Outcomes of double WD mergers

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SN Ia meeting LiJiang

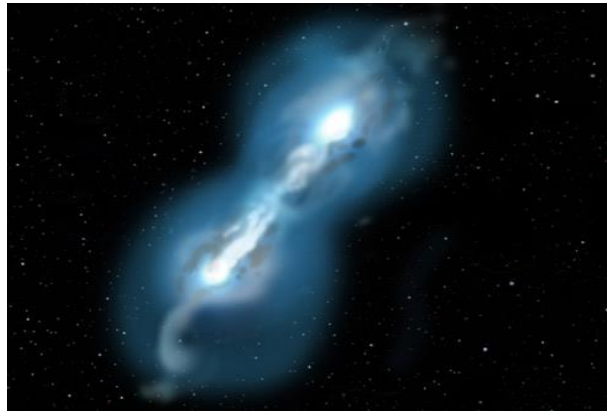
Progenitor model

➢ Single degenerate model

(e.g. Whelan & Iben 1973; Nomoto 1982; Wang et al. 2009)

➢ Double degenerate model

(e.g. Iben & Tutukov 1984; Webbink 1984)



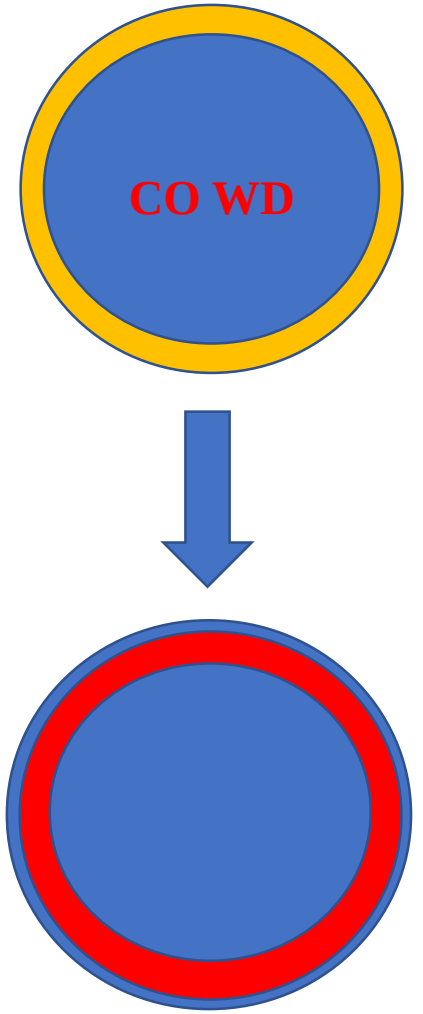
Rapid mass transfer influences the evolution

- **Rapid mass transfer process leads to the off-center carbon burning**

  (Nomoto & Iben 1985)

  (Saio & Nomoto 1985, 1998, 2004)

- **The temperature of flame is related to the ignited conditions**
- **The evolution of CO WD under this condition may be different**



Method

- **Slow merger**

(Mochkovitch & Livio 1990)

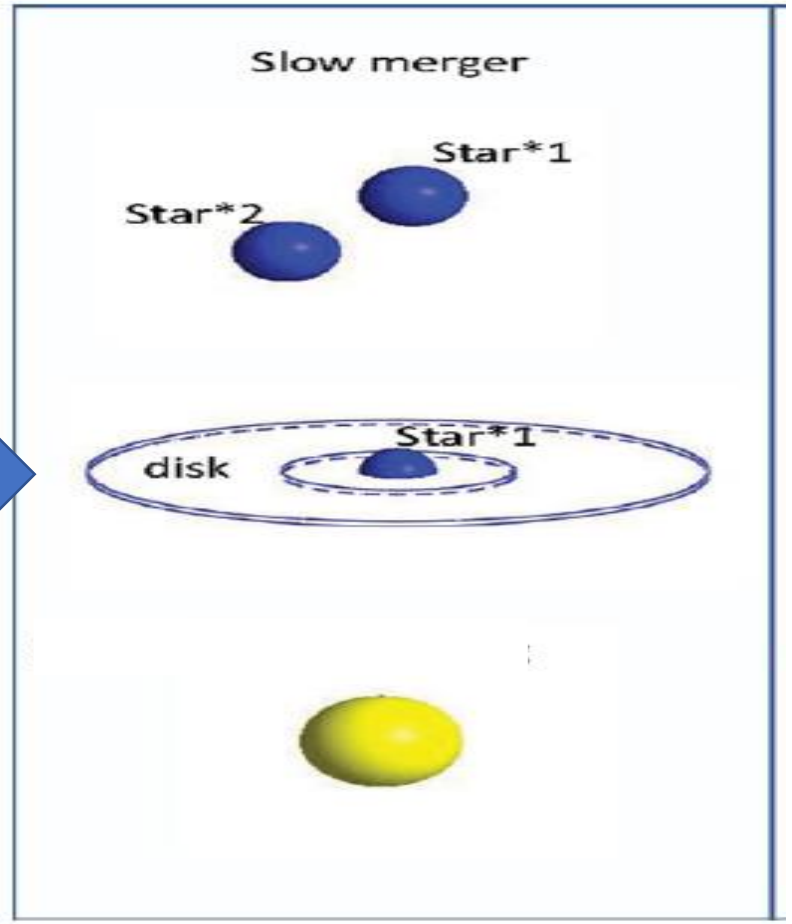
$$\frac{\dot{M}_1}{M_1} = \left(\frac{\dot{J}}{J}\right)\left(\frac{\varsigma(M_1)}{2} + \frac{5}{6} - \frac{M_1}{M_2}\right)^{-1}$$

$$\varsigma(M_1) = \mathrm{d}\ln R_1 / \mathrm{d}\ln M_1$$

$$q \equiv \frac{M_1}{M_2} < \frac{5}{6} + \frac{\varsigma(M_1)}{2}$$

q_{cr} **~ 0.64**

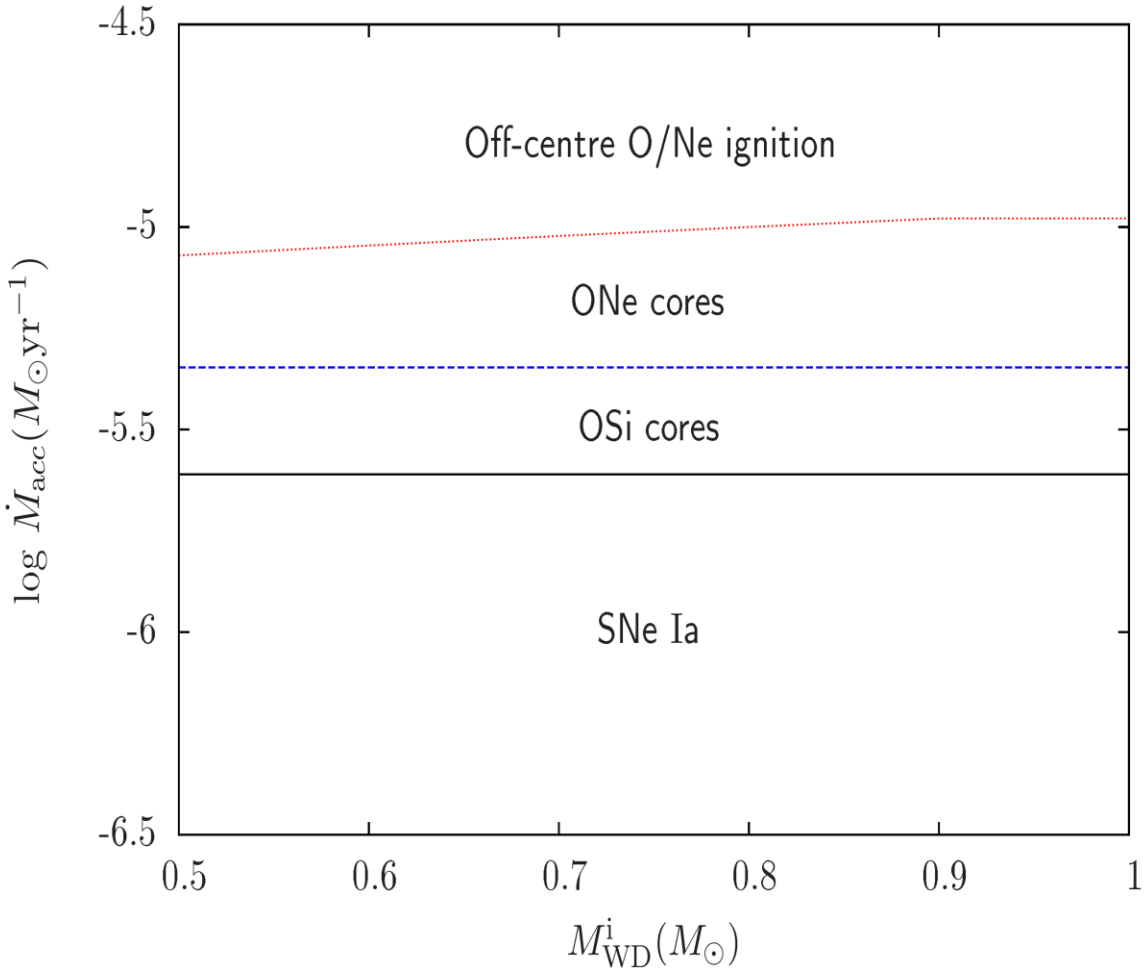
Timescale of accreting disc
10^4-10^6yr

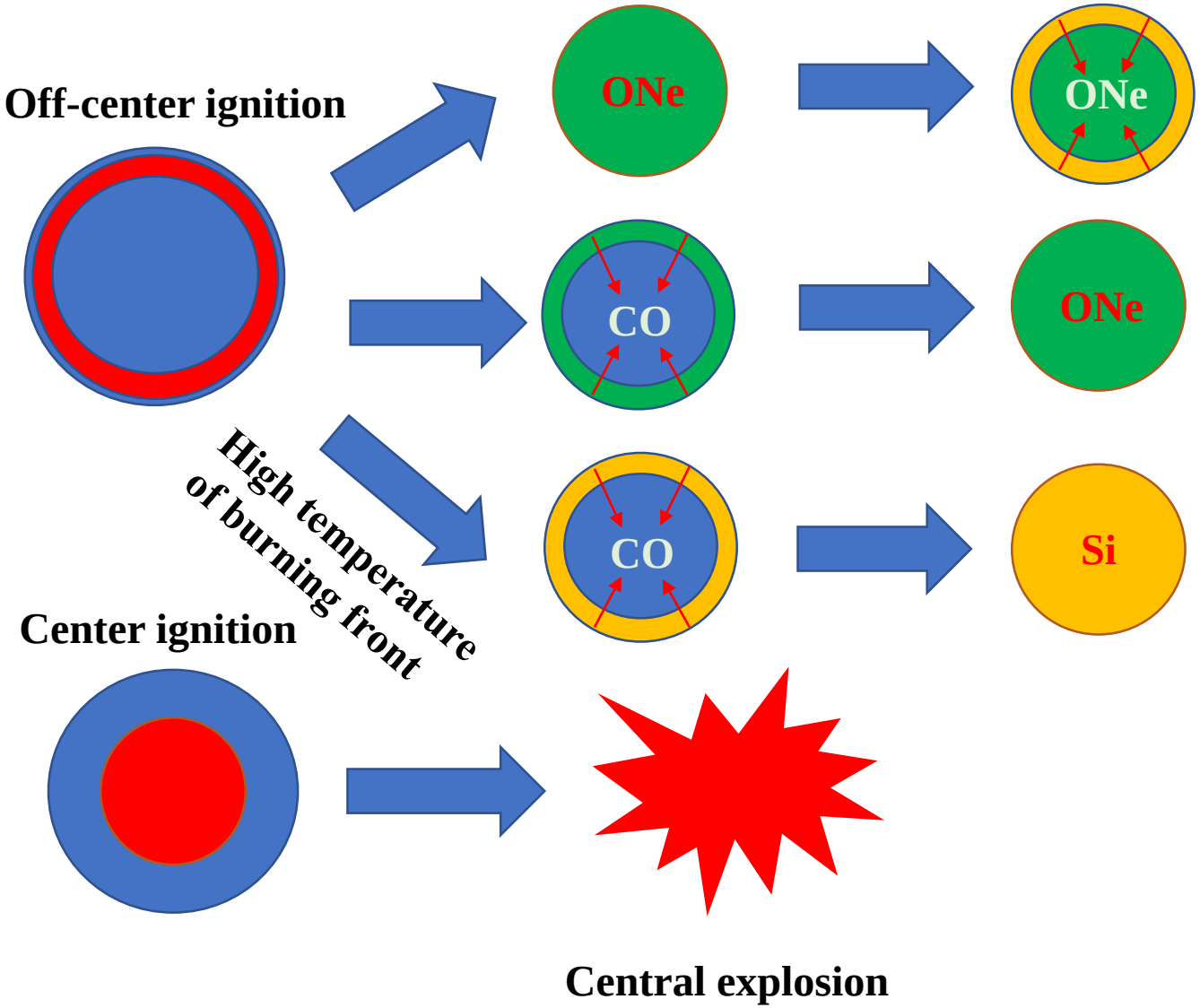


- **Accretion rate: 2d-6 – 2d-5 $M_\odot$/yr**

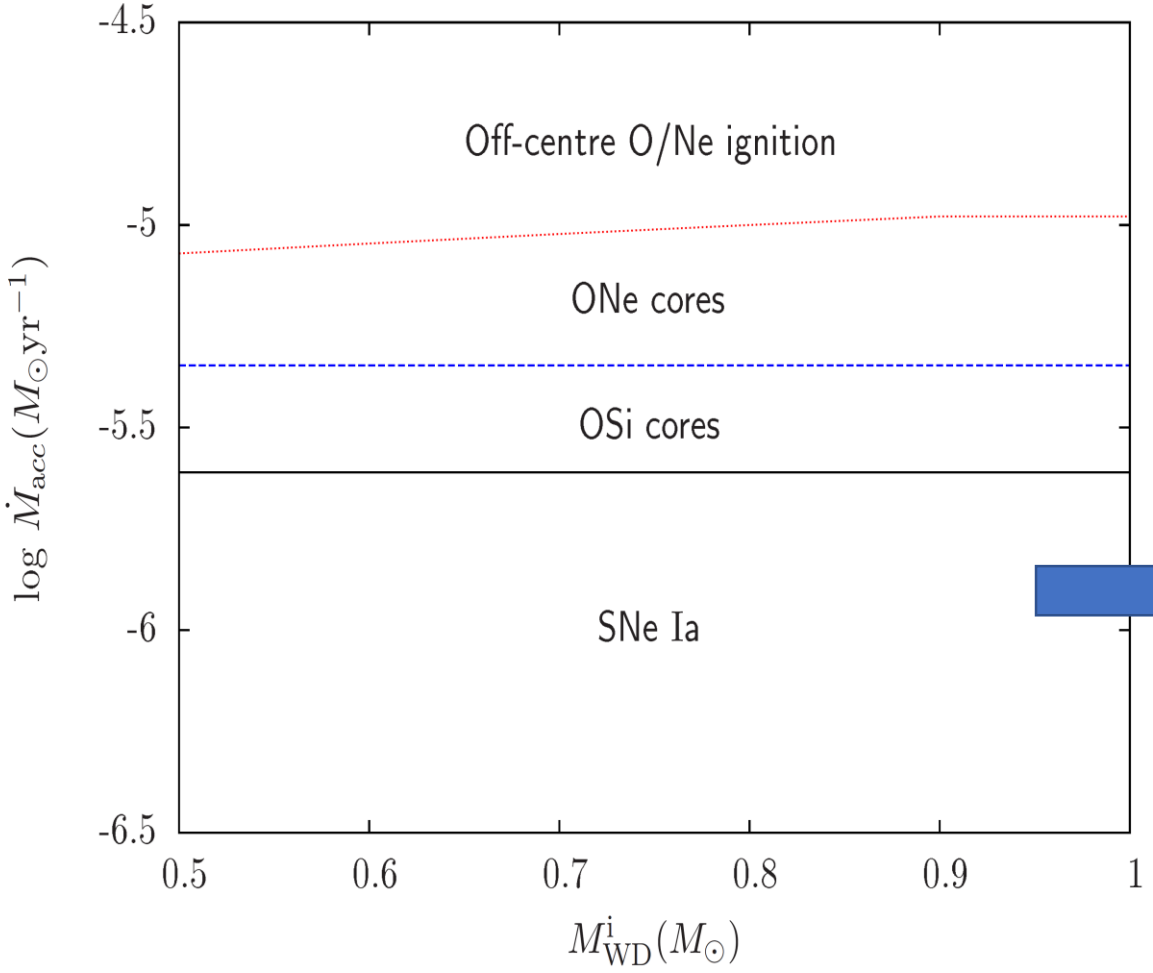
Zhang & Jeffery (2012)

Outcomes of CO WDs



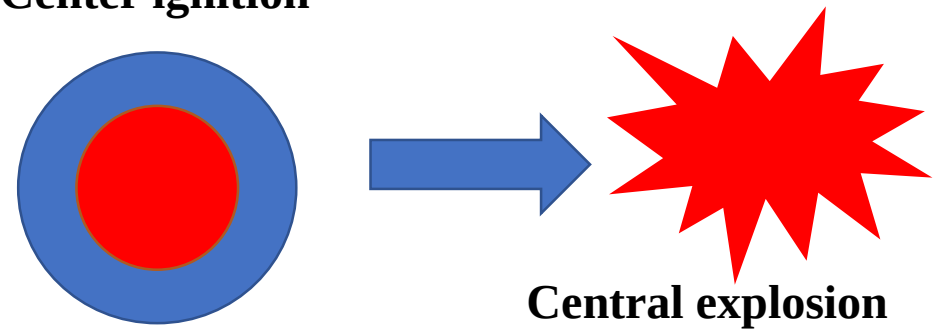


Formation of SN Ia

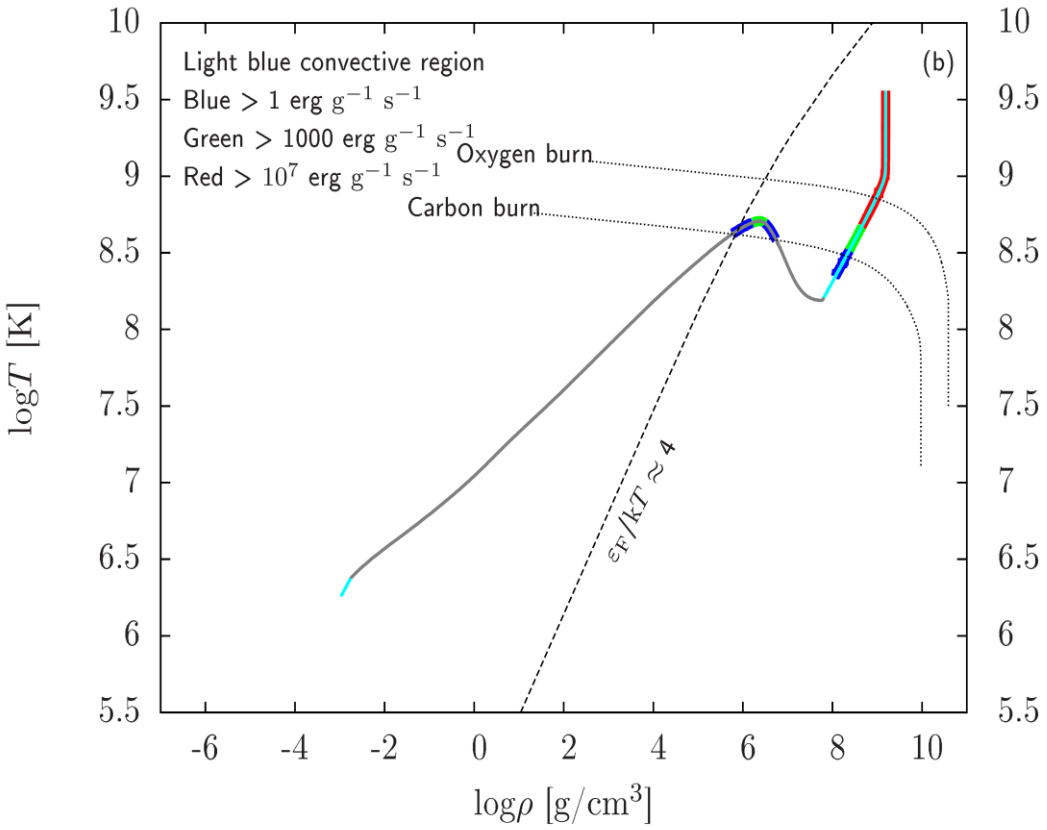


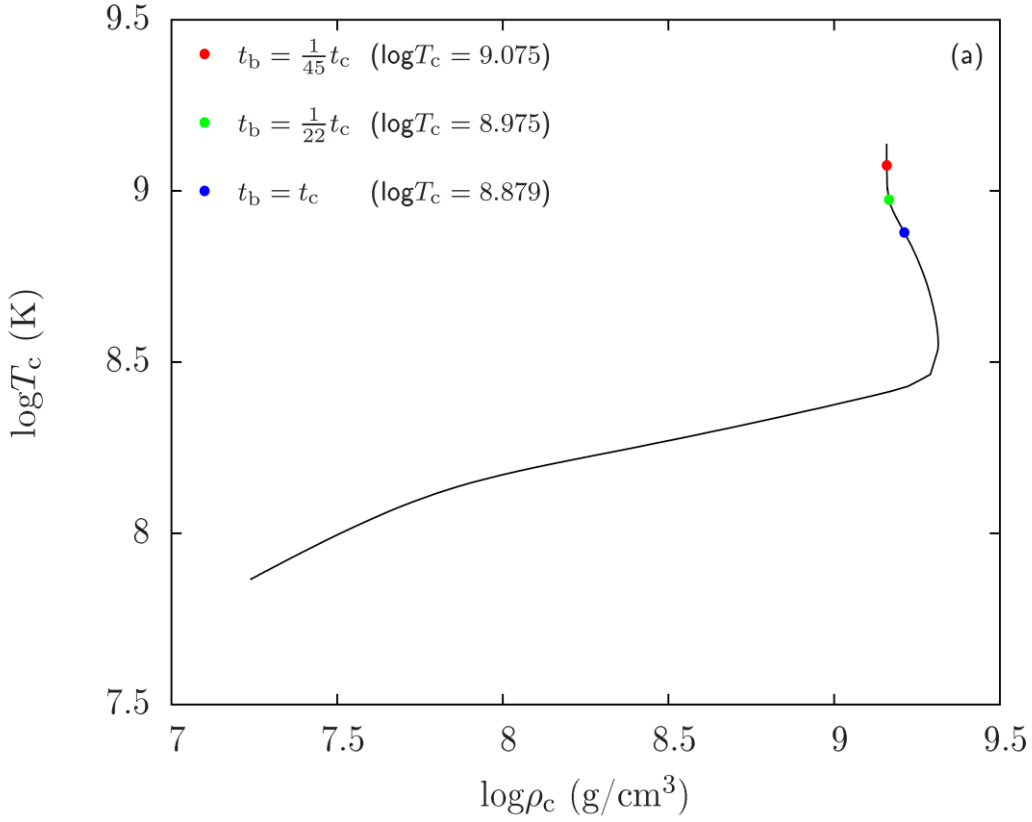
M_{acc}<2.4d-6 $M_\odot$/yr

Center ignition



Central explosion

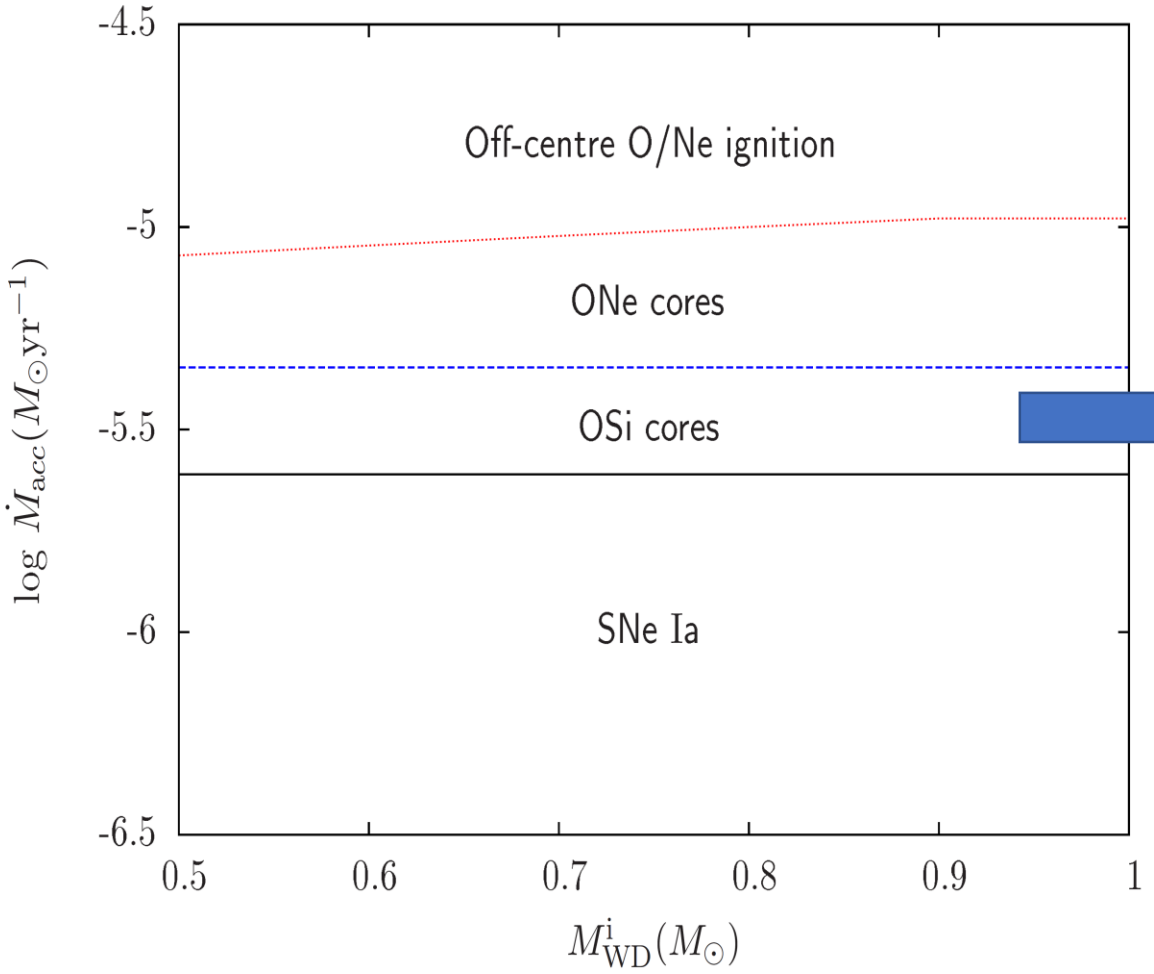




WD mass：0.9M$_\odot$
Accretion rate：2.4d-6 M$_\odot$/yr

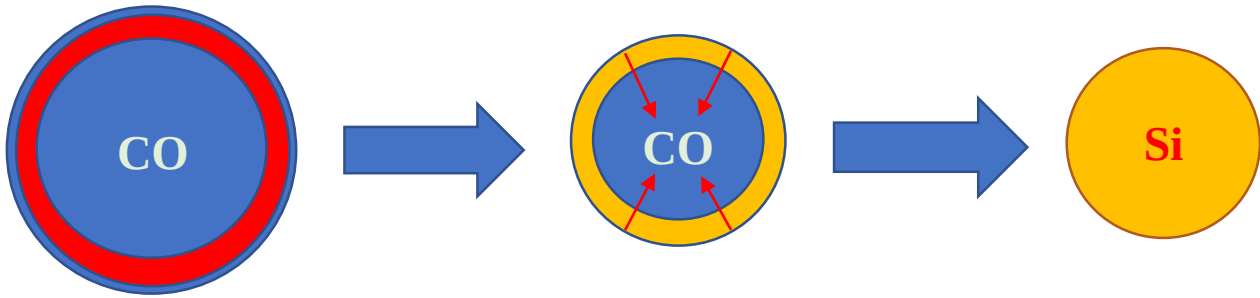
Final mass：1.375M$_\odot$
Eps_nuc： 10^{26} erg/g/s

Formation of OSi core

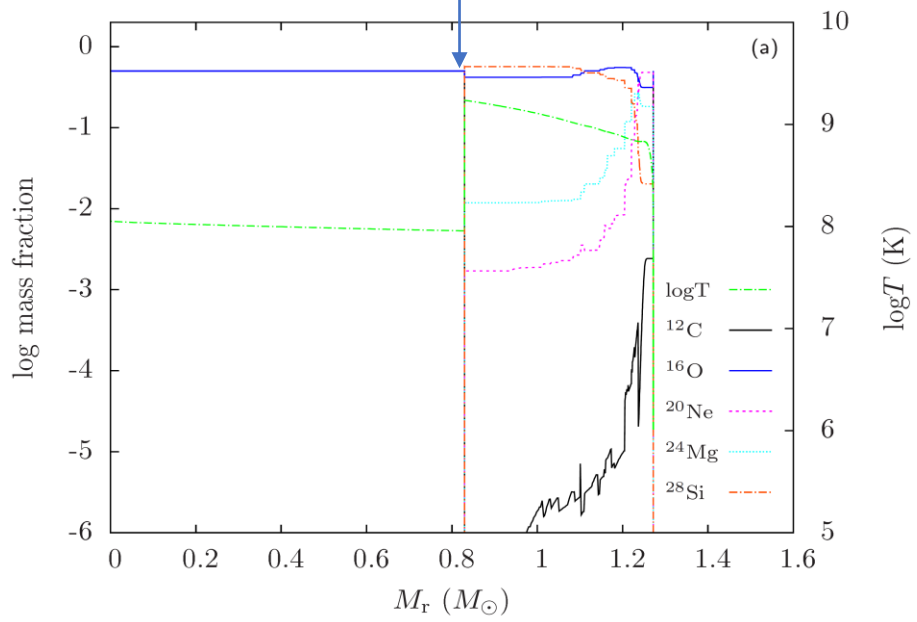


M_{acc}=2.45—4.5×10^{-6} $M_\odot$/yr

Off-center ignition



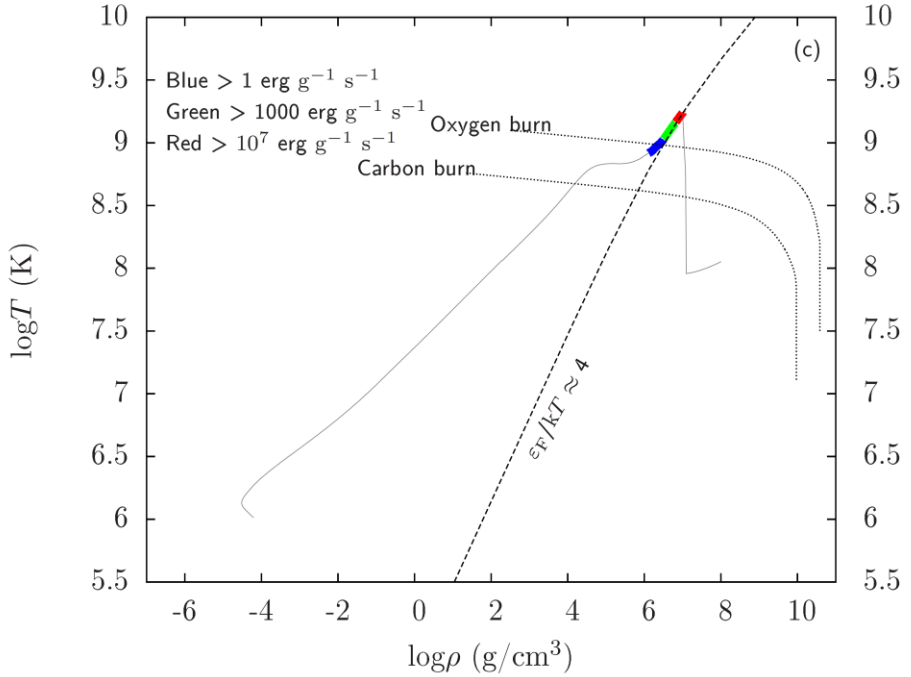
Position of flame

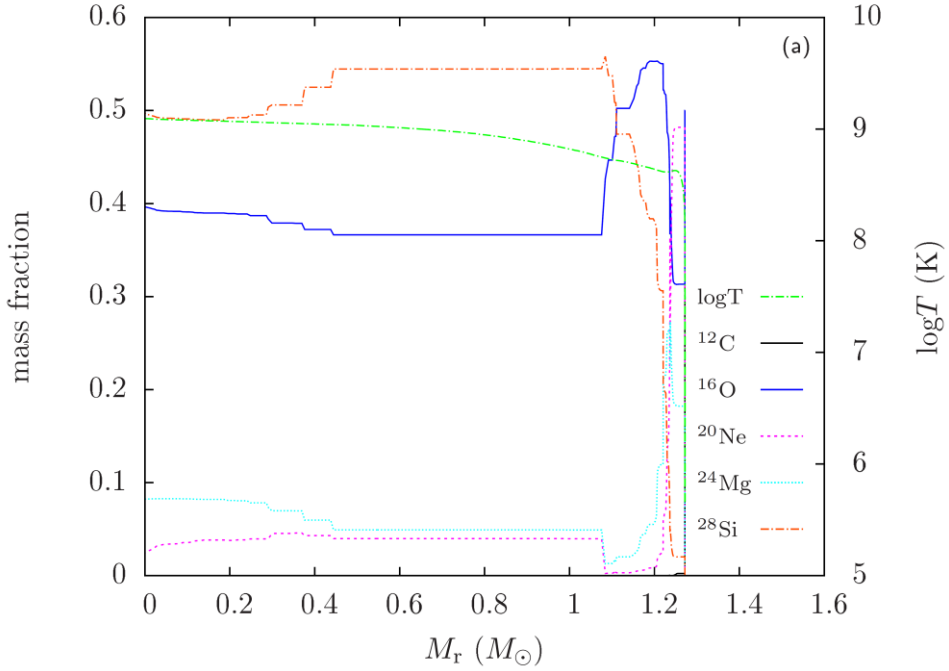


Initial mass：0.9$M_\odot$
Accretion rate：4.0d-6 $M_\odot$/yr

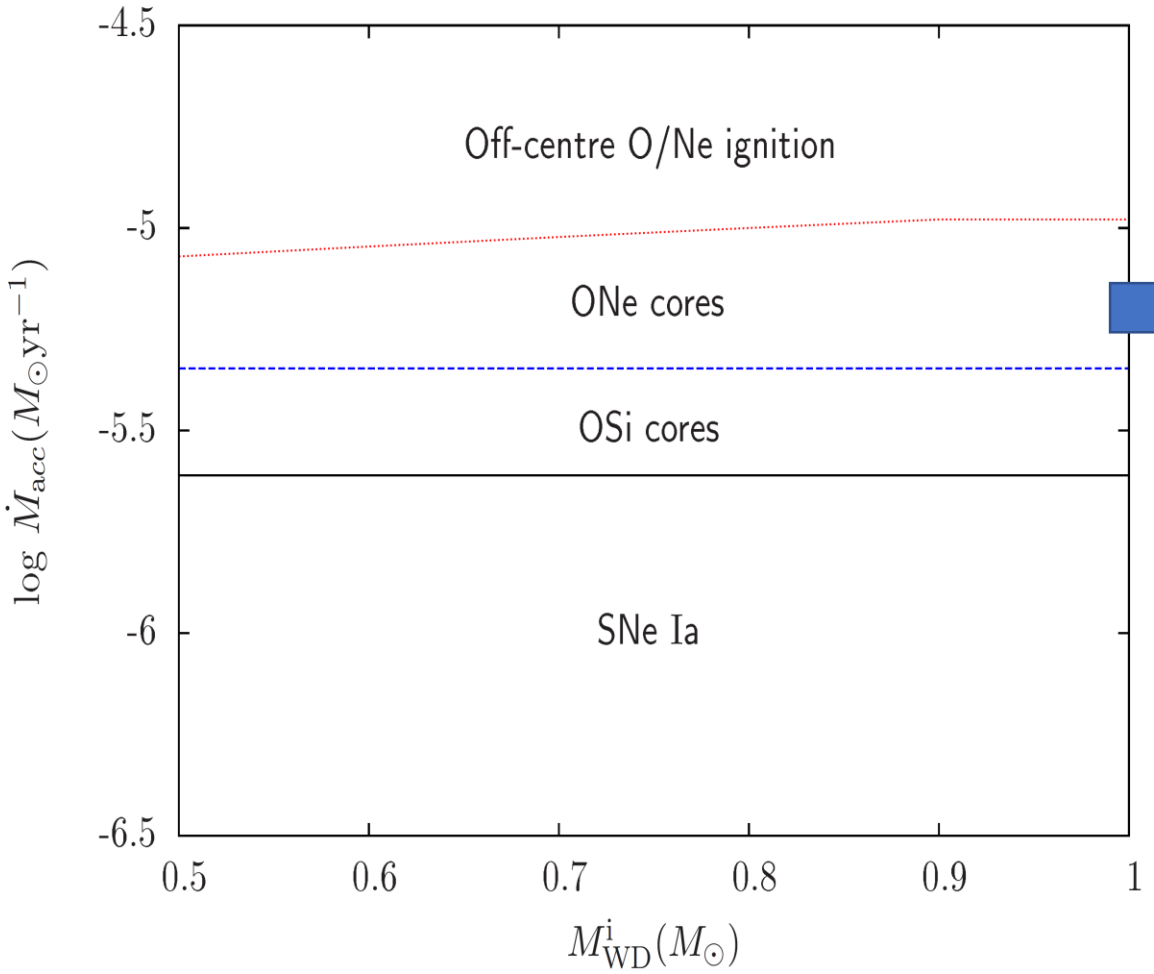
Temperature of the flame: logT>9.2

The carbon flame reaches center in 94 years – Si-rich core



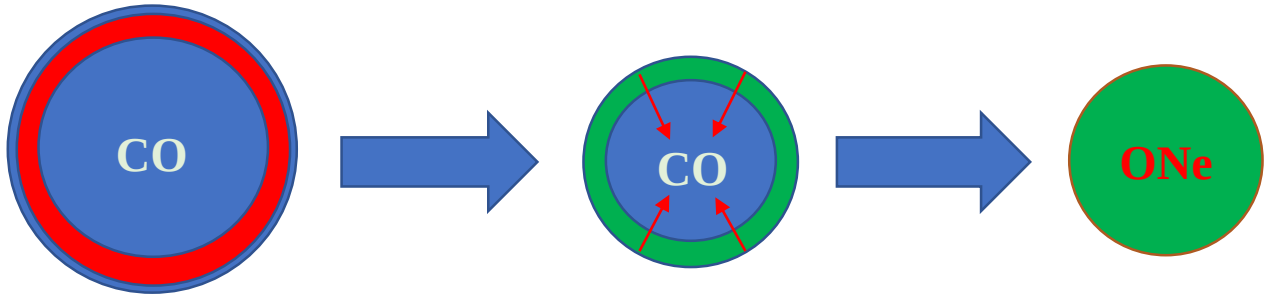


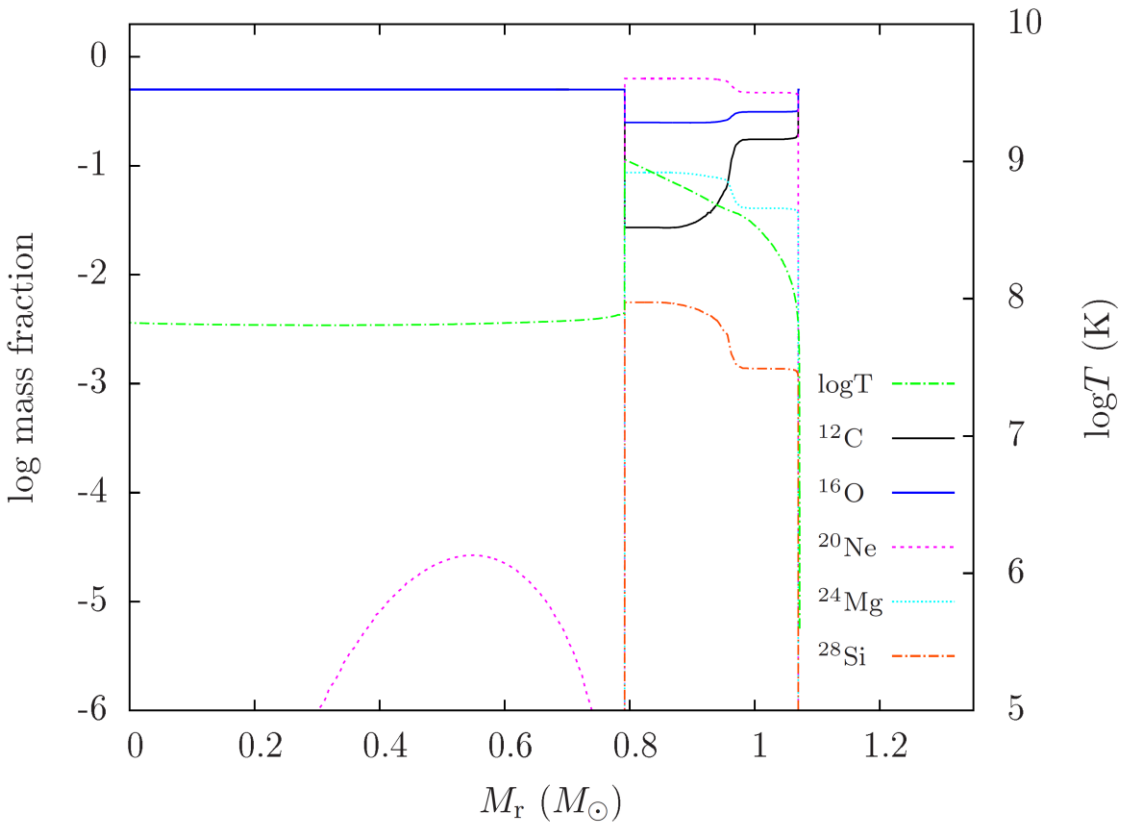
Formation of ONe core



M_{acc}=4.5--10.5×10^{-6} $M_\odot$/yr

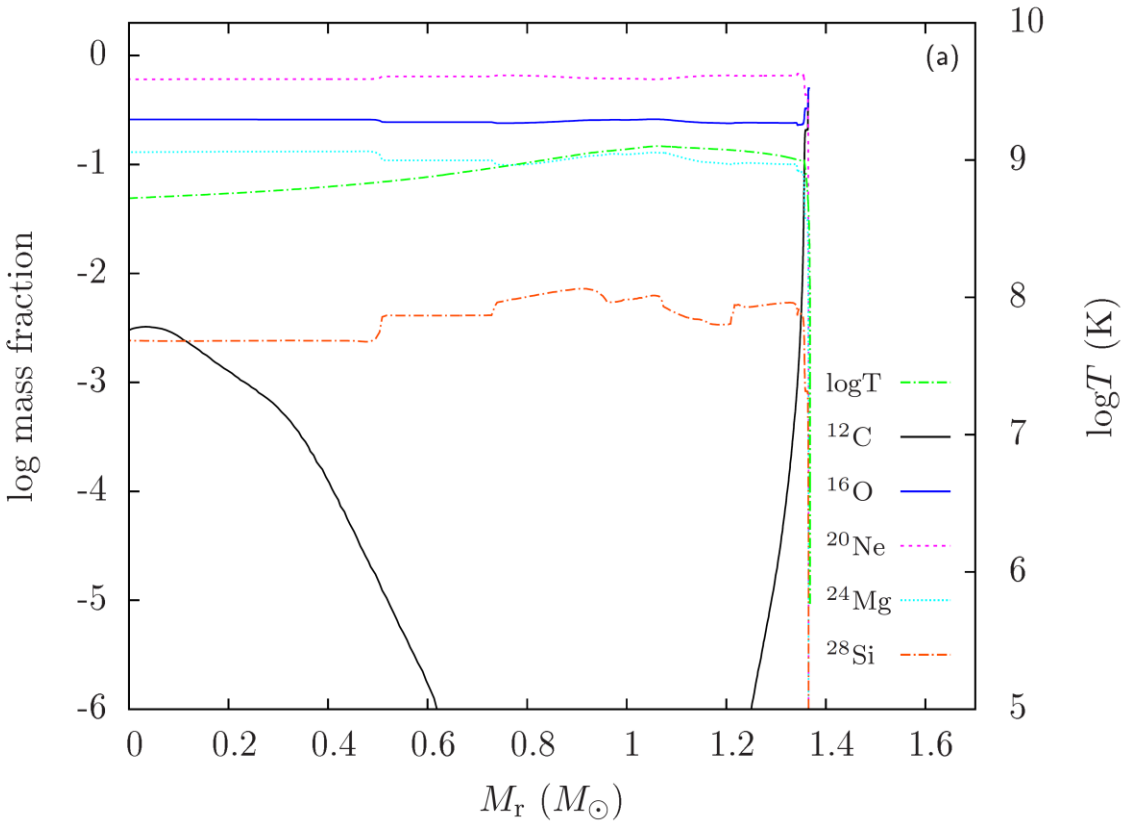
Off-center ignition





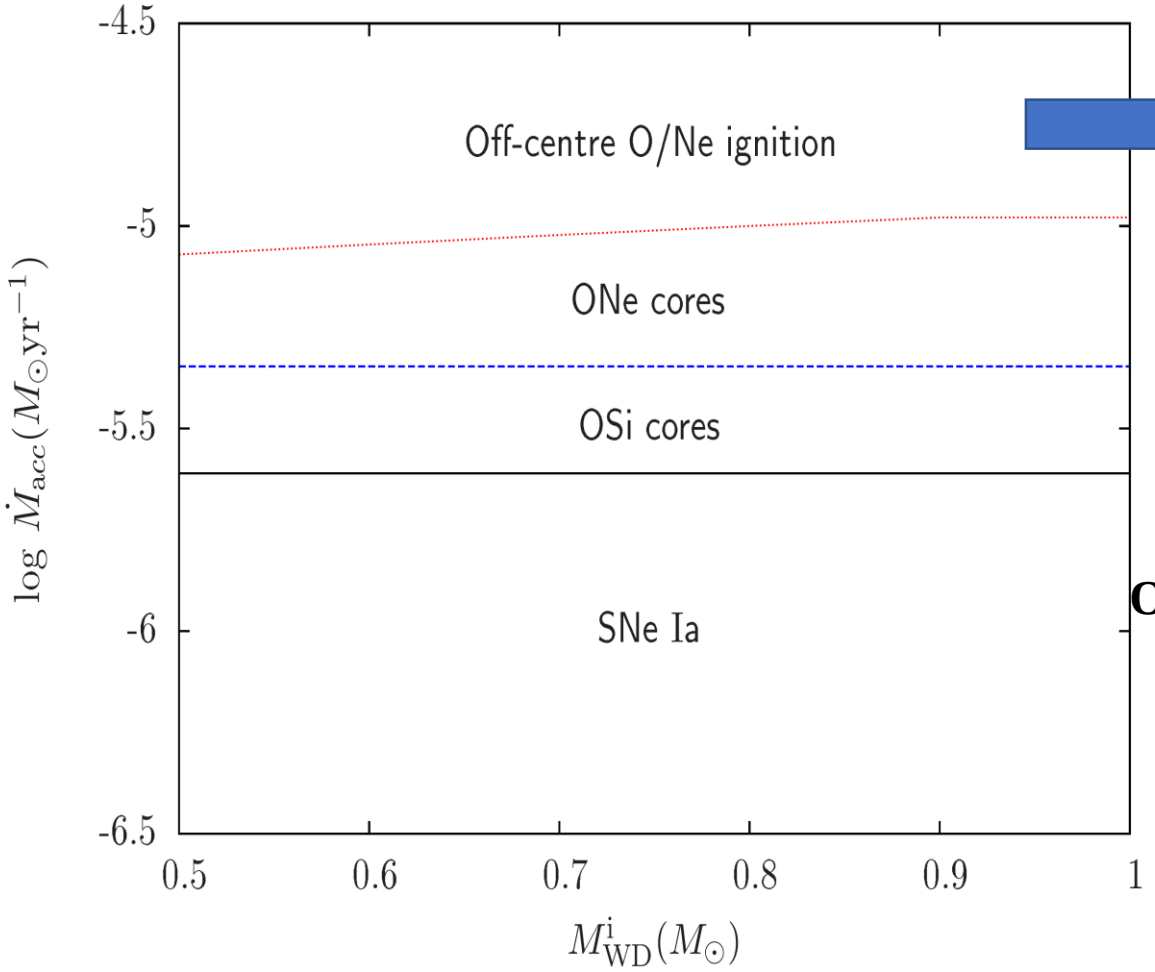
Initial mass：0.9M$_\odot$
Accretion rate：1.0d-5 M$_\odot$/yr

Temperature of the flame: logT ~ 9.0

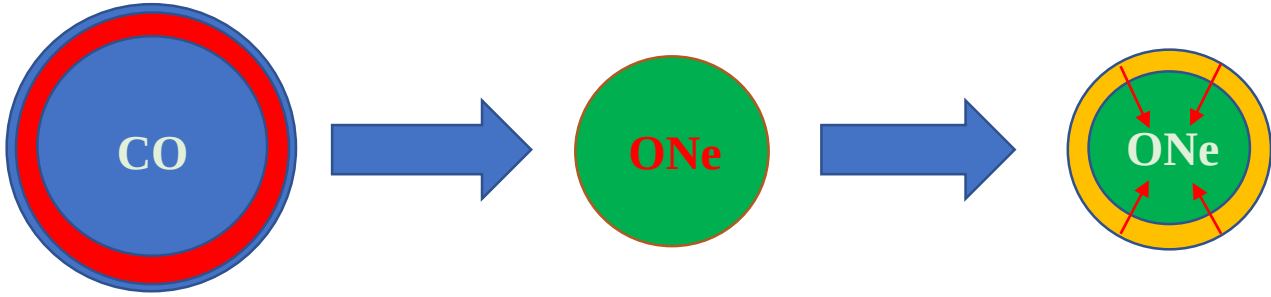


The carbon flame reaches center in 5000 years – ONe core

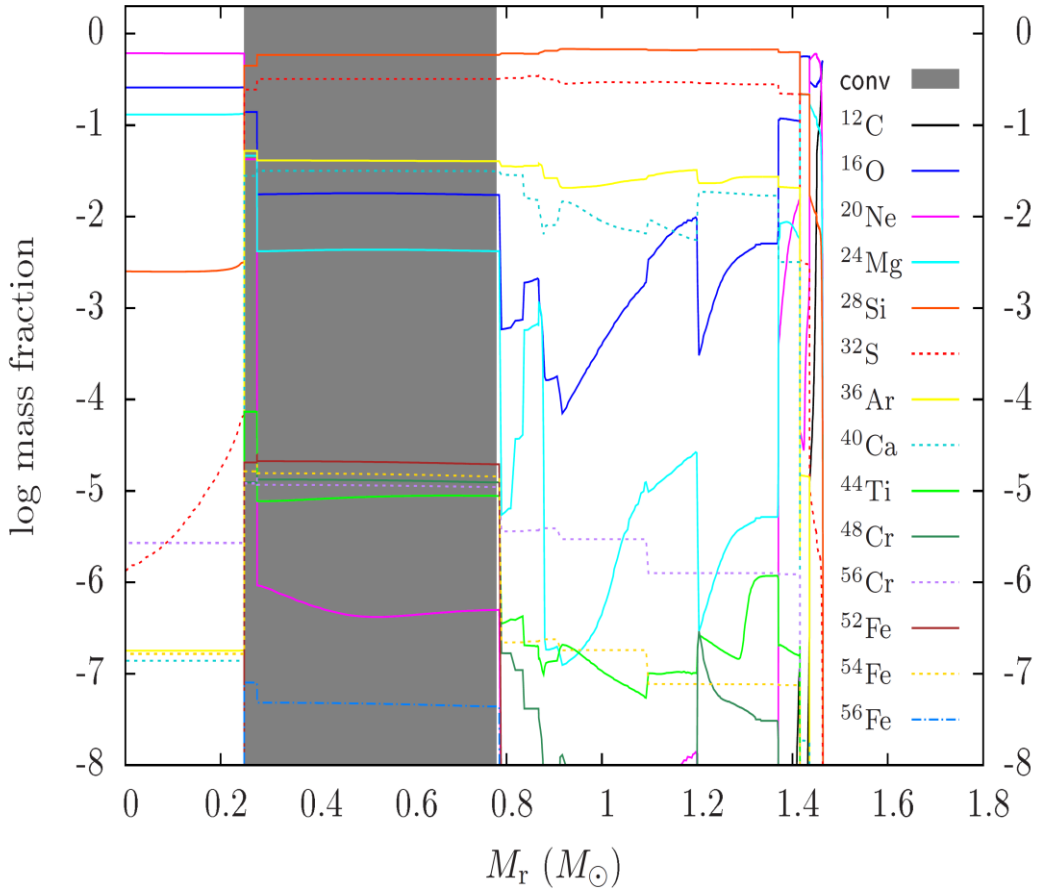
Off-center Ne burning



$M_{acc}>10.05\times10^{-6}\,M_\odot/yr$



Off-center ignition



Initial mass：$0.9M_\odot$
Accretion rate：1.5d-5 $M_\odot$/yr

- **Carbon flame – ONe core**
- **Off-center Neon ignition**
- **Dynamical process when M_r~0.25 $M_\odot$**

- **Mass fraction:**
- **Si-group > 90%**
- **Ar, Ca ~ 3-4%**

Summary

mass-accretion rates influence the evolutionary process

- **Slow merger**
  - **M_{acc}=1d-5 -- 2d-5 ⟶ ONe core ⟶ O/Ne explosion**
  - **M_{acc}=4.5d-6 -- 1d-5 ⟶ ONe core**
  - **M_{acc}~2.45 -- 4.5d-6 ⟶ O/Si core ⟶ iron core collapse NS**
  - **M_{acc}<2.45d-6 ⟶ SN Ia**
- **Violent merger ⟶ SN Ia (e.g. Pakmor et al. 2010,11,12)**
- **Fast merger ⟶ iron CCSN (e.g. Schwab et al. 2016)**

Thanks for your attention!