

## Preface – 1<sup>st</sup> Edition

Theodor von Oppolzer's 1887 *Canon der Finsternisse* (Canon of Eclipses) stands as one of the greatest accomplishments in computational astronomy of the nineteenth century. It contains the elements of all 8000 solar eclipses and 5200 lunar eclipses occurring between the years -1207 and +2161, together with maps showing the approximate positions of the central lines of total, annular and hybrid solar eclipses.

To make this remarkable achievement possible, a number of approximations were used in the calculations and maps. Furthermore, the 19th century ephemerides for the Sun and Moon, which are critical to eclipse predictions, cannot compare to the accuracy and precision of modern ephemerides. Finally, the 1887 canon did not take into account the shifts in latitude and timing of ancient eclipses due to Earth's variable rotation rate and the secular acceleration of the Moon.

Nevertheless, von Oppolzer's canon remained the seminal reference on predictions of eclipses until well into the 20th century. With the arrival of the electronic computer, the time was ripe to produce updated solar<sup>1</sup> and lunar eclipse canons. In 1979, Meeus and Mucke published *Canon of Lunar Eclipses: -2002 to +2526* containing the Besselian elements of 10,936 lunar eclipses. It was intended mainly for historical research and served as the modern day successor of von Oppolzer's great canon.

The Meeus-Mucke work also contains data on penumbral eclipses that are not included in von Oppolzer's canon. Neither of these publications offers diagrams or maps to illustrate the geometry or visibility of each eclipse. Espenak's *Fifty Year Canon of Lunar Eclipses* (1989) includes individual Moon-shadow geometry diagrams and eclipse visibility maps of all lunar eclipses, but it covers a relatively short period from +1986 to +2035.

Both of these recent lunar eclipse canons are based on *Newcomb's Tables of the Sun* (1895) and Brown's lunar theory (1905), subject to later modifications in the *Improved Lunar Ephemeris* (1954). These were the best ephemerides of their day but they have since been superseded.

The *Canon of Lunar Eclipses 1500 B.C.–A.D. 3000* (Liu and Fiala, 1992) uses modern theories of the Sun and the Moon prepared by the *Bureau des Longitudes* of Paris. However, it does not contain individual eclipse geometry diagrams or maps. Instead, it offers a series of map templates to approximate the geographic regions of eclipse visibility, and an optional computer program do generate these figures for any eclipse in the canon.

The present publication is the first to offer eclipse geometry diagrams and visibility maps for every lunar eclipse (12,064 eclipses) over a period covering five thousand years from -1999 to +3000. The following points highlight the features and characteristics of this work.

- based on modern theories of the Sun and the Moon constructed at the *Bureau des Longitudes* of Paris rather than the older Newcomb and Brown ephemerides
- ephemerides and eclipse predictions performed in Terrestrial Dynamical Time
- covers historical period of eclipses as well as one millennium into the future
- diagrams for each eclipse depict the Moon's path through Earth's penumbral and umbral shadows
- world maps identify geographic regions of visibility for each phase of every eclipse
- visibility maps are based of the most current determination of the historical values of  $\Delta T$
- estimates of eclipse visibility map accuracy based on the uncertainty in the value of  $\Delta T$  (i.e., standard error in  $\Delta T$ )

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<sup>1</sup> Several new solar eclipse canons were published in the second half of the 20th century. Meeus, Grosjean, and Vanderleen published *Canon of Solar Eclipses* (1966) containing the Besselian elements of all solar eclipses from +1898 to +2510, together with central line tables and maps. The aim of this work was principally to provide data on future eclipses. The Mucke and Meeus work *Canon of Solar Eclipses: -2003 to +2526* (1983) was intended mainly for historical research and served as a modern day successor of von Oppolzer's great canon. Espenak's *Fifty Year Canon of Solar Eclipses* (1987) includes individual detailed maps and central path data for all solar eclipses from +1986 to +2035. Finally, the Espenak and Meeus work *Five Millennium Canon of Solar Eclipses: -1999 to +3000* (2006) contains individual maps of every solar eclipse and uses modern ephemerides of the Sun and Moon.

A primary goal of this work is to assist historians and archeologists in the identification and dating of eclipses found in references and records from antiquity. For example, an ancient mechanical calculator known as the Antikythera mechanism was apparently designed to calculate eclipses and other astronomical phenomena (Freeth, et. al., 2008). The decoding of this device was possible in part by comparing its combination of wheel positions with the dates of lunar eclipses.

Correlating historical records with specific eclipses is no easy task since there are usually several possible candidates. Accurate visibility maps using the best available values of  $\Delta T$  coupled with estimates in the standard error of  $\Delta T$  are critical in discriminating among potential eclipses candidates. Ultimately, historical eclipse identification can lead to improved chronologies in the time line of a particular culture.

The maps can also be used to quickly estimate the approximate circumstances for any geographic location during each eclipse without any calculations. The position of the moonrise and moonset curves for each eclipse contact show which eclipse phases can be seen from any location.

The *Canon* will also be of value to educators, planetariums, and anyone interested in knowing when and where past and future eclipses occur. The general public is fascinated by eclipses—with each major eclipse, the question always arises as to when a particular location experienced its last and next eclipses. The maps presented here are ideally suited to addressing such queries.

— Fred Espenak and Jean Meeus, 2009 January

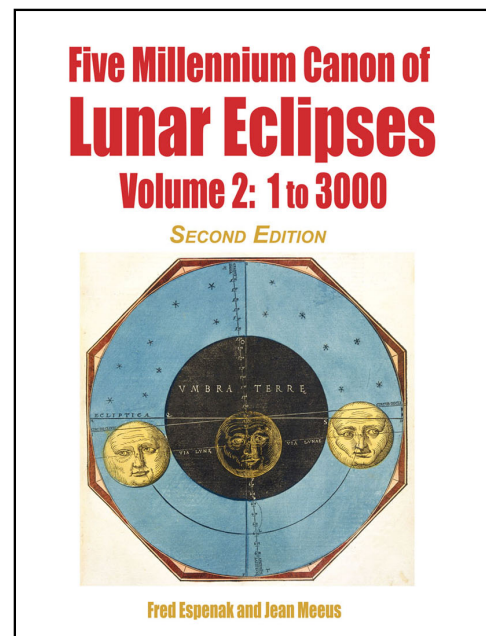
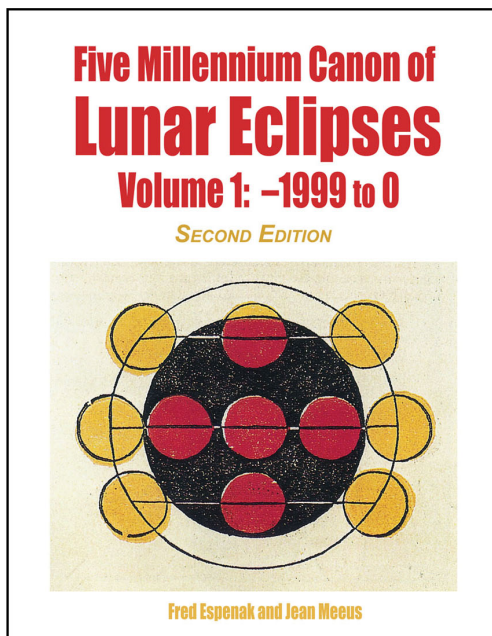
## Preface – 2<sup>nd</sup> Edition

The *Five Millennium Catalog of Lunar Eclipses: -1999 to +3000* was first published in October 2009 (NASA TP-2009-214173). As a NASA Technical Publication it had a limited publication run and distribution. The available supply of hard copies was depleted within 12 months of publication although the PDF version continues to be available.

A decade later, the *Five Millennium Canon of Lunar Eclipses* is available again in hard copy in this Second Edition through Astropixels Publishing. Because of the large number of pages in the publication it has been necessary to create a completely new layout for the book, and to divide it into two parts.

Volume 1 covers eclipses for the years -1999 to 0, while volume 2 covers eclipses for the years 1 to 3000. A new section (Section 4: Eclipses and the Moon's Orbit) has also been added to this second edition.

— Fred Espenak and Jean Meeus, 2021 August



See: <http://astropixels.com/pubs/5MCLE2.html>