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Using Demonstrations during Lectures

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Abstract: I shall present a series of easy demonstrations that can be carried out during formal astronomy lectures. Since astronomy is physics we have developed on Earth applied to celestial objects, there are many useful experiments that can be carried out with relative ease by physics teachers in order to help pupils grasp the workings of the universe and to relate them with every day experiences. One of the difficulties in teaching science is that we use two-dimensional pictures to explain a three-dimensional reality. Using models helps students understand some of the properties of celestial objects. Although it is important to have pupils experiment on their own, some demonstrations are so simple that it is enough to have the teacher carry them out during the lecture to have pupils grasp their importance or at least keep their attention focused on the topic at hand. The demonstrations can be used in elementary education as well as in introductory astronomy courses and teacher workshops.

Keywords: astronomy education

1 Introduction

In general students have difficulty learning science. There are several reasons for this; amongst them is that science is a new language they have to learn how to cope with, and sometimes they cannot make sense of what is being conveyed to them. Added to this is a general prejudice about its difficulty. Astronomy can be a mind-broadening experience; it can convey scientific knowledge in a way that can be attractive to basic school-level students. We should train teachers to help them teach science—in the References we cite several publications on the teaching of astronomy.

One way in which we can help our students understand astronomy is by doing demonstrations during our formal lectures. This helps them to: focus on the topic, recall what is fundamental, understand the basic physical principles, observe three-dimensional models and consequently grasp better the idea being explained. In other words, demonstrations help make scientific language meaningful in a familiar way by presenting a simple concept which can later be increased in complexity and generality.

In the following paper, several very simple experiments that can be carried out during a formal astronomy lecture are presented. These must serve as a complement to the lecture; each must be accompanied with the physical ideas and mathematical development pertaining to the subject, according to the level at hand. Many astronomy teachers have physics laboratory facilities available, so they can use equipment that already exists to carry out demonstrations during their lectures. Actually the idea is to repeat standard physics experiments but in the astronomical context—one must keep in mind that astronomy is the physics we have developed on Earth applied to the rest of the universe.

A conclusion I have drawn from my lectures is that one tends to believe one's students have understood physics during basic courses, but this is not necessarily the case. However, if one explains the basic principles so that students can understand them, they will internalise physics in a way that makes sense to them.

2 Demonstrations

2.1 The Earth is Round

One can begin a lecture on our planet's shape by pointing out that 2000 years ago, several Near East cultures thought the Earth was flat and held by elephants on a turtle surrounded by a snake. The Babylonians realised that during a lunar eclipse the Earth's shadow is cast on the moon, and they could compare their model with observations.

After this introduction one should encourage students to experiment with shadows by presenting them with different objects, including a small elephant, a sheet of paper and a ball so that they can realise that the only body that always projects a circular shadow is a sphere. One can show pictures of lunar eclipses to students and have them place a sheet in front of the figure so they observe that it is round, and consequently understand how humans used this observation 2000 years ago to discover our planet's geometry.

One can proceed with the lecture by explaining how to measure the Earth's circumference by using Eratosthenes' method. A way to approach this employs a long piece of foam rubber (about 1 m long, 10 cm wide and 4 cm thick) and a few sticks (6 in total, 20 cm tall, 2 mm wide). One first inserts the sticks along the piece of foam rubber and places it on a flat surface to show students how the shadows of each of them would be equal if the Earth were flat. Now one proceeds to bend the foam rubber along its length so students realise that at noon, since our planet is round, the different sticks cast different shadows, the difference becoming larger as the circumference becomes smaller. If one has access to projection facilities, one can show a slide of the Earth seen from space in which half of it is in

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the dark, and bend the foam rubber along its lit edge to make the qualitative concept of the different shadows cast by obelisks easier to grasp.

One can subsequently mention that Mesoamerican cultures realised that the zenithal pass of the sun did not happen on the same date in their cities at different latitudes. They dug long narrow holes in several sites to measure this phenomenon. When the sunlight penetrated these deep holes, the zenithal pass occurred. If one takes the sticks out of the foam rubber, one can explain the procedure and mention how this is an alternative for measuring the Earth's curvature.

Finally one can mention that Eratosthenes used an obelisk and a well to carry out his experiment, which is equivalent to using a rod and a hole, a combination of the explanations given before.

The rest of the lecture can be carried out in the standard fashion using the equivalence of internal alernal angles and the distance between Siena and Alexandria to quantitatively measure the Earth's circumference (Figure 1).

2.2 Translational Periods of Planets

When one lectures on the properties of the solar system, one is tempted to present a table. To pupils this makes no sense—they do not realise that by studying a table, similarities and differences pop out immediately.

Figure 1 (see text)

Students have trouble trying to relate to the different entries, so this is a great chance to use analogies. For instance, when it comes to describing the translational periods of planets, one can use a series of dolls, or pictures of people, that have ages from 3 months, 7 months, etc. to 80 years old and have students try to imagine how they were and will be at those ages. One can then mention that these are precisely the translation periods of the planets. (For periods of 150 and 247 years one can use dolls (or pictures of people) dressed in the fashions of the times (Figure 2).

When it comes to explaining why planets revolve around the Sun in the first place, one can do the classical experiment of making water spin over one's head so that pupils understand that satellites are continuously falling towards the Earth, and that in the same fashion planets are continuously attracted towards the Sun. Since students have seen this demonstration done many times, and, I must insist, have not necessarily understood the physics behind it, one should carry it out once more. One way to do it is by placing a crystal cup holding a liquid on a velvet-covered board held at its edges with strings. With a little practice one can easily spin it without dropping the cup. This way of doing the demonstration amazes them in such a way that they will willingly follow the equations that explain why the crystal cup does not fall.

2.3 Extraterrestrial Creatures

It is my feeling that one must treat students as intelligent persons and provide challenges for them. If they do not understand science, it may be a question of semantics—if we let them express science in their own words, we will achieve a lot.

If we are discussing the existence of extraterrestrial life one can have pupils build a model alien that has adapted to certain extreme life conditions, for instance by living on a planet that is totally gaseous or has only a liquid surface. Once they have completed their task, one must ask them how they would communicate with their creature. In my experience when pupils create aliens (with homeless children I have them build puppets), they rarely include ears so it is straightforward to talk about communication difficulties. Needless to say, this exercise is a great introduction to the topic of extraterrestrial life (Figure 3).

2.4 Centre of Mass and Binary Stars

Sometimes during a lecture, mention is made of the fact that binary stars spin around their common centre of mass. Since not all pupils have an intuitive idea of what this means, the teacher can carry out the following activity. He will need a rod (about 40 cm long, 3 mm wide), a loop of string about 40 cm long, several balls of play dough (preferably two small red ones of the same size, larger orange and green ones and a large blue one) and a large one made of light material.

The teacher places two small balls on the extremities of the rod and insert the loop in the middle and makes the system spin. After this, the teacher substitutes a small

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Figure 2 (see text)

Figure 3 (see text)

ball with successively larger ones, the outcome being that he has to move the point at which he places the centre of the loop towards the heavier ball. He should also use the large light ball to show that the location of the centre of mass does not depend on the volume but on the mass. Using a very heavy and a very light ball will help pupils understand why sometimes the centre of mass lies inside the more massive object.

This demonstration is also useful in explaining eclipsing binaries. Pupils can see how one star can eclipse another total or partially (Figure 4).

2.5 Interstellar Absorption

Several candles can be used to explain how, by comparing their apparent luminosities, one can estimate their distances, assuming all the objects are the same. These candles can later be employed to show how another method of distance determination works, namely measuring interstellar absorption. The instructor can place tinted viewgraphs amongst the candles to show how light intensity decreases as a result of absorption and dispersion, and that consequently it is possible to estimate distances to stars by assuming that extinction is proportional to distance.

The teacher should mention the difficulty of calculating distance to an extended object, such as a planetary nebula, whose envelope varies in size. He can explain how, by comparing the extinctions of stars of known distance that are in its vicinity to that of the planetary nebula, its distance can be estimates. A model planetary nebula, made out of

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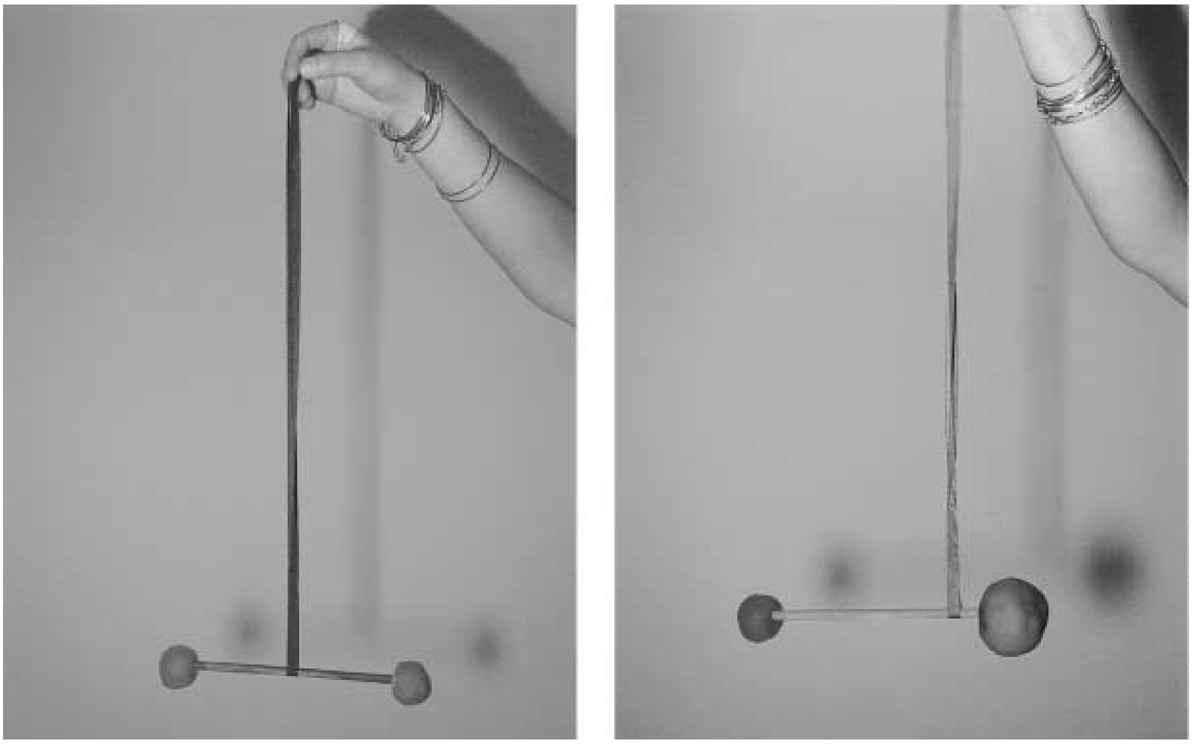

Figure 4 (see text)

Figure 5 (see text)

Figure 6 (see text)

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Figure 7 (see text)

cardboard, can be placed amongst the candles to make this point even clearer (Figure 5).

2.6 Telescopes

Some students do not understand that the main purpose of a telescope is to gather light. One can explain that all the light that comes into our eye does so by entering our pupil, and that if it could expand to several centimetres, our eye would have a much larger gathering power. If the teacher places some funnels in front of his eyes, students immediately grasp the idea of a telescope being an instrument capable of intercepting a larger number of photons than our eyes.

If the teacher is explaining charged coupled devices, he can use an ice cube tray to represent the chip and coloured buttons to simulate photons—as they fall on the tray they create the image. The instructor can explain how a filter works by only using buttons of a particular colour, or having pupils look at the buttons through coloured cellophane (Figure 6).

2.7 Chaos

Students of all school levels are interested in modern physics, and one can find ways to explain it to them so that students get a general feeling about the problems it addresses. One such problem is the case of chaos.

One can alternatively toss a candy and a balloon and show how different their trajectories are, one being totally predictable and the other unpredictable. One can also mention that each balloon's trajectory is different, so the physics of chaos is that of diversity.

2.8 Tablecloth

The goal of this demonstration is to make students realise that one of science's strengths is predictability. This is a classic experiment, but one must realise that our students may not necessarily have understood it. One needs a smooth square of fabric, about 70 cm on a side, upon which one places several objects, for instance a lit chandelier, a vase with flowers and a cup of wine. One withdraws the 'tablecloth' by pulling it firmly downwards with both hands. Of course, the objects stay put due to inertia (the experiment can also be used to explain inertia). This experiment invariably works (Figure 7).

After the experiment has been carried out by several students, the teacher should mention how dependable scientific knowledge is—the objects do not fall if the tablecloth is pulled out correctly. When an astronomer claims that there will be a solar eclipse in the year 2002, or that the sun will live for another 4500 million years, our students should perceive that these claims are based on strong foundations developed during hundreds of years of solid research.

3 Conclusion

It is useful and easy to carry out simple demonstrations during formal lectures. Teachers can deliver them

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in almost all astrophysical classes. This helps students to focus on the topic, and assists them to understand by witnessing everyday experience with three-dimensional objects that applies to the rest of the universe. I must emphasise the fact that not all high-school and college-level students will become scientists, so it is important to help them cope with the new language of astronomy in such a way that they both understand how science works and learn to enjoy it.

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