STEM-MED: a co-design project in the Mediterranean

ENGLISH

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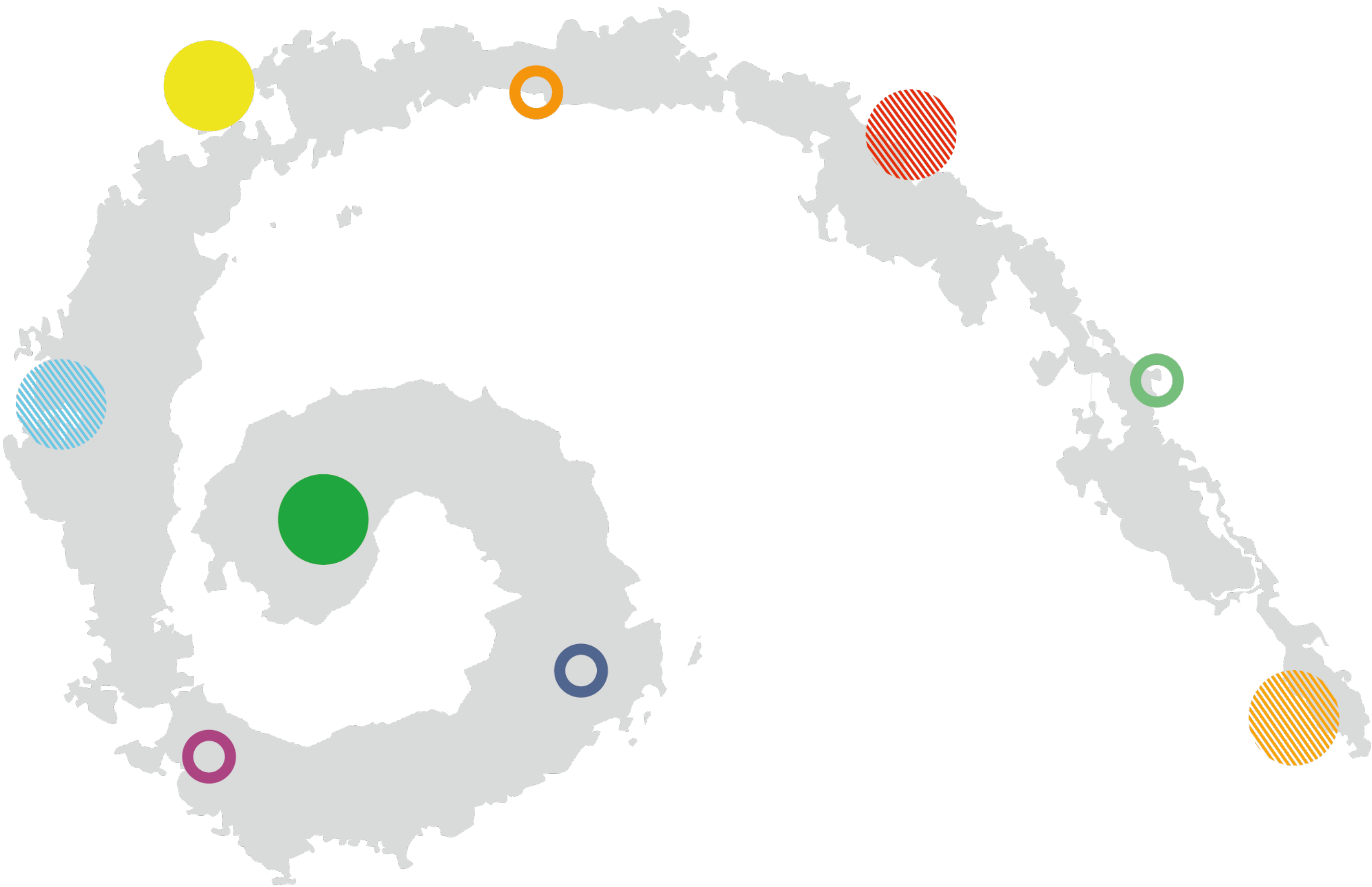

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Figure 1: Lampedusa 2022 - OAE Center Italy team

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The Italy Office of Astronomy for Education (I-OAE) is the first IAU OAE Center to provide long-term support to the goals of the IAU OAE. The Astronomical Observatory of Rome (OAR), managed by the National Institute for Astrophysics (INAF), hosts its Headquarters.

The OAE's mission is to support and coordinate astronomy education by astronomy researchers and educators, aimed at schools worldwide. To this aim, the I-OAE specialize to emphasize child-centered learning methodologies for children in primary schools (5-12 years, U12) worldwide. In the Mediterranean region, I-OAE helps to support and organize IAU OAE activities building a community of practice around Astronomy Education. I-OAE also provides an experience-based consultancy for the optimization (implementation and dissemination) of non-English based versions of the open access platform astroEDU.

The I-OAE collaborates with a growing network of OAE Centers and OAE Nodes to lead global projects developed within the network. The other OAE Centers and Nodes are: the OAE Center China–Nanjing, hosted by the Beijing Planetarium (BJP); the OAE Center Cyprus, hosted by Cyprus Space Exploration Organization (CSEO); the OAE Center Egypt, hosted by the National Research Institute of Astronomy and Geophysics (NRIAG); the OAE Center India, hosted by the Inter-University Centre for Astronomy and Astrophysics (IUCAA); the OAE Node Republic of Korea, hosted by the Korean Astronomical Society (KAS); OAE Node France at CY Cergy Paris University hosted by CY Cergy Paris University; and the OAE Node Nepal, hosted by the Nepal Astronomical Society (NASO).

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OAE Center Italy

Preface

This collection of classroom activities aimed at primary school children is one of the outcomes of two international projects promoted by the Office of Astronomy for Education Center Italy (I-OAE), i.e., the MIRTO (Mediterranean Informal Round Table Online) and STEAM-Med project.

MIRTO and STEAM-Med were developed to support learning in the primary schools of Mediterranean countries. All of them, regardless of borders, conflicts, or wars.

Two key principles inspire our actions: equal collaboration on the participants' part and the development of activities focused on the children of each community involved.

The final objective is the creation of a dozen activities that primary school teachers and educators may combine in learning paths.

But who devised the activities? And how can the resources be tailored to suit each country? Is it realistic to think that a task planned in Spain or Croatia can be implemented as it is in Egypt, Syria, or Iran? What tailoring may be necessary?

The protagonists of this long journey that began in September 2021 are the National Coordinators of Astronomy for Education (NAEC), i.e., astronomers, educators, and teachers certified by IAU. They play the vital role of intermediaries between the Office of Astronomy for Education and the teaching community.

A miny website narrates the story of this process, illustrating the steps that have led us up to the present day, like in a photo album:

- The first online contact between countries that are physically close but distant simultaneously.
- The light, a distinguishing feature of astronomy, was collectively chosen as a theme to connect all the activities.
- The choice of the specific resources to be carried out jointly.
- The three discussion rounds, first in pairs and then in a general debate, to integrate the different perspectives and enrich the work with alternative teaching suggestions.
- The final step, the workshop in Lampedusa, a place that symbolizes Mediterranean dialogue, during which a joint meeting was carried out face-to-face consolidating and planning.

- The discovery of English as a lingua franca – spoken by everyone but not as native speakers: a common language, but an imperfect one.

- The images, the videos, the photos and the bonds among the participants created by that experience, thanks to their shared willingness to build a better future.

All the activities are available in all the languages of participating countries: a collection in each language.

Each activity is built in blocks so that the teachers of each country can use it and adapt it to their needs and the needs of the children in the classroom. Help yourselves to the materials: you can disassemble them, re-assemble them, and change them as you prefer.

If you want to share your experiences, please drop us a line at `oae@inaf.it`

On the website below you will find a more detailed description of the learning path.

Link alla pagina web delle risorse, in Italiano, e codice QR

Link to the resources webpage, in English, and QR code

Stefano Sandrelli OAE Center Italy Manager
June 2023

List of Resources and path

This is a list of available resources tested, produced and translated by NAEC teams in the Mediterranean in the framework of STEM Med project. There are still a number of activities not ready yet for publication or not fully translated. We will keep pushing this process but we would also see if teachers and other NAEC team that did not participate in the process find this resources helpful to re-use and re-mix in their practice. In this section we are listing the resources available and some idea of possible educative path imagined together in Lampedusa.

Resources and translation available on June 2023

Proponent	Authors	Title	Facilitator	Languages
Turkey	A. Yelkenci, K. Yelkenci, M. Koçer	The sun in our box	A. Zanella, S. Varano	Arabic (M. Bou Zeid), English (A. Yelkenci), French (G. Giobbi), Italian (S. Ricciardi), Portuguese (J. Gonçalves), Slovenian (D. Fabjan), Turkish (A. Yelkenci)
Lebanon	J.-P. Saghbini, M. Bou Zeid	Let there be light... but not too much	C. Mignone	French (J.-P. Saghbini, M. Bou Zeid), Arabic (J.-P. Saghbini, M. Bou Zeid) , English (J.-P. Saghbini, M. Bou Zeid), Italian (C. Mignone)
Syria	M. Alassirry, T. Jbour, T. Alkhateb	How Telescopes work?	S. Varano	English (T. Alkhateb), Arab (T. Alkhateb), Italian (S. Varano)
Spain	J. Á. Vaquerizo	The colors of light	S. Varano	English (J. Á. Vaquerizo), French (G. Giobbi), Italian (S.Varano)
Croatia	A. Guštin and D. Hržina	The sky at our fingertips	A.Zanella	Arabic (M. Bou Zeid), Croatian (A. Guštin and D. Hržina), English (A. Guštin and D. Hržina), French (G. Giobbi), Italian (G. Giobbi), Portuguese (J. Gonçalves), Turkish (E. Karabal)

Proponent	Authors	Title	Facilitator	Languages
Slovenia	A. Guštin and D. Hržina	Chasing the Moon	A.Zanella	Arabic (M. Bou Zeid), Croatian (A. Guštin and D. Hržina), English (A. Guštin and D. Hržina), French (G. Giobbi), Italian (G. Giobbi), Portuguese (J. Gonçalves), Turkish (E. Karabal)
Portugal	J. Gonçalves and R. Doran	Earth and Sun sizes in my body	A.Zanella	English (J. Gonçalves and R. Doran), Italian (G. Giobbi), French(G. Giobbi), Portuguese (J. Gonçalves)
Italy	S. Ricciardi, S. Rini, F. Villa	Light Play: a tinkering workshop	S. Ricciardi	English (S. Ricciardi), French (G. Giobbi), Italian (S. Ricciardi, S. Rini, F. Villa))
Morocco	H.Madani, H.Darhmaoui	Orion constellation	A.Zanazzi	English (H.Darhmaoui), Italian (A.Zanazzi)
Palestine			work in progress	

Possible Education path we co-design in Lampedusa

The physics of Light

In this educational journey, we explore the physics of light. We begin with the camera obscura to understand light propagation that is straight. Then we work with light plays by the interaction between different materials and light: solid objects that cast shadows, transparent objects that let light through entirely or, if colored, act as a filter, translucent objects that stand in the middle, and finally, reflective things on which light bounces to other directions. With light plays, we experiment from a physics point of view, especially with subtractive color mixing. It is possible to experiment with additive mixing using the same materials to construct three colored lights (red, green, and blue) and then observe what kinds of shadows are formed. In addition to these activities, one can build a spectroscope and then analyze the spectral lines of different types of lamps and clouds in the sky.

- The sun in our box: inquiry about how images forms and how the light propagate.
- Light Play: interaction between different materials and light, solid object that cast a shadow, transparent object that let the light pass complitely or if colored act as filter, trans-lucid object. Subtractive color mix. Possible additive color mix using same material to build colored light and observation of shadow.
- Spectroscope: In this workshop, you will build a spectroscope from simple and recycled materials. With this instrument then we will embark on an investigation about different lights and their spectra.

Light in Astronomy

With this educational path we can explore how light is used in astronomy to make measurements and estimate the properties of astronomical objects in the sky. It begins with an activity related to the functioning of telescopes. By using magnifying glasses, mirrors, and laser pointers it is possible to follow the light path, infer its behaviour, and understand how telescopes work. We can then turn our eyes to the sky to identify the Moon and the constellations, determine their position, and measure how their location changes as time passes. This will bring us to determining the orbit of the Moon, its inclination, and understand its phases. Finally, we can gauge the size of the Sun and relate it to the size of the Earth and other known celestial objects.

- How do telescopes work? is an activity focusing on the behaviour of light, how it is reflected and refracted, and how its properties are important when building and using telescopes
- The Sun at our fingertips allows the participants to determine with simple methods the position of the Moon with respect to the stars, recognize constellations, and

understand how we can use their light to get oriented in the sky

- Chasing the Moon is the next natural step and focuses on determining the orbit of the Moon and its phases, relating them to the Sun orbit

- Earth and Sun sizes in my body allows the participants to relate the size of astronomical objects (e.g., the Sun, the Earth) to the size of familiar and daily objects (e.g., their body), to gauge and better imagine the relative dimensions of celestial bodies.

Scientists in our History

This educational path can be exciting for European classrooms and Arab country classrooms. Schools in many European countries are multicultural, with many first, second, or third-generation immigrant children from Arabic-speaking countries. For these children to rediscover their cultural heritage in school will have a very positive effect, and they will feel valued by studying in school some influential scientists akin to their own family culture. Noting that in the European Middle Ages, a cultural spring was happening in the Arab countries will surely prompt reflections of cultural relativism in all children.

In addition, it is interesting from the point of view of History to construct time strips that bring different cultures together by putting together all the cultures of origin of the children in the class.

- The sun in our box: inquiry about how images forms and how the light propagate and the figure of teh famous scientist Ibn al-Haytham

- how Telescope works?: Hans Lippershey, Galileo Galilei and Newton through their experiments

- We have other resources connected to Arab Scientists including female Scientist proposed by Syrian NAEC; those are not ready for publication and we will add ASAP

Contents

ACTIVITY FROM CROATIA

The sky at our fingertips

Authors: Andrej Guštin and Damir Hržina

Translation: Andrej Guštin and Damir Hržina

Simple methods of determining the position of the Moon among the stars, which include determining the position without the use of instruments and/or using simple instruments (self-made and/or camera). Recognizing stars and constellations on the celestial sphere, plotting the position and phase of the Moon on a sky map and determining coordinates in the ecliptic coordinate system.

Keywords - Celestial sphere, Moon, constellations, stars, observations, angle and Lunar phase measurements, star charts

Aims and participants

- **Aims of the activity** - Show how angular distances can be measured using one's own body and a simple self-made aid in order to determine the position of a celestial object on the celestial sphere.
- **Educational level** - Primary, Middle school.
- **Age range** - 11-12+
- **Time** - 1 hour of preparation at school, minimum 2 evenings.
- **Group size** - Individual or group; Group size 4 people (maximum one schoolclass).
- **Location** - Indoor and outdoor.

List of material

Material needed to build the cross-staff (Figure 1).

- a sheet of stiffer paper (A4 at least 200 g/m^2)
- 40 cm ruler
- pen

- scalpel
- scissors
- adhesive tape
- Cross-staff cardboard mask

Additional material.

- Star chart (Figure ?? and)
- Camera/mobile phone (optional)

Figure 1: Material needed to build the cross-staff.

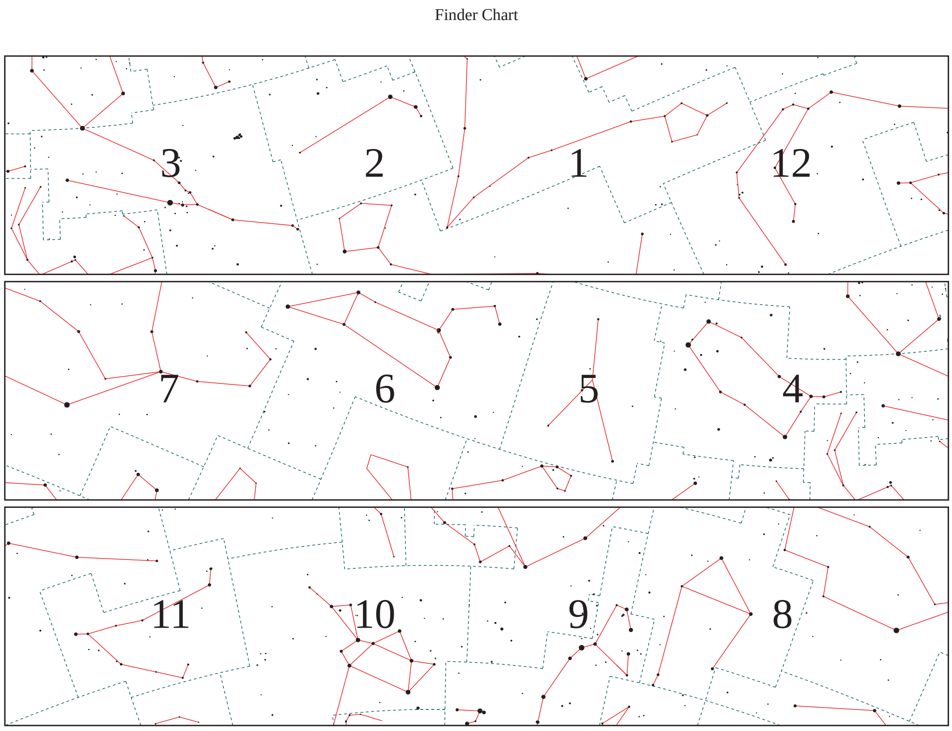


Figure 2: Star finder chart. More detailed charts are reported in Appendix

Goals of the activity

Learn about:

- Orientation in the sky.
- Learning about constellations and bright stars.
- Stargazing.
- Measuring with angles applicable between celestial bodies.
- Lunar phase.
- Using sky charts.
- Measurements on the sky charts.

Description of the activity

Students should be introduced to star charts and the starry sky to identify where the Moon is among the stars. By simply measuring the angular distances between the Moon and nearby stars at night time without the use of instruments, it is possible to approximately determine its position and phase. A simple instrument such as cross-staff can be used for better accuracy, and the camera can be used to achieve even greater accuracy (comparing the position in the shot using the star chart).

How to build your own cross-staff

To build the cross-staff you can follow these instructions (Figure **??**).

1.1 Redraw the outline from the sketch onto a harder paper.

1.2 On the sheet, use a scalpel to cut an opening that corresponds to the dimensions of the ruler that will be passed through it. The opening on the sketch is drawn to fit a ruler 4 cm wide and 3 mm thick.

1.3 According to the sketch, cut the model.

1.4 Fold the model along the marked dashed lines. Align the corresponding points A, B, C and D to overlap. With adhesive tape, stick the edges between points A and D, as well as between points B and C. What we have made is called aimer. The aimer has a slot and sleeve for a ruler and a visor with an opening.

2.1 Print out a page with a measuring tape and a double scale for measuring an angle in a scale of 1:1. Check that the measuring tape is exactly 32.0 cm long.

2.2 Stick the measuring tape on the ruler. Place the edge of the tape where it says 8 cm exactly 8 cm from the edge of the ruler (not from the 0 cm mark on the ruler).

3 Slide the ruler through the opening (between points C and D) of the aimer and through

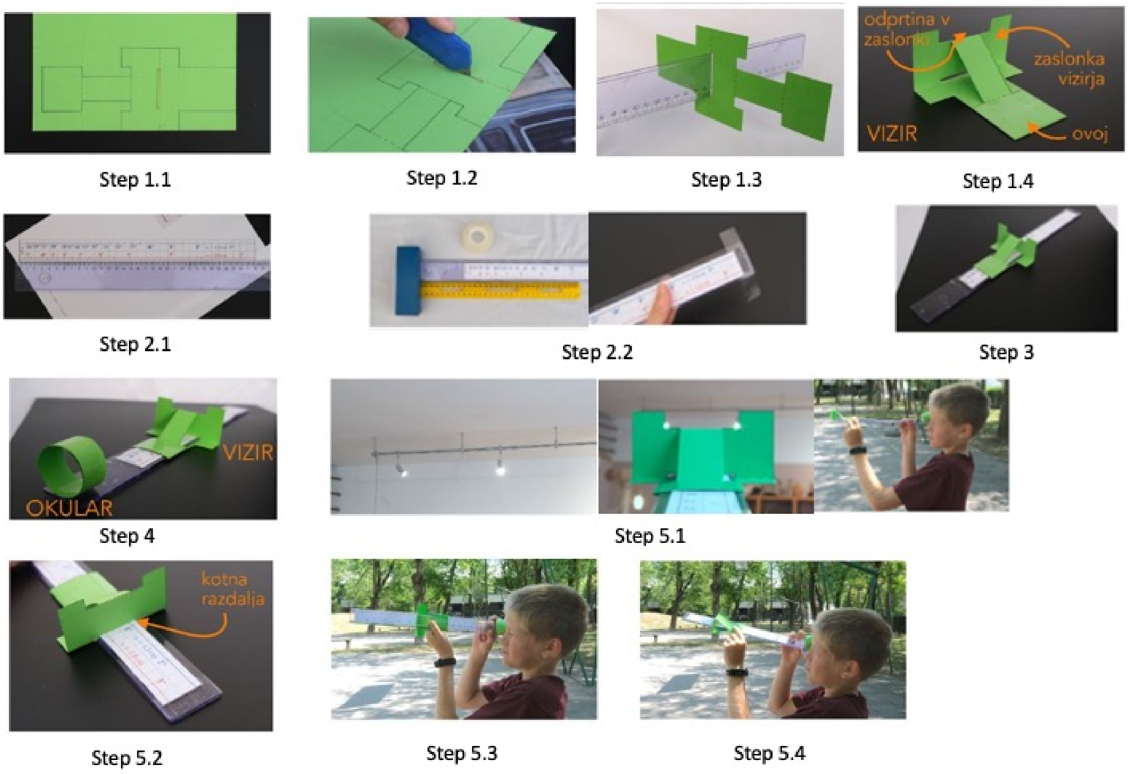


Figure 3: Steps to build and use the cross-staff.

the pre-cut hole. The aimer can now be moved along the ruler. The blue scale on the measuring tape corresponds to the width of the measuring screen of 4.5 cm, and the red scale to the width of the measuring screen of 2 cm.

4.1 Cut a strip of width $a = 2$ cm along the shorter side of the harder A4 paper. Fold the rectangle into a roll and glue it so that it does not fall apart. Stick the roller to the edge of the ruler on the side where the 8 cm mark is on the measuring tape. From now on we call the roller the eyepiece.

The cross-staff is now ready (see Figure 2). We use the scale with blue color.

Figure 4: Cross staff measurements. (photo: A. Guštin)

How to use the cross-staff

5.1 Place the cross-staff against your face so that you look through the eyepiece with one eye. Choose two distant objects that are slightly apart (e.g. two light bulbs on the road, a chimney and a lightning rod, etc.) and measure the angle between them. The angle is measured by moving the aimer along the ruler to the position when the objects are on the edges of the measuring screen.

5.2 Angular distance can be read from the measuring tape in the place where the aimer screen is.

5.3 If the cross-staff is rotated by 90 degrees, then with it we can measure angular distances in the vertical plane. With a cross-staff, measure the apparent angle at which you see the tree from the ground to the top of the crown.

5.4 Angular distances can also be measured with a cross-staff in a plane inclined at any angle.

Look for the Big Dipper asterism in the clear night sky. Measure the distances between its stars with a cross stick. In order to easily read the angular distance, illuminate the measuring scale with a dimmed red light.

Now, based on the measurements, students can draw the phase and position of the Moon on a prepared celestial map and determine its coordinates in the ecliptic and/or equatorial celestial coordinate systems. Students will learn the basics of astrometry, that is, how they can determine the position of a celestial body (in this case the Moon) on the celestial sphere, and also that the Moon has a noticeable apparent motion between the stars.

Possible suggestions

You could map meteor showers on the same used maps.

What's going on: physical explanation

Measuring angles in astronomy is of great importance. By knowing the positions of celestial objects and their apparent movements, we can find out where we are among them, in which direction we are moving, predict eclipses, transits, occultations or even if we are in danger of colliding with one of the newly discovered asteroids. We can also find out the characteristics of other star and planetary systems or go back in time and analyze historical events. The positions of distant objects such as stars, star clusters, nebulae, galaxies, etc. are plotted in star maps where stars are represented by circles of different diameters depending on their apparent brightness (a brighter star is represented by a larger circle).¸In order to plot objects in star charts and determine their coordinates, it is necessary to define appropriate coordinate systems. The most frequently used celestial coordinate system is the equatorial one, whose main advantage is that it coincides with the Earth's orientation in space. The reference plane is the celestial equator which coincides with the Earth's, only the vernal equinox was chosen as the origin. Coordinates are right ascension and declination. The ecliptic coordinate system, in which the reference plane is the ecliptic plane measured with ecliptic longitude and latitude, is more suitable for describing motion in the solar system. Angles can be determined by the ratio of the distance and the size of the object. Using the method of similarity of triangles, it can be shown that it is possible to measure the mutual angular distances of distant objects. In fact, the same principle is used when measuring angles, for example with a cross-staff or fingers.

Evaluation

- Marking the result of a student's work.
- Discussion about different methods of measurements on the celestial sphere.

Interdisciplinary ideas

7th and 8th grade elementary schools curricula

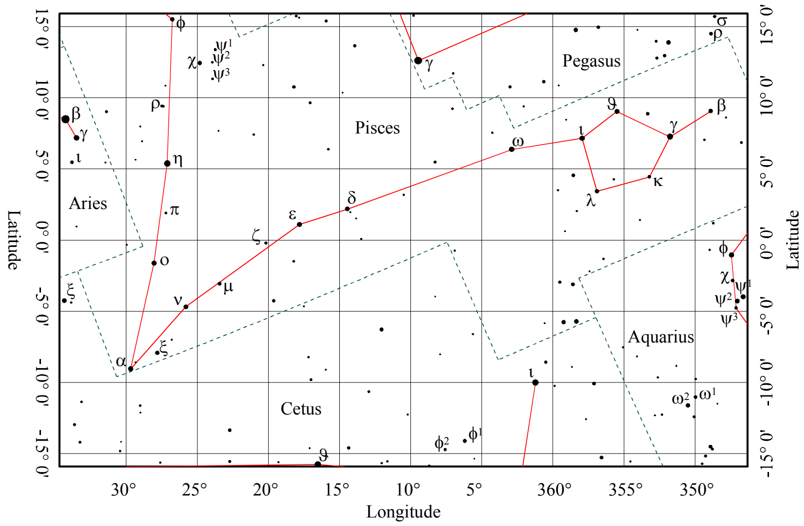
Connection to other activities and why

The activity "Chasing the Moon" shows one of the practical applications of these measurement methods.

Further Reading

- https://pwg.gsfc.nasa.gov/stargaze/Scrostaf.htm
- http://www.scholarpedia.org/article/Astrometry

Additional finder charts



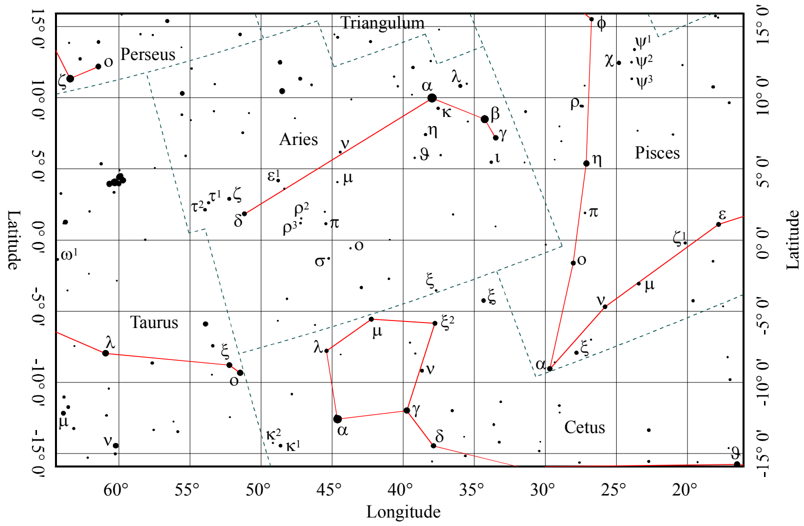


Figure 5: Additional finder charts.

ACTIVITY FROM ITALY

Light Play: a tinkering workshop

Authors: Sara Ricciardi, Stefano Rini, Fabrizio Villa

Translation: Sara Ricciardi

Abstract: This tinkering activity is largely inspired by the work of the Tinkering Studio and in particular the activity of the same name. The authors' work focused on localizing the workshop in Italian elementary school. The first step was to reconstruct the kit so that it would be usable by schools. Then we worked in co-design with teachers to integrate the tinkering workshop into the school educational curriculum. The projects "Officina degli Errori" and "Officina della Luce" have worked along these lines. Tinkering is used as an opening moment in which we can ask deep questions while physical artifact takes shape. These questions in part will be investigated during the activity itself but in part may be the cue for a broader journey and will be deepened and reformulated in other formal and informal learning opportunities.

Keywords - Light and materials: opaque, transparent and reflective materials- geometric shadow - artistic expression through science - subtractive mixing of light - research community - scientific methods

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Aims and participants

- **Objectives of the activity** - to interrogate and stimulate questions about light and the interaction of light-matter through a creative and inclusive activity
- **Education level** - Primary and Lower Secondary schools
- **Age range** - 6-12 years old. Also for children ages 4 and up with a more open setting
- **Time** - 2 hours (excluding preparation of materials and classroom)
- **Ideal number of participants** - This is a group activity: children work optimally in pairs. Normally the activity is offered in classes of up to 25/26 children and as far as possible, an attempt is made to have two teachers at the same time

- **Environment** - Inside a room in semi-darkness and if possible in the final part it is very scenic that you can further darken the room until almost complete darkness is achieved.

Materials:

The "constructive" purpose of the workshop is to create a kinetic light sculpture for each pair of children. Each kinetic sculpture is placed in a box-screen lit from the inside. The lights and the boxes are part of the sculpture contributing to the uniqueness of the installation.

Materials are then organized into:

materials at each workgroup location

- Each pair or small group will have a box open on two sides to build the scene: a cardboard box (size: about 40x40x60 cm) to be opened on the two larger sides, one of which is covered with a translucent sheet (tracing paper);

- A DC electric motor with a reduction with about 4-6 revolutions per minute (gear motor), powered by 3 V batteries;

- Battery holders and batteries suitable for powering the motor. For motors powered between 3 and 6 V, 2-stylus (AA) battery holders are fine.;

- alligator cables (2 per box);

- an adjustable clamp lamp;

- Translucent paper to build the screen. We have often used baking paper, but recently we have been using tracing paper, which is much easier to fix and more durable though less economical.

the table of materials

The materials with which the children will build the sculpture should be easily accessible to the children throughout the entire workshop without creating any snags or danger; the materials should also be divided physically into the categories listed below so as to encourage an initial consideration of the behaviors of different materials in relation to light.

- A set of salvaged materials that create shadows or patterns, for example: graters, strainers, baskets, grids, and nets of any kind;

- A set of light-coloring materials, for example: colorful soap bottles, clear plastic bottles and containers, colorful notebook covers;

- A set of salvaged materials that create light reflections, for example: mirrors, sequin fabrics, mylar , silver paper, reflective sticky paper.

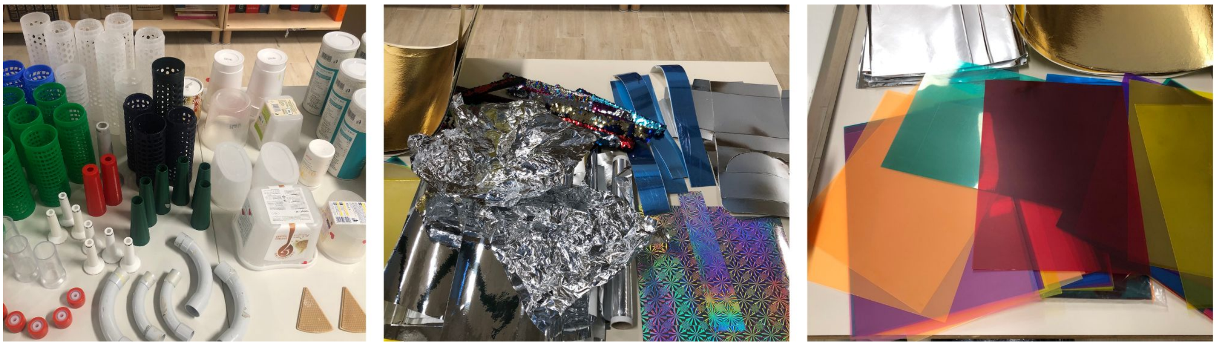


Figure 1: The raw materials used to construct the kinetic sculptures divided with respect to how they interact with light: opaque materials that create shadows and patterns, materials that reflect light, and semitransparent materials that act as filters by coloring the light

useful tools

- Useful tools: hot glue gun and hot glue, wire cutter, hacksaw, scissors, utility knife, paper tape

Objectives of the activity

Tinkering as an educational practice does not and cannot have structured and fixed learning goals, but the goals will change depending on the curiosity and the thoughts of children. What is certain is that this workshop meshes well with a scientific exploration of light and materials. The teacher in this activity acts as a facilitator. Depending on the interests and questions of the children this activity can move between art and science without discontinuity; indeed an artistic exploration may promote scientific questions and vice versa. This pliability thus allows us to build a truly inclusive and meaningful activity for children and work beyond stereotypes. This activity if situated in the classroom can be used by the teacher in many ways and can then be supplemented with more formal moments. In working with teachers we have seen this workshop used by teachers for example as:

- A moment of creativity and experimentation to introduce and germinate questions about light and light-matter interaction

- An artifact to build stories and narratives

- Mediating activity for social inclusion, intercultural and gender interventions

- an activity to experiment on one's community what it means to work in a research community that builds new knowledge

- Moment of reflection on the value of knowledge as a continuum beyond disciplinary knowledge

In this way, tinkering becomes a fundamental and open moment for children's questions. The idea is that in order to co-construct shared knowledge, one must start precisely from a deep question that can arise in an open, rich and cooperative environment. Questions generated in open sessions can then also be answered through more traditional teaching (hands-on workshops, experiments, text study, videos, interviews with experts). On this pages an in-depth look at the project for the moment only in Italian https://play.inaf.it/officinadellaluce/

Figure 2: The co-designed workflow during the educational tracks with Italian schools

Description of the activity

Opening

You can start by showing kids a light play kit and some examples of how different materials create interesting light reflections or shadows and then encourage them to experiment. With boxes of the proposed size we recommend that you have the kids work in pairs. You can create larger settings and build groups of three. Space management is an important key to the success of the workshop as well as giving yourself a relaxed time frame and facilitating the session without imposing your own ideas.

Workshop

After participants have experimented for a while with a limited number of materials, we can introduce the full table of materials and start with the actual workshop by asking participants to build a scene made of moving lights: a kinetic sculpture. It is usually helpful to show a simple example to give an idea of the possibilities for the activity. The example should suggest the complexity and goals of the project without becoming too convincing or complicated. We don't want participants to be intimidated by the example or simply want to replicate it. It is often best to start with an example that could easily be improved.

Calculate to spend at least two hours in this way of working and, if necessary, to resume the activity several times by re-launching the children's own ideas. Encourage experimentation through trial and error as much as possible. It is important that kids have enough time to dwell and understand the different phenomena, the relationships between the light source, the object interacting with the light by building a shadow or reflection, the shadows or reflections on the screen. The activity is designed for explorers who will grapple with the complexity of shapes, sizes, depth, position and geometry of shadow and reflections. It is also crucial for the teacher/facilitator to support the effort of the participants and intervene in moments of frustration without offering immediate solutions but stimulating them to shift their point of view, to observe the work of others in search of innovative solutions, to reformulate their problem so that they can approach it in a new way.

Debriefing e sharing

When each group has completed their box, we ask them to move it off the tabletop (or wherever they are building) and add it to the common installation. This operation could be tricky so consider having the kids build the light plays so that they do not need to move it in order to make a common installation (e.g., at school we usually have them build on tables set in a circle or semicircle). Let's take some time to admire the boxes all together and the effect of lights and shadows as a whole.

We then ask each pair to say something they are particularly proud of about their scene or a problem that proved particularly challenging, and what they did to solve it. We often start the conversation by asking each group to come up with a name or title for their moving scene. Try to get each participant to tell something about the experience.

Tips

If you are doing the activity in a school, we recommend that if possible you set up the workshop in an atelier room or otherwise in a place where you can leave materials for later sessions.

What happens: an explanation of the physical phenomenon

opaque objects:

grids, transparencies, silhouettes, gear motors and various light sources are used. Participants in this station will have the opportunity to become familiar with the use of motors and lights, paying particular attention to grids, shapes and repetitive patterns. Having more lights available will encourage experimentation with overlapping grids. In general, after a bit of work, children become familiar with the idea of shadow, noting that an object's shadow is larger when the object is closer to the light source because it actually manages to block more light. In facilitating, one may work by taking it to the limit by bringing the object so close to the light that it completely obscures it because it is blocked, or, conversely, so far away that there is virtually no shadow.

reflective objects:

properties of reflective objects and materials are highlighted. The motors and both white and colored lights available will encourage participants to pay close attention to how reflections and caustic images can be manipulated and can interact with colored lights. Materials at this station could include sheets of mylar (such as Easter Egg or commercial snacks wrappers), reflective fabrics, mirrors, sequins, and other reflective objects. In this case, the different behaviors of flat reflective surfaces (mirrors) and sequin fabrics can be noted. Children notice that in the former case the beam of light ”stays whole” when reflected while in the latter case it is chopped or divided depending on where the light hits the sequin fabric. Through these experiments, one can arrive at the reflection of light.

semi-translucent objects:

we focus on colored objects and white lights: participants experiment with how to create various colors and colored shadows by filtering light through gels, clear plastic wrap, plexiglass scraps and other translucent objects. A colored filter is a type of material that lets through only one ”color” of light. For example, a red filter lets through only red. Children sometimes divide light into two parts by applying two different filters. It is very interesting to see what kinds of shadows are cast on the screen.

Assessment

This activity is not only limited to the acquisition of knowledge, but also involves the development of soft skills. Therefore, it is essential that the assessment process reflect this twofold nature. Each teacher can construct an assessment grid from this document translated into fourteen languages: Learning Dimensions of Making and Tinkering and build his or her own personalized rubric. By observing the children during the work we could focus on the different dimensions of their learning thus making it visible to our eyes as facilitators or teachers, as well as to their eyes, thus also in a metacognitive key. It is important that the documentation is capable of making visible the contribution of the individual as well as that of the group. The class in this case works similarly to the research group, sharing information, solutions and points of view.

Interdisciplinary ideas

This activity is extremely adaptable and can be incorporated into various educational designs not only for an initial approach to light and light-matter interaction but also for storytelling. It therefore lends itself very much to projects that involve storytelling. As an example, in a school in Bologna, children used individual lightplay boxes as narrative moments in a story. They then recorded the scenes - also using sounds and interventions by the children in a real performance - and edited them to make a single animated short film that they then shared with families and the school community. The editing stage also used the voices of the parents saying goodnight in their languages of origin (the school is in a context with a high rate of interculturalism). In this case, the lightplay becomes one of the elements - perhaps the most significant - of a long transdisciplinary journey that involved almost all school 'subjects' and engaged them in curricular and extracurricular moments. On this page the video of this class' work: youtube video.

Links with other activities and motivation

This activity can be used as a time of open experimentation for pathways on the physics of light for example in conjunction with activities proposed by NAEC teams Syria, Spain and Turkey.

Further reading

The light play workshop was designed by the Tinkering Studio. The list of materials and modalities are offered on this dedicated page. Our original contribution is that we wanted to bring tinkering activities to schools not as stand-alone activities but as part of classroom educational planning.

Documentation

If you carry out the activity, please send us your experiences. Here are some pictures of activities in schools in Italy

Figure 3: An installation of the works takes shape. It is very interesting to observe and comment both sides. some boxes are built a lot by looking inside, others more by observing what is happening on the screen. In this image, a work with teachers-in-training

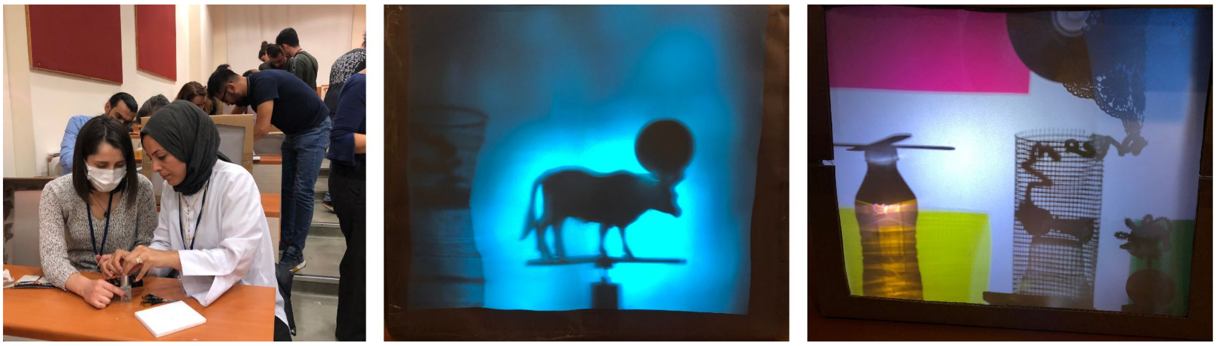


Figure 4: Teachers at work during professional IAU Teacher Training Workshop organized by NAEC Turkey: Astronomy Support for Primary School Curricula 8-9 October 2022 Istanbul Kültür University, Atakoy, Istanbul

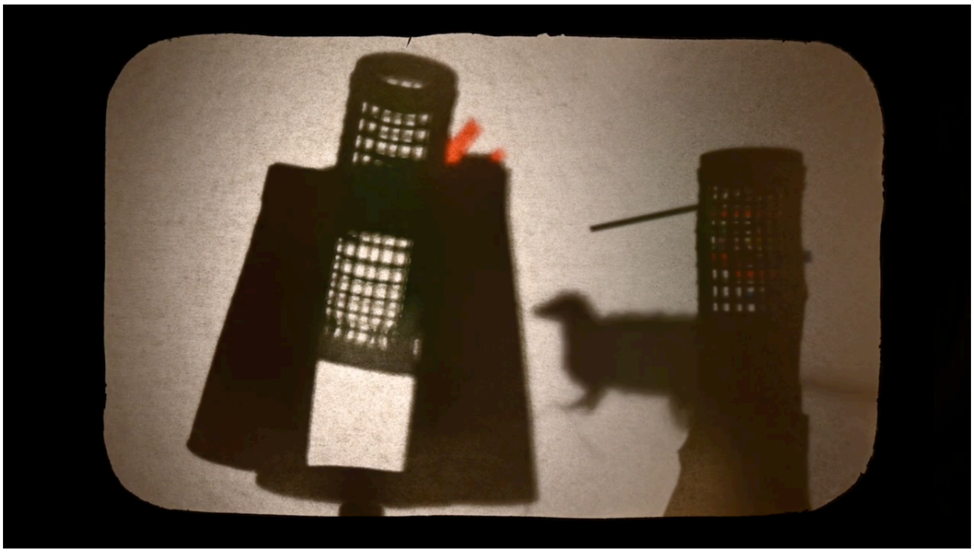


Figure 5: The work of some schools in italy is documented here: light play tinkering studio

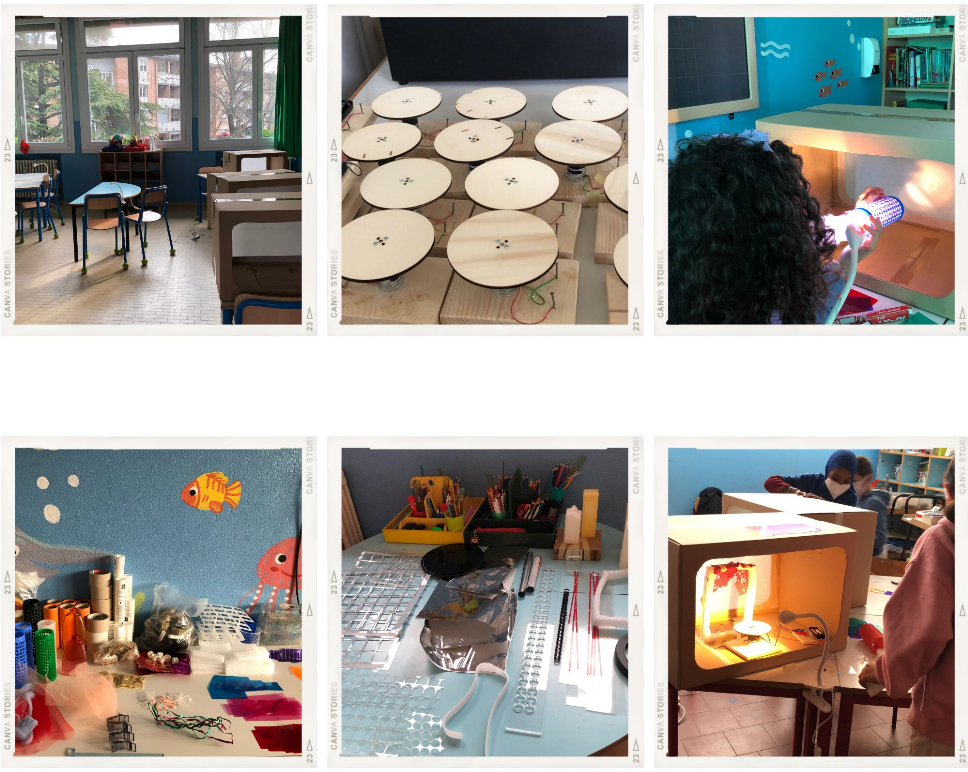


Figure 6: Setting of the classroom workshop

ACTIVITY FROM LEBANON

"Let there be light"... but not too much

Authors: Jean-Pierre Saghbini, Marc Bou Zeid

Translation: Jean-Pierre Saghbini, Marc Bou Zeid

Abstract: This is the English translation of the activity proposed by NAEC Lebanon within the STEAM-Med co-design project. This hands-on activity involves the creation of a model to show the impact of light pollution on the night sky and raise awareness about this subject.

Keywords - Light - Pollution - Night Sky - Stars - Sea Turtles - Lamps - Night observation

Email address: jp.saghbini@gmail.com; marc.bouzeid@gmail.com

Aims and participants

- **Aims of the activity** - Awareness of light pollution
- **Educational level** - Primary school and Middle school
- **Age range** - 7-12 years old
- **Time** - 2 hours
- **Group size** - This is a group activity: 2 to 4 students per group is an ideal group size and the maximum number of people at once can be 20 to 25 students per group.
- **Location** - Outdoors (during the night) or indoors (in a dark room).

List of material

- A piece of wood representing the ground.
- A piece of wood in the background representing the night sky.

- Blue paint for the sky.
- Led light lamps (e.g. Christmas tree lights) to represent the stars.
- Black sandpaper covering the ground.
- A piece of reflective paper.
- Three different light designs:
  - the first one is unshielded and fully directed towards the sky;
  - the second one is partially shielded;
  - the third one is well shielded and directed downwards.

Figure 1: The model with the three different light designs.

Goals of the activity

The activity has several goals:

- Observe the impact of the different types of lighting on the night sky in order to choose the adequate one.
- Observe the impact of reflected light from a reflective floor.
- Explain the damage caused by light pollution in the sky and its impact on biodiversity (especially the sea turtles).
- Raise awareness among the young generation about light pollution.

Description of the activity

Making the model

The first part of the activity involves building the model:

1- Cover the wood board representing the ground with black sandpaper.

2- Paint the wood board representing the sky in blue.

3- Make tiny holes on the board representing the stars (they can be in constellation forms)

4- Put the small led lamps (Christmas Tree Lights) into the holes to represent the stars.

5- Put a removable reflective paper on the ground when needed.

Observations

Once the model is ready, students are encourage to observe the model under different lighting configurations:

A- Observing the model with no lighting added (Absence of Light pollution):

B- Observing the model when bad lighting is added (Light pollution):

C- Observing the model when better lighting is added (Minimize light pollution effects):

D- Observing the model with the reflective floor (effect of reflective floors even with good lighting):

General remarks

- It is very important to raise awareness among the new generation about the negative impact light pollution can have on the night sky and on biodiversity; explaining these impacts through presentations and talks is very important but showing it through a hands-on model for students is not very easy. This is the importance of this idea.

- However, presenting this model and showing the effects of the light during class hours might be difficult sometimes in some schools where a completely dark room may not be available.

Possible suggestions

If the activity is taking place in a school we can suggest that, afterwards, the students who worked on the activity take a tour of the school and give their opinion on whether the external lighting installed meets the requirements to minimize light pollution and if not to submit their suggestions to the management.

What's going on: physical explanation

Light pollution is the excessive and disruptive use of artificial light that disrupts the natural patterns of wildlife, contributes to the increase of carbon dioxide $CO2$ in the atmosphere, disrupts human sleep patterns, and obscures the stars in the night sky.
Like noise pollution, light pollution is a form of waste energy that can cause adverse effects and degrade environmental quality. Moreover, because light (transmitted as electromagnetic waves) is typically generated by electricity, primarily by the combustion of fossil fuels, it can be said that there is a connection between light pollution and air pollution (from fossil-fueled power plant emissions). Therefore, controlling light pollution will help conserve fuel (and money), reduce air pollution, and mitigate the more immediate problems caused by excessive light. Although light pollution may not appear to be as harmful to public health and welfare as pollution of water resources or the atmosphere, it is an environmental quality issue of no small significance. Better-adapted lighting solutions significantly reduce light pollution and generate savings.
This workshop aims to present this type of pollution to the general public to encourage them to take responsibility for reducing light pollution.
By building this model and using different lighting setups, the students can learn how to use outdoor lighting responsibly by only using it where it's needed and in the amount required. This model takes into consideration the nature of the ground and its reflectivity (albedo) in order to show its effect on the diffusion of light where it's not needed.

Evaluation

In order to evaluate how well students can now make the difference between good and bad lighting setups, the teacher can give them a list of images showing different light configurations that should be classified as acceptable or unacceptable based on what they learned in order to limit light pollution. An example of possible configurations is provided in figure 7. Further examples, in the form of a card game, are available in section .

Interdisciplinary ideas

Light pollution is a problem affecting not only astronomers and people who simply want to enjoy the beauty of a starry night. Light pollution has adverse impacts also on birds, sea turtles, and other animals.
Many migratory birds, for example, fly by night, when light from the stars and Moon helps them navigate. These birds are disoriented by the glare of artificial light as they fly over urban and suburban areas. It has been estimated by the American Bird Conservatory that more than four million migratory birds perish each year in the United States

by colliding with brightly illuminated towers and buildings. Light pollution contributes to the dramatic decline of certain migratory songbird populations over the past several decades.

Connection to other activities and why

This activity can be connected to all-night sky observation activities and anti-pollution environmental activities.

Further Reading

Resources about light pollution in English (from the International Dark-Sky Association)

- What is light pollution? https://www.darksky.org/light-pollution/
- Light pollution - take action: https://www.darksky.org/get-involved/
- Outdoor Lighting Basics: https://www.darksky.org/our-work/lighting/lighting-for-citizens/lighting-basics/
- https://www.britannica.com/science/light-pollution

Pictures

If you do the activity please send us pictures of the activity performed in other countries.

Evaluation game

An example of a card game used in the evaluation shows lighting configurations to be classified into good and bad.

Figure 2: The model without artificial light.

Figure 3: The model in the presence of a bad lighting configuration.

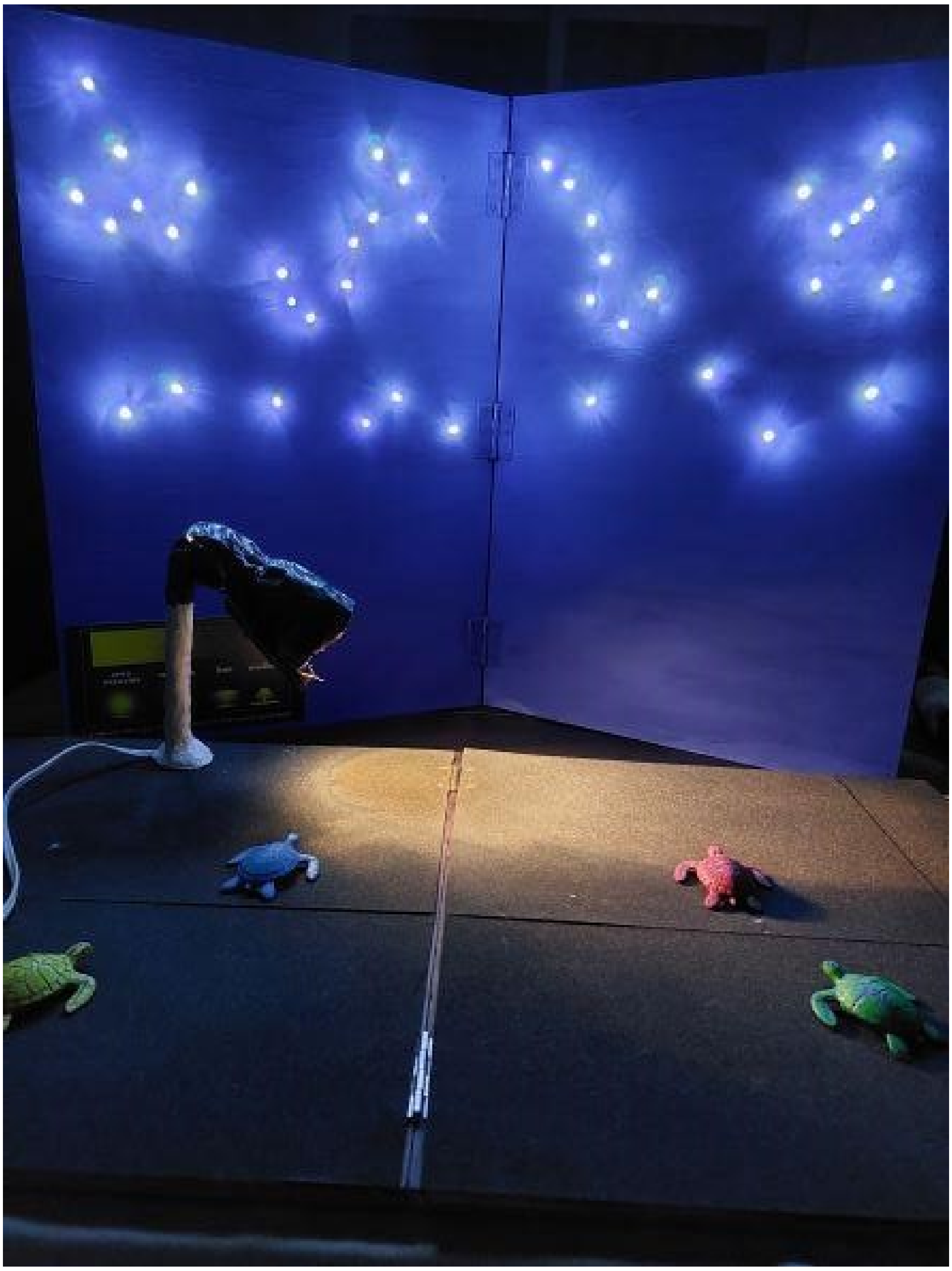


Figure 4: The model in the presence of a better lighting configuration.

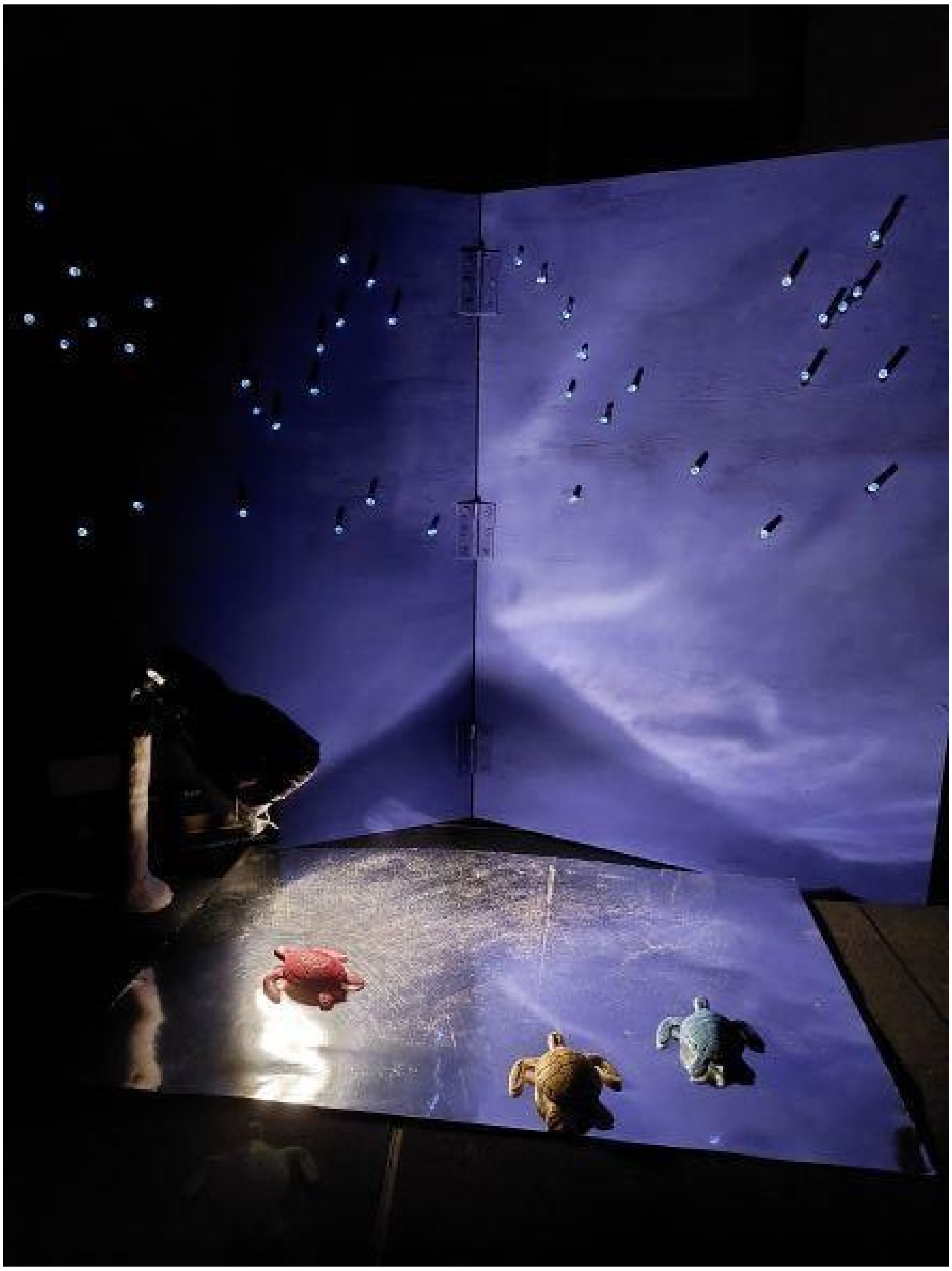


Figure 5: The model in the presence of good lighting but also a reflective floor.

Figure 6: Some of the effects of light pollution. Source: International Dark-Sky Association

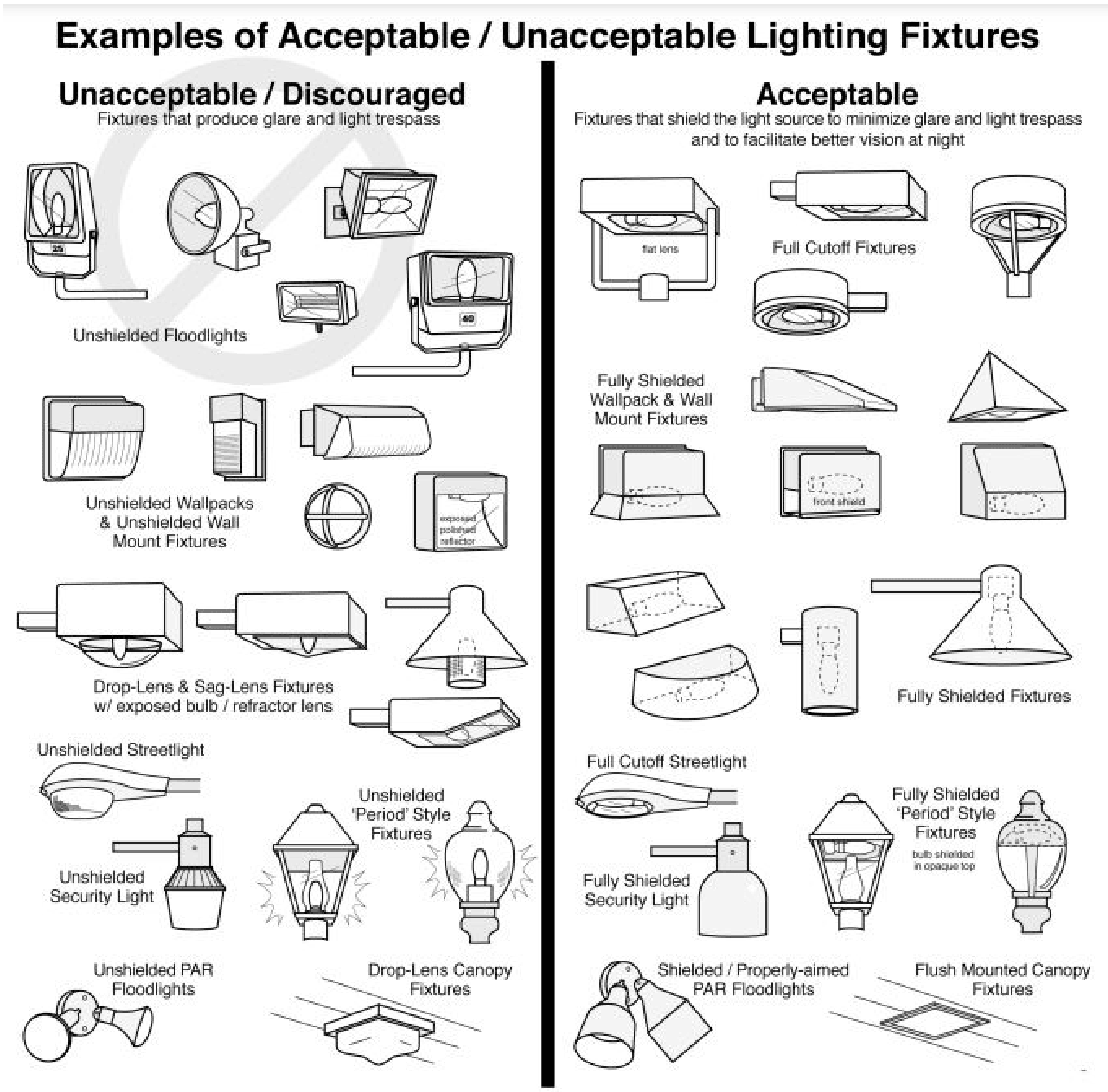
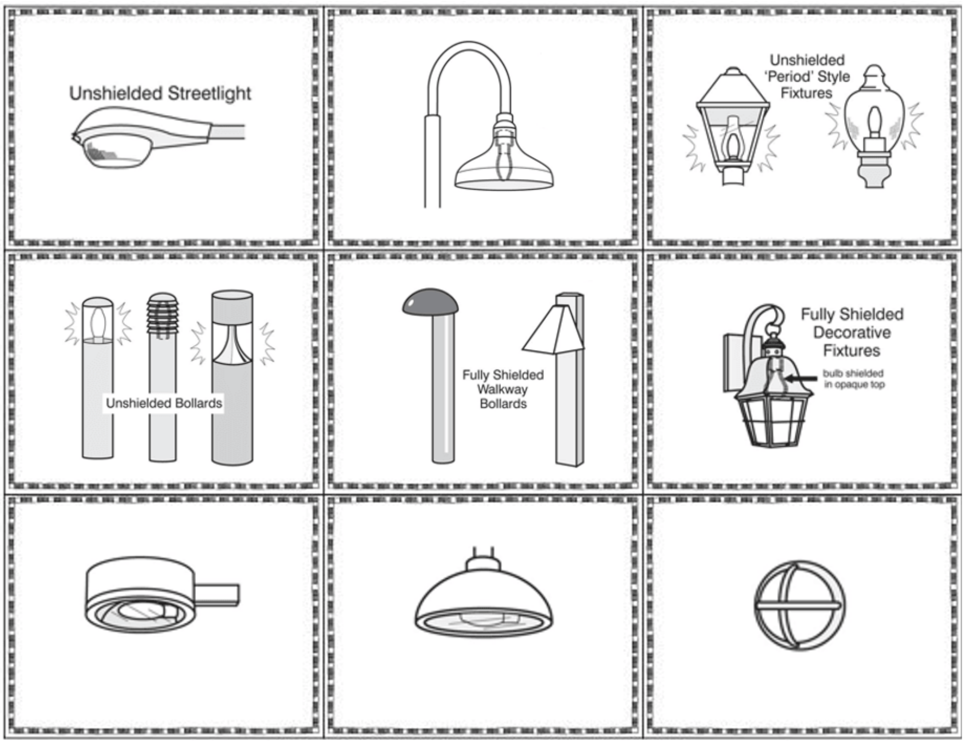
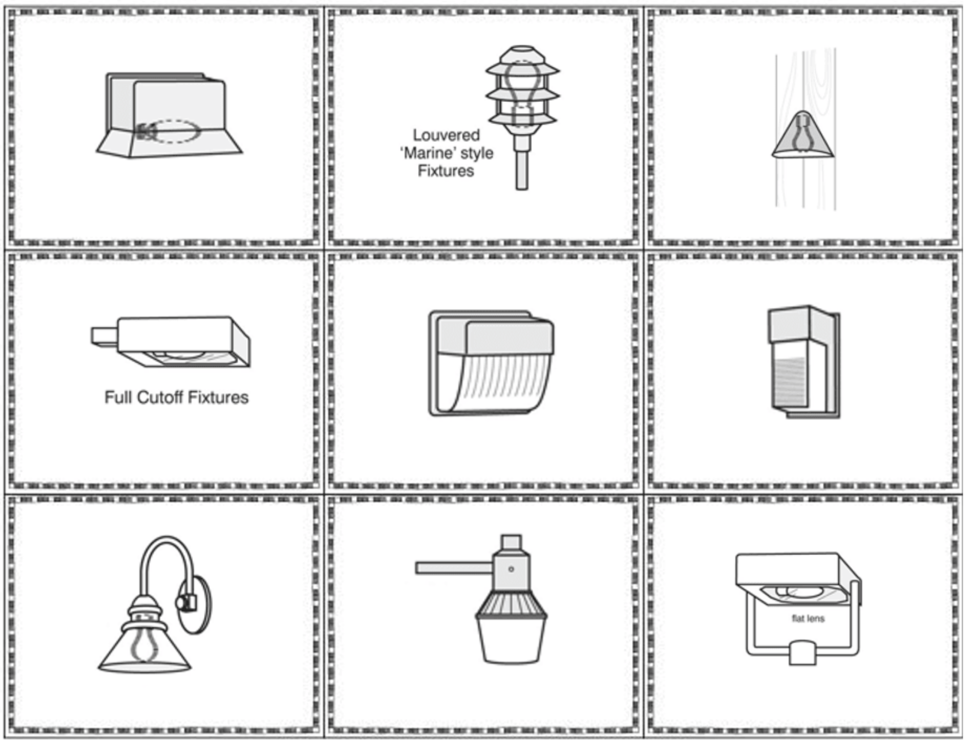
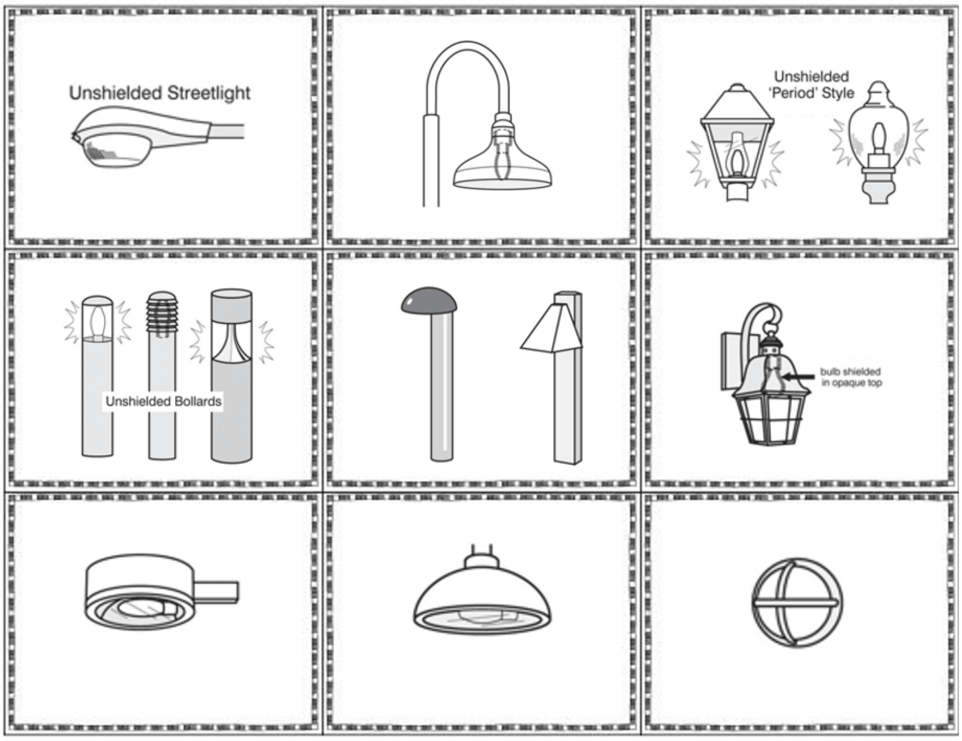


Figure 7: Examples of acceptable and unacceptable lighting configurations.

Figure 8: A light pollution workshop during the "Festival d'astronomie de Fleurance au Liban".




Louvered
'Marine' style
Fixtures
Full Cutoff Fixtures
flat lens


Unshielded Streetlight
Unshielded
'Period' Style
Unshielded Bollards
bulb shielded
in opaque top

ACTIVITY FROM MOROCCO

Orion constellation

Authors: Hatim Madani, Hassane Darhmaoui

Translation: Hassane Darhmaoui

In this activity pupils make a simple 3D model of the Orion constellation.

Keywords
- Constellations
- Mythology
- Size, Color, Age, Temperature of stars
- Scale
- Light year
- Arabic names of stars
- Life cycle of stars

Aims and participants

- **Aims of the activity** - To learn about the Orion constellation, the size of its major stars, their colors and ages, and how far they are from Earth.
- **Educational level** - Primary and Middle school
- **Age range** - 9 - 13
- **Time** - 2 hours
- **Group size** - The activity involves approx 30 students, Working in groups of 2-3.
- **Location** - Indoor.

List of material

- Styrofoam board (A little bigger than the size of an A4 paper, thickness 1 to 3 cm) - It could be cut from packaging Styrofoam sheets (see Fig. 1).
- 10 BBQ wood spikes (20 - 30 cm long)
- Modeling clay (colors: white, blue, light blue, orange, and red).

- Ruler, meter.
- Scissors or cutter to cut the sticks.
- Tape or glue.

Figure 1: Styrofoam boards for the activity.

Goals of the activity

Learn about constellations in general. Learn about the Orion constellation and its mythology. Learn about scaling: Stars distance from earth, sizes. Learn about star colors, temperatures and ages, star evolution. Learn about Arabic names of stars.

Description of the activity

Presentation

The facilitator gives a 30 to 40 minute presentation about the Orion constellation, its different stars, their arabic names, their sizes, their colors, their temperatures, their ages, and their distances from us. Optional: discuss the life cycle of stars and introduce Orion Nebula. (check the online references in Further Reading section).

Workshop

1. Glue or tape the drawing of the Orion constellation (see Fig.) on the Styrofoam board (or draw the constellation directly on the Styrofoam board).

2. Use the modeling clay to make spheres that correspond to the different stars of the Orion constellation respecting the given scales and colors of the different stars of the constellation (see Fig.).

3. Cut wood spikes proportionally to the distances from Earth of the stars in Orion constellation (use the table in Fig. to calculate the spikes' length).

4. Stick each wood spike on the corresponding star of the drawing on the Styrofoam plate.

5. Put the corresponding sphere (star) on top of each stick.

6. Make a small container with the clay which corresponds to the Orion nebula and put inside it a few newborn stars (the Trapezium). See Fig. 2.

Possible suggestions

- Homework: using the same method, make 3D models of other constellations (Big Dipper, Cassiopea, Taurus, Scorpius, etc..). Each group of students will pick a constellation and make a 3D model.

- Make a hanging constellation (instead of sticks, use strings).

What's going on: physical explanation

A constellation is a group of stars that appear to be close together and form an imaginary pattern, while they can also be very far away, from us and from each other. Stars can be of different colors; the color of a star depends on its surface temperature, red stars being colder than blue ones. Stars have a life cycle; forming stars and dying stars are both visible in the Orion Constellation.

Evaluation

A possible evaluation tool is the quiz reported at the end of the activity.

Interdisciplinary ideas

- Science: Stars, Constellations, Temperature, Colors, Light year, star evolution.

- Geometry: spheres, 3D.

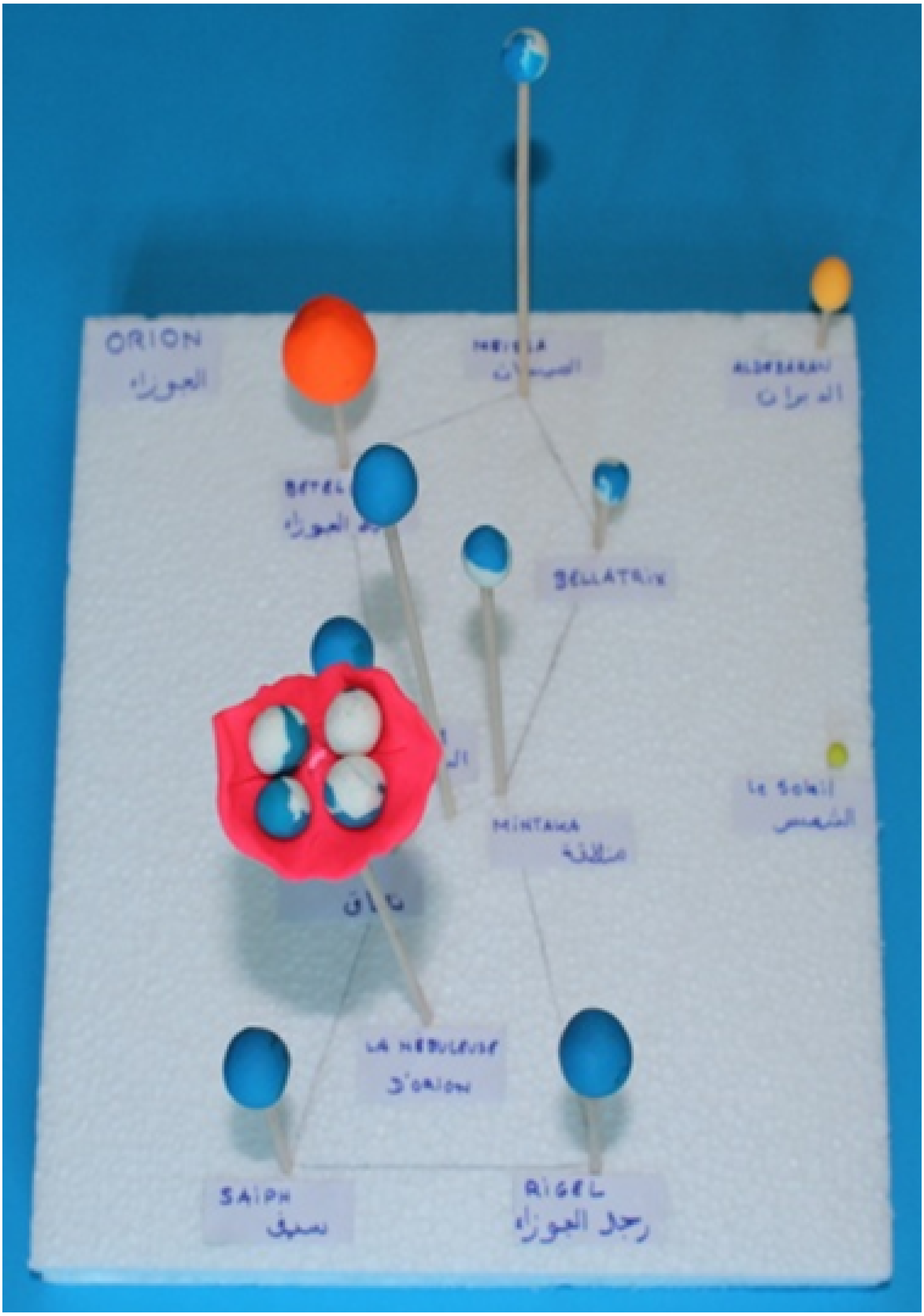


Figure 2: Resulting representation of the Orion constellation. The small container represents the Orion Nebula, containing newborn stars.

- Maths: scaling, measurements.

- History and Technology: Arabic names of stars, mythology.
- Art: colors, use of modeling clay, imagination and decoration of Orion Nebula.

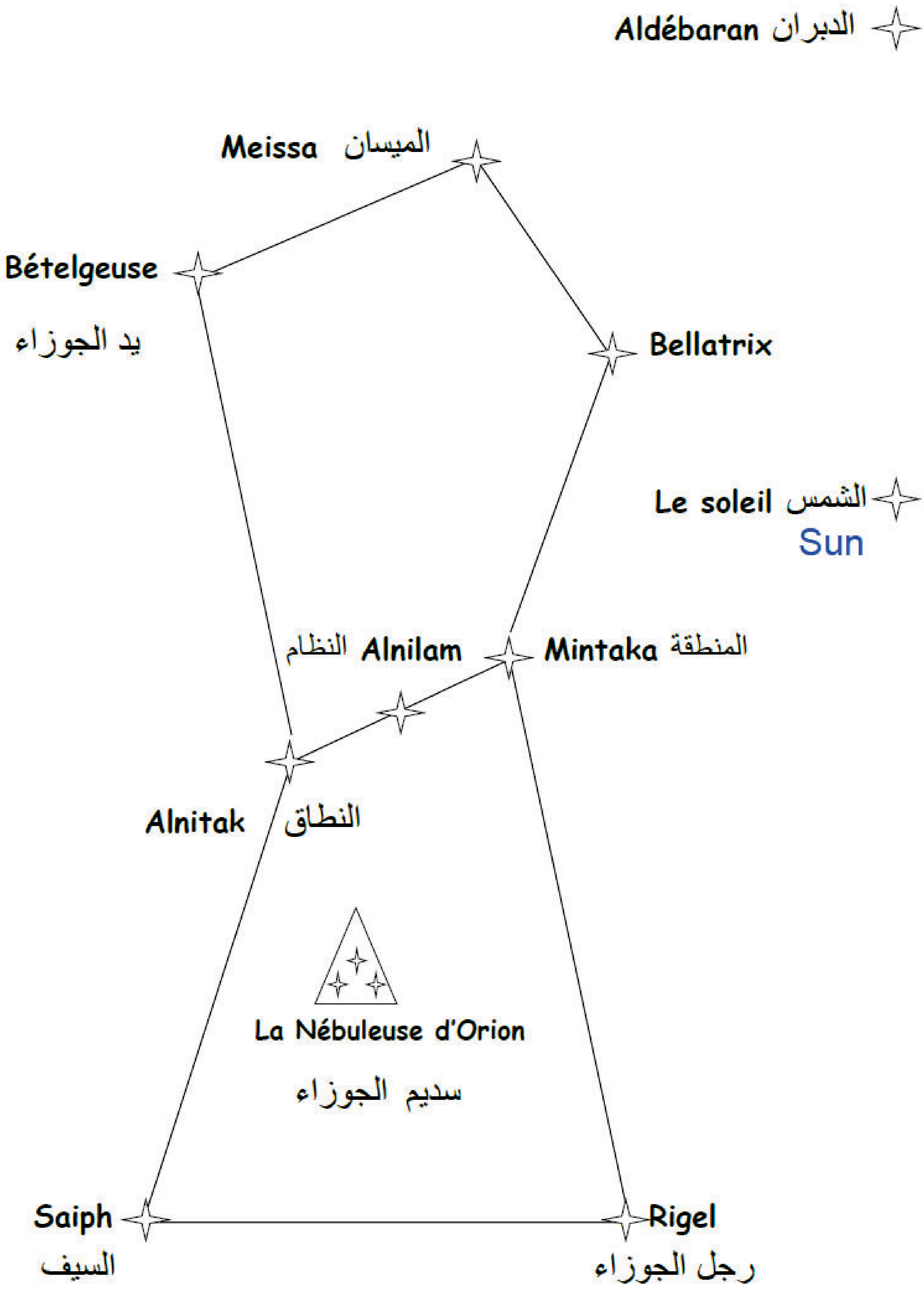
Connection to other activities and why

This activity can be connected to:

- **Earth and Sun sizes in my body**, to talk about scales and sizes of celestial bodies.

Further Readings

- What's In The Orion Constellation? link
- Constellations for kids: link
- Life cycle of Stars for kids: link
- link
- link



ORION الجوزاء - الجبار

Let's make a model of the Orion constellation by calculating the diameter of each star and its distance from the sun.

Nature and distance of the stars of the constellation of Orion:

Stars	Nature	Distance from sun (Light Year)	Length of spike (cm) Scale: 1cm => 75 Light Year	Corresponding Diameter in cm - Dwarfs: 2 mm - Giant: 1 cm - Supergiants/ Blue-White: 1.5 cm - Supergiant/ Red-Orange : 3 cm
Meissa	Giant Blue/white	1055		
Betelgeuse	Supergiant/ Orange	420		
Bellatrix	Giant/ Blue-white	240		
Alnitak	Supergiant/ Blue	820		
Alnilam	Supergiant/ Blue	1340		
Mintaka	Giant Blue/White	910		
Saiph	Supergiant /Blue	720		
Rigel	Supergiant / Blue	770		
Aldebaran	Giant/ Orange	75		
Sun	Yellow Dwarf	0		

Nebula	Nature	Distance from sun (Light Year)	Length of spike (cm)	Corresponding Diameter
The Orion Nebula	Red Gas and dust Cloud	1500 Light Years		4 cm in diameter containing 4 young white-blue giants

Note: It will be necessary to add around 2.5 cm more for each spike corresponding to the depth of the polystyrene plate.

Quiz (source:https://quizizz.com/) :

1. A constellation is a group of visible _____________ that form a pattern when viewed from Earth.

a- planets
b- stars
c- creatures
e- patterns

2. The constellation pattern may take the shape of ____________, ____________, ____________, ____________ or object such as a crown or compass.

a- planets, stars, animals, people
b- man, animals, stars, planets
c- stars, animals, people, man
d- animals, mythological creature, man, woman,

3. The stars we see in each constellation are very close to us.

a- True
b- False

4. The stars in a constellation appear to be close to each other in the shape, but may be ________________ in space.

a- very close
b- some are close
c- great distances apart
d- some are great distances apart

5. Constellations may be only visible during certain seasons due to the Earth's orbit around the___________________.

a- Earth
b- Mars
c- Planets
d- sun

6. Orion is visible during the winter night sky and is one of the most recognizable constellations – it contains some of the _________________ stars that we can see and is named for the hunter from Greek mythology.

a- biggest
b- brightest
c- smallest
d- darkest

ACTIVITY FROM PORTUGAL

Earth and Sun sizes in my body

Authors: José Gonçalves and Rosa Doran

Translation: José Gonçalves and Rosa Doran

The children will learn in an empirical way what is the size of astronomical objects like the Earth and the Sun, and to compare them.

Keywords - Earth, Sun, dimensions, Physics, Astronomy, size, diameter, star, planet

Aims and participants

- **Aims of the activity** - Experience what is the size of astronomical objects and relate it to daily life sizes, such as the size of human body.
- **Educational level** - Primary and middle school.
- **Age range** - $<$ 11, 11 - 12+
- **Time** - 50 minutes.
- **Group size** - Group; group size 3 people (maximum 24 people at once).
- **Location** - Any location is fine.

List of material

Age: $<$ 11 years old

- rice or marbles or bottle caps
- paper
- pen

Age: 11-12+ years old

- Internet to check the Earth and Sun sizes, and to investigate other information
- rice or marbles or bottle caps

- paper
- pen

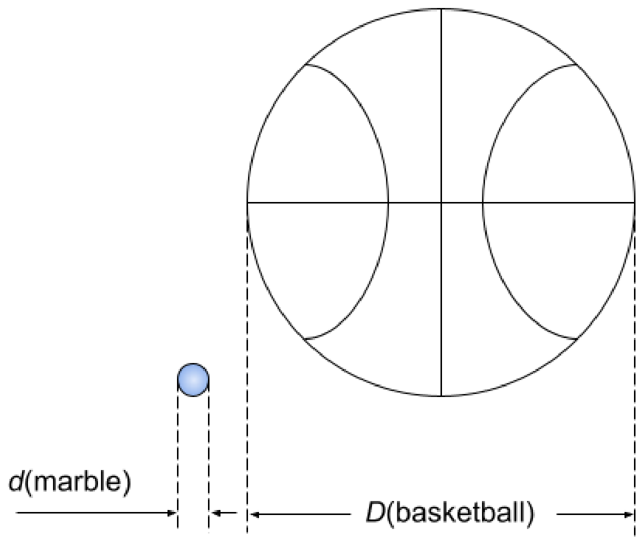


Figure 1: Relation between the size of the basketball and the size of the marble.

Goals of the activity

Age: < 11 years old: Learn about sizes in the Solar System.

Age: 11-12+ years old: Learn about sizes in the Solar System. Learn about proportions.

Description of the activity

Preparatory activity

Start the activity by discussing with the children. Ask them questions such as: “Can you tell me how big our Sun is? And our Earth? Which one is larger? By how much?”.

Let the children make their own hypothesis.

Ask them ”How many Earths do you think you can align along the diameter of the Sun?”. Tell the students that to find the answer to those questions they can start to use marbles and a basketball.

Measuring ratios

They can start to find the proportion between the size of a marble and a basketball (see Figure 1).

Ask them to measure the relative size of the basketball with respect to the marble. In other words, they need to find the ratio of the size of the marble and the basketball by using a piece of paper and a ruler. Different groups could find different ways to carry out the measurement. For example, some students could measure the size of the ball and of the marble, and they can calculate the ratio:

$$\frac{size(basketball)}{size(marble)}$$

Other students could instead align the marbles along the basketball radius and count how many marbles are needed to cover the basketball size. In any case, they are supposed to find the same value.

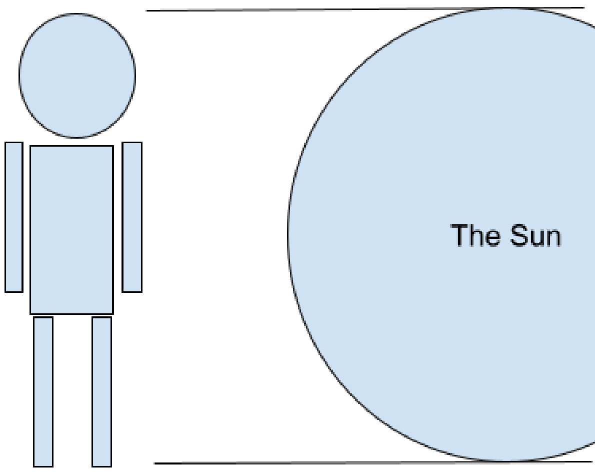


Figure 2: Compare the size of the Sun with the height of the student.

Final activity

As a final activity, try to connect the relative size of Earth and Sun with the dimension of every-day objects that the students might know. This last part of the activity can be performed differently, according to the age of the students.

For students with age $<$ 11 years old

Tell the students to imagine that one marble has the size of our Earth. Now we have to figure out how bigger the Sun is, with respect to our Earth. Tell them that our Sun is 110 times bigger than our planet. How can we re-create this ratio by using the marbles? Suggest them to align 110 marbles in a straight line. Then, they can draw a circle by using half of this length as a radius. Or you can ask them to draw a circle with that size (e.g.: you can use a rod and a stick to draw the circle on sand or a pencil on paper). That circle would be the size of the Sun, when the Earth is represented by a marble. Ask the students: Did you expect that? How do you feel to know this information?

For students with age > 11 years old

Teachers can start the activity as mentioned earlier. However, if the students already know how to calculate ratios, the section "Measuring ratios" can be skipped.

Ask the students to imagine how big the Earth is, if the Sun had the size of one of the pupils. Suggest them to measure the height of one student from their own group. Each group will try to find out some information about Earth radius and Sun radius (or you can provide those values). They will perform calculations to discover that the ratio of the Sun and Earth radii is about 110. By using proportions ($\frac{d_{\text{Sun}}}{d_{\text{Earth}}} = 110$ ou $d_{\text{Sun}} = 110 \times d_{\text{Earth}}$) and assuming the Sun has the size of one of the pupils, they will calculate the size of the Earth. Ask them what object in their everyday life has this size that they have calculated.

They can also use the size of an insect (or other thing) as the Earth, to calculate how big the Sun would be. Ask them to indicate objects with the calculated Sun size.

Note: if you want, you can reverse the problem by asking them the size of an object if one student represents the size of the Earth.

Optional extension of the activity

They can create an activity to present to the community. The activity could be in the format of a song, a storytelling, a game, a poem, a video, ... Let the creativity of the children be ahead!

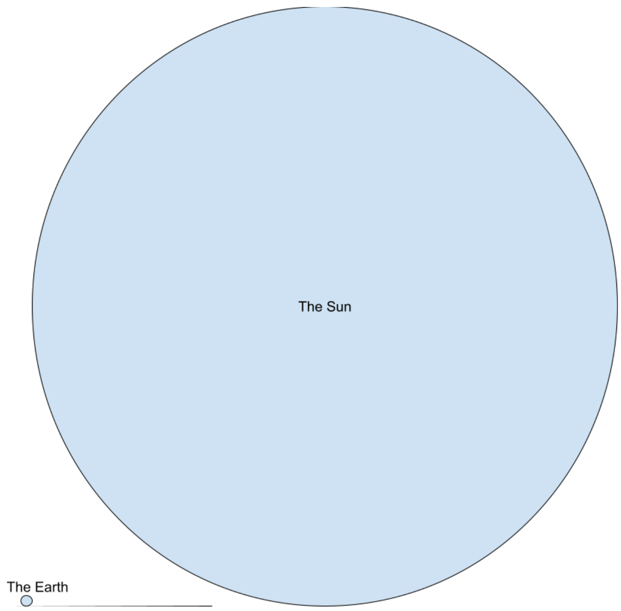


Figure 3: Compare the size of the Sun and the Earth. Image not to scale.

What's going on: physical explanation

The diameter of the Sun is:

$$D_{\text{Sun}} = 1.39 \times 10^6\,\text{km}$$

The diameter of the Earth is:

$$D_{\text{Earth}} = 1.27 \times 10^4\,\text{km}$$

The ratio can be calculated and we obtain:

$$\frac{D_{\text{Sun}}}{D_{\text{Earth}}} = \frac{1.39 \times 10^6}{1.27 \times 10^4} \sim 110$$

It means that the Sun is almost 110 times bigger than our planet.

Let's take the average size of a person 1.70 m. To find out the size of a body that could be our Earth in this case, we use:

$$\frac{D_{\text{Sun}}}{D_{\text{Earth}}} = \frac{D_{\text{person}}}{D_{\text{object}}} \Longleftrightarrow 110 = \frac{1.70}{x} \Longleftrightarrow x = 0.015\,\text{m} = 1.5\,\text{cm}$$

So, the size of the object that can represent our Earth if the person is the Sun, must have a size of 1.5 cm!

Evaluation

Age: < 11 years old: ask the students to draw the Sun by knowing that Earth has 1 mm.

Age: 11-12+ years old: ask the students to find the ratio between the size of Jupiter and Earth and ask them to draw Jupiter, if the Earth is 1 mm.

Interdisciplinary ideas

Sizes and distances in Solar System (11-12 years in Portugal).

Connection to other activities and why

Pinhole camera (measure the diameter of the sun).

Further Reading

- Star sizes: https://www.schoolsobservatory.org/learn/astro/stars/class/starsize
- Information about the Sun: https://en.wikipedia.org/wiki/Sun
- Information about Earth: https://en.wikipedia.org/wiki/Earth
- The biggest star: https://www.space.com/41290-biggest-star.html
- ESA missions to the Sun: https://www.youtube.com/watch?v=YYTh3ontyh4
- ESA Solar System: https://www.esa.int/Enabling_Support/Operations/Solar_system
- NASA Solar System: https://solarsystem.nasa.gov/

ACTIVITY FROM SLOVENIA

Chasing the Moon

Authors: Andrej Guštin and Damir Hržina

Translation: Andrej Guštin and Damir Hržina

Determination of some characteristics of the Moon's orbit, especially the difference between the synodic and sidereal periods (months) of the Moon and the inclination of its orbit relative to the ecliptic.

Keywords - Moon, angle measurements, star charts, orbit of the Moon, constellations.

Aims and participants

- **Aims of the activity** - Show that it is possible to determine some characteristics of the Moon's motion around the Earth with simple measurements.
- **Educational level** - Primary, Middle School.
- **Age range** - 11-12+
- **Time** - 1-2 hour of preparation and analysis at school.
- **Group size** - Individual and group; group size 4 people (maximum group size one school class).
- **Location** - Indoor/outdoor

List of material

Material needed to build the cross-staff (see also the activity "The sky at your fingertips").

- a sheet of stiffer paper (A4 at least 200 g/m^2)
- 40 cm ruler
- pen
- scalpel

- scissors
- adhesive tape
- Cross-staff cardboard mask

Additional material.

- Star chart (Figure ?? and)
- Camera/mobile phone (optional)

Figure 1: Material needed to build the cross-staff.

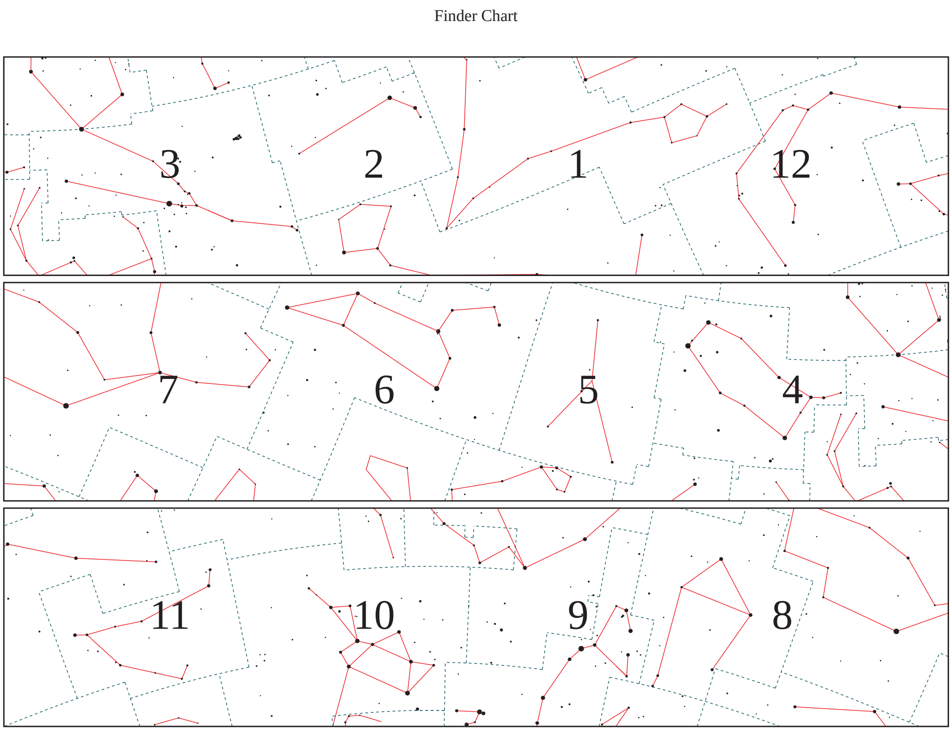


Figure 2: Star finder chart. More detailed charts are reported in Appendix

Goals of the activity

The main goals of the activity are:

- Measuring with angles applicable between celestial bodies and as a classroom activity.

- The movement of the Moon across the sky and in space.
- Orbit of the Moon.
- Eclipses.
- Analysis of measurements.

Description of the activity

Description of the activity Determining the synodic and sidereal periods of the Moon can be done using previous measurements of the positions and phases of the Moon. Of course, there will be large errors in these measurements, but the pedagogical purpose of the observations will still be achieved. Students will learn about the apparent motion of the Moon in the sky, its approximate speed, the reason for the difference between the sidereal and synodic periods, and the basic elements of the Moon's orbit.

Determining the sidereal period of the Moon

By observing the Moon and simply plotting its position on a star chart drawn in the celestial ecliptic system (by comparing real position on the sky with sky chart or, for better accuracy, using a simple method described in the activity Measurements on the celestial sphere and the sky charts), it is possible to obtain the coordinates in the celestial ecliptic system (ecliptic longitude and latitude). To determine the sidereal period, a minimum of two longitude measurements are required, for example in two consecutive evenings (a period of about one day is the fastest method, because the results can be obtained in about 24 hours). In order to achieve better results, the measurements can be carried out over a longer period of time and over several evenings. After making the measurements, apparent angular speed (ω) of the Moon around the Earth, and corresponding sidereal period (P_{sid}) are calculated as:

$$\omega_{sid} = (l_2 - l_1)/(t_2 - t_1)$$

$$P_{sid} = 360 \deg / \omega_{sid}$$

where:

- ω_{sid} - apparent angular speed of the Moon around the Earth (in degrees per day)
- P_{sid} - sidereal period of the Moon (in days)
- l_1 - longitude (in degrees) at moment t_1 (in days), that is first measurement
- l_2 - longitude (in degrees) at moment t_2 (in days), that is second measurement

  If $(l_2 - l_1) < 0$ then add 360deg to that difference in longitude.

Determining the synodic period of the Moon

As the Moon orbits the Earth, it changes its phases as a result of the change in the mutual position of the Earth, the Moon and the Sun. By measuring the change in the phase of the Moon over a certain period, the synodic period of the Moon can be determined. Previous measurements can be used, or carry out our own. To convert Moon phase (ratio between lit section and diameter of the Moon) to phase angle (angle between the Earth and the Sun as viewed by the Moon) avoiding the use of trigonometric functions, graphical methods (explained in figure 1) or previously prepared tables can be used. When phase angles in some interval of time are known then the synodic period (P_{syn}) is calculated as:

$$\omega_{syn} = (\Phi_1 - \Phi_2)/(t_2 - t_1)$$

$$P_{syn} = 360 \deg / \omega_{syn}$$

where:

- ω_{syn} - apparent angular speed of the Moon around the Earth wrt. to the Sun (in degrees per day)
- P_{syn} - synodic period of the Moon (in days)
- Φ_1 - phase angle (in degrees) at moment t_1 (in days), that is first measurement
- Φ_2 - phase angle (in degrees) at moment t_2 (in days), that is second measurement

  If $(\Phi_1 - \Phi_2) < 0$ then add 360deg to that difference in phase angle. Note that phase angle is decreasing over time, and between the new and full Moon is negative, for eg. phase angle of the first quarter is -90deg (Figure 3)!

Determining the inclination of the Lunar orbit around the Earth with respect to the Ecliptic

For this activity measurements performed for the previous activity, *Determining the sidereal period of the Moon*, can be used, but a longer period is needed (at least more than a half month). On the sky maps (celestial ecliptic projection) plotted positions of the Moon are used to determine Lunar path between the stars. A curve can be drawn through the points and extreme values can be found on it in relation to the ecliptic. If the interval is long enough the curve can have more than one extreme. The measured inclination in that case will be equal to the arithmetic mean of the absolute values of the extremes found. Another way to determine the inclination is to measure the angle of inclination of the curve at the point where it intersects the plane of the ecliptic (the so-called node).

What's going on: physical explanation

The Moon orbits the Earth on a path that is not circular and that does not lie in the plane of the ecliptic (the plane of the Earth's orbit around the Sun). As the Earth also revolves around the Sun, the Moon shows a complex motion. By careful measurements, even over a shorter period of time, it is possible to show that the Moon moves among the stars. By determining the angular velocity, it is possible to roughly determine its sidereal period (the period when the Moon will complete one orbit around the Earth relative to the stars), and by comparing it with the synodic period (the period of changes of the Moon's phases, that is, period when the Moon will complete one orbit around the Earth relative to the Sun) it can be seen that they do not coincide as a result of the Earth's motion around the Sun. If the measurements are carried out over a longer period of time, it can be noticed that the Moon's motion is not uniform, and that its orbit is tilted in relation to the ecliptic which is the reason that we don't have eclipses on every full or new moon, but only when the Moon is also near one of the nodes.

Evaluation

- By marking the result of a student's work.
- By discussion about Moon dynamics with students.

Interdisciplinary ideas

Connections to the 7th and 8th grade elementary schools curricula.

Connection to other activities and why

In the activity "The sky at your fingertips" simple methods that can be used for measuring angle distances on the celestial sphere needed for determining positions of the Moon on the sky charts are explained.

Further Reading

- https://pwg.gsfc.nasa.gov/stargaze/Scrostaf.htm
- http://www.scholarpedia.org/article/Astrometry

Additional finder charts

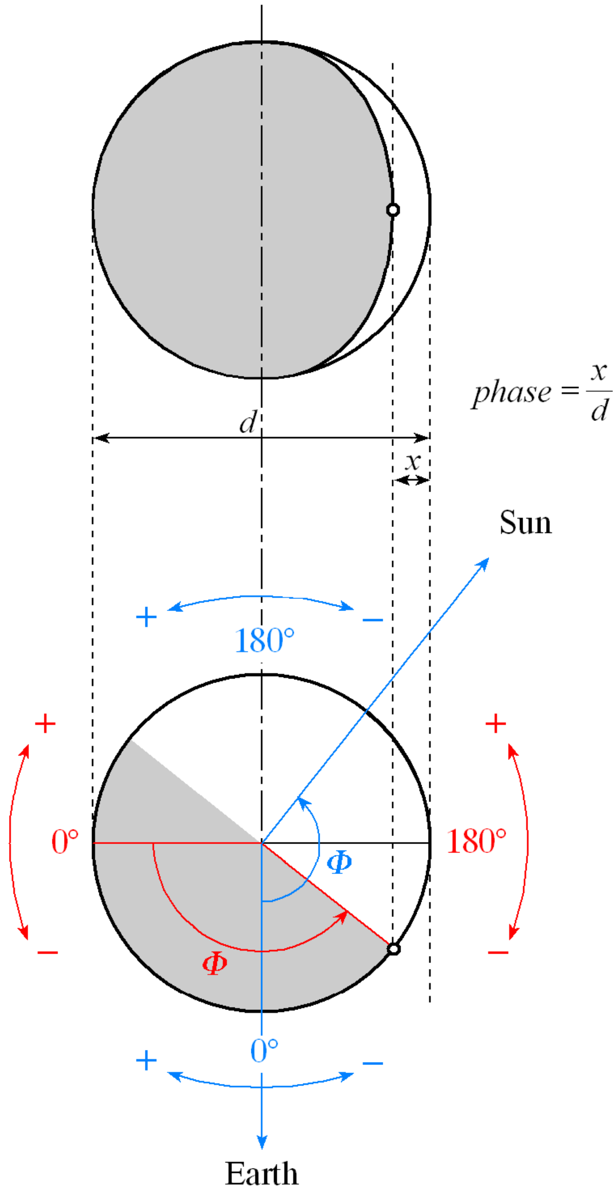
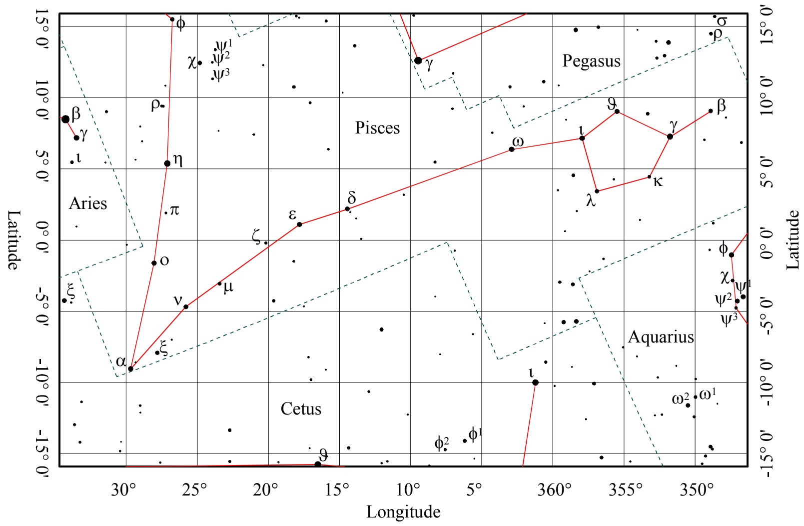


Figure 3: Determination of the phase angle Φ from the drawing of the Moon. In our case the phase angle is measured from the Earth-Moon direction to the Moon - Sun direction and there are two possible ways shown in blue and red. Values of the phase angle are between -180deg and 180deg. Corresponding sign is represented by "+" and "-". Note that: phase $= 0$ (new moon) -> $\Phi = -180\,\text{deg}$ (or 180deg); phase (first quarter) $= 0.5$ -> $\Phi = -90\,\text{deg}$; phase $= 1$ (full moon) -> $\Phi = 0\,\text{deg}$; phase $= 0.5$ (last quarter) -> $\Phi = 90\,\text{deg}$



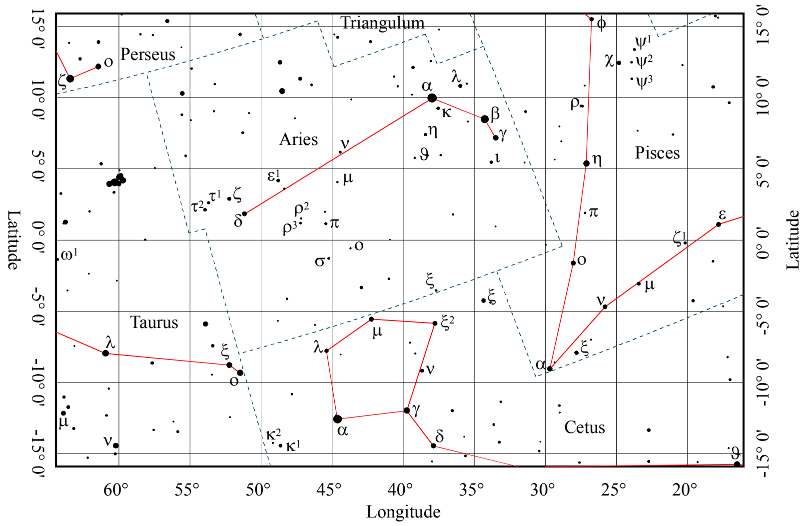


Figure 4: Additional finder charts.

ACTIVITY FROM SPAIN

The colors of light

Authors: Juan Ángel Vaquerizo

Translation: Juan Ángel Vaquerizo

The precise colors coming from a light source can be seen when its light is spread into a spectrum by a spectroscope. In this activity, we will make a papercraft spectroscope to see all the colors that make up the light from different sources.

Keywords
- Light
- Spectroscope
- Colors
- Spectrum
- Wavelength

Aims and participants

- **Aims of the activity** - To introduce the basics of spectroscopy and to show how white light is composed of different colors.
- **Educational level** - Primary school
- **Age range** - 9 - 12+
- **Time** - 1 - 1.5 hour
- **Group size** - The students will Work in groups of 2-4, but making one paper spectroscope each.
- **Location** - Outdoor or indoor (room with a window).

List of material

- A4 dark colored cardboard.
- A4 printed template.
- Scissors and (for older kids) utility knife (or cutter).

- CD or DVD wedge.
- Tape and/or paper glue.
- Aluminum paper (optional, for the slit).

Figure 1: Materials for the activity.

Goals of the activity

Observe the behavior of light. See the formation of a spectrum from a light source. Understand how white light is composed of different colors (wavelengths). Use light sources to create a spectrum. Explain the basics of how a diffraction grating works. Evaluate the different types of spectra (continuum, emission and absorption).

Description of the activity

A spectroscope is a scientific instrument that splits light into its different wavelengths, which can be seen as different colors. Violet has the shortest wavelength and red the longest. Light usually contains a mixture of different wavelengths, so by studying these, scientists can find out useful information, such as the chemical elements present at the source of the light or its temperature. Spectroscopes are widely used in astronomy, chemistry, and other areas as mineralogy. In this activity we will make a paper spectroscope to study the spectrum of different types of light sources.

Preparatory activity

We can first study the rainbow formation to deduce the components of white light. Rainbow is a well-known optical phenomenon that appears as a multi-color arc in the sky (Fig.2). Where do these colors come from? Why are they always in the same order with red on one side and blue on the other? The rainbow is formed due to the process of refraction of sunlight from rain droplets. It is a great demonstration of the fact that light is composed of a spectrum of wavelengths, each associated with a different color. Rainbow can be observed not only on rainy days but on sunny days too, near a fountain or a waterfall, where water droplets are present in the air.

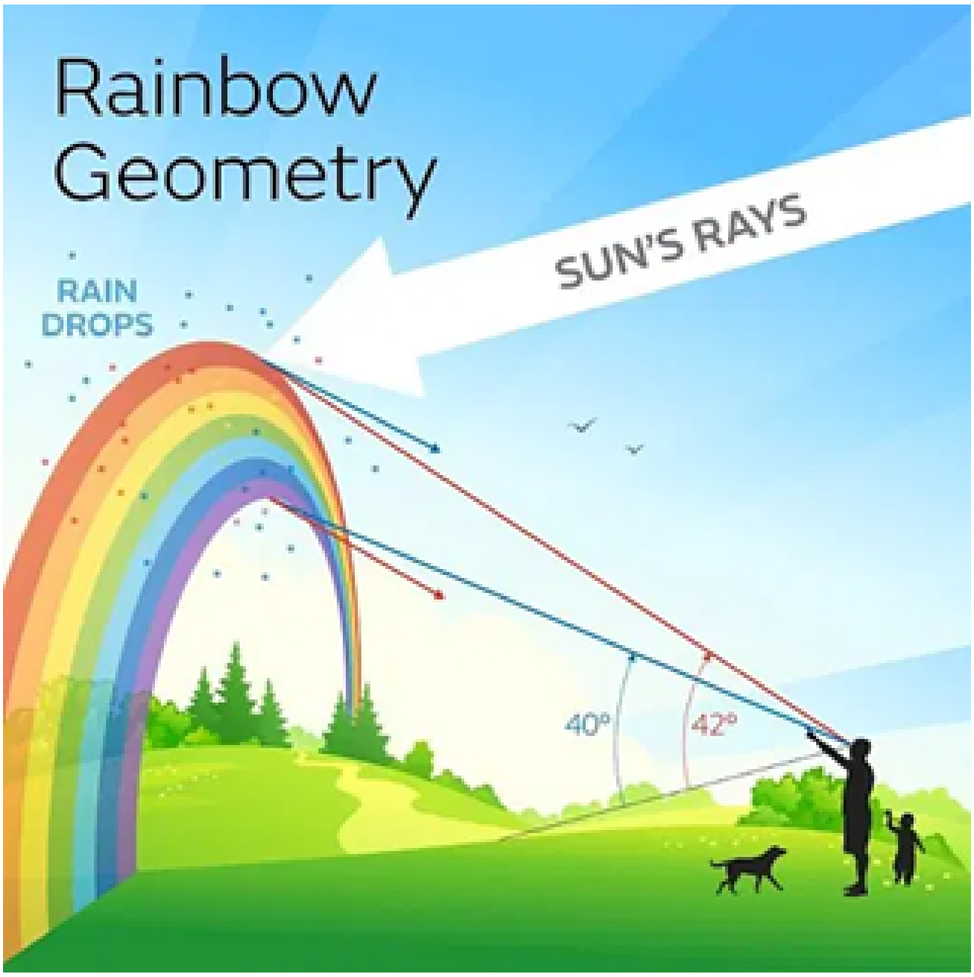


Figure 2: The formation of a rainbow. Credit: metoffice.gov.uk

Making the papercraft Spectroscope

1. To make a papercraft spectroscope, copy the template (you can find it at the end of this chapter) onto (or print it using) an opaque paper or cardboard and cut it out (Fig.3). Darker colors as black, navy blue, dark grey or dark green work better.

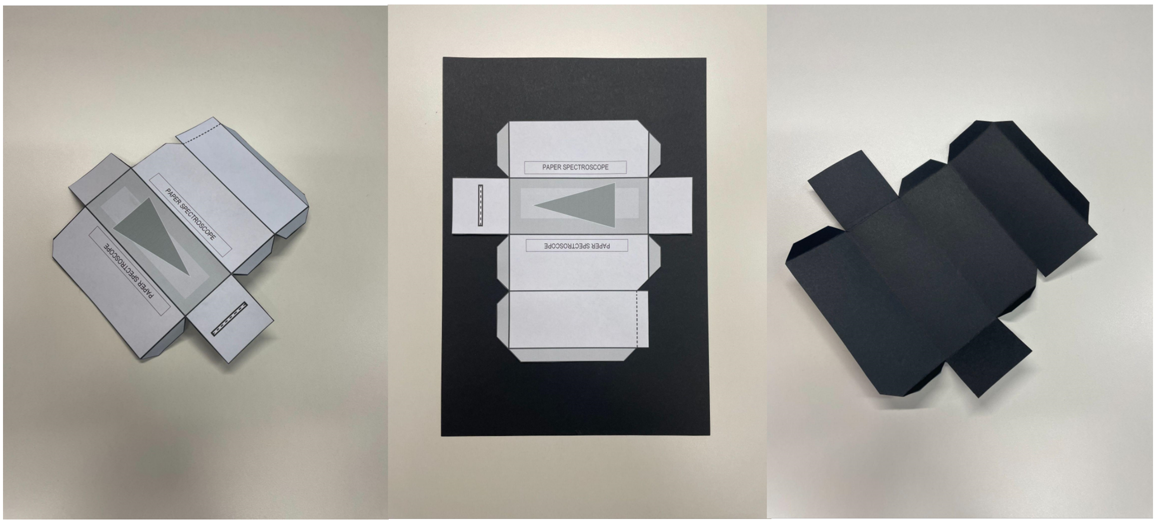


Figure 3: How to prepare the cardboard of the spectroscope.

2. Cut on the continuous black lines, including the small slit (dotted line). Don't cut on grey lines, these must be folded. Cut the slit with straight edges carefully, about 0.5 mm wide, to let through some light (Fig. 4). Alternatively, you can cut it wider, and then form a narrow slit by the gap between two pieces of opaque tape or paper attached. Also, it could be easier to cut the slit on an aluminum sheet and then attach it to the front window of the spectroscope.

3. Now cut a used DVD or CD into wedges using a pair of stout scissors (Fig. 5 and Fig. 6). You can get up to 16 useful wedges out of one CD to use them as diffraction gratings. You can also use blank CDs or DVDs. Be careful when cutting the CD so that the reflective part does not peel off.

4. Attach a wedge of CD on the bottom part, on the side of the paper that will become the inner part of the "black box" (usually the unprinted side). Make sure the iridescent shiny side is exposed but cover the mirror-like part at the narrow point with tape or glued on paper (Fig.7).

5. Fold on the gray lines of the cardboard to make a little dark box with the CD piece inside on the bottom. Glue or tape closed edges (A to A, B to B, E to E, etc.) accurately close, so that they don't leak light, but do not cover the slit. You can tape C and D less thoroughly so the back can be opened to look at or readjust the CD piece (Fig. 8).

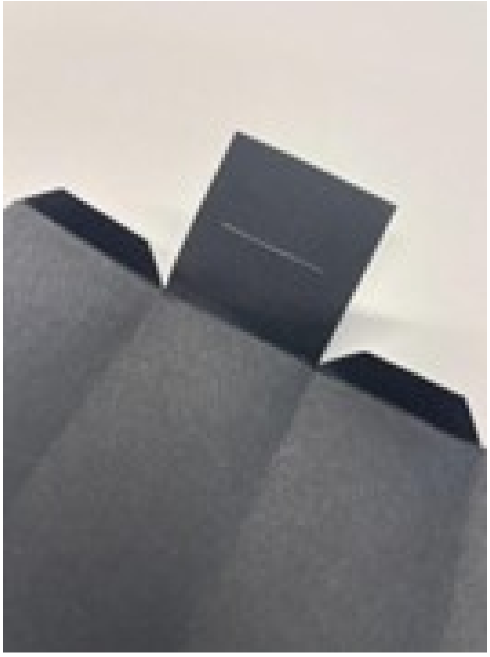


Figure 4: How to create a slit on the cardboard of the spectroscope.

Taking the spectrum of various light sources

Now point the slit at a light source and look through the hole at the CD. Try looking at different types of light. For example, try looking at an incandescent light bulb and then at a fluorescent light bulb (Fig. 9).

Try other light sources (see some examples of possible spectra in Fig. 10, but NEVER LOOK AT THE SUN! A bright spectrum of sunlight can be seen if you look in the general direction of a window. Look at light reflected off on colored paper. What happens if you widen the slit?

Looking for the information given by spectra

Compare the obtained emission or absorption spectra with laboratory emission spectra of different chemical elements to discover the composition of the light source. Like a fingerprint detective, it is possible to deduce the composition of the light source (gas contained in a light bulb or star). For upper school levels, it is possible to introduce that the continuous spectrum produced by a light source is related to its temperature, so by studying the continuous spectrum of a star, it is possible to deduce its temperature.

Possible suggestions

- Try making slits of different widths to understand how they affect the spectrum. Students will understand the importance of the slit to be as narrow as possible, but wide enough to let light pass through it to see the spectrum clearly.

- Try making windows with different sizes to understand how they affect the spectrum.

Figure 5: Creating gratings out of a DVD.

Students will understand the importance of the window to be as small as possible to let the inside of the box to be as dark as possible.

- Try different orientations for the CD to check the formation of the spectra. One crucial step for the spectrometer to work is that the concentric grooves along the CD are lined up such that they are "horizontal", that is, they need to be parallel to the slit. If they are not parallel to the slit, the diffraction is difficult or even will not take place.

- Try to recognize the type of spectrum obtained (continuous, emission or absorption).

- Try to check if it's possible to discover the fingerprints of chemical elements in the spectrum by comparison with a given set of laboratory spectra of chemical elements.

What's going on: physical explanation

There are different types of light spectra, classified by the nature of the physical process that produces them (Fig. 11).

Continuous Spectra

In a continuous spectrum, the emission varies evenly from color to color, and in an ideal continuous spectrum, there are no missing colors. This is the type of spectrum that objects like a star, planet, or light bulb filament emit based simply on their surface temperature. This type of spectrum is useful because the shape of the curve and the peak wavelength

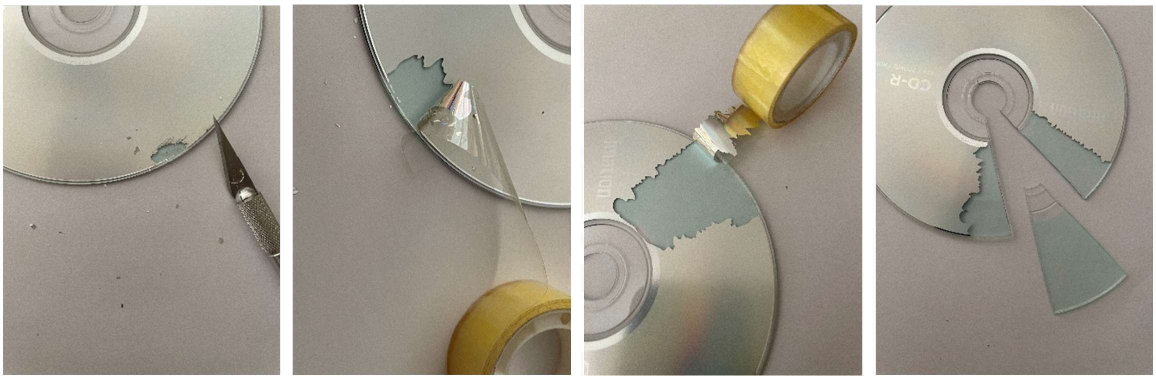


Figure 6: Creating gratings out of a CD.

Figure 7: How to attach the wedge of a DVD (on the left) or CD (on the right) on the cardboard of the spectroscope.

(i.e., the brightest color) are directly related to surface temperature and nothing else. Hot stars emit more blue than red light, and therefore appear bluer in the night sky. Cool stars emit more red than blue light and appear redder.

Absorption Spectra

An absorption spectrum looks like a continuous spectrum, but with some colors significantly dimmer than others, or nearly missing. These missing colors appear as black lines known as absorption lines. This is because when light passes through a material (a dense gas, for example) atoms and molecules in the gas absorb some wavelengths. What is interesting and very useful for scientists is that each chemical element or compound in the gas absorbs a very specific pattern of wavelengths. If you recognize the "signature" of that element or compound, you know it exists in the gas. The relative strengths of the absorption lines (how dark they are) gives you an idea of the different amounts of each material and the temperature and density of the gas. (Why does each element have a specific signature? It has to do with those electrons moving between energy levels, which

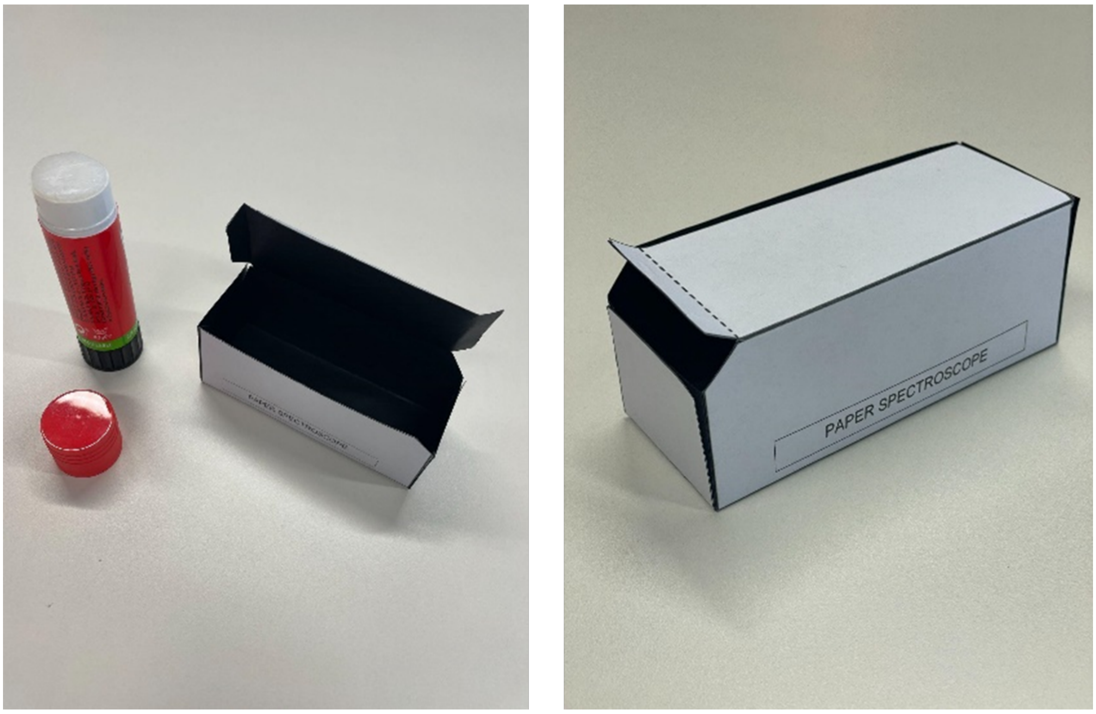


Figure 8: How to fold the cardboard for creating a spectroscope.

we explain more in a bit.)

Emission Spectra

The pattern of an emission spectrum is the inverse of an absorption one. An emission spectrum is mostly dark with bright colored lines known as emission lines. Emission lines also correspond to specific chemical elements. Each element has a specific pattern of colors that it emits. In fact, the wavelengths of an element's emission lines are the same as the wavelengths of its absorption lines. Emission spectra are particularly useful for studying clouds of hot gas. The difference in brightness of different emission lines can give us information about the temperature and density of the gas and the relative amounts of different elements in the gas.

Evaluation

A possible evaluation tool is a class discussion. Possible guiding questions for a class discussion:
- Is the size of the slit important? Better narrower or wider?
- Are there differences between using a CD or a DVD as diffraction grating?
- Is it important to get a closed blackbox inside the spectroscope?
- Is it better to use light colors or dark colors for the interior of the box?
- Is it important the size of the window? Why?
- What differences or similarities did you notice between the spectrum of the light sources you chose?

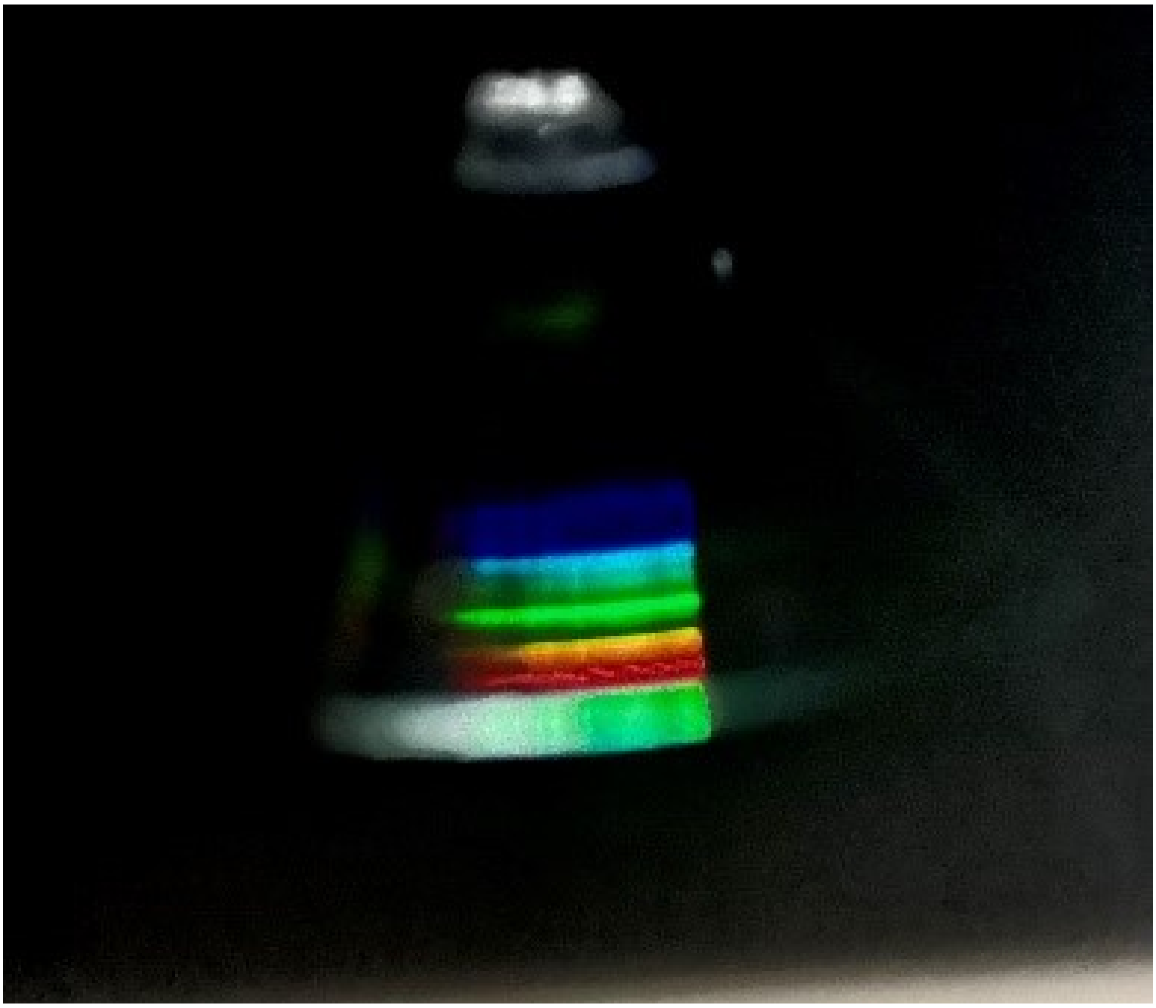


Figure 9: Fluorescent light bulb spectrum.

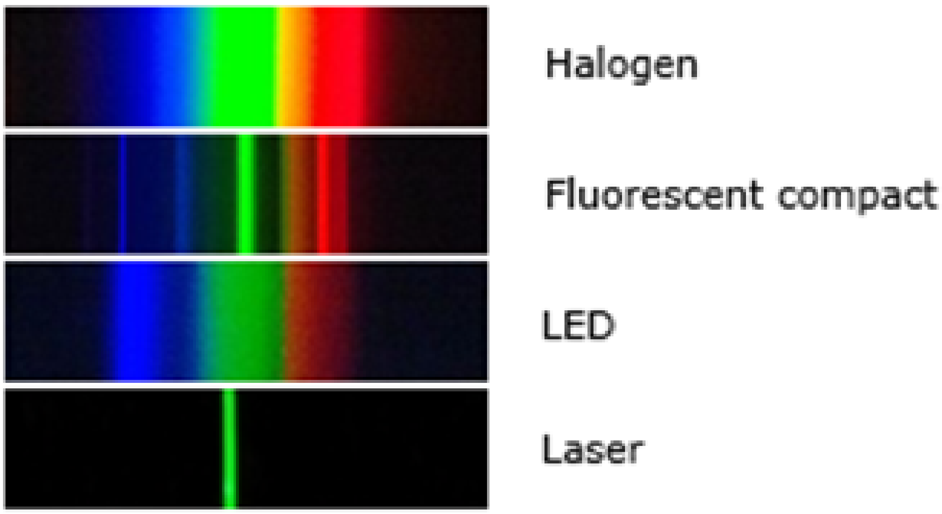


Figure 10: Spectra from several types of lights.

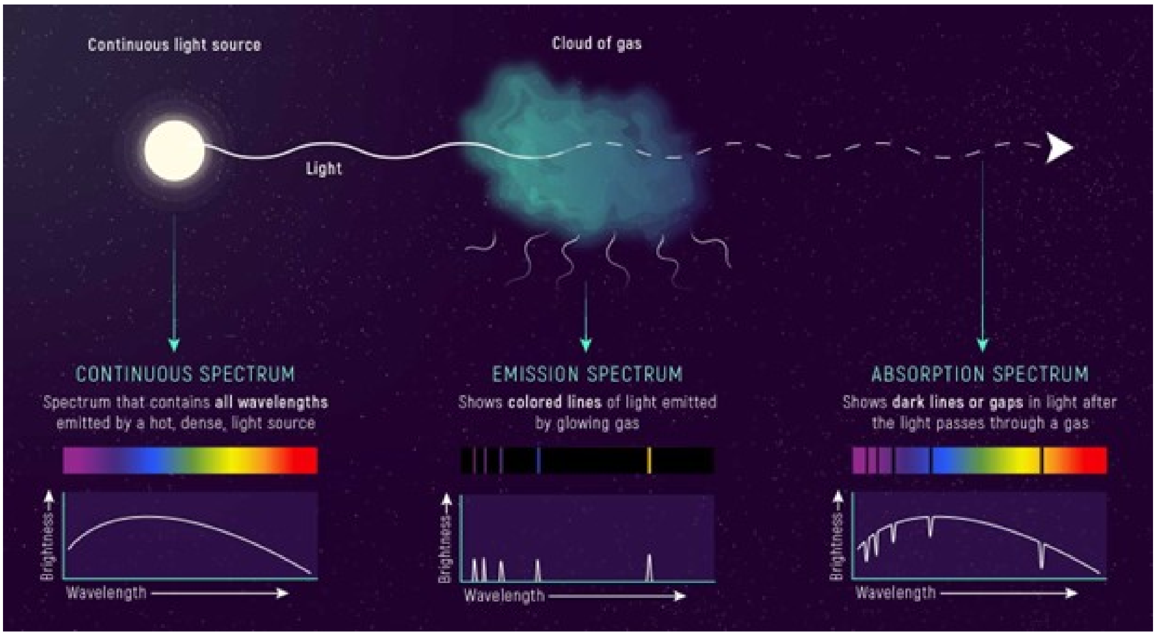


Figure 11: Different types of spectra. Credit: NASA, ESA, Leah Hustak (STScI).

Interdisciplinary ideas

- Science: Sun, Stars, Spectroscopy, Chemical composition, Temperature, Light.
- Geometry: position of grooves, concentric circles and parallelism.
- Optics: diffraction gratings, reflection of light.
- Chemistry: spectral fingertips of elements.
- Math: reflection and diffraction angles.
- History and Technology: history of instruments and optics (e.g., prism).
- Art: Spectroscopy for Artwork Analysis (https://sensing.konicaminolta.us/us/blog/spectroscopy-for-artwork-analysis/).

Connection to other activities and why

This activity can be connected to:

- **How telescopes work**: some telescopes are equipped with devices to obtain light spectra.

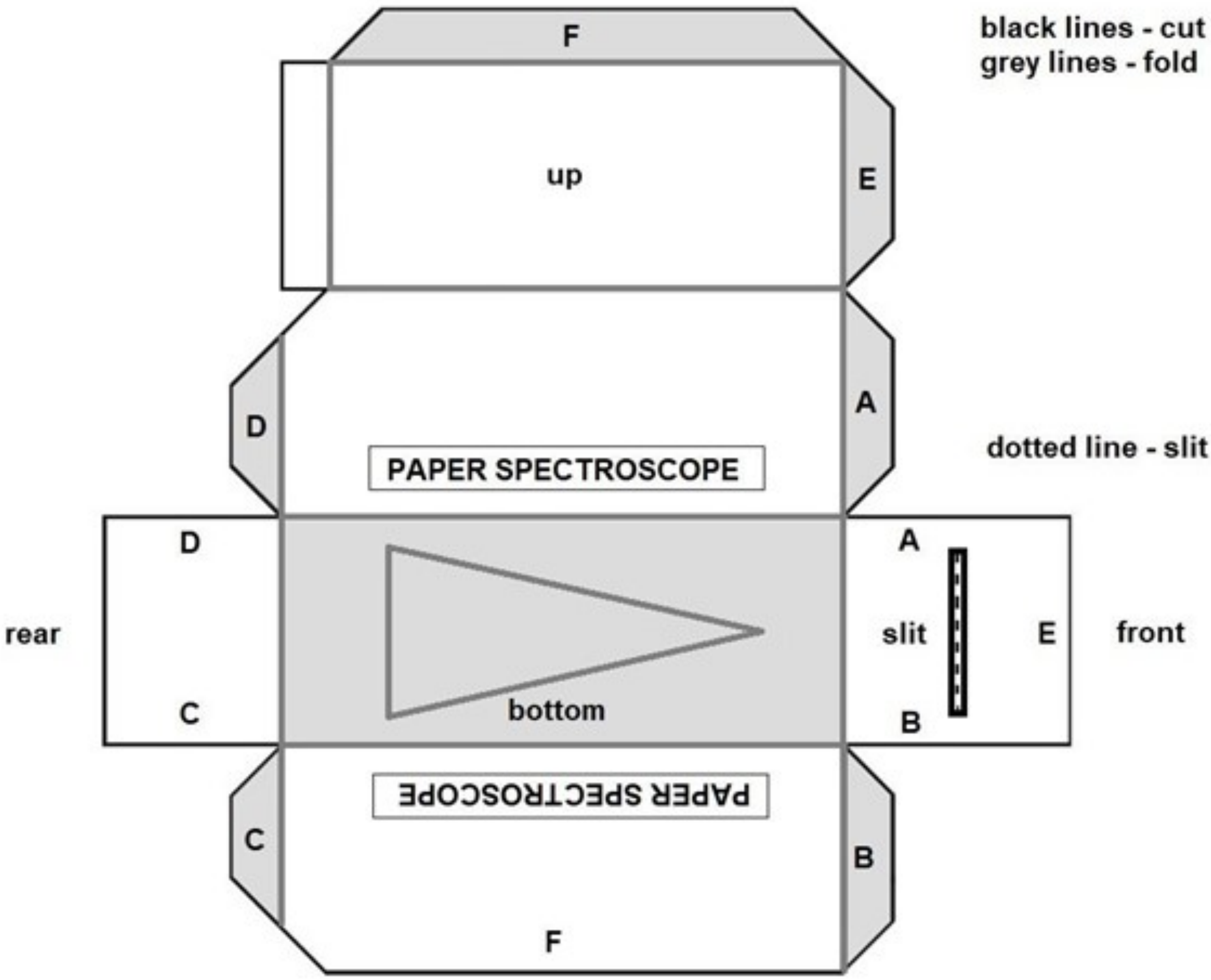
Further Readings

- Spectrometry at school: hands-on experiments link in Science in School – The European Journal for Science Teachers – Issue 14 (April 2010).

- What are the stars made of? link In Science in School – The European Journal for Science Teachers – Issue 37 (September 2016).

- Spectroscopy in Astronomy link – European Southern Observatory.

- Exploring the Universe with Spectroscopy link – Lesson plan (pdf) – Material Research Laboratory at UC Santa Barbara.


black lines - cut
grey lines - fold
dotted line - slit
F
up
E
D
A
PAPER SPECTROSCOPE
D
A
rear
slit
E
front
C
bottom
B
PAPER SPECTROSCOPE
C
B
F

ACTIVITY FROM SYRIA

How do telescopes work?

Authors: Muhammad Alassirry, Turkieh Jbour, Tareq Alkhateb

Translation: Tareq Alkhateb

This activity uses ordinary lenses and mirrors to learn about how telescopes work and the behavior of light in general.

Keywords
- Light
- Telescope
- Mirror
- Lenses
- Refraction
- Reflection
- History

Aims and participants

- **Aims of the activity** - Introducing different types of telescopes and the techniques used to get information about the observed objects.
- **Educational level** - Primary school
- **Age range** - 10 - 12+
- **Time** - 1 hour
- **Group size** - Group activity, in groups of 2-3
- **Location** - Outdoor or indoor (room with a window)

List of material

- 10 – 15 lenses (magnifier lenses will work)
- 10 – 15 small mirrors.
- 3 – 4 laser pointers.

- glass of water.
- teaspoon
- glasses of soap and/or juice.

Goals of the activity

Get to know telescope history and the different types of telescopes. Get to know different types of lenses and how light behaves when passing through them. Get to know how light behaves when reflected on mirrors. Get to know the importance of using a telescope, how to use one, and how we observe the universe.

Description of the activity

The telescope is a great instrument that is shared all over the world, everybody knows about it and yet not all know how it works. This instrument has a great history of development and modifications by great scientists and amateur astronomers. We will start discussing the history behind this great tool, and we will go through stories about scientists using and developing it while we do the experiments.
We can introduce the activity with a little presentation about where do telescopes come from, telling the story of the Dutch inventor Hans Lippershey[1] and then telling about the great scientist Galileo Galilei and his implementation of the device in Astronomy[2] and the impact it had on the way we look at the sky. This activity is made of a series of smaller activities that can be done in different orders, so feel free to rearrange them as you like.

First activity

Our first activity is to imagine ourselves disassembling an ordinary telescope like the one shown in Fig.2.

Telescopes are composed of several lenses. By using several ordinary lenses (for example magnifiers) we can make our own Telescope just like Lippershey or Galileo. Take a lens and start examining its behaviour. You could have them work together when using the lenses in an open space or by standing opposite to one another and moving towards each other to achieve focus. Try to ask the following questions and discuss ideas with kids:
- What happens to the image when I move the lens away from my eye? Or closer to my eye?
- Is the image upside down? How can I correct it? Will rotating the lens work?
- Is the lens that I am using flat? Or does it have a curve?

Using a laser pointer (careful when using laser pointers around kids) can be an effective way to better explain this idea by seeing how light refracts when passing through the lens

[1] Hans Lippershey: link
[2] How Galileo turned the "looker" into a telescope: link

(see Fig.3 and 4)

You can use a white wall or screen to see the different positions of the laser beam, how it is changing according to the position of the lens, and then add another one and observe the light beam on the wall.
You can also introduce the idea of refraction by simply showing a glass of water and a teaspoon in it. Possible questions to drive the discussion: What is happening to the spoon? Why does it look broken? Is it actually? Discuss the answers and introduce the concept of *refraction* of light.
So light is refracted when passing through water. You can now divide the children in groups and give them different kinds of liquids to add to the glass of water, (like soap or juice). Observe with them how light is refracted through these glasses, like in Fig.5.

Second activity

To move on to the next activity we have to ask the question: Are there other ways of changing the path of light? Yes, and the next scientist we talk about changed our perspective of the universe: Issac Newton' (more about Newton in the links below). He thought: "what if we used something other than lenses?". We can ask the same question to the kids and discuss what these "other" tools could be in Newton's idea. The answer would be mirrors: Newton wasn't thinking about refraction, but reflection! Newton used the idea of bouncing light off mirrors to make his own telescope. Now, let's build the telescope that Newton built by using 2 mirrors and a laser pointer (again please be careful!) as shown in Fig.6. You can put the mirror on one side of a table (if you like you can put it on carton paper like in the picture) and then put the other mirror in front of it but tilted 45 degrees. Then you can shine the laser pointer on the bigger mirror and watch the laser beam reflecting on the other one, and then reflecting to the side. You can adjust the mirrors as you like to make the laser beam clearer.

Third activity (facultative)

Now that we know about the 2 main kinds of telescopes, let's see what happens if we combine mirrors and lenses in the same telescope. These are called a "catadioptric telescopes" and in them light experiences both refraction and reflection. We could ask the participants to try and make a simple optical bench by using lenses or mirrors.

Possible suggestions

An interesting activity to do with older students is to have them search about the subject inside the class or as homework (if you are a classroom teacher). You can discuss with the kids how there are also telescopes sent to space, launched in big rockets to help study the universe better away from light pollution. You can also use pictures of telescopes, as the Hubble Space Telescope[3] or the CoRoT space telescope[4] to explain the idea furthermore.

Having a telescope in the classroom would be awesome, for the kids to see an actual one,

[3]The Hubble Space Telescope: link
[4]The CoRoT (Convection, Rotation and planetary Transits) space telescope: link

or maybe planning after the activity is done a field trip to a nearby observatory.
One possible way of widening the activity is to also talk about eyepieces. You can't really see anything when looking into a telescope without an eyepiece, it is an important part of telescopes. You can hint out that we need an eyepiece with the use of a telescope to see the final image and sometimes we use cameras instead.
A storytelling approach to this activity and the stories of scientists is very helpful, like you can invent a character that travels through time and meets scientists and learns to use telescopes, it works great with little kids. The third activity is a way to leave the kids wondering about the universe and its mysteries and how we can unlock some of them, if we think and work hard enough. So, try focusing on explaining this idea to them. A final note is that if you avoid asking the questions to the kids (according to our experience) they will end up asking at least one of them so make sure to read about them just a little bit more (you can use some of the web links reported in Sec.).

What's going on: physical explanation

Light rays change direction, following specific geometrical paths, when they reflect off a surface (reflection) or move from one transparent medium into another, as in the case of lenses (refraction). Telescopes use this behaviour to collect the light received from very dim and really far away objects celestial objects. To do that, the mirrors or lenses have to be really big. The bigger the mirrors or lenses, the more light the telescope can gather and concentrate. That light is what we see when we look into the eyepiece of a telescope. The first telescopes focused light by using lenses. Modern telescopes use mirrors, because they are lighter and easier to make perfectly smooth. The mirrors or lenses in a telescope are called the "optics." The optics of a telescope must be almost perfect. That means the mirrors and lenses have to be just the right shape to concentrate the light. The telescope that use lenses must have one convex lens since it can magnify the objects by bending the path of light. The concave lens is used to extend the focal length in some of the designs of the telescope. The mirrors in reflective telescopes are concave, they are made that way so they can reflect all points of light entering the Telescope tube and concentrate them into a single point, but since you are using a laser pointer you can explain the general idea with the use of normal mirrors. Both reflective and refractive Telescopes have their components painted with special material to make the refractivity or reflectivity of their optics more efficient.

Evaluation

Possible guiding questions for a class discussion:
- What is the use of a telescope tube?
(Answer: to hold the lens or mirrors in the correct place, and to focus on one region in the sky).
- Having a bigger diameter in a telescope a good thing?
(Answer: when we have a bigger telescope, more light can enter, the clearer the image is going to be).
- Should we build a telescope near very tall buildings? or build one near a very bright light source?
(Answer: NO, we need to see the sky, and NO, the surrounding light will affect the way

we observe).
- Why do we use Telescopes?
(More a prompt for discussion, to see how much this was achieved).
A quick small activity we like to call "explain it your own way" can be implemented, where a kid can stand in front of the classmates and explain a small idea: in this activity it can be "explaining how a certain type of telescope work", for example.

Interdisciplinary ideas

This activity can be employed in many curricular subjects, such as: Science; Physics; Mathematics; History and Technology; History of instruments and stories of scientists.

Connection to other activities and why

This activity can be connected to:

- **"Let there be light"... but not too much**: which can discuss the effect of light pollution on the using of the telescope.

Further Readings

Here we report some resources about space telescopes.

- Hubble Space Telescope images, info, videos and other interesting information: link link.
- Some interesting videos to look at about *Hubble's Servicing Mission*, designed and launched for fixing and updating the Hubble Telescope in space: link link.
- James Webb Telescope Gallery: link.
- James Webb Telescope Launch: link

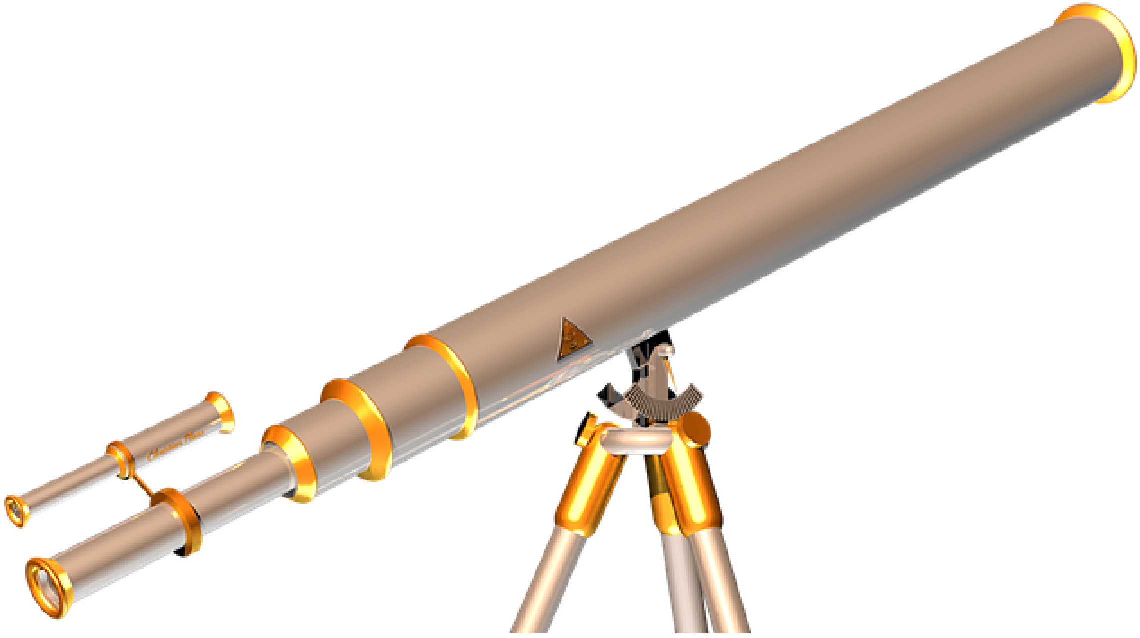


Figure 2: A refractor telescope.

Figure 3: Seeing through lenses.

Figure 4: Seeing through lenses.

Figure 5: Seeing through lenses.

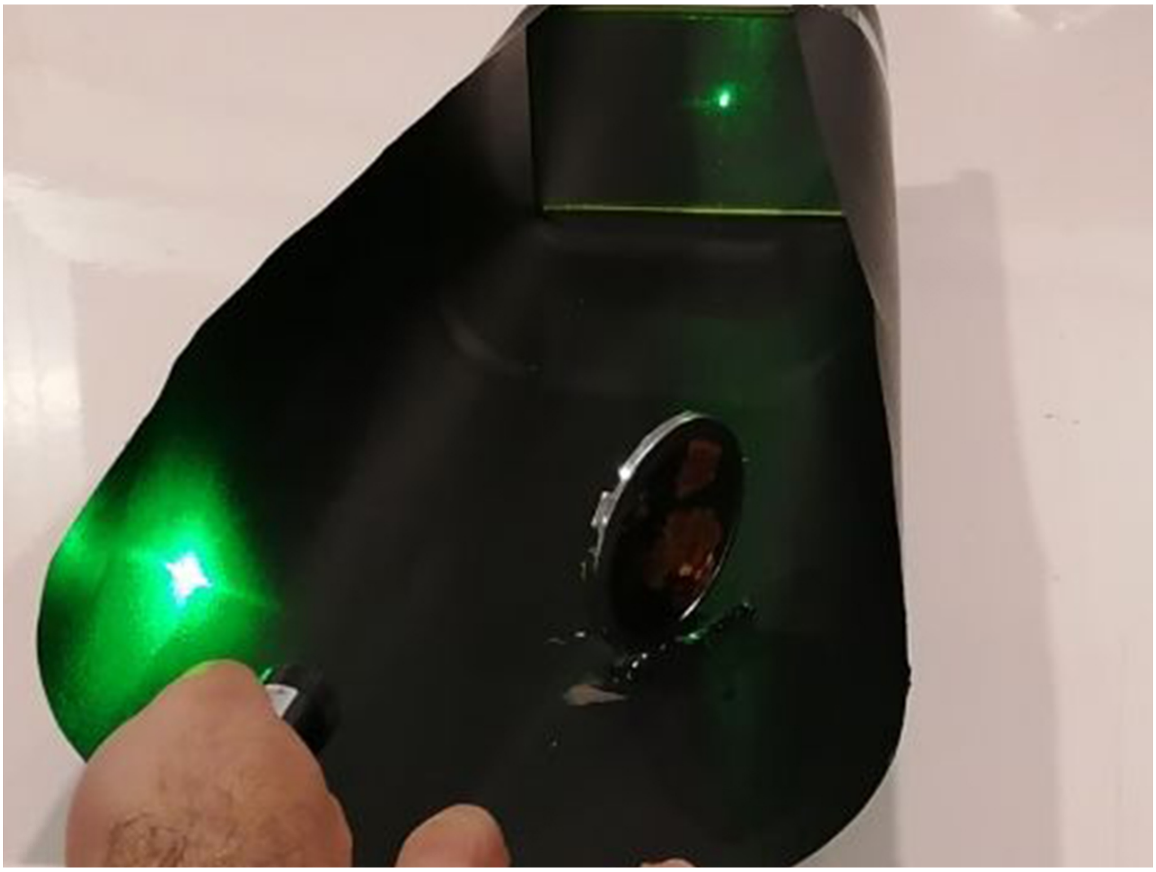


Figure 6: Lightreflecting on mirrors.

ACTIVITY FROM TURKEY

The sun in our box

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Translation: Aysegul Yelkenci

This is the English translation of the activity proposed by NAEC Turkey within the STEAM-Med co-design project.
This activity uses some simple optics to project an image of the Sun by building and using a pinhole camera, and some simple geometry to determine the size of the Sun.

Keywords - The Sun, Pinhole camera,Distance, Size, Diameter, Parallax.

Aims and participants

- **Aims of the activity** - Comparing the Size of the Sun and the Earth Using a Pinhole Camera.
- **Education level** - Primary school
- **Age range** - 9-11; 11-12+ and with small adjustments (e.g., no calculations): 7-8
- **Duration** - 2 hours
- **Type of activity and group size** - group activity (2-4 students per group). Maximum 25 people at once.
- **Location** - Outdoor or indoor (room with a window)

List of material

- 3-4 layers of (colored) cardboard 45 X 65 cm
- Aluminum foil or cardboard
- Baking sheet (Wax paper)
- ruler, meter
- pin/needle

- pen, tape
- Scissors and (for older kids) utility knife
- A4 paper

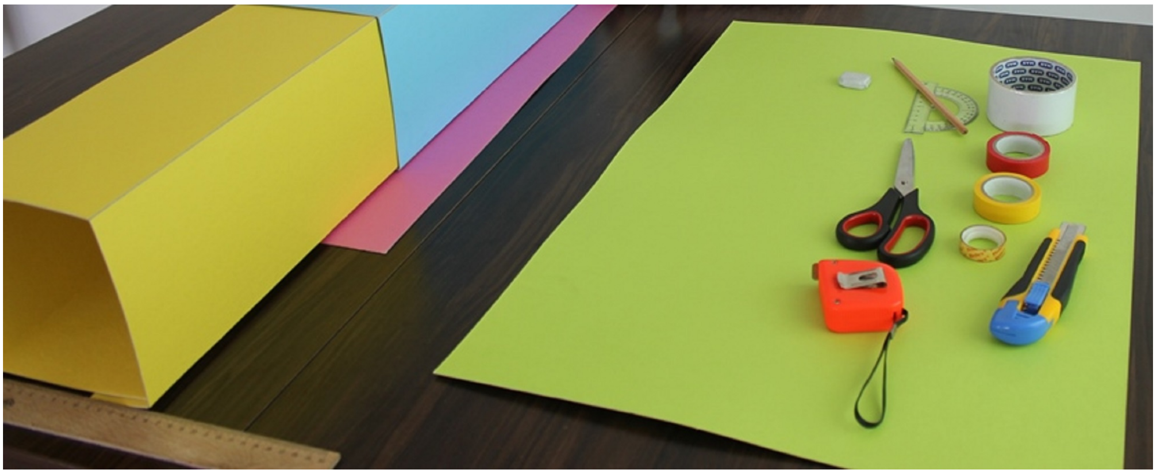

Figure 1: Materials

Goals of the activity

Observe the behavior of light. See the formation of an image with an objective from a light source. Understand how light rays travel in straight lines Use light rays to create a photographic image. Explain the basics of how a pinhole camera works. Evaluate the sizes in the solar system

Description of the activity

A pinhole camera can be used to project images from a variety of light sources. When used to project an image of the Sun or the Moon, you can determine the diameter of the source. The image of the light passing through the hole falls on the projection paper at the other end of the pinhole camera box. Using the image of the Sun formed here, we can infer the true diameter of the Sun.

Preparatory activity

First, examine the behavior of a simple pinhole camera [Fig 2]: make a small pinhole in a piece of paper, take another piece of paper for projecting the image (or simply project on the floor), and head outside. Face the pinhole toward the Sun, and examine the projected image on the other piece of paper. Change the distance between the pinhole and the paper, and observe the changes in the image.

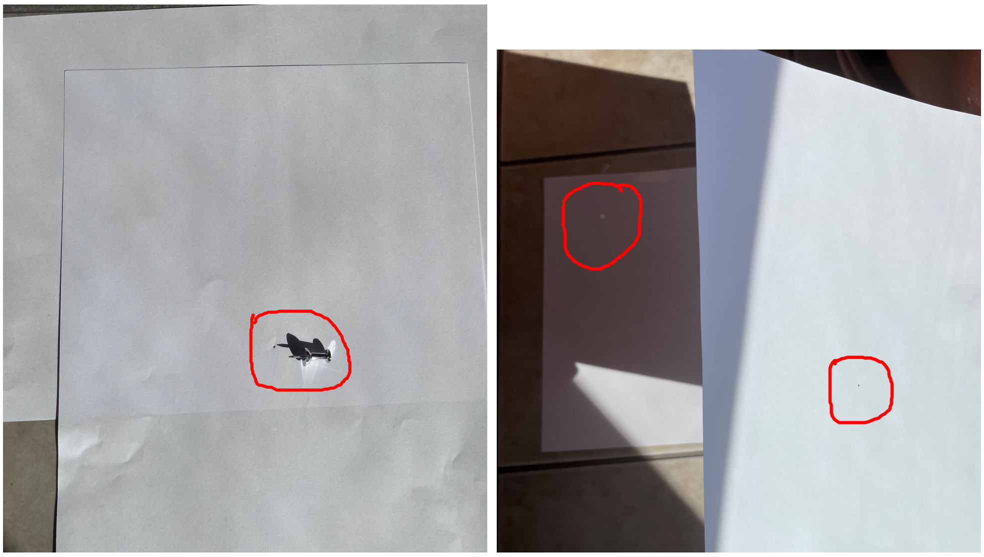

Figure 2: Preparatory Activity: Examine the behavior of a simple pinhole camera

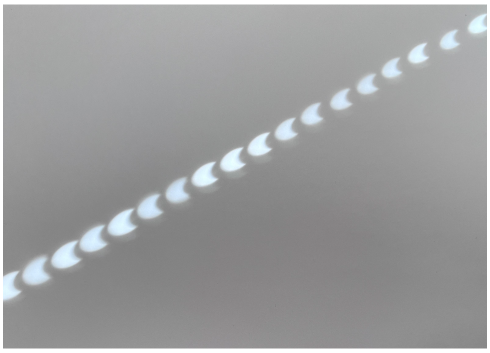

Figure 3: Observing partial solar eclipse on Oct.25, 2022.

Making the Pinhole Camera

- The pinhole camera will be a rectangular or cylindrical prism box with 15 cm wide on each side. Mark the cardboards every 15 cm. Make light cuts with your utility knife (or use the side of the table or a ruler) to make folding easier.

- Fold all three cardboards and attach them end to end. (If you fold the edges of the cardboard in the middle (blue) to 15.3 cm, the other cardboards (yellow and pink) will fit inside easily.) Adjust the length of our cardboards to be 100 cm totally. You can also try this application as 200 cm, 300 cm.

- Cover one end of your pinhole camera box with a baking sheet (wax paper) as a screen. Optionally, you can also make a visor for this part.

- On the other end of the box, place a piece of aluminum foil or the cardboard over the opening and tape it in place at the edges.

- Using a pin or a needle puncture the foil or cardboard to produce a small hole at the center. You now have a pinhole camera.

Figure 4: Making the Pinhole Camera:cut!

Figure 5: Making the Pinhole Camera:fold!

Measuring the Size of the Sun

- Hold the pinhole camera so that the light from the Sun passes through the hole and falls on the wax paper on the other end.

- Using your ruler or a polygon to measure:

  - The diameter of the image of the Sun on the wax paper d =...

  - The distance from the pinhole to the wax paper r = ... (it is better to adjust to 100 cm or 200 cm, ..)

Figure 6: Making the Pinhole Camera:pin it!

You can also use a semi transparent paper and put a grid to find the size of the image of the Sun in the paper.

- You can calculate the diameter of the Sun using the following formula:

$$D = \frac{d}{r}R \tag{0.1}$$

where D: Diameter of the Sun, R: Distance from the Sun, d: Diameter of the Sun's Image, r: Distance of Pinhole to Screen paper

The students can be provided with the distance from Earth to the Sun. In alternative they can calculate it using the speed of light (300000 km/s) and the time taken from the light to travel from Sun to Earth (8.31 min). Include the comparison with the size of the Earth (real result D=109E). instead of calculations use the size as given and proportions (d vs D) to simplify the numbers for younger students. Diameter of Earth is 12742km (E=12742km). Distance from Earth to the Sun (R= 149580000km).

Possible suggestions

- Try making small pinholes with different shapes to understand how they affect the image. For example, use triangle pins or nails to make the hole. an arrow head shaped diaphragm. Observe that the image of the arrow is inverse. Another way to tackle this: look at the image of the Sun through the leaves in an outdoor environment

- Use the pinhole camera to look out for other objects outside like a tree to find out if the image is reversed right to left or upside down. Show why the image of the tree, as viewed through a pinhole camera, would get smaller as the camera is moved away from the object.

- Try to check if you can see sun spots.
- Make a room-size pinhole camera covering the windows with black cardboard and making a hole in the middle, use the board or the sidewall as a screen.
- You can use the same procedure to measure the diameter of the Moon. You'll need to pick a night with a full (or near full) moon. Note: The distance to the Moon is approximately 384,000 kilometers. Compare the size of Sun and Moon

What's going on: physical explanation

The proportion used to calculate the dimension of the Sun originates from the similar triangles method.

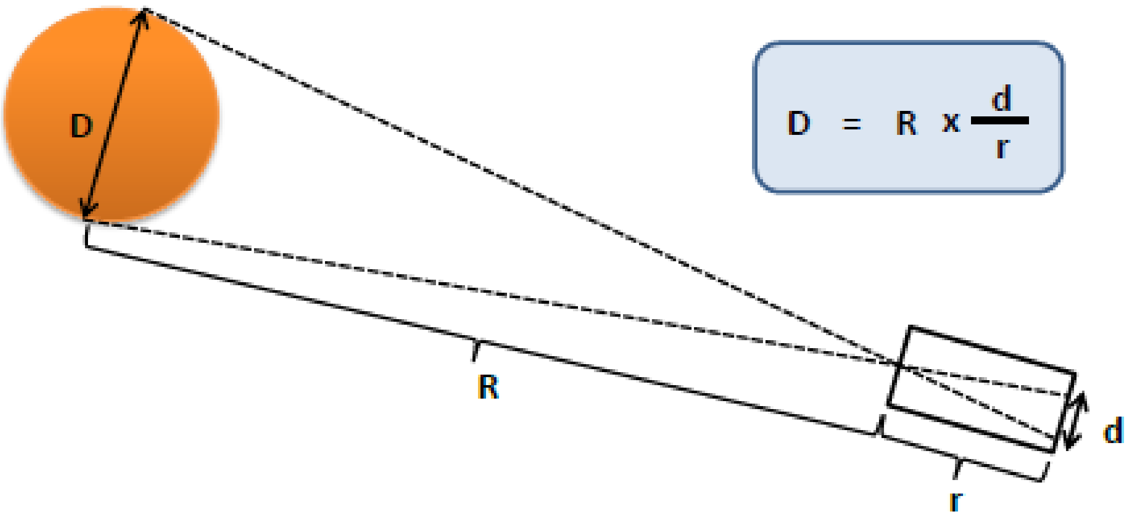

Figure 7: Model

$$D = \frac{d}{r}R \tag{0.2}$$

where D: Diameter of the Sun, R: Distance from the Sun, d: Diameter of the Sun's Image, r: Distance of Pinhole to Screen paper,

If the tube is longer the bottom side of the small triangle will be longer giving a bigger value for d which would be easier to measure. Changing the shape of the pinhole does not affect the image shape we see because the light rays passing through the pinhole are traveling straight forming an inverse image of the same source. The image is not the shadow of the hole.

Having smaller and defined edged holes as pinholes produces sharper images as they work as a diaphragm.

Even if the Sun is that much bigger than the Earth, it looks relatively small in the sky because of its huge distance. And that's also why the Moon, which is much smaller than the Sun, but even much closer, has the same apparent angular size as the Sun in the sky. By the way, the two objects having the same angular sizes in the sky is only a lucky chance, also responsible for the wonderful Solar eclipses we are able to see.

Evaluation

A possible evaluation tool is a class discussion. Here we provide a series of guiding questions for a class discussion:

- Whose pinhole camera worked really well? Why? How does the size of the pinhole affect the brightness of the image on the wax paper? (Answer: The bigger the hole, the brighter the image.)
- How does the size of the pinhole affect the sharpness of the image? (Answer: The bigger the pinhole, the blurrier the image.) How many times larger is the Sun than the Moon? Why if the Sun is so much larger, doesn't it appear larger in the sky?
- Does the shape of the pinhole affect the image? (Answer: no, we always see a circular image. Try making small pinholes with different shapes)
- Where can you use your pinhole camera?

If the activity is proposed in higher grades, also a questionnaire can be used for evaluation. Possible questionnaire for higher grades:

- Question-1: What is the distance between the Earth and the Sun in kilometers? (R=?) Answer-1: 8.31 X 60 = 498.6 seconds ; 498.6 X 300000km = 149580000km
- Question-2: What is the diameter of the sun in kilometers? (D=?) Answer-2: If we make the height of our box 200 cm, we will measure 1.86 cm in diameter of the image of the Sun. D = 149580000 X (1.86 x 10-5/ 200 x 10-5) = 149580000 X 0.0093 = 1391094 km
- Question-3: How many Earth diameters completes one Sun diameter? (D/E =?) Answer-3: D/E = 1391094km / 12742km = 109 times.
- Question-4: what is the most accurate measurement? Answer-4: find the average and error.

Interdisciplinary ideas

- Science: Sun, Moon, Solar System, light.
- Geometry: proportions, similar triangles
- Maths: take several measurements, make an histogram, find average, error, exclude outliers, ...

- History and Technology: history of instruments and geometry (e.g., similar triangle method)

- Art: decoration of the tube (stencil, collage, ...)

Connection to other activities and why

- How huge is the Sun (from Portugal) → compare the size of Earth and Sun

- History of light with Ibn El Haytham (from Lebanon + Egypt) → Ibn El Haytham has been the first one to build the pinhole camera and explain optics

- Observing the Moon and parallax (from Croatia + Slovenia) → how to measure angular sizes

- Solar and Lunar eclipses (from Palestine) → Sun vs Earth position and size

- One million Earths inside our Sun (from AstroEdu: link) → measurement of volumes/sizes of Sun and Earth

Further Reading

Turkish example: http://astrookul.org/atolyeler/pinhole-kamera/

Pictures

If you do the activity please send us pictures of the activity performed in other countries.

Figure 8: Pinhole camera activity done with 5th grade students in Turkey.