1 Week 5. SPAAAAAAAAAAAAAAAAAAAAAAAAACE

With this out of the way,

1.1 The Sun

1.1.1 Solar properties

- Mean distance $d_0 = 1.5e11m = 1AU$
- Mass $M_0 = 2e30kg$, typical for *main sequence stars*
- Radius $R_0 = 7e8m$. Sharply defined (photosphere)
- Luminosity $L_0 = 3.84e26W$. Can use $E = mc^2$ to get $\frac{dm}{dt} = 10^9 kg/s$
- About 80% hydrogen

Logarithmic star luminosity grows linearly with logarithmic mass

$$L/L_0 = (M/M_0)^\alpha$$
$$3 < \alpha < 4$$

A star 10 times heavier will burn mass 1000 times faster. Lower lifetime.

1.1.2 Hydrostatic equilibrium

Assume: Sun is perfectly spherical. Chop it up in spherical shells, radial distance r, thickness dr. Local matter density ρ. M_r - total mass inside shell.

Use force balance to get relation between acceleration, gravity and radial change in pressure (pressure forces).

Set acceleration to zero for hydrostatic equilibrium and solar death rays to kill for maximum awesome,

$$\frac{dP}{dr} = -GM_r\rho/r^2$$

Integrate shells $(4\pi r^2)$ from 0 to R_0.

$$3\langle P\rangle V = \int_0^{R_0} \rho G M_0 4\pi r dr$$

Right side is gravitational energy. Assume volume is filled with a plasma, N protons, N electrons, temperature T.

$$\langle P\rangle = 2Nk_bT/V$$

Integrating, we get an average temperature $2.3e6K$. Maximum can reach $1.6e7K$

1.1.3 Proton proton chain reaction (pp I chain)

Input: 10 protons. Output: 2 protons,

Total energy release - $26.22MeV$.

1.1.4 Solar luminosity

Energy density proportional to T^4. Total radiative energy you get by multiplying by volume. Luminosity can be gotten as total energy over average time to reach solar surface.

Simplest assumption for a photon going straight from solar center gets you a photon getting there in $500s$.

The plasma is not transparent! Photons get absorbed, scattered, reemitted...

- Free free absorption (inverse bremsstrahlung)
- Bound free absorption (photoionization)
- bound bound absorption (photoexcitation)
- electron scattering (Thompson, Compton scattering)

Mean free path for Thomson scattering in solar interior is $2cm$, that's awfully low. This means photons don't go in a straight line but diffuse in a random walk

$$\langle R^2 \rangle = D\tau_{ph}$$

Under this assumption, a photon takes $10e8y$ to escape. And this fits the experimental data..... Whoa.

We get the result that luminosity scales as M^3. Just what we began with for main sequence stars!