Astronomy for the Blind and Visually Impaired

Simon Kraus
Physics Education Research Group,
University of Siegen, Germany
kraus@physik.uni-siegen.de

Keywords
Visually impaired, accessibility, disabilities

This article presents a number of ways of communicating astronomy topics, ranging from classical astronomy to modern astrophysics, to the blind and visually impaired. A major aim of these projects is to provide access which goes beyond the use of the tactile sense to improve knowledge transfer for blind and visually impaired students. The models presented here are especially suitable for young people of secondary school age.

Introduction

The desire to give visually impaired and blind people access to astronomy has long been pursued. In Germany these efforts can be traced back to the 1960s. These projects have mainly tried to communicate classic astronomy, using, for example, models of the Moon, a representation of the Sun's activity or a planisphere. All of these techniques centred on tactile elements (Henschel, 1965) and so too have many of the more modern attempts, mimicking their predecessors but using modern lightweight materials (Carvalho and Aquino, 2015).

To give everyone a chance to develop a world view that is compatible with our scientific knowledge, engagement with astronomy needs to go beyond classic astronomy and integrate astrophysical topics. Modern attempts to communicate scientific advances in the field of astronomy have involved, for example, tactile images of currently active instruments, specifically the Hubble Space Telescope (Grice, 2007; Grice et al., 2007; and Arcand et al., 2010).

The first aim of the work presented here is to give visually impaired people access to different astronomical subjects. This should include classical astronomical questions as well as modern astrophysical topics.

The second aim is to extend such astronomical models beyond the use of the tactile sense. Many details, such as the temperature of an object, can be represented in a model, leading to a stronger connection between the model and the original phenomenon. Examples of models which respond to different senses will be presented in this article.

Currently all the models have a plain design, because they were mainly made for entirely blind people. Further information in the form of colour can easily be added if they are to be used by a mixed audience.

Model one: the tactile constellation

The first model is limited to the tactile sense since there seems to be no proper way of switching to another sense. The main goal of this model is to show the difference between the appearance of a constellation of stars in the sky and their actual magnitudes and positions in space.

Not every constellation of stars can be converted into a model because some of them include giant stars which are visible over huge distances. Without making use of a logarithmic length scale, a model of such a constellation would be too large to manage.

With this in mind and after some consideration the constellation Cassiopeia was selected. The model (shown in Figure 1) shows how the constellation appears on the sky, with five main stars that have almost the same apparent magnitude. The model further contains information about the real distances of these five stars

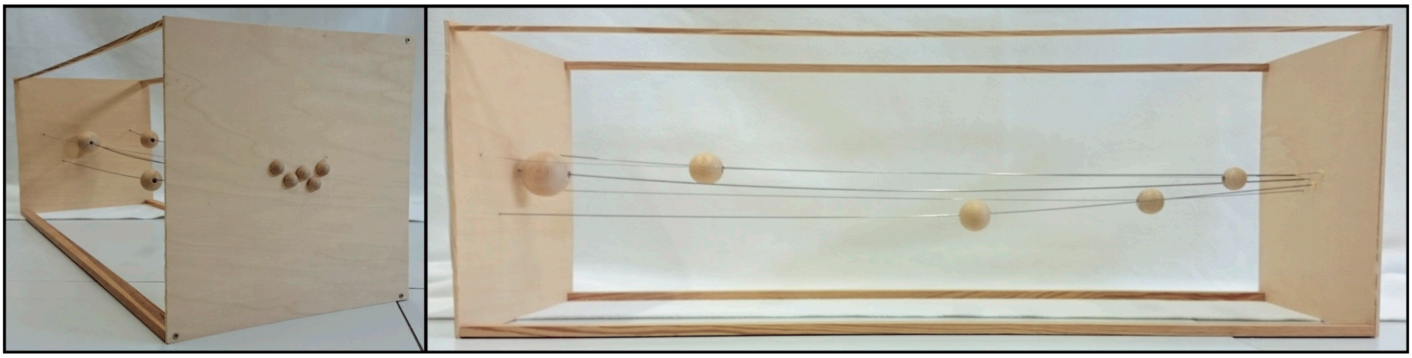

Figure 1. *The model Tactile Constellation shows the apparent magnitudes and distribution of the stars in the constellation of Cassiopeia (left) and the real magnitudes and distances of the stars (right). Credit: S. Kraus*

Figure 2. *The three spheres shown here represent different main sequence stars. Credit: S. Kraus*

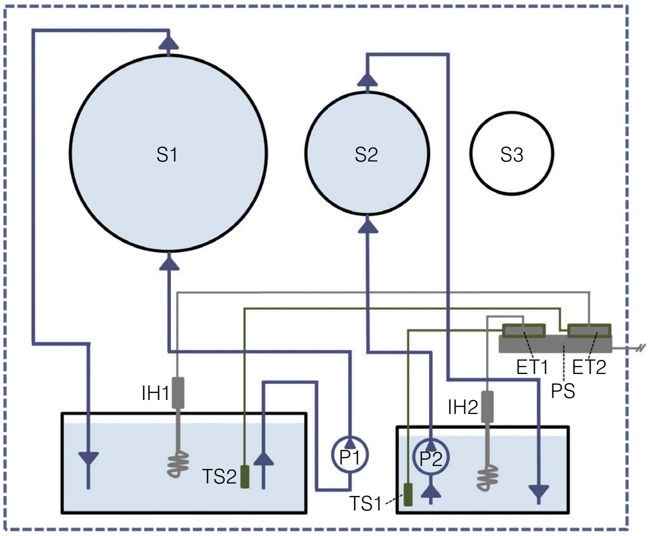

Figure 3. *Schematic overview of the main sequence star model: spheres (S), pumps (P), immersion heaters (IH), electronic thermostats (ET), thermostat sensors (TS) and power strip (PS). Credit: S. Kraus*

from each other, and from the observer. It becomes clear that the appearance of the constellation has no relation to the real distribution of the stars in the Universe.

The second important piece of information one can obtain from this model is that the absolute magnitudes of the stars increase with increasing distance from the observer. Absolute magnitudes are represented by the different diameters of the wooden spheres mounted on the wires. Each wire connects one of the spheres with one of the hemispheres mounted on the model's front.

The combination of these simple physical facts leads to the insight that this constellation is unique for observers positioned in our Solar System.

Hertzsprung–Russell diagram

The second model leads us away from classical astronomical observations. Instead it represents an important relationship between two properties in astrophysics, namely the luminosity and temperature of main sequence stars. The Hertzsprung–Russell diagram (HRD) illustrates the connection between these variables. It can be shown through the diagram that for main sequence stars a higher surface temperature necessarily implies a larger radius of the star — big stars are hotter than smaller ones.

Since temperature is key to this concept it is desirable to represent it within the model. The model therefore comprises three metal spheres with different diameters and temperatures. The smallest sphere is at room temperature while the other spheres are warmed to temperatures of 33°C and 42°C.

The temperature is regulated by two containers filled with water, heated by immersion heaters and controlled by electronic thermostats. Warm water is pumped through flexible tubes from the container to the corresponding sphere. These pumps can be easily sourced at low cost. In our project one pump (P1 in figure 3) was originally designed to be used in a computer's water cooling system. The second pump (P2 in Figure 3) was made for an aquarium. This setup guarantees a uniform temperature over the whole surface of each sphere.

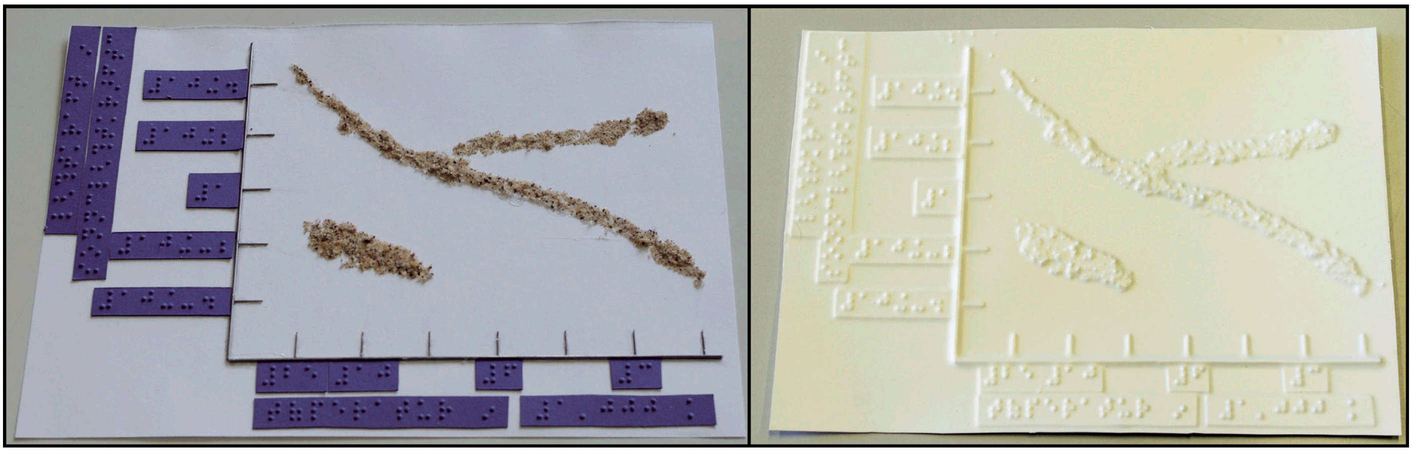

Figure 4. *Tactile image of the Hertzsprung–Russell diagram and the corresponding template. Credit: S. Kraus*

Students can handle the model and compare the diameters and temperatures of the spheres to deduce how the properties of the stars are correlated. The high temperature and twenty-centimetre diameter of the biggest sphere led one student to describe it as a star “with tremendous power”.

To supplement this activity, students can study a tactile image of the complete HRD, which can easily be produced out of everyday objects (Figure 4). They thereby have the chance to compare their impressions with this graph.

Model three: sunspots

The third model represents a phenomenon which can easily be observed even with small telescopes: sunspots. These are caused by strong magnetic fields breaking through the Sun’s photosphere. This causes convection to slow down and decreases the temperature by more than 1500 K in comparison with the periphery. Therefore, the model should communicate both the (relatively) low temperature of the spots and the magnetic field.

Unlike other models (Isidro and Pantoja, 2014) there is no tactile element to the model Sun’s surface. Given that the main effect is caused by temperature differences the model instead makes use of the sense of temperature. To achieve this, the model Sun is made out of a plastic globe. On its inner surface several thermoelectric elements are placed with their cool sides pointing outwards. Small fans are mounted in the globe, pointing towards the thermoelectric elements and enhancing their cooling effect. The elements come in groups of two, illustrating the ideal bipolar sunspot groups that can often be observed on the Sun (see Figure 5 for schematics).

In the first step the model is explored with the fingertips and sunspots are identified by the drop in temperature over the elements. In the second step the exploration can be continued by means of a magnet. A magnet is a well known and very simple tool and is therefore appropriate for the exploration of the sunspots’ magnetic fields. A student will be able to detect the opposite magnetisation within a single group of sunspots and between the two hemispheres of the Sun.

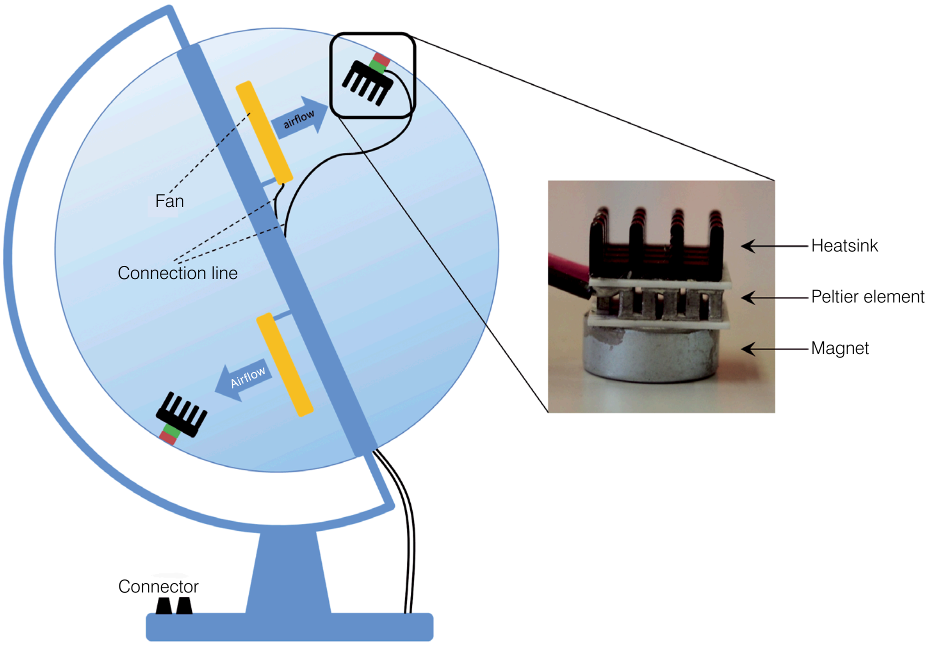

Figure 5. *Schematic illustration of the model “sunspots”. Credit: S. Kraus*

Altogether the model allows students to identify the temperature drop, recognise the presence of a magnetic field, find the ideal appearance of the sunspots in bipolar groups and compare the relationship between the magnetic polarisation within a group of sunspots and between the two hemispheres.

The model is nevertheless limited in its representation of a sunspot for technical reasons, and the restricted resolution of our sense of temperature. There can be no differentiation between the umbra and penumbra of a single spot, which can easily be recognised with a small telescope thanks to the different colours.

Conclusion

The development of models for visually impaired people not only gives these students access to an important natural science but is also an important step towards a conception of the world that is complete and compatible with modern scientific knowledge.

What is more, adapting a topic to suit the needs of visually impaired or blind students may yield models and concepts that can be of great advantage to sighted people too.

References

Arcand, K. K. et al. 2010, CAPjournal, 8, 15

Carvalho, C. L. & Aquino, H. A. 2015, CAPjournal, 17, 36

Grice, N. 2007, Astronomy Education Review, Vol. 5

Grice, N. et al. 2007, *Touch the invisible sky*, a multi-wavelength braille book featuring tactile NASA images, (San Juan)

Henschel, G. 1965, *Astronomie in der Oberschule für Sehgeschädigte*, in Blick in das Weltall, 9, 80

Isidro, G. M. & Pantoja, C. A. 2014, CAPjournal, 15, 5

Kraus, S. 2015, *Astronomie für Blinde und Sehbehinderte*, Dissertation, Universität Siegen, http://dokumentix.ub.uni-siegen.de/opus/volltexte/2016/976/index.html

Biography

Simon Kraus obtained his doctorate at the University of Siegen, Germany. In his dissertation he demonstrated new methods for teaching astronomy and astrophysics to blind and visually impaired learners. He is also interested in using science fiction in physics lessons and finding ways to implement experiments and models about renewable energy in school.