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Are Brown Dwarfs Reliable Astrophysical Clocks?

S.R. Valluri
Physics and Astronomy, University of Western Ontario

Collaborators : Sayantan Auddy, Shantanu Basu

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Outline

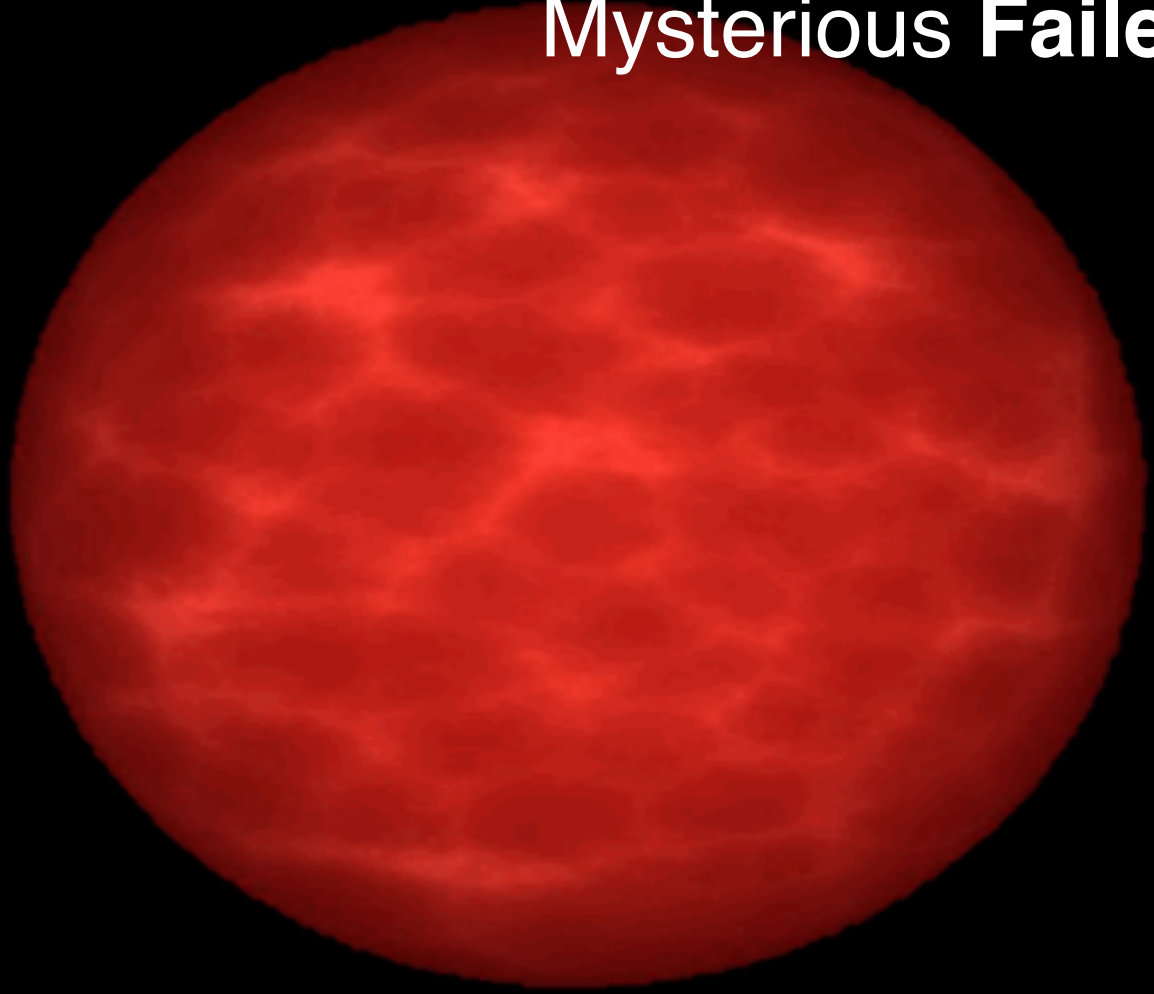
- What are ***Brown dwarfs***?
- Age indicators
- Our Model
- Luminosity Variation with time
- Brown Dwarfs as Clocks
- Conclusions

What are these Mysterious Objects ?

Are these Planets or Stars ?

Brown Dwarfs are :

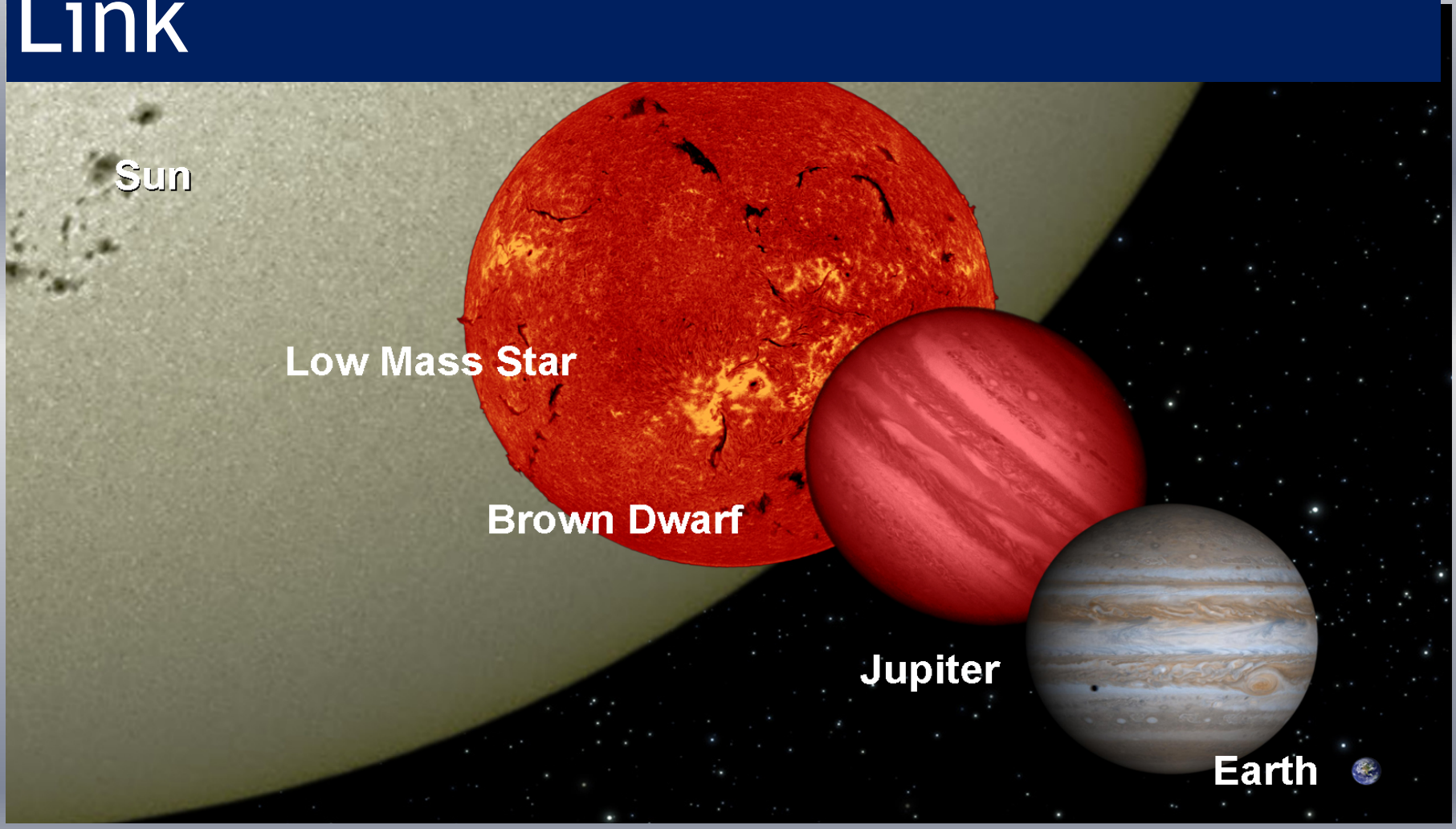
Mysterious **Failed Stars**



What are Brown Dwarfs?

- **Sub stellar objects** with too low a mass to sustain stable hydrogen fusion and too much mass to be called a planet
- **Failed stars** where the electron degeneracy pressure prevents the gravitational collapse. The stability is reached at a temperature much lower than what is necessary for stable nuclear fusion.
- **Super Jupiters** since they do not fuse hydrogen and the size is comparable to Jupiter

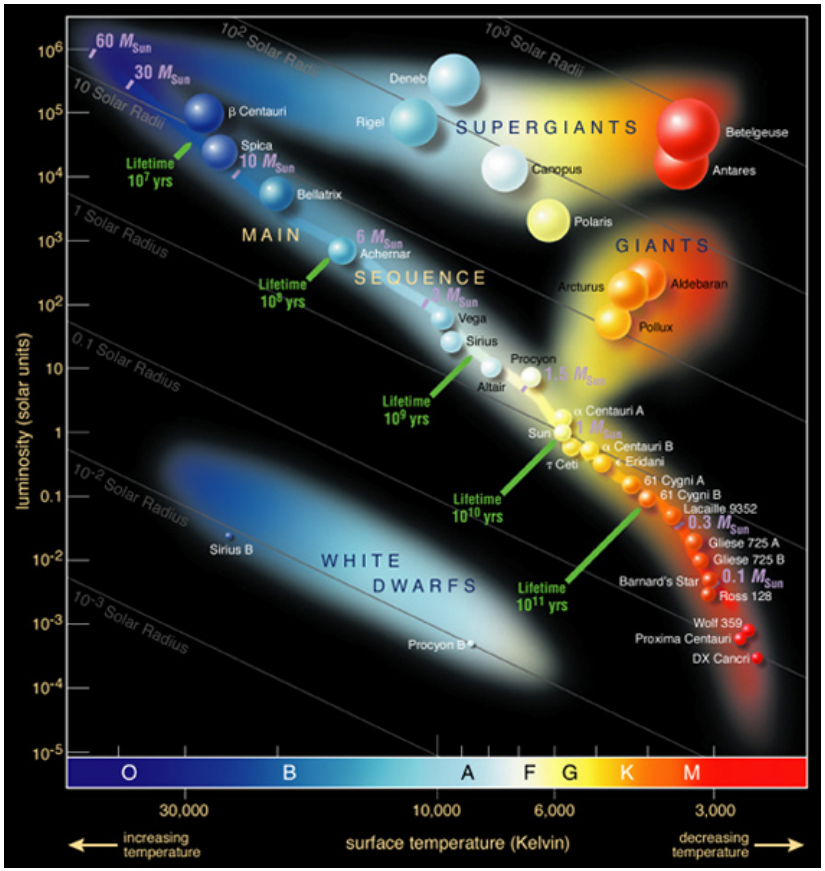
Not Quite Stellar : The Missing Link



http://www.personal.psu.edu/mpr201/blogs/professional_website/2012/05/the-discovery-of-the-coolest-radio-flaring-brown-dwarf.html

Age Indicator

- 90 percent of the observed stars are in the main sequence.
- They can have ages between 10 million to billions of years



From wikipedia

Clocks Of Li

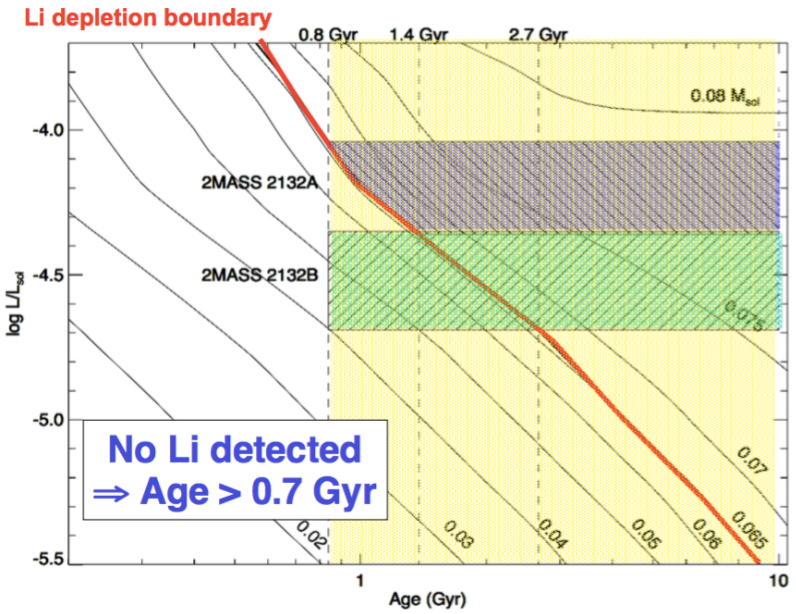
- Li is fused to exhaustion in the cores of objects with $M > 0.065\ M_{\odot}$, ages > 50 Myr
- For ages < 200 Myr, Li depletion depends strongly on both age and mass
- For clusters with ages ≈ 50-200 Myr the Li depletion boundary provides an alternative age dating method

(e.g. Rebolo et al. 1992; Bildsten et al. 1997; Stauffer et al. 1998)

Clocks Of Li

- For ages > 500 Myr, Li is fully depleted in massive
- BDs and stars ⇒ **Li becomes mass detector**
- Li ⇒ $M < 0.065\ M_{\odot}$ ⇒ BD
- no Li ⇒ $M > 0.065\ M_{\odot}$

Luminosity where Li line disappears can be matched to a corresponding mass & age



Stauffer et al. (1998)
see also Barrado y Navascués et al. (1999); Stauffer et al. (1999); Oliveira et al. (2003); Manzi et al. (2008)

Slide Courtesy Adam J. Burgasser

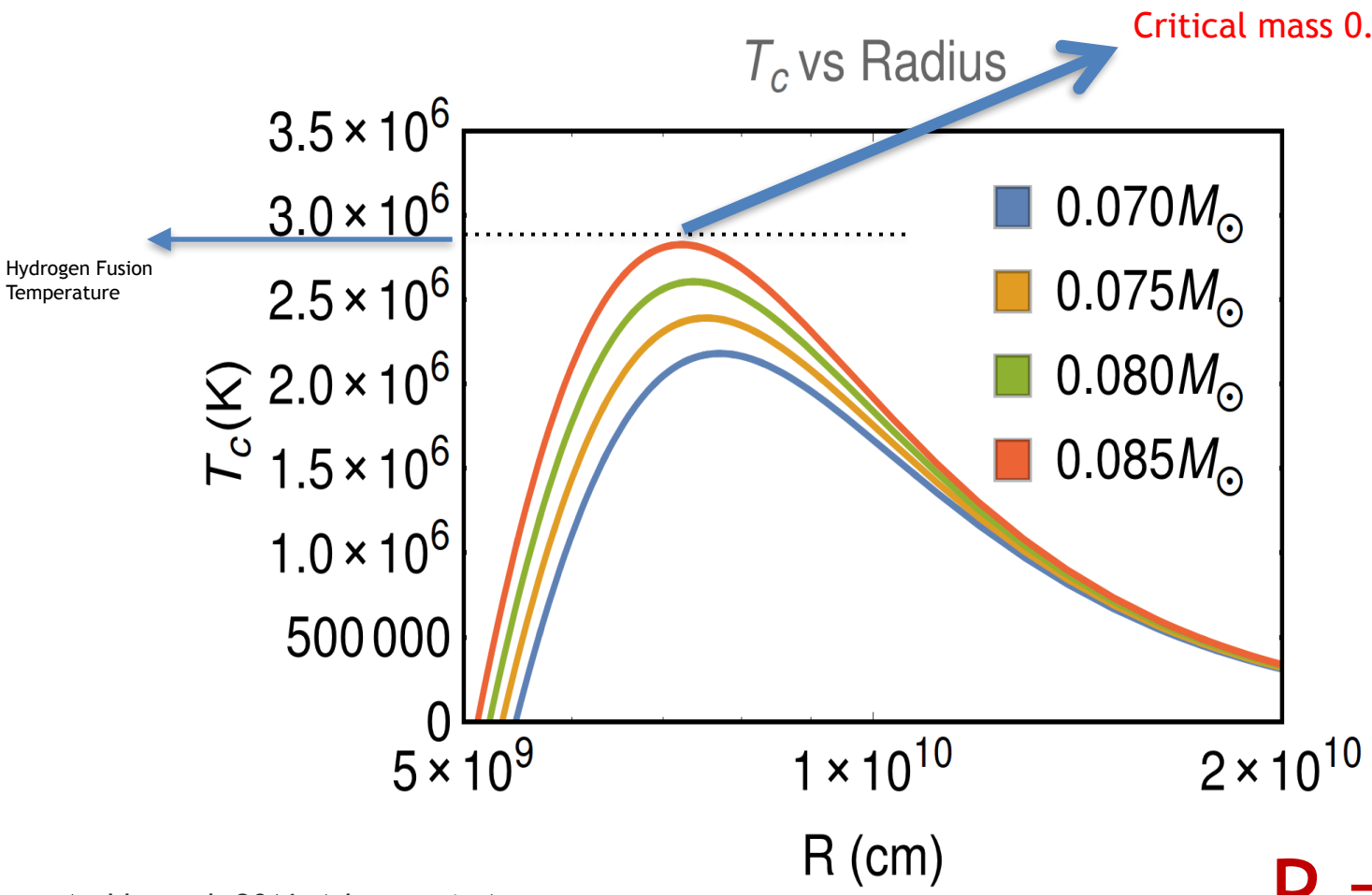
Our Model

Equation of State

- Sub stellar objects like brown dwarfs derive their stability from the electron degeneracy pressure.
- The total pressure is a combined effect of both electrons and Ions

$$P = P_F + P_{ions}$$

M-R relation



$$R = Cont\,\frac{K}{M^{1/3}}$$

n =1.5

$$P = K\,\rho^{(1+1/n)}$$

Auddy et al. 2016, Advances in Astronomy

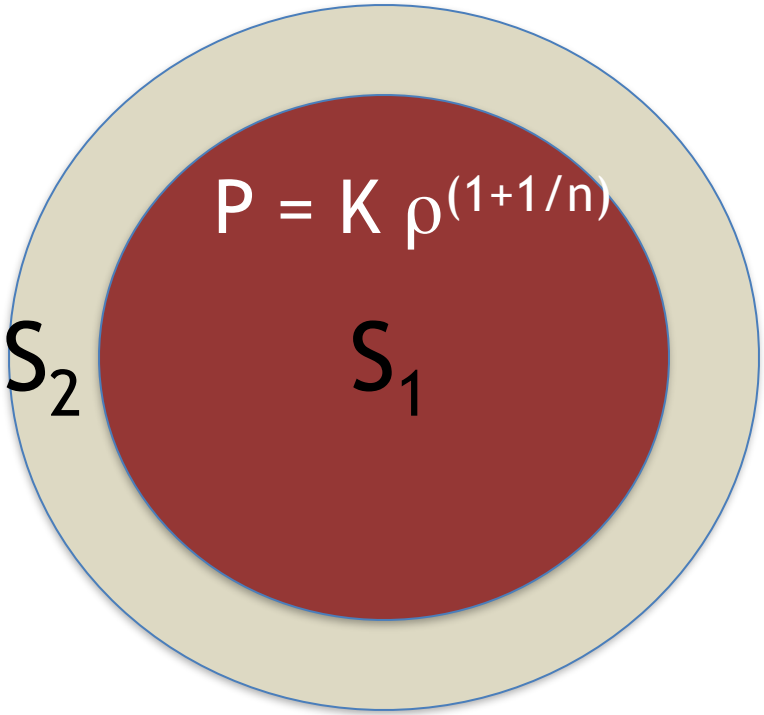
Entropy

Entropy at the interior for partially ionized hydrogen and molecular helium is $S_1 = f(T,\rho)$.

$S_1 = S_{Electron} + S_{Ions} + S_{Radiation}$

Entropy at the photosphere for molecular hydrogen and helium is $S_2 = f(T,\rho)$.

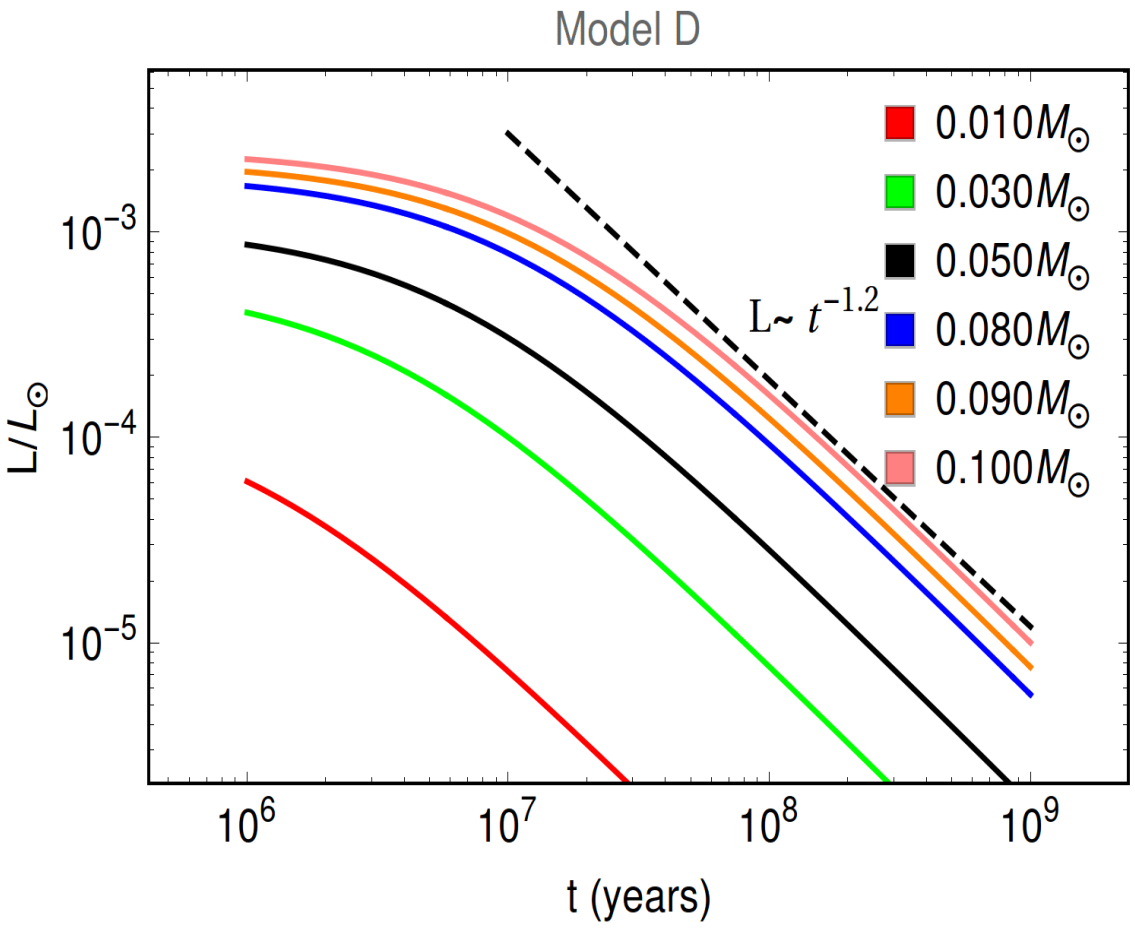
$S_2 = S_{Electron} + S_{molecules} + S_{radiation}$



$$\Delta S_{T,p} = S_2 - S_1$$

The Change of entropy is used to calculate the surface temperature

Luminosity of LMO



$$L = 4\pi R^2 T_e^4$$

$$L \sim M^{2.63} t^{-1.2}$$

Auddy et al. 2016, Advances in Astronomy

Luminosity

- Brown dwarfs radiate in the infrared
- Our model is consistent with the results of detailed numerical simulation code MESA (*M*odules for *E*xperiments in *S*tellar *A*strophysics)
- Once BD settle in a steady state they can in principle live for billions of years

Brown Dwarfs As Clocks

$$L \approx L_{\odot} \, (M/M_{\odot})^{2.63} \, (t/10^{7}\text{yrs})^{-1.2}$$

- Luminosity decreases by two orders of magnitude in ~ 100 Myr
- This can be calibrated to serve as an astronomical clock
- If we know the mass and the luminosity the age can be estimated, unlike for main sequence stars

Conclusions

- Brown Dwarfs can act as a **reliable astrophysical clock**
- As luminosity is a time variable, one can estimate the age of the BD based on its mass and luminosity
- This can allow more reliable estimates of the **ages** of associated **stellar clusters** or **exoplanetary** systems