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Measuring the Solar System: A Collaborative Global Student Program

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Abstract

Students regularly recreate historic observations in which the Earth's size and the relative scale of the inner solar system are determined. The transit of Venus on 5 June, 2012 provides the opportunity to replicate the entire chain of measurements from the ancient Greeks' determination of the Earth's diameter to the Sun-Earth distance in kilometers. A yearlong program of simple hands-on classroom projects, culminating with Venus transit, will be organized, disseminated and managed by Astronomers Without Borders.

1. Introduction

From the time of Eratosthenes, scientists have endeavored to measure the dimensions of the Earth and the inner solar system. These efforts began with measurements of the length of the shadow of a gnomon at various dates and locations. By the 17th century the invention of the telescope permitted measurements to be made during planetary transits of the Sun. The transits of Venus, occurring only six times in the 400 years since the telescope's invention, allowed for the scale of the solar system to be measured in terrestrial units, prompting observing expeditions to sites around the world during the 18th and 19th century events in order to obtain the most precise results possible.

Students regularly recreate the early observations in which the Earth's size and the relative scale of the inner solar system are determined. The transit of Venus on 5 June, 2012 – the last such event during the 21st century – provides the opportunity to replicate the entire chain of measurements from the ancient Greeks' determination of the Earth's diameter to the Sun-Earth distance in kilometers. Internet communications now allow students to collaborate with others in different locations to obtain the multiple, widely-separated observations needed for many of these measurements. Real-time communication between classrooms provides a unique opportunity for first-hand experience of the Earth's shape and size through shared observations.

The fortuitous concurrence of new technology and the first Venus transit since these technologies were sufficiently developed provides an unparalleled opportunity for worldwide education. Attention from science organizations and media assure that the Venus transit will be a high-profile event.

2. Program Description

A yearlong program of classroom projects, culminating with Venus transit, will be organized, disseminated and managed by Astronomers Without Borders. Classrooms worldwide will be engaged in these measurements and encouraged to collaborate with other classrooms in distant locations. The program consists of a series of simple hands-on projects to make measurements of the size of the Earth and inner solar system using instrumentation created with common, easily obtained materials augmented by instructional materials disseminated by Astronomers Without Borders and others.

Most of the projects in this program have been performed by students regularly but the upcoming Venus transit is only the second to occur anywhere on Earth since the 19th century. The first transit in modern times, on 8 June, 2004, was visible at least in part from slightly over half of the world but it occurred before many of the technologies that will be used in this program. The 2004 transit also occurred before the existence of worldwide networks, such as Astronomers Without Borders, and the communications technology that will make this collaborative program possible.

This program will be the first to bring together all of these projects under a single program open and readily available to classrooms anywhere in the world where an Internet connection is available. The program will continue after the Venus transit when the majority of these projects are still easily performed, with the network and infrastructure created in the run-up to the transit remaining in place to serve an ever-increasing number of schools as the

Internet reaches more sites. The program will also be expanded to create international observing programs in education at all levels, and including amateur astronomers, as Astronomers Without Borders has been doing on a smaller scale. These observational programs will include not only the objects and phenomena that are always available (stars, planetary motion, solar motion, etc.) but also transient events such as lunar occultations, variable stars, meteor showers, comets, near-Earth asteroids, solar phenomena and other transient events.

3. Individual Projects

The following are some of the projects that will be performed by students. More may be added in the future.

Measuring the size of Earth and one's location on it
Measuring the radius of the Earth by measuring the minimum gnomon shadow on the same day at various latitudes and/or longitudes. Classes at different latitudes but the same longitude will work together on the same day, sharing observations in real time.

Observation of the disappearance of a gnomon's shadow on "zero shadow day" (tropical locations only). Classes will share their zero shadow observation with other classes at different latitudes, comparing locations on an Earth globe or map.

Measurement of the observer's location on Earth (latitude and longitude) by measuring the minimum length of a gnomon's shadow on the dates of the solstices and equinoxes. The cardinal points of the compass will also be found. Classes will compare their gnomon shadow length with others. For classrooms at latitudes where the Sun is overhead in different directions north and south, the direction of the shadow will also be compared. Their locations will also be compared on an Earth globe or map.

Measuring the relative scale of the solar system
Measurement of the ratio of the orbital radii of Earth and Venus. There will be two methods available: 1) measurement of the maximum angular separation of Venus and the Sun and, 2) measurement of the parallax of Venus as observed from different locations on Earth. The experiment is simplified when schools are on the same latitude or longitude but more advanced classes might opt to adjust for differences on both axes. Classes at different locations will work together, combining their measurements to obtain the results.

Measuring the relative size of the Sun and observing its phenomena
The angular diameter of the Sun will be measured directly. At the same time, many solar phenomena can be observed including sunspots (their nature and changes over time), the solar rotation period, limb darkening, and phenomena such as prominences and flares observed in H-alpha light (where appropriate equipment is available). Observations will be checked and augmented by satellite images available online. The solar constant will also be measured directly. Simple spectrographs made in the classroom from paper and a CD will be used to observe the solar spectrum.

Measuring the absolute size of the solar system during the Venus transit
There are two steps to this project: 1) measuring the Earth-Sun distance relative to Earth's diameter by making observations from two or more locations and then, 2) calculating the actual distances between the Earth, Venus and the Sun in kilometers. There are two methods for obtaining these results: 1) timing the contacts of the Venus transit from different locations on Earth and, 2) measuring the angular velocity of Venus during transit (Halley's method). A phone app and website applet for use in making timing measurements and sending them to a central site is being considered. Classes at different locations will work together, combining their measurements to obtain the results.

4. Outcomes

The Venus transit and the expanding use of online communications technologies of online communities combine to provide a unique opportunity to engage classrooms around the world with limited restrictions due to geographic location, geopolitics or cultural differences. Students will gain not only scientific knowledge and an understanding of simple scientific methodology through inquiry-based learning but also knowledge of the wider world in which they live. Scientific knowledge and curiosity, along with geographic and cultural awareness will all be enhanced. For many students this will provide the first such opportunities for experiences that may have a significant impact with potential lifelong benefits.