Lesson Module:
Drawing the sky: the position of celestial bodies

TEACHER'S GUIDE

approx. duration

Introduction

The lecture module deals with definition and use of the two main systems of celestial coordinates: the *altazimuthal (or horizontal) system* and the *equatorial system.*
Both systems are a particular case of *polar* coordinates, hence they use angular values as coordinates.
For this reason the first topic deals with the usage of angles as proxy measure for length, introducing, by geometrical steps, the trigonometric concept of the *tangent* of an angle: this topic, while apparently not directly linked to astronomical issues, helps the students to start thinking of angles as quantity linked with position; moreover, the same method here used is related to the first technique historically used for the measure of star distances, the measure of the *parallax angles* of stars (first operated by Friederich Bessel in 1838).
The second topic illustrates the two coordinate systems in a practical and interactive way and makes use of augmented reality devices.

These methodologies are very important to materialize spatial concepts that often remain explained only in a theoretical way and make the students able to actualize, by their movements and observations, the definitions they are dealing with.

While cartesian coordinates are generally well treated in mathematical teaching, this kind of coordinate system is generally omitted in both the Astronomy and Maths scholastic curricula, while being crucial for the materialization and comprehension of all the topics related to the apparent motion of celestial bodies.
Moreover, all the activities presented here contain multiple links to general topics of Maths and Geography such as coordinate systems and trigonometry, thus consenting to introduce such topics in a practical and engaging way.

Material

For the students:

- 1 paper Coordination Measurement Device (from now on CMD) every 2 students
- Smartphone with internet connection and the "Star Walk 2" application installed
- 1 copy of the student's handbook for each student, filled with the altazimuthal coordinates in *Table 1* and *Table 2* correct for the location, date and time of the activity.
- Roller meter
- Goniometer (the paper CMD can be used as goniometers as well)
- Writing instruments.

For the teacher:

- 1 Coordinates Measurement Device (such as the one present in the TASTE tool proposal)
- Smartphone with internet connection and the "Star Walk 2" application installed
- *Table 1* and *Table 2* completed with the proper altazimuthal coordinates

Preparation

- Prior to the starting of the activities, the teacher has to compile *Table 1* and *Table 2* with the correct altazimuthal coordinates for **location, date and time** of the activities. This information can be easily found in the Star Walk 2 app as well as in any other astronomy application such as Stellarium.
- Both teacher and students need to have an astronomical app installed with the Augmented Reality mode on their smartphones. The present work uses the Star Walk 2 app in the free release, but another astronomical app such as Stellarium Mobile can work as well. It is important to remember that the Augmented Reality mode could not work on every device, so remember to verify the correct work of the app on a sufficient number of devices.
- The activities can be performed in both outdoor and indoor environments, as long as it presents some objects or features suitable for Exercise 1a and 1b. The teacher must verify such presence prior to the starting of the lesson.

Topic 1: Angles as a proxy for lengths

Duration: approx. **30 min.**

Didactical purposes: students familiarize with the concept of "view angle" (or altitude) and with its usage in the measuring of lengths, being thus introduced, in a very practical way, to the basilar trigonometric concept of *tangent* of an angle.

Methodology: after a geometrical introduction, as shown in the student's book, the teacher guides the students through the activities described in the student's book, showing the activities step by step with the big Coordinates measurement device. Students replicate the activities using their paper version.

Exercise 1a: "How high is…?" - measuring (or knowing) distance and view angle of an object from a given position, calculating its height.

Exercise 1b: "How far is…?" - measuring (or knowing) height and view angle of an object from a given position, calculating its distance.

Didactical hints/to remember:

- It is important that students can actually verify their calculation about heigh and distance of the chosen object. This can be done a) by choosing objects whose height and distance can be directly measured with the roller meter after the calculation is done b) by choosing monuments or reference points whose height and distance can be found from other sources (e.g. from the web).
- Given the mathematical trend of the tangent function, a small error in the measure of the view angle can translate into a big error in the calculated value of height and distance: it is therefore important to ask the students to be as accurate as possible in the measurements (ideally within the sensitivity of the CMD, 1°).
- The functional principles of the big CMD and of the small paper CMD are slightly different (for technical constraints), even being both very intuitive: the teacher can possibly explain the difference if asked by the students.

Topic 2: Angles as a measure for position: celestial coordinates

Duration: approx. **40 min.**

Didactical purposes: students learn about the two principal coordinate systems used in Astronomy: altazimuthal (or horizontal) system and equatorial system. Then, using an augmented reality astronomical app (as the proposed Star Walk 2), they identify and position on a stellar map some celestial objects, linking the given coordinates to the actual position of the object in the sky, in both coordinate systems.

Methodology: the teacher guides the students through the activities described in the student's book, showing the activities step by step with the big CMD. Students replicate the activities using their paper version.

The activity is thus divided:

Exercise 2a: "Find your star!" – the students learn about the altazimuthal coordinate system and locate some celestial objects in the sky using their coordinates, verifying the position of the invisible ones by an augmented reality app such as Star Walk 2 (used in the present document).

Exercise 2b: "Drawing the sky" – students learn about the equatorial coordinate system and use an augmented reality app to find these coordinates for some given objects: they then use the found coordinates to place the objects in a polar celestial map.

Didactical hints/to remember:

- Since altazimuthal coordinates are depending on observer position and on date and time, the teacher has to fill in the related table with the correct values according to location, date and time in which the activities will be performed.
- The celestial object to be found both in Exercise 2a and in Exercise 2b can be adjusted to the teacher's preferences; it would be useful to choose at least one object with negative altitude (i.e. below the local horizon).
- The Sun can be included in the list of the object **only if the measure is performed with a CMD equipped with the provided Astrosolar filter; in no other cases the students should look directly at the Sun.** The teacher must strongly assess this prior to the beginning of the activity.
- The definition of the coordinates in the equatorial system is quite complicated and can be at first confusing for some students: on the other hand, such definition is not necessary for performing Exercise 2b. For this reason, it has been postponed and can be given at the end of the activity, possibly to the interested students.
- The Star Walk 2 app, as any other augmented reality app, asks the mobile phone to be equipped with *gyroscope* and *accelerometer* sensors, which may not be present in every mobile phone; therefore, the augmented reality mode could not work on some devices. The teacher must make sure that a convenient number of devices can run the augmented reality mode, and let the students familiarize with the app and the augmented reality mode before the activity in Exercise 2b.

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