417.17: Syzygy Information: Lunar Limb Profiles at Total Solar Eclipses

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Abstract

The topographic 3D mapping of the lunar surface by the Japanese Kaguya and NASA's Lunar Reconnaissance Orbiter has led to greatly improved predictions of Baily's beads at total solar eclipses. This information has been included in the program Solar Eclipse Maestro. Matching the predictions with observations of Baily's beads made at total solar eclipses, including the 21 August 2017 eclipse as well as any total, annular, or hybrid solar eclipse, may even improve the accuracy of the IAU's nominal solar diameter.

Introduction

This Great American Eclipse of 21 August 2017 was the first to be observed in detail in the era in which accurate 3D mapping of the lunar surface is available. Lunar topography has been incorporated in the program Solar Eclipse Maestro by one of us (XMJ); the program also can be used to control camera photography. A wide variety of mapping resources is available online at the site one of us (JMP) maintains for the Working Group on Solar Eclipses of the International Astronomical Union, http://eclipses.info. You can zoom in and move around on Jubier's Google Map; clicking at any location gives an information box that includes eclipse duration, both with and without limb profiles incorporated.

Preliminary imaging and other results from the Williams College Expedition is available at http://totalsolareclipse.org

Acknowledgments

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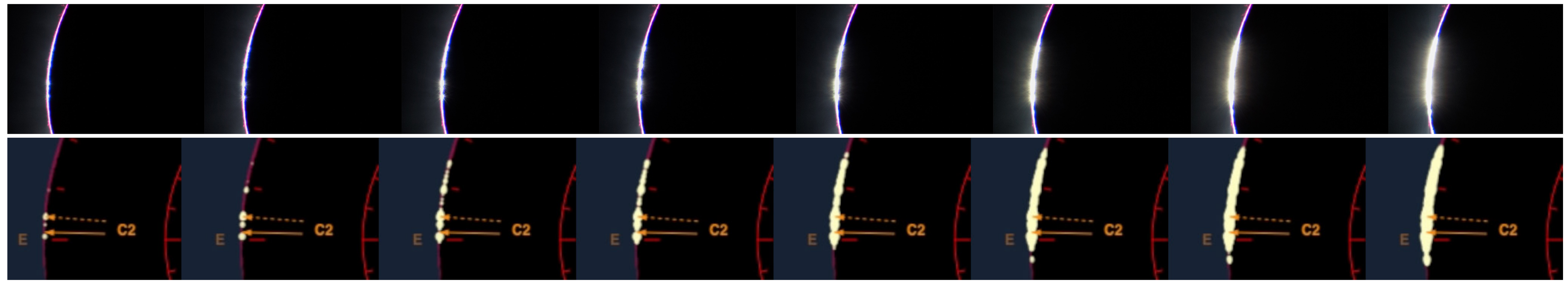
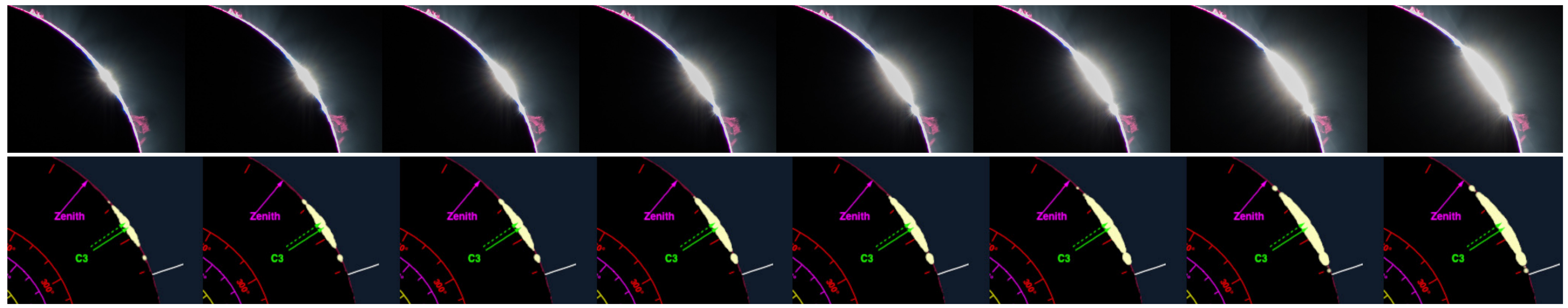
Participants in the photographic aspects of the expedition included Williams College students Christian Lockwood, Cielo Perez, Tim Nagle-McNaughton, and Erin Meadors for organizing the cameras and this data reduction, as well as Declan Daly, Ross Yu, Connor Marti, Brendan Rosseau, and Charles Ide; Anna Rousseva; graduate-student alumni/ae Amy Steele (U Maryland), Allen Davis (Yale), and Muzhou Lu (U Colorado); graduate student David Sliski (U Penn); and alumni Ph.D.'s Duane Lee and Marcus Freeman.

The eclipse images were taken with Nikon D810 cameras using Nikkor 400 mm and 800 mm lenses, lent by Photographic Division, National Geographic Society, and by Nikon Professional Services.

Map

The path mapped by XJ is available (with various aspects of the map turned on) at:
http://xjubier.free.fr/tse2017map/





The solar radius used for eclipse predictions

The IAU 2015 value—695,700 km is 959.22" at 1 au—is more of a conversion factor than a true photospheric solar radius to be used for solar-eclipse predictions. To succeed in making eclipse-totality predictions valid to a fraction of a second, that is one of the issues that need to be understood and tackled.

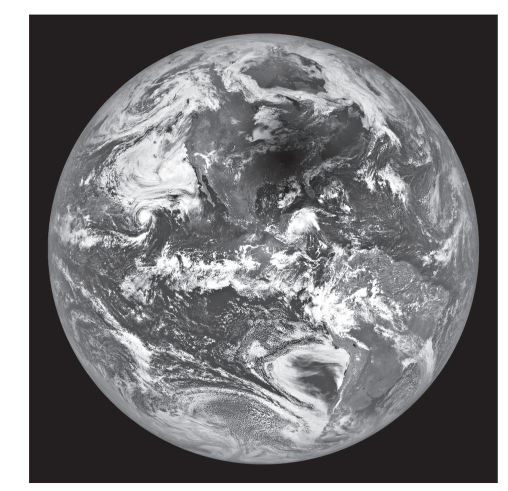
The IAU 1976 value is the one derived by Auwers in 1891 and this is the value all solar-eclipse predictions use by default: 959.63" at 1 au or 696,000 km. http://adsabs.harvard.edu/full/1980MitAG..48...59L

This webpage does a summary: https://en.wikipedia.org/wiki/IAU_(1976)_System_of_Astronomical_Constants

So, if we were using the IAU 2015 resolution conversion factor for solar-eclipse predictions, then the totality duration would be even longer, up to two seconds longer, than with the IAU 1976 value, which gives a duration that is already far too long!

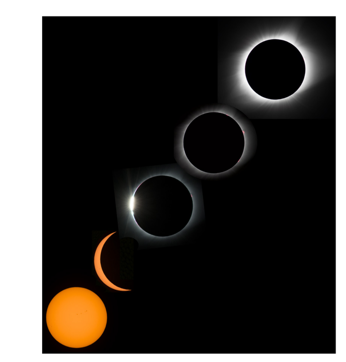
We now have everything to show that the true photospheric solar radius is indeed even larger than the IAU 1976 value, not smaller. Work with Solar Eclipse Maestro and other eclipse simulators show that with either the IAU 1976 or 2015 solar radius values, it is meaningless to correct for the true lunar limb profile.

959.98" at 1 au ±0.02" is Xavier Jubier's suggested true photospheric solar radius; from the preliminary study for TSE 2017, it remains the best value.

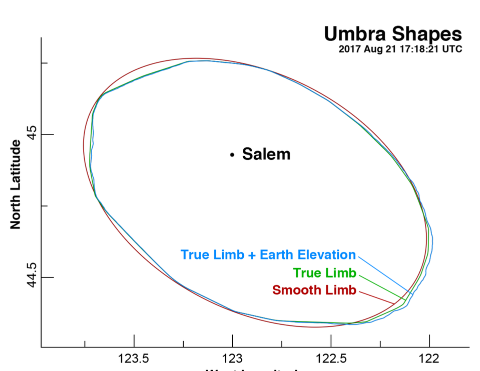


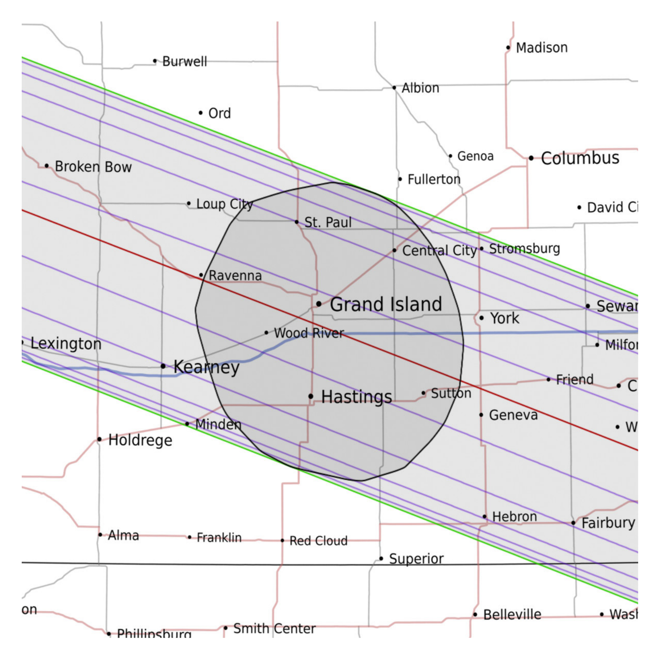
The view of totality over Illinois seen from LRO orbiting the moon.

Edmond Halley's map predicting the eclipse of 1715, and requesting crowdsourcing of observations. His predictions were within 20 miles and 4 minutes of the actual path and time.

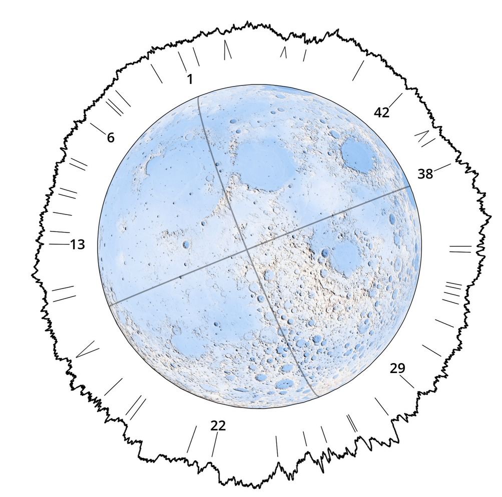


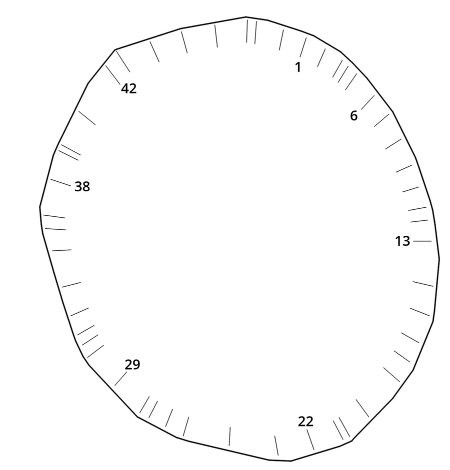
Partial phases (through a filter), diamond ring, prominences, and the inner solar corona imaged from our site at Willamette University in Salem, Oregon, with a Nikon D810 and a Nikon 800 mm f/5.6 lens, ISO 100.



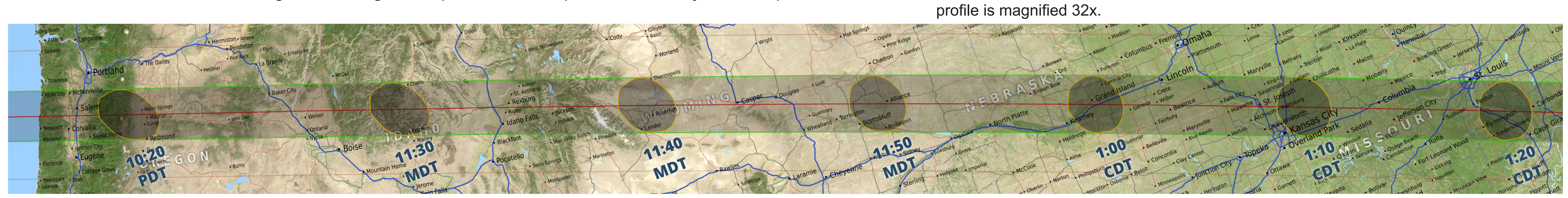


The shape of the umbra on the ground is the locus of all points on the surface of the Earth at which the photosphere of the Sun is completely blocked by the Moon. The nominal calculation of this shape (left) assumes that the Moon is smooth and that all observers are at sea level. Accounting for the limb of the Moon (green) produces a polygonal umbra shape. Accounting for Earth terrain tends to shift the shape toward the Sun's azimuth by approximately h*cot*(a), where h is the height of the observer and a is the azimuth of the Sun. In the left figure, the umbra is over Salem, Oregon, and its leading (eastern) edge has begun to interact with the higher elevations of the Cascades. In the figure to its right, the position corresponds to the adjacent map of Nebraska.





The limb of the Moon (left) produces a polygonal umbra shape on the Earth's surface (right). Each side of the polygon corresponds to a single valley on the lunar limb, either the last valley admitting photospheric light prior to second contact, or the first valley admitting sunlight just after third contact. Here, with 18,000 points equally spaced in position angle around the limb, the umbra is determined by just 49 points, some of which are labeled. The correspondence between umbra edges and limb points allows the position angle of the diamond ring and the last Baily's bead to be predicted. Observers at a particular edge, where two umbra polygon sides meet, see a first or last Baily's bead in the corresponding valley on the lunar limb.
At 18:00:00 UTC on August 21, 2017, the umbra is in eastern Nebraska. The location was chosen for this figure to minimize the additional effects of Earth elevation. The lunar limb profile is magnified 32x.



Science Visualization Studio, NASA's Goddard Space Flight Center, and USRA; https://svs.gfsc.nasa.gov/eclipse2017

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