The Universe in my pocket

Night and Day

TUIMP

No. 32

THE UNIVERSE IN MY POCKET

Rogério Riffel

DepAstro/IF

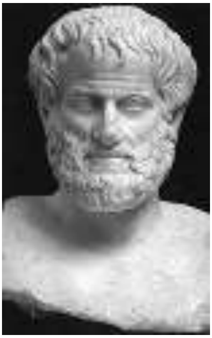
UFRGS, Brasil

Night, as represented by 12 year-old Davi Michalski.

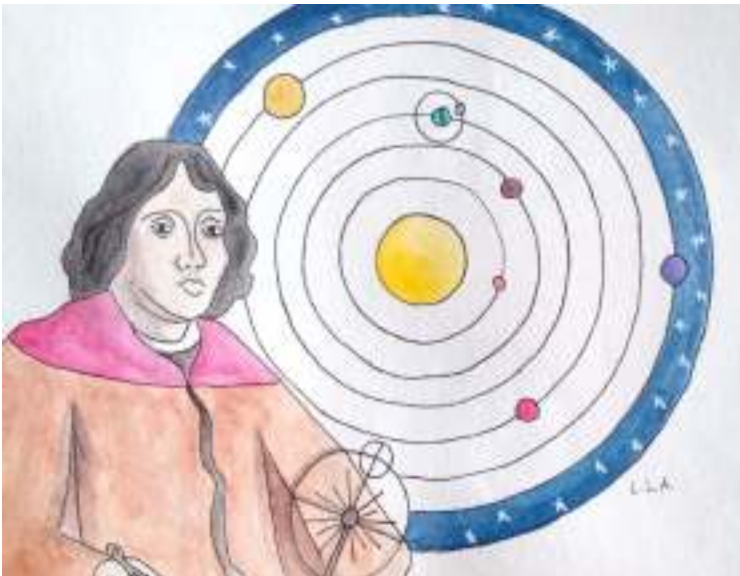
Day, as represented by 12 year-old Davi Michalski.

Night and Day

Since the times of the archaic and pre-scientific flat-earth view, humanity has sought to understand the periodic changes of illumination that are observed on the surface of the Earth. Such changes are denoted as Night and Day. As we can see in the pictures on page 2, the main actor is the light of the Sun. When the Sun is above the horizon we have a beautiful and sunny day and when it is below we have the splendorous darkness of night. When observing the daytime movement of the Sun, we have the false impression that the Earth is stationary and the Sun is moving around the Earth. In reality what we observe is the diurnal movement of the Earth's rotation around its own axis.



Roman-era bust of Greek philosopher **Aristotle of Stagira** (384-322 BC) found under the Acropolis in Athens in 2006.

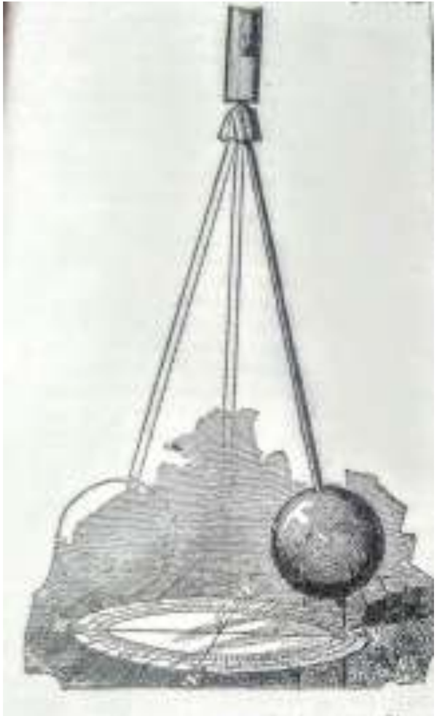


Ptolemy's Geocentric model and Copernicus' Heliocentric model. Illustration Larissa Luciano Amorim.

Planetary movements

The ancient Greek philosophers, whose ideas shaped the worldview of Western civilisation, were conflicted about the movement of the planets around the Sun. Aristotle's idea that the Earth was fixed at the centre of the universe (geocentrism) prevailed throughout antiquity and the Middle Ages. The most successful geocentric model, which lasted for 1300 years, was that of Ptolemy, who used a combination of circles to describe the motion of the planets. In 1543, Copernicus, studying the hypotheses advanced by Aristarchus in 300 BC, proposed the heliocentric model. This model places the Sun at the centre with all the planets orbiting around it.

Léon Foucault



A picture of the Foucault pendulum (1851)

Foucault's pendulum at the Pantheon in Paris. Photo: Rémih

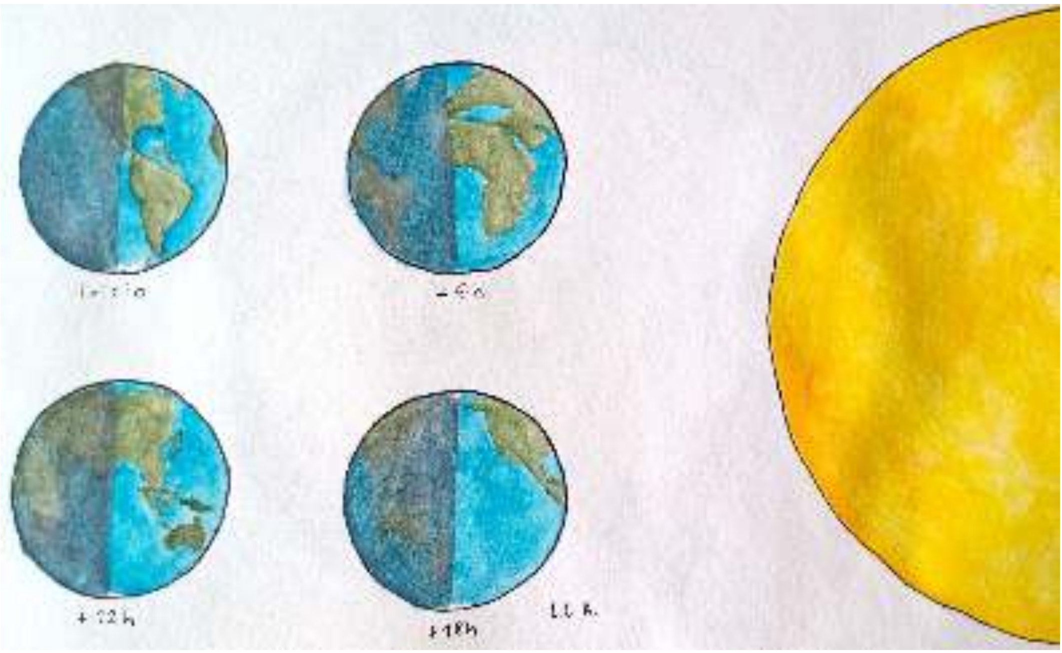
Drawing of the Earth and its axis of rotation, according to Maria Cecilia Feltes Riffel at the age of 5.

The Earth's rotation

The most important idea introduced by Copernicus was that the Earth is only one of six planets (then known) revolving around the Sun. A premise of these ideas is that day and night are produced by the Earth's motion about its own axis: rotation.

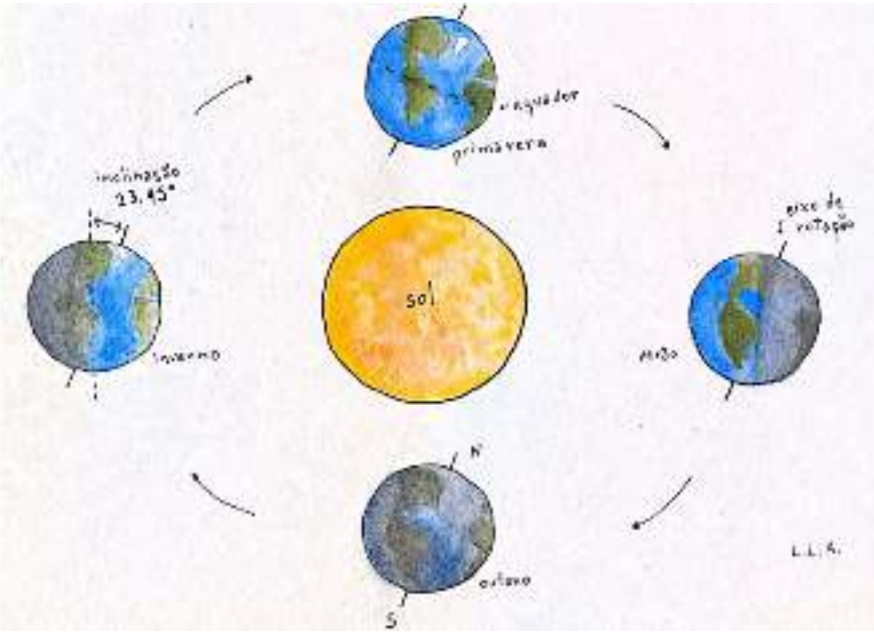
However, to prove Earth's rotation was not easy. The first measurement of its speed of rotation was made by the French physicist Léon Foucault, using a pendulum. The public demonstration of the experiment was in February 1851 at the Paris observatory : due to the rotational motion of the Earth the pendulum rotated clockwise at a rate of 11.3° per hour, at the latitude of Paris. If the experiment had been performed at a latitude of ±90° (at the North or the South pole) it would have resulted in a rotation of about 15° per hour.

Diagram showing the Sun illuminating one face of the planet Earth. On this face we see directly the light of the Sun and we have day. The other face is in the shadow of the planet and we have night. As the Earth rotates around its axis we see that different regions of the Earth are illuminated in 24h. The figure is not to scale and does not consider the inclination of the Earth's axis of rotation. Illustration by Larissa Luciano Amorim.

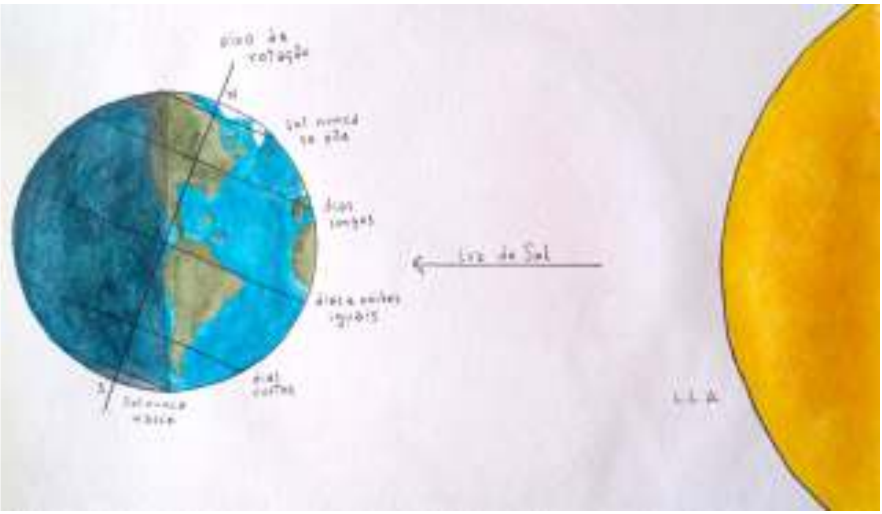


Rotation and the effect of night and day

As we can see, the factor responsible for the night and day effect is the rotation of the Earth. The duration of the so-called 'sidereal day' - which is the time necessary for the Earth to complete one complete revolution about itself - is 23h 56min 4.09s. If we consider a point on the Earth's equator, we determine a rotation speed of 1675 km/h. The duration of illumination may be mistakenly understood to be 12h (the half of 24 h). This is indeed the case at the Earth's equator. However, due to the inclination of the Earth's axis of rotation, the illumination duration vary as a function of latitude. It can reach 24 hours continuously during some parts of the year, that is, the Sun does not set at all.



Effect of the tilt of the rotation axis, combined with the movement of the Earth around the Sun, on the illumination and seasons .



Example of the inclination of the rotation axis at the beginning of winter in the Southern Hemisphere.

Illustrations by Larissa Luciano Amorim.

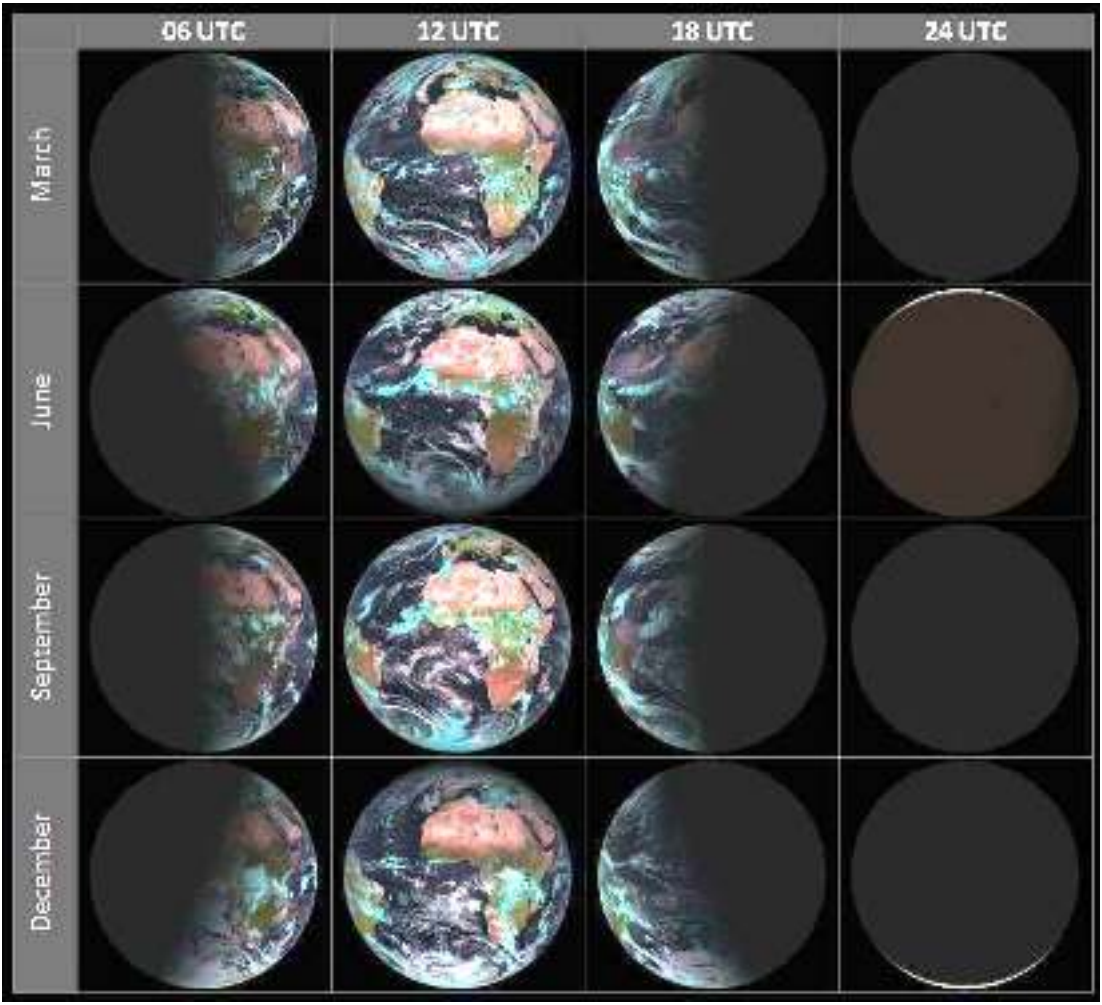
The day and the seasons

The figures on the left show how the duration of daylight depends on the time of year and on the latitude, because the Earth's rotation axis has an inclination of 23.5° with respect to the plane of the ecliptic (the plane of the Earth's orbit around the Sun).

In extreme cases, we have the so-called eternal night, which lasts more than 24 hours, a phenomenon that occurs in the region bounded by the polar circles. The opposite phenomenon, when the Sun stays above the horizon for a long time, is called midnight sun.

The inclination of the Earth's rotation axis is also responsible for the seasons of the year: The Sun's rays fall at different angles on the Earth's surface in different regions of the globe, thus causing summer (perpendicular rays) and winter (very oblique rays).

The Earth as seen from space with the EUMETSAT satellite, as it passes close to the equator on the days of the solstices (June and December) and equinoxes (March and September) at different times UTC (Universal Time Coordinated, which is a timescale maintained by the International Agency for Weights and Measures). Credits : Eumetsat



Earth from space

With the technological progress of the late 20th century, it became possible to observe the Earth from space and observe the phenomenon of night and day at different times and different positions of the Earth in its orbit around the Sun.

On the opposite page are satellite images, showing the illumination of the Earth at characteristic times such as the equinoxes (when day and night have the same duration) and solstices (when the length of the day is maximal or minimal). We clearly see the part directly illuminated by the Sun (day) and the part in the shadow of the Earth itself (night).

Why doesn't the Sun always rise in the same place? (answer on the back).

Sunset on the Lake Guaíba River in Porto Alegre, Rio Grande do Sul, in December 2019. Photo: Márcio Maia.

The annual movement of the Sun

As a result of the movement of the Earth around the Sun, the Sun's position among the stars changes throughout the year. The annual path of the Sun among the stars is called the *ecliptic*. The ecliptic is nothing more than the projection of the Earth's orbital plane onto the sky. As the Earth's orbital plane is inclined by 23°27' with respect to its equator, the Sun's apparent annual path has the same inclination to the celestial equator. As a consequence, the points on the horizon where the Sun rises (in the East) and sets (in the West) vary throughout the year, as does its maximum elevation above the horizon during the day.

The Universe in my pocket no. 32

This booklet was written in 2021 by Rogério Riffel and revised by Marina Trevisan (both from the Astronomy Department of the Federal University of Rio Grande do Sul). I dedicate this booklet to my children Maria Cecilia and João Pedro, who make my days brighter.

Cover image: Photo of 21 June 2021, Winter Solstice in the Southern Hemisphere observed by Meteosat-11. Credits EUMETSAT.

To find out more about this collection and the themes presented in this booklet, you can visit http://www.tuimp.org.

Trad: Stan Kurtz