On the evolutionary status of the donors in the low mass X-ray binary systems containing black holes or neutron stars

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WE CONSIDER four LMXBs:

IGR J17451-3022

P_{orb} = 0.2618 d   probably contains a NS

X2127+119/AC 211   in M15

P_{orb} = 0.7125 d   probably contains a NS, van Zyl et al. (2004) suggest $q \geq 10$

GS 2023+338/V404 Cyg

P_{orb} = 6.471 d   contains a BH $M_{BH} = 9.0\ M_{SUN}$

Sp = K0-K3 III $M_{opt} = 0.54 \pm 0.05$ (from rot. broadening of abs.lines)

GRS 1915+105/V1387 Aql

P_{orb} = 33.85 d contains a BH $M_{BH} = 12.4\ M_{SUN}$

Sp = K0-K3 III

OPTICAL COMPONENTS OF LMXBs

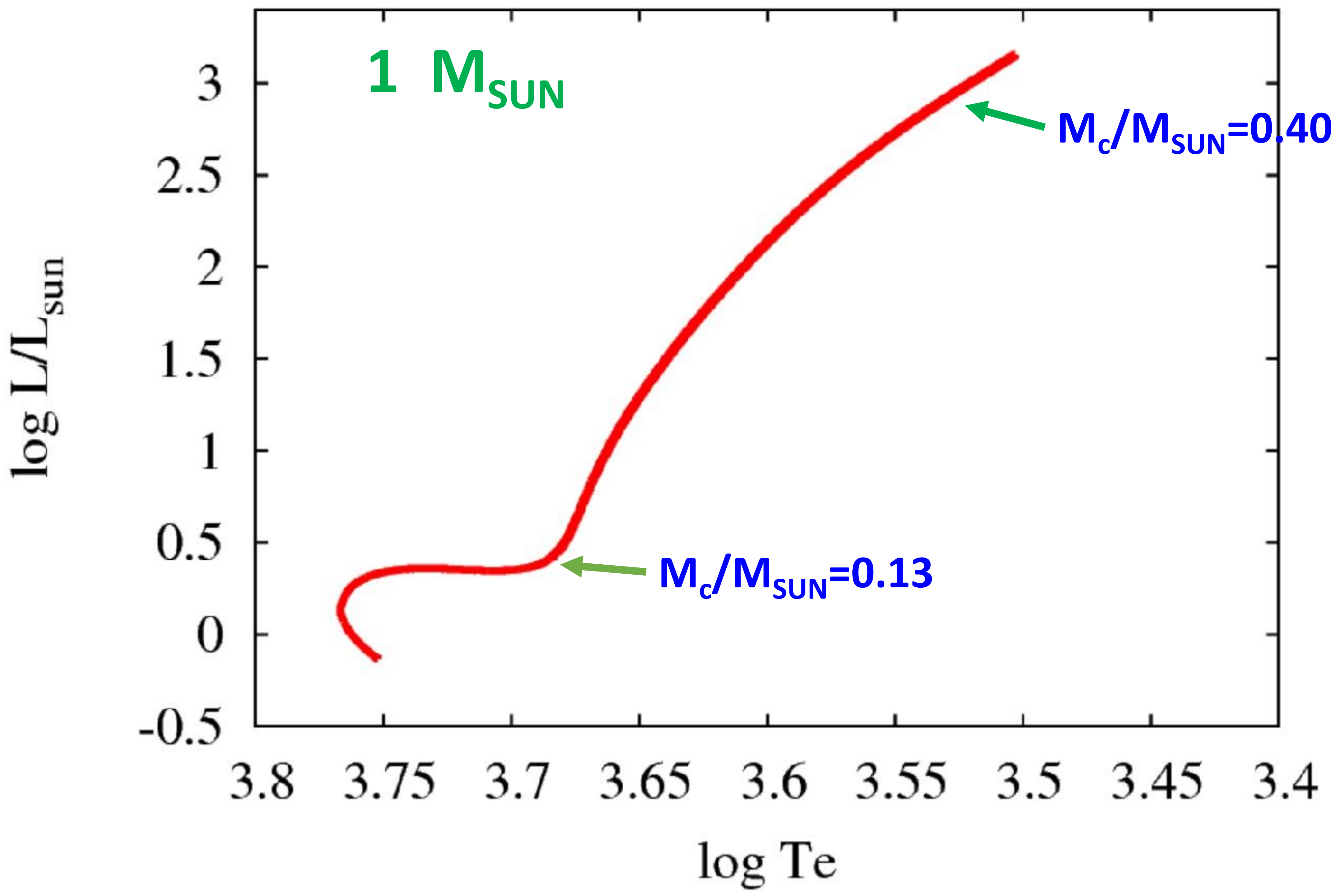
Radius is one of the most accurately determined parameters of the optical component

For the star filling its Roche lobe:

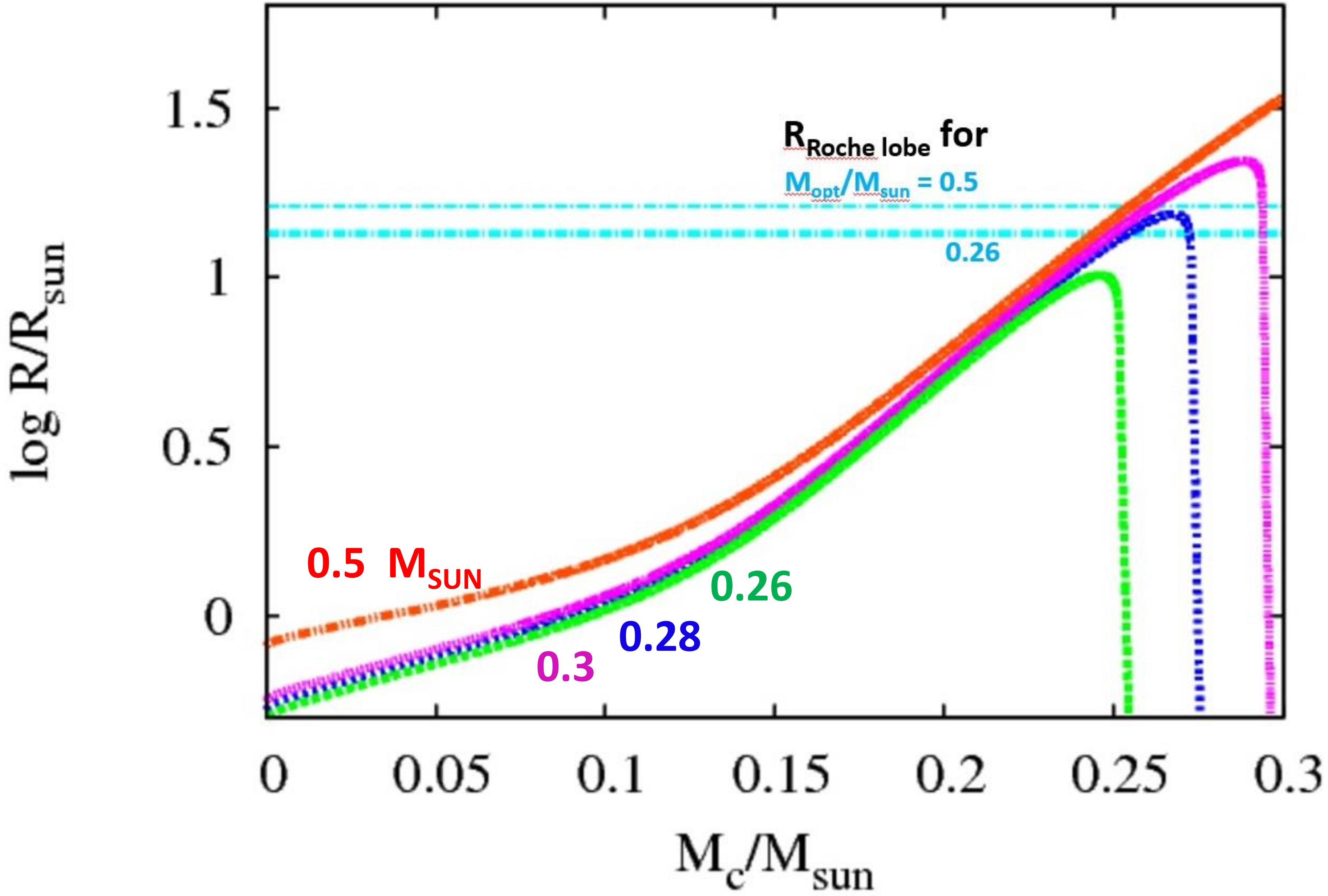
$$R_{opt}/R_{SUN} = 1.944\ (P/1d)^{2/3}\ (M_{opt}/M_{SUN})^{1/3}$$

orbital period is known with high precision and the dependence on M_{opt} is weak

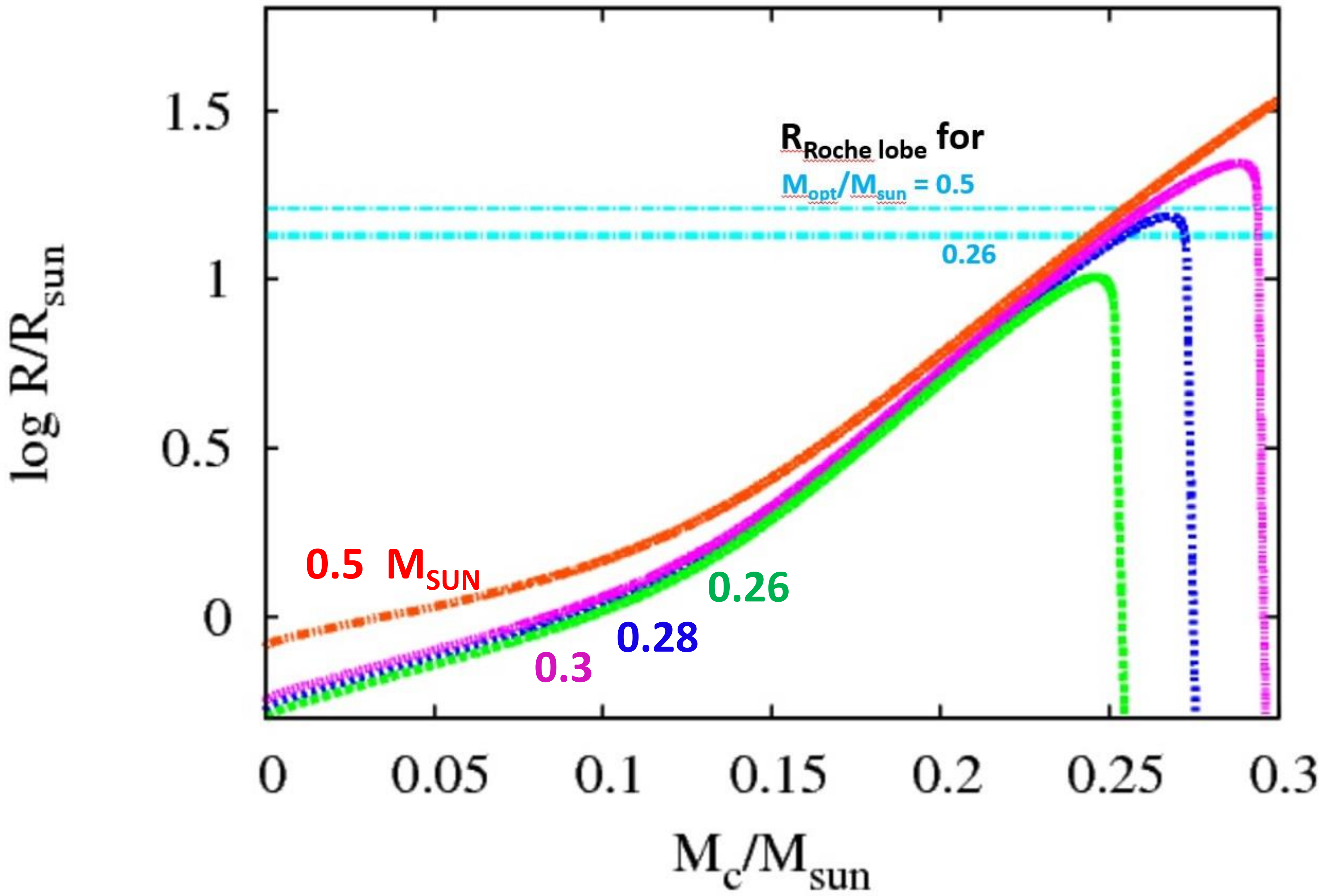
optical component is typically a more or less “stripped” giant

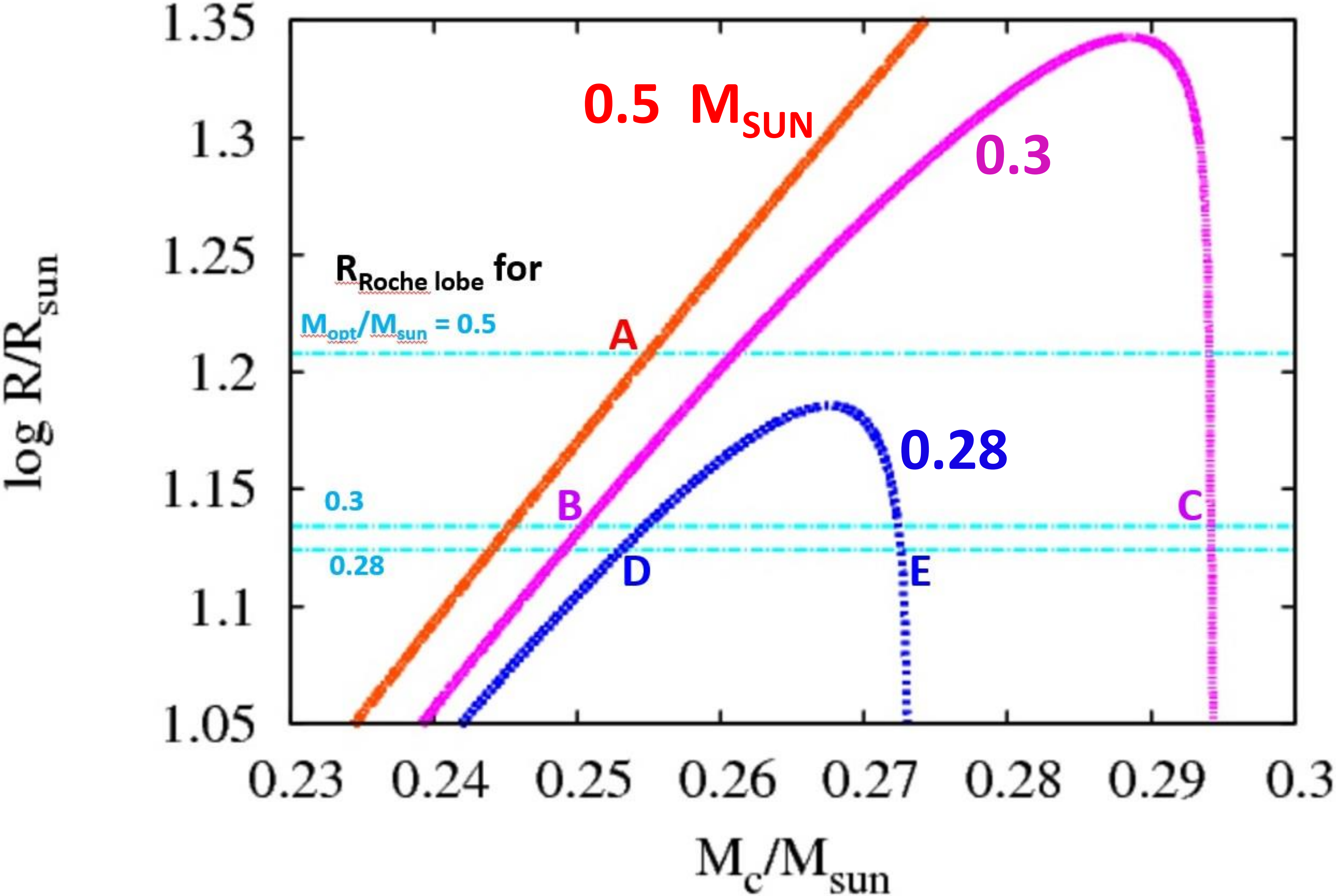

1 M_SUN
M_c/M_SUN=0.40
M_c/M_SUN=0.13
log L/L_sun
log Te
3
2.5
2
1.5
1
0.5
0
-0.5
3.8
3.75
3.7
3.65
3.6
3.55
3.5
3.45
3.4

Both “stripped” and “unstripped” giants satisfy well defined core mass –radius relation

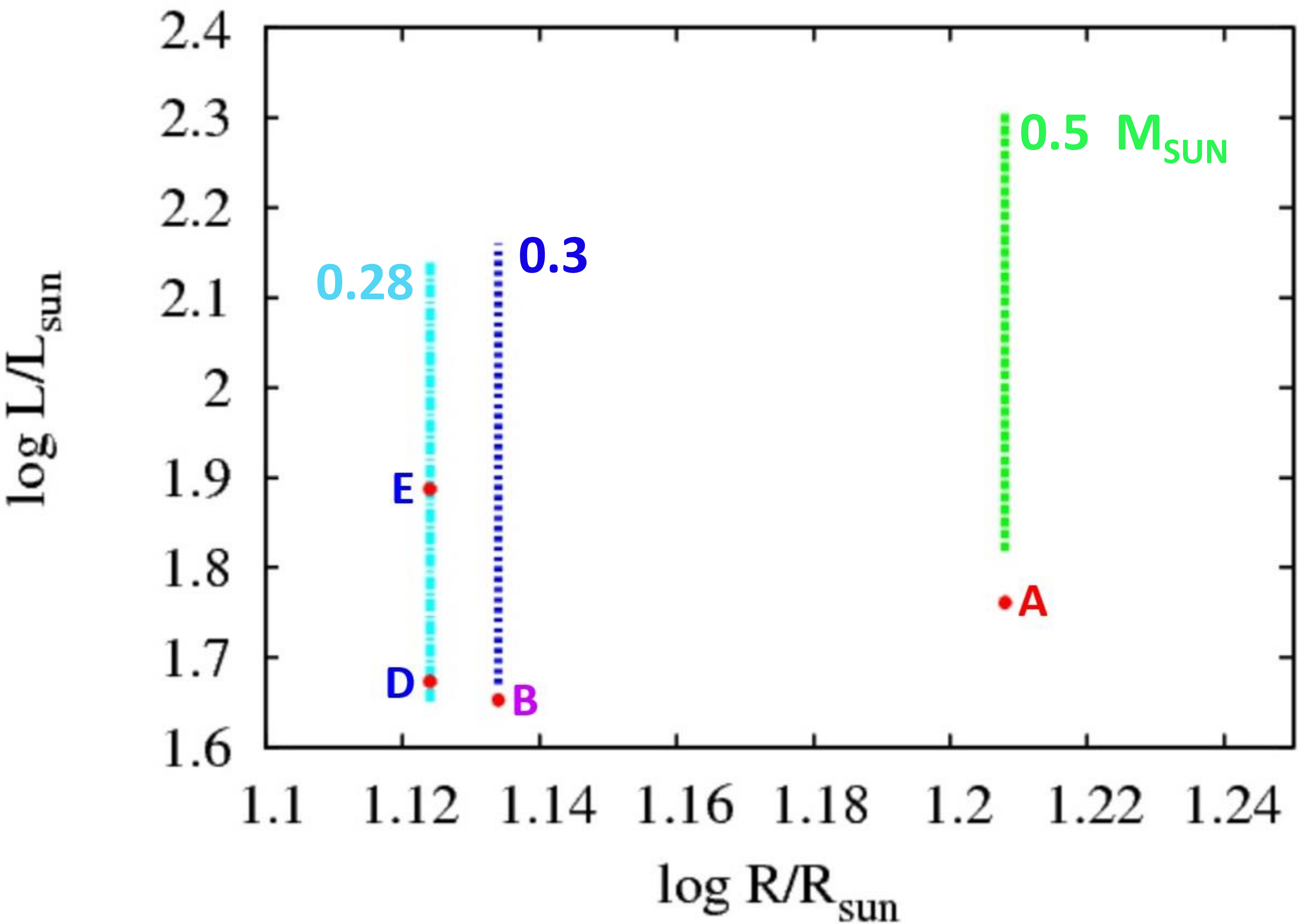


Both “stripped” and “unstripped” giants satisfy well defined core mass –radius relation





0.5 M_{SUN}
0.3
0.28
$R_{Roche\ lobe}$ for
M_{opt}/M_{sun} = 0.5
0.3
0.28
A
B
C
D
E
1.35
1.3
1.25
1.2
1.15
1.1
1.05
log R/R_{sun}
0.23
0.24
0.25
0.26
0.27
0.28
0.29
0.3
M_c/M_{sun}



0.5 M_{SUN}
0.3
0.28
E
D
B
A
log L/L_{sun}
log R/R_{sun}
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.1
1.12
1.14
1.16
1.18
1.2
1.22
1.24

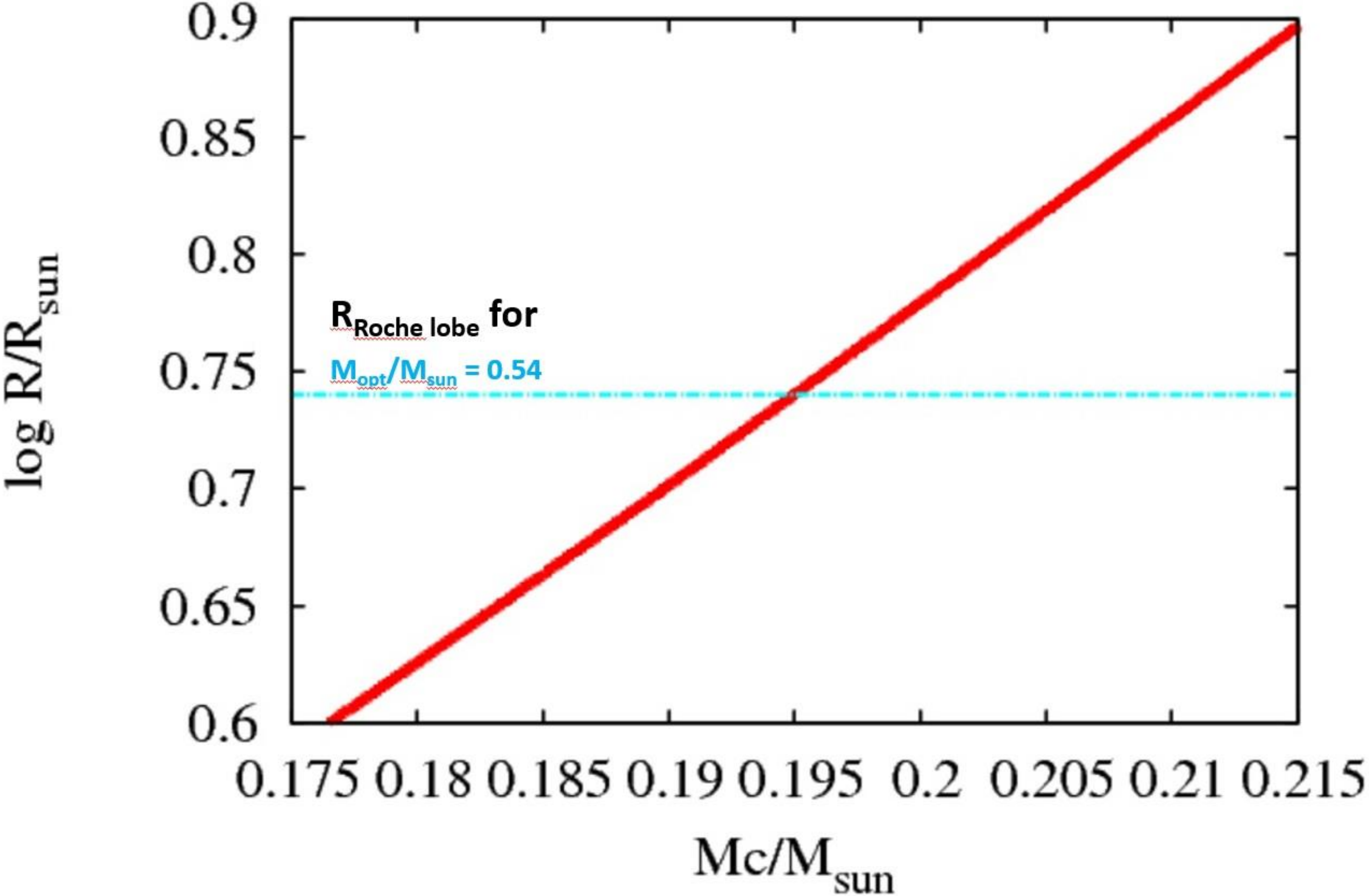
By far, the best fit to L and R is obtained for model E. Unfortunately this model is unphysical as it does not permit the mass transfer

GRS 1915+105/V1387 Aql

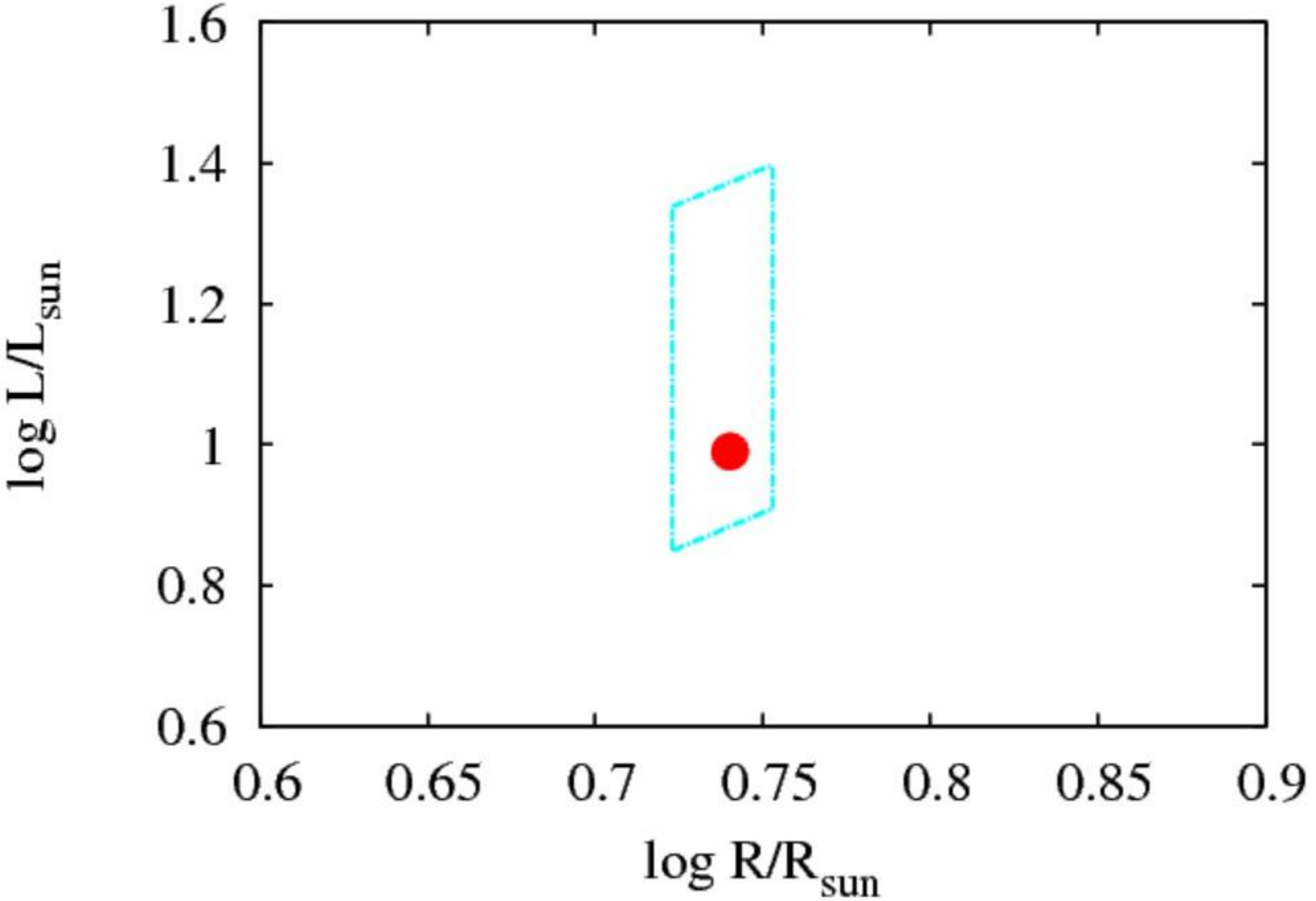
Our analysis indicates that the most likely solution is a highly stripped giant of mass ~ 0.28 M_{SUN} . However, a moderately stripped giant of mass ~ 0.5 M_{SUN} cannot be ruled out.

Model D (0.28 M_{SUN}) located in a binary with P_{orb} = 33.85 d with a 12.4 M_{SUN} BH as a companion would transfer mass at the rate 8.5 x 10^{-10} M_{SUN} /yr which translates into duty cycle ~ 0.6 %.

For model A (0.5 M_{SUN}) the numbers are 5.2 x 10^{-9} M_{SUN} /yr and ~ 3.6 %.



0.9
0.85
0.8
0.75
0.7
0.65
0.6
log R/R_sun
R_Roche lobe for
M_opt/M_sun = 0.54
0.175 0.18 0.185 0.19 0.195 0.2 0.205 0.21 0.215
Mc/M_sun

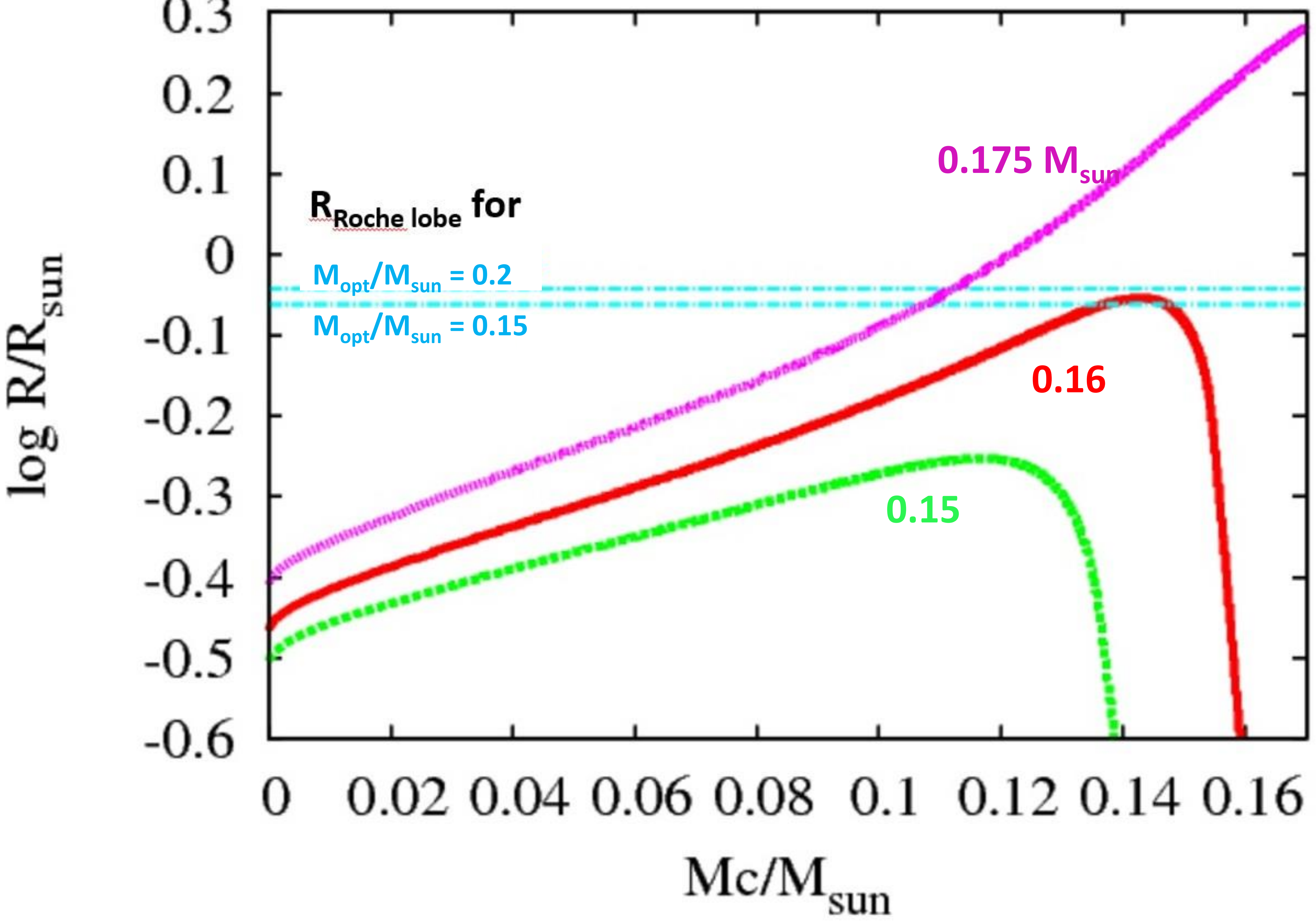


1.6
1.4
1.2
1
0.8
0.6
log L/L$_{sun}$
0.6
0.65
0.7
0.75
0.8
0.85
0.9
log R/R$_{sun}$

GS 2033+338/V404 Cyg

Our analysis supports the value of the mass estimated from the rotational broadening of the absorption lines of V404 Cyg (~ 0.54 M_{SUN}).

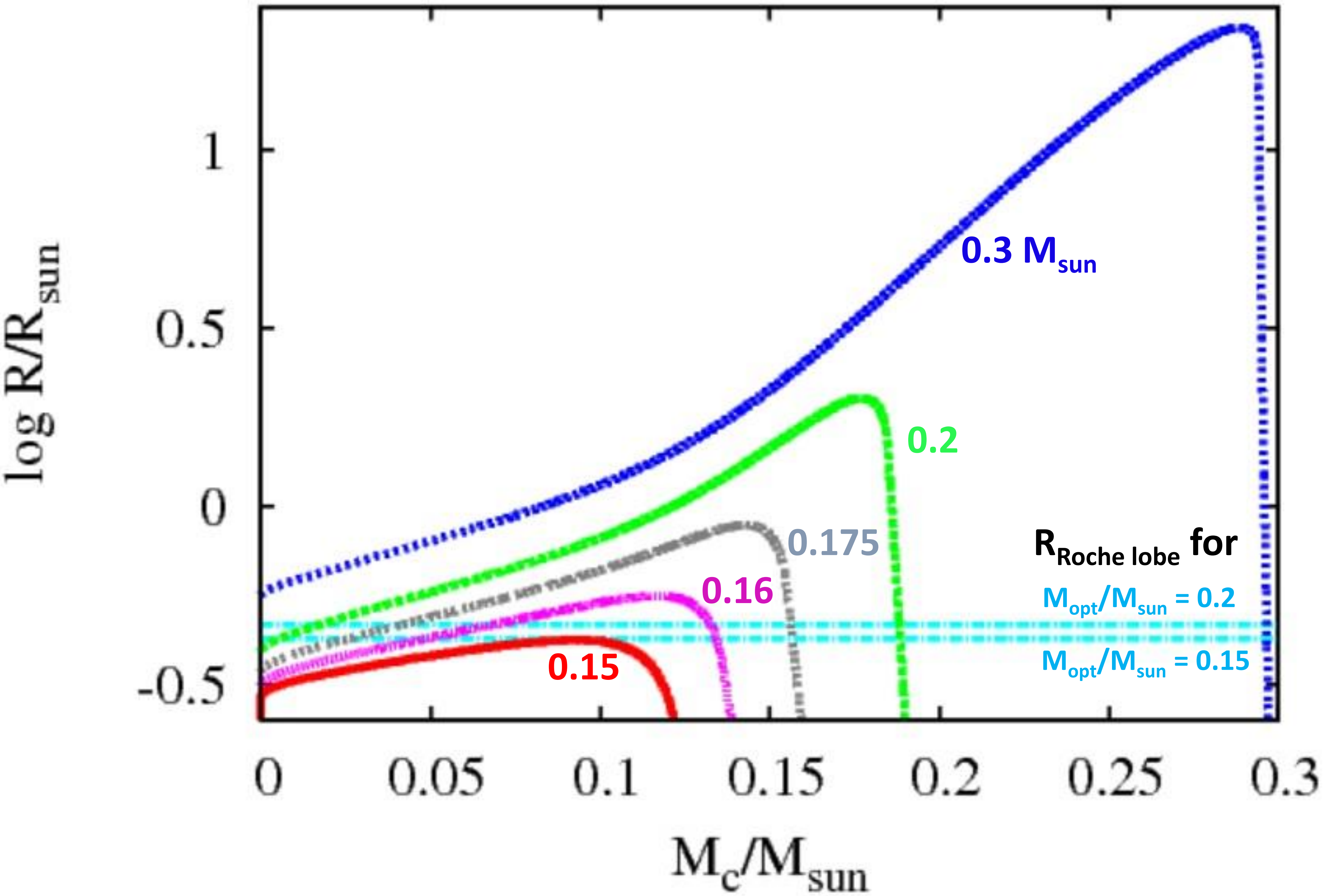
Our model (0.54 M_{SUN}) located in a binary with P_{orb} = 6.47 d with a 9.0 M_{SUN} BH as a companion would transfer mass at the rate 1.2×10^{-9} M_{SUN}/yr.



0.175 M$_{sun}$
R$_{Roche\ lobe}$ for
M$_{opt}$/M$_{sun}$ = 0.2
M$_{opt}$/M$_{sun}$ = 0.15
0.16
0.15
log R/R$_{sun}$
Mc/M$_{sun}$
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16

X2127+119/AC 211

Our analysis together with the suggestion of van Zyl et al. (2004) that the mass of the optical component must be very low ($\leq 0.15\ M_{SUN}$) indicate the mass ~ 0.16-$0.17\ M_{SUN}$.



log R/R_sun
1
0.5
0
-0.5
0
0.05
0.1
0.15
0.2
0.25
0.3
M_c/M_sun
0.3 M_sun
0.2
0.175
0.16
0.15
R_Roche lobe for
M_opt/M_sun = 0.2
M_opt/M_sun = 0.15

IGR J17451-3022

Analysis carried out by Zdziarski et al. (2016) using evolutionary tracks similar to those shown in Fig. 6 led to the conclusion that the mass of the optical component is most likely in the range 0.15-0.2 M_{SUN} . However, the alternative solution with the MS star of the mass ~ 0.5-0.8 M_{SUN} is also possible.