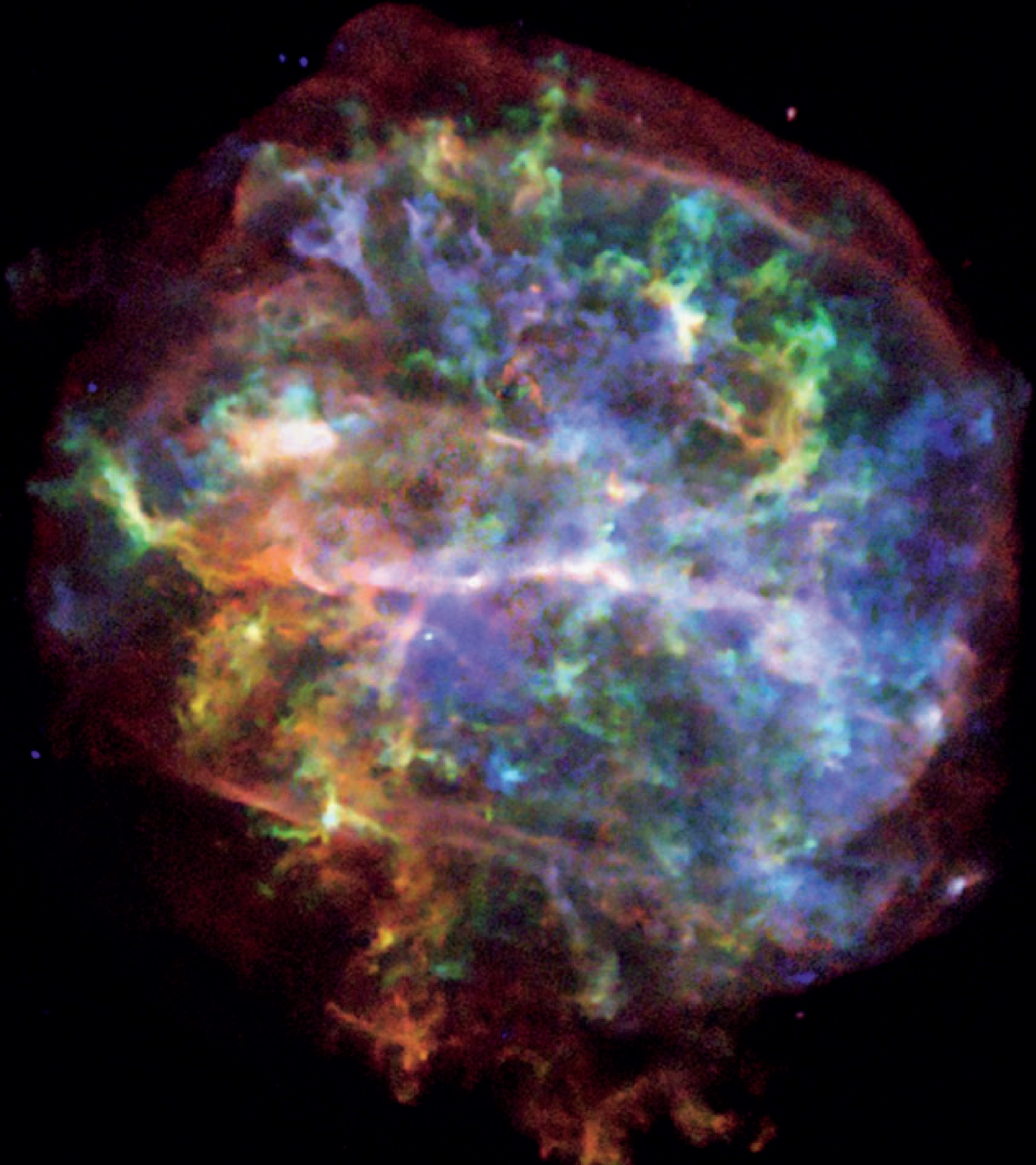


8

THE X-RAY AND HIGH ENERGY UNIVERSE

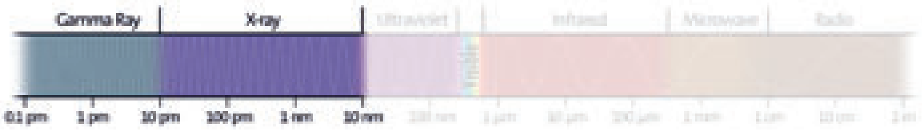
FIGURE 58: SUPERNOVA REMNANT G292.0+1.8 IN X-RAYS

This beautiful Chandra X-ray Observatory image shows the supernova remnant G292.0+1.8. This is the aftermath of the death of a massive star. Ejected material from the supernova races outwards and slams into the surrounding gas creating intense shock waves that heat the material and make it emit X-rays. By mapping the distribution of X-rays in different energy bands, the Chandra image traces the state of the material ejected by the supernova. The results imply that the explosion was not symmetrical. For example, blue (silicon and sulphur) and green (magnesium) are seen strongly in the upper right, while yellow and orange (oxygen) dominate the lower left. These elements light up at different temperatures, indicating that the temperature is higher in the upper right portion of G292.0+1.8.

Beyond the ultraviolet we reach the highest energies of the electromagnetic spectrum. From X-rays to the even more energetic gamma rays, the increasingly rare photons have to be counted one by one. Only the most dramatic phenomena will generate light at this far end of the spectrum. This means that X-rays and gamma rays are our window into the study of cataclysmic processes such as the explosions of massive stars and the neutron stars and black holes they leave behind, as well as hot plasmas in galaxy clusters and in nearby stars.

X-ray and gamma-ray **photons** have **wavelengths** so tiny that they must be measured in billionths (**nanometres**) and trillionths (**picometres**) of metres. There is no “smallest” wavelength at the gamma-ray end of the **spectrum** beyond the practical limits of just how much energy can be crammed into a single photon by the processes that generate them. Astronomers detect these photons on a case-by-case basis, making it challenging to build up images in the X-ray band, and even more impractical in the gamma-ray band. In fact, very few gamma-ray “images” have been constructed to date, so the focus in this chapter will largely be on X-rays.

X-ray regimes



Lower energy X-rays, overlapping with the extreme ultraviolet **regime**, 8 nm – 0.2 nm, are known as “soft X-rays”. These are susceptible to absorption by atoms and, like visible and ultraviolet light, tend to be obscured by dense clouds of dust and gas.

Hard X-rays are the highest energy X-rays and overlap with the regime of lower energy gamma rays: 0.2 nm – 10 pm. They are less easily absorbed and so tend to penetrate the clouds.

Gamma rays range from 10 pm and downwards and represent the highest energy end of the **electromagnetic spectrum**.

Sources of X-rays

Thermal X-rays

X-ray photons have energies that are thousands of times larger than the visible-light photons detected by our eyes. If these photons were purely the result of **thermal**, or **blackbody**, processes, there would have to be many objects with temperatures between about a million and a hundred million °C (See Figure 59). The discovery of some sources at these temperatures came as a surprise since even the most massive stars are not nearly this hot.

But while the stars themselves may not reach temperatures of millions of degrees, the explosion of massive stars can. As the hot debris blasted out by the explosion slams into the surrounding interstellar medium, the resulting shock waves can heat it even more. It is a kind of cosmic sonic boom, but instead of hearing the boom, we see the photons generated from the shock. These supernova remnants can make spectacular targets for X-ray telescopes.

However, it does not take a supernova to heat up at least some of the gas around a star. Even our Sun has an outer "atmosphere", or corona, that can reach millions of degrees. Falling outside of what we think of as its visible surface, this sparse gas is heated by processes that puzzled the astronomers who discovered its X-ray emission. Violent phenomena on the surface — often around the darker, slightly cooler sunspots on the Sun's surface — create sound and magnetic waves that propagate upwards into the increasingly tenuous outer atmosphere, the chromosphere and the corona. As the density decreases, the waves become more and more extreme, rather like water waves breaking on a shelving beach. Eventually they become shock waves that superheat the gas.

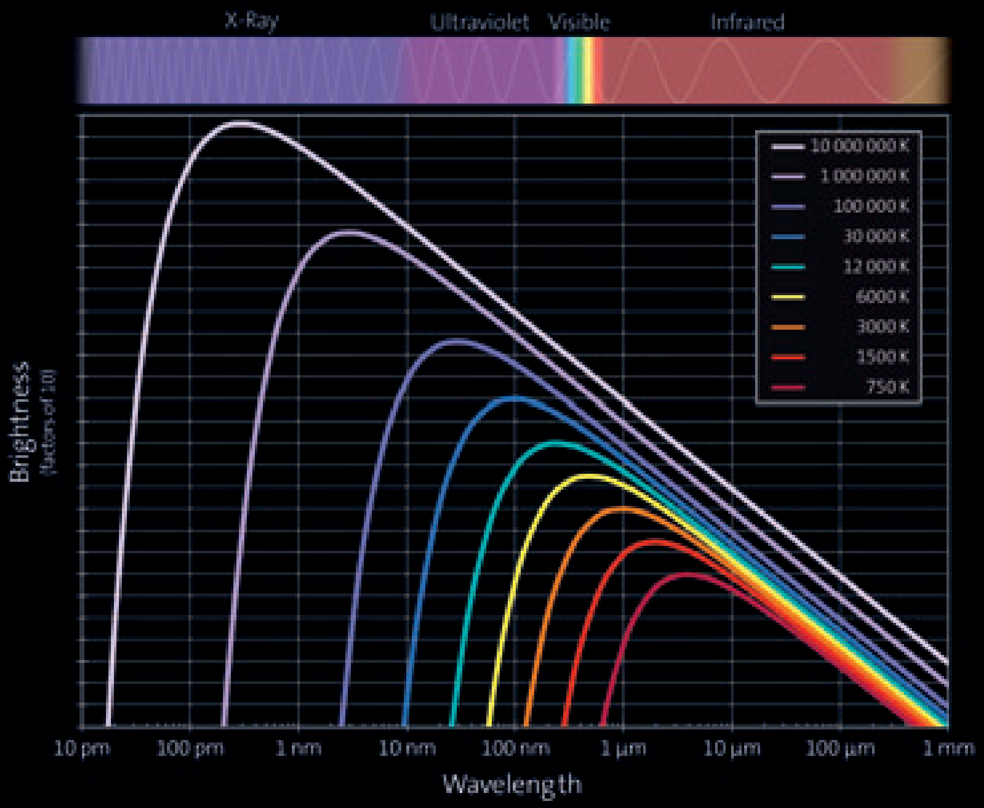


FIGURE 59: HOT BLACKBODIES

Here blackbody radiation from 1 million degree warm objects is compared with the blackbody radiation from different stars.