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# The Earth-Moon Distance Through Parallax in Basic Education

## Strategies for Physics Teaching

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**Abstract.** In this work we present a classroom strategy to approach the concept of parallax and the procedures to calculate distances in Astronomy for high school students, relating these concepts with those learned in Physics at this level. We used images of the Moon in total eclipse photographed simultaneously from Montreal (Canada) and Selsey (UK), and aligned using stars in the field. We present a procedure using the DS9 software. Based on the average angular size of the lunar disk, we measure the relative angular displacement of the Moon among the stars of the field, when observed from these different cities, students are encouraged to obtain the trigonometric parallax of the Moon. From the parallax we calculate the distance between Earth and Moon. The students involved obtained the Earth-Moon distance from the parallax in real measurements, directly and with inaccuracies lower than 10%.

**Resumo.** Neste trabalho nós indicamos uma estratégia de sala de aula para apresentar o conceito de paralaxe e os procedimentos para calcular distâncias em Astronomia para estudantes do ensino médio, relacionando esses conceitos com aqueles aprendidos em Física. Nós usamos imagens do eclipse total da Lua fotografadas simultaneamente de Montreal (Canada) e Selsey (Reino Unido), alinhadas por meio de estrelas visíveis. Com base no tamanho angular médio do disco lunar, medimos o deslocamento angular relativo da Lua entre as estrelas do campo, quando observada destas diferentes direções, estudantes determinaram a paralaxe trigonométrica da Lua. Da paralaxe nós calculamos a distância entre a Terra e a Lua. Os alunos envolvidos obtiveram a distância da Terra à Lua a partir da paralaxe em medidas reais, de forma direta e com imprecisões inferiores a 10%.

**Keywords.** Astronomy – Angular distance – Earth-Moon – Education

## 1. Astronomy in Basic Education

Astronomy teaching in High School may be a strategy to rise the student curiosity about phenomena that allow the basic understanding of the technologies used in the space conquer (BRASIL, 2002). Among the basic question that involves Physics one of them is the procedure to measure distances in Astronomy. The determination of linear distances and sizes in Astronomy is, in most cases, according to angular measurements made in the sky and whose relations are important to be explored with the young students. The most important example of this type of relation is the case of trigonometric parallax. The same triangulation which is learned in geometry to measure distances of objects on Earth allows it to obtain much greater distances (Figure 1).

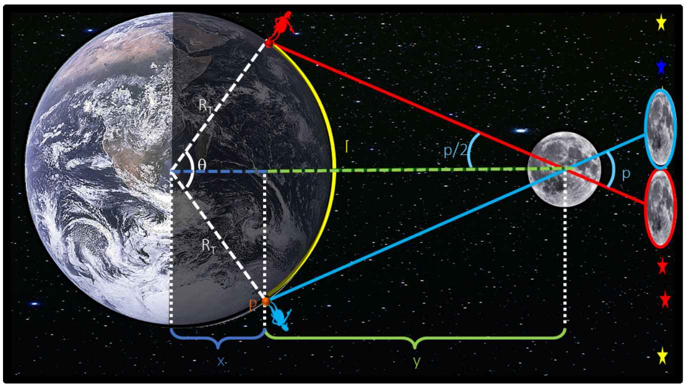


**Figure 1.** Geocentric Parallax where two observers at different positions of the Earth observe the Moon in different positions of the sky in relation to the background of stars.

## 2. Educational Objectives

General objectives: Construct a didactic sequence to determine the Earth-Moon distance and correlate the subject with Physics and Mathematics in an interdisciplinary way.

Specific Objectives: Conduct a discussion with the students, involving the problem situation and present a short video about the distances in the solar system; To compare the stellar fields about two images of the Moon taken during a lunar eclipse observed from two different cities: Montreal (Canada) and Selsey (UK); Find, through the parallax method, the angular distance between the Moon positions observed from Montreal and Selsey, using the DS9; Elaborate and fill in a chart with the observational data; Explain how to calculate the distance between Earth and Moon; Compare the values found with the values of the specific literature and with those of the other groups; Discuss the experimental difficulties observed in the usage of the DS9 program and how they may have affected the results; Awaken curiosity through the questions involving the Astronomy study.

## 3. Proposed Activity and Classroom Strategies

First lesson: Building Links: In this lesson, beyond the presentation of the theme and videos that involve Astronomy and distances in the celestial space, students make a practical demonstration based on Figure 2, to introduce the concept of parallax, obtaining the angular distance among the apparent positions of the object which is in the middle of the classroom; Next, the dis-

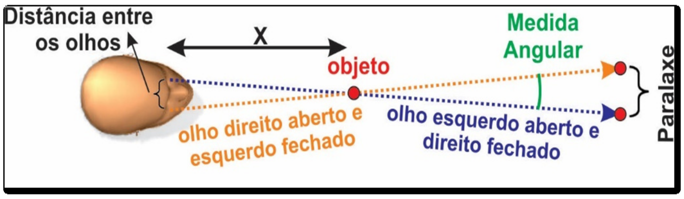


**Figure 2.** Parallax identification through the apparent positions of an object observed by each eye (one at a time) of the observer.

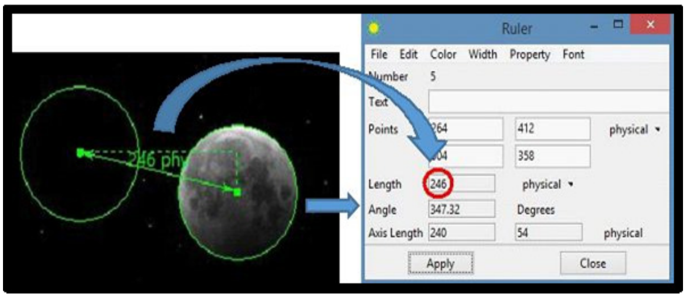


**Figure 3.** Measuring the pixel distance between the two images using the ruler tool for the observed positions of the eclipsed Moon from Montreal and Selsey.

tance X is calculated, using the distance between the eyes in the calculations;

Second lesson: Using the DS9 for determining the Earth-Moon distance The DS9 software, a professional program developed for visualization and analysis of astronomical images, mainly in the FITS (Flexible Image Transport System) format, is used to determine the trigonometric geocentric parallax. We used the images of Moon eclipses seen from Montreal (Canada) and Selsey (UK). These observations were recorded by Lawrence et al (2004) on December 6, 2004. The observations were adequately adapted and made available by Scarano Jr (2017). To execute the activity you must install the DS9 program through SAOImage and then import the files from the Moon images to the DS9 in Scarano Jr (2017) webpage. The data obtained with the program must be recorded in the data table, which will provided to the students in the third class.To execute the activity students import the images to DS9 SAOImage. The data obtained with the program were recorded in the data table, which will be presented by the students in the third class.

Using the equivalence between the angular diameter of the Moon (obtained in pixels in DS9), and its apparent average value in degrees, of 0.52 degrees (Oliveira Filho & Saraiva 2013) and the value obtained by the ruler for the parallax in pixels, just use the simple rule of three to get the parallax (p) in degrees;

$$p = \frac{d_{DS9} 0,52}{2R_L} \qquad (1)$$

Third lesson: Calculation of the Earth-Moon distance and analysis of its results Students present their calculations and compare the values found with the specific literature values (presented by the teacher) and those of the other groups; The class should discuss the experimental difficulties encountered in using the DS9 program and how they may have affected the results; This meeting is finalized with the debate on the question presented in the first lesson, involving the interaction forces between the celestial bodies and the relation with their distance, through the Universal Gravitation Law; To calculate the angular

$$d_{TL} = x + y = R_T \cos\left(\frac{\theta}{2}\right) + \frac{R_T \cdot \sin\left(\frac{\theta}{2}\right)}{\tan\left(\frac{p}{2}\right)} \qquad (2)$$

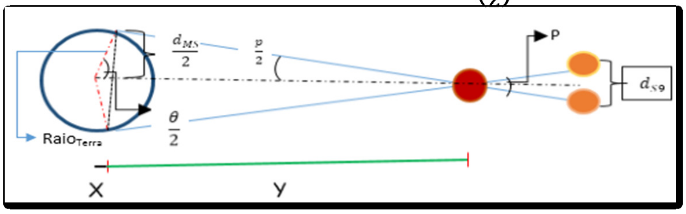


**Figure 4.** Measuring the pixel distance between the two images using the ruler tool for the observed positions of the eclipsed Moon from Montreal and Selsey.

distance between Montreal and Selsey, we used the $\theta = d_{MS}/R_T$ where $\theta$ is the arc measuring the angular distance, in radians, between Montreal and Selsey; $d_{MS}$ is the distance between cities (Selsey and Montreal) in km; $R_T$ is the Earth's radius, in km.

To calculate the angle q and angle p, we consider the following data defined as Selsey-Montreal distance: $d_{MS}$ = 5.218 km and Earth's radius: $R_T$ = 6.370,0 km (Oliveira Filho & Saraiva 2013, p.118).

Through the triangulation method, we calculate the distance between Earth and Moon, according to Figure 4.

## 4. Results and Application

This activity was applied to four classes of professional master degree in Physics teaching (MNPEF - Polo 11).The results obtained had less than 10% of imprecision. The astrometric calibration of the images, uncertainties in the measurements using the DS9 program, inaccuracies in the manipulation of the DS9 tools, the approximations of values used as reference for the distance between Montreal and Selsey, for the Earth's radius, for the angular diameter of the Moon and for the distance between the Earth and the Moon were some discussed points in the analysis of the results. The distance between the Earth and the Moon is the first step that allows us to answer the stimulating question about the man's travel time to the Moon, but does not respond to it completely. This is a hook for a next step to be given, exploring the concept of velocity by the average velocity escape.

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