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Making sciences with smartphones: The universe in your pocket

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Abstract. We propose a set of modern and stimulating activities related to the teaching of Astronomy orientated to high school or university students using smartphones. The activities are: a) the experimental simulation of asteroid light curves including the determination of the period of rotation of asteroids, b) the experimental simulation of exoplanet detection by transit method, c) the experimental simulation of stellar distances using parallax and d) the use of virtual and augmented reality.

Keywords. smartphones, asteroid light curves, stellar distances, virtual and augmented reality

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Smartphones are pocket computers with many sensors that can be used as portable laboratories for a wide variety of scientific and educational activities, Vieyra et at. (2015). Here, we show some activities useful in basic courses of astronomy or geosciences.

Asteroid light curves. The vast majority of asteroids are irregular objects, which due to their small size and great distance can hardly be appreciated as points of light from the best astronomical observatories. However, a careful analysis of the sunlight reflected by an asteroid allows in some cases to determine some characteristics of its shape, as well as its period of rotation around its axis. This photometric method is called the *light curve*. If asteroids were spherical and uniform in color, their light curves would be flat. The more irregular its more complex shape the curve and the greater the changes in brightness. We propose to simulate this photometric technique using a scale asteroid which can simply be a bit of molding mass or a real asteroid, from real data, made with 3D printer. Data files can be obtained freely at https://nasa3d.arc.nasa.gov/models/printable. The scale asteroid is rotated on a circular platform, a turntable or by the axis of a slow motor. While it is rotating the light intensity is measured with a smartphone's light sensor by means of an app like Physics Toolbox or PhyPhox (left panel of Fig. 1).

Exoplanets and planetary transits. In recent years the discovery of planets orbiting stars other than the Sun, called extrasolar planets or simply exoplanets, has become one of the most innovative and fastest growing themes of modern astronomy. Today more than 3,500 exoplanets have been confirmed. The great distance to which the stars makes it impossible to observe them directly with the necessary resolution, even for the largest telescopes. Thus, several techniques have been developed to discover exoplanets by indirect detection methods. One of these methods is planetary transit, a photometric method that involves observing the light of a star and measuring the small change in brightness that occurs when an exoplanet passes in front of the star. Several characteristics of exoplanets can be determined from light curves as size (estimated from the reduction in the brightness of the star) or the orbital period (determined from the periodicity of the

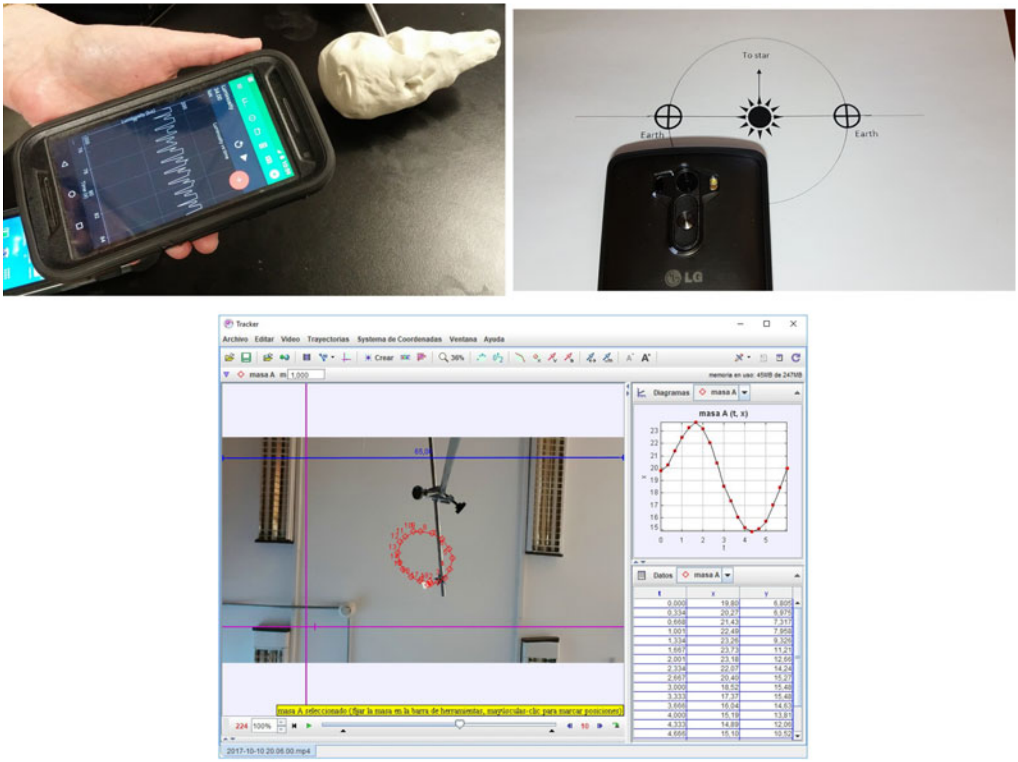

Figure 1. Some examples of the activities discussed in this presentation.

light curve). To simulate the transit method a lamp can be used as a star, spheres of different sizes as planets (which are rotated around the star) and the light sensor of a smartphone to record the light curve using a suitable app as mentioned in the previous activity (Barrera-Garrido 2015).

Parallax and parallactic ellipse. Usually, astronomers employ different methods to determine the distance to celestial objects according to the scale of astronomical distances in question. To measure the distances of the stars, the method par excellence and the oldest is that of parallax. Parallax is the change in the angular position of an object when the point from which it is observed is changed. Here we model the effect of parallax and show how can be used to measure stellar distances.

Annual parallax can be used to determine the distance to the stars thanks to the translational movement of the Earth around the Sun. To observe the parallax effect, we just take two photographs from different positions and observe the change of position with respect to the background as proposed in Fitzgeral et al. (2011). To observe the parallactic ellipse, a scaled star is placed on top of a scaled solar system (center panel of Fig. 1). The experiment consists of recording a video with the smartphone, while it moves as if the camera lens were the Earth above the paper with the scaled solar system and later analyze the video, to determine the parallactic ellipse and calculate the distance at which the star is located (right panel of Fig. 1).

Virtual reality consists of the generation of three-dimensional images, which provide a sense of depth and spatiality. For this reason there are some applications for smartphones that what they do is generate two images on the phone screen, left and right, one for each eye. In this case, it is needed the help of special lenses such as Google Cardboards, which are made of cardboard or some other more comfortable model that

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today are very economical (of the order of a few dollars). The smartphone is placed inside these special lenses and thus each image is sent to each eye separately, generating the sensation of *spatiality*. Virtual Reality *apps* take advantage of the smartphone sensors to recognize perspective changes when we turn our heads or tilt them up or down. For this reason, acceleration, gyroscope and magnetic field sensors are required.

Augmented Reality consists of overlapping several real images with virtual images. This technique is increasingly used in several industrial contexts, in games and, of course, also in education. A very interesting example to get closer to the world of space exploration is the NASA Spacecraft 3D app, which allows you to visualize several spacecraft, robots and other devices linked to space. Augmented reality not only creates the illusion that an object is in our environment but can also be observed from different perspectives and distances as if it were a real object that we are seeing through the camera.

As a conclusion, we remark that smartphones and mobile-devices in general offer a very wide variety of possibilities for experimentation in Astronomy teaching.

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