

# iSky: Smart Measurements of the Heavens



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## 1 | Summary

How can mobile phones be used for astronomy? Starting with planetarium apps, we can go on to take measurements of objects in the sky by day and night. By determining the altitude of stars or of the sun, we can learn about orientation, our position on the Earth and the size of our planet.

- ▶ **Keywords:** measuring altitude, latitude, longitude
- ▶ **Disciplines:** ICT, mathematics, geography, astronomy
- ▶ **Age level of students:** 14-18 years
- ▶ **Android apps:** Angle Meter, Google Maps, Planetarium, Smart Protractor, Star Chart, Theodolite droid
- ▶ **iOS apps:** Angle Meter, Solar Walk, Star Chart, GPS Essentials, Theodolite

## 2 | Conceptual introduction

Is it possible to find a geographic location by reference to the stars? We live on a big sphere that rotates and moves around the sun. This gives us changing perspectives and patterns in the sky and makes it difficult for us to orientate ourselves and determine our location in space.

Throughout history, the use of the stars has been an important tool for determining the position of individuals and places on the Earth. From the viewpoint of European history, the astrolabe could be considered the first mechanism that was used to locate a star in space. During the great voyages in the fifteenth century, it was used to determine positions at sea by measuring the altitude of Polaris—its height above the horizon—which gives the local latitude. In this context we have to note that an error of only  $1^\circ$  in the altitude causes an error of more than 100 km in the position.

The precision was increased by using a Davis sextant, mainly to measure the altitude of the sun at noon. But it was not until Harrison's invention of the marine chronometer that it was also possible to determine the local longitude.

Nowadays we can determine positions by using electronic methods, but the use of classic astronomical techniques still allows us to compare and evaluate the degrees of accuracy of the different methods. We can also combine traditional and modern methods in order to learn about historical measurements such as the famous experiment of Eratosthenes to determine the size of the Earth.

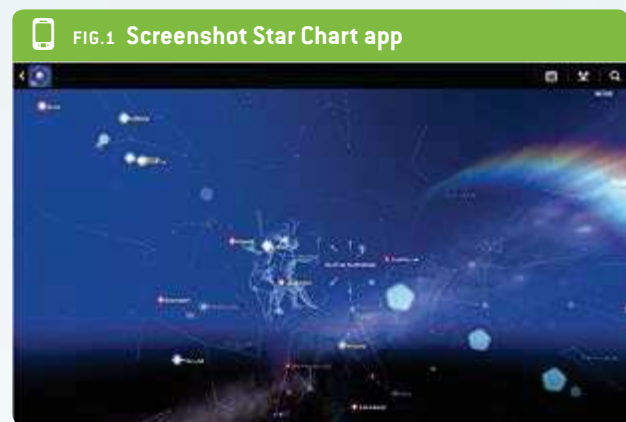
In most countries, the treatment of this subject in the school curriculum is rather theoretical. Students are not given any examples of how to apply the methods of calculation or any opportunities to compare classic methods with the use of

mobile devices. Therefore, this will be the focus of our work. The objectives to be achieved are:

- ▶ Gaining basic orientation regarding the night sky by using smartphone apps.
- ▶ Reconciling the use of ICT (apps for mobiles and tablets) with traditional techniques for obtaining results in the area of astronomy.
- ▶ Measuring the altitude of two stars (Polaris and the sun) by using a smartphone and the associated applications.
- ▶ Calculating the circumference of the Earth by means of an experiment similar to that of Eratosthenes.

## 3 | What the students do

### 3 | 1 Introduction: Planetarium—the sky above



We use Planetarium apps such as Google Sky Map or Star Chart to orientate ourselves in the sky and to learn astronomy.

**Basics:** horizon, zenith; the constellations and their movements; the sun, the moon and the planets; coordinates.



### EXERCISES Star Chart

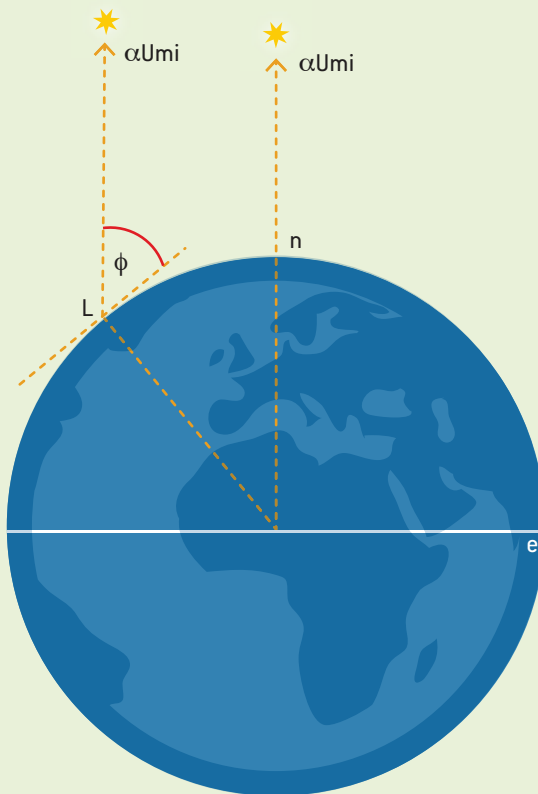
- ▶ Use the fixed mode (AR mode off).
- ▶ Search for the horizon. Turn around virtually one time ( $360^\circ$ ), and “look” in every direction.
- ▶ Go up vertically — what can you observe? How far can you go?
- ▶ Search for the planet Saturn and zoom in until you can see its moons. Tap on one of them and note the information about it. What do you notice during the very close zooms?
- ▶ Change to 3D Explore mode and make a virtual journey around the poles of the Earth.
- ▶ Activate the time/date mode and look toward the southern horizon. Try taking different time steps and note your observations.



### 3|2 Measurement: Altitude of Polaris

Determine the local latitude by measuring the altitude of Polaris. Of course the “altitude” of an astronomical object is not a distance, but the angle from the horizon straight up to the object. FIG. 2 shows that the altitude of Polaris is the same as the local latitude.

 FIG. 2 Altitude of Polaris; altitude of Polaris = latitude



latitude =  $\Phi$  | horizon = n | equator = e  
altitude of Polaris:  $\alpha Umi$

How can you measure the altitude of a star using your smartphone? Try using angle measurement apps. It will be important to adjust the phone properly and to look along the edge. How accurate are the measurements? You can compare the results with GPS data in order to estimate the accuracy of your experiment.

**A hint:** Locating this star is tricky, because it is not very bright. You may be able to train your measurement skills by starting with brighter objects such as planets or the moon.

FIGS. 6-8 show a tool that enables you to support the measurement by stabilizing the phone and positioning it using a tripod.

### 3|3 Measurement: Altitude of the sun

Throughout history, it was important for navigators to be able to determine the altitude of the sun at noon. For a long time, this was the only way to determine the position of a ship at sea (latitude).

Determine the altitude of the sun at noon at your location by using a mobile device. DANGER: Do not look directly at the sun! When you located Polaris you may have looked along an edge of your phone, but this is not possible with the sun! However, you can use a shadow cast by the sun to make your measurement.

**Suggestion:** Attach a straw to one edge of the phone with adhesive tape. Search for the minimised shadow at noon and measure the slope of the phone with an angle measurement app.

 FIG. 3 Easy measurement of the altitude of the sun

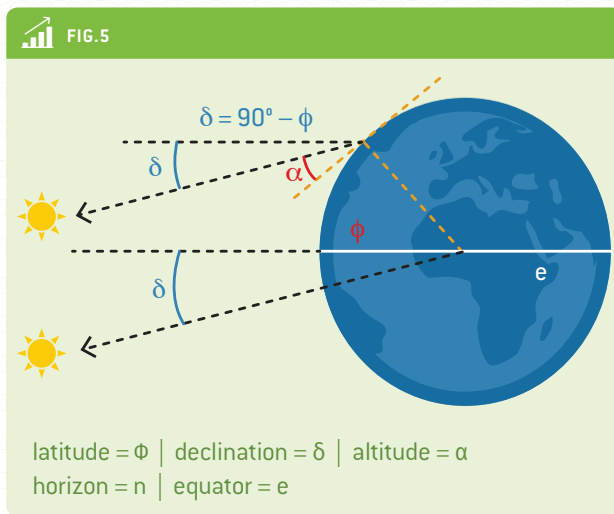


Use the Planetarium app to get the relevant data (e.g. the time of real noon, the declination) and compare the data with your measurement. How accurate was your measurement?

 FIG. 4 Planetarium app



FIG. 5 shows the angles involved. If you know the declination, you can determine the latitude:



**Alternative suggestion:** For a more stable positioning of the mobile phone, we suggest that you build a device that can be placed on a tripod. This way it will be easier to point precisely to the sun's position from anywhere.

#### Equipment needed:

- ▶ Tripod
- ▶ Smartphone
- ▶ Medium-density fibreboard (MDF) 3 mm
- ▶ Wood strip 1 × 2 cm
- ▶ PVC pipe 13/16 mm
- ▶ 1/4" BSW (British Standard Whitworth) full nut
- ▶ Elastic string
- ▶ Glue

You can see the assembly process at [www.science-on-stage.de/iStage2-downloads](http://www.science-on-stage.de/iStage2-downloads).

## 4 | Cooperation option



### Eratosthenes experiment

Measure the altitude of the sun at real noon at different locations. By using Google Maps, we can get the air-line distances and calculate the radius of the Earth.

**Step by step for two locations:** Decide on a day X to perform the experiment. Note the weather forecast—clear skies are necessary at noon at both locations. Find out the time of real noon and the air-line distance for each location.

**Day X:** Determine the altitude of the sun at real noon at the two locations. Share the data and determine the difference between the two altitudes. Calculate the circumference of the Earth using Eratosthenes' method.



**FIG. 9 Example of measurement:**  
 Tarragona – Lyon 495 km map source: OpenStreetMap



**FIG. 6 · 7 · 8**





- ▶ Day X: 21 June. Planetarium app (FIGS. 10 and 11).
- ▶ Altitude of the sun (should be measured): 72.2°
- ▶ Altitude of the sun: 67.7°
- ▶ The angular difference is:  $72.2^\circ - 67.7^\circ = 4.5^\circ$
- ▶ Calculation:  $4.5^\circ$  corresponds to 495 km.  
Circumference  $c = ?$
- ▶  $4.5^\circ : 360^\circ = 495 \text{ km} : c$
- ▶  $c = 495 \cdot 360 : 4.5 = 39,600 \text{ km}$

#### How accurate is the measurement?

- ▶ We can measure the angle with an accuracy of 0.1°, e.g. Tarragona: 72.3°, Lyon: 67.7°. Difference: 4.7°.
- ▶ We calculate  $c = 37,914 \text{ km}$ . So we can expect an accuracy of about  $\pm 2,000 \text{ km}$ .
- ▶ If the angular difference is bigger, the error will be smaller.

## 5 | Conclusion

Smartphones are powerful and multifunctional tools. We can learn a lot of basic astronomy not only from simulations such as planetarium apps, but also by using smartphones as measurement tools. The built-in acceleration sensors permit a precision of 0.1° in slope angles. This enables us not only to locate our own position on the Earth using the North Star or the sun, but also to estimate the circumference of the Earth according to Eratosthenes' method. The charm of this experiment lies in the fact that we are performing historical experiments using modern devices, comparing the methods and evaluating the accuracy of the measurements.

We can see that the use of smartphones does not mean we can work less carefully. We have to learn how to use them correctly, and we will have to repeat our experiments in order to increase our accuracy. Even when we use new technologies, we still need old virtues too; this remains the case when we do real science.





# Imprint

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