

# Lecture 5

January 31, 2012

Introduction to Stellar Structure and  
Evolution

Properties of Stars

# News

- Hand in reviews of faculty candidate talks by today.
- First homework due Friday, February 3<sup>rd</sup>
  - Available on class website
  - Can discuss the homework with classmates, but solutions should be in your own words.
  - If you are having difficulty with a problem, you are encouraged to discuss it with me.
    - Office hour: Thursday 3-4 PM, 302W Serin; or email me to see when we can meet.

# Virial Theorem

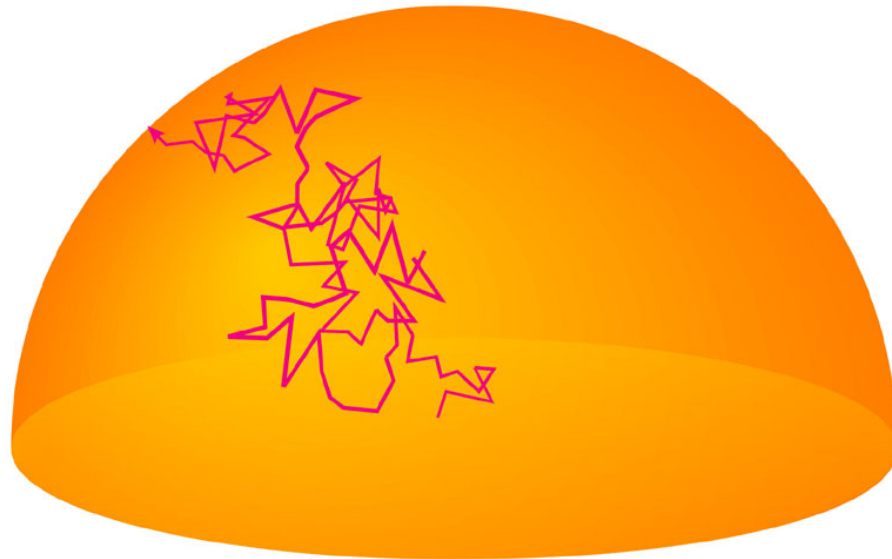
- $\langle P \rangle = (1/3) (-E_{GR}/V)$ 
  - $E_{GR} = -q(GM^2/R)$ , where  $q$  is a dimensionless integral that depends on the internal distribution of mass. For Sun,  $q \approx 3/2$ .
  - Thus,  $\langle P \rangle = (1/3)[q(GM^2/R)]/(4\pi R^3/3) = (q/4\pi)(GM^2/R^4)$
- For a non-relativistic ideal gas:  $2E_{KE} = -E_{GR}$ 
  - $E_{tot} = -E_{KE} \quad \& \quad E_{tot} = E_{GR}/2$
- For an extreme relativistic ideal gas:  $E_{KE} = -E_{GR}$ 
  - $E_{tot} = 0$

# Kelvin-Helmholtz time

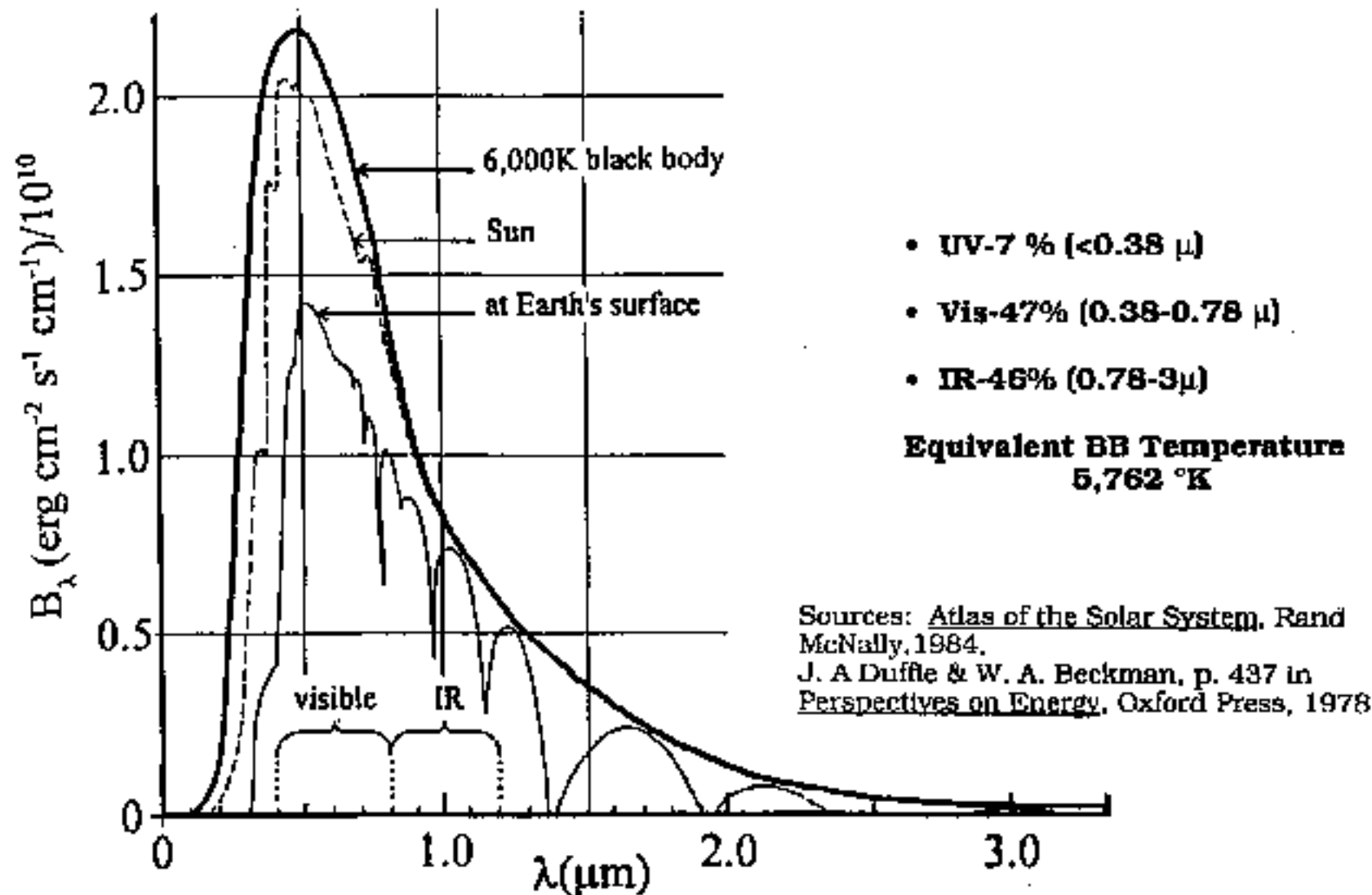
- $t_{\text{KH}} = |E_{\text{tot}}|/|dE/dt| = |E_{\text{tot}}|/L$  is a characteristic time for change.
- Using the virial theorem:
  - $t_{\text{KH}} = |E_{\text{GR}}/2|/L = (q/2)(GM^2/LR)$
  - $\rightarrow t_{\text{KH}} = (2 \times 10^7 \text{ yrs})(M/M_{\odot})^2(L/L_{\odot})^{-1}(R/R_{\odot})^{-1}$
- Thus:  $t_{\text{KH}} \ll t_{\text{dyn}}$ 
  - Changes happen slowly and use of virial theorem is justified after-the-fact.
- Why is  $t_{\text{KH}} \ll t_{\text{dyn}}$  ?

# Time for photons to escape the Sun

- Free streaming:  $t = R/c$
- But the Sun is opaque, so photons must diffuse out: radiative diffusion.



**The Intensity of Solar Radiation at the Earth's Surface is Reduced From that in Space**



Sources: Atlas of the Solar System, Rand McNally, 1984.  
 J. A Duffie & W. A. Beckman, p. 437 in Perspectives on Energy, Oxford Press, 1978