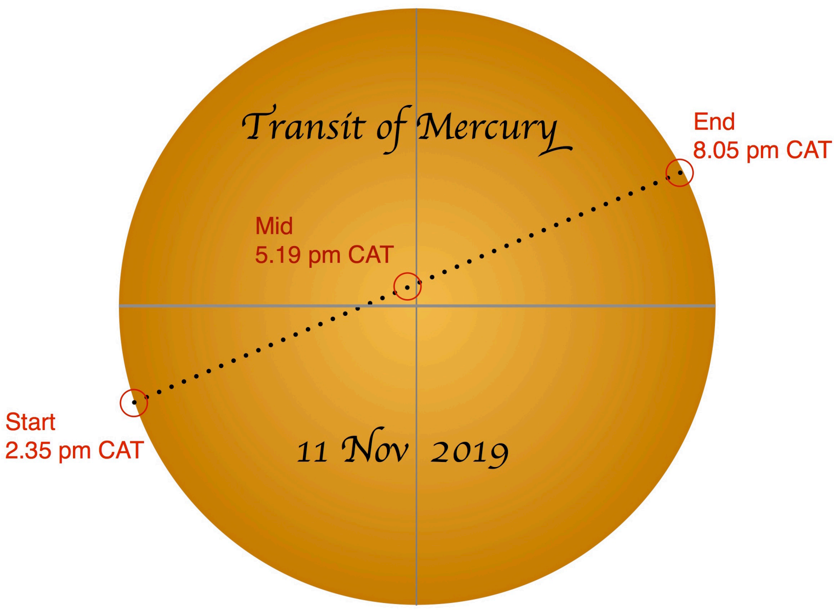
Your guide to the Transit of Mercury of 11th November 2019



"The African Transit"

For more information

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Acknowledgements

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Adapted by Niruj Ramanujam (SARAO) from the Handbook on Transit of Mercury (2016), published by the Public Outreach and Education Committee of the Astronomical Society of India (ASI POEC)

October 2019

DID YOU KNOW?

The next transit of Mercury that will be on 11 Nov 2032!

The last transit of Mercury that was visible was on 9 May 2016.

1. Transit of Mercury

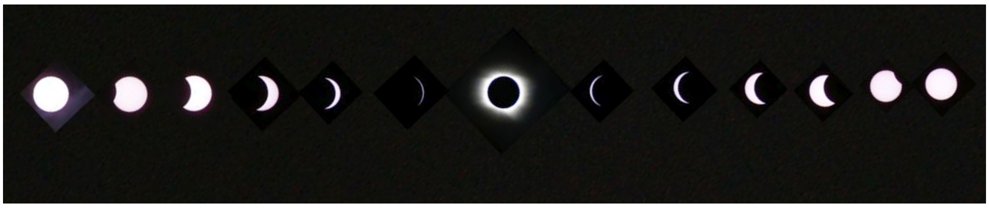
Transit of Mercury, 9 May 2016, photographed by Elijah Mathews. The sharp dot left and below the centre is Mercury and the fuzzy spot higher up is a sunspot

The planets, with their moons, steadily revolve around the Sun, with Mercury taking 88 days and Neptune taking as much as 165 years to make one revolution. We barely notice any of this, unless something spectacular happens to

Solar Dynamics Observatory's Ultra-high definition view of the transit of Venus on 6 Jun 2012. Each black dot is the image of Venus taken at regular intervals.

remind us how fast this motion actually is. We are all familiar with eclipses – when the Sun, the Earth and our Moon align in a straight line. However, there are other kinds of eclipses too, and transits are one of them. Since

Mercury and Venus lie within the orbit of the Earth, they can sometimes come exactly in between us and the Sun and can be seen crossing the face of the Sun over a duration of a few hours. These two planets are much farther away from us than the Moon and hence appear to be much smaller in the sky than the Moon. Hence, during a transit, Mercury and Venus will appear as small black dots moving across the face of the Sun, compared to a solar eclipse, where the Moon can cover the entire Sun itself!



DID YOU KNOW?

A transit of Mercury or a transit of Venus is also a form of an eclipse.

A Transit of Mercury will occur on the evening of 11th November 2019 and will be visible from all of Africa, when Mercury comes in between the Sun and the Earth. What does this mean ? If we project the image of Sun through a small telescope on this date at 2.35 pm CAT, and watch very carefully, we will see a small black dot, about 190 times as small as the Sun itself, slowly come into view, at the edge of the Sun's disk. This is Mercury, a 5000 km sized rocky planet that is the innermost in our solar system. We will see this black dot move across the face of the Sun over the next 5.5 hours. We will no longer be able to see the transit after sunset, of course. As the Sun moves from east to west, sunset occurs later for more western locations. Therefore, the more west you are in Africa, the longer you can see the transit. While Somalia will get to see less than 2 hours of the transit, Senegal will be able to see the whole of it

All the planets move around the Sun in almost the same plane, but not

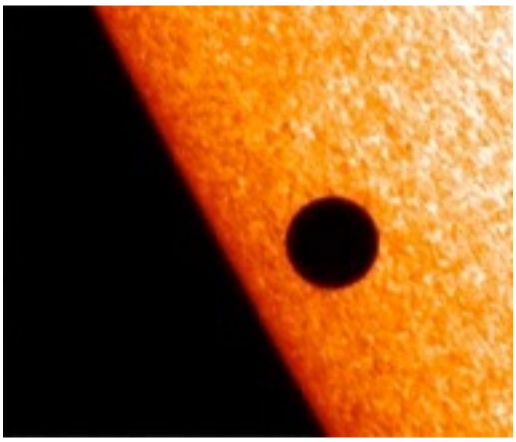
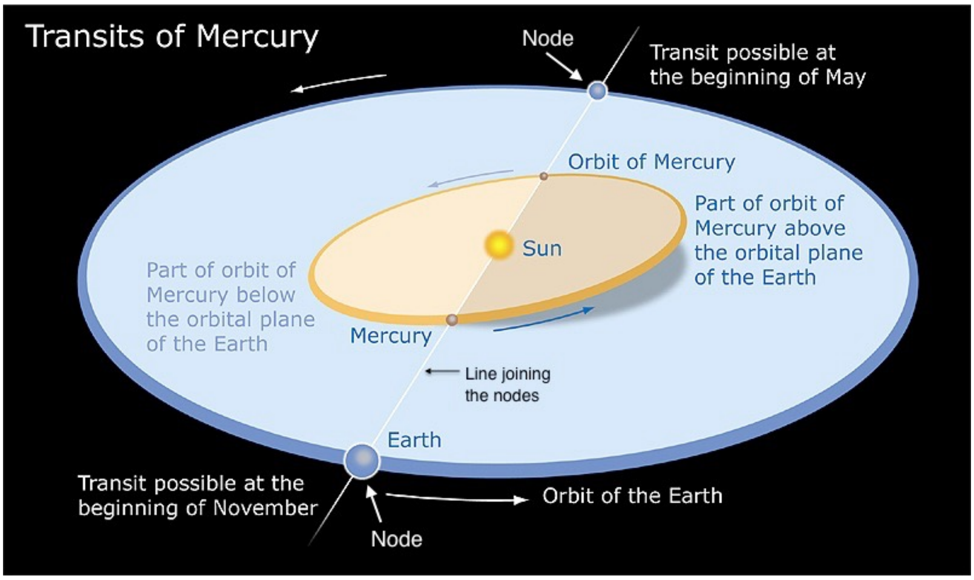


Image of the transit of Mercury taken by the Hinode satellite on 8 Nov 2006. Image credit: Hinode JAXA/NASA/PPARC exactly so. In fact, the orbits of Earth and Mercury around the Sun are tilted with respect to each other by 7 degrees. We all know that we do not get a solar or lunar eclipse every new moon or full moon. This is because the orbit of the Moon around the Earth is inclined with respect to the orbit of the Earth around the Sun. Hence, for example, during new moon, sometimes the moon passes just above the Sun, or just below the Sun. It is only when it is exactly in between us and the Sun do we get a solar eclipse. If the moon is off by a very small amount, we get a partial eclipse instead of a total solar eclipse. Similarly, we do not get to see a Transit of Mercury every time we have a 'new mercury', also known as the 'inferior conjunction'. Only an inferior conjunction where the alignment is almost exact will lead to a Transit.

DID YOU KNOW?

If the orbit of the Moon around the Earth was in the exact same plane as the orbit of the Earth around the Sun, then there would be a solar eclipse every new moon and a lunar eclipse every full moon!



The plane of orbits of Mercury and Earth are inclined at 7 degrees and they intersect at two nodes. When the two planets are at the nodes on the same side of the Sun, we get a transit of Mercury.

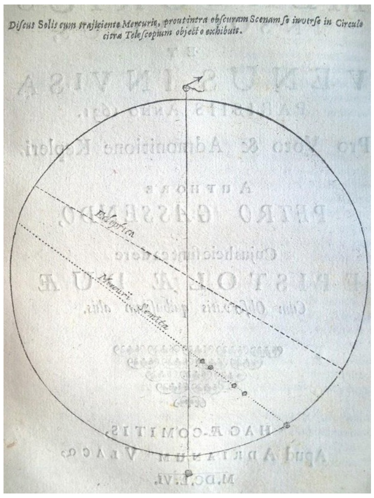
2. The Transit of Mercury : a history

Johannes Kepler
(1571-1630)

The story starts in 1629, with Johannes Kepler. Kepler had earlier demonstrated that planets move around the Sun in elliptical orbits, and described exactly how they moved in these orbits. In 1629, based on his Rudolphine tables, Kepler predicted that a transit of Mercury would occur on 7th Nov 1631 and that a transit of Venus would occur on 6th Dec 1631. The transit of Mercury was seen but the transit of Venus was not visible from most of Europe. It was due to new calculations by Jeremiah Horrocks that Horrocks and his friend Crabtree could see the next Venus transit on 4th Dec 1639.

The transit of Mercury that was predicted to occur on 7th Nov 1631 by Kepler, was indeed seen in Europe. Pierre Gassendi published his telescopic observations of the

Pierre Gassendi
(1592-1655)



Gassendi's drawing of the transit of Mercury in 1631. Image credit: RAS

transit from Paris. Gassendi was a remarkable astronomer, who managed to observe and measure the transit with ingenuity and skill. Remember, the telescope had been invented only twenty years before then! The transit was

DID YOU KNOW?

We know that Johannes Kepler discovered the 3 laws that govern the motion of planets based on observations of Tycho Brahe.

He also wrote a seminal book on optics, describing several principles for the first time. He was one of the strongest proponents of the Copernican theory.

He used his observations of the Supernova of 1604 to question Aristotles's idea of immutability of the heavens.

also seen by Johann Cysat from Innsbruck, Austria and Johannes Quietanus from Alsace in France.

The next transit of Mercury which was observed was from India by Jeremiah Shakerly. He had himself predicted a transit of Mercury to occur on 3rd Nov 1651 and he was able to observe Mercury on the face of the Sun.

Christiaan Huygens observed the next transit in 1661, and the following one was observed by Edmund Halley (of Halley's Comet fame) in 1677 from St. Helena, along with many others. Soon after, Halley published a paper where he explained the tremendous importance of these transits, leading to two centuries of international expeditions to time them accurately. But more on that later. *Te-Whanganui-o-Hei* on the northern island of New Zealand was named Mercury Bay in honour of the place where James Cook and Charles Green observed the transit of Mercury on 9th Nov 1769.

There have been many published historic observations from Africa by astronomers of European origin, notably of the transits of Mercury on 5 Nov 1868 from Cape Town in South Africa, on 10 Nov 1894 from Grahamstown in South Africa, on 14 November 1907 from Johannesburg in South Africa, Chiloanga in DRC and Mauritius.

DID YOU KNOW?

Edmund Halley was the person instrumental in persuading Isaac Newton to publish his work, which we now know as the *Principia*!

He used Newton's theory to predict the return of the comet which is now named after him.

3. Why are transits important?

Some of the most famous European astronomers spent all of two centuries chasing down transits of Venus and Mercury across the globe. Why did they do so? It all started with mankind's historic quest to measure the Universe. The trigger was an idea formulated in the 18th century by Edmund Halley. Using the laws of Kepler, astronomers could measure the relative distances between the Sun and all its planets. That is, all distances were known only as ratios of each other. Hence, if any one distance could be measured in absolute units (e.g., km), then all other distances between objects in the solar system could be calculated immediately. Extending the method devised by James Gregory, Halley showed in his paper that if we could accurately time the transits of Mercury and Venus from different places on Earth, we could then use simple trigonometry to calculate the distance between Earth and Venus. Now do you see why these expeditions were so important?

Edmund Halley (1656-1742)

Halley's idea was simple. Imagine you are walking by and you notice a nearby object like a hut or an electric pole. As you walk past, your position changes, and this object appears to be in front of different parts of the distant landscape. Similarly, astronomers

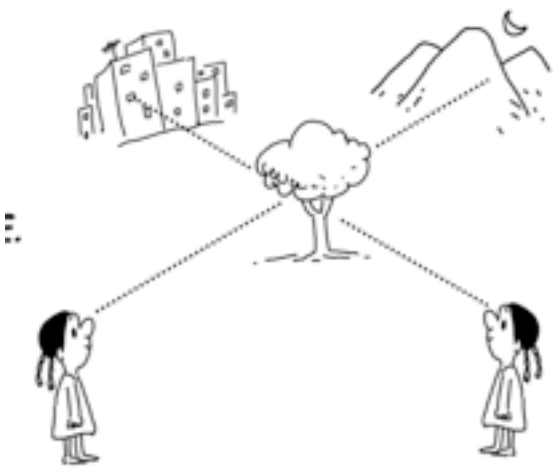
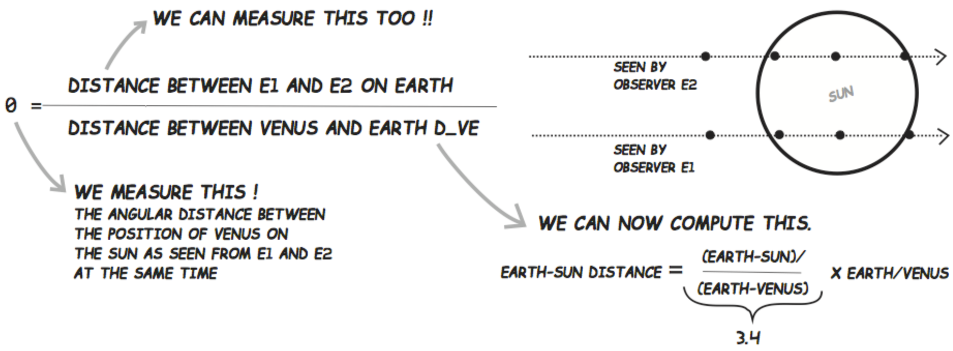


Illustration courtesy Reshma Barve (from the comic on Transit of Venus) seeing the transit from two different places on Earth would see Venus or Mercury against different parts of the Sun's disk. Halley wanted all these astronomers to note down, at the same time, where on the Sun's disk they saw Venus or Mercury.



The calculation for the transit of Venus. The same principle applies to the transit of Mercury as well. Illustration courtesy Reshma Barve (from the comic on Transit of Venus)

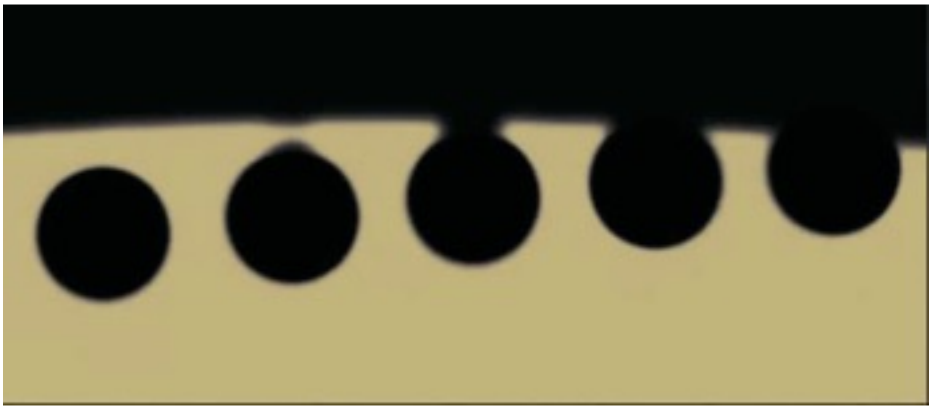
Making measurements at the exact same time, from different parts of the Earth, was incredibly difficult 300 years ago. Especially since these had to be done with a precision of 1 second. Hence Halley also came up with another method which did not need all these astronomers to synchronize their observations to within one second. It was enough for each astronomer to measure the amount of time that Mercury took to cross the Sun's disk. Since, as seen from different places, the chord travelled by Mercury on the Sun would be different, these measured durations would let us calculate the distance between the transiting planet and us. And in fact it did. Measurements of the transit of Venus, especially in 1874 and 1882, gave us a distance between the Sun and Earth as 149.59±0.31 million km. Compare this with the modern value of 149.597870700 ±0.000000003 million km!

Since Mercury is closer to the Sun compared to Venus, the errors in the distance estimates are less if we use the transit of Venus compared to the transit of Mercury. Historically, however, it was after successfully timing the transit of Mercury from St. Helena in 1677 that Halley turned his attention to the utility of these transits for the measurement of the distances in the solar system. Unfortunately, a peculiar effect called the Black Drop Effect limited the accuracy of Halley's hope of using transits to determine distances.

The black drop effect happens when Venus or Mercury enters or exits the Sun's image. A black extension connects the image of the planet and the Sun's edge, that lasts for a minute, making it impossible to measure the ingress or egress to an accuracy of a second that Halley wanted. A satisfactory explanation for this effect was given only in 2005 as due to a combination of optical blurring and the darker edge of the Sun.

DID YOU KNOW?

The correct explanation for the black drop effect was not understood till as late as 2005!



The black drop effect seen during the transit of Venus on 8 Jun 2004. Image credit : J. C. Casado

DID YOU KNOW?

Mercury's orbit has the largest inclination (7°) of all planets with respect to Earth's orbit.

The angle between the rotation axis & the revolution axis around the Sun is the least for Mercury and is almost zero.

4. Mercury's orbit and the transit

The orbits of Earth and Mercury around the Sun are inclined at 7 degrees to each other. Hence, the apparent paths of the Sun and Mercury on the sky are also inclined at 7 degrees to each other on the sky. These will intersect at two points on the sky, called nodes. If the Sun and Mercury are near the same node at the same time, and if Mercury is on the same side of the Sun as we are, then we get to see a transit of Mercury. Mercury takes 88 days to go around the Sun, which is almost 3 months. These orbital parameters cause some regular patterns in the occurrences of the transit.

All transits of Mercury take place within several days of either May 8 or November 10. The May transits correspond to when the Sun is at one node and the November ones to when the Sun is at the other node. However, when the Sun is near one of these nodes, Mercury is usually somewhere else in its orbit. Only those occasions in May and November when Mercury is also close enough to the same node such that it can come between us and the Sun will result in a transit. Mercury's orbit is elliptical and is near aphelion (farthest from the Sun) during the May transits and near perihelion (nearest to the Sun) during the November transits. Since planets move slower near aphelion compared to perihelion, the probability of a November transit is twice as high as a May transit. Do you see why? November transits recur at intervals of 7, 13, or 33 years while May transits recur only at intervals of 13 or 33 years.

There are four important events during a transit, namely two ingresses and two egresses. When the leading edge of Mercury is about to enter the Sun's disk, the moment is called the exterior ingress and when the trailing edge of Mercury has just fully entered the Sun's disk, the moment is called the interior ingress. Similarly, when the leading edge is about to leave the Sun's disk, it is the interior egress and when the trailing edge has just left the Sun's disk, it is the exterior egress. Many resources you may access to learn more about the transit will use these terms.

5. The planet Mercury

DID YOU KNOW?

Many ancient civilisations believed that the Mercury as the Morning Star and as the Evening star were two different planets since it moves so fast in the sky!

This figure shows Mercury and Earth to scale

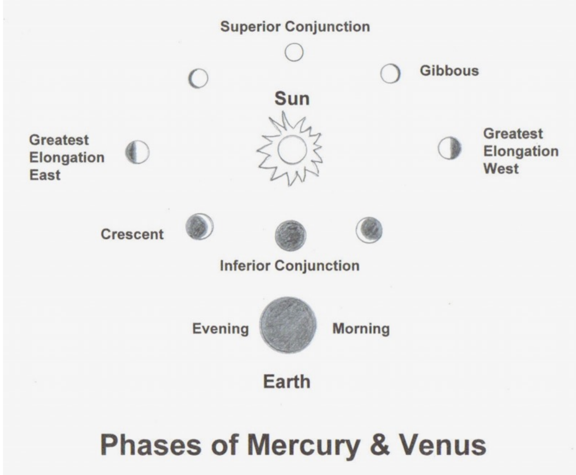
Mercury, the nearest planet to our Sun, is also the smallest planet, with a radius of only 40% that of the Earth and a mass of only 5.5 % that of the Earth. Since it is the closest planet, it also moves the fastest (remember Kepler's third law), completing one revolution around the Sun in 88 Earth days. Mercury's orbit is inside that of the Earth, which means that, like Venus, it can never be seen too far away from the Sun. Hence, these two planets will always be seen either in the morning towards the east, or in the evening, towards the west, and are called the Morning Star and Evening Star as well. Can you figure out why this is so? When Mercury is passing close to the Sun, we cannot see it because of the glare of the Sun, unless of course it passes directly in front of the Sun, like it will on 11 November this year. Such a transit can indeed be seen, and soon we will tell you how you can see it too.

DID YOU KNOW?

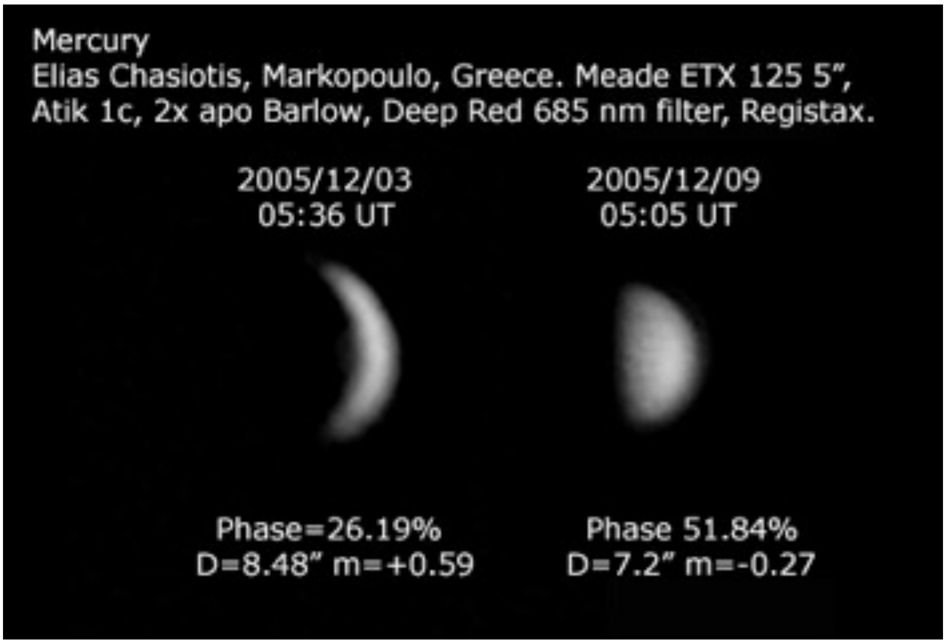
Mercury and Venus are the only planets with no moons of their own.

Mercury is the closest planet to the Sun. Still, Mercury is only the second hottest planet. Venus is the hottest because of its runaway greenhouse effect!

If you look at Mercury or Venus through a telescope and track it over a few weeks, you will see that they exhibit the full range of phases, just like our Moon. In fact, Galileo used his observations of the phases of Venus to confirm that Venus goes around the Sun, and not around the Earth. Do you see why?



Mercury and Venus exhibit phases because their orbits are inside the Earth's orbit. Transits can occur only when either planet is in inferior conjunction.



Photographs of Mercury showing a crescent phase and a gibbous phase. Since it is farther away from us in the gibbous phase, it looks smaller. The photograph was taken by Chasiotis Elias (http://www.weasner.com/etx/guests/2005/guests_planets.html)

The surface temperature of Mercury varies quite a bit, from -173 deg C in some parts to +427 deg C in some parts. This huge variation is partly due to the almost complete lack of atmosphere, coupled with the fact that the inclination of the rotation axis of Mercury to its orbit is as small as 0.034 degrees. So small is this angle that the floors of some craters near the poles never receive direct sunlight and

DID YOU KNOW?

At a particular time in its orbit, there are two locations on Mercury from where the Sun will rise three times before it sets!

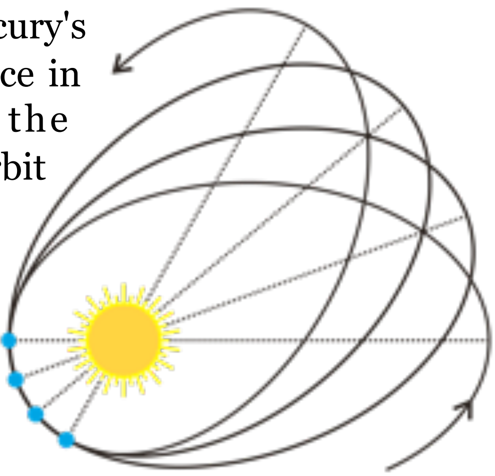
Try this!

Ask your friend to be the Sun, and you can be Mercury. If you revolve around the Sun three times in the period you rotate around your axis twice, can you see that a 'Mercury day' lasts two 'Mercury years'?

even have water in the form of ice, despite being so close to the Sun!

The orbital parameters of Mercury lead to some very strange effects indeed. The period of rotation about its own axis is exactly 2/3 of its period of revolution around the Sun (which is 88 days). It is therefore tidally locked with the Sun in a 3:2 resonance. You can conduct a role playing game with your friends to convince yourself that this means that, for a given location on Mercury, a 'Mercury day' lasts two Mercury years! Can you figure out why? This occurs due to the fact the Mercury's rotation period is not much smaller than the revolution period (like it is for Earth). This is not all. The orbit of Mercury is quite eccentric, with its farthest distance to the Sun being about 50% larger than its closest. For a few days near perihelion (or closest approach to the Sun), its orbital angular speed (degrees per second) around the Sun becomes slightly larger than its rotational angular speed before dropping back to a lower value again. What does this mean? This means that, during this period, for an observer on certain parts of its surface, the Sun will rise, and when it is about half way through the sky it will reverse direction and set, and then rise again to continue its journey. In fact there are two points on its equator where, at a particular time, the Sun rises three times before it goes on to set. A very strange day indeed!

Yet another feature of Mercury's orbit is of historical importance in Physics. We know that the position in the elliptical orbit when a planet is closest to the Sun is called its perihelion. It was observed more than a century ago that this perihelion of Mercury was slowly moving. This, of course, could be explained by the gravitational effect of all other planets on Mercury. This effect



The precession of the perihelion of Mercury causes its orbit to rotate slowly and hence the planet no longer follows closed orbits.

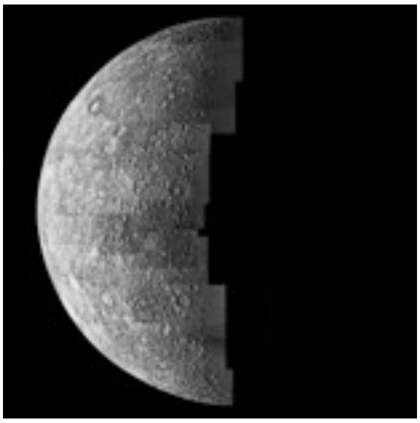
DID YOU KNOW?

BepiColombo will take six years to reach Mercury since it will use the slingshot effect to reach it. This is when a controlled close passage near a planet is used to accelerate a spacecraft and hence save fuel.

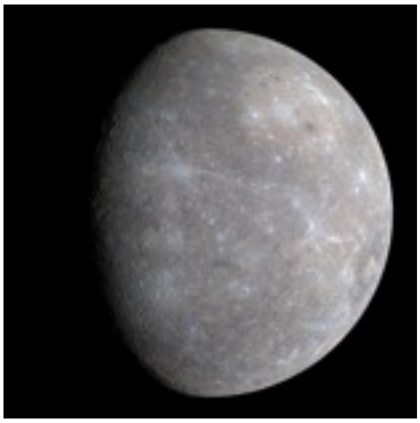
BepiColombo is named after the first person who implemented this effect for space probes, viz Mariner 10. Voyager 1 Cassini, Mangalyaan etc all used this technique.

makes the entire orbit rotate around the Sun, and hence the perihelion point as well. This precession of Mercury's perihelion is 574.1 arc seconds per century. However, it was soon noticed that the combined effect of all known planets, calculated using Newton's theory, was not sufficient to explain this measurement. In fact this accounted for only 531.63 arc seconds per century. It was Einstein who showed that his General Theory of Relativity could exactly explain this remaining precession of 43 arc seconds per century. This was one of the first confirmations of the correctness of his theory.

Though getting to Mercury is quite difficult, we have sent two probes to the planet so far. Mariner 10 visited the planet in 1974-75, and imaged it, showing us a surface which resembled the moon, full of craters, ridges and plains. Many years later, the MESSENGER spacecraft visited Mercury in 2011, providing us valuable information about the surface and interior as well as its structure and magnetic field. A third probe, BepiColombo was launched in October 2018 and will reach Mercury in 2025.



A mosaic of photographs of Mercury taken by Mariner 10 when it was 125000 miles away



A photograph taken by the Wide Angle Camera of MESSENGER during its closest approach

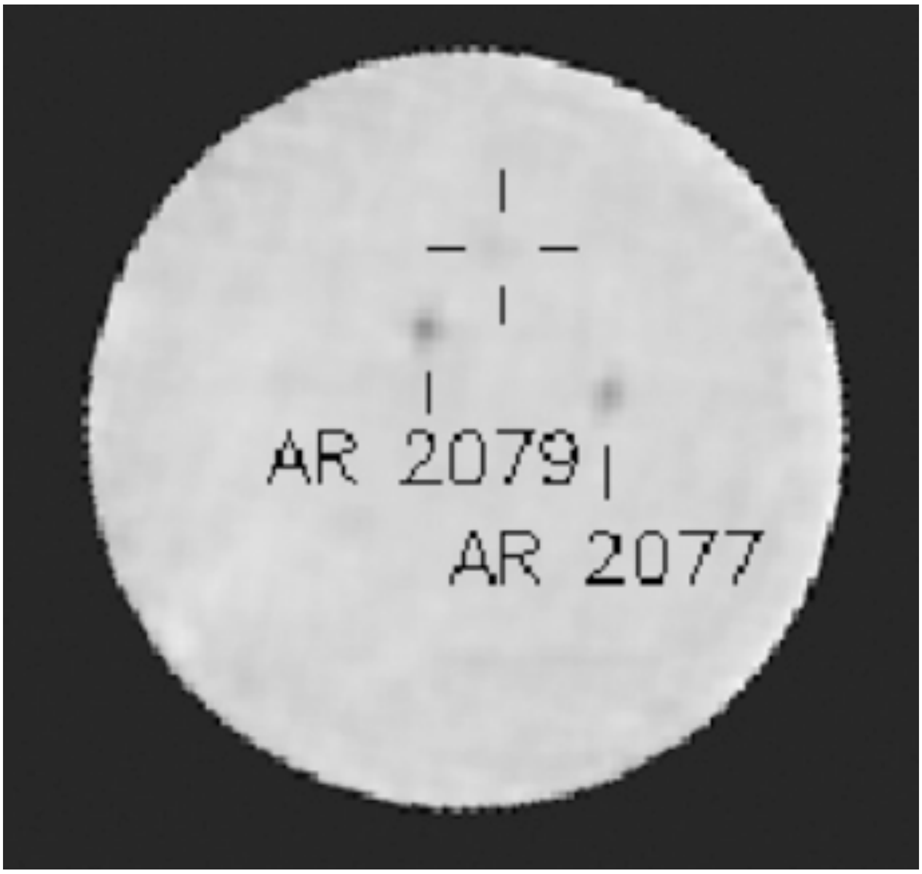
Many civilisations across the world knew of the planet Mercury. It was probably first noted by Assyrians in the 14th century BC! Mercury was called Nabu by the Babylonians, Stilbon or Hermes by the Greeks, Mercury by the Romans, the 'Hour Star' by the Chinese, Budha by the Indians, and so on. In Africa, it is known as Nozantya in

DID YOU KNOW?

We have seen a transit of Mercury from the surface of another planet! The *Curiosity* rover on Mars imaged the transit in 2014.

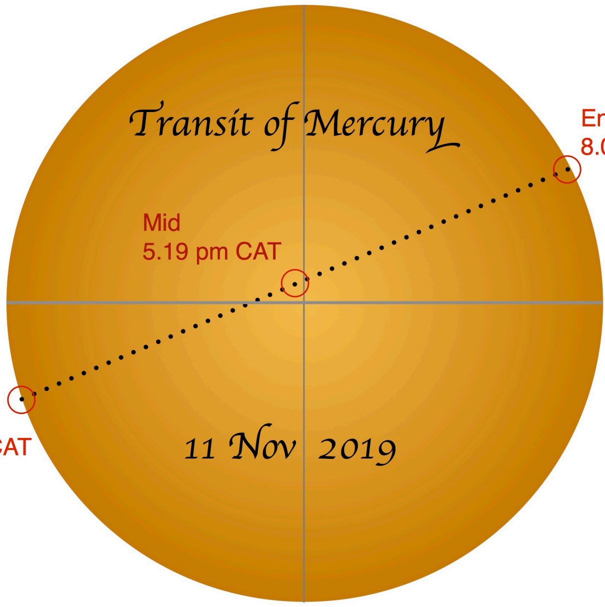
isiXhosa, Nomjubane in isiZulu and Utarid/Zebaki in Kiswahili, among other languages.

We have seen the transits of Mercury for many centuries now from Earth and we have even sent spacecraft to the planet. Do you know that we have even seen a Mercury transit from outside Earth? Thats right, the *Curiosity* rover imaged a transit of Mercury from Mars on 3rd June 2014, when Mercury came in between the Sun and Mars!



A photograph taken of the Sun by the telephoto-lens of the Mast Camera of the Curiosity Rover on the surface of Mars. The two dark spots marked AR 2079 and AR 2077 are sunspots and the faint smudge between the crosshairs is Mercury! This is not only the first photograph of Mercury from Mars, this is also the first photograph of any planetary transit observed from any planet other than Earth. Image credit: NASA/JPL-Caltech/MSSS/Texas A&M

6. The Transit of Mercury on 11th Nov 2019



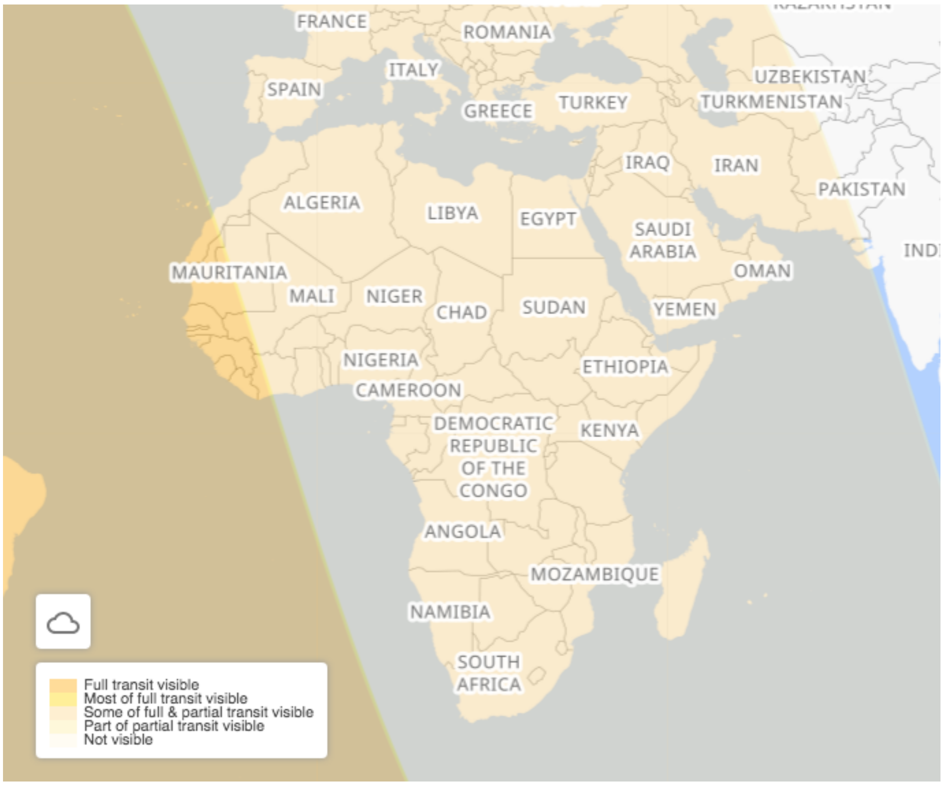
The transit starts at 2.35 pm Central Africa Time (12.35 pm Greenwich Mean Time, 1.35 pm West Africa Time, 3.35 pm East Africa Time, and 4.45 pm for Mauritius and Seychelles Time) and lasts for about 5.5 hours. This transit is special since the path of Mercury will pass much closer to the centre of the Sun's image on the sky compared to the previous transits.

Time Zone	Start	Mid	End
Greenwich Mean Time	12.35 pm	3.19 pm	6.05 pm
West Africa Time	1.35 pm	4.19 pm	7.05 pm
Central Africa Time	2.35 pm	5.19 pm	8.05 pm
East Africa Time	3.35 pm	6.19 pm	9.05 pm
Mauritius & Seychelles	4.45 pm	7.19 pm	10.05 pm

Correcting for the time zones, the start and end times in the table are at the same instant. Will the transit start at exactly the same moment for all of Africa? Not really. People in Senegal will see the black disk of Mercury entering the disk of the Sun in the sky at 12.35.37 Greenwich Mean Time. However, if you are observing the transit far away in

Somalia instead, this moment will happen at 12.34.57 Greenwich Mean Time. These small differences of a minute or two were what Halley originally set out to measure! The entire disc of Mercury then fully enters the Sun within 1 minute and 40 seconds. Remember, Mercury will be about 190th as small as the Sun, a very small dot indeed. It will then race across the Sun and take about 5.5 hours to exit the Sun.

So for how long can you see the transit from your location ? Till your local sunset of course. The Sun sets earlier in the east and later in the west. Hence, the more westerly your location, more you can see of the transit,. For west African countries like Senegal, Guinea, Sierra Leone, Liberia etc, the entire transit will be visible. For countries like Libya, Chad, DRC, South Africa etc, the sun will set when the transit is almost three quarters over. For Madagascar, Mauritius etc, the sun will set before half the transit is over. However, even from the eastern most parts of Africa, we can see almost 2 hours of the initial part of the transit.



The western most parts of Africa will see the entire transit and the eastern most parts of Africa will see a bit less than half of it. Pic credit: [timeanddate.com]

DID YOU KNOW?

The length of the day on a given date is a strong function of your latitude.

E.g., if you are at -50 deg latitude, day time lasts for 16 hrs in summer and only 8 hrs in winter!

There is an added complication. The local time of sunset not only varies with longitude, but also with latitude. The more south your latitude, later is your sunset, since the transit occurs during November. This is because the Sun is in the southern hemisphere at this time, and the Earth's axis is tilted at an angle. Can you figure out why this is so ? Hence, to determine how long you can see the transit, you need to know at what time will sunset be at your location on 11th November. You can find this out from the reference given at the end of this handbook.

Now that you have found out your local sunset time on 11th November, you are ready to see Mercury swim into view (how you can do that safely with a telescope is explained in the next section, read it carefully!). However, you probably want to be the first among your friends to spot Mercury, as soon as it enters the Sun's disk. How will you do that? The first thing to see is if there are any black spots on the Sun's surface. You will probably find a few. These are called sunspots and are cooler regions on the Sun's surface which last for days or weeks. Hence, we urge you to look at the Sun's surface **SAFELY** (as described in the section below) for a couple of days before the transit to familiarise yourself with the sunspots present. You can easily see these spots move within 2-3 days due to the rotation of the Sun.

Next, you need to know from which direction will Mercury be entering in front of the Sun's disk. The position angle of ingress is about 114 degrees. This means that Mercury will enter from a direction which is 24 degrees south from east, which is close to east. So how do you know which is east on the projected image of the Sun? Simple, just do not do anything at all! The Sun's image will then drift across the screen due to Earth's rotation and the leading edge will touch the edge of the field of view before starting to disappear. The point where the leading edge just touches the field of view is west and the opposite point on the Sun's disk is east. It is within 24 degrees of this eastern point that Mercury will appear at 2.35 pm CAT.

Now you have all the necessary information about the transit of Mercury. All that remains is to know how to observe it safely. Read on.

7. How to observe the transit safely ?

DO NOT TRY TO LOOK AT THE SUN DIRECTLY OR THROUGH ANY OPTICS,

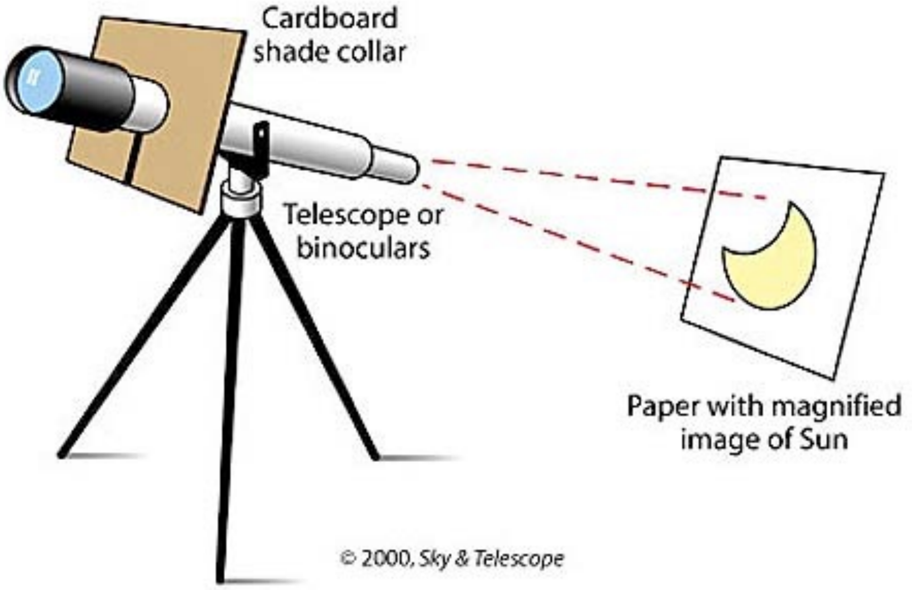
THIS COULD LEAD TO PERMANENT BLINDNESS!

You may have seen a solar eclipse through eclipse goggles, a pin hole camera or even through the shadows cast by tiny holes in between leaves of a tree. You may even have seen the transit of Venus in 2012 through a very simple telescope. However, Mercury will be about 190^{th} the size of the Sun's disk, and you would therefore certainly need a small telescope to see the transit. An image of the Sun that is at least 15-30 cm in diameter is needed in order that Mercury can be seen as a dot of 1-2 mm size on its surface.

Safety first !

Viewing the sun through any optical device like binoculars or telescopes or magnifying glasses is extremely dangerous. You will risk permanent blindness. Looking at the Sun with your bare eyes is dangerous as well. **DO NOT** attempt to look at the Sun directly, either with your naked eyes or through any optics!

The safest way to see the transit is to project the image of the Sun on to a sheet of paper or a screen, and see this image. By using a telescope to project a steady, well focused and large image of the sun, one will be able to study the sun at one's leisure, with no risk to the eyes. It has the added advantage that many people can see the transit at the same time. For students interested in making some quantitative measurements of the sun or even the transit, projection is the best method.



So what do you need to see the transit? You need a small telescope, with an aperture diameter between 2 and 4 inches. The Sun is a very bright object and its rays will heat your telescope quite a bit. Using much larger telescopes than a 5 inch is not going to be very helpful. We need as large an image of the sun as possible, and hence, a large focal length objective for the telescope is preferable. Note that the eyepiece should not be cased in plastic, as this will melt when the telescope is pointed at the sun.

Why don't you use this transit as a good reason to make your own ? You can ask your nearest planetarium, science centre, or even the Physics departments of your school or college to help you make one. Make sure that the eyepiece casing is made of metal and not plastic and get an objective and eyepiece of good quality.

Once you have a small telescope, you need to find a way to mount it, so that you can rotate it to point to any direction in the sky. Now, take it outside, aim it at the Sun, and try and project the focussed image of the Sun onto a piece of paper or screen. A clever way to make the telescope point at the Sun exactly is to look for its shadow and ensure that the shadow is as small as possible, and is the outline of the cross section of the telescope tube. Now, you will need to adjust the distance between the eyepiece and the objective, and the position of the screen as well, to get a good large

image of the Sun. **However, please be careful that neither you nor any one else near you happens to look through the telescope directly at the Sun, even by accident.** This is very important!

We suggest that you try projecting the Sun's image for a few days before 11th November so that you get used to doing so. You may also see sunspots during the week preceding the transit. If you mark the positions of the sunspots on the

Projecting an image of the Sun onto a screen. The green cardboard blocks direct sunlight from the screen, increasing the contrast. Image courtesy: Navnirmiti Learning Foundation.

Sun's disk everyday, you will see that they move, due to the rotation of the Sun itself. In fact, you would be repeating Galileo's discovery of the Sun's rotation!

Remember that the disk of Mercury will be 190th as small as that of the Sun. Hence, for you to be able to see Mercury, the Sun's image should be about 15-30 cm in diameter. How can you ensure this? One way is to get a lens that has a large enough focal length. The second and easier way is increase the distance between the eyepiece and the screen. However, when you do this, you will notice that the image

becomes fainter. There is a simple and effective way to deal with this problem. First, we suggest that you attach a ring of cardboard around your telescope tube to block direct sunlight from falling onto your screen. This will increase the contrast of your image. Second, we suggest that you make a darkened box with a screen (white paper) on one end and a hole on the other, and project the image into this box. You would have to cut another hole on the side of the box to see the image. You can either attach the box to the eyepiece tube or place it on a table such that the image goes into the box. Pasting black paper on the remaining sides of the box will further increase the contrast. You can even use just a screen and shade it from many sides. Use your imagination and ingenuity to design such a dark box and share the transit of Mercury with your friends!

Projecting the image of the Sun through the telescope eyepiece into a cardboard box during the transit of Venus in 2004. Image courtesy: Nehru Planetarium, Delhi.

8. Resources

8a. Where can you see the transit from?

We are compiling a list of all the science centres, telescope owners and amateur astronomy groups who are organising a public viewing of the transit of Mercury on 11 November. See the list at

- https://www.africanastronomicalsociety.org/transit-of-mercury/
- https://www.ska.ac.za/outreach/
- https://www.saao.ac.za/outreach/

8b. Information about the transit

You can find the time of sunset at your location on 11th November as well as the exact times of the start and end of the transit at your location using the interactive map at

https://www.timeanddate.com/eclipse/map/2019-november-11

8c. How to make a simple telescope and project the image of the Sun

Here are some links that teach you how to make a simple telescope and also use it to project the Sun safely.

- https://www.skyandtelescope.com/astronomy-news/how-to-look-at-the-sun/#projection
- http://www.skyandtelescope.com/observing/celestial-objects-to-watch/observing-the-sun/
- https://www.youtube.com/watch?v=y4O-DUpZGk4

8d. Social media

	Facebook	Twitter
SKA	skasouthafrica	ska_africa
SAAO	saaonews	saao
AfAS	afas2.0	