

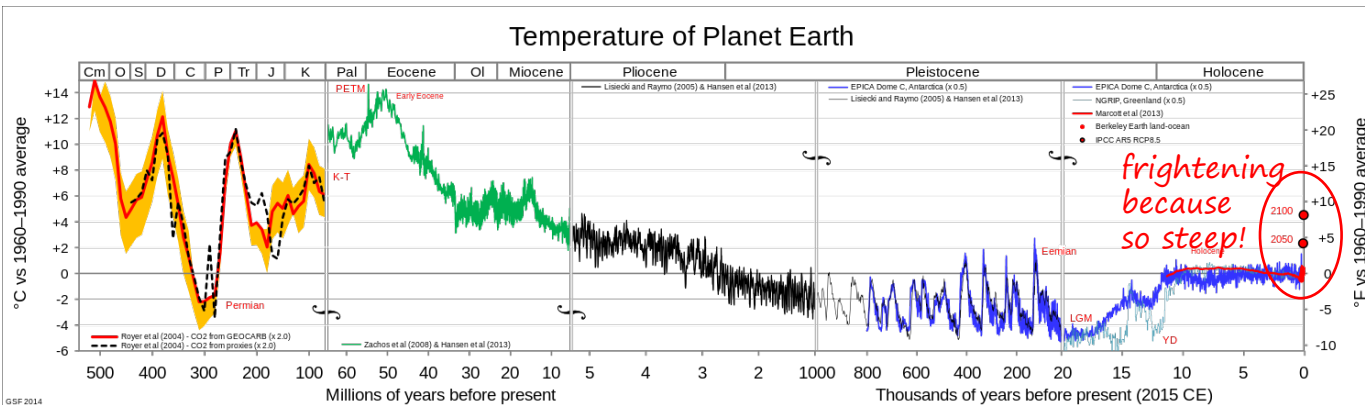
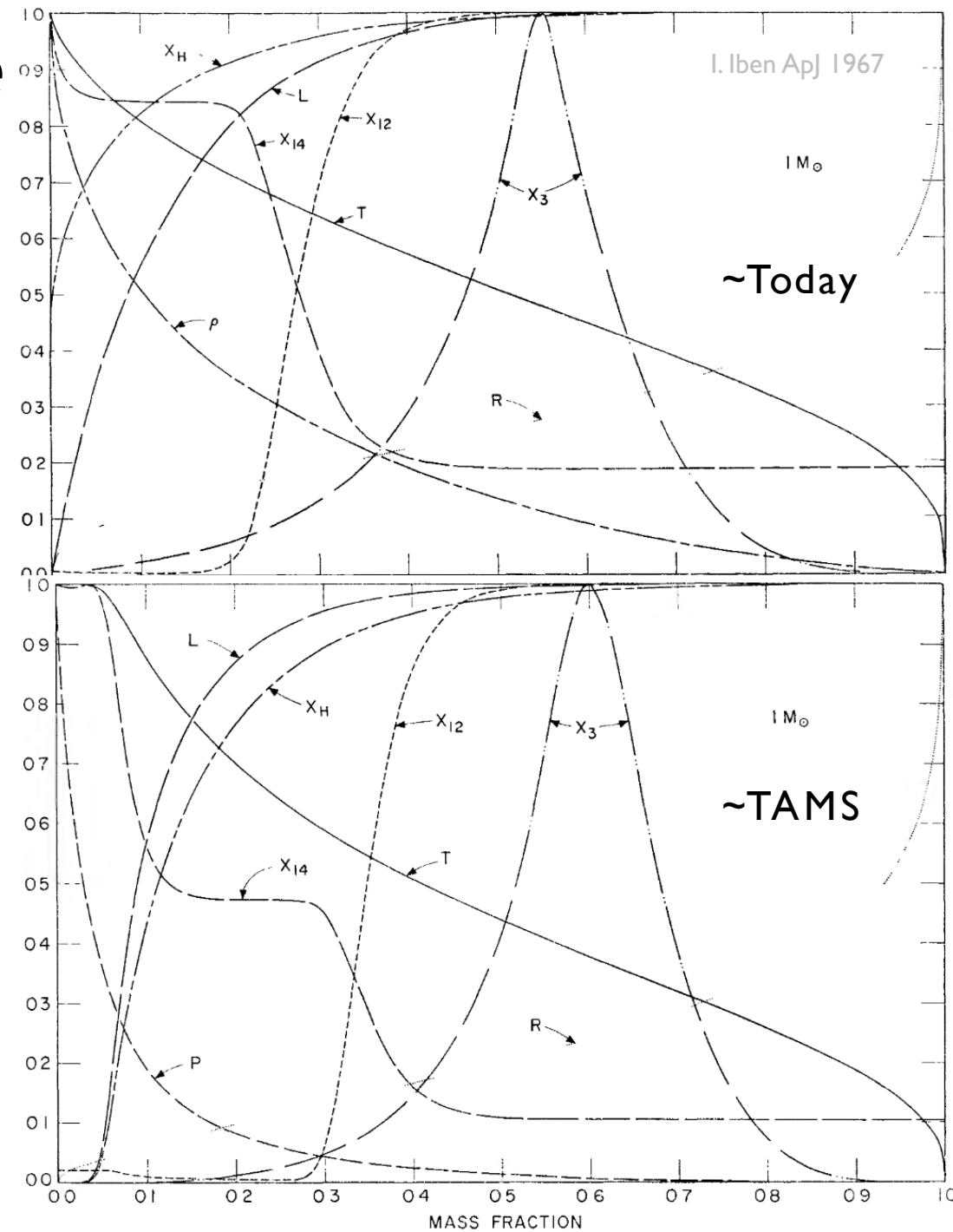
Quick notes on
End of Earth

Zach Meisel

Ohio University - ASTR4201 - Fall 2020

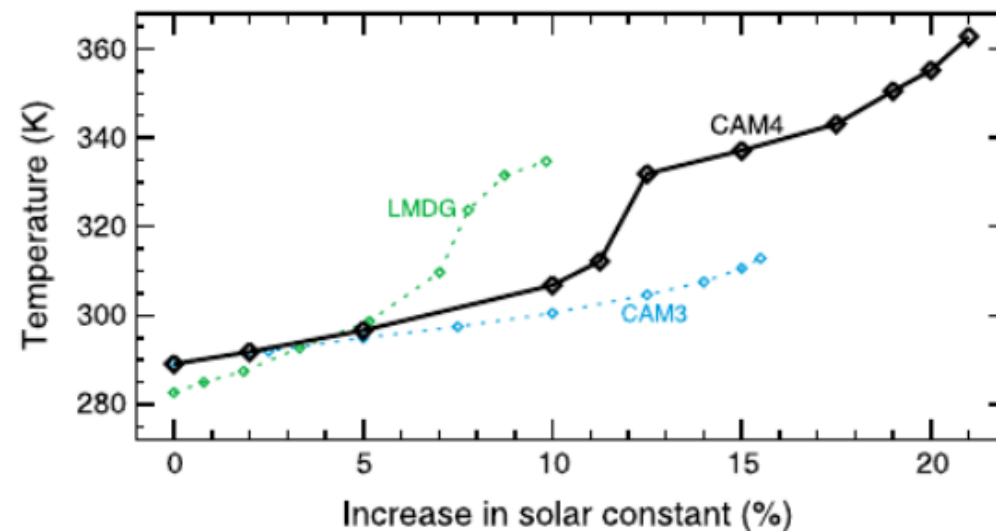
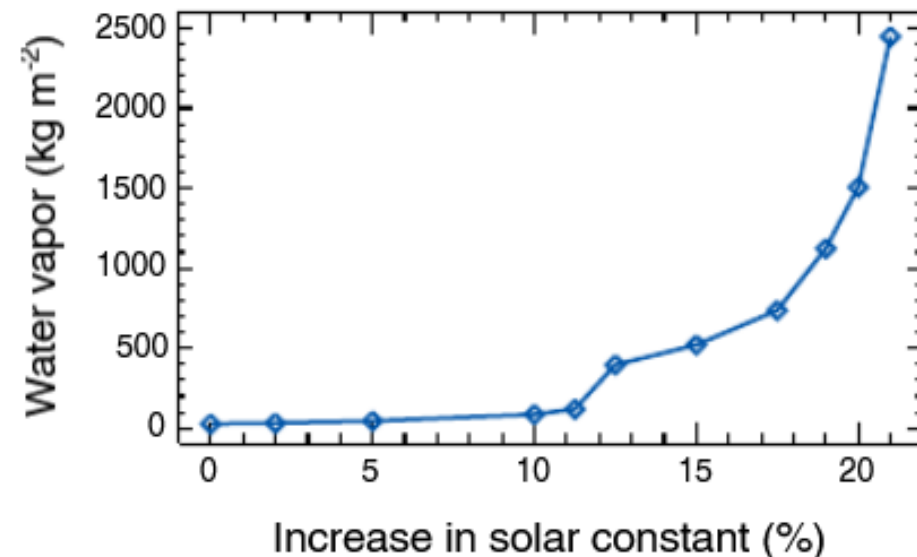
Sun evolution on the main sequence

- Core hydrogen is steadily exhausted, converting to helium, creating a more dense environment
- The reaction rate scales with ρ^2 , so the energy generation rate increases. This corresponds to an increase in luminosity.
- The increase is $\sim 1\%$ every 0.1 Gyr
- Interestingly, geologists say Earth's temperature has actually decreased, on average, due to reduced greenhouse warming



Earth in ~ 1 Gyr

- The increase 1.2 billion years from now will amount to $\sim 12\%$ brightness increase
- At that point, the atmosphere has a high moisture content, which has a large opacity to infrared light
- The high opacity limits radiative cooling
- ...which in turn heats a layer low in the atmosphere, but still above the Earth's surface
- ...which leads to a temperature inversion, which then shuts off convection, thereby removing this source of cooling.
- The end result is a sharp increase in average global temperature to $\sim 140^\circ\text{F}$
- In ~ 2 billion years, after a $\sim 20\%$ brightness increase, water vapor content is so high that water is lost to space. (all of it over the following Gyr)



The End

- Around 5.5 billion years from now, the sun's core hydrogen will be gone and the pressure provided by the core radiation will disappear
- The core will contract and, by the virial theorem, heat up
- Prior to core helium burning, shell hydrogen burning occurs
- As with core hydrogen burning, shell hydrogen burning acts like a thermostat, keeping the temperature about constant. So, the total kinetic energy is about the same and yet the core has contracted, decreasing potential energy. By the virial theorem, the shell must expand.
- This is the “mirror principle” in stars with shell fusion: if the core contracts, the shell expands (and vice versa)
- Anyhow, this expanding radius means the inner solar system will be engulfed over $\sim 2\text{Gyr}$
- Taking into account tidal interactions and drag, the Earth will actually plunge into the sun at this point

