EPSC Abstracts
Vol. 10, EPSC2015-40, 2015
European Planetary Science Congress 2015

Outreach Testing of Ancient Astronomy

Miguel Blanco Marcos, Juan R. Sanmartín
Escuela Técnica Superior de Ingeniería Aeronáutica y del Espacio
Universidad Politécnica de Madrid

Abstract

This work is an *outreach* approach to an ubiquitous recent problem in secondary-school education: how to face back the decreasing interest in natural sciences shown by students under 'pressure' of convenient resources in digital devices/applications. The approach rests on two features. First, *empowering* of teen-age students to understand regular natural events around, as very few educated people they meet could do. Secondly, an understanding that rests on personal capability to test and verify experimental results from the oldest science, astronomy, with simple instruments as used from antiquity down to the Renaissance (a capability restricted to just solar and lunar motions).

Because lengths in astronomy and daily life are so disparate, astronomy basically involved observing and registering values of angles (along with times), measurements being of two types, of angles on the ground and of angles in space, from the ground. First, the gnomon, a simple vertical stick introduced in Babylonia and Egypt, and then in Greece, is used to understand solar motion. The gnomon shadow turns around during any given day, varying in length and thus angle between solar ray and vertical as it turns, going through a minimum (noon time, at a *meridian* direction) while sweeping some angular range from sunrise to sunset. Further, the shadow minimum length varies through the year, with times when shortest and sun closest to vertical, at summer *solstice*, and times when longest, at winter solstice six months later. The extreme directions at sunset and sunrise correspond to the solstices, swept angular range greatest at summer, over 180 degrees, and the opposite at winter, with less daytime hours; in between, spring and fall *equinoxes* occur, marked by collinear shadow directions at sunrise and sunset.

The gnomon allows students to determine, in addition to latitude (about 40.4° North at Madrid, say), the inclination of earth equator to plane of its orbit around the sun (*ecliptic*), this fundamental quantity being given by half the difference between solar distances to vertical at winter and summer solstices, with value about 23.5°. Day and year periods greatly differing by about 2 ½ orders of magnitude, 1 day against 365 days, helps students to correctly visualize and interpret the experimental measurements.

Since the gnomon serves to observe at night the moon shadow too, students can also determine the inclination of the lunar orbital plane, as about 5 degrees away from the ecliptic, thus explaining why eclipses are infrequent. Independently, earth taking longer between spring and fall equinoxes than from fall to spring (the solar anomaly), as again verified by the students, was explained in ancient Greek science, which posited orbits universally as circles or their combination, by introducing the *eccentric* circle, with earth placed some distance away from the orbital centre when considering the relative motion of the sun, which would be closer to the earth in winter. In a sense, this can be seen as hint and approximation of the elliptic orbit proposed by *Kepler* many centuries later.

Secondly, by observing lunar phases and eclipses from the ground, students could also determine, following *Aristarchus of Samos* in the 3rd century BC, 4 length ratios involving moon and sun distances to earth, and radii of all three, moon, sun, and earth. The angular width of the moon could be first determined with simplest optical devices as about half a degree; this yields the ratio between moon diameter $2R_M$ and distance D_M to earth. Next, eclipses of sun prove its angular width, and thus ratio $2R_S/D_S$, similar to the lunar one, though the relatively high lunar orbital eccentricity, 0.055, does result in not quite a full eclipse if at lunar apogee. Further, at a half-moon phase, when the angle sun-moon-earth is a right one, the angle moon-earth-sun observed at earth, though also extremely close to $90°$ and tough to measure, determines the distance ratio D_M/D_S. Finally, at a lunar eclipse, observation of the shadow-cone width at the moon behind the earth, over 2.6 times the moon diameter, yields the ratio R_E/R_M. An actual measurement of R_E on earth, as crudely carried out by *Eratosthenes*, again in the 3rd century BC, could then yield all 4 values of moon and sun sizes and distances to earth.

References

Carlos Conde -Rector/Universidad Politécnica de Madrid-, *Proyecto para la difusión del conocimiento técnico y de la ingeniería en la sociedad*, presentation at the *Real Academia de Ingeniería* of Spain, Madrid, 10 April 2014.

Benito Bails, *Principios de Matemática de la Real Academia de San Fernando*, Volume III (2nd edition, Imprenta de la Viuda de Ibarra, Madrid, 1790).

George Sarton, *Ancient Science through the golden age of Greece*, pp. 174-175 (Dover Publications Inc, Mineola, N.Y., 1993)

Histoire générale des sciences. Volume 1, *La science antique et médiévale. Des origins à 1450*, René Taton, editor (Presses Universitaires de France, Paris, 1966).

Michael J. Crowe, *Theories of the World from Antiquity to the Copernican Revolution* (Dover Publications Inc, Mineola, N.Y., 1990).