Suppose that thermonuclear fusion stopped suddenly in the Sun. Would the Sun’s luminosity also decrease abruptly? Explain why or why not.

Recall that a photon produced by fusion in the Sun’s core does not pass through the star directly but interacts with the remainder of the Sun’s mass on the way out. The random-walk process, radiative diffusion, causes the photon to take millions of years to reach the surface of the Sun. So if fusion in the core of the Sun suddenly stopped, the surface would continue to shine for millions of years, and therefore, the luminosity would not decrease abruptly.

We also now know that if the energy source were turned off, the Sun would contract and the energy from this contraction would continue to power the Sun. This is the Kelvin-Helmholtz mechanism described in class.

If blue star and red star both the same radius and same distance from the Earth, which one will appear brighter? Explain why.

Recall that the brightness of the star (energy per unit area per time) is

\[ b = \frac{L}{4\pi d^2} \]

where \( L \) is the luminosity of the star, and \( d \) is the distance from Earth. And the luminosity for a star is

\[ L = 4\pi R^2 \sigma T^4. \]

Putting these expressions together, the brightness in terms of radius, distance and temperature is:

\[ b = \frac{R^2}{d^2} \sigma T^4. \]

Since these two stars have same radius and same distance from the Earth, the ratio of brightnesses only depends on temperature:

\[ \frac{b_{\text{blue}}}{b_{\text{red}}} = \left( \frac{T_{\text{blue}}}{T_{\text{red}}} \right)^4. \]

From Wien’s Law, we know that the blue star will have higher temperature and therefore will appear brighter.
8 Suppose that a dim star is located 2 million AU from the Sun. Find the distance to the star in parsecs. Find the parallax angle \((p)\) of the star. Would this star’s distance be measurable using current techniques?

Recall that 1 parsec \((pc)\) = 206265 AU, so the distance to the dim star is \(d = 2 \times 10^6/206265\) pc = 9.70 pc. The relation between parallax angle \((p)\) and distance is \(d(pc) = 1/p(\text{arcsec})\), so \(p = 1/d(pc)\) arcsec = 0.103 arcsec. With current techniques, astronomers cannot measure parallaxes smaller than about 0.01 arcsec or 0.001 arcsec from space, but either way, this star’s distance is measurable.

4 How much dimmer does the Sun appear from Pluto as from the Earth? (Use the semi-major axis for the distance.)

Again, the brightness of the star is \(b = \frac{L}{4\pi d^2}\), where \(L\) is the luminosity of the star, and \(d\) is the distance from Earth. The semi-major axis for these distances \(d_{Pluto} = 39.5\) AU, \(d_{Earth} = 1\) AU. Therefore

\[
\frac{b_{Pluto}}{b_{Earth}} = \frac{d_{Earth}^2}{d_{Pluto}^2} = \frac{1^2}{39.5^2} = 6.41 \times 10^{-4}.
\]

So the Sun appear \(6.43 \times 10^{-4}\) times dimmer from Pluto than from the Earth. To put this in perspective, this ratio is closest to the ratio of the faintest star visible to the naked eye and the brightest star in the night sky (approximately 8 magnitudes).
What determines a star’s *spectral type*?

The temperature sets the star’s color and determines its surface brightness: how much light comes from each square meter of its surface. The atmospheric pressure depends on the star’s surface gravity and therefore, roughly, on its size telling whether it is a giant, dwarf, or something in between. The size and surface brightness in turn yield the star’s luminosity (its total light output, or absolute magnitude) and often its evolutionary status (young, middle-aged, or nearing death). The luminosity (when compared to the star’s apparent brightness in our sky) also gives a good idea of the star’s distance.

The temperature of the star may be further refined by looking at which elements are absorbing photons or emitting photons. Recall that the spectral lines of an element are associated with well-defined energies. The relative strength of these lines from different elements can then be used to pinpoint the temperature.

Appended to the basic spectral type may be letters for chemical peculiarities, an extended atmosphere, unusual surface activity, fast rotation, or other special characteristics. See Chapter 19-5 for lots more details.
What is the Hertzprung-Russell Diagram?

The Hertzprung-Russell diagram (usually referred to by the abbreviation H-R diagram or a Color-Magnitude diagram abbreviated by CMD) shows the relationship between absolute magnitude, luminosity, classification, and effective temperature of stars. The diagram was proposed by Ejnar Hertzsprung and Henry Norris Russell in 1910.

There are several forms of the Hertzprung-Russell diagram. The original diagram displayed the spectral type of stars on the horizontal axis and the absolute magnitude on the vertical axis. Spectral type is often replaced by the color of the stars, an easier quantity to measure from observations. Another form of the diagram plots the effective temperature of the star on one axis and the luminosity of the star on the other. This is what theoreticians calculate using computer models that describe the evolution of stars.

The H-R diagram is used to define different types of stars and to match theoretical predictions of stellar evolution using computer models with observations of actual stars. It is then necessary to convert either the calculated quantities to observables, or the other way around, thus introducing an extra uncertainty.

Most of the stars occupy the region in the diagram along the line called main sequence. During that stage stars are fusing hydrogen in their cores. The next concentration of stars is on the horizontal branch (helium fusion in the core and hydrogen burning in a shell surrounding the core). Another prominent feature is the Hertzsprung gap located in the region between A5 and G0 spectral type and between +1 and -3 absolute magnitudes (i.e. between the top of the main sequence and the giants in the horizontal branch). RR Lyrae stars can be found in the left of this gap. In the upper section of the instability strip Cepheid variables are residing.