come.

By using computer programs (most of which are free, and available to run on home computers) the positions of hundreds of thousands of asteroids can be calculated and compared with the precise star positions measured by Gaia. In this way, the paths of thousands of yearly asteroid occultations can be predicted. On average there's usually a nice “event” potentially visible at least once or twice a week from any place on Earth (and usually lesser ones every clear night).

An interesting aspect of occultations is that your observing location on Earth is ***unique***. As mentioned above, the shadow an asteroid casts across the Earth runs in a very narrow band – often only several to a couple hundred miles wide, but thousands of miles long. As such, YOU have as much opportunity to view (and possibly record and measure) an occultation as any professional astronomer at a major observatory. As such, observing occultations is one of the few activities in astronomy where amateurs can contribute valuable scientific data which can be on par with that of the professionals.
More info on occultations can be found at: http://occultations.org/occultations/what-is-an-occultation/

How do you observe an asteroid occultation?

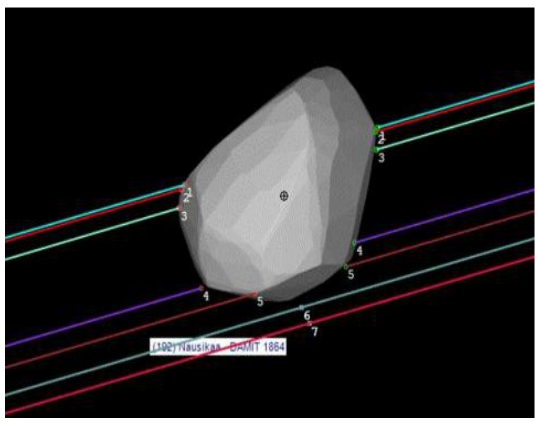
Predictions of events are readily available on the Internet or you can generate them with your own computer (more on that below). You should have a program to generate star charts to locate the “Target Star”, and have intermediate computer, telescope and astronomy skills. In the simplest way, an occultation can just be observed visually and you can enjoy watching a star blink “off”, then “back on” again. A rather small telescope is sometimes all that is needed – for the brighter events.

This article is geared more toward observers who might like to do a little more; record the occultation, measure it, and submit data on the observation – thus increasing our knowledge of asteroids. The organization that collects this data is the **International Occultation Timing Association (IOTA).**

How is an asteroid occultation recorded?

In short, you obtain a prediction, locate yourself in or near the predicted shadow path, attach a very sensitive video camera to your telescope, and record the starfield centered on your “Target Star” around the time of the predicted “event”. In most cases, the asteroid will be fainter than your Target Star (and you really don't need to be able to actually see the asteroid). You do need to VERY accurately record the time the Target Star might disappear (or fade) and reappear – to an accuracy of *at least* a tenth of a second (and preferably much better). You also need to very accurately know the latitude, longitude and elevation of your observing site.

For various reasons, predictions have uncertainty factors, and you may not always witness an event. Usually this is due to the uncertainty of the asteroid's orbit – and to a lesser extent, the uncertainty in the star's position. The predicted shadow paths almost always show this uncertainty. If you are certain that the Target Star was NOT “occulted”, you would report this as a “Miss” (or “Negative”) to IOTA. Reporting a Miss can be almost as valuable as observing a “Positive” event – as it says where the asteroid's shadow WASN'T. This can sometimes be a crucial bit of information, as in chord “6” in the image below. That miss helped constrain the bottom edge of the asteroid. If you do witness an event, you measure the times of disappearance and reappearance, and submit your observation to IOTA using a standard report form.



Teamwork can play a very important part in occultation observing. Consider a 20 mile wide asteroid passing in front of a star. It will essentially cast a 20 mile wide “shadow” across the surface of the Earth. Let's say that 20 mile wide shadow runs from Los Angeles to Boston. Anyone along that narrow, but very long path has the opportunity to witness the event. Asteroid shapes vary, but in general, most are some sort of an ellipse. As a result, an observer near the center of the actual shadow path may witness the star “blink out” for a longer period of time than someone near the edge of the shadow path – as the observer near the “centerline” will see the star pass behind a wider “chord” of the asteroid's shape.

If enough observers are scattered along the WIDTH of the path (irregardless of where they are ALONG the path), each observer will witness the star “disappear” for a different length of time. When the disappearance “chord lengths” are combined (after correction for geographic location), an actual shape (and thus size) for the asteroid can be determined. With between 5 and 10 observations, details in the shape of the asteroid can be determined – FAR exceeding the resolution that can be obtained from any ground based telescope, and even the Hubble. Not bad considering all you may need is a small, perhaps 3 to 6-inch telescope!

The above shows the predicted shadow path (between the red/blue lines) of asteroid (319) Leona when it occulted the bright naked-eye star Betelgeuse (one of the brightest stars in Orion) on December 12th, 2023.
Each telescope represents an observer who "signed-up" in the program OccultWatcher and announced their intent to try and time the event. Coordination between observers in OccultWatcher can be on a world-wide scale.

Once you are versed in using your equipment, occultation observing (from home) may not take a lot of time. Perhaps 45 minutes to setup the equipment and locate the Target Star, then do the observation, and then 20 minutes to tear down. From experience tho.... **ALWAYS** allow (considerably?) more time than you think you may need for setting up, and locating the Target Star! ***This can't be understated.***

Sadly, for about half of the "positive" observations (an actual observed disappearance and reappearance) that are reported to IOTA, there is only ONE observation per event. Though that one observation is useful (it does confirm the prediction was reasonably accurate and *can* help to further refine the asteroid's orbit), having just 1 chord doesn't do much to define a size or shape. Thus the need for as many observers as possible. This is the primary reason for why this article was written –

more observers are needed!

A brief mention about "Unattended Stations"........
From what's mentioned above, it stands to reason that if several observers can capture a single occultation, this increases the number of chords for the event – and more chords often gives more value to the overall observation. In an attempt to gather multiple chords, sometimes a single observer will set several "unattended stations" - with each station spaced apart by perhaps one to many kilometers. Each station is "automated" to capture video of the event. After the event time has passed, the sole observer goes back and collects the unattended stations they have placed. In this way a single observer can capture multiple chords. Advanced observers sometimes use this method.

An **Important** note on **ACCURACY**......

For those reporting observations, remember the adage, "bad data can be worse than no data at all." So for persons wanting to measure and report their observations, they need to be willing to work to a rather high degree of precision. This especially pertains to reporting the times of disappearance and reappearance to an accuracy of a tenth of a second – and preferably much better. Many observers report time accuracy on the order of 1 frame of standard NTSC video (1/30th of a second) – which amounts to 3/100th of a second. Thus, you need to base your timings on a very accurate timing source. The best time reference is currently time signals obtained from GPS satellites. The GPS-based time you report is stated in "Universal Time" (UTC). Submitted observations do get reviewed, and the persons who do this volunteer their time. So it should be noted, if you aren't willing to put care into your efforts, then occultation timing may not be for you.

A GENERAL DESCRIPTION OF USEFUL OCCULTATION SETUPS

Telescope:

Many brighter events have been nicely captured by telescopes with an aperture of between 2 to 4 inches, however, if possible, a telescope with an aperture of at least 4 to 6 inches is recommended. Unlike in astrophotography, while a clock drive helps, it is often NOT necessary when using a smaller telescope. This is because most occultations state a predicted time which is often accurate to +/- 5 seconds, and the cameras used in occultation work usually have a wide enough field of view (FOV) that you can let the star “drift” across the camera frame during the predicted time. To find your camera's FOV, point your telescope to the celestial equator – 0 degrees Dec. Time how long in seconds it takes for a star to drift across the camera frame. Multiply this by 15.04 and divide by 60 to get your FOV in arc minutes. Now, for future Target Stars, you can apply the formula: FOV / (15.04xCos(Dec)) --- and arrive at how many minutes it will take for the Target Star to drift across the camera field (“Dec” being the declination of the star in the sky). Typically this could be 2 minutes. Thus, for a 2 minute drift time, if you have your Target Star on the east edge of the camera's FOV, 1 minute before the event, the Target Star should be near the center of the frame AT the predicted time of the event. The initial analysis program, PyMovie, has the capability to automatically track (while measuring the brightness of) the recorded Target Star as it drifts across the camera frame. Obviously, if you don't have a clock drive, a shorter focal length instrument (wider FOV) is much preferred. This is also why the IOTA “starter” camera (Night Eagle 3) is supplied with a focal reducer – as it also helps to widen the FOV. There is a trade off though.... more aperture allows fainter stars to be seen (and thus more potential occultations), but usually results in a longer focal length, and a narrower field of view. Thus, a large telescope *should* ideally have a clock drive. To a point, the longer you can record the “Target Star”, before and after the predicted event time, the better (you could even capture an unknown asteroid satellite!). In a typical video recording, you might capture the Target Star for at least 1 to 2 minutes before the predicted time, and continue to record the Target Star for 1 to 2 minutes afterward.

Camera:

In order to obtain proper timings, video recording the occultation is mandatory, in which case you will need a camera that is very light sensitive, ideally recording at a fairly high frame rate. A common frame rate is 29.97 frames per second. The RunCam Night Eagle 3 is a low cost starter camera which has been found to work well (it can be purchased through IOTA). More on cameras below.....

Timing Device:

You need to use a highly precise time reference. (!!!!!)
A very common misconception is that the internal clock can be set in the computer that is recording the video (using common programs designed to do this), and the timing will always be accurate enough. This is NOT true. For several reasons, timings done using this method are often unacceptable. Ideally, your time reference needs to be inserted into your video BEFORE the video reaches the computer.

--- There are a few ways to properly timing occultations: ---

- A common method which is used for cameras with an analog output (cameras which use BNC or RCA output jacks) has been to purchase a “VTI” (video time inserter). This device inserts a running clock readout directly into the video. The VTI has an antenna which picks up time signals from GPS satellites and can provide a timing reference accurate to a few thousandths of a second. The VTI is inserted into the signal chain between the analog camera and the computer input. IOTA sells an excellent VTI for around $250 to $275.
- Another means is to purchase a camera designed solely to record occultations. These 'special' cameras have a GPS receiver built directly into the camera itself. As each frame of video is

exposed, a GPS-based time - accurate to a few milliseconds - is written directly into each frame of the video – prior to the video being output from the camera. Two cameras currently can do this, the QHY174M-GPS and the Astrid.

- For those with existing digital cameras, a method that has been employed is to use a device that imparts precisely timed LED light flashes into the video before and after the potential occultation. Again, the device picks up time signals from GPS satellites and logs the times of the flashes to millisecond accuracy. The flashes become 'bookends' in the video and programs used to analyze the video can then interpolate a time for each individual video frame between the flashes. Though this method (“flash timing”) is not perfect, in general it yields acceptable results. See below for more information on these timing methods.

Note: Up until a few years ago two phone apps were available ("Occult Flash Tag" and "AstroFlashTimer") which used the camera flash in a smartphone to place flashes in the video and provide acceptable timing via NTP. I mentioned these apps in an earlier version of this document but...

Sadly, *both of these apps are no longer readily/easily available*.

Also, be advised that recording audio time signals (say from a radio station like WWV) on the audio channel of a video recording can have the problem of the audio and video NOT recording in proper time sync. I once tested this and found almost a 0.2 second discrepancy – too inaccurate for proper reporting to IOTA.

Computer:

You will need a computer to capture the output of the video camera to a video file. Commonly used video formats for occultation work are .AVI or .FITS (and there are a few others). For .AVI you must use the Lagarith codec which saves your video in a lossless, uncompressed format. What computer to buy is up to you - a specific recommendation can't be given. Note that most of the software used in occultation work tends to be Windows-based. Most modern computers should work fine. Laptops (or Mini-computers) are needed if you wish to travel and “Go Mobile”. If your computer is to be used away from AC power outlets, a critical consideration is the ability to supply adequate power to the computer for possibly an extended period of time (laptop batteries sometimes run down quickly in colder temperatures). Some mobile observers use “power stations” which are essentially large battery packs, and many of these have internal inverters which can supply 120VAC sine-wave power. Some observers use low-power mini-computers which can run off 12VDC power packs / batteries. Avoid running any non-essential programs during your recording. Running other programs while you are recording your video increases the chance of “dropped frames” and timing errors.

Video Capture Device (If needed):

These devices are essentially an interface between an analog camera/VTI, and your computer. Quite small and inexpensive, they are used to convert the analog output of some cameras (after it passes out through a VTI's RCA-style output jack) to digital form. The digital video signal is then input into the computer via a USB jack. A commonly used device is the StarTech SVID2USB232 (shown), which costs about $40.

Video Capture Software (If needed):

Analog cameras (like the RunCams) often require a dedicated program to capture the video input to a file on your computer. For Win10 or 11 computers IOTA recommends that you try IOTA VideoCapture, available for free here: http://occultations.org/observing/software/. Some newer digital cameras (such as the QHY174M-GPS and Astrid) do not require capture software as it is built into the camera control program supplied with them (such as the popular camera control program - SharpCap).

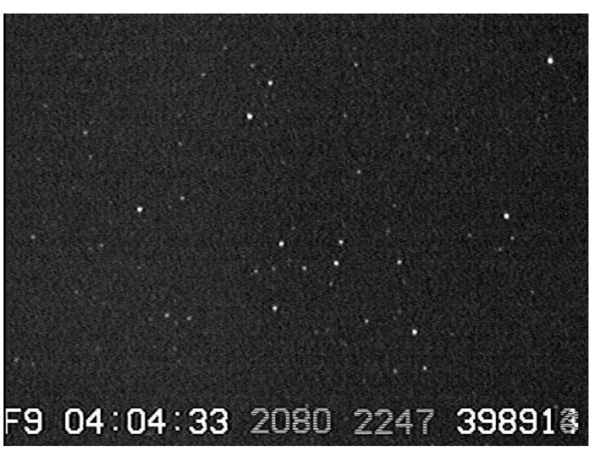
ASSEMBLING AN ACTUAL ASTEROID OCCULTATION RECORDING SETUP

What's listed below is what might be considered a good “**starter**” setup. **MANY other configurations are possible**, and new equipment is coming out all the time. Occultation observing often employs technology that is in a rapid form of change. (As such, I *try* to keep versions of this document as up-to-date as possible).

You might want to visit this site and see what IOTA recommends and read their comments:
http://occultations.org/observing/educational-materials/equipment/analog-video-recording-in-windows/

Camera – The RunCam Night Eagle 3 ($195 with adapters and a focal reducer – shown to the right) has a single, set exposure of 1/30th of a second (more specifically 29.97 frames per second), and outputs an analog signal (via an RCA video jack). The “NE3” camera is VERY small and LIGHT! It fits in a standard 1.25” focuser. It was originally designed for flying on amateur drones at night, but has been found to be a very sensitive low-light camera for use in astronomy. How faint can it record?.... Roughly speaking, this camera can capture all the stars you can see visually through a telescope, and perhaps go a tad fainter. There are 3 ordering options. It is best to get the kit supplied with the two spacers and a focal reducer. Here's a link for ordering: http://occultations.org/night-eagle-2-pro-astro-edition-ordering-page/ (the link says “Night Eagle 2”, but it links to the “Night Eagle 3” - an updated version). Note that there are other cameras that are also used, but the Night Eagle 3 is perhaps the best, and least expensive “starter” camera. The output of this camera can be captured and digitized into a USB-2 or USB-3 connection. It needs to be used in combination with a VTI to precisely time events.
[Note: Though a commonly used camera in the US, it appears that few Night Eagle cameras are used outside of North America. As such, the author can not recommend purchase of this camera outside North America at this time].

VTI (Video Time Inserter) – This unit obtains ultra-precise time (in Universal Time - UT), latitude, longitude, and elevation from GPS satellites, and can insert that information into the video.
IOTA sells their own VTI (cost $249 or $274 depending on options). It has the advantage of a fast start-up, and the analysis program – PyMovie - can read its timing stamps automatically. Here's a link to the VTI sold by IOTA: http://occultations.org/observing/recommended-equipment/iota-vti/.



To the left is a sample of some of the information the IOTA VTI can insert into video from a Night Eagle 2 camera (The display for a NE3 camera would be similar).
To far left, “F9” states it is locked to 9 GPS satellites (a min of 4 are required). It then displays a time of 4:04:33 Universal Time and the two groups of 4 numbers in light gray list the fractional seconds for each video field. In essence, the time that can be extracted here is to a few hundredths of a second for each frame of video. The analysis programs that are used can use “optical character recognition” to read the times embedded into the video.

At the time I put my first system together, the IOTA VTI was unavailable so I purchased the Sprite3-U VTI from The BlackBoxCamera Company in England (price depends on the current exchange rate but is about $220) http://www.blackboxcamera.com/pic-osd/sprite.htm. (Given the choice between the two VTI's, the IOTA VTI is **much** preferred, as its time stamps are read *much* more easily read by PyMovie).

Please note that in using any VTI, after powering it up, you **MUST** give the unit time to receive the latest “almanac” from the GPS satellites, and correctly update its UT time. Otherwise the displayed time might be wrong by several seconds! In general, after applying power to your VTI (and with the VTI's antenna having a clear view of the sky), you should wait about 20 minutes before assuming the displayed time is correct. It is recommended that after that 20 minute wait that you check the displayed VTI time against radio station WWV or smart phone apps that obtain precise time via Network Time Protocol (NTP) servers. ***Do NOT assume that just as soon as a time is displayed on your VTI that it is correct!***

Above is an image of an IOTA VTI with its external antenna. (Note the 4 US quarters across the top as a size reference).

At times a handy tool to have.......
PVC Camera Extender Tube (if needed)**:**

Often the cameras used in occultation work use a focal reducer lens. This widens the field of view, but at the same time requires that the camera be moved “inward” - more toward the primary optics - in order to reach focus. For some scopes – particularly Newtonian reflectors – the focuser simply can't be “racked in” far enough. This 1.25”-to-2” adapter is handy as it will allow the RunCam Night Eagle 3 (or previous “NE2”) camera to reach focus in nearly any telescope - provided that scope has a 2-inch focuser. Plans (in .pdf format) to build one, which include step-by-step photos, can be found here: http://occultations.org/observing/recommended-equipment/optics-accessories/. The image above shows the older Night Eagle 2 camera beside a PVC holder. The camera slides inside the holder and is secured by 3 set-screws. When the PVC holder is slid inside the 2-inch focuser, the front lens of the focal reducer (attached to the RunCam) can then actually be even with the inside of a Newtonian's tube – often gaining an inch or more of additional focus "in-travel".

(Yet..) EVEN MORE ABOUT CAMERAS! (Options)...

One of, if not <u>the</u> biggest decision you can make involves which camera to use to capture your occultation events. Like buying a car, there's the “economy model” or you go all out for the “high performance model”. In general, the more elaborate (and expensive) the camera, the more features and options you will have. To start off, you have 2 choices; a camera that is analog (like most “old-style” cameras), or one that is digital.

ANALOG Cameras.......

In the past, nearly all cameras available for occultation work have been analog. In order to use these cameras, the analog output (usually in the form of an RCA or BNC-style connector) needs to first run into a device that inserts a UT “timestamp” into the video. In most cases this is done with a VTI. The analog output of the VTI, is then run into a small device that converts the analog signal to a digital signal. This “digitizer” or A-to-D converter (like the $40 units sold by StarTech) has a USB connector as its output, which is then plugged into the USB port on the recording computer.

Popular analog cameras that are or have been recently used are the RunCam Night Eagle 2 (now discontinued), RunCam Night Eagle 3, and the Watec series of cameras (some of which have also been discontinued).

The RunCam series (mentioned and shown above) has been quite popular for beginners as it is an easy to use, sensitive, yet very small and inexpensive camera – but it has limited versatility. The current Night Eagle 3 is quite sensitive, but only has one exposure setting – 1/30th of a second. It's a good “beginner's camera”. A VTI is required between the output of the RunCam and prior to the signal being input into the computer. So total cost = RunCam + VTI + Startech A-to-D converter.

The Watec 910 series of camera has been a workhorse for occultations for many years. Unfortunately it seems the NTSC version (geared toward North American camera standards) is no longer available. The PAL (European) version of the Watec 910HX/RC, is still available – cost being about $640. This camera will work with the IOTA VTI (if a switch inside the unit is changed). It is capable of a wide variety of exposures. Like the RunCam, a VTI is required, so total cost = Watec + VTI + Startech A-to-D converter.

DIGITAL Cameras.......

Digital cameras have been around for some time, but only in the last few years have some models been produced which are designed specifically, or can work well, for occultation work. Two cameras will be mentioned – the QHY174M-GPS and Astrid.

The **QHY174M-GPS** camera was perhaps the first digital camera which was designed specifically for occultation work. This camera has a GPS module built right into the camera head. An antenna lead attaches directly to the camera and precise GPS time is then written into each frame of video as the camera takes the images. The camera is controlled by the popular program called SharpCap. This is a highly versatile, and rather advanced camera - and carries a price tag to match – costing about $1300. The QHY plugs directly into a computer's USB port. No VTI or A-to-D converter is required.

Astrid – Recently a new digital camera has been developed called Astrid (for Astronomical Imaging Device). As of this writing (Feb '24) only a limited number of Astrids have been available, and these units are sold in “kit” form – so partial assembly is required. Astrid not only has a GPS time module built in, but also a Raspberry Pi 4 Model B “mini-computer” in the camera head. Astrid is “programmed” by another computer (like a laptop) via a WiFi connection, which allows the *option* to disconnect Astrid from the programming computer and Astrid can then continue to capture the occultation “unattended”. It also has a wide usable exposure range from 30 frames per second, up to exposures of about 15 seconds per (video) frame. A key consideration in its design is the ability to use it as an “unattended” station. Total cost (including all required parts) to assemble an Astrid is about $500. IOTA is considering selling pre-assembled units, but as of this writing Astrid is only available in “kit” form.

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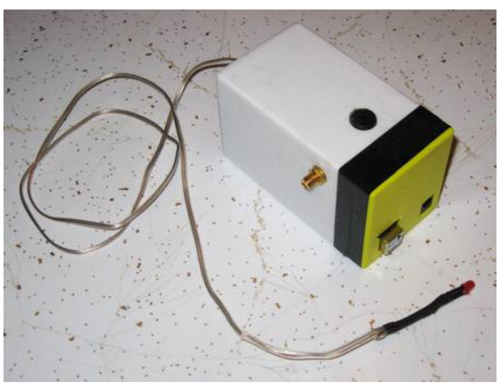
Though technically not a camera, mention should be made of a “Flasher” device.... as it can allow “most any” existing video-capable camera – either analog or digital – to accurately time occultations.



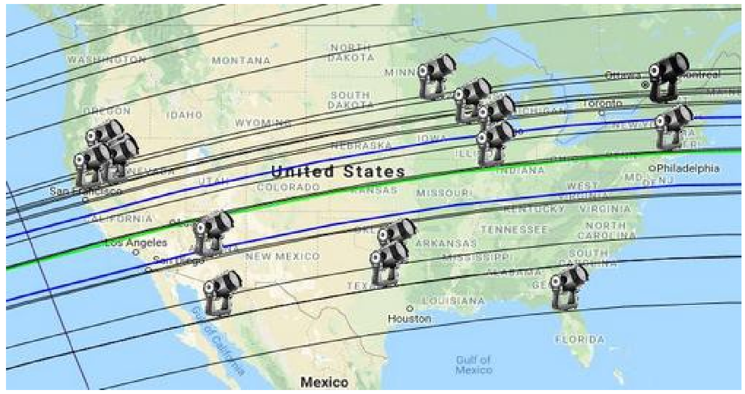
Flashers – At the time of this writing, for observers already owning a digital camera (intended for standard astroimaging, but which have an option for recording video), the only option is to use a “flasher” device. These Arduino-based devices use an LED to place a “flash” into the video. The device has an internal GPS chip which allows for the time of each flash to be precisely logged on a micro-SD card. The flashes place “bookends” in the video at a time somewhat before and after the occultation event. The analysis program PyOTE enables entry of the logged UT times of each flash and the program then interpolates a time for each “in-between” frame of video. Timings by this method are not flawless, but in general produce acceptable results. Currently such devices are only available to persons willing to build such electronic units from plans. Pre-assembled versions ~may~ be available in the future, but as of this writing it's a DIY project. In the above image a GPS antenna screws onto the gold connector and the red LED (at the end of the long wire) is placed by the front opening of the telescope. This image is of a prototype design.

(Quite) Ideally – Any time reference should be inserted into the video signal
BEFORE the signal reaches your computer.

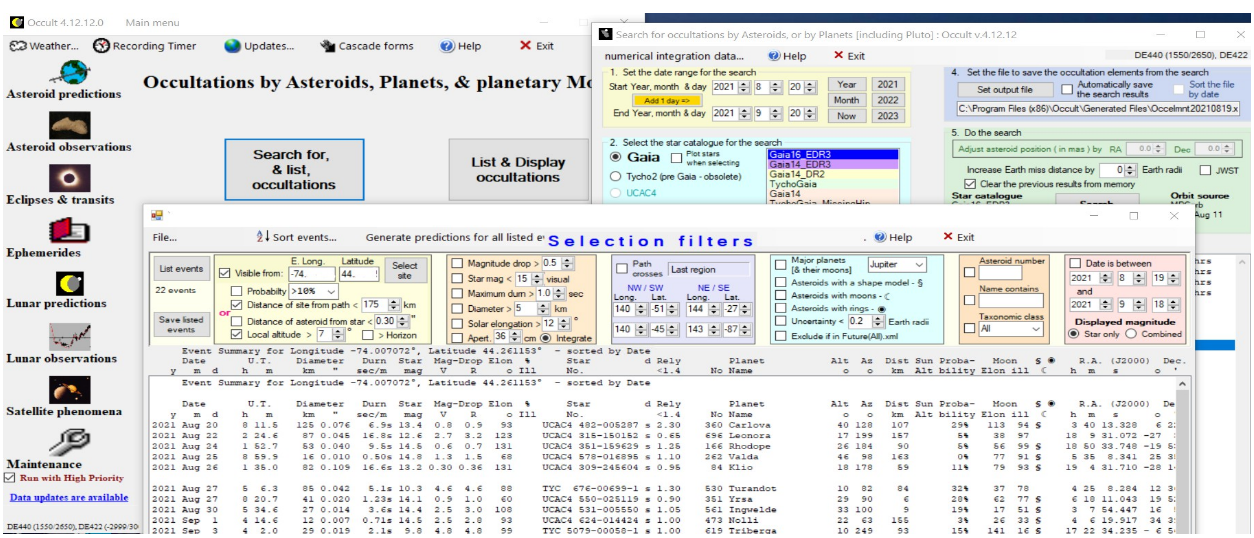
OBTAINING ASTEROID OCCULTATION PREDICTIONS

There are two very good sources for obtaining predictions specifically for your geographic location. Both are free computer programs which you can load on your home computer. They are “OccultWatcher” and “Occult”. Both are **EXCELLENT**, and highly recommended. Downloads for both programs can be found at: http://occultations.org/observing/software/

- **OccultWatcher** - (“OW”) is quite an amazing program which serves to both provide local predictions and also to coordinate observers together (worldwide!) to observe the same events. In short, it allows observers to “sign-up” for an occultation, and provides precise information for your location. It then displays where each observer falls in relation to the shadow path. Its capabilities are vast – too encompassing to describe here. In general, it displays the “better” occultation possibilities for your location. Above is a screenshot from OW showing observers “signed-up” to try for the occultation of a large Trans-Neptunian Object. (The TNO's estimated diameter encompasses the blue lines, with the center of the predicted shadow being the green line). OccultWatcher has both a desktop version (which you load on your home computer), and an 'on-line' version called OccultWatcher Cloud.



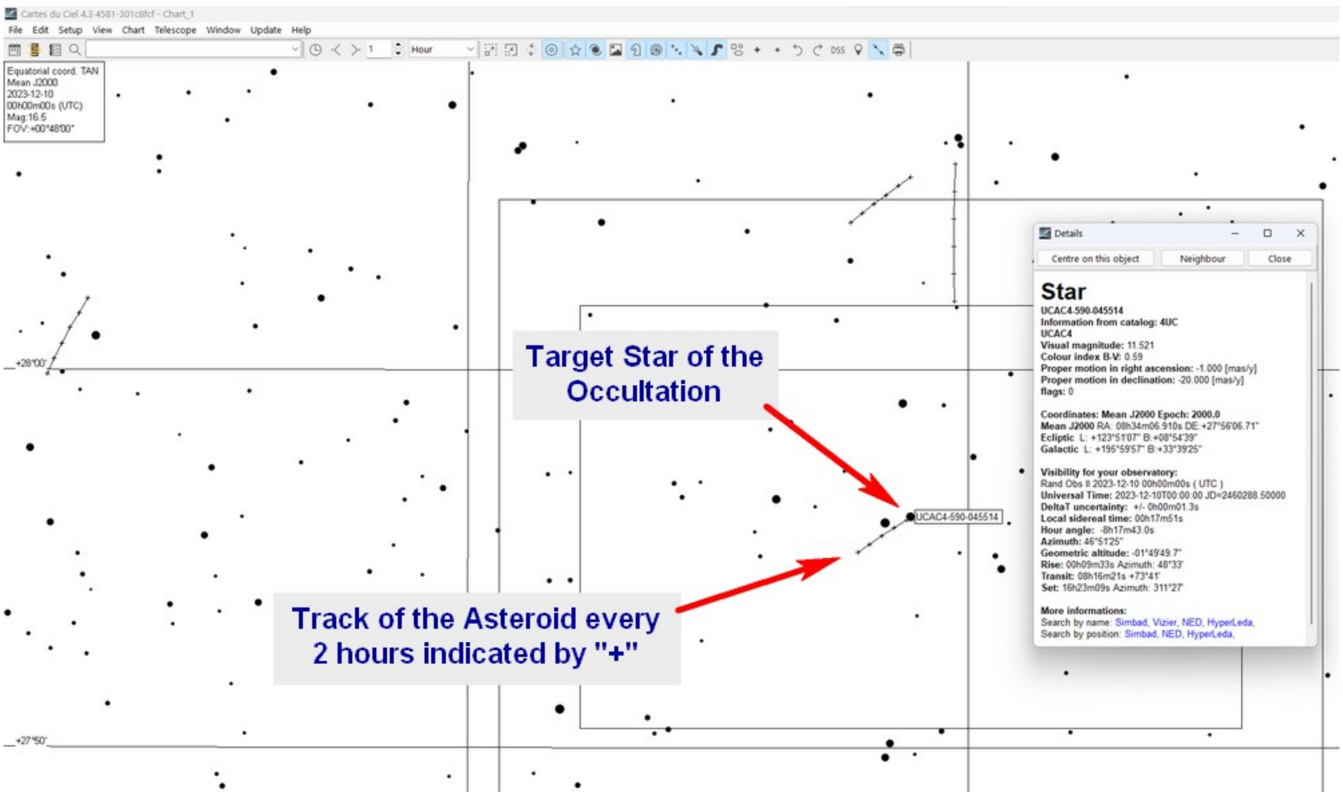
- **Occult** - (not to be confused with OccultWatcher) is also quite an amazing program which, among many other things, also provides local predictions, but has the capability to provide MANY more (usually “lesser”) events than “OW”. It doesn't serve to coordinate observers, but is the actual prediction generating program for many of the events listed in OW. Once set up properly (there are MANY options), this is the program that can generate a “decent” event to try for on almost any clear night (sample screenshot below). Overall, it's the more “advanced” and “deeper” program, and it should be noted that initial configuring of this program to make local predictions can be involved. Beginners are advised to start with OccultWatcher first. Occult can also predict lunar occultations (and lunar grazes) of stars.



REGARDING STAR CHART and ASTEROID PLOTTING PROGRAMS

Just a quick mention of the open-source freeware program Carte du Ciel (French translation - “Sky Charts”) – which can generate very useful, highly configurable star charts (example below). It can download the asteroid database (MPCOrb) from the Minor Planet Center and very accurately plot asteroid tracks – making great finder charts. Note that to ideally use it for occultation work, you **must** install the optional UCAC4 star catalog. This catalog contains stars to mag 16.5. Carte du Ciel and the UCAC4 catalog used with it can be downloadable from:

https://www.ap-i.net/skychart/en/download



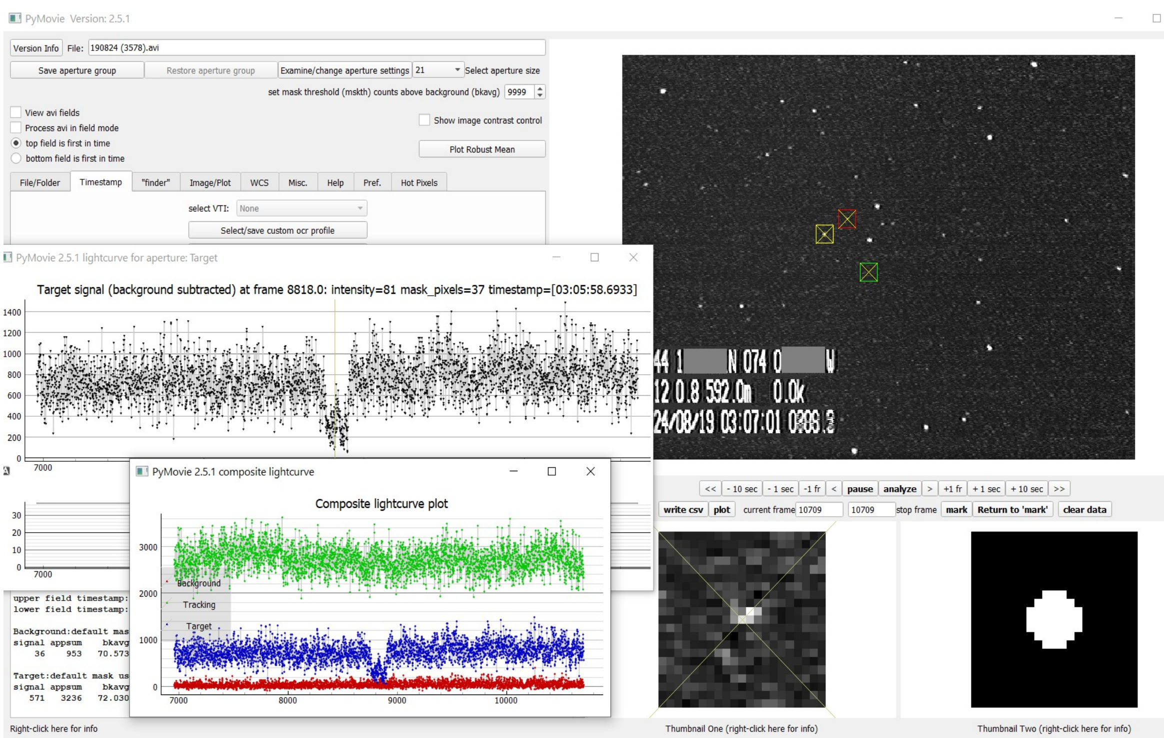
Some occultation observers recommended the use of the program “Guide9”, tho I have had no experience with it to date. Another program which I have tried, and others often use, is the freeware program “C2A”. Research these programs on the Internet, and you can choose for yourself. As of this writing, the author's program of choice is Carte du Ciel. For persons interested in the program, it's suggested that you download the **beta** version 4.3 (or higher number) as the important Pre-point function (see below) was added in this release. (For persons wanting some details in setting up Carte du Ciel for occultation work, you can contact me using the email at the end of this article).

Curious about past occultations that others have observed? Here's a link to IOTA's Reviewed Results for North America page (many years of results are listed):
http://www.asteroidoccultation.com/observations/Results/Reviewed/index.html

ANALYZING YOUR RECORDED VIDEO

Once you have recorded an occultation to a video file on your computer, you need to analyze it. The "old standard" program that was used was LiMovie (which is still somewhat useful), but recently the program - PyMovie - has been developed, and is much preferred.

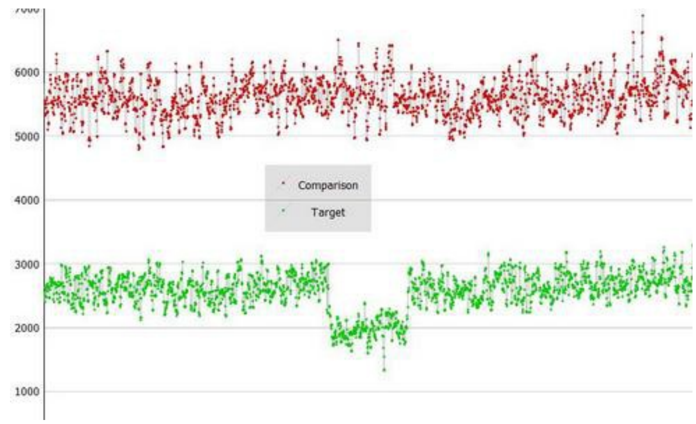
PyMovie - [Initial] Video Analysis Software (Free):
This is an excellent initial video measurement/analysis program, which reads an AVI video file, or a series of FITS images (and a few other formats). When used in "Drift" mode it can lock onto the star(s) it is measuring. This is very handy if you recorded video with a telescope that doesn't have a drive system. PyMovie will clearly allow you to see if you recorded even a low mag dip or very brief occultation. Using Optical Character Recognition (OCR), PyMovie can read the time (timestamps) written into your video from a couple popular VTIs. It can also read times directly inserted into the video frame "headers" by the QHY and Astrid cameras. It then creates a spreadsheet of your recording that IOTA requires. This program is available as a free download from:
http://occultations.org/observing/software/



Above is a screenshot from an analysis of a positive event detected using PyMovie. Three "apertures" for measurement are shown in the starfield video. The red box encloses the Target Star (shown magnified in the view below). The yellow box is a star that was used for tracking, and the green box was used to sample the background level. In the composite light curve, the measurements are shown as the blue, green, and red plots respectively. PyMovie can track on a Target Star as it drifts across the field of view, and can take into account any field rotation when using a stationary alt-az mounting.

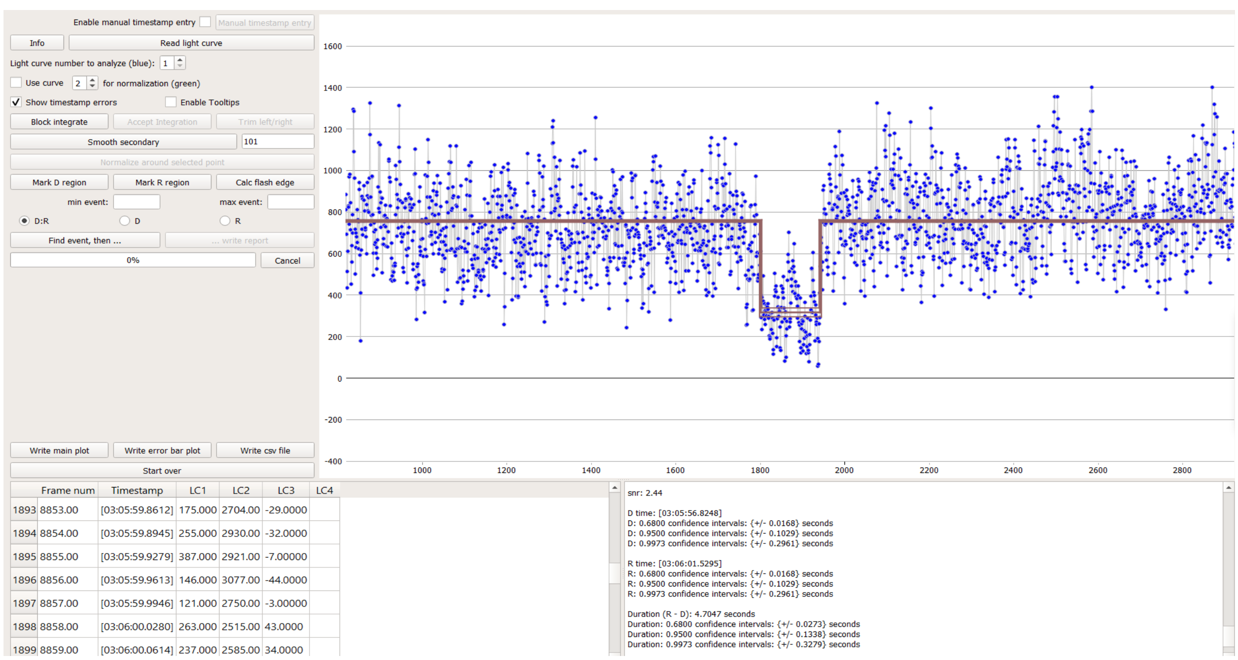
Bob Anderson, the author of PyMovie, has several good tutorial videos on YouTube describing the operation of the program (do a YouTube search using the keywords "PyMovie Anderson"). These videos show quite earlier versions of the software, but for the most part, they still illustrate the basic operation of the program.

To the right, in green, is a plot of what the earlier-mentioned (389) Industria occultation looked like when run through PyMovie (12.4 mag asteroid passing in front of a 12.4 mag star - light drop of 0.7 magnitude). In visually watching the recording, the occultation didn't clearly show. Looking at the graph produced by PyMovie clearly shows the event (the upper plot in red is a comparison star).



If it appears you observed a "Miss" (no occultation), then the next step is to fill out IOTA's standard Occultation Report Form with details of your observation. IOTA's standard Asteroid Report Form can be found here: http://www.asteroidoccultation.com/observations/Forms/AsteroidReportForms.html

PyOTE - [Final] Video Analysis Software (Free):
If you DID observe an occultation, you need to do further analysis to obtain EXACT disappearance (D), and reappearance (R) times. It's suggested you download the free analysis program - PyOTE - from http://occultations.org/observing/software/. Follow the download and operational instructions. Again, submit results via the IOTA Asteroid Report Form. There are a few other analysis programs, but PyOTE is perhaps the "easiest", and a good one to start with.



The example above shows the first PyMovie event, which was then analyzed in PyOTE to extract the exact disappearance (D), reappearance (R), as well as the signal to noise ratio and confidence intervals (all values IOTA likes reported). PyOTE reads the Excel-style .CSV file created by PyMovie.

Despite the apparent complexities, after getting used to them, doing an analysis with PyMovie and PyOTE is actually fairly quick and easy, and yields accurate results.

It should be stated that there are other analysis programs besides the PyMovie/PyOTE combination. There is also a program called **Tangra** – if you care to look into it (the author of this .pdf is unfamiliar with it so it's hard to comment on).

THE USEFULNESS OF OCCULTATION OBSERVING

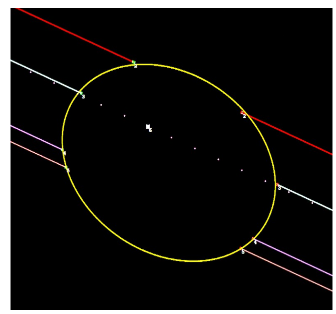
At a very basic level, an observation of an occultation can serve to demonstrate that the universe isn't "static", but is always changing. If the event is relatively bright, and the magnitude drop is large, witnessing an occultation can be rather dramatic. The better, more certain events can be good subjects for showing at star parties (today's video cameras can allow many to view the event at once).

Looking at things from a more "productive" standpoint, a properly observed and timed occultation event can yield valuable scientific data. Here's a few examples:

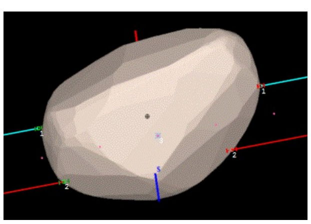
Astrometry:

Astrometry is the branch of astronomy concerned with measuring positions (usually extremely precise positions) of objects in the sky. As mentioned earlier, essentially every star in the sky, visible with the naked eye or through a telescope, has had its position measured to amazing accuracy. Most of these positions have been obtained by specialized satellites dedicated to obtaining this astrometry from space (astrometry by ground-based telescopes is limited by the distorting effect of the Earth's atmosphere). Telescopes on Earth dedicated to astrometry often report an accuracy of 0.1 arc seconds or so for asteroid positions. In comparison, the astrometic satellite Gaia routinely achieves positions for stars well over 100 times better. For the great majority of asteroids (especially the higher-numbered ones), their orbits (and thus their position at a given time) still have varying degrees of uncertainty. In general, the position for an asteroid (at a certain moment in time), is MUCH less certain than the position of a star. Still, we now know many orbits well enough that we can make reasonably reliable occultation predictions (and indicate estimated path uncertainties). As a result, a single occultation observation can 'link' an asteroid's position to the very precise position that has been obtained for the star it "occults". This can greatly aid in refining the orbit of the asteroid. As compared to asteroid astrometry done by dedicated Earth-based telescopes operated by professional astronomers, asteroid astrometry obtained from an occultation is often 20 to 50 times better.

Discerning Asteroid Sizes and Shapes:

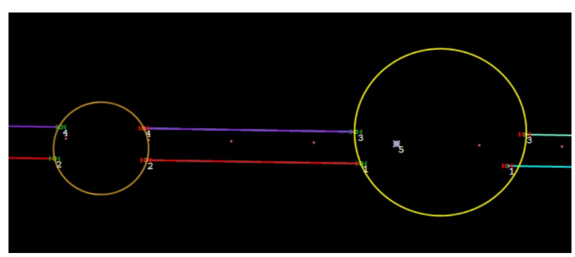


In general, the more observers there are for a single asteroid occultation, the more useful the observation can become. As mentioned earlier, if a number of observers (perhaps 3 or more) can be spread across the WIDTH of the shadow path, they can all witness the star pass behind different cross-sections ("chords") of the asteroid. As a result, when the different observer's occultations are analyzed, in many cases a size and possibly a shape can be determined.



For some asteroids, a "shape model" (or models) is already available. Most shape models are the result of observers measuring an asteroid's brightness variations (as it rotates) over long periods of time. The resulting "light curves" can be fed into a computer, and the computer may be be able to come up with a "shape" (and rotation rate) the asteroid must have in order to display the observed light variations. At times a couple different shape models may satisfy the observed light curves. Observing an asteroid occultation can then help discern which shape model may be correct. (Taking this further, if a size and shape can be determined for an asteroid, studies can be made to ascertain rough densities, and other physical properties for these bodies of our solar system).

Discoveries.....



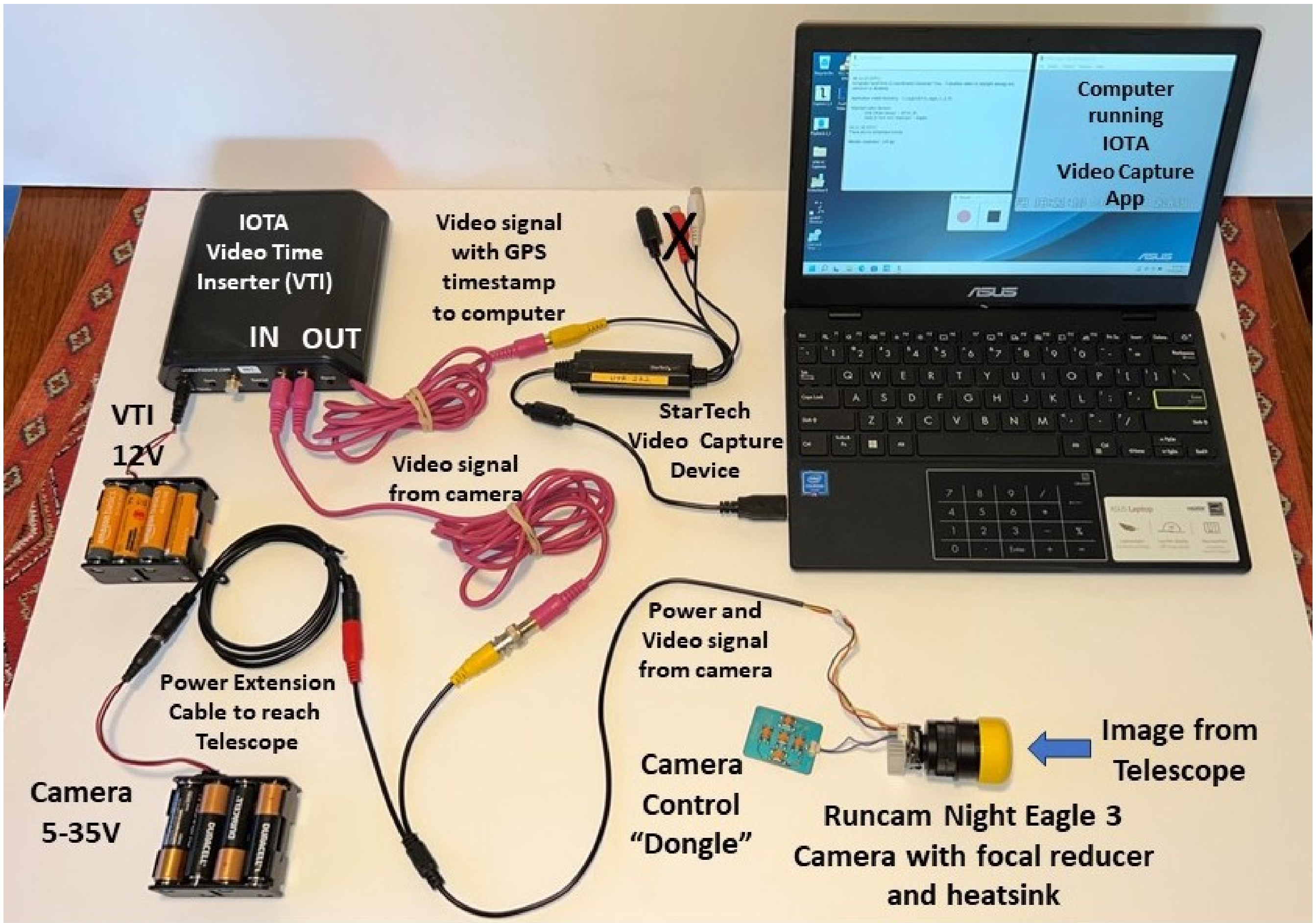
There have been cases where observers have seen a star 'disappear' not once, but TWICE during an occultation. In some cases this has lead to the discovery that the asteroid is not composed of one body, but rather two that are orbiting each other (a "binary" asteroid). In other cases occultations have proven that the occulted star is not a single star, but rather a very close "double star".

Near-Earth Objects:

In early 2021 IOTA launched a campaign to observe occultations by the Near Earth Asteroid, (99942) Apophis. At the time there existed a slim chance that this asteroid could pose an impact danger to the Earth in near-future fly-bys. Expeditions to observe occultations of stars by Apophis were organized, and several occultations were observed. These observations combined with other precise positions of the asteroid obtained through radar observations (and conventional astrometry) succeeded in removing any risk of an impact in the next 100 years. Apophis will next pass by the Earth in April 2029 at 1/10th the Earth-Moon distance – so close that it will be visible to the naked eye as a point of light, slowly moving across the sky. The 2021 observations ruled-out any chance for an impact during this close approach.

IOTA's Own Complete Occultation Recording Kit :

IOTA sells a “Complete Occultation Kit” - which includes the RunCam Night Eagle 3 camera, IOTA's own VTI, the StarTech SVID2USB232 A-to-D converter, cables, and battery holders. Install some free video capture software on your computer, add some batteries, and you will be set to record occultations with your telescope. Cost: $550 plus shipping. Here's a link to an ordering page: http://occultations.org/observing/recommended-equipment/iota-vti/



IOTA “Kit” components as of December 2023 (image courtesy of Ted Blank of IOTA). This image shows the current version of the camera – the Night Eagle 3 (black in color).
All other parts of the current IOTA kit are as shown (you supply the computer for recording)

In the kit, the camera is powered by a 2-sided battery holder (holds 8 AA batteries). The analog output of the camera runs to the VTI through the yellow/pink RCA plugs. The IOTA VTI is to the upper left. The VTI is also powered by a second 2-sided battery holder (holds 8 AA batteries). From the VTI, the video (still analog at this point), again runs through RCA plugs into the StarTech SVID2USB232 frame grabber where it is converted into a digital signal. The other end of the frame grabber has a USB connector and plugs into your computer. The computer then records the video (using the free IOTA Video Capture software).

A note regarding the StarTech SVID2USB232 frame grabber..... Be sure to ALWAYS load the most up to date video driver for this device (from the StarTech web site)!

Some other example 'Occultation Rig' Images:

The Author's Older "Mobile Battery Powered Laptop Setup"

(This is an older rig I used to use, but I left this and the following example in this article as it may give you an idea of how all components of an occultation rig are connected and can be fit in a convenient enclosure)

A - Video capture device - StarTech SVID2USB23 (now superseded by the SVID2USB232)
B - VTI Unit – Sprite3-U (the IOTA-VTI also works here too)
C - VTI's GPS antenna
D – TalentCell 12VDC 6000mAh rechargeable Battery Power supply
E - Night Eagle Camera in PVC housing
F - Homemade 12VDC "Y" power splitter (3 male ends – powers VTI & camera)
G - 16-foot cable to camera (video & power)

The laptop is an old Windows XP(!) machine that was simply given to me – but it works great! Nothing against new ones, but older computers, especially if you can obtain them for next to nothing, are worth a try. Once you get your computer rig working well, try to avoid any updates or connection to the Internet, and try to use it ONLY for occultation work.

An "Observatory / AC Power Rig"

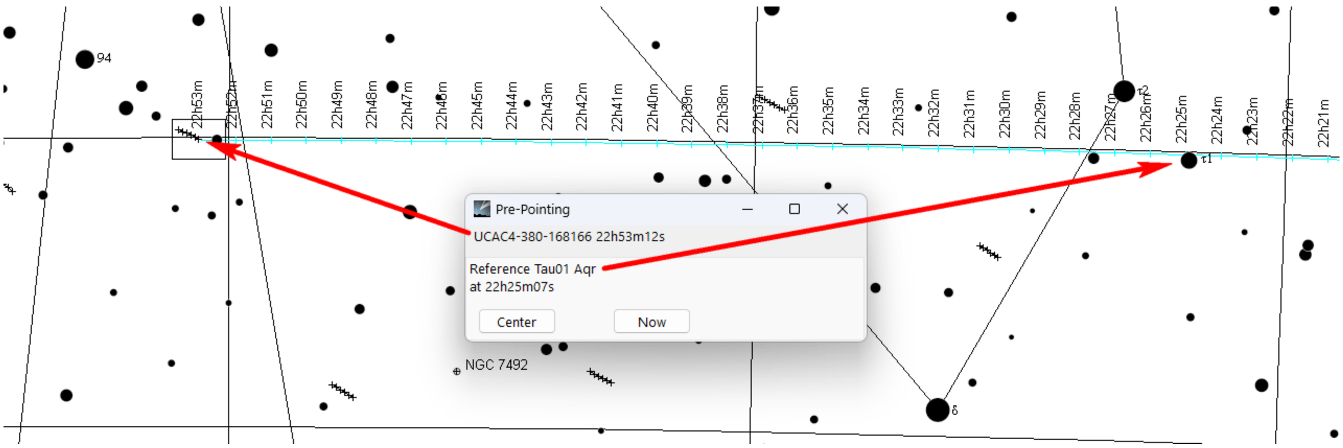
(Note: I made the white painted box to house the laptop, power supplies, AtoD converter, and VTI so I could use this setup in quite cold winter temperatures):

A - Laptop (closed and sitting on the box edge)
B - VTI Unit – Sprite3-U (the IOTA-VTI also works here too)
C - Video capture device - StarTech SVID2USB23 (now superseded by the SVID2USB232)
D - Laptop's AC power supply adapter
E - AC to 12VDC power supply (required for VTI & camera)
F - 16-foot cable to camera (video & power)
G - Night Eagle Camera in PVC housing
H - VTI's GPS antenna
I - (optional) External Mouse
J - (optional) External Keyboard

When in use (image at right), the laptop is on top of the VTI and power supplies, and just the screen shows (the laptop is held in place by a small black Velcro strip near the VTI). Often the external USB mouse and USB keyboard are used (especially in cold weather). For remote work (no AC power), the 12 Volt Battery Power Supply (from the above mobile rig) replaces the AC power supplies (D & E). (In quite cold temperatures, a rag can be wrapped around the base of the laptop screen and the heat from the laptop and power supplies will keep the laptop, VTI, and electronics warm and dry inside the box). *A side benefit of having several components in the box is that it minimizes the flexing (and breakage) of some rather fragile wires.*

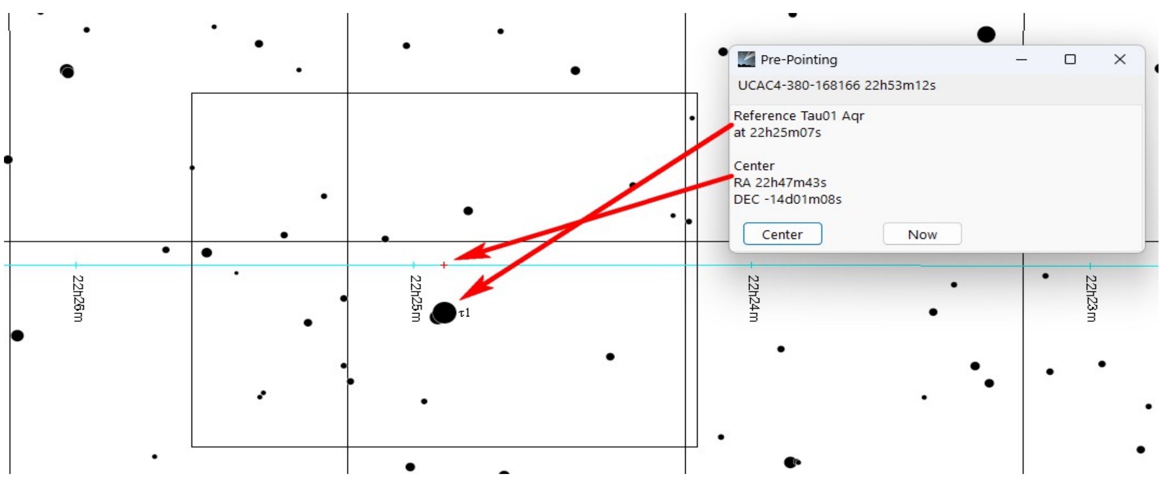
RECORDING OCCULTATIONS USING THE "PRE-POINTING" METHOD

Pre-pointing is a method sometimes used to locate your Target Star – especially when the telescope you're using does not have a drive for tracking the stars. In short, if a fairly bright star exists somewhat nearby, and directly west of your Target Star (ie., at very close to the same Declination), you can center your <u>undriven</u> scope on this brighter star, and wait the "time difference" in Right Ascension between the brighter star and your Target Star. The Earth's rotation will then bring your Target Star to the center of your camera's field of view (FOV) right at the time of the predicted occultation.



Shown above is a Pre-point set up in Carte du Ciel where the asteroid (15735) is due to occult the Target Star UCAC4 380-168166 at 22:53:12 UT on Jan 22nd, 2024. To the left (east), the rectangular camera field of view (FOV) is first centered on the Target Star, and a Pre-point line is generated by right clicking on the Target Star, selecting "Pre-point", and entering in the time of the occultation. After zooming out, it's noticed that the rather bright, 5.7 mag star Tau01 Aquarius is at nearly the same Declination and just west of the the Target Star. Tau01 Aqr is then chosen as the Pre-point star. By right-clicking on it, and selecting "Pre-point", then "Measurement", Carte du Ciel calculates that Tau01 Aqr needs to be in the camera's FOV at 22:25:07 UT.

If the user then clicks on the button labeled "Center", Carte du Ciel then displays the FOV which encompasses Tau01 Aqr as shown below. The FOV that is displayed then represents how the camera FOV should be composed (with Tau01 Aqr included) at 22:25:07 UT so that if using a telescope without a drive, the Earth's rotation will then cause the Target Star of the occultation to be near the center of the camera's FOV <u>at</u> the predicted time of the occultation.



Note: Carte du Ciel added the Pre-point function on versions 4.3 (beta) or higher of the program.

Some issues with Pre-pointing are; 1) You will need to be at your observing site, and have all equipment set-up that much sooner. 2) You may have to settle for some “less than bright” Pre-point stars – sometimes even your most promising ones may be rather dim. 3) Your skies should be completely clear. If it's partly cloudy, there's the chance your Pre-point star might be behind a cloud at the time you should be centered on it! Even if it is clear, it would be wise to select a couple other Pre-point stars (or FOV's) east of your planned one in the case that you don't get on your primary Pre-point star in time. 4) With a stationary telescope the length of time you can record your Target Star is limited.

The above is a basic example of how Pre-pointing can be done. Although I have never used them, it has been mentioned to me that there are plug-ins for OccultWatcher which can call up the star charting programs C2A or Guide9 and automatically generate a Pre-point line for any OW event listing. Both programs can also generate Pre-point lines as “stand alone” programs – without referencing OW. A feature of C2A is a real-time moving “bulls-eye” on the Pre-point line which moves in time with the computer's internal clock.

The method of Pre-pointing is frequently used by observers who set out “Unattended Stations” (several unmanned stations set some distance apart). By using this method, one observer can Pre-point several telescopes well in advance of the time of an occultation, then after the event time is passed, go back and collect the telescopes they have “hidden”, and hopefully a number of the telescopes will have captured a positive event. Thus one observer can capture multiple chords – which lends much more value to the observation than a single positive observation can.

Pre-pointing can also be useful if your normal observing location is a yard with scattered tall trees or buildings blocking your view low down toward the horizon at various points (in azimuth). By using the method of Pre-pointing you can plan in advance (several hours ahead) of an occultation, where you can place your telescope in the yard in order to have an unobstructed view of the area of the sky containing the Target Star at the predicted time of the event.

As it can be tricky adding and subtracting time, if needed, here's a site on the Internet that can help make your time calculations easy: https://www.calculator.net/time-calculator.html

SOME THOUGHTS and CONSIDERATIONS

= If possible, consider having a computer that is dedicated to nothing but recording occultations. Once you set up a system that is reliable, think twice about applying “updates”. Do them only when absolutely necessary. (Windows updates have been notorious for wreaking havoc with video drivers).

= In setting up a system, don't dismiss the possibility of trying an older computer. Even an older “given-away” laptop with an earlier operating system may work just fine. If given an older, unwanted laptop, always ask for the original operating system “reinstall disk”. Sometimes a slow, older computer can become quite fast if the drive is wiped clean and the operating system is reinstalled. (A laptop I used to use with my RunCam ran Windows XP, and a laptop I used to use for my QHY174M-GPS ran Windows Vista - and both worked very well). You also won't feel so much pain if the older “free” computer dies in the harsh outdoor conditions we sometimes subject them to. Then again, new computers are fine too!

= When you first start out (and even for the experienced), it's handy to have a checklist of needed items, especially if you plan to do mobile observing. Avoid the headache of doing a long drive, only to realize you forgot a cable or power supply!

= While watching the computer screen during the actual recording of a possible occultation, it can be nice to have an audio time reference playing in the background. It's sometimes difficult to watch both the Target Star and the time display from a VTI simultaneously! Don't use the audio time signal as your actual timing reference, just use the audio as a background reference so you can visually monitor the Target Star around the time of the predicted event to see if indeed you may have captured an occultation. If the audio time is from a reliable source, it can also help verify that the time on your VTI / GPS device is correct. Good audio time reference sources are radio station WWV or a phone call to the US Naval Observatory's Master Clock at 202-762-1401 (their alternate number is 202-762-1069). Note that the USNO may only allow a connection for a minute or so.

= If you DO observe a positive event, it is a good practice to verify that the time displayed by your VTI/GPS device is accurate <u>while your video recording is still in progress</u>. Simply compare your VTI's time display to a known reliable source – like the US Naval Observatory's Master Clock, mentioned above. [Note that in comparing times, your camera should be operating at a fairly high frame rate – $1/8^{th}$ sec or faster].

= Always try to use the shortest integration (exposure) time possible which can still record your Target Star well. The goal is to adequately record the Target Star, but still use a short integration time which will yield a higher time resolution. As a guide, you should be able to see your Target Star in **EVERY** frame of video, prior to the event. If not, consider increasing your exposure time if you can.

= Be careful not to saturate the pixels of your camera by a bright Target Star. This is especially important if the anticipated magnitude drop is small. Some video capture programs (like IOTA Video Capture or SharpCap) can be set to alert you to saturated pixels. If you notice saturation, shorten your integration time first. If that isn't enough then reduce gain. Next you can try to de-focus the telescope somewhat (PyMovie will still be able to measure it). If that isn't enough, stop down the telescope's aperture until the target is no longer saturated. Always try to avoid saturated pixels on your Target Star.

= If you are using a camera/VTI that can display its menu in your video (like the Night Eagle 3 can), then it can be a good practice to call-up the menu on the video display just prior to starting your recording. This can be handy as you can then log details about your exposure setting, gain, possibly the latitude and longitude of your site, among other info. Record this info for a few seconds at the start of your video, then turn off the menu and continue recording your event. Having this info right in your video can come in handy. Recording the latitude and longitude can be handy if you are doing mobile observing. When you do an analysis, simply start your analysis after the menu information is gone.

= For each observation, you should make a note of your sky conditions, the start and end time of your recorded observation (a VTI may log this), the camera integration setting (other camera settings are helpful to record too – such as gain), the latitude and longitude of your site, the telescope used including any focal reducer, and any other pertinent info. You will need this later in your report.

= Be conscious of centering up a field of view that includes not only your Target Star, but a few “Comparison Stars” that are preferably a bit brighter or fainter than your Target Star. They should be as close to your Target Star as possible. This is especially important if you have intermittent thin cloud conditions. A cloud passing through the FOV can mimic the fade of an occultation. If your Comparison Star exhibits a similar “fade” at nearly the same time as your Target Star, then you might question the validity of an event. Comparison Stars may also allow you to “correct/compensate” for thin clouds passing by – by a process called Normalization.

= For Northern Hemisphere observers, in the summer (and late spring, early fall), you will need an observing site that has a reasonably clear southern (and to some extent SE and SW) horizon. Many occultations occur in the rich starfields around Sagittarius, and the ecliptic runs low there. So in the summer, the less obstructions around your southern horizon, the better.

= Consider giving yourself the ability to “go mobile” - that is, to have a transportable occultation rig. You can greatly increase your chances to catch positive events, and you can avoid the frustration of having that “top rated event of the year” fall right BEHIND that lone tall pine as seen from the permanent pier in your yard. Some observers travel hundreds of miles (or more!) to place themselves nicely in the predicted path, greatly increasing the chance of recording a positive event.

= Be careful of repeated flexing of wires – especially in quite cold conditions. If you can, strain-relief cables as best you can. This especially applies to wires coming off cameras (and power supplies). Putting all your components in a single enclosure can minimize wire flexing and is recommended.

= A note to die-hard, deep-sky astro-imagers... Occultation observing can be a productive project for nights rather unsuitable for taking top notch images, such as during a bright Moon, during rather poor seeing, or under rather hazy, or somewhat light polluted skies.

= The smaller the size is of an asteroid, the more value a single positive observation may have. This is because the uncertainty of where the center of the asteroid actually is in reference to the Target Star is reduced. The smaller (higher number) asteroids also tend to have more uncertainty in their orbits.

= When possible, a lot more can be accomplished if you consider making teamwork a part of your observing plan. Join in when you see others signed up for an event on OccultWatcher. Ideally if you can find others in your area, you can all observe the same event from different locations, and if it's clear for you, it may be clear for all – so it's possible that multiple chords can be obtained. <u>This can greatly increase the value of the observation!</u>

Hope this helps. Clear Skies and Happy Shadows,

George Viscome / Lake Placid, NY, USA / georvisc@yahoo.com

ALL SPECS / PARTS / LINKS / INFO SUBJECT TO CHANGE. MAY NOT BE AS I ORIGINALLY EXAMINED / PURCHASED THEM. STUDY HOW EVERYTHING COMES TOGETHER TO ENSURE WHAT YOU ORDER / DOWNLOAD, ETC. WILL WORK. All links worked and correct as of the date of this version.

Version 5.1.3 – February 1st, 2024