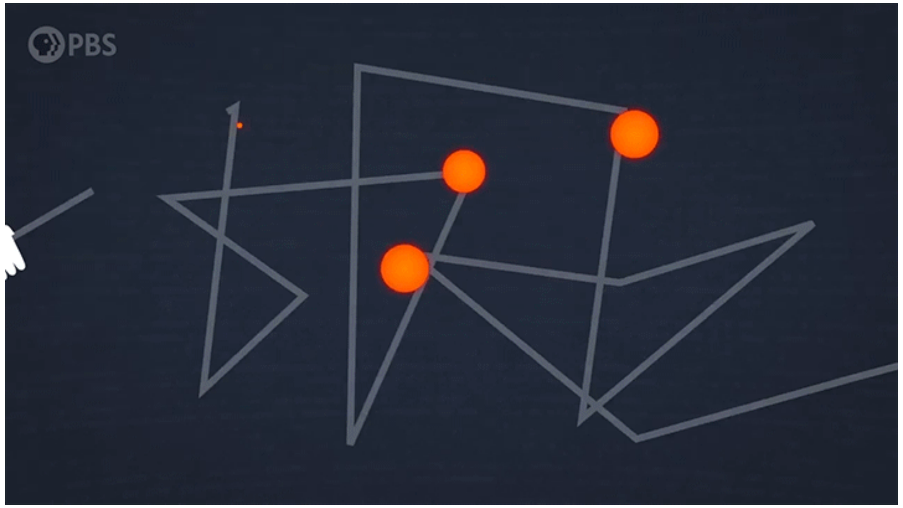
Quick notes on

Photon Diffusion Time

Zach Meisel

Ohio University - ASTR4201 - Fall 2020

Photon Diffusion Timescale

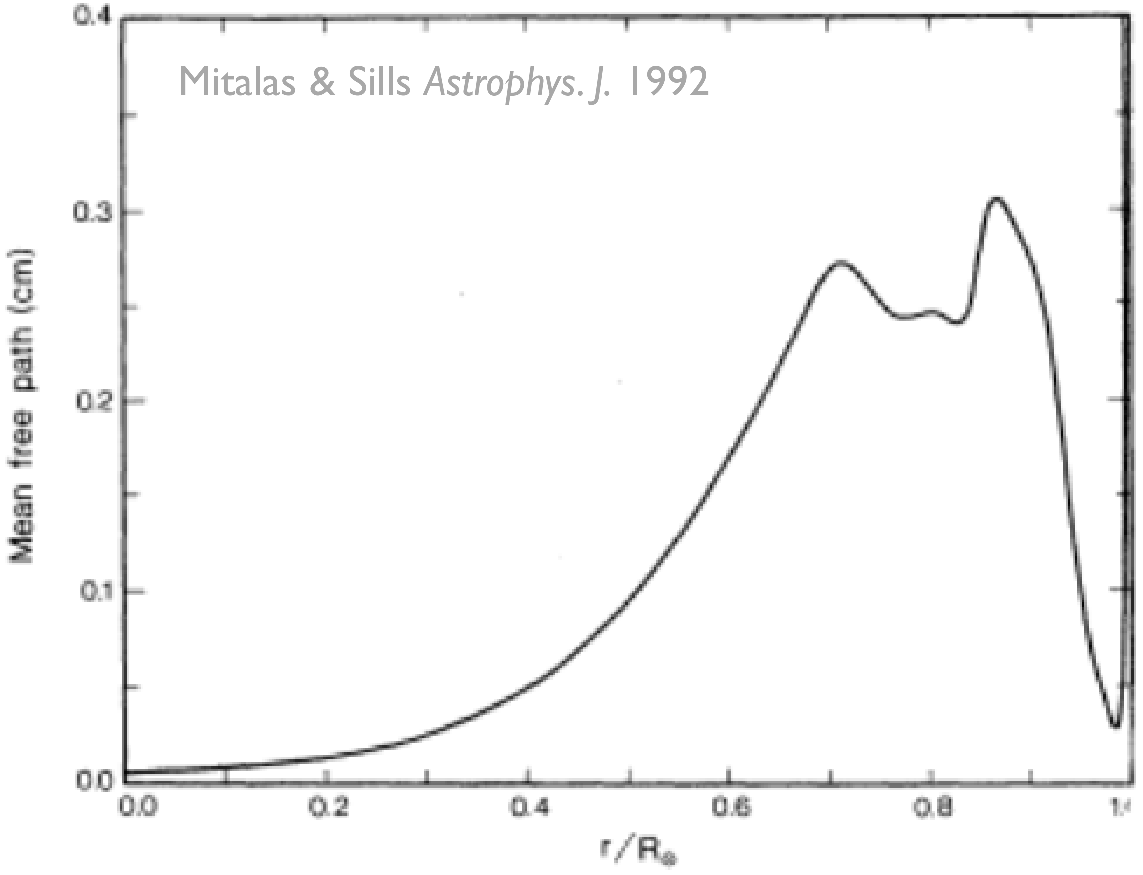


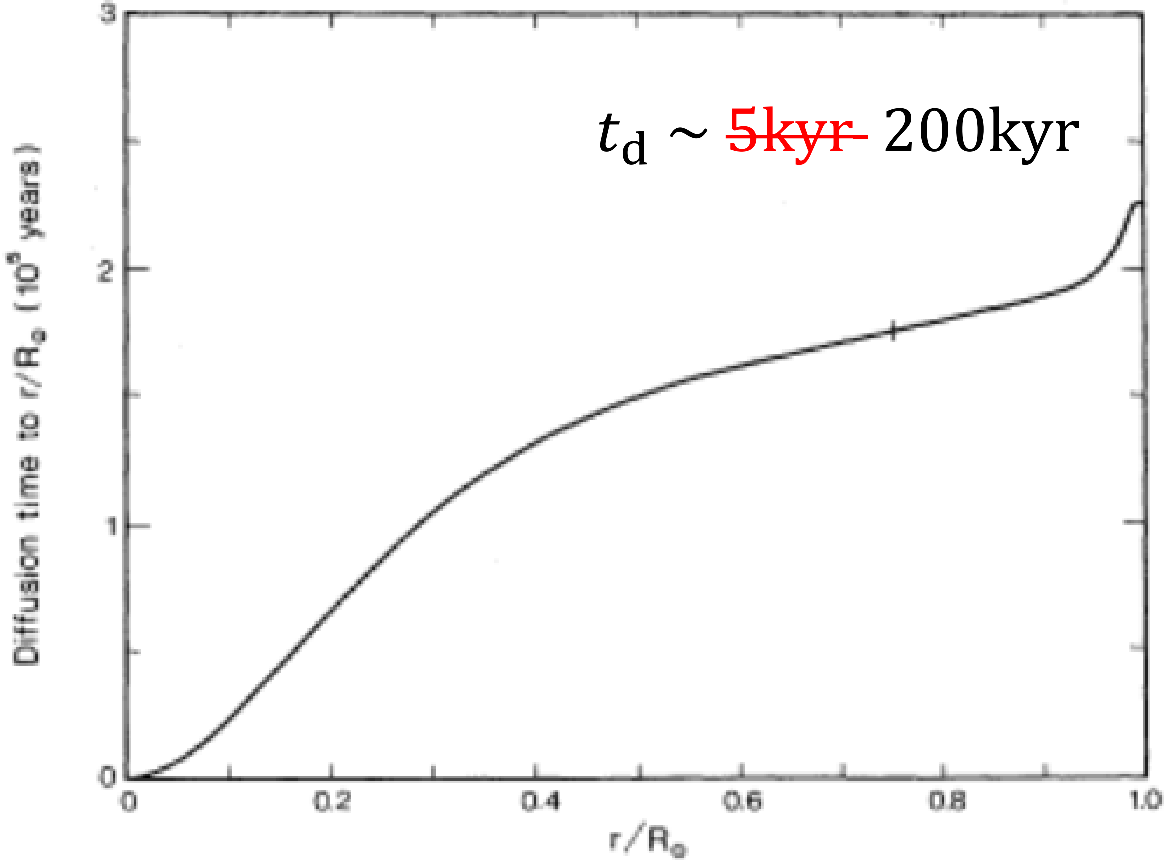
- If a photon streamed straight out of the sun, it would take $\frac{R_{\odot}}{c} \sim \frac{6.96e8 \text{ m}}{3e8 \text{ m/s}} \sim 2.3 \text{ s}$
- However, the mean free path $l \sim 1 \text{ cm}$, so a photon random walks it's way out of a star
- In the next Quick Notes, you'll see that the distance traveled after N steps in the random walk is $l\sqrt{N}$
- Meaning, to get to the surface requires $l\sqrt{N} \sim R_{\odot}$
- The diffusion time will be corresponds to the total photon travel time:
  - $t_{\mathrm{d}} \sim N \frac{l}{c} \sim \left(\frac{R_{\odot}}{l}\right)^2 \frac{l}{c} = \frac{R_{\odot}^2}{lc} \sim 5\text{kyr}$

Photon Diffusion Timescale

- Really, $l \leq 0.1$ cm for most of the star because the density is far greater than the average for much of the star (~150g/cm^3 as opposed to ~1.4g/cm^3)

Cautionary tale: Don't take the constant density model too seriously!

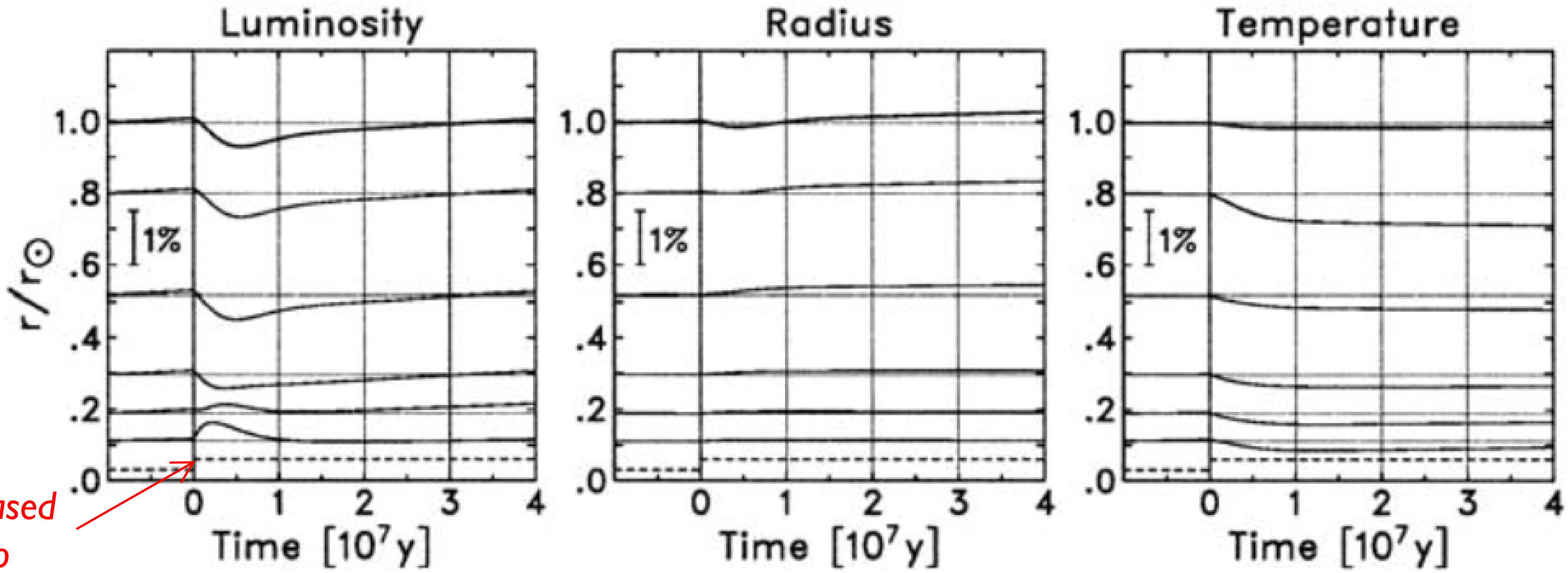




Thermal Timescale …*not the Photon Diffusion Timescale!*

- The energy density of photons $U_{\text{rad}} = aT^4 \ll U_{\text{gas}} = \frac{3}{2}\frac{NkT}{V}$ for the sun
- So, photon energy is a perturbation on the total energy and photons are in thermal equilibrium with the environment. The energy is essentially converted into kinetic energy which must be radiated away.
- which is done on the Kelvin-Helmholtz time scale.

M. Stix *Solar Physics* 2003



Nuclear energy increased by 2% at time zero