High mass X-ray binaries

Martin Quast

Argelander Institut für Astronomie

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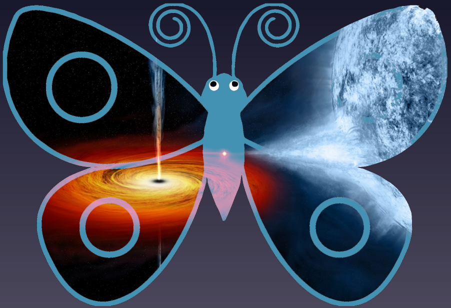
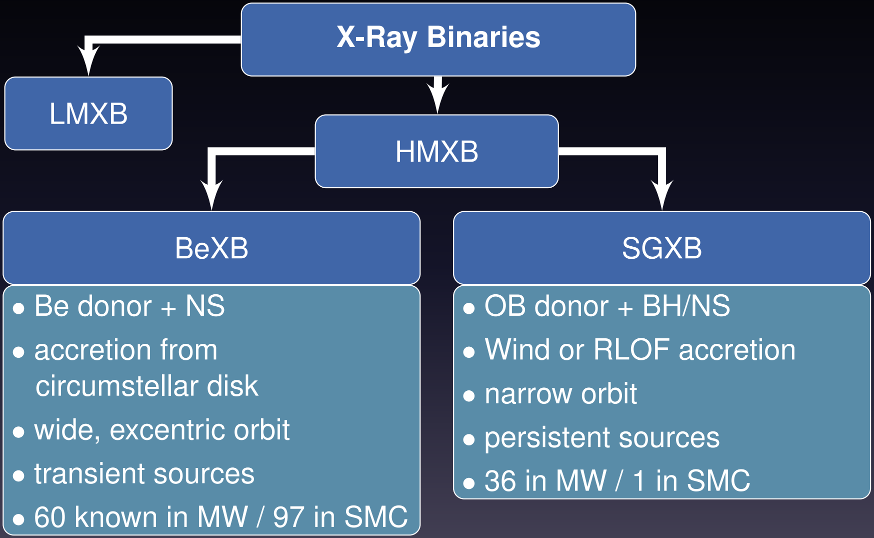


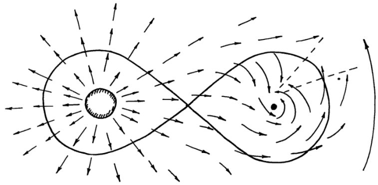
X-ray binaries

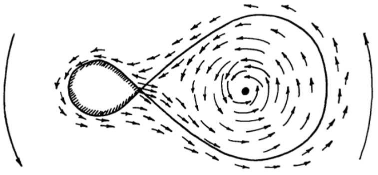


(Walter 2015; Haberl & Sturm 2015)

Mass transfer in SGXB

Wind or Roche? That is the question!





Bondi-Hoyle model:

Accretion radius (by energy)

Accreted fraction by geom. cross section

$$\dot{M}_{acc} = \frac{G^2 M_A^2}{a^2 v_w^4} \dot{M}_w$$

(Bondi 1952)

Roche lobe: $\Phi = \Phi(L_1)$

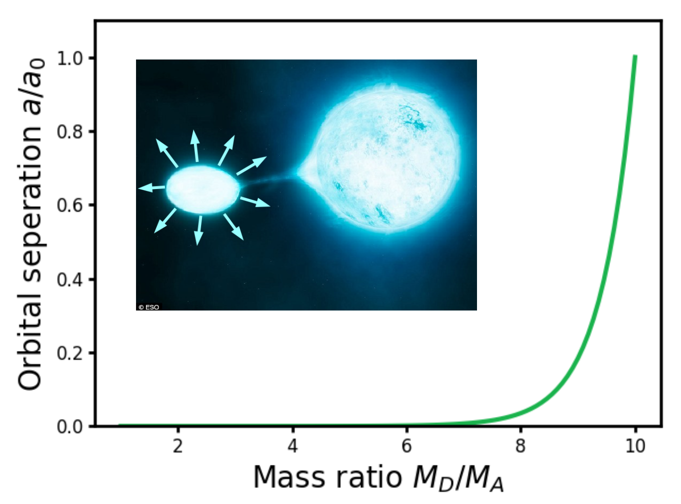
$\approx$ sphere with R_L

$$R_L = f(q) \times a$$
$$q = M_D / M_A$$

(cf.Eggleton 1983)

Orbital evolution

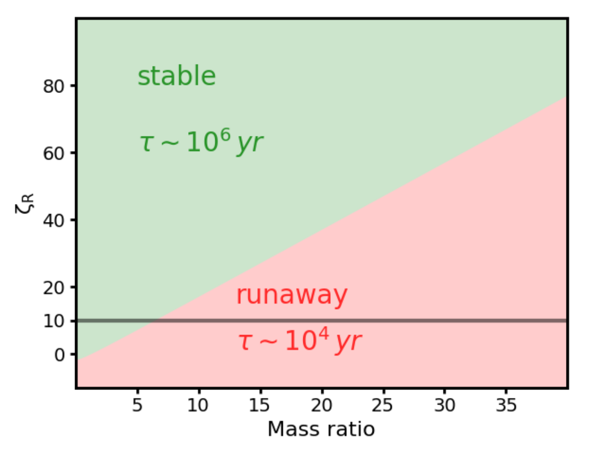
Isotropic reemission (Tauris & van den Heuvel 2006)



What's the issue with RLOF?

Mass-Radius exponents $\zeta_R = \frac{\partial \log R_\star}{\partial \log M}$ and $\zeta_L = \frac{\partial \log R_L}{\partial \log M}$

MT stable if $\zeta_R > \zeta_L$



(Tauris & van den Heuvel 2006)

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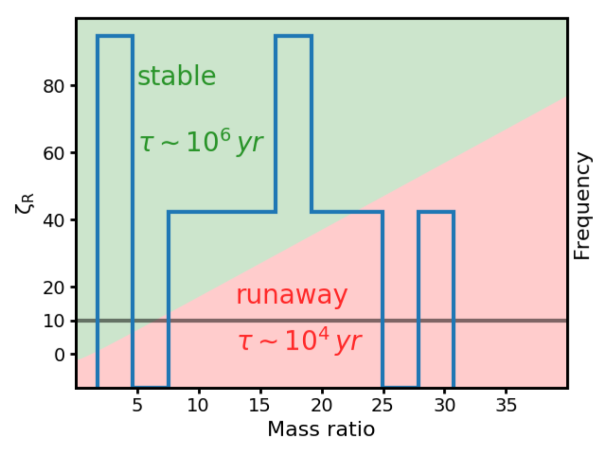

(Tauris & van den Heuvel 2006)

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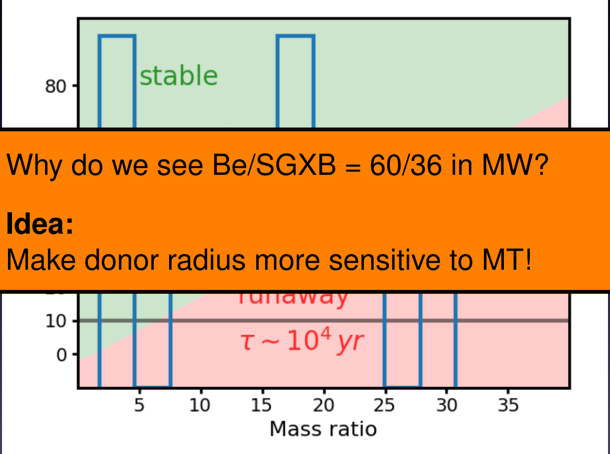
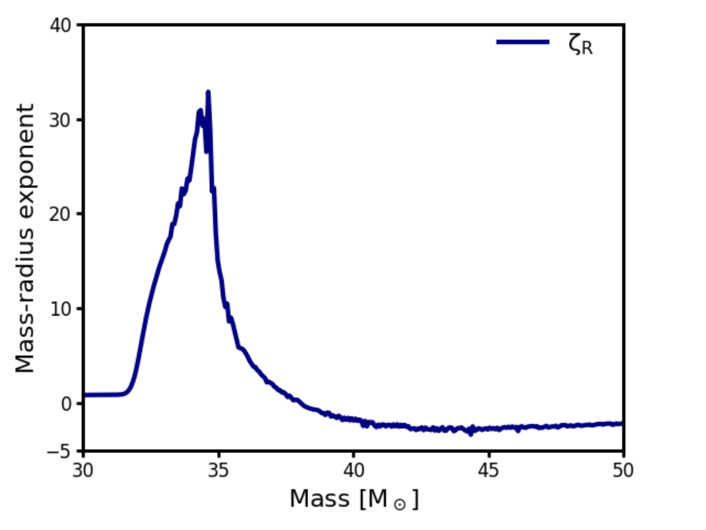
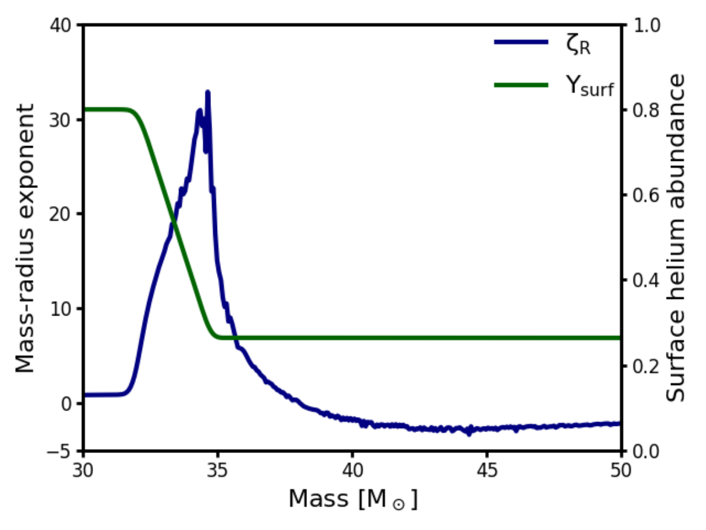


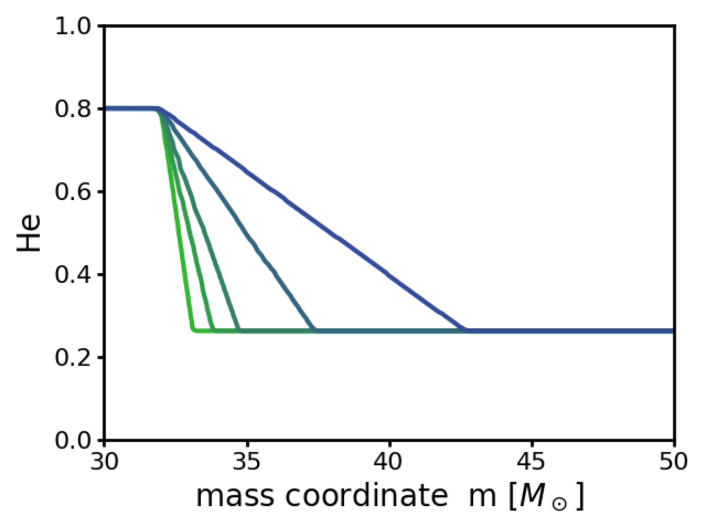
Why do we see Be/SGXB = 60/36 in MW?

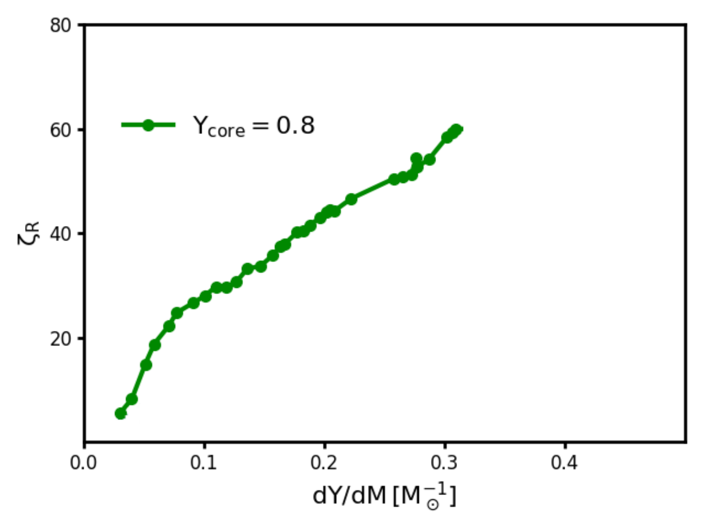
Idea:
Make donor radius more sensitive to MT!

(Tauris & van den Heuvel 2006)

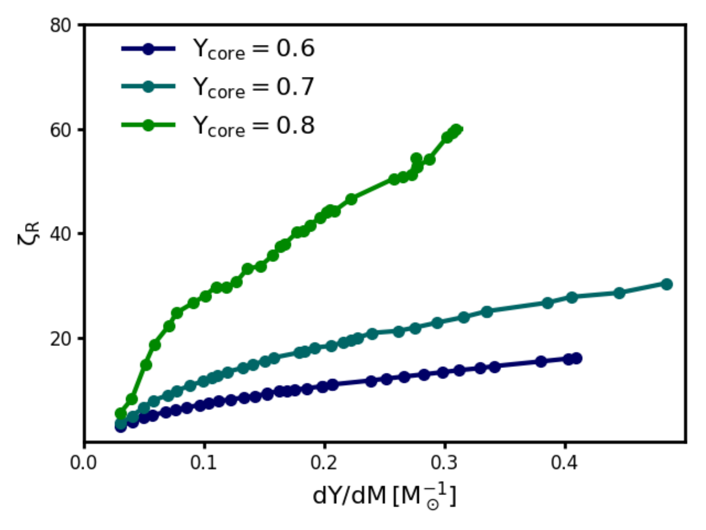

ζR
Mass-radius exponent
40
30
20
10
0
−5
30
35
40
45
50
Mass [M ⊙]


Mass-radius exponent
Surface helium abundance
Mass [M$_\odot$]
ζ_R
Y_{surf}
40
30
20
10
0
−5
1.0
0.8
0.6
0.4
0.2
0.0
30
35
40
45
50


1.0
0.8
0.6
0.4
0.2
0.0
He
30
35
40
45
50
mass coordinate m [$M_\odot$]



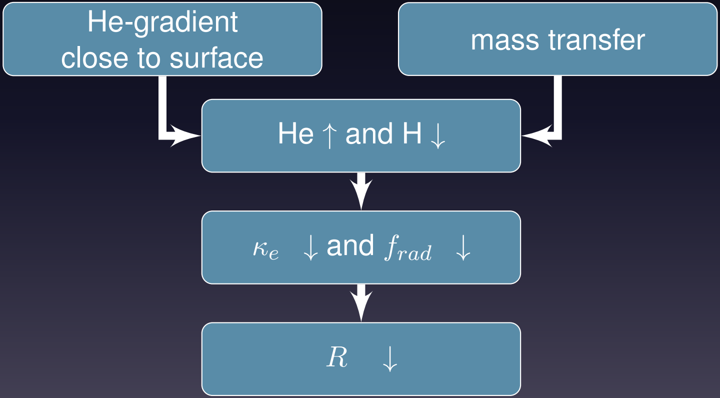
$Y_{core} = 0.8$
80
60
40
20
ζ_R
0.0
0.1
0.2
0.3
0.4
$dY/dM\ [M_\odot^{-1}]$



$Y_{core} = 0.6$
$Y_{core} = 0.7$
$Y_{core} = 0.8$
ζ_R
80
60
40
20
0.0
0.1
0.2
0.3
0.4
$dY/dM\ [M_\odot^{-1}]$

In the envelope:

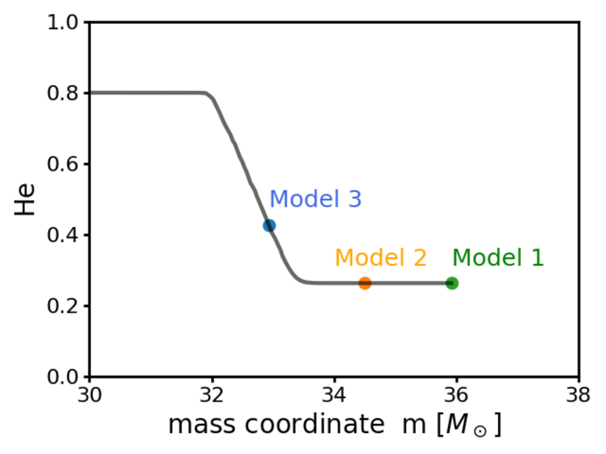
$$f_{rad} = \frac{\kappa L}{4\pi c r^2} \quad \text{vs.} \quad f_g = \frac{GM}{r^2}$$



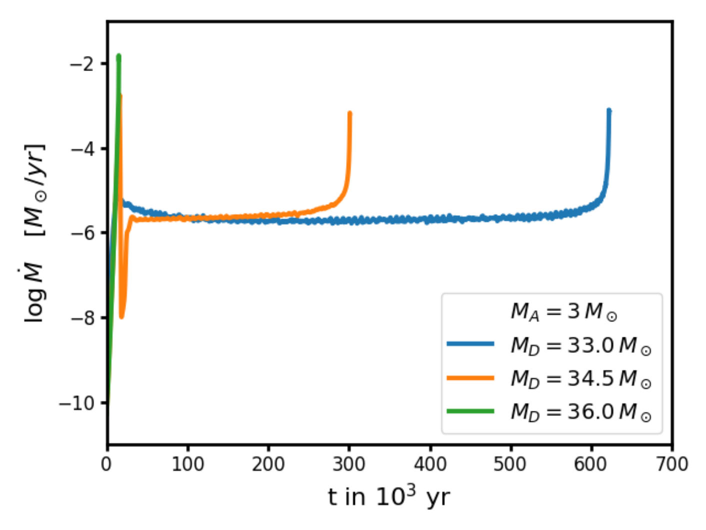
Set up binary models

⇒ 3 donor stars + 3 $M_\odot$ accretor (point mass)

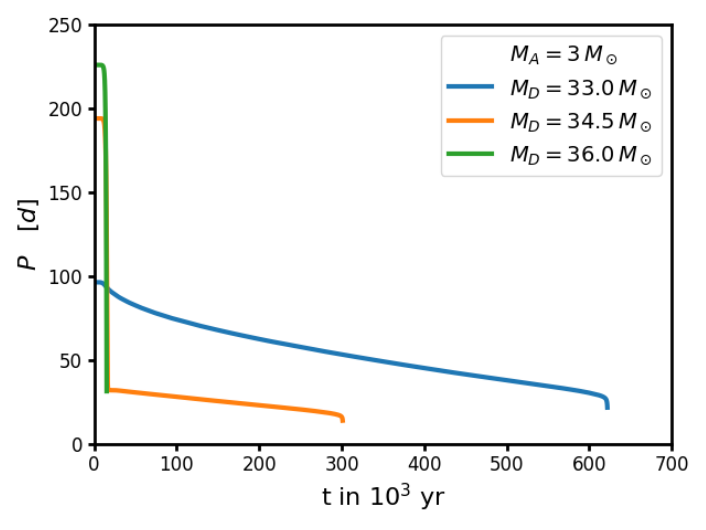
⇒ choose orbital seperation that $R_\star = R_L$



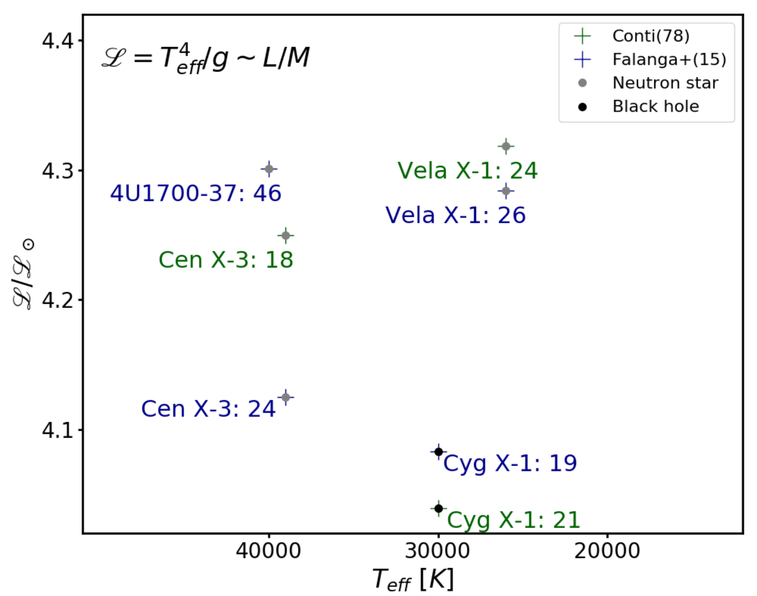
Mass transfer evolution



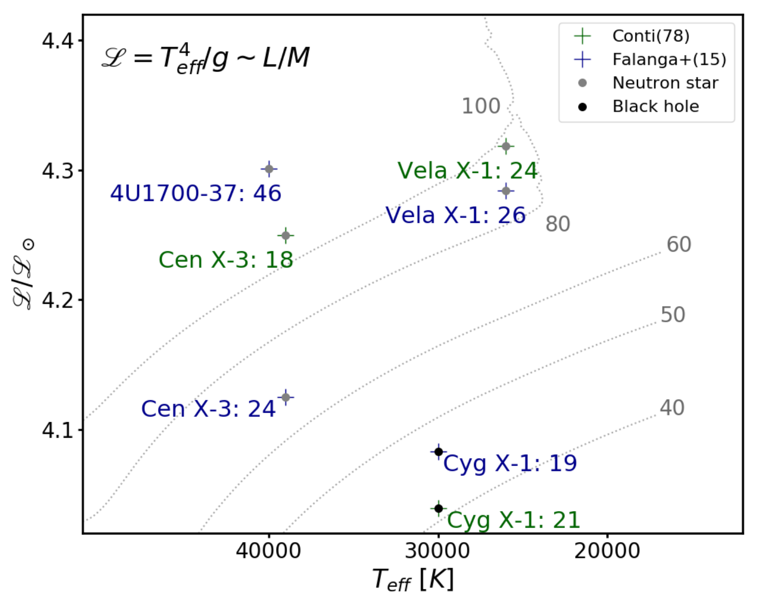
Orbital evolution



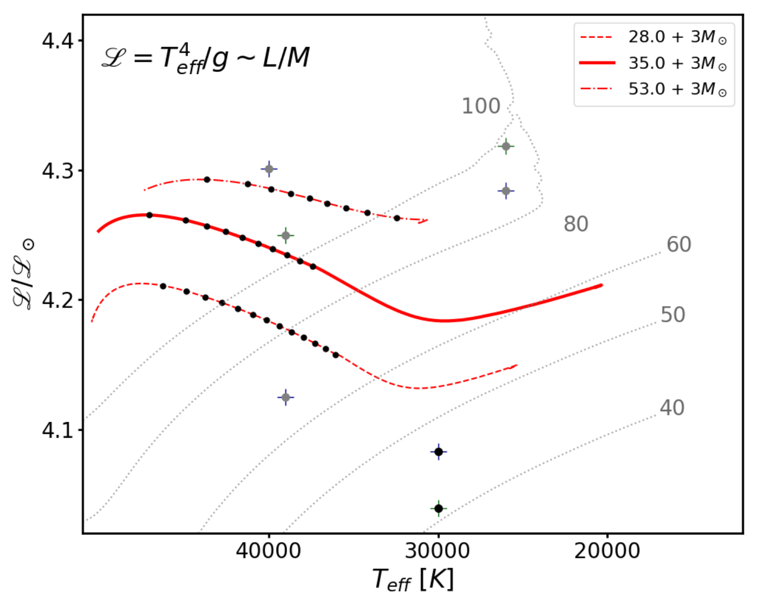
HMXB and overluminosity



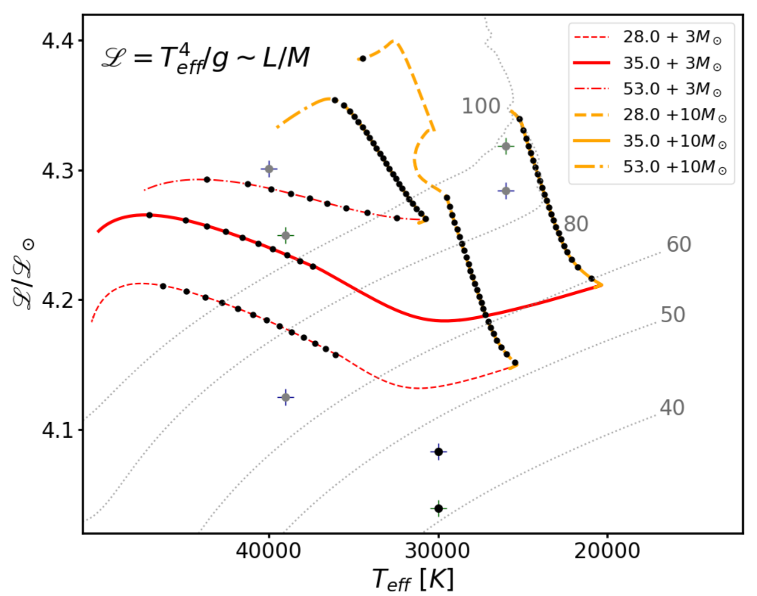
HMXB and overluminosity



HMXB and overluminosity



HMXB and overluminosity



ULX

Ultraluminous X-ray sources

$\rightarrow$ objects with $L_X > 10^{39}$ erg/s
(i.e. brighter than $10\,M_\odot$ BH)

NGC 7793 P13

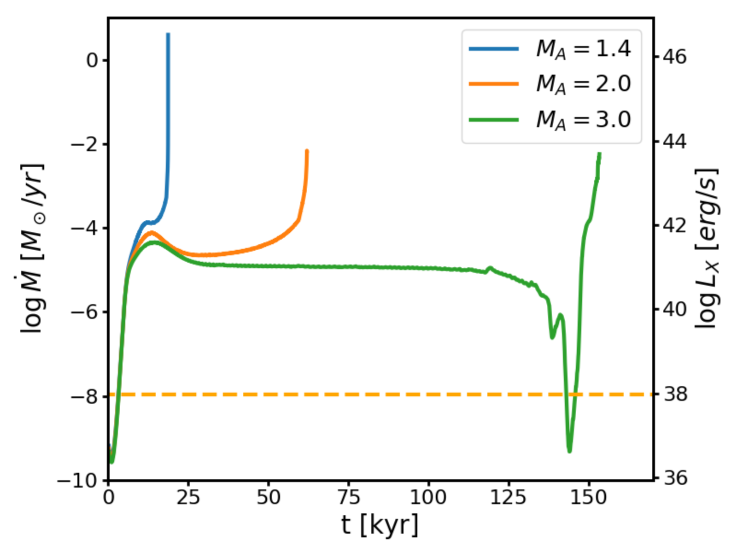
$\rightarrow$ shows X-ray pulsations (NS) and luminosity of $\sim 10^{40}$ erg/s

$\rightarrow$ $P_s = 417$ ms, $\dot{P}_s = 3 \times 10^{-11}$ ss^{-1},
$P_{orb} = 64$ d, donor mass $\sim 20\,M_\odot$
(Fürst + 2017)

At least two more NS hosting ULXs!

ULX

Evolved $27\,M_\odot$ main sequence donor and a...

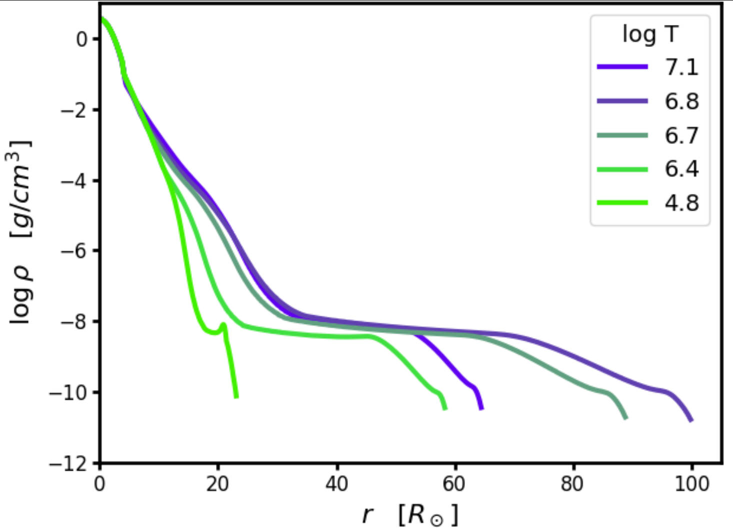


Conclusion:

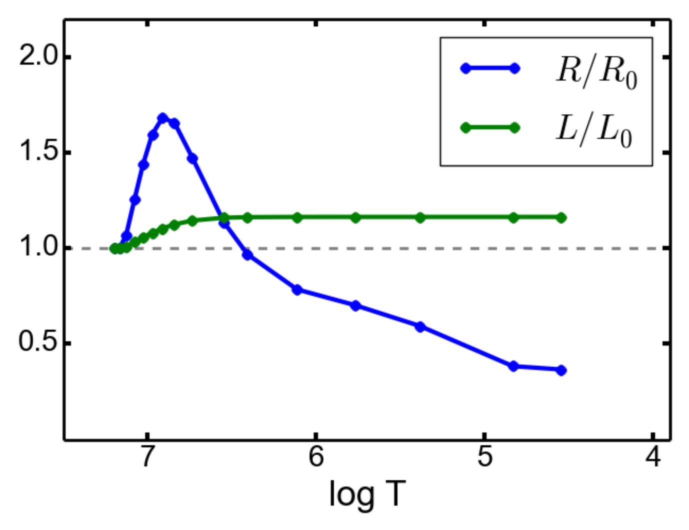
1. We found a new way to stabilize Roche mass transfer!
2. Need: Surface He-gradient. Remove H-rich envelope.
3. Observational supports:
   $\Rightarrow$ Low Be/SGXB ratio in MW
   $\Rightarrow$ Overluminousity / He-abundances of HMXB
   $\Rightarrow$ NS hosting ULXs

Outlook:

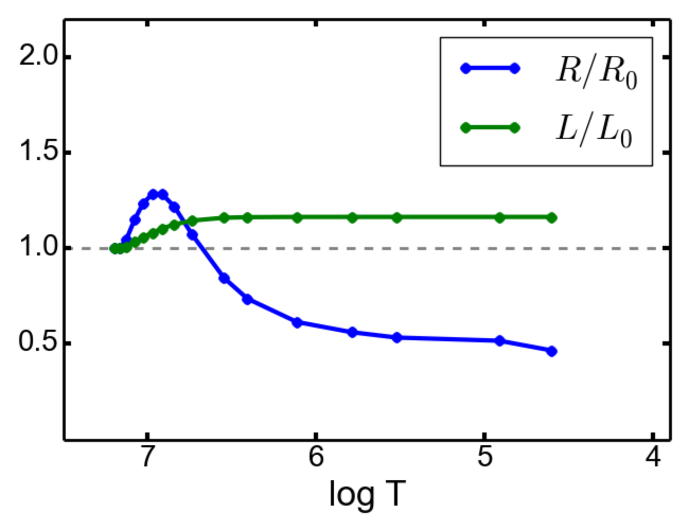
1. How actually remove H-rich envelope?
2. Including this effect, what is expected for Be/SGXB from population synthesis?



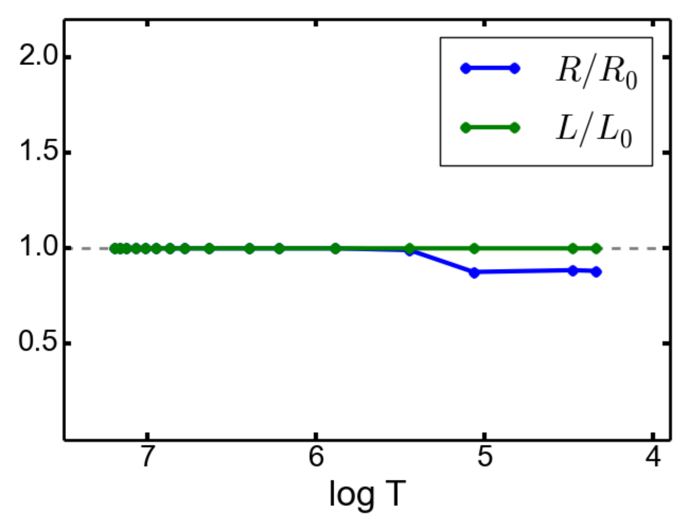
log T
7.1
6.8
6.7
6.4
4.8
0
−2
−4
−6
−8
−10
−12
0
20
40
60
80
100
log ρ [g/cm³]
r [R⊙]



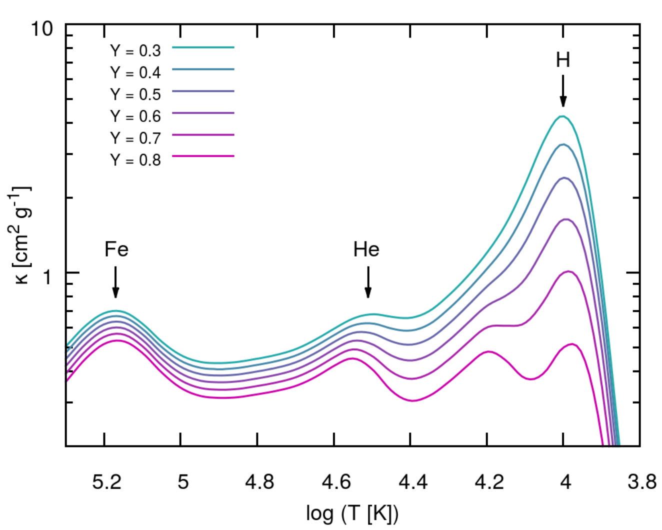
2.0
1.5
1.0
0.5
7
6
5
4
log T
R/R_0
L/L_0



2.0
1.5
1.0
0.5
7
6
5
4
log T
R/R_0
L/L_0



2.0
1.5
1.0
0.5
7
6
5
4
log T
R/R_0
L/L_0


Y = 0.3
Y = 0.4
Y = 0.5
Y = 0.6
Y = 0.7
Y = 0.8
H
Fe
He
10
1
κ [cm2 g-1]
5.2
5
4.8
4.6
4.4
4.2
4
3.8
log (T [K])