Astrophysics I: Stars and Stellar Evolution

AST 4001

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Stars and Stellar Evolution, Fall 2008

Overview

SN 1987A

Supernova Energetics

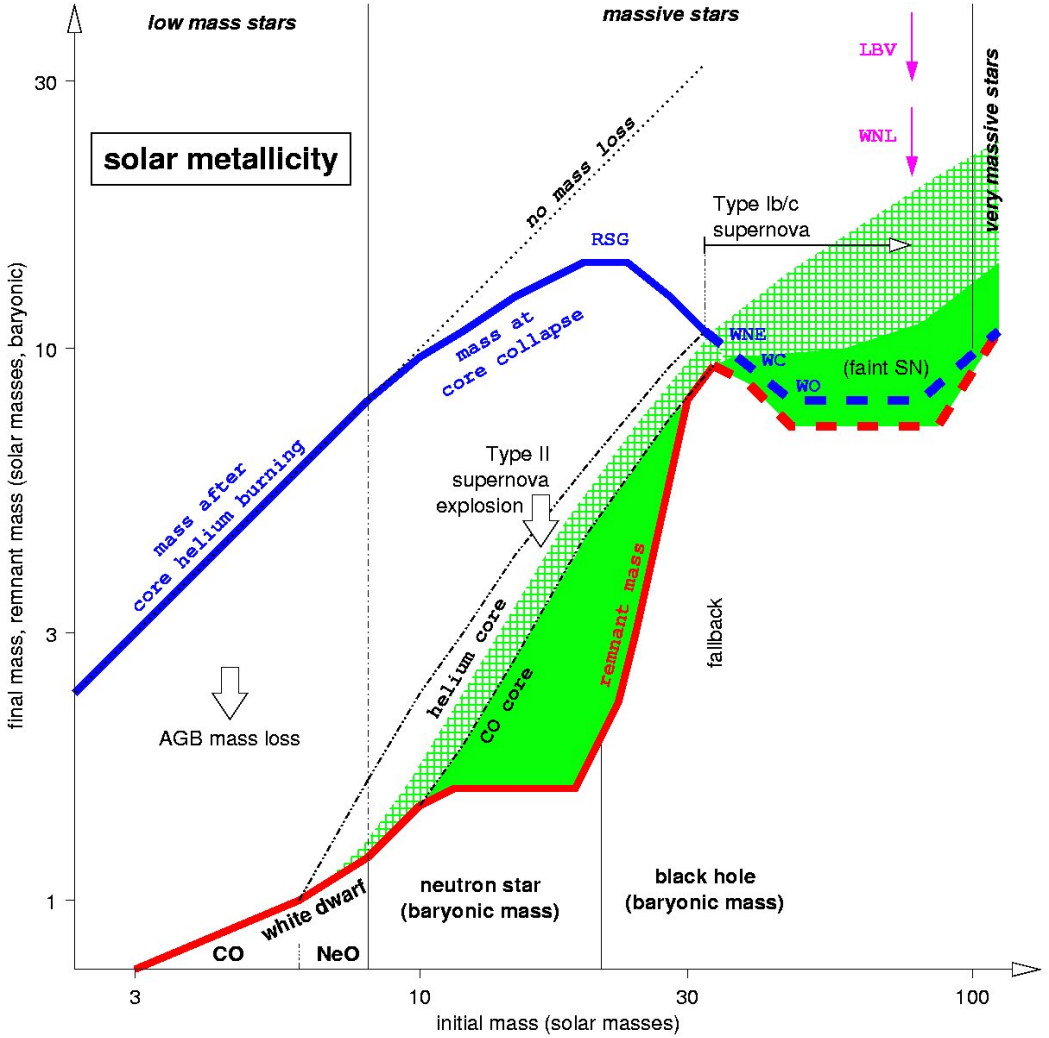
- Core collapse Supernovae (neutron star - Type Ib/c, II)
  - $\sim 3 \times 10^{53}$ erg in neutrinos
  - $\sim 10^{51}$ erg in mechanical (kinetic) energy
  - $\sim 10^{49}$ erg in (visible) photons
  - $\sim 0.1\,M_\odot$ ^{56}Ni
- Type Ia supernovae (thermonuclear)
  - $\sim 10^{51}$ erg in mechanical (kinetic) energy
  - $\sim (2-3) \times 10^{49}$ erg in (visible) photons
  - $\sim 0.5\,M_\odot$ ^{56}Ni

origin of ^{56}Fe in the sun:

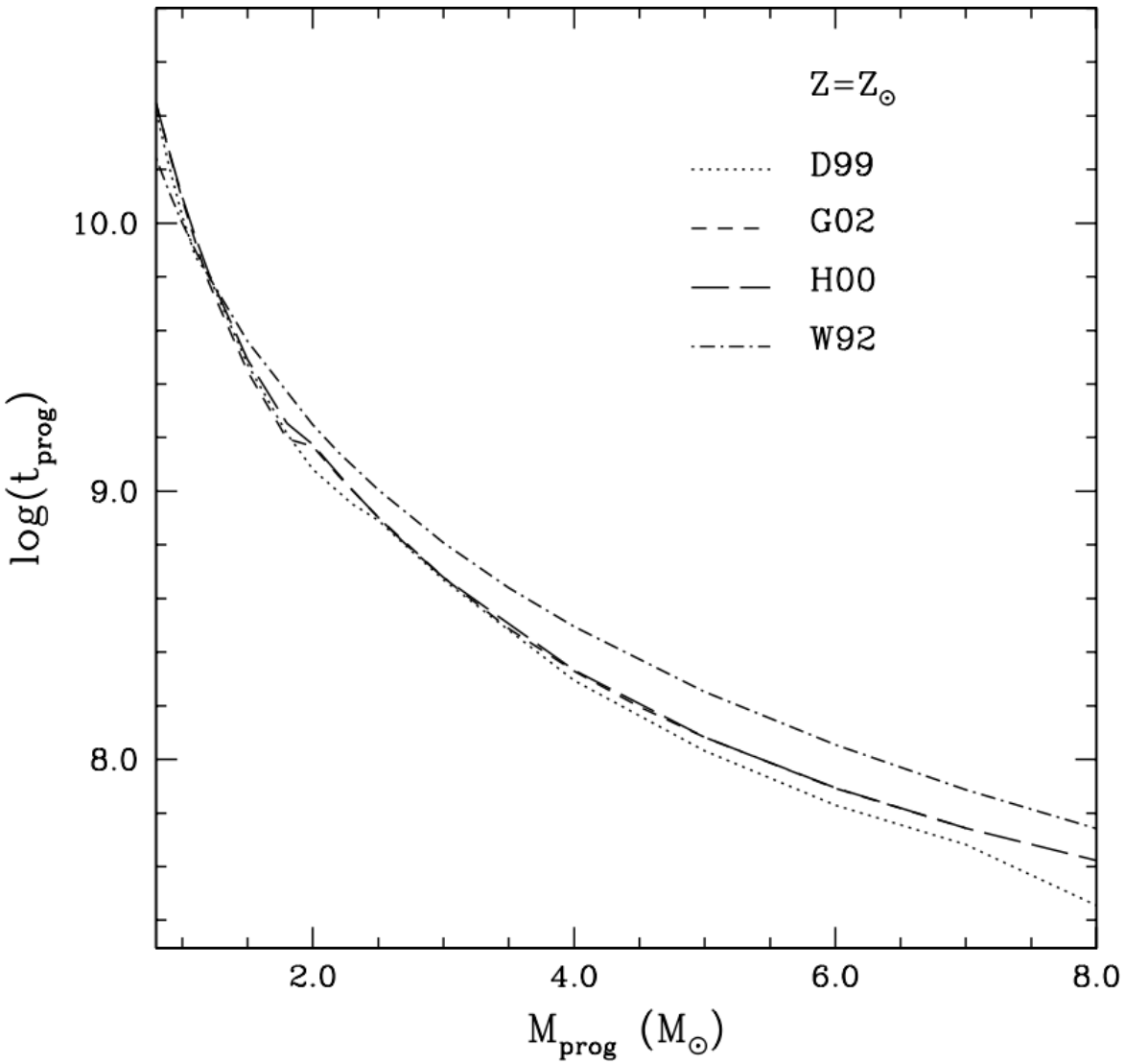
- $\sim \frac{1}{3}$ from core collapse supernovae
- $\sim \frac{2}{3}$ from Type Ia supernovae

Overview

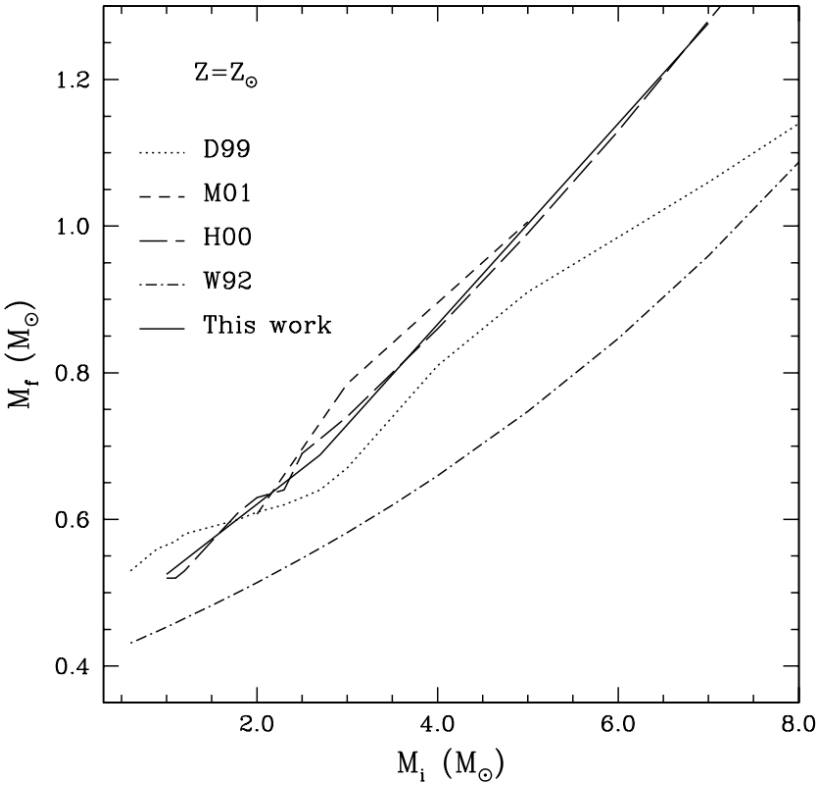
Stellar Mass Ranges - Solar Metallicity

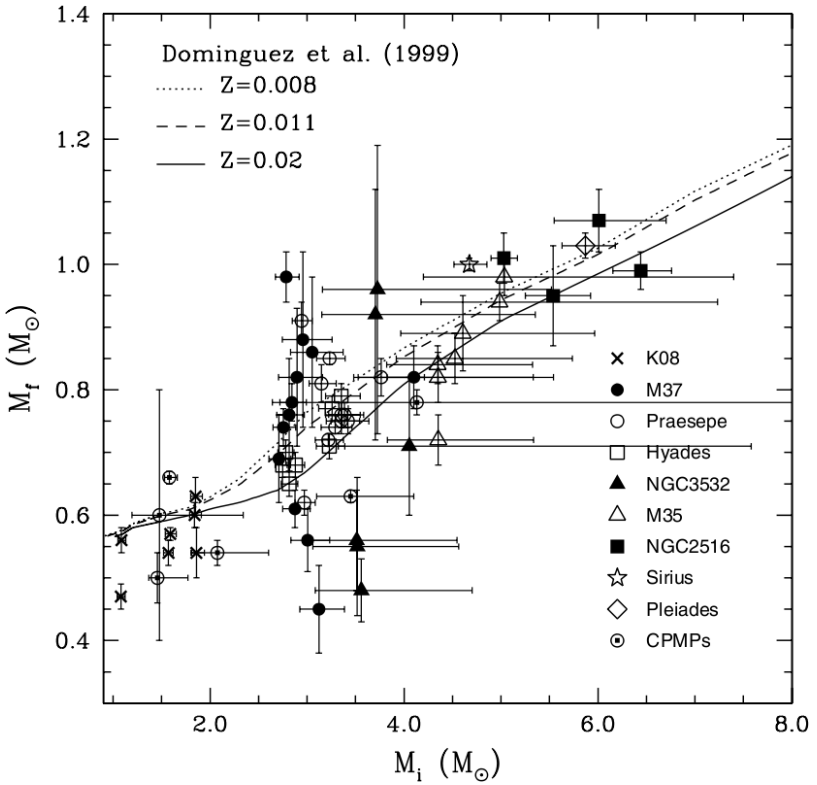


Lifetimes of Low-Mass Stars

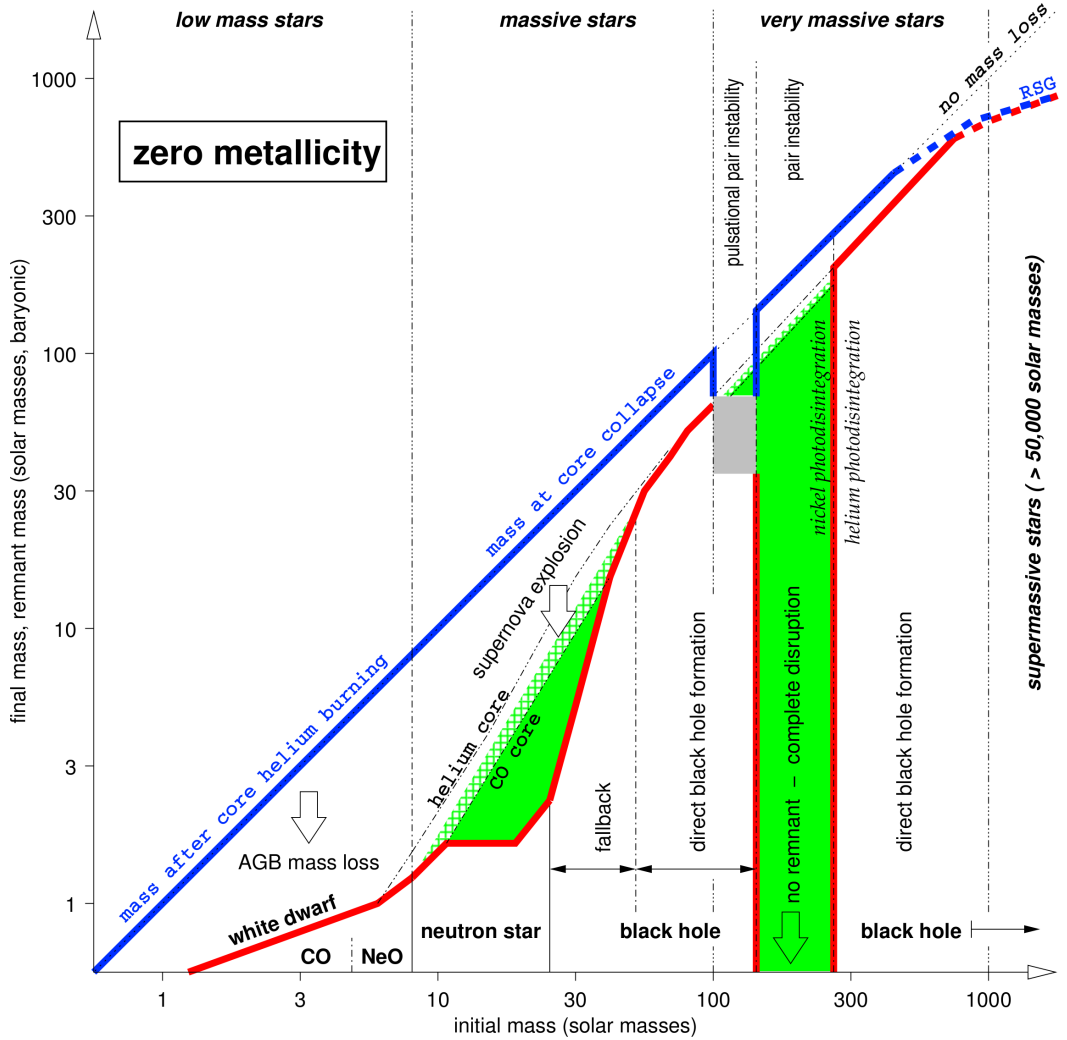


White Dwarf Initial-Final Mass Function

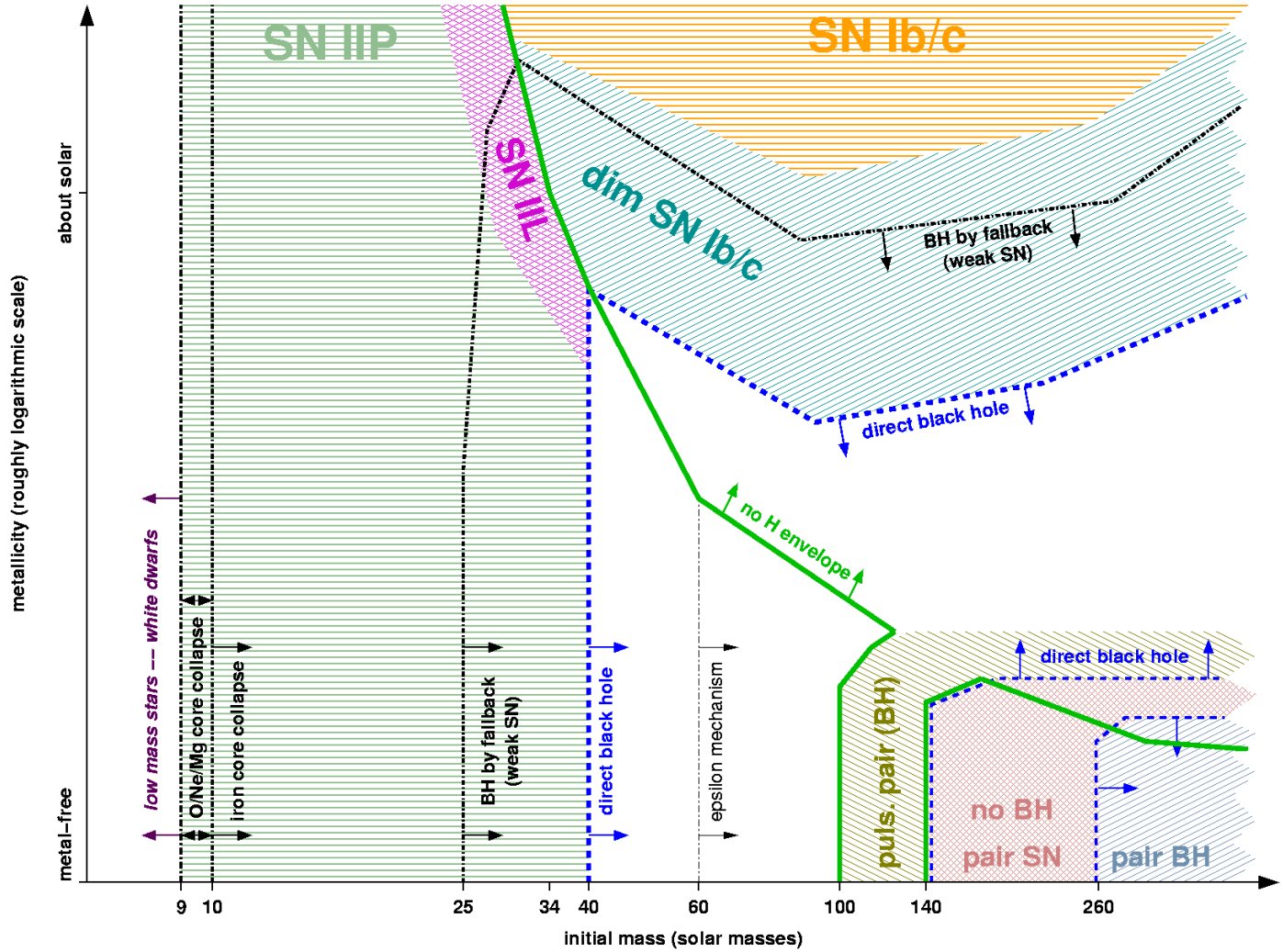




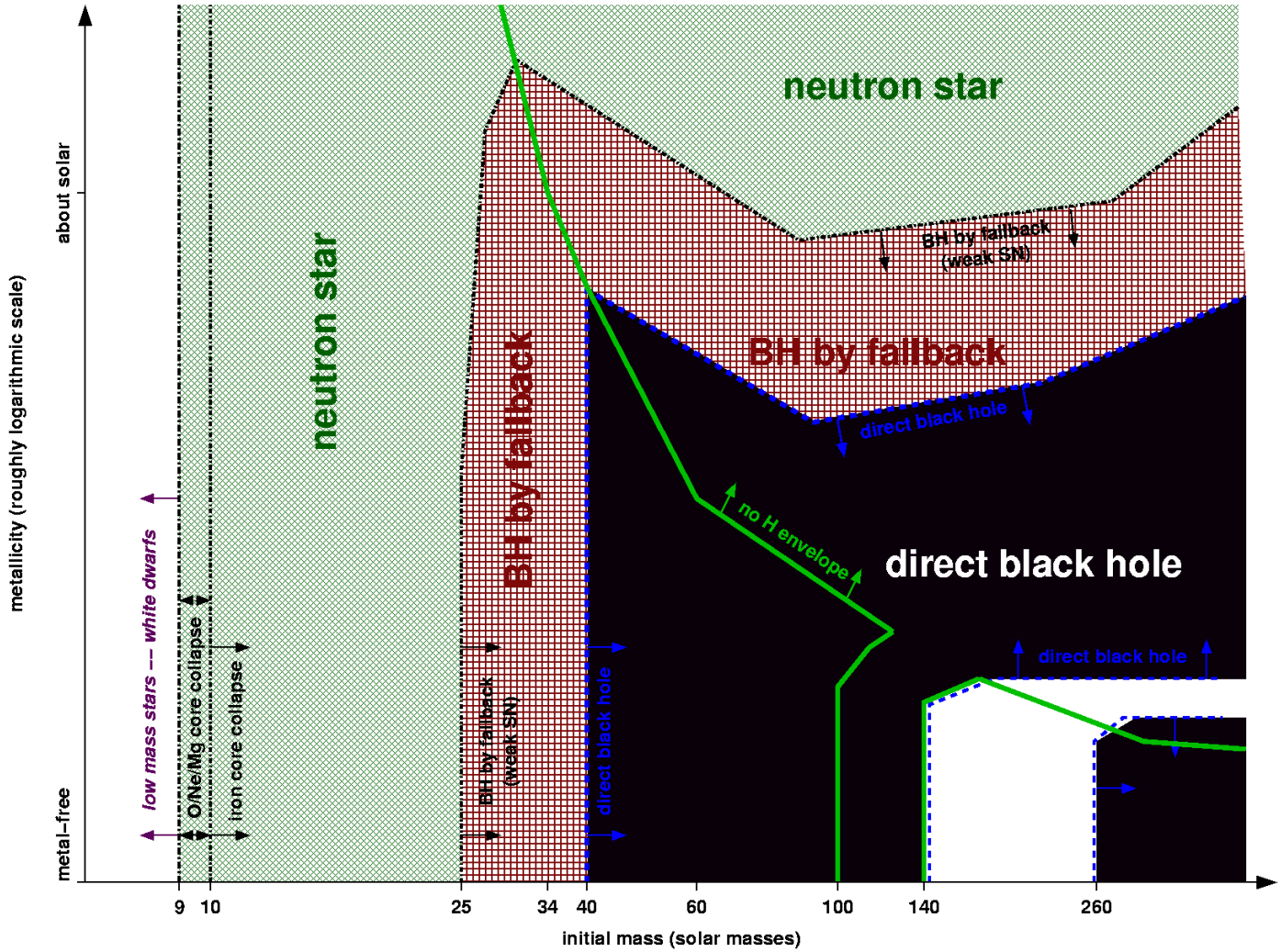
Stellar Mass Ranges - Population III Stars



Supernovae - Mass and Metallicity

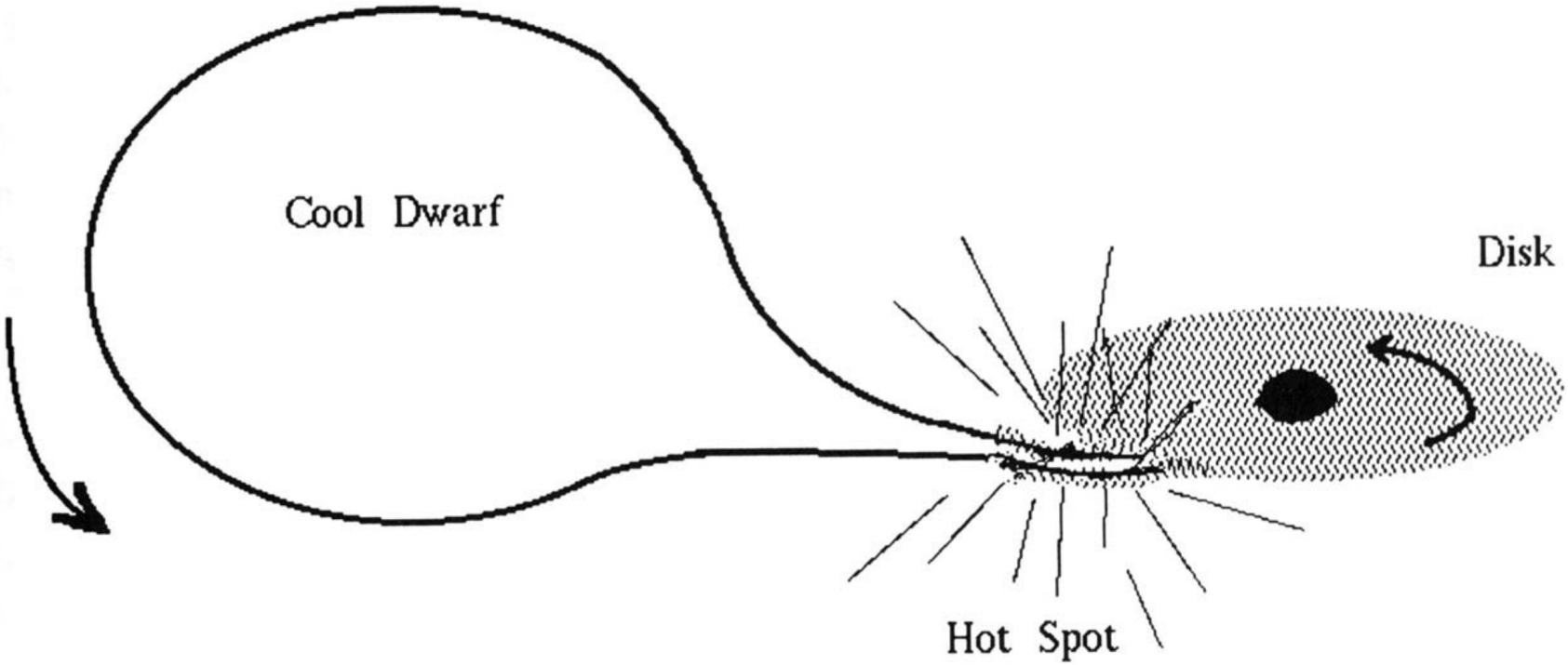


Remnants - Mass and Metallicity



Overview

Binary Stars ('Binaries')



Binary Types

Binary Stars

about half of all massive stars are in binaries

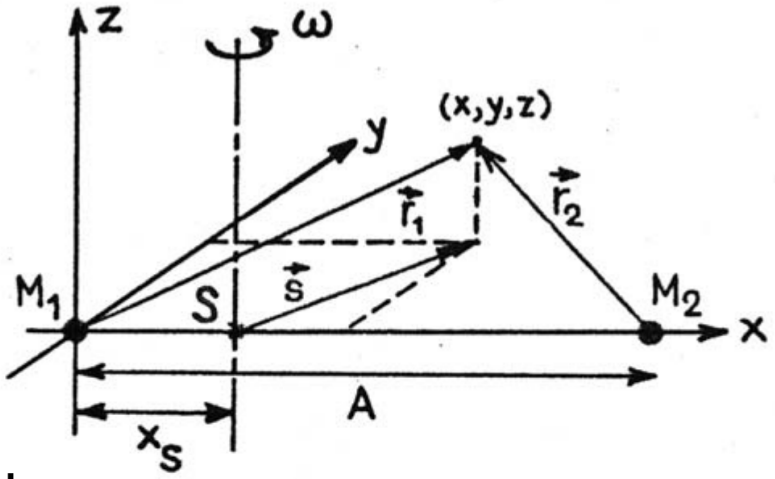
close binary: interaction in lifetime of star
wide binary: no interaction

Observationally:
- **spectroscopic binaries**
- **eclipsing binaries**
- **resolved binaries**

Roche Model

$$\phi(x,y,z) = -\frac{GM_1}{|\vec{r}_1|} - \frac{GM_2}{|\vec{r}_2|} \underbrace{- \frac{1}{2}|\vec{s}|^2\omega^2}$$

centrifugal potential



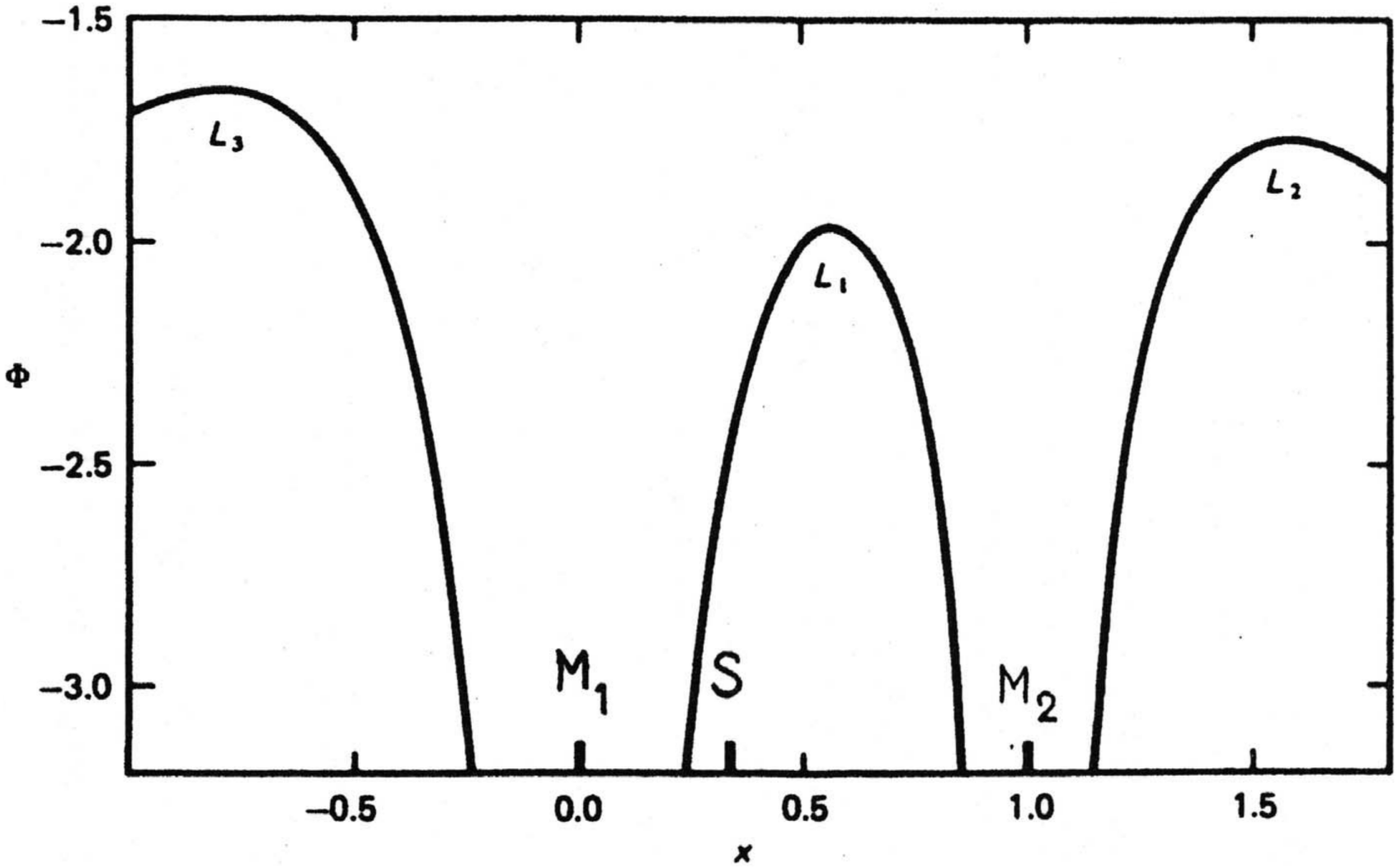
$$|\vec{r}_1| = (x^2+y^2+z^2)^{1/2} \quad , \quad |\vec{r}_2| = ((A-x)^2+y^2+z^2)^{1/2}$$

$$|\vec{s}| = ((x-x_s)^2+y^2)^{1/2} = \left[\left(x - \frac{M_2}{M_1+M_2}A\right)^2 + y^2\right]^{1/2}$$

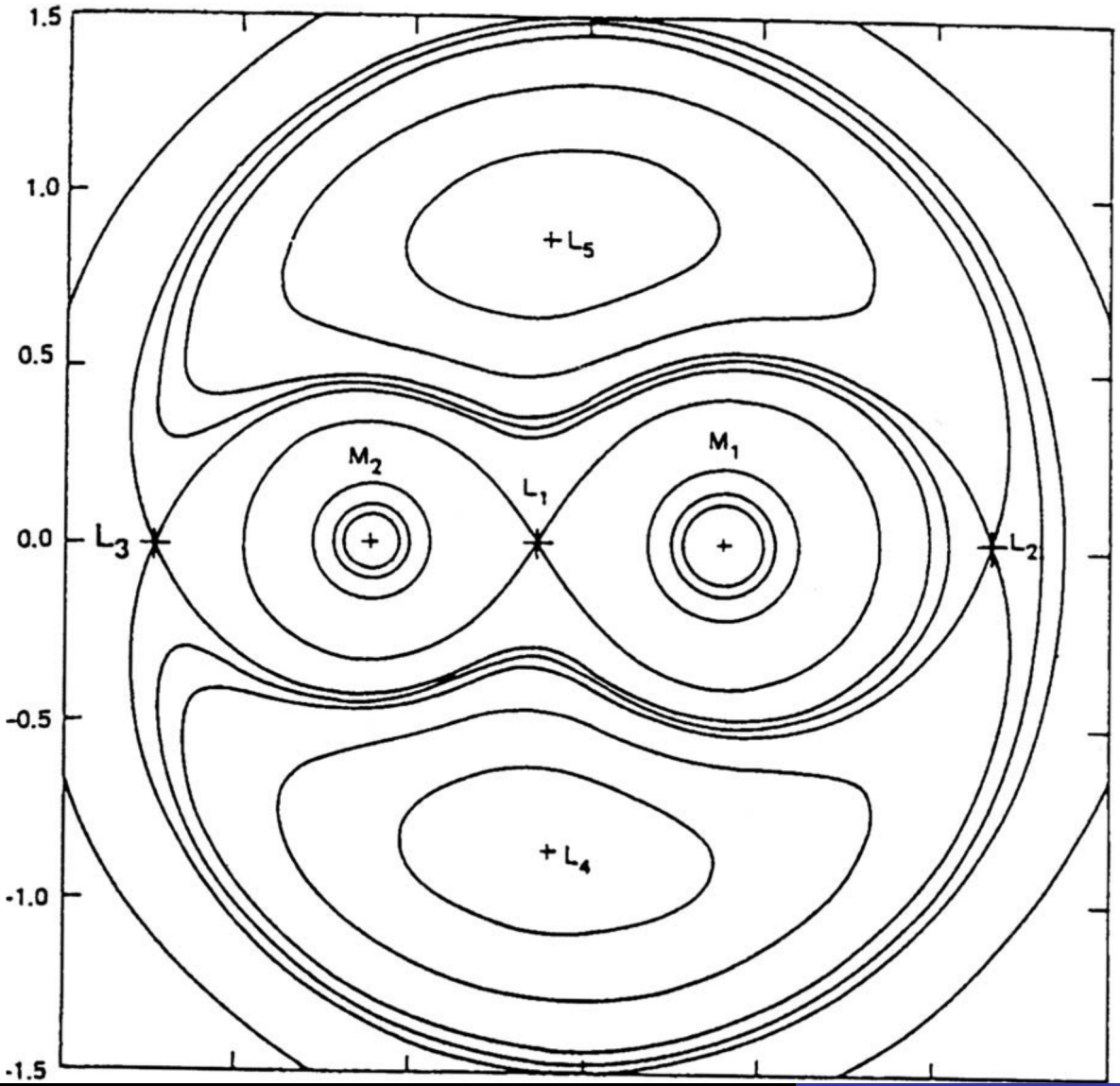
$$\omega^2 = \frac{G(M_1+M_2)}{A^3} \quad : \quad \text{3rd Kepler's Law}$$

Introduce dimensionless variables: $\xi = \frac{x}{A}$; $\eta = \frac{y}{A}$; $\zeta = \frac{z}{A}$; $q = \frac{M_1}{M_2}$

Roche Potential



Lagrange Points

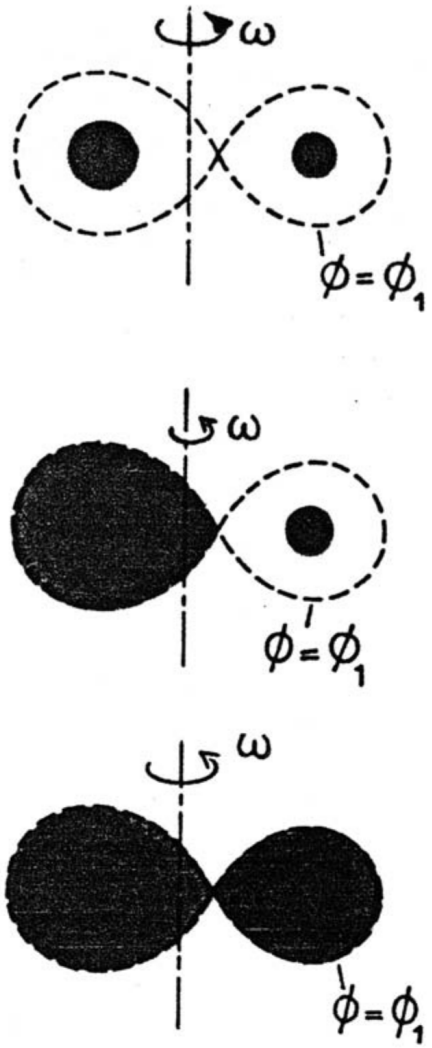


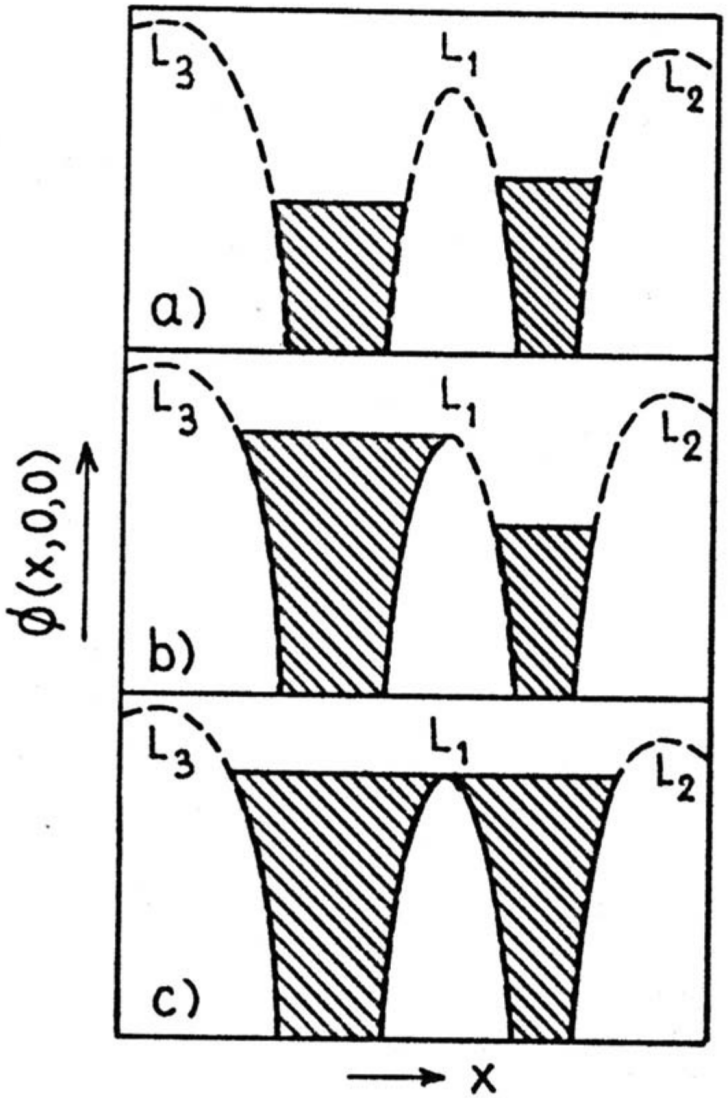
Five Lagrange points:

L1, L2, L3: unstable

L4,L5: stable

Contact Binaries





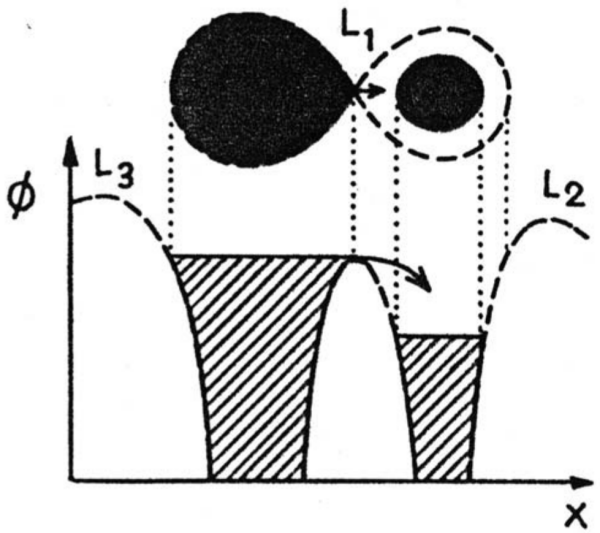
detached

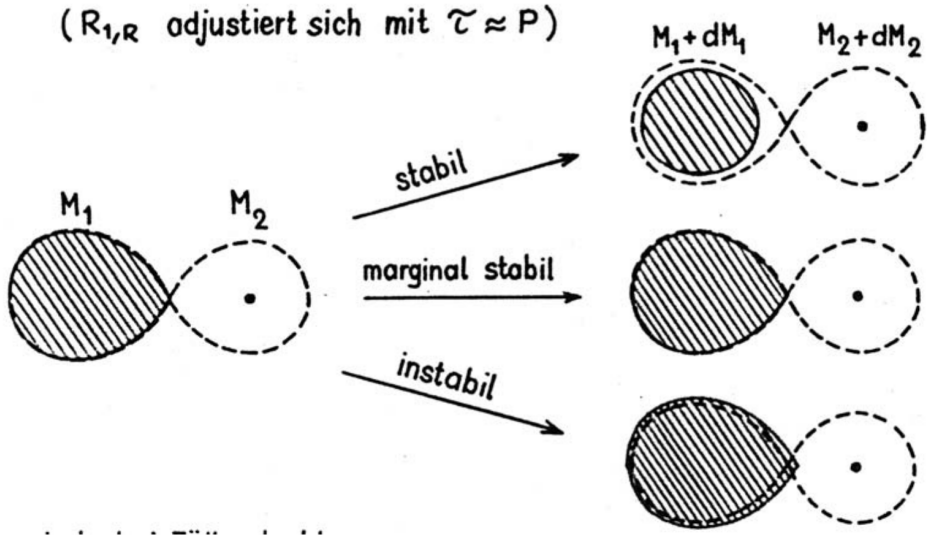
semi-detached

contact

Binary Mass Transfer

Stability of mass transfer depends on reaction of donor and receiving star





Compact Binary Types

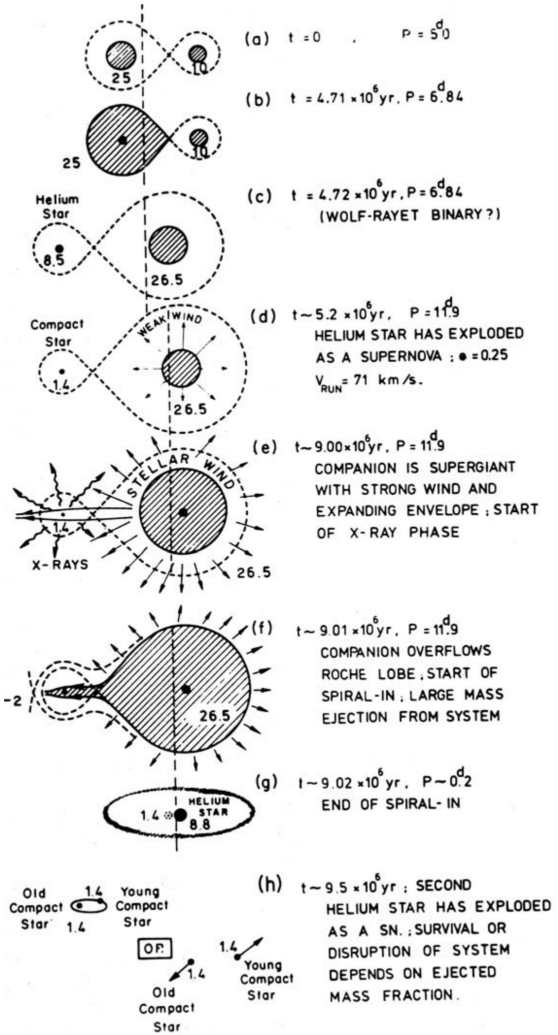
Star + compact remnant + Roche-Lobe overflow: X-ray binaries

WD + companion:
Novae, Dwarf Novae, Type Ia supernovae

NS + companion:
X-ray bursts, millisecond pulsars, ...

NS+NS: Binary pulsars

Binary Pulsar Production



Supernovae from Binaries

Binaries

initial mass	binary mass transfer			single star
$M_\odot$	Case A	Case B	Case C	
~8…13	WD	WD	SN Ib, NS	SN IIp, NS
~13…16	WD	SN Ib/c, NS	SN Ib, NS	SN IIp, NS
~16…25	SN Ic, NS	SN Ib, NS	SN Ib, NS	SN IIp, NS
~25…35	SN Ic, NS	SN Ic, NS	SN Ib, BH	SN IIL, BH
>35	SN Ic, NS/BH	SN Ic, NS/BH	SN Ib, NS/BH	SN Ic, NS/BH