# ASTEROID OCCULTATION OBSERVING

and recording - (almost) Every Night Eclipses

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 about 800,000 asteroids that have known orbits – many of them very well defined. There are also billions of stars visible thru 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 out 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. The image to the right shows the shadow path of the asteroid (389) Industria crossing the northern United States.

(389) Industria - August 17, 2018
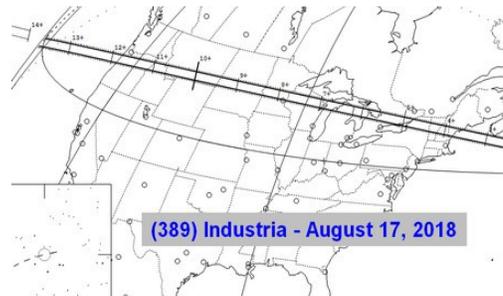
Of course in order to predict the shadow path, it is also important to know exactly where the star is in the sky. In 2013, the European Space Agency launched a satellite named Gaia. Its mission is to very precisely measure the positions of a couple billion stars in the sky – to an angular accuracy of 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 small 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 (some 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 about 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?

In the simplest way, it 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. Predictions 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.

This writing is geared more toward observers who might like to do a little more.... record the occultation, measure it, and submit the observation – thus increasing our knowledge of asteroids. The organization that collects this data is the **International Occultation Timing Association – IOTA.**
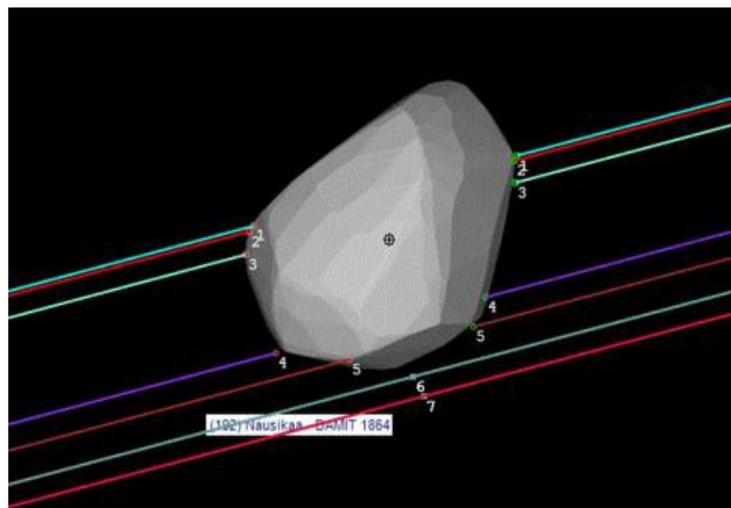
More info at: http://occultations.org/observing/observing-basics/

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 image of the starfield surrounding, and including, your "target star" around the time of the predicted "event". You need to VERY accurately record the time the target star might disappear and reappear – to an accuracy of tenths of a second or 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 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 should report this as a "Miss" (or "Negative") to IOTA. Reporting a "Miss" is almost as valuable as observing a "Positive" event – as it says where the asteroid's shadow WASN'T. This can sometimes be a very crucial bit of information, as in chord "6" in the image below.

That "miss" helped constrain the southern 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.

(192) Nausikaa - DAMIT 1864

Teamwork can play a very important and interesting 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 Portland, Maine. 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, an actual shape (and thus size) for the asteroid can be

determined. With between 5 and 10 observations, details in the variance of 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 6-inch telescope!

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 setup 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), 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 word 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 the type of person willing and accustomed to working to a fairly 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. You will need to obtain these times using a very accurate timing reference. The best time reference is currently time signals obtained from GPS satellites.

A description of a "useful" occultation setup:

- **Telescope** - In order to capture a good number of occultations, a telescope with an aperture of at least 6 inches is recommended. Unlike in astrophotography, a clock drive helps, but is often NOT necessary when using a smaller telescope. This is because most occultations state a predicted time which is often accurate to +/- 15 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. Typically this could be 2 minutes. Thus, for a 2 minute drift time, if you placed 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 LiMovie 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 recommended "starter" camera (Night Eagle 2 Pro Astro) is supplied with a telecompressor – 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. In actuality, the longer you can record on the "target star", the better (you could even capture an unknown asteroid satellite!).
- **Camera** - Video recording the occultation is highly recommended, in which case you will need a very light sensitive camera recording in "real-time", ideally at the standard video rate of 30 frames per second. The RunCam Night Eagle 2 Pro Astro edition is a low cost starter camera.
- **Timing Device** – You need to use a very accurate time reference, preferably recording it directly onto your video. There are a few ways of doing this. By far the best way is to purchase a "VTI" (video time insertion) device which inserts a running clock readout directly into your video. The two VTI's listed below do that to an accuracy of thousandths of a second. A

"temporary" method makes use of the smartphones many people already have. Free apps ("Occult Flash Tag" or "Astro Flash Tag") are available which use the phone's camera flash to put "markers" on the video (before and after the event). The app will record the times of the flashes to an accuracy of a few thousandths of a second, and you can use these flashes in your video to interpolate accurate disappearance and reappearance times. Consider this only as a way to get started!! IOTA doesn't endorse this method – as it does have its quirks. Using a VTI is considered to be the ONLY proper way to time occultations reliably and accurately. Be advised that recording audio from radio station WWV on the audio channel of a video recording can have the problem of the audio and video NOT recording in perfect time sync. I once tried this and found almost a 0.2 second discrepancy – too inaccurate for proper reporting to IOTA.

- **Computer** – Used to capture the output of the video camera to a video file – ideally in .AVI format. For .AVI you must use the Lagarith codec which saves your video in a lossless format and avoids dropping any video frames. Laptops are needed if your scope is "mobile".
- **Video Capture Device** (If needed) – Essentially an interface between the camera and your computer. Often quite small and inexpensive they are used to convert the analog output of some cameras (with RCA jacks) to digital form, which is then input into the computer via a USB jack. A commonly used one is the StarTech SVID2USB23, which costs $35.

Obtaining Asteroid Occultation Predictions:

There are two very good sources for obtaining predictions specifically for your geographical location. Both are free computer programs you can load onto 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 events – kind of an "Occultation Astronomy Club". In short, it allows observers to "sign-up" for an occultation, provides precise information for your location, and it 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. To the right 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).

- **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 any clear night. In general, it's the more "advanced" and "deeper" program. Occult can also predict lunar occultations (and lunar grazes) of stars.

A general listing of the best worldwide events can also be found via the Internet at: http://asteroidoccultation.com/

A Useful (Free) Star Chart / Asteroid Plotting Program:

Just a quick mention of the open-source freeware program Carte du Ciel (French translation - "Sky Charts") – which can print very useful, highly configurable star charts. It can download the asteroid database (MPCOrb) from the Minor Planet Center and very accurately plot asteroid tracks – making great finder charts. It's downloadable from:
> https://www.ap-i.net/skychart/en/download

Note that some folks have recommended the use of the program "Guide9", tho I have had no experience with it to date. IOTA references this program often.

A brief word on "**Pre-pointing**"....
Pre-pointing is a method sometimes used to locate your target star. In short, if a bright(er) star exists fairly nearby, and directly west of your target star (ie., at the same declination), you can center your scope on this star, turn off any drive, wait the "time difference" in right ascension between the bright(er) star and your target star, and the Earth's rotation will center your target star for you. A wide FOV helps. If you want to try this, research it on the Internet for more information.

ASSEMBLING AN ASTEROID OCCULTATION RECORDING and ANALYSIS SETUP

First, visit this site and see what IOTA recommends and read their comments:
http://occultations.org/observing/educational-materials/equipment/analog-video-recording-in-windows/
After considerable trial and error, what's listed below is what I've found that works - **for me**. **MANY** other configurations are possible, and new equipment is coming out all the time Below is what I've found to work well – as of this writing – February 2019. What's listed below is what might be considered a good "**starter**" setup. The very specific links to equipment below may or may not be valid at the time you read this. (I'll try to keep links updated in subsequent versions of this document).

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* **Camera** - RunCam Night Eagle 2 Pro Astro Edition ($180). This camera gives an analog output (via an RCA video jack) at the standard video rate of 29.97 frames per second. There are 3 ordering options. Best to get the full kit (with two spacers and focal reducer). This camera is SMALL and LIGHT! It fits in a standard 1.25" focuser. Originally designed for flying amateur drones at night(!), it has been modified for doing astronomy.
http://occultations.org/night-eagle-2-pro-astro-edition-ordering-page/
Note that there are other cameras that are also used (but the Night Eagle is perhaps the best, and least expensive "starter" camera). There's even a camera with a built-in GPS unit which internally inserts precise GPS derived time into the video – the QHY 174M-GPS (priced about $1,240) – though its availability may be limited. New "live video" cameras are starting to become common – though nearly all are MUCH more expensive than the Night Eagle Astro.

* **VTI (Video Time Inserter)** – This unit obtains ultra-precise time (in Universal Time - UT), latitude, longitude, and elevation from GPS satellites, and inserts that 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 – LiMovie - can read its timing stamps automatically. Here's a link to the VTI sold by IOTA: http://occultations.org/observing/recommended-equipment/iota-vti/.
At the time I put my system together, the IOTA VTI (and their "Full Kit") 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 $200). Note that LiMovie will NOT automatically read the time from the Sprite. When required in subsequent reduction programs, times will have to be manually entered – which is not a problem, as long as **care is taken**.   http://www.blackboxcamera.com/pic-osd/sprite.htm.
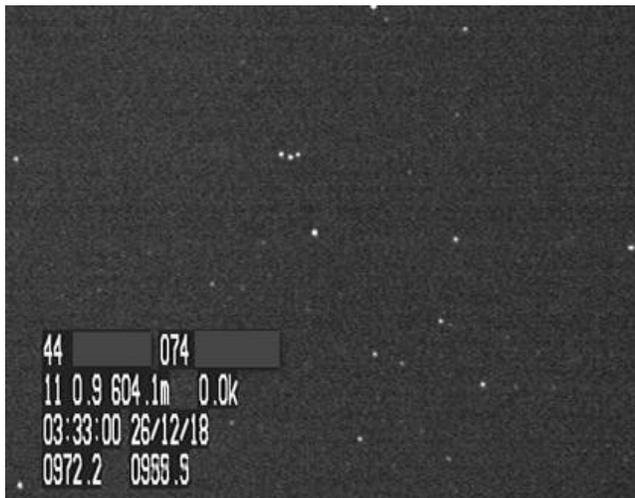
To the left is a sample of what information the Sprite3-U VTI can insert into video from the Night Eagle Astro camera (the IOTA VTI is similar). On the top line is the latitude and longitude (in this case I grayed-out the exact figures). 2nd line states it is locked to 11 GPS satellites (a min of 4 are required) and the altitude is 604.1 meters. 3rd line states it is 3:33:00 UT on Dec 26th, 2018, and the 4th line adds fractional seconds (the 1st digit should always be zero) so the time this video field was read-out was 3:33:00.9722 UT.

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 time. Otherwise the displayed time might be wrong by one or more whole seconds! Read your VTI's manual. Often this time is 15 to 20 minutes. So start your VTI early! It is highly recommended that you then 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 that it is correct!

* **Computer** - That's up to you. A specific recommendation can't be given. I'm using an old Windows XP laptop that was given to me and it works excellently. Most modern computers should work fine. A laptop is a must if you want to "go mobile". Reduce to a minimum the amount of other programs running when recording occultations. Your recording must not "drop" any video frames.

* **Keyboard** (optional for use with laptop) ($11.99):
www.amazon.com/gp/product/B07B93562V/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1

* **Mouse** (optional for use with laptop) (under $10):
Any optical USB mouse
Example - www.amazon.com/Logitech-800dpi-Optical-3-button-Ambidextrous/dp/B003L62T7W/ref=sr_1_6?s=electronics&ie=UTF8&qid=1542414701&sr=1-6&keywords=optical+USB+mouse

* **12VDC from AC Power Supply** ($11.95):
Powers both camera and VTI. Use this if you have available AC power.
www.amazon.com/gp/product/B00K919SHG/ref=oh_aui_detailpage_o01_s00?ie=UTF8&psc=1

* **12VDC "Y" Splitter cable** - 1 female end, 2 males ($6.60):
For use with the above AC power supply
www.amazon.com/SIM-NAT-Splitter-Adapter-Security/dp/B01GPRLQCC/ref=sr_1_9?s=electronics&ie=UTF8&qid=1542564862&sr=1-9&keywords=12v+dc+y+power+splitter+cable

* **12VDC Battery Power Supply** ($29.99):
Powers both camera and VTI. Use this if you are "going mobile".
www.amazon.com/gp/product/B00MF70BPU/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1

* **12VDC "Y" Splitter cable** - all (3) male ends
This is required as the _Battery_ power supply needs to power both the camera, and VTI, and all 3

have female jacks. I could not find a splitter with 3 male ends – so I had to custom make one. Purchase individual male leads (parts $9.70) and solder together an "all male Y".
www.amazon.com/gp/product/B072BXB2Y8/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1

* C**amera video & power cable** ($7.99):
Video from, and power to the camera - all in one cable.
www.amazon.com/gp/product/B019TUJ0MK/ref=oh_aui_detailpage_o06_s00?ie=UTF8&psc=1

* **Camera Analog to Digital USB converter** – StarTech SVID2USB23 ($33.51):
Digitizes the camera signal and inputs that into the computer via USB.
www.amazon.com/gp/product/B00535BRBI/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1

* **Video Capture Software** (FREE):
This will depend on the computer you have, and simply what works. I use the program VirtualDub and love it, but supposedly it only ideally works with Windows XP. If you have an old computer and you need VirtualDub, do a search for it on the Internet.
For Win10 computers IOTA recommends that you try IOTA Video Capture, available here:
http://occultations.org/observing/software/

In short, all the hardware for properly recording occultations should currently run about $500 to $550. (Not including the computer, and optional external keyboard and mouse for use with a laptop).

* **PVC Camera Extender Tube:**
(You would have to make this - easily made, and inexpensive) .
This is very handy as it will allow the RunCam Night Eagle camera to reach focus in nearly any telescope - providing that scope has a 2-inch focuser. NOTE: Most cameras requires an "in-focus" a bit further in than is required by most all

eyepieces - and the stronger the telecompressor, the more "in" focus is required. This can present a problem, especially for reflectors.
When using the Night Eagle Astro camera, this extender tube is also useful in very cold temps as the end extending out of the telescope can be "plugged" lightly with a cloth, and the heat generated by the camera will keep the camera from getting "too cold" - when used in temperatures below, perhaps 10 or 20 degrees. DO NOT plug the end in temps above freezing as the camera DOES generate a notable amount of heat, and in warm temps, that heat MUST be dissipated. 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/

ANALYZING YOUR RECORDED VIDEO

Once you have recorded an occultation to a video file on your computer, you need to analyze it.

**LiMovie** – [Initial] Video Analysis Software (Free):
This is an excellent initial video analysis program, and reads an .AVI format video file. 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. LiMovie will clearly allow you to see if you recorded even a low mag dip or very brief occultation. It also creates an Excel spreadsheet of your recording that IOTA wants. (Note: LiMovie will not automatically read the Sprite3-U VTI time off the video. When needed, you will have to enter this manually). This program is available as a free download from:
http://occultations.org/observing/software/

To the right is an image of what the (389) Industria occultation looked like when run through LiMovie (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 really show. Looking at the graph produced by LiMovie clearly showed the event. (Pink is a comparison star).

A good intro tutorial on LiMovie by the late Brad Timerson of IOTA can be found on YouTube under the title "Basic Use of LiMovie".
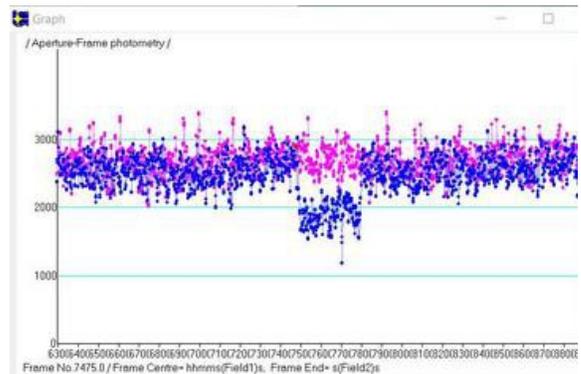

The above is all you need if you observed a "Miss" (No occultation). You then output the resulting .CSV file created from LiMovie, and fill in the required IOTA Asteroid Report Form:
http://www.asteroidoccultation.com/observations/Forms/AsteroidReportForms.html

PyOTE (Free):
If you DID observe an occultation, you need to do further analysis of the video to obtain EXACT disappearance (D), and reappearance (R) times. It's suggested you download the Free analysis program "PyOTE" from http://www.asteroidoccultation.com/observations/. Follow the download and operational instructions. You may have to manually key in times from your video. Again, submit results via the IOTA Asteroid Report Form. There are several other analysis programs, but PyOTE is perhaps the "easiest", and a good one to start with.
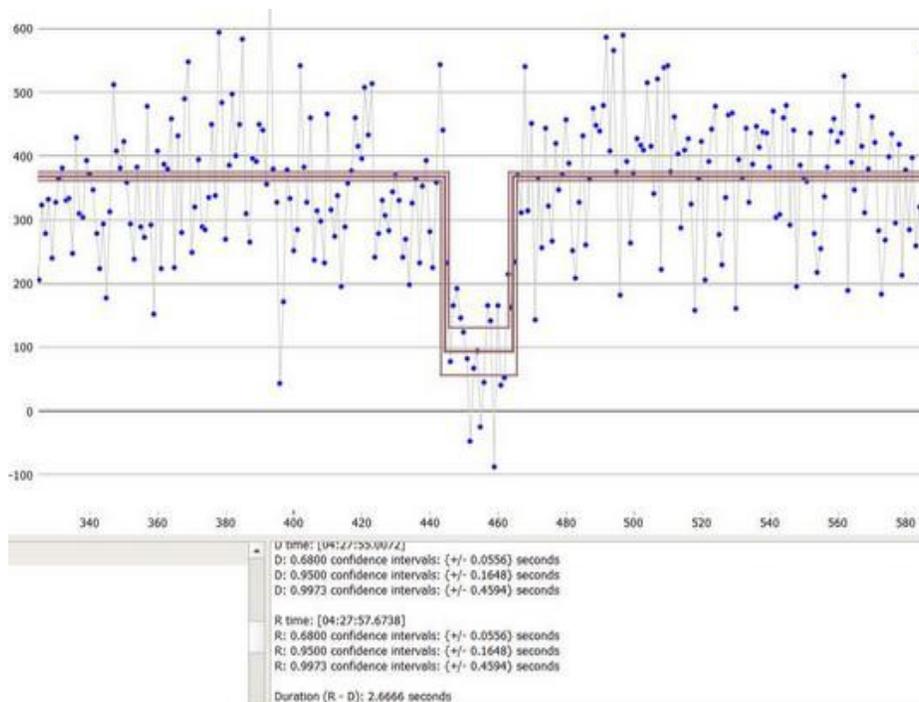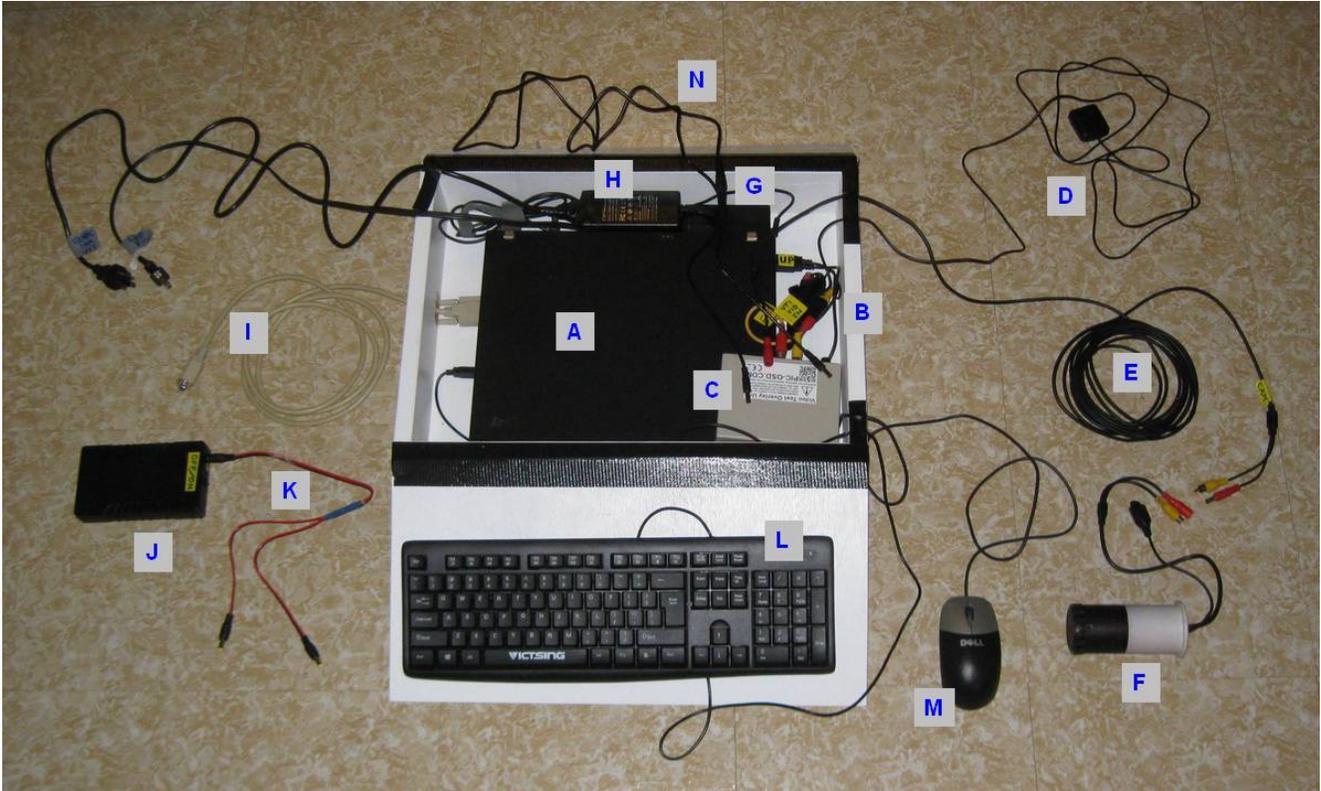

Above: PyOTE analysis of another event

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Some example 'Occultation Rig' Images:

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 the rig in cold winter temperatures):
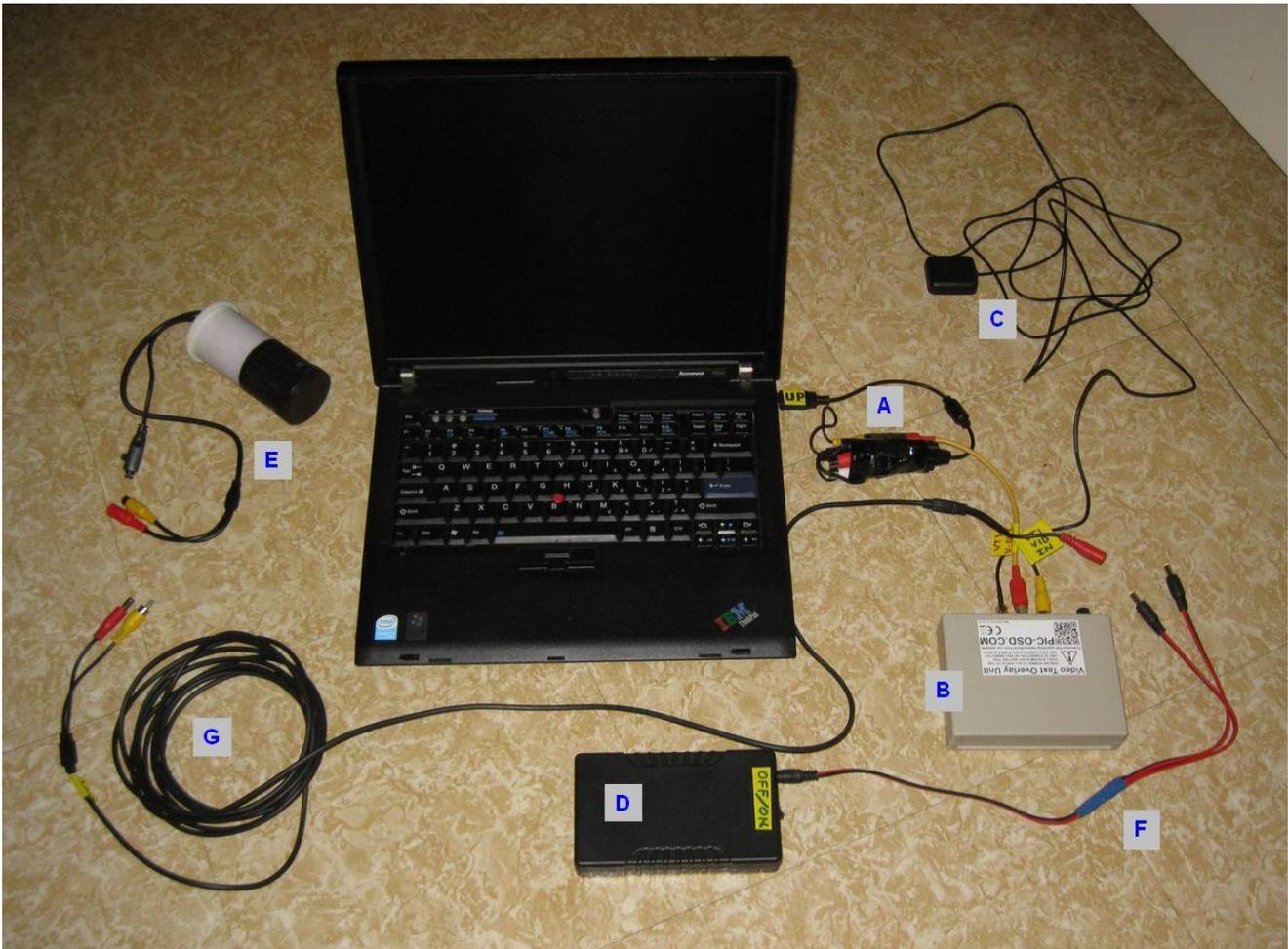

A - Laptop (closed)
B - Video capture device - StarTech SVID2USB23 (not well seen)
C - VTI Unit – Sprite3-U (the IOTA-VTI also works here too)
D - VTI's GPS antenna
E - 16-foot cable to camera (video & power)
F - Night Eagle 2 Pro Astro Camera in PVC housing
G - AC to 12VDC power supply (required for VTI & camera)
H - Laptop's AC power supply adapter
I - (optional) external monitor cable
J - 12VDC Battery Power supply (not needed if AC is available)
K - Homemade 12VDC "Y" power splitter for above (3 male ends)
L - (optional) External Keyboard
M - (optional) External Mouse
N - "Y" adapter cable from AC to 12VDC power supply (plugs for VTI & camera)

IOTA's Own Complete Occultation Recording Kit (components similar or the same as above)**:**

Note: IOTA now sells a "Complete Occultation Kit" - which includes the Night Eagle 2 Pro Astro camera, IOTA's own VTI, the StarTech SVID2USB23 A-to-D converter, and all needed cables, battery holders, etc.... Just add a laptop and install some free video capture software. Cost: $518 plus shipping. Here's a link to the page: http://occultations.org/observing/recommended-equipment/iota-vti/

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A "Mobile Battery Powered Laptop Rig"

A - Video capture device - StarTech SVID2USB23
B - VTI Unit – Sprite3-U (the IOTA-VTI also works here too)
C - VTI's GPS antenna
D - 12VDC 6000mAh rechargeable Battery Power supply
E - Night Eagle 2 Pro Astro Camera in PVC housing
F - Homemade 12VDC "Y" power splitter (3 male ends – powers VTI & camera)
G - 16-foot cable to camera (video & power)

***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.*

Hope this helps. Happy Shadows,

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

It is requested that I be advised of any revisions made to this document **before** it is further distributed to the public. Please
also inform me of any public links made to it (helps me keep versions out there current), and if parts of it are used in writing
other similar documents, I would appreciate this document being listed as a reference.

Version 2.3.2 – February 7th, 2019