Modelling the depletion in post-AGB binaries with dusty circumbinary discs

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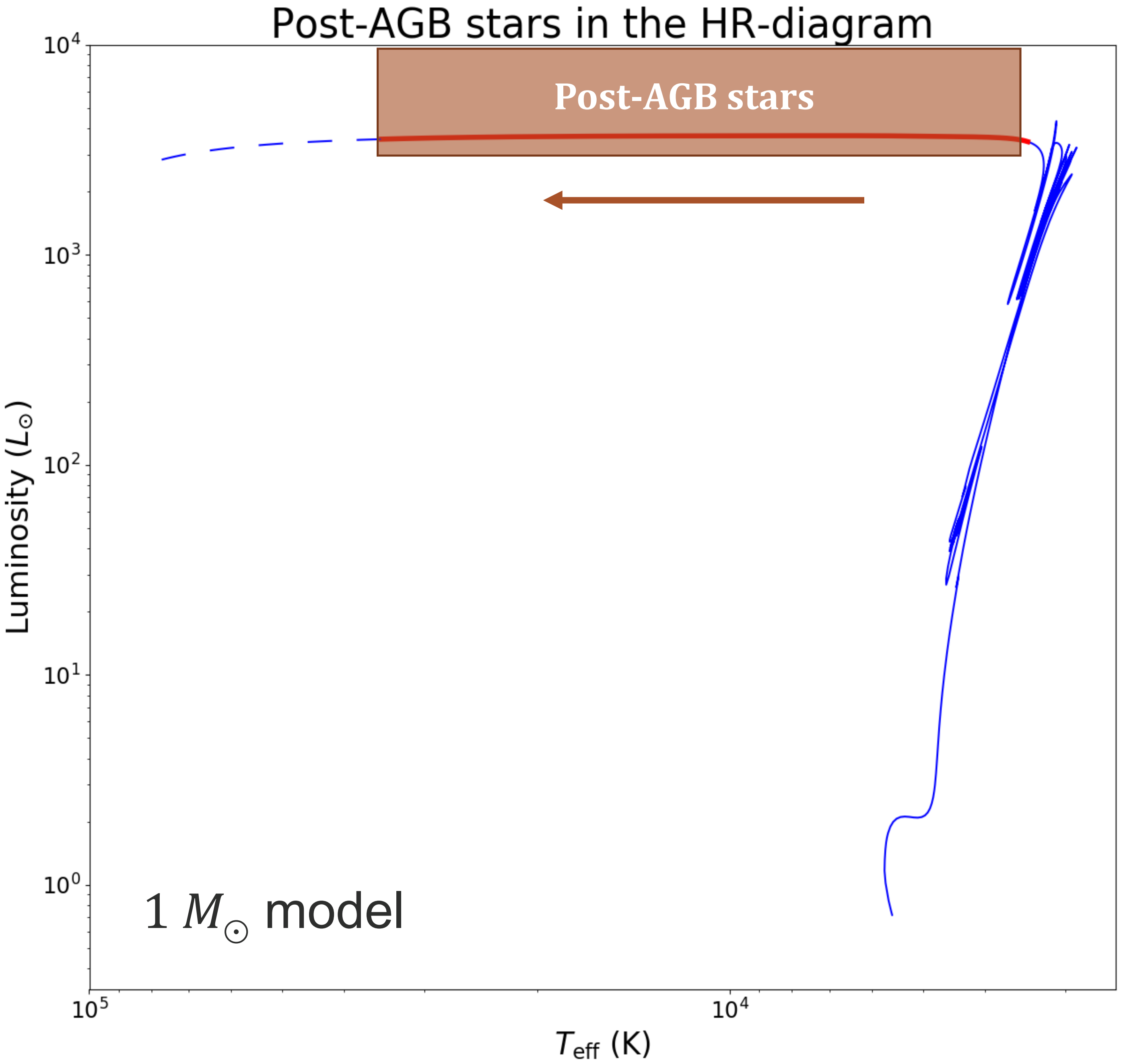


POST-AGB PHASE

Initial mass: $1 - 8\ M_\odot$

$\tau \sim 10^2 - 10^5$ yrs

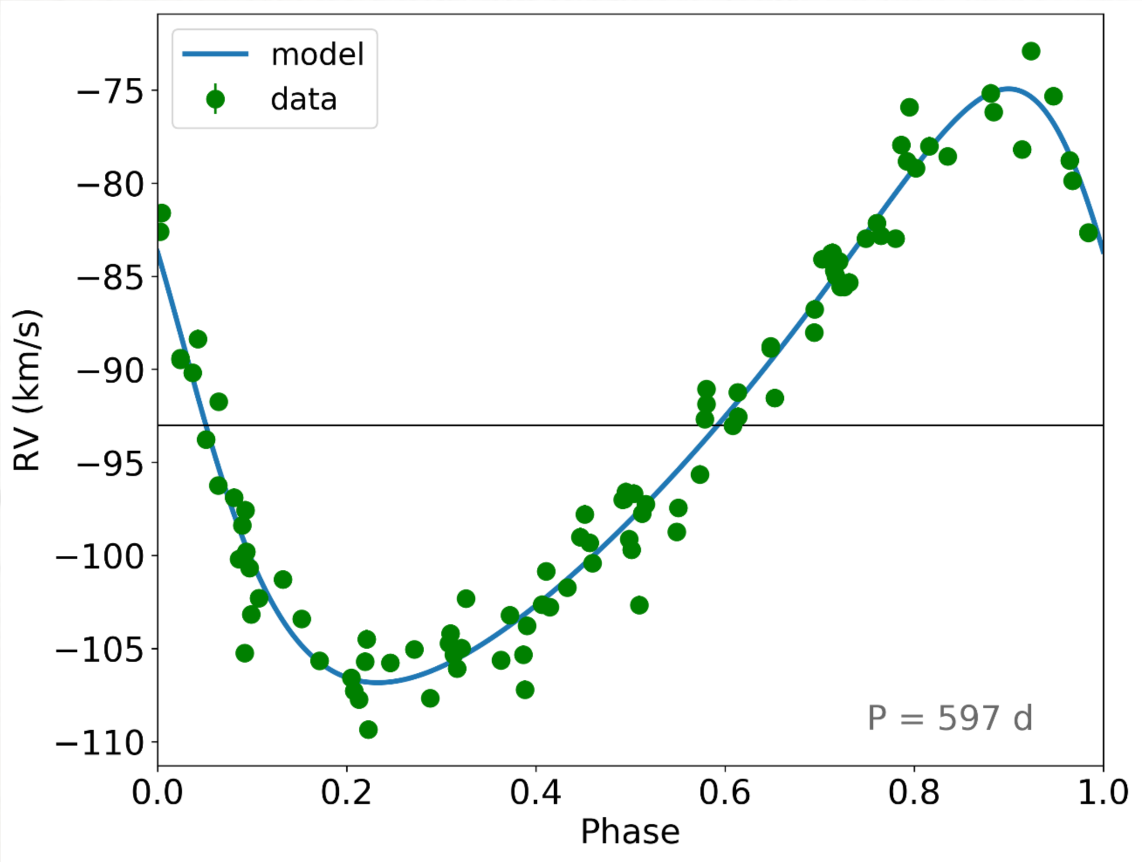
Transition: AGB → PN

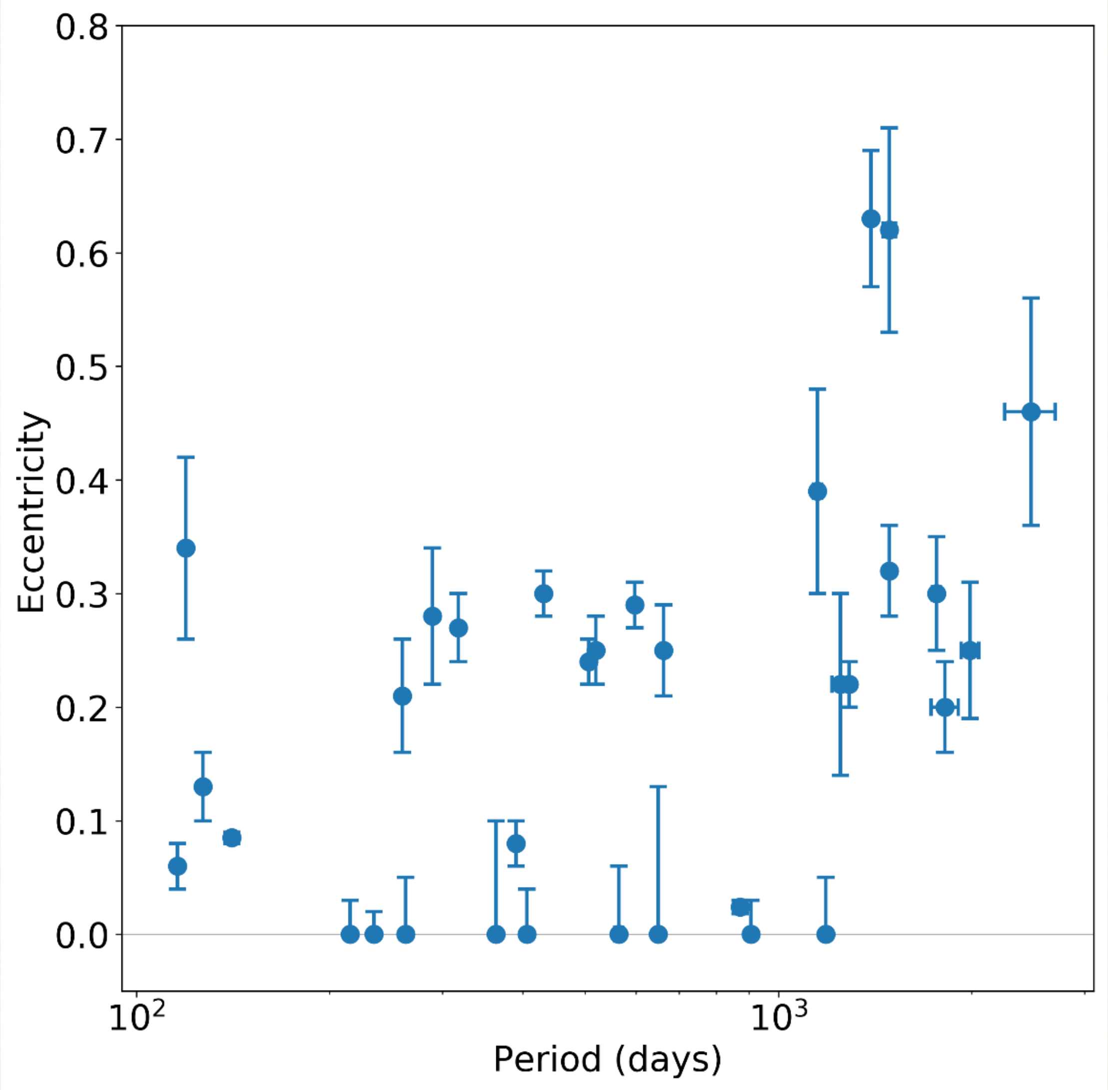
T_{eff}: 3000 K → 30000 K

Radius: 1 AU → 1 $R_\odot$

Binarity of post-AGB stars

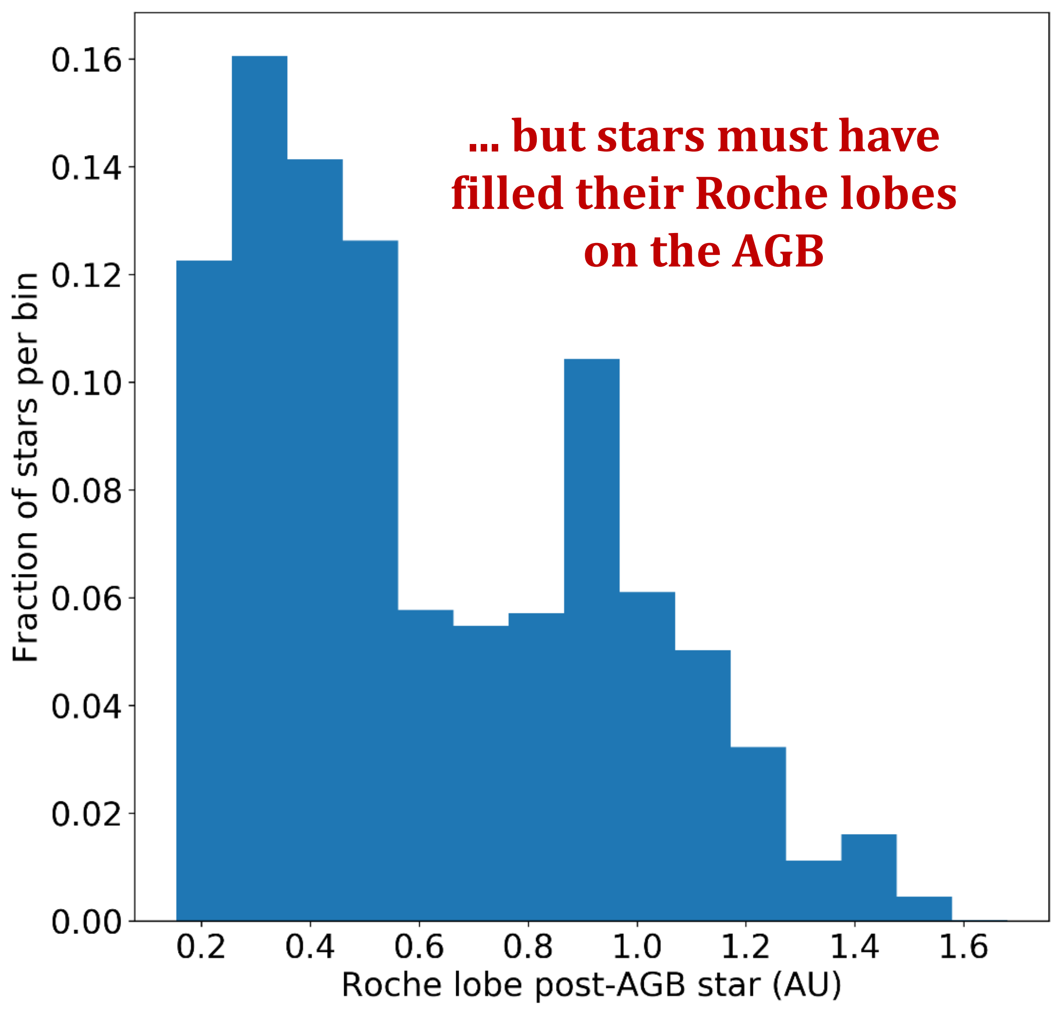
Orbits are “wide” and eccentric





Oomen et al. (2018)

Why are post-AGB binaries interesting?



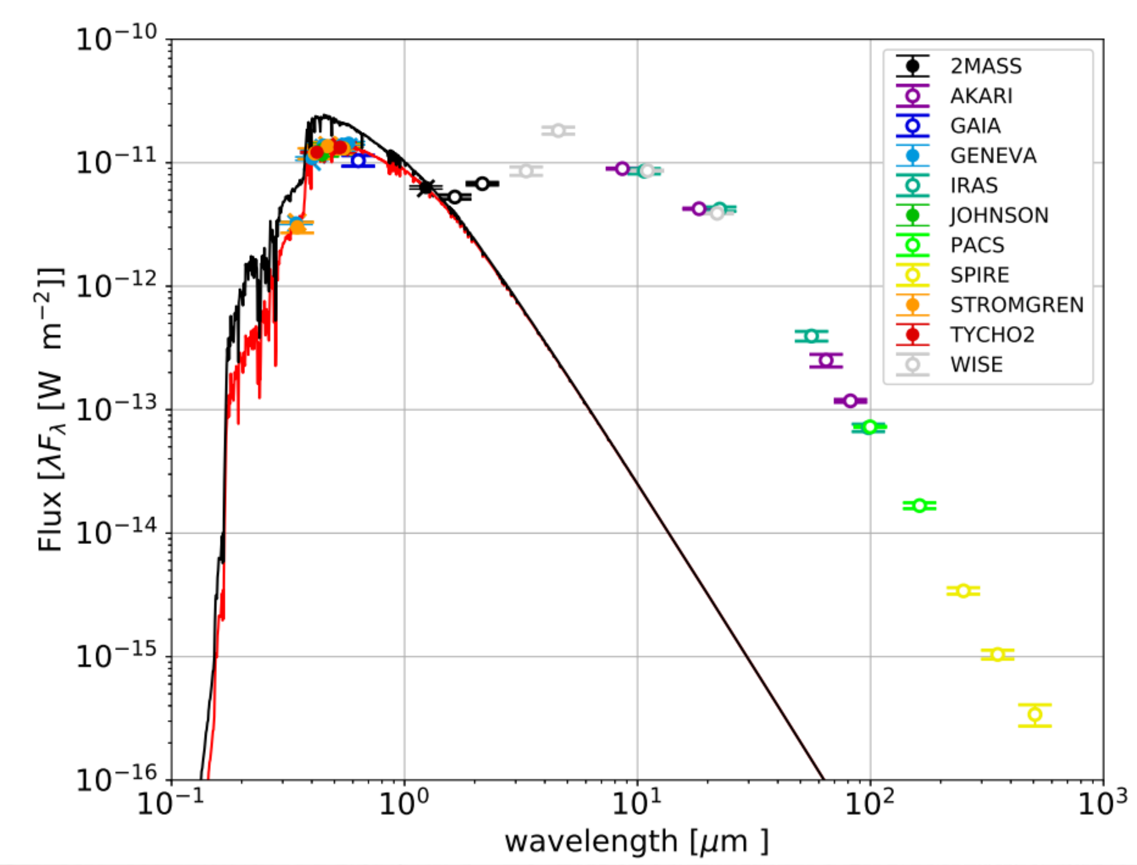
- Binaries somehow avoided in-spiral
- Orbits are eccentric despite strong tides

→ Binary evolution is not well understood

Oomen et al. (2018)

Why are post-AGB binaries interesting?

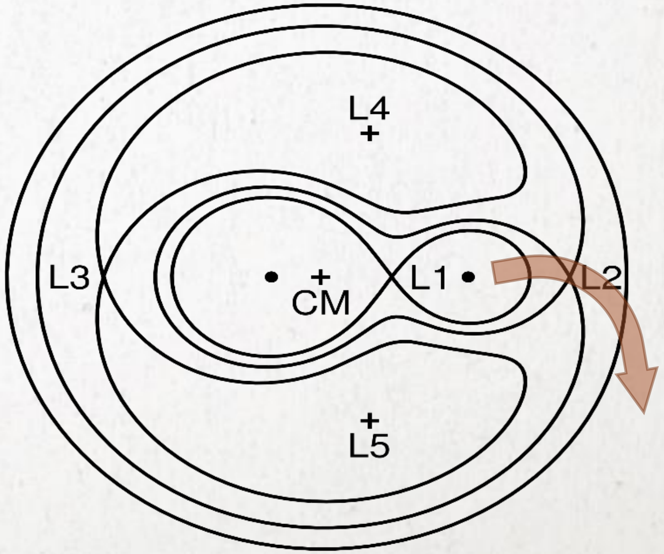
HD 108015



All confirmed post-AGB binaries have a circumbinary disc!

→Disc formation as a product of binary interaction:

Mass loss along the L2 point



Shu et al. (1979)

Why are post-AGB binaries interesting?

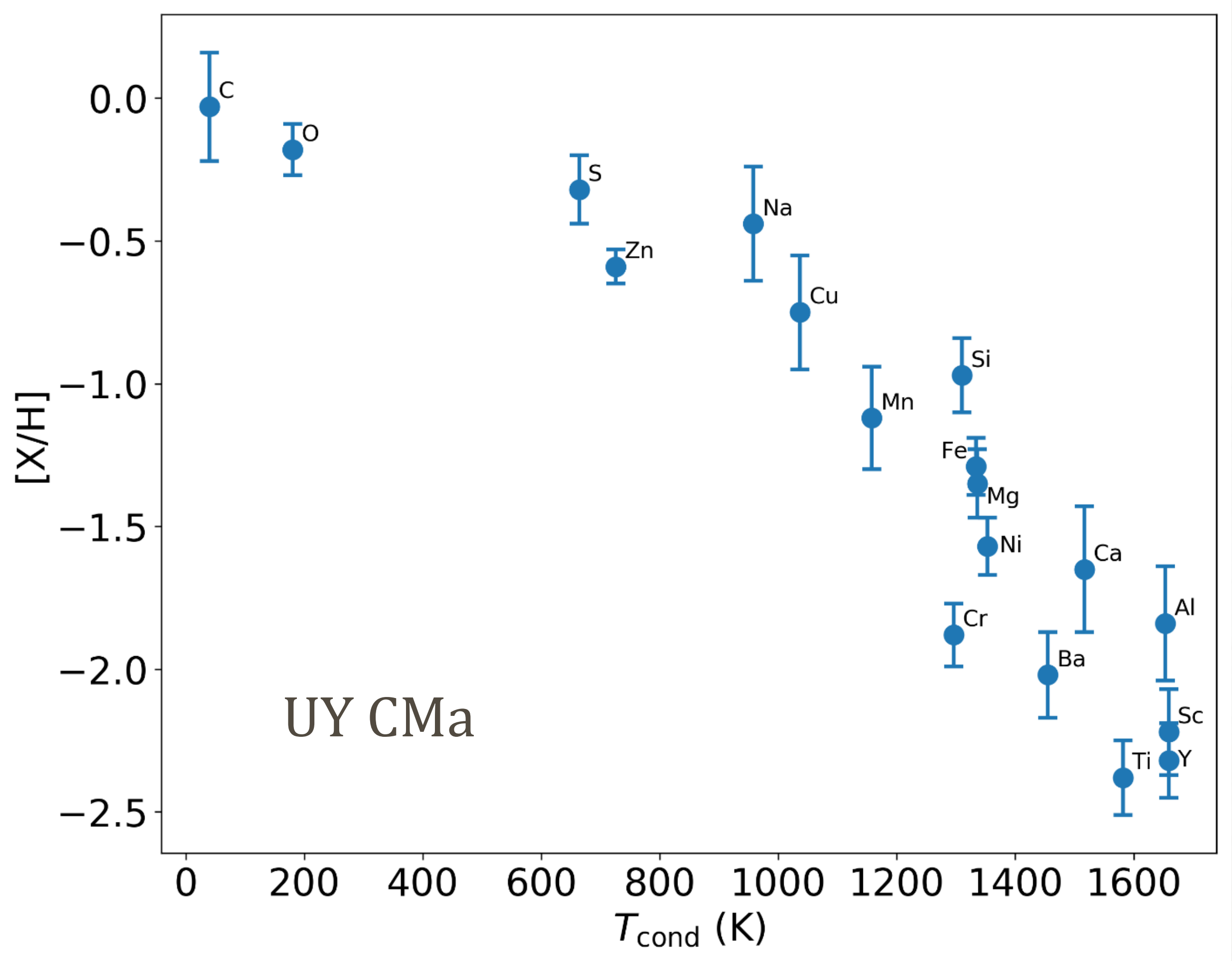
Most disc-type post-AGB stars have a chemical peculiarity called depletion

Higher condensation temperature

↓

More depleted

- Re-accretion of metal-poor gas
- Dust remains in circumbinary disc



Waters et al. (1992); Van Winckel et al. (1995); Van Winckel (1997); Maas et al. (2005); Giridhar et al. (2005)

Goals

Can re-accretion of gas produce the observed depletion patterns?
If yes, what accretion rates are required?

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How does re-accretion of gas from a circumbinary disc impact post-AGB evolution?

Methods

- Sample of 58 out of ~90 known disc-type post-AGB stars with abundance data from literature

- Use Gaia distance to determine luminosity (and mass) of post-AGB stars

- Compare observed depletion values to MESA models of similar mass

MESA

Paxton et al. (2011, 2013, 2015, 2018)

Accretion in MESA

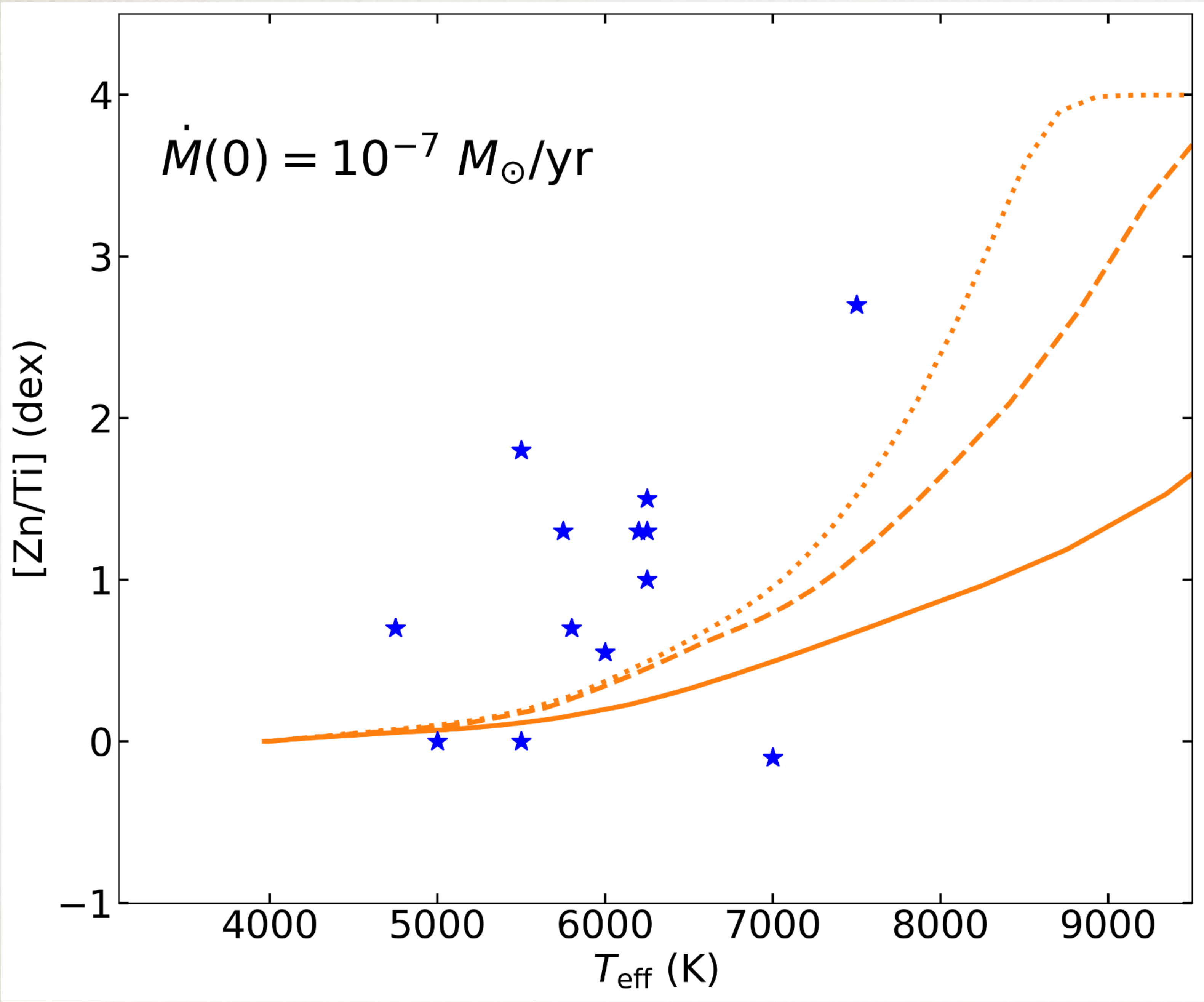
- Use prescription from Rafikov (2016) for the viscous evolution of a disc:

$$\dot{M}_{\rm accr}(t) = \frac{\dot{M}(0)}{2}\left(1 + \frac{2\dot{M}(0)t}{M_{\rm d}}\right)^{-3/2}$$

Parameters:

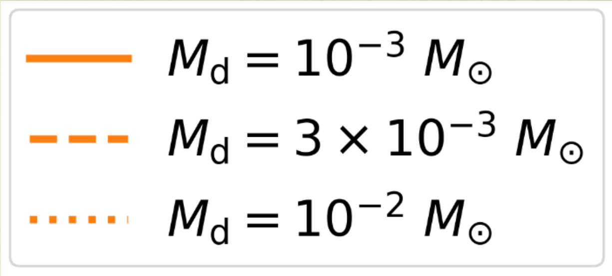
- $\dot{M}(0)$: 10^{-8}, 3×10^{-8}, 10^{-7}, 3×10^{-7}, 10^{-6} $M_\odot$/yr
- M_d: 10^{-3}, 3×10^{-3}, 10^{-2} $M_\odot$
- T_0 : 3500, 4000, 5000, 6000 K
- Post-AGB masses: 0.40, 0.45, 0.55, 0.60, 0.65 $M_\odot$

Results

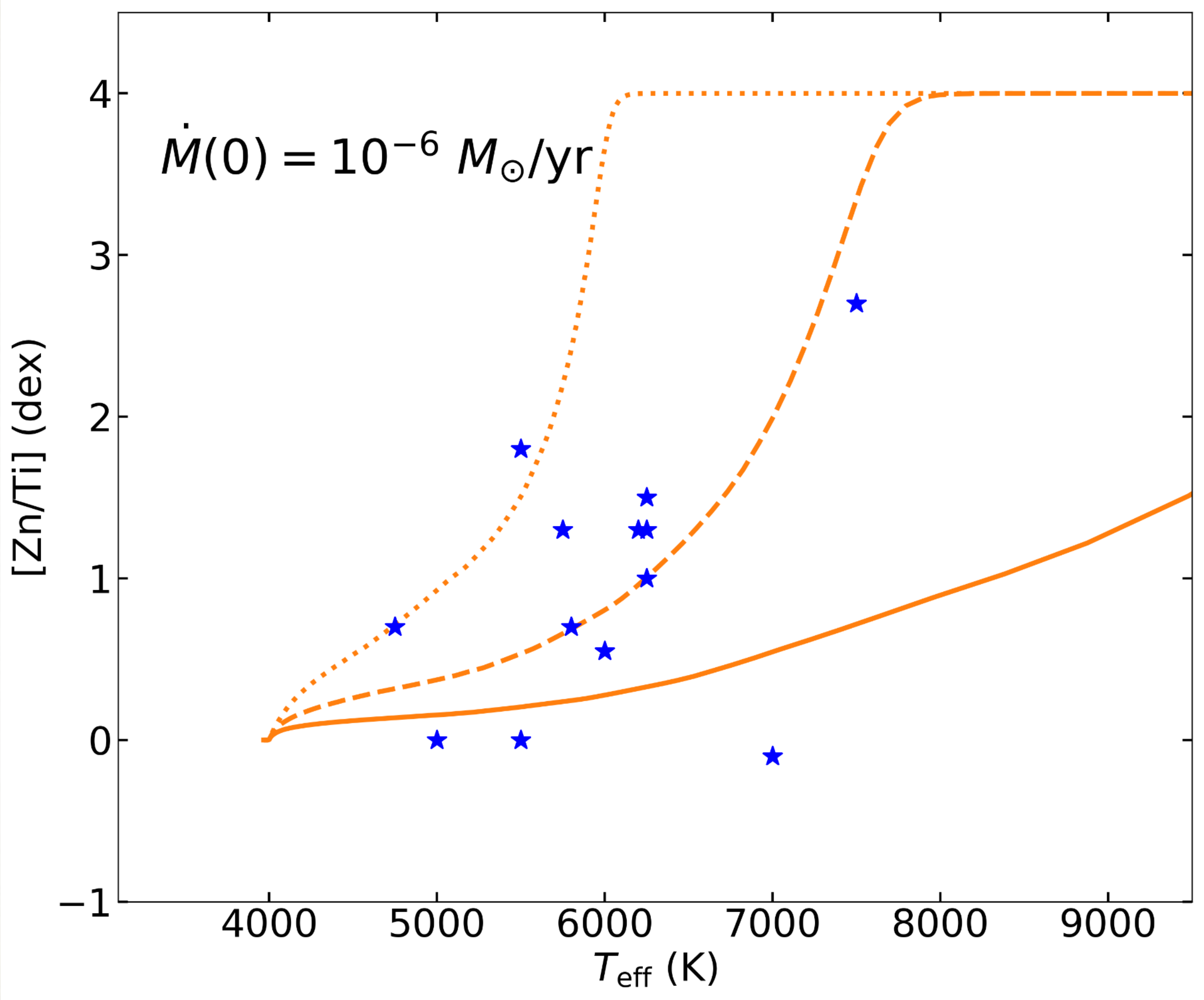


0.55 $M_\odot$ models

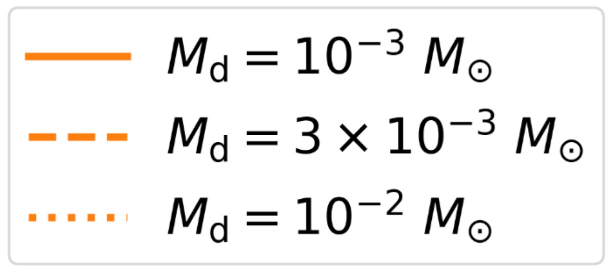
Medium accretion

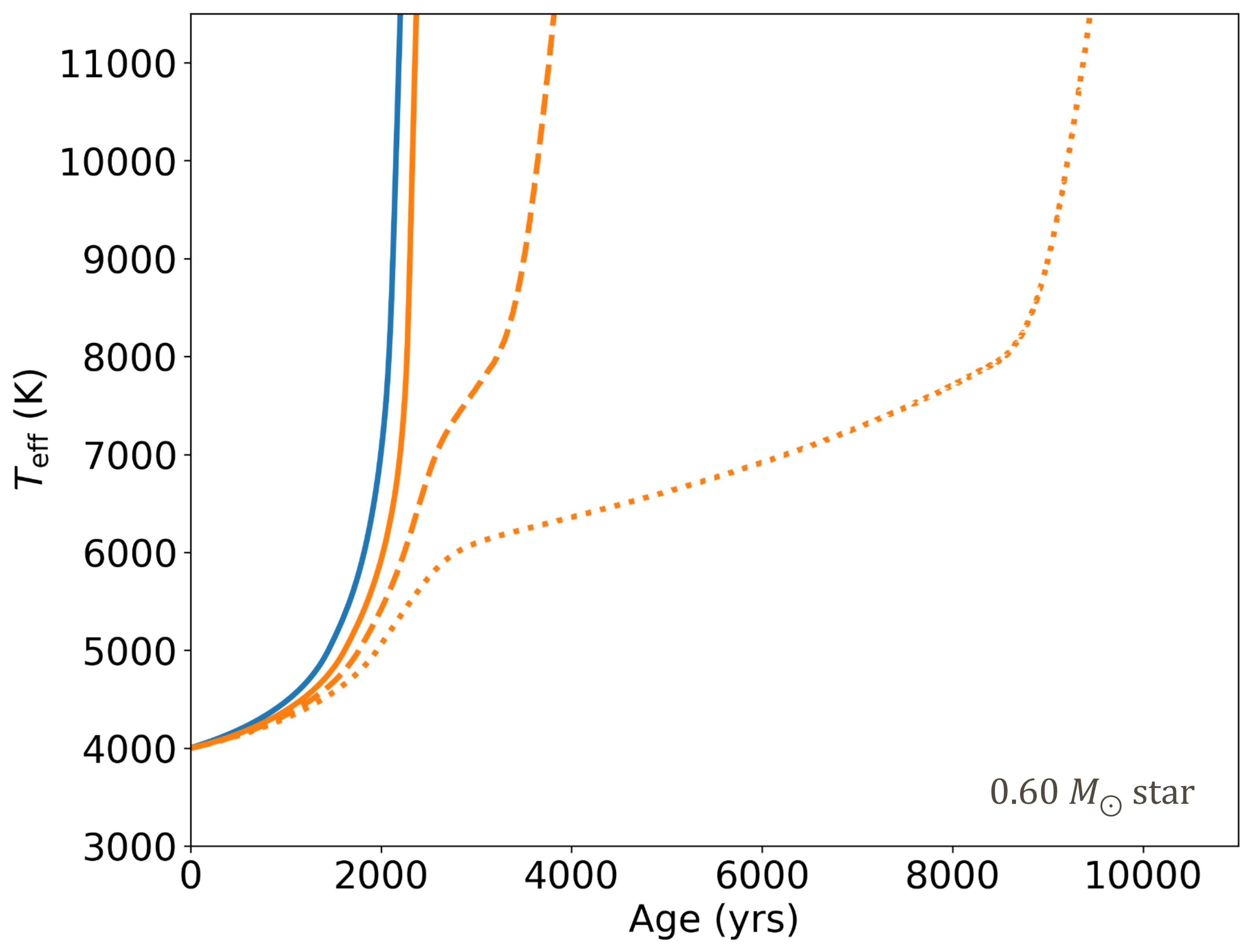


$0.55\ M_\odot$ models



High accretion





Impact on evolution timescale

Combination of high disc mass and high accretion extends evolution!

Conclusions

- Accretion of metal-poor gas is able to explain the depletion phenomenon.
- High accretion rates and disc masses are required to explain some strongly depleted stars at low effective temperatures.
- High accretion rates can effectively prolong post-AGB evolution.

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Modelling depletion by re-accretion of gas from a dusty disc in post-AGB stars

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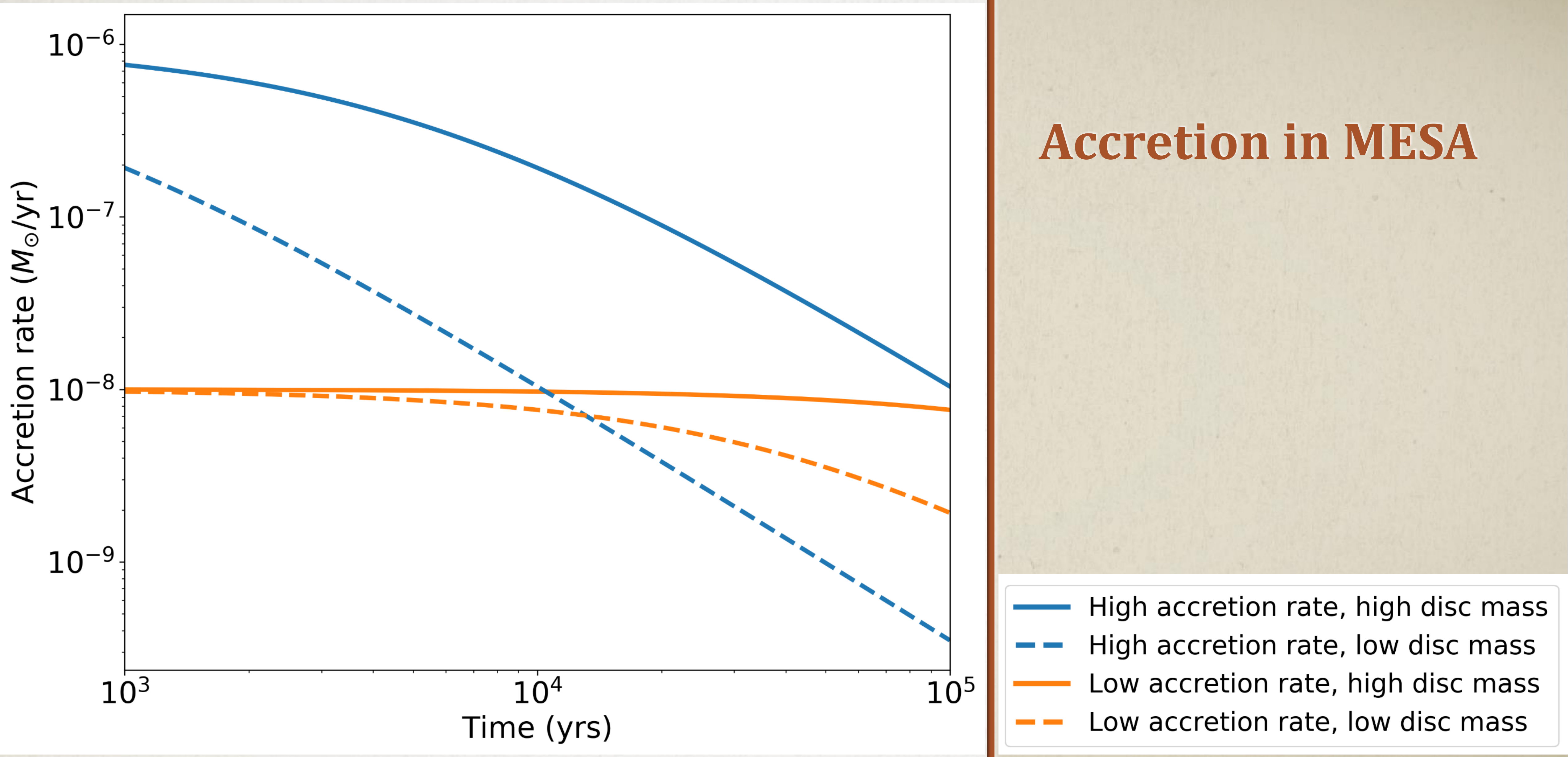
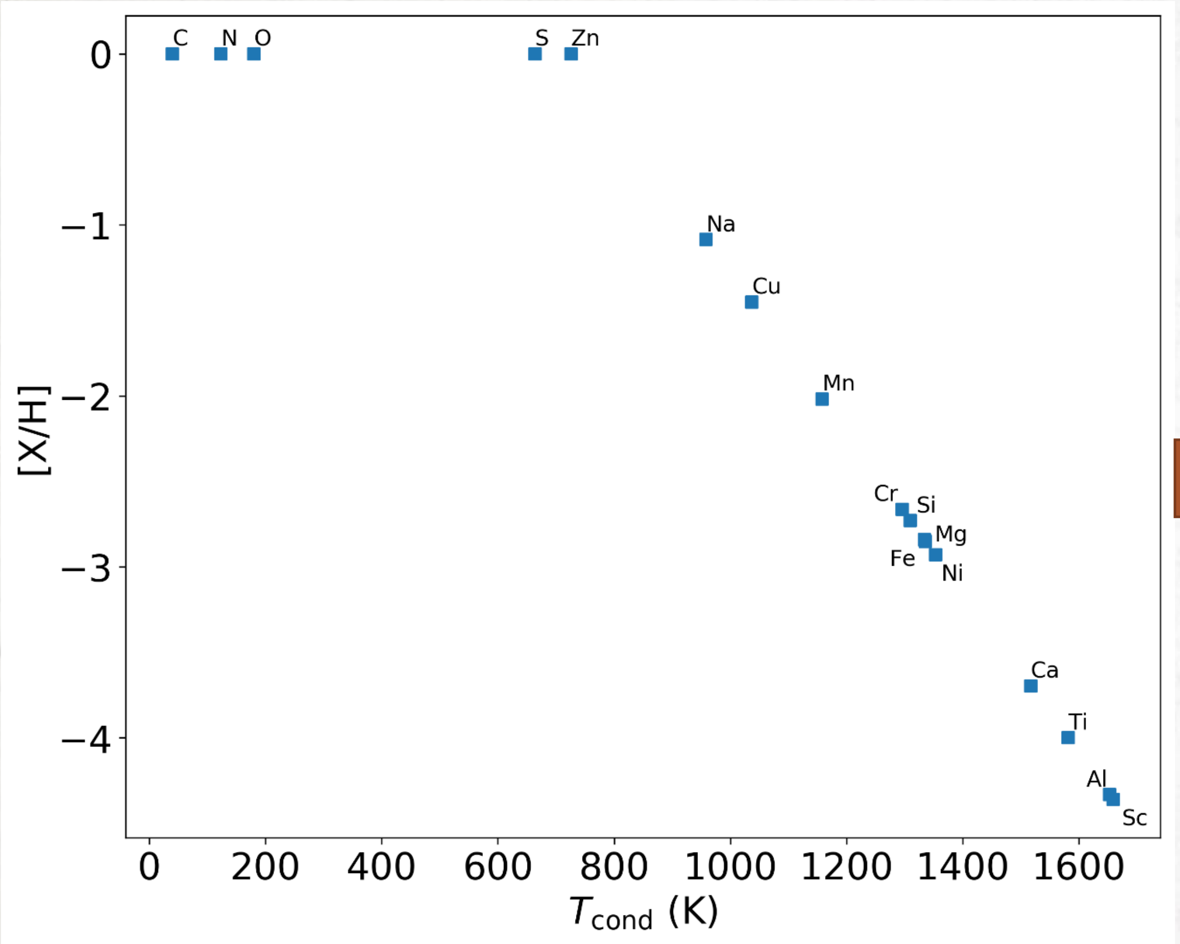
Extras

Accretion in MESA



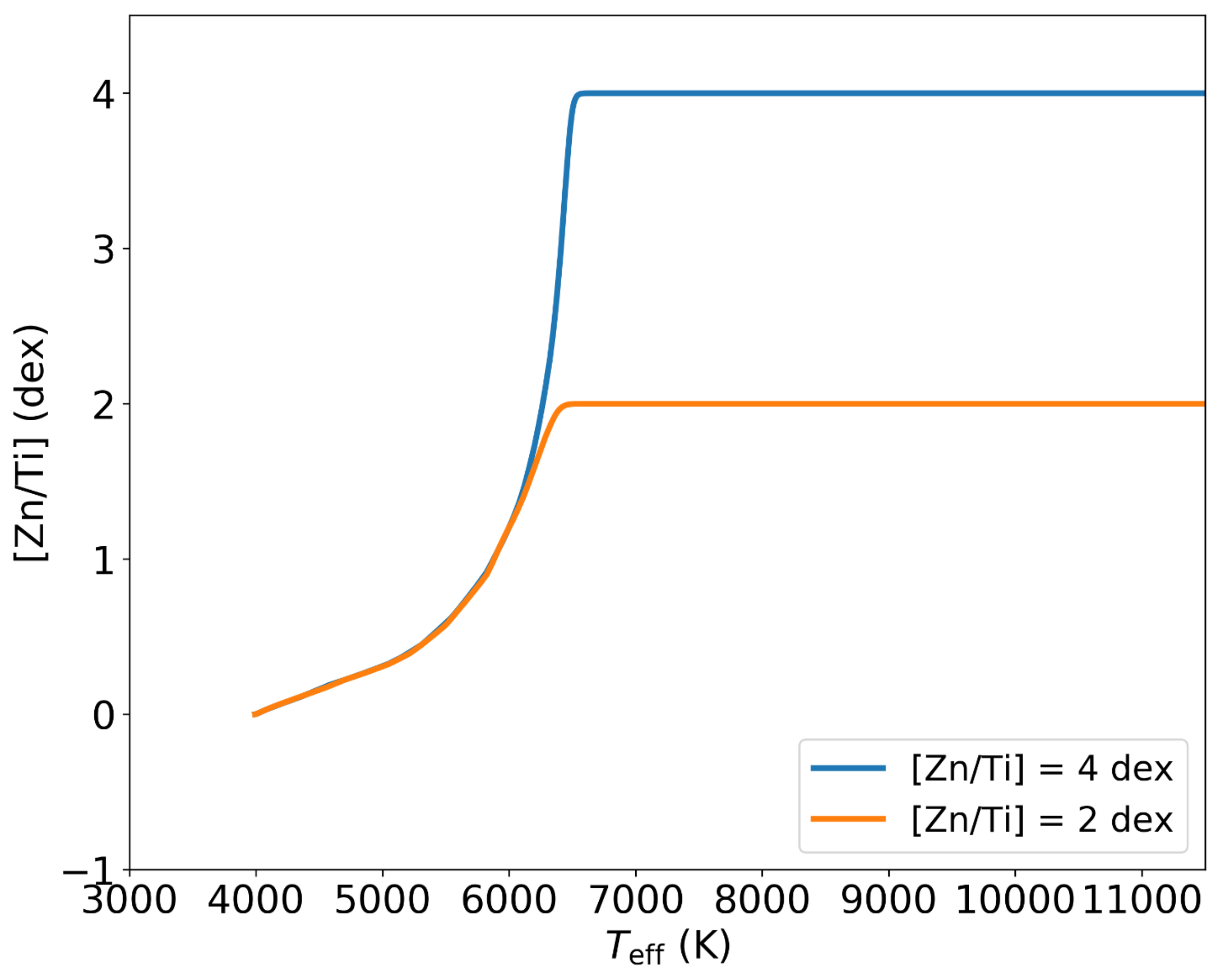
Comparing models to observations



Only one accretion composition in our models…

But many accretion compositions in nature!

Comparing models to observations



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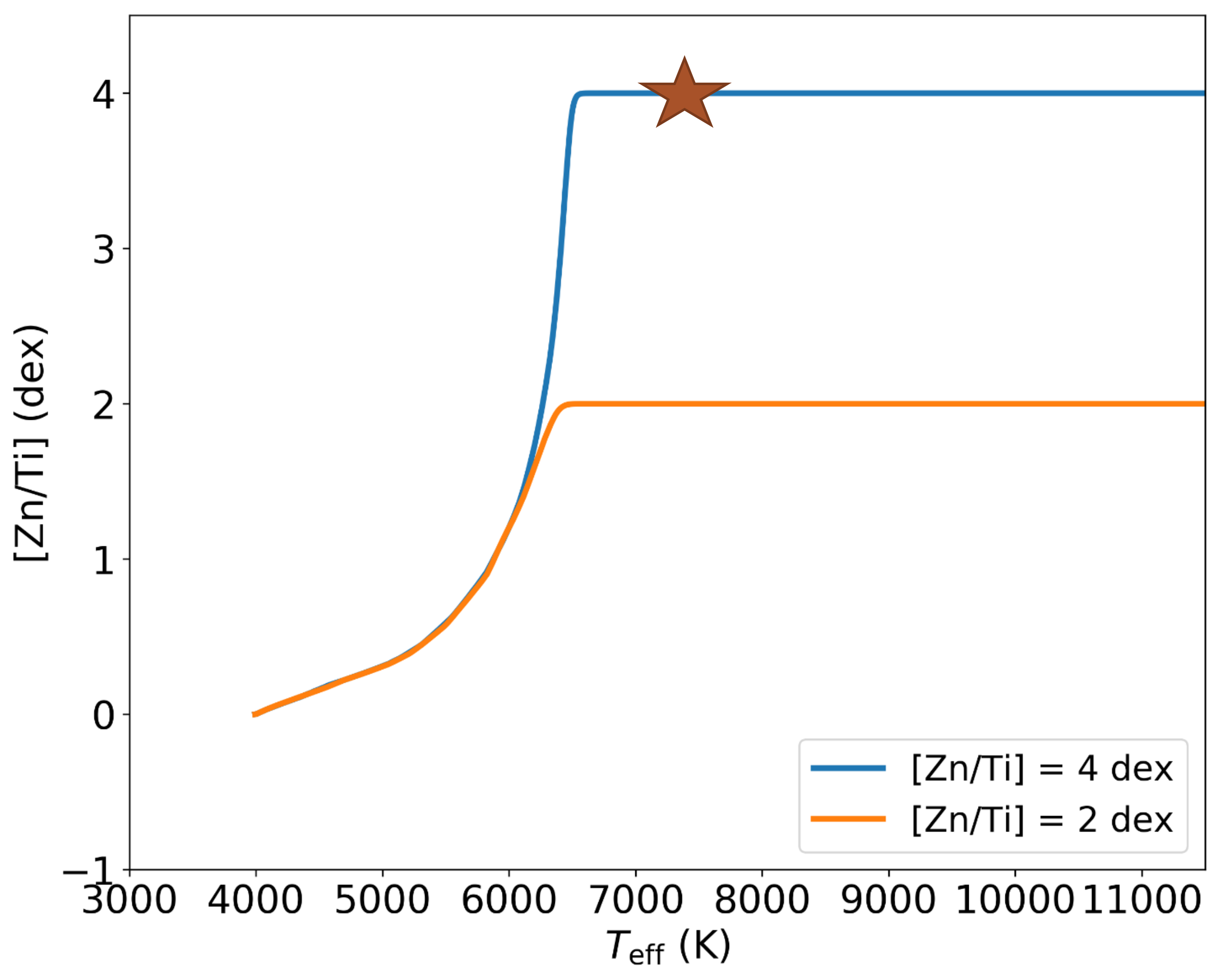

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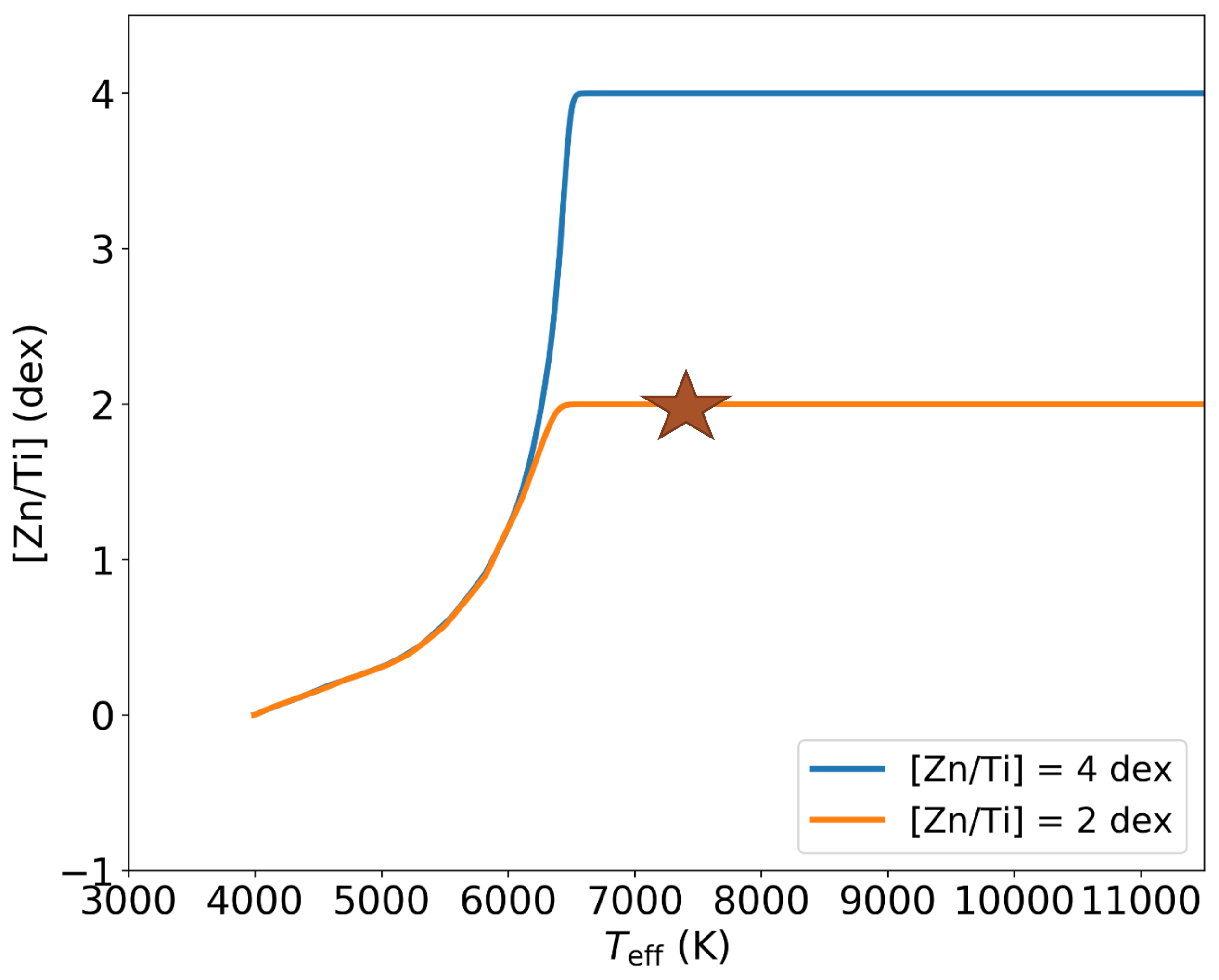

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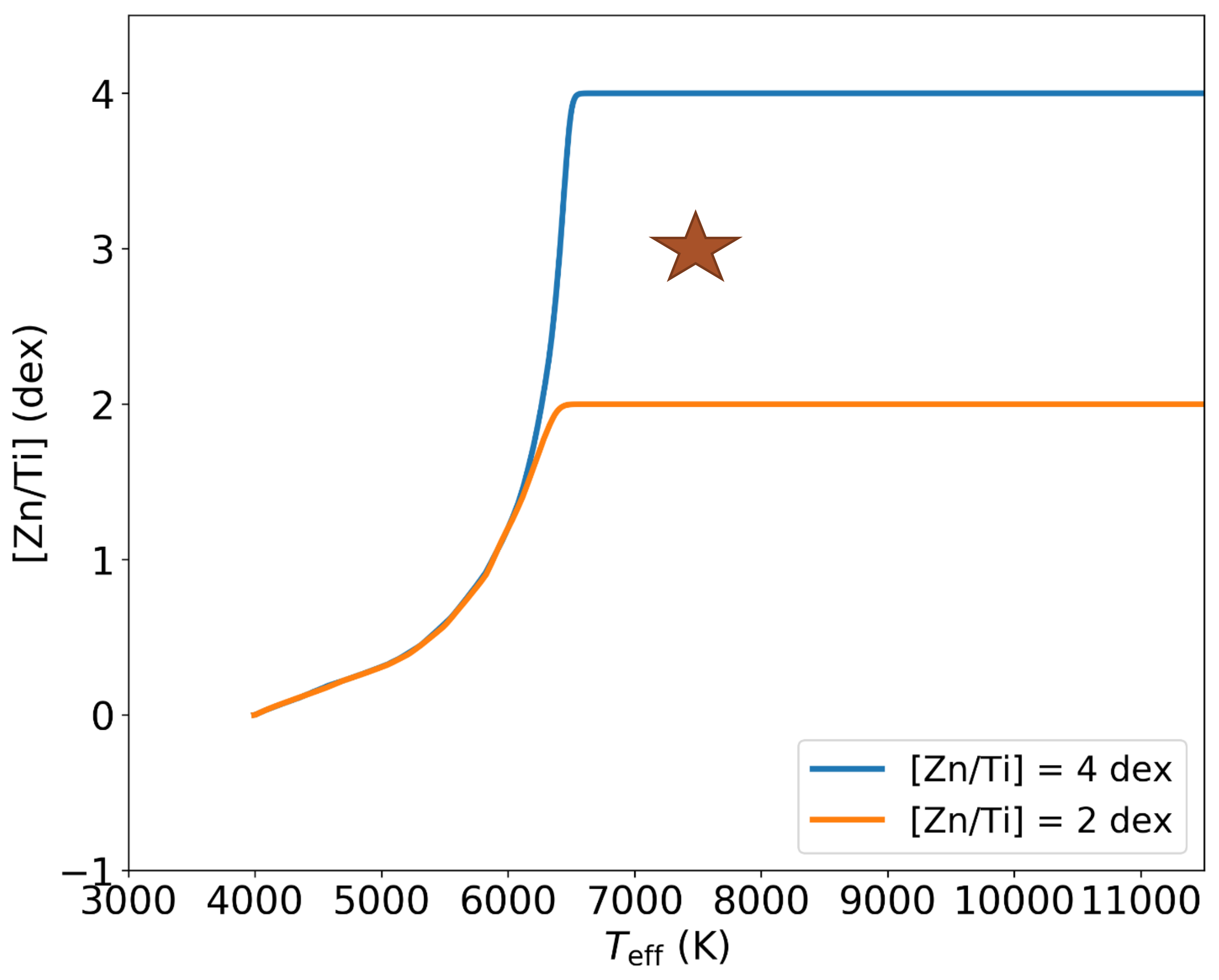
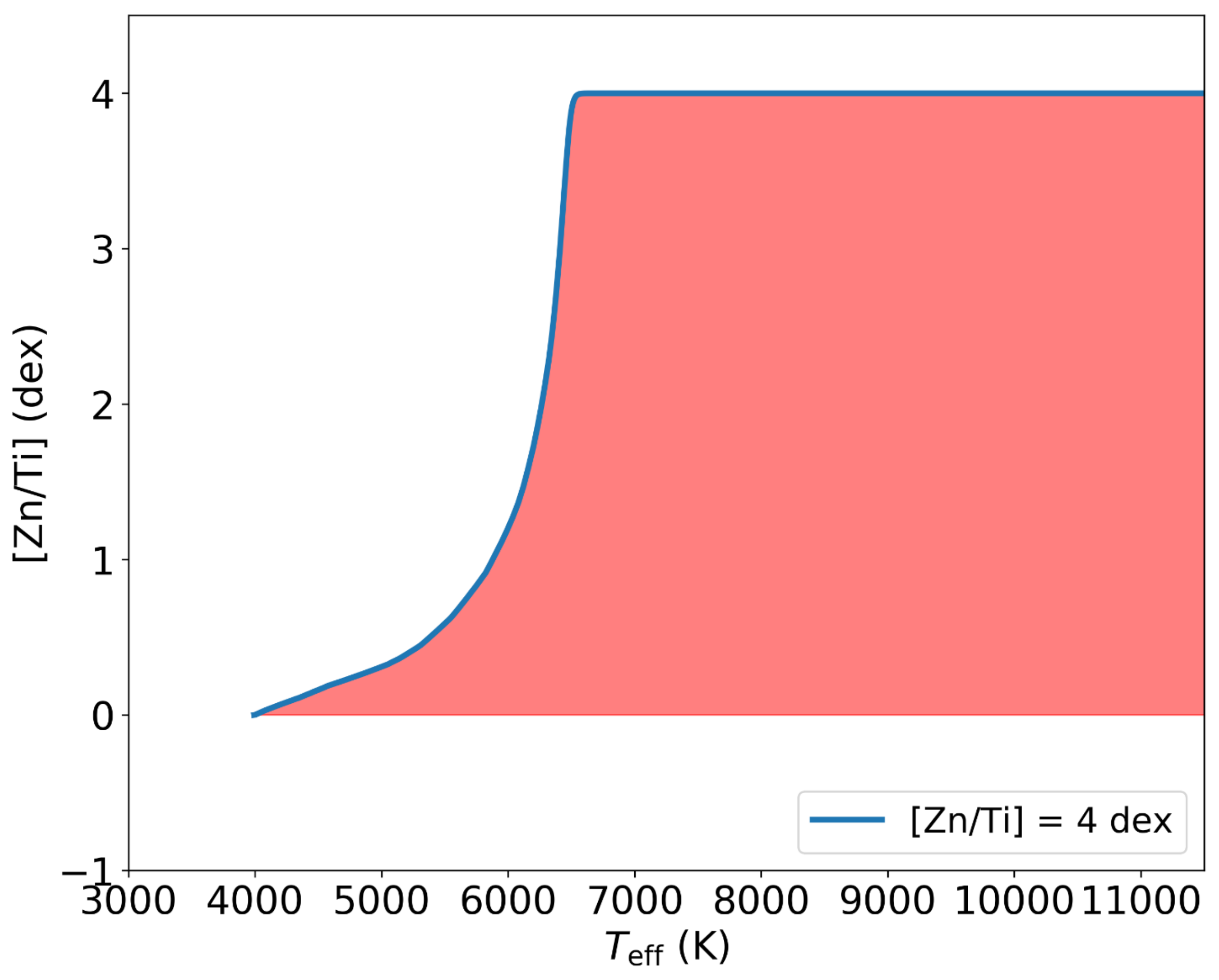


Comparing models to observations



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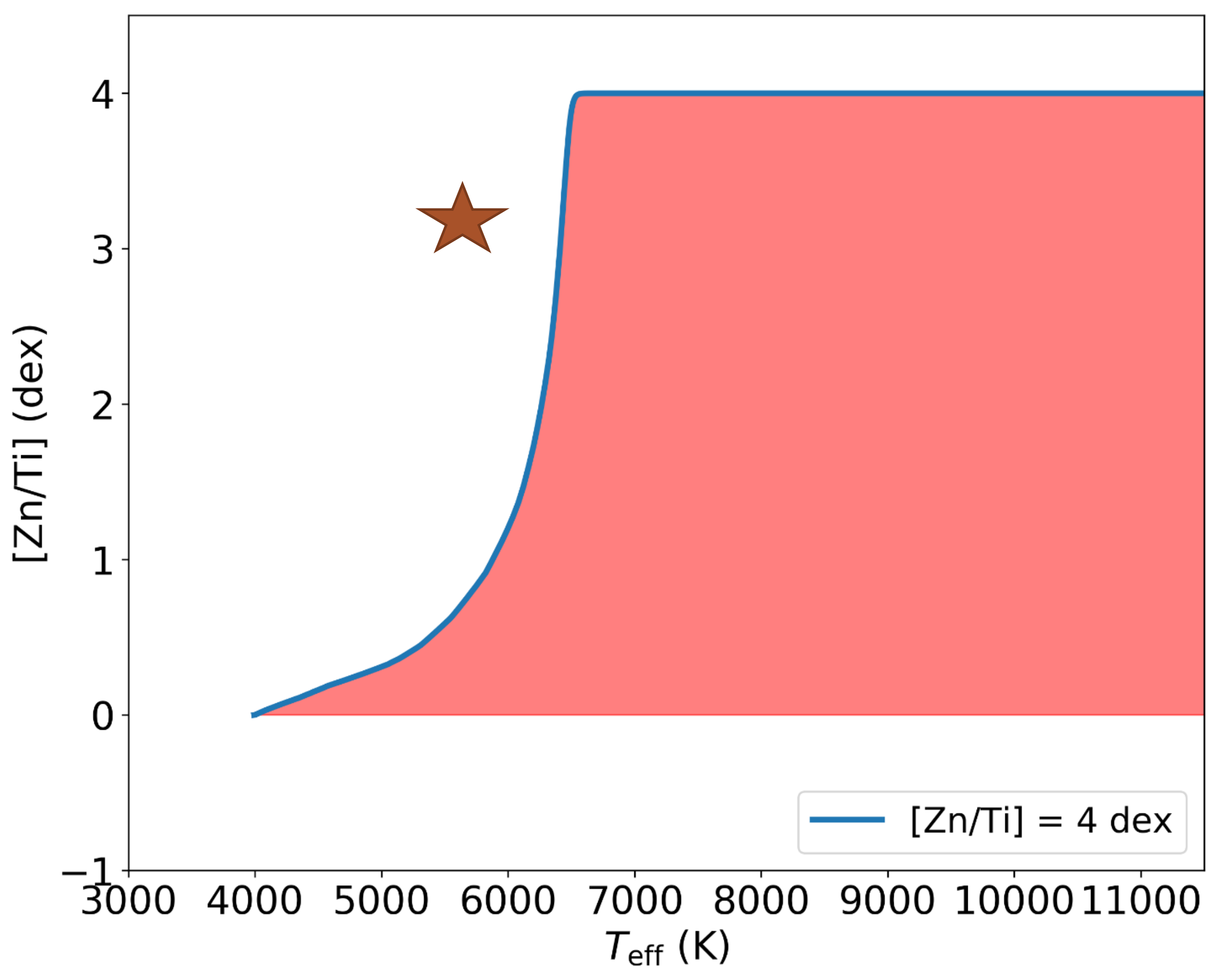
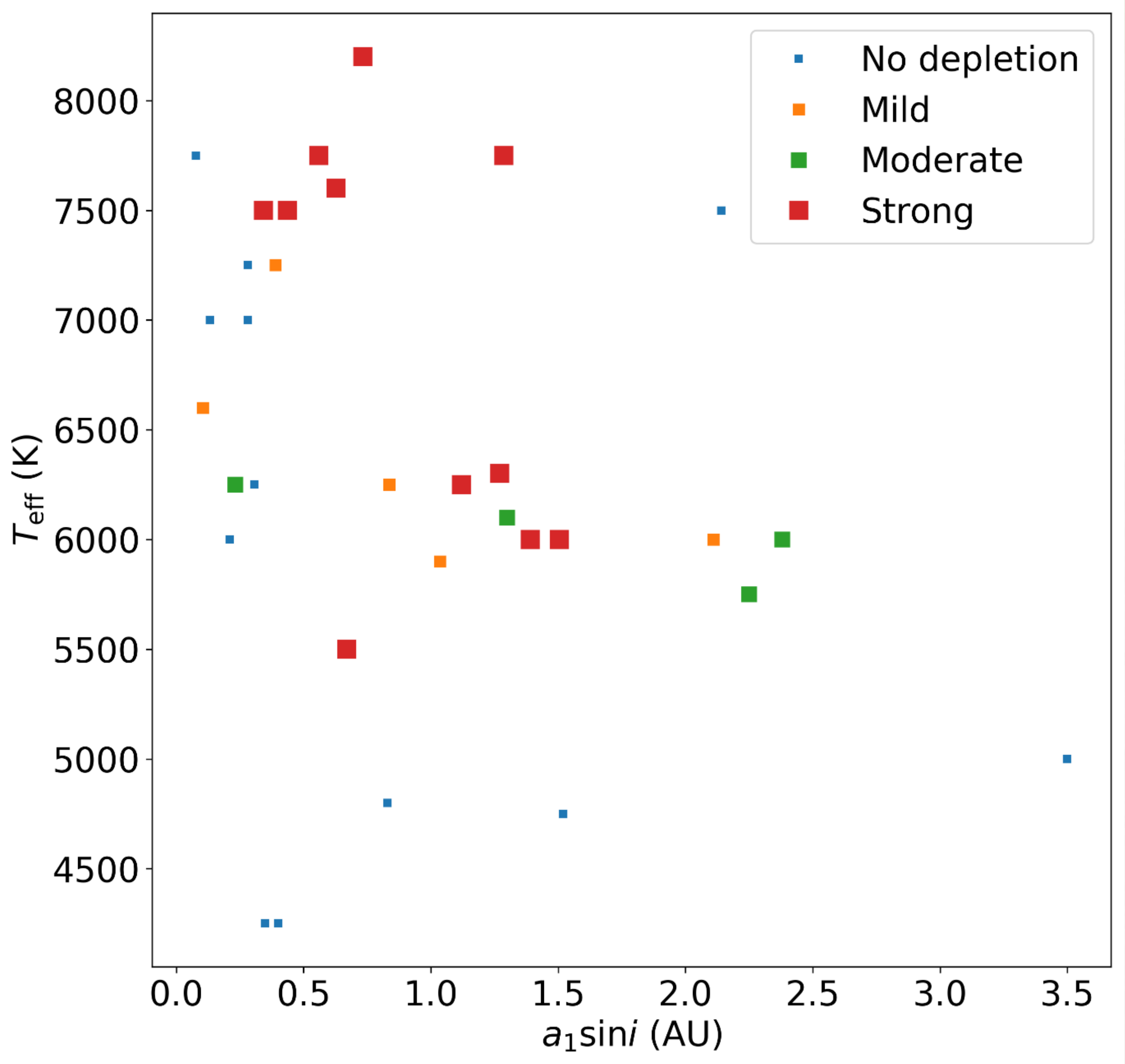


Link to binarity

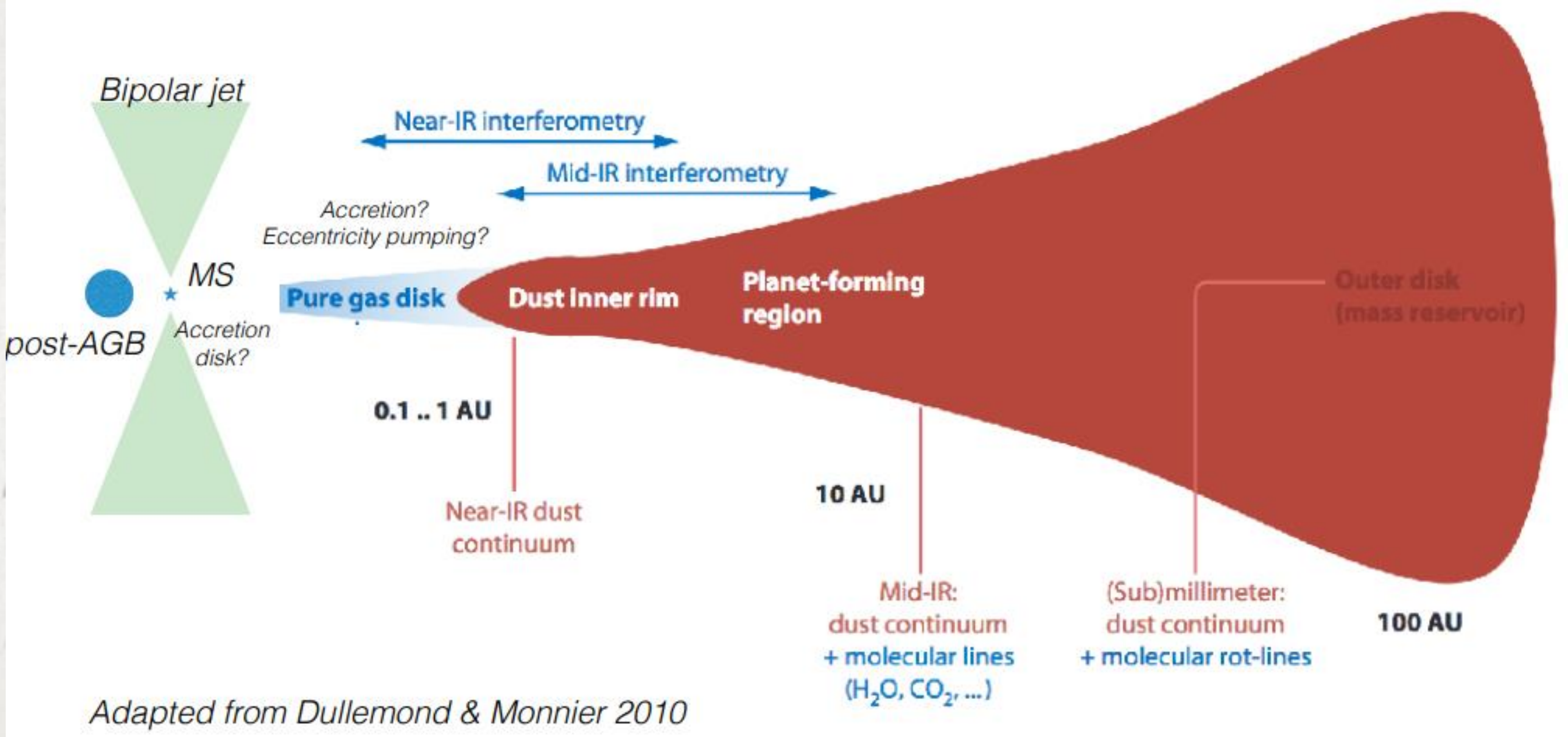
- Small orbits: no depletion!

→ Connection between accretion composition and orbital size?



Oomen et al. (2018)

Link to binarity



$$R_{\text{dust}} \propto \sqrt{L_*}$$

$$R_{\text{disc}} \approx 2\,a$$