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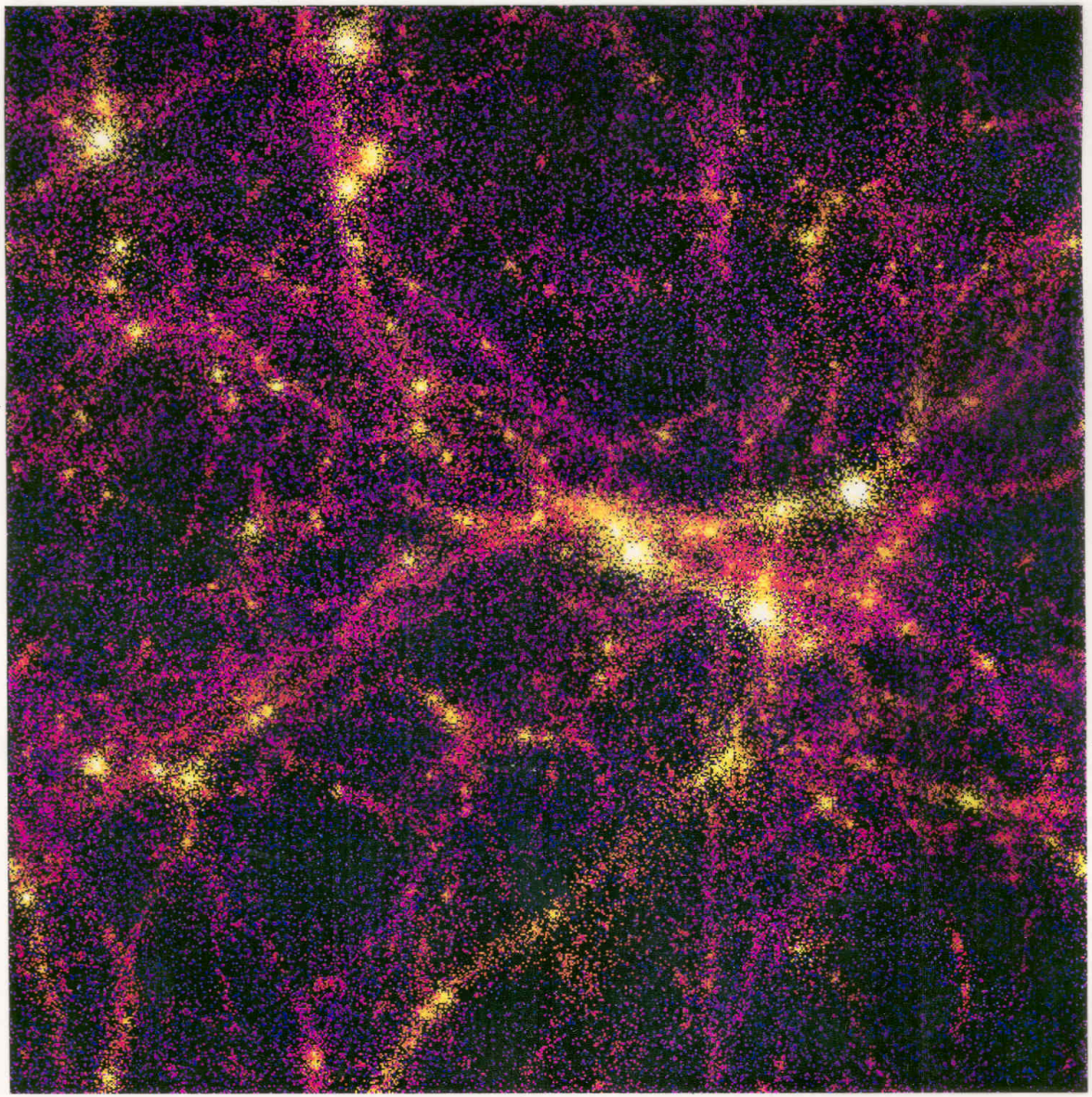
Matter in the Universe

June 19, 2002



BLUE = FEW $\times 10^3$ K

YELLOW = 10^7 K

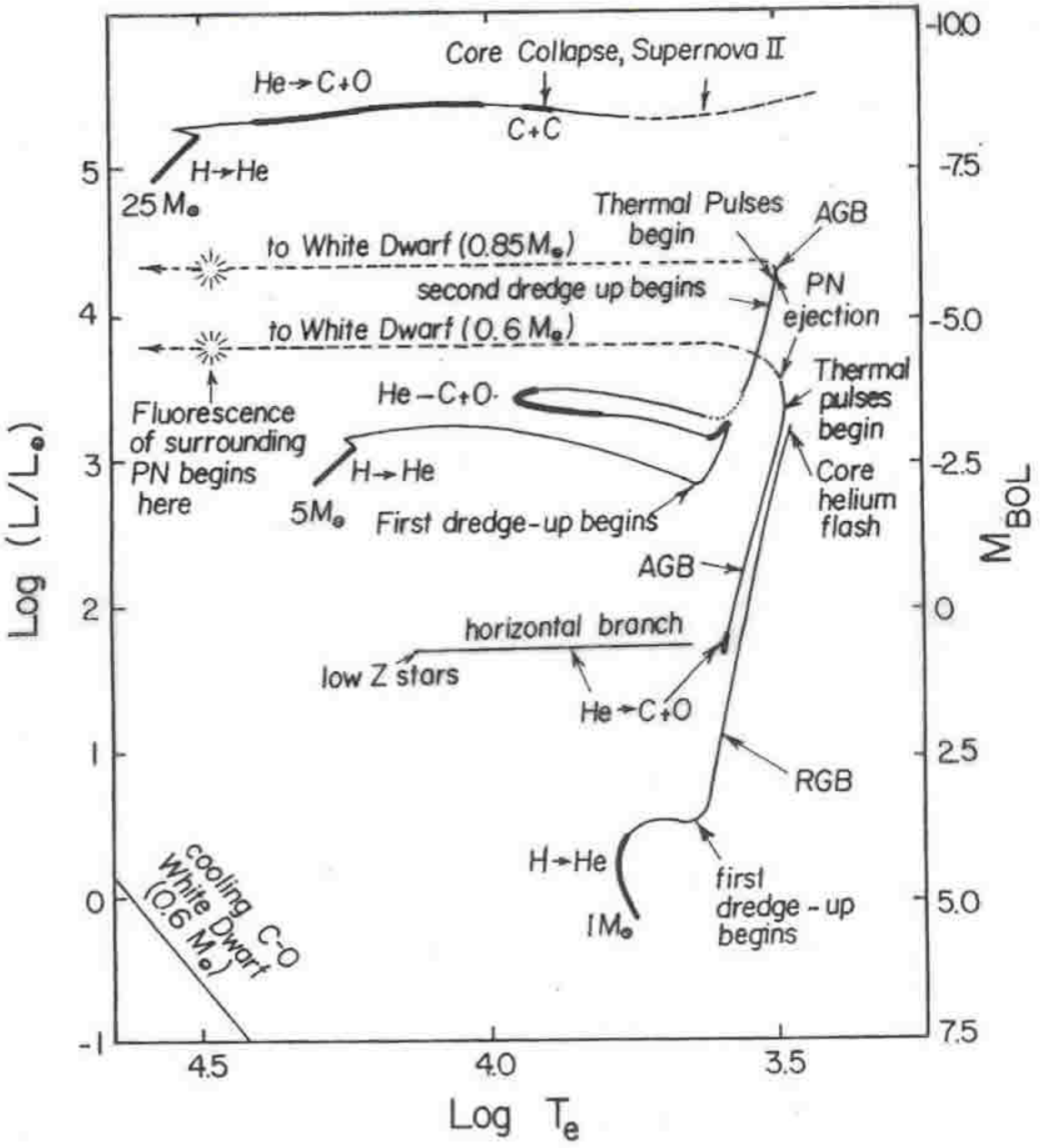
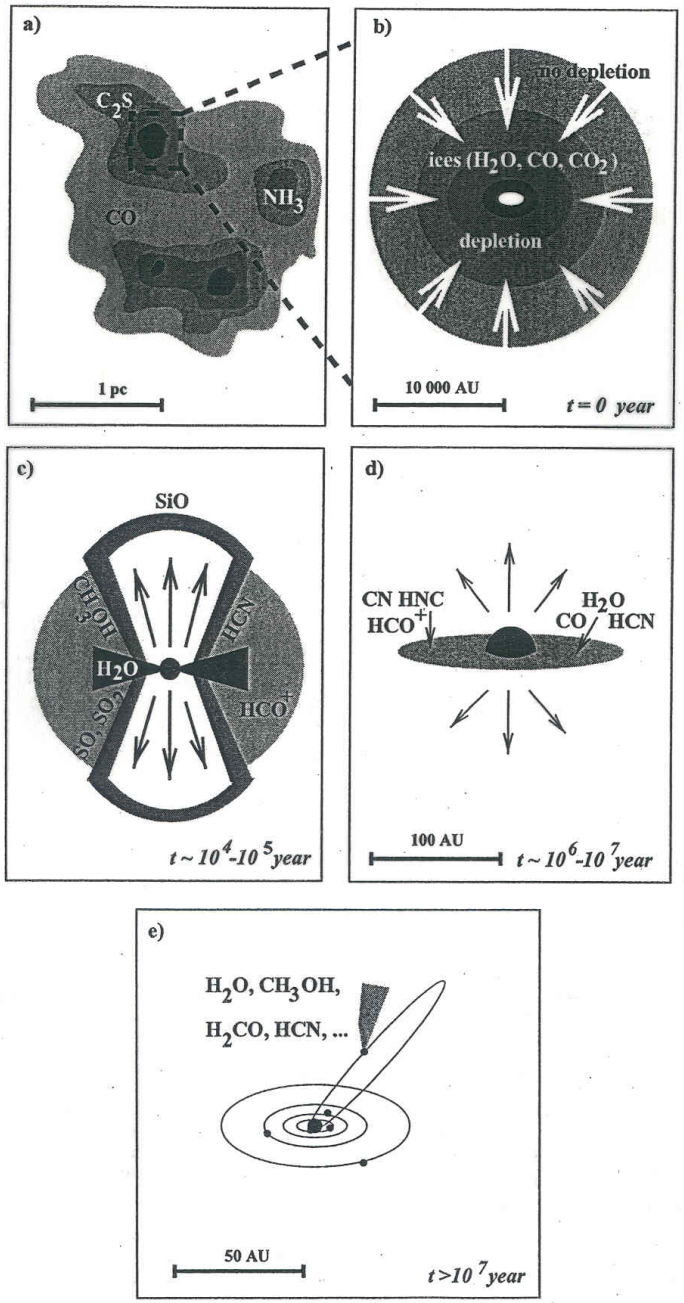

Core Collapse, Supernova II
He→C+O
C+C
H→He
25 M⊙
Thermal Pulses begin
AGB
to White Dwarf (0.85 M⊙)
second dredge up begins
PN ejection
to White Dwarf (0.6 M⊙)
Thermal pulses begin
He–C+O
Fluorescence of surrounding PN begins here
H→He
5M⊙
First dredge-up begins
Core helium flash
AGB
horizontal branch
low Z stars
He→C+O
RGB
H→He
1M⊙
first dredge-up begins
cooling C-O White Dwarf (0.6 M⊙)
Log (L/L⊙)
Log Te
M BOL
5
4
3
2
1
0
-1
4.5
4.0
3.5
-10.0
-7.5
-5.0
-2.5
0
2.5
5.0
7.5

TABLE 1. Gas Phase Interstellar/Circumstellar Molecules - High Resolution (11/96)

H_2	CH	CH^+	NH	OH
C_2	CN	CO	CSi	CP
CS	NO	NS	SO	HCl
NaCl	KCl	AlCl	AlF	PN
SiN	SiO	SiS	CO^+	SO^+
H_3^+	CH_2	NH_2	H_2O	H_2S
C_2H	HCN	HNC	HCO	HCO^+
HOC^+	HN_2^+	HNO	HCS^+	C_3
C_2O	C_2S	SiC_2	SO_2	OCS
MgNC	MgCN	N_2O	NaCN	NH_3
H_2CO	H_2CS	HCCH	$HCNH^+$	H_2CN
C_3H (lin)	c-C_3H	HCCN	HNCO	$HOCO^+$
HNCS	C_2CN	C_3O	H_3O^+	C_3S
CH_4	SiH_4	CH_2NH	H_2C_3(lin)	c-C_3H_2
CH_2CN	NH_2CN	CH_2CO	HCOOH	C_4H
HC_2CN	HCCNC	HNCCC	C_4Si	H_2COH^+
C_5	CH_3OH	CH_3SH	C_2H_4	CH_3CN
CH_3NC	HC_2CHO	NH_2CHO	HC_3NH^+	H_2C_4 (lin)
C_5H	CH_3NH_2	CH_3CCH	CH_3CHO	C_2H_3CN
C_6H	HC_4CN	C_8H	$HCOOCH_3$	CH_3COOH
CH_3C_2CN	CH_3OCH_3	C_2H_5OH	C_2H_5CN	CH_3C_4H
HC_6CN	CH_3COCH_3	CH_3C_4CN?	NH_2CH_2COOH?	HC_8CN


a)
C_2S
NH_3
CO
1 pc
b)
no depletion
ices (H_2O, CO, CO_2)
depletion
10 000 AU
t = 0 year
c)
SiO
CH_3OH
HCN
H_2O
SO, SO_2
HCO^+
$t \sim 10^4$-10^5 year
d)
CN HNC
HCO^+
H_2O
CO / HCN
100 AU
$t \sim 10^6$-10^7 year
e)
H_2O, CH_3OH,
H_2CO, HCN, ...
50 AU
$t > 10^7$ year

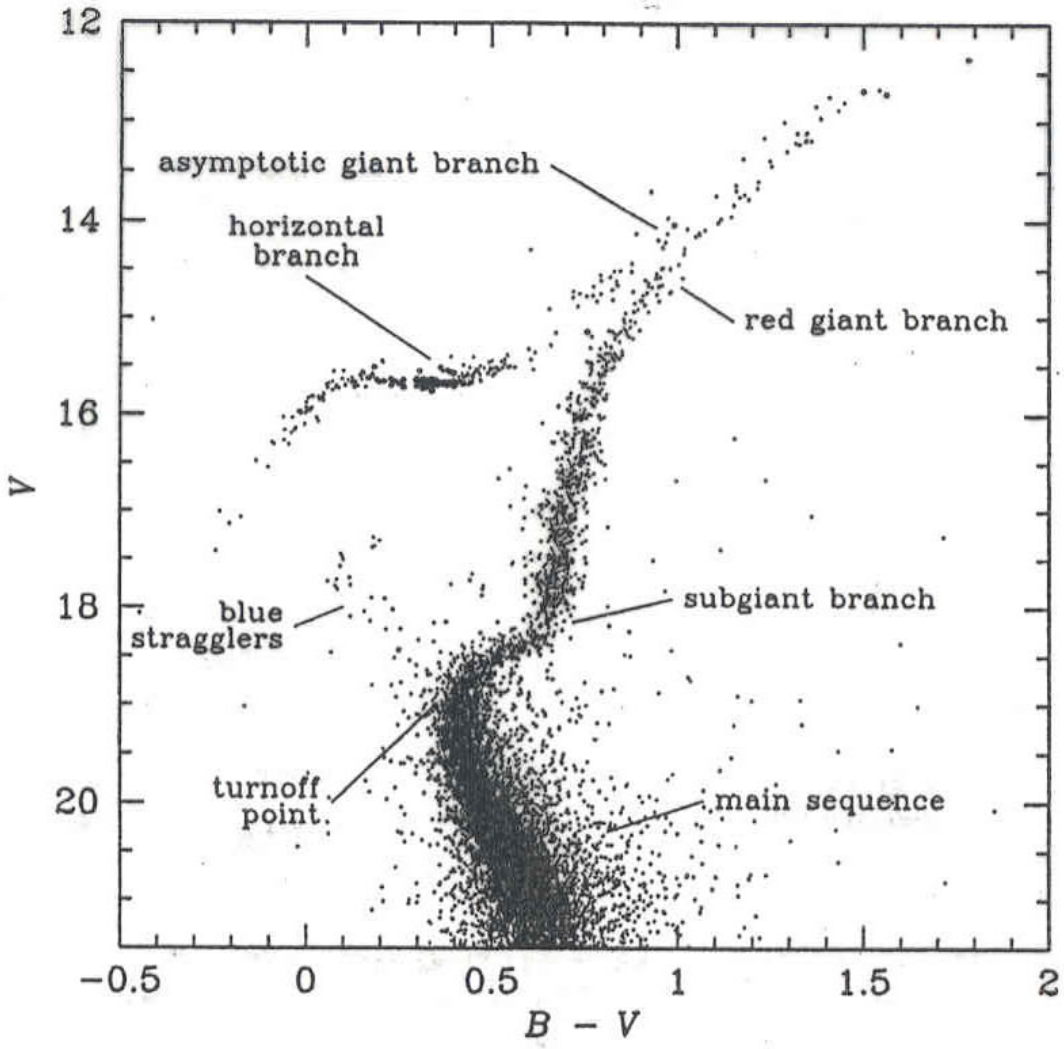
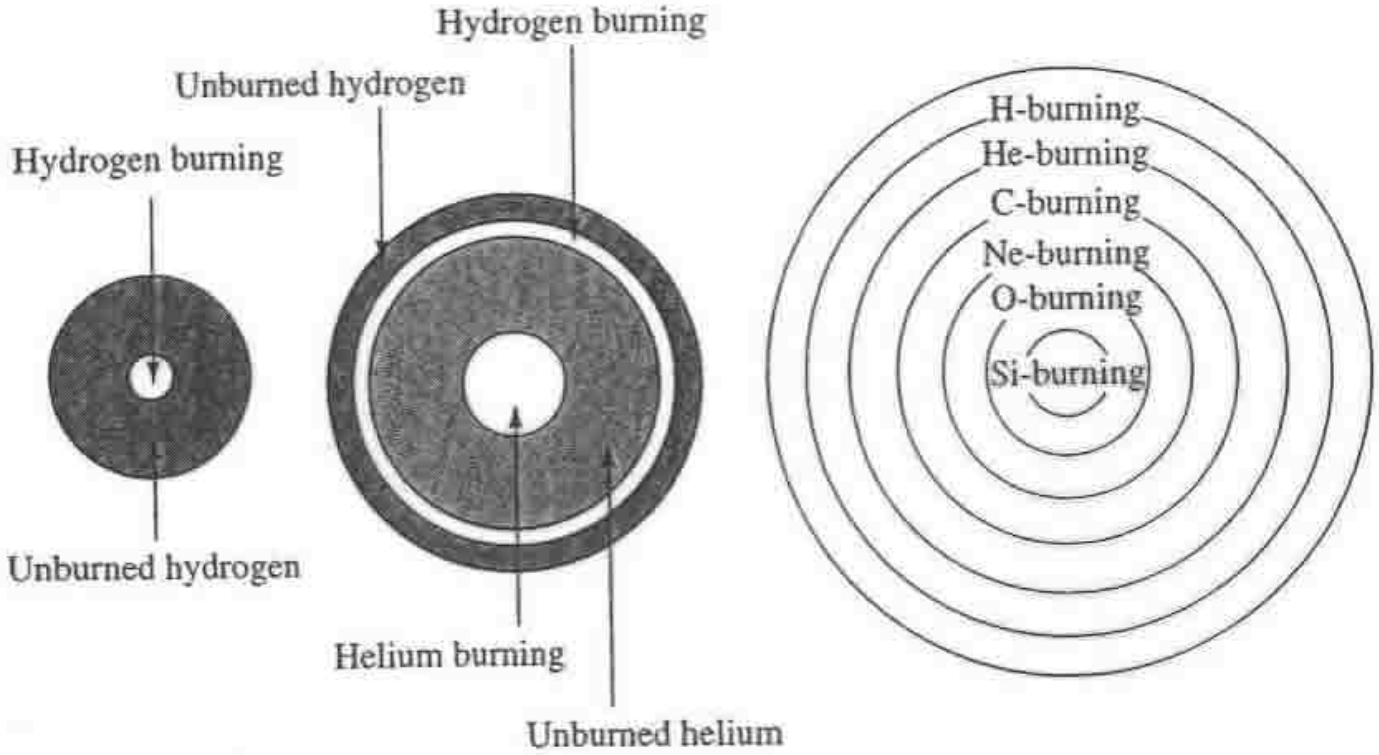


Figure 6.2 The color-magnitude diagram for the globular cluster M3. Known variable stars are shown as open circles, and the principal sequences are annotated. [From data published in Buonanno *et al.* (1994)]

$$
\begin{aligned}
p + n &\longrightarrow d + \gamma \\
d + d &\longrightarrow {}^3\mathrm{He} + n, \quad {}^3\mathrm{H} + p \\
{}^3\mathrm{He} + d &\longrightarrow {}^4\mathrm{He} + p \\
{}^3\mathrm{H} + d &\longrightarrow {}^4\mathrm{He} + n \\
{}^3\mathrm{H} + \alpha &\longrightarrow {}^7\mathrm{Li} + \gamma \\
{}^3\mathrm{He} + \alpha &\longrightarrow {}^7\mathrm{Be} + \gamma \\
{}^7\mathrm{Be} + n &\longrightarrow {}^7\mathrm{Li} + p \\
{}^7\mathrm{Li} + p &\longrightarrow 2\,{}^4\mathrm{He}
\end{aligned}
$$



Name of process	Fuel	Products	Temperature
Hydrogen-burning	H	He	60×10^6 K
Helium-burning	He	C, O	200×10^6 K
Carbon-burning	C	O, Ne, Na, Mg	800×10^6 K
Neon-burning	Ne	O, Mg	1500×10^6 K
Oxygen-burning	O	Mg to S	2000×10^6 K
Silicon-burning	Mg to S	Elements near Fe	3000×10^6 K

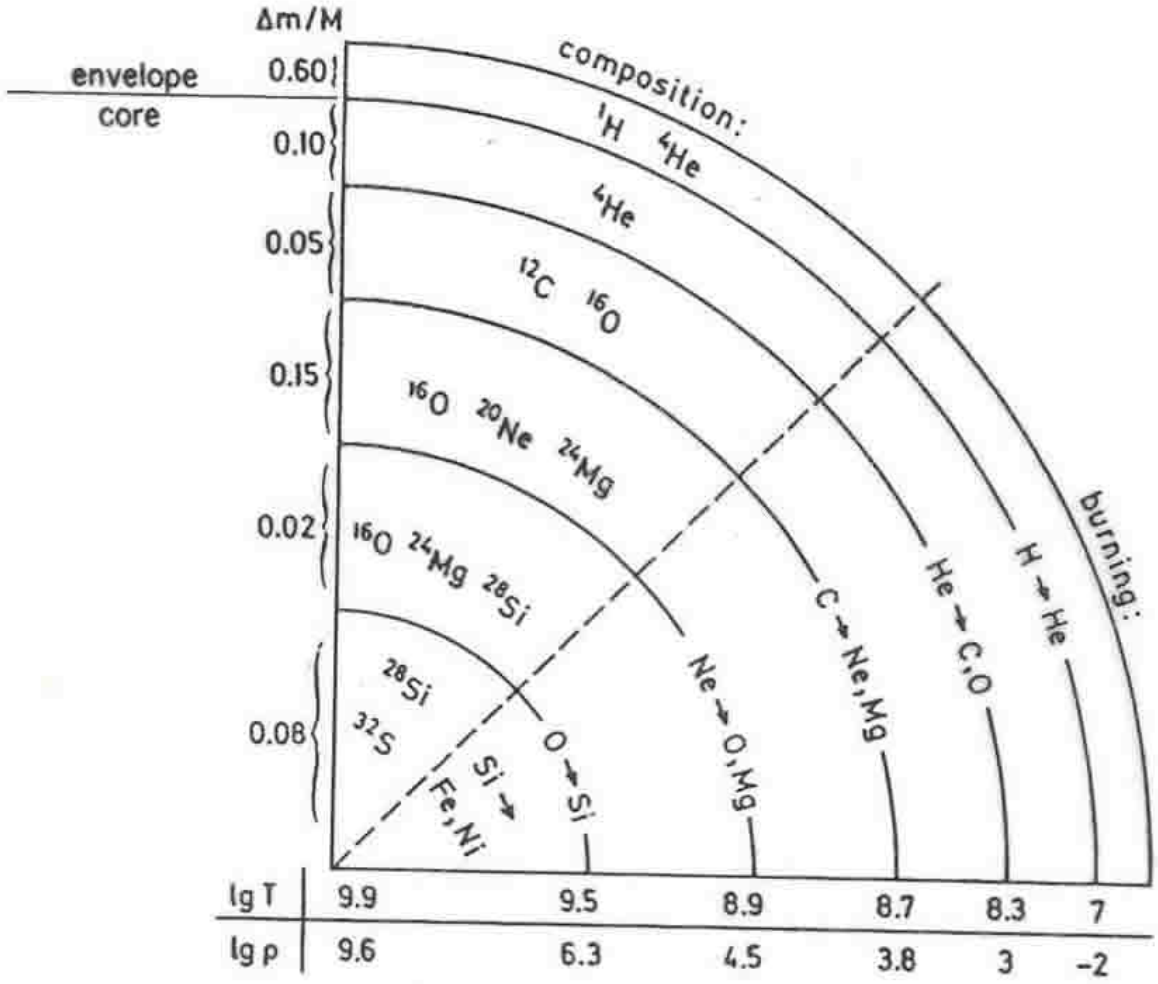


Fig. 5.8. Schematic illustration (not to scale) of the 'onion-skin' structure' in the interior of a highly evolved massive star ($25M_{\odot}$). Numbers along the vertical axis show some typical values of the mass fraction, while those along the horizontal axis indicate temperatures and densities (gm cm^{-3}). Adapted from R. Kippenhahn & A. Weigert, *Stellar Structure and Evolution*, Springer-Verlag 1990.

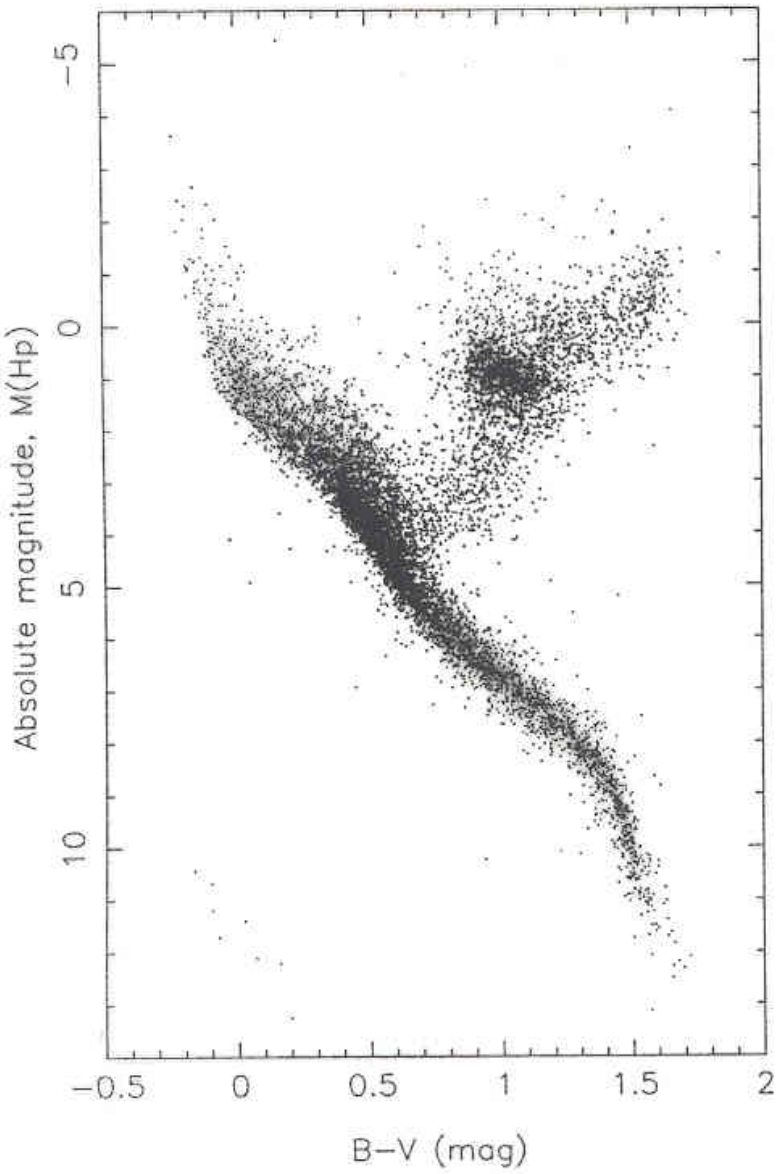


Figure 3.5 The CM-diagram for 10 793 stars with good Hipparcos parallaxes. The great majority of stars fall along the MS that runs diagonally from bottom right to top left. The subgiant, red giant, and white-dwarf sequences are also apparent, as is the red clump. The MS and WD stars were selected to have parallaxes with errors smaller than 10%, while the giants were chosen to have parallaxes in error by $< 20\%$. [After Perryman *et al.* (1995) courtesy of M. Perryman]

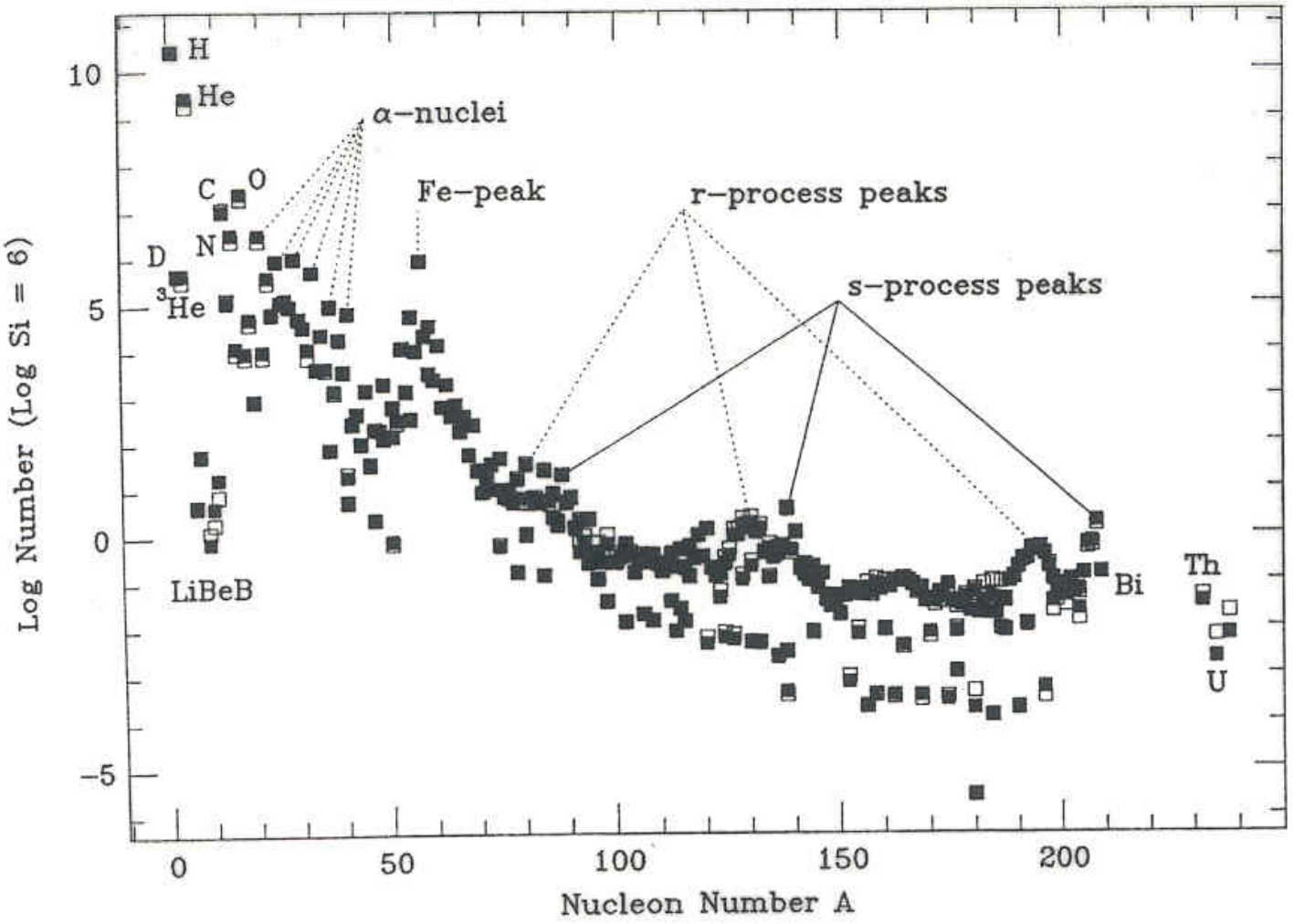


Fig. 2.1. Abundance Features