

LESSON 5

THE EFFECT OF MASS LOSS ON STELLAR EVOLUTION

- HIGH MASS STARS

- LOW MASS STARS

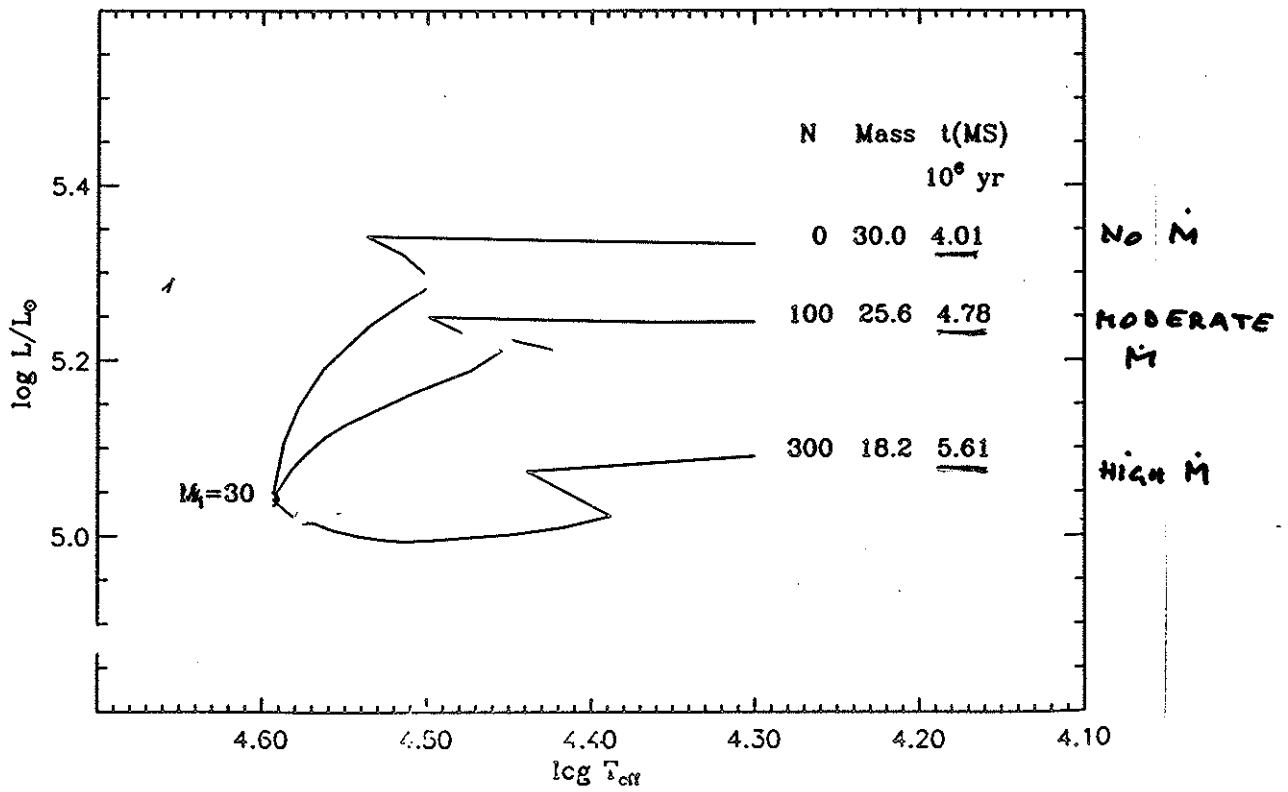
AGB PHASE

FORMATION OF WD

THE EFFECTS OF MASS LOSS ON STELLAR EVOLUTION

- CHANGES IN THE SURFACE COMPOSITION
- LUMINOSITY
- LIFETIME
- LACK OF RED SUPERGIANTS
- PLANETARY NEBULAE
- MASSES AND FORMATION OF WHITE DWARFS

THE EFFECT OF MASS LOSS ON THE MAINSEQUENCE



- STAR IS LESS BRIGHT
- MAIN SEQUENCE PHASE LASTS LONGER.
- MAIN SEQUENCE IS WIDER.

DE LOORE + LAMERS
1978

MASS LOSS PREVENTS RED SUPERGIANTS

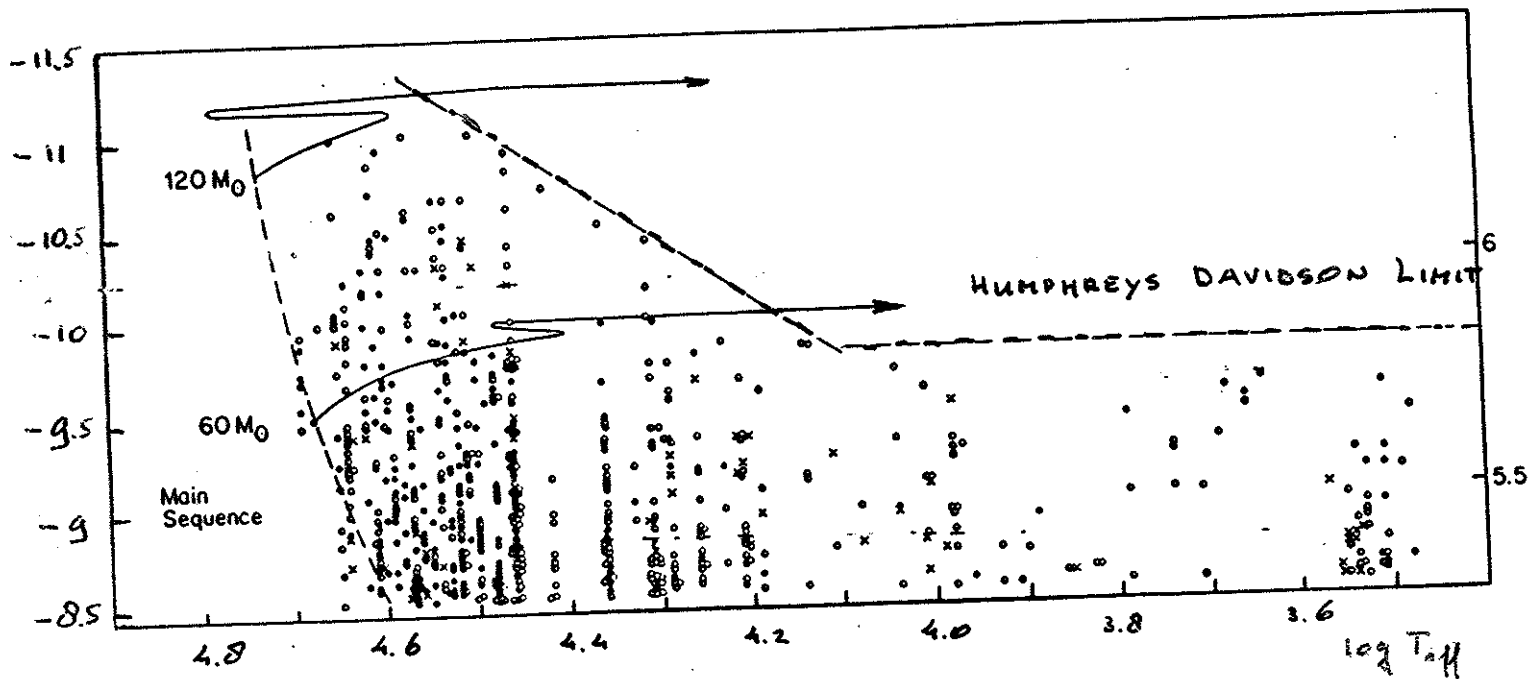
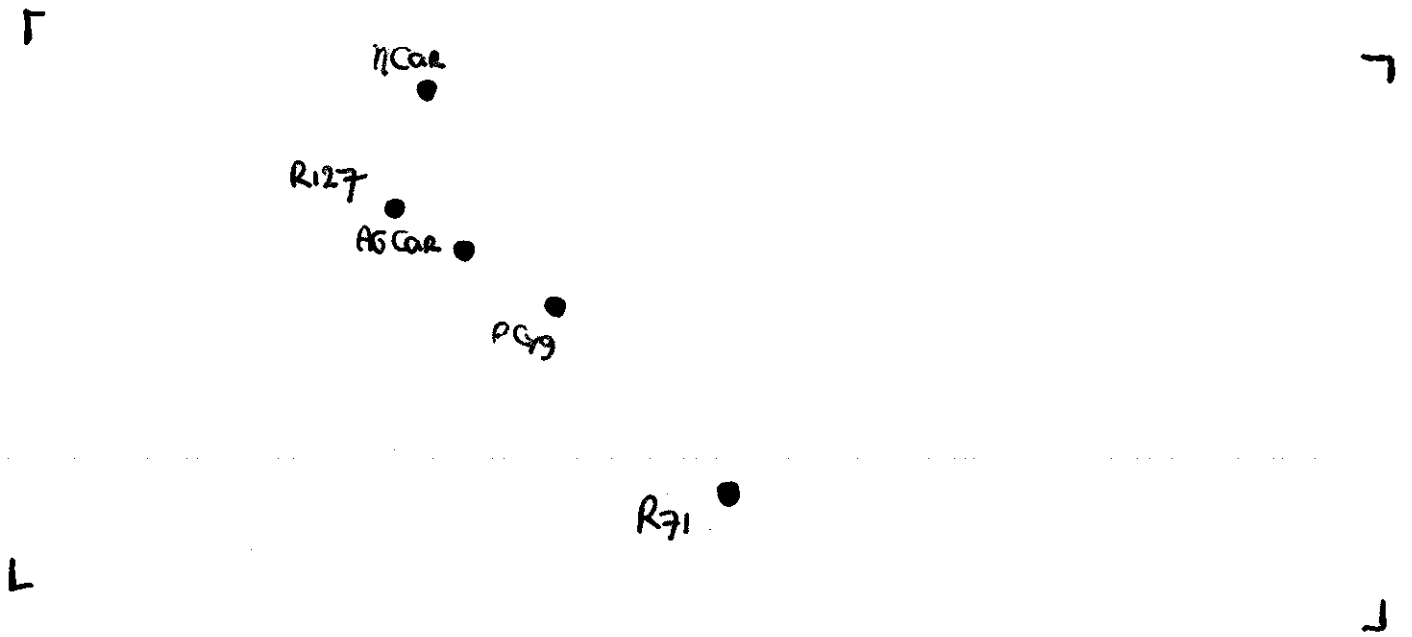


Figure 1 - The M_{Bol} vs. $\log T_{\text{eff}}$ diagram for luminous stars ($M_{\text{Bol}} \leq -8.5$ mag) in the Galaxy, LMC and SMC. The upper luminosity boundary (dashed line) is based on the distribution of the most luminous normal stars in these three galaxies.



LUMINOUS BLUE VARIABLES

EVOLUTIONARY TRACKS

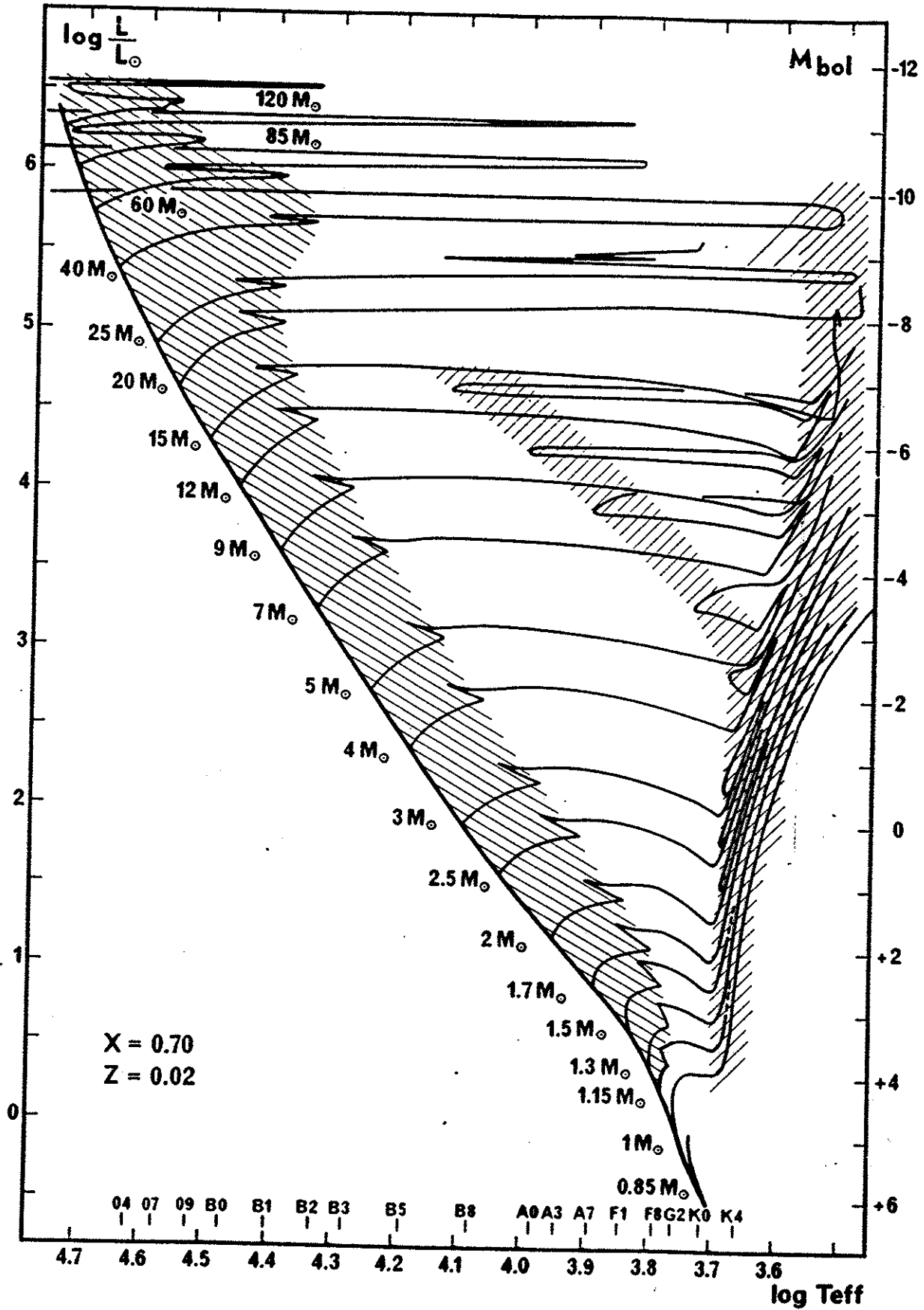
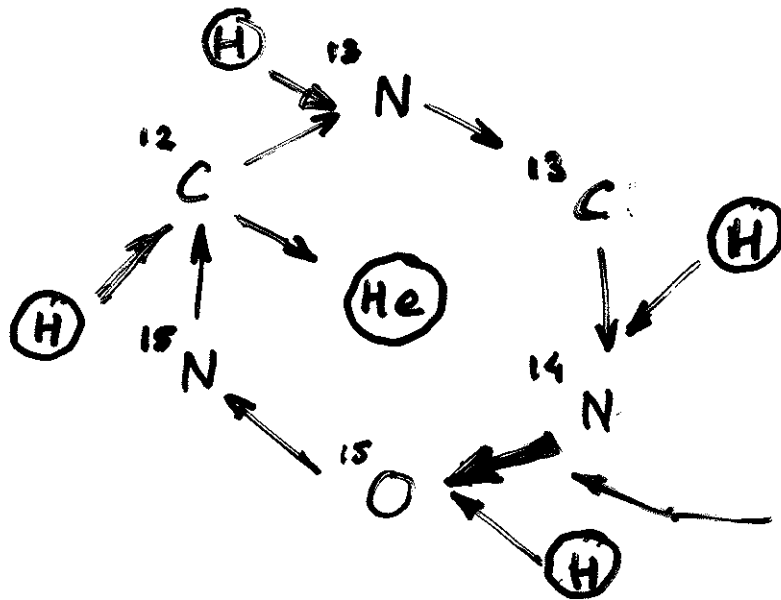


Fig. 15. Theoretical HR diagram for the ensemble of the calculated models with an overshooting parameter $\alpha_{\text{over}} = d_{\text{over}}/H_p = 0.25$ for initial masses $M > 1.15 M_{\odot}$. The slow phases of nuclear burning are indicated by hatched areas

H BURNING VIA CN cycle
 $T > 2 \cdot 10^7$ K



SLOWEST
 REACTION



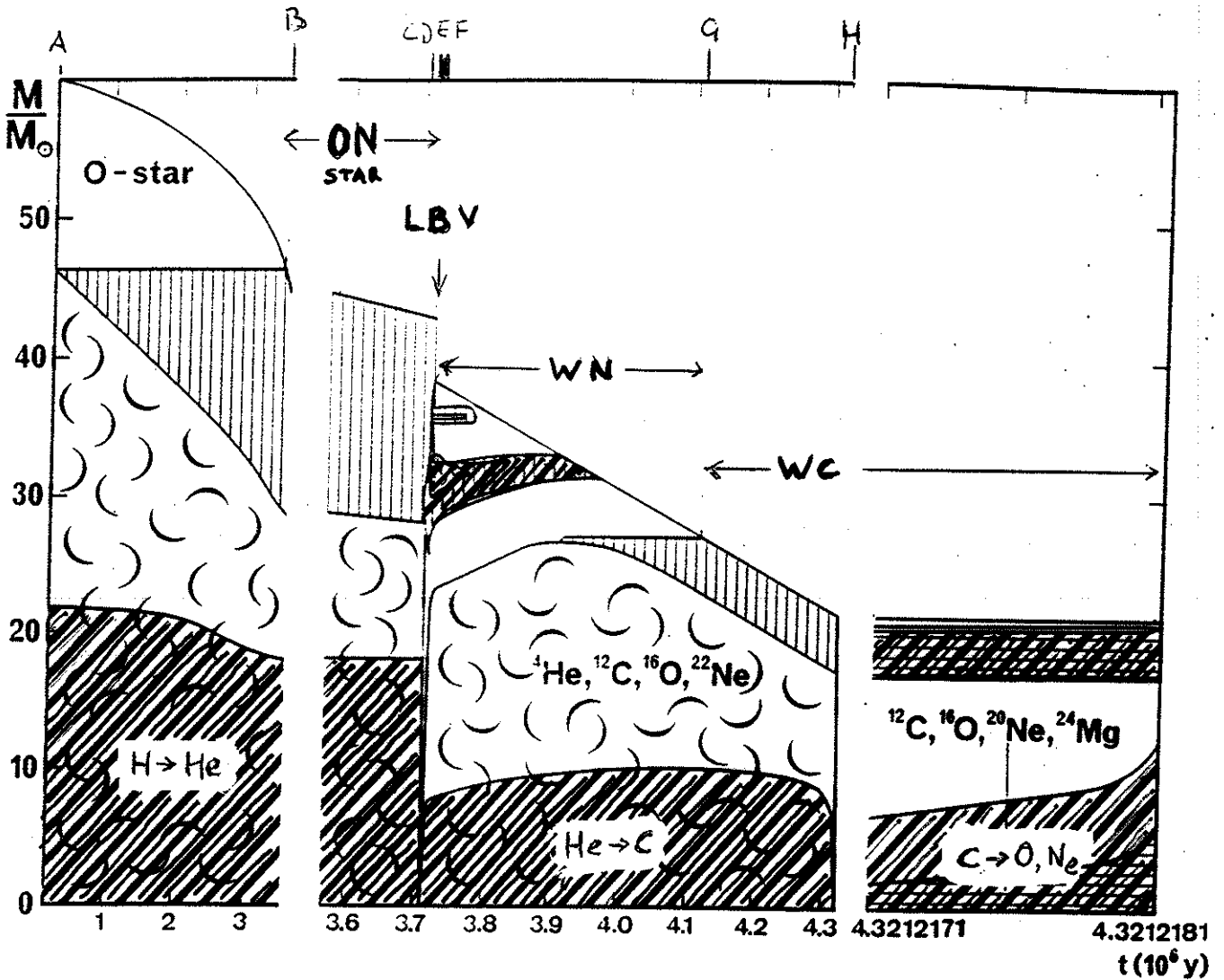
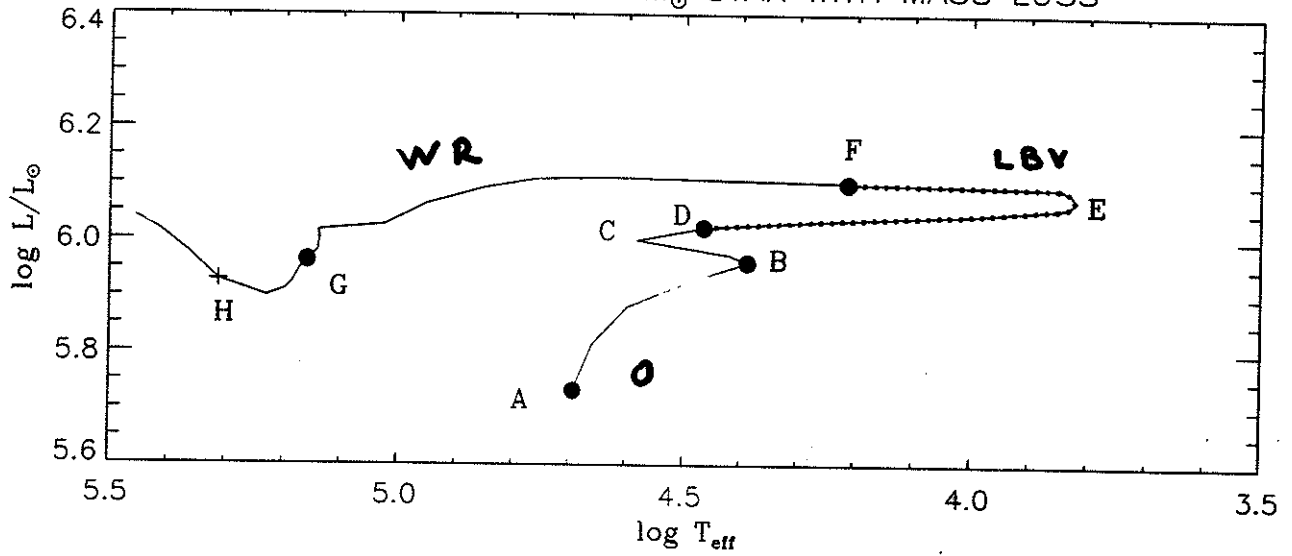
PILE-UP
 OF ^{14}N

^{14}N ↑
 ^{12}C ↓

NUCLEAR PRODUCTS AT THE SURFACE

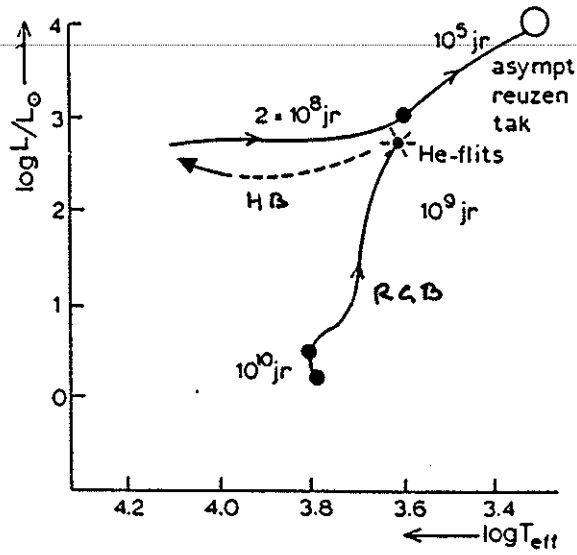
1. $^{14}\text{N} \uparrow$ $^{12}\text{C} \downarrow$ H-BURNING
2. $\text{He} \uparrow$ $\text{H} \downarrow$ H-BURNING
3. $\text{C} \uparrow$ $\text{He} \downarrow$ $\text{N} \downarrow$ HE-BURNING

EVOLUTION OF A 60 M_⊙ STAR WITH MASS LOSS

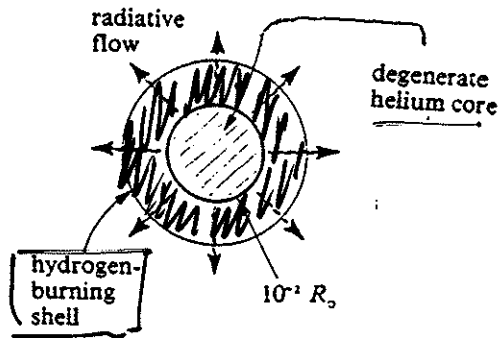
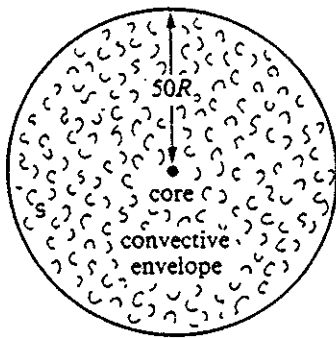


THE CHANGES IN THE INTERNAL STRUCTURE OF A 60 M_⊙ STAR

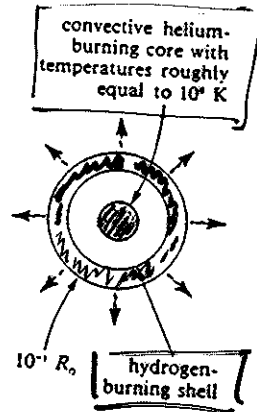
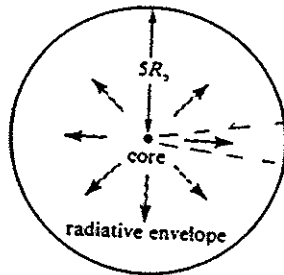
EVOLUTION OF A LOW MASS STAR



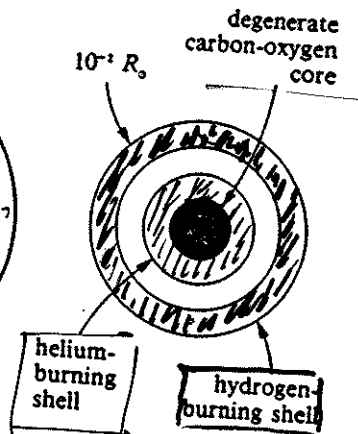
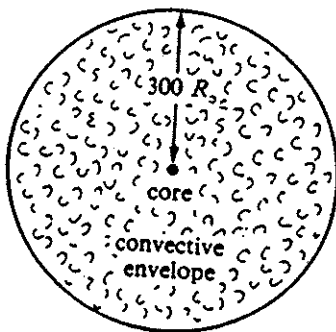
RGB



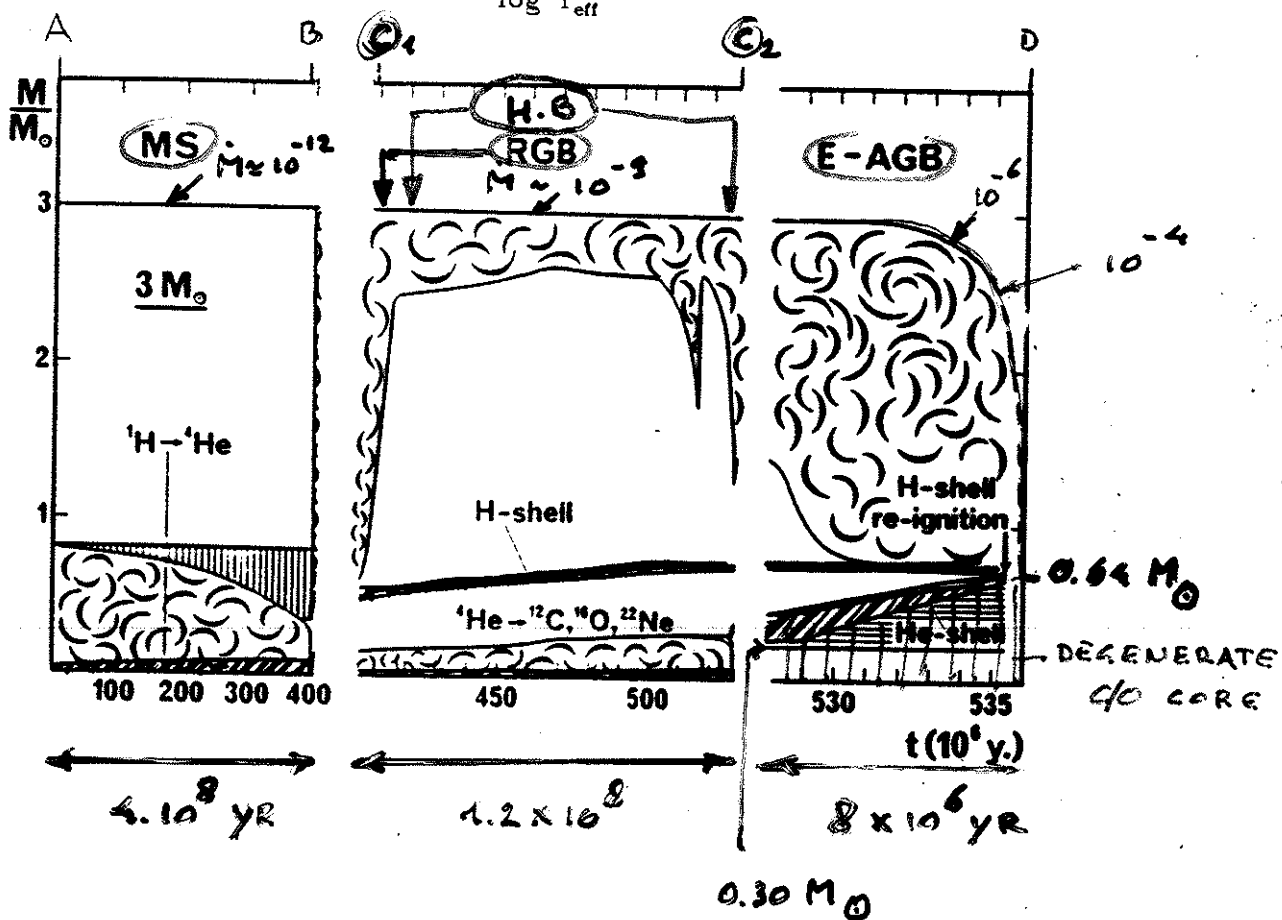
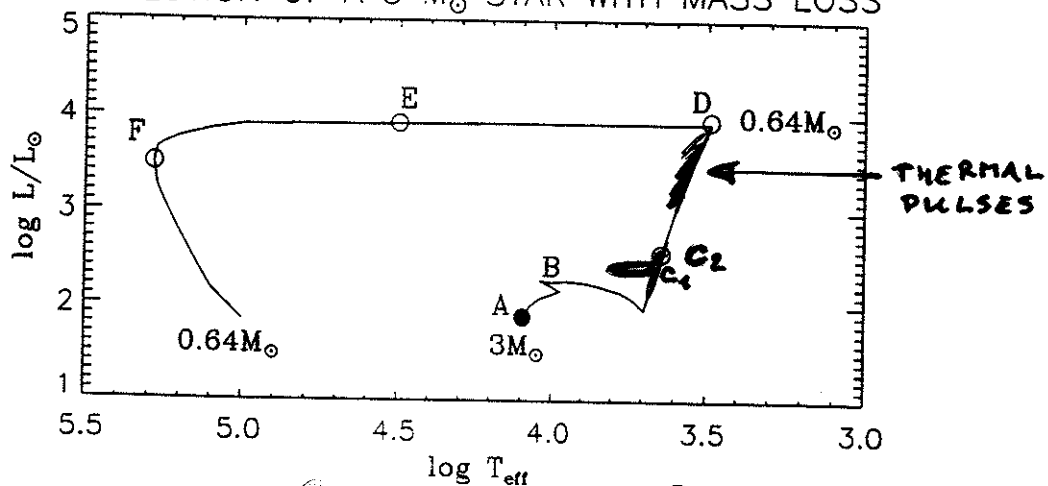
HB



AGB



EVOLUTION OF A 3 M_⊙ STAR WITH MASS LOSS



A SIMPLE ESTIMATE OF THE AGB PHASE

- CORE MASS ↔ LUMINOSITY RELATION (PALZINSKY RELATION)

$$L_* / L_{\odot} \approx 5.2 \times 10^4 (M_c - 0.456)$$

$$M_c = 0.52 \rightarrow L = 3.10^3$$

$$M_c = 0.70 \rightarrow L = 1.2 \times 10^4$$

- CORE MASS INCREASES WITH TIME

$$\frac{dM_c}{dt} = \frac{L_*}{E_H} \approx 1.0 \times 10^{-11} L_*$$

$$E_H = 6 \times 10^{18} \text{ ERGS/GM}$$

- COMBINE (1) AND (2)

$$\frac{dL}{dt} = 5.2 \times 10^{-7} L \rightarrow L = L_0 e^{(t-t_0)/2 \times 10^6}$$

$$M_c = 0.456 + \frac{L_0}{5.2 \times 10^4} e^{(t-t_0)/2 \times 10^6}$$

- MASS LOSS RATE

$$\dot{M}_w = f(L, R, M)$$

$$\dot{M}_{ENV} = \dot{M}_w + \dot{M}_c$$

- INTEGRATE $\int \dot{M}_{ENV} dt$ UNTIL $M_{ENV} \approx 10^{-3} M_{\odot}$

L, M, t AT TIP OF AGB

CORE

ENVELOPE

THE FORMATION OF PN

● AT TIP OF AGB: $\dot{M} \approx 10^{-4} - 10^{-5} M_{\odot}/\text{YR}$

$$v_{\infty} \approx 15 \text{ km/s}$$

$$M_{\text{ENV}} \approx 10^{-3} M_{\odot}$$

● DURING CROSSING AGB \rightarrow PN

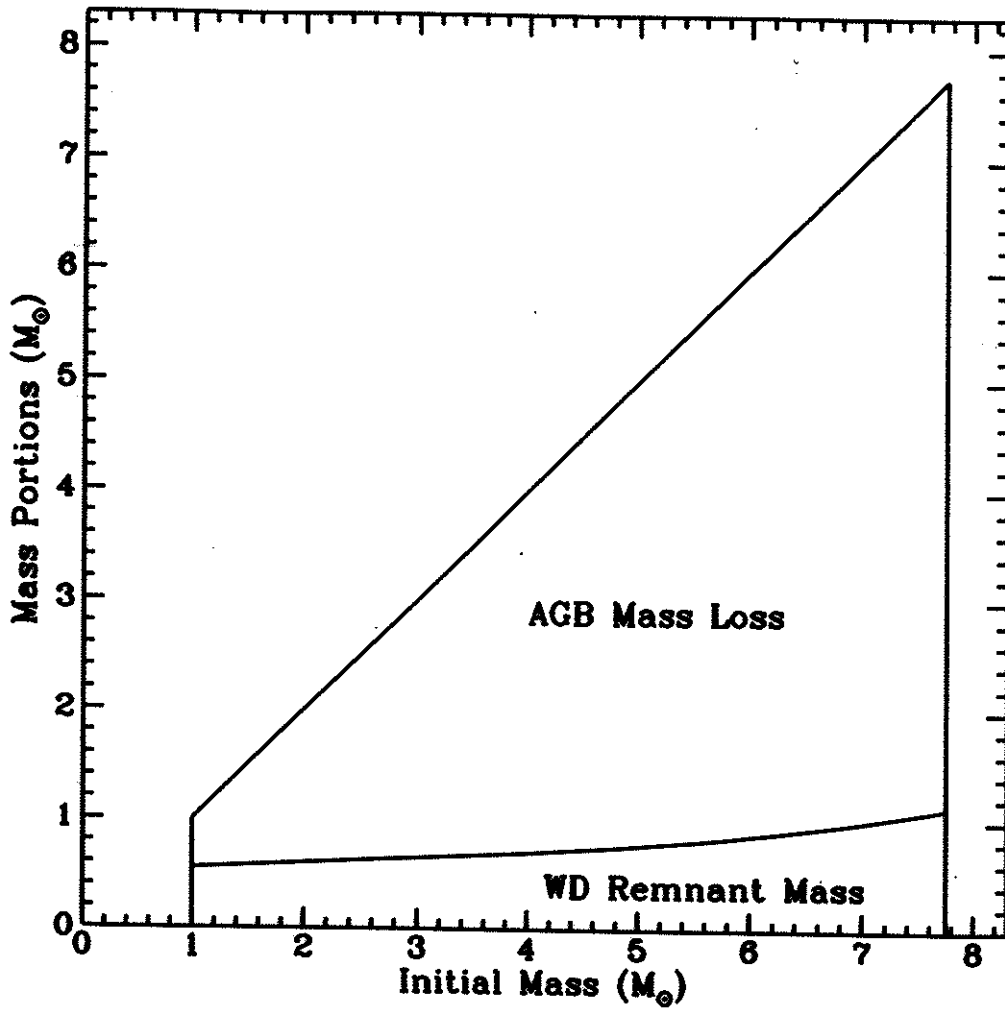
T_{EFF} DEPENDS ONLY ON M_{ENV}

$$T_{\text{EFF}} \approx 30,000 \text{ K IF } M_{\text{ENV}} \approx 10^{-4} M_{\odot}$$

$$\dot{M}_{\text{ENV}} \approx \dot{M}_{\text{L}} \approx 1.0 \times 10^{-11} L$$

$$\Delta t (\text{AGB} \rightarrow \text{PN}) \approx \frac{10^{-3} M_{\odot}}{\dot{M}_{\text{ENV}}} \approx \frac{10^8}{L} \text{ YRS}$$

MASS LOSS DURING AGB PHASE



AFTER THE AGB PHASE THE REMNANT
HAS A MASS OF $\sim 0.6 M_{\odot} \rightarrow$ WD

NS OR BH

