


ASTR 1040: Stars & Galaxies in Fiske Planetarium



Blinking Eye Nebula

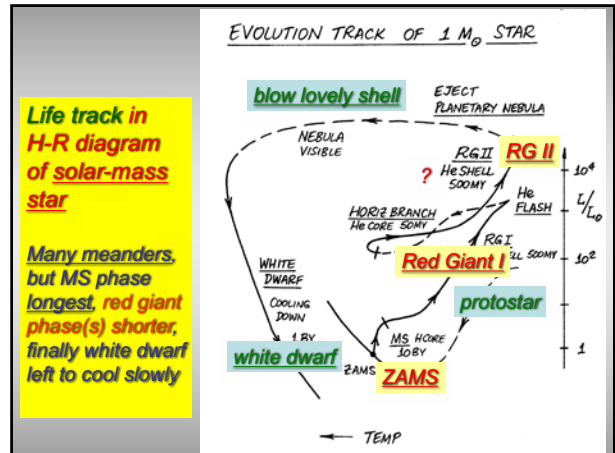
Prof. Juri Toomre TAs: Peri Johnson, Ryan Horton
Lecture 15 (mid-course!) Tues 6 Mar 2018
zeus.colorado.edu/astr1040-toomre

Topics for Today & Thur

- Life tracks of massive stars: late stages allow fusion like "layers of an onion"
- Massive stars end life with supernova explosion, when iron core exceeds $1.4 M_{\text{sun}}$
- Pulsars – fast spinning neutron stars with fierce magnetic fields; gradually slow down
- We take a tour of our galaxy, then turn to Black Holes show

Things to do


- Review 17.3 'Life as High-Mass Star'
- Read Chap 18: "Bizarre Stellar Graveyard" and white dwarfs in detail, neutron stars next lecture
- Homework #6 now graded (plus answers), outside for pickup
- Observatory Night #4 tonight (signup)



Life after brief "planetary nebula" stage

Hot central core emerges as

WHITE DWARF



Ring Nebula

7. White Dwarf

Inert C core, He & H shells

electron degeneracy pressure holds it up

Very dense, size of Earth

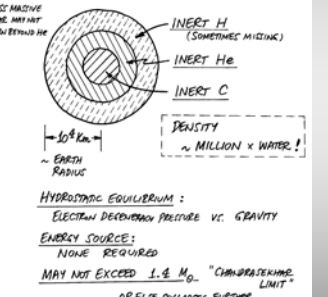
max mass of $1.4 M_{\text{sun}}$

STEP 7. WHITE DWARF

FOR $1 M_{\odot}$ STAR, CARBON CORE NEVER HOT ENOUGH TO BURN

⇒ HOT DWARF SITS & COOLS VISIBLE ~ 1 BY

LESS MASSIVE STARS MAY BE BURNING HE

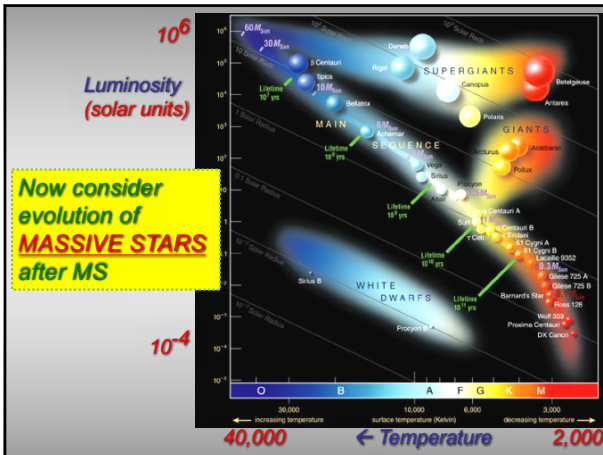
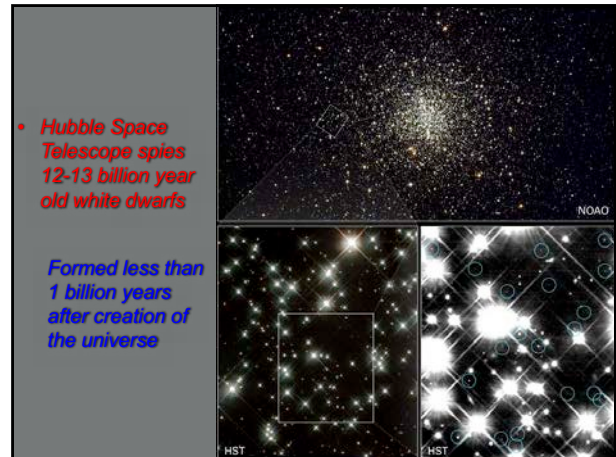
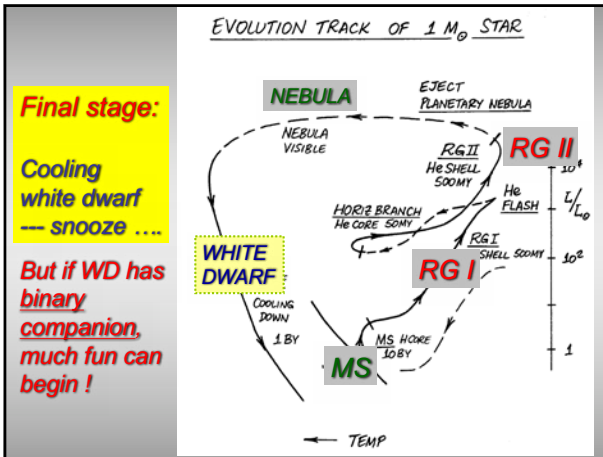


DENSITY ~ MILLION x WATER!

HYDROSTATIC EQUILIBRIUM: ELECTRON DEGENERACY PRESSURE VS. GRAVITY

ENERGY SOURCE: NONE REQUIRED

MAY NOT EXCEED $1.4 M_{\odot}$ "CHANDRASEKHAR LIMIT" ... OR ELSE COLLAPSES FURTHER



Clicker review – red giants

• The main source of energy for a star as it grows in size to become a red giant is

B.

- A. gravitational contraction
- B. hydrogen fusion in a shell around core
- C. helium fusion in the core
- D. hydrogen fusion in the core

EVOLUTION OF MASSIVE STARS M > 2 M_⊙

SO WHAT IS DIFFERENT?
"CLOCK" CAN RUN MUCH FASTER
CAN BURN MORE ELEMENTS (C, O, Ne, Si...)
FINAL FATE CONTROLLED BY HOW MUCH MASS LEFT BY STRONG WINDS

Evolution of massive stars

Clock runs faster, can burn heavier elements

First 4 steps pretty familiar, but no helium flash

- 1. MAIN SEQUENCE** H CORE BURNING, C-N-O CYCLE
STERNE WINDS M & (4H → HE)
- 2. RED GIANT I** HE SHELL BURNING
INERT HE CORE SLOWLY CONTRACTING
- 3. HORIZONTAL BRANCH** LESS SPACE, NO DEGENERACY IN HE CORE (IF M > 2.5 M_⊙)
→ NO HELIUM FLASH
SMOOTH TRANSITION TO HE CORE BURNING: TRAPEZOID (3He → C)
- 4. RED GIANT II (SUPERGIANT)** HE SHELL BURNING STARTED, H CONTINUES TO BURN IN SHELL
INERT C CORE SLOWLY CONTRACTING, MAY BECOME DEGENERATE MATTER!

MASSIVE STARS ...

Successive core & shell fusion burning of C, O, Ne, Si ...

all with "alpha capture" (or He)

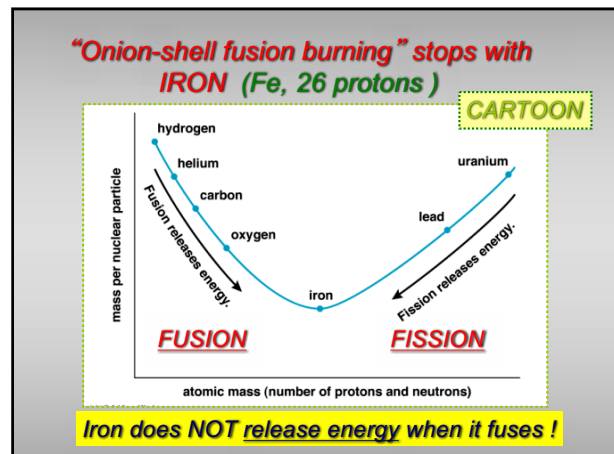
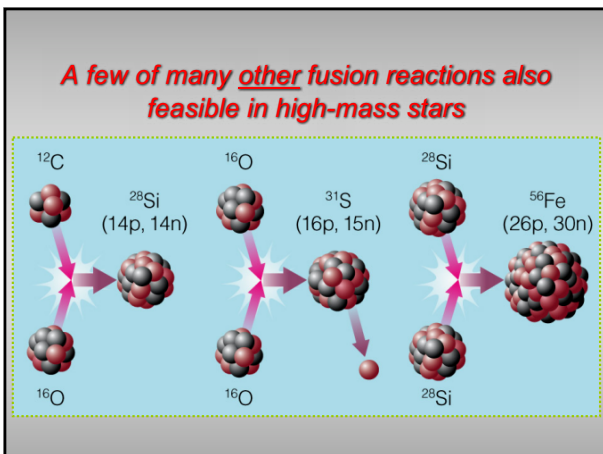
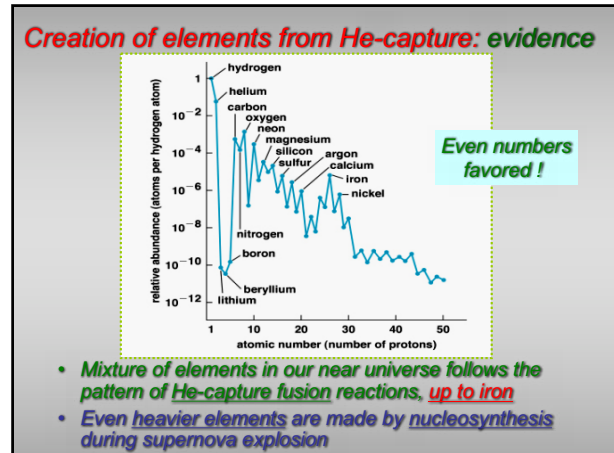
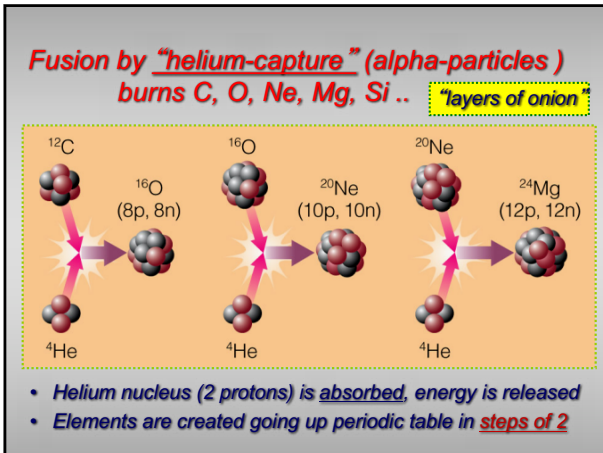
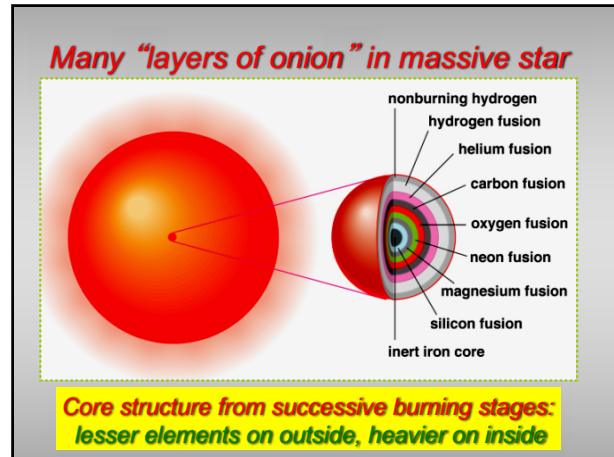
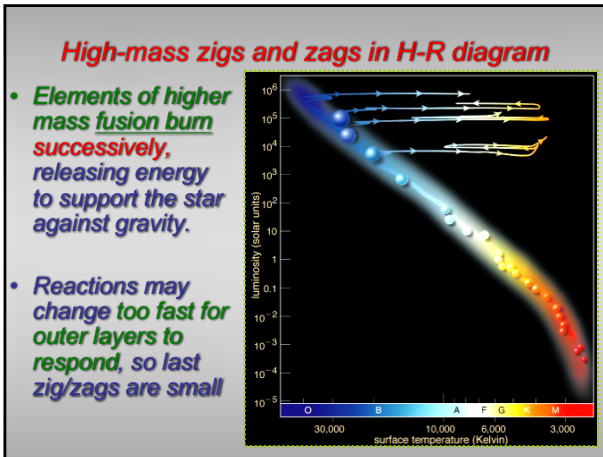
stars make many shallow H-R loops

5. CARBON FLASH INITIATES CARBON BURNING IN DEGENERATE CORE WITH EXPLOSIVE FLASH
"ALPHA CAPTURE"
C + He → O + ENERGY
A. EXPLODE AS SUPERNOVA TYPE I OR
B. REMOVE DEGENERACY, EVEN QUIETLY IN STAGES TO PRODUCE IRON IN CORE

6. HORIZONTAL BRANCHES, RED SUPERGIANTS (MANY LOOPS IN H-R DIAGRAM!)


AT CENTER OF SUPERGIANT: H SHELL, HE SHELL, O... C BURNING SHELL, INERT Fe CORE

IF M ≥ 8 M_⊙, SUCCESSION OF CORE AND SHELL IGNITION "ONION RING" STRUCTURE OF BURNING SHELLS



MENG 4

Several fates for massive star

1. Strong winds *shrink* star, may end as **WHITE DWARF**
2. Or core burns to Fe, eventually sudden **CORE COLLAPSE!**
 **SUPERNOVA**

FINAL FATE OF MASSIVE STAR

TWO POSSIBILITIES

1. LOSES ENOUGH MASS IN WIND/PLANETARY NEBULA
 $< 1.4 M_{\odot}$ LEFT \Rightarrow WHITE DWARF
 (W.D. COMPOSED OF HEAVIEST ELEMENTS PRODUCED)
2. ENTIRE CORE BURNS TO IRON
 NO MORE NUCLEAR ENERGY CAN BE RELEASED!
AND $> 1.4 M_{\odot}$ LEFT
COLLAPSE CANNOT BE STOPPED BY ELECTRON DEGENERACY PRESSURE
 \Rightarrow NEUTRON STAR
 OR
BLACK HOLE

Now on to travels within our galaxy
with the big-sky of the planetarium

... and then the black-holes program