Observing the Parallel Earth

from different locationson our planet

A project of the "International Dday of Light" and "the great experience of Science in Aaction"

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Since the International Year of Astronomy in 2009, the International Astronomical Union's working group NASE (Network for Astronomy School Education) has been contributing to the development of the astronomy teaching skills of thousands of teachers around the world. Several times, as with the "Power of the Sun" project, held in 2019, NASE has promoted projects that involve teachers around the world in a joint venture of promoting Astronomy, in schools and for the general public, using common experiments. In 2020, NASE joined teachers and schools from many countries, like Andorra, Argentina, Bulgaria, Ecuador, Finland, Germany, Greece, Indonesia, Iran, Italy, Japan, Paraguay, Philippines, Portugal, Romania, Senegal, Serbia, South Korea, Spain, Tanzania, Uganda and the United States to use the didactic material "Parallel Earth". They used the power of having the observations of the "solar path" and daylight changes around the world to provide this global knowledge to students to explore the material.

Over the years, the European Association for Astronomy Education (EAAE) and NASE have worked in tight cooperation in all NASE's projects involving European countries, and it is a privilege to have done this again. I would like to thank Rosa Maria Ros for this cooperation and for her outstanding coordination of NASE working group that continuously keeps performing work not only in Europe, but, most of all, in emerging countries where NASE is most of the time the only promoter of Astronomy teacher training. "Parallel Earth" is another success, as we can see by the number of countries involved.

"Parallel Earth" is a powerful tool to enhance students' knowledge and vision about the world. Whilst it highlights geographical differences that explain the many cultural differences from country to country, it shows us that we are only one world, with all these different situations.

Using "Parallel Earth" can improve students' engagement with Astronomy, Geography and Maths. If explored properly it makes us remember that we look out to Space and that improving our knowledge about Space has allowed us to develop technology and many things that are part of our daily life. The beginning of all knowledge must be our own planet, not only because it is the closest, but because it has many features that can develop thinking skills using Earth's relations with its star or satellite, and most of all, because it's the most beautiful of all the planets we know and we must learn how to nourish and take care of it.

Faro, October 2020
Alexandre da Costa Ferreira
President of the Executive Council of EAAE

Introduction

The “Parallel Earth” is a proposal of the NASE Program (Network for Astronomy Education) that arises as part of the “International Day of Light” and whose closing event is hosted by the international program “ Ciencia en Acción “, as the Great Experience of it.

“Ciencia en Acción” is a project for teachers from Spanish and Portuguese speaking countries that recognizes and promotes the activities carried out by teachers from all these countries who have a common language. It was planned to invite to the final of “Ciencia en Acción”, various countries participating in “Parallel Earth”. Also, it was planned to place, in different locations in the host city, Murcia, various models of the Earth and to interest passers-by and visiting students. But the situation of the pandemic, in Spain, made it impossible to develop this program and instead an online meeting was held in which many of the countries involved in this project participated.

Fig. 1: Participants in the final event of the Parallel Earth, Great Experience of Science in Action. (Photo: Rosa M Ros)

The online meeting was open to all “Ciencia en Acción” participants in the 2020 edition and in any of the pre vious ones since 2000, and via “YouTube” to all family members and those interested in following the activity live.

1. The Parallel Earth: Project within UNESCO's International Day of Light

This year 2020 the project chosen to carry out in all the participating countries is Parallel Earth. It is easy to replicate and can be done in all countries with a minimum of financial resource. In fact, if you do not have a terrestrial globe, you can do it with a ball and draw the contour of the continents on its surface. All teams of teachers and students were invited to repeat the experiment over half a year, between the equinoxes, from March 20 to September 23, 2020. It was enough to send the required data, along with the location (Latitude and Longitude). The photograph of the simple observation can be made anywhere by taking a snapshot with a mobile phone.

In general, the teachers and professors carried out the experiment with the students, in other cases the students, with the support of their teachers and local institutions, participated in a local festival to invite the inhabitants of their city to participate in the experience. The reports were then sent to NASE.

In 2019, the project was a reinterpretation the Bunsen photometer, to determine the power of the Sun using a simple incandescent light bulb, a sunflower oil stain on paper and the cheek of a volunteer. In 2018, the project replicated the detection of infrared light by the same method as that used by William Herschel in 1800.

2. The method used to carry out the Project

Observing the movement of terrestrial translation, which is the origin of the seasons, is not easy. There is a simple strategy that allows us to see the Earth from outside and with the illuminated and shaded part in the model, which correspond to each day and each hour, it is the so-called Parallel Earth. That is, a terrestrial globe illuminated in the same way as the Earth by the same focus of the Sun.

If the Sun illuminates two spheres, it produces the same shapes of light and shadow on them (figure 2). It is enough to orient the terrestrial globe correctly corresponding to the Earth and there will be the same areas with light and shadow. So we can see our planet as if we were an astronaut located further away than the International Space Station.

We will therefore use a terrestrial globe of the usual type, only we will remove it from its stand and place it, correctly oriented, on a glass, to observe the seasons in the different countries in which the experiment is carried out. From March 20 to September 23, all student teams who wish to do so are invited to send their photographic observation of the terrestrial globe and understand what season it is in.

Fig. 2: Projection of shadows on spheres of different diameter (Photo: José M. Gómez, Astronomical Observatory Prof. Alexis Troche, University of Asunción (25ºS, 57ºW), San Lorenzo, Paraguay).

3. Parallel Earth, how to install and use it

The terrestrial globe, with the usual support, does not serve as a model. The terrestrial globe must be located outside, on a glass and well oriented, with the place from which we observe at the top, to be a useful model.

We will therefore use a terrestrial globe of the usual type, only that we will remove it from its stand and place it on a glass (figure 3a). The axis of rotation of the terrestrial globe is set in the same direction that the Earth actually has (we can help ourselves with a compass that will guide us to the north-south direction).

Fig. 3a: Orienting the axis of rotation in the north-south direction in Indonesia (Photo: Ihsan Muharrik, Daarul Uluum Senior High School, (7ºS, 107ºE), Bogor, Indonesian). Fig. 3b: Positioning at the highest point using a cylindrical pen (Photo: Ivo Jokin, Municipal Center for Extracurricular Activities of Dolna Mitropolia, (43ºN, 25ºE), Baykal Village, Bulgaria).

Fig.4a: We can place a doll indicating our position and pieces of plasticine to indicate the line of the light / shadow area. (Photo Josephine Maria Windajanti, Santa Maria Catholic Senior High School (8ºS, 113ºE), Malang, Indonesia), Fig. 4b: As the hours go by, this light / shadow line will run away. You can also place some pieces of toothpicks to study their shadows, (Photo: Margarita Metaxa, Tositseio Arsakeio Ekali High School, (27ºN, 78ºE), Athens, Greece).

We also know that the position of our city must be in the upper part of the globe, since, wherever in the world we live, if we move in a straight line in any direction for many kilometres, it is clear that we will always end up descending on the surface of the globe. So our position is always the highest. Consequently, we will use a compass that indicates the north-south direction to orient the axis of the globe and we will place our city at the top. To check that it is correctly placed we can leave a pencil on the city in balance (figure 3b). If it is at the top it will not fall. If the pencil falls, the position must be corrected a little until it is stable. We can illustrate this position by placing a doll (figure 4a).

With little pieces of "plasticine" we can mark the sun / shadow line and we will see that it will slowly move across the surface of the globe as the hours go by and reach a time when it will be night (figure 4b). We can also put small pieces of toothpick as gnomons and see how the shadows are and how they move throughout the day and so visualize the effects of the rotation on the Earth.

Fig. 5a and 5b: Advancement of the shade throughout a day. The first photo was taken at 9:00 and the second photo at 12:30. In 3 and a half hours (at 15º per hour) it has moved about 50º (which can be verified without more than counting the 5 parallels, from 10º to 60º, between the first and the second photo). (Photos: Shila Rose D. Sia, Philippine Normal University, (14ºN, 120ºE), Philippines)

4. The Seasons

The most interesting thing to visualize is the translation movement, this is to see how the sun / shadow line is located throughout the year. This can be observed at the equinoxes on March 21 (figure 6a) and September 23 (figure 6c) and in the northern hemisphere in summer and in the southern hemisphere in winter (figure 6b).

Fig. 6a and 6c: The line of separation of day and night passes through both poles, that is, the first day of spring and the first day of autumn. Fig. 6b: In the northern hemisphere, the north pole is in the sunny zone, therefore it means that it is summer for this hemisphere and we are observing the phenomenon of the midnight sun. In the southern hemisphere, the south pole is in shadow and it is winter. (Photos Juan A. Prieto, Huerta de la Cruz de Algeciras School (36ºN, 6ºW), Spain).

Fig. 7a: Various globes show the northern hemisphere illuminated during the solstice of June 21 (summer) in Boston (Photo: Mirjana Bozic, Outdoor Science Education Team (42ºN, 71ºW), Boston, USA) summer. Fig. 7b: Terrestrial sphere in the southern hemisphere during the solstice of June 21 (winter) in Asunción (Photo: José M. Gómez, Prof. Alexis Troche Astronomical Observatory, University of Asunción (25ºS, 57ºW), San Lorenzo, Paraguay)

5. The Parallel Globe and research in didactics of Astronomy

"High is for everyone the direction of the sky, low is for everyone the direction of the centre of the Earth"
"From space we all bow but each one, in his way, looks straight"
"We do not notice that the Earth is round because we are so small that we do not see the curvature"
10-year-old children from Rome in Diario del cielo AS 2013-14, N: Lanciano et al, New Press Ed.

A big problem in Astronomy is to agree what we see around us and what we experience with the senses, with what we know and think.

For example, we see the Sun rise at different points on our Eastern horizon on different days of the year, travel an arc in the sky and set in the West. We say that "The Sun rises and sets", but we think that it is the Earth that, by rotating itself, causes the sunrise and sunset, and therefore day and night. What we see and say is what Ptolemy saw and said, but our structured and shared "knowledge" is closer to the world system that Copernicus elaborated. Our research tells us, however, that to be a convinced and aware Copernican we must have looked at the cosmos for a long time from our only point of view, which is Earth, and recognize that we keep talking and seeing how Ptolemy saw it.

The more we look at the relationships between the Sun and the Earth, in the same place, from our topocentric position, the more able we will be to imagine and model what happens in other points on the Earth at the same time, and also what happens

at other times of the year. Looking "here and now" allows us to broaden our gaze towards a global vision of the planet.

Getting used to looking carefully and observing the Parallel Globe exposed to the Sun several times a day during the year is very useful to grasp which elements vary and which ones remain constant as the hours and days pass. All of this can be seen on the Parallel Globe.

We all learn that when it is winter, for example in the Southern Hemisphere, the South Pole is in shadow and the North Pole is illuminated by the Sun all day. With a white sphere we can identify the two poles and see the seasons: on the white sphere we draw the great circle, called the terminator, for every hour for a whole day. The terminator separates the dark from the illuminated areas.

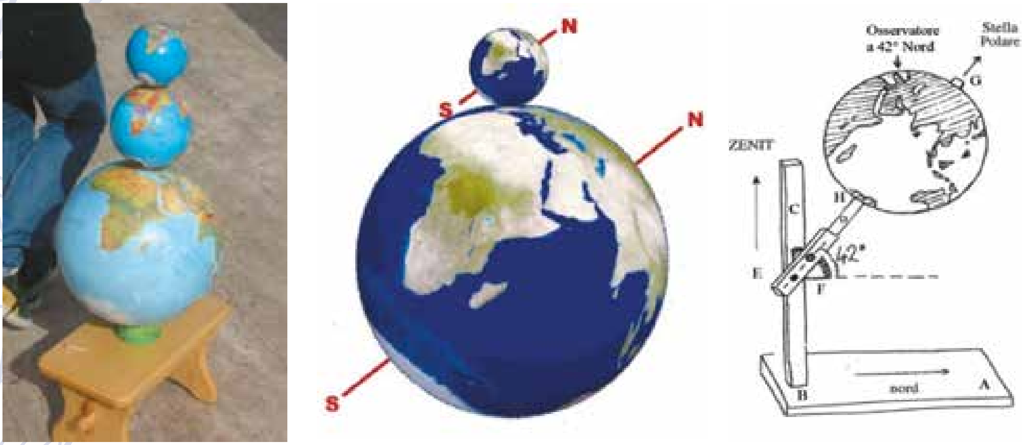

Fig. 8a, 8b and 8c: The Parallel Globe, we have named it this way because: it has the axis that passes through the poles that is parallel to the axis of the Earth that passes through the planet's geographic poles, and the plane tangent to the sphere of the Parallel Globe is parallel to the horizontal plane at the point corresponding to each country. (Photos: Nicoletta Lanciano, Università La Sapienza, (42º N, 12º E) Rome, Italy).

Fig. 9a and 9b: If we observe the shadows of the gnomons placed on the Parallel Globe and look at our shadow on the ground, we discover which are the directions on the flat terrain (those indicated by the compass) and on the Earth's sphere (with meridians and parallels drawn on the globe). This allows us to continue talking between what you see around you on the ground and what happens and you see on the sphere. (Photos: Nicoletta Lanciano, Università La Sapienza, (42º N, 12º E) Rome, Italy).

Fig. 10a: White spheres to the Sun. On the days of the solstice in June, North hemisphere Rome latitude 42 ° N, the blue point indicates the North Celestial Pole, Fig. 10b: The day of the equinox Esquel 43 ° S. The blue point indicates the South Celestial Pole, Fig. 10c: The day of the equinox in Rome. The blue point indicates the North Celestial Pole (Photos 10a and 10c: Nicoletta Lanciano, Università La Sapienza, (42º N, 12º E) Rome, Italy), (Photo 10b: Néstor Camino, Plaza del Cielo CONICET Complex, National University of the Patagonia S. Juan Bosco, (43ºS, 71ºW), Esquel, Argentina)

Fig. 11a and 11b: Logo and website page in many languages of the Globolocal International Project www.globolocal.net (Photos: Nicoletta Lanciano, Universita' La Sapienza, (42º N, 12º E) Rome, Italy)

The difference between studying this in a book and repeating a phrase from memory and instead, "seeing" on the Parallel Globe that this really happens, is much stronger from the point of view of emotion, astonishment and evidence and it therefore remains in the memory. It is even more impressed in the memory because you have seen it with your own eyes, even without being able to physically approach the Pole! In this way we learn to be more aware of the phrases we repeat and to check their meaning.

However, we must be patient to wait for the Sun to rise and there to be no clouds!

The Parallel Globe lets us travel to all the countries of the world! If we are in the North we can see what happens in Ecuador or in the South. If it is day we can see where it is night. If it is summer we can see where it is winter! For this it is an instrument and not just a model of the Earth.

But above all, the Parallel Globe returns to each and everyone their position on top of the world: that is why it is a democratic tool!

6. Summary of activities with Parallel Earth according to the age of the students

The Parallel Earth allows many didactic approaches at different levels, as reflected in this summary by its author Juan A. Prieto, collaborator of Ciencia en Acción and participant in NASE projects within the Great Experience. As a primary and secondary teacher, he has carried out the activities that he mentions and that he presented online.

Observations throughout the year

1) The reason that there are seasons on the planet is the translation of the Earth. When it is winter in the northern hemisphere, it is summer in the southern hemisphere and vice versa. #, #

2) In terms of daylight hours: #, #

a. In summer there are more hours of light than darkness (in the hemisphere considered). Also at the polar cap for a while there is no night.

b. On the other hand, in winter there are fewer hours of light than hours of darkness, just as the pole is almost always in darkness (in the hemisphere considered).

c. In spring and autumn the duration of the hours of light and darkness are very similar, coinciding with the equinoxes.

Immediate observations

a) Regarding the terminator:

1) Observe that some land areas are without light, while others have it. #

2) Observe the direction in which the illuminated area of the Earth advances and thus determine the direction of rotation of the Earth. #, #

3) Determine that while the place of observation is in daylight, there are places where the Sun sets to the West and others where it rises to the East. #, #
4) Determine the approximate time that the Sun will set in your location on the day of observation and the time that it will dawn the next day. #, #
5) When it is winter in the northern hemisphere, the North pole does not receive solar radiation, while in summer it receives radiation throughout the day (the opposite in the southern hemisphere). #, #
6) On the first day of spring and the first day of autumn the terminator passes right along the axis of the Earth, so that while in exactly half of the planet it is day, in the other half it is night. #, #
7) If the meridians are observed, it can be deduced that the terminator advances 15º every hour, in this way it is possible to know what time it is at any point on the planet.#, #

B) Regarding the projection of the shadow of a gnomon.

1) Locate the point where the Sun appears to be directly overhead, the Sun is at the zenith. #, #, #
2) If small gnomons are placed on the surface of the Parallel Earth, the evolution of the shadows is observed in different parts of the planet and at different times. #, #
3) If gnomons are placed along the same meridian, it is observed: #, #
  a) That in all places on the same meridian it is the same time.
  b) That the shadows they produce all go in the same direction depending on the hemisphere, but the direction varies according to the latitude of the place.
  c) That the shadows go West in the morning, North at noon (or South, depending on the hemisphere) and East in the afternoon.
  d) That the shadows, at noon, indicate the meridian line.
  e) That at dawn and dusk, the shadows are very long and are shorter than at noon.
  f) That closer to the equator the shadows are shorter, and the further towards the poles, they are longer.

We can conclude that in places on the same meridian it is always the same time; that the closer to the poles, the Sun's rays fall more obliquely and this is the reason why the climate is colder at the poles than at the equator.

4) If gnomons are placed along the same parallel, it is observed that throughout the day, the shadows go from West to East, passing through the North (through the South in the opposite hemisphere), and can be calculated from the approximate time of the place of observation. #, #

Students < 12 years old, # Students between 12 and 18 years old, # Students > 18 years old

7. Other lesser known utilities of Parallel Earth

Measurement of the Earth's radius according to Eratosthenes

The experiment of Eratosthenes to determine the size of the Earth is well known and collaborative projects are organized from different locations. But these projects usually have a serious drawback, which can be solved using the Parallel Earth.

Many times it has been cloudy at the planned observation time, with the consequent frustration of our students. The bad weather in the North of Spain gave rise to this idea: Couldn't we do the measurement ourselves without external help? Eratosthenes did it by himself. He knew the datum of a place where the Sun was at its zenith at a precise moment. Using the parallel globe we can obtain this data.

We will not necessarily do it at noon or measure the length of a meridian, but rather that of the great circle that passes through our town and the place where the Sun is at its zenith at the time chosen for our activity. There is always a single great circle that passes through two specific points on the Earth's sphere and its length will be the same as that of a meridian.

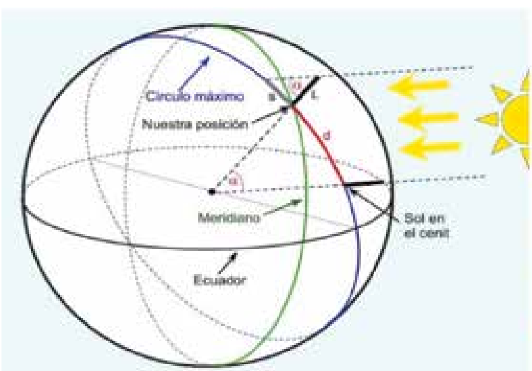

Fig. 12a: There is a single great circle that passes through our position and the point with the Sun at the zenith, and its length is the same as that of a meridian, Fig 12b: When the gnomons are ready, students from IES Bertendona de Bilbao precisely places the globes. (Photos: Esteban, Durango Astronomy Classroom, (43º N, 3º W) Spain)

At any time that the sun rises, we determine the place that the Sun is at the zenith at that instant, we measure the shadow S of a gnomon of length L, where we are, and we calculate the angle , which is obtained as = arctan (S / L), or else drawing a similar triangle and measuring it with a protractor.

By proportion, the ratio of angle   to the full angle of 360º is the same is the ratio of the distance d between the two places (which can be obtained with the Google maps that will give us an exact value), to the length of the great circle, that is 2 R (where R is the radius of the Earth):

$$/360^\circ = d/2\ R.$$

Solving for R, we obtain the radius of the Earth:

$$R = 360^\circ\ d/2$$

It is important to be very precise both in placing the globe and in determining the point with the Sun at its zenith, to avoid any error. To make sure that our location is exactly at the top of the globe, we can place a flat head screw on our location and rotate the globe until the screw is visually aligned with vertical items such as street-lights or walls.

The North-South direction can be obtained by orienting a portable sundial, which if used properly is more accurate than a compass because it is not affected by magnetic declination. The determination of the point with the Sun at its zenith must be done with a gnomon completely perpendicular to the surface, and it is usually not easy. It can be done by taking another screw and sliding its head across the surface of the globe until there is no shadow: We insert it into a strip of cardboard whose ends we grasp and move in the opposite direction to its shadow until the shadow disappears.

Fig. 13: Determination of the point with the Sun at the zenith, (Photos: Esteban Esteban, Durango Astronomy Classroom, (43º N, 3º W) Spain)

In doing so, the final maximum error does not usually exceed 4% and this method has several advantages because it can be programmed every year. The observations can be done at any sunny time during class time and individually or with pairs of students so that everyone will participate actively, allowing easy detection of possible errors.

Visualization of the shadows of distant buildings or monuments

It is very interesting and motivating to work with scale models to appreciate building shadows in real time. View from home the shadow of your house and see how far it reaches your patio and play a game avoiding the Sun on a sunny day, or observe the shadows of famous buildings. The shadow of the Eiffel Tower: Is it crossing the River Seine right now? Does the shadow of the Statue of Liberty leave the small island where it is erected?

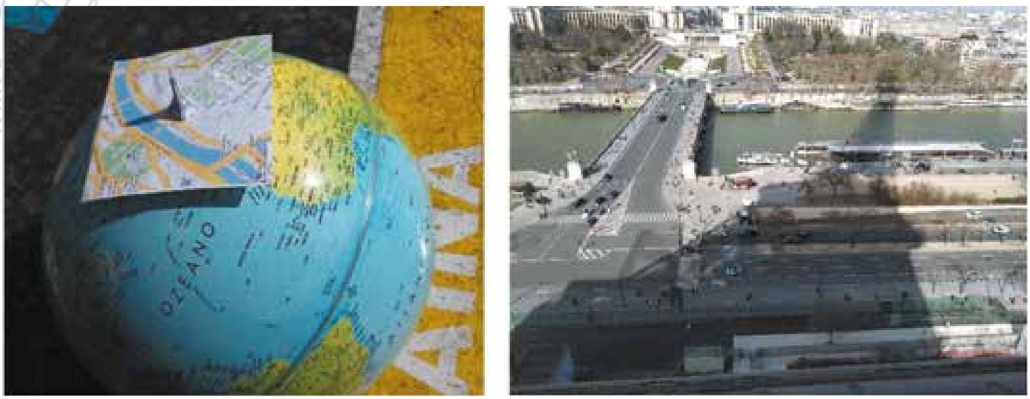

Fig. 14a and 14b: In 2017 the experiment was carried out in the ikastola Alkartu in Barakaldo, at the same moment that a relative of a teacher was in Paris, he sent us the real image and we saw that it coincided with the Parallel Earth model. (Photos: Esteban, Durango Astronomy Classroom, (43º N, 3º W) Spain)

The curvature of the Earth would prevent us from placing our models with the appropriate inclination, but we solve this with the Parallel Earth: For the example of the Eiffel tower, we print a small plan of the area of Paris where it is located and at the same scale we model the tower with plasticine. We place the globe parallel and on it, in Paris, we place the model keeping the North direction and if it is sunny, we will see what its shadow is like at that moment.

If we leave everything in place and observe it at various times of the day we will see the changes, we will obtain interesting results related to the evolution of the length and direction of the shadows but with greater motivation provided by curiosity.

8. Parallel Earth and sundials

Observing the Parallel Earth throughout the day, we can see that the line that separates day from night (the terminator) moves from East to West or from West to East. Thus, while in the places that are further to the East it is getting dark, it dawns in the places located further to the West. We also see that this line moves 15º every hour. Thus we can understand that the time zones are each of the 24 spherical sectors into which the Earth is divided, as a result of distributing the 360º of the sphere between the 24 hours that it takes in making a complete turn on its axis.

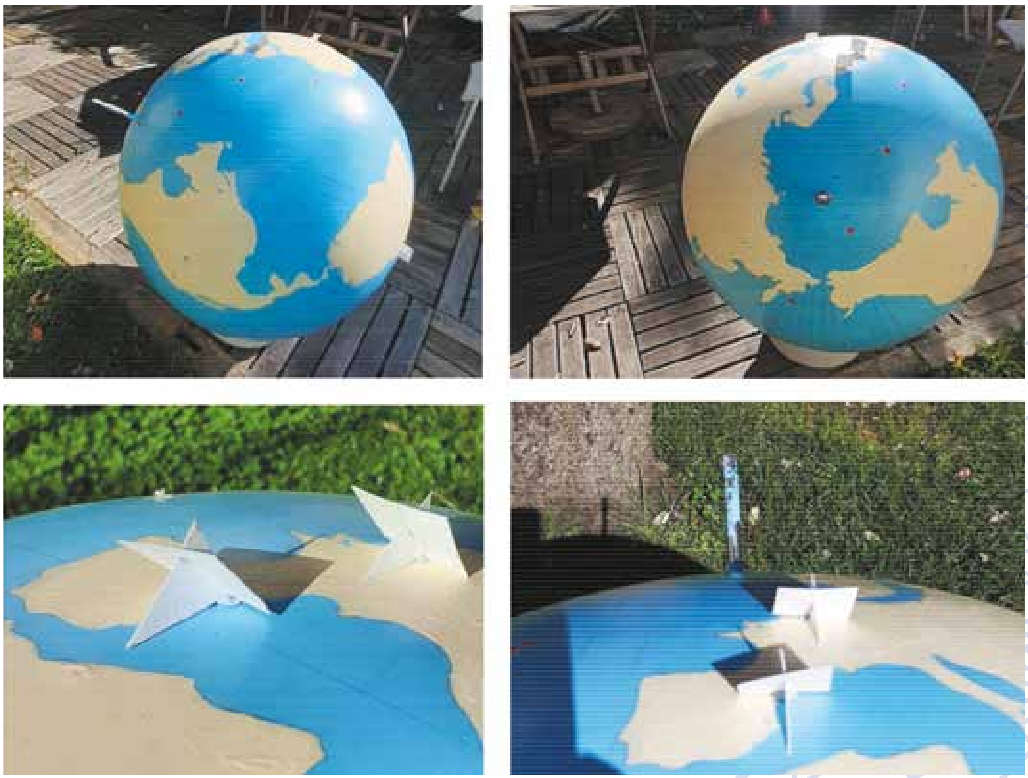

Fig. 15a and 15 b: Equatorial sundial, with the plane of the clock according to the equator and the gnomon according to the Earth's axis of rotation. The angle of inclination of the gnomon corresponds to the latitude of the place where the sundial is installed. Fig. 15c and 15d: Different equatorial clocks on the Parallel Earth. (Photos: Carme Alemany, CEIP El Roure Gros, Santa Eulalia de Riuprimer, (42º N, 2º E), Spain)

To know the time somewhere in the world, the Greenwich meridian or meridian zero is taken as a reference. From there we add one hour for each time zone that is towards the East and we subtract one hour for each time that is towards the West.

It is very interesting to build an equatorial sundial and place it next to the sphere of the Parallel Earth to understand that the two planes that compose it correspond to the axis and to the Earth's equator (figure 15). The hour marker functions as the Earth's equator and the gnomon as the axis of rotation. Thus, the angle of inclination of the gnomon corresponds to the latitude of the place of observation.

Fig. 16a and 16b: Placing images of landscapes, types of houses, and images of animals on the ground, it is possible to understand the influence of the climate on the inhabitants of the area.

By comparing the time that the sundial marks with that which we can deduce from the Parallel Earth we can understand its operation.

If we build a small equatorial sundial and place it on the globe, at the place where we are observing, we will see how the two clocks mark the same solar time.

If we build small sundials, with the inclination of the plane of the hour marker corresponding to the latitude of the place where we want to place it, we will be able to know what solar time is at that place. Thus we can conceive the model of the Parallel Earth, conveniently located, as a sundial, and at the same time understand the operation of the equatorial sundial.

Observing the Parallel Earth with children, apart from the astronomical study itself, we can relate learning from various areas of knowledge (geography, social sciences, mathematics, knowledge of the natural environment and economics), which are often studied erroneously when disconnected from reality.

- We can bring them closer to the idea of living in a global world, in which all living beings that inhabit it are interrelated and depend on each other and we all depend on our planet together. We can understand the idea of the physical border as a result of our human organization and reflect on its effects, such as migrations.
- It can be a starting point to try to know the life of boys and girls who live in different areas of the Earth, to see how their activities, their games and their customs are closely related to the environment in which they live, as much as to the wealth of their countries.
- From images of landscapes of areas of the Earth from the air, it is possible to have a discussion about the reality that they show us and introduce concepts about landscape, climate, work, economy, ways of life and protection of the environment.
- Placing small cut-outs of animals on the surface of the Earth, in the place of their natural habitat, we can understand their morphology, their diet and their relationships. Likewise, we can do it with images of crops and relate them to the climate and diet of the inhabitants of the area.

In short, the model of the Parallel Earth can be a globalizing element of learning and stimulating dialogue and reflection - so necessary in school.

9. The Parallel Earth for the blind

The construction material of the Parallel Earth is decisive in certain aspects.

For example, a fiberglass Parallel Earth like the one shown in figures 17a, 17b and 17c, allows people with visual difficulties, simply by passing their hand over the surface, to perceive the difference in temperature caused by the incidence of solar rays on different areas of the Earth. The areas that remain in shade are cooler than areas that receive sunlight. In particular, the area where the Sun hits perpendicularly is hotter than other areas where the incidence of solar rays is more oblique and that when passing the hand they feel less hot.

Fig. 17 a, 17b and 17c: When passing your hand over the surface, you can feel the difference in the temperature caused by the incidence of the Sun.

Fig. 18a: As a sphere could not be obtained, an inflatable balloon where the pole, the equator and the Greenwich meridian were drawn (Photo: Aboulaye Ba, Cheikh Anta Diop University (15ºN, 17ºW), Dakar, Senegal), Fig. 18b, With the contours of the continents drawn on an onion (Photo: Alejandra Pachamé, ISFD35, Las Lomas de Zamora (34ºS, 58ºW), Argentina), Fig. 18c, With a poriexpan sphere with the terminator lines are drawn on. (Photo: Viviana Sebben, EETP 471, Rosario (33ºS, 61ºW), Argentina).

The continents painted on the model have a different roughness than that of the oceans, which makes it possible to distinguish between oceans and continents.

10. The Parallel Earth in different parts of the world

And in conclusion, some original examples to arrange the Parallel Earth. In some countries it is difficult to find a terrestrial globe and it is also very expensive. In other cases, the confinement due to COVID-19 or the specific situation of the city in the country, made it difficult to find a globe.

When it is not easy to get a terrestrial sphere, anything goes, from an inflatable balloon, to an onion, to a polystyrene sphere (figures 18a, 18b and 18c).

Teams around the world have conducted this experiment and emailed their photos during the half year the project was active. The experiment was carried out by groups of all ages and with different cultures. Several examples can be seen at http://sac.csic.es/astrosecundaria/es/proyectos_con_unesco/la_tierra_paralela/ListaDocs.php or at http://www.naseprogram.org

Fig. 19: Primary students from Ágora International School, Andorra. Their teacher had prepared Parallel Earth for another group of high school students, but they went to ask what it was for and how it was used. So it was they who did the activity, they made a mistake the first time, they did it again and it turned out well. The error helped them understand and then they sent their photos to the international program. (Photo: Carlos Moreno, Ágora International School Andorra, La Massana, (43ºN, 2ºE), Andorra)

On other occasions the images that came to us from Parallel Earth give us their cultural context, as is the case in Japan.

Or for example, in 2011, in Serbia, a large blue globe was built in the city of Sabac, which has become the symbol of the city.

In the online connection from Romania we had a live connection with classroom, full of students during their physics class.

Fig. 20: From the Shitennoji Temple High School in Osaka. (Photo: Akihito Tomita, Wakayama University, (34ºN, 135ºE), Japan)

Fig. 21: Primary school students with their teacher with Parallel Earth in Šabac, (Photo: Goran Stójievi, Center for Professional Development, (45ºN, 20ºE), Sabac, Serbia).

Fig. 22: On the day of the solstice, the angle between the terminator and the meridian is equal to the angle between the axis of rotation of the Earth and the normal to the ecliptic (23.5 degrees). This is clearly seen in the image. (Photo: Goran Stojićević, Center for Professional Development,

FFig. 23a and 23b: Paula Chis connected live from the classroom in Cluj-Napoca Romania. She with her students prepared a Parallel Earth with a ball, but it is equally useful when there is no other available. (Photos, Paula Chis, Colegiul National George Baritiu, Cluj-Napoca (46ºN, 24ºE), Romania)

In the case of South Korea, a high school, Incheon Yesong Middle School, carried out the project with a group of students and it was presented, in the live connection, by an English-speaking student from the group.

Fig. 24a: Soo Young Cho high school student from Incheon presenting her work with her classmates and Professor Mikyong Kim in Incheon, South Korea (37ºN, 121ºE) (Photo Rosa M. Ros). Fig. 24b: The group of students preparing the Parallel Earth. (Photo Mikyong Kim, Incheon Middle School (37ºN, 121ºE), South Korea)

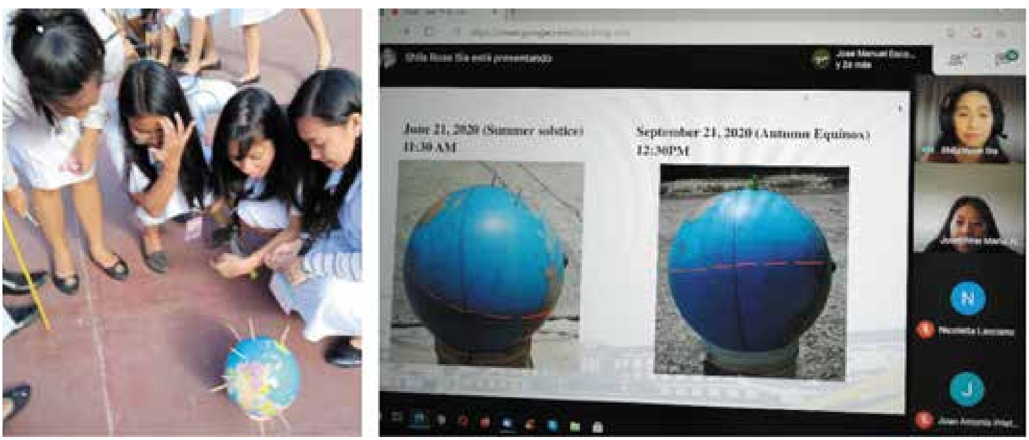

Fig. 25a: Observing in Caloocan City (Photo: Shila Rose D. Sia, Philippine Normal University, Caloocan City (14ºN, 120ºE), Philippine), Fig. 25b: Online connection with the presentation of Shila Rose Sia. (Photo: Rosa M. Ros)

The online presentation from the Philippines was very comprehensive in the sense of comparing their own observations from different times and periods of the year. Analysing the rotational and translational movements with a good number of observations with students of different educational levels.

In the Otto Trust presentation for Uganda the teacher commented on several questions his students asked him when using Parallel Earth, in particular one of which is essential in terms of misunderstood concepts. The question is “If the Earth is spherical, why don’t the people of South Africa fall off?” Without a doubt this is a key question and the Parallel Earth can lead us to understand that the concept of above and below is relative. Where the observers are always up, how are they going to fall?

“Gravity is a force that draws everything that has mass towards the centre of the Earth. Therefore, people in South Africa are being pulled towards the centre of the Earth and cannot fall.”

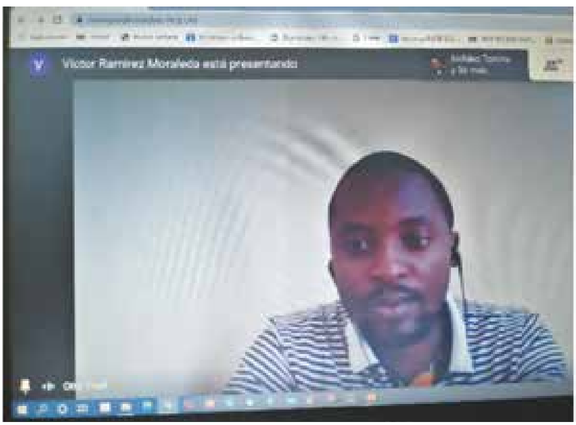

Fig. 26th: Otto Trust, during his online presentation. (Photo Rosa M. Ros). Fig. 26b: Parallel Earth in Kampala, Uganda, (Photo Otto Trust, Mbarara University of Science and Technology, Kampala (0ºN, 33ºE), Uganda).

11. National experiences linked to the Parallel Earth Project

Portugal

In Portugal, the experiment was carried out in several primary schools simultaneously. The organizer Alex Costa told us: “During the time of the project,we also held

Astronomy story-reading sessions for children from the Ferradeira, Areal Gordo and Penha Primary Schools, from the same School Group. Many stories and tales of Astronomy were read. Under the same scope, the book "Parallel Earth" (reference in the bibliography) was explored with the elementary teachers from these schools who then explored the activities with their students. Observations with the Parallel Earth were carried out in all schools throughout the year and, depending on the COVID-19 situation, whenever it was possible".

"In the João de Deus School Group, observations were made with secondary school students, in January, March, May, June and September 2020 using a globe with gnomons in various latitudes and placing the city of Faro on top of the world (the May and June observation involved only a few students due to COVID-19)".

"The students were able to see the difference at various latitudes each day and observe that as time passed during the day of the equinox, the North and South poles were half on the dark side and half on the light side. They also observed that at noon (solar) the Sun was over the Equator. The students were surprised to see that in June, as the day progressed across the North Pole, it was always light and at the South Pole it was always dark. This is quite strange because they knew (by heart) that at the poles there are six months of daylight and six months without Sun, but clearly they had not appropriated the concept. They also seemed surprised (all but one) that even at the summer solstice the Sun never passed the zenith, although many of them knew that the Tropic of Cancer was where the Sun travelled farthest North. This clearly shows that students sometimes memorize things without knowing what they really mean".

"On the March equinox the high school students also performed the Eratosthenes Experiment with a gnomon and using Google Earth as a slave to give us the distance to the Equator (the place where the Sun was at the zenith). Faro's latitude is 37 ° 01'09" N (37.019122º in decimal notation) and the students used a gnomon with a height of $L = 92.80 \pm 0.05$ cm and the shadow was $S = 68.95 \pm 0.05$ cm, which means an angle at the top of $a = 36.9686°$,

$$a = \arctan (S/L)$$

which is the experimental result for the latitude difference with respect to Ecuador".

"Since Google Earth gives us a distance (on our meridian) to the equator of 4116.14 km, the calculation of the circumference of the Earth is 40,083 km, which has an error of 0.2% of the theoretical polar circumference of 40008 km".

Fig. 27a: The Parallel Earth with a collection of gnomons that were observed as they evolved periodically. Fig. 27b: Explaining stories for children with some enigmas to decipher, it is necessary to know astronomy and have some knowledge of the constellations. (Photos: Alexandre da Costa, João de Deus School Group, (37ºN, 8ºE), Faro, Portugal).

Iran

Some teams prepared special projects, such as the activities carried out by the Iranian association ITAU (Iranian Teacher Astronomical Union), which after organizing various activities between the two equinoxes brought together a dozen children and students on the day of the June solstice in front of the Malek Building south of Bushehr.

They were from 8 in the morning until 12 noon observing the movement of the Sun throughout that time. They began with observing the direction and size of their own shadow and then continued observing the Parallel Earth (figures 28a, 28b, 28c and 28d). This was a very serious activity for students of such a young age (4-9 years old) who discovered things they had never observed before.

Fig. 28a, 28b, 28c and 28d: Students in Iran, doing a shadow study throughout the day. In turn they compared with the shadows on the Parallel Earth, (Photos Mahdi Rokni, Iranian Teachers Astronomical Union, (29ºN, 51ºE), Bushehr, Iran).

"The children compare their shadow with the shadow of the Parallel Earth, then they look for the shorter shadow of the Earth. There is a place on the Parallel Earth where there is no shadow at that time. At noon, the children returned to it and now they look at their shadows, very surprised. It is very hot, but ... the children look for a place without shadows on the Parallel Earth. The previous point now has a shadow, and there is another on the Parallel Earth without a shadow ...".

Fig. 29a and 29b: In Iran, children observing the Parallel Earth. In the drawing on the right, it can be seen perfectly that the shadow that began in front of the student was very long (at 8:15) and ended behind them and short (at 12:15), so there was almost a passage through the zenith on the 21st June (the latitude of the place, Bushehr with latitude 28.9º, is close to the tropics. (Photos Mahdi Rokni, Iranian Teachers Astronomical Union, (29ºN, 51ºE), Bushehr, Iran).

Fig. 30a and 30b: The teachers preparing the Parallel Earth with the Sun near the zenith in Iran and with the Persian Gulf in the background. In the drawing on the right, four children leave front and long shadows at 8:00 AM and the short ones next to it at 12:00 PM, (Photos Mahdi Rokni, Iranian Teachers Astronomical Union, (29ºN, 51ºE), Bushehr, Iran).

Indonesia

Some countries organized serious observation campaigns with groups of amateurs, educational centres and other institutions. For example, Indonesia held their observations especially at the September equinox. Among others, both ITERA, Institut Teknologi Sumtera, State University in Lampung and the KS ANDROMEDA Association in Yogyakarta encouraged their members (who worked in collaboration, comparing the results among themselves) to participate with terrestrial spheres, inflatable balloons and even sports balls.

The results of the observations made in a few days and in different islands and places in Indonesia can be found on the NASE website, but here we will highlight the interest of a work carried out in the same country that extends over an area of lengths between 95ºE and 140ºE, that is to say 3 hours of time difference.

Fig. 31a: With chopsticks at both ends of the country. (Photo: Aditya Abdilah Yusuf, ITERA, Lampung (5ºS, 105ºE) Indonesia), Fig. 31b: Preparing the Parallel Earth. (Photo Iswanto Adi Setya Utomo, Jogja Astro Club, Yogyakarta (8ºS, 110ºE) Indonesia, Fig. 31c: With plasticine pointing to the terminator as the hour advances. (Photo: Yudhiakto Pramudya, KS ANDROMEDA, Bantul, (3ºS, 111ºE) Indonesia), Fig. 31 d: Noting the position on the different meridians of the country. (Photo: Agung Laksana, Senior High School Muhammadiyah 1, (7ºS, 110ºE), Yogyakarta, Indonesia).

12. The Parallel Earth to explain specific concepts

Midnight Sun

But one of the most spectacular images came to us from the Arctic Circle. As its author Sakari Ekko told us: "In the polar region, north of the Arctic Circle, there is a time around summer when the Sun does not set at all. It's called the hour of the midnight sun. It is easy to demonstrate using the Parallel Earth method".

Fig. 32: A single photo does not indicate that it was taken at midnight, but a series of photos visualizes the path of the Sun in the northern sky. (Photo: Sakari Ekko, European Association for Astronomy Education, Hetta, 2º north of the Arctic Circle (68ºN, 24ºE), Finland).

"My summer home is in Finnish Lapland, about 2º North of the Arctic Circle, near a small town called Hetta. On the summer solstice, the Sun is more than 2º above the horizon at midnight. The sun doesn't set at all on Hetta for almost two months. "

"What about winter? Well, it is not possible to use the Parallel Earth method in the middle of winter in Hetta because the Sun does not rise at all for more than a month. However, the darkness is not total "

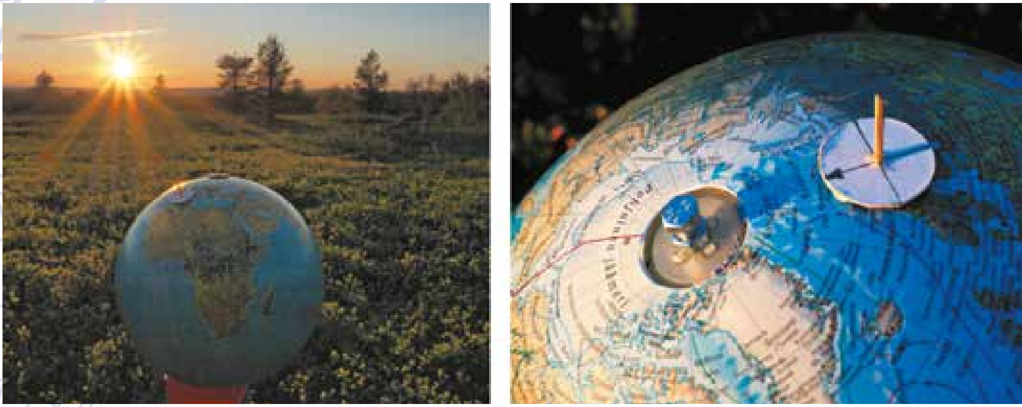

Fig. 33: Midnight sun in Hetta. 2º north of the Arctic Circle, (Photo: Sakari Ekko, European Association for Astronomy Education, (68ºN, 24ºE), Hetta, Finland).

Fig. 34a: At noon, on the winter solstice, the light has a wonderful blue colour that reflects off the snow. Hetta's "blue hour" lasts several hours! Photo 34b: Winter simulation in Hetta (yellow arrow). (Photo: Sakari Ekko, European Association for Astronomy Education. (68ºN, 24ºE), Hetta, Finland).

"It is possible to show the polar night with the Parallel Earth method. Using the globe at your latitude on the winter solstice, you will find that the region north of the Arctic Circle is in shadow. This is perhaps the most instructive property of the Parallel Earth method: it can see the altitude and azimuth of the Sun throughout the illuminated hemisphere."

Photo 35: In winter, only auroras and moonlight usually illuminate the landscape. (Photo: Sakari Ekko, European Association for Astronomy Education. (68ºN, 24ºE), Hetta, Finland).

Explain the stations in the equatorial zone

Another vision to consider a special area of the planet came to us from Tanzania, a country in the equatorial zone. As its author Noorali Jiwaji told us: "We do not experience the four seasons that are taught in books. We really only have three seasons: hot, rainy, cold, or even just two: hot and cold. So learning from books is simply reading without understanding. But Parallel Earth shows why it is hot all year round in the tropics and the importance of the tilt of the Earth's axis is understood."

In order to understand the phenomenon, comparisons can be made as follows: "Long shadows at high latitudes can be compared with the long shadows, in our latitudes, in the cooler mornings and afternoons."

Fig. 36: La Tierra Paralela ayuda a explicar por qué no hay estaciones durante todo el año en los trópicos (Foto: Noorali Jiwaji, Open University of Tanzania, (7ºS, 39ºE), Dar es Salaam, Tanzania)

Fig. 36: The Parallel Earth helps explain why there are no seasons throughout the year in the tropics. (Photo: Noorali Jiwaji, Open University of Tanzania, (7ºS, 39ºE), Dar es Salaam, Tanzania)

Fig. 37a and 37b: Lng shadows from different latitudes can be compared to understand the difference in temperatures. (Photo: Noorali Jiwaji, Open University of Tanzania, (7ºS, 39ºE), Dar es Salaam, Tanzania).

9. Results and conclusions

A total of 90 projects were sent by fifty teachers from countries on four continents (Africa, America, Asia and Europe). They show how they had the opportunity to directly observe the movement of the Sun over half a year and share the information obtained from colleagues from other educational centres and even with other colleagues from different countries. A total of 22 countries have been involved: Andorra, Argentina, Bulgaria, Ecuador, Finland, Germany, Greece, Indonesia, Iran, Italy, Japan, Paraguay, the Philippines, Portugal, Romania, Senegal, Serbia, South Korea, Spain, Tanzania, Uganda and the United States.

There were eighteen countries that participated in the closing session of this project, included as a Great Experience, with an international profile, within the Science in Action festival in 2020. The Connection took place live, with the Google Meet platform of the Technical University of Catalonia and with live broadcast thanks to the YouTube channel of Science in Action. Several teams of teachers and students participated in a live connection for 3 hours showing their results and sharing their experience on YouTube with other people, motivating them towards science in general and astronomy in particular. The broadcast remains recorded on the Science in Action channel and after a few months it still receives downloads from interested students and teachers.

The success was considerable:

- The CEA program plans a new "great experience" related to an observational activity in the field of astronomy that can be easily organized in many countries without having to have a large infrastructure and that is easy to take to the general public as a live and direct science experiment.
- The NASE Working Group plans to repeat a new global project by 2020 involving countries on different continents and repeat a final event probably in more than one country to facilitate face-to-face or online meetings between multiple teams.

Finally we want to thank several international institutions that provide support to the "Parallel Earth Project" promoting it in their countries and areas of influence:

CONICET, National Council for Scientific and Technical Research, Argentina.
CSIC, National Research Council, Spain.
EAAE, European Association for Astronomy Education.

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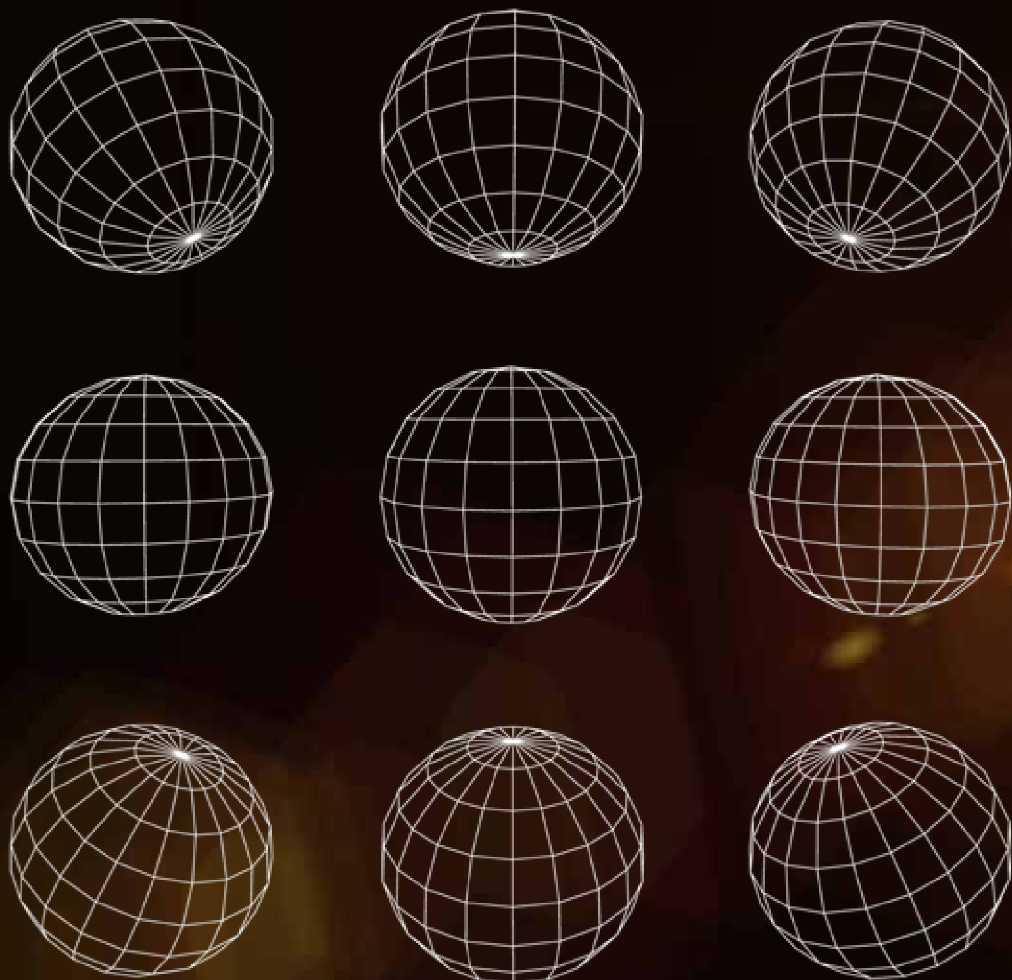

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Ciencia en Acción

IAU
100 Years: Under One Sky

UNESCO
United Nations Educational, Scientific and Cultural Organization

International Day of Light 16 May