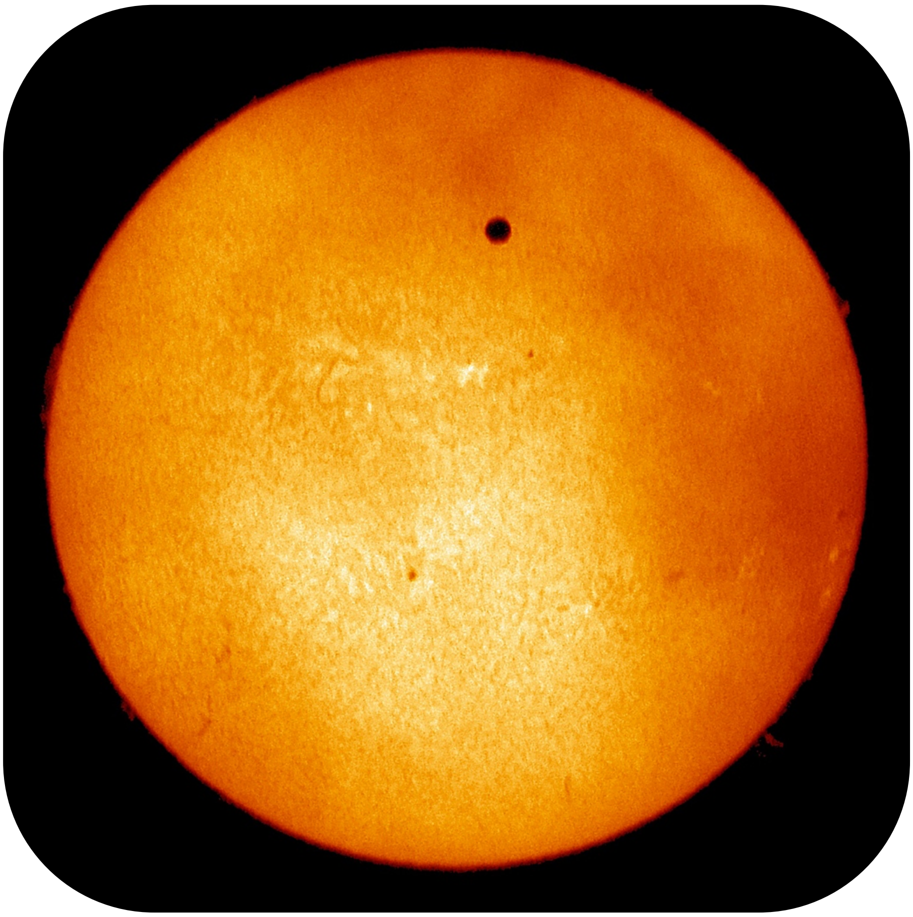
The Venus-Sun distance

Student's Guide – Basic Level

CESAR's Science Case



Introduction

In everyday life we use rulers or measuring tapes to measure small distances like the length of a table. But for example, if we want to calculate the distance between to cities, which is much larger, we have to move from one city to an other and use an odometer. With today's experiment, **we're going to find out the distance between Venus and the Sun**, without even moving from Earth.

Material

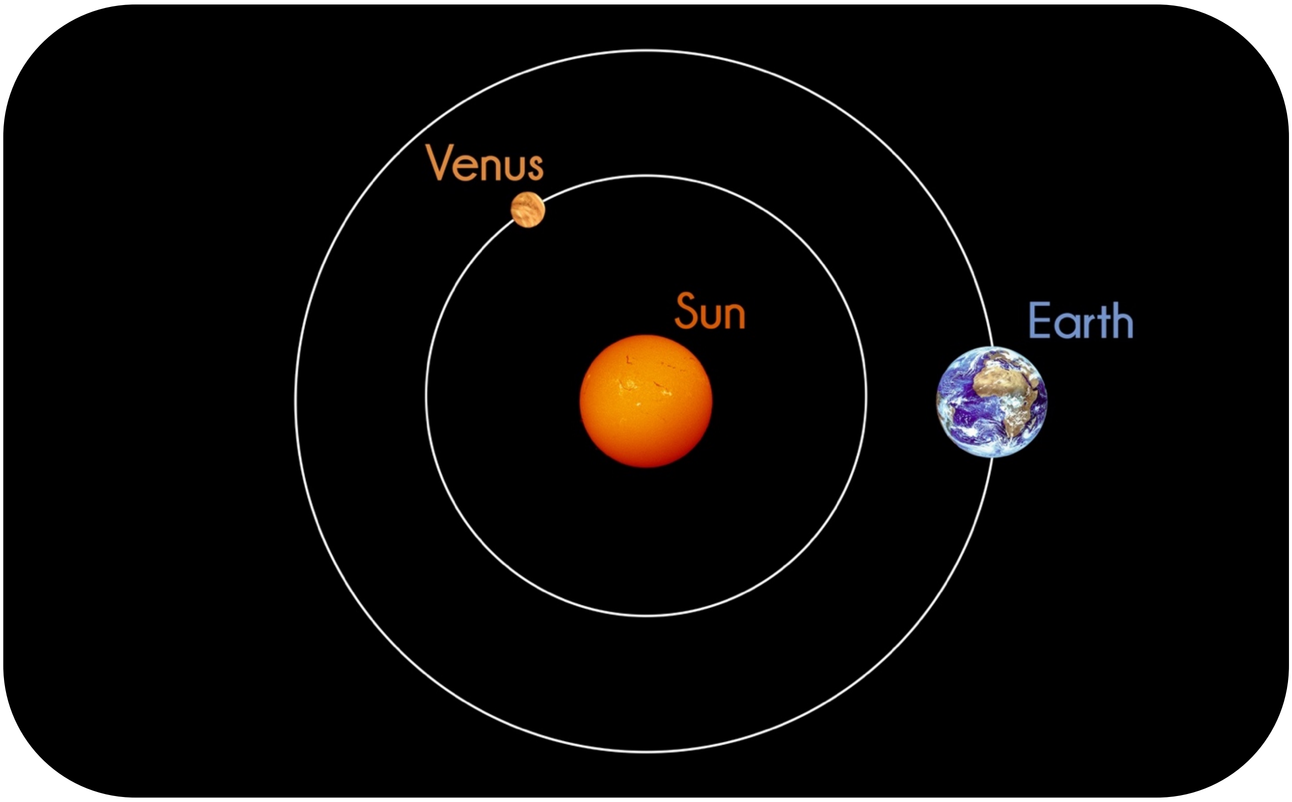
What will you need?

- The Venus-Sun distance Student's Guide.
- Computer with Web Browser and Internet Connection.
- Google Earth or similar program to look for coordinates.
- Access to CESAR web tools.
- Paper and pen.

Background

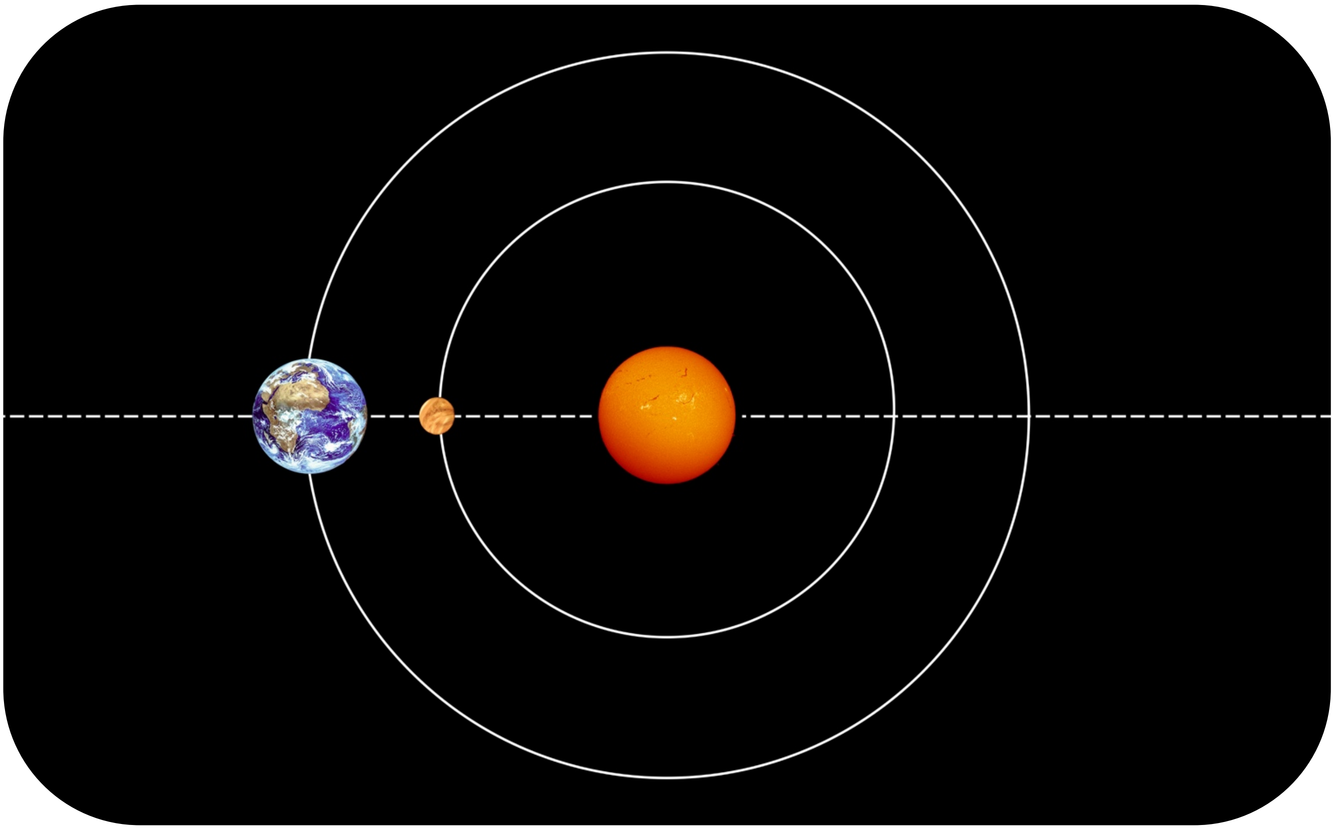
Transits

To understand how we are doing this huge measure, lets first draw the positions of the Earth and Venus around the Sun:



At some random day, things would look like in the previous picture, the Earth and Venus are orbiting the Sun without noticing each other. In such a day, if we call Adam, an astronomer living in Svalbard (Norway), and we ask him about his observations, he will tell us that Venus is somewhere in the sky, far away from the Sun.

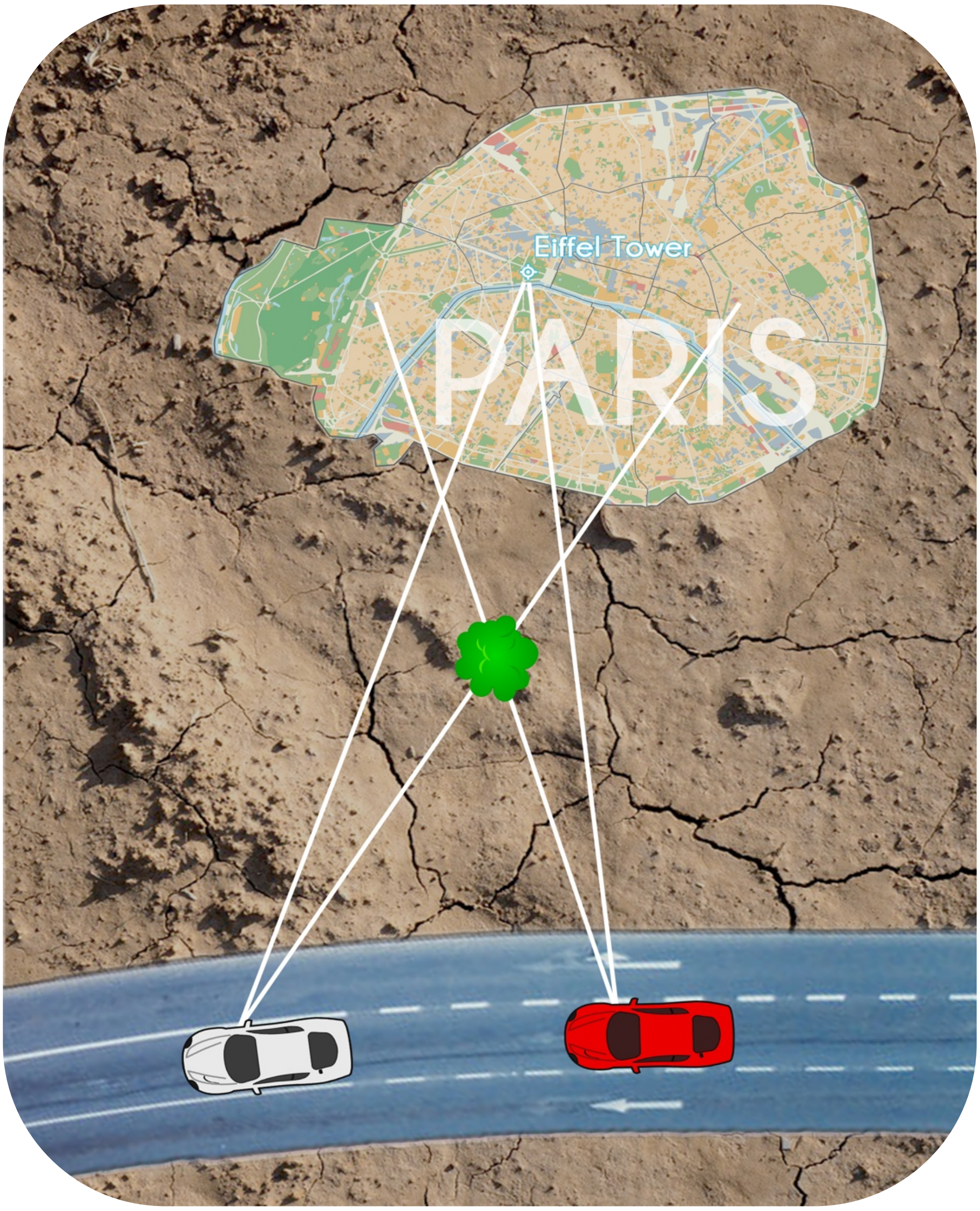
But then, at some point, after some days have passed and the planets have moved around, things may look as in this other picture:



If we call Adam this particular day, he will tell us that **Venus is in front of the Sun**. Adam would see the planet Venus as a dark circle, moving across the Sun disk, just as shown in the title page of this guide. **We call this phenomenon a transit**. Of course, this situation doesn't happen every day, so Adam will hurry to take a lot of pictures of the Sun and Venus crossing its surface. He will keep taking pictures until the planets move a little bit and the transit is over.

Parallax

Before we take a look at Adam's pictures, lets think about another situation: Imagine we were actually measuring the distance between two cities, lets say from Berlin to Madrid. At some point of the trip, Paris will be at our right, far away from the road, as in the picture below.



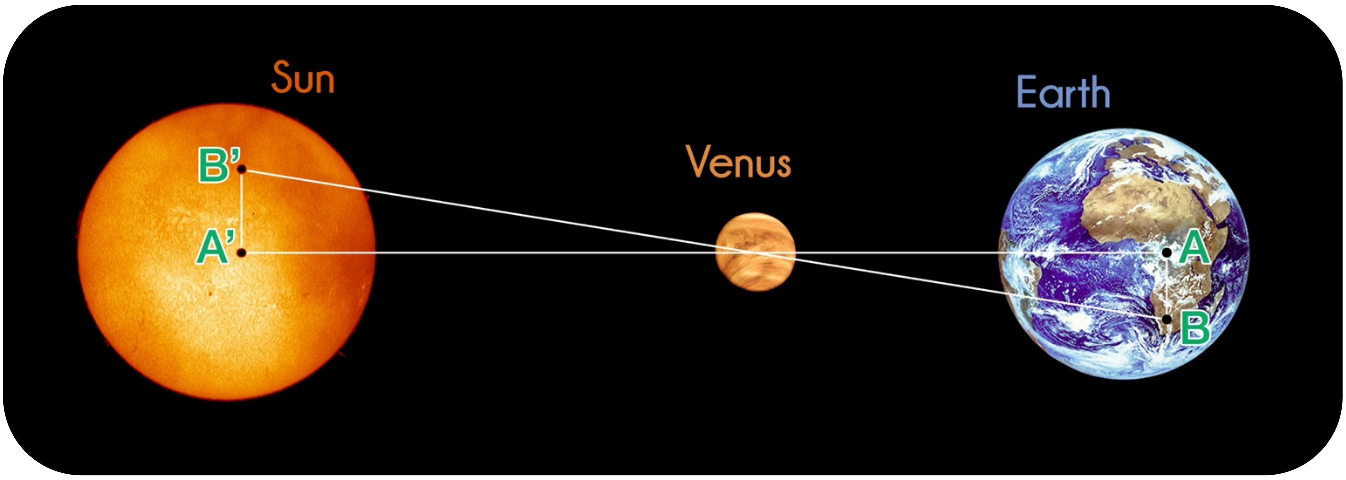
You may notice there's a green tree close to the road. If you were driving the red car and you looked at Paris, this tree would seem to be at the left of the Eiffel Tower. But if you were driving the white car and still looking at Paris, then the tree would look as if it was at the right side of the Eiffel Tower. So even if the tree is still, **it's seen in two different positions depending on where you are looking from. This difference in the apparent position of an object when viewed from two different places is called the parallax effect**. It may look clearer with the next images.

If the red car's co-pilot took a picture of Paris, it would look like this:

But if the white car's co-pilot took the same picture, it would look like this:

They are both taking the same Paris picture, but because they are in different positions, the tree is seen in different places. If this is not clear to you, go back to the red car and white car image, and try to imagine how would your Paris picture look like if you were the co-pilot. Try to imagine where would the tree be in the picture.

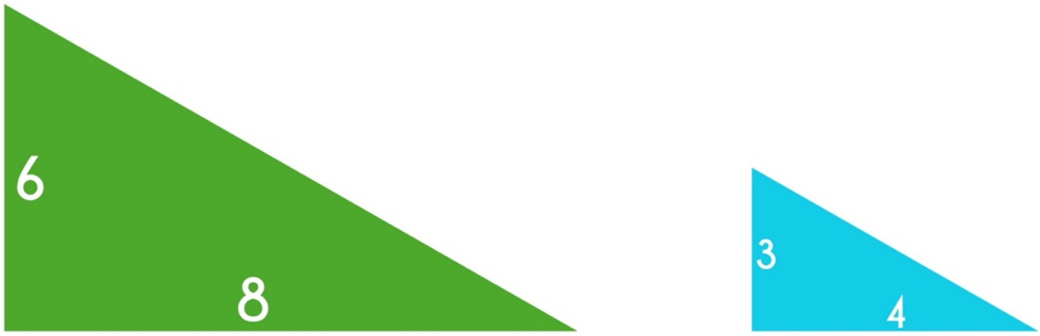
Now let's go one step further: Imagine that Paris is the Sun, the tree is Venus, Adam is the red car, and the white car is Brian, an astronomer from Canberra (Australia). Because Adam and Brian are in different places, if they both take pictures of the Sun (Paris) they would see Venus (the tree) in two different positions. Again, maybe an image will make it easier:



In this last picture, Adam and Brian are represented by A and B; and A' and B', are the positions in which they would see Venus crossing the Sun surface. As in the tree example, here, **Venus is seen in two different places crossing the Sun disk, depending on where are you're taking the picture from**. In the same way the tree seems to be in two different positions if we look at the pictures taken from the red car and from the white car, Venus would seem to be in different positions if we look to an image taken from Svalbard, and an image taken from Canberra. So going back to the title page image, the black spot wont be in that exact place if the picture had been taken from an other place.

Proportionality

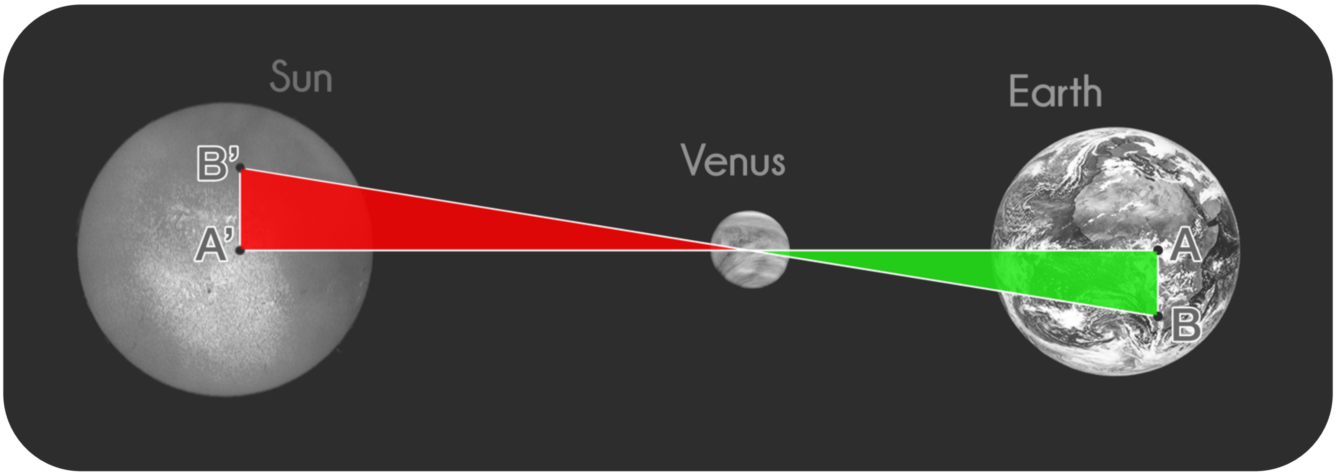
One last thing before we go back to the transit images: Look at the triangles below, they are exactly the same, but one is bigger than the other (also the are painted in different colours).



Because the triangles are exactly the same, once we notice that (8) the long edge of the green triangle is twice as long as (4) the long edge of the blue one (8 = 4 x 2), we already know that (6) the short edge of the green triangle is also going to be twice as long as (3) the short edge of the blue one (6 = 3 x 2). Let's have an other example:

In this case, once we notice that (3) the short edge of the red triangle, is three times (1) the short edge of the violet one (3 = 1 x 3), we already know that (6) the larger edge of the red triangle will also be exactly three times longer than (2), the larger edge of the violet one (6 = 2 x 3). When two or more figures behave this way, we say **they are proportional to each other**.

This teaches us, that when two triangles are exactly the same, if we know the length values of some edges, we may be able to find the unknown ones. We can use this in our experiment: If you carefully look at this image of the transit, you may notice two triangles that are proportional to each other, even if one of them is upside down.



In this case:

- The short edge of the green triangle is the distance between Adam and Brian, which is the distance between Canberra and Svalbard.
- The long edge of the green triangle is the distance between the Earth and Venus.
- The short edge of the red triangle is the distance between A' and B', the difference in the apparent position of Venus in the Sun pictures taken from A and B.
- The long edge of the red triangle is the distance between Venus and the Sun.

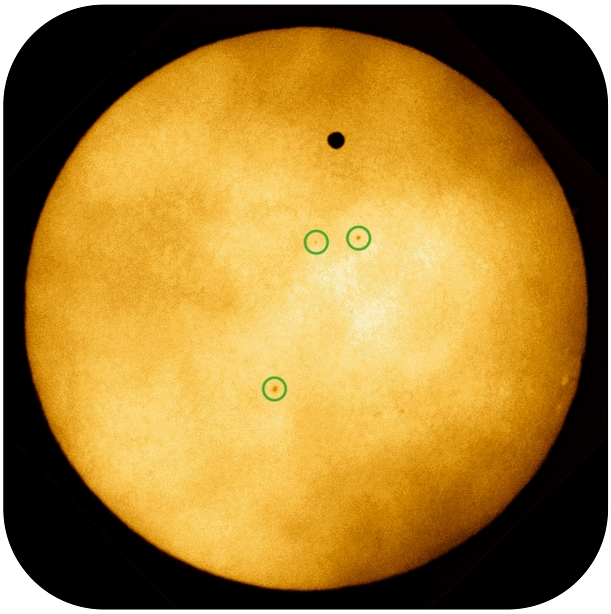
So, if we manage to measure the distance between A and B, and also between A' and B', we can use our knowledge about proportional triangles to obtain the distance between Venus and the Sun!

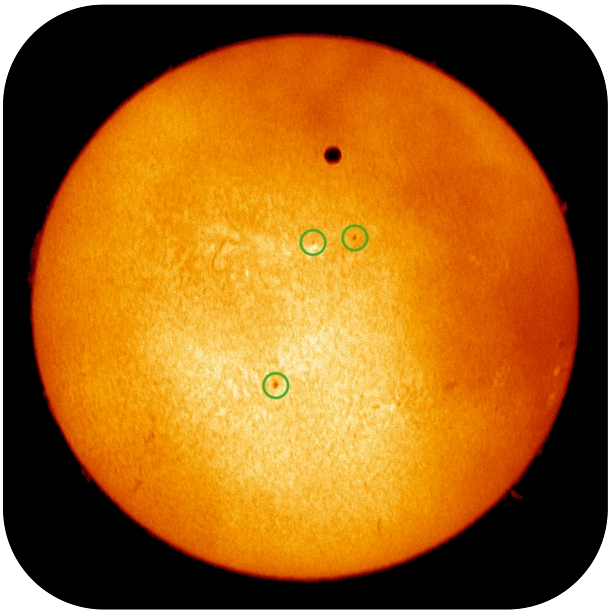
Laboratory Execution

Step 1

To get the distance between A’ and B’, we first need images from the transit taken by Adam and Brian, both from Svalbard and Canberra. In CESAR’s web tool you can choose a pair of images that looks good enough to continue.

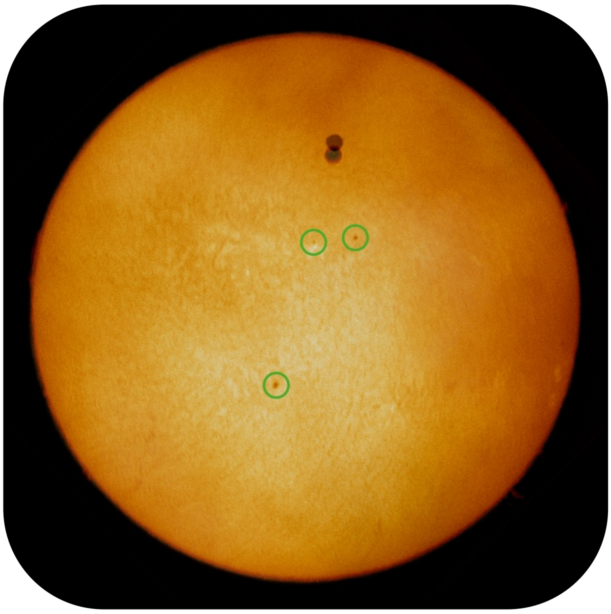
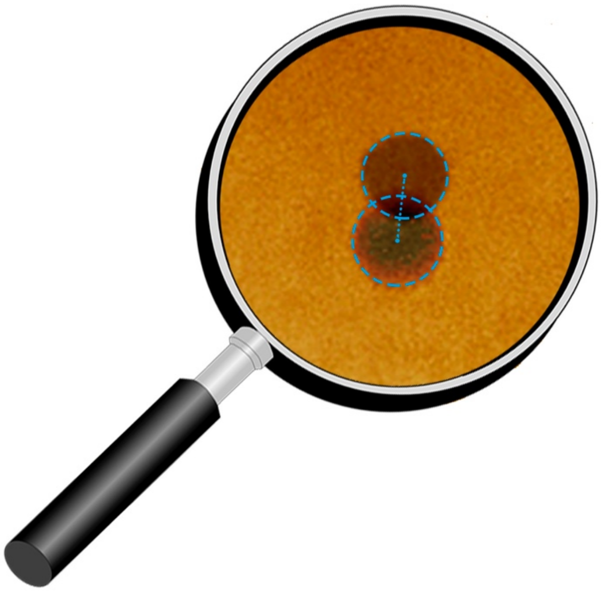
You will see that in any image you choose there is one black circle in the Sun disk, that would be Venus. You should also note some smaller dark dots, those are sunspots.





Once you access the images, you must measure the distance between A’ and B’. But of course, A’ and B’ are the position in which Venus is seen by our two different astronomers, so the spots A’ and B’ are in different images. To measure the distance, we should first **merge those two images in one**, so that we have a final image in which we do can **see both points at the same time**.

Before merging them, you may have to **align the images**, so that the sun is in the exact same position in both. That can be done with the web tool too. The best way to align the images is by checking the position of the sunspots (those green circled). Just let one image be fixed as reference, and move and rotate the other one until the sunspots in both of them are in the exact same position. After merging them, you should get something like the image below, where the sunspots from both original images are in the same position, and the two images of Venus are visible.

It's a standard procedure in science to align astronomy images to a standard. You may download from the SOHO webpage an image of the Sun that was taken at the same time as the other two. Then set it fixed (as this is the standard reference) and move the other two together to align them to the SOHO one, using the same procedure as before.

The SOHO database is

sohodata.nascom.nasa.gov/cgi-bin/data_query

You may choose max resolution for the HMI Continuum. Images are named:

yearmonthday_hourminutes_imagetype_resolution.jpg

choose one of the same date and time as the ones from Svalbard and Canberra.

Now that we have an image where we can measure the distance, we may wonder between which two points exactly we should measure, choosing one random point in each A' and B' Venus images would be way too imprecise. With the tool, we will **measure the distance** between the two centres of each Venus, as shown in the magnifying glass image. Write down this value.

Note that before measuring the distance between the two Venuses you must measure the sun diameter for calibration.

Step 2

We now know the distance between A' and B', but that's only one edge of the red triangle. Let's also find the value of an edge from the green triangle, that is, the distance between Adam and Brian.

To obtain this distance, we'll use the coordinates from the two observatories A and B. The coordinates from Canberra and Svalbard can be obtained using Google Earth or any similar program. (If you don't have access to such as program, the coordinates could also be found on the web.) Once you've got the coordinates, you may use the tool provided in the CESAR webpage to obtain the distance between them.

Now we also know the length of an edge from the green triangle (make sure it's in kilometers).

Note: Alternatively, you can use the tool in the link below, to calculate the distance between those two coordinates. movable-type.co.uk/scripts/latlong.html

Step 3

Since now we know the length of the short edges from both triangles, and we know how they are related, **we can use our knowledge about proportional triangles** to find out the length of the unknown edges. **To find out the value of the red triangle's long edge**, which is the Venus-Sun distance, use the CESAR webpage tools, you only have to introduce the values you calculated in steps one and two.

And that is it!

Conclusions

In this laboratory you have obtained the Venus-Sun distance out of Venus transit images, to do so, you've used knowledge about proportional triangles. To obtain the value of one unknown edge of the triangle, you've previously measured.

- The distance between A' and B', out of the transit images you merged.
- The distance between A and B, out of the coordinates you looked for.

Once you have found the Venus-Sun distance, it's a good idea to check it with some previous known data, for example: We know that the closer planets to the Sun are Mercury, Venus and Earth, look in the web for the Mercury-Sun distance and the Earth-Sun distance. The Venus-Sun distance you've calculated must be somewhere in between.

If you do have obtain a consistent value, try to use it somehow, for example: Look in the web for the Earth-Sun distance. During the transit, how much further away from the Sun than Venus is the Earth?