The Role of Magnetic field of White Dwarfs in the Symbiotic Channel for Type Ia Supernovae

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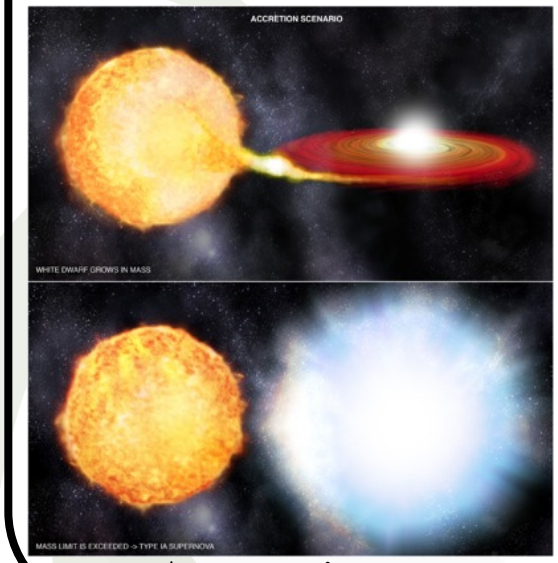
Contents

(Ablimit I., Podsiadlowski Ph., Di Stefano R., Rappaport S., Wicker J., 2022, ApJL, 941, L33)

1. Introduction

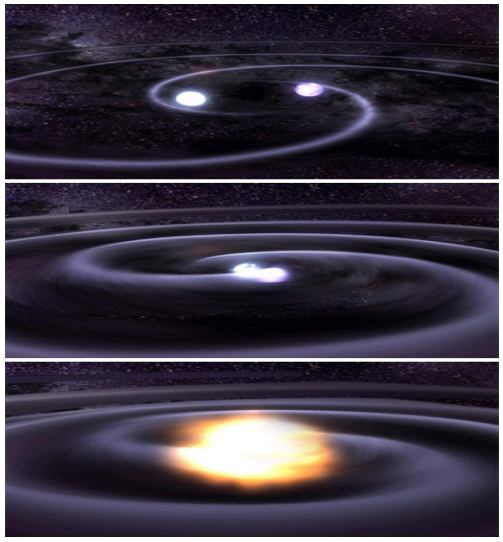
SNe Ia progenitor models

SD scenario



A companion star

DD scenario



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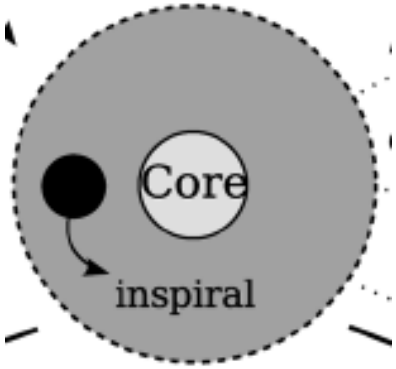
Core-merger scenario



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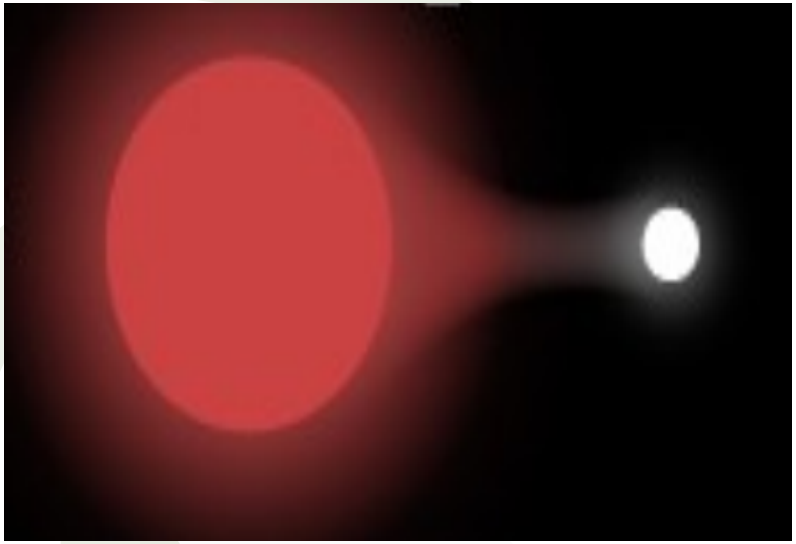
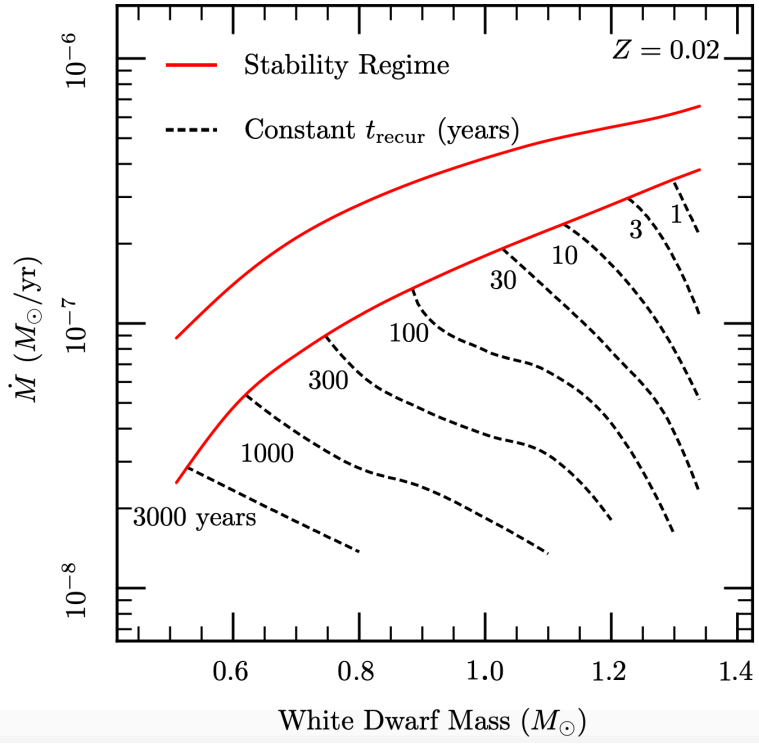
2. The Classical Symbiotic model

If the mass transfer proceeds on a (sub)thermal timescale at a rate of ~ 10^-7 – 10^-6 Msun/yr, the accreted H and He can stably burn on the surface of the WD
(e.g., Nomoto 1982; Wolf et al. 2013; Hillman et al. 2015, 2016).

So it appears as the (supersoft) X-ray binary!

The enhanced Wind-mass- loss model was proposed in the classical symbiotic channel of SNe Ia.





Constraints with symbiotic stars

- The observational results of known symbiotic stars can not be satisfied by the classical model (Kenyon 1986; see Merc, Galis and Wolf (2019) for the catalog)
  - too low accretion rate for the steady burning
  - T CrB, P_{orb} = 227.55 hr(Fekel et al. 2000), M_{RG}=1.12 $M_{\odot}$, M_{wd}=1.37 $M_{\odot}$(Stanishev 2004); likely filling RL

- Enhanced mass transfer? Yes. Mass transfer via RLOF? Also yes (e.g., Jmik et al. 2001,2002)
  - How does the RLOF work for the S-type Sym stars? How about the typical wind + RLOF? And the WD's B field?

Magnetic confinement

- A considerable fraction (≥10%) of WDs are magnetized (polars and intermediate polars); Magnetize WDs have been detected in symbiotic binaries and supersoft X-ray binaries (Kahabka 1995; Sokoloski & Bildsten 1999; Osborne et al. 2001)

- Strong magnetic fields may confine the accreted matter within the polar cap, so this may enable stable burning even at low mass transfer rate

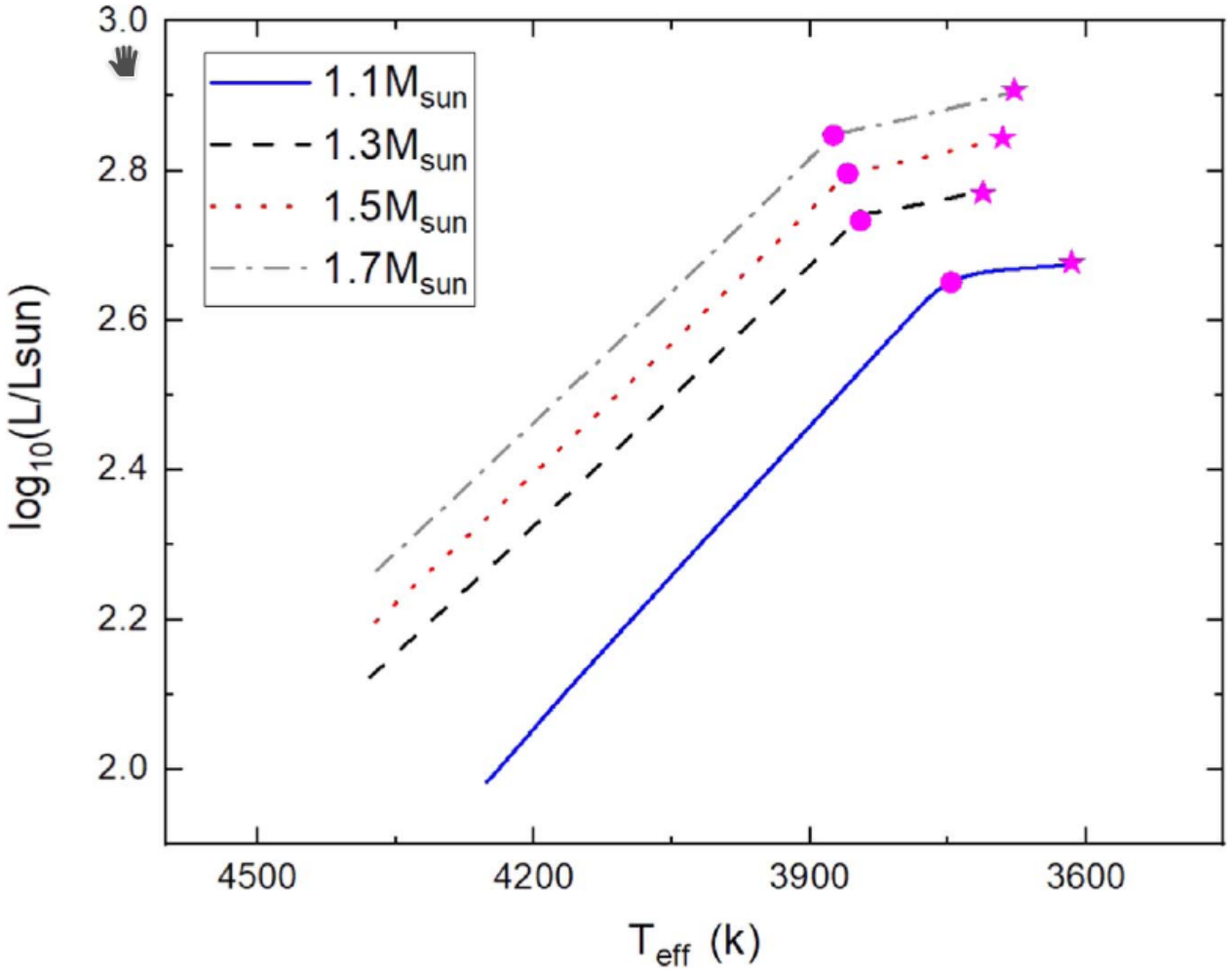
1D Model Simulations with MESA stellar evolution code

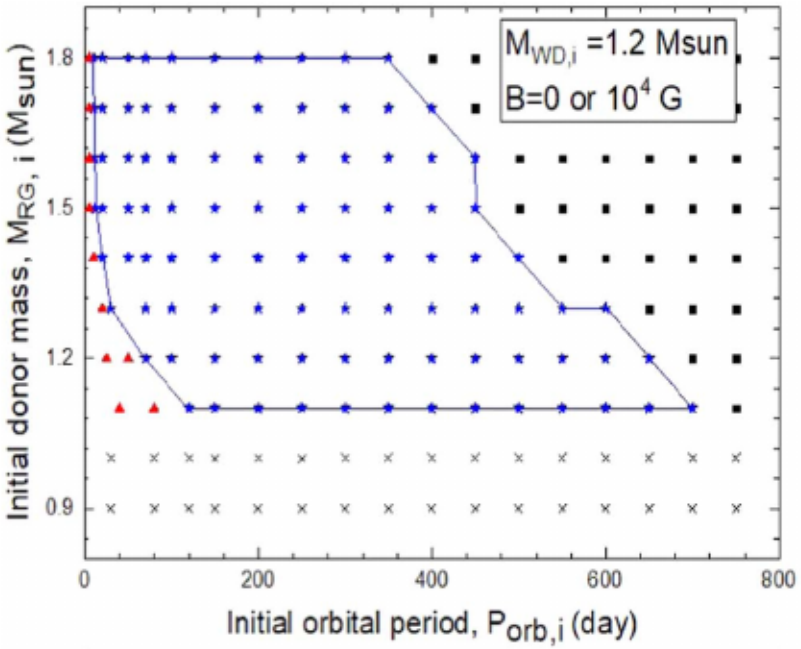
1. Symbiotic binary (WD+RG): typical wind (Reimers scheme) + RLOF (Kolb and Ritter 1990)

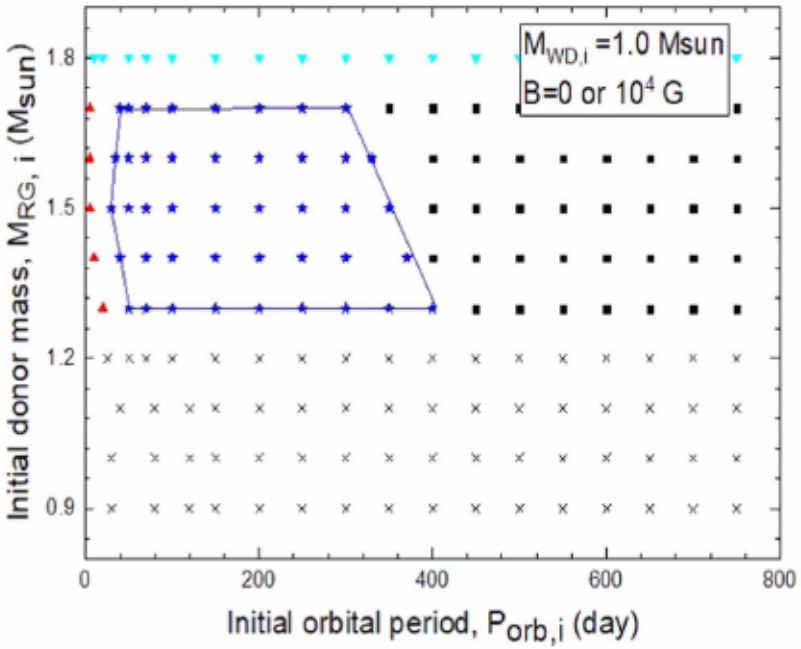
2. Symbiotic binary (WD+RG): typical wind (Reimers scheme) + RLOF (Kolb and Ritter 1990) + magnetic confinement

3. Results

Non-mag case




$M_{WD,i}$ =1.2 Msun
B=0 or 10^4 G
Initial donor mass, $M_{RG,i}$ (M_{sun})
Initial orbital period, $P_{orb,i}$ (day)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B=0 or 10^4 G
Initial donor mass, $M_{RG,i}$ (M_{sun})
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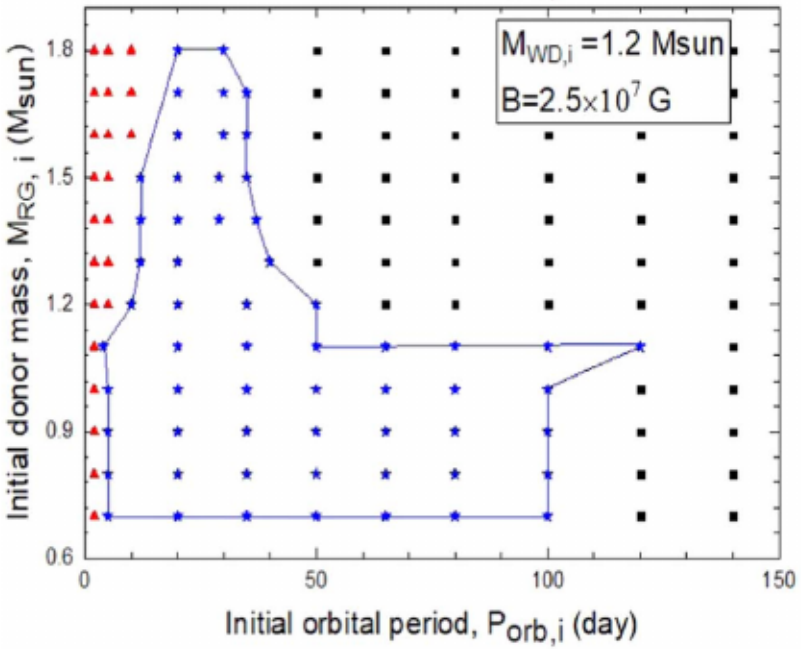
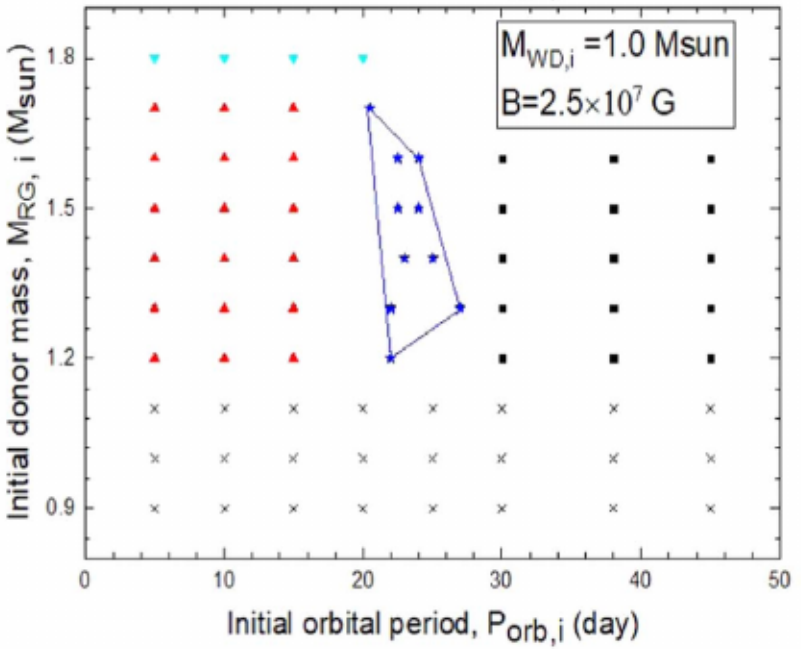

$M_{WD,i}$ =1.2 Msun
B=2.5×10^7 G
Initial donor mass, $M_{RG,i}$ (M_{sun})
Initial orbital period, $P_{orb,i}$ (day)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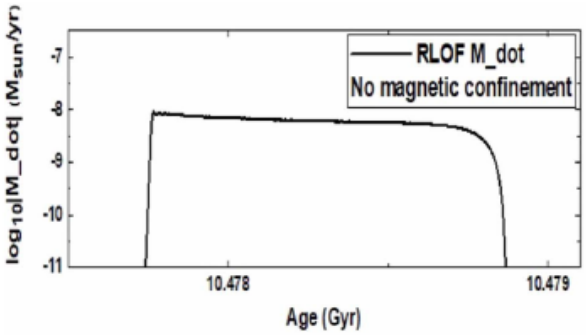
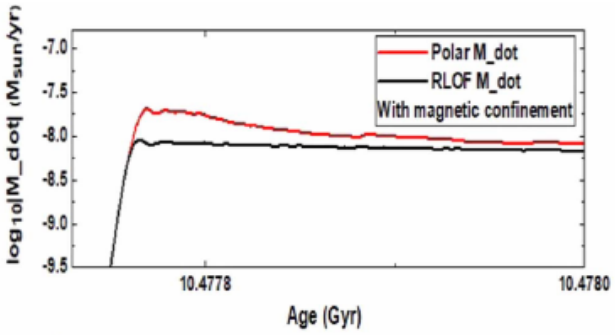
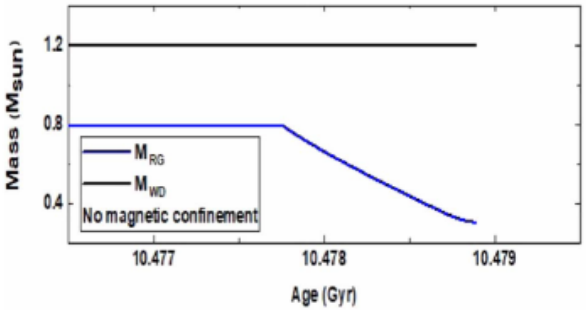
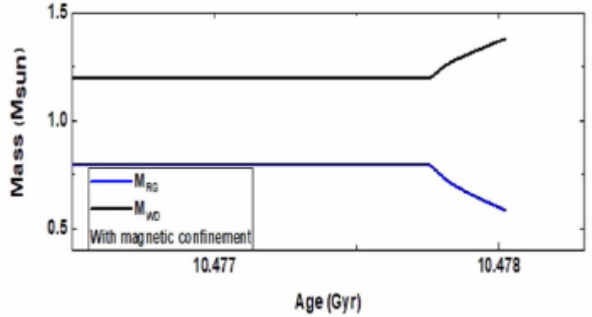
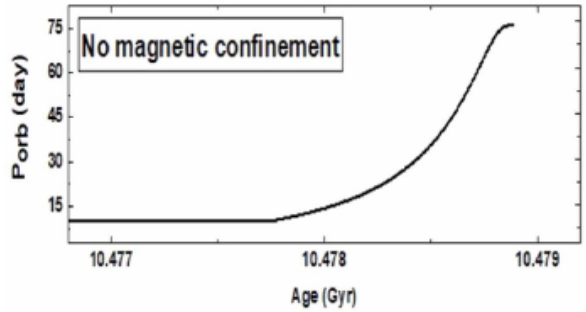
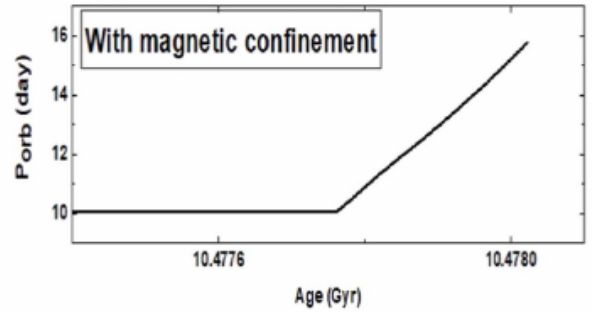

RLOF M_dot
No magnetic confinement
log10|M_dot| (Msun/yr)
-7
-8
-9
-10
-11
10.478
10.479
Age (Gyr)

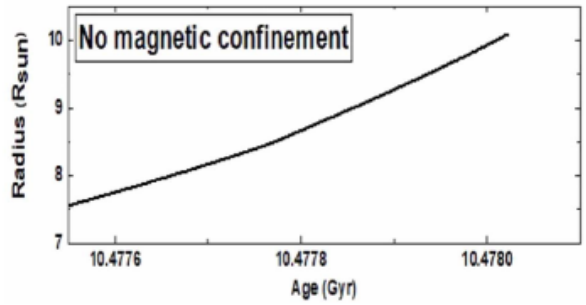

Polar M_dot
RLOF M_dot
With magnetic confinement
log10|M_dot| (Msun/yr)
-7.0
-7.5
-8.0
-8.5
-9.0
-9.5
10.4778
10.4780
Age (Gyr)

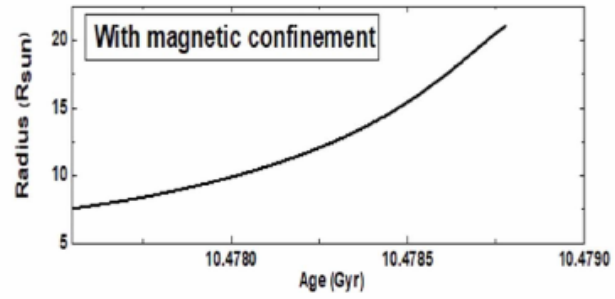

Mass (Msun)
1.2
0.8
0.4
M_RG
M_WD
No magnetic confinement
10.477
10.478
10.479
Age (Gyr)

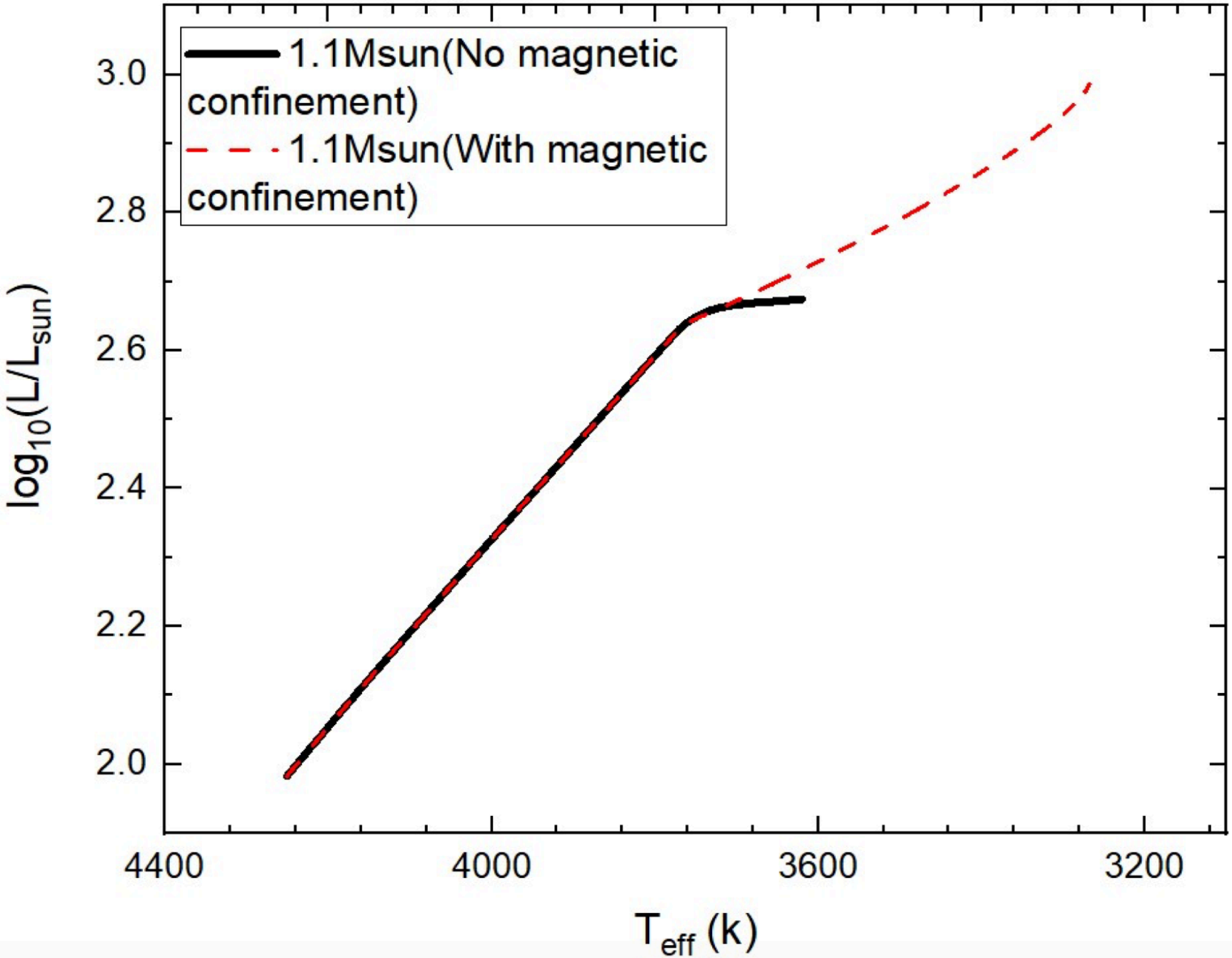

Mass (Msun)
1.5
1.0
0.5
M_RG
M_WD
With magnetic confinement
10.477
10.478
Age (Gyr)


No magnetic confinement
Porb (day)
75
60
45
30
15
10.477
10.478
10.479
Age (Gyr)


With magnetic confinement
Porb (day)
16
14
12
10
10.4776
10.4780
Age (Gyr)


No magnetic confinement
Radius (Rsun)
10
9
8
7
10.4776
10.4778
10.4780
Age (Gyr)


With magnetic confinement
Radius (Rsun)
20
15
10
5
10.4780
10.4785
10.4790
Age (Gyr)


1.1Msun(No magnetic confinement)
1.1Msun(With magnetic confinement)
3.0
2.8
2.6
2.4
2.2
2.0
log10(L/Lsun)
4400
4000
3600
3200
Teff (k)

For the case without magnetic confinement (combining the results for M_WD,i = 1.2 and 1.0 M_sun):

The range of orbital periods is 21.3−2521.5 days; range of donor mass 0.59−1.23M_sun;

range of orbital velocity 13.5−57.7 km/s; ranges of luminosity and effective temperature are 1.94−3.62 (in log(L/L)), and 2960−4458 K, respectively,

For the magneticconfinement case:

They are 5−652 days, 0.41−1.21M_sun,

22.3−100.5 km s−1, 1.08−2.83 (in log(L/Lsun)), and 3268−4700 K,respectively.

4. conclusion

Classical models cannot reproduce parameters of all symbiotic binaries for observations

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

The new results in our model may provide more additional information for the unresolved symbiotic binaries (this is not about ruling out other models).

Our model may be the progenitors of those observed peculiar SNe Ia (relatively dim ones).

THANK YOU