Asteroid Occultation Observations

2013 Sigma Pi Sigma Undergraduate Research Award

Final Report

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Introduction

As an asteroid orbits the Sun, it will occasionally pass directly in front of a distant star as seen from an observer on Earth. The Earth-based observer will see the light from the star dim for a few seconds as the asteroid crosses in front of it. This event is called an asteroid occultation [1].

The geometry of an asteroid occultation may be easier to visualize if one thinks in terms of the shadow cast by the asteroid. Because the star is effectively at an infinite distance from the asteroid, the light rays from the star are parallel and the asteroid shadow has the same size and cross section as the asteroid itself. The combination of the asteroid's orbital motion and the rotation of the Earth will cause this shadow to sweep across the Earth's surface, creating a shadow band several kilometers wide and several hundred kilometers long (see Fig. 1).

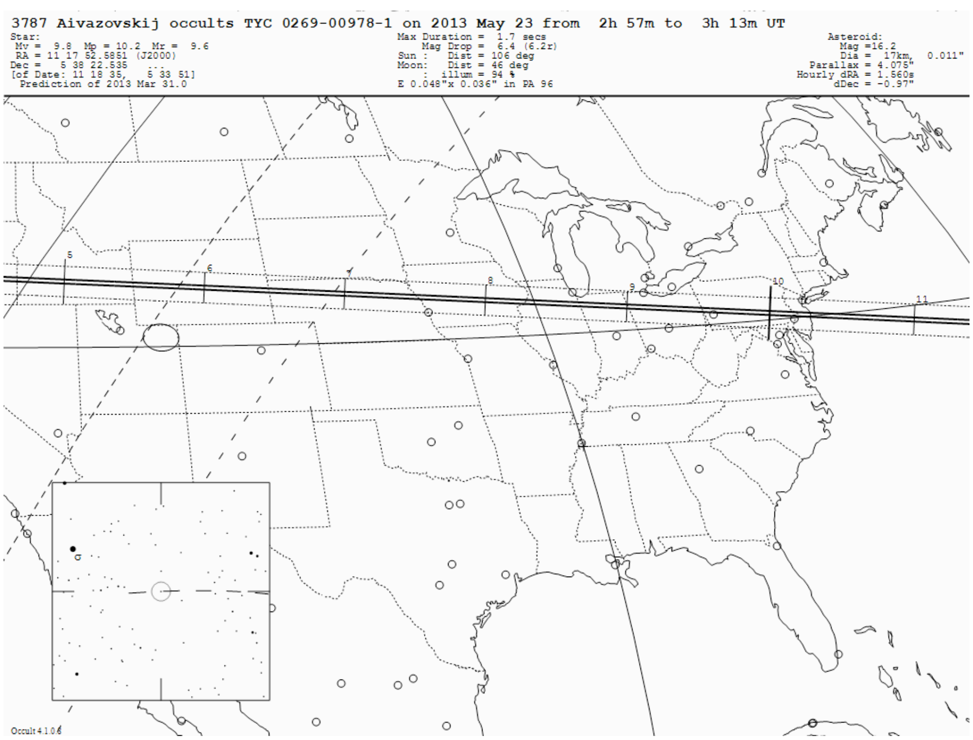

Figure 1: Example of an asteroid shadow path prediction. The dark lines represent the predicted shadow path, while the lighter gray lines are the 1-sigma confidence interval.

Any observer within the asteroid's shadow path can potentially observe the asteroid occult the distant star, and the duration of the occultation is a measure of the width of the asteroid along the line joining from the observer to the star, passing through the asteroid. If several observers situated across the shadow path each measure the duration of the occultation event, each will measure a different time interval and thus a different diameter corresponding to a different chord passing through the asteroid. Combining these different occultation measurements makes it possible to reconstruct the size and shape of the asteroid (Fig. 2).

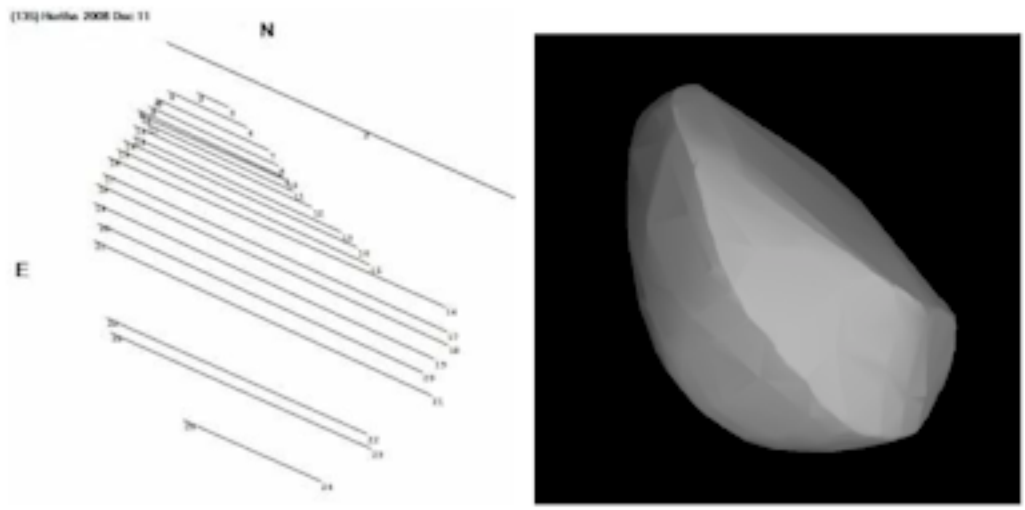

Figure 2: Profile determined by asteroid occultation observations (left) compared with the shape determined by radar methods (right) for asteroid 135 Hertha.

Asteroid occultations are thus one of the few ways to directly determine the physical properties of an asteroid, and the only method available to those without highly specialized equipment (i.e. spacecraft or large radio telescopes).

Asteroids have captured the attention of the scientific community for several reasons. Because asteroids did not go through the heating and differentiation processes common to the Earth and the other terrestrial planets, the material that makes up asteroids reflects the composition and distribution of matter in the very early Solar System, almost five billion years ago. Asteroids are the fossils of the Solar System, and their shapes and rotational behavior preserves a faithful history of its formation and evolution. Recently, there has been a growing realization of the dangers posed by impacts with near-Earth asteroids, and an associated effort to track and characterize these potential threats to life on Earth. Finally, several public and private organizations are developing plans to launch space missions to touch down on asteroids, with the goals of returning samples for study on Earth and to explore the potential for mining the rich mineral deposits present in asteroids.

Project Goal

Given the ever growing importance of asteroids in scientific studies, policy making, and even commercial mining interests, there is a pressing need for more detailed information about their individual and collective physical properties. The goal of the research project supported by the Sigma Pi Sigma Undergraduate Research Award is to record asteroid occultations and determine the size and shape of the asteroid using measurements carried out by teams of students from the Juniata College Chapter of the Society of Physics Students.

Methods

The successful observation of an asteroid occultation and the determination of an accurate shape and cross section of the asteroid involves several steps: planning, observation, and data analysis.

Planning an asteroid occultation is made much simpler through the use of the freely available software, *Occult Watcher* [2], which provides accurate predictions for asteroid occultations based on the observer's latitude and longitude (Fig. 3). Most helpfully, it can superimpose the calculated asteroid shadow path onto Google Maps, making it possible to plan precise observing locations in advance of the occultation (Fig. 4).

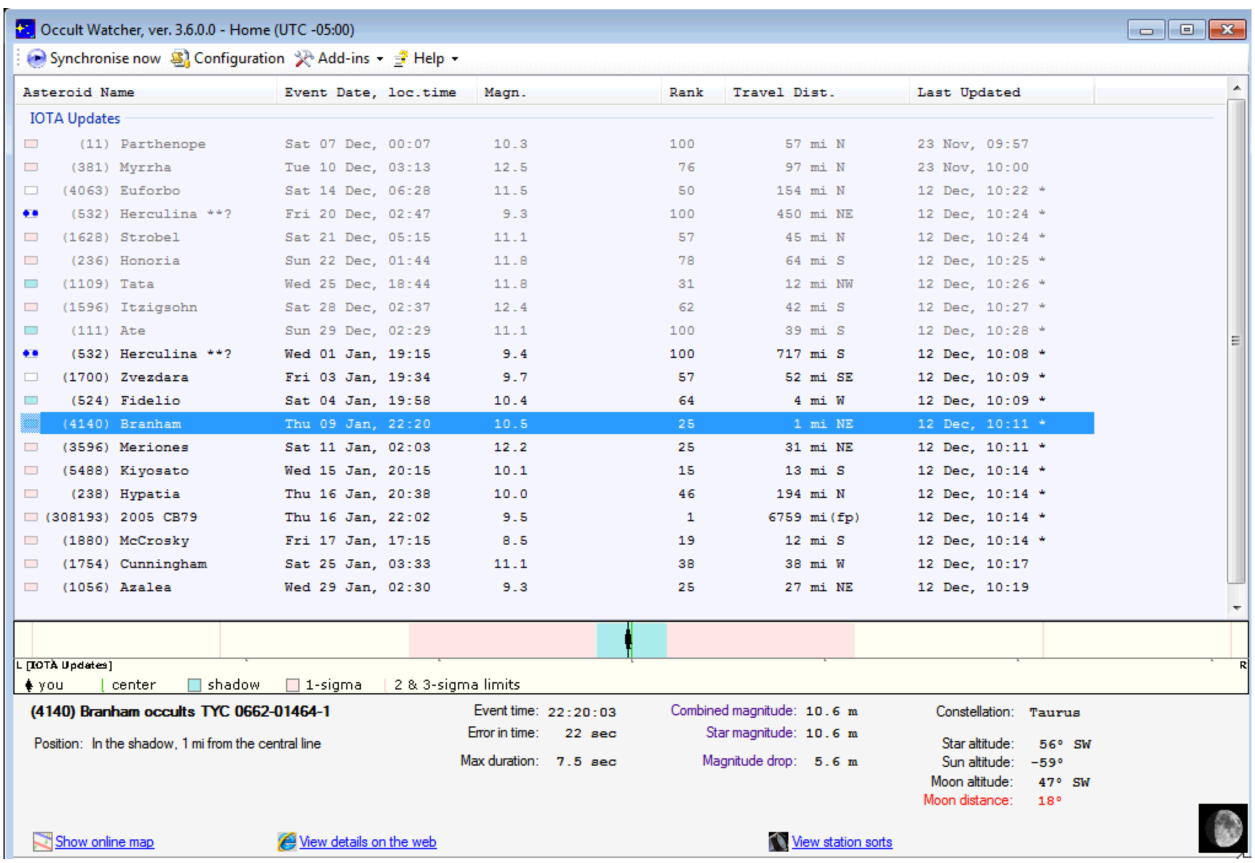

Figure 3: A screenshot of the list of asteroid occultation predictions for Juniata College generated by the software package *Occult Watcher*.

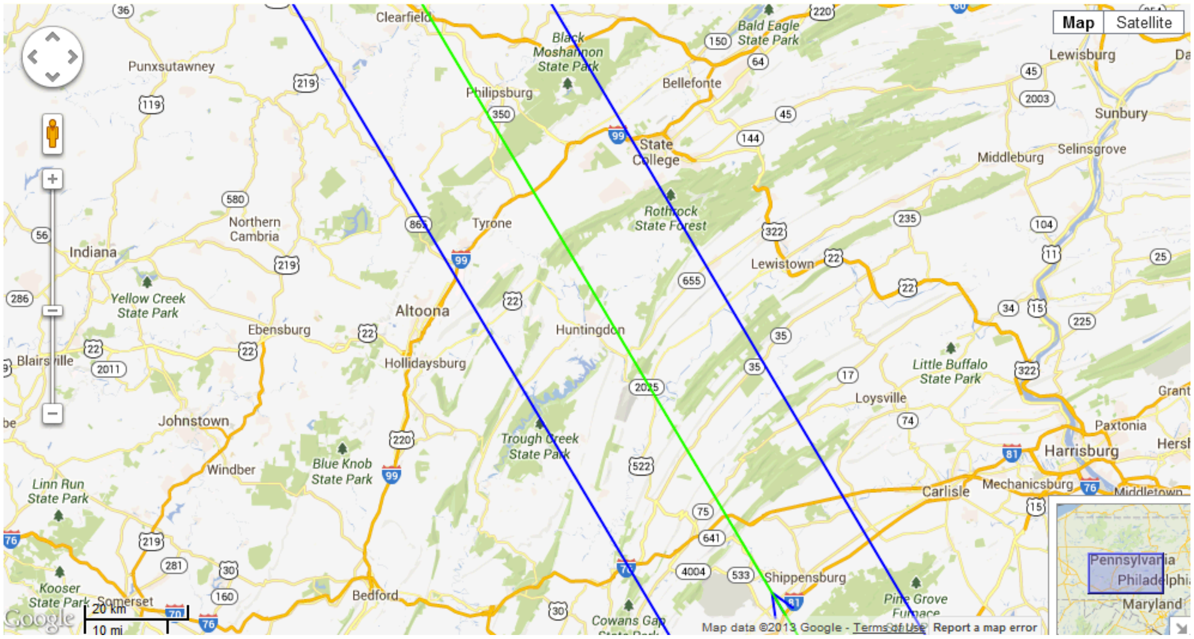

Figure 4: An example of the overlay of the asteroid shadow path on Google Maps as generated by Occult Watcher. The green line is the predicted center line of the shadow path, and the blue lines are the predicted shadow limits.

Once the details of the asteroid occultation event are established, three teams of observers are sent to predetermined locations spanning the asteroid shadow path. Each team has a complete recording setup consisting of a portable telescope, a low-light video camera, a video time inserter, a digital video camcorder, and a portable 12 volt power supply (details are provided under **Equipment** below). If the projected shadow path passes across the Juniata College campus, then a fourth observing team will use the permanent telescope at the college's Paul E. Hickes Observatory. Each observing team makes a video recording of the occultation event via the low-light camera installed in place of the telescope eyepiece. The video will show the occulted star dim for several seconds before returning to its normal brightness.

After the successful recording of an asteroid occultation by one or more of the observing teams, the video(s) of the occultation is copied to a computer and analyzed using the free software package LiMovie [3], which determines and plots the brightness of the target star frame-by-frame. The occultation will appear on the plot as a sudden drop in the star's brightness, followed by an equally rapid return to its original brightness a few seconds later (Fig. 5). When combined with the GPS timing information overlaid on the video by the video time inserter, the start and end times of the occultation event can be determined to within 1/30th of a second. Finally, the timing data from the three or four Juniata groups is collected together to establish the rough shape of the asteroid. The results of all timing observations is also be submitted to the International Occultation Timing Association, where it is combined with observations of the same occultation by all observers along the shadow path in order to produce a more detailed cross sectional outline of the asteroid.

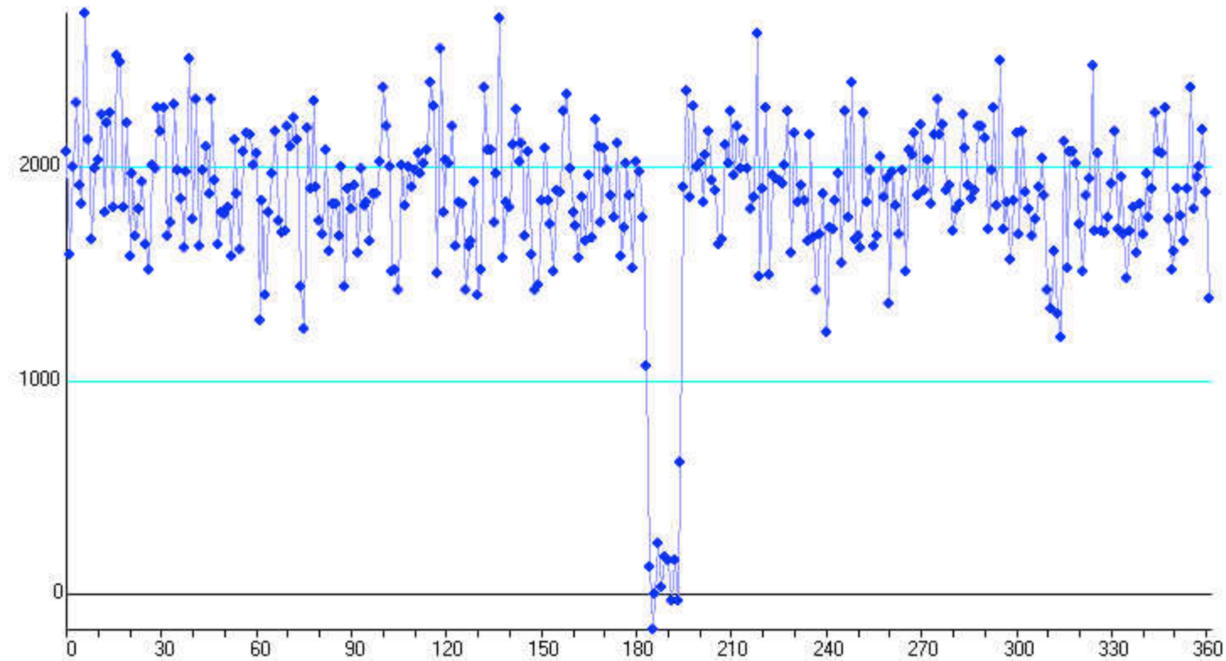

Figure 5: LiMovie plot of a successful occultation observation of Asteroid 1998 RV1, recorded by Kerry Coughlin on December 28, 2008.

Equipment

The funding provided by the Sigma Pi Sigma Undergraduate Research Award was used to purchase the equipment necessary to provide three teams of observers with a complete asteroid occultation recording setup. A fourth observing team at the Paul E. Hickes Observatory on the Juniata College campus could use equipment already owned by the Juniata Physics Department.

A list and brief description of the equipment involved in this project is provided below.

<u>Meade ETX80 Telescope</u>: This 80 mm aperture telescope is capable of finding and tracking celestial objects (such as the target star) through the included Autostar handset. As a bonus, the specific model purchased came with a backpack for easy storage and transportation.

<u>SuperCircuits PC164CEX-2 Low-Light Video Camera</u>: Designed for low-light surveillance, this camera is ideal for precisely recording the changing brightness of the (generally dim) target star throughout the occultation event.

<u>Focal reducer and adapter</u>: These are used to connect the low-light camera to the telescope in place of the telescope eyepiece, and to reduce the focal length of the telescope in order to provide a wider field of view.

<u>IOTA Video Time Inserter</u>: The video signal from the low-light camera passes through this device before being recorded by the JVC digital camcorder. Using a built-in GPS chip, the video time inserter overlays a highly precise timestamp on each frame of the video recording.

JVC camcorder: The video with the corresponding time overlay is recorded to a SD card using these camcorders. These were already owned by the Juniata College Physics Department and not purchased with grant funds.

Celestron 12 amp-hour Power Tank: When fully charged, these power tanks can provide several hours of current at 12 volts to power all of the equipment at the remote occultation observing site.

Activities and Future Plans

Upon receipt of the funds made available through the SPS Undergraduate Research Award, orders were immediately placed for the required equipment. By mid-March, 2013, all items had been received.

During the remainder of the spring semester, a group of about 10 students from the Juniata College Society of Physics Students Chapter met several times to learn how to set up and use the portable occultation observing kits. The first meetings were held indoors, but later practice sessions were held under the stars at night. By late April, 2013, the student observers were sufficiently prepared to attempt a “live” occultation observation.

The best asteroid occultation opportunity of the spring semester took place at approximately 11:00 pm EDT on May 22, 2013. The asteroid 3787 Aivazovskij was projected to pass in front of the relatively bright star TYC 0269-00978-1 for an occultation duration of 1.7 seconds, with the approximately 20 km wide shadow path falling very close to the Juniata College campus. Observing locations across the shadow path were determined in advance, and observing teams prepared for the event. Unfortunately, while clear skies were predicted for the night of the occultation event, skies were in fact overcast and the event could not be observed.

Bad luck persisted throughout the fall semester as well. During September and early October, there were no asteroid occultation events predicted to occur within 50 miles of Juniata College. Between late October and mid-December, three asteroid occultations were predicted whose shadow path would pass near Juniata College. The November 3 and December 7 occultation events were not possible to observe due to cloudy skies, while the November 29 event took place during Juniata’s Thanksgiving break, when all of the occultation observing team members were away from campus.

Despite the lack of successful observations during 2013, the members of the Juniata SPS Chapter remain committed to the goals of the project and are excited about making successful occultation observations during 2014. The equipment, skill, and enthusiasm is there; all that is needed is cooperation from the weather.

Budget Summary

Budget Line	Quantity	Approved	Spent
Supercircuits PC164CEX-2 Low-Light Camera	3	$420.00	$420.00
Focal Reducer & Adapter	3	$150.00	$150.00
Celestron 12 amp-hour Powertank	2	$120.00	$120.00
IOTA GPS Video Time Inserter	3	$750.00	$750.00
Meade ETX80 Telescope, backpack edition	2	$520.00	$520.00
TOTAL		$1,960.00	$1,960.00

References

[1] Nugent, R. *Chasing the Shadow: The IOTA Occultation Observer's Manual*. 2007.

[2] Occult Watcher v3.6: http://www.hristopavlov.net/OccultWatcher/OccultWatcher.html

[3] LiMovie Light Measurement Tool v0.9.29b: http://astro-limovie.info/occultation_observation/limovie_en.html