Computer Animations of Ancient Greek and Arabic Planetary Models

Dennis Duke, Florida State University

A new set of computer animations is available for those who teach the ancient models of planetary motion, those who want to learn those models, or even those who enjoy simply contemplating just how clever the ancient astronomers were. The animations include the models from Ptolemy's *Almagest* (*ca.* 150 AD) and those from the Maragha school of Arabic astronomy (*ca.* 1250-1350 AD), and thus cover over one thousand years of astronomical history. Since the models are (intentionally) geocentric, the animations might also be useful for thinking about how heliocentric planetary motion actually appears to us on Earth.

The animations are designed to illustrate a number of the major features of the various models:

- the *Almagest* solar model and the simple model of the Moon at syzygy (both of which date back at least to Hipparchus, *ca.* 130 BC) show the equivalence of models with (a) a concentric deferent and a moving epicycle, and (b) a moving eccentre carrying a deferent. The fact that these are geometrically equivalent formulations was known at least as far back as Apollonius of Perge (*ca.* 200 BC), and various elaborations using that equivalence were created by many astronomers from Hipparchus forward.
- The full *Almagest* models for the Moon and for Mercury (Fig. 1) involve similar and somewhat intricate crank mechanisms, and for some people the animations will make it easier to visualize how the mechanisms work.
- The *Almagest* models for the planets involve both the first, or zodiacal, anomaly – the fact that the planets move at different speeds in different parts of the zodiac, and the second, or solar, anomaly – the fact that Venus and Mercury always stay near the Sun, while Mars, Jupiter and Saturn all show retrograde motion related to the position of the Sun. The animations show how both anomalies interact, especially in the case of a planet with large eccentricity, such as Mars (Fig. 2).
- The *Almagest* planetary models succeed primarily due to the equant, a point of uniform motion that is *not* at the center of a sphere of motion. This violation of Aristotelian principles was remedied in a series of new geometric models proposed by the Arabic astronomers in the 13th and 14th centuries. The animations show these models, compared to the *Almagest* models, for the Moon and the five planets (Fig. 3). These are also useful for explaining the background to the Copernican models.
- A pair of animations illustrates the relationship between geocentric and heliocentric planetary motion for an inner and an outer planet (Fig 4).

Each animation generally shows both a moving body of interest and the mean Sun, which is a fundamental point of reference, in one way or another, for all the models. A set of mouse-clickable controls enables the user to start the motion in forward or reverse, and to pause the motion. The user can also vary the speed of the motion, and toggle on/off trails of the trajectories of the moving bodies. In many cases the user is able to fade in/out the various components of an animation (Fig 4). The animations are generally to scale, unless some exaggeration is desired for clarity. A rather brief introduction to the background of the models is provided, but many users will want to consult one or more of the standard texts for detailed explanation. Two excellent places to start are the books of James Evans[1] and Hugh Thurston[2], and references therein.

The animations come in two varieties. One set will run in a web browser if the browser is equipped with an appropriate plug-in. Most browsers in use today either have the plug-in already, or will prompt the user automatically if it is needed. Another set of the animations provides stand-alone executable programs for both Microsoft Windows and Macintosh operating systems. All of the animations are free for non-commercial use and may be downloaded from www.csit.fsu.edu/~dduke/models.htm.

It is likely that the existing animations will continue to evolve, and new ones will be added, for some time. Users are particularly invited to offer suggestions.

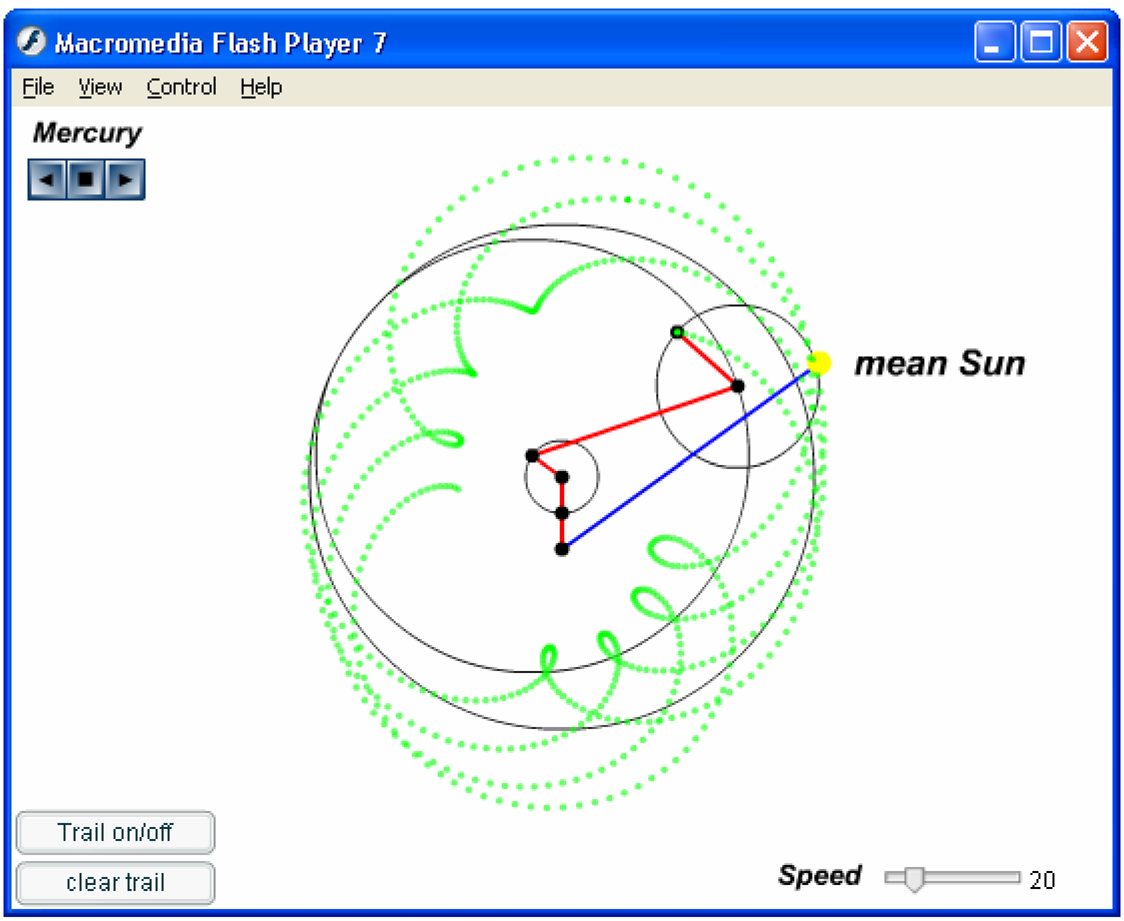

Figure 1

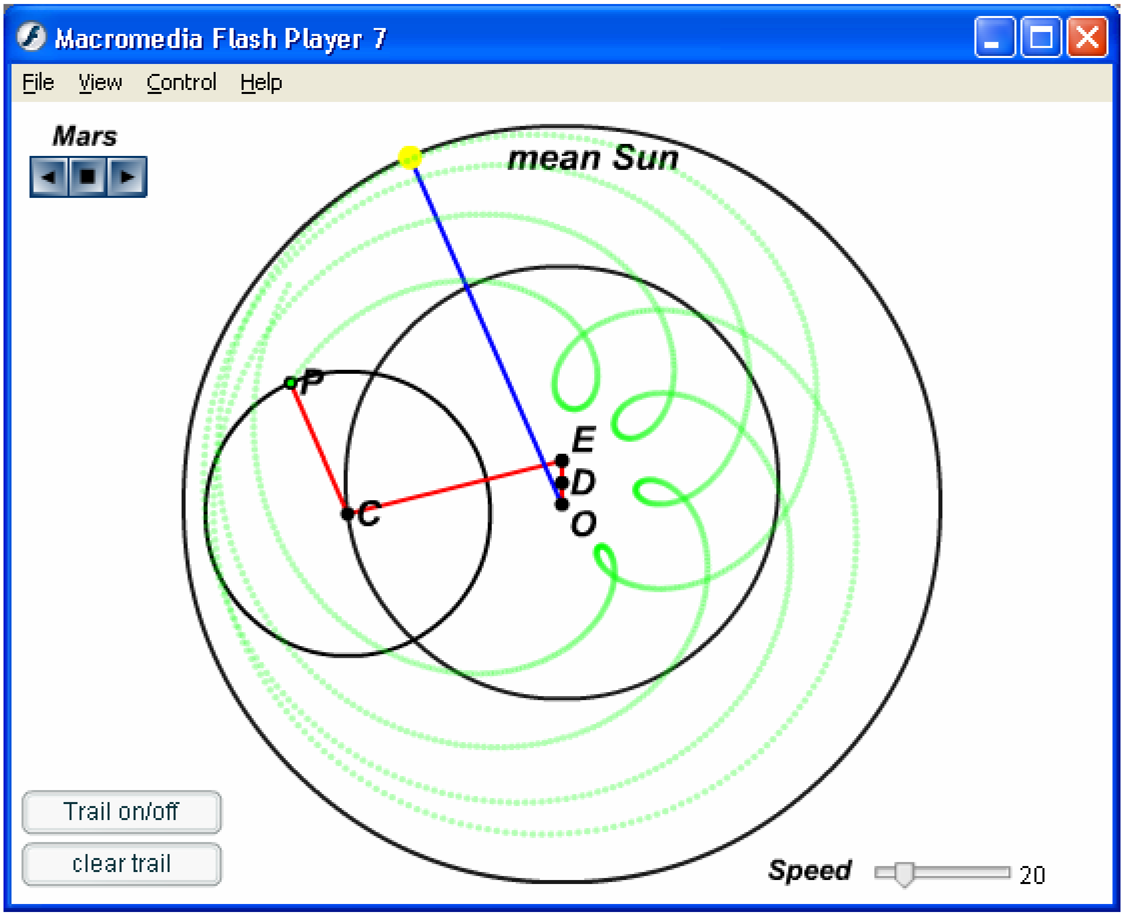
Macromedia Flash Player 7
File View Control Help
Mars
mean Sun
P
E
D
C
O
Trail on/off
clear trail
Speed
20

Figure 2

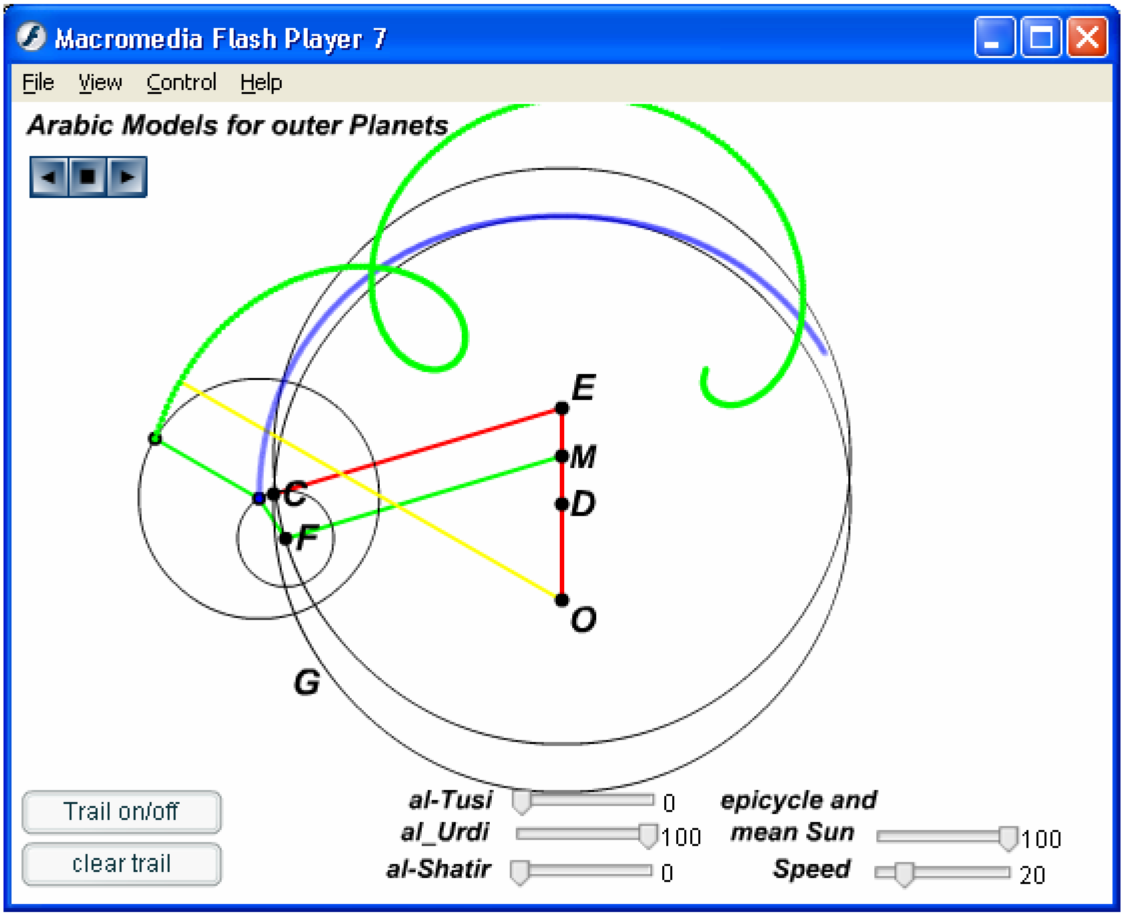
Macromedia Flash Player 7
File
View
Control
Help
Arabic Models for outer Planets
E
M
C
D
F
O
G
Trail on/off
clear trail
al-Tusi
0
al_Urdi
100
al-Shatir
0
epicycle and
mean Sun
100
Speed
20

Figure 3

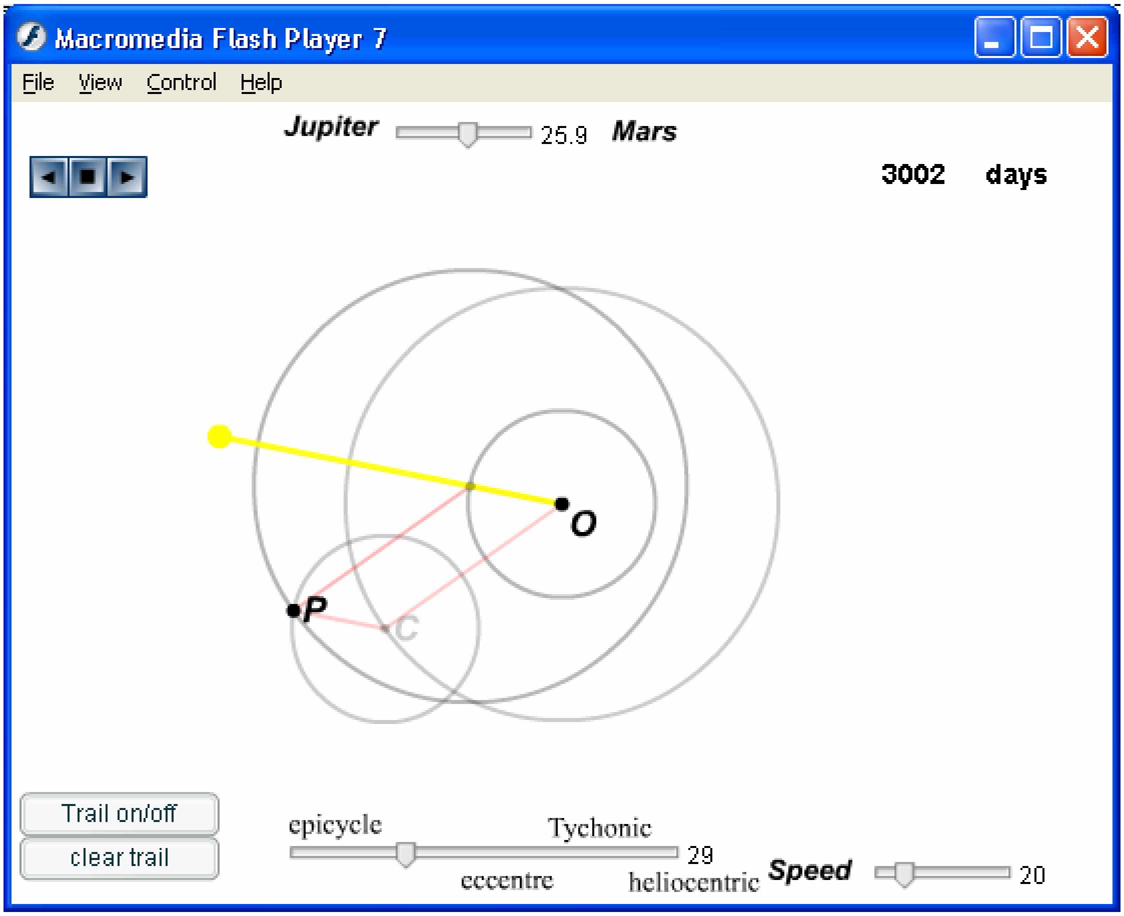

Figure 4

REFERENCES

[1] James Evans, *The History and Practice of Ancient Astronomy*, Oxford University Press (1998)

[2] Hugh Thurston, *Early Astronomy*, Springer (1994).