Exoplanets in physics classes

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I present the opportunity to use a new scientific discovery in physics lessons to illustrate how they can be interpreted in the course of public education. Students were asked to estimate the mass of a red dwarf star using the data regarding its planets published in an article, and through the use of the learned laws of physics.
The aim is to develop the students' knowledge of mechanics, to expand the elements of the Newtonian approach, to deepen their astronomical knowledge and to practice research methods. This new approach was tested in 2 classes, and the results were the basis of the thesis of a graduate teacher. The problem was also solved by 70 college freshmen.

The course of the lesson
Introducing the topic
Analyzing the text of the online news article[1] through questions
Calculating the mass of the red dwarf in three different ways
Calculating the mass of Jupiter from the data of its moons as a homework
Watching, analyzing, and comparing similar news reports on exoplanets

Questions asked about the article:

1. What did the researchers discover?
2. Where is the telescope with which the discovery was made?
3. Where were the researchers?
4. What methodology did the researchers use?
5. What kind of celestial body were investigated? How far is it from us?
6. Why did the researchers continue to explore and what tools did they use?
7. What further research is planned and what will they use?
8. How long have we known about exoplanets and how many were discovered?
9. What types of exoplanets have been first discovered and why?

A simple problem was solved using the data published in the article.

The problem
Seven small, Earth-sized planets circulate around a so-called dwarf star named TRAPPIST-1, about 39 light years from us, so relatively close by. It was announced by researchers at NASA in a press conference on 22th February 2017. The circulation preiod and the average distance of the planets from their star is given in the table below, and it was also depicted in a graph.
- Use the data and the graph (Figure 1) to estimate the mass of the dwarf star!
- Compare the mass of this star with the mass of the Sun!
- What approximations and assumptions were used in the estimation?

One Astronomical Unit is the Sun - Earth distance of $1.5 \cdot 10^{11}$ m, the gravity constant is $\gamma = 6.67 \cdot 10^{-11}$ Nm^2/kg^2, the mass of the Sun is $2 \cdot 10^{30}$ kg.
Calculations using the data of planets or moons is a part of the compulsory curriculum, so it can be solved as a regular task in class. For the graph method, it is an important element to discover the Kepler's Third Law in the equation of the fitted curve (the exponent being 1.5).

1 https://m.ipon.hu/elemzesek/a-het-torpe-meg-a-voros-torpe/3101

R (AU)	*T* (day)
0.011	1.51
0.015	2.42
0.021	4.05
0.028	6.1
0.037	9.21
0.045	12.35
0.06	20

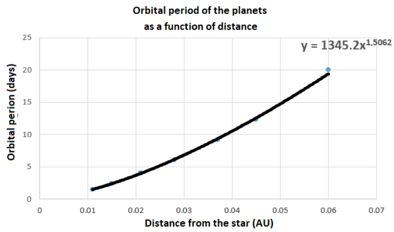

Fig. 1. The orbital data of the planets.

The foundations of the solution

Newton's law of gravitation is applied to the planetary system, where *M* is the mass of the star, and *m* is the mass of one planet. The orbit of the planet is approximated to be circular, the effects of the planets on each other is ignored. The motion equation is:

$$\frac{\gamma \cdot M \cdot m}{R^2} = m \cdot R \cdot \omega^2 \qquad \text{where} \quad \omega = \frac{2 \cdot \pi}{T} \tag{1}$$

$$\frac{\gamma \cdot M \cdot m}{R^2} = m \cdot R \cdot \frac{4 \cdot \pi^2}{T^2} \quad , \tag{2}$$

hence we can simplify with the mass of the planet *m*

$$\frac{\gamma \cdot M}{4 \cdot \pi^2} = \frac{R^3}{T^2} \tag{3}$$

which is actually Kepler's Third Law, which we can rearrange to the following form for further calculations:

$$T^2 = \frac{4 \cdot \pi^2}{\gamma \cdot M} R^3 \tag{4}$$

Three methods of solving the problem

1. Calculations using the data of each planet using the equation above.
2. Using Excel or other spreadsheet software, applying computer skills.
3. In the graph method it is an important element to discover the Kepler's Third Law in the equation of the curve.

School Trial

The above methods were tried out in a session on gravitational interactions in a high school physics class. The only difference was that the teacher only used SI units so the students didn't have to convert. The text was to be read by the students at home and the questions were answered individually, which was then discussed together. The students liked this kind of lesson and the appearance of such a new discovery on the classroom.

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