Astronomy is the Trojan Horse for Teaching Physics Invisibly

Experiences from Star-gazing with both Students and the Public at a University Observatory

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Problem
- valid for university students and the public

- Physics is perceived as hard subject.
- Difficulties in physics are based on mathematics and complex theories.
- Cognitive “understanding” of physics can not be reached by memorizing simple facts.
- Learning physical concepts is essential.
- Physical misconceptions are widely spread.

A Solution
- astronomy helping to learn physics invisibly

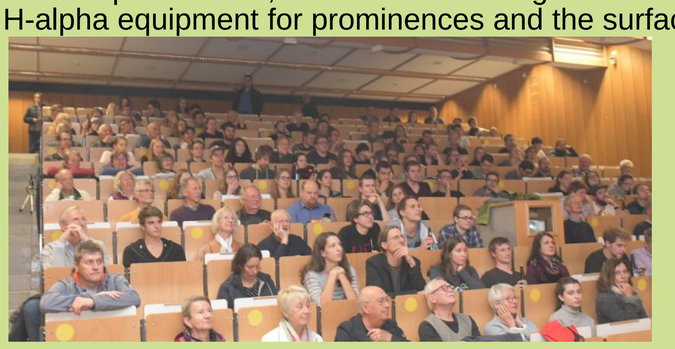
- Astronomy attracts the masses:
  - general astronomy courses are overbooked,
  - hundreds of people visit observatories for eclipses, transits of planets in front of the sun,
  - space flight, unveiling the secrets of our galaxy and beyond, in public talks, TV-series, the internet show increasing interest by everybody,
- Most people do not know that astronomy is “just a form of physics” therefore:
  ➔ star gazing helps to teach physics invisibly.
- Well working examples are shown.

Starting Point

- Rosenheim in Bavaria/Germany has 60.000 inhabitants.
- Rosenheim University of Applied Sciences has 6.000 students.
- The observatory is part of the university and used for:
  - Course ‘Introduction to Astronomy” for students (General Studies)
  - provide star gazing tours once a week for everybody interested in the general public or school classes.
  - 4 to 5 times a year a professional astronomer gives a public talk about astronomical topics.
- More than 2000 people are in contact with astronomy per year, many being scientific novices.

Observatory Equipment

- 5 m dome
- 14 inch Schmidt-Cassegrain (Celestron 14), 4000 mm focal length
- 8 inch Schmidt-Cassegrain (Celestron 8), 2000 mm focal length
- 6 inch Apo refractor, 1000 mm focal length
- H-alpha equipment for prominences and the surface of the sun



General Aspect

- How do astronomers find out facts without travelling to the stars and planets?
- How do they measure temperatures and distances far away from earth?
- How do they find out about stellar speeds, stellar evolution without waiting for ages?

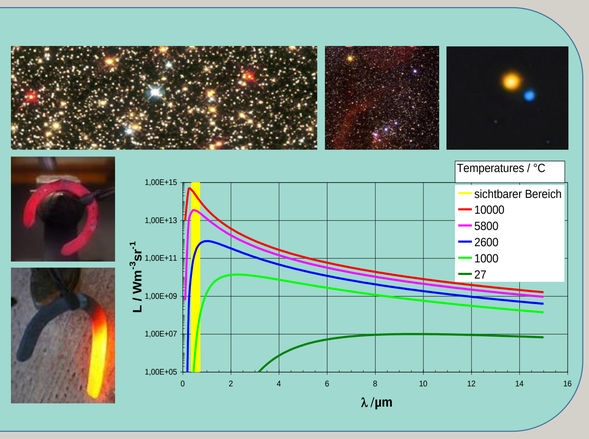
➔ Astronomers use physics validated in labs and apply these methods to investigate stellar movement and the light coming from the stars. Spectra are cosmic bar codes of knowledge.

Example 1: Wien’s Displacement Law

- Stars are colored. We observe eg. Betelgeuse in Orion (α-Ori) or Albireo in Cygnus (β-Cyg) and see their red or orange/blue emission.
- While heating a horseshoe its color and emission intensity changes with temperature: Planck-curves increase and their maximum shifts to shorter wavelengths → red stars are colder than blue stars

➔ Temperature Measurement with $\lambda_{max}T = \text{const}$

¿ But why is planet Mars red? Does it emit red light like Aldebaran, Arcturus or Betelgeuse?



Example 2: Conservation of Angular Momentum

- Observing HII-regions like in Orion and stellar clusters like the Hyades or Pleiades star formation is discussed final leading to solar systems
- All planets orbit the sun in the same direction and (almost) all planets spin around their axis in exactly the same direction. Solar rotations period is 1 month.
- Neutron stars spin several times per second.

➔ The law of conservation of angular momentum well known from ice-dancing: $J\omega = \text{const}$

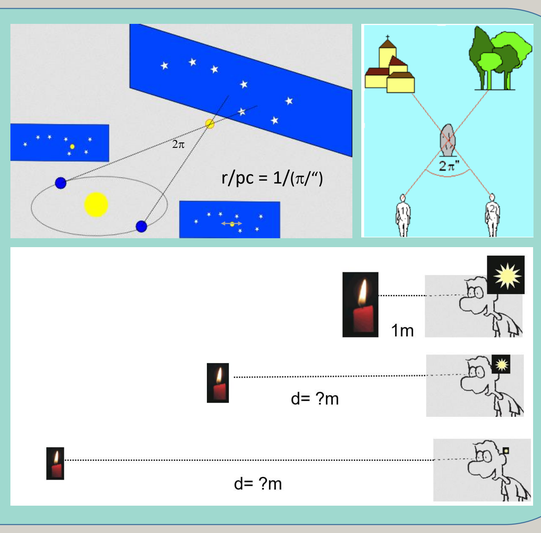
¿ Why is Venus rotating backwards?

Example 3: Measuring distances of stars

Nobody could measure distances in the universe with a tape measure… ☺

- Astronomers use the methods of geodesy by using the parallax angle 2π with moving the base of measurement, i.e. comparing the positions of a star in January & July.
- An alternative for bigger distances are cosmic standard candles like Cepheides or supernovae Ia; here the luminosity of the ‘candle’ is known and the distance can be calculated by comparing the magnitudes m and M: $m - M = 5 \cdot \log r - 5 \Rightarrow r/pc = 10^{\frac{m-M}{5}+1}$

¿ What is the astronomical distance ladder?



More examples of teaching physics in star gazing tours at an observatory

- Measuring speed with the optic Doppler effect, well known in acoustics standing at a road. This leads to age of star clusters by comparing their openness e.g. in Hyades and Pleiades.
- Knowing star distances one can compare Sirius and Betelgeuse distances thus leading to energy output differences of these two stars and thus to nuclear fusion processes.
- Birth, aging and dying of a single star can not be observed. But investigating big groups of stars one can model stellar evolution and compare its results with the observations.

Summary

- Star gazing tours – both with the naked eye and with telescopes at an observatory are an ideal Trojan horse to teach physics, even to people with (perceived) difficulties in physics and STEM subjects, as the motivation of everybody for astronomy is high.
- The methods how astronomers make their findings are deep down physics and can easily be compared with problems from daily life, which makes it easy to transport physical content.

Poster at PERC July 2019 in Provo/Utah (USA).
PERC = Physics Education Research Conference

Details: https://www.compadre.org/per/conferences/2019/ and https://www.aapt.org/Conferences/sm2019/