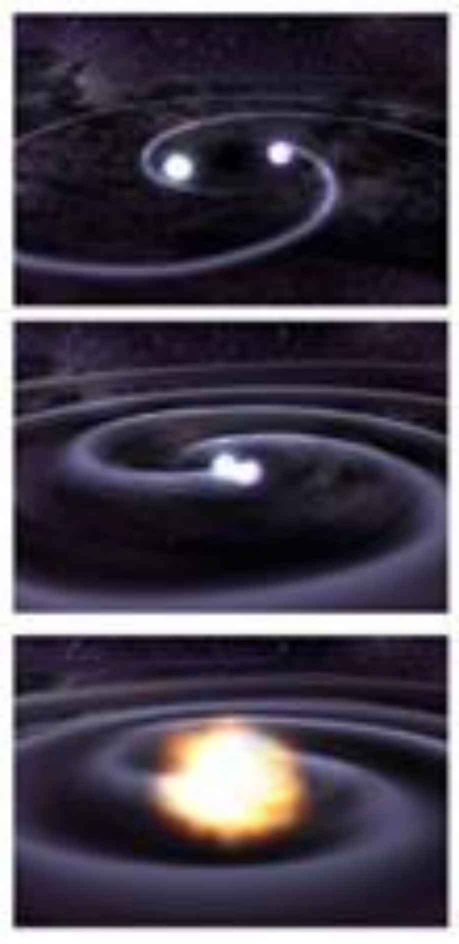
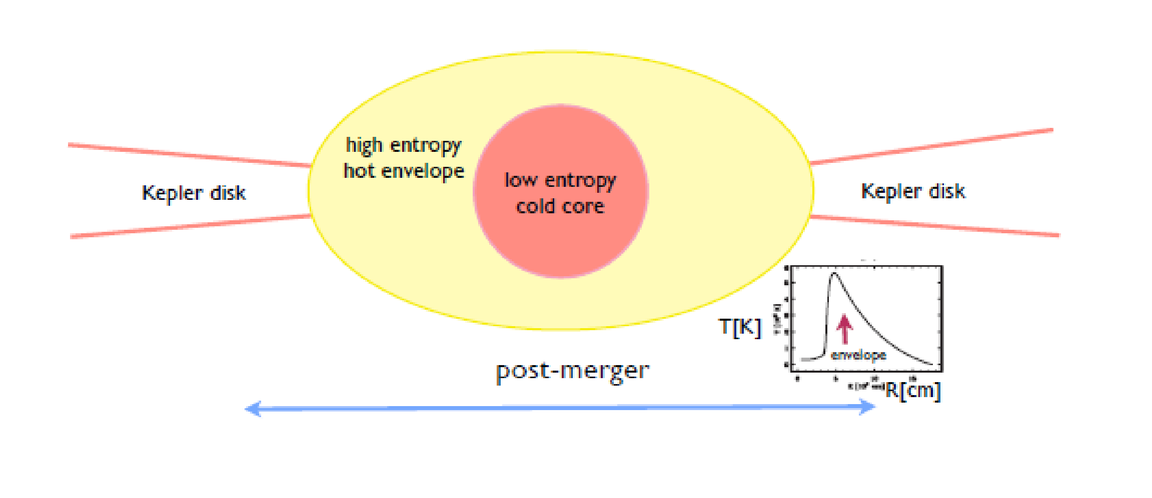
THE MERGING OF DOUBLE HELIUM WHITE DWARFS

Xianfei Zhang & C. Simon Jeffery

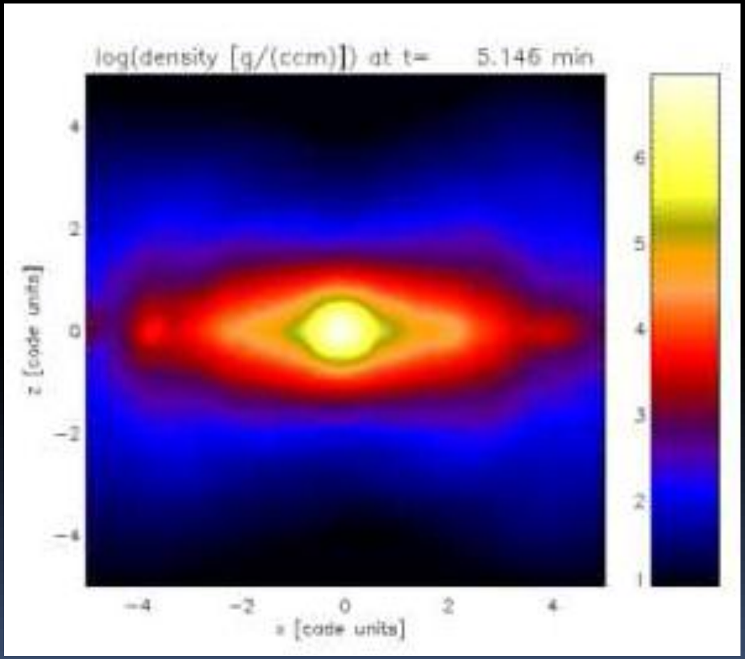
Armagh Observatory



SPH results

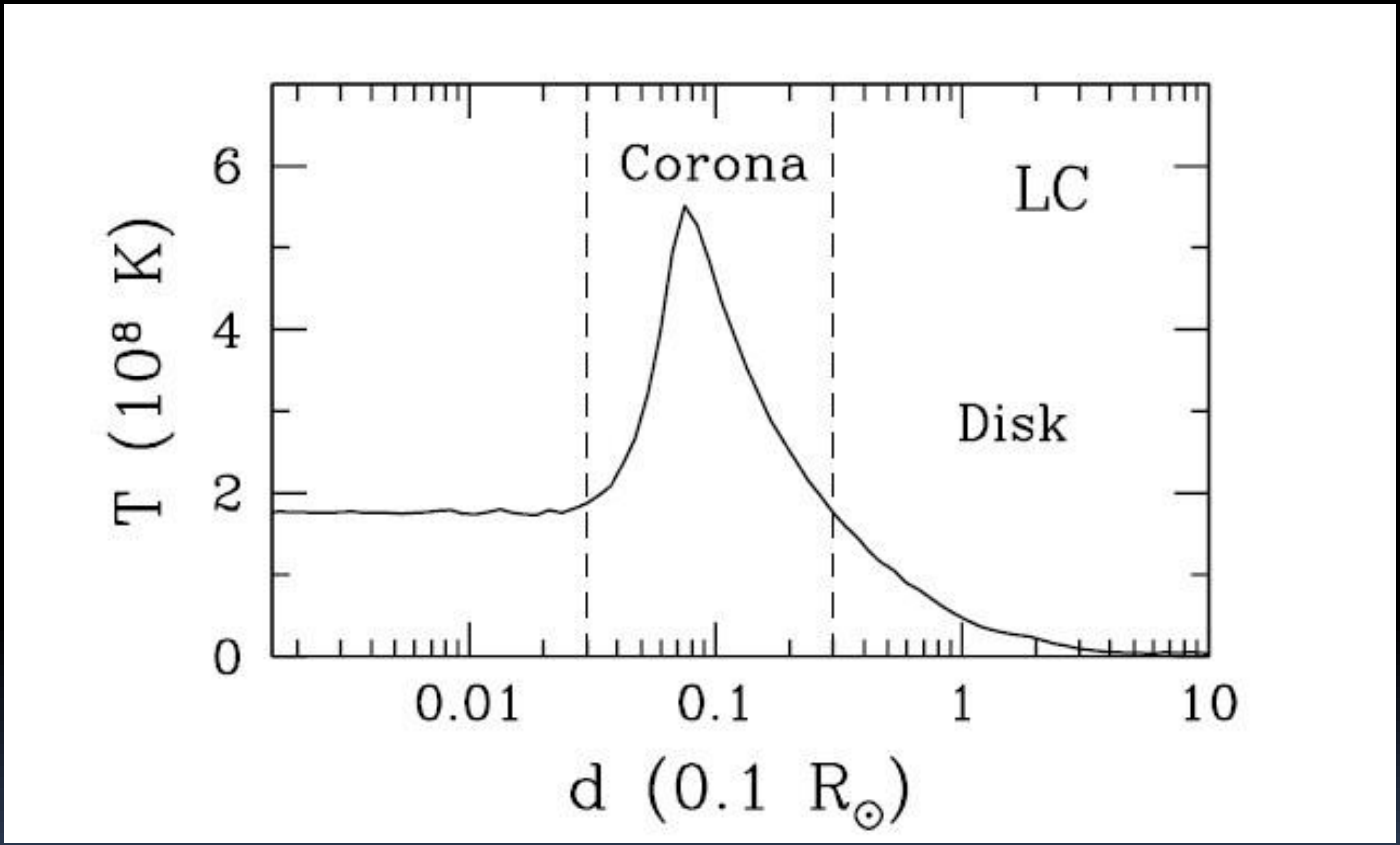


(1) the mass of the hot envelope contains about 30% ~50% of the mass of the secondary and the rest of the secondary forms the Keplerian disc.
(2)the maximum temperature in the hot envelope is about 10^8 K.
(3)the disc is thin.
(4) most of the nuclear reactions occur when the accretion stream hits the surface of the primary.
(5)the mass accretion rate from the Keplerian disc is possibly smaller than 5.0 $X10^{-6}$ Msun/yr.



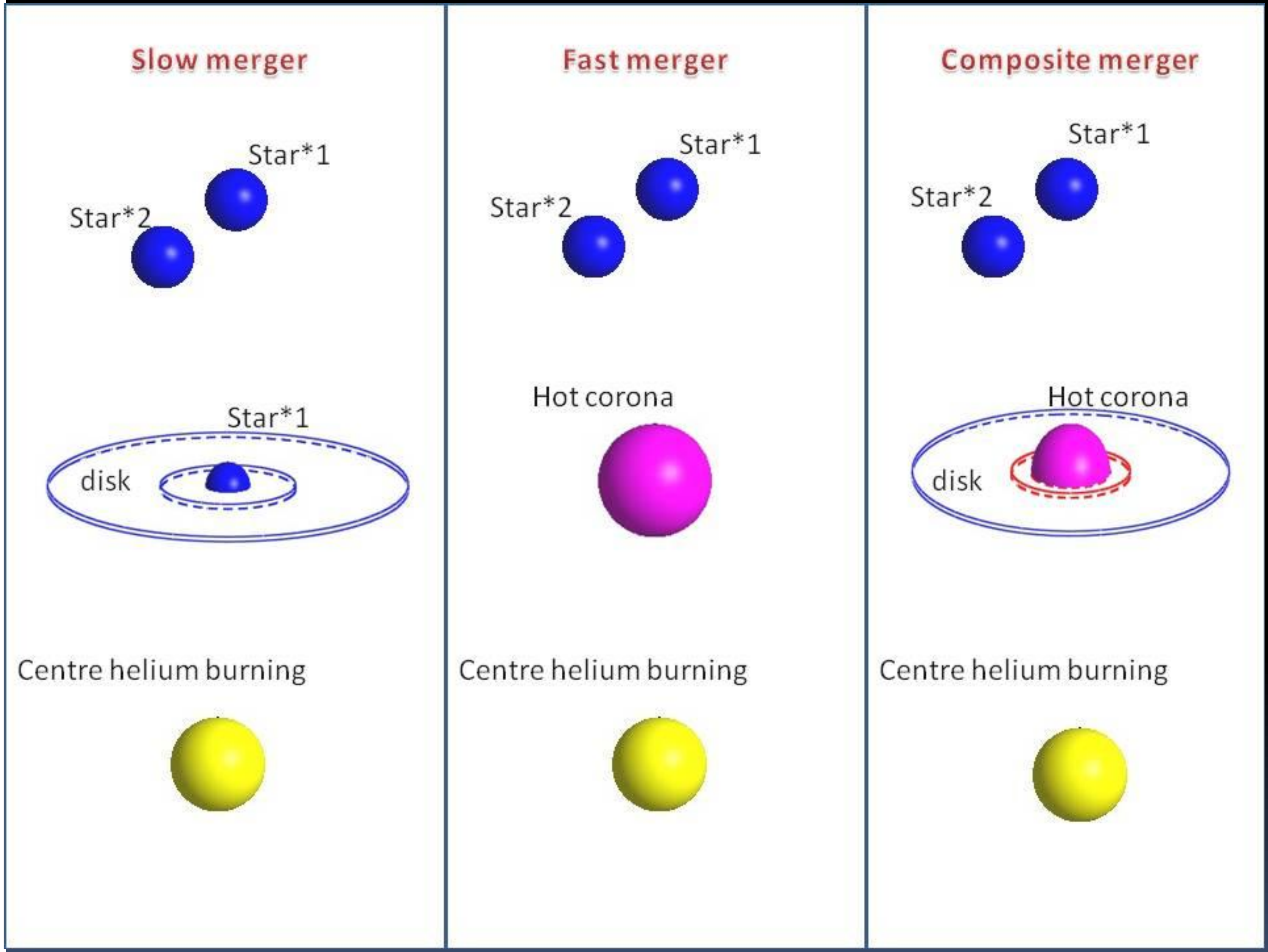
Yoon et al. 2007

Story of white dwarf merger



Lorén-Aguilar et al. 2009, 2010

Three possible ways



(1) Slow merger
(2) Fast merger
(3) Composite merger

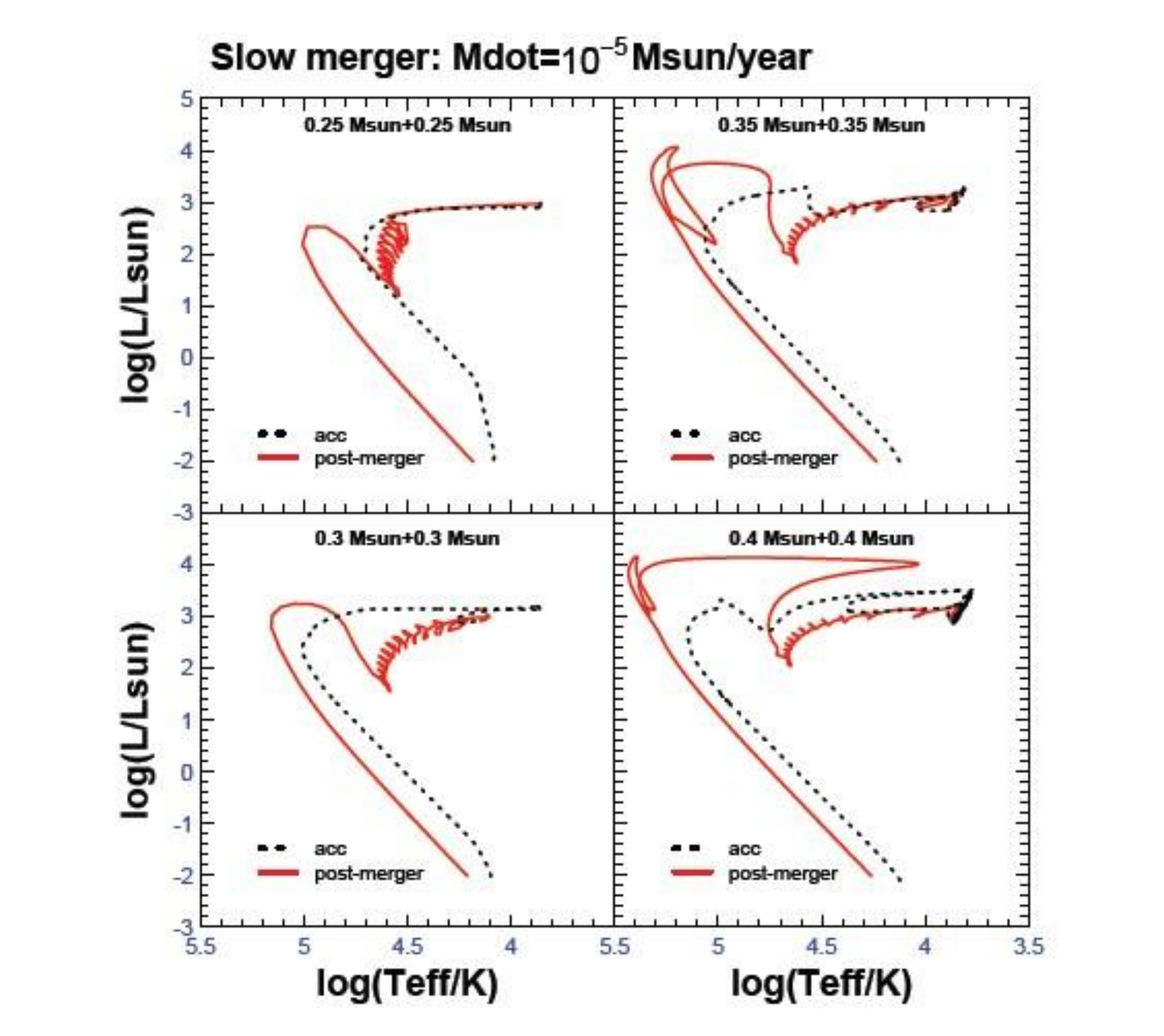
STEP one: 2.0 Msun ZAMS evolve to required core mass -> reduce mass to pre-WDs (naked helium core) -> cooling to WD

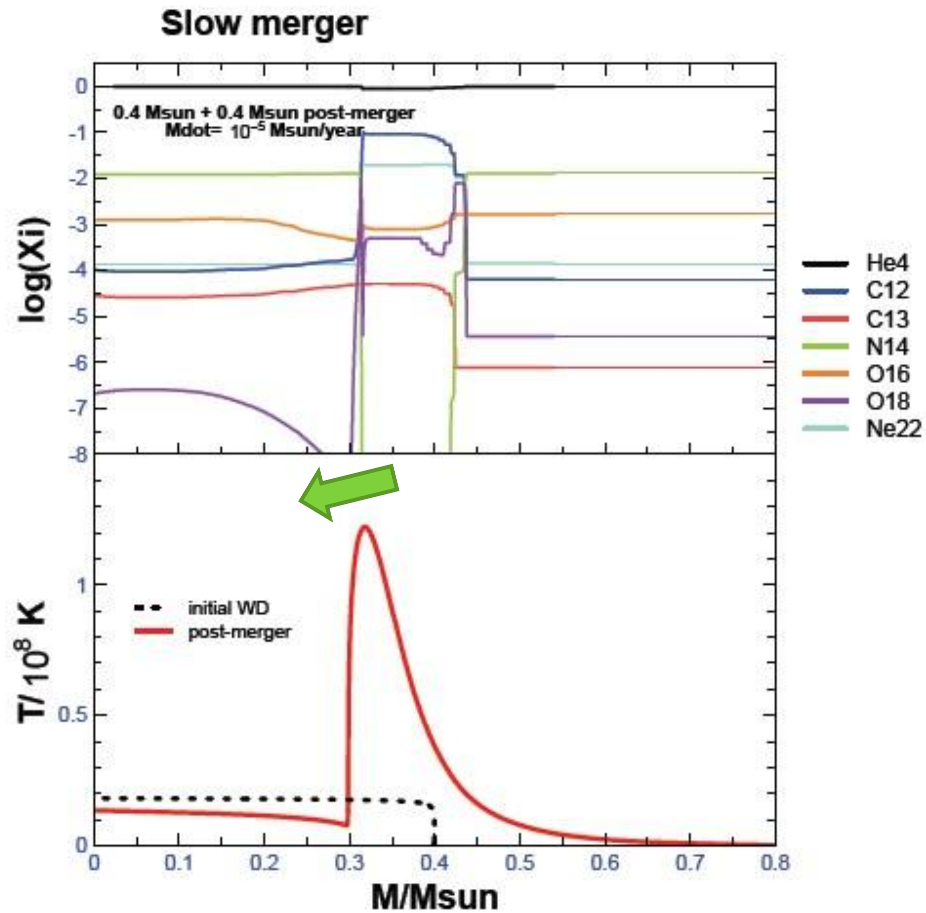
STEP two:

Initial models	0.25 WD	0.30WD	0.35WD	0.40WD
slow merger (10^-5 Msun/yr)	0.25 disk	0.30disk	0.35disk	0.40disk
fast merger (10^4 Msun/yr)	0.25 corona	0.3 corona	0.35 corona	0.40 corona
composite merger (mixed)	0.15 corona +0.1 disk	0.20 corona + 0.1 disk	0.25 corona + 0.1 disk	0.30 corona + 0.1 disk
final mass	0.50 Msun	0.60 Msun	0.70 Msun	0.80 Msun

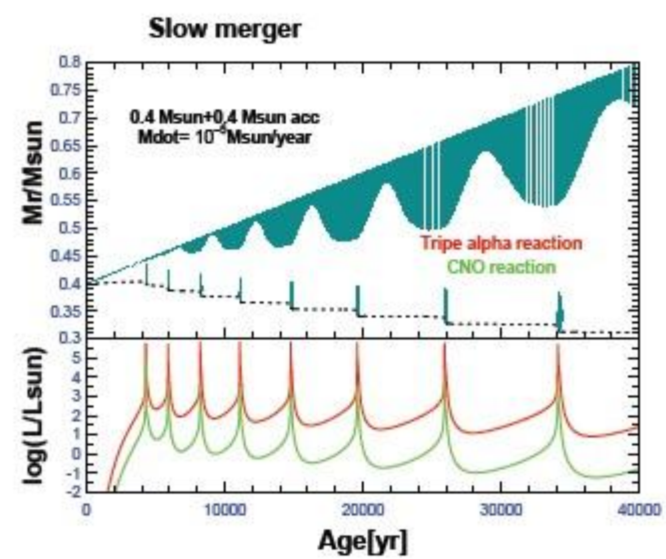
STEP three: evolve each models to WD again

(1)Slow merger

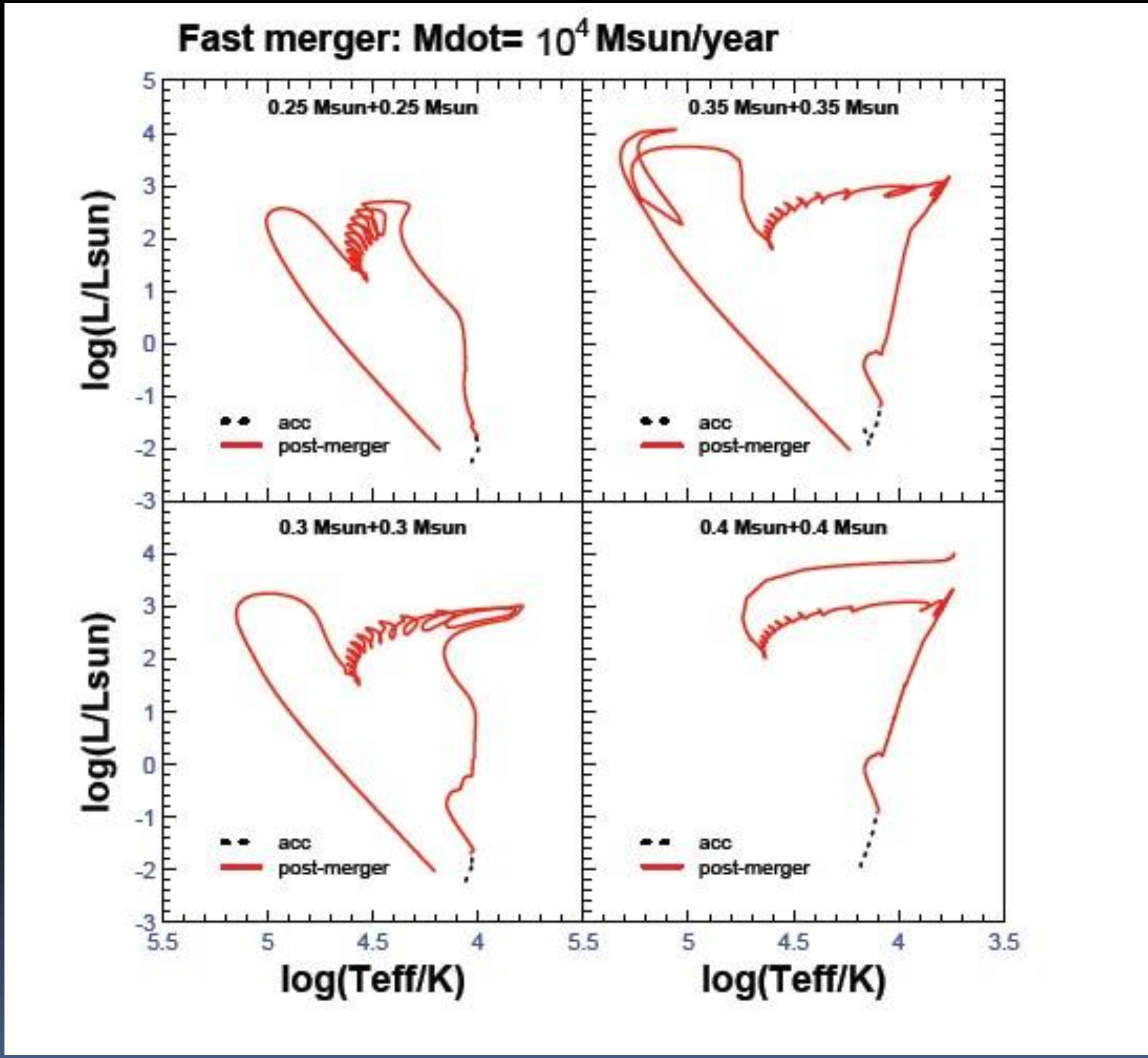


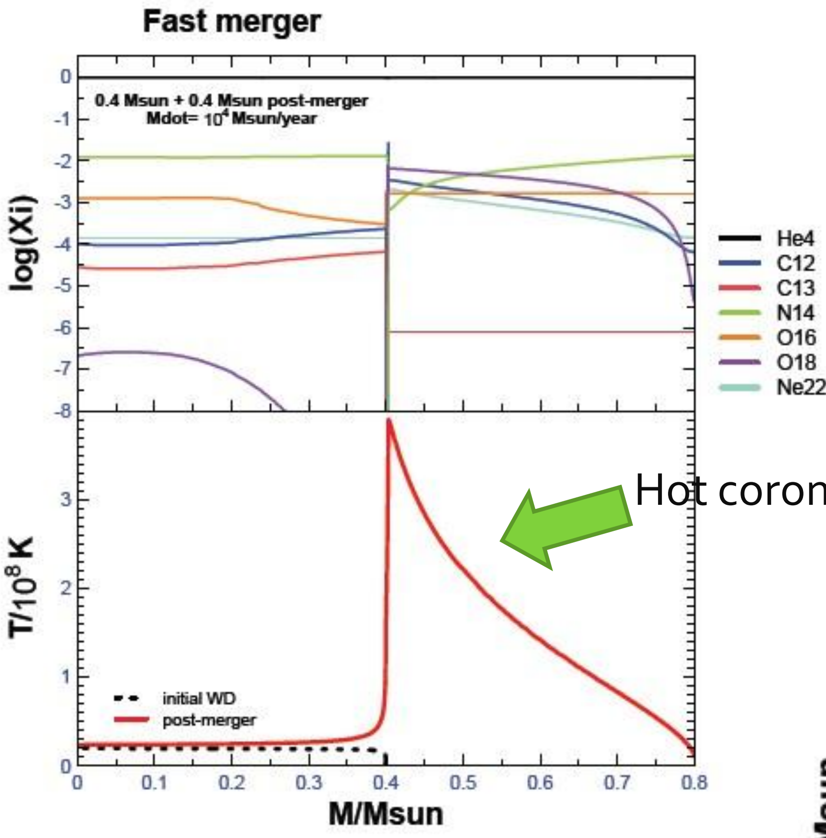

Slow merger
0.4 Msun + 0.4 Msun post-merger
Mdot= 10^-5 Msun/year
log(Xi)
He4
C12
C13
N14
O16
O18
Ne22
initial WD
post-merger
T/ 10^8 K
M/Msun

0.4 M_{sun}


Slow merger
0.4 Msun+0.4 Msun acc
Mdot= 10^-5 Msun/year
Mr/Msun
Tripe alpha reaction
CNO reaction
log(L/Lsun)
Age[yr]

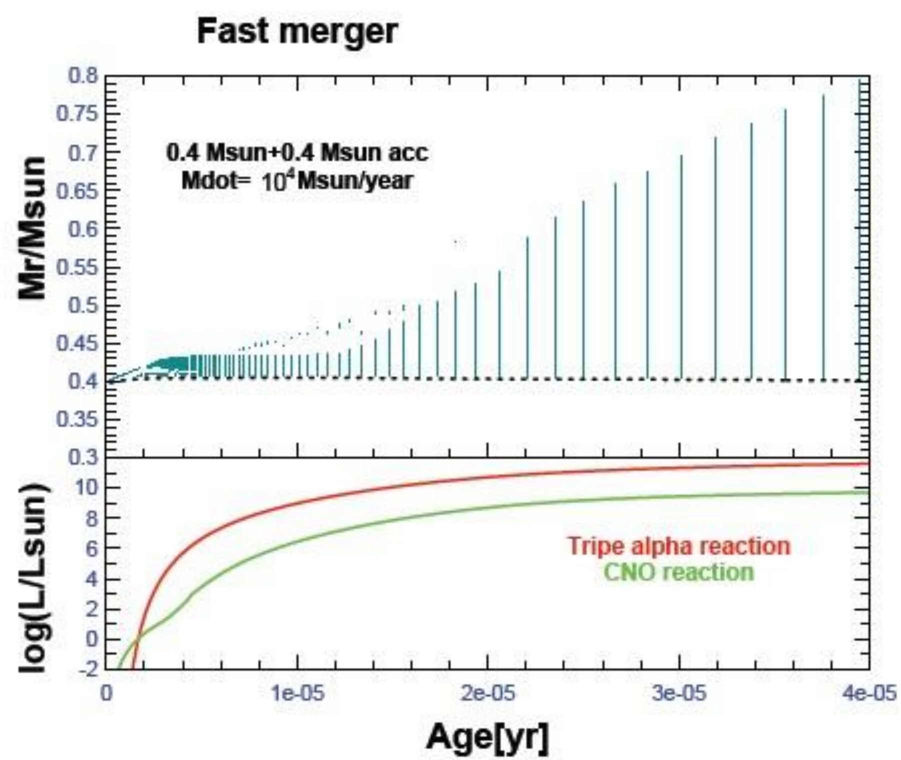
(2)Fast merger



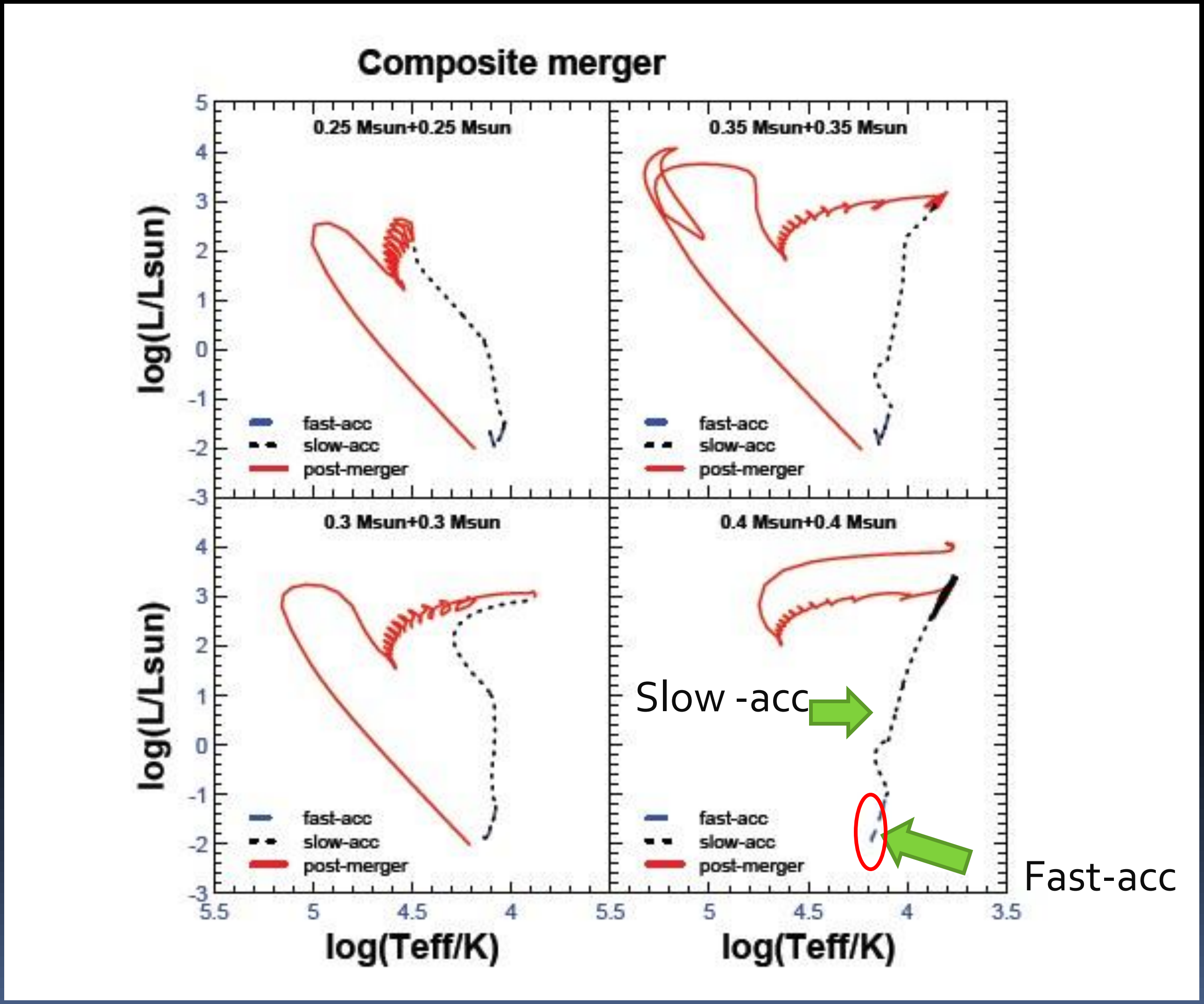


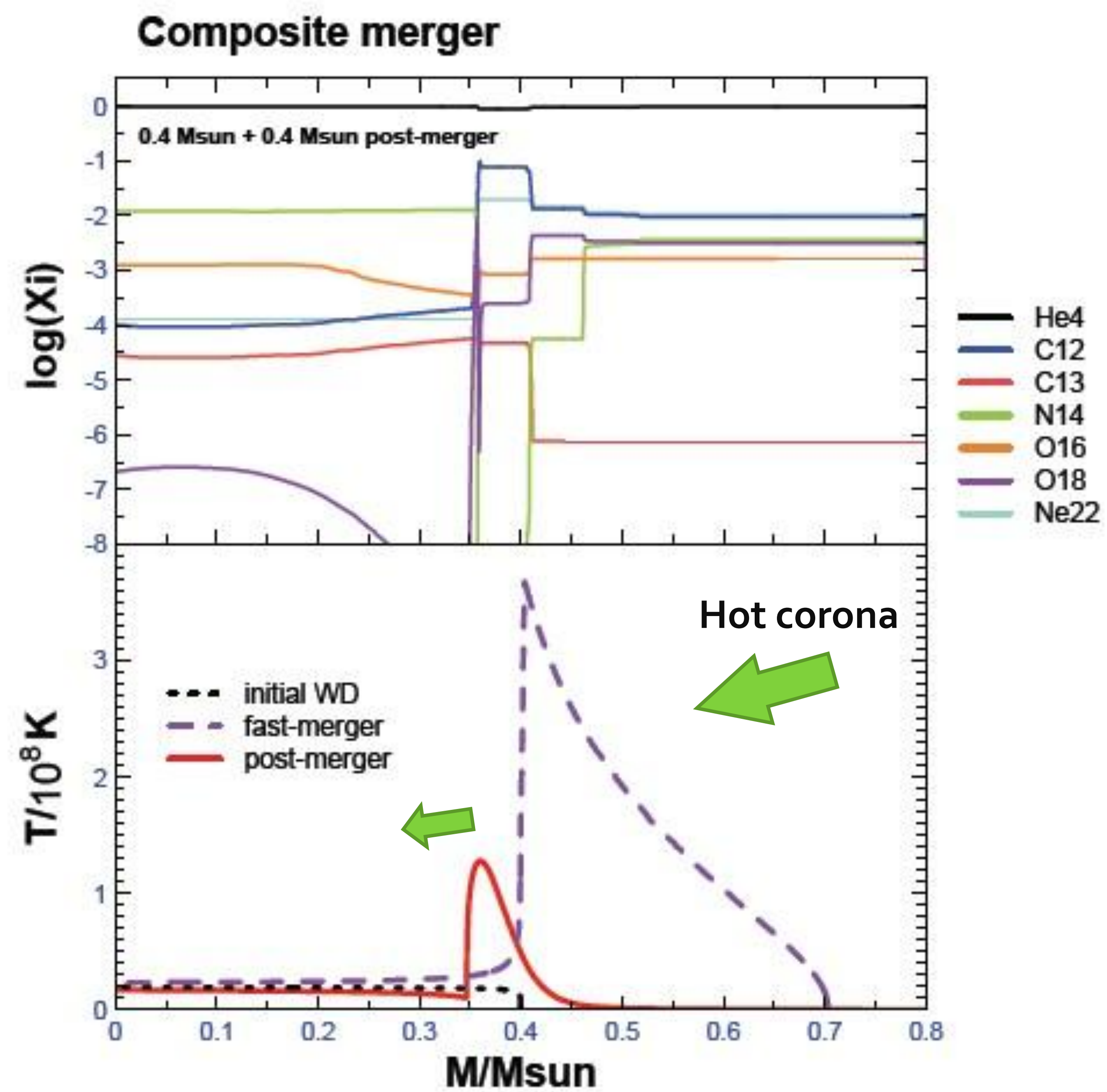
Hot corona

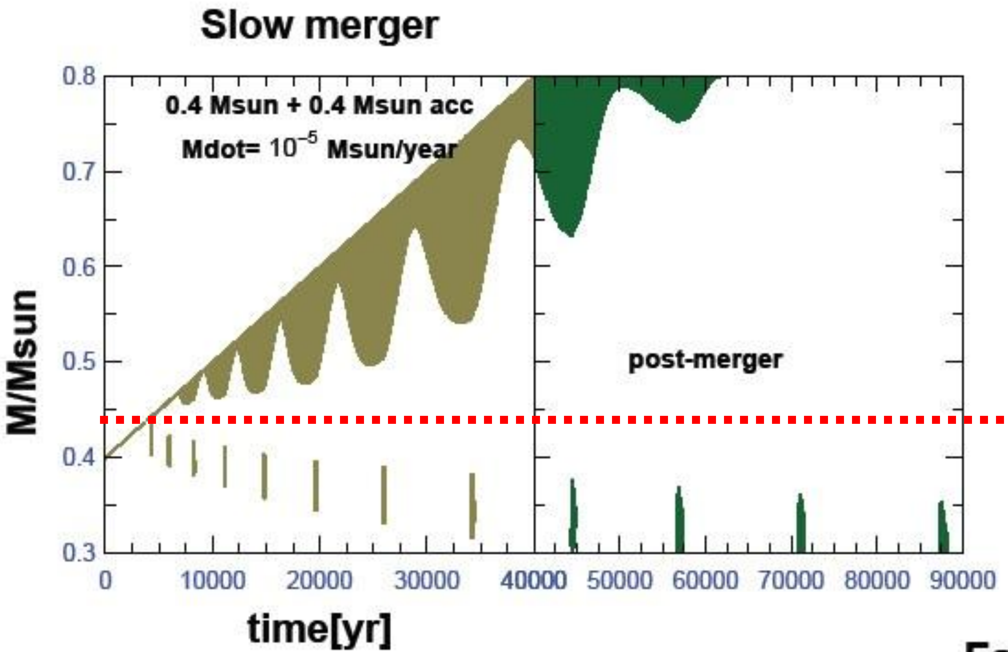
$0.4\ M_{sun}$



(3)Composite merger

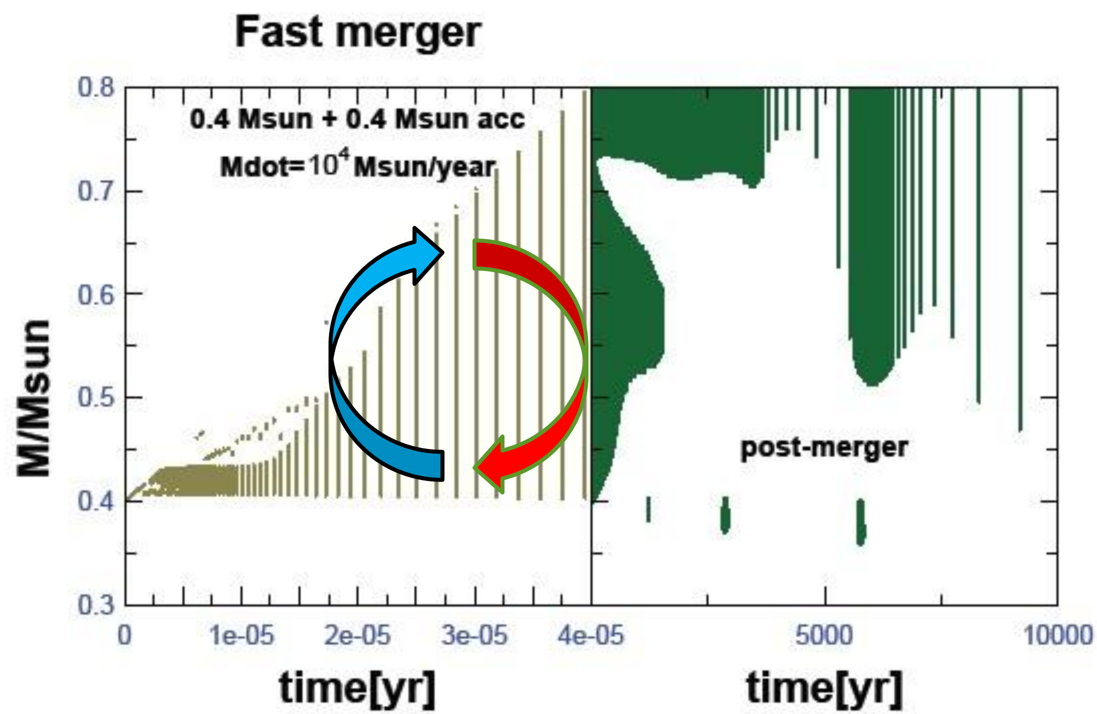



Composite merger
0.4 Msun + 0.4 Msun post-merger
log(Xi)
0
-1
-2
-3
-4
-5
-6
-7
-8
He4
C12
C13
N14
O16
O18
Ne22
Hot corona
initial WD
fast-merger
post-merger
$T/10^8K$
3
2
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
M/Msun

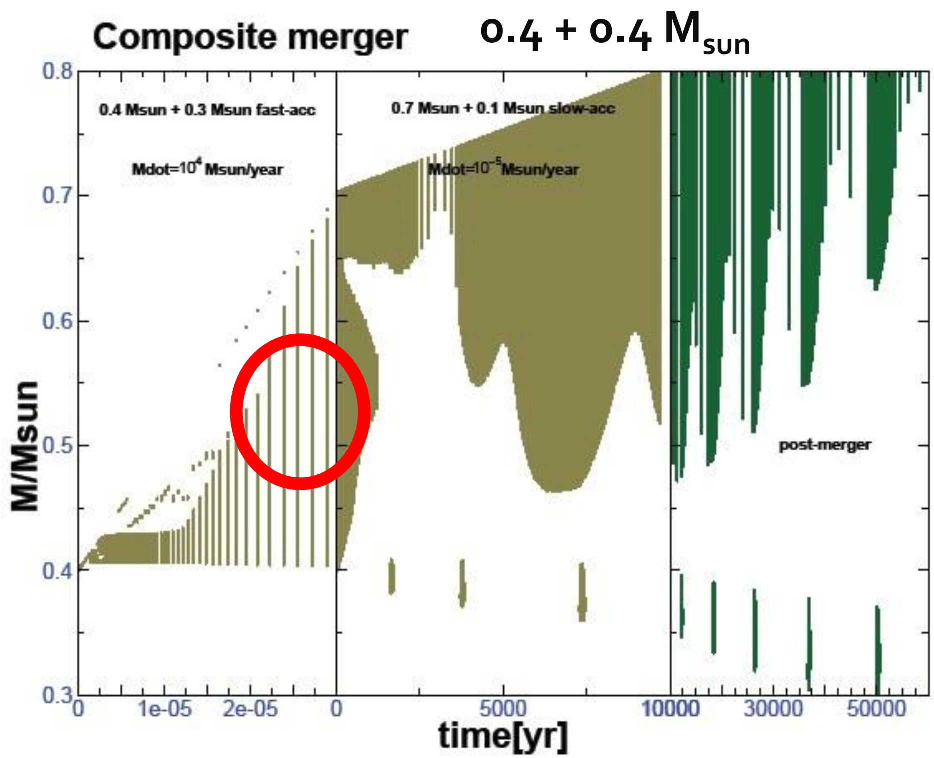


N-rich

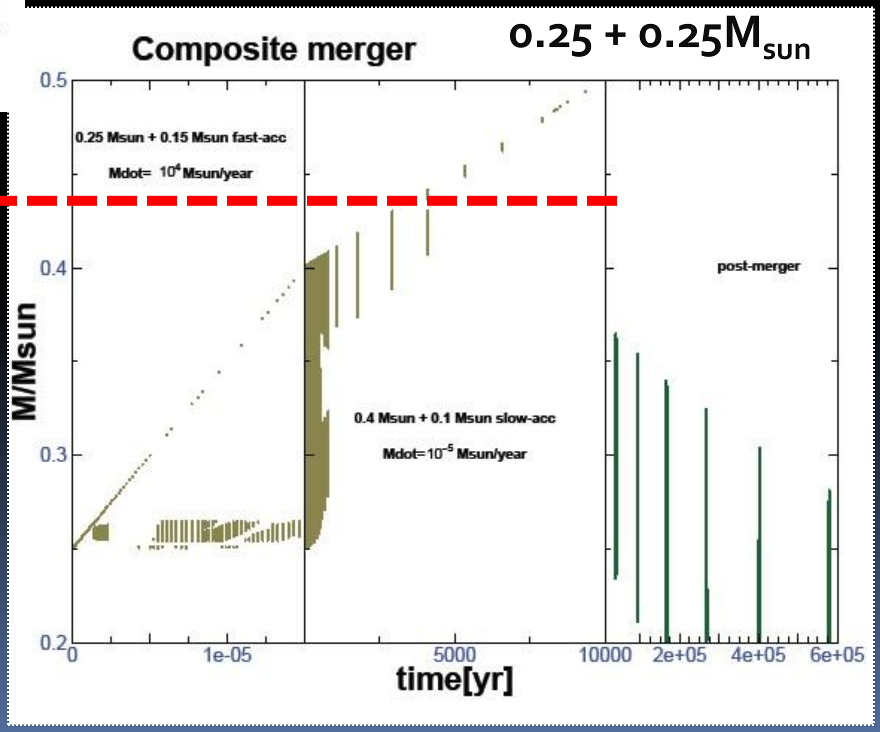
carbon



C-rich



C-rich



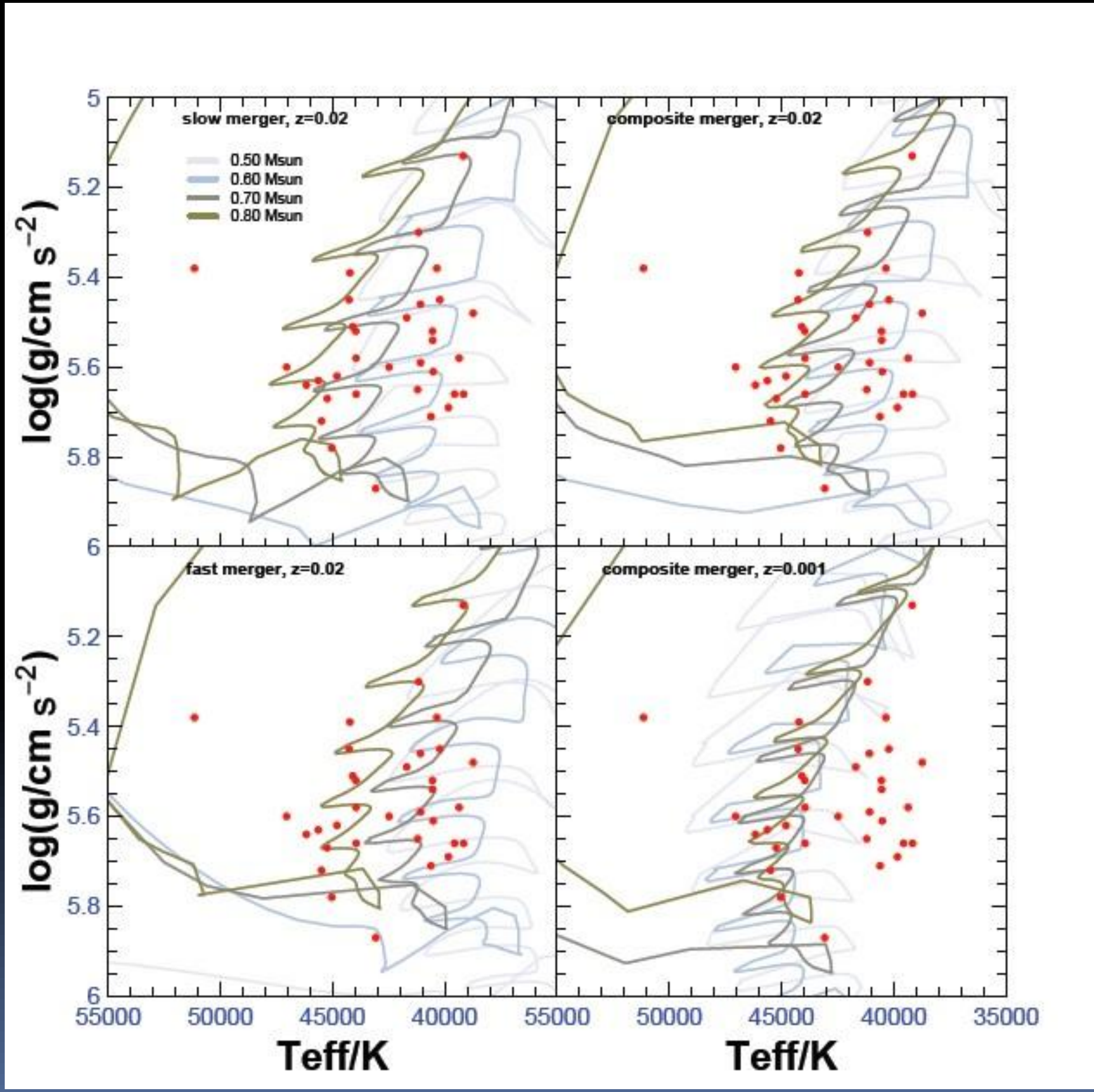
carbon

N-rich

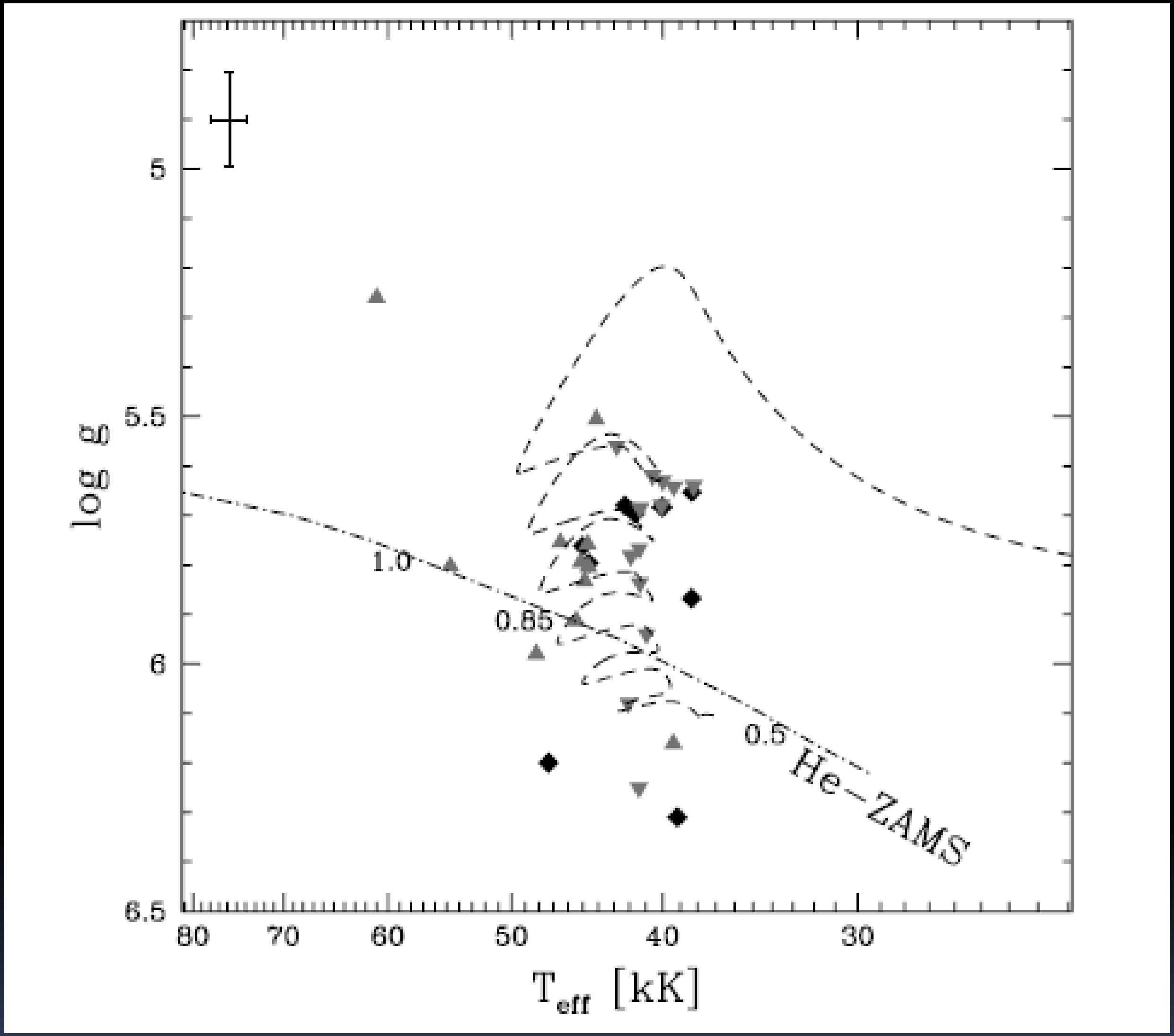
Observation

- 33 He-sdO (Hirsch et al. 2009)
- 6 He-sdB (Naslim et al. 2010)

log(g)-T_{eff}



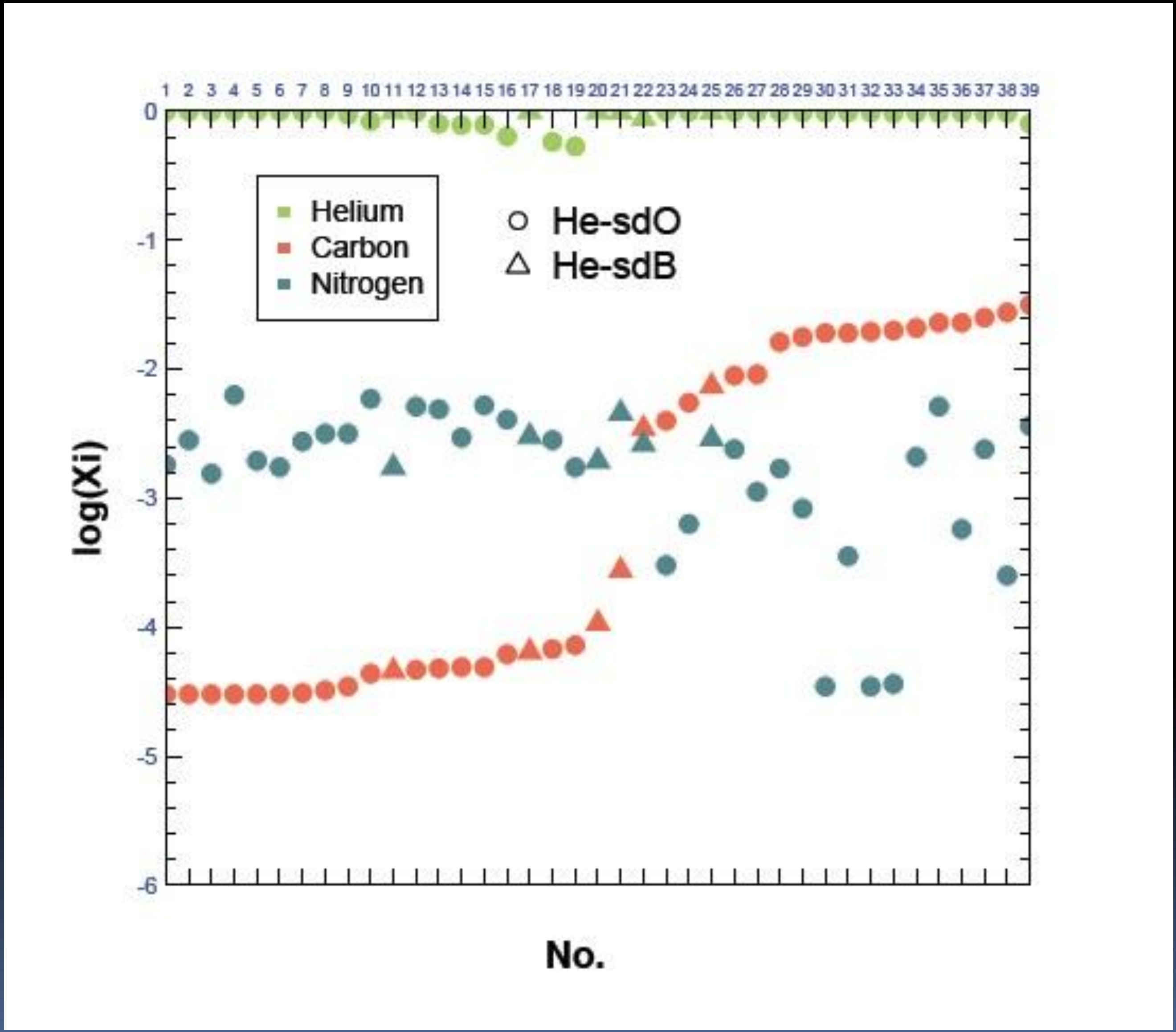
slow merger, z=0.02
0.50 Msun
0.60 Msun
0.70 Msun
0.80 Msun
composite merger, z=0.02
fast merger, z=0.02
composite merger, z=0.001
log(g/cm s^-2)
Teff/K
5
5.2
5.4
5.6
5.8
6
55000
50000
45000
40000
35000



Stroeer et al. 2007

Late Hot Flasher

Abundance of He-rich hot subdwarfs

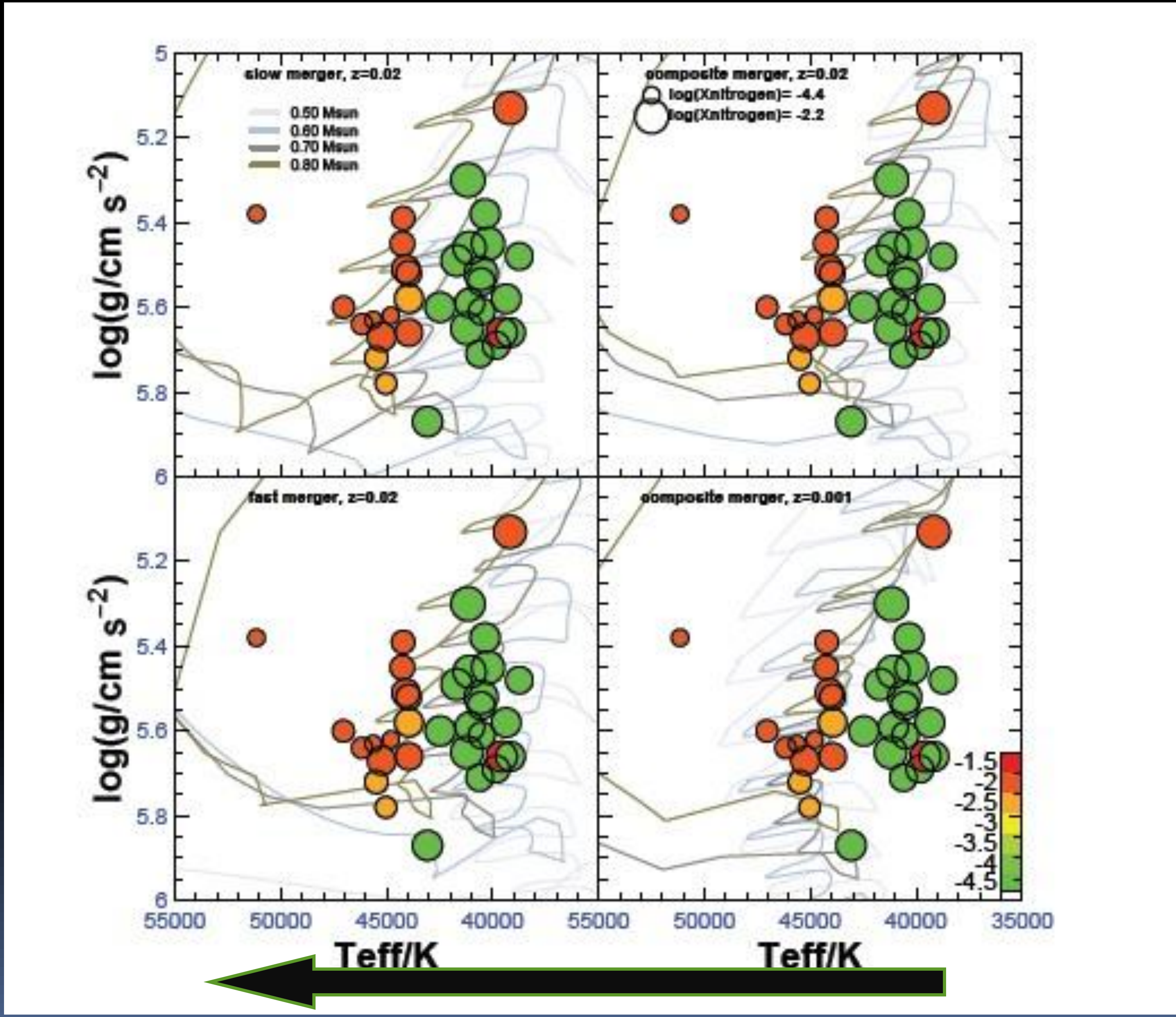


Final mass [$M_\odot$]	Z_0	H	He	^{12}C	^{13}C	N	O
0.49145 (SM*)	0.001	0.2137	0.7475	0.0365	1.57×10^{-6}	1.22×10^{-4}	1.52×10^{-3}
0.49104 (DM)	0.001	2.42×10^{-4}	0.9450	0.0267	7.47×10^{-3}	0.0106	4.77×10^{-5}
0.48545 (DM)	0.001	4.60×10^{-6}	0.9524	0.0264	7.73×10^{-3}	0.0134	4.53×10^{-5}
0.48150 (DM)	0.001	2.41×10^{-6}	0.9666	0.0107	5.79×10^{-3}	0.0185	3.79×10^{-5}
0.47770 (SM)	0.01	0.0780	0.8682	0.0426	6.26×10^{-6}	1.30×10^{-3}	6.84×10^{-4}
0.47744 (SM*)	0.01	0.0261	0.8996	0.0642	2.36×10^{-6}	6.59×10^{-4}	7.43×10^{-4}
0.47725 (DM)	0.01	2.27×10^{-5}	0.9464	0.0382	6.12×10^{-3}	4.35×10^{-3}	2.94×10^{-4}
0.46921 (DM)	0.01	1.02×10^{-5}	0.9560	0.0211	6.13×10^{-3}	0.0128	2.92×10^{-4}
0.46644 (DM)	0.01	4.61×10^{-6}	0.9592	0.0193	5.52×10^{-3}	0.0122	3.16×10^{-4}
0.47378 (SM)	0.02	0.3822	0.5978	1.23×10^{-3}	8.96×10^{-5}	7.57×10^{-3}	4.69×10^{-3}
0.47250 (SM*)	0.02	9.56×10^{-3}	0.9273	0.0425	1.93×10^{-5}	2.94×10^{-3}	8.64×10^{-4}
0.47112 (DM)	0.02	9.05×10^{-6}	0.9389	0.0420	4.27×10^{-3}	4.88×10^{-3}	6.96×10^{-4}
0.46410 (DM)	0.02	1.05×10^{-5}	0.9460	0.0273	6.41×10^{-3}	0.0120	7.680×10^{-4}
0.46150 (DM)	0.02	4.66×10^{-6}	0.9480	0.0263	5.67×10^{-3}	0.0116	1.01×10^{-3}
0.46521 (SM)	0.03	0.2227	0.7271	0.0197	7.79×10^{-5}	8.09×10^{-3}	5.18×10^{-3}
0.46470 (SM)	0.03	4.71×10^{-3}	0.9239	0.0380	4.12×10^{-4}	6.10×10^{-3}	1.58×10^{-3}
0.46367 (SM*)	0.03	1.63×10^{-3}	0.9249	0.0390	3.25×10^{-3}	6.48×10^{-3}	1.62×10^{-3}
0.46282 (DM)	0.03	7.48×10^{-6}	0.9333	0.0420	1.74×10^{-3}	7.04×10^{-3}	1.55×10^{-3}
0.45660 (DM)	0.03	9.22×10^{-6}	0.9382	0.0341	4.09×10^{-3}	0.0103	1.67×10^{-3}
0.45234 (DM)	0.03	1.94×10^{-5}	0.9411	0.0273	4.76×10^{-3}	0.0134	2.14×10^{-3}

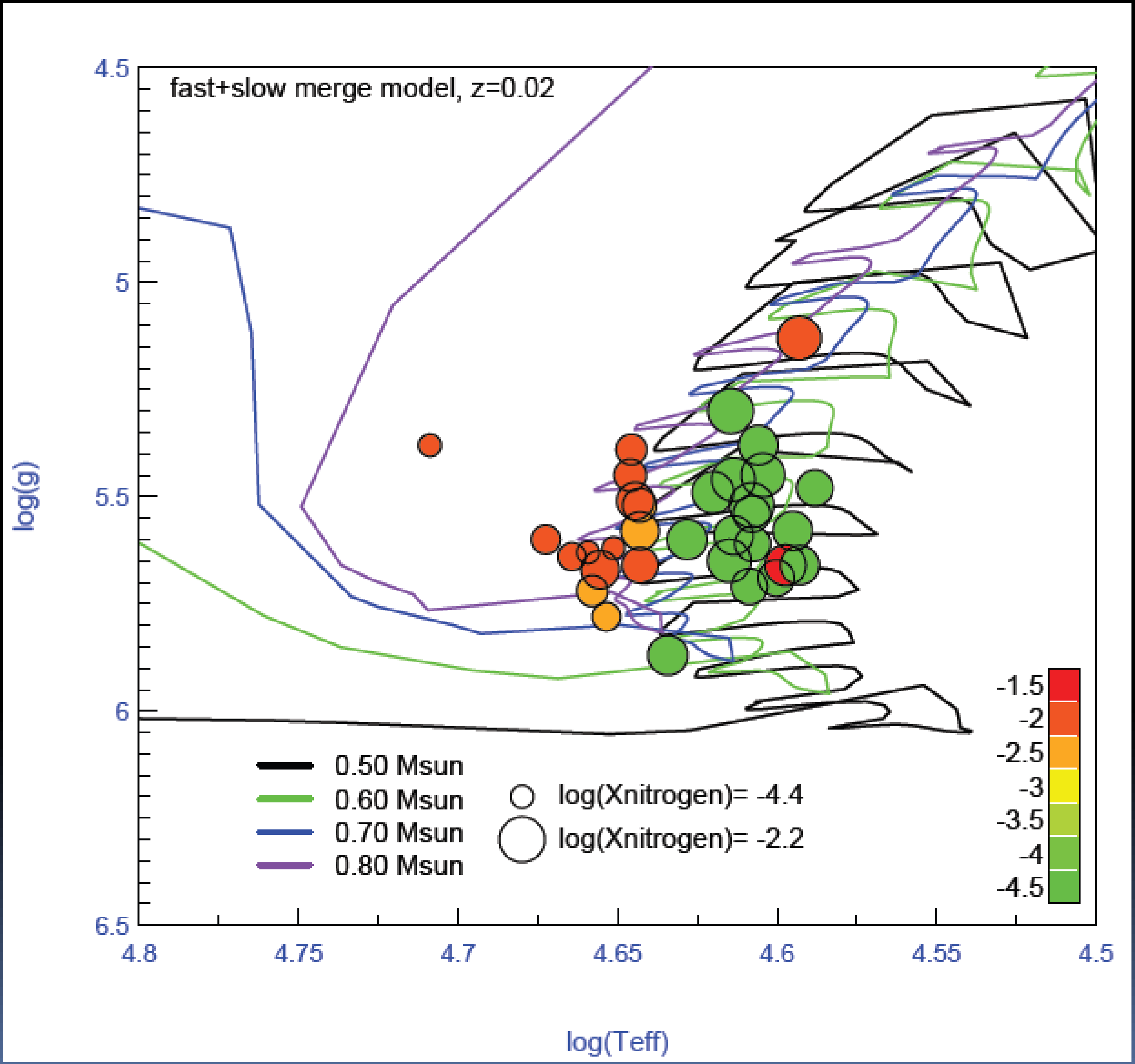
C-rich

Miller-Bertolami, 2008

log(g)-T_{eff}



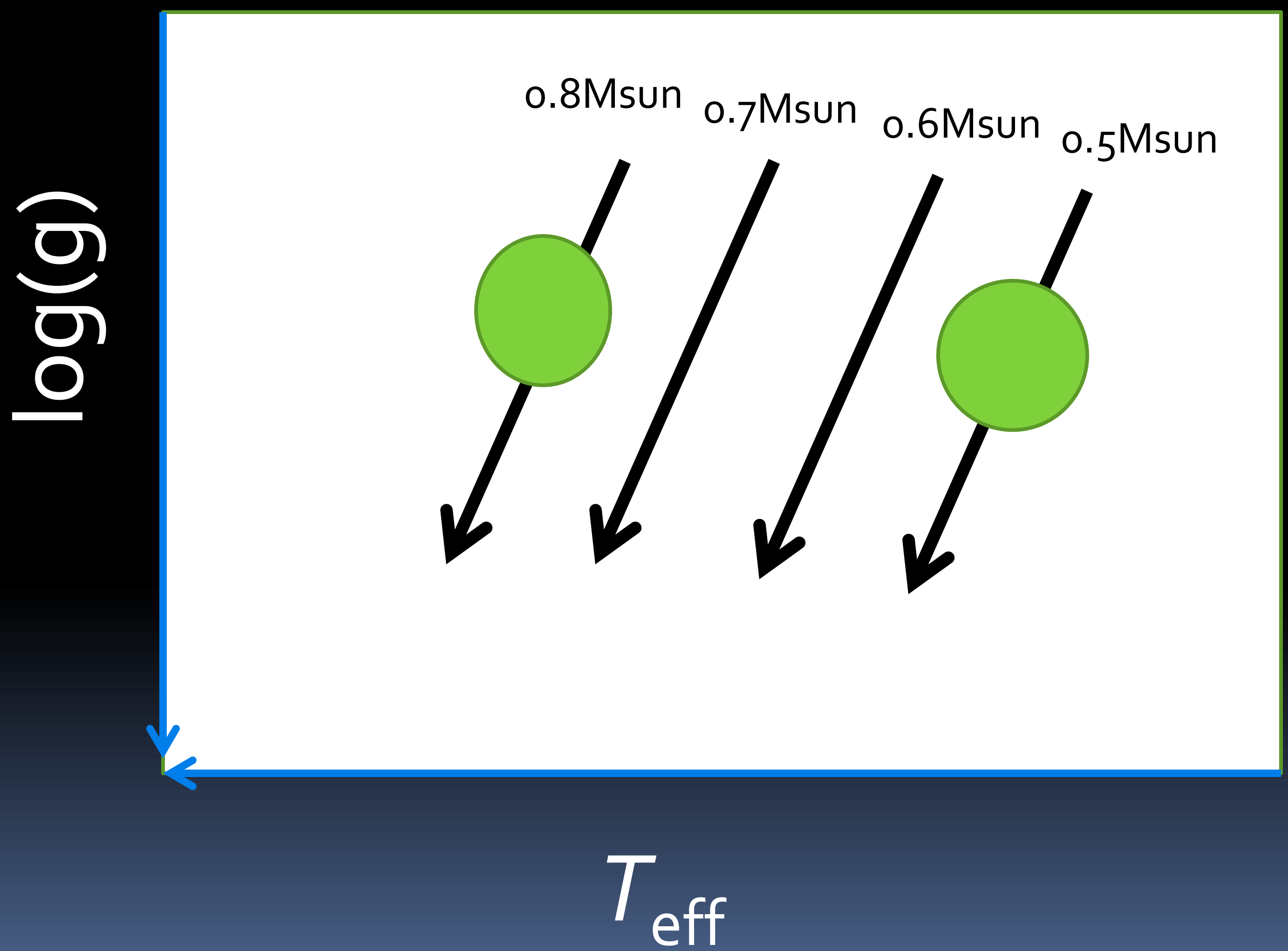
slow merger, z=0.02
0.50 Msun
0.60 Msun
0.70 Msun
0.80 Msun
composite merger, z=0.02
log(Xnitrogen)= -4.4
log(Xnitrogen)= -2.2
fast merger, z=0.02
composite merger, z=0.001
log(g/cm s^-2)
Teff/K



fast+slow merge model, z=0.02
log(g)
log(Teff)
4.5
5
5.5
6
6.5
4.8
4.75
4.7
4.65
4.6
4.55
4.5
0.50 Msun
0.60 Msun
0.70 Msun
0.80 Msun
log(Xnitrogen)= -4.4
log(Xnitrogen)= -2.2
-1.5
-2
-2.5
-3
-3.5
-4
-4.5

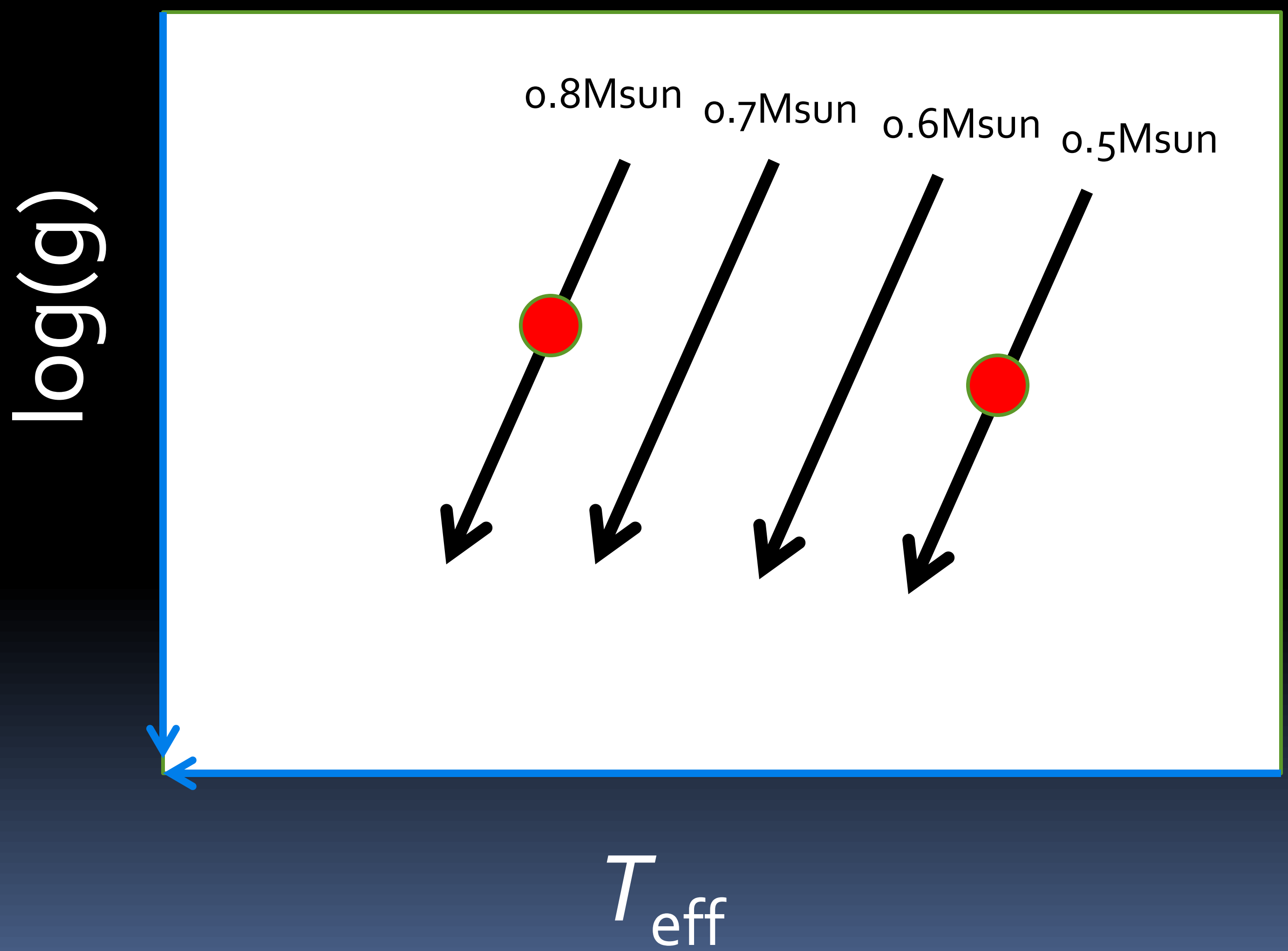
log(g)-T_{eff}

(1)Slow merger: N-rich



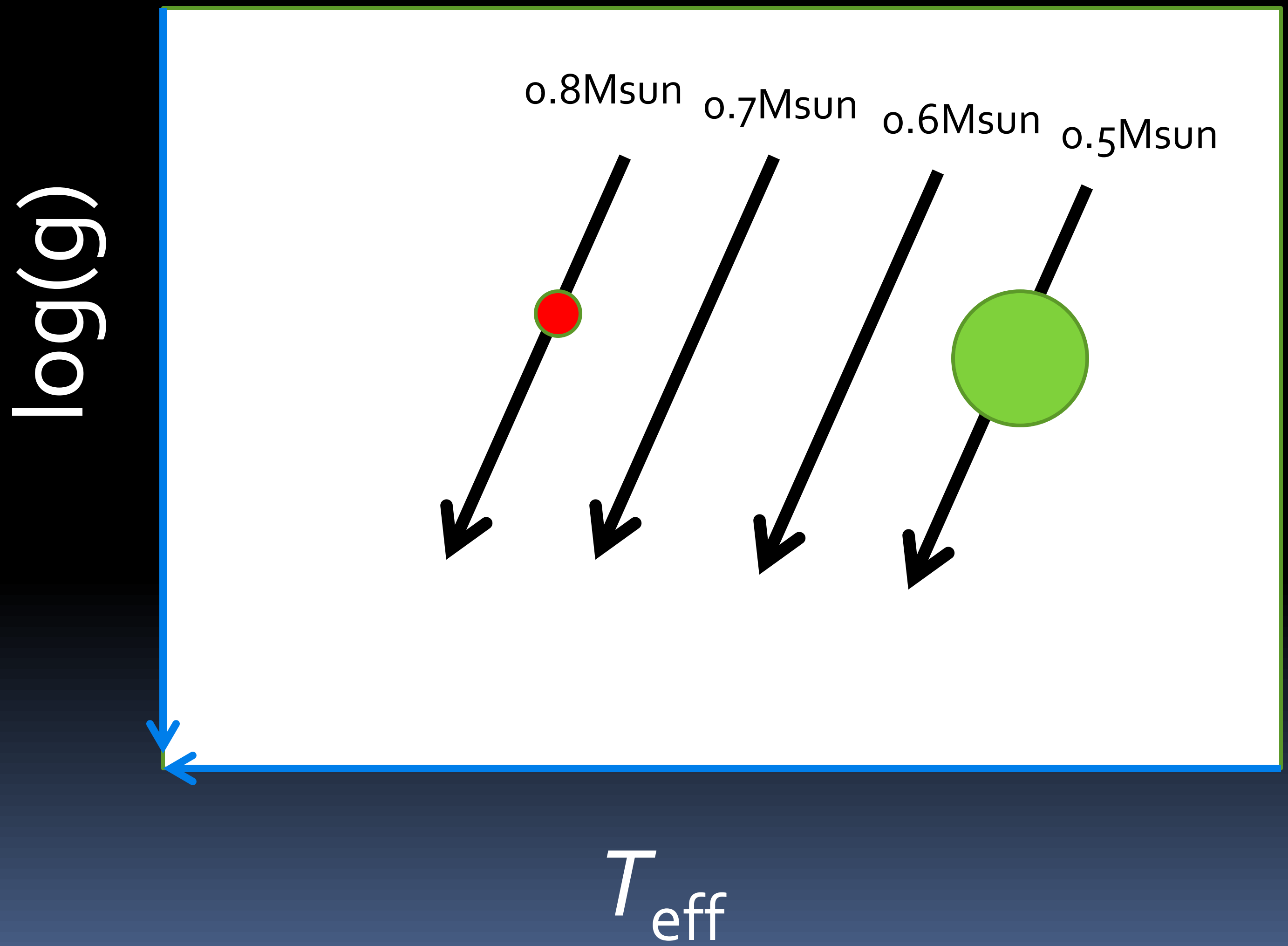
log(g)-T_{eff}

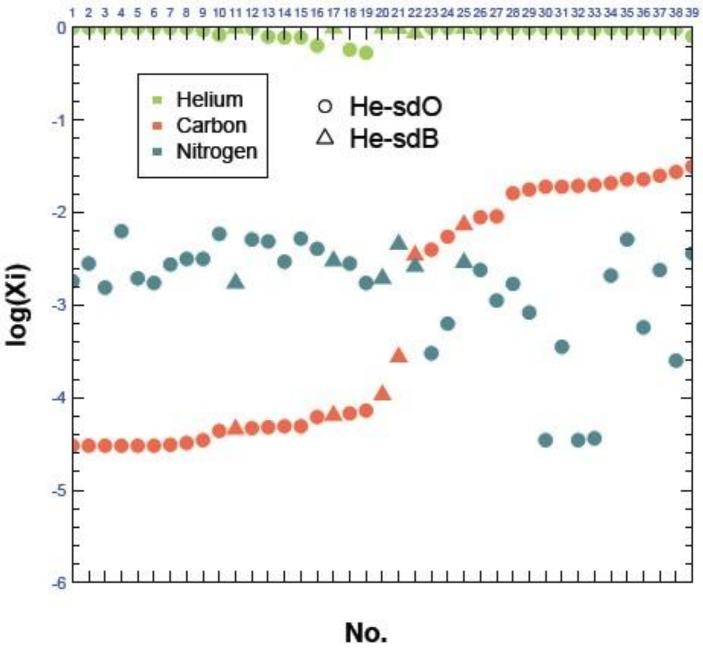
(2)Fast merger: C-rich

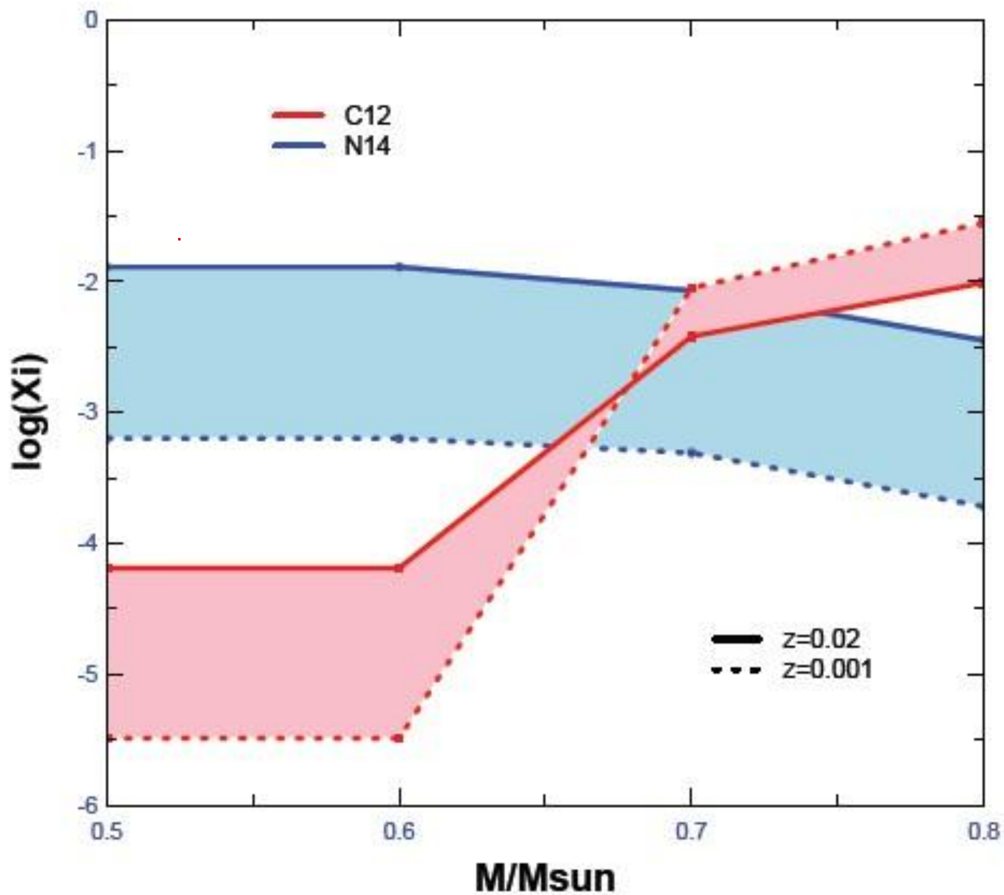


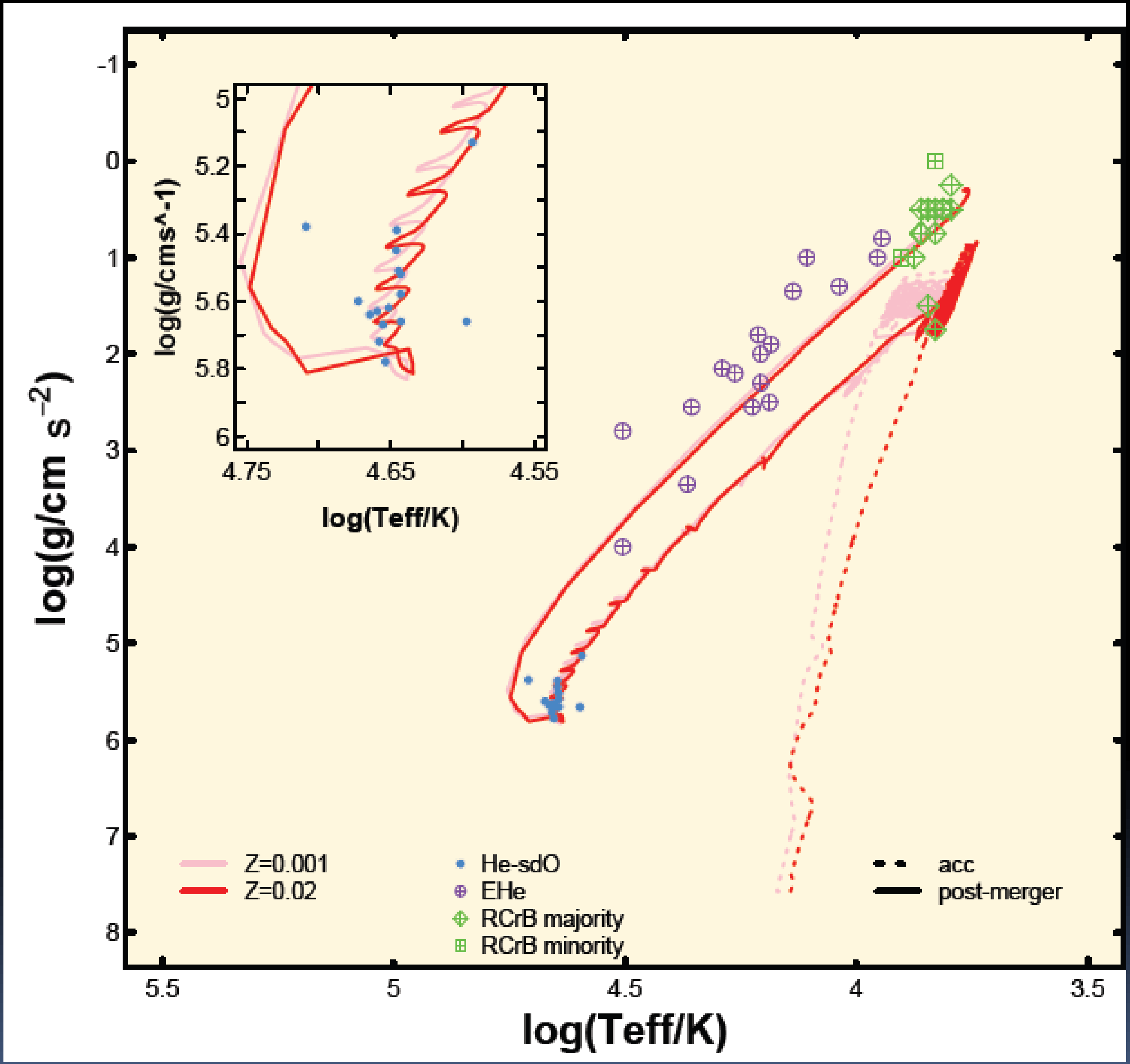
log(g)-T_{eff}

3)Composite merger:
N-rich to C-rich depends on mass

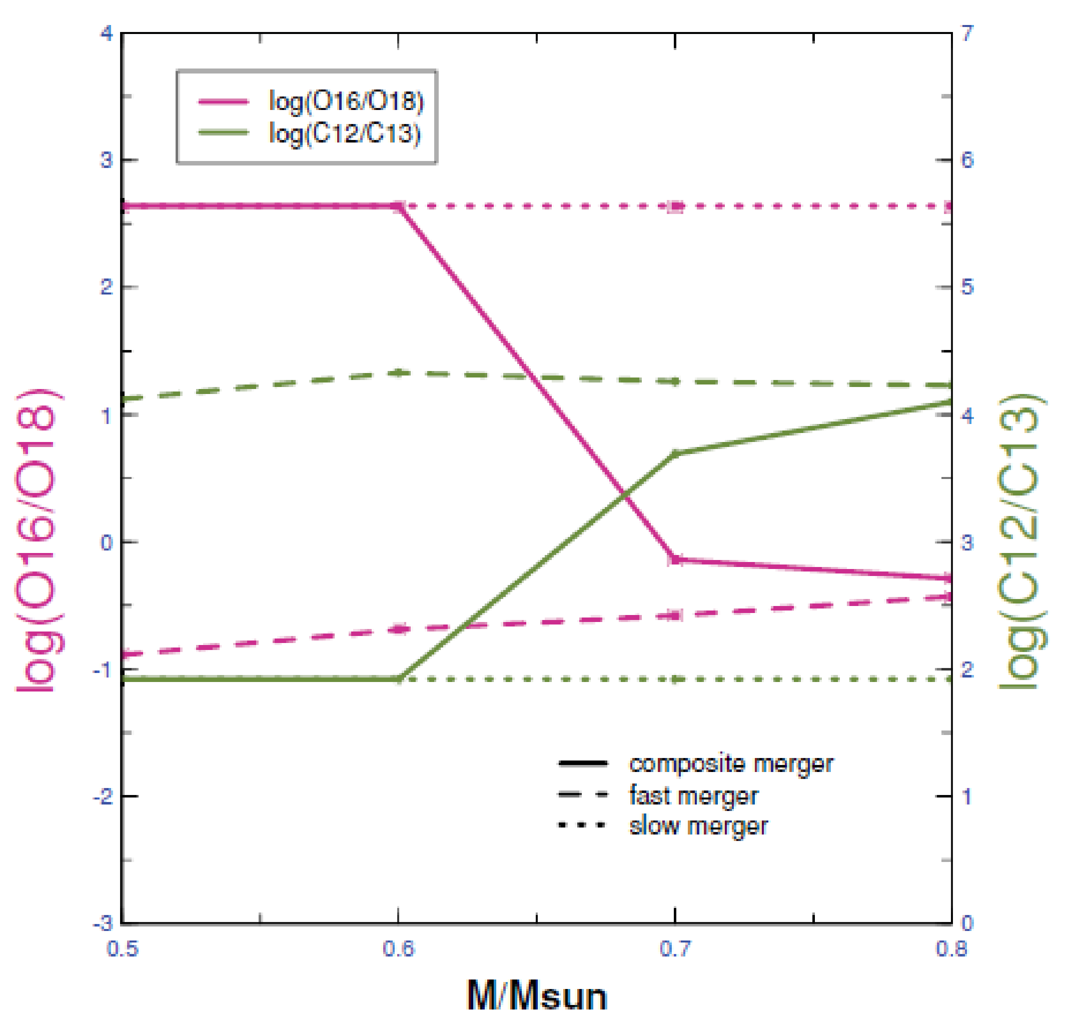



Helium
Carbon
Nitrogen
He-sdO
He-sdB
log(Xi)
No.


C12
N14
z=0.02
z=0.001
log(Xi)
M/Msun



He-rich hot subdwarf -> EHe star -> RCrB star



Sun:

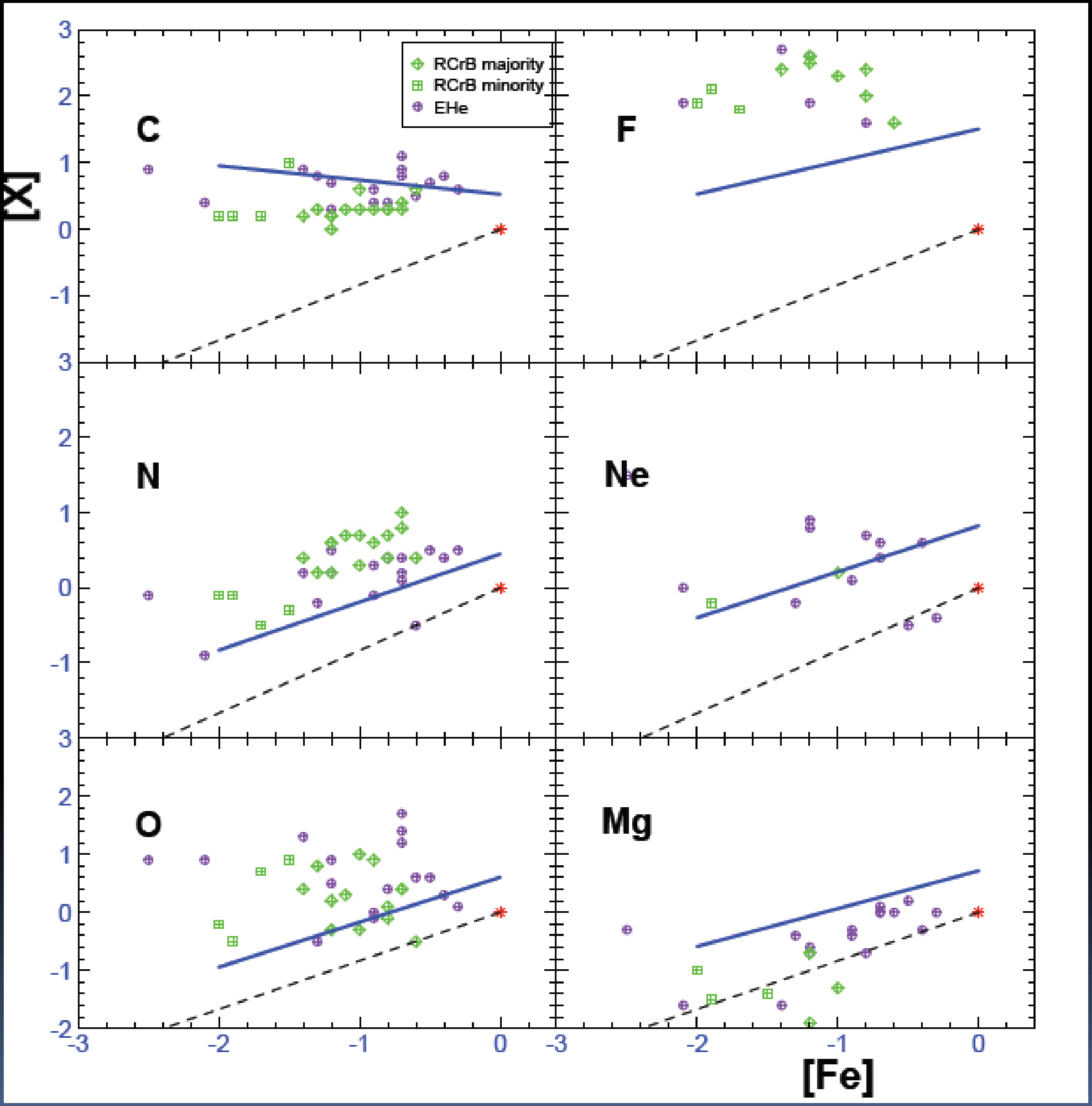
$^{16}O/^{18}O$ ~500

$^{12}C/^{13}C$~90

RCrB:

$^{16}O/^{18}O$ ~1

$^{12}C/^{13}C$~500


RCrB majority
RCrB minority
EHe
C
F
N
Ne
O
Mg
[X]
[Fe]
3
2
1
0
-1
-2
-3
-2
-1
0

Conclusion

- Three possible ways: slow merger, fast merger and composite merger.
- Composite merger model can reproduce the observed distribution of helium-rich hot subdwarfs.
- Nitrogen-rich star $M<0.65\ M_{sun}$
- Carbon-rich star $M>0.65\ M_{sun}$
- He-rich hot subdwarf -> EHe star -> RCrB star

Thank you