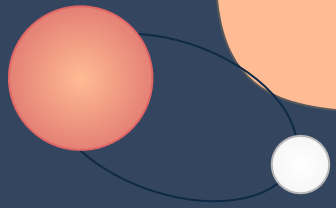
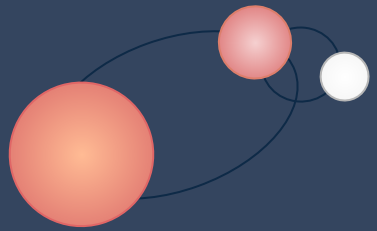
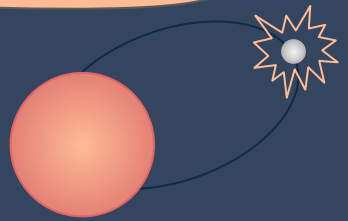
56 Ursae Majoris: a binary evolution puzzle







Ana Escorza

with D. Karinkuzhi, A. Jorissen, S. Van Eck, J. T. Schmelz, G. L. Verschuur, H. M. J. Boffin, R. J. De Rosa, and H. Van Winckel

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"la Caixa"

56 UrSae Majoris in the literature

- G8III + faint lower-mass companion
  (Keenan & McNeil 1989)
- V = 5.03 mag (Ducati 2002)
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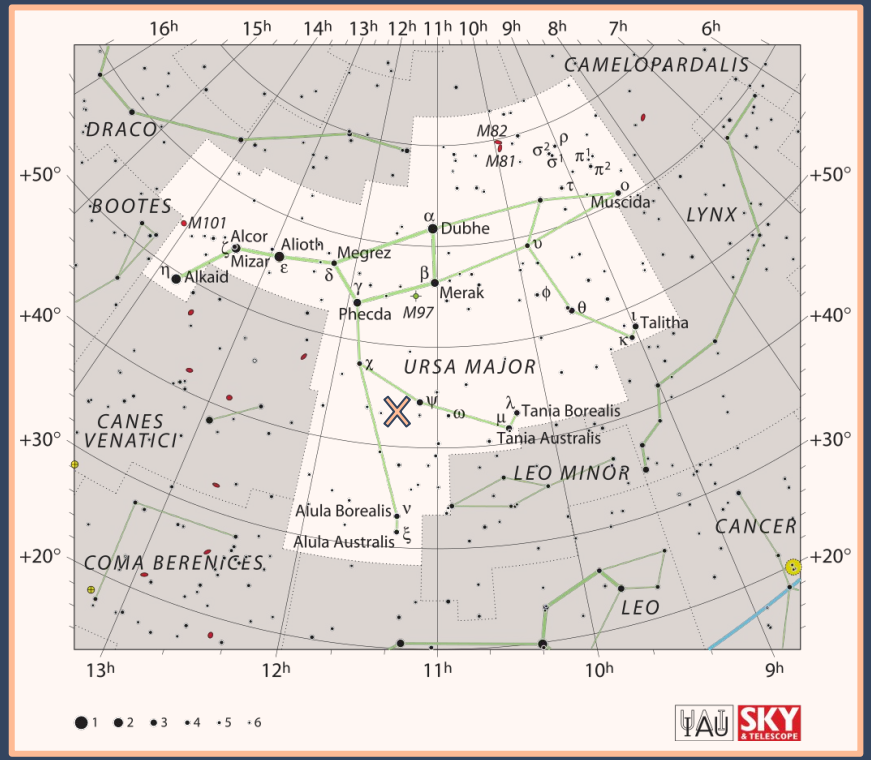

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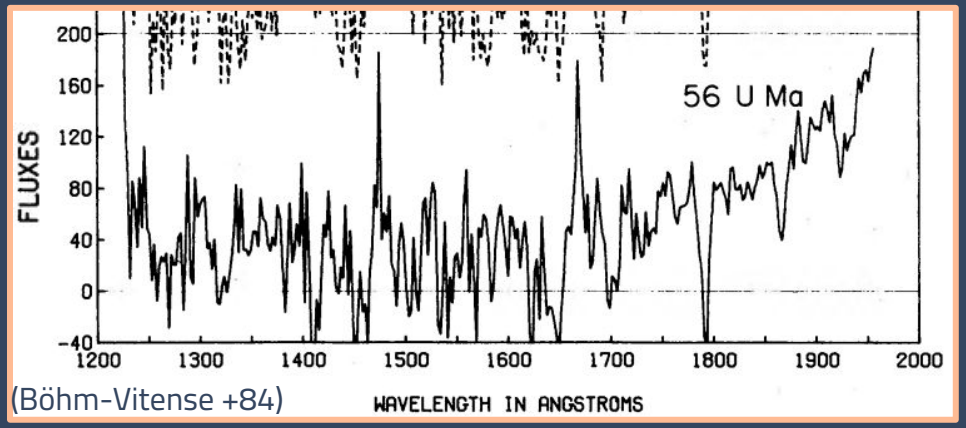

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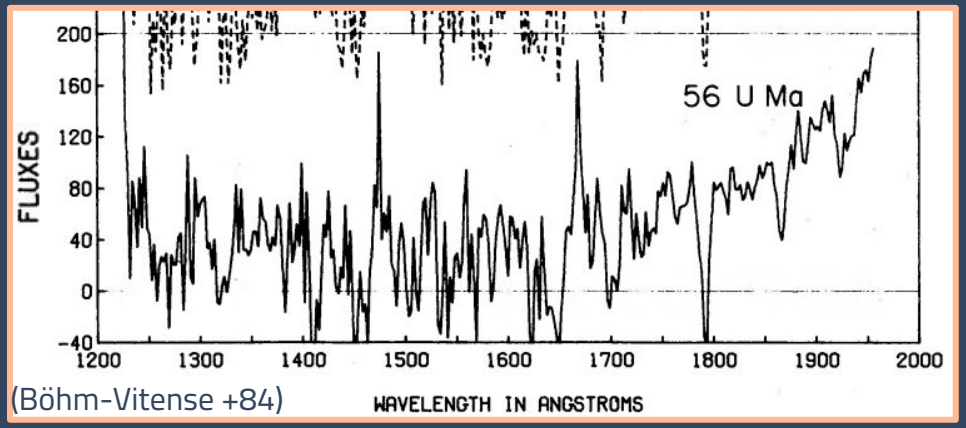

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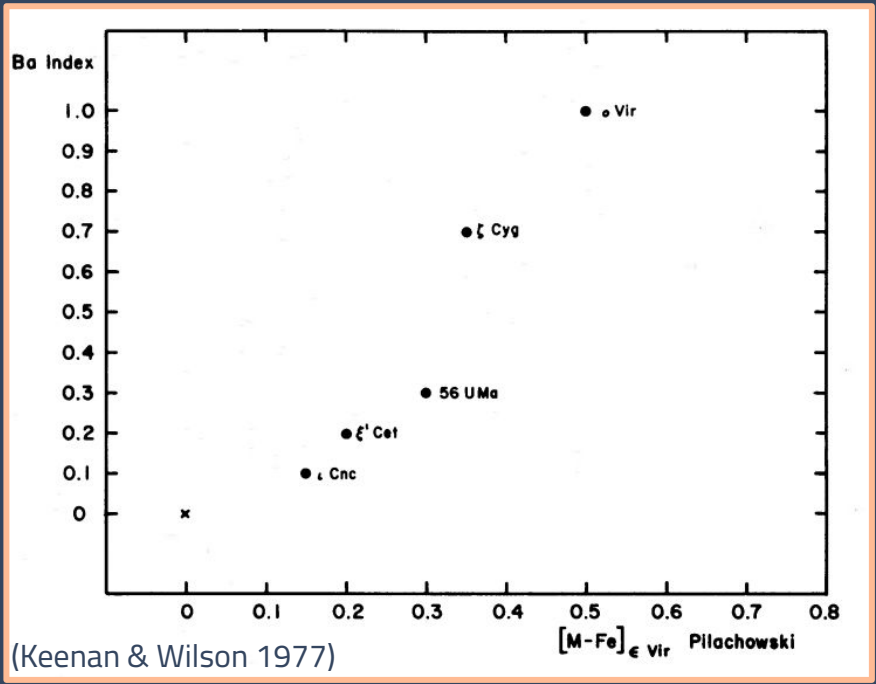

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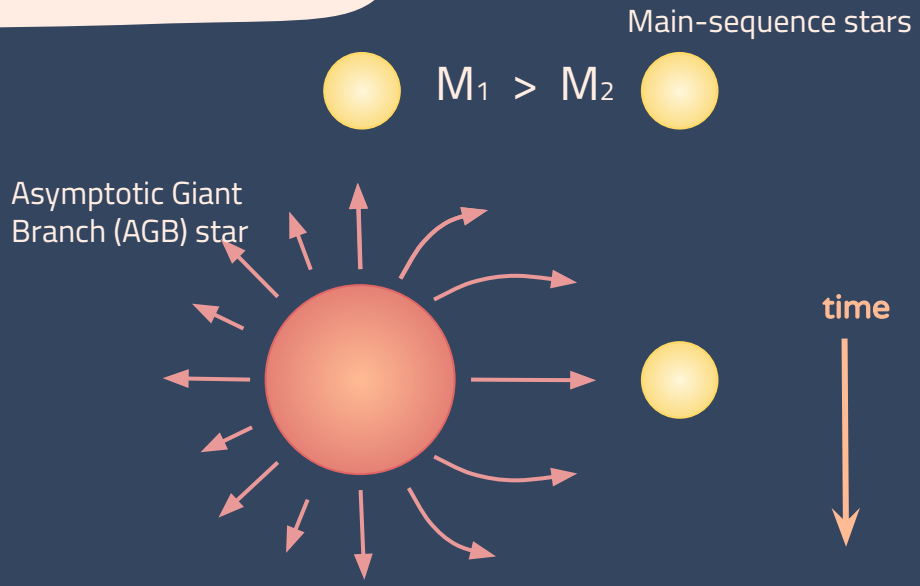

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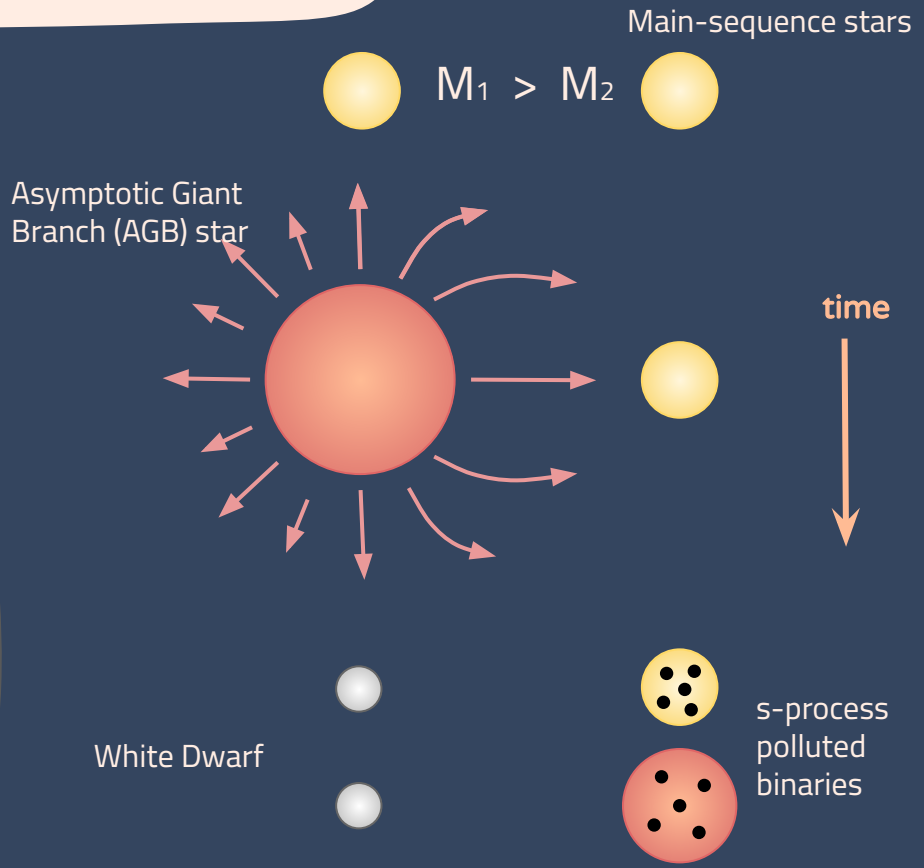

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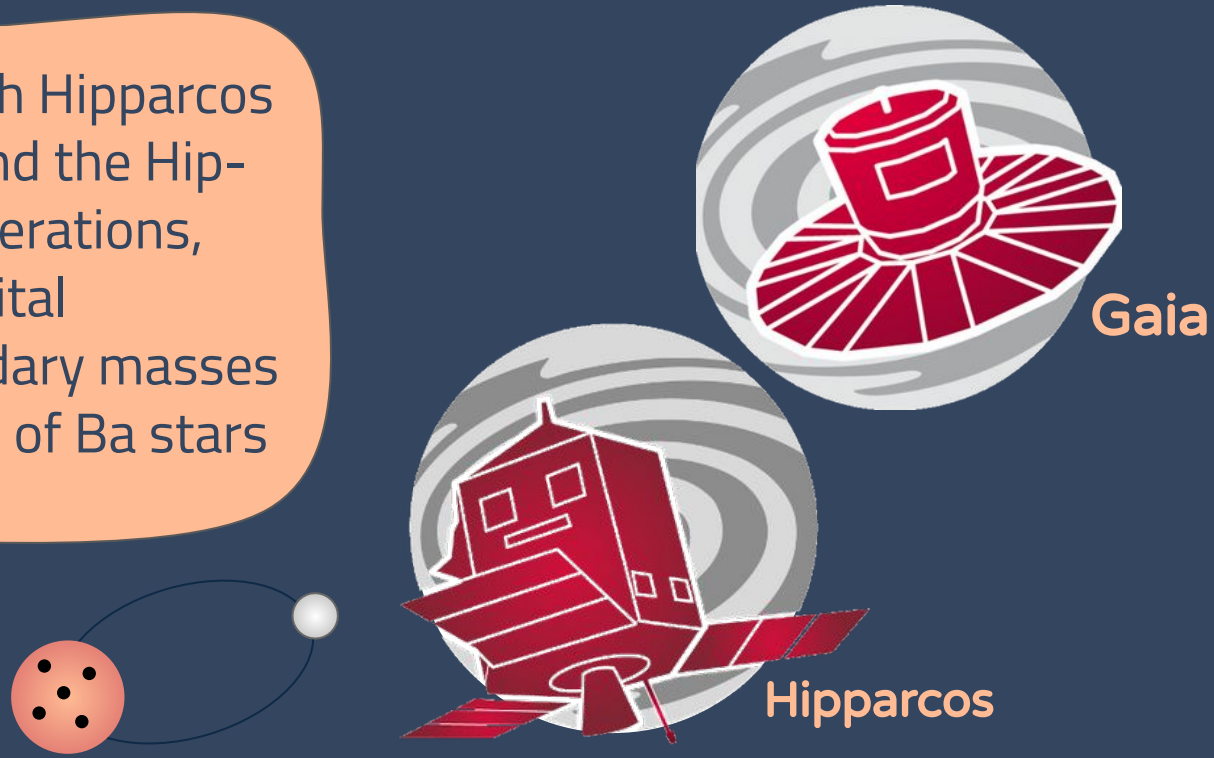
If the giant is a Ba star,
the companion MUST be a white dwarf

The masses of the WD companions of Ba stars

Combining RV data with Hipparcos and Gaia astrometry and the Hip-Gaia catalogue of accelerations, we could constrain orbital inclinations and secondary masses for 60 WD companions of Ba stars
(Escorza & De Rosa 2023)



work done using ORVARA (Brandt et al. 2021)
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The masses of the ~~WD~~ companions of ~~Ba~~ stars

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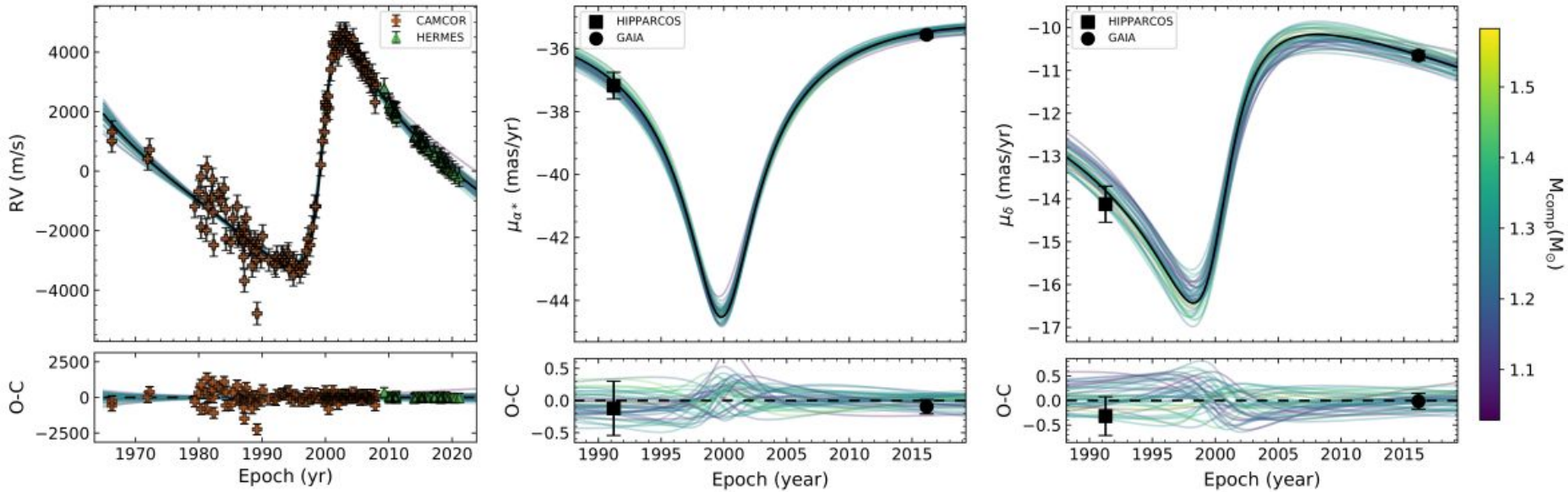

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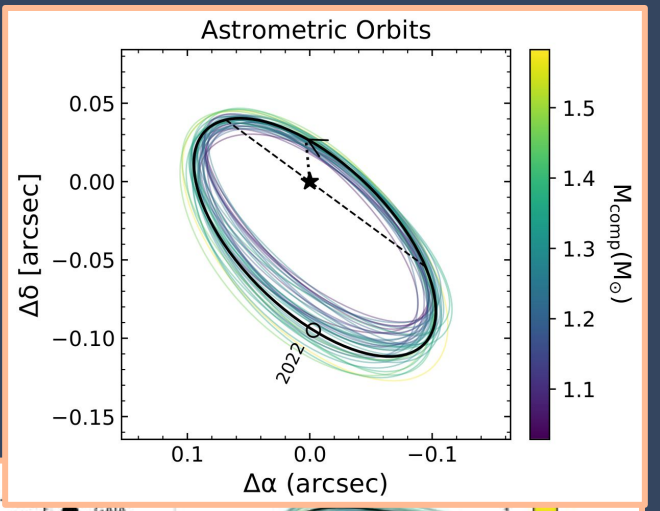
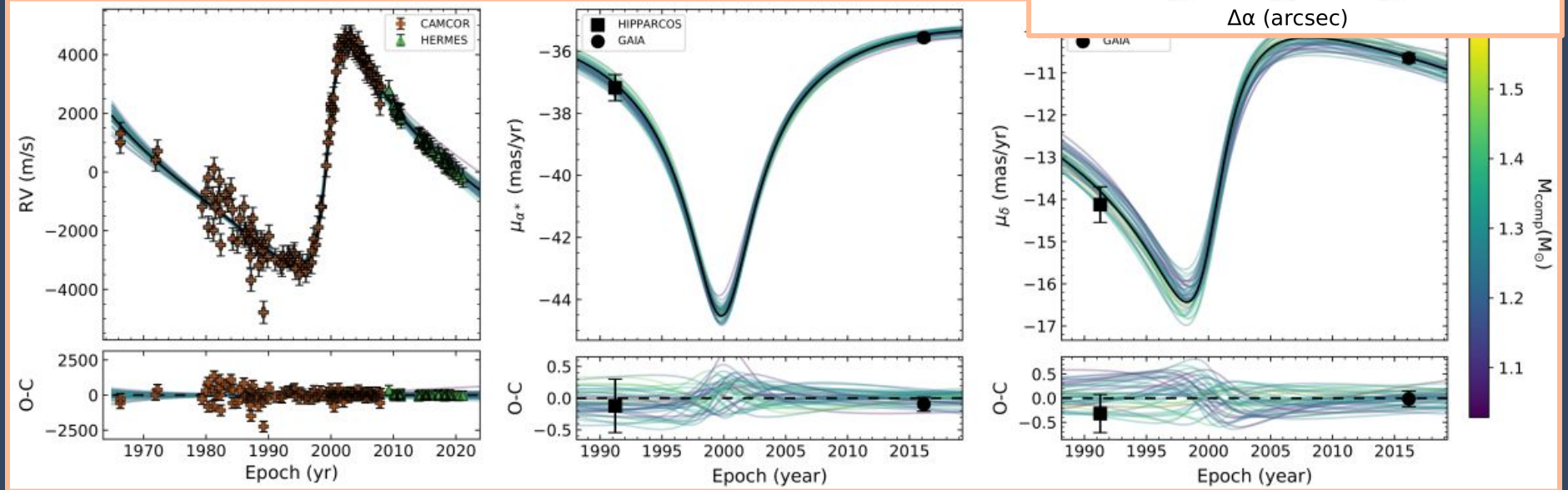


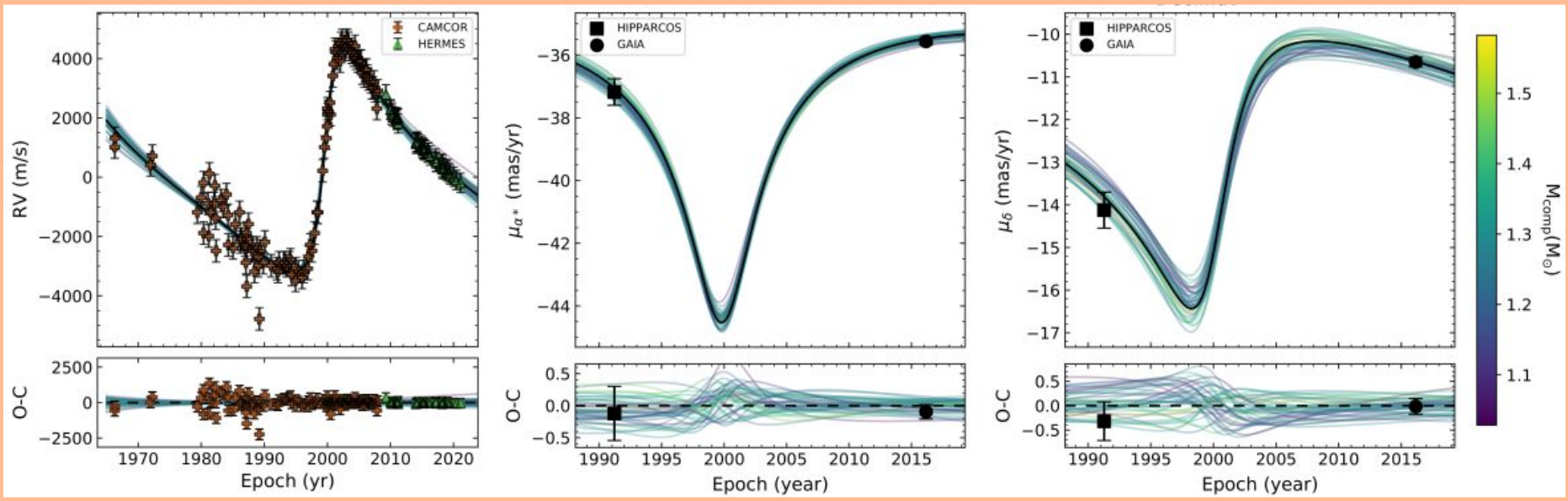


The masses of the ~~WD~~ companions of ~~Ba~~ stars

RV data + Hipparcos-Gaia acceleration

+ Hipparcos epoch astrometry => 56 UMa has a 1.31 ± 0.12 $M_\odot$ companion

(Escorza & De Rosa 2023)



The mass of the faint component in 56 UMa

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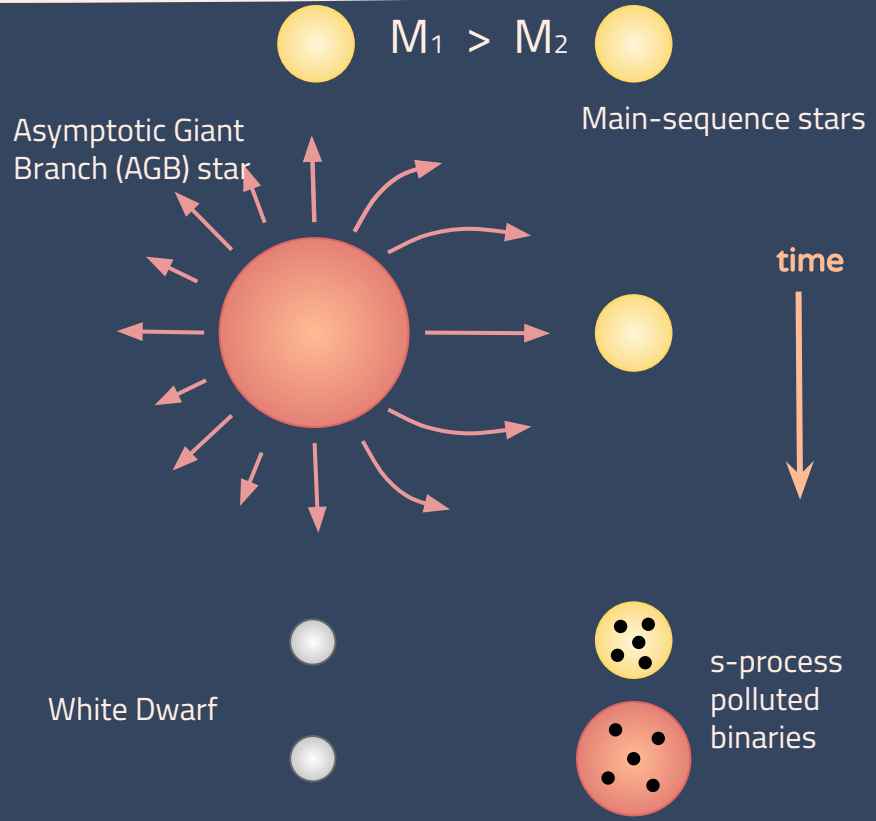

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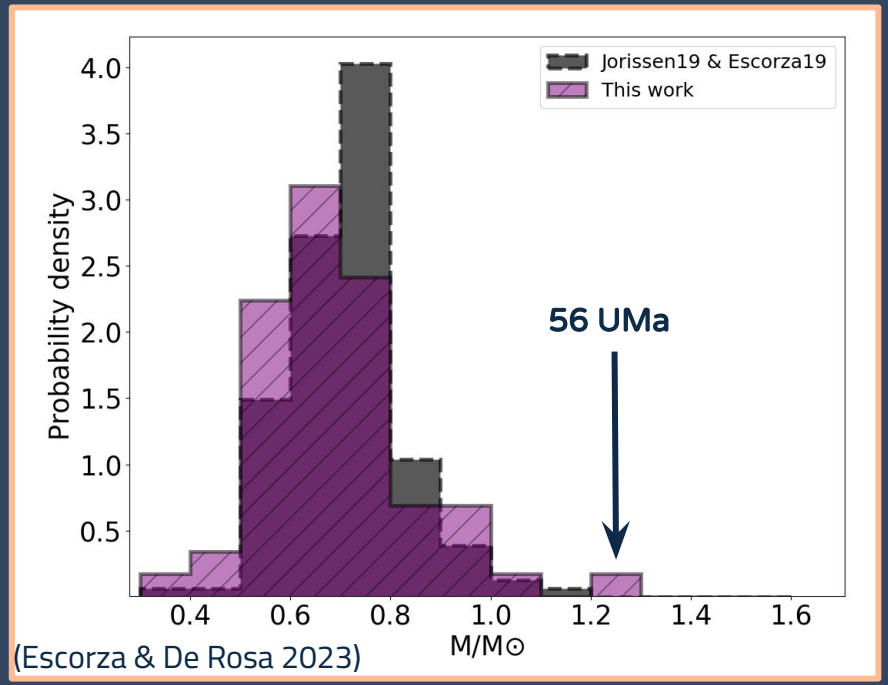

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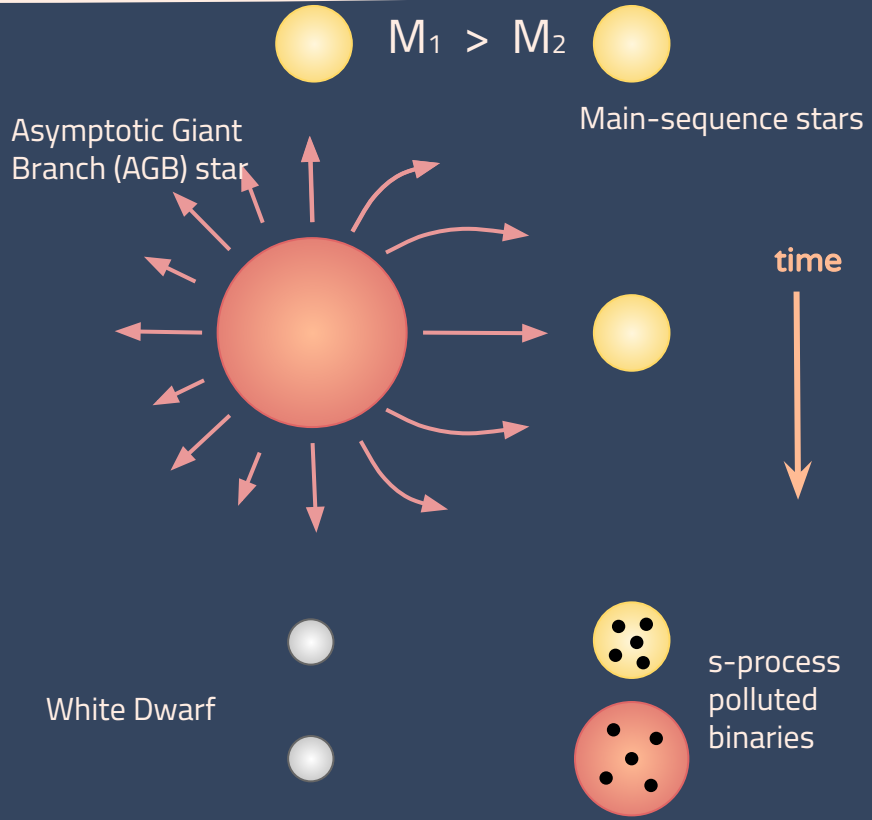
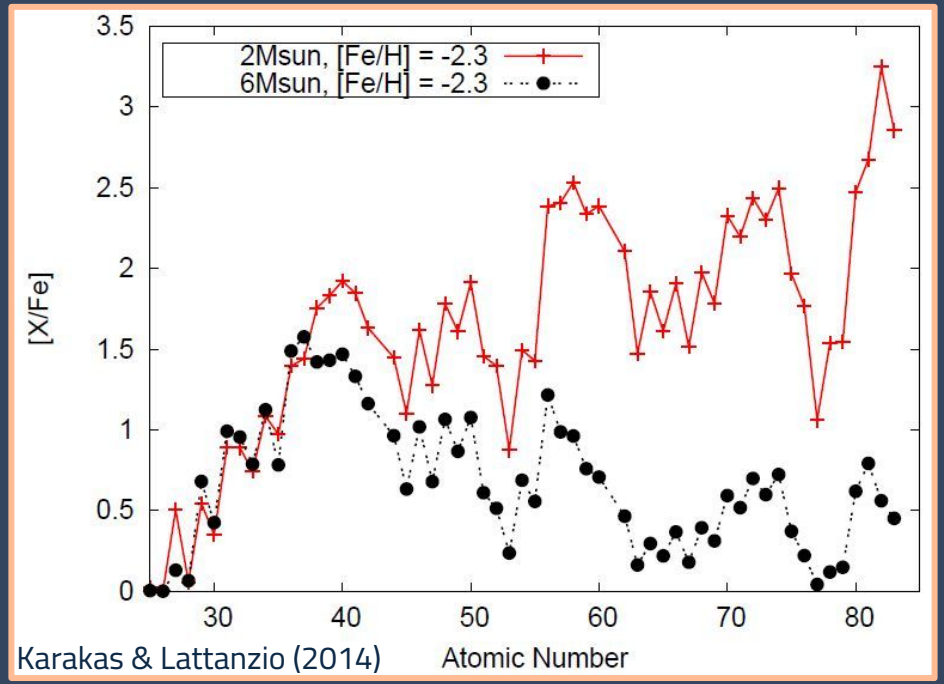
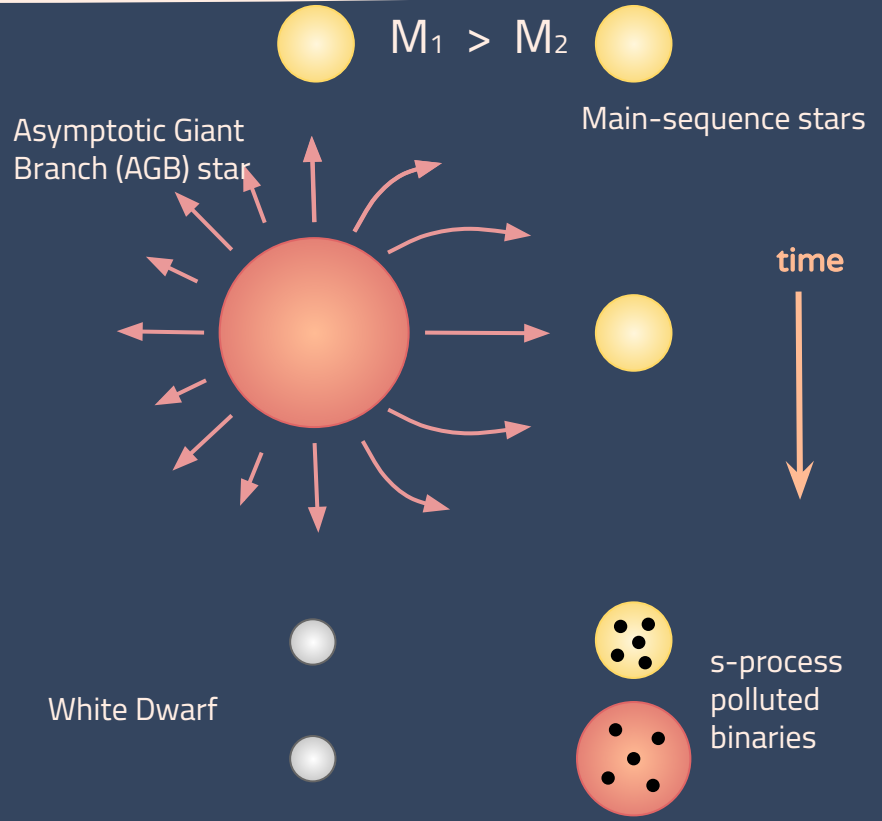


The mass of the faint component in 56 UMa

Could the AGB progenitor of such a WD have made a Ba star?



Karakas & Lattanzio (2014)



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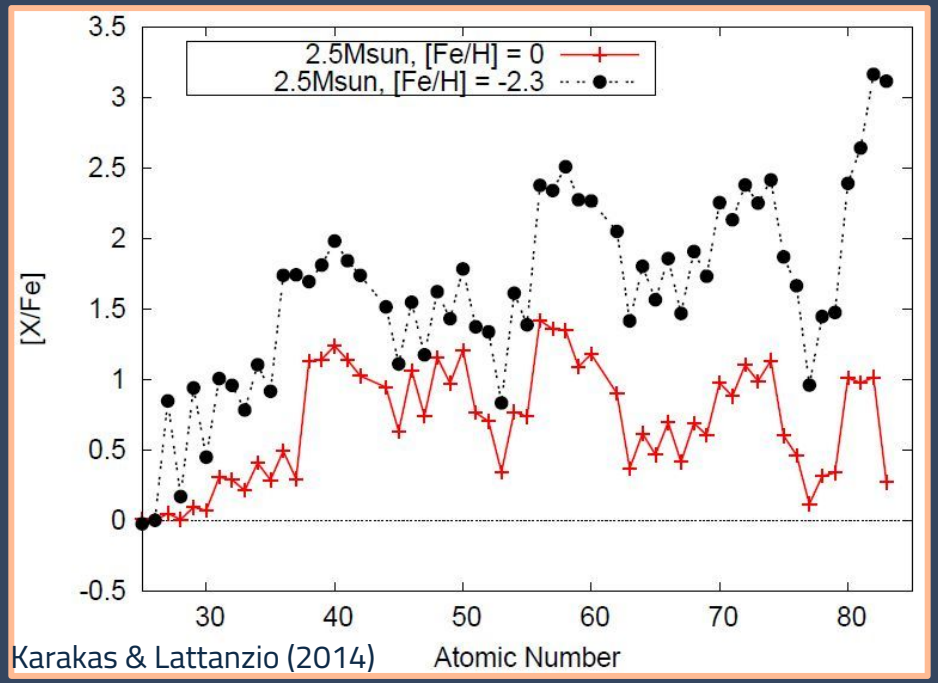

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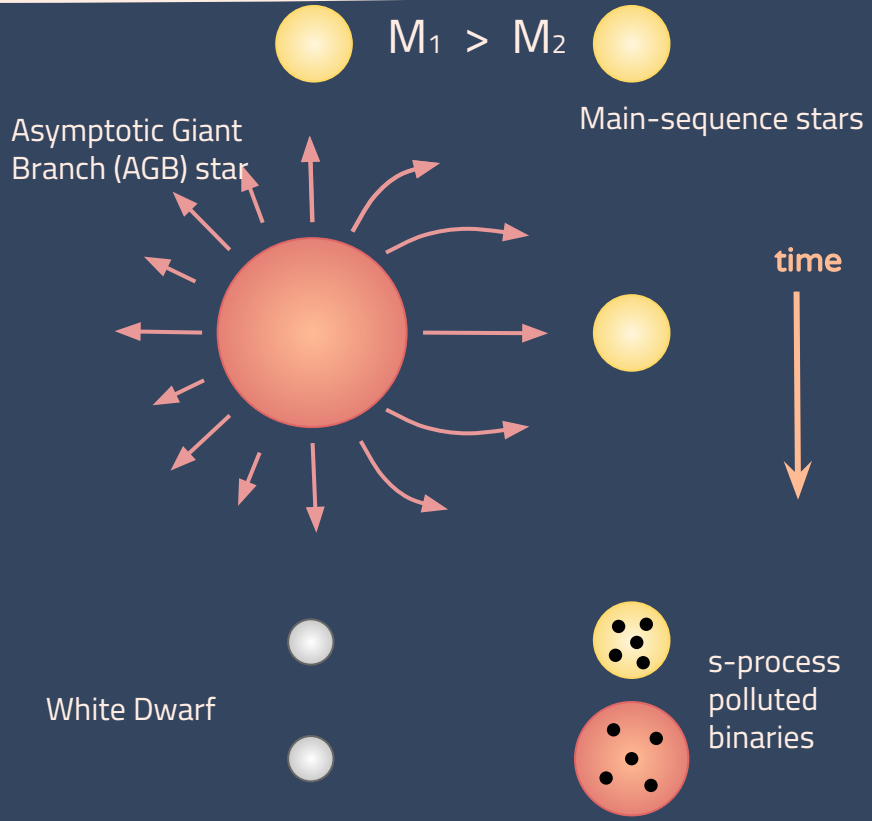

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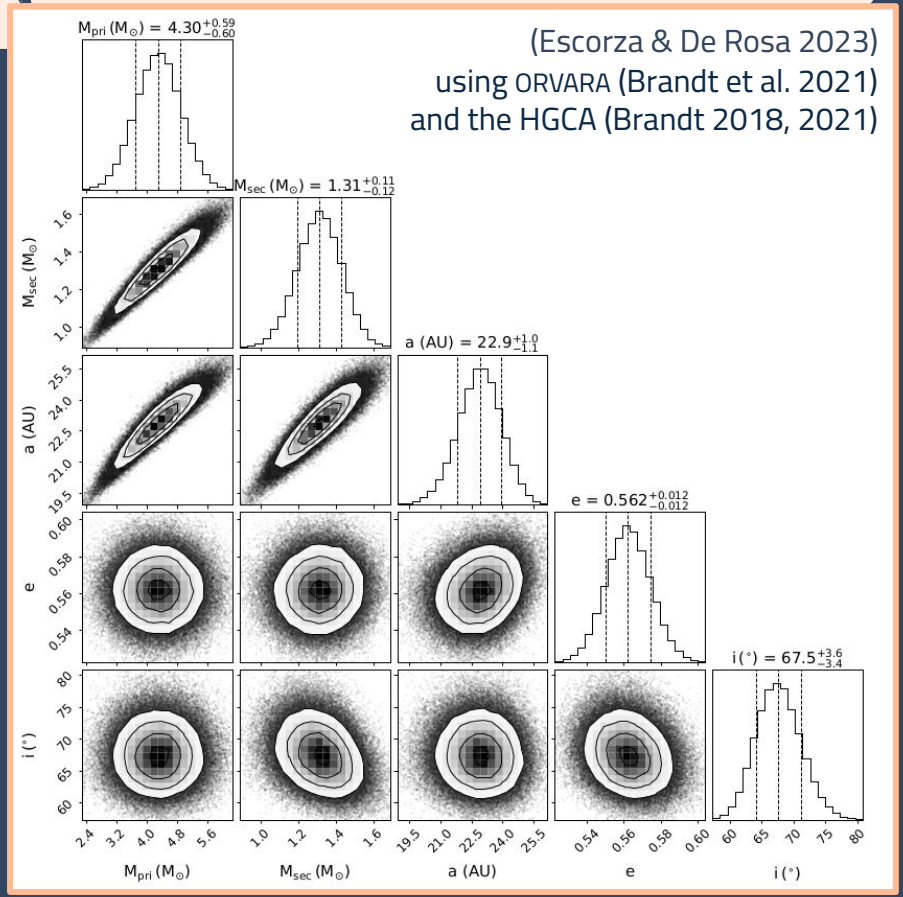

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The mass of the faint component in 56 UMa

Is the primary mass correct?

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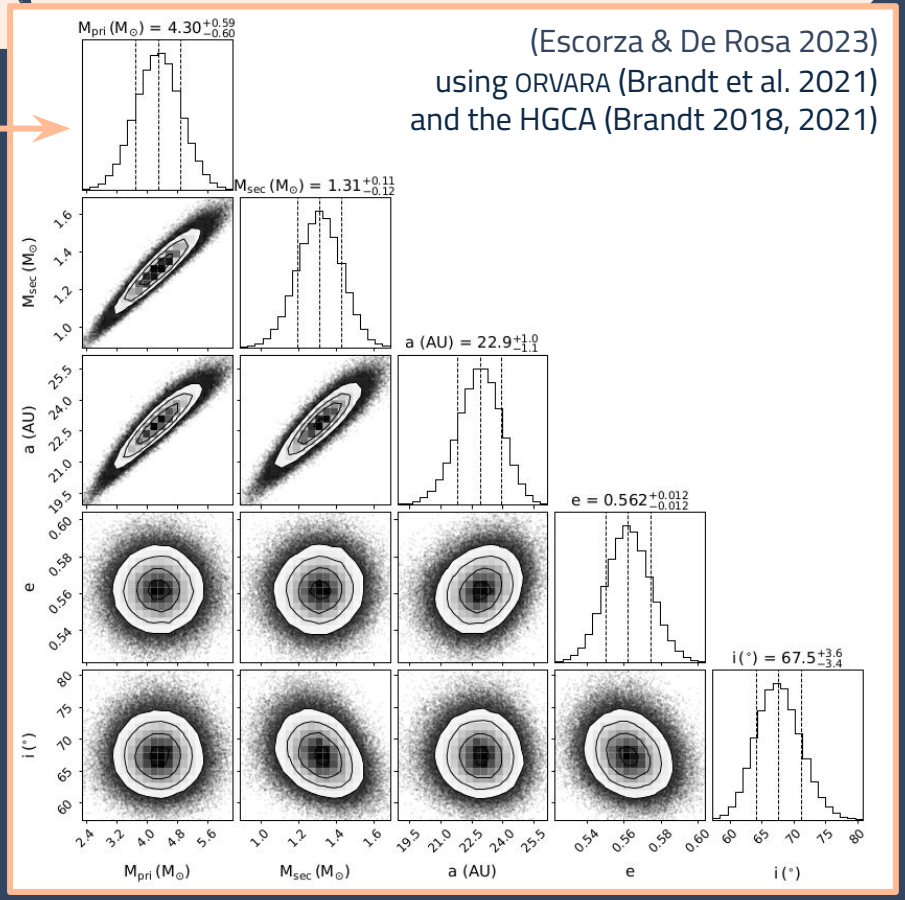
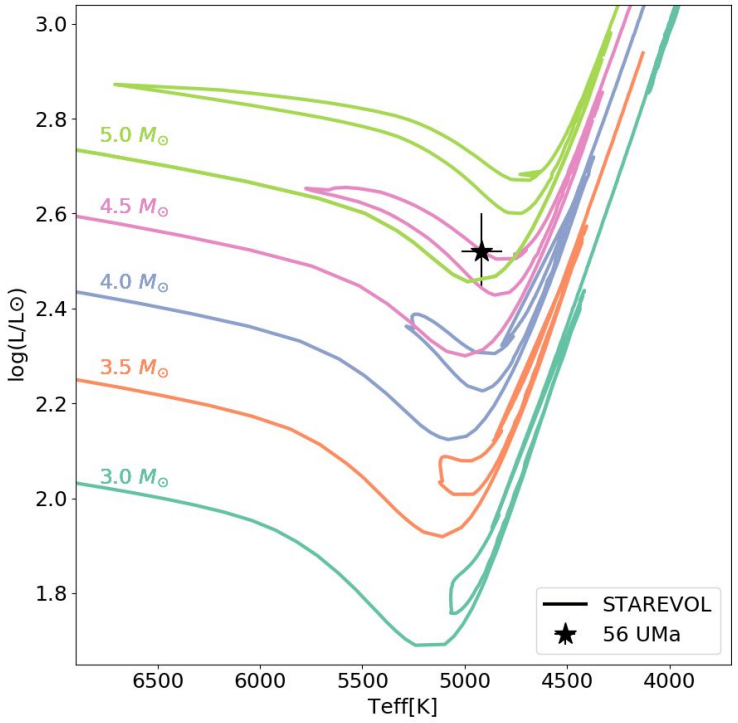


The mass of the red giant component in 56 UMa

Jorissen et al. (2019); Escorza et al. (2023)



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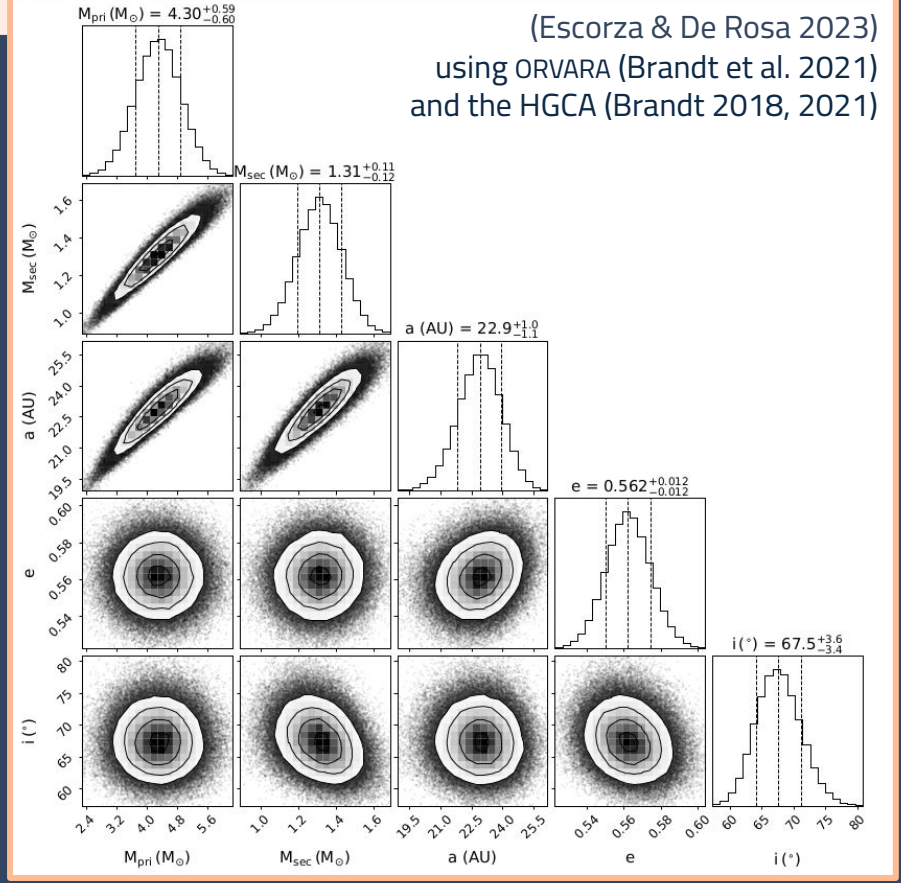

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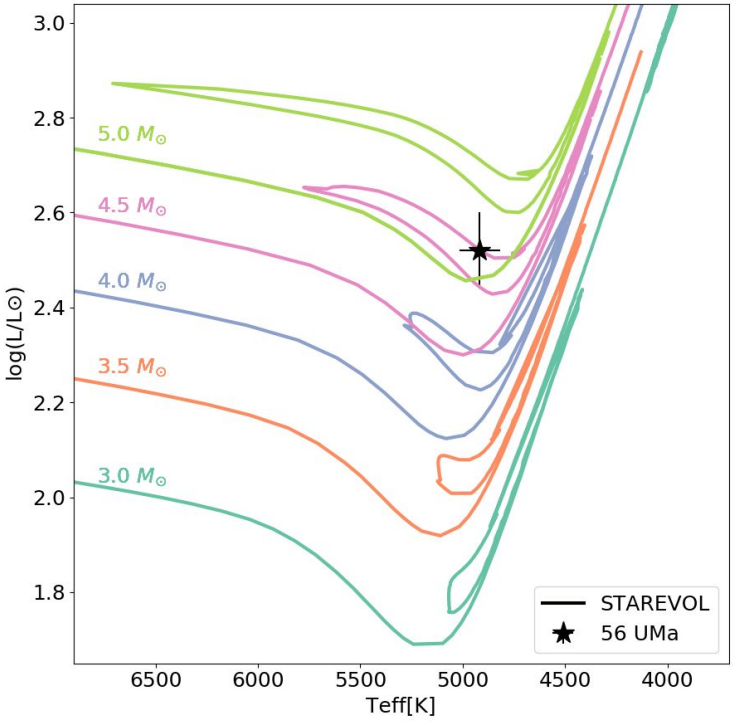
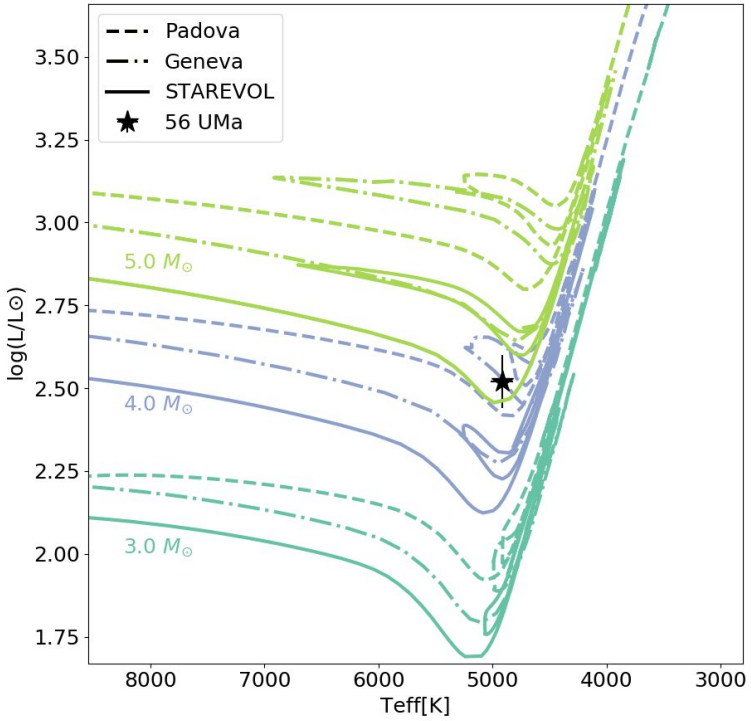
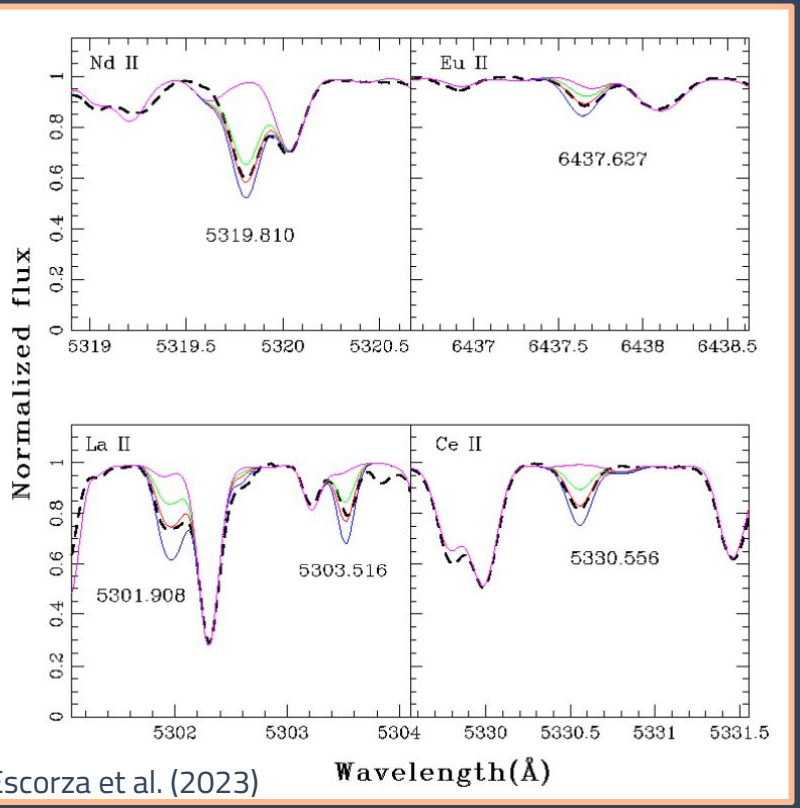




The heavy metal abundances of the red giant



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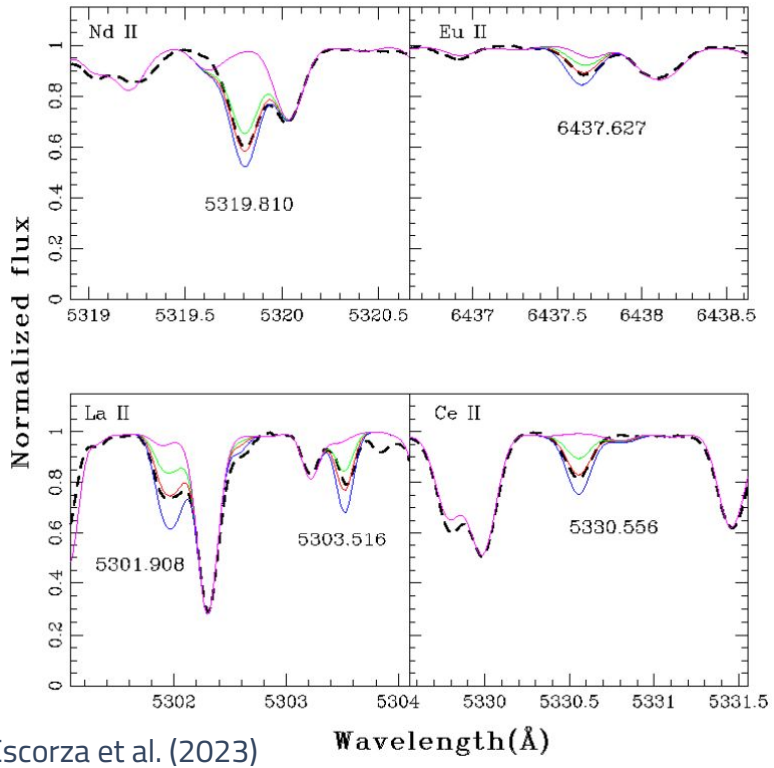

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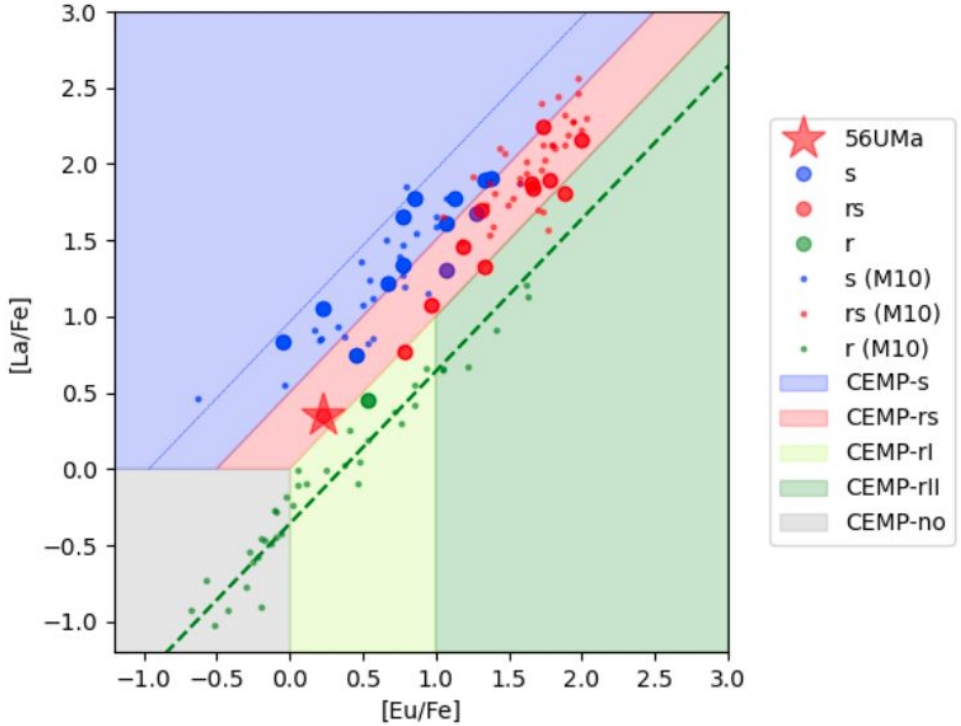
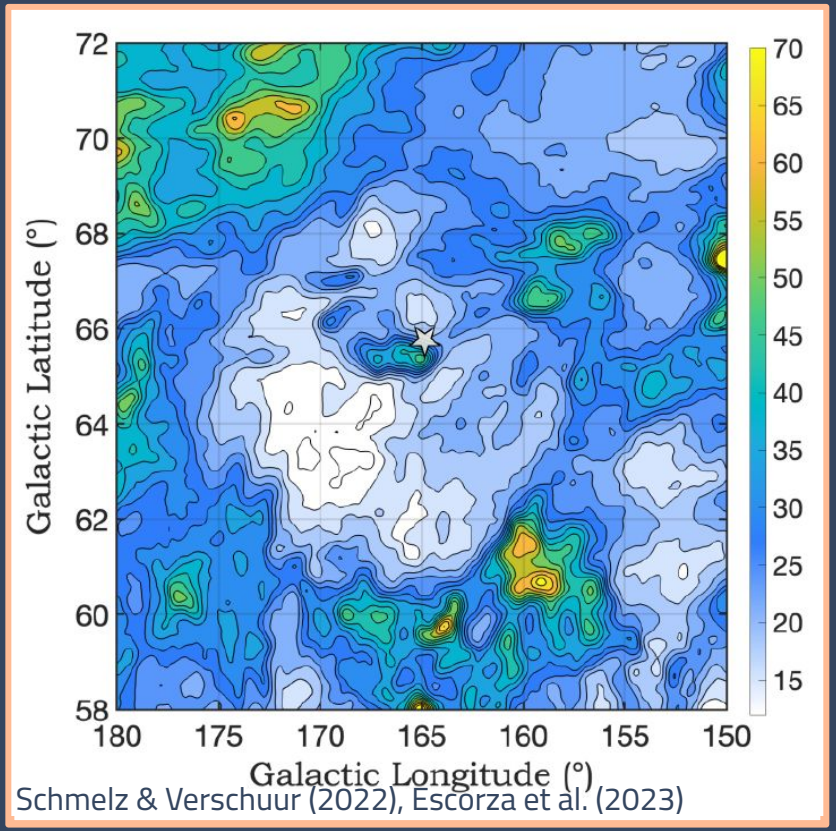


Escorza et al. (2023); comparison CEMP stars from Karinkuzhi et al. (2021)

The neutral gas cavity around 56 UMa



Schmelz & Verschuur (2022), Escorza et al. (2023)

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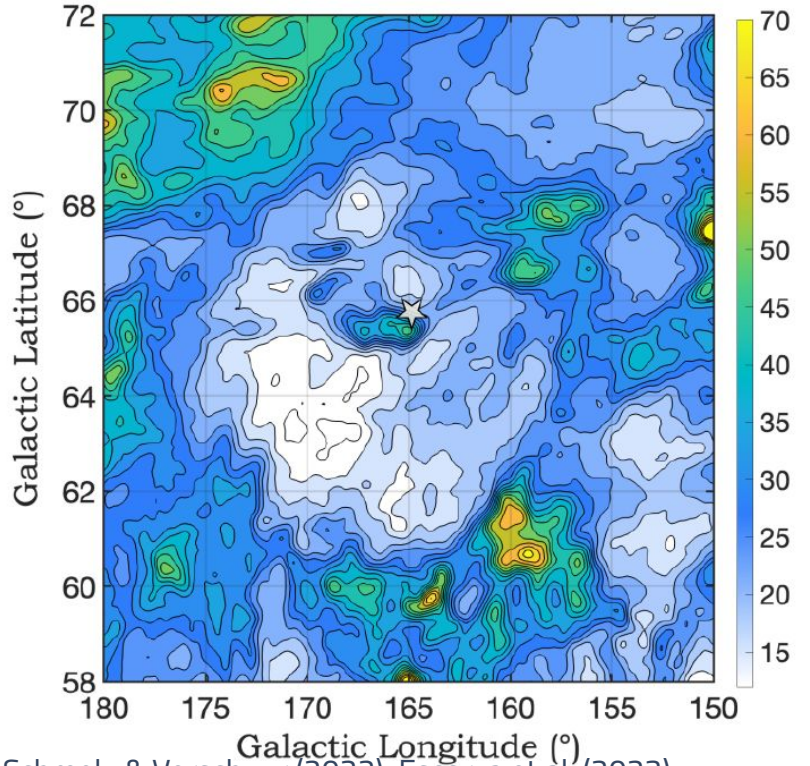

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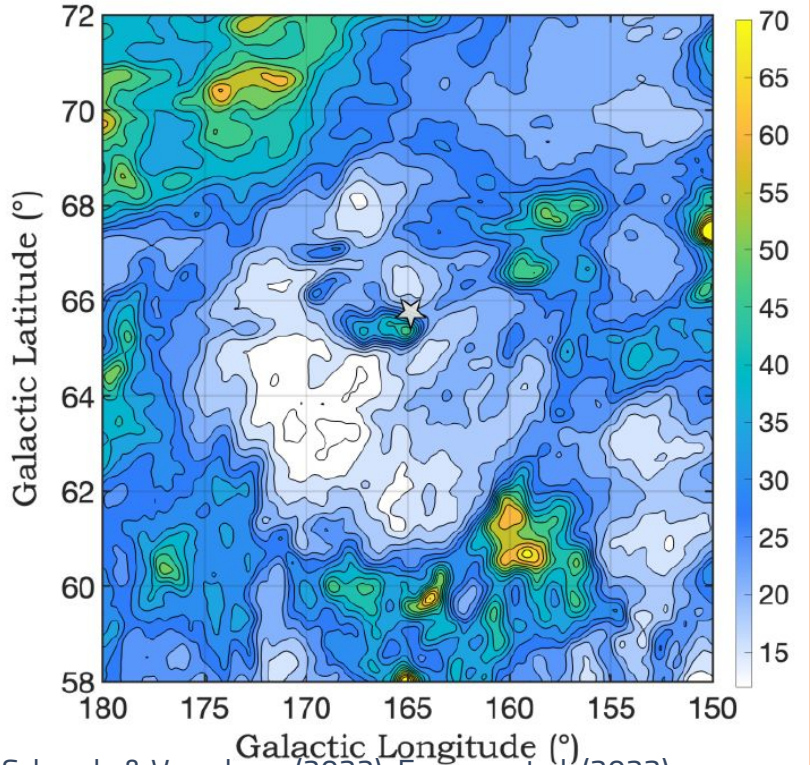

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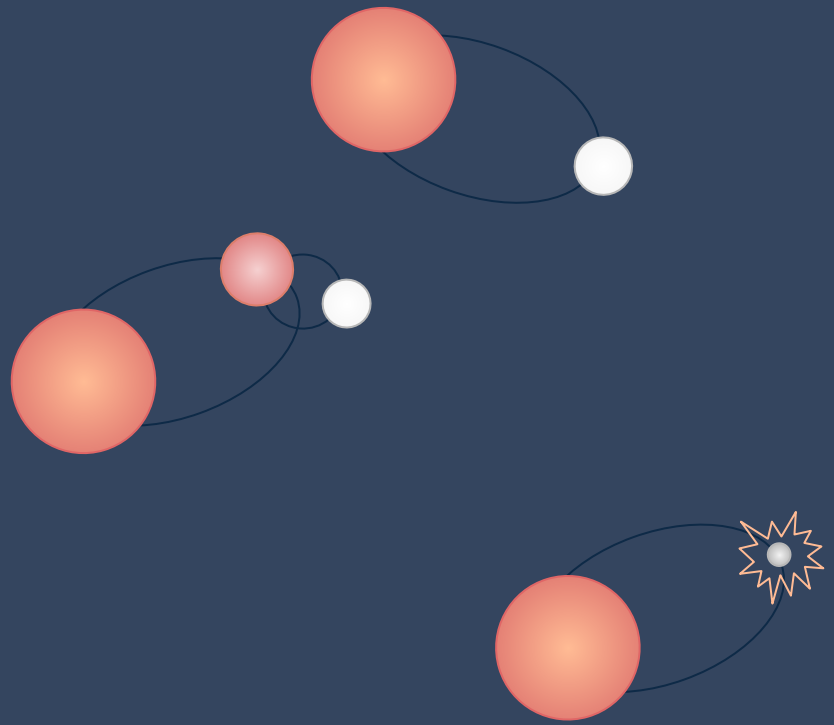

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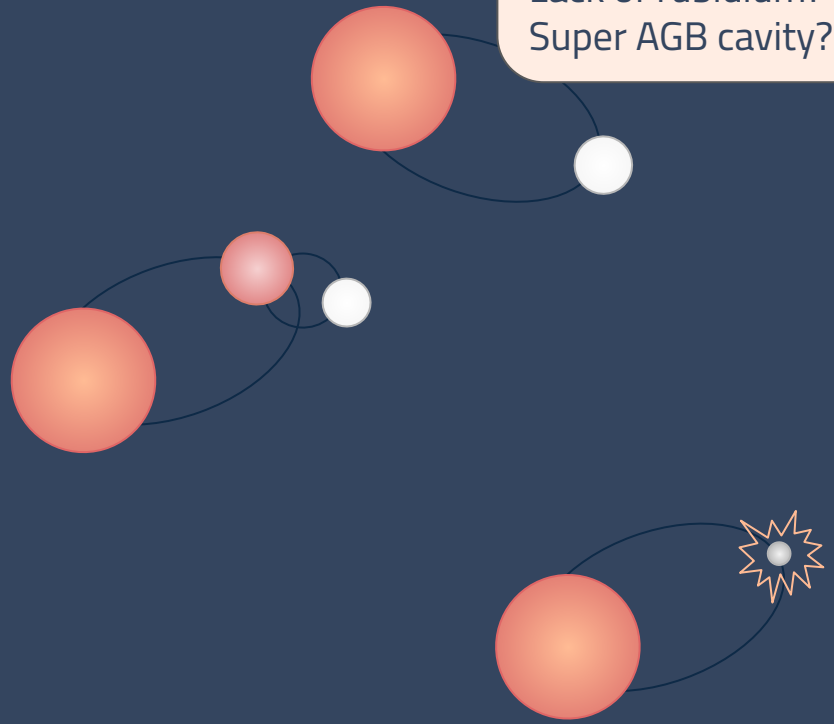
Lack of rubidium?
Super AGB cavity?



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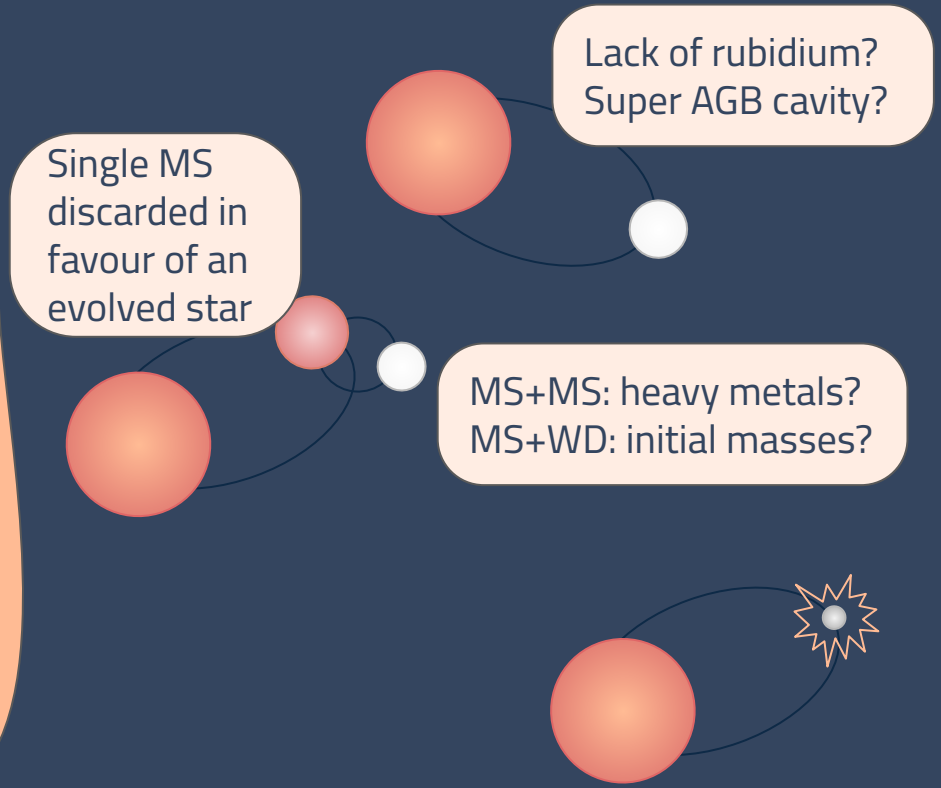

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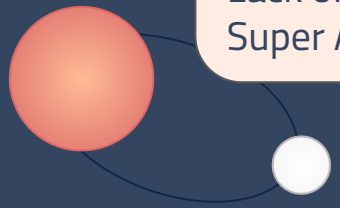
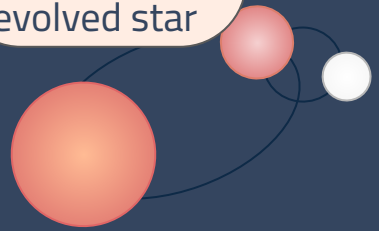
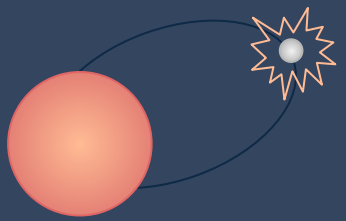


Single MS discarded in favour of an evolved star



MS+MS: heavy metals?
MS+WD: initial masses?

SN occurrence rates?
initial masses?



Thanks!

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Table 1. Stellar and orbital parameters of the 56 UMa system.

Parameter	Median ± 1 σ
Temperature, $T_{\rm eff}$ [K]	4917 ± 34
Surface gravity, log g	2.3 ± 0.6
Metallicity, [Fe/H]	−0.05
Microturbulence, ξ [km s^{-1}]	1.56
Primary mass, M_1 [$M_\odot$]	4.3 ± 0.2
Period, P [days]	$16\,911^{+438}_{-401}$
Eccentricity, e	$0.562^{+0.012}_{-0.012}$
Semi-major axis, a [AU]	$22.9^{+1.0}_{-1.1}$
Argument of periastron, ω_1 [°]	$286^{+2.3}_{-2.3}$
Time of periastron, T_0 [HJD]	$2\,468\,401^{+432}_{-385}$
Parallax, ϖ [mas]	$5.86^{+0.03}_{-0.04}$
Ascending node, Ω [°]	60^{+3}_{-3}
Inclination, i [°]	$68^{+3.6}_{-3.4}$
Secondary mass, M_2 [$M_\odot$]	$1.31^{+0.11}_{-0.12}$
Center-of-mass velocity [km s^{-1}]	0.13 ± 0.01
Center-of-mass $\mu_{\alpha*}$ [mas yr^{-1}]	−37.32 ± 0.01
Center-of-mass μ_δ [mas yr^{-1}]	−12.18 ± 0.01

Table D.1. Individual abundances of the giant component in 56 UMa

	Z	log $\epsilon_\odot^{\rm a}$	log ϵ	σ_s (N)	[X/Fe] ± $\sigma_{\rm [X/Fe]}$
C[b]	6	8.43	8.20	0.06(4)	−0.18±0.15
^{12}C/^{13}C			19		
N[c]	7	7.83	8.40	0.09(30)	0.62±0.21
O[d]	8	8.69	8.70	0.00(2)	0.06±0.22
Na I	11	6.24	6.40	0.10(4)	0.21±0.40
Mg I	12	7.60	7.50:	0.10(2)	−0.05±0.16
Fe I	26	7.50	7.45	0.10(65)	–
Rb I	37	2.52	2.50:	0.00(2)	0.03±0.10
Sr I	38	2.87	3.30:	0.10(1)	0.48±0.35
Sr I$_{\rm NLTE}$	38	2.87	3.49:	0.10(1)	0.67±0.35
Y II	39	2.21	2.40	0.05(7)	0.24±0.17
Zr I	40	2.58	2.43	0.13(3)	−0.10±0.30
Zr II	40	2.58	2.65	0.06(2)	0.12±0.30
Ba II	56	2.18	2.72:	0.09(2)	0.59±0.11
La II	57	1.10	1.40	0.12(8)	0.35±0.22
Ce II	58	1.58	1.70	0.13(8)	0.17±0.24
Pr II	59	0.72	0.75	0.05(3)	0.08±0.25
Nd II	60	1.42	1.72	0.13(13)	0.35±0.22
Sm II	62	0.96	1.08	0.13(4)	0.17±0.32
Eu II	63	0.52	0.70	0.00(2)	0.23±0.32
Gd II	64	1.10	1.40	0.10 (1)	0.35±0.21
Dy II	66	1.10	1.30	0.10 (1)	0.25±0.18
Hf II	72	0.85	1.10:	0.00(2)	0.30±0.32
Os II	76	1.40	1.60:	0.10 (1)	0.25±0.20