DSCHUBBA (DELTA SCORPII): A BLACKBODY MODEL

Link to: physicspages home page.

To leave a comment or report an error, please use the auxiliary blog.

Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 3, Problem 3.9.

The star Dschubba (δ Sco) has been causing some excitement in the astronomical community over the past few years. The star is the centre of the scorpion's head ('dschubba' comes from the Arabic for 'forehead') and in the past, its visual magnitude was $V = 2.3$. In June 2000, the star flared up for an as yet unknown reason so that it brightened to around magnitude 1.7. It has been behaving erratically ever since, and so far there is no consensus on exactly what is going on with it.

We'll take a look at a model of Dschubba in which we approximate it by a blackbody. Using the data in Carroll & Ostlie's problem 3.9, we have

$$T = 28,000 \text{ K} \tag{1}$$

$$R = 5.16 \times 10^9 \text{ m} \tag{2}$$

$$d = 123 \text{ pc} \tag{3}$$

To get its luminosity, we use the Stefan-Boltzmann law that gives the total power radiated per unit area

$$j = \frac{2\pi^5 k_B^4}{15h^3c^2}T^4 = \frac{\pi^2 k_B^4}{60\hbar^3c^2}T^4 \equiv \sigma T^4 \tag{4}$$

where σ is the Stefan-Boltmann constant, with the value

$$\sigma = \frac{\pi^2\left(1.3806488 \times 10^{-23}\right)^4}{60\left(1.05457173 \times 10^{-34}\right)^3\left(2.99792458 \times 10^8\right)^2} \tag{5}$$

$$= 5.67 \times 10^{-8} \text{ W m}^{-2}\text{K}^{-4} \tag{6}$$

The luminosity is j times the surface area of the star:

$$L = 4\pi R^2 \sigma T^4 \tag{7}$$

$$= 1.166 \times 10^{31} \text{ W} \tag{8}$$

The Sun's luminosity is $L_S = 3.846 \times 10^{26}$ W so Dschubba has about 30,000 times the luminosity of the Sun. From this, we can get the absolute magnitude:

$$\begin{aligned}
M &= M_{Sun} - 2.5 \log \frac{L}{L_{Sun}} && (9)\\
&= 4.74 - 2.5 \log \frac{1.166 \times 10^{31}}{3.846 \times 10^{26}} && (10)\\
&= -6.46 && (11)
\end{aligned}$$

Given the distance d in parsecs we can find the apparent magnitude from the distance modulus:

$$\begin{aligned}
m &= M - 5 + 5 \log d && (12)\\
&= -6.46 - 5 + 5 \log 123 && (13)\\
&= -1.00 && (14)
\end{aligned}$$

This value is much brighter than the visual magnitude of $V = 2.3$ (or even the more recent 1.6). This is because the calculated magnitudes are bolometric magnitudes; they take into account radiation over the entire spectrum. As Dschubba is a very hot star, much of its radiation is in the ultraviolet, so visually it appears dimmer than it actually is.

The distance modulus is

$$m - M = 5.46 \qquad (15)$$

The radiant flux at the star's surface is just j from 4:

$$j = \sigma T^4 = \left(5.67 \times 10^{-8}\right)(28000)^4 = 3.485 \times 10^{10} \text{ W m}^{-2} \qquad (16)$$

The flux at the Earth is

$$\begin{aligned}
F &= \frac{L}{4\pi d^2} && (17)\\
&= \frac{1.166 \times 10^{31}}{4\pi \left(123 \text{ pc} \times 3.0857 \times 10^{16} \text{m pc}^{-1}\right)^2} && (18)\\
&= 6.44 \times 10^{-8} \text{ W m}^{-2} && (19)
\end{aligned}$$

The solar irradiance is 1365 W m^{-2} for comparison.

Finally, we can get the peak wavelength from Wien's displacement law:

$$\lambda_{max} = \frac{2.901\times10^{-3}\text{m K}}{T} \tag{20}$$

$$= 1.036\times10^{-7}\text{ m} \tag{21}$$

$$= 103.6\text{ nm} \tag{22}$$

The ultraviolet region of the spectrum is from 100 nm to 400 nm, so Dschubba's peak wavelength is at the extreme low end (highest energy) UV, almost in the X-ray region. This explains the high bolometric correction of $m_{bol}-V=-3.3$.

PINGBACKS

Pingback: Bolometric magnitude from flux