Proceedings for the
3rd Shaw-IAU Workshop
on Astronomy for Education

What Everybody Should Know about Astronomy Education

12 – 15 October, 2021

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The following is a summary of the 3rd Shaw-IAU workshop on Astronomy for Education held 12 – 15 October, 2021 as a virtual event. The workshop was organised by the IAU Office of Astronomy for Education. More details can be found on: https://astro4edu.org/shaw-iau/3rd-shaw-iau-workshop/.

The Office of Astronomy for Education (OAE) is hosted by the Haus der Astronomie on the campus of the Max Planck Institute for Astronomy in Heidelberg. The OAE's mission is to support and coordinate astronomy education by astronomy researchers and educators, aimed at primary or secondary schools worldwide. The OAE is an office of the International Astronomical Union, with substantial funding from the Klaus Tschira Foundation and the Carl Zeiss Foundation. The Shaw-IAU Workshops on Astronomy for Education are funded by the Shaw Prize Foundation.

Foreword

3rd Shaw-IAU Workshop on Astronomy for Education

Teaching astronomy takes both solid knowledge of the subject itself as well as educational skills, such as knowing appropriate methods and techniques for teaching. To this, specific sub-fields of astronomy education add their own specialized skill sets: knowing how to operate remote telescopes, for instance, or the ins and outs of daytime observations. Last but not least, there are the skills needed in order to make our teaching fair, equitable, and inclusive.

In practice, most of us who are active in astronomy education have only been taught a subset of those skills in our academic training. Those who come from professional astronomy and have branched out into education and outreach typically have advanced training in astronomy, but not in the relevant areas of pedagogy. Most teachers, on the other hand, have pedagogical training as well as training in the subjects their teach, but often that does not include formal training in astronomy and astronomy education.

If this description includes you, and if in consequence you have ever felt motivated to expand your astronomy education skill set, then this workshop was, and is, meant for you. It is the third in a series organised as a collaborative venture between the Shaw Prize Foundation and the International Astronomical Union, and with 89 talks and 50 posters in a total of 18 sessions, it provides a fairly comprehensive "Astronomy Education 101".

For those who were unable to attend, or did not manage to attend all of the sessions they were interested in, we present these proceedings, and the associated talk videos from the workshop. While they lack the interactivity that the 580 workshop participants enjoyed as they posed their questions to the speakers, or interacted in the chat, we do believe that they are valuable in their own right — and we asked speakers to include in their write-ups helpful pointers to additional resources, so you have the opportunity to delve deeper. If you find these resources useful, and I hope they will be useful to many, please share them widely.

The workshop was made possible by funding from the Shaw Prize Foundation, for which we are very grateful. You can find the names of the individuals and institutions who organised the workshop on p. 6 — a big "Thank you!" to all of you!

For us at the International Astronomical Union's Office of Astronomy for Education (IAU OAE), this is just the start. Helping those who are active in astronomy education to grow their skills, and to become more professional in their activities, is one of our main objectives. Stay in touch if you want to make sure not to miss what is next — from additional events to more resources. On the web, you can find us at http://astro4edu.org, and on that page, you can also find your country's National Astronomy Education Coordinator Team. We are also on Twitter and on Facebook as @astro4edu.

Markus Pössel
Director, IAU Office of Astronomy for Education
Heidelberg, November 16, 2021

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In addition to the efforts from the OAE office in Heidelberg, Germany, the following OAE Centers and Node made key contributions to organizing this event:

OAE Center Italy

OAE Center Cyprus

OAE Node Nepal

The OAE Center India was not formally established at the time of this workshop but also made significant contributions.

Daytime Astronomy

Session organiser: Markus Nielbock, Office of Astronomy for Education/Max Planck Institute for Astronomy, Germany

Session overview

Daytime astronomy challenges our expectations of what astronomy entails. Our first associations revolve around the night sky, rich in fascinating objects like the Moon, planets, stars, constellations, nebulae, globular clusters, and galaxies. However, there are many exciting concepts connected to celestial objects that everybody can witness even in daylight. Firstly, there is the Sun, but we can also find the Moon and certain bright planets during the day or in the twilight of dusk and dawn.

Daytime astronomy also helps us to connect with our cultural heritage. Seasons, timekeeping, and the calendar are closely related to observing the apparent annual motion of the Sun and the Moon.

One major advantage of daytime astronomy activities is they happen during regular school hours. As such, they potentially reach many children and enrich their teaching with easily accessible hands-on exercises. Therefore, daytime astronomy is exceptionally well suited to teach basic astronomical concepts with few barriers concerning availability during the day and avoiding possible safety issues at night.

This session highlights a series of six talks and three posters that present various activities and best practices to teach fundamental phenomena of the Sun-Moon-Earth system. They include examples for diurnal and annual solar motions, activities to measure the size of the Earth, as well as tips for observing solar eclipses safely.

Sun, Shadow and Sky: Glimpses of "Daytime Astronomy" Activities

Speaker: Venkateswaran Thathamangalam Viswanathan, Vigyan Prasar, New Delhi, India

Time reckoning and seasons are linked to the apparent position of the Sun in the sky. Outdoor project work helps to determine the cardinal directions, local (astronomical) noon & standard clock time, yearly noon shadow changes, rough time reckoning and seasonal day length changes. Few activities can be completed during the day, and some will require measurements and observations on different days of the year. The learners observe and note the key aspects, contextualise them, undergo a cognitive apprenticeship, help analyse and interpret information, and learn to work in groups. Observing and interpreting the gnomon's shadow and the project encourages young people to participate in knowledge generation.

Talk link: `https://youtu.be/IMXicn-eFJ0`

Astronomy evokes the image of the starry sky, Moon looming large, and the planets meandering in the background of the celestial sphere. One may even consider that "daytime" and "astronomy" to be opposite of each other and that "daytime astronomy" is an oxymoron. Yet, in the history of human civilisation, the dawn of astronomy was marked by the observations of the Sun in the sky and the shadows it casts. The sun provided the cue for computing the time elapsed since the sunrise (or the time remaining before dusk falls) and longer time-division such as seasons and years. Daytime astronomy (DTA) activities attempt to recapitulate these for education, popularisation, and outreach efforts.

What can we observe in the daytime? We will illustrate some of the activities that can be carried out in the daytime by observing the motion of the sun and the shadows it creates.

Sun does not rise in the east: A simple activity would clarify that the Sun does not "rise" at the same point on the eastern horizon. Choose a spot on your terrace with an unhindered view towards the east, and mark it. You will have to stand on that spot many times during this exploration, making the mark durable. Watch the sunrise as it goes above the parapet wall. Ask your collaborator to place a stone on the parapet wall such that the stone and the rising Sun are in a straight line. Come back to the same spot, say after every fifteen days, for say two to three months, and at each time place a new stone that marks the sunrise point. Mark each stone with the date and time at which you made the observation. We can quickly find that successive sunrise points are moving towards the southeast for the six months, and towards the northeast,

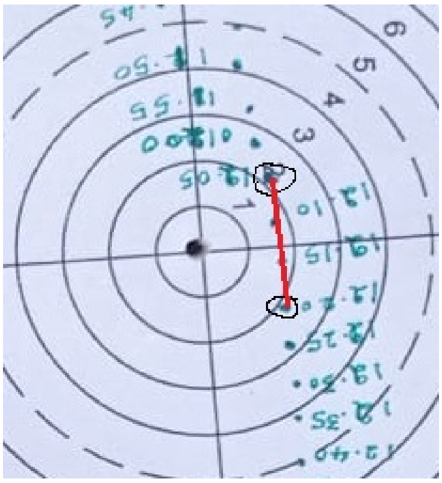

Figure 1: When you join two points on the same circle, we get the west-east line.

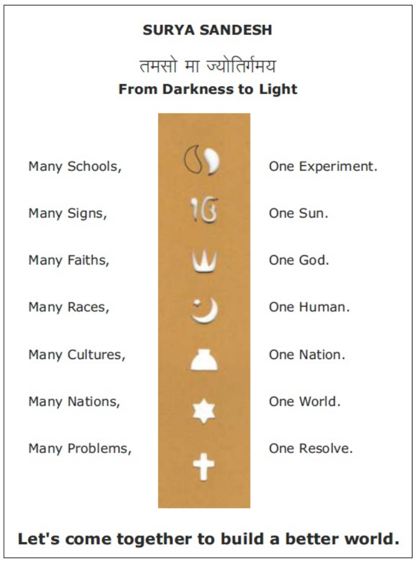

Figure 2: The holes perforated in the shape of various faith symbols project distinct images when held closer and all become circles when the distance to the screen is increased.

in the next six months. The southeast position is closer to December 21 (winter solstice), and the northernmost place is closer to June 21 (summer solstice). "Sun rises in the east": as we understand it, is not that correct. With careful observations (and nudging from the facilitator), we can find that the sunrise point is very close to the actual east on two days in a year called the equinoxes.

Your shadow your clock: An ancient verse in Tamil tells us how to compute the time during daytime from measuring your shadow with your feet measure. Choose a rock or the edge of the pavement (or any fixed object) as the mark. Adjust your position in such a way that the shadow of the tip of your head kisses its edge. Now measure the length of your shadow, with your feet, by slowly tiptoeing towards the stone/pavement.

In the old days in the southern part of India, they used a time division called "Nazhigai", which is equivalent to 24 minutes. From sunrise to sunset, there were 30 Nazhigai. If your shadow length is 98 feet measure (by your feet! This is important, remember), then from sunrise, it is not more than one Nazhigai (or 24 minutes). Alternatively, if it is afternoon and the shadow is pointing towards the east, then in 24 minutes, the sunset will take place. If the shadow length is 45 feet measure, then it is two Nazhigai (48 minutes). The table is given a pair. The first number is the shadow length in feet, and the second number is the time in Nazhigai since sunrise or the time remaining for sunset. (98:1), (45:2), (28:3), (19:4), (14:5), (10.5:6), (8:7), (6:8), (4.5:9), (3.5:10), (2.5:11), (1.75:12), (1:13), (0.5:14), (0:15). This works roughly for southern India; I am not sure this would work for your place as it is. Why not try measuring the shadow lengths? Prepare a table for your area.

When is "midday"?: The clock time 12:00 is not when the Sun crosses the meridian line at your place. Place a vertical pole. Draw concentric circles on paper (as shown in Figure 1) and place a vertical rod (pencil) at the centre. Note the shadow point of the tip of the pole every five minutes. When two points fall on the same circle, add the clock time of these two points and divide by two; we get the astronomical noon. In Figure 1, the points corresponding to 12:05 and 12:20 are on the second circle. Add them 12:05+12:20 and divide them by two. We get 12:12; that is the midday/astronomical noon at the location where this observation was made.

Cardinal directions: Draw a line connecting the two points falling on the circle (Figure 1); that is, the east-west line. Now draw a perpendicular to that line passing through the centre, we get the north-south line.

Shadow flips: If you watch the pole's shadow during the astronomical noon every day, we will observe an interesting phenomenon. In Chennai, from August 18 to April 24, the pole's shadow would be towards the southern direction. On April 25, the direction of the shadow would be west-east. At astronomical noon, there will be no shadow – Zero Shadow Day! However, on April 26, the shadow would be pointing north! It would point towards the north until August 16. On August 17, once again, the shadow would be west-east and at noon, no shadow. Once again, Zero Shadow Day. From the next day, August 18, the shadow of the vertical pole flips to the southern direction.

Message from the Sun: The Surya Sandesh Sun card, developed by Dr Vivek Monterio (Figure 2), shows how science activities make us reflect on our understanding of the world and produce a much better mutual understanding amongst us. In these dark times of hate, sectarian violence, demonisation of people belonging to other "faiths" and belief systems, good science education must also cultivate what in India we call as "scientific temper"; an attitude that is steeped in temperament for reform, humanism and spirit of enquiry. "Surya Sandesh" means "message from Sun". When you hold the card, with perforations marking various faith symbols close to the ground, in the shadow cast, each symbol appears distinct. When we slowly raise the card towards the Sun as high as possible, initially, all faith symbols become the same; circles of light. When we go even higher, the circles touch and merge into each other, symbolising our essential oneness as human beings, as citizens of planet Earth. We are One under the Sun.

Only a few illustrative activities are listed above. Fun and learning are possible with many more such activities using low cost/no-cost contraptions. One can make a sundial, measure the altitude of the Sun at midday to trace the path in the sky, find your latitude and many more. Even in the resource-poor scenario, these are eminently feasible. For example, Navnirmithi, a Mumbai based science education group, had developed "Ball-mirror assembly" solar projection. With this, every school around the world can have a solar observatory for exploration and learning[1]. Roleplay[2] is also an effective tool. The Public Outreach Committee of the Astronomical Society of India[3] is also developing apps/activities. You can also watch DTA videos by Vigyan Prasar[4].

[1]see for the construction and uses of the ball-mirror assembly: https://www.vidyaonline.org/dl/sun-earth-games.pdf

[2]https://www.arvindguptatoys.com/arvindgupta/role-play-eng.pdf

[3]https://astron-soc.in/outreach/activities/zero-shadow-day/

[4]https://www.youtube.com/watch?v=YUYA7NWocO8&t=4s and https://www.youtube.com/watch?v=9FHT6R-Hm4Y&t=5s

Where Are We? How Do We Move?

Speaker: Edgardo Quintana, Colegio San Francisco Javier, Puerto Montt, Chile

If somebody asks me "What Everyone Should Know About Astronomy Education", it would be concepts like "Where Are We?" and "How Do We Move?". I think that this information and associated activities and methods, give us a perspective about who we are. The talk shows the movements of the Earth in the southern hemisphere, the path of the Sun during the day, the connection with the southern celestial pole, and the different experiences with activities that complement this journey.

Talk link: https://youtu.be/3wiFEWsZpdU

What everybody should know about Astronomy Education: I think we need to add an approach that connects astronomy with the humans; something like what is generated when you find yourself contemplating a starry night, but from an education point of view; an assimilation of the context in which we situate ourselves as beings. I think that this "assimilation" of astronomical knowledge is important and contextualizes our existence. By educating about astronomy, we can connect life with what science tells us about what the Universe is like. We ask ourselves again "what are we" "how does life originate".

And well how do we achieve this?: My opinion on what we should know about astronomy education is based first, as a start, on explaining, "where we are" and "how we move" in space.

Where are we?: "We are in the solar system, within a spiral galaxy called the Milky Way, at a distance of 28,000 light years from the center, where there is a supermassive black hole. At the same time this galaxy is immersed in groups of galaxies."

When thinking of our Solar System we can observe the Moon and the Sun during the day. The Sun is eight light minutes and the Moon is one light second away. From our observatory, it is also possible to photograph them. The following activities are possible:

Concerning the craters of the Moon, students can point at those visible from our location.

Students can recreate their bound rotation through an activity in which they revolve around each other while facing each other and wearing masks of the Sun and the Moon. They show why only one side of the Moon is visible.

Students can also visualize sunspots and their movement through time while observing the rotation of the Sun with the help of information from the SOHO satellite page.

Students can make a solar system scale model. A tactile model would also allow for activities including blind people.

To comprehend sizes, students can compare the diameters of the Moon, the Earth, and the Sun with images that are to scale.

To understand eclipses, students can take pictures, work with a lunarium and a lunar calendar.

While applicable to any object orbiting a massive object, such as Jupiter, the Sun, the Moon, etc., it is possible to carry out a mapping of the distance scaling of Galactic objects. Here you can take advantage of Kepler's Third Law and the concept of uniform circular motion to extend the laws valid in the Solar System to also calculate the mass of the galactic central black hole with the star S2, knowing the period and the distance at which the star is from the center. It joins with trigonometry, in Chile for 11th graders.

I find that there is information that is very important if we want to understand where we are. This is related to the location of the star closest to us "Proxima Centauri" at 4.3 light years. This star is not observable during the day, but it is possible to refer to it when we see how the Earth revolves around the southern celestial pole. In this part, it is possible to explain what one light year is and calculate that distance in kilometers or compare it to the Earth-Sun distance.

Students can create a velocity-time graph assuming that we want to travel to that star. It can refer to the highest speeds that human beings have been able to reach when traveling through space. This touches the concept of uniform rectilinear motion. In passing, we can connect the activity with the study of exoplanets Proxima Centauri b and c.

Finally, students can realize that at 70,000 km/h it is possible to reach that star from Earth in 100,000 years. Consequently, we are very far from other objects. If there is no nearby life in the Solar System, we would be even more alone. That tells us that our planet behaves like an island in the middle of a huge ocean.

How do we move?: "The Earth rotates and is tilted with respect to the ecliptic. We move on a nearly circular orbit at a speed of approximately 100,000 km/h around the Sun. The solar system also moves around the center of the Galaxy".

The rotation of the Earth is possible to appreciate with the apparent movement of the Sun through the day. In our city, Puerto Montt, it is possible to see the Sun rise in the morning from the mountain range towards the sea, passing over Lake Llanquihue. It is very important to have a reference since in this way we can compare different sky positions. From here, we see the volcanoes Osorno, Calbuco and Puntagudo. With the months changing, we can observe the apparent path of the Sun. In winter, we see the Sun pass at a low altitude and in summer at noon it is possible to appreciate it near zenith.

Possible activities (some may be complementary) include students producing simulated or photographic time-lapses or multi-exposures during the day for various seasons, e.g. one in summer and one in winter. For photographs, they need a clear sky. Producing such visualizations is easier and independent of weather conditions if they use a software like Stellarium.

In addition, children can produce hands-on scale models of the Sun crossing the sky. They can glue several circles representing the Sun placing on a semi-spherical transparent dome. The figure above represents the apparent movement of the Sun in winter and summer. This movement can also be illustrated in several complementary ways.

At night, the apparent movement of the stars around the southern celestial pole show us how the Earth rotates under the sky. During the day, an activity with a Foucault pendulum helps to witness the rotation of the Earth. Students can create a time-lapse that illustrates the variation of the angle with respect to the pendulum's plane of oscillation. Finally, adequate software like Stellarium, star map or skywalk helps to visualize the effects we see due to the Earth's rotation.

Now, we are alone in the Universe and we move very fast.

Top left: Image obtained by students from the Christopher Clavius Observatory. The sea of tranquility is just visible. Top right: Masks to explain why we only see one side of the Moon. Bottom left: The Sun and sunspots obtained by students at the school's observatory. Bottom right: The Moon photographed by day.

Left: Work that students can develop to show the apparent path of the sun in the sky from Puerto Montt. Right: Foucault pendulum from the school to show the rotation of the Earth.

The Globolocal Project and the Use of the Parallel Globe

Speaker: Nicoletta Lanciano, Università di Roma "La Sapienza" e Gruppo di ricerca sulla pedagogia del cielo del MCE (Movimento di Cooperazione Educativa), Italy

From didactic research we fund initial conceptions with big difficulties in understanding the point of view of astronomy, geometry, physics, and geography about the spherical Earth. With a globe in the same orientation like the Earth in space, the Parallel Globe, we observe fundamental astronomical relationships between Earth and Sun, in real time. The international Project Globolocal is democratic, because we distinguish concepts like high-low, above-under and North-South. Each location, seen from the place of observation, is at the top of the world, so it helps to have a correct image of the Earth in the space.

Talk link: https://youtu.be/qTvZVTIl14k

I presented the Globolocal Project and the use of the Parallel Globe that is a tool for working on Astronomy during the day, but not only that. We also work with the Sun and in the open air. It means that we must wait for a sunny day with no clouds. It is an ecological aspect of our work because we must be patient and wait and recognize that we depend on nature. Being in the open air is a very important aspect of our health and our wellness, meaning that school is also conducted in the open air, in a garden, and not only in the classroom.

The Parallel Globe allows many didactic approaches at different levels, with children, young students, and adults because we know from research that adults also have difficulties explaining quotidian astronomical phenomena. The Parallel Globe is very easy to construct: we remove the usual terrestrial globe from its stand, fixed and universal. It is enough to place the globe on a cup, well oriented with a compass, with the North Pole to the North and the South Pole to the South, and our location on the top: in fact, anywhere we are, the entire planet is below our feet.

If I am in Rome - Italy at 42° North, I put the globe with Rome on the top. However, if I am on the Equator, in Kenya or Colombia, the terrestrial axis is quite horizontal and if I am near the South Pole in Antarctica, the axis is rather vertical. So, everybody and every country are in turn at the top of the world and in the part of the globe facing up.

We can put the globe on a cup, or we can build a new flexible stand. With this globe, it is evident that "north-south" is different from "high-low" and from "up-down"! Instead, the fixed globe makes us think that there is an absolute up and down. The Parallel Globe helps us to see that "North" is a global geographical reference, while "up" is a local and physical indicator. Then, we put the Parallel Globe in the same position that the Earth has relative to the Sun. The globe and the Earth are in a homothetic orientation, and the globe assumes the same position as the Earth has in space. So, the Sun illuminates one half of Earth's sphere and one half of the sphere of the globe, with the same countries in light and in shadow. This instrument allows us to see the Earth from outside because in every moment the model is illuminated like the planet.

It helps us to find the connections between the local topocentric perspective and the global geocentric one; to reflect on a heliocentric global view: our local situation is considered in a global dimension. In fact, we can observe on the Parallel Globe where it is midday and the shadow of a gnomon disappears, where it is night or day, where they have sunset, or sunrise, and much more. Observing the Parallel Globe several times a day, and several days in a year, we can see which elements vary and which remain constant.

If we observe the terminator, that is a great circle of the sphere, that separates the light from the shadow, we see the direction of Earth's rotation. We can also measure and calculate how many hours of light we have in a day, related to the local latitude and the period of the year. Looking at this instrument is very different from studying these phenomena in a book and repeating a phrase from memory; it is much stronger from the point of view of emotion, of astonishment, of memory.

The Parallel Globe lets us travel to all the countries of the world. If we live in the North, we can see what happens in Ecuador or in South America. If it is daytime, we can see where, now, it is night. If it is Summer for Italian people, we can see where it is Winter, for example, in South Africa. For this reason, it is an instrument and not just a model of the Earth. It helps us to ask questions and to find answers. Why the name "Parallel Globe"? Because the axis of rotation of the globe is set in the same direction that the Earth has. The angle between the axis and the horizontal plane is equal to the latitude. At every point of the planet, the horizontal plane is parallel to the tangent plane of the globe. If we put some toothpicks or pieces of plasticine in a radial position as gnomons, we see their shadows, with their direction and longitude, with reference to the inclination of the Sun's rays. We can put more gnomons on the same meridian, in places with the same longitude, or on the same parallel, in places with the same latitude. With the Parallel Globe we can work on common errors and difficulties: for example, we can approach problems with perceptive and cognitive difficulties like "why don't people in Argentina fall off?". And we can see that at noon, even at a Summer Solstice, in most places, the Sun is never at the Zenith, like a lot of young and adults for example in Europe think! And Summer is not due to the position of the Earth being closer to the Sun. In fact, we have two different hemispheres that are in different seasons at the same time.

Globolocal is a Project developed by Italian and Argentine researchers, for teaching Astronomy and for helping understand astronomical phenomena, with attention to different countries in the world with their geographical and astronomical differences, from the Equator to the Poles. Usually, representations and models refer to the Northern Hemisphere as if it were universal: this is a problem of power and furthermore causes many difficulties in comprehending astronomical phenomena for many. On the web site of the Project we collect photos, didactical experiences and reflections about the use of the Parallel Globe. The website www.globolocal.net, is now under revision.

But above all, the Parallel Globe returns to each and everyone their position on top of the world and that is why it is a democratic tool! Democracy means to recognize the dignity of every position in the world and also the dignity of every language. "The school has the task of stimulating a profound awareness of the interdependencies of our being in the world and of promoting a responsible awareness of the local dimension in the planetary dimension." (MCE)

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The Eratosthenes Experiment: a 2300-Year-Old Ingenious Measurement

Speaker: Angelos Lazoudis, Ellinogermaniki Agogi, Pallini, Athens, Greece

In ca. 240 B.C., the Greek astronomer Eratosthenes made the first good measurement of the size of Earth. By noting the angles of shadows in two cities on the summer solstice and by performing the right calculations, he was able to make a remarkably accurate calculation of the circumference of Earth. In our educational activity, students repeat the experiment by using e-learning tools, simple instruments, and a platform (eratosthenes.ea.gr) that allows schools to collaborate with each other. Our aim is to turn this international activity into an important world event, giving students, teachers and educators from around the world the opportunity to actively engage in building online learning communities, exchange ideas and material through innovative initiatives.

Talk link: https://youtu.be/Fs4pC1KniMc

Over the past, many methods highlighting science education have been proposed for measuring the Earth's radius. Proposed experiments are based on pure mathematics (e.g. the Al-Biruni method) or even on using modern technology, e.g. a digital camera.

We follow the steps of Eratosthenes, who was an astronomer, scientific writer and chief librarian at the Library of Alexandria. In ca. 240 B.C., Eratosthenes made the first good measurement of the size of Earth. By noting the angles of shadows in two cities on the summer solstice and by performing the proper calculations, he made a remarkably accurate calculation of the circumference of Earth.

In our educational activity, students repeat the experiment using e-learning tools, simple instruments, and a platform (http://eratosthenes.ea.gr) that allows schools to collaborate.

The main objectives of our proposed educational activity are to:

- Describe the geometry of how sunlight strikes Earth at different latitudes
- Describe how the circumference of Earth was first measured millennia ago
- Describe how to determine local noon
- Measure the angle of the Sun at local noon
- Collaborate with another school some distance away to determine the radius of Earth.

We use two different types of tools: Map tools such as Google maps or Mapmaker offered by National Geographic, and Tools for calculating the local noon time such as Stellarium or the NOAA solar calculator. The latter tools provide us with the necessary information as the experiment needs to be performed at local noon when the Sun reaches the zenith.

The proposed day for the experiment is during the spring equinox day, on March 21st 2022, because we know that on that day, the solar rays fall perpendicular on the equator. Thus, the distance that needs to be calculated between any school and the place where the rays fall on the ground at 90 degrees is the one from the school to the equator.

As schools register with their geographic coordinates, we match those sharing the same or close longitudes to perform the experiment collaboratively on March 21st or any other day. When two schools are matched, they measure by following Eratosthenes' steps, the angle corresponding to the arc distance between their school and the equator. By sharing measurements and using simple geometry, they can relate the difference of the two angles to the distance between the two schools. Having exchanged this data leads to calculating the Earth's radius by using the mathematical rule of three.

Our presentation provides sample recordings from previous events with schools that shared a common longitude but were far apart, e.g. a school in Athens (Greece) and another in Vantaa (Finland).

Moreover, we exhibit some photos from Antarctica. During the spring equinox, the solar rays are parallel to the ground making the shadow of an object – in theory – almost infinite. Our photos were taken by Robert Schwarz outside the Amundsen-Scott station located precisely at the South Pole. Robert's (being 1.83 m tall) shadow is estimated to be more than 100 meters long!

The Eratosthenes experiment is usually followed by a photo competition. The competition is open for teachers, and the winning prize is a trip – with all expenses covered – to the DiSTARS summer school. (http://www.distars.eu)

Our aim is to turn this international activity into an important world event. It gives students, teachers and educators from around the world the opportunity to actively engage in building online learning communities and also exchange ideas and material through innovative initiatives.

Analemmas in Education

Speaker: Vegard Lundby Rekaa, NAEC-Norway, Norway

Analemmas are fascinating. Their shape arouses curiosity about what it can mean, while knowledge of their origin challenge an old notion that the sun is always in the same place at noon, every day. From the analemma, it is possible to calculate simple quantities such as the latitude of where they are observed, as well as the inclination of the earth's rotational axis. It is also possible to deduce solar mean time is constructed, and that it is only exact on four days every year. The exercise taught in this session allows students to carry out measurements of the suns motions themselves and, based on these, calculate some basic quantities in the movements in our solar system.

Talk link: https://youtu.be/KMmaz3lCYWo

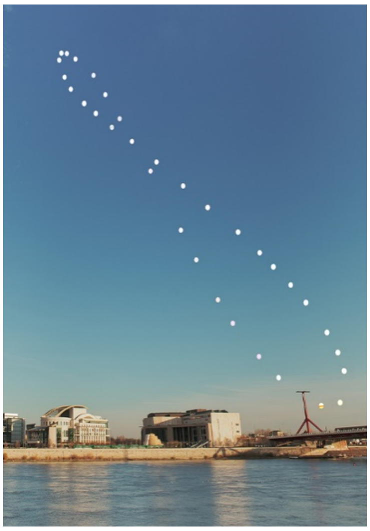
An analemma is created by observing the Sun's position every day during the year, at the same time each day. The observation can be done directly or indirectly using a sundial or a shadow from a pole.

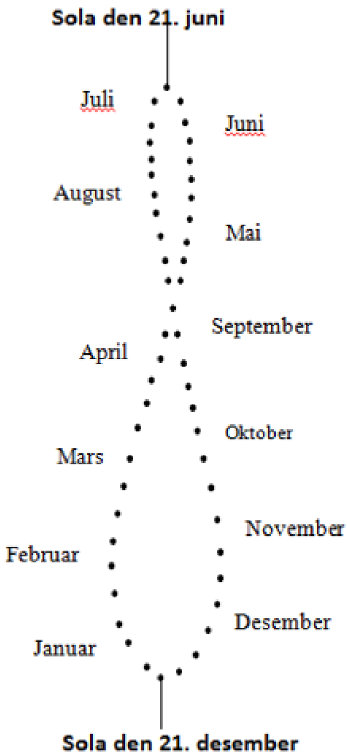
The analemma is a phenomenon well suited to use in education and demonstrates basic concepts in space and celestial mechanics. And it is an exciting way to observe the sky, even during daytime. The Sun is our nearest star and an object from which we have learned a lot about our own solar system and other planetary systems.

Whichever method you choose to make an analemma: the resulting geometrical shape you get is something close to a figure eight. Most people are aware that the Sun varies in height during the year but believe that the Sun is directly towards the South (or the North if you are in the southern hemisphere) at noon. This last detail is only true on four days each year! By finding a way to record the actual position of the Sun each day at noon, we get pictures like the ones shown in the Figures.

The primary reason for the change in the Sun's position, and the "motion" in the analemma, is due to the tilt of the rotational axis of the Earth. This causes the Sun to pass high in the sky at noon during summer, and low in the sky during winter. As a result, we find a vertical "motion" of the Sun's position when compared to the days before and after. The Sun will thus mark the top and bottom turning-points of the analemma during the summer and winter solstices.

The secondary "motion" of the analemma, sideways, is an expression of the Sun not being exactly south (or north) at noon. Or put in other words, the Sun is not on the meridian! Most of the year, the Sun is either ahead (i.e. passing the meridian before noon) or after (i.e. passing the meridian after noon).





This is caused by two horizontal motions that do not follow the mean solar time, or the expectancy that the Sun has completed one lap around the skies during 24 hours. These motions can be explained by the tilt of the rotational axis and the ellipticity of the Earth's orbit.

One day is defined as one rotation of the Earth around itself, measured relative to the Sun's position in the sky. The rotation of the Earth is, however, not just 360 degrees. During one rotation around its axis, Earth also moves approximately one degree on its orbit around the Sun, thus leading to a 361 degree rotation during one day.

Earth's rotation is not in the same direction as its orbit. Instead, the rotational axis of the Earth is tilted by 23,5 degrees with respect to the ecliptic. This causes a seasonal variation in the final contribution of the one-degree rotation since time is defined and measured along the equator.

Near the solstices, the Sun is either high or low in the sky, with little change in height from one day or the other. On such days, the equator appears parallel to the ecliptic. This causes the 1-degree contribution to be at its largest since none of the orbital motion is vertical with respect to the equator.

Near the equinoxes, the orbital contribution (one degree) is 23,5 degrees off the equator. Therefore, only a component of the motion contributes to a movement that can be measured in hours and minutes, i.e. parallel to the equator. The orbital contribution is thus reduced by 10%.

This gives us the impression that the Sun slows down during spring and autumn, and the Sun will be crossing the meridian later during the day. During winter and summer, the Sun "speeds up" again. Just before the seasons change to autumn or spring, the Sun races ahead and crosses the meridian before noon.

The final velocity component that causes the Sun not to be in the South (on the meridian) at noon comes from the slightly elliptic shape of the Earth's orbit. As the Sun is somewhat closer to the Sun during winter (in the northern hemisphere) and further away during summer, the Sun moves faster around the Sun during winter than it does during summer. The difference in distance and velocity is merely 3% (measured relative to the average distance and orbital speed). Still, this contribution is enough to give the analemma the asymmetry between the winter and summer lobes of the "figure eight".

You can make an analemma too!

The easiest and safest way is to attach a horizontal pole on a wall facing southwards. Make sure that the pole is steady and can withstand wind, rain and snow. Put also a ball, a plate with a hole, or a cross at the end of the pole. This makes it easier to mark the exact position of the shadow from the tip of the pole on to the wall.

Add marks with a pen or a marker every day you have sunlight. Remember to get someone to help you if you are away for several days. It is best if you can get 2-3 markings every week. Good luck!

Observing Solar Eclipses

Speaker: Sarah Abotsi-Masters, NAEC Ghana, Ghana Planetarium, Accra, Ghana

A solar eclipse is one of the most awe-inspiring spectacles that can be witnessed. The recommended method for viewing an eclipse safely is using eclipse glasses or a telescope fitted with a solar filter. But these tools are not available to the majority of people around the world. This talk will showcase two simple methods (pinhole and mirror projection) for viewing a solar eclipse using household objects, thus making eclipse viewing easy, affordable and accessible.

Talk link: https://youtu.be/9Q6RR4xwwfI

A total solar eclipse is possibly the most spectacular and awe-inspiring astronomical phenomenon that can be witnessed. There are between 2 and 5 solar eclipses each year worldwide. However, any given location will experience a solar eclipse on average only once in around 400 years, so if you have the opportunity to see one, make sure not to miss it!

Solar eclipses provide a unique opportunity for science communication to the general public. This is particularly important in areas where scientific literacy is generally low. For example, in Ghana, where I live, there is virtually no science journalism. It is very rare to see or hear articles about science or astronomy in the mass media. But the total solar eclipse of March 2006 made headlines across the country!

The geometry of a solar eclipse provides a multiplicity of rich teaching opportunities since, in order to explain how a solar eclipse occurs, it is necessary to explain the relative sizes of the Moon and Sun, the relative distances of the Moon and Sun, the phases of the moon (since the eclipse occurs at new moon), the elliptical shape of the moon's orbit (annular eclipse) and the inclination of the plane of the moon's orbit (the reason we do not have solar eclipses every month).

Many organisations have developed resources and activities that demonstrate the true scale of the Earth, Moon and Sun, e.g. Astronomical Society of the Pacific and NASE (Network for Astronomy School Education); see resources below.

So the aim is to encourage as many people as possible to observe a solar eclipse when one occurs in their region. The specially-designed eclipse glasses are the "gold standard" for eclipse viewing. However, in many regions, they may not be easily accessible or affordable. Hence it is extremely important that communication about eclipses includes how to view the eclipse SAFELY without eclipse glasses. (And it is the partial phase being referred to here since, during the period of totality, the Sun can be safely viewed with the naked eye).

Fortunately, there are simple ways to do this, and I will outline two methods; basic pinhole and reflected pinhole.

The great advantage of the pinhole viewing method is that there is no need to build, buy or make any special equipment, since any household utensil with small holes (no more than a few millimetres) in it will do, such as a colander, grater, or straining spoon.

The pinhole method works because an illuminated object reflects light in all directions. A pinhole is small enough such that only the rays that travel directly from different points on the object can pass through and hence form an image of the object on a surface on the other side.

If you have no utensils to hand, there are many other ways to produce pinhole images, e.g. simply make a small hole in a piece of paper, use the small spaces between interlocked fingers, or use natural features such as the spaces between leaves on a tree. The end result is that light from a partially eclipsed Sun, passing through the pinhole, will produce an image of the Sun on the ground or a sheet of paper placed a metre or so away. You can vary the distance between the pinhole object and the ground or paper to get sharper or brighter images. You can even get creative and create pictures using a pattern of holes!

The reflected pinhole method requires a little more effort to set up, but can also give good results, and has the advantage of producing a larger image that many people can enjoy. Take a mirror, cover it in paper or tape, leaving a gap (a pinhole) of just a few millimetres. Position the mirror so that it reflects sunlight onto a screen or wall, preferably inside a darkened room. You can experiment with the size of the pinhole and the distance to the screen; a smaller pinhole produces a sharper image, but it will be less bright. A greater distance to the screen should produce a larger image. The mirror will need to be taped or held in place with blu-tack or similar to keep it steady.

These simple, accessible and affordable methods enable people anywhere and everywhere to have an amazing experience viewing the eclipse safely, a once-in-a-lifetime opportunity they will never forget!

Resources:

- Easy pinhole methods: https://www.africanastronomicalsociety.org/solar-eclipse-2020/easy-pin-hole-methods-to-view-the-eclipse/
- Safe viewing methods: http://www.eclipseafrica.org/Info/WatchEclipse.shtml#PinholeTrees
- Worksheet to explain how pinhole projection works: http://www.eclipseafrica.org/Info/PinholeProjectionFocus.pdf
- Reflected pinhole method: http://www2.eng.cam.ac.uk/~hemh/transit.htm
- Yardstick eclipse activity: https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=327
- Yardstick eclipse activity document: https://nightsky.jpl.nasa.gov/docs/ModelMeaningfulEclipses2016.pdf
- Phases and Eclipses from NASE: http://sac.csic.es/astrosecundaria/en/cursos/formato/materiales/conferencias/T3_en.pdf

Reckoning Earth's Size by Taking a Dip: A Hands-on Site-based Learning Activity

Presenter: William H. Waller, IAU/OAE/US-NAEC, Endicott College and The Galactic Inquirer, USA

An engaging technique for determining the Earth's size makes use of one's local horizon and its dependence on one's height. I have made use of a nearby beach, from which a stone breakwater is visible near my local horizon. Equipped with binoculars, I slowly walk into the water while sighting a piece of the breakwater that appears just above my horizon. As I descend, I watch for the moment when that piece just submerges below my apparent horizon. The measured height from the waterline to my eyes is related to the distance of the breakwater and the Earth's radius by the Pythagorean theorem, and so I can readily calculate the radius of Earth. Over several years, I have successfully engaged high-school students in conducting this experiment amid a wide variety of ocean conditions.

Poster link: https://youtu.be/MrDVMjmKHy0

Many astronomy educators have taught the famous experiment by Eratosthenes (250 BCE), whereby he estimated the circumference of Earth by comparing the angle of the Sun at noon on the Summer Solstice as observed from Syene (Aswan) vs. more northerly Alexandria in present-day Egypt. A similar experiment can be conducted nowadays by measuring the solar angle at any time simultaneously from two locales that are located at the same terrestrial longitude but are separated by a known distance of several hundred kilometers. The key to ensuring simultaneity is to preset the date and time to observe the Sun from each site or, equivalently, to communicate live between the respective observers via cellphone.

An alternative approach to reckoning the Earth's size can be done solo, without the need for another observer located hundreds of kilometers away. This approach makes use of one's local horizon and its dependence on one's height. I have made use of a nearby beach, from which a stone breakwater is visible near my local horizon. Equipped with binoculars, I slowly walk into the water while sighting a piece of the breakwater that appears just above my horizon. As I descend, I watch for the moment when that piece just submerges below my apparent horizon. By noting where the water line was on my body, I can then use a meterstick to measure the distance between the waterline and my eyes. That height is related to the distance of the breakwater and the Earth's radius by the Pythagorean theorem, and so one can readily calculate the radius of Earth.

Over several years, I have engaged high-school students in conducting this hands-on site-based experiment amid a wide variety of ocean conditions. That means having a few good pairs of binoculars available for use. I have learned that the trick to getting good results is to make sure that the student is spotting a piece of rock that is just barely above their local horizon and then tracking that piece while descending until it just barely disappears from view. If done correctly, one should be able to determine the radius of Earth to well within 10 percent of its nominal value (6387 km). You can view an example of this exercise at https://sites.google.com/site/sciencegazette/presentations

If an open sea is not available to you, a similar experiment can be conducted on flat land by making use of some object that appears near one's local horizon and is at a known distance from you. You will have to find some way to adjust and measure the height of your eyes (or camera) to make this method work.

Using Innovative Technologies to Study the Sun

Presenter: David Lockett, IAU-OAE NAEC USA Team, Space Station Explorers, Astronomy in Chile Educator Ambassador, NASA Solar System Ambassador

Our sun, a dynamic star, varies constantly. It also produces energy and solar wind that impact us on Earth. See how students can discover the ever-changing power of the sun through innovative technologies such as VR, 3D printed images, Helioviewer and NASA's Space Weather Action Center. How do you create hands-on and engaging activities to teach about the Sun? Virtual reality, 3D printing and dynamic images of the Sun will be used to teach important concepts related to our dynamic star, the Sun.

Poster link: https://astro4edu.org/siw/p43

Space. It is this wonderful, exciting thing to explore for students. Astronomy is an interesting subject to tackle in the early years. Kids love to look up at the stars at night, especially if they get to stay out past bedtime! Interactive computer exercises and hands-on activities encourage questioning, experimentation and exploration and accommodate diverse learning styles.

You can introduce astronomy concepts through a variety of hands-on demonstrations and art projects. You can teach a simple astronomy unit that covers topics like: Observation, Stars, the Sun, and our planet Earth.

You can explore the principles of astronomy through hands-on demonstrations and projects that display the concepts in action. Observe the sun through Parker Solar Probe and use Merge Cube to learn more about how NASA is studying the sun's Corona. The Sun is a yellow dwarf star at the center of our Solar System. All the planets of the Solar System orbit around the Sun. The Sun and the Solar System orbit around the center of our Galaxy, the Milky Way. The Sun is a star, the only one we can see during the daytime. When we look in the night sky, we see endless dots of light, every one of them is a star just like our Sun.

Children learn about the layers of the Sun and discover how Earth's magnetosphere acts like a giant shield to protect us from all kinds of space weather from the Sun's activity. Introduce your students to the astronomy curriculum focusing on the Sun. This poster session contains engaging inquiry-based and hands-on science activities developed specifically for learners in the primary grades.

Daytime Astronomy with CLEA Resources

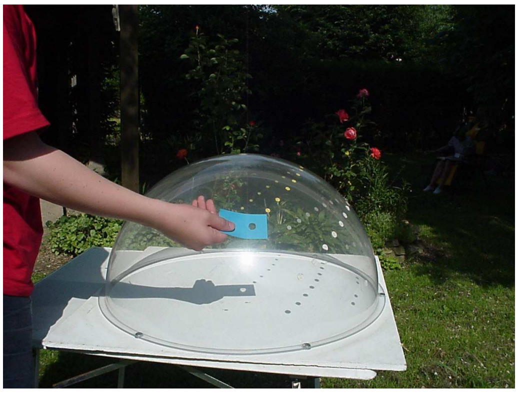
Presenter: Frédéric Pitout, Observatoire Midi-Pyrénées, Université Toulouse 3 – Paul Sabatier, Toulouse, France, Comité de Liaison Enseignants et Astronomes (CLEA)

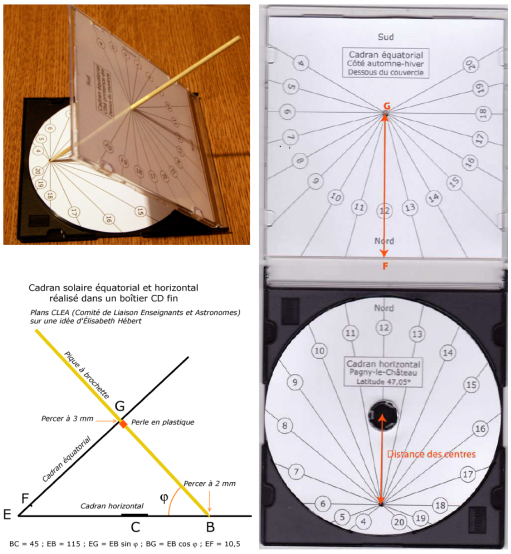
Organising a night-time observing session in schools is not always easy for various reasons: logistical issues, lack of equipment, etc. Yet, we tend to forget that observing our Sun is also a great way to study astronomy. In this poster, we shall present a few activities used by CLEA and detailed in a book, entitled The Sun, issued in 2018. Some of those activities are very easy to carry out with very little material; some require some more elaborated equipment.

Poster link: https://youtu.be/yRj0j0mlRjk

Teachers sometimes tend to forget that they may practice astronomy during the day. We present in this document two activities produced by CLEA, the Liaison Committee Teachers and Astronomers, which is a non-profit organisation that has promoted astronomy in education since 1976. The first activity is about studying the path of the Sun in the sky with a salad bowl; the second one explains how to build a sundial with a CD case.

The path of the Sun with a salad bowl: The idea here is to avoid any tricky spherical to planar projection problems and model the celestial vault with a transparent salad bowl. The virtual





observer is at the centre of the circle. Therefore, the location of the Sun on the bowl is correct when the shadow or the image of the Sun reaches the centre of the circle (see figure below). The students mark, with a marker pen or small stickers, the location of the Sun on the salad bowl during the course of the day, every 30 min or so. To obtain the two extreme trajectories, this should be done several times at various times in the year, ideally at solstice and equinox. Having done all this, the students may draw several conclusions. i) The trajectory of the Sun is longer (longer day) in Summer than in Winter; ii) all trajectories are parallel to each other (and in fact perpendicular to the rotation axis of the Earth; iii) one may determine the latitude of the place from the inclination of the trajectories.

A sundial with a CD case: Here, we use a cheap CD case as a sundial. The angle between the two parts, one being horizontal and the other perpendicular to the Earth's rotation axis, is set to equal the location's latitude. In both parts of the case, we insert the dials (available on the CLEA website) available for several latitudes. The equatorial sundial, in the inclined part of the case, consists of two dials: one for Spring-Summer when the Sun is above the celestial equator, and another one for Autumn-Winter when the Sun is below the celestial equator. A stick is inserted as a gnomon, and a small pearl blocks the CD case in the right location. When all set and the sundial are correctly oriented, the stick casts its shadow on the two dials (horizontal and equatorial) and indicate the local solar time.

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Discussion summary

During the live panels following the talks, most of the comments from the audience were positive. They indicated the participants could take away many valuable ideas of teaching astronomy with very simple and powerful tools. However, a discussion sparked over the choice of language used during the workshop. All speakers and participants agreed that even using English as a default language constitutes a significant barrier for many skilled educators worldwide and misses out on much of the expertise available globally.

We learned about Zero Shadow Day. Any location between the Tropics of Cancer and Capricorn sees the Sun at zenith twice a year, when objects do not cast a shadow at local noon. This day may serve as an opportunity to advertise astronomy in many countries.

The session host received a comment from one participant that most of the talks focused on observing the Sun. Asking about other daytime activities, e.g., with the Moon, we learned that one could relate the lunar phases to the angular separation between the Sun and the Moon.

During the discussion, we also learned about an astronomy teacher network in Chile. Their activities are listed on the webpage https://redastropp.blogspot.com, together with a selection of school exercises in Spanish.

A collection of activities, available in Italian, is connected to the highly praised "Parallel Globe" tool. Our partners from the OAE Center Italy are willing to help with translations.

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