The opportunity of the 2016 transit of Mercury for measuring the solar diameter

Costantino Sigismondi
(ICRA/Sapienza Università di Roma and IIS F. Caffè)
F. Castiglioni, D. Cicogna, L. F. Cardoso
(Sapienza Università di Roma, Solar Physics Lab A. Cacciani)

Abstract

The transit of Mercury occurred two times in this century: 2003, May 7 and 2006, November 8. In 2016 there is another opportunity to observe this phenomenon and measure the solar diameter with the method of comparing the ephemerides with the observations. This method has been presented by I. I. Shapiro in 1980, the data of the observed transits (since 1631) have been re-analyzed by Sveshnikov (2002) and an improvement on the observed data, to avoid the confusion given by the black-drop effect, has been presented by C. Sigismondi and collaborators since 2005 by exploiting the idea of measuring the chord drawn by the solar limb with the disk of the transiting planet presented by G. Di Giovanni (2005) on the transit of Venus: the improvement is obtained by extrapolating to zero the analytic chord fitting the observations without the black drop, but in the ingress/egress phases. For the transit of 2006 K. Reardon with IBIS (California) and J. Pasachoff with Mauna Kea (Hawaij) telescopes were ready to get useful data but the weather's conditions were not good, and only the SOHO data (M. Emilio, 2012) contributed to the solar diameter monitoring. A network of European observers (IOTA/ES) and observatories (coronograph of Bialkow, PL 56 cm; IRSOL, Locarno CH - 45 cm Gregorian telescope; carte du ciel, Paris, FR 30 cm, Torre Solare di Monte Mario, Rome 26 cm) are active for the 2016 transit.

Introduction

On May 9, 2016 there is the fifth planetary transit of this century: 3 of Mercury (2003, 2006 [8] and 2016) and 2 of Venus (June 8, 2004 and June 6, 2012). For measuring the solar diameter Venus offered a unique opportunity with long lasting ingress and egress phases of almost 20 minutes, while for Mercury such phases last about 4 minutes; the grazing

transit of 1999 was longer and gave the opportunity to study the black drop, similar to the shadow's attractions [4,10].
The comparison between the ephemerides and the observed timings of the ingress/egress allows us to compute the diameter of the Sun, in the hypothesis of spherical Sun [1,2,5].
This hypothesis is well confirmed within the errorbars of our measurements (RHESSI data, 2008 and SDS data show the Sun circular with an oblateness of 8 parts in 10^6 [6]).
Dicke (1960s) searched for a solar oblateness to find room for his scalar-tensorial theory of gravitation alternative to Einstein's one. Now the interest in the solar figure is mainly for its subsurface activity and for the variations of the diameter with eventually consequences on Earth's climate [7].

Method and data useful for measuring the solar diameter

It is important to stress that the absolute timing of the four contacts is important, but it is more important to have several images (>50) with their absolute timings taken during the ingress (this is visibile in all Europe). From the images, as in the case of planetary images, we can select them with good local seeing, or temporary calm (being the seeing a statistical measurement of the optical turbulence of the atmosphere).
50 of such images sampling the 191 s of the ingress will allow to fit the chord planet-solar limb and to find the times when it is zero (t1 and t2 of the ingress). These two (absolute) times t1 external contact, t2 internal contact, will be compared with the ephemerides. The location (adress and city) of the observer has to be known to compute precise ephemerides.
Summary: **1.** A sequence of UTC timed photos (or frames from a video) is recorded during the ingress phase (egress when available); **2.** the best photos of each stage are selected for avoiding seeing confusion; **3.** the analytic function of the chord

c(t) [3] is fitted to the data to find c(t1, t2)=0. **4.** the comparison with the ephemerides of such t1, t2 allows us to calculate the variations of the solar radius with respect to the standard one of 959.63" in visible light. Note that in case of Hα filters the value of the solar radius is different, so a note on the filters used during the transit for recording the photo is important.
As "best choice" method we select about 50 images like in fig. 1 during the ingress from 13:12:10 to 13:15:21 TMEC.
During the preparation to this event is crucial to verify how to focus perfectly the solar spots visible, and the maximum resolution obtainable with the "best choice" method.
5. In alternative to **3.**: the distance d(t) of the entering Mercury limb to the solar limb is a linear function of time, when it exceeds the angular diameter ±ΔD of Mercury, t2±Δt2 is found.

References

[1] I. I. Shapiro. Science, Vol. 208, 51 - 53 (1980).
[2] Sveshnikov, M. L., Astronomy Letters, 28,115-120 (2002).
[3] Di Giovanni, G. Astronomia UAI, 2, p. 15 - 19 (2005)
[4] Pasachoff, J. M, et al.(2005) (source for figure 1)
http://web.williams.edu/Astronomy/eclipse/transits/IAU_UK_pasachoff_final.pdf
[5] Sigismondi C., et al.
http://adsabs.harvard.edu/abs/2015mgm..conf.2369S (2015)
[6] Fivian, M. D. et al.,
http://adsabs.harvard.edu/abs/2015TESS....120325F (2015)
[7] Sofia, et al., MNRAS 436, 2151 (2013)
[8] Emilio, M., ApJ 750, 135 (2012), Mercury transits in 2003-6
[9] TRACE Satellite orbital parameters
http://nssdc.gsfc.nasa.gov/nmc/spacecraftOrbit.do?id=1998-020A
Periapsis 520 km Apoapsis 547.2 km Period 95.48 minutes Inclination 97.84° Eccentricity 0.00098
[10] C. Sigismondi, https://youtu.be/c5o69RmrqGM

Fig. 1 Fasi dell'ingresso di Mercurio sul Sole osservato da TRACE, Transition Region and Coronal Explorer, satellite della NASA, il 15 Novembre 1999 [4,9]: transito radente che ha permesso di studiare l'origine ottica del black drop. Su immagini così si applicano l'algoritmo delle corde e della distanza.