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Students' Preconceptions in Astrophysics – How to break them down?

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Abstract. At any stage of education, the students begin to study astrophysics with previous incorrect preconceptions that impedes the understanding of new scientific notions. It is a waste of time to add new concepts on a "weak basis". In this case the duty of any teacher is to spend more time to carefully remove preconceptions from students' minds. In the present article there are reviewed some of the most common preconceptions of the students when they are learning astrophysics with the right solutions to break them down using some active teaching methods, especially experiments and models.

Keywords. Education, gravitational lensing, solar wind, stellar color

1. Introduction

The term preconception refers to the previous knowledge that the student has gained from his own experience, before starting to study a new subject. This includes the ideas and concepts that each student has reach from the environment. Some of these preconceptions are often incorrect and even illogical that create a real problem for science teachers in their didactic approach. Usually when we say preconception we mean a wrong idea about something. "Science teachers, even more than others if that is possible, don't understand that one doesn't understand", Bachelard (1967). When the students begin to study astrophysics they have previous preconceptions that impedes the understanding of new scientific notions. Too much effort is spend to add new concepts on a "weak basis", so it is the duty of any teacher to spend more time to carefully remove preconceptions from students' minds.

2. Content

In the present article there are reviewed some of the most common preconceptions of the students when they are learning astrophysics with the right solutions to break them down. There are indicated some active teaching methods, especially experiments and models, as provided K. Tobin in his book about constructivism, Tobin (1993).

First preconception: How does the light propagate?

Usual answer: The light propagates rectilinearly. The student, even the one in the high school has this opinion after his direct observations and also from the experiments and theory of geometrical optics. Scientific answer: The light propagates curvilinearly. When the student studies the electromagnetic waves and he finds out about the momentum of the photon, he can understand that the photon has a kinetic mass and only in this case he realizes the notion of the curved trajectory of the light. The scientific answer comes from the quantum optics.

Figure 1. The model for Einstein cross.

To reinforce this new concept of propagation of the light on a curved trajectory we propose to our students a contest: which group of three students makes the most interesting and correct presentation of the famous Edington's experiment in 1919, as the first prove of Einstein's theory of general relativity. We give them the bibliography and the next hour, when they present their works we can discuss also about Sun total eclipse and the space curvature. To motivate the students to be curious and to study the astrophysics with pleasure, we introduce a tricky concept the gravitational lensing, where a massive cosmic object focuses light from another object beyond it to produce a distorted or magnified image. This is the same effect studied by Edington, but in this case the deflection of the light is made by any kind of star, a constellation or a galaxy. The astronomical discovery of gravitational lenses in 1979 gave additional support for general relativity.

To explain better this concept we use 3D videos simulations or drawings, e.g. ESA simulation [https://www.spacetelescope.org/videos/heic1106a] and then we made with the students simple experiments, we learned during the courses of the Network for Astronomy School Education (NASE). These experiments are explained in the book "14 Steps to the Universe", Moreno *et al.* (2017). Every teacher can reproduce the models for the Einstein's cross (Figure 1) or the Einstein's ring after watching the corresponding videos [https://www.youtube.com/watch?v=v1SdQE1pZZo], using very common materials.

Second preconception: What is between the Sun and the Earth?

Usual answer: ... there is vacuum or nothing. If the light can come so big distance from stars to us, the students believe that it must be nothing in space between stars and the Earth. The scientific answer: there are clouds of interstellar dust and the solar wind (electrons, protons and few ions).

The solar wind is invisible and the students doubt it is something real after all explanations about the Earth magnetic field and the charged particles of this wind and the solar composition [http://solar-center.stanford.edu/FAQ/Qsolwindcomp.html]. In the moment of the discussion about the northern light or aurora borealis their ideas begin to change. There are so many great photos, videos with this very nice phenomenon so the students are very motivate to find out that the aurora is the result of collisions between gaseous particles in atmosphere with charged particles from the solar wind. The

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students' question is: why the huge curtains in the sky have different colors and the they have to find the answer on internet, as homework. Another question for a project is: do other planets have auroras and if yes, what are the differences between them?

Third preconception: Does the Sun move?

Usual answer: NO! The students consider that the planets move around the Sun, but the Sun is at rest; even when the students know that there is no celestial body at rest, they cannot imagine the entire Solar System in movement. This error comes from the fact that the representations of the Solar System are drawn in plan not in space. The scientific answer: Our whole Solar System orbits around the centre of Milky Way and in the same time the Sun rotates around its axis.

There are videos with models in 3D with the trajectories of the planets around the Sun, meanwhile our star is moving in the galaxy [https://www.youtube.com/watch?v=rQJDEhlE-DY]. In order to emphasize the real rotation movement of the Sun around its axis there is a NASA simulation [https://solarsystem.nasa.gov/solar-system/sun/in-depth/] and a NASE experiment with the solar sunspots in the same book "14 Steps to the Universe", Costa *et al.* (2017). The students are very astonished when they realize that Galileo Galilei has calculated with centuries ago that the Sun rotation period decreases from the Equator to the Poles, using only the observation of these sunspots. To be sure that the students will retain the concept of the movement of the Sun in space it's a good exercise for them to compare the values of the revolution velocities for the Earth and the Sun.

Fourth preconception: What percentage of the entire Solar System mass is the Sun mass?

Usual answer: The Sun mass represents any value between 10% to 70% of the entire Solar System mass, but more often the students choose the value of 50%. Students believe that the Sun has a mass about as large as the entire mass of the rest of the Solar System because the figures about the Solar System can't be made to scale. The real value is 99.8%. To remove this preconception we use a "sweet" experiment with 100 pieces of cubic sugar on a tray. We ask the students to put aside the sugar that represents the mass of the Sun. It is an experiment very interesting for young students. We take care to ask those who know the answer to come into play. Students train and their curiosity grows as the answers are more and more varied. When they find out that only a small part of a sugar cube remains for the entire mass of the Solar System, most exclaim: it is not possible, how can it be so? Then it follows the explanation of the law of universal gravitational attraction between any two bodies.

There are many other students' preconceptions in astrophysics learning. Here we will review shortly only two: First, the hotter stars are the red ones: the students associate the red color with the wood fire and they deduce that the hottest stars are the red ones. They don't think that the flame of methane gas is blue and they don't know that it's temperature is higher than that of the wood fire. They understand everything after we teach them the Wien law, the stars life and the interpretation of the Hertzprung-Russel diagram. Many years, our students achieved a model of HR diagram we learned in 2007 at the First ESO-EAAE Astronomy Summer School, Radeva (2007). Second, the galaxies are moving through the Universe: the students believe that the galaxies move through the space but it is the space which expands, dragging the galaxies. A very simple experiment with a model to "see" this expansion using a balloon and some glued "paper galaxies" on it (Figure 2), is explained in the same NASE book "14 Steps to the Universe", see Figures 8a and 8b in Moreno *et al.* (2017).

Figure 2. The “paper galaxies” are not moving in the space.

3. Conclusion

Preconceptions are very deeply imprinted in the student’s mind. Every teacher must identify the preconceptions, to break them down and then to reconstruct the concepts using especially active teaching methods: experiments and models. This educational approach means many hours of lesson preparation and a great teaching experience.

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