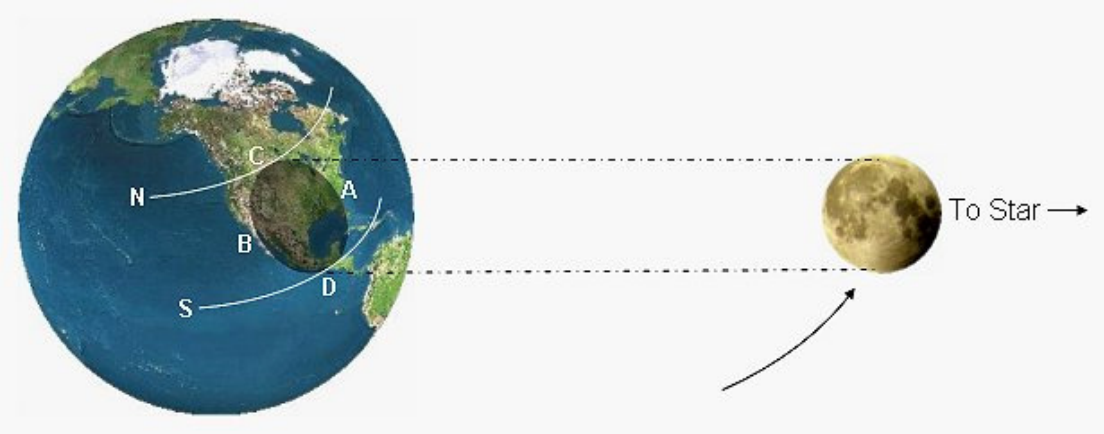
A BRIEF OCCULTATION TUTORIAL

This is intended to describe the basics of occultations in a condensed setting. It may help the reader decide whether to explore interest in one aspect of occultation observing or another. There are two basic areas of occultation astronomy: lunar occultations and asteroid occultations, though there are other types of occultations such as those of stars by comets and occultations of stars by Trans Neptunian Objects (TNOs), Kuiper Belt Objects (KBOs) and others. These latter objects are covered under the grand heading "asteroid occultations". Occultation observing is a fun venture that almost anyone with any background can do and can lead one toward a potential career in astronomy.

Basics of Occultations



As the Moon moves in its orbit, its projection on Earth results in a total lunar occultation for those observers between points C and D**,** while a grazing occultation occurs at points **C** and **D** or anywhere along lines N and S.

Lunar occultations are more easily observed by those with small telescopes since they do not involve having to locate a dim star in the sky. Simply find the Moon and locate the position along the edge of the lunar surface where the predicted star is expected to be before it slides behind the lunar features. Usually these features are not illuminated by the Sun (the Moon's dark non-sunlit side) making detection of disappearances and reappearances easier (because of the higher contrast). Start with total occultations which occur nightly from nearly everywhere on Earth, and then graduate to grazing occultations at the north or south poles of the Moon. These events are more rare and may require travel outside of your immediate area.

Observing lunar occultations tend to be fun and not as important scientifically as they were in the last century. They provide novice observers with a training tool from which they can make timings using visual means or more advanced methods such as with video. After experiencing

how interesting lunar occultation observing can be, one can progress to the next level – asteroid occultations.

What Do You Need in the Way of Knowledge and Equipment?

You will need first a good, independent ability to find stars in the sky, a telescope with or without a tracking platform, and basic internet access. One cannot completely depend on automatic GO-TO telescopes to do all the work to find a target star which is scheduled to be eclipsed by a passing asteroid. It is mandatory to learn how to use star charts and in particular, to know how to "star hop" to the target star which could be anywhere from 6th magnitude to 13th magnitude depending upon the level of difficulty of the occultation target star. This area of occultation work provides the greatest opportunity for real discovery – unknown double stars, determination of the shape and size of minor planets, and possible detection of a new natural asteroid satellite!

To observe a total lunar occultation you need:

a) telescope,

b) recorder that can record your voice, either cassette or digital voice recording device,

c) shortwave radio that can pick up time signals at either 5, 10 or 15 Mhz (North America),

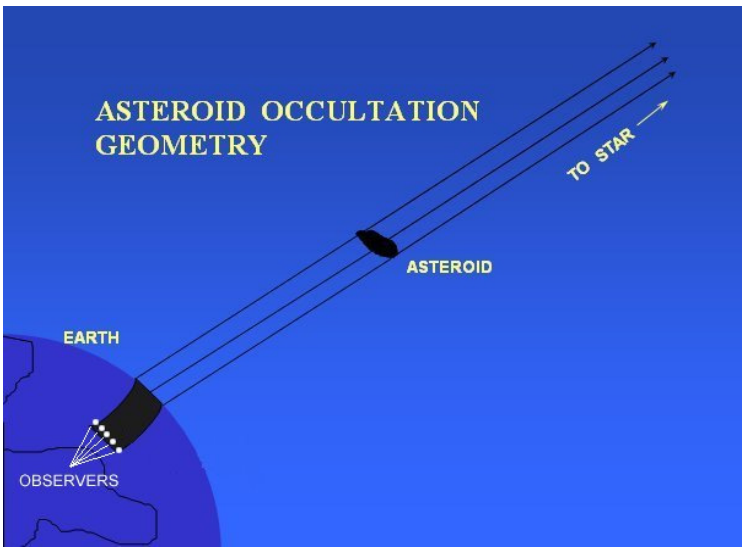
d) predicted time of the occultation event at your location.

You will begin by observing a star undergoing a lunar occultation, then recording it and consulting the *IOTA Manual** (chapter 3 and other online IOTA resources) to reduce and report your data. The next phase will be to test your ability to observe (and perhaps record using the same the same equipment) an asteroid occultation. Your prediction resource will be from www.asteroidoccultation.com which will aid you in geographic areas of best viewing, key information on each occultation, and star charts; then www.poyntsource.com/New/Global.htm to give you access to very detailed interactive maps to help you select an observing site and identify its precise geodetic coordinates in latitude and longitude. The *IOTA Manual** Appendix F will show you how to submit your observations.

If you enjoy this observation you can then advance to the next phase which is video recording of an asteroid occultation but this will require an investment of perhaps $300-$500 more or less to obtain a Supercircuits PC164C-EX-2 video camera, battery, camcorder (or digital video recorder, DVR), PA3 microphone; Canon ZR camcorder (usually from ebay) associated cables and an *IOTA VTI GPS time inserter*** . In lieu of the IOTA VTI GPS Time Inserter, once can use a shortwave radio (approximate cost $50-$75) to receive time signals as stated above.

The GPS based video time inserter will identify and record the observing site location's latitude and longitude. The GPS (Universal Time, UT) time will be overlaid on the video in real time to

1/100 of a second or better. Bright star asteroid occultations usually require that the observer be mobile and travel. Only occasionally (typically a few times/year) can one observe an asteroid occultation from his/her home – the path widths (20km – 250 km) must cross over where you live. Being mobile will bring more events into range and provide more opportunities.



Above: Asteroid occultation geometry. As the asteroid moves in its orbit, a shadow is created from light cast by the star about to be occulted. The shadow then moves across the Earth. (Diagram not to scale)

Sample video frames from a GPS Video Time Inserter.

LEFT – Star about to be occulted by the Moon. RIGHT – star is occulted by the Moon's dark side. Notice the 0.033sec time increment from the left frame to the right frame. Moon's dark side is barely visible, sunlit part of Moon is extreme upper right

LEFT: Time/date displays reads: 3h 47m 30.574sec, March 26, 2010

RIGHT: Time/date displays reads: 3h 47m 30.607sec, March 26, 2010, this is 0.033sec (one video frame) later

More about asteroid events and how to observe them is in the *IOTA Manual** Chapter 6 and timing techniques for occultations see Chapter 8.

Single Observers vs. Multiple Observers

For both lunar and asteroid occultations a single observer can produce but one data point, unless he/she is highly experienced in setting up multiple unattended video stations. One observer can achieve success but must never do so at the expense of other observers. Therefore there is a great need for a team of individuals working in coordination with one another or with other individuals/teams either nearby or in other geographic regions in order to maximize the amount of data that can be collected for a particular occultation.

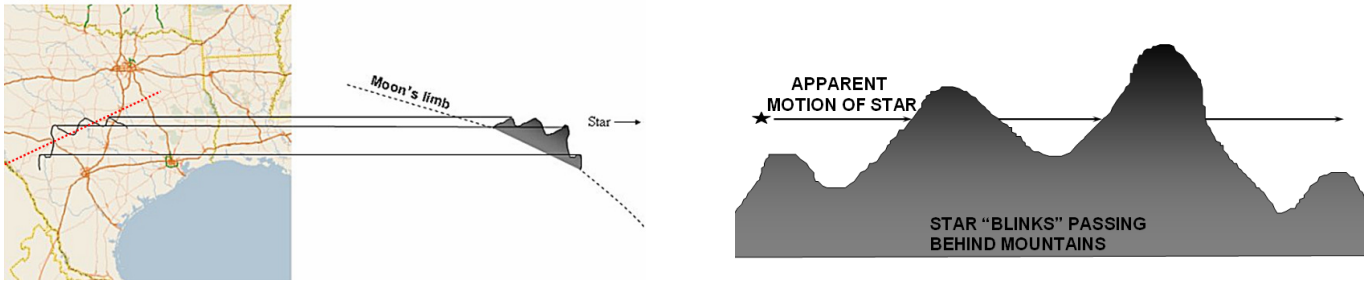
*Occult Watcher*** is a program that displays the intended locations for observing asteroid occultations. Each observer inputs a location which then pops up as an icon on the path map. This allows one to avoid duplication of sites to optimize coverage and promote teamwork. Advance coordination of observation should be done in order to maximize results but especially to overcome weather obstacles. An experienced observer should be responsible to help train new people in the proper methods of understanding the predictions and how to accomplish successful data collection. The goal, beyond that of having fun, is to collect information that will be scientifically useful. Discipline and adherence to procedure will help achieve that.

For lunar occultations, a single observer can only sample one small region of the lunar terrain as the star alternately disappears and reappears. By including other observers located at different places and spaced perpendicular to the first one, sampling of successive areas north and south can be made until the farthest observer is actually outside the path and sees no disappearance or reappearance. A "miss" (no occultation seen) observation might seem rarely useful but in occultation astronomy that data can be scientifically valuable. It can an define the upper limit(s) of certain lunar features. A team is needed for a different reason where asteroid occultations are observed since the predictions are less reliable. A single observer may or may not actually see the asteroid occultation, but a broadly spaced team of observers will help ensure that the asteroid is actually observed to occult the star and can define areas where no occultation is seen. This provides valuable clues as to the prediction quality and can more accurately define the size of the asteroid shadow and size limitations of the asteroid.

What an Observer Should Expect to See

A total lunar occultation will result in the star disappearing once, then reappearing tens of minutes later. For lunar grazing occultations, an observer should expect to see (from the diagram below) the star first as it approaches the lunar limb, then as it is alternately hidden by changing topographic features. The sequence of events typically lasts from less than one minute to perhaps 2-4 minutes. Predictions of these events are generally quite accurate; the idea is to accurately time each disappearance, blink, dimming, reappearance and any other optical phenomena visible

during the graze. This is best and most precisely accomplished with a sensitive surveillance-grade video camera attached to a telescope since the human eye/brain combination cannot react fast enough in the case of rapidly occurring activity. Step events (where the star's brightness does not drop or return instantly) may also be detected. Such events may be a signal of a double star. As can be seen by the diagram below of the projection of the Moon's limb onto the Earth's surface, a team of observers are needed to map the entire limb. They should be spread out perpendicular to each other to cover the entire mountain range.



LEFT – Lunar Grazing occultation geometry. Projection of Moon's edge on Earth.

RIGHT – as the Moon moves, the star disappears/reappears as it passes behind very specific lunar features.

For asteroid occultations it is not required to see the asteroid --*only the star*. The asteroid is usually several magnitudes fainter and most of the time too faint to be detected in a small telescope. Predictions provide information on the level of drop in the star's light and the expected duration (unlike that for grazing occultations). An observer can expect to see a single disappearance (or drop in starlight) and a single reappearance though it is possible to see step events. All changes in the star's light must be accurately recorded and timed. A video camera and GPS time inserter are the best tools for this since passing clouds or poor seeing conditions can confuse a visual observer.

As the asteroid moves in its orbit, it projects a shadow across Earth. Rarely, an unknown asteroid Moon moving with it creates opportunity for discovery. Such secondary occultations should be expected to occur within +/- one minute of the actual asteroid occultation and be of very short duration, perhaps a fraction of a second

In many cases the predictions for asteroid occultations will result in no occultation observed. This may be due to inaccurate data on the star position and/or asteroid orbit. Individually or combined, such errors contribute to what is termed a "miss" observation. Unlike some disciplines of astronomy, such negative data is always useful as these "misses" define size limitations on the asteroid observed.

Will I Be Paid for My Observations or Equipment?

No. There is no payment for your effort. Occultation observing is primarily the result of amateur astronomy. The word amateur means the equivalent of 'lover of'; work is voluntary except by those from the professional community. You will have to obtain your own telescope, timing equipment, video camera and any other tools necessary to observe. While IOTA has attempted to obtain funding in the past, it has so far eluded us. This does not mean that a creative individual or group could not locally find a way to obtain money to provide equipment for observers as is done in schools for sports.

Timing

Without having a record of accurate time, your observations are relatively useless for scientific contribution. If you are calling out your times into a voice recorder while watching through the telescope, your reaction time (difference between the moment you saw the event and when you called it out) varies from a large fraction of a second to several seconds depending upon the level of experience of the observer and other factors. Occultation timings are generally needed to millisecond accuracy (0.033sec) or better. This is best accomplished by video with a GPS time inserter. Beginning visual observers can use a tape recorder and voice "call outs" to record an observation but one will soon easily see upon attempting to reduce data from several closely spaced observers that there are significant errors in the visual observing / timing process. The best method of recording an occultation of any type is with a sensitive video camera, a GPS time inserter and a digital or analog camcorder--*not a computer*. While a laptop computer seems like an ideal method to record video/timing with the multitude of software applications/video capture cards – there are inherent problems and processing delays with these setups that can lead to timing errors of 0.10sec and larger. If you have a laptop computer, there is a way to record and time occultations with it tat is GPS Time based. See Gerhard Dangl's website which explains how to do it: http://www.dangl.at/menu_gge.htm

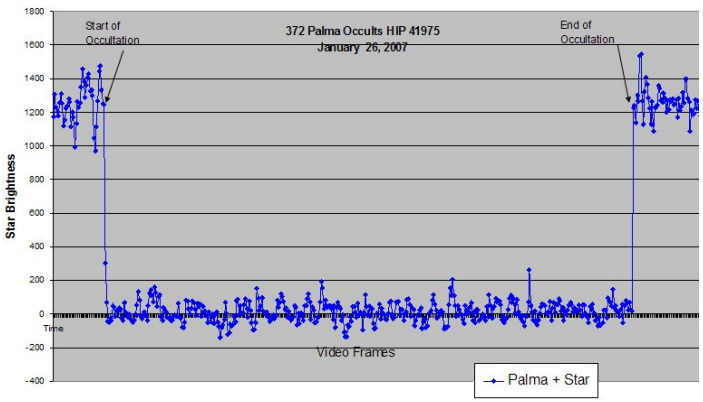
The necessary equipment (video camera, camcorders, DVR's) for occultation timing can be obtained in part from the used marketplace such as on www.astromart.com and www.ebay.com.

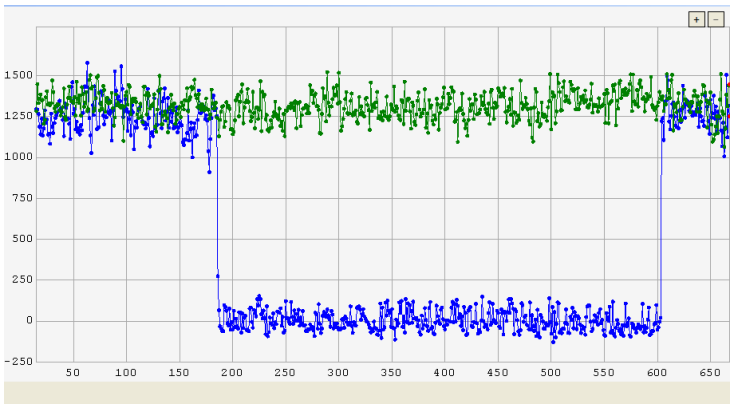
The Importance of Timings and Your Ground Position

Time is the most important element in occultation observing for two reasons. You must have the most accurate time for your observations. Secondly, time is of the essence in planning for a particular occultation. The observer will have to define a 'timeline': planning the location of the site (if not observing at home), traveling to it, assuring its security, setting up equipment, dealing with unanticipated problems, locating the target star, and then making the observation. There are many factors that can impact execution of the timeline. In addition, your position in latitude and longitude needs to be known to ±100 meters for an asteroid occultation and ±10 meters for lunar/grazing occultations. Your elevation (altitude) needs to be known to ±5 meters. The GPS Video Time inserter described above displays the ground position and altitude on your recorder. Or one can determine their position/altitude from a low cost GPS commercially available receiver and/or online topographic maps.

Data Reduction

Data from your efforts using video can be reduced by the software programs *LiMovie*[1] or *Tangra*[2] which will take video data and analyze it for occultation events, both for grazing occultations and asteroid occultations. *LiMovie*[1] or *Tangra*[2] are free and are accurate tools. It can be learned at home on your own. There are also more experienced *LiMovie*[1] and *Tangra*[2] users who can be consulted if one has questions. Dr. Richard. Nolthenius has a website explaining how to get your videos into a format for *LiMovie*[1] - http://www.cabrillo.edu/~rnolthenius/astocc/HowTo.html





Both graphs above show a 13-second duration drop in a star's light level caused by the asteroid 372 Palma passing in front of it.

LEFT – Light curve from *LiMovie*[1]. It shows the exact video frame of disappearance and reappearance of the target star (each blue dot represents a video frame, 0.033sec interval). **RIGHT** – Same results from the program *Tangra*[2]. Green data points are from a comparison star in the field whose brightness remained constant.

The Importance of Focal Reducers

Finding a target star is the biggest challenge for asteroid occultations. The widest possible field of view is required especially for the dimmest target stars. To obtain this a focal reducer is extremely helpful. If one is not used the process of finding the target (or refinding it) tends to be quite long and if an observer is having difficulty it could become an impossible task if one does not have sufficient star finding skills or have enough time.

Sources of Useful Information

The *IOTA Manual** is a primary source for your reference. You may also Google the International Occultation Timing Association online to consult its various sites for key items, results, processes, publications and names of key people in the field. The *Journal of Occultation Astronomy* (JOA) is the official publication which documents results of IOTA work.

Obtaining Advice and Communicating With Others

IOTA has a list server which can be used for (important and timely) written communication between occultation observers. It can also be used to obtain key contacts and advice. *It is not a tool for trivial conversation*. Planning and coordination amongst local observers should be done by phone, email or other communication tool; usually face to face communications is best. But the IOTA list server[3] can be an important aid in getting answers to questions for which you are experiencing great difficulty. The IOTA list server[3] page has many useful photos, files, charts, and graphs that may have already answered some of your questions; study them before you post on the list server.

Reporting Your Data

There are report forms for lunar and asteroid occultations and they must be submitted as soon as possible after your observation has been made. These forms have been developed over the years and are vital to collecting the minimum amount of detail necessary to process raw data into really useful information.

Asteroid occultation report forms can be found at
http://www.asteroidoccultation.com/observations/Forms/AsteroidReportForms.html

Lunar occultation Report forms are in Excel format and can be downloaded from http://www.timerson.net/IOTA/LunarOccultationReportFormV2.0c3.xls

These report forms are also listed and explained in the *IOTA Manual** Appendix F.

Rewards and Recognition

Beyond simply enjoying an occultation in real time, your work may lead to being cited in a science publication or even a co-authorship of a technical article; it may result in a discovery credited to you or your group or to local recognition by an astronomical society. Occultation projects have been presented at science fairs. Some lucky amateurs have had an asteroid named after them and others have been the recipient of the prestigious Homer DaBoll Award[4] given out by IOTA for outstanding achievement in the field.

*IOTA Manual - http://www.poyntsource.com/IOTAmanual/Preview.htm

**IOTA VTI GPS Time Inserter - http://videotimers.com/home.html

***Occult Watcher - http://www.hristopavlov.net/OccultWatcher/OccultWatcher.html

[1]LiMovie - http://www005.upp.so-net.ne.jp/k_miyash/occ02/limovie_en.html

[2]Tangra - http://www.hristopavlov.net/Tangra/Tangra.html

[3]IOTA List Server - http://tech.groups.yahoo.com/group/IOTAoccultations/

[4]Homer Daboll Award - http://asteroidoccultation.com/observations/DaBollAward/DaBoll.htm