

OBSERVATIONS OF THE ANNULAR ECLIPSE ON 2012 MAY 21 BY THE GENERAL PUBLIC IN JAPAN

MITSURU SÔMA

National Astronomical Observatory of Japan, 21-1, Osawa 2-chome, Mitaka, Tokyo 181-8588, Japan

E-mail: Mitsuru.Soma@nao.ac.jp

(Received November 30, 2014; Reviced May 31, 2015; Accepted June 30, 2015)

ABSTRACT

We had a campaign of observing the annular solar eclipse on 2012 May 21 by naked eye through eclipse eyeglasses to determine the limit line of annularity. As a result, we had about 15,000 reports through our website. In addition there were many observation groups for which about 30,000 people in total participated in the observations. The overall result was that the limit we observed by naked eye through eclipse glasses coincided with a prediction that took into account the lunar limb irregularity within the error of ± 500 m. This error of the limit line location corresponds to about ± 200 km of the radius of the Sun.

Key words: eclipses: Sun's radius

1. INTRODUCTION

An annular solar eclipse occurred on 2012 May 21 in Japan, and large cities like Tokyo, Osaka, and Nagoya were in the annular eclipse zone (Fig. 1). As a result, about 2/3 of the Japanese population were able to see the annularity in their homes. On this occasion, in order to promote the interests of the general public for such a great astronomical phenomenon, we had a campaign of eclipse observations. In particular, we encouraged people to report if they were able to see the annularity at their location by naked eye through eclipse eyeglasses in order to determine the limit line of the annular eclipse zone. In Japan only the northern limit line could be observed since the southern limit line was over the ocean. In this paper we describe the results of the campaign.

2. NORTHERN LIMIT OF ANNULARITY

In Japan only the northern limit line could be observed since the southern limit line was over the ocean (see Fig. 1). To tell the truth, the northern limit line predicted by the NASA Eclipse Web Site: <http://eclipse.gsfc.nasa.gov/eclipse.html> and that by the Ephemeris Computation Office of the National Astronomical Observatory of Japan (NAOJ): <http://eco.mtk.nao.ac.jp/koyomi/> were different by about 2.7 km (Fig. 2) and people were curious to know where the actual limit line would pass.

Takeshi Inoue of the Akashi Municipal Planetarium found that the northern limit line passes through Akashi City and planned to determine where the actual location of the limit line would be from observations by the citizens in the city. On 2011 May 21 (1 year before the

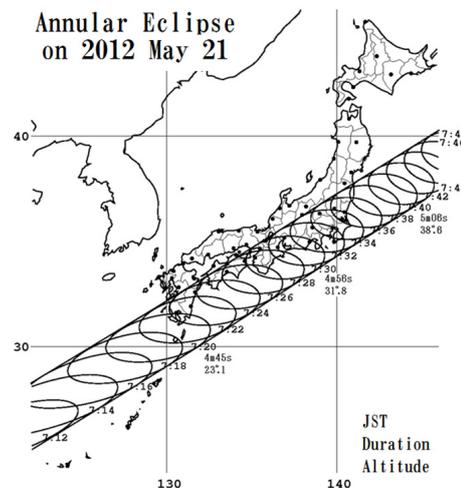


Figure 1. Areas which saw annular eclipse on 2012 May 21



Figure 2. Northern limit of annularity

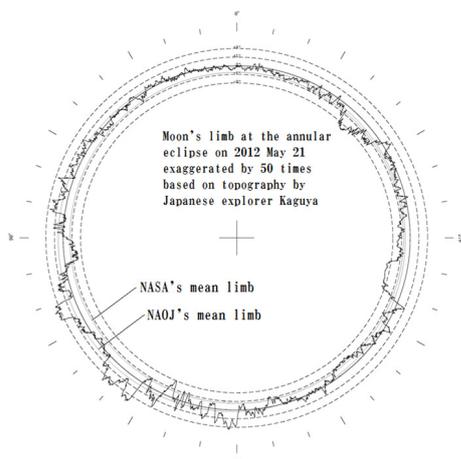


Figure 3. Moon's limb at the annular eclipse

eclipse date) the 1st Symposium of Annular Eclipse was held in Tokyo. In that Symposium Inoue talked about his plan for the observations. After that observations by school children and the general public were also planned at other places along the limit line.

Reasons for the differences between predictions can be summarized as follows:

- Moon radius ($k \times$ Earthradius)
NAOJ (Current Ephemerides): $k = 0.2725076$
NASA: $k = 0.272281$
The difference between them for the Moon's radius is about 1.4 km. This leads to about a 2 km difference in the limit line.
- Correction for the difference between gravity center and figure center of the Moon (about 0.5 arcsec)
This leads to about 1 km difference in the limit line.
- $\Delta T = TT - UT1$
NAOJ:67s and NASA:67.7s
Here TT is Terrestrial Time based on the atomic clock and UT1 is Universal Time determined by the Earth's rotation. The actual value of ΔT at the time of the eclipse was 66.75s. The difference in ΔT between NAOJ and NASA leads to about 0.2km difference in the limit line.

For precise location of the limit line we need to take into account the actual limb profile of the Moon.

3. LUNAR LIMB PROFILES

The Japanese Lunar Explorer KAGUYA was launched on 2007 Sept 14 and lunar observations by Kaguya were made for about 2 years afterwards. A global accurate and precise topographic map of the Moon was constructed from the data obtained by LALT (laser altimeter), which was one of the instruments on board KAGUYA. Lunar limb profiles can be precisely predicted from the lunar topographic data by Kaguya LALT for each eclipse and for each observation station. Such lunar limb profiles for the annular eclipse of 2012 were drawn as given in Fig. 3. Sôma et al. (2012) used the lunar limb profile and calculated the precise location of the northern limit line in Japan.

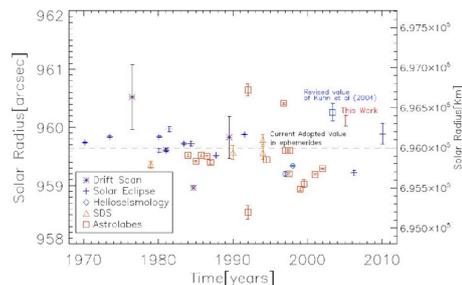


Figure 4. Published solar radius (Emilio et al. 2012)

NASA's LOLA (Lunar Orbiter Laser Altimeter) on LRO (Lunar Reconnaissance Orbiter launched on 2009 June 18) also provides a high-resolution global topographic model. It turned out that the lunar limb profiles from Kaguya LALT and LRO LOLA agree well.

4. SOLAR RADIUS

The IAU adopted radius of the Sun is 696,000 km. This value is based on the Auwers (1891) value of 959.63 arcsec \pm 0.05 arcsec for the Sun's apparent radius as seen from 1 AU. However, as Fig. 4 (from Emilio et al. 2012) shows, the measured radius of the Sun shows scatter by about \pm 500 km, which indicates that the radius of the Sun is not yet determined precisely.

5. LIMIT LINE OBSERVATION CAMPAIGN

As was already demonstrated, the lunar limb profiles can be precisely known, but the radius of the Sun is not known accurately. The location of the northern limit line of the annular eclipse of 2012 depended on the Sun's radius; if the Sun's radius is bigger by 100 km, the northern limit line moves northward by about 300 m (measured perpendicularly to the limit line). Therefore, if we can determine the limit line from observations, we can determine the Sun's radius. This fact attracted public interest.

At the occasion of the annular solar eclipse on 2012 May 21, in order to promote the interests of the general public for such a great astronomical phenomenon, we had a campaign of eclipse observations. In particular, we encouraged people to report if they were able to see the annularity at their location by naked eye through eclipse eyeglasses in order to determine the limit line of the annular eclipse zone.

In the end 14,844 people reported the results of their observations by naked eye with eclipse glasses through our website (Fig. 5). In addition there were 23 local groups for which about 30,000 people in total participated in the observations. Each group reported their limit line observation result with respect to the prediction made using the Kaguya lunar limb profile. Their results were "we determined that the limit line was about 300 m north of the prediction (Osaka North Group)" and "the limit line was found to be about 250 m south of the prediction (Shiojiri City Oka Junior High School)". Overall the limit line from observation agrees within \pm 500m from the limit line predicted by taking the lunar limb profile into account. This error of the limit

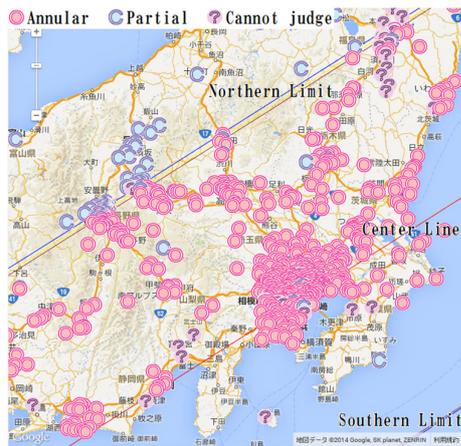


Figure 5. Results obtained from the campaign

line location corresponds to about ± 200 km for the radius of the Sun. Considering the accuracy of the radius hitherto obtained, this accuracy should be surprising. There was also a group of amateur observers who made video observations of Baily's Beads through telescopes to determine the precise radius of the Sun. Their observations are still under analysis.

Related topics were presented by Kouji Ohnishi (Nagano National College of Technology, Japan) at P7-28 and P7-29 in this meeting of APRIM 2014.

REFERENCES

- Araki, H., Tazawa, S., & Noda, H., et al., 2009, Lunar Global Shape and Polar Topography Derived from Kaguya-LALT Laser Altimetry, *Science*, 323, 897
- Auwers, A., 1891, Der Sonnendurchmesser nach den Beobachtungen an den Heliometern der deutschen Venus-Expeditionen, *Astro. Nach.*, 128, 361
- Emilio, M., Kuhn, J. R., Bush, R. I., & Scholl, I. F., 2012, Measuring the Solar Radius from Space during the 2003 and 2006 Mercury Transits, *ApJ*, 750, 135
- Sôma, M., Araki, H., Noda, H., Tazawa, S., Goossens, S., & Hayamizu, T., 2005, Northern Limit of the Annular Solar Eclipse on 2012 May 21 in Japan, Report of the NAOJ, 15, 1