Chapter 8

The Birth of the Sun

In This Chapter

- Young stars glowing like toasters
- H-H objects sending off jets
- T Tauri stars flickering
- The Sun is a dwarf
- How old are you, Mr. Star?

We love the Sun because it is ours, but, in the words of Gilbert and Sullivan's comic operetta *H.M.S. Pinafore*, we also need to study "his sisters and his cousins, whom he reckons up by dozens, and his aunts." Studying many stars, singly and in groups, tells us how stars like the Sun formed and shows us similar objects today.

Flying Toasters in the Sky

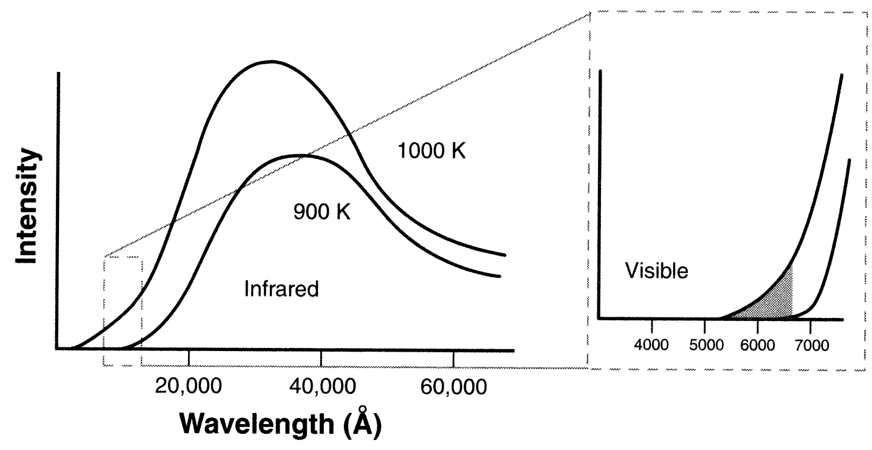
Toasters are known to fly across computers as screensavers and traditionally have been given out by banks for opening accounts, but did you know that they can remind us of young stars? If you look inside a toaster as you turn it on, you can see that the wires soon begin to glow dully. Then they begin to turn a little reddish. Later they glow bright red. We are seeing what astronomers call black-body curves.

A black body is a perfectly radiating body. By "black," we mean that it isn't polka-dotted or otherwise varying from place to place. It is uniform, and we can describe the radiation that it gives off by only one number. We call that number the temperature. The temperature really describes how fast the particles of matter are moving every which way.

The Solar Scoop

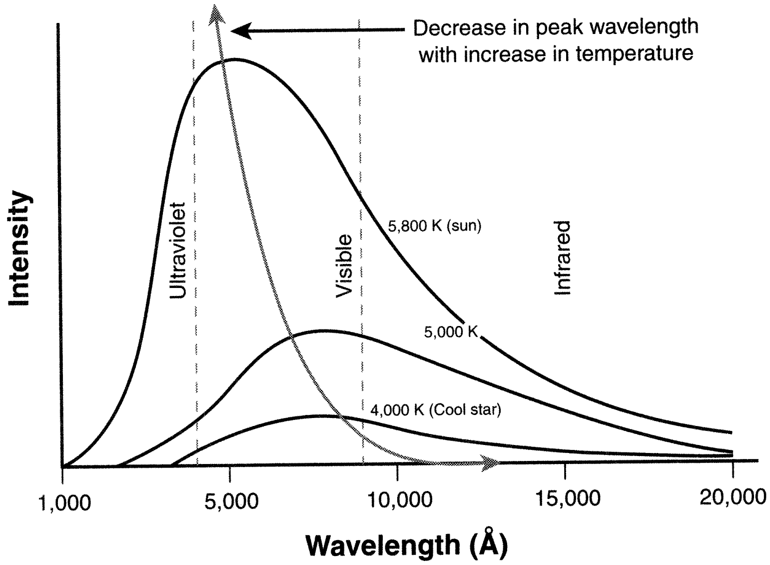
The peak of the Sun's spectrum is in the yellow-green part of the spectrum, so we humans may well have evolved to have our greatest sensitivity there. Since Superman has x-ray vision and was born on the planet Krypton, can we conclude that Krypton's star is much hotter than the Sun and thus shines more brightly in x-rays?

A black body gives off radiation, but how much radiation it gives off and the amounts of radiation at different colors depend on its temperature. For any radiating black body, there is a certain color at which it gives off more energy than any other color. At colors corresponding to longer wavelengths, it gives off less energy. At colors corresponding to shorter wavelengths, it gives off less energy. If we graph the energy that it gives off as a function of wavelength, we see a peaked curve (see the following figure). Sometimes this curve is called a black-body curve. It is also often known as a Planck curve, after the scientist Max Planck, who found a mathematical formula for it just over 100 years ago.



A toaster heat element is about 1,000°C and thus glows red hot. At that temperature, though most of the radiation is in the infrared, a small fraction is in the visible part of the spectrum, so we see the toaster wires begin to glow visibly. The hotter the wires become, the larger the fraction of energy that is emitted in the visible.

When you heat up an object, the peak of its radiation starts way out in the infrared. As you heat it up more, the peak moves to shorter and shorter infrared wavelengths—that is, it moves closer to the red. At this temperature, you see the toaster (or a star being born) glowing reddish. As it heats up more, it gives off more energy in the red, though the peak of the radiation is still out in the infrared. When it gets hot enough, to several thousand degrees, the peak of the radiation actually moves into the red. Then, when it reaches the 5,800 °C of the Sun, the peak has actually moved beyond the red into the yellow-green.



Wien's Displacement Law tells us where the peak of radiation for a black body is. An object at 4,000 kelvins peaks in the red, while at object at 5,800 kelvins peaks in the yellow-green and an object at 7,000 kelvins peaks nearly in the blue.

Since the Sun gives off most of its radiation in the yellow-green, we humans have evolved so that our eyes are most sensitive there. Our eyes have rods that sense even dim light and cones that come in three types, each sensitive to a different color. Used together, the cones give us our perception of color.

As a cloud of gas contracts, it first gains its energy from gravity. That energy is enough to make it glow slightly. But it has to turn on and start nuclear fusion to get enough energy to become yellow-hot. Fortunately, the toaster in your kitchen never gets that hot. But an iron poker in a fire can go beyond red-hot to yellow-hot and even to white-hot.

Fun Sun Facts

Sugars and starches caramelize, making toast, at about 320°F (160°C). When they carbonize, at still higher temperatures, you've burned your toast.

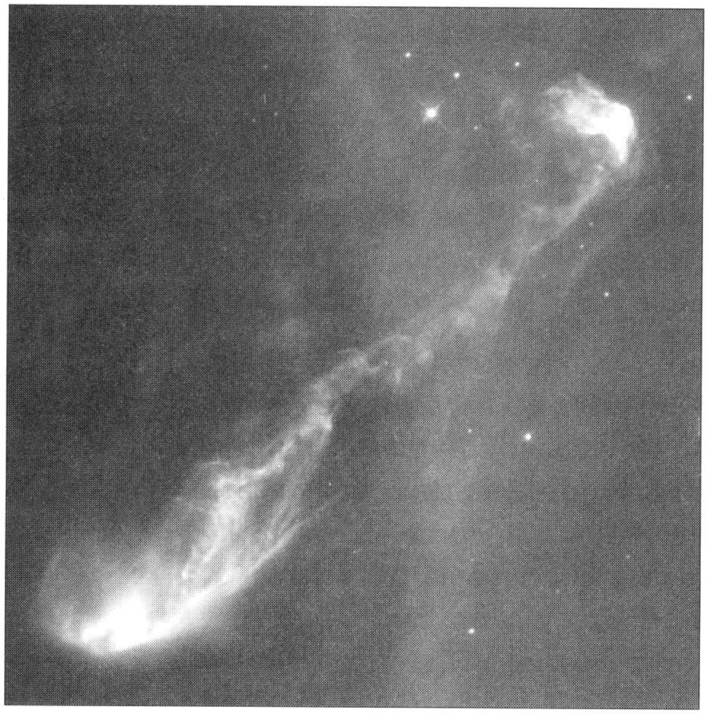
Riding Madly Off in All Directions

In *Gertrude the Governess, a Nonsense Novel* by Canadian humorist Stephen Leacock, a hero "flung himself upon his horse, and rode madly off in all directions." Something similar happens with young stars. Since they are spinning, there is a preferential direction along their poles for gas to escape. With the aid of the magnetic field, gas is squirted out along the axes into space.

This gas was seen before it was understood. American astronomer George Herbig and Mexican astronomer Guillermo Haro found some dozens of places in the sky where bits of nebulosity seemed to be associated with young stars. They cataloged them; they are now called Herbig-Haro objects and often called simply *H-H objects.* Modern telescopes, now including the Hubble Space Telescope, were required to see them clearly. These newer observations show that the gas is ejected in opposite directions from a young star (see the following figure). In the images, sometimes the star itself is buried in dust so that we can't see it. In some of these cases, looking with telescopes and detectors sensitive to the infrared, we get radiation that penetrates the dust, and we can see through to the central star. With these optical and infrared observations, H-H objects have been transformed from mere curiosities to important signals of how stars like the Sun form.

Sun Words

H-H objects are jets of gas given off by young stars.



A Hubble Space Telescope view of HH-47. We see gas being ejected by a young star, though the star itself is hidden by dark clouds of gas. This view reveals that the jet has punched a cavity through the dense gas cloud into interstellar space. The wobble in the jets suggests that the hidden star might be wobbling, possibly because of the gravity of a companion star.

(J. Morse/STScI, and NASA)

Flickering Starlight

When Copernicus's famous book *On the Revolutions* was published in 1543, modern astronomy began. Copernicus put the Sun instead of the Earth at the center of the universe so that we live in what we now call the solar system. But Copernicus still had fixed stars around the edges of his diagram of the solar system. It was a big surprise when, only about 50 years later, in 1596, David Fabricius discovered a star that varied in brightness. He called it *Mira*, from the Latin for "miraculous." We still call the star Mira, though it also has its place as omicron Ceti in the labeling scheme set out by Johann Bayer in his beautiful star atlas of 1603.

A couple hundred years ago, the deaf-mute amateur astronomer John Goodricke went on to discover several other important variable stars, including the Cepheid variables that allow astronomers to tell the distances to other galaxies. These variable stars are at the center of our understanding of how old the universe is and are, therefore, also at the center of our understanding that a Big Bang occurred some 14 billion years ago.

Sun Words

Mira was the first variable star discovered.

The Solar Scoop

A wonderful amateur astronomy association, the American Association of Variable Star Observers (AAVSO), collects and assembles observations of variable stars made by people around the world. On the association's website, you can get the light curve—the graph of brightness over time—of any variable star for any period of time. You can also get a finding chart to show you how to find the variable stars of your interest in the sky. See www.aavso.org.

The first variable star in a constellation is known as R with a form of the name of that constellation. Thus the first variable star in the constellation Corona Borealis is known as R Coronae Borealis, or R CrB. The next variable star is S, the next is T, and so on. After Z, you start with RR, as in the important variable star RR Lyrae. Now we know of hundreds of variable stars in each constellation, so we are merely numbering them; the letter designations have long since been exhausted.

Thus, from the name *T Tauri*, we know that this star was the third variable star discovered in the constellation Taurus, and it must have been known as variable for a long time. T Tauri itself is just one of many similar objects known as T Tauri stars. These are stars that are now in the stage that the Sun was in about five billion years ago.

Sun Words

T Tauri stars are young stars that are still unsteady in brightness, resembling the early years of the Sun's life.

T Tauri stars vary irregularly in brightness. When astronomers take their spectra, the spectra show emission spectral lines, revealing that there is still hot gas around the star that hasn't disbursed or collapsed into the star's surface.

The Sun was a T Tauri star about five billion years ago, but our star has grown out of this adolescence. T Tauri itself has now been studied in various parts of the spectrum. Images in the infrared have revealed that it is actually a double star with a nearby companion, which makes it different from our Sun.

The Least You Need to Know

- The sun was first red-hot and now is yellow-hot.
- Newly formed stars that resemble the early Sun give off beautiful jets of gas.
- Cepheid variable stars allow us to find the distances to galaxies and the age of the universe.
- Variable stars like T Tauri haven't yet settled down to radiate steadily.