Observation of the Venus Transit

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Abstract: Transit of the Venus before the disc of the Sun is a rare event: nobody who is living today could observe it until the 8th of June 2004. The lecture first describes the event itself, its periodicity, some problems of observing it, and its role in determining the astronomical unit, i.e. the distance of the Earth from the Sun. Experiences of this year's transit will be reviewed, using also the observations done in Terkán Lajos Public Observatory, Székesfehérvár. The lecture has an aspect of the history of astronomy as well. A lot of astronomers left for long expeditions to observe the Venus transit of 1769. One of these astronomers was János Sajnovics, who was born not far from Székesfehérvár, the town of our Institute of Computer Engineering.

1 Movement of Venus and Earth

Transit of Venus means that Venus moves before the disc of the Sun. The planet Venus is in line between the Sun and the Earth. This line is referred to as the node line, and the Venus is in such a case close to one of the two node points: the ascending node, where Venus moves from below to above the orbit of the Earth, or the descending node, where Venus moves from above to below the orbit of the Earth. This occurence has an interesting periodicity, because the orbit of Venus has an inclination relative to the orbit plane of the Earth. The value of this inclination is 3.394° (Fig. 1.).

The Earth moves 360° around the Sun (sideral orbital period): 365.256 days. The Venus moves 360° around the Sun (sideral orbital period): 224.701 days. This means that Venus sometimes takes over the Earth. The time between two conjunctions is the synodic orbital period of Venus: 583.92 days.

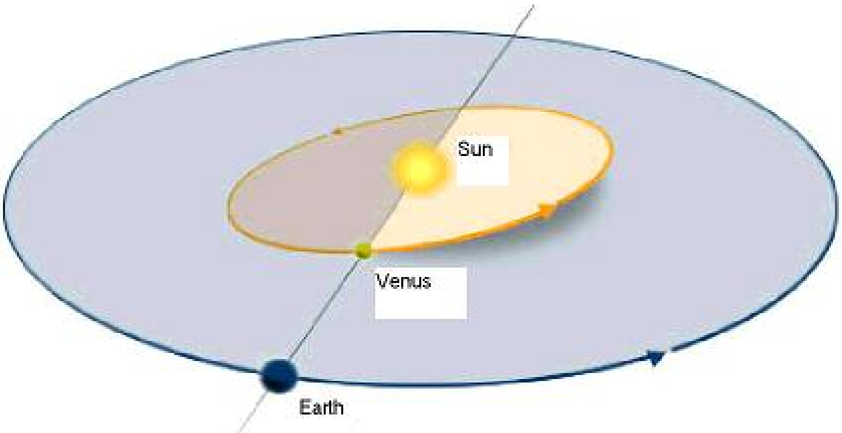

Figure 1. Orbits of Venus and Earth, the transit of Venus

What is the periodicity? Eight times the sideral orbital period of the Earth is very close to five times the synodic orbital period of Venus:

8*365.256=2922.048

5*583.92 =2919.6

It can mean that 8 years after a transit occurs another transit. But it is true only once, becase of the inclination of the orbits (Fig. 2.).

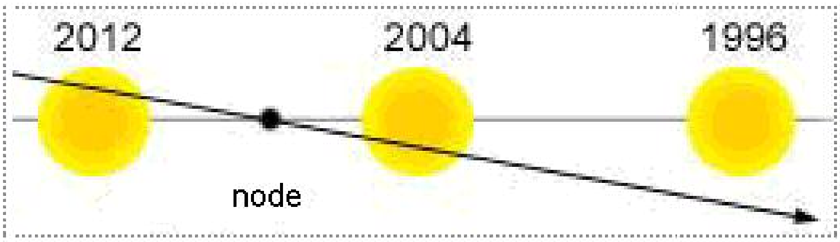

Figure 2. Transits of 2004 and 2012

Venus transits have two series: transits in the ascending node and those in the descending node. Venus is in the ascending node always in june, and in the descending node in december. The periodicity of transits after more exact calculations is the following:

Time since previous transit:

121.5 years (ascending node – june)

8 years (ascending node – june)

105.5 years (descending node – december)

8 years (descending node – december)

The total period is 243 years long. Table 1 shows the years of some Venus transits.

June (ascending node)	**December (descending node)**
	1631
	1639
1761	
1769	
	1874
	1882
2004	
2012	

Table 1. List of some transits

2 Observing transits

In the 18th and 19th centuries observing Venus transits from more sites was used to determine the astronomical unit, i.e. the distance of the Earth from the Sun. This topic will be discussed in chapters 5 and 6.

Observing of the transit of Venus means observing the Sun. Problems of observing the Sun are well known, so here we mention only a special problem of transits : the „black drop" effect: a black bridge between the disc of Venus and the border of the border of Sun (Fig. 3.). It was first documented in 1761 and it hardened the exact determination of the contact times.

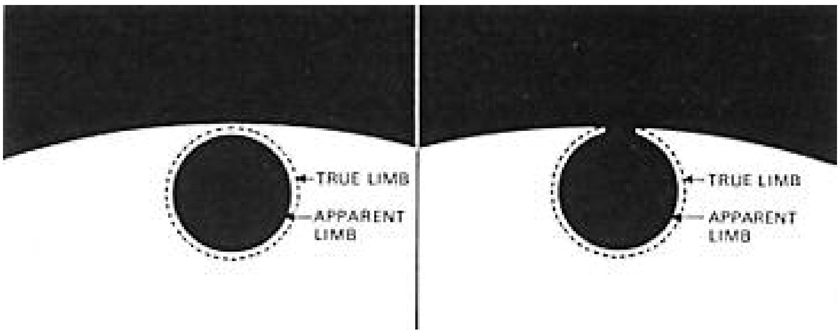

Figure 3. The black drop

As transits occure rarely, this effect is not very well known, and its cases are under discussions. Possible causes are the diffraction, the refraction in the atmosphere of Venus, the so-called seeing (disturbances in atmosphere of the Earth) and that the border of the disc of the Sun is darker then its inner part.
It seems that the atmosphere of Venus can not play a primary role in the black drop effect, becase it was observed at the Mercury transit as well.

3 The transit of 2004

Figure 4 shows the pathes of Venus transits of 2004 and 2012 on the solar disc, and the meanings of the four contact times.

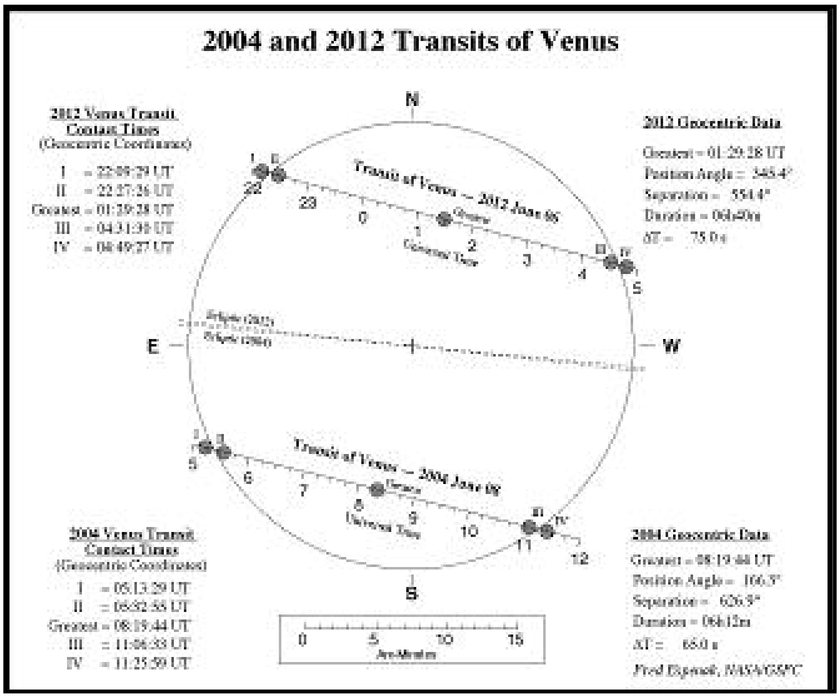

Figure 4. Venus transits of 2004 and 2012 on the solar disc

As shown on Fig. 5, 2004 transit of Venus was visible from Hungary as well, so we made observations in Terkán Lajos Public Observatory, discussed later, in Chapter 4.

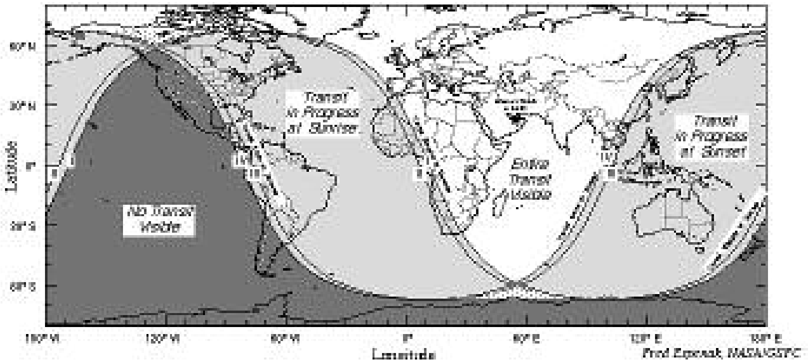

Figure 5. Visibility of Venus Transit 2004

Here, we give a short and partial preliminary review of other observations.
As today the Venus transit has no more importance in determining the astronomical unit, most of the preliminary reports deal with the black drop effect. Some observers saw it, others did not. From some observing places it could be seen at egress, from other sites at ingress. So we have to suppose, that atmosphere of the Earth plays an important role. Some experts say that telescopes are better today then in the 18th and 19th centuries, therefore black drops occur not always.
Figure 6 is a photo taken by NASA's TRACE mission. Atmosphere of the Venus can also be observed. Figure 7. is a photo of Fred Espenak, taken in Grece at the second contact. The black drop can be seen.

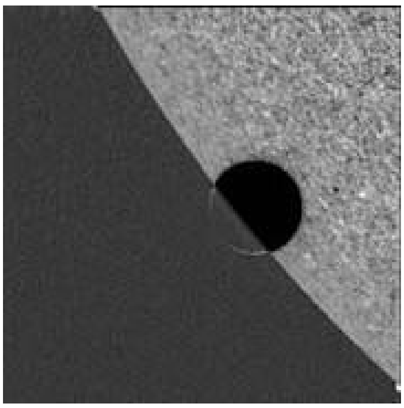

Figure 6. Atmosphere of the Venus

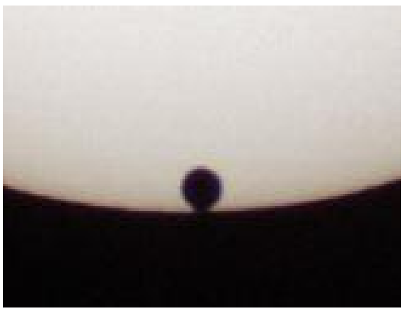

Figure 7. The black drop

4 Observations in Terkán Lajos Public Observatory

In addition to demonstrations to the public with smaller telescopes, we made photos with a 300 mm Newtonian telescope and digital camera using ocular projection.

Time measurement was accomplished by the internal clock of the camera and a watch synchronized to a radio clock (accuracy 1 second).

Settings of the camera at ingress pictures (Fig. 8.): exposure time 1/500, diaphragm 4.0, sensitivity ISO50, focus 16.2 (equivalent to 35 mm film)

Settings of the camera at egress (Fig. 9.) and the composed (Fig. 10.) pictures: exposure time 1/200, diaphragm 8.0, sensitivity ISO50, focus 7.8 (equivalent to 35 mm film)

At the ingress, in the morning, when the Sun was on the lower part of the sky, we could not see a good picture, the time of the 1st and 2nd contact could be determined with an uncertainty of more than 5 seconds. At ingress we saw the black drop. At egress, at a high altitude of the Sun, black drop was not visible. So, our experience shows the influence of the Earth's atmosphere. But, referring to the other opinion, our telescope is probably not bet better, than the telescopes of the 19th century.

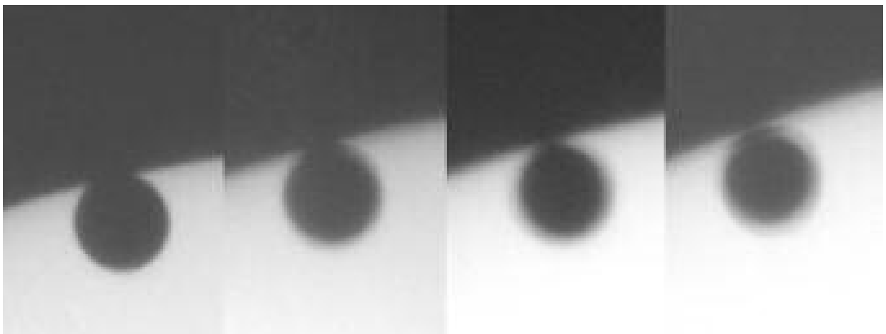

Figure 8. Ingress pictures (with black drop), times from left to right:
UT 05:38:27, 05:39:13, 05:39:34 05:39:50

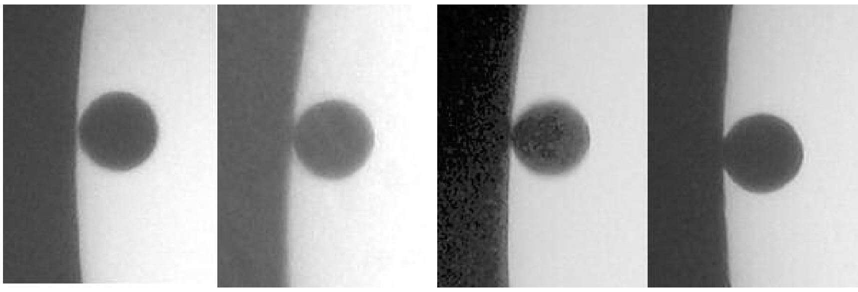

Figure 9. Egress pictures (without black drop), times from left to right:
UT 11:03:21, 11:03:43, 11:04:00, 11:04:14

We made a composed picture using GIMP image processing program. Rotation of the pictures was done on the base of measuring the angle of the two largest sun-spots. Moving and fitting was done on the base of sun-spots and the border of the solar disc.

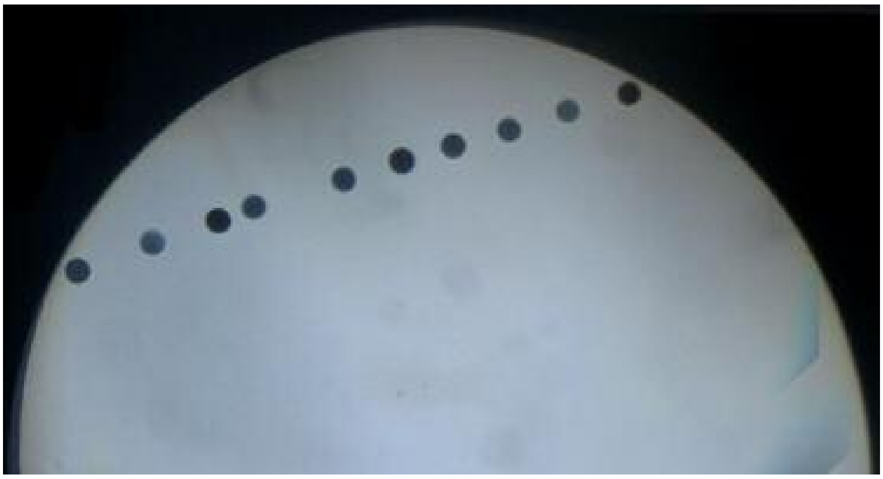

Figure 10. Composed picture, times from right to left(!):
UT 05:42:25, 06:19:49, 06:51:46, 07:25:13, 07:56:53 , 8:30:52, 9:21:12, 9:44:42, 10:20:27, 11:00:14

5 Determining the astronomical unit using Venus transit observations

Here we sketch an extremely simplified principle of determining astronomical unit. Some complicating factors will be mentioned later. Figure 11. shows the Earth, the Venus and the Sun.

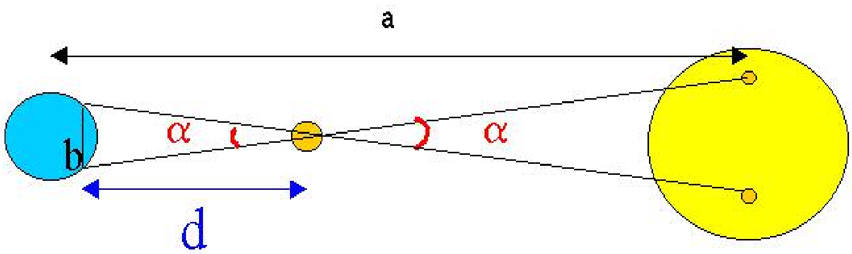

Figure 11. Simplified methode of determining astronomical unit
a: astronomical unit
b: distance of two observing sites on the Earth
d: distance of the Earth from the Venus
α: parallax angle of the Venus between the two observing sites

Astronomical unit can be determined by this simplified model as follows:

$\alpha = b/d$

$1 = (b/\alpha) * (1/d)$

$a = (b/\alpha) * (a/d)$

a/d is known from Kepler's third law

Instead of angle measurement one can measure the transit times at each observing sites. The transit time is proportional to the length of the chord of the circle. So α can be determined (Fig. 12.).

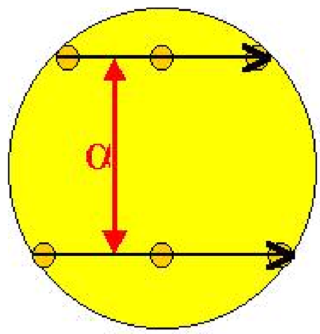

Figure 12. Chords seen from different observing sites

Of course, there are a lot of complicating factors, e.g.:

- b should be calculated to be perpedicular to the Earth-Venus line
- b does not passes through the Earth's centre
- longitude of observation places is different
- orbits are ellipses instead of circles
- orbit plane of Venus is different from the ecliptic plane
- Duration of the transit is several hours
- earth is rotating
- movement of Earth and Venus is not linear
- Right ascension and declination of the Sun is changing during the transit
- Venus seems a disc, not point
- Not the actual distance, but the half major axis of Earth's orbit is to be determined

Discussion of these factors will require a separate lecture some time.

6 Venus Transit in 1769

Astronomers prepared theirselves intensively for observing the Venus transit of 1769. They wanted to determine the astronomical unit, as we wrote in chapter 5. In the preparations they made use of the experinces of the 1761 transit.

More then 100 important observing sites were established in a worldwide co-operation.
For example: in Russia (eastern part), Sweden (Uppsala, Nordkapp), in different sites of Northern America.

From France Choiseuil led an expedition to Eastern India, Chappe d'Auteroche to Southern California, Pingré to Northern America

The most famous expedition is probably that of captain James Cook and the astronomer Charles Green to Tahiti

Because in Europe it was night, observation was possible only inside the polar circle.

King Christian II. of Denmark and Norway invited an expedition to the island Vardö. The leader of this expedition was Maximilian Hell from Vienna, who take with him János Sajnovics from Nagyszombat (Trnava).

We deal with this expedition in a more detailed way, because of the Hungarian relations.

We know the history of the expedition from the diary of Sajnovics. They left from Vienna April 28th 1768, they were staying on Vardö from Oct. 11. 1768. until June 27. 1769. When the transit took place (3rd of June) they had a lucky weather. Returning from Vardö they were staying in Copenhagen from Oct. 17. 1769. until May 22. 1770. They arrived to Vienna August 12th of 1770.
Evaluation of observation data was done in Copenhagen (as they were the guests of the Danish king). Hell received very good results. He was accused of altering their data, but later he was cleared (unfortunately only after his death).
Both Hell and Sajnovics published their book in Copenhagen: Hell about the observations and the evaluation, Sajnovics about the relationship of Hungarian an Lapp languages.

7 János Sajnovics

János Sajnovics was born in 1733, Tordas (between Buda and Székesfehérvár). He died in Buda, 1785.

Sajnovics was a Jesuit monk (similarily to Maximilian Hell). He worked in Vienna with Hell, then at the university in Nagyszombat. After the expedition to Vardo he returned to Nagyszombat (Trnava). Then he moved with the university to Buda.

He established the Finno-Ugrian comparing linguistics in his mentioned. This book, and also his diary was published in Hungarian only in the second part of the 20th century.
In 1778, when Sajnovics worked for the University Observatory in Buda, he published the first astronomical textbook in Hungary (in Latin). Its Hungarian translation was published in 1993, Székesfehérvár (translated by Rezső Nagy, sr.)

The contents of the book:

Observing astronomy includig obsevatories, devices and methods

Calculating astronomy including stellar catalogues, planetary tables and ephemerides

Physical astronomy including physical system, phisical and „moral” effects of stars

Uses of astronomy in chronology, geography, navigation and in recognizing God

From the point of view of this lecture the most interesting section of the book lists the distance of the planets from the Sun (in German miles). **The astronomical unit is determined from the observation results of 1769 Venus Transit.** Proportions of the distances known from Kepler's 3. Law.

Conclusions

In this lecture we dealt with the event of Venus transit, its periodicity, its observation, and its importance in the history of astronomy.

We discussed the observation of 2004 transit in Terkán Lajos Observatory, the „Hungarian” expedition of 1769 and Sajnovics's textbook of astronomy, published in 1778.

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