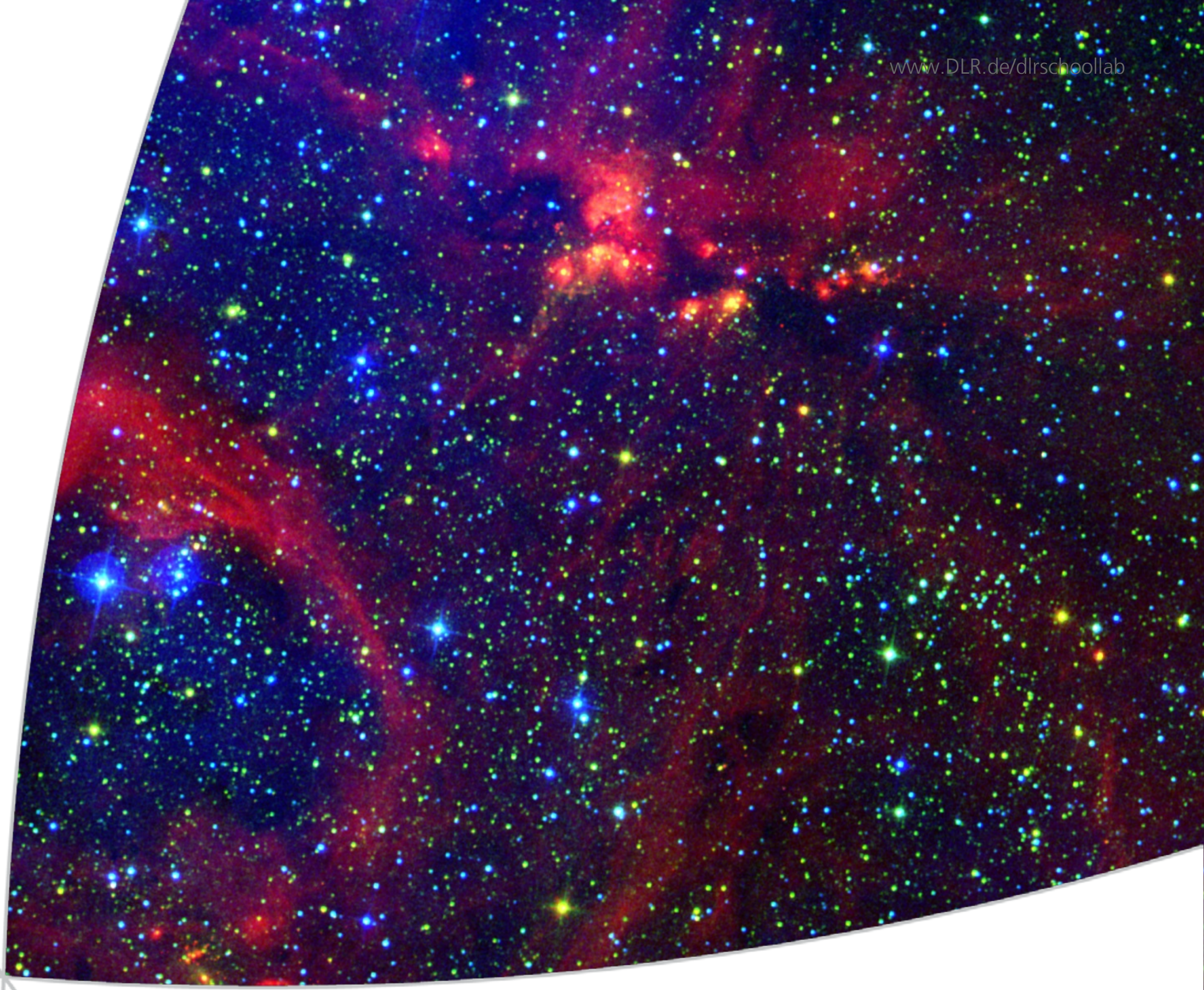


DLR_School_Lab Köln

Infrared

Beyond the rainbow

William Herschel was confused. The German-born British musician, mathematician, astronomer and engineer had just carried out an experiment in which he measured the temperature of light. He had used a dispersive prism to break light up into its spectral components. He wanted to know if green light was warmer than yellow or red light. In order to do this he had placed thermometers in the different spectral sections of visible light. The thermometers standing in the light measured higher temperatures than that in the surrounding room. That he had expected. He did not measure any differences in temperature between the different spectral colours. But he had placed a thermometer in the shade, next to the red light. And this thermometer was showing the highest temperature! Herschel realised that there must be more, invisible radiation beyond the red light. He named it infrared (from the Latin "infra", meaning "beneath").

Humans cannot see infrared radiation (IR) but they can feel it as heat. This helps us to perceive the direction from which heat is coming. Some snakes however, are much better at perceiving infrared radiation. They have pit organs with which they "see" thermal infrared radiation, which is useful when hunting warm-blooded prey in the darkness. The Australian "fire beetle" *(Merimna atrata)* can perceive forest fires that are up to 30km away.

Fig. 1: Frederick William Herschel (1732-1822), discoverer of infrared radiation.

Making the invisible visible

Many CCD cameras – such as you may have in your mobile phone – can perceive and display infrared radiation. Try this out yourself: Our kitchen is equipped with a surveillance camera. Even when it is completely dark in there, we on the outside can see what is happening within. This camera does not, however, measure heat but instead emits infrared and then uses the reflection of the radiation from different surfaces.

If you want to measure temperatures, you need a thermometer that is as accurate as possible. Perhaps you have encountered IR thermometers which are often used to take a person's temperature when they are ill. If we want to produce a thermal image, we have to measure the thermal emission from each point of a dot matrix image and display the temperature using false colour imagery (see illustrations 2 a-c). The infrared camera you will be working with uses this technology. You can save thermal images and take them home with you.

The advantages of having fur

Have a look at your fellow pupils using the IR camera. What parts of their faces are particularly warm or cold? Why do you think that is? Consider illustration 3 and try to explain why having "fur" can be an advantage.

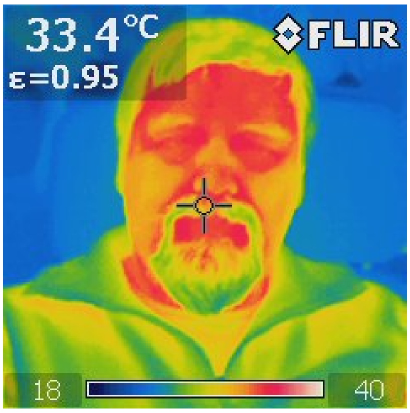


Fig. 3: Thermal portrait

Sieves for waves

You are probably familiar with mechanical filters such as kitchen sieves or coffee filters. They separate objects according to size. Electromagnetic waves such as light can also be filtered. Try it out: Red light cannot get through a green filter and the world looks a little different. What about infrared radiation? Can metal, a bin bag or perspex act as filters for IR?

We will reveal that you will be able to look through a coloured balloon using our IR camera (Fig. 4a). Perhaps James Bond's camera can see through walls after all? Try it out!

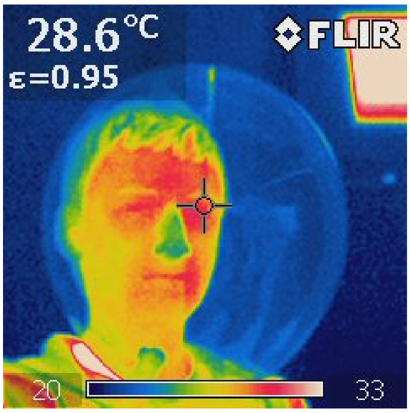


Fig. 4A: IR passes through a coloured balloon...

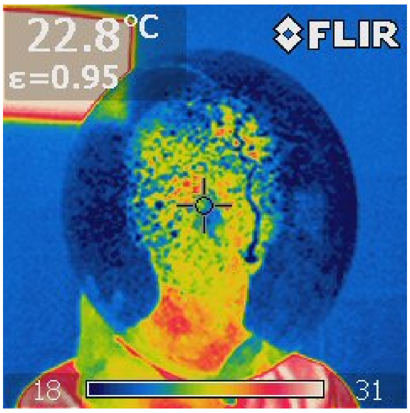
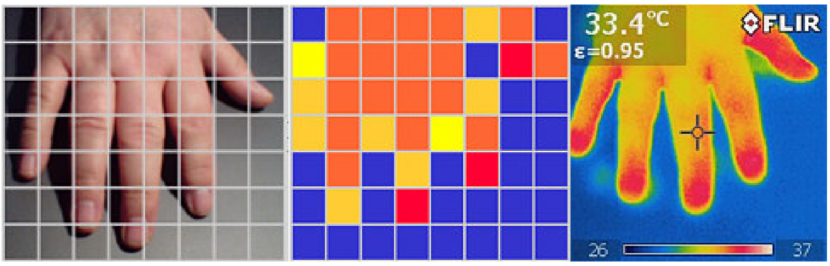


Fig. 4B: ...but water gets in the way!

Searching for heat

Surfaces that are made of isolating materials retain heat for a surprisingly long time. Sit on a chair or press your hand down onto a table. Are there particularly warm objects in the DLR_School_Lab? Has our radiator been bled? How good is the isolation surrounding our windows and is the air-con working? Identifying sources of heat not only reduces energy costs but can also be used to test the safety of electric circuits.

Pour hot water into different cups and take thermal images. Which cup is more likely to burn your fingers and which more likely to burn your mouth? Why?



A B C

Fig. 2: Creating a thermal image: the temperature of each square in the matrix is measured and displayed in false colours. By making the squares smaller we improve the quality of the picture.

Scottish cube

Sir John Leslie (1766- 1832) was a Scottish mathematician and physicist. Among other things, he sought to understand heat transmission and flows. A sheet copper cube was named after him. One side is painted black, one white. Fill the cube with water and measure the heat emitted from both surfaces respectively. This will tell you whether or not the Scots should paint their radiators black or white and which colour car is better to have.

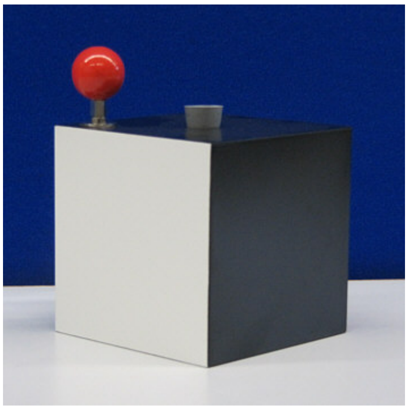


Fig. 5: Leslie's cube demonstrates the heat radiation from different surfaces

Infrared transmission

Most remote controls use pulsed IR signals to transfer information to our appliances. We cannot see the signals but by using a photoelectric cell connected to a speaker, we can hear them and understand why our remote controls and devices sometimes seem to speak different languages.

Thermal messages from space

Frederick William Herschel discovered that our Sun emits infrared radiation. Others stars do this too. The balloon experiment showed you that IR can pass through material that absorbs visible light. IR is able to travel through vast cosmic nebulas that absorb other forms of electromagnetic radiation.

Astronomers are therefore very interested in photographing the night's sky using IR-sensitive cameras in order to discover new stars.

However, the balloon experiment also showed that IR cannot pass through water (ill. 4b). Clouds and atmospheric water vapour interfere with IR astronomy. Therefore, the telescope needed for such observations has to be positioned above the clouds.

The Hubble Space Telescope has been orbiting Earth at an altitude of 575 km since 1990. In this time, it has taken sensational pictures within the visible, IR and UV spectrums. The "successor" telescope was the "Herschel Space Observatory", which was active from 2009 until 2013.

SOFIA is chasing young stars

Space telescopes and cameras on the International Space Station are not enough to satisfy the curiosity of all the world's astronomers. NASA and DLR have therefore built a flying observatory: A reflector telescope was built into a Boeing 747SP. In autumn 2010, SOFIA (Stratospheric Observatory for Infrared Astronomy) took its first pictures.

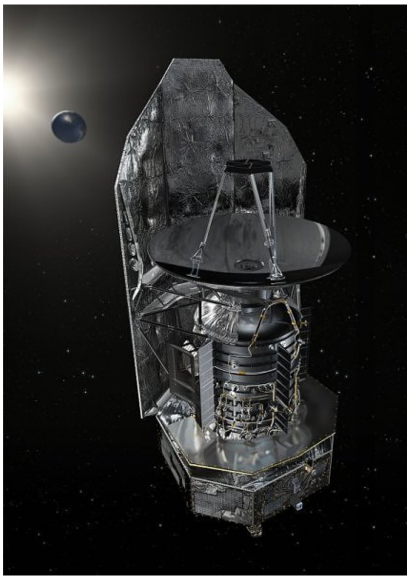


Fig. 6: Herschel Space Observatory

Illustration 8 contrasts pictures of the star constellation Orion taken in the visible and infrared spectrums. Radiation sources can be seen in the second picture, which are hidden behind gas and dust nebulas in the first. New stars are either being born or have been born there.

Fig. 7: SOFIA, the flying telescope (Picture: NASA/C. Thomas)

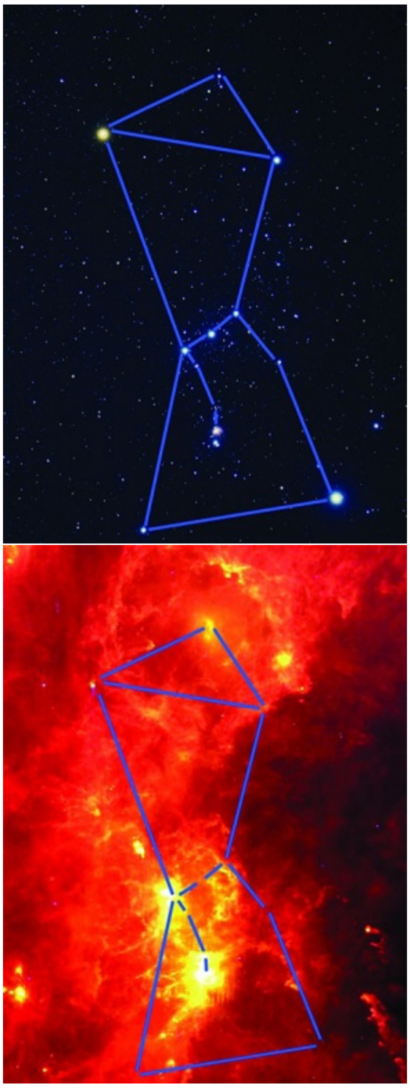


Fig. 8: The star constellation Orion as seen in the visible spectrum (a) and the infrared spectrum (b). Gas and dust nebulae in the centre are regions in which new stars are born.

Webseiten:

http://www.dlr.de/desktopdefault.aspx/tabid-4220/
(SOFIA)

http://www.dsi.uni-stuttgart.de/
(Deutsches Sofia Institut)

http://www.dlr.de/next/desktopdefault.aspx/tabid-6734/11050_read-25257/

http://www.dlr.de/next/desktopdefault.aspx/tabid-6738/11073_read-25276/

http://www.dlr.de/eo/desktopdefault.aspx/tabid-5733/10088_read-21273/
(EnMAP)

DLR at a glance

DLR is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport, digitalisation and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 20 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Dresden, Goettingen, Hamburg, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Stade, Stuttgart, Trauen, and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

DLR Cologne

Aviation, space travel, transportation, energy and safety are the research areas pursued in the nine research facilities at DLR Cologne. The basis of the research and development carried out on site are the large testing facilities such as wind tunnels, turbine and materials test benches and a high-flux density solar furnace. The 55 hectare/ 136 acre site is home not only to the research and administrative facilities of the DLR, but also to the European Space Agency's (ESA) European Astronaut Centre (EAC). The DLR has around 1400 employees in Cologne.

About the experiment:

Recommended for grade(s): 4 to 10
Group size: 5 to 6
Duration: 50 minutes
Subject matter:
Physics
Astronomy

DLR Deutsches Zentrum für Luft- und Raumfahrt

DLR_School_Lab Köln
Linder Höhe
51147 Köln

Head: Dr. Richard Bräucker
Telephone: 02203 601-3093
Telefax: 02203 601-13093
E-Mail: schoollab-koeln@dlr.de
Internet: www.DLR.de/dlrschoollab