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Mercury, its time has come

By Suzanne Gurton

Introduction

You'll be seeing more in the news about our tiny neighbor in coming years, and there are two good reasons. One is that NASA launched a spacecraft named MESSENGER to help answer some questions about this mysterious little planet back in 2004. The other reason is that on Wednesday, Nov 08, 2006 the planet Mercury will be seen in silhouette against the brilliant Sun (a phenomenon called a transit) for the first time since 2003.

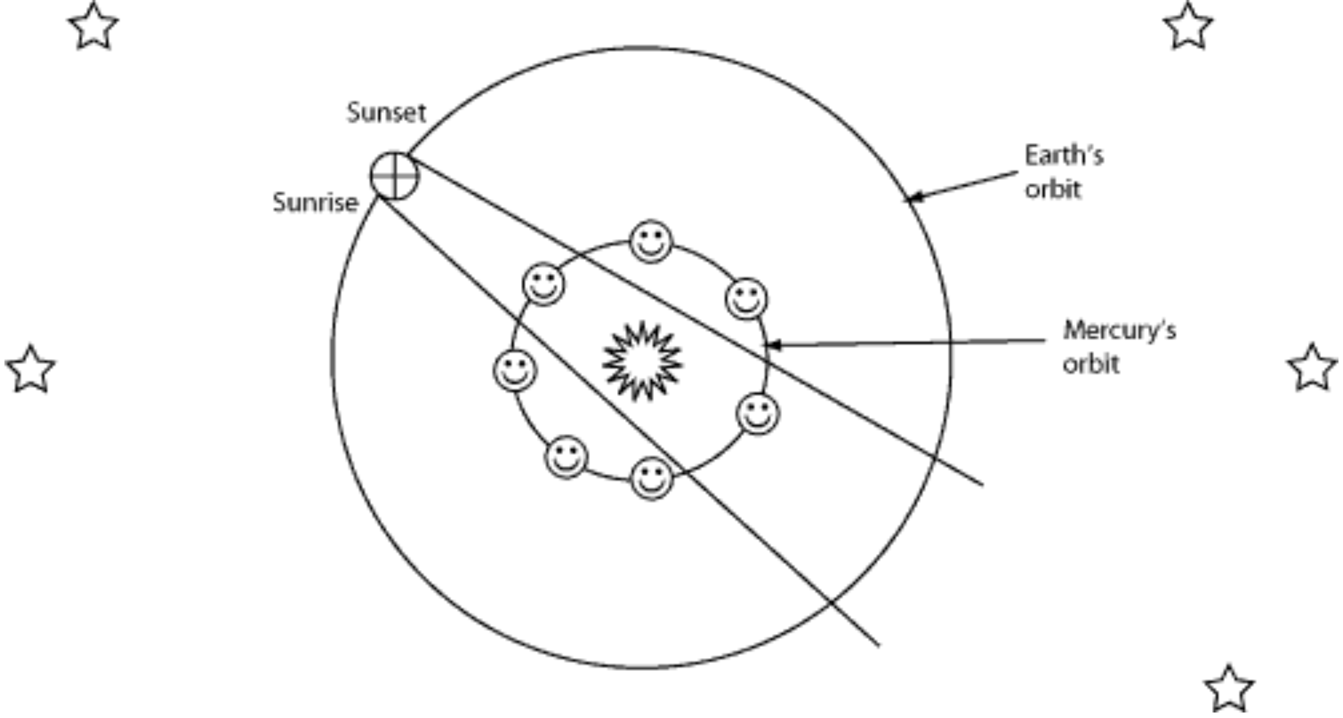
In this issue, we'll take a look at both the mission to Mercury and how to safely observe the transit with your students. (To brush up on some Mercury basics, review *Sun Scorched Mercury*,[1] a past issue of Universe in the Classroom.

back to top

Catching a glimpse

Observing Mercury in the evening or morning sky is a tricky thing. Three characteristics contribute to the challenge. First it is a small planet; only Pluto is smaller. Second, since it orbits closer to the Sun than we do on Earth, it is moving more quickly in its orbit. Named for a fleet-footed messenger of the gods, this little planet speeds around the Sun in just 88 days. At that rate it doesn't sit around waiting to be observed. And finally, we can only catch glimpses of it in the morning before sunrise or in the evening after sunset. This is simply because Mercury orbits closer to the Sun than we do.

When looking at the diagram below, imagine yourself on Earth for one day, rotating on your axis in a counterclockwise direction. The side of the Earth facing the Sun is in daylight and the side facing away is in night. The side marked "Sunset" has just turned so that the Sun has set below the horizon. If Mercury is located anywhere in its orbit above that line, it will be visible as an "evening star". If it is located below the line marked "Sunrise" it will be visible in the predawn hours just before the Sun comes up and would be a "morning star". Notice that as the Earth continues to rotate into the night, Mercury would not be visible at all. This planet, like Venus, is never seen late at night. If Mercury is in one of the spots between those two lines it will be lost in the glare of the Sun (rising and setting with the Sun), so it will not be visible at all.



With an orbit of 88 days, Mercury rushes back and forth from dawn to dusk in just a few months. See Activity 1 for a way to demonstrate this kinesthetically with your students.

back to top

The Transit

Mercury's tiny orbit keeps it so close to the Sun, that it's tough to observe. Every few years, however, its orbit is aligned with ours and we can watch Mercury silently glide across the face of the Sun. The actual sight is more of a curiosity than a spectacle, nonetheless, it is a teachable moment not to be missed.

A quick glance at the map below will tell you whether or not you're on the side of the Earth facing the Sun during the transit. Those in the white area will be able to see the entire transit, those in the light grey areas will be able to see part of it and those in the dark grey areas are out of luck and will have to watch it on a web cast. If you miss this one, the next one isn't for another 10 years.

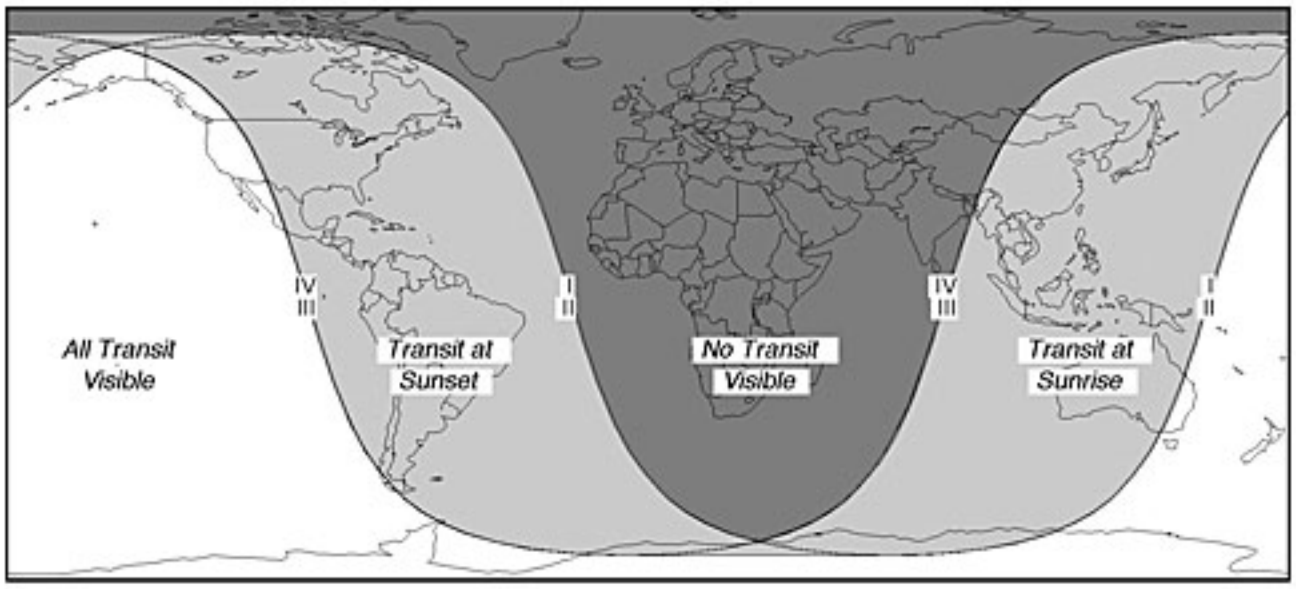


Image credit: F. Espenak, NASA/GSFC

Goddard Space Flight Center is the home of the Sun-Earth Connection Education Forum and they have a wonderful resource[2] to calculate the altitude of the Sun during the Mercury transit from your school. I'll warn you, though, don't be intimidated by the technical look of the site.

If you teach trigonometry, you may be interested in the whole page, but for the rest of you, go down to the links to download the Excel spread sheet titled "Transits of Mercury: 1901 CE - 2300 CE". To answer the question, "Will it be visible from where I am?", you'll need to know the latitude and longitude of your city, which you can find by visiting www.maporama.com and entering a street address. The spreadsheet is set up for New York, but all you have to do is click on each of the green cells and replace the information there (location, latitude, longitude) with your information. It will automatically calculate the altitude of the Sun during all of the transits. Go down to line 44 and you'll find the 2006 transit. If the altitudes in some or all five of the columns to the right of the sheet are yellow, you're in luck and the transit will be visible from your location.

If it is, and if it's at a convenient time during the school day to take advantage of observing it live, I recommend that you brush up on your safe solar observing techniques (see activity 3 in *Our Solar Connection*[3] and *Eclipse Watching: How to make a Solar Filter*[4]). The entire transit lasts for 5 hours, and some part of it is visible in all of North America with the west coast being in the lucky spot where one can see it in its entirety. Take a look at the map to see if you're in a location where you'll be able to see it during school hours or consult the diagram below. Convert times from Universal Time (UT) to your local time using the following equations:

UT - 8 hours = PST
UT - 7 hours = MST
UT - 6 hours = CST
UT - 5 hours = EST

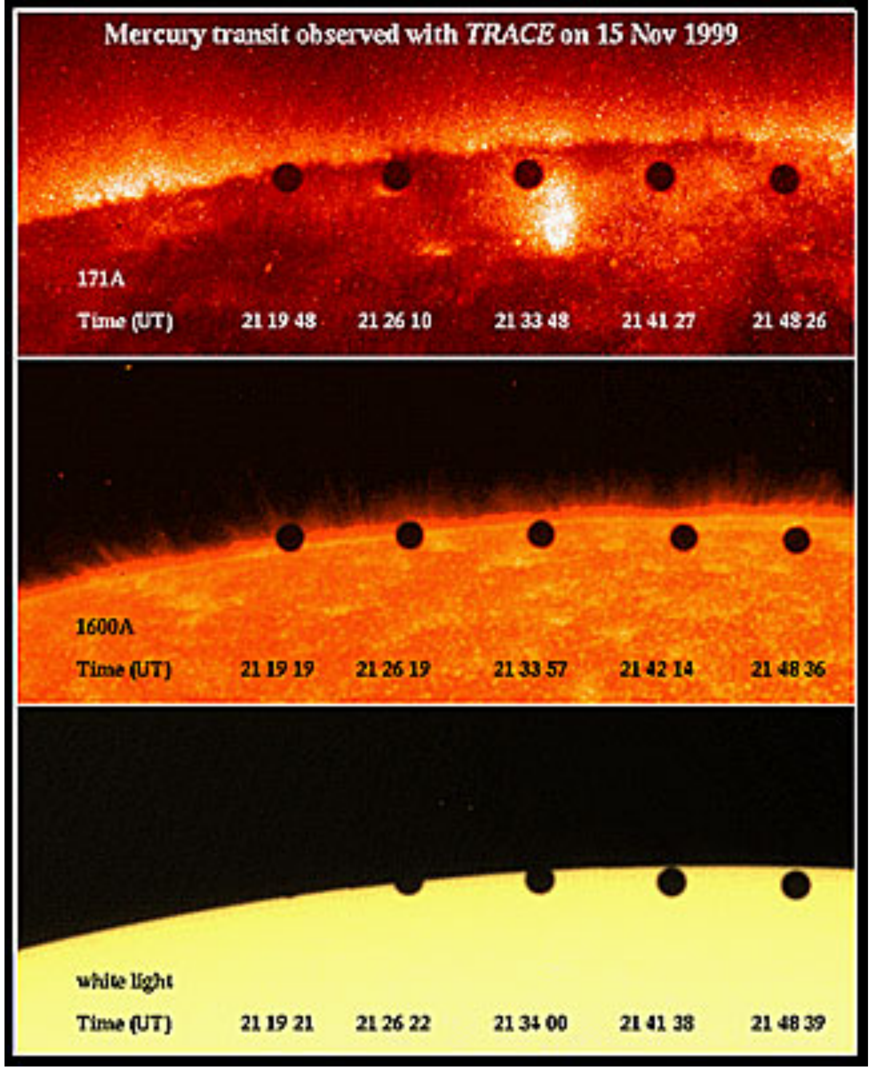
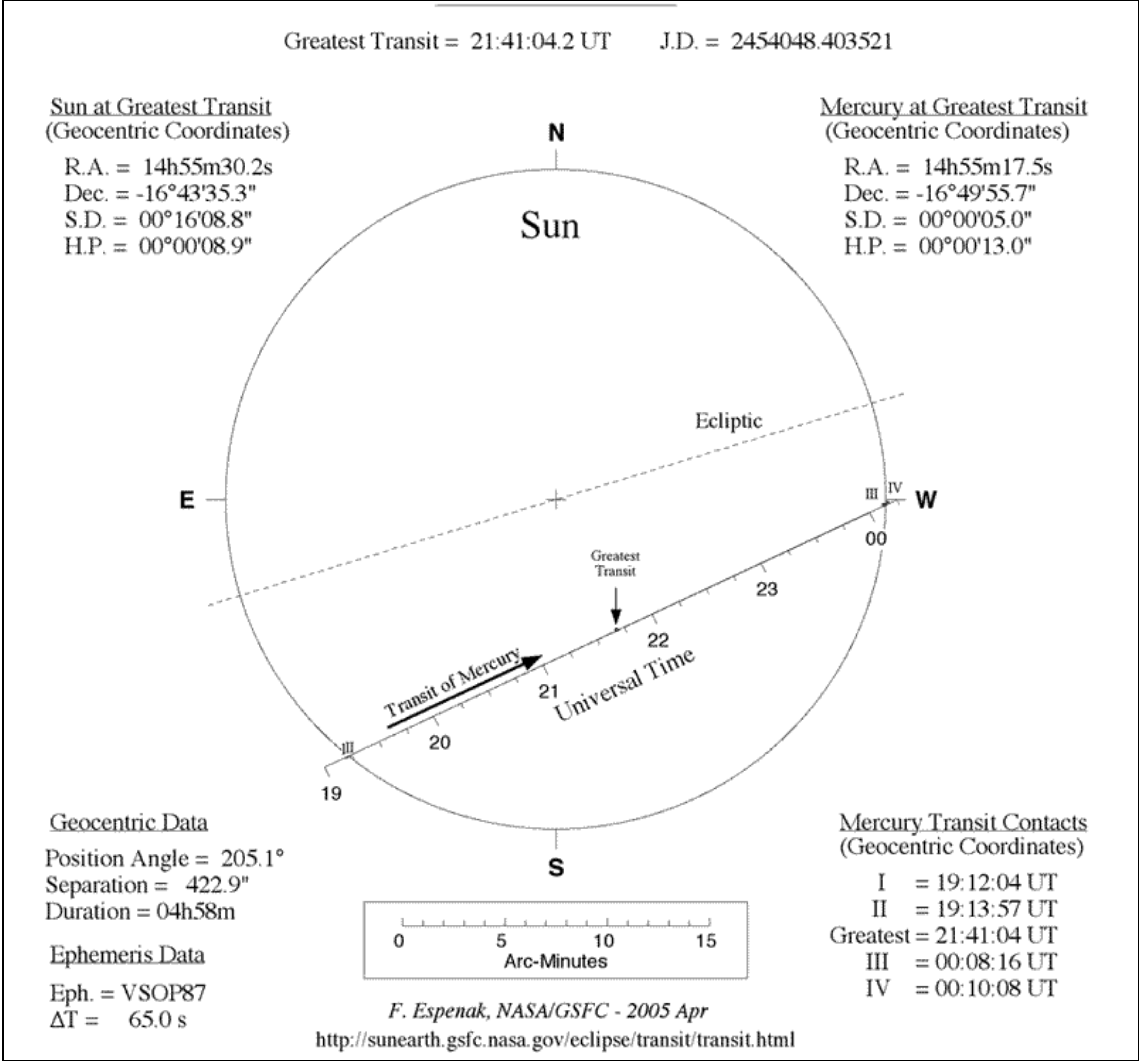


Image credit: The Transition Region and Coronal Explorer, a mission of the Stanford-Lockheed Institute for Space Research, and part of the NASA Small Explorer program



back to top

What will you see?

A transit is not as dramatic as an eclipse, it is simply a little black dot racing across the face of the Sun. As you can see in the diagram above, it takes nearly 2 minutes from the time that the leading edge of the planet meets the disc of the Sun (contact I) until the trailing edge is in front of the Sun (contact II). Over the next 5 hours it will get to the other side and it will take another 2 minutes for the leading edge (contact III) and then the trailing edge (contact IV) to move out from in front of the Sun.

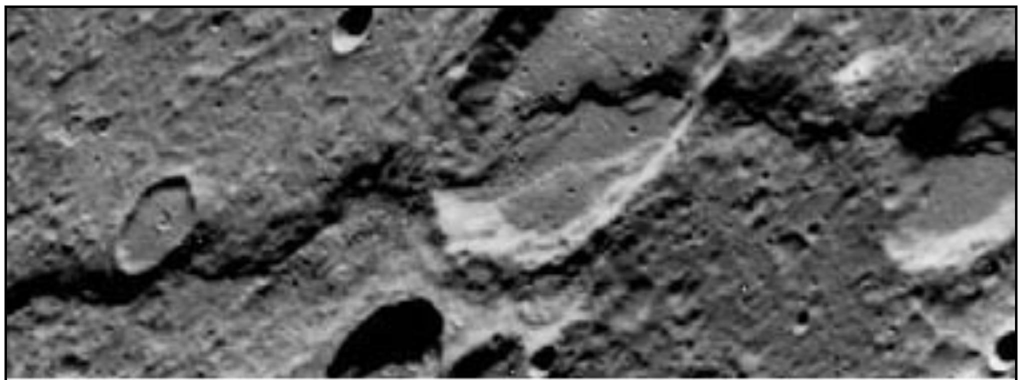
Of utmost importance when observing the Sun (or a transit) is safety. You all tell your students to never look directly at the Sun, so if you are going to observe it, be sure to emphasize the safety precautions taken. Sky and Telescope has a good article, *A Beginner's Guide to Solar Observing*.[5] Since that article was written, some wonderful safe solar viewers have come on the market, such as the Solarscope[6] and the Sunspotter.[7]

For this event, eclipse glasses will be a safe way to see the Sun, but the small black dot of Mercury will be very difficult to spot, so they are not recommended.

The Night Sky Network (NSN) is also a useful resource. These are amateur astronomy clubs who are particularly interested in doing outreach and sharing the skies with their communities. To find a NSN member near you, go to: http://nightsky.jpl.nasa.gov/

back to top

Exploring the Planet



Cooling and contraction of Mercury's core may have been the driving force behind the global wrinkling that formed the planet's lobate scarps. This scarp, Discovery Rupes, is nearly a mile in height

Image credit: NASA/ Carnegie Institution/ Johns Hopkins University

Pluto is the only planet in our solar system not to be visited by a spacecraft, but Mercury hasn't received much more attention. It's only had one visitor, Mariner 10 back in 1974 (twice) and again in 1975. During these three fly-bys, over 2,700 pictures were taken, covering 45% of Mercury's surface.

With less than half the surface mapped by these images (crude by today's standards) there are many more questions than answers to be found in the archives. So what do we know about it? Here are few facts, but check out these sites to get more details:

Views of the Solar System: Mercury[8]

Nine Planets: Mercury[9]

- Mercury is named after the Roman messenger of the gods, the fellow with wings on his feet, because it seemed to move more quickly across the sky than any other visible planet.
- Although others were theorized, none have been found, so it is the closest planet to the Sun.
- Of the planets in our solar system, only Pluto is smaller than Mercury. Its diameter (4880 km or 3032 mi) is 40% smaller than Earth and 40% larger than the Moon. It is even smaller than Jupiter's moon Ganymede and Saturn's moon Titan.
- Mercury's day is 176 Earth days long and its year is 88 Earth days; that means a day on Mercury – the time from one sunrise to the next – is two Mercury years long!
- Since Mercury's rotation axis does not tilt as much as Earth's, the planet doesn't have seasons in the same way as we do on Earth.
- Viewed from Mercury the Sun looks nearly three times as large as it does from Earth, and is up to 11 times brighter!
- We know that Mercury has a weak magnetic field.
- Mercury surprised us by having a very thin atmosphere. But it turns out to be particles captured from the Sun. This solar wind doesn't form a stable atmosphere, though, like ours. It seems to be constantly moving on and being replaced by fresh solar wind particles.
- The heavily cratered surface at first glance may look like the moon, but upon closer inspection may be more like a prune with ridges caused by wrinkling as the planet has apparently shrunk.

back to top

Unsolved Mysteries

We do know more about its cratered surface, but would also like to know more about the planet as a whole and its history. Mercury can better help us understand how each of the planets in the solar system formed, including our home planet, Earth. Both the NASA mission page for MESSENGER[10] and the Johns Hopkins University pages[11] do a great job of giving details not just about the spacecraft and its exploration goals, but also summarizing just why we are interested in going back there in the first place. There are six key questions that they hope to answer:

1. Why is Mercury so dense?
2. What is the geologic history of Mercury?
3. What is the structure of Mercury's core?
4. What is the nature of Mercury's magnetic field?
5. What are the unusual materials at Mercury's poles?
6. What volatiles are important at Mercury?

back to top

The Journey: MESSENGER is on its way

LAUNCH STATUS:

Launch Date: Tuesday, August 3, 2004
Launch Time: 2:15:56.537 a.m. EDT
Location: Cape Canaveral Air Force Station, Fla.

MISSION UPDATE:

The MESSENGER spacecraft lifted off on-time aboard a Boeing Delta II rocket from pad 17-B at Cape Canaveral Air Force Station, Fla., at 2:15:56 a.m. EDT. MESSENGER has successfully begun its mission to unravel the mysteries of planet Mercury.

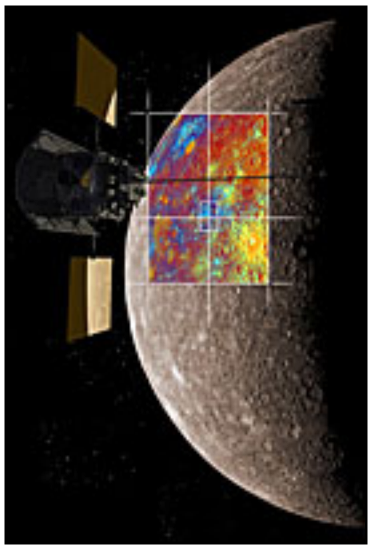


Image credit: MESSENGER - NASA/ Carnegie Institution/ Johns Hopkins University

It seems like falling in toward the Sun would be a short trip, but it turns out that falling in towards the Sun in a controlled way is pretty tricky. To not just fly by Mercury but actually go into orbit is going to require some fancy maneuvering and several years of slowing down. With just 93 million miles between us the Sun, you might think a trip to Mercury would be shorter than that. But MESSENGER must take a route that flies by Earth once, Venus twice, and Mercury 3 times before attempting to drop into orbit. All told, MESSENGER will travel 4.9 billion miles (7.9 billion kilometers) from launch in summer 2004 until beginning orbit around Mercury in March 2011. Over the following Earth year in orbit, it will travel 22.7 million miles (39.9 million kilometers) around Mercury.

back to top

MESSENGER Fellows

Another important aspect of this program is that they want to work with you, K-12 educators. They are currently looking for teachers to join the ranks of teachers training teachers on the Mission Education Modules. Their goal is to have a cadre of thirty Fellows master science educators conduct teacher training workshops nationally, training up to 27,000 grades pre K-12 educators over the mission lifetime. Fellows train educators on education materials (termed MESSENGER Education Modules) developed by the MESSENGER education and public outreach team. To date, over 3,800 educators across the nation have been trained by the MESSENGER Educator Fellows. Taking part in the MESSENGER Educator Fellowship Program is a great opportunity for educators to make a broad, yet profound impact in science education in the pre K-12 community. Find out more and download the pdf about the program at the MESSENGER Fellows website.[12]

back to top

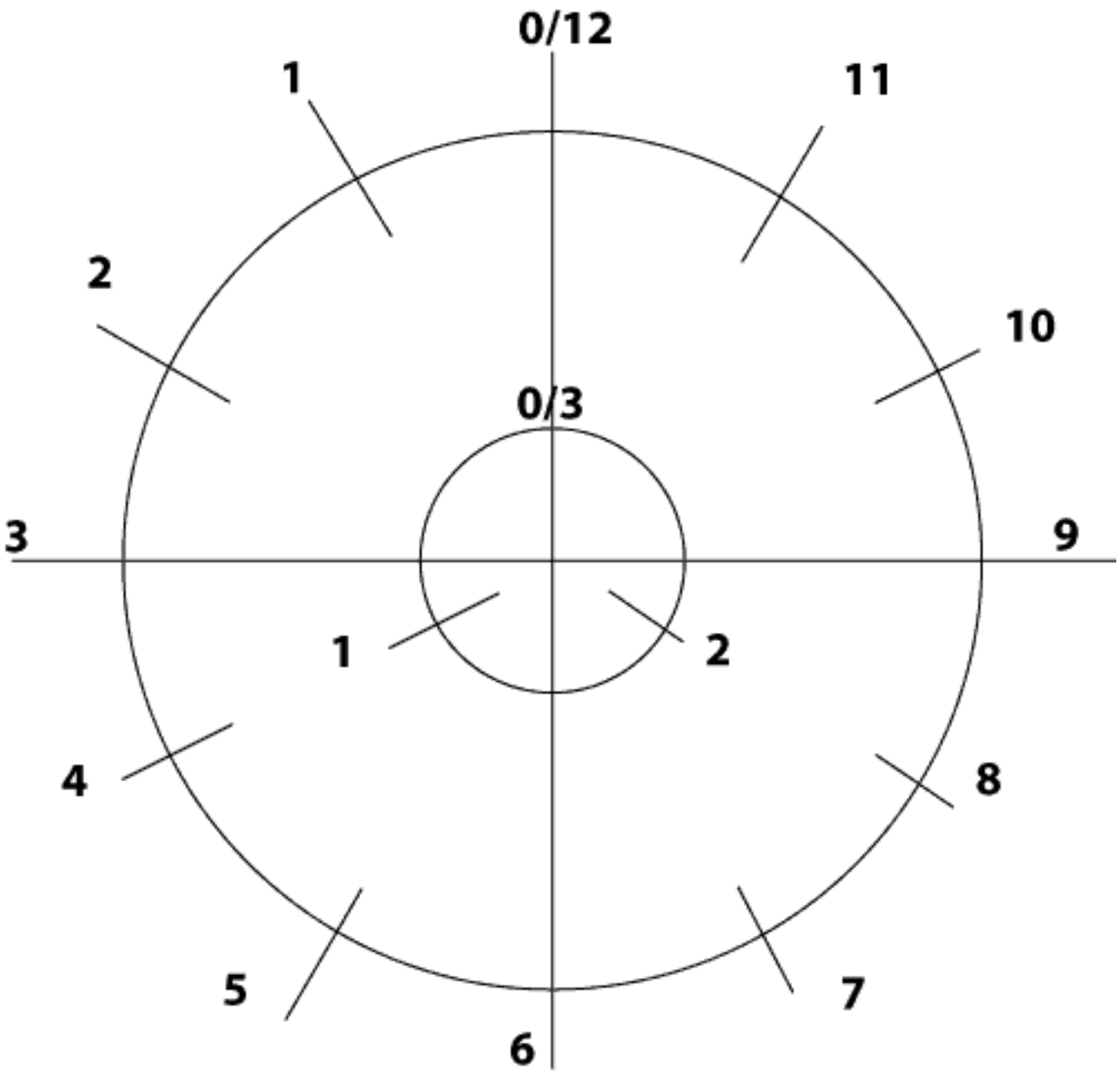
About the Author

Suzanne Gurton is the education manager of the Astronomical Society of the Pacific, overseeing the organization's many programs for astronomy educators — for classroom teachers, as well as informal educators and amateur astronomers. She was formerly editor of the Universe in the Classroom. She has also been involved in astronomy education through her work at the Morehead Planetarium in Chapel Hill, North Carolina, the Griffith Observatory in Los Angeles, the Hayden Planetarium at the Museum of Natural History in New York and the Planetarium at Santa Fe Community College.

back to top

Activity 1: Mercury's orbit compared to Earth's

Mark out two circles on the floor. The large one should be about 9 feet in diameter. Divide it into 12 equal sections like a clock face. The idea is to make the circle big enough, so that a student can take one step to get to each number. This represents the Earth's orbit and each step represents a month, so 12 steps around the circle is a full year.



The inner circle will represent Mercury's orbit and should only be about 3 feet in diameter. Mercury completes one orbit around the Sun in just 88 days. For this model, we'll round that up to 90 days, so in 3 months (or 3 big steps), Mercury will be all the way around its orbit once.

Clap or beat a drum to indicate when students should take a step. With each clap, students should move to the next number. Have each student start on the "0" for their orbit. Have each practice one orbit. Clap 12 times and Earth will be back to its starting point. Then let Mercury take at turn, 3 claps and it's back to where it started. For each of these planets, that is their year.

Now put both students in motion at the same time, with both starting at their own zero point. Note that they make a straight line with each other and the Sun. Clap once. Stop and notice how far around each is. (Earth is 1/12, Mercury is 1/3 of the way around) Since Mercury seems so far ahead of Earth, ask students to predict when they will meet up again and be in a line with the Sun. Clap a second time, each takes one step and note where they are (Earth is 1/6 and Mercury is 2/3) Clap a 3rd time, and Mercury has completed one year, but Earth is just changing seasons. Clap a 4th time and see what happens. Mercury has lapped the Earth and is back in line between it and the Sun. Keep clapping and counting and note where Mercury and Earth meet up again.

This would seem to imply that we could have 3 Mercury transits each year. But we don't. See why with Activity 2.

back to top

Activity 2: Why are Transits so Rare?

In this activity, you'll use the "Earth as a Peppercorn" scale to set up a model of the inner solar system. While pacing off the entire solar system requires half a mile, you'll just need 27 paces to fit in the celestial bodies we're concerned with here. If you're interested, take a look at the full write up[13] for this powerful scale model activity developed by Guy Ottewell.

To create a transit of Mercury across the face of the Sun as viewed from Earth, have your students work in pairs. They don't have to model complete orbits for this activity, just the short portion where Mercury is lapping the Earth as it races around the Sun.

Materials needed:

Sun-any ball, diameter 8.00 inches, one for every 4 or 5 teams

Mercury-a pinhead, diameter 0.03 inch, one for every team

Earth-a peppercorn, one for every team

To do the activity:

Place the Sun balls down, spread out so that the teams will not interfere with each other and start pacing.

10 paces. Have the Mercury-bearer step up with his/her pinhead. Have them stay put while you pace off to find the Earth's location. They should find a comfortable position, sitting or kneeling.

Another 9 paces. Venus would go here.

Another 7 paces. Earth will go here.

This scale model is truly mind-boggling. Here is Guy Ottewell's comments from his explanation of the activity:

> "Already the thing seems beyond belief. Mercury is supposed to be so close to the Sun that it is merely a scorched rock, and we never see it except in the Sun's glare at dawn or dusk-yet here it is, utterly lost in space! As for the Earth, who can believe that the Sun could warm us if we are that far from it?
>
> The correctness of the scale can be proved to skeptics (of a certain maturity) on the spot. The apparent size of the Sun ball, 26 paces away, is now the same as that of the real Sun-half a degree or arc, or half the width of your little finger held at arm's length. (If both the size of an object and its distance have been scaled down by the same factor, then the angle it subtends must remain the same.)"

Now have Mercury freeze, holding the pinhead in plain sight (out in front of themselves at arms length) and have Earth try to align him/her self so that the peppercorn, pinhead and Sun ball make a straight line. When they have successfully done this, you can have them trade places so each team member has the view from Earth.

In journals, have them reflect on the impact of pacing out the distances with the sizes of the planets to the same scale. Include observations about what must be necessary for a transit to be observed. Why don't we have three Mercury transits every year?

back to top

Resources

1. Sun-scorched Mercury – The Universe in the Classroom No. 22, Winter 1992-93
Provides information about the planet an activity for exploring the scale of the solar system.
http://www.astrosociety.org/education/publications/tnl/22/22.html

2. Visibility of Transits of Mercury and Venus
From the Goddard Space Flight Center, this page provides an Excel spreadsheet that can be used to determine the visibility of the transit from any location.
http://sunearth.gsfc.nasa.gov/eclipse/transit/catalog/Visible.html

3. Our Solar Connection – The Universe in the Classroom No. 68 Summer 2005
Ideas for exploring various solar phenomena and how they affect us on Earth, as well as tips for safe solar observing.
http://www.astrosociety.org/education/publications/tnl/68/solar.html

4. Eclipse Watching: How to Make a Solar Filter – The Universe in the Classroom No. 41, Winter 1998
http://www.astrosociety.org/education/publications/tnl/41/filter.html

5. Beginner's Guide to Solar Observing from Sky & Telescope
http://skyandtelescope.com/observing/objects/sun/article_162_1.asp

6. Solar Scope at the ASP's AstroShop
http://www.astrosociety.org/cart

7. Sunspotter at the ASP's AstroShop
http://astrosociety.org/astroshop/index.php?p=product&id=32&parent=4

8. Views of the Solar System: Mercury
http://www.solarviews.com/eng/mercury.htm

9. Nine Planets: Mercury
http://www.nineplanets.org/mercury.html

MESSENGER Mission pages

10. NASA
http://www.nasa.gov/mission_pages/messenger/main/index.html

11. Johns Hopkins University
http://messenger.jhuapl.edu/index.html

The MESSENGER spacecraft was launched in 2004 to study Mercury.

12. MESSENGER Fellows
The MESENGER team is currently looking for teachers to join the ranks of teachers training teachers on the Mission Education Modules, in order to conduct teacher training workshops nationally.
http://btc.montana.edu/messenger/teachers/fellows.php

13. Earth as a Peppercorn
A powerful scale model of the solar system with both size and distance to scale.
http://www.noao.edu/education/peppercorn/pcmain.html

back to top

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<< previous page | 1 | 2 | 3 | 4 | next page >>

back to Teachers' Newsletter Main Page