Discover a black hole in the classroom: the "Pear-Star" Project

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Is the notion of black hole only a part of a theory called astrophysics? If they are black, and swallow everything, how can we find them? How the method, photometry is used in research? Can also we use the shots made by the Faulkes telescope? By the way, what are the Faulkes telescopes? Is it difficult to learn SalsaJ? These questions above and similar ones will be discussed spiced with students' in-situ measurements. And, what do these do with a pear, you will find out.

I. Introduction

The concept of black holes is a very popular one. Our students can meet it in science fiction movies and surely in computer games. It is frequently in the media, also in the news. In our days it is an important scientific topic.

Last year the gravitational waves were discovered. These results were announced in the beginning of this year. In the researchers opinion the cause of the detected gravitational waves is two black holes moving closer and closer to each other, and finally colliding.

This discovery has an exceptional role in many aspects. One of this is that black holes are invisible. They can be detected exclusively by their effects.

No question, this topic is highly motivating for the students.

Many dedicated science and physics teachers are eager to teach or at least mention this topic in their classrooms. Rosa Doran and her colleagues recognized this need for help in the society of teachers. They called a project to life: the Galileo Teacher Training Program [1].

Figure 1. The logo of GTTP

Each year GTTP organizes sessions for physics and science teachers with other societies to promote their methodological solutions worked out especially in the fields of astrophysics and cosmology. We had a possibility to participate in one of these sessions, namely the one that was organized in Leiden in 2014 in cooperation with ESA. In the workshops we met many results and useful methodological tools of their didactical research, including SalsaJ and Stellarium [2] programs. SalsaJ enables us to identify black holes also by analyzing the brightness of stars.

II. Possible Reasons for the Changes of Brightness of Stars

It is important to overview why the brightness of stars can change. As the "Twinkle twinkle little star…" rhyme says the change in brightness of stars is called twinkling in everyday life. The change (=twinkling) can be either non-periodic or periodic.

Twinkling in the scientific context is an irregular effect caused by the changes of the atmosphere. It must be considered in all ground-observations. There are one-fold glazings too, for example:

- the explosion of novas or supernovas
- gravitational lensing or microlensing
- starpots.

The phenomena of periodic changes in brightness can be interpreted with numerous reasons. These reasons can be internal (we call these intrinsic variability) or external (we call these extrinsic variability). We can see one of the groupings in figure 2.

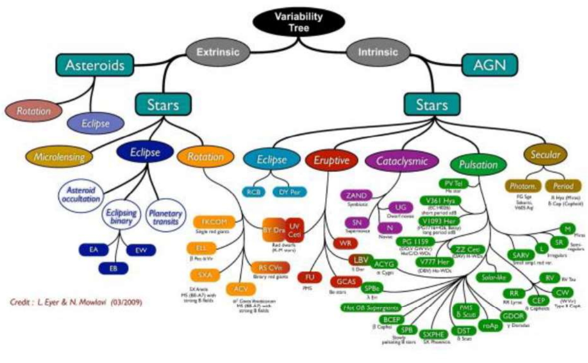

Figure 2. The Eyer-Mowlavi graph

There are many types of variable stars. We propose a site in English, where our students can broaden their knowledge:

https://www.aavso.org/education/vsa

We focus on systems containing at least one star. Since more stars may belong to a system we need to restrict our studies to binaries. In secondary school education the topic of binaries is also a challenging task. Our "pear-star" project is dedicated to them.

Both members of the binary may be a star, a star and an exoplanet, or a star and a black hole. Two celestial bodies can affect one another in a number of ways. The spectacle informs us about the types of binaries:

- astrometry binaries
- spectroscopic binaries
- eclipsing binaries
- ellipsoidal binaries

If a star "wobbles" in the sky, it is a gravitational influence of a companion (astrometry binaries). If spectral lines move due to the Doppler Effect, we speak about spectroscopic binaries. In photometric measurement a periodic change in the apparent magnitude implies eclipsing binaries. If two celestial bodies are very close to one another, the shape of the star may alter to an ellipsoidal one. The light curve of this is very important in our project. We can study this in Figure 3.

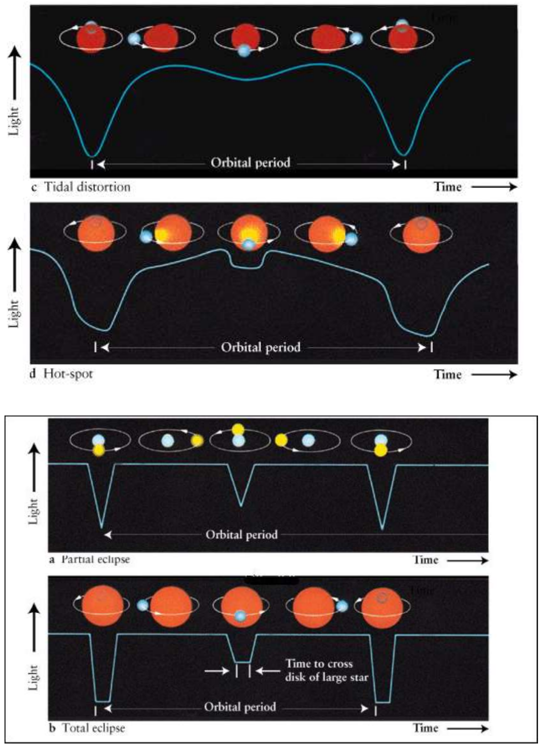

Figure 3. The light curves of eclipsing binaries [3]

The light curve is similar even if one of the celestial objects is a black hole. This is one clue for detecting the effect of black holes.

III. THE "PEAR-STAR" PROJECT

A. *What do we need?*

First of all we need to overview what will be needed for our project. Surely, we can't work without a series of real pictures that were taken of the astronomical objects that we want to study. Also a program is needed for doing the actual analysis.

Dr. Martin C. "Dill" Faulkes (figure 4.) raised the Faulkes Educational Project to support the Faulkes Telescope Project (FTP).

Figure 4. Dill Faulkes, the businessman, who supports telescopes

The FTP provides free access to 1 500 hours of observation time on two 2-meter class telescopes. These are located in Hawaii and Australia (figure 5.). First it was available for students and teacher in the UK, but recently has been opened for studies in Europe and the USA as well. Any group from the mentioned areas can register and take advantage of the possibility for free. It has been so since 2004. Detection time can be booked and the requested images are available via the internet, even online.

Figure 5. One of the Faulkes telescopes

For analyzing the data we may have gained for example from the FTP we need a simple program that is able to measure quantities like the magnitude of a star. A Java application, called SalsaJ is appropriate for the task. It is excellent for teaching purposes. We can demonstrate the work of astronomers, to give a hint about present-day astronomical research, and still, it is not overcomplicated. We can download it for free from this link:

http://www.euhou.net/index.php/salsaj-software-mainmenu-9

This application is user and student-friendly (figure 6.). It is not only multi-platform, but also multi-lingual. We can find versions with or without associated images for Windows, Linux and Mac OS X as well.

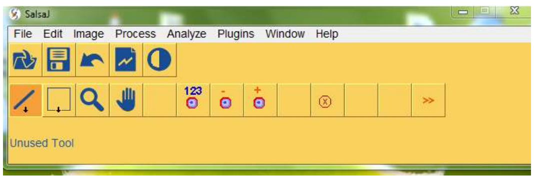

Figure 6. The window of the SalsaJ program

We can also find video manual on the site in the following topics:

1. How to open a file
2. How to display the properties of an image
3. How to set the scale of an image
4. How to measure distances inside an image
5. How to create an animation with several images
6. How to measure the flux inside an image
7. How to process a spectrum

SalsaJ is presented in the framework of EU-HOU SRT Network Project. On the site we can find inspiring projects that can give us ideas or are free to be repeated. We highlight a few from our favourites that gave us courage to have a go with our “pear-star” project in a secondary technical school:

1. From Doppler effect to exo-planets
2. A black hole lurked at the centre of our Galaxy?!
3. Life cycles of a star -- Plotting your own HR diagram!
4. Discover an exo-planet: the transit method

B. Dispelling a misconception

The study of misconception is one of the leading areas of science didactics research. First we decided to introduce the SalsaJ program with a task in service of this. Our students tend to think that most stars should be seen red because of the well-known effect, called red-shift, while some stars should be visibly blue because of the similar reason. Also many find it disappointing to make personal observations with a telescope since the spectacle falls short to the magnificent ones that are in most albums or on the title-pages of magazines.

First we open the SalsaJ program with our students. We can give them a picture (figure 7) like this one:

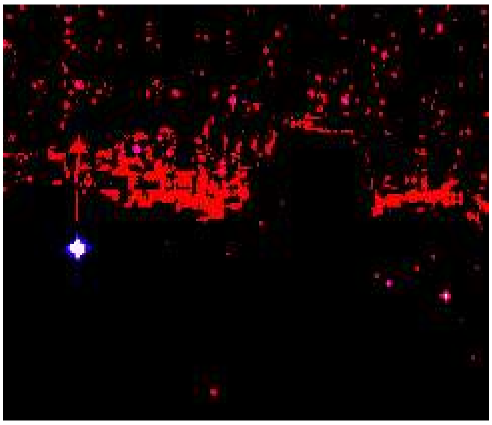

Figure 7. What is on the picture?

It is very unlikely that anybody can identify what is on their screen. Now, we can show them that using this program we can make things visible, and doing so they can understand that the same picture can stay hidden from us if we use different filters, use different brightness or contrast settings. In the program we follow this route:

image / adjust / brightness & contrast

We reveal our “hidden” picture in a famed form: the Horse-Head Nebula (figure 8.).

Figure 8. The Horse Head nebula

We ask our students to check that the information in the image doesn’t change as we change the spectacle of the given picture by pulling the sliders. We do this following these steps and comparing the data:

image / show info

We can enjoy this session with our student very much. They are eager to change the sight and test each other on images of actors, their own pictures, etc. Surely, it isn’t a crucial part of the project, still necessary for the oncoming steps. It proves to be a time consuming task, still we make fun whilst helping our students to acknowledge very important steps of processes in the fields of astronomy and its popularization.

C. Discover a Black Hole

We have a series of 60 pictures that were evenly shot in time, made by a Faulkes Telescope. These were asked for our specific purpose to give our students a possibility to discover a black hole.

Our students get this series. Each image is similar to this one, not necessarily in an easily recognizable format, but now they understand that no information changes as they choose a spectacle more likeable or more comfortable to work with.

In the middle of our images (figure 9.,10.) there are four stars that form a rhombus.

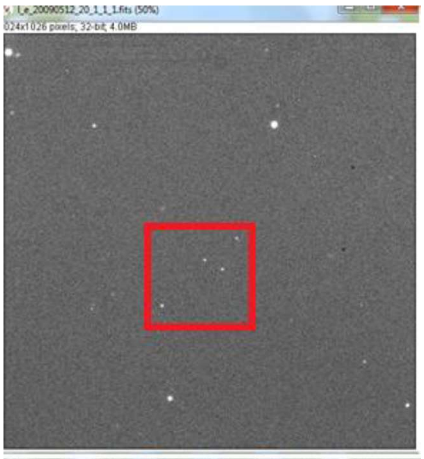

Figure 9. One of the 60 images

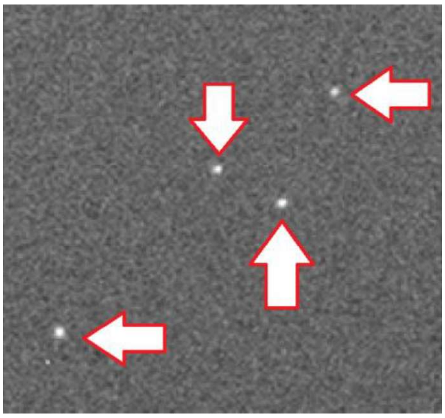

Figure 10. The four stars forming a rhombus

We can measure the intensity (or brightness) of these four stars easily by these steps in SalsaJ:

analyze / photometry /click

We copy our results into Microsoft Excel. This program also provides the completion of the next task: plotting intensity versus time graph. These are the light curves for each of the chosen stars.

The results of our measurements are these:

For star we called Right-Top is (figure 11.):

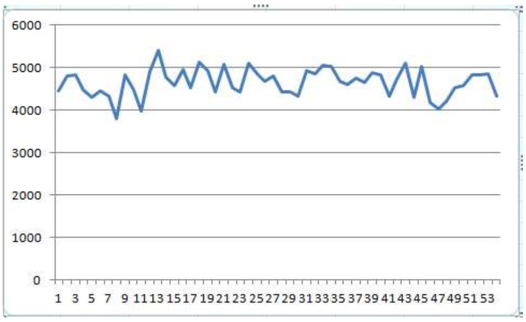

Figure 11. The graph for star "RT"

For the star we called Middle-Top is (figure 12.):

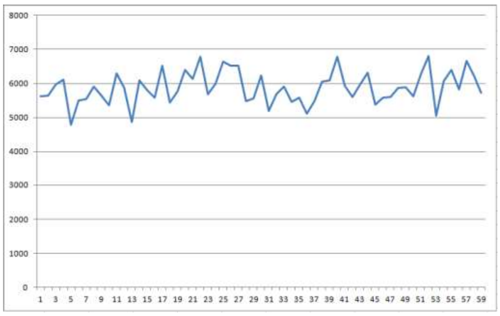

Figure 12. The light curve for the "MT" star

The light curve for star Left-Under is shown in figure 13..

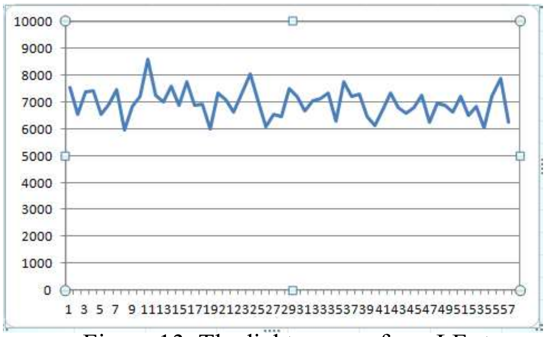

Figure 13. The light curve of our LF star

And, finally the curve for the Middle-Lower star is as follows (figure 14.):

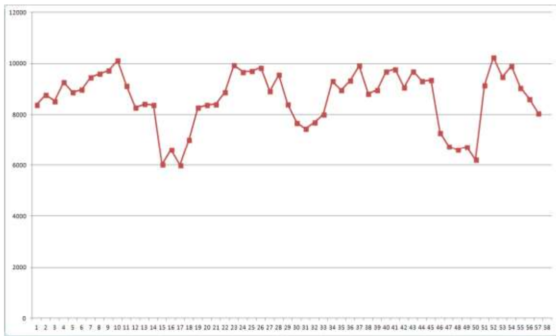

Figure 14.The light curve of ML star

We can discuss the size of the measured data and the extent and pattern of the dispersion of the results for each star.

It is obvious to notice that our ML star has a particular period in the results of intensity. We can estimate the time period to 30 "picture-time"-s, and the range in intensity to about 50%.

We note that these units are unusual in the physics classroom, but our purpose is to a give a hint for the methods of astronomical research rather than give an exact analysis. Those students who are interested can make a deeper study and calculate these quantities by using the information that is encoded in the images.

It is also obvious that the period consists of a smaller and a bigger decrease of intensity. From this note we can conclude the possible form of the star we are studying. Our students can easily figure out or accept that this shape could be one of a pear. From each side to us the magnitude is at its maximum. When the "calyx" is to us a bigger decrease in the intensity can be measured. When the stem is to us a smaller decrease can be detected. That's why the name of the project is the "pear-star" project.

Now, that we know the shape of the "pear-star", we can go back to some of our images and recognize that our star is not in the same place in the images. It wobbles slightly. By checking what we can find close to the star we can't find another star that could be the partner in a double-star duplex (binary). By checking the spectrum and thus disqualifying other possibilities that could explain this phenomenon, we get closer and closer to the idea that our "pear-star" has its shape because of a black hole.

D. *The implementation*

We announced the "pear-star" project in Trefort Ágoston Technical Secondary School, Budapest in the spring of 2015. We had an eager group of 14 students who showed interest in the topic and also had a good command of English. These boys were all students of IT in the bilingual section of the school (figure 15.).

Figure 15. IT students in mentor class

First, we visited the TIT Budapest Planetarium [6], where we watched two shows: Wonders of the sky and Hubble Universe. We also had a session there with one the astronomers (Mr. Gyula Nyerges) of the institution to promote the project.

In one of the IT seminar rooms we spent a nice afternoon together getting to know SalsaJ and finding The Black Hole (figure 16.).

Figure 16. Tamás and Tomi analyzing the intensity data of one of the appointed stars

IV. Summary

The concept of black holes is an up-to-date one so in research as in our everyday life. Teenagers are highly motivated to study the subject. Today's innovations in information technology do open a whole new world in didactics and methodology.

We planned and carried out a project, called The "Pear-Star" Project for eager secondary school students of IT. We visited a Planetarium, where our astronomer also led us into the details of their informatics in use. We registered to the Faulkes Telescope Project to get a series of images for free. We got these via e-mail. We downloaded a Java Application, named SalsaJ. We used it on our computers in the school's seminar room. We utilized Microsoft Excel to collect the data of 240 measurements, and also to plot a graph that we could analyse. During the project we found a lot of other educational and astronomical sites that we could examine together, and made good use of the most.

Our idea could not have turned into practice without computers and the internet. IT promoted our project in astrophysics.

While in higher education programming and simulation is in the focus of the projects, like the Monte Carlo simulation [8], programming plays little role in secondary school mentoring, though we can find examples for this too [9]. The use of the internet, and especially the use of some free-to-download programs widens the possibilities for those who work in secondary school education.

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- each of the students who participated in The Pear-Star Project

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