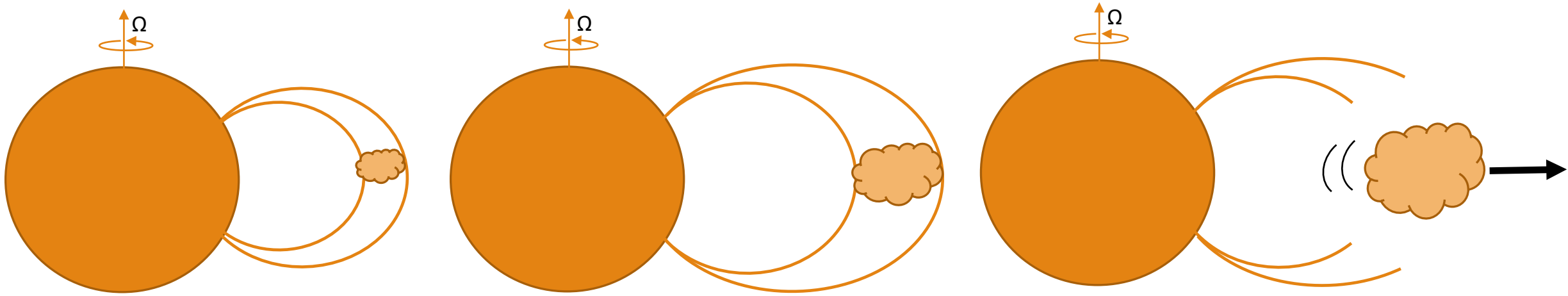
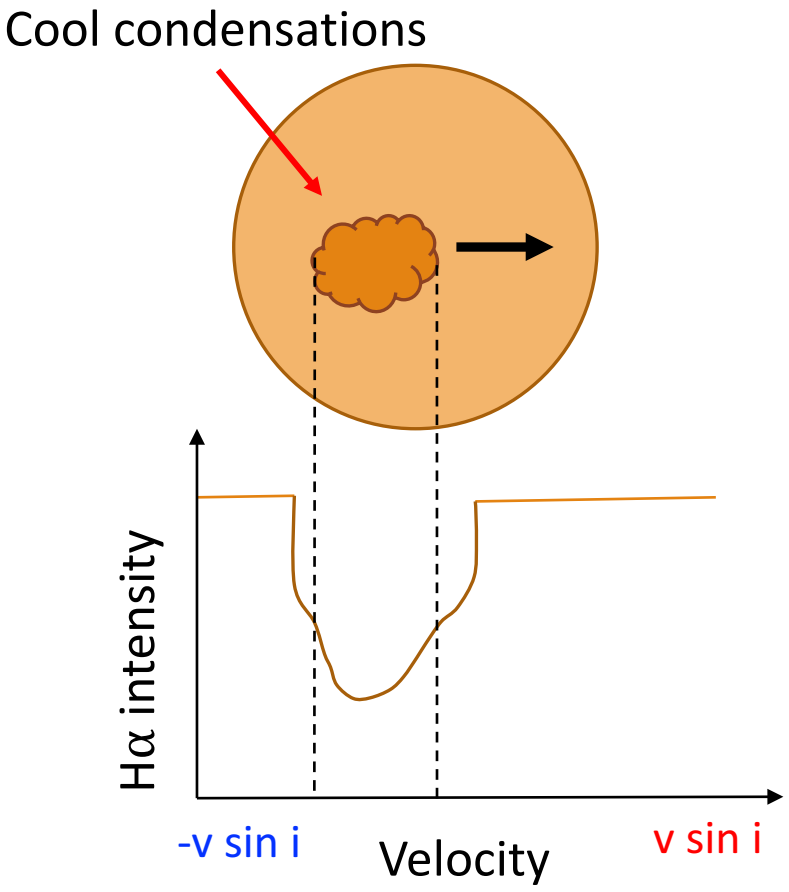


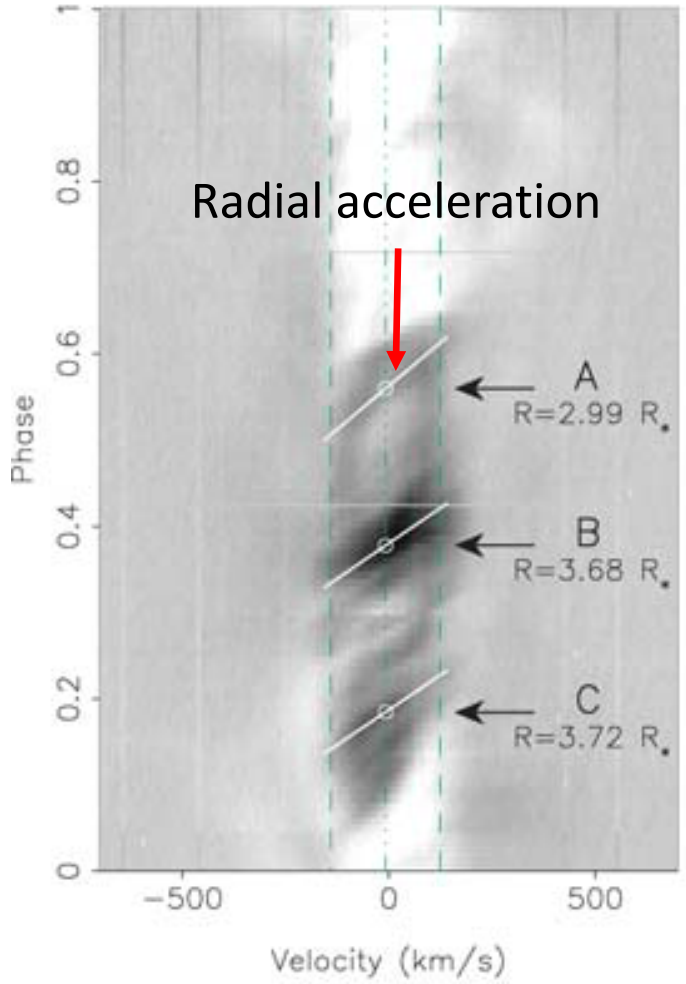
Slingshot prominences evolution in Cool Stars

CAROLINA VILLARREAL D'ANGELO, MOIRA JARDINE, ANDREW COLLIER CAMERON, VICTOR SEE & ROSE WAUGH

University of St Andrews

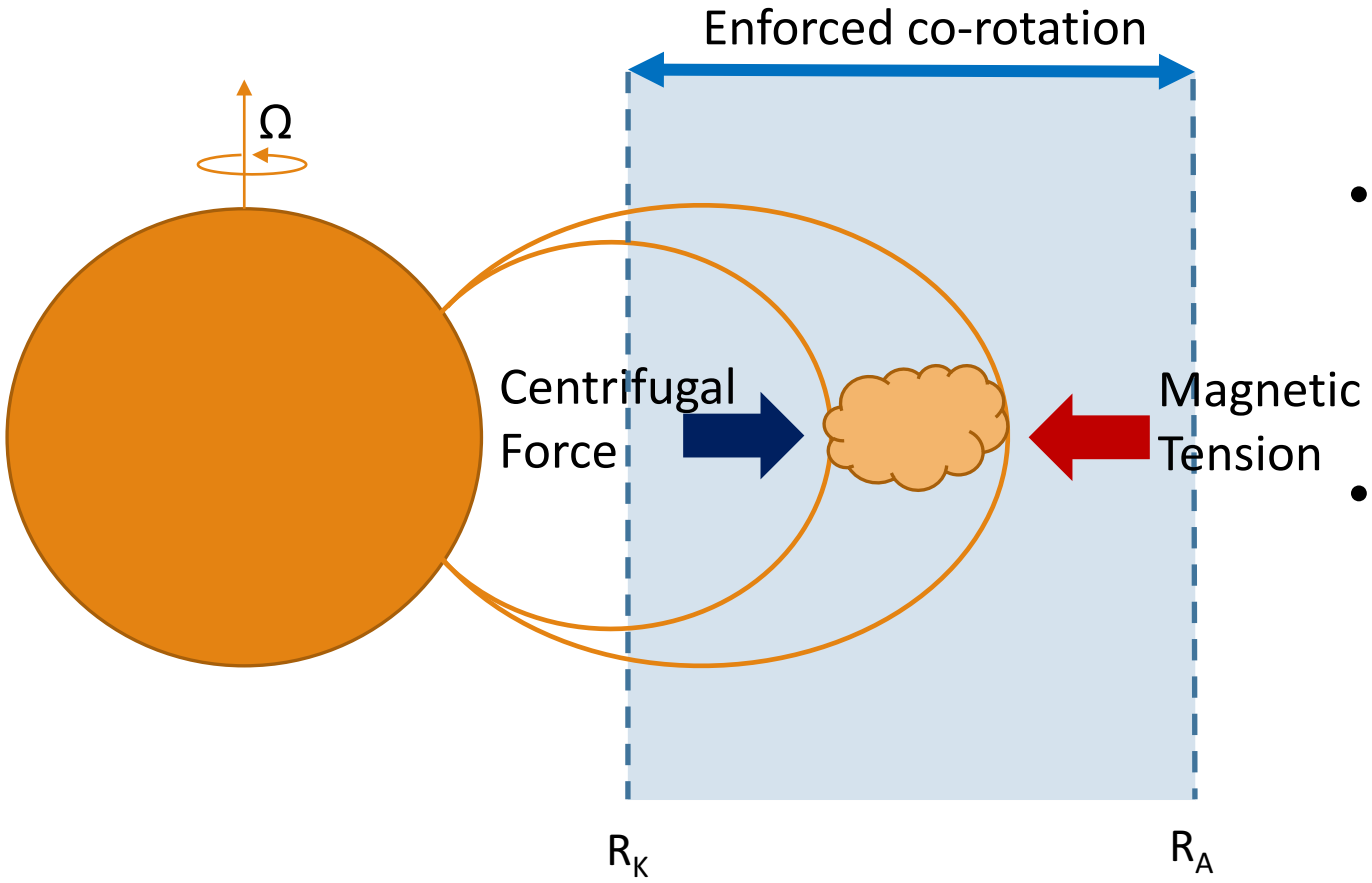
Cool condensation of mass co-rotating with the star





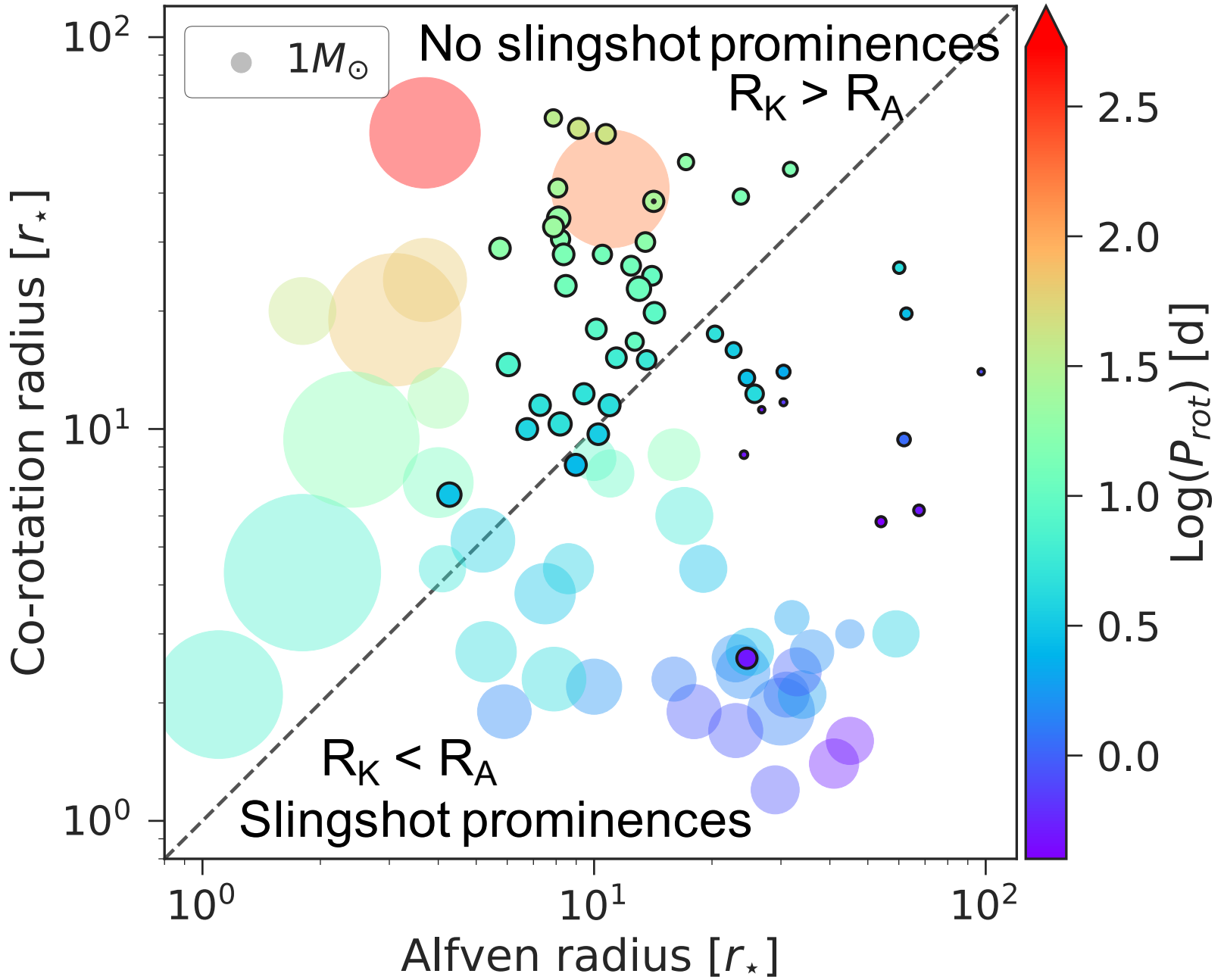
- First seen on AB Dor (Collier-Cameron+ 1989,1990)
- $\Omega_{AB\ Dor}$= 0.5 d
- prominence lifetime= 1-2 d

Force balance to support prominences



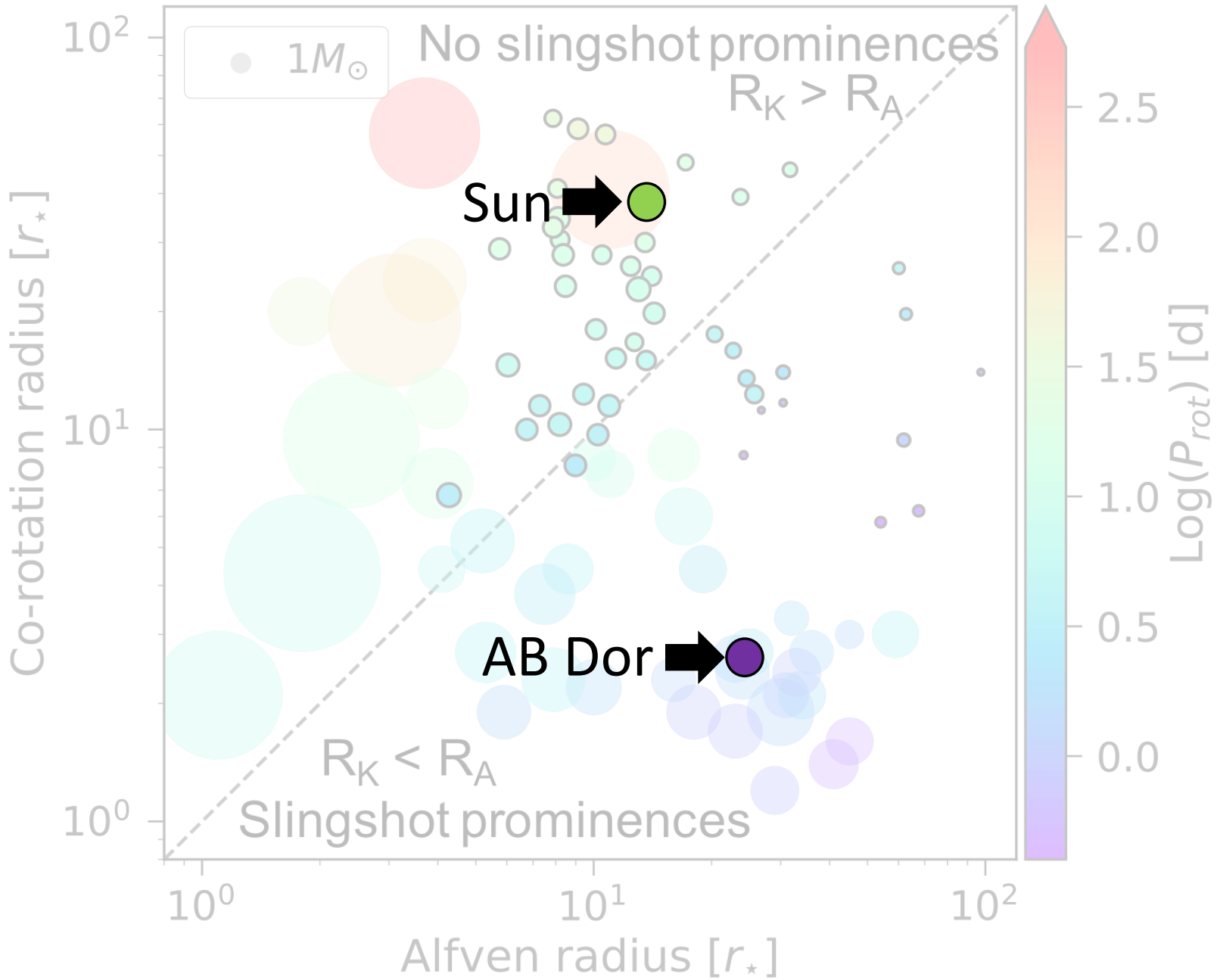
- Material will accumulate in a potential minima (Ferreira+2000, Jardine+2001)
- Radial force balance must occur (Collier Cameron+1989)

Where are slingshot prominences found?



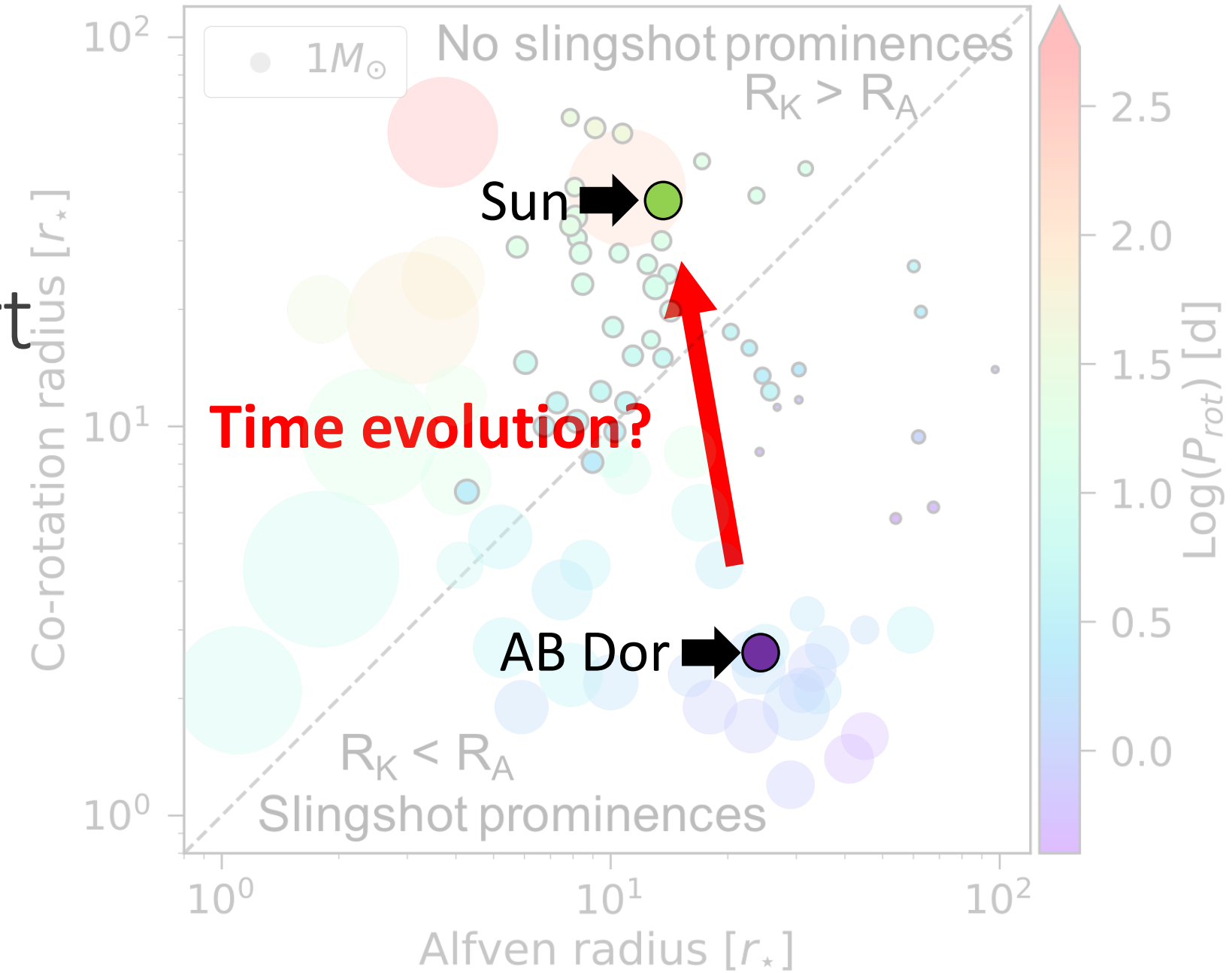
Cool Stars (Villarreal D'Angelo+2018)
+ Massive stars (Petit+2015)

Where are slingshot prominences found?

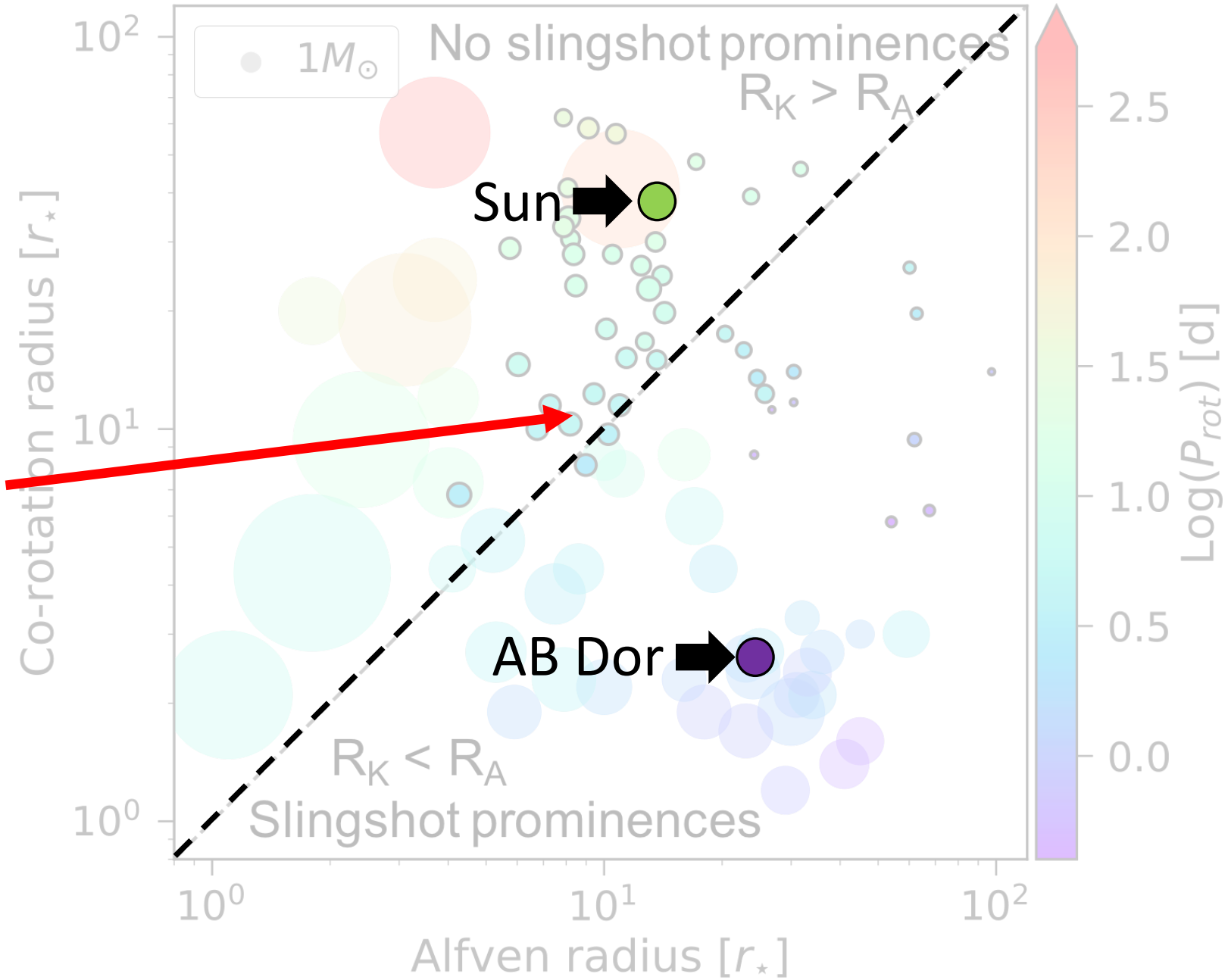


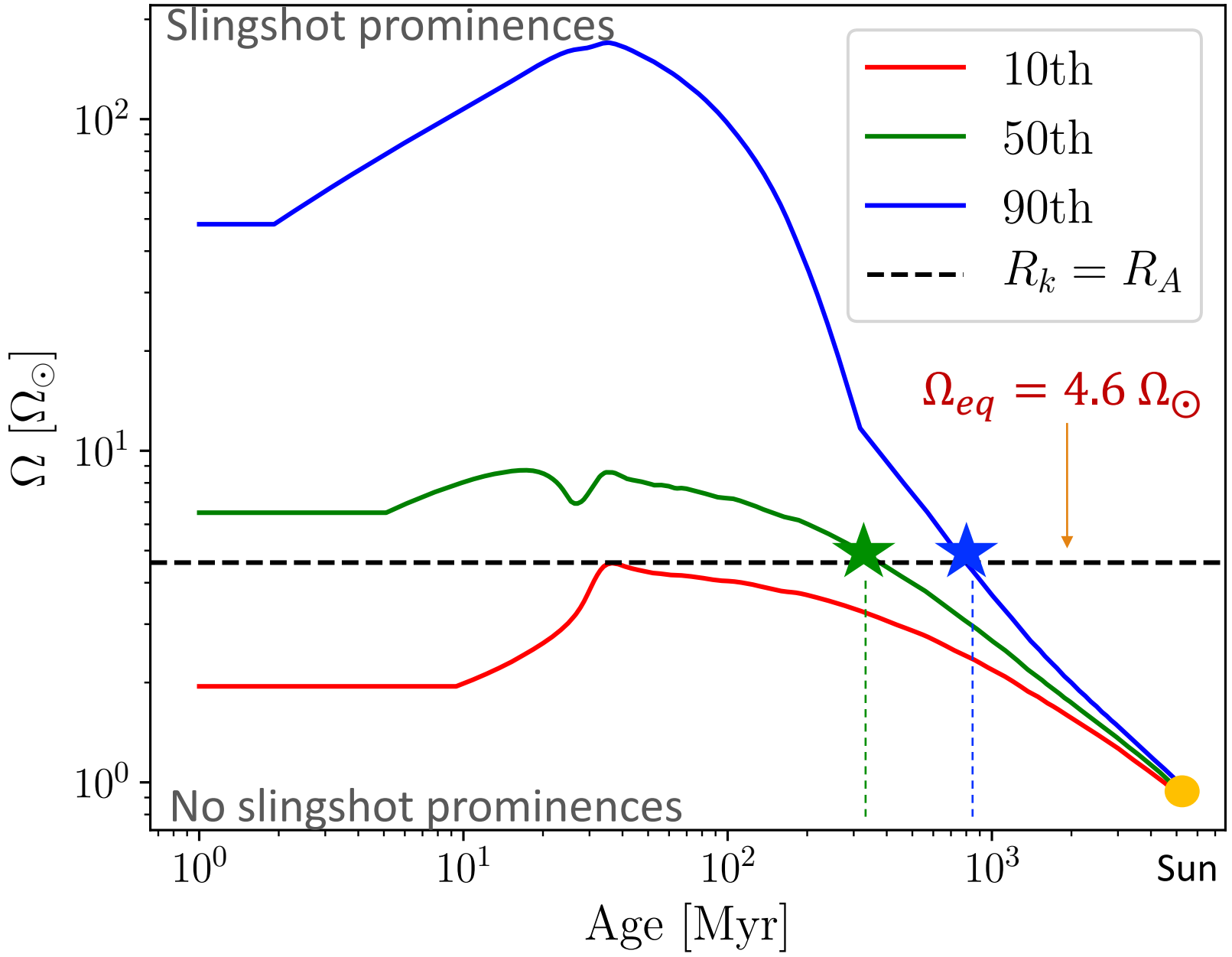
Cool Stars (Villarreal D'Angelo+2018)
+ Massive stars (Petit+2015)

Older solar like star can't support prominences



A solar like star will have R_k=R_A when P_{rot} ~6 days





Johnstone+(2015) and Tu+(2015)

Slow rotators can't form prominences?

$\Omega_{eq} \longrightarrow$ ~376 Myr (50th)

$\Omega_{eq} \longrightarrow$ ~797 Myr (90th)

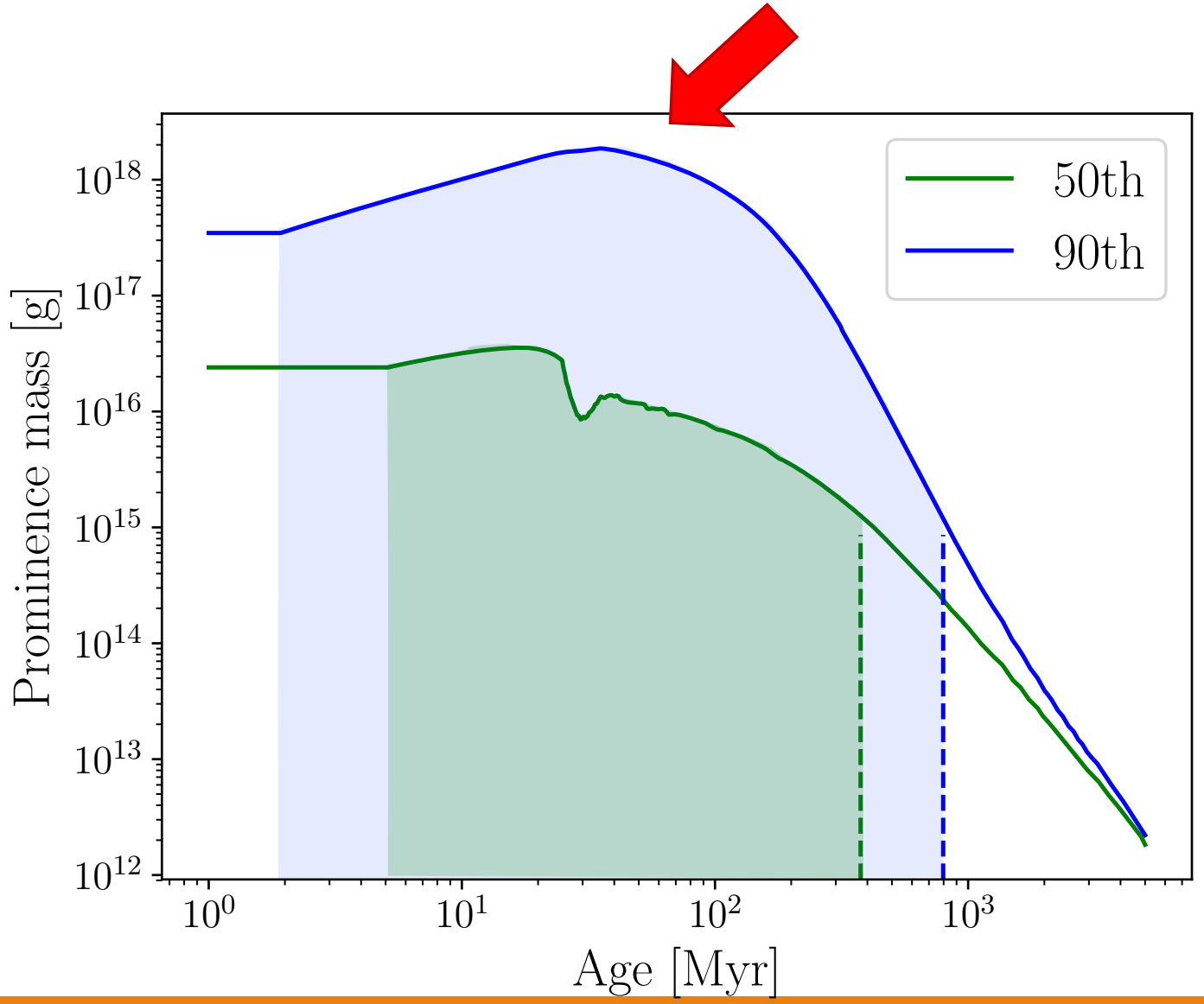
10th never reach the Ω_{eq}

Evolution of prominence mass

$$\rho_b \sim \frac{B^2}{4\pi R_c} \frac{1}{[\Omega^2 r - GM_\star/r^2]}$$

$$m_p \propto \rho_b$$

Max. mass range: $[10^{18} - 10^{16}]$ g.



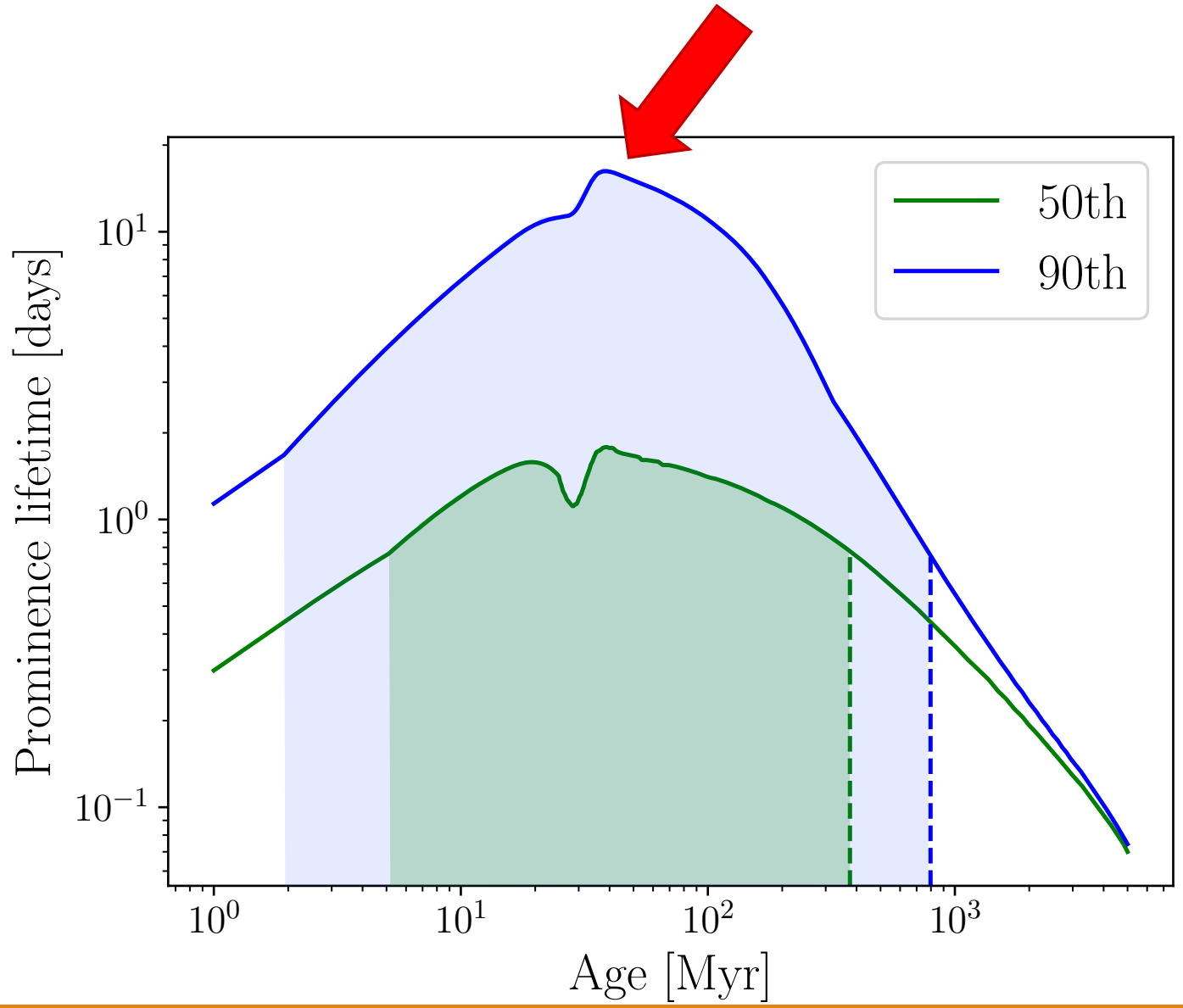
Villarreal D'Angelo+2018a, 2018b (in prep)

Evolution of prominence lifetime

$$\dot{m}_p \propto \dot{M}_\star$$

$$t_p = \frac{m_p}{\dot{m}_p}$$

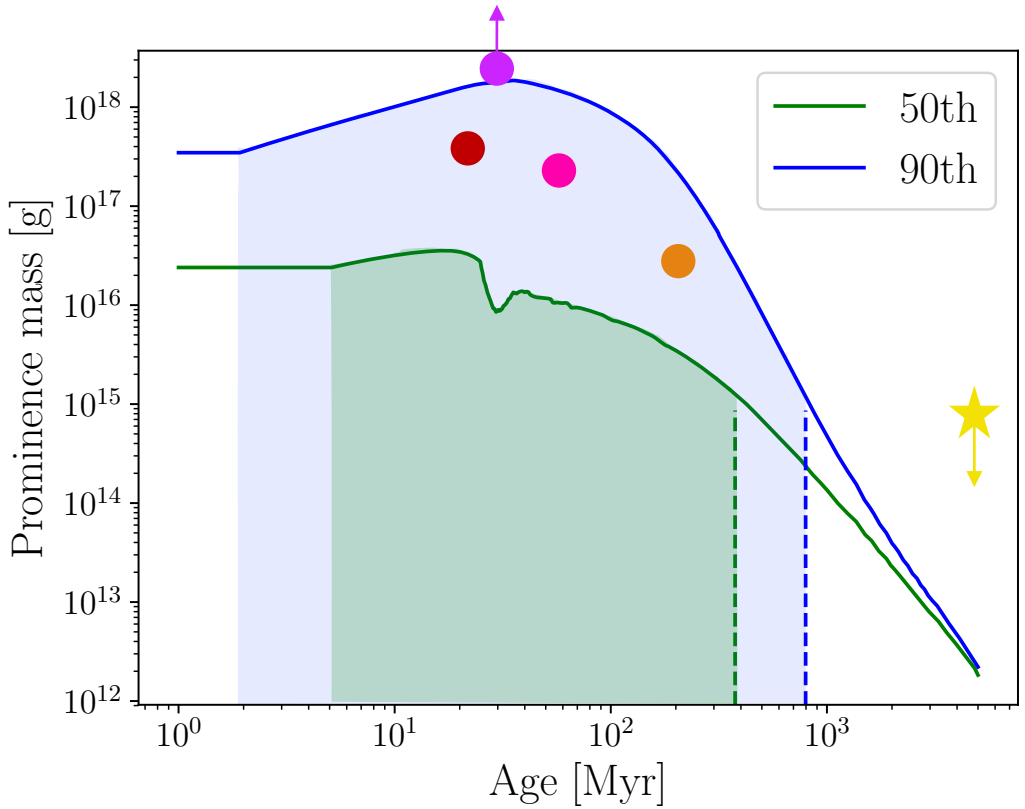
Max. ejection time range: [1-14] days.

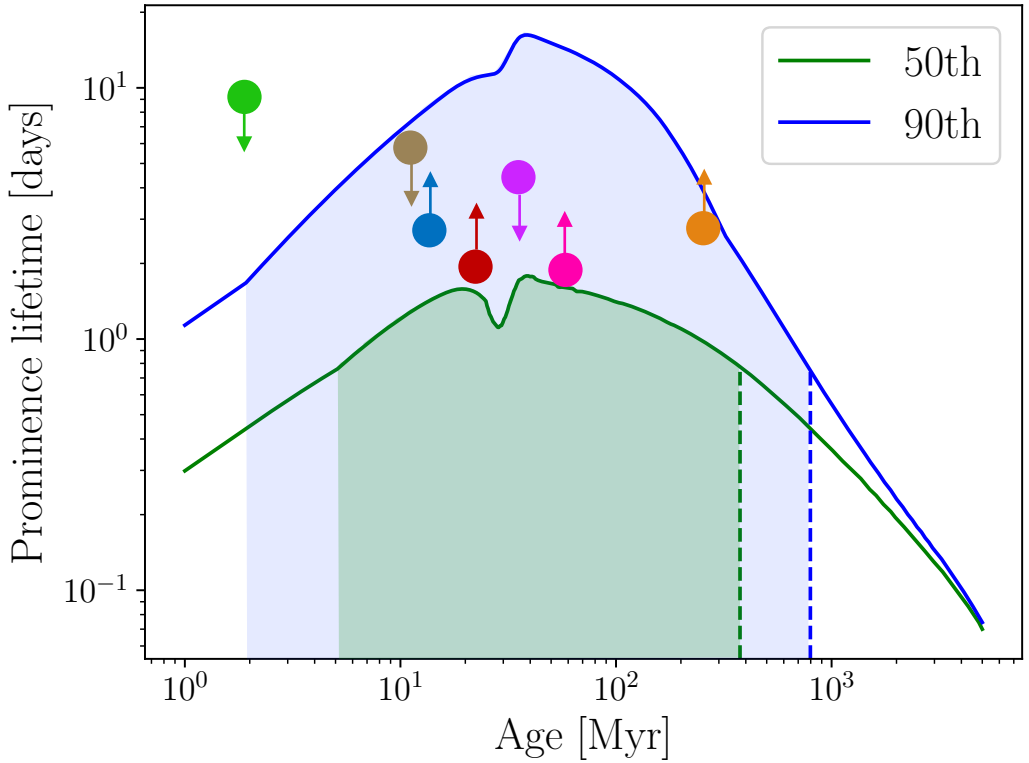


Villarreal D'Angelo+2018a, 2018b (in prep)

Prominence observed in a broad range of ages!

- AB Dor (K2 V)
- V410 Tau (K3)
- Pz Tel (G6.5)
- Solar prominences
- Speedy Mic (K3V)
- TWA 6 (K7)
- LQ Lup (G8 IV)
- HK Aqr (dM1.5)





Resume

Slingshot prominences:

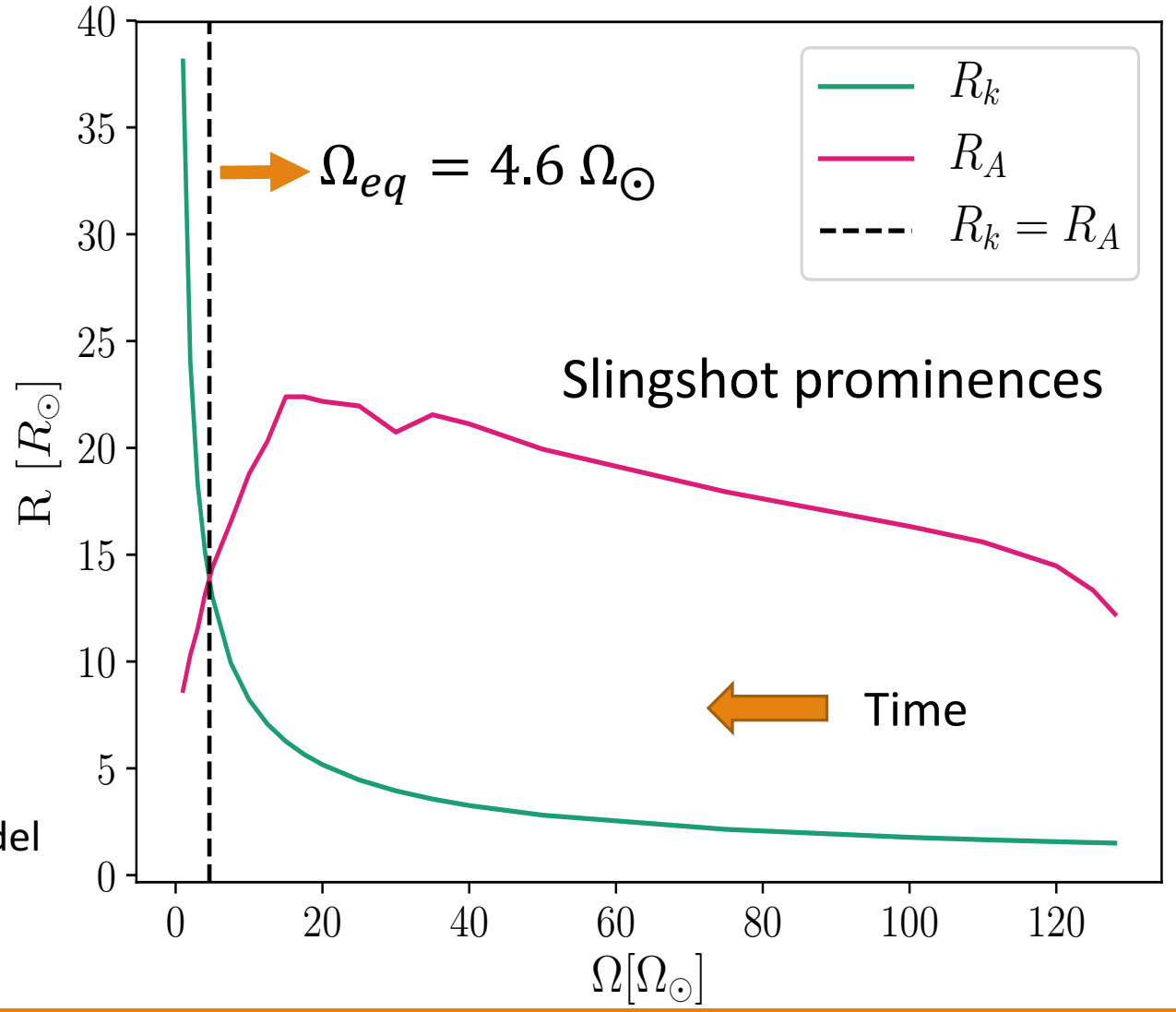
- Predicted masses and lifetimes agree with observations.
- Present until the late heavy bombardment for our Sun.

Why do we care:

- Slingshot prominence can trace the coronal structure (poster 149).
- Help us to estimate the mass loss rate of the star (poster 149).
- Do they influence the evolution of planetary atmosphere?.

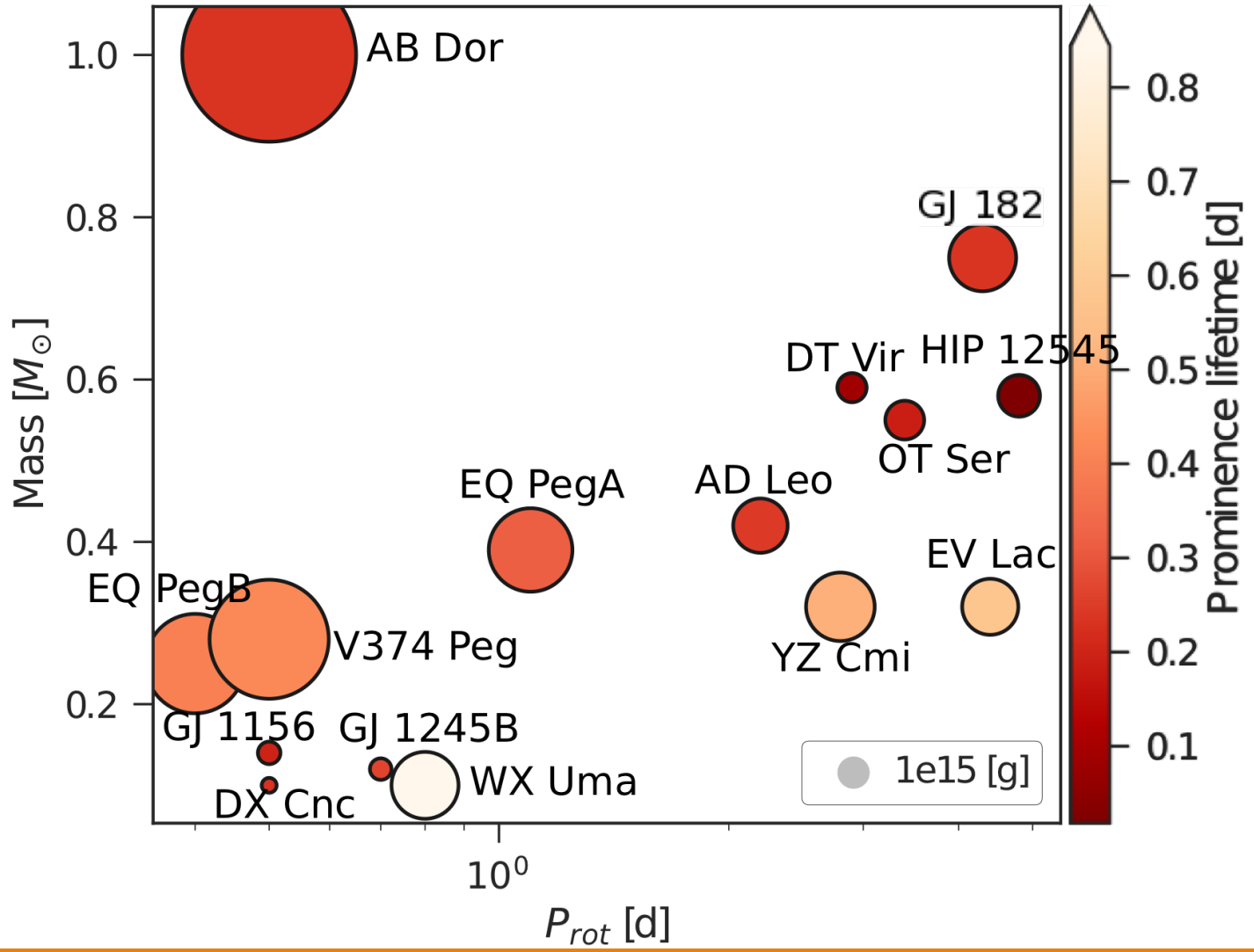
THANK YOU!

R_K and R_A as a function of time



Rotational evolution model for a solar like star (Johnstone+ 2015)

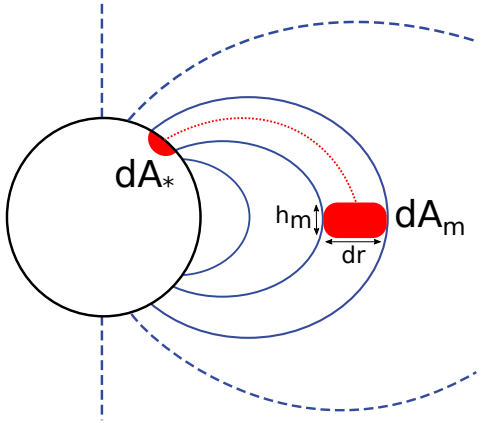
Prominence model



$$M_p = \frac{B_*^2 R_*^4}{G M_*}\left(\frac{R_*}{R_k}\right)^2 F(\nabla\bar{r}, \nabla\varphi), \quad (\bar{r} = \frac{r}{R_k})$$

$$\dot{M}_p = \frac{\dot{M}_*}{4\pi R_*^2} 2dA_*$$

$$\tau_p = \frac{M_p}{\dot{M}_p}$$



(Villarreal D'Angelo+2018)