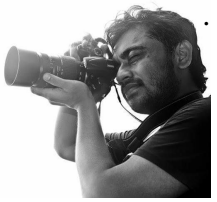
Astrophysics for Fun

Sushan Konar & Sourav Mitra

The Astronomy Module : Lodha Genius Program



Astronomical Measurements : Radius of the Earth

Most of you must be aware of an interesting astronomical phenomenon that can be observed from Kolkata, from Chennai, from Mumbai but NEVER from Delhi (or anywhere north of Agartala in the east or Udaipur in the west)! Right now (18-19 May) this can be observed from places like Nashik in Maharashtra or Puri in Orissa but alas, never in Delhi. 😉

Yes, we are talking about the ***Zero Shadow Day*** (ZSD), a day on which the midday Sun casts no shadows. The explanation of the event lies in the fact that the Earth's axis of rotation makes an angle of 23.5° with the plane of its orbit (around the Sun).

In today's reading material (a blogpost from 2021), you'll learn how this phenomenon was used by ancient scientists to find the radius of the Earth, long before fancy technologies could be used for such measurements. Today, we shall use this same method, except for the fact that we are not going out and hoisting a pole and measuring the shadow angle. Indeed, you can't do this experiment in Delhi, for the reason stated above. Instead, do the following.

1. Choose 10 pairs of places that you would use to determine the radius of the Earth. Each group should have differet sets of places. Now, Eratosthenes needed to satisfy two conditions while choosing his pair of cities. What are they? Do you also need to satisfy both or one or none? Justify. [Eratosthenes : Same latitude pair, and the latitude $\leq \pm 23.5^\circ$. Students : Only same latitude pair.]
2. Knowing the latitudes of these places and their distances (use internet to obtain these quantities) find the mean value of the radius of the Earth.
3. Compare your result with the known value of the radius. What is the error? What is the standard deviation?
4. How does the result of your group compare with the results of other groups? Find the error on the mean (of the results from all the groups) and the standard deviation.
5. Comment on the reasons for large deviations and errors.
6. Use the ASI-POEC app to find the ZSD dates for the places that you have chosen. Why do the dates appear in pairs?

Teaching Assistants

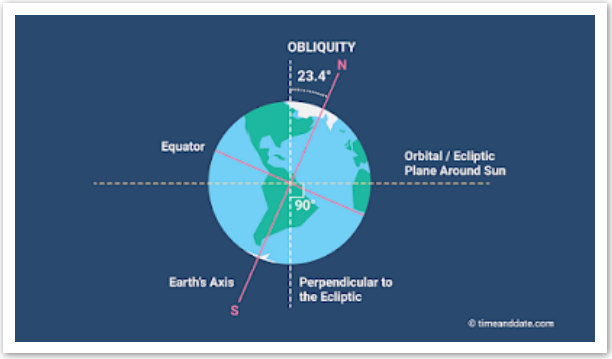
Anantharaman S V & Umang Kumar

Monday Musings

Monday, 17 May 2021

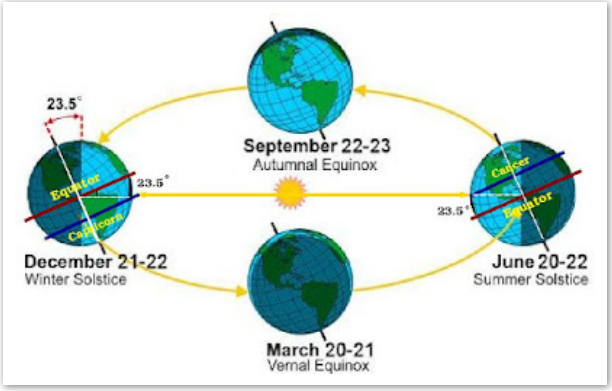
17.05.2021 : The geometry of shadows..

Cyclone (ঘূর্ণিঝড় / চক্রবাত - what expressive names!) Tauktae is here. The visuals coming in from Bombay are quite scary. But Pune being protected from the coastline by the Ghats (পশ্চিমঘাট পর্বতমালা), the weather here is more like that of a regular rainy season. Has been like this since Friday, just allowing us to enjoy the Zero Shadow Day (ZSD) on Thursday. Those who are yet to witness a total eclipse (lunar or solar) in its majestic glory, 'Zero Shadow' is one of the spectacular astronomical phenomena to behold.



We naively think that everyday at noontime, the Sun passes directly overhead. Not quite. Sun being very distant, its rays can be considered to be effectively parallel at Earth's surface. Earth is a large globe and a set of parallel rays can not be aligned to its local vertical at every point. Therefore the Sun can be directly overhead (at noon) only at a particular set of locations (places with the same latitude). Now, these locations would have been fixed, had Earth's spin-axis not been tilted (at 23.5 degrees) with respect to the plane of the Ecliptic (plane of the Earth's orbit).

Because of this tilt, in the course of the year, the Sun moves in the sky plane, being directly overhead to places with latitudes between 23.5N (Tropic of cancer) and 23.5S (Tropic of Capricorn). The Sun is directly overhead at the Tropics (Cancer on summer solstice, Capricorn on winter solstice). Quite clearly, in between we have the days of the Spring and Autumnal equinoxes when the Sun is directly overhead on all points on the Equator - making the day time and night time equal in length. (No matter what I want to talk about, my Musings seem to have a tendency of coming back to Solstices & Equinoxes! 😬).



So ZSD, of a certain location, is the day on which the Sun is directly overhead at noon - casting no shadows. Clearly, ZSD happens twice a year - while approaching the summer solstice and when moving away from it. Naturally, such a phenomenon happens only for places with latitude less than 23.5 degrees. People living at higher latitudes do not have the privilege of experiencing a ZSD there. In India, the Tropic of Cancer passes through Ahmedabad, Bhopal, Ranchi.. Of course, for locations right on the line of tropics, the ZSD occurs only once a year - on the day of the summer solstice.

Sushan Konar

Theoretical Astrophysicist, Science Writer (of sorts) and the perennially hassled mom of a terrific (her words!) teen..

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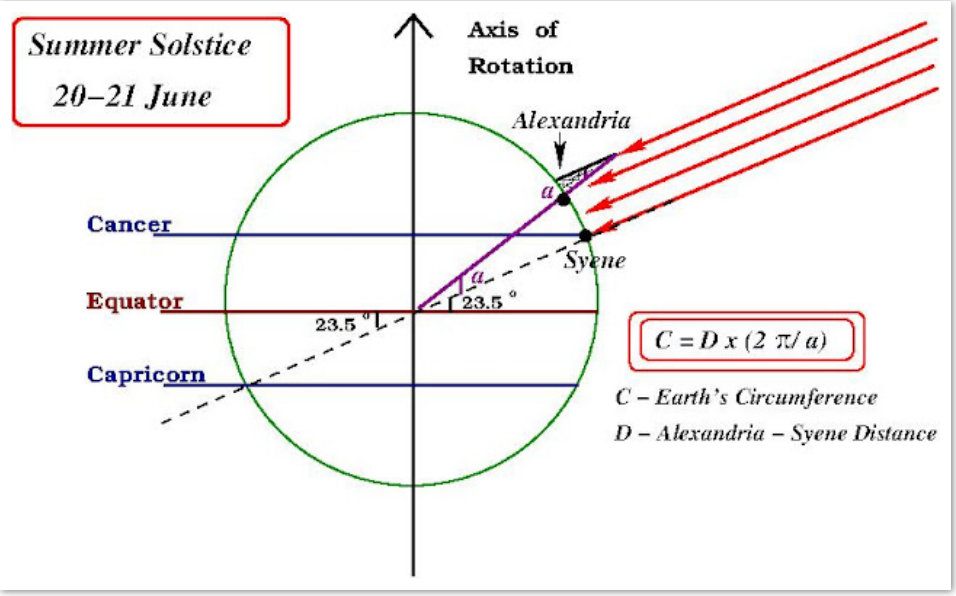
Thanks to the amazing activity of our outreach professionals, many people are now aware of this remarkable phenomenon. [ASI-POEC has pooled in an excellent collection of resources related to the ZSD, available at - http://astron-soc.in/outreach/activities/zero-shadow-day/]



However, what I find truly remarkable is the use of this phenomenon to calculate the circumference of the Earth, more than 2250 years ago! Greek scholar Eratosthenes (friend of Archimedes) used a simple concept to measure the circumference (and hence, the radius) of the Earth. The concept is quite simple. He chose two places which are on the same meridian (same longitude), with one lying on the Tropic of Cancer. [He chose Alexandria (31.2001° N, 29.9187° E) and Syene (Aswan 24.0889° N, 32.8998° E). Though Syene, at ~24°N, is quite close to the tropic of Cancer, it does not have the same latitude as Alexandria.] On the day of Summer solstice, Syene would experience a ZSD. Now, take a tall pole in Alexandria. The pole, its shadow and the line joining the tip of the pole and the shadow would form a right-angled triangle. From simple geometry we see that the top angle of this triangle ('a' in the image above) would be equal to the difference in latitudes of Syene and Alexandria. Knowing the distance between Alexandria and Syene, Eratosthenes could easily calculate the circumference of the Earth (and hence its radius). No modern gadgets, no fancy measurements, just simple geometry of shadows and he had a reasonably accurate estimate of Earth's radius!

There are likely to be many more things in heaven and earth, than are dreamt of in Horatio's philosophy. But I am sure very few can match the wonder that is human intellect! 😃

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at May 17, 2021

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