Evolution of magnetized WD binaries to Type Ia Supernovae

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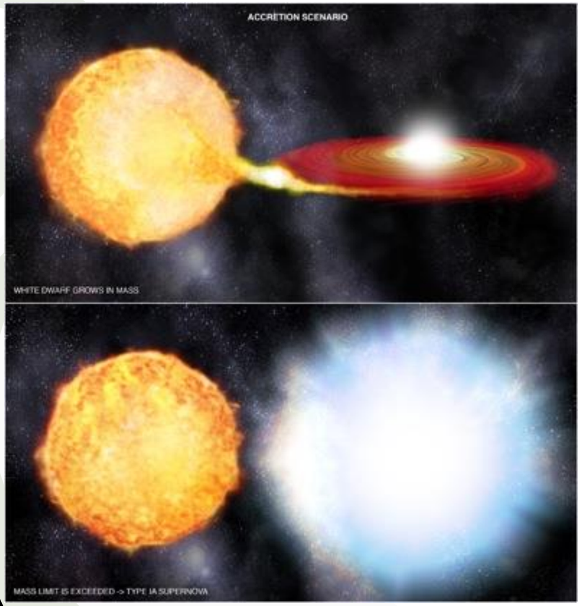
1. Introduction

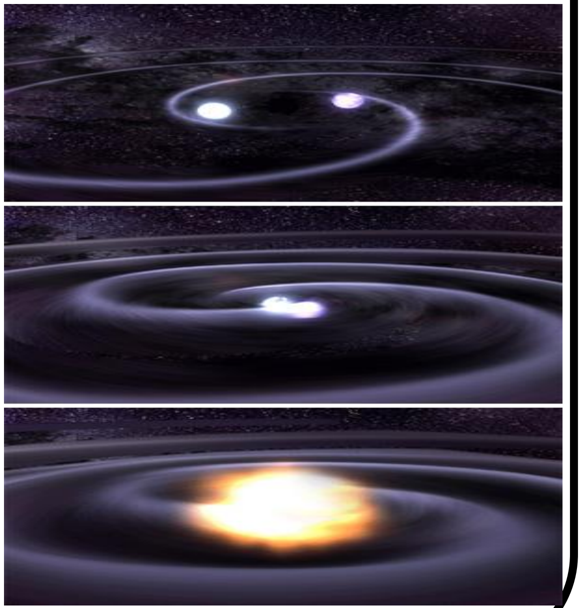
SNe Ia progenitor models

SD models



A companion star

DD models



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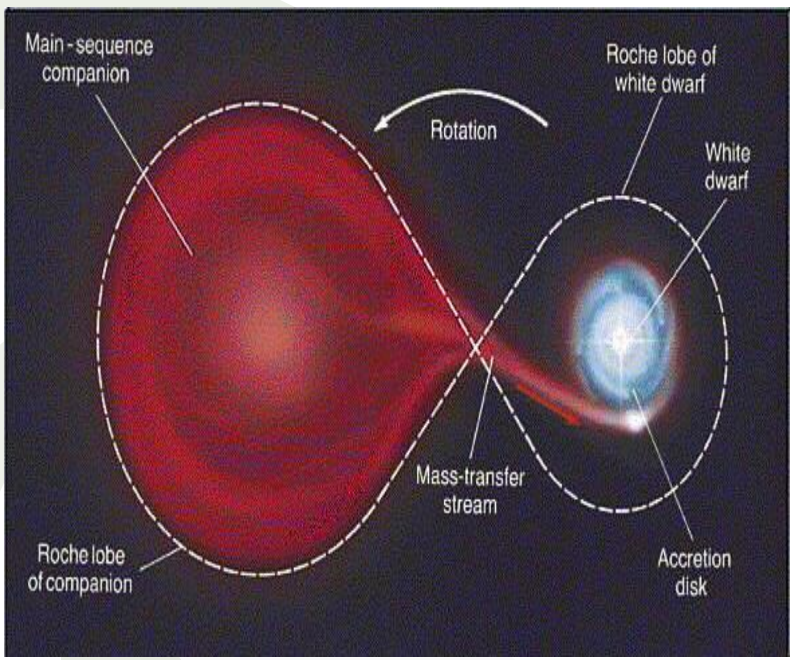
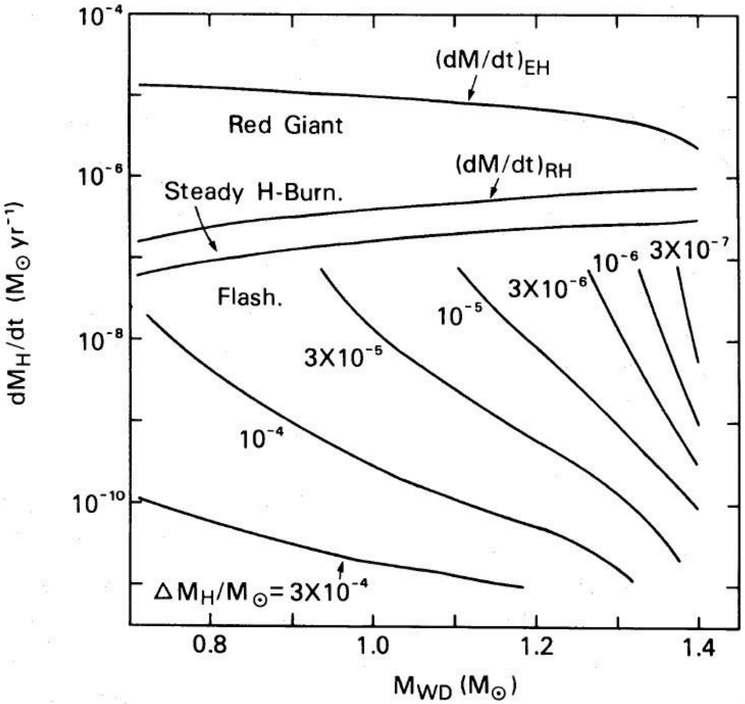
2. The SSXB model

- When $M_{donor} > M_{WD}$ mass transfer proceeds on a (sub)thermal timescale at a rate $\sim 10^{-7} - 10^{-6} M_{\odot}/yr$, so that the accreted H and He can stably burn on the surface of the WD (Van den Heuvel et al. 1992) .
- Appear as supersoft X-ray binaries (SSXBs)





Constraints on the SSXB model

- The donor star during mass transfer
  - 1E0035.4-7230, P_{orb} = 4.126 hr, M_2<0.6 $M_\odot$(Schmidtke et al. 1996)
  - CAL 87, $P_{orb,i}$ = 5.7 hr(Naylor et al. 1989), $M_{2,i}$=0.63 $M_\odot$, M_2=0.34 $M_\odot$(Oliveira & Steiner 2007)

- X-ray luminosity (Di Stefanoet 2010a,b; Gilfanov & Bogdán 2010) of SSXBs
  - observation results $<$ theoretical results

$$L_{WD,nuc} = \epsilon_H X \dot{M}$$

Constraints on the SSXB model

- The optical properties of possible surviving companion stars after SNe Ia

SNe Ia	M_V or V	References
SNR0509-67.5	$M_V = 8.4$	Schaefer and Pagnotta (2012)
SN1572	$M_V \geq 9.5$	Ruiz-Lapuente et al.(2004); Kerzendorf et al.(2012a,b)
SN1006	$M_V \approx 4.9$	Gonzalez Hernandez et al.(2012)

Constraints on the SSXB model

- Low-mass donor stars are required!
- However, in traditional models, mass transfer is driven by magnetic braking, at a rate too low to allow stable burning
- Possible solutions
  - Increase the mass transfer rate
  - Increase the burning efficiency at a given accretion rate

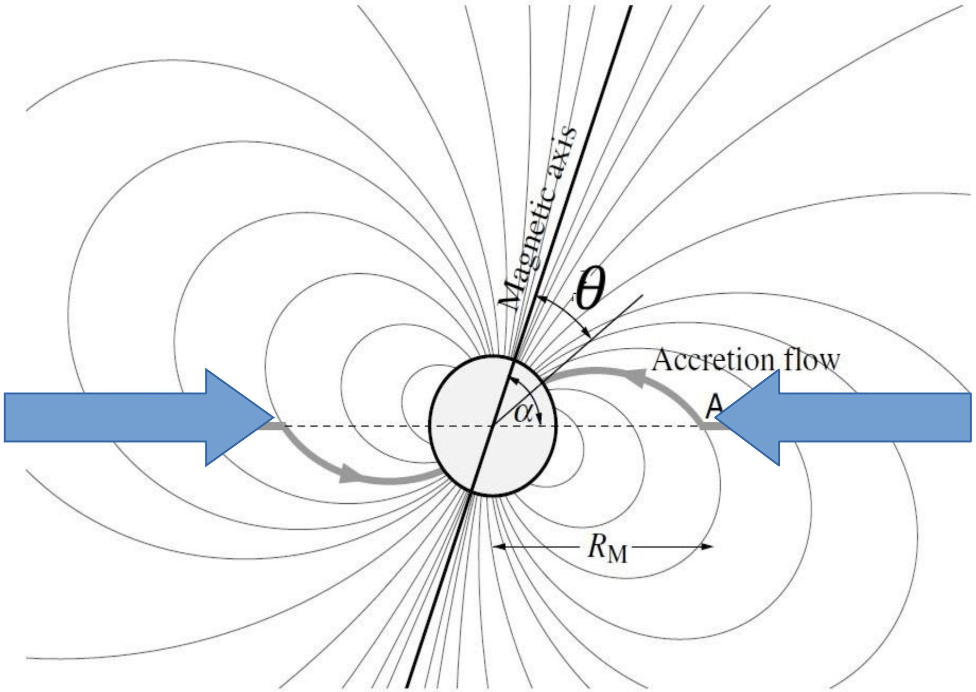
Magnetic confinement

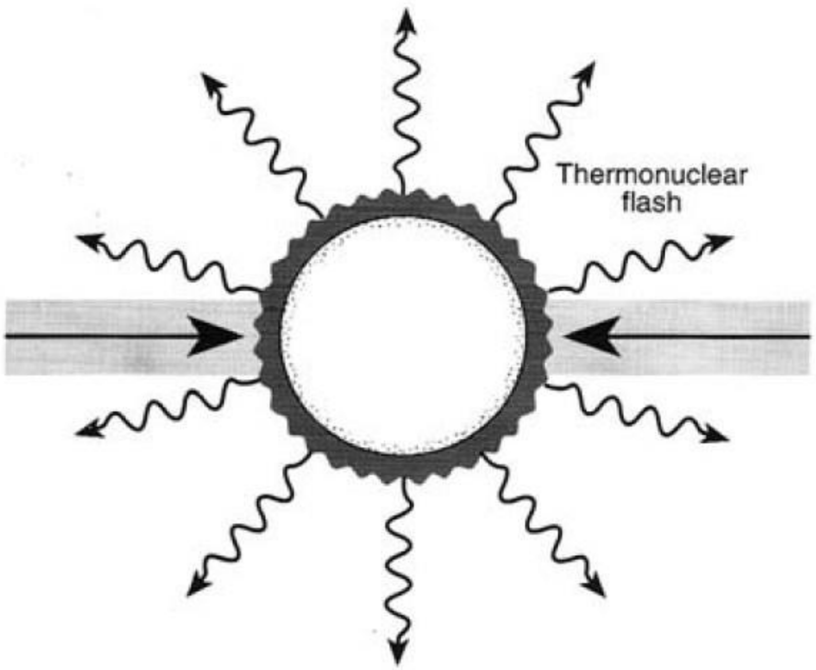
- A considerable fraction (⩾10%) of WDs are magnetized (polars and intermediate polars)
- Strong magnetic fields may confine the accreted matter within the polar cap, so that the accretion rate per unit area is higher than in spherical accretion case
- This may enable stable burning even at low mass transfer rate
- Indeed the average mass of WDs in IPs (~0.88 $M_{\odot}$, Yuasa et al. 2010.) is higher than in CVs (~0.6 $M_{\odot}$, Lasota et al. 1989), suggesting possible mass growth

Conditions for magnetic confinement

The WD can confine the accreted matter at the polar caps without the envelop expansion

$$B \geq 9.3 \times 10^7 (\frac{R_{\rm WD}}{5 \times 10^8 cm})(\frac{P_b}{5 \times 10^{19} dyne/cm^2})^{7/10} (\frac{M_{\rm WD}}{\rm M_\odot})^{-1/2} (\frac{\dot{M}_{\rm WD}}{10^{-10} \rm M_\odot yr^{-1}})^{-1/2}, G$$

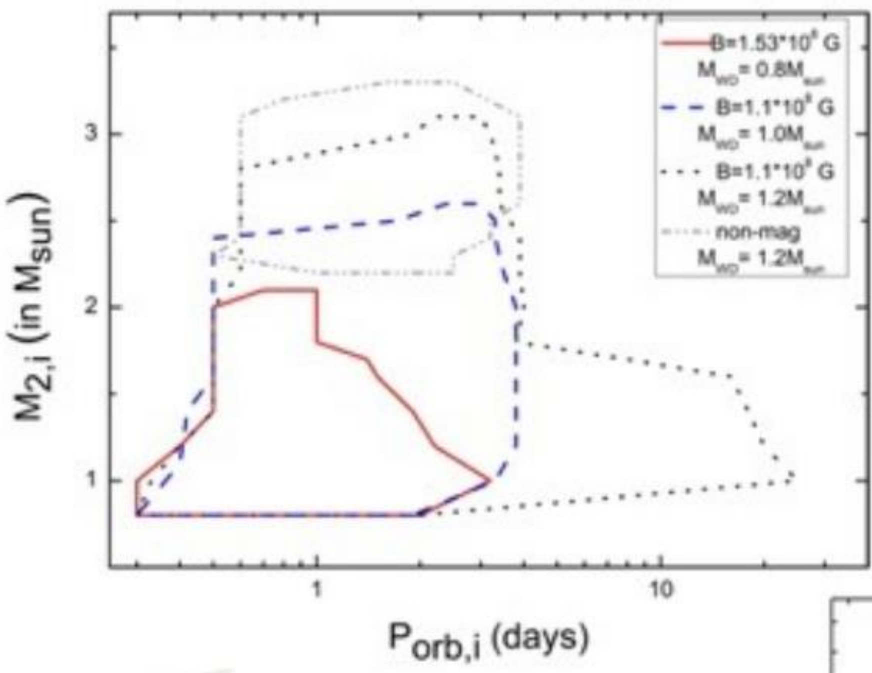

Magnetic axis
θ
Accretion flow
α
A
R_M


Thermonuclear flash

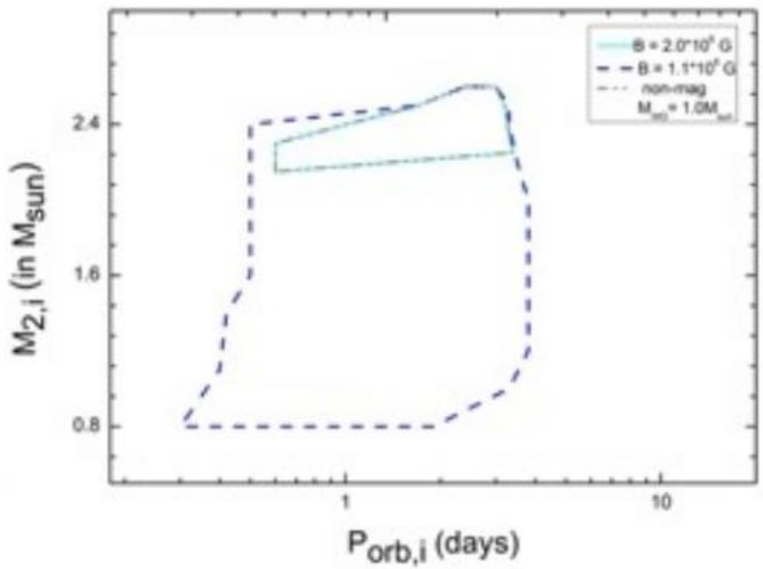
Model calculations

- SSXB + magnetic confinement

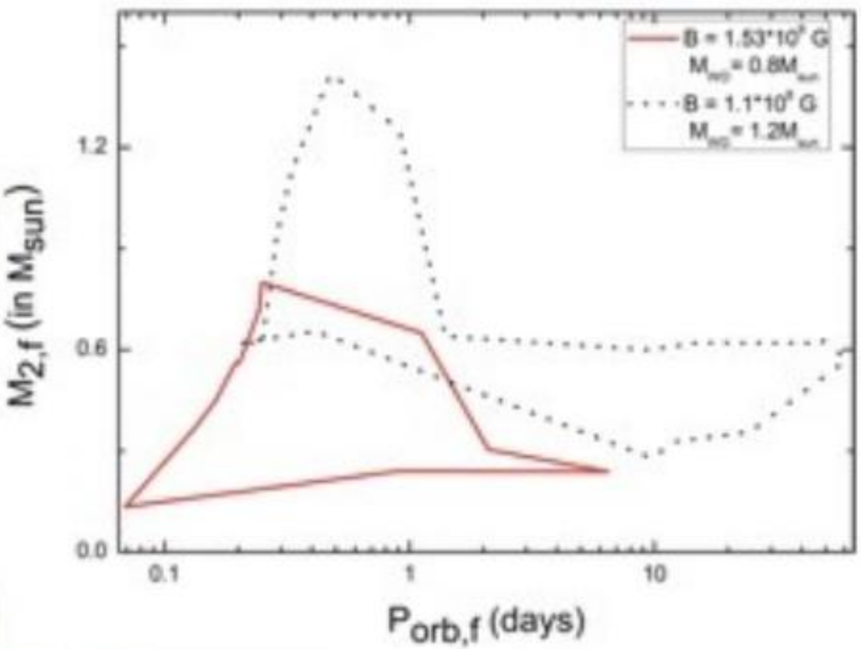
3. Results

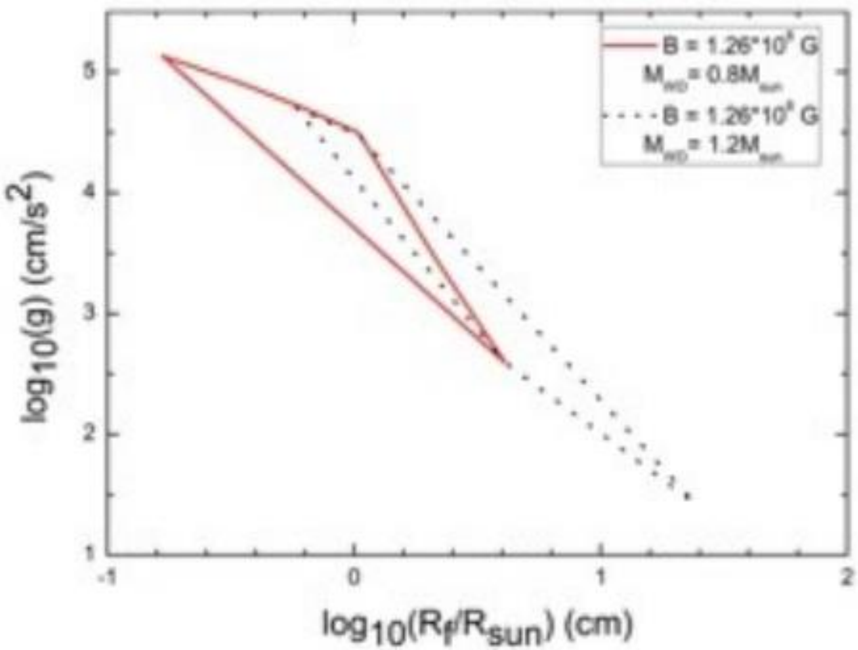


P_{orb} vs. M_2

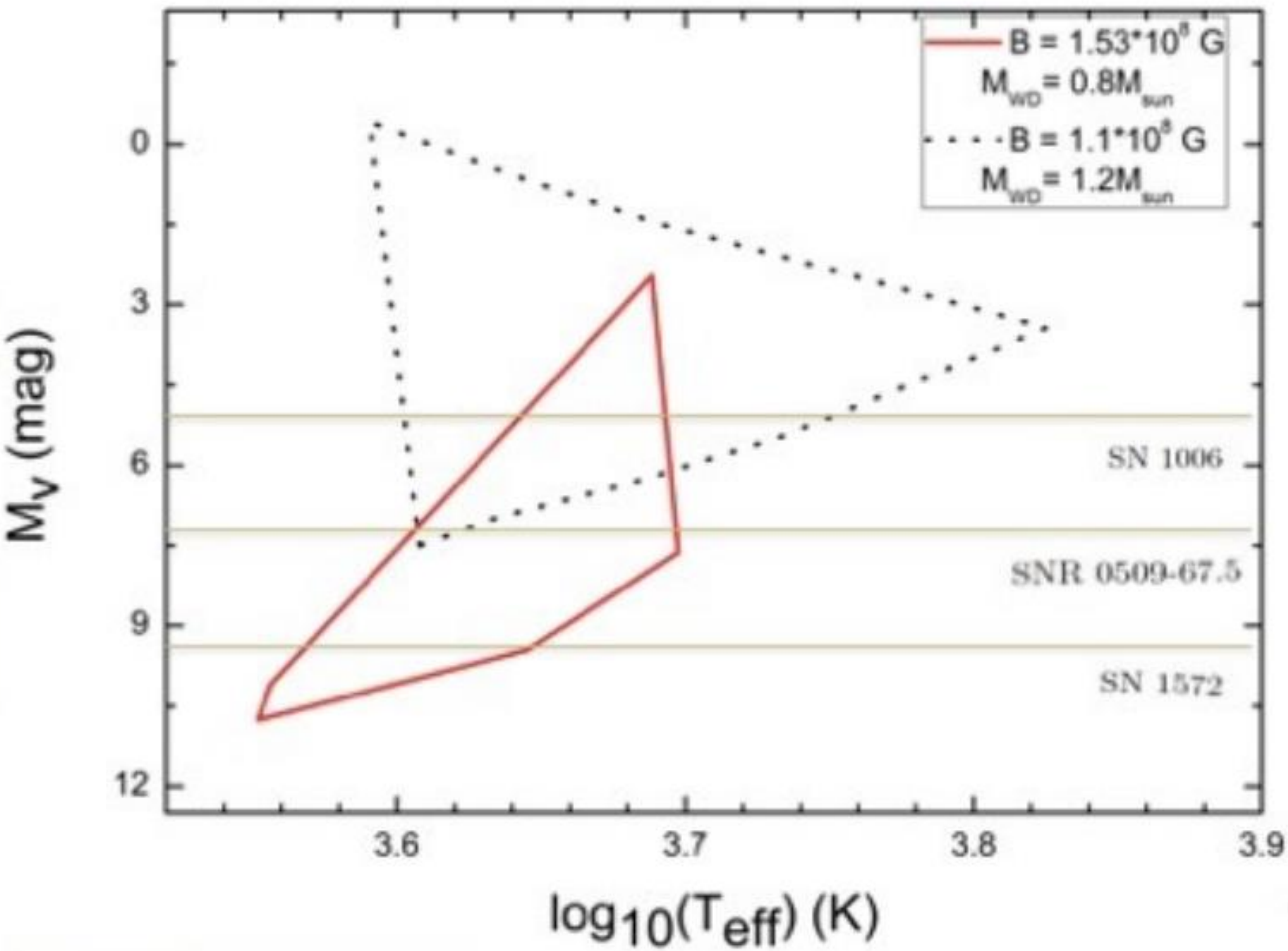


$P_{orb,f}$ vs. $M_{2,f}$, R_2 vs. g,





M_V vs. T_2



B = 1.53*10^8 G
M_WD = 0.8M_sun
B = 1.1*10^8 G
M_WD = 1.2M_sun
SN 1006
SNR 0509-67.5
SN 1572
M_V (mag)
0
3
6
9
12
3.6
3.7
3.8
3.9
log10(T_eff) (K)

Other considerations

- How exactly(how long, how extent) the magnetic field of WDs confine accreted matter their polar caps?

- Calculated M_V can be real values of the survived companion stars? (SN ejecta may affect the MS companion(Liu et al. 2012; Pan et al. 2012)

4. conclusion

- Observation results require low-mass donor stars. Classical models cannot reproduce lower enough mass SSXBs for observations

Considering the magnetic confinement models . We use polar-like WD binaries to calculate the evolution process of SSXBs, WDs → SNe Ia.

- The low mass SSXBs in our model may be the progenitors of those observed particular SNe Ia with high M_V.

THANK YOU