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Invisible rays

TopFoto

Right: *William Herschel conducting his experiment*

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Electromagnetic spectrum
Experimental control
Scientific publication

William Herschel was an astronomer. When he discovered Uranus in 1781, he became the first person since ancient times to identify a new planet. However, he is also known as the 'accidental' discoverer of infrared radiation. Is this a fair description? Can such discoveries really happen by accident?

At the end of the eighteenth century, William Herschel was a well-established scientist. He was appointed court astronomer in 1782, which allowed him to establish an observatory in Slough, near Windsor Castle. He worked there with his sister Caroline; together they produced a vast catalogue of nebulae, distant clusters of stars which appear as cloudy patches in the night sky.

Box 1 William Herschel (1738–1822)

1738 Born in Hanover, Germany.
1752 Joined army band as oboist.
1757 Emigrated to England.
1766 Became church organist in Bath; developed interest in astronomy.
1773 Started making telescopes.
1781 Discovered Uranus.
1782 Appointed court astronomer.
1800 Discovered infrared radiation from Sun.
1822 Died in Slough.

Box 2 Caroline Herschel

William Herschel's sister Caroline was a greatly respected astronomer in her own right. She discovered 14 nebulae and 8 comets. She and her brother jointly constructed the telescope with which they discovered Uranus. She died aged 98 in 1848.

Through a glass darkly

During the day, William used his telescope to make observations of the Sun. The intensity of the Sun's rays makes this dangerous, so he used coloured glass filters to reduce the brightness to a safe level. Something concerned him: some of the filters seemed to transmit more of the light, while others let through more of the heat. As he wrote:

> I used various combinations of differently-coloured darkening glasses. What appeared remarkable was that when I used some of them, I felt a sensation of heat, though I had but little light; while others gave me much light with scarce any sensation of heat.

Any good scientist would recognise that this was important. Could the filters be affecting his observations of the Sun? William set about finding out.

Comparing colours

When light falls on a dark surface, it is absorbed and the surface gets hot. Energy from the light has become heat energy in the absorbing surface. William wondered if different colours of light might have different heating effects. Might a green filter, for example, let through little heat because green light has a weak heating effect? He set up an experiment to find out.

In a darkened room, he arranged a piece of cardboard with a slit in it so that a narrow beam of light came through the window. The beam struck a glass prism, forming a spectrum on his workbench. Now he could measure the heating effect of each colour in the spectrum.

He set up three thermometers side by side on a sloping stand, so that he could move the central thermometer into different regions of the spectrum. The thermometers to the right and left were outside the spectrum; they acted as experimental controls, to check that any rise in temperature recorded by the central thermometer was due solely to the absorption of light.

Table 1 lists the temperature rises he noted after 10 minutes in each case. (Notice that English scientists at the time used the Fahrenheit scale of temperature.)

Herschel was able to conclude that red light has the greatest heating effect of all colours in the spectrum of visible light. He wrote: 'The heating

David Parker/SPL

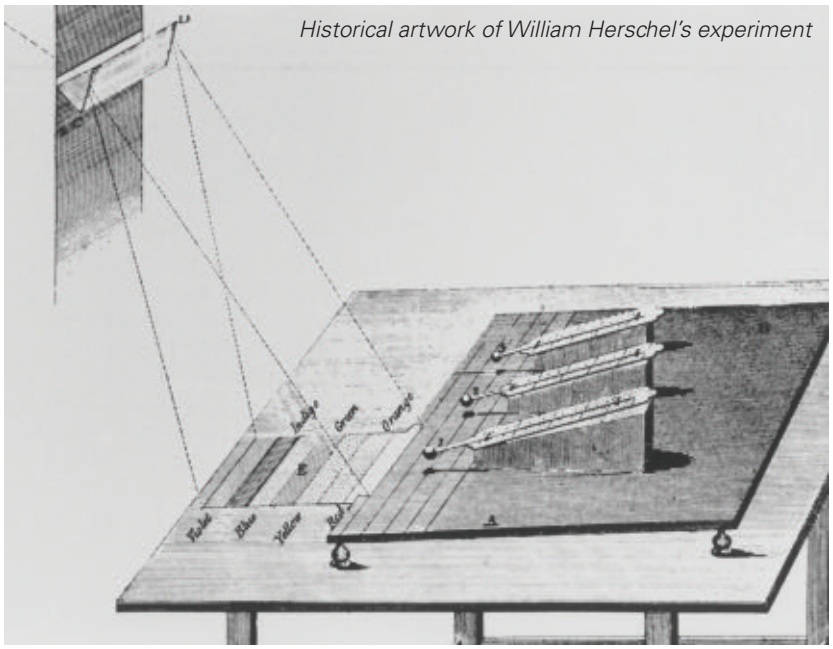
The William Herschel telescope in its opened protective dome at dusk on La Palma

The William Herschel telescope on the island of La Palma in the Canaries is a reflector telescope — its mirror is the third largest in the world.

Table 1 *Average rise of temperature after 10 minutes in Herschel's experiment*

Type of light	Average temperature rise
Violet	2.0°F
Green	3.2°F
Red	6.9°F

To convert Herschel's temperature rises to °C, multiply by 5/9.



Historical artwork of William Herschel's experiment

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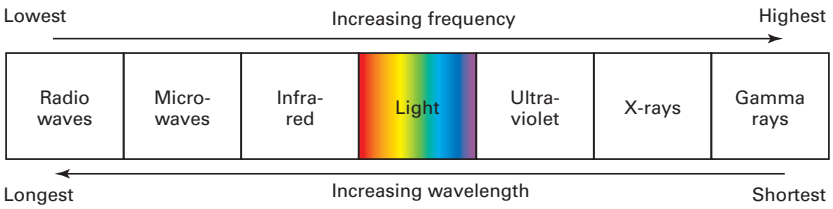

Figure 1 *The electromagnetic spectrum*

Box 3 Useful websites

- You can download Herschel's original papers, which appeared in the *Philosophical Transactions* of the Royal Society for 1800, from:
http://tinyurl.com/v45fh
http://tinyurl.com/yxb3m3
http://tinyurl.com/y82dsk
Select *Open Full Text* to read them.
- Follow this link to see how to repeat Herschel's experiment:
http://coolcosmos.ipac.caltech.edu//cosmic_classroom/classroom_activities/herschel_experiment.html
- Watch two short videos of the Herschel Space Telescope at:
www.esa.int/esa-mmg/mmg.pl?type=V&mission=Herschel

Unexpected and unplanned findings are called serendipitous discoveries.

The European Space Agency is to launch an infrared space telescope — the Herschel Space Telescope, named after William and Caroline. It will look at distant objects in space which are so cool that they do not emit visible light.

power of the prismatic colours is very far from being equally divided, and the red rays are chiefly eminent in that respect.' This was a new observation, of importance in itself. But there was more to come.

Beyond the red

Herschel noticed that the heating effect of light was greatest at the red end of the spectrum. He wondered if it might extend beyond there, to a region where the Sun's rays were invisible. He set up his thermometers accordingly and discovered that, as he had suspected, the central thermometer's temperature rose. In fact, the greatest temperature rise was at a point a little beyond the red end of the visible spectrum.

What conclusion could Herschel draw? He realised that the Sun's rays consist of both visible light rays and invisible heat rays. Today, we call these invisible rays **infrared radiation**. Herschel was working in the winter of 1799–1800, and sunny days were few and short. Before darkness fell, he quickly checked to see if he could find a heating effect beyond the violet end of the spectrum, but without luck.

Herschel's explanation

Were these two types of different rays? Herschel thought not; the simplest explanation was that both light and heat were forms of the same radiation: '...we are not allowed, by the rules of philosophising, to admit two different causes to explain certain effects, if they may be accounted for by one.'

This is an example of a principle known as **Occam's Razor**; complex explanations should be rejected if a simpler one can be found. Today, we would say that both light and infrared are forms of **electromagnetic radiation**, and that they lie on a much-extended spectrum, stretching from gamma rays and X-rays at one end to radio waves at the other (Figure 1).

Herschel presented his findings to a meeting of the Royal Society, and published them as three papers in the Society's *Philosophical Transactions*. These papers are easy to read; you can find them on the internet (see Box 3).

A happy accident?

Some accounts of Herschel's experiment suggest that he left the room for a while. The Sun moved across the sky, and the spectrum moved across the workbench. When he returned, his test thermometer was no longer in the spectrum, and yet he noticed that it still showed a high reading. He then made careful measurements to find out what was going on.

Many important findings are described in this way. Something unexpected and unplanned happens, it catches the eye of a keen scientist, and a great discovery is made. We can't say if this is what happened to Herschel. His papers present a logical development of ideas, with each observation suggesting further measurements, leading to the discovery. But that is how scientists present their findings — it's how you are expected to write up your investigations.

Conclusion

Herschel noticed a trend in the heating effects of different colours of light, from violet through green to red, and then had the sense to see if the trend continued further. This seems a more likely description of his work than the 'happy accident' version.

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