

## Opportunities for the hybrid eclipse of April 20, 2023 in solar astrometry with smartphone videos

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**Abstract** The hybrid eclipse presents a narrow umbral zone. The lunar shadow is broken by Northern and Southern Baily beads, within only a few km. We need simple unfiltered VGA videos at zoom 4x, 30fps, ISO=100 and EV=-2, made from steady smartphones, geolocated, in the 10 minutes around the eclipse maximum. A 10 milli-arcsecond angular accuracy on the angular solar diameter by comparison with ephemerides, can be obtained after recovering the solar limb darkening function inflexion point. Some observational hints are recalled, to avoid unwanted technical mistakes.

**Sommario** L'eclissi ibrida del 20 aprile 2023 presenta una stretta fascia di ombra. L'ombra della Luna sarà rotta da "grani di Baily" prodotti da valli lunari sia a Nord che a Sud del nostro satellite, entro pochi chilometri di distanza a terra. Servono semplici video a zoom 4x, in formato VGA (30 fotogrammi al secondo e bassa risoluzione spaziale) ISO fissato a 100 ed EV=-2, geolocalizzati, che coprano 10 minuti a cavallo del massimo dell'eclissi, da posizione fissa. L'accuratezza di 10 millisecondi d'arco sul diametro solare angolare può essere ottenuta calcolando il punto di flesso della funzione di oscuramento al bordo solare attraverso l'evoluzione della luminosità dei Baily beads nelle varie valli lunari. Alcuni suggerimenti osservativi vengono forniti per sfruttare al meglio questa unica occasione, usando smartphones senza filtri con ghost image, ed evitare banali errori.

**Keywords** Sun, Solar diameter, Baily's beads, Videotiming, Geolocation, Limb darkening, Inflexion point, Smartphone, Astrometry, Citizen Science.

**Introduction** The hybrid eclipse of may 9th 1567 in Rome, is still bringing to our attention, after J. A. Eddy (1931-2009)<sup>1</sup>, the problem of the secular variation of the solar diameter.

The dispute on that issue was concentrated, in the late seventies, to the inner corona appearance, in order to validate the observation published by Christopher Clavius (1538-1612). Clavius did not indicate his position in Rome<sup>2</sup> (then it should have been a normal one for him, like the Collegio Romano square, the former site of his University<sup>3</sup>).

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<sup>1</sup> <https://www.nytimes.com/2009/06/18/us/18eddy.html> J. A. Eddy obituary

<sup>2</sup> Clavius, *Commentarius in Sphaeram*, Venice, 1581 edition.

<sup>3</sup> [▷ Collegio Romano \(info.roma.it\)](http://info.roma.it) Palace of Giovanni Salviati in front the arch of Camillus, from 1557 to 1584 site of the Jesuit's University.

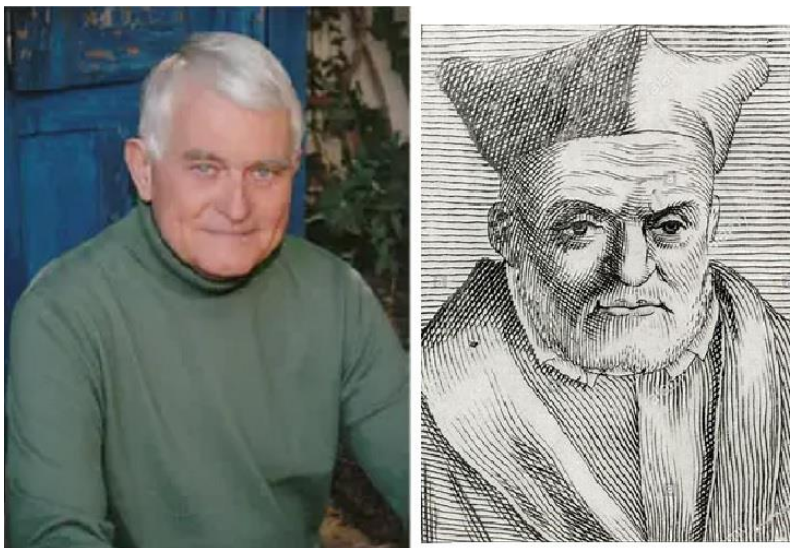


Fig. 1 Eddy and Clavius.

**Hybrid Eclipses** The nature of that 1567 eclipse was rapidly changing in a few km from total to annular, like the one of 2023. Clavius already observed a total eclipse in Coimbra in 1560 and he was expecting for full totality. Comparing with the ephemerides, the observation of Clavius, could be explained with a solar diameter increase of 4" with respect to the mean value of 1919.63" adopted by IAU. The search for secular variations of the solar diameter through total eclipses come out in the following decades. Either in the United States of America with the 1979 eclipse, jointed with data from the 1925 one, either with the Halley eclipse of 1715; in all of them the limits of the totality strip were known by observational accounts. For the 2023 hybrid eclipse, local people can be involved into science observations with their smartphones.

**Baily beads for solar astrometry**

D. W. Dunham in 1973 had proposed to observe the total eclipses from the limits of the totality to increase the duration of the Baily's beads, through which accurately locate the extension of the Moon shadow. The lunar profile of C. B. Watts (1963) was updated by Kaguya satellite in 2009, allowing a

very precise reference. Raponi and Sigismondi (2012) proposed to recover the inflexion point of the solar limb darkening function through the Baily beads' luminosity function, due to the varying exposed photospheric area.

Therefore combining information on the observer's position, lunar profile and Baily's beads absolute timing an accuracy up to 10 milli-arcsecond of arc become possible, as scientific result of a total or annular solar eclipse expedition.

### **Smartphones array for the hybrid eclipse**

Disposing an array of **unfiltered smartphones** from the very limit of the eclipse (zero totality) to the place of the maximum, may allow a precise estimate of the solar diameter through the duration timing of the Baily beads. Video of the eclipse at 30 fps with maximum 4x zoom and **fixed ISO 100 EV=-2**, (then **not filtered**) within such a limited area could help to recover the angular diameter of the Sun during such eclipse with an accuracy below 0.01". When a **ghost image appear** in the video **the accuracy is even better**, because the Sun always saturates the image around it, even if there is a single bead.

**Unwanted mistakes** The smartphones are now fully automated and this is not good for limb darkening sampling, because the fainter is the light the higher is the ISO set by the camera, while we need a **fixed ISO and EV** to compare faint and bright phases of the beads. The spatial resolution of 4x digital (or optical) zoom is very low, the Sun is about 32 pixel diameter.

Do not believe, never, that the video is wrong and useless!

We are looking for 1/30 s timing resolution and a moderate angular resolution of 1' is tolerable.

Absolute timing resolution is always welcome (through imaging a reference watch) but the automatic setting of the camera through internet will allow always a good relative timing. So no problem if you have not such watch in the video.

The **camera may go off focus** automatically, especially if it aims only the Sun. **Let it go** and not change anything during the video. You can do a test of the camera setting leaving the Sun going behind a wall and recording that event for 4-5

minutes, two times. Better if the wall is 20 m far, like a bell-tower, a skyscraper or... an obelisk.<sup>4</sup> The camera has to be fixed during the 10 minutes video, you can use books or small object to set it. **The video of the eclipse has to be continuous.** Make sure it is enough memo space for 20 minutes video.



Fig. 2 Smartphone set with Nov 3rd 2013 hybrid eclipse and 2006 march 29 last bead icon in Zawayet-al-Matallah, Egypt.

Do not go in front of the camera: it change focus, but never stop recording, always people are around. **Describe in voice what you see by eye or binoculars**, to increase data accuracy.

**Conclusions** We are eager to analyze these videos to obtain the current value of the solar diameter by using the most accurate ephemerides of Sun and Moon available and the upgraded lunar profiles from Jaxa Satellite Kaguya. Recording the hybrid eclipse with an unfiltered smartphone camera with 100 ISO offers a great opportunity for citizen science in solar astrometry

**References** C. B. Watts, *The marginal zones of the Moon* [link](#)  
J. A. Eddy, et al., *Shrinking Sun*, Sky & Tel. **60**, p. 10, (1980).  
D. W. Dunham and J. B. Dunham, Moon **8** 546 (1973) [link](#).  
A. Raponi, et al. Solar Physics **278** 269 (2012). C. Sigismondi, [https://youtu.be/wcMh3\\_n-pmM](https://youtu.be/wcMh3_n-pmM) & <https://youtu.be/e7OsR9WdeTc> (2023)

<sup>4</sup> <https://youtu.be/-q-lBvPRixw> Apr. 4 2023: on focus with ghost image  
<https://youtu.be/t5xYtBnL4YY> Apr.10: eclipse off focus at the Vatican obelisk. April 11 2023: Video [tutorial](#)s in English and [eclipse simulation](#).