Introductory Astronomy

Week 5: Stellar Evolution

Clip 4: Post-Main Sequence Sun-I

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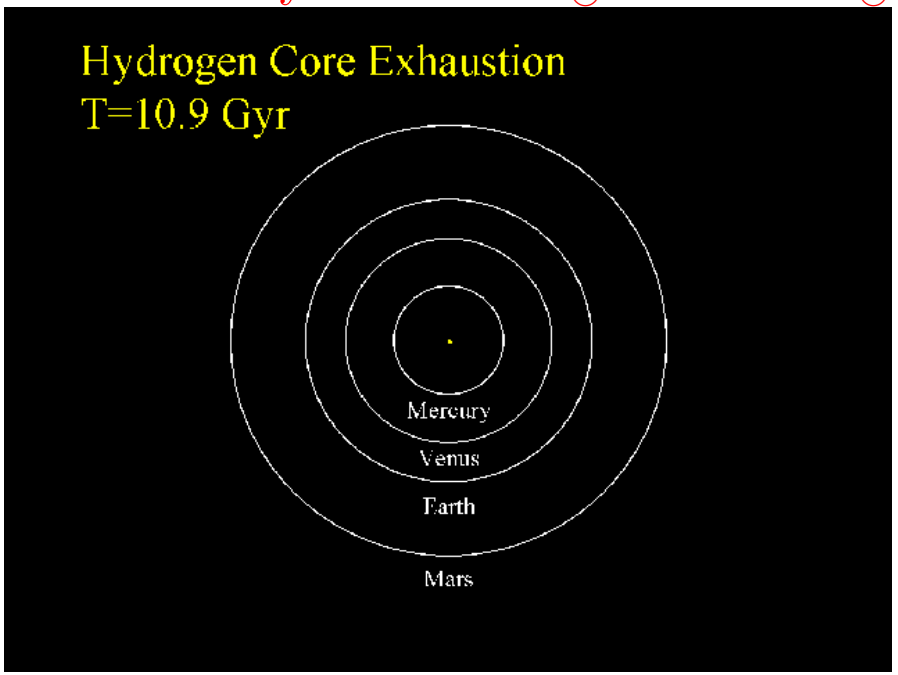
On the Main Sequence

- Hydrogen fusion in core supports envelope by thermal and radiation pressure
- Luminosity, surface temperature determined by mass, composition, rotation, close binary partner, atmospheric and interstellar effects
- Main Sequence thickened by variations in these
- Over time core contracts and heats
- Fusion rate increases
- Envelope expands slowly with little change in temperature
- Evolutionary track turns away from Main Sequence

Running Out of Gas

- Inner 3% inert Helium core is isothermal
- Hydrogen fusion in shell exceeds previous core luminosity
- Envelope expands and cools
- Inert core grows

$T \sim 10.9\text{Gy}\ R \sim 1.58R_\odot\ L \sim 2.21L_\odot$



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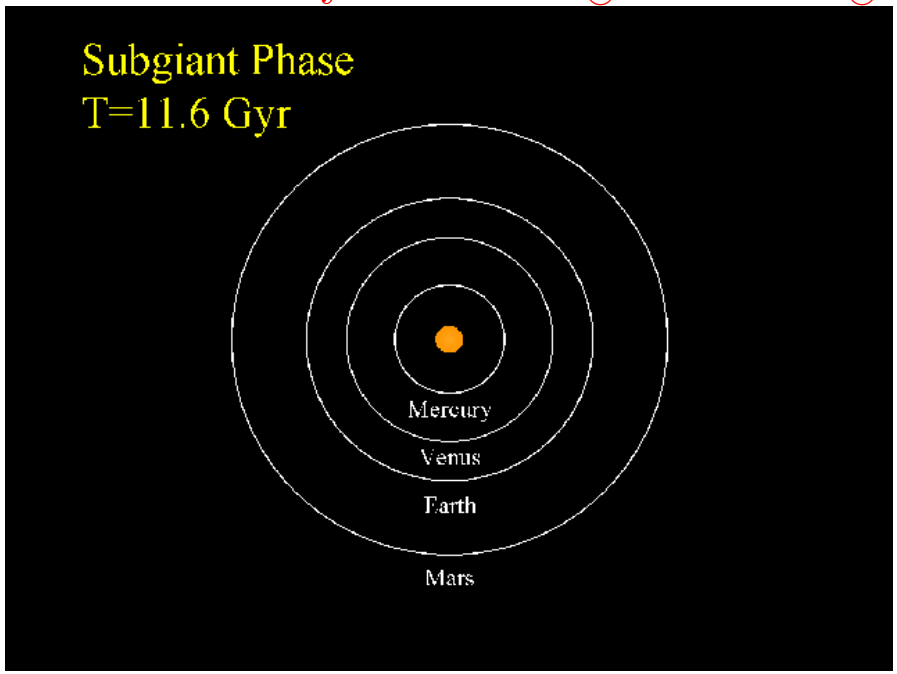
Sub-Giant Branch

- In isothermal core pressure gradient maintained by density gradient
- If core too large $M_c \geq 0.08M$ cannot support outer layers.
- Core collapses rapidly (KH scale)
- Gravitational energy expands envelope
- Temperature decreases
- Sub-Giant Branch

$T \sim 11.6\mathrm{Gy}\ R \sim 2.3R_\odot\ L \sim 2.2L_\odot$



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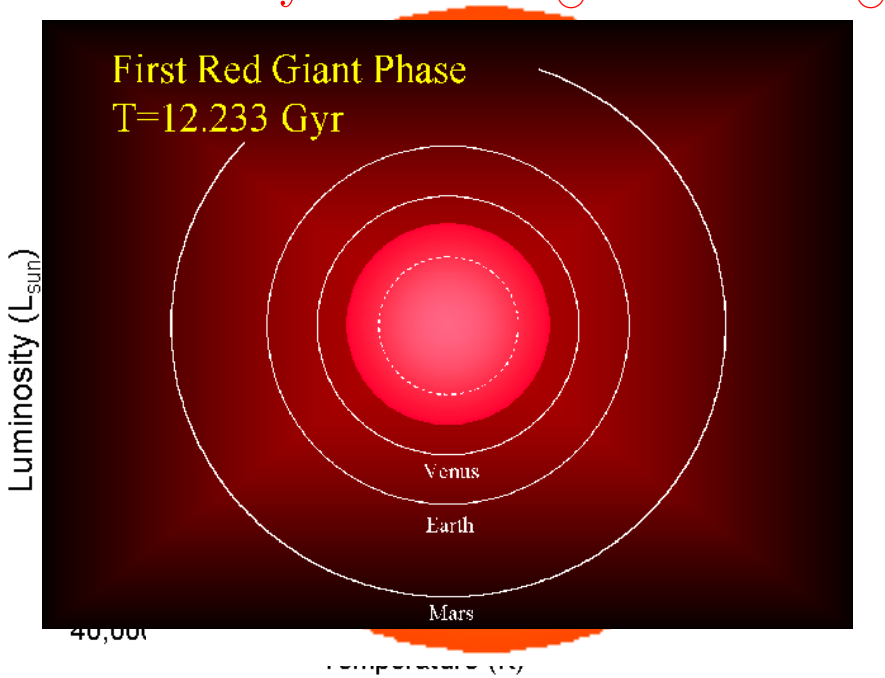
Red Giant

- Core collapses
- Compression heats shell increasing luminosity
- Envelope expands and cools, H^- opacity creates deep convection
- First dredge-up brings fusion products to atmosphere
- Mass loss up to 28%

$T \sim 12.233\text{Gy}\ R \sim 166R_\odot\ L \sim 2350L_\odot$



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Then What?

- Core does not collapse due to electron degeneracy pressure
- Quantum effect of Pauli exclusion principle
- Squeezing electrons into small space requires occupying higher energy states
- Produces temperature-independent contribution to pressure

$$P_e = K_e \rho^{5/3}$$

$$K_e \sim 3.2 \times 10^6 \, \mathrm{Nm}^{-2}/(\mathrm{kgm}^{-3})^{5/3}$$

- This is smaller than thermal pressure in Hydrogen core today
- In compressed inert Helium core degeneracy pressure stops collapse

Credits

- Stellar Evolution Figures: R. Pogge, OSU (with permission)
  http://www.astronomy.ohio-state.edu/~pogge/Lectures/vistas97.html
  http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit2/lowmass.html