HOW DO WE KNOW
WHAT STARS ARE MADE UP OF?

Scientists identify different elements in any object, even a distant one like a star, by studying the spectrum of radiation emanating from it. Spectrum refers to the way energy is distributed among the different wavelengths of radiation, which correspond to the familiar colours in the case of visible light.

Let us understand this better. We know that the electrons that orbit the nucleus in any atom occupy fixed energy levels. When an electron drops from a higher energy level to a lower energy level, the atom releases energy equal to the difference in the two energy levels. This energy is emitted in the form of a particle of light, which we call a photon. In contrast, to make an electron move from a lower to a higher energy level, the atom needs to receive the energy difference between the two levels from an incoming photon, which is then absorbed. Photons were proposed by Einstein in the early twentieth century, and physicists accept that they can also show wave-like behaviour. Higher energy photons behave as waves with shorter wavelengths. This is why, for example, blue light, which has photons of a higher energy than red light, also has a shorter wavelength than red light. Lastly, we know that the energy levels of different levels are fixed for each element. Thus, a particular element will absorb or emit radiation at certain fixed wavelengths. These wavelengths are defined by differences in the energy levels of its atoms. We use this knowledge to analyse the spectrum of radiation emitted by an object. If certain frequencies are weaker or absent in the radiation we receive from an object, we infer that the radiation is passing through elements that absorb these particular wavelengths.

To understand how we use this to study stars, let us take the example of our sun (see **Fig. 1**). The light that leaves the sun's surface forms what is very nearly a **continuous spectrum**, one containing a range of wavelengths. However, as it passes through the sun's outer atmosphere, specific wavelengths of light are absorbed. This results in a spectrum that shows prominent absorption lines (see **Fig. 2**). Laboratory experiments show similar signatures of sodium, calcium, magnesium, iron, and other elements. We know that these elements filter out very specific wavelengths from a continuous spectrum coming from a hotter inner layer. Astronomers study these lines and match them to lines from known elements. This is how they are able to determine the gases present in the sun's atmosphere.

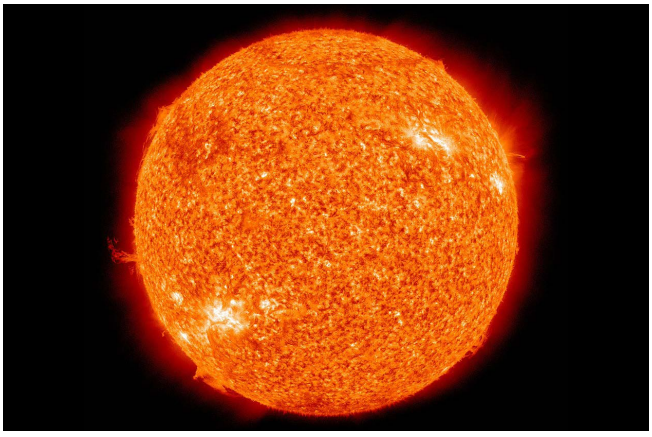

Fig. 1. An image of our sun.

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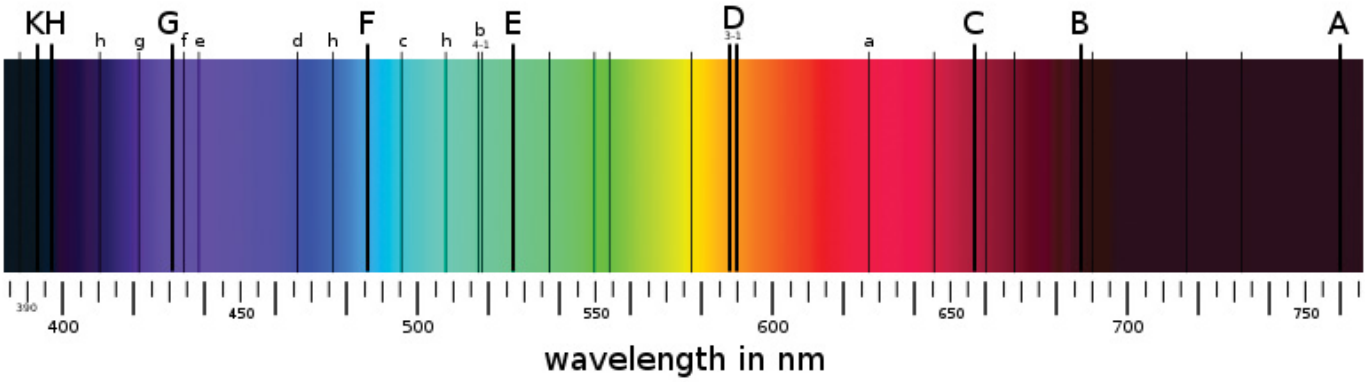

Fig. 2. Solar spectrum with Fraunhofer lines.

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But what if an absorption line in the sun's spectrum does not match that of any known element? One example of this comes from the spectra that the French astronomer Jules Janssen obtained of the sun during a total solar eclipse on 18th August 1868 from Guntur (in today's Andhra Pradesh). Solar eclipses offer a rare opportunity to view emissions from the outermost layers of our sun without the glare of the main disc. On analysis of the bands of light in this spectrum, Janssen observed a very bright yellow emission line that appeared below 588 nm. This did not correspond to any terrestrial element known at the time. On 20th October 1868, the English Astronomer Norman Lockyer spotted the same unusual yellow line independently. Lockyer identified this as a new extraterrestrial element that he named helium after Helios, the Greek personification of the sun. It was only in 1882 that the same spectral line was observed by the Italian physicist Luigi Palmieri, in the form of an almost nonreactive atomic gas, in his analysis of lava from Mount Vesuvius, Italy. This was the first indication that helium existed on earth too. This was confirmed in 1894 when the Scottish chemist William Ramsey isolated helium by treating the mineral cleveite with mineral acids. Helium is the only element to be discovered by astronomers — Jannsen & Lockyer share joint credit for its discovery.

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