Measurements made during the transit of Mercury

Autor(en): **Brodbeck, Roland / Pesendorfer, Marc**

Objekttyp: **Article**

Zeitschrift: **Orion : Zeitschrift der Schweizerischen Astronomischen Gesellschaft**

Band (Jahr): **62 (2004)**

Heft 321

PDF erstellt am: **24.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-898325

Measurements Made During the Transit of Mercury

ROLAND BRODBECK, MARC PESENDORFER

In the article «*Determination of the Astronomical Unit on the Basis of a Transit of Venus*» we presented a method for the determination of Venus's parallax during a transit.
The diurnal parallax of Venus or Mercury can be used for the determination of the astronomical unit (AU) in kilometers assuming a known movement of the Earth's centre. Based on this method the times of contact or the angular distance measurements separating the Sun's and the Planet's centers during a transit (passage in front of the Sun's disc) allow to do the required evaluation. As a practical application of the method the authors have performed these measurements during the transit of Mercury of 7 May 2003 and obtained an AU to 10% accuracy.
This paper is based on the article; «Determination of the astronomical Unit (AU) based on a transit of Venus», published in [1]

Introduction

The «Project Venus 2004» [2] is presently being carried out by Swiss amateur astronomers under the leadership of ANDREAS INDERBITZIN, president of the Astronomical Association of Zurich (Astronomische Vereinigung Zürich - AVZ)[1]. The aim of the project is, using the present day means of amateur astronomers, to determine the astronomical unit/AU (approx. the Sun-Earth distance). The idea is to learn and experience as much as possible astronomy in theory and practice. The object of the project is to promote personal education, and has no scientific pretence. One can therefore concentrate on the more exciting aspects of the questions involved and for example – as in the present case – assume the movement of the centre of the Earth within the solar system to be known (see the corresponding remark in the appendix).

The method described in the above mentioned article allows to use the measured times of contact and angular distance between the Sun's and planet's centers. Our question was: will it be possible, with amateur astronomer equipment, to measure the angular distance between Sun and Venus during the transit of 8 June 2004 sufficiently accurately to obtain a value of the AU within an acceptable range? Such measurements were made, as a general tryout, during the transit of Mercury on 7 May 2003. The difference between the diurnal parallax of Mercury and Sun (the value to be measured) is significantly smaller than the difference of the diurnal parallax of Venus and Sun. Hence, if the measurement for Mercury succeeds within our premises, it could only give better results for Venus.

The Expedition

As equipment we had at our disposal an older model of a Meade LX 200 with 20 cm aperture and a Meade ETX 125 with 12.5 cm aperture (Figure 1). During the transit we photographed the Sun and Mercury with a digital camera CoolPix 990. Both instruments were equipped with a Baader sun filter. The ETX was used to allow visual observations. The site (south of Memmingen, Germany) was chosen to allow free sight to the east. Similarly to the awaited Venus transit on June 8th, 2004, the transit of Mercury began shortly after sunrise. Any unforeseen buildings, trees and mountains obstructing the direction where the Sun rose would have prevented us from following the beginning of the phenomenon.

The chronometric progress of the angular distance between the Sun's and Mercury's centers was to be determined later based on the photographs. All the data required for evaluation was gathered during the transit. A GPS (Navigation with satellite signal) receiver was used as a chronometer; but a radio-controlled clock would also do the job just as well. The geographical position is less critical for the intended measurements; and it is not necessary to have a GPS for that purpose. The geographical coordinates read from a good map are satisfactory.

A picture was taken every two minutes during the more than five hours of the transit, resulting in about 200 exposures. The photographic field was chosen to show a significant portion of the Sun's limb including also Mercury. Regularly, we checked the quality of the exposures using a laptop, so that corrections of image sharpness and exposure time could be undertaken. As the transit lasted during the whole morning and the Sun's elevation increased, the exposure time varied considerably: for an effective sensitivity of 400 ASA, from 1/125 to 1/1000 second. All pictures were sized as 2048 x 1360 pixels.

The Evaluation

The images were then evaluated at home. First, however, the optical distortion of the complex digital camera - telescope system had to be determined, in order to correct to a certain extent the pictures. The object then being to evaluate the distance between the centre of the Sun and the centre of Mercury straight from the pictures. A small self-developed program was adapted to that end so that a test-image (a card 30m away photographed though the telescope) was to a large extent corrected (Figure 3). This correction was then being applied to seven of the best transit exposures.

The corrected pictures were then evaluated with the help of a CAD-Program, AutoCAD. To begin with, we choose three points on the Sun's limb; AutoCAD automatically plotted a circle through them. The radius of this circle corresponds to the known apparent Solar radius in arc seconds at the day of transit. Thus, the scale of the picture (resp. CAD-drawing) is determined. Likewise a circle was drawn around Mercury's disc (Figure 4).

The program gives the distance between both centers straight in arc seconds. This is the desired value of the angular distance at the time of the exposure.

In order to get a first impression of the usefulness of these measurements we considered seven measured points (angular distance Sun's centre - Mercury's centre at a determined time). Then, based on the model described in [1], the AU was determined as a free parameter. An astronomical unit of 145 million kilometers best fitted our measurements (a better value is 149.6 million kilometers). A professional program for evaluation of physical measurements (ProFit of Quantumsoft) gave an error of 13 million kilometers (Figure 5). A subsequent comparison of the angular Sun-Mercury distance with the professional NASA ephemerides gave an error for our measured positions of 0.5 to 1.5 arc seconds.

Conclusion

We have shown that it is possible, using amateur astronomical equipment and with an acceptable investment of time and effort, to determine the angular distance between a planet (Mercury or Venus) and the centre of the Sun with an accuracy of one arc second from digital pictures. This is sufficient for the purpose of measuring the diurnal parallax and, if the position of the Earth's centre in the solar-system is known (geocentric ephemeris), to determine the astronomical unit within an error up to a maximum of 10%. By evaluating more then 7 exposures it would surely be possible to improve the obtained result. However, the process of learning how to apply the method, in the case of Mercury, was achieved and in this respect it would not bring an essential improvement by evaluating, let us say, 30 instead of 7 exposures.

For us the undertaking was a success. During the preparation we learned a lot about celestial mechanics and then had the opportunity to put that knowledge to practice for the transit of Mercury. Thereby we have been in a position to successfully link theory and practice. We hope that during the centenary event of Venus's transit we will be able to repeat the experiment.

Translation:

RENY O. MONTANDON

Reference

[1] Orion 312 (5/2002) ISSN 0030-557-X, Seiten 4-9, Oktober 2000
Download: http://eclipse.astronomie.info/transit/venus/theorie/parallaxe.pdf

[2] *Interntet: http://www.astronomie.info/projektvenus*

```
double modellMerkur(double t, double AE, double Zeitfehler, // in Sekunden
                    double Breite,
                    double MeridianzeitSonne, // fuer Zuerich 11.35
                    double MeridianzeitMerkur)
{
    const double c = 299792.458;
    double  DV,DS,RAS, DKS, RAV,DKV; // Rektaszension und Deklination der Gestirne
    double  B,R,w,DEG,DK,v,f,Erdradius;
    f         = 1/298.257;  // Erdabplattung

    t         = t + (Zeitfehler/3600.0);
    DV        = 0.5590598235; //Abstand des Merkurs in AE, geozentrisch, 08:00 UT
    DS        = 1.0090144706; // Abstand der Sonne in AE am Transittag.

    B         = pi*Breite/180.0;  // geographische Breite
    Erdradius= 6378.14 * sqrt(sqr(cos(B)) + sqr((1-f)*sin(B)));
    R         = Erdradius/(DS*AE);
    DEG       = 180.0/pi;
    v         = cos(B)*2*pi*6378.14/86170/c;

    //SONNE, Meridiantransit um 11h22m
    w         = 2*pi/(24.0);
    DK        = pi*(16.639305 + 1.162836e-2*t - 3.9379320e-6*t*t
                -9.103703e-9*t*t*t + 2.574965e-10)/180;

    AB_RK     = v*cos(w*(t-11.35))/cos(DK); // ca. taegliche Abberation
    AB_DK     = v*sin(w*(t-11.35))*sin(DK);

    RAS       = (43.574332 + 4.032411e-2*t + 1.984386e-6*t*t)
                - DEG*R*cos(B)*sin(w*(t-11.35))/cos(DK) + DEG*AB_RK;
    DKS       = DEG*DK + 1.0*DEG*R*(cos(B)*sin(DK)*cos(w*(t-11.4))
                - sin(B)*cos(DK)) + DEG*AB_DK;
    RAS       = RAS/DEG;
    DKS       = DKS/DEG;


    // Merkur, Meridiantransit 11h21m}
    R         = Erdradius/(DV*AE);
    w         = 2*pi/(24.0 - 6.5/60.0);
    DK        = pi*(17.055739 -1.883552e-2*t -7.647848e-6*t*t
                      + 7.100407e-8*t*t*t)/180.0;
    AB_RK     = v*cos(w*(t-11.35))/cos(DK) ;
    AB_DK     = v*sin(w*(t-11.35))*sin(DK);
    RAV       = (43.976210 - 2.224217e-2*t - 5.005218e-6*t*t + 1.25023e-7*t*t*t)
                - DEG*R*cos(B)*sin(w*(t-11.35))/cos(DK)  + DEG*AB_RK;
    DKV       = DEG*DK + DEG*R*(cos(B)*sin(DK)*cos(w*(t-11.35))
                - sin(B)*cos(DK))  + DEG*AB_DK;
    RAV       = RAV/DEG;
    DKV       = DKV/DEG;

    // Abstand zweier Punkte auf der Himmelskugel
    return 3600*DEG*acos( cos(RAS)*cos(RAV)*cos(DKS)*cos(DKV)
                        + sin(RAS)*sin(RAV)*cos(DKS)*cos(DKV)
                        + sin(DKS)*sin(DKV) );
}
```

Appendix to [1]

Doesn't the cat bite its own tail, when utilizing an assumed movement of the Earth's centre?

The calculation of the movement of the planets around the Sun is based on the Newtonian gravitation law (plus Einstein's general relativity). Beyond the Sun's attraction, the far lesser relative attractions of the planets which perturbs their orbits have also to be considered. In order to predetermine the movements of the planets or to interpret these movements afterwards, the IAU (International Astronomical Union) system of astronomical units is used instead of the basic units, meter, kilogram and second:

Length: Astronomical Unit (AU), defined as the radius of a circular orbit in which a body of negligible mass, and free of perturbations, would revolve around the Sun in a precise number of days (approx. one year).

Mass: the mass of the Sun (S).

Time: is a time interval of one day (D) of 86400 SI seconds (SI - Systeme International)

The constant of gravitation being in this astronomical system of units:

All calculations are then carried out in this astronomical system of units. Only when one wants to calculate the apparent position of a planet (or of the Sun) in the sky for an observer at the Earth's surface has one to consider the distance of the celestial body, expressed in meters. This effect is the parallax that has been measured using the method described above, as well as in [1].

As the measurement has no (longer) to fulfill a scientific objective, the AU being today known up to a few 10 meters, one can concentrate dedicate oneself to the process of learning the celestial mechanics involved in theory and practice.

We have not considered the transformation of the centre of gravity of the Earth-Moon system to the Earth's centre of gravity. Also, we have not attempted to clarify if in the 18^{th} Century, as for example when JAMES COOK observed Venus's transit from Tahiti (Point Venus) in order to later determine the AU with the help of observations made by many other astronomers throughout the world, sufficiently accurate ephemeredes were available to use the method described in [1]. The answer is probably no. But it would have been feasible during both of Venus's transits at the end of the 19th Century. Authoritative contributions to this theme would interest us.

Appendix 2

Modelling function, angular distance Sun-Mercury at the day of transit.

The AU is then the free parameter that has to be fitted to the measured distances. The program is C++. The theory is given in [1]. The function calculates the apparent angular distance between Sun and Mercury at the instant *t*.

'*t*' in hours UT at the day of transit. A constant offset to the time, of approx. 128 seconds, has to be considered. The model gives exact results for the day of transit.

AU: astronomical unit in kilometres.

Latitude: observer's geographical latitude.

Meridian passage: the moment when the celestial body reaches its maximum altitude crossing the observer's meridian at the day of transit.

ROLAND BRODBECK
Im Berg 3
CH-8259 kaltenbach
info@astronomie.info

MARC PESENDORFER
Schattengasse
CH-5318 Mandach

1 The AVZ is a section of the Swiss Astronomical Society (Schweizerische Astronomische Gesellschaft -SAG).

KLEIN INSERATEN
PETITES ANNONCES

- *Wegen zu wenig Gebrauch billig zu verkaufen:*
1 Newton Teleskop,
D200, F1200mm Badener Montierung mit Antrieb.
2 Dobson Newton,
D105, f1000mm.
1 Newton
ohne Montierung, D105, f500mm.
1 Newton
ohne Montierung, D100, f400mm.
1 Celestron C90, Maksutov Teleskop.
1 Spectiv Celestron 20/60.
1 Fernrohr für sonnenbeobachtung
D50, f1500mm mit Daystar Filter.
Anfragen an: Kurt Hauenstein, Hubwiesen 2, CH-8588 Zihlschlacht. Tel 071 422 25 85.

- *Zu verkaufen*
Meade LX 200, 12" (Kaufdatum Mai 1999), komplett mit Stativ und weiteren Zubehörteilen (Okulare, Taukappe, Sonnenfilter etc.). VB Fr. 5000.—.
Prof. Peter Mürner, 031 631 82 58