The Origin of Universality in the Inner Edges of Planetary Systems

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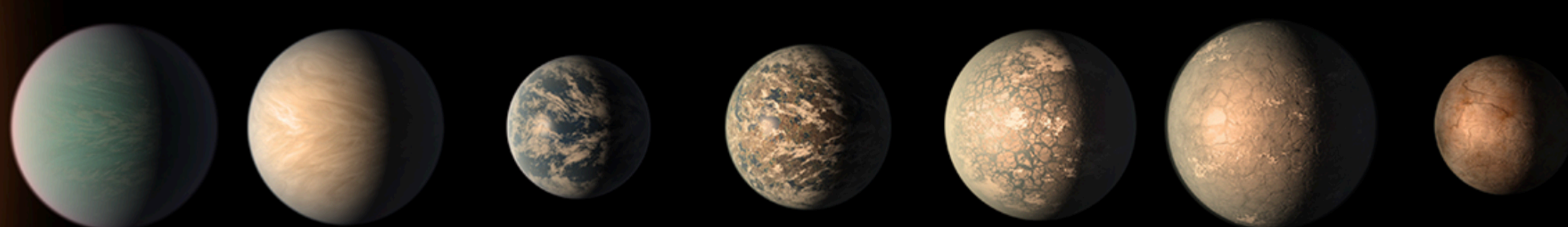
Jupiter (M ≈ 0.001 M_{sun})

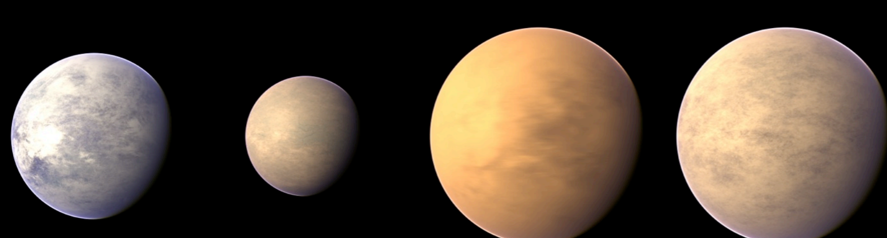
P_{IO} ≈ 1.8 days

Trappist 1 (M ≈ 0.09 M_{sun})



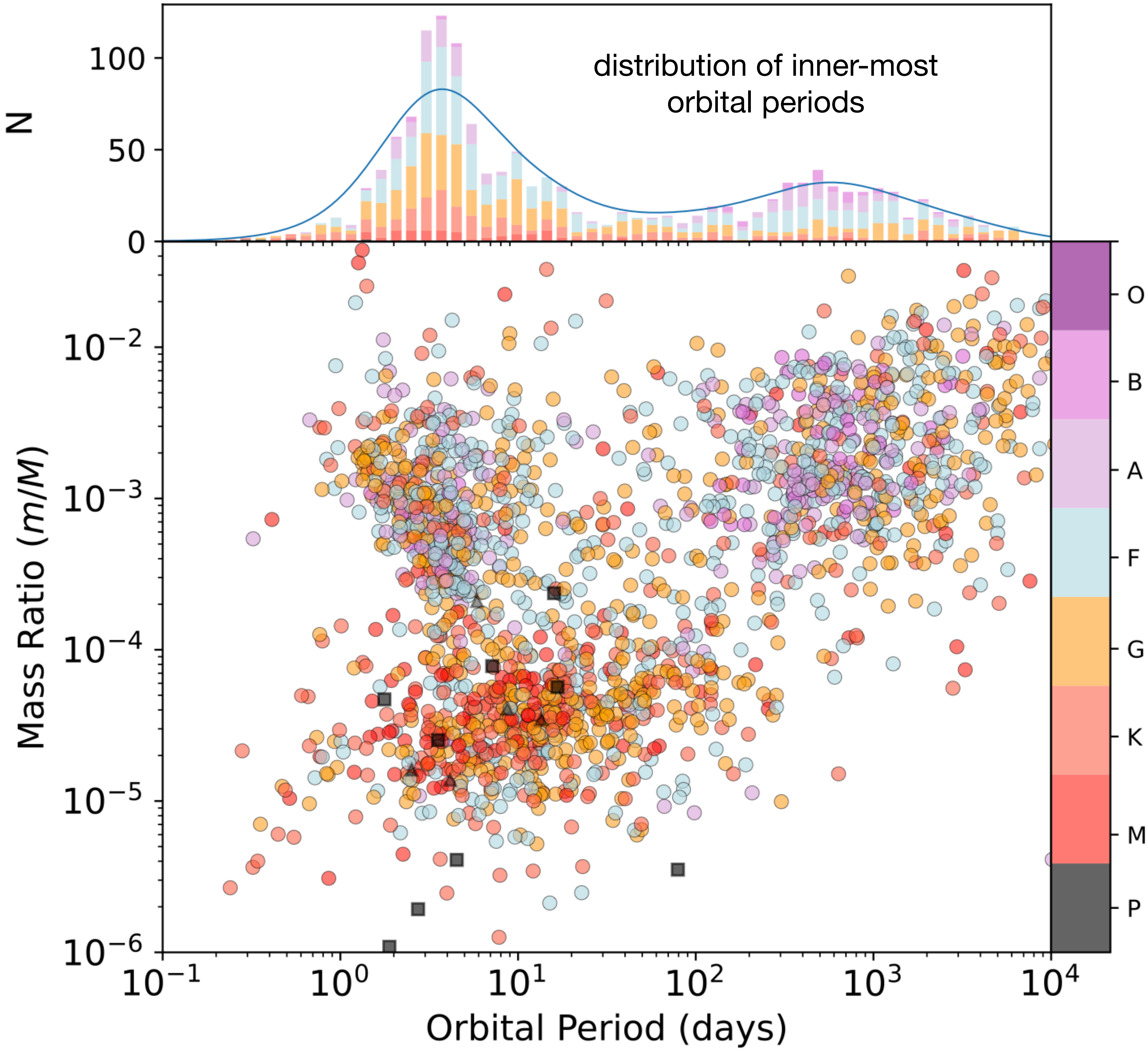
P_b ≈ 1.5 days

Kepler 256 (M ≈ 1 M_{sun})



P_b ≈ 1.6 days

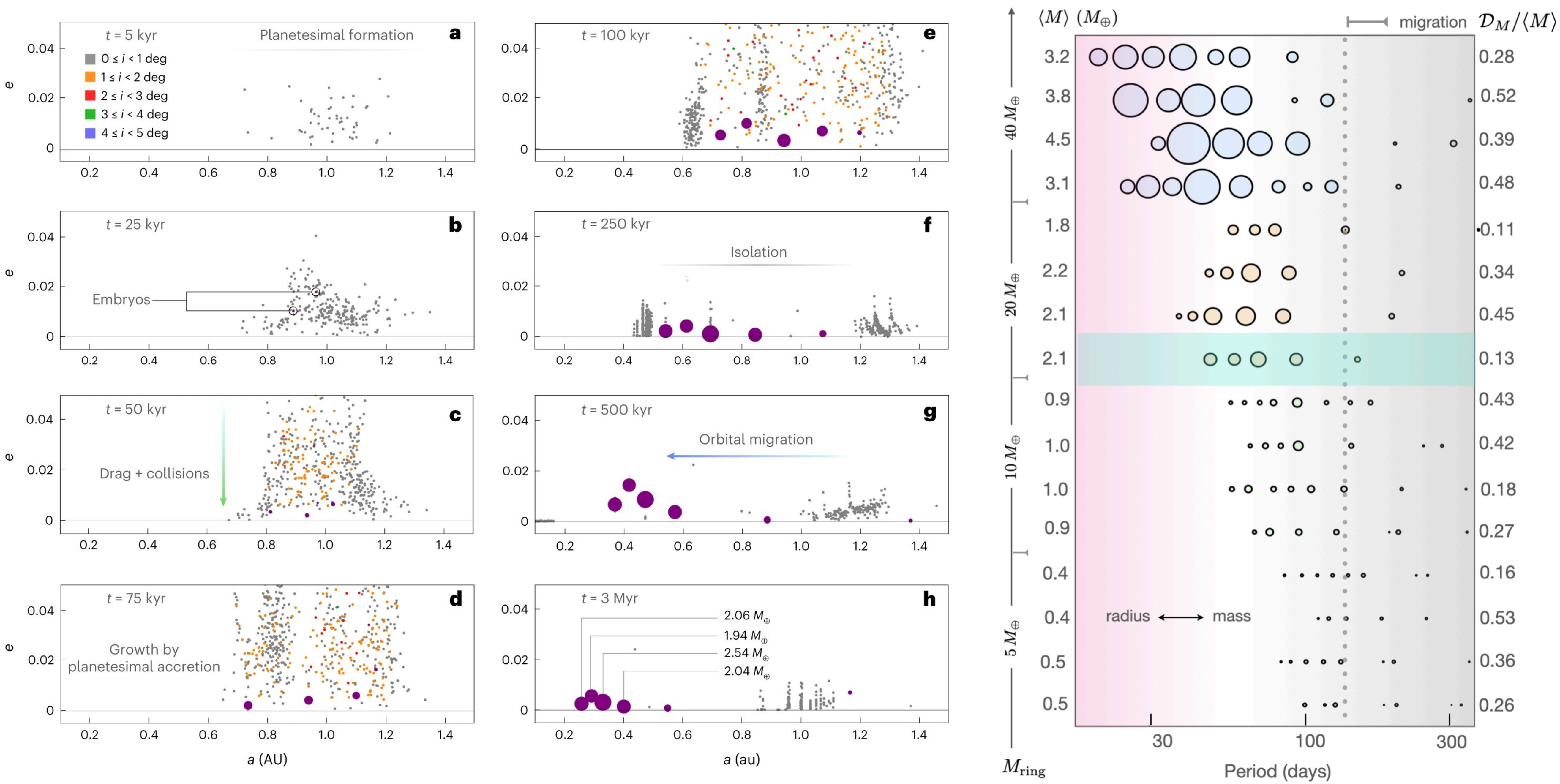
Fig. from Batygin et al (2023)



Formation of rocky super-earths from a narrow ring of planetesimals

Konstantin Batygin & Alessandro Morbidelli Nature Astronomy 7, 330–338 (2023) | Cite this article

- silicate-rich composition
- intra-system uniformity
- typical mass ~ few x Earth
- link to Jup, Sol



Orbital migration delivers planets to the disk's inner edge, where they stabilize. Thus, at face-value, the data appears to suggest that disks are truncated at an orbital period of ~3 days, independent of the central mass…

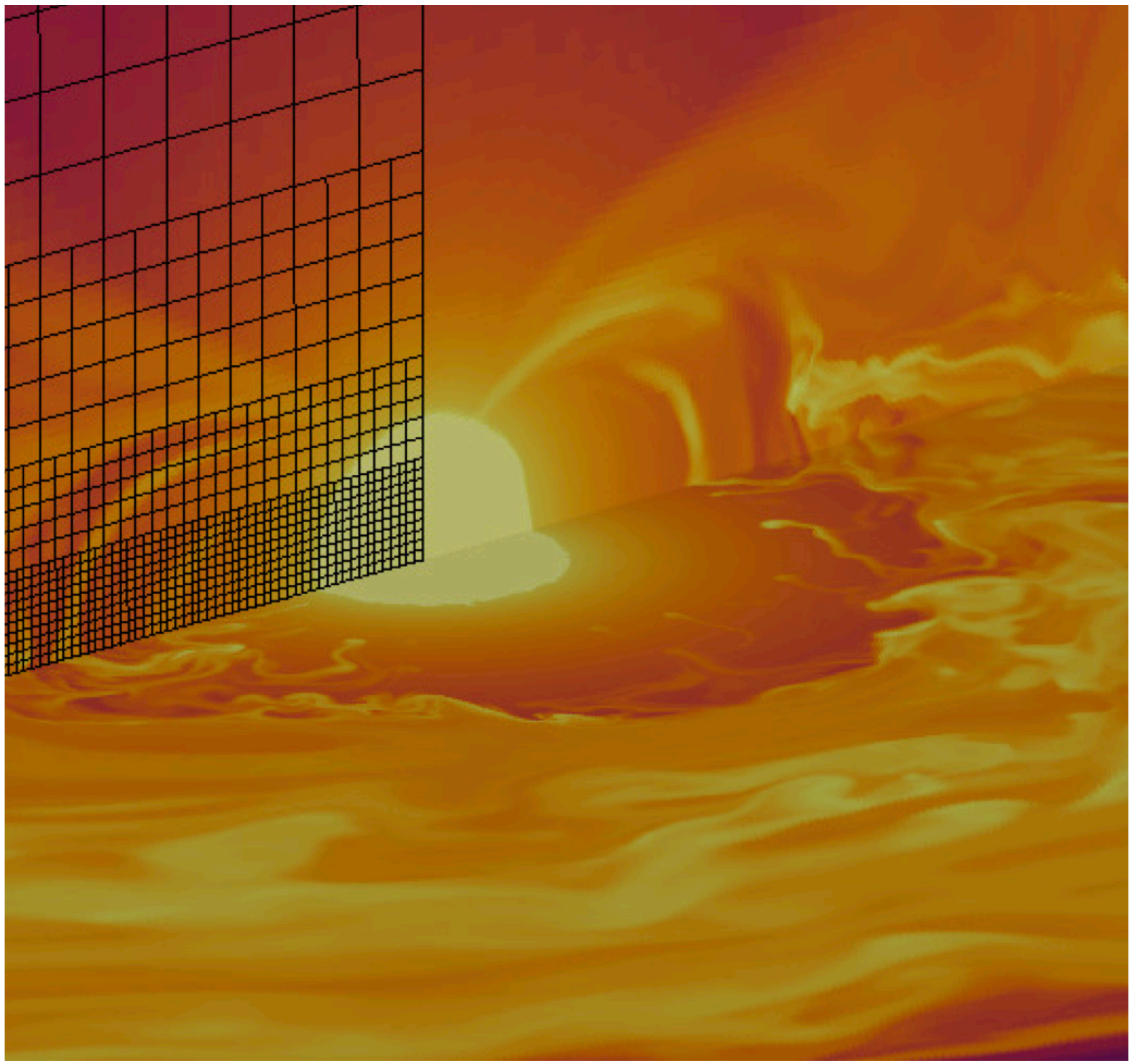


Fig. from Zhu et al (2023)

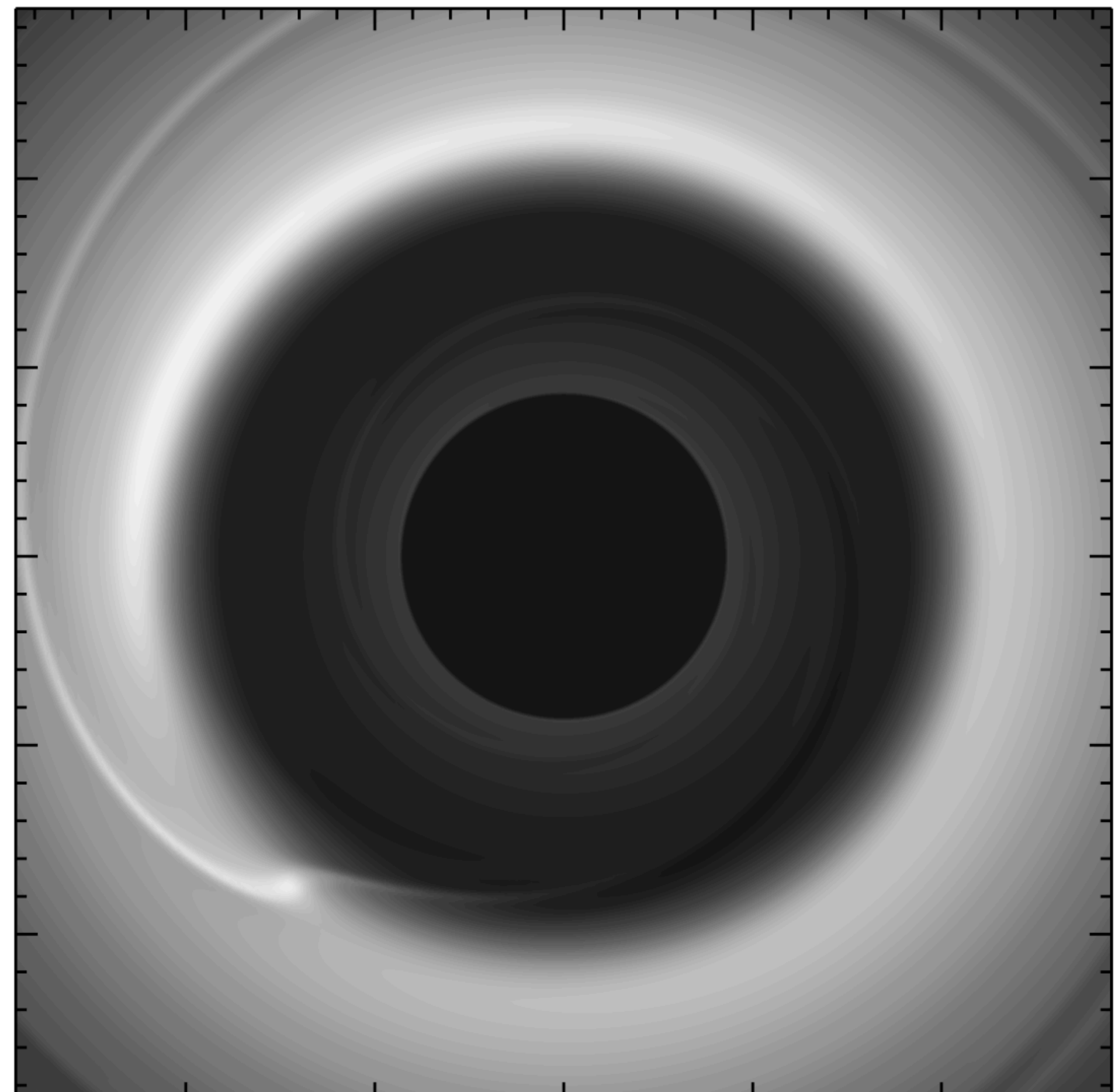
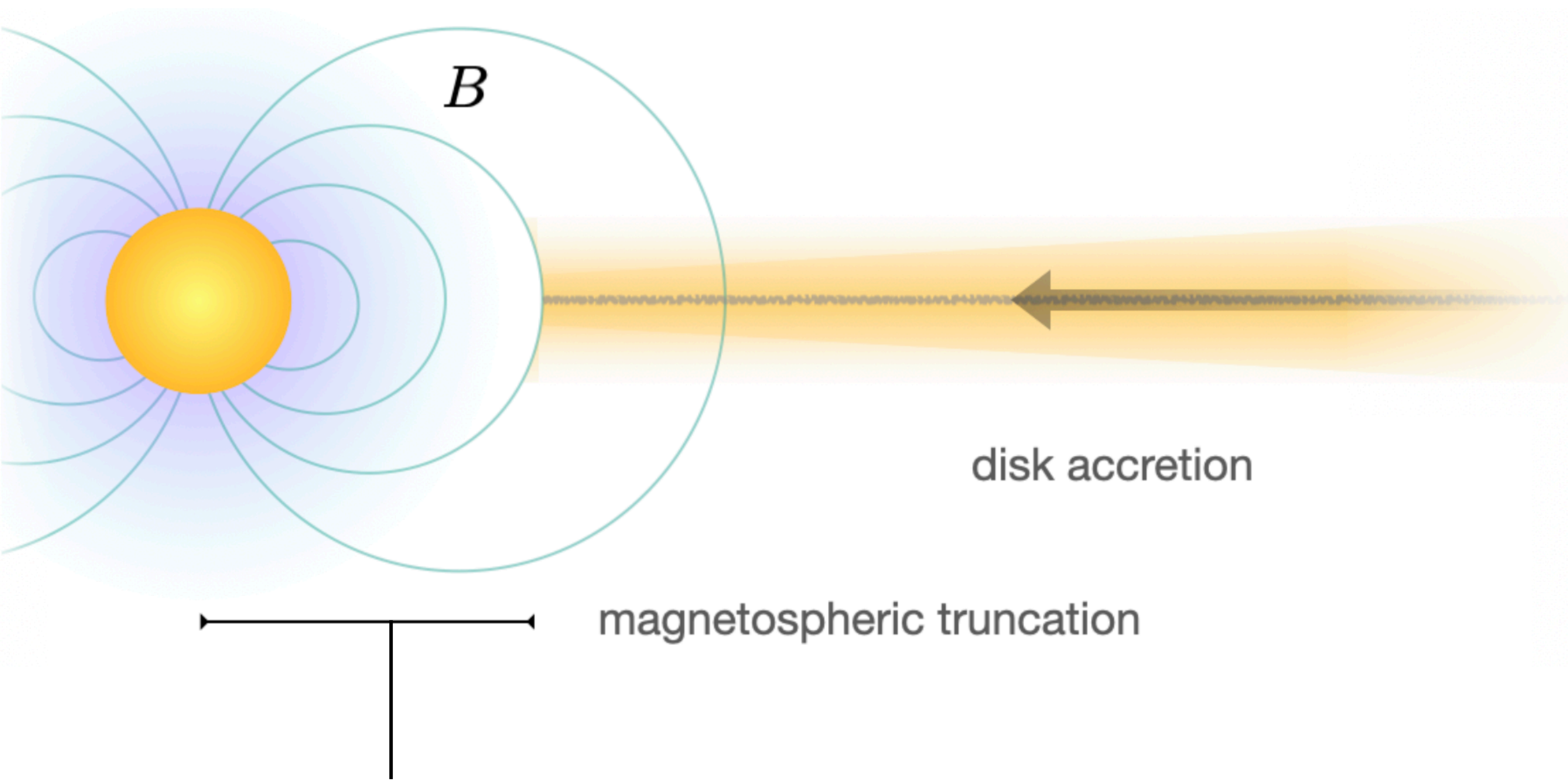
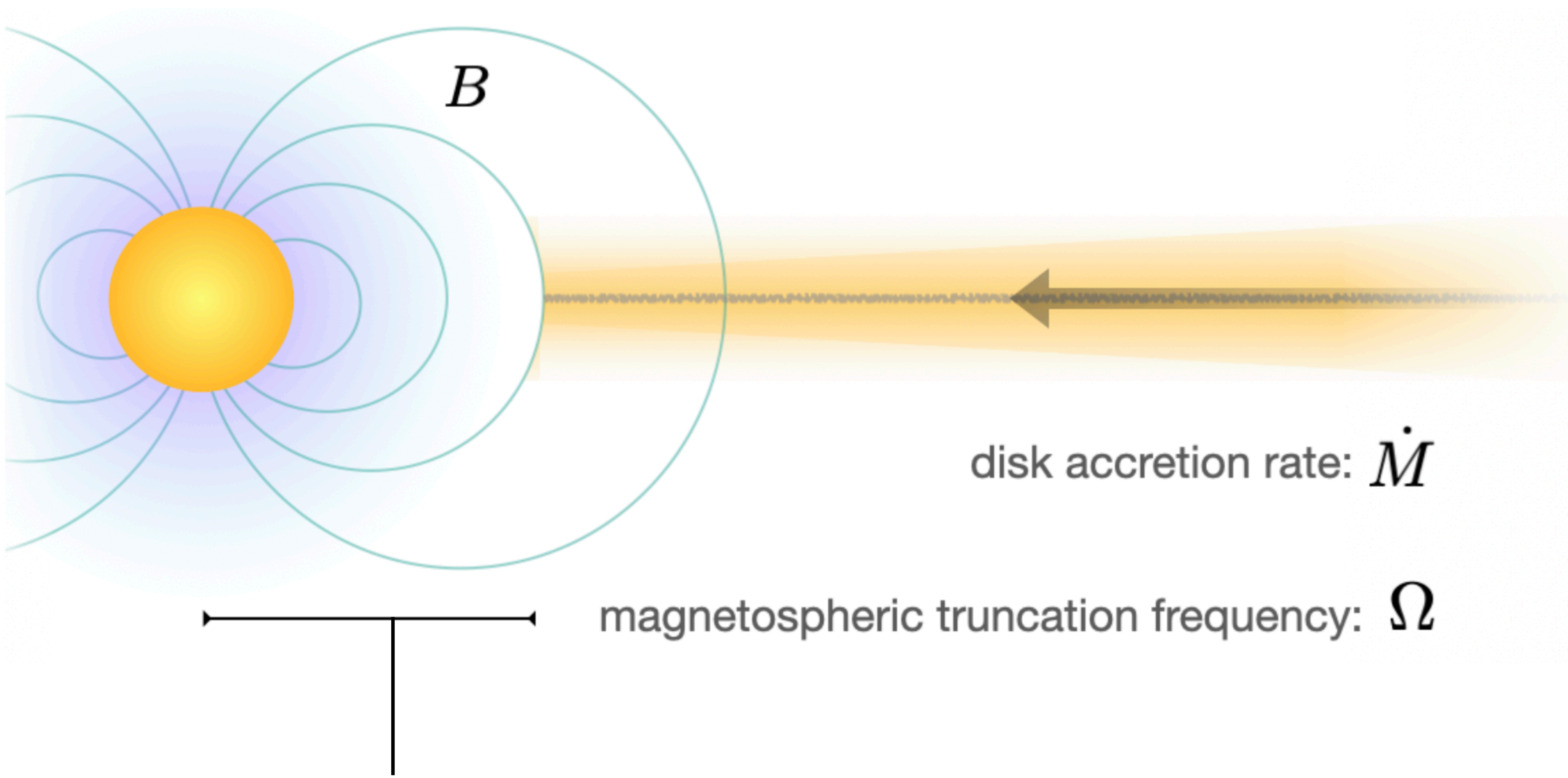


Fig. from Masset et al (2006)

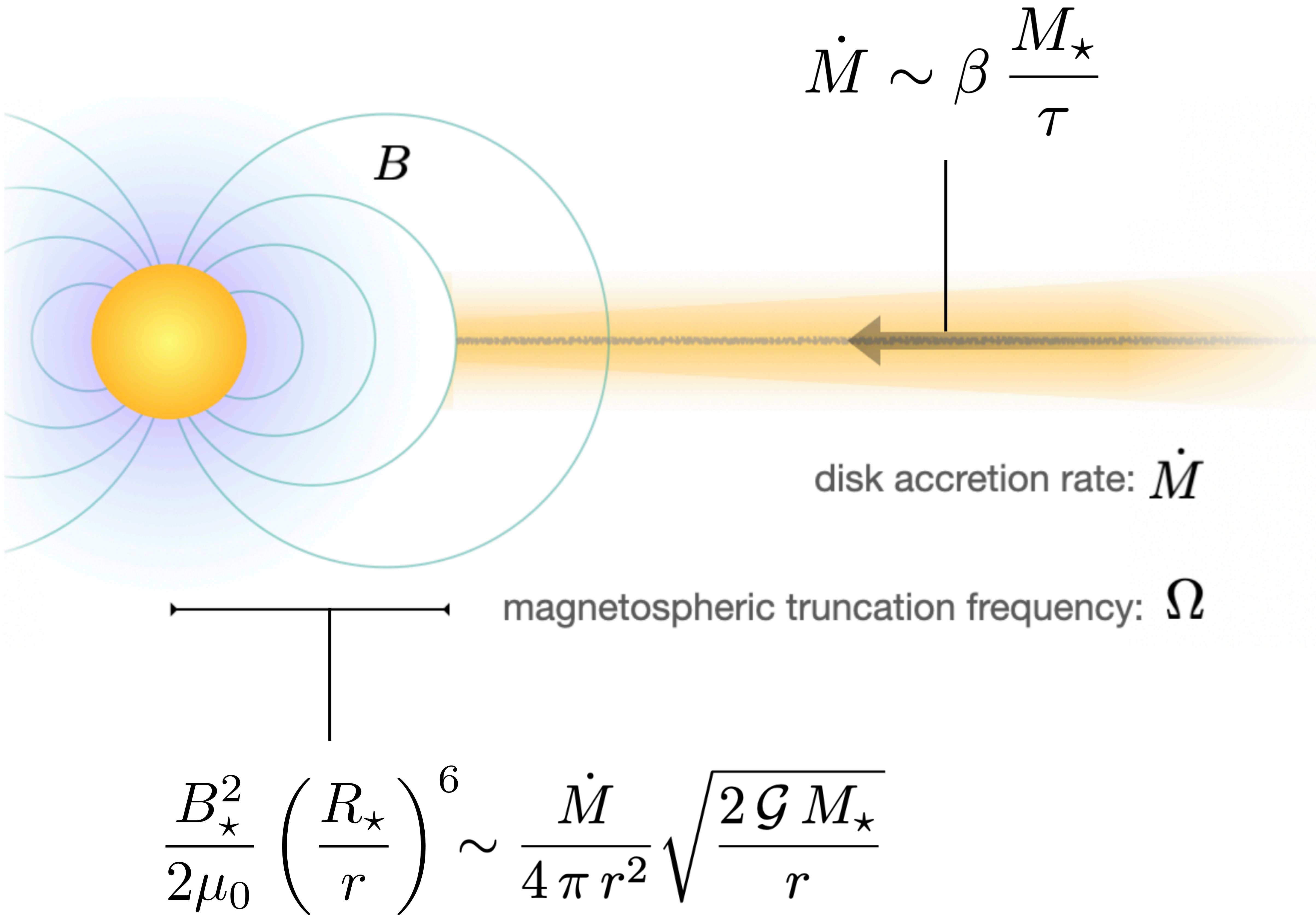


$$P_{\mathrm{mag}} \sim P_{\mathrm{ram}}$$

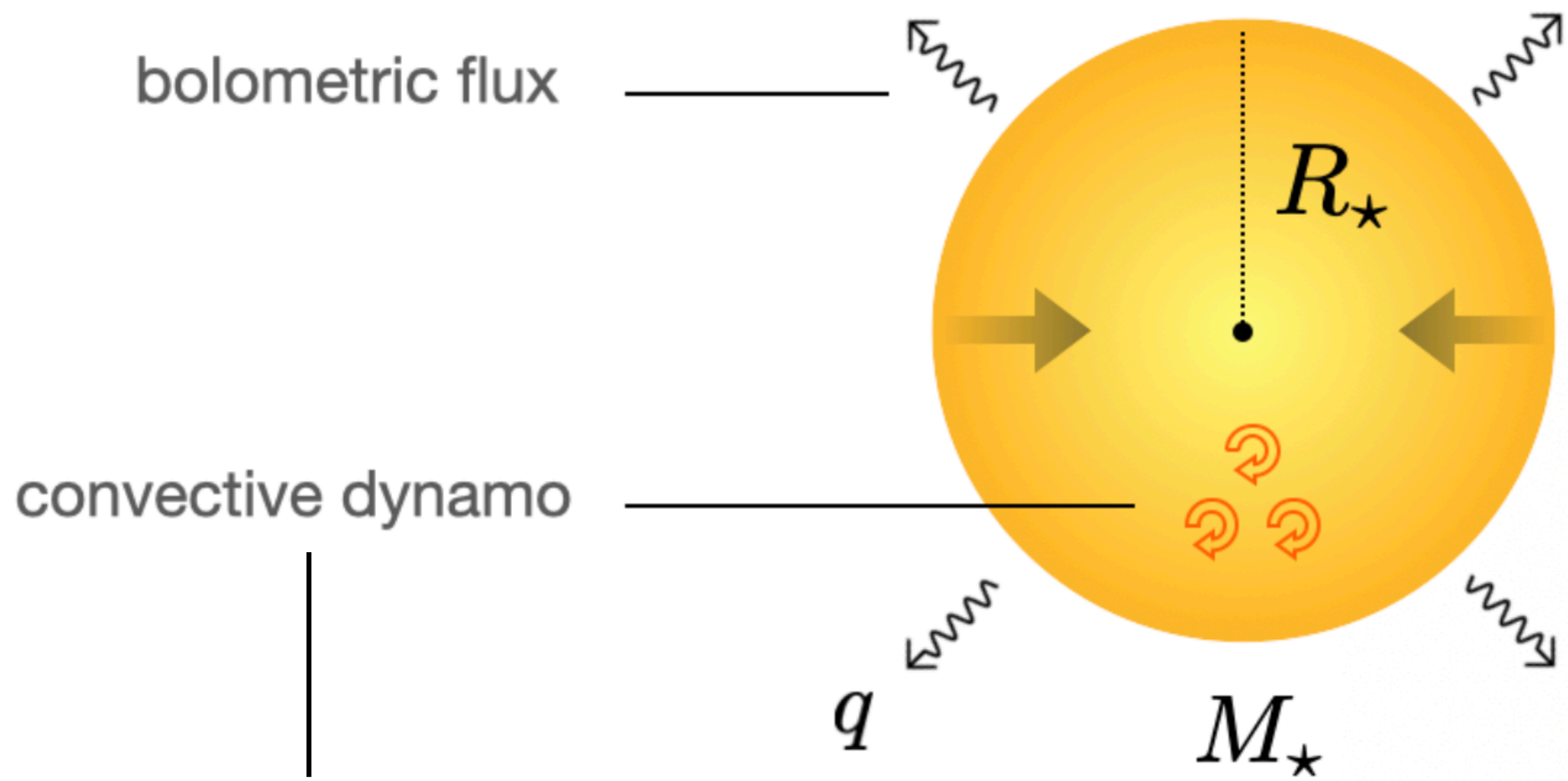
We need a theory that will connect stellar field (*B)*, radius (R), accretion rate (*M-dot)* etc.



$$\frac{B^2}{2\mu_0} \sim \frac{B_\star^2}{2\mu_0}\left(\frac{R_\star}{r}\right)^6 \sim \frac{\dot{M}}{4\,\pi\,r^2}\sqrt{\frac{2\,\mathcal{G}\,M_\star}{r}}$$

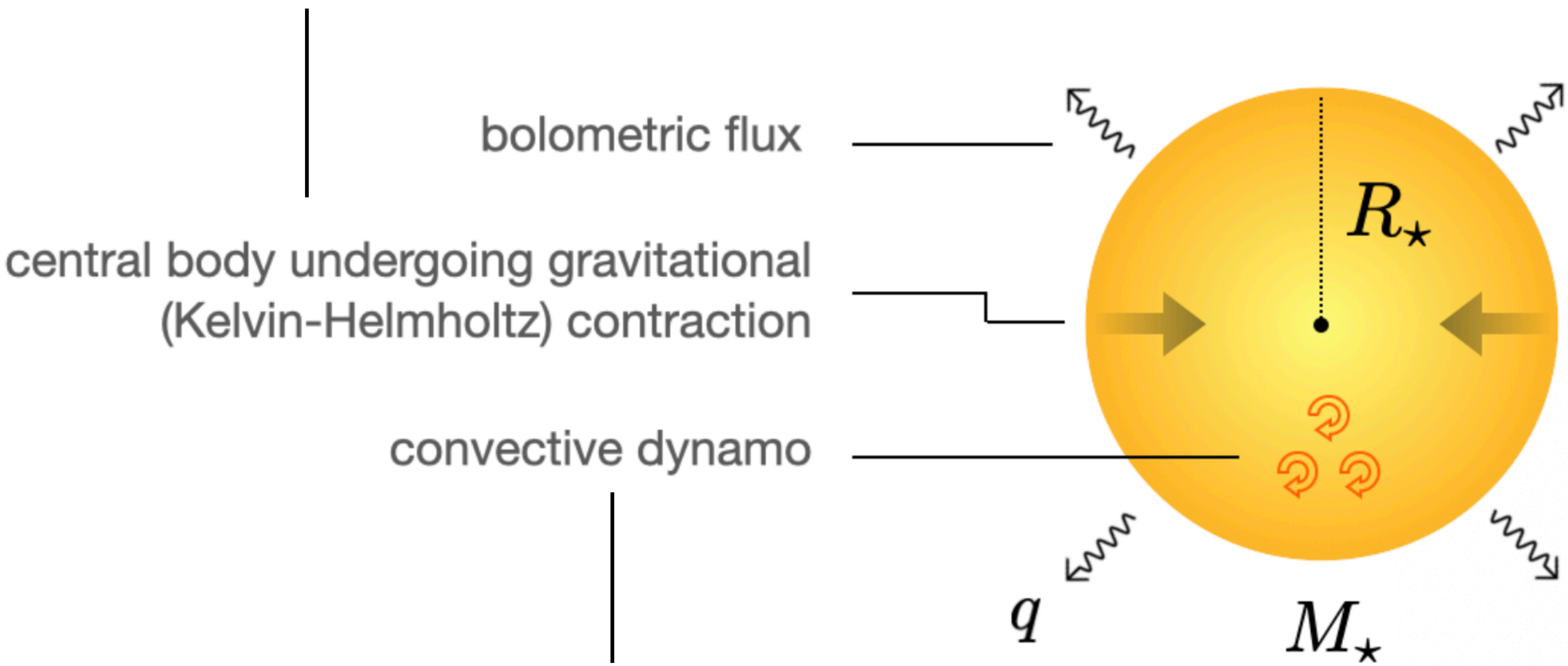


$\dot{M} \sim \beta \, \frac{M_\star}{\tau}$
B
disk accretion rate: $\dot{M}$
magnetospheric truncation frequency: Ω
$\frac{B_\star^2}{2\mu_0} \left(\frac{R_\star}{r}\right)^6 \sim \frac{\dot{M}}{4\,\pi\,r^2} \sqrt{\frac{2\,\mathcal{G}\,M_\star}{r}}$



$$\frac{\langle B \rangle^2}{2\mu_0} \sim \rho\, v_{\mathrm{conv}}^2 = c\, f_{\mathrm{ohm}}\, \langle \rho \rangle^{1/3}\, (\mathcal{F}\, q)^{2/3}$$

$$R_\star \approx \left(\frac{b\, G\, M_\star^2}{12\, \pi\, q\, \tau} \right)^{1/3}$$



$$\frac{\langle B \rangle^2}{2\, \mu_0} = c\, f_{\mathrm{ohm}}\, \langle \rho \rangle^{1/3}\, (\mathcal{F}\, q)^{2/3}$$

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The Origin of Universality in the Inner Edges of Planetary Systems

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$$\Omega = 2\,\xi \left[\frac{\sqrt{2}}{(3\,b\,\mathcal{F})^2} \left(\frac{\pi\,\beta\,\gamma^2}{c\,f_{\mathrm{ohm}}} \right)^3 \frac{(\mathcal{G}\,\langle\rho\rangle)^3}{\tau} \right]^{1/7}$$

$$\approx 2.4 \times 10^{-5}\,\mathrm{s}^{-1} \approx \frac{2\,\pi}{3\,\mathrm{day}}$$