Stellar rotational evolution on planetary atmospheres in single and binary star systems

Colin P. Johnstone

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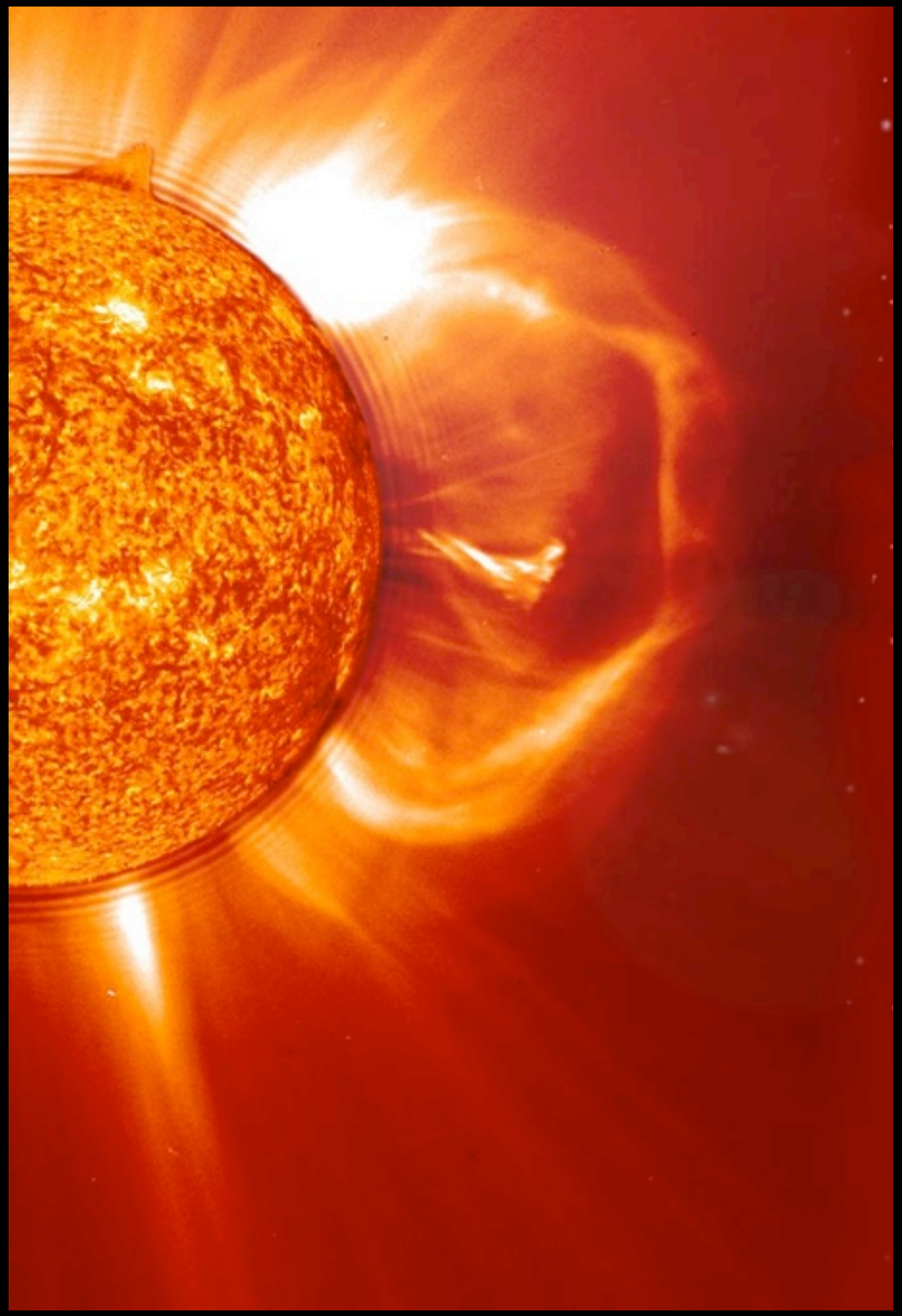
Stars produce winds and X-ray/EUV radiation



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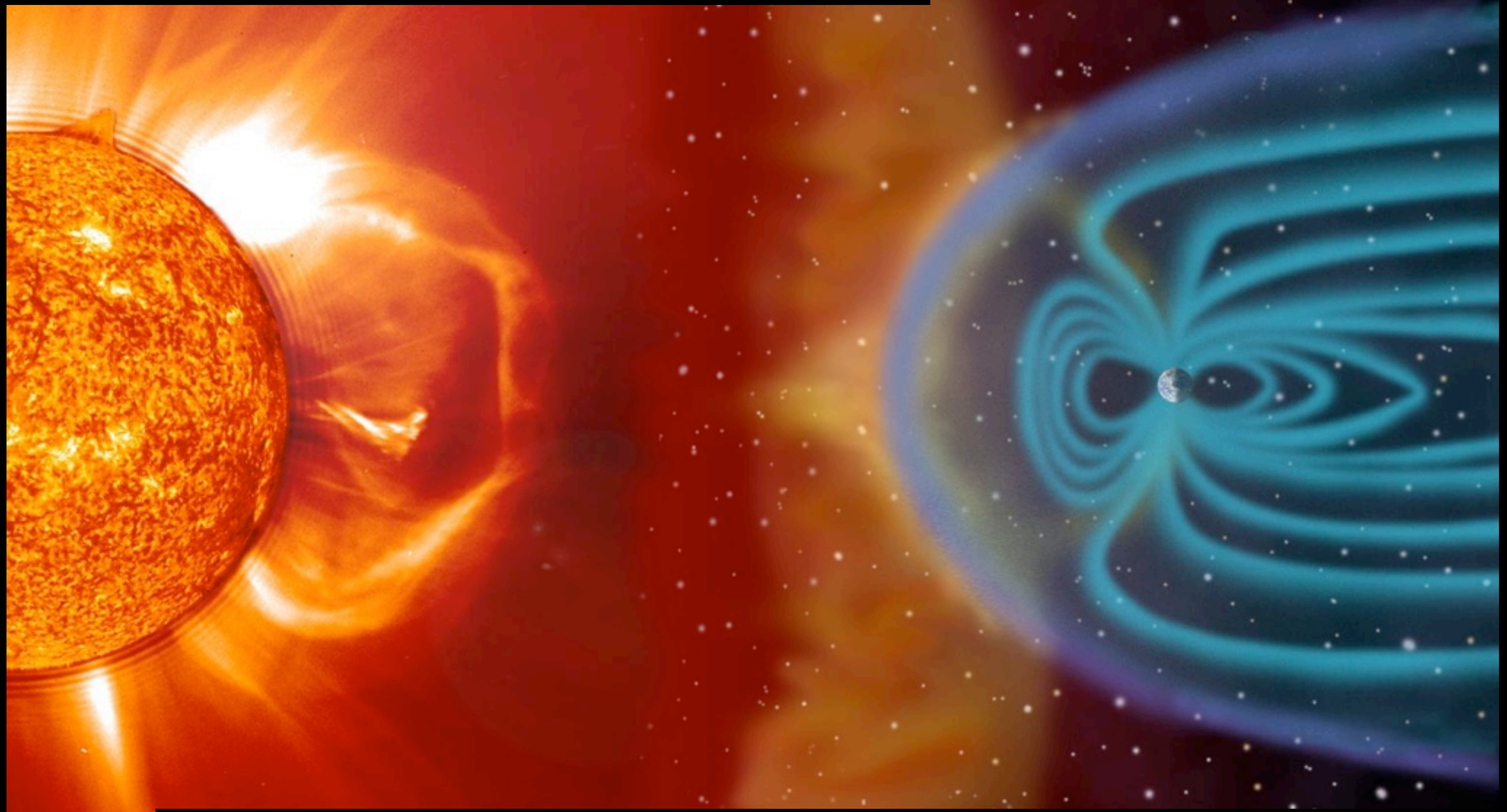
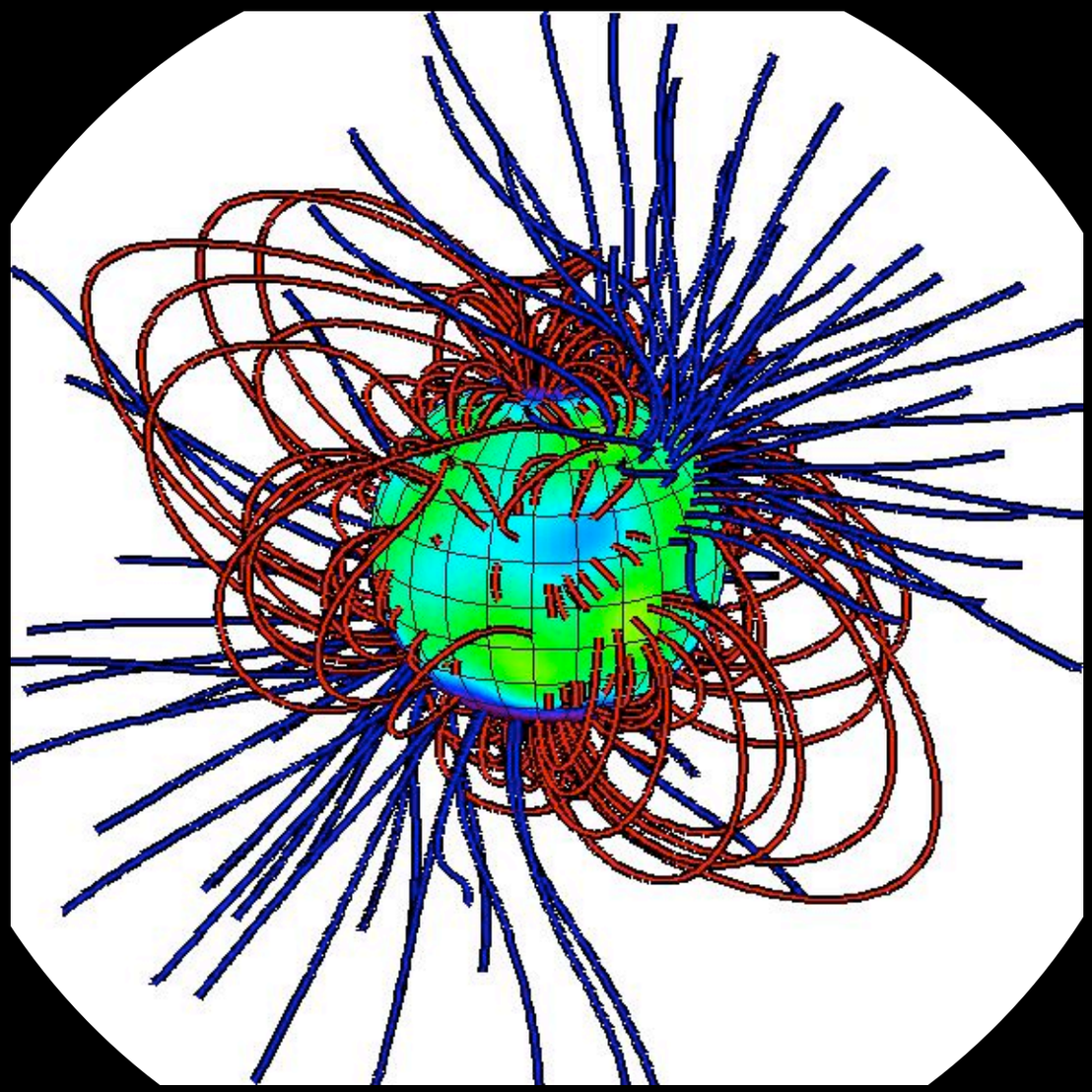


Winds/radiation influence evolution of planetary atmospheres

dB/dt can mean Eddy-current heating of planet interior



Non-axissymmetric stellar field means planet sees time changing interplanetary B

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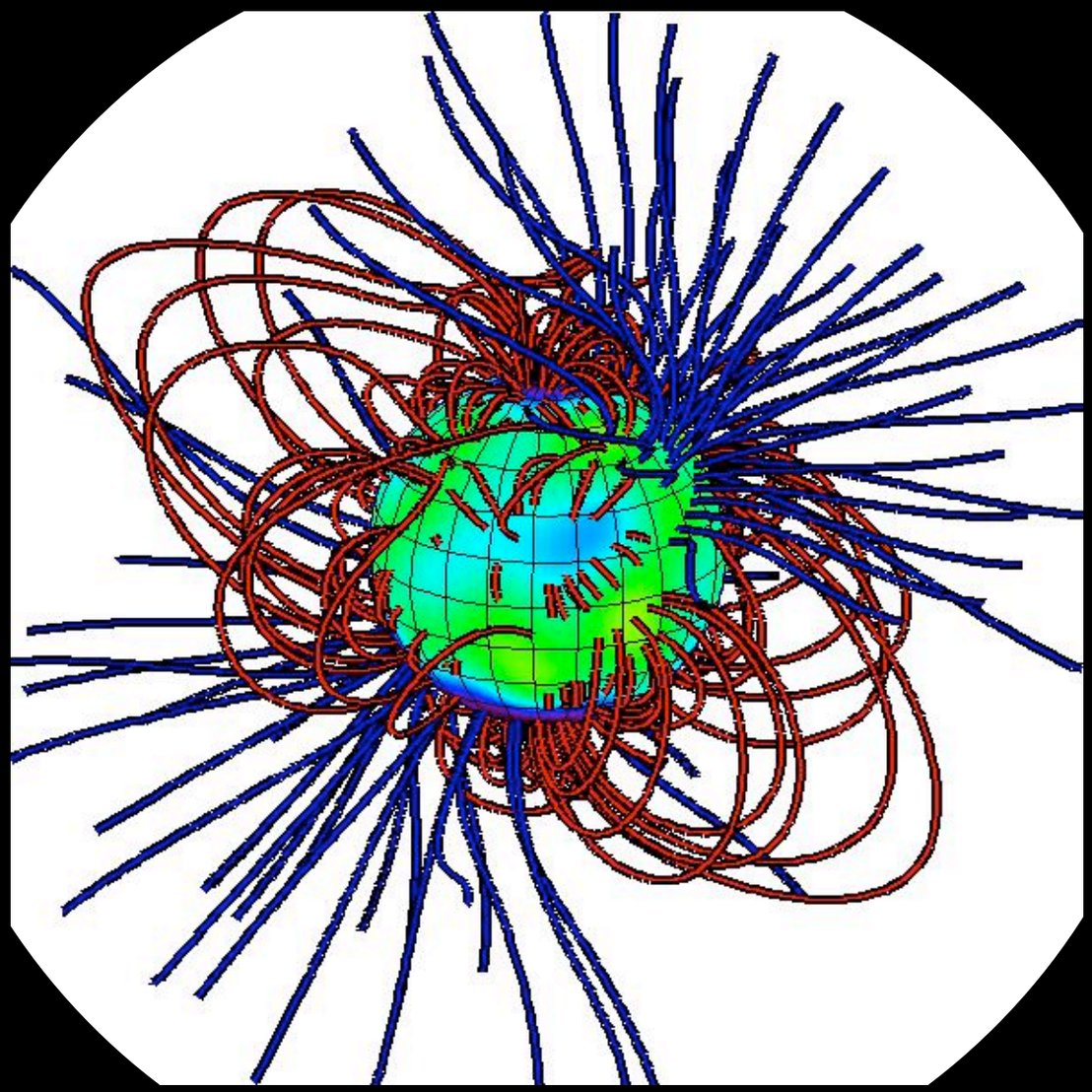
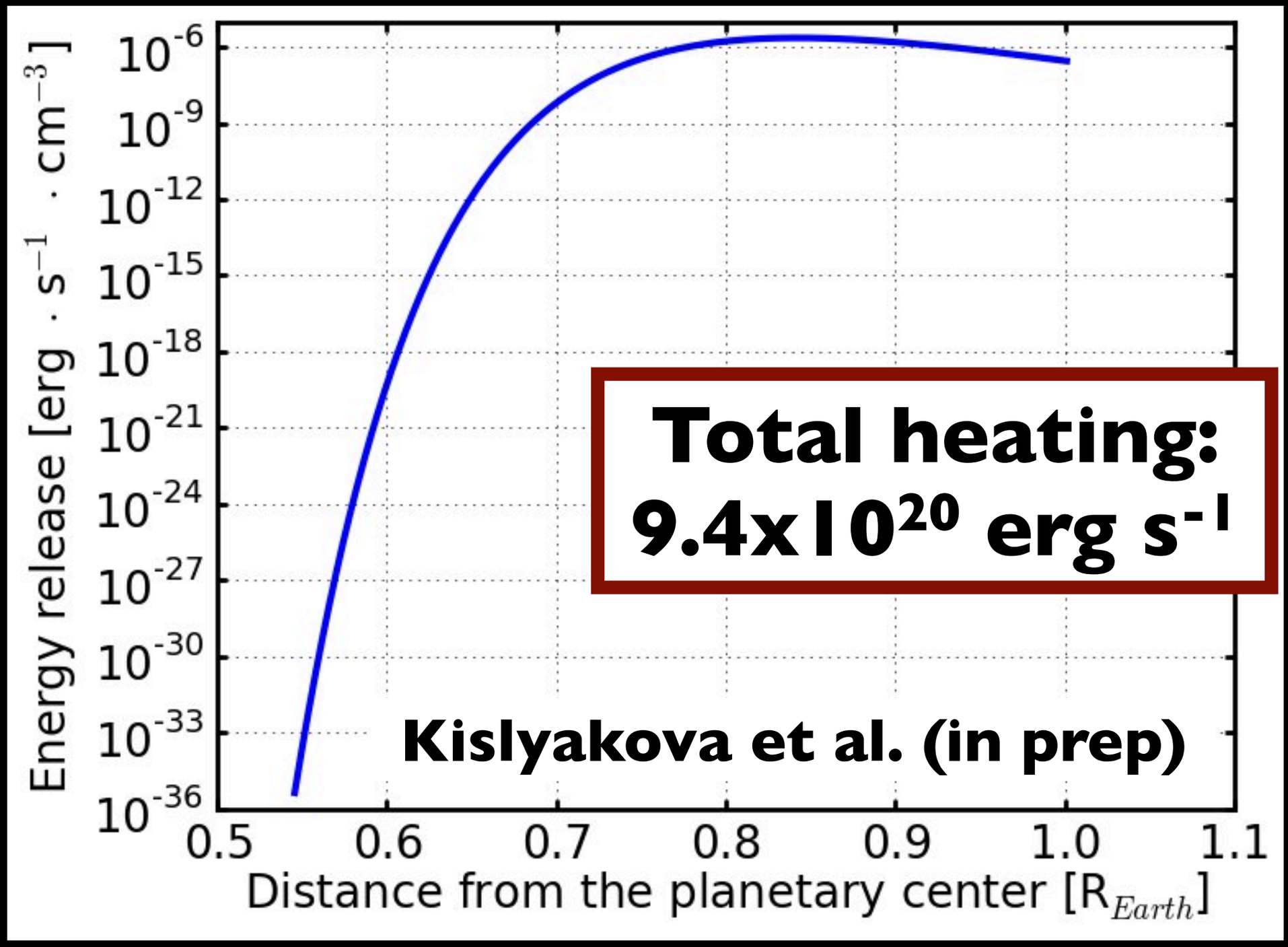


Non-axissymmetric stellar field means planet sees time changing interplanetary B

Simple case: WX UMa

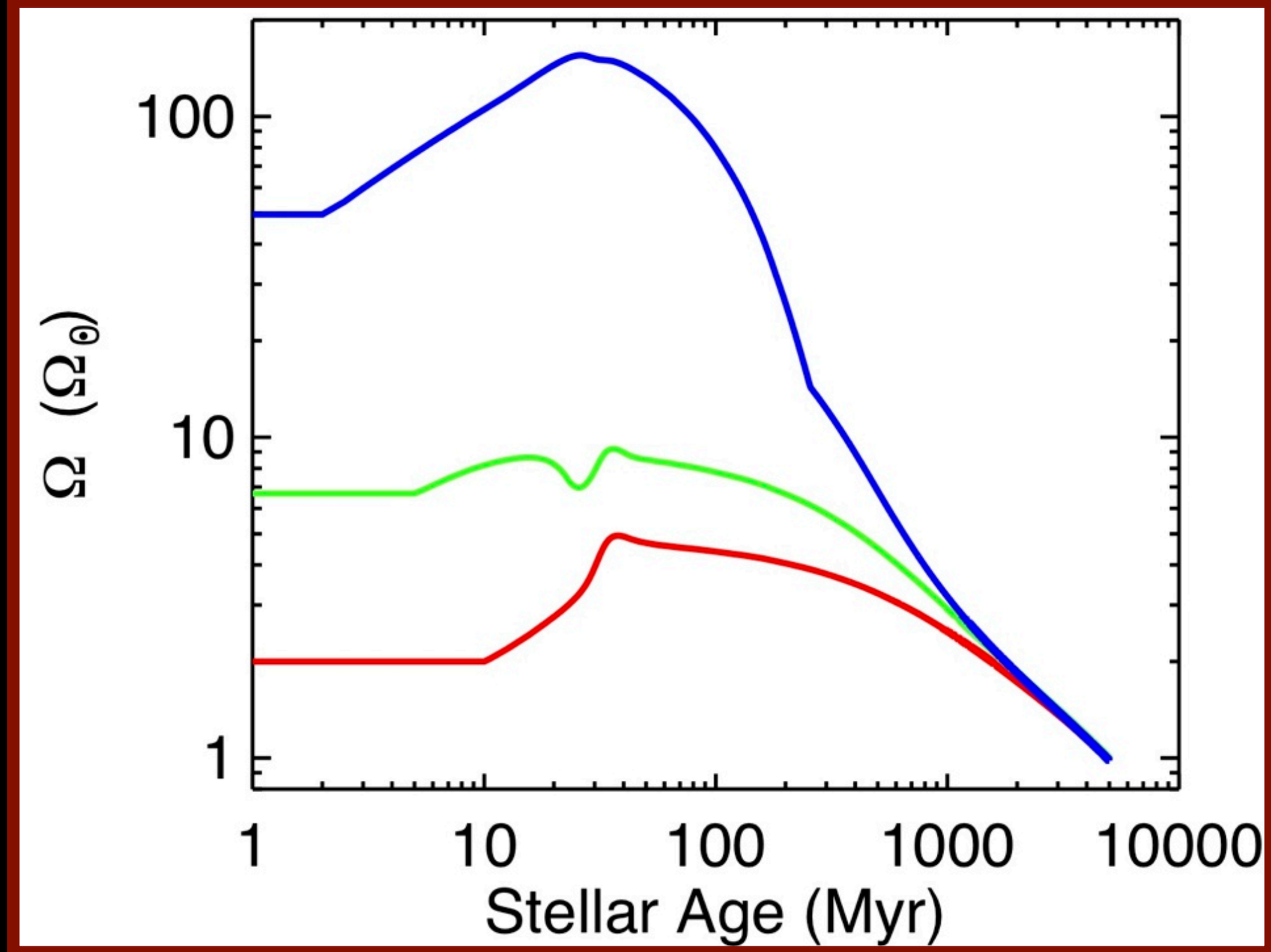
Dipole field strength = 3.9kG tilt = 40 degrees

Terrestrial planet at 0.046 AU (habitable zone)



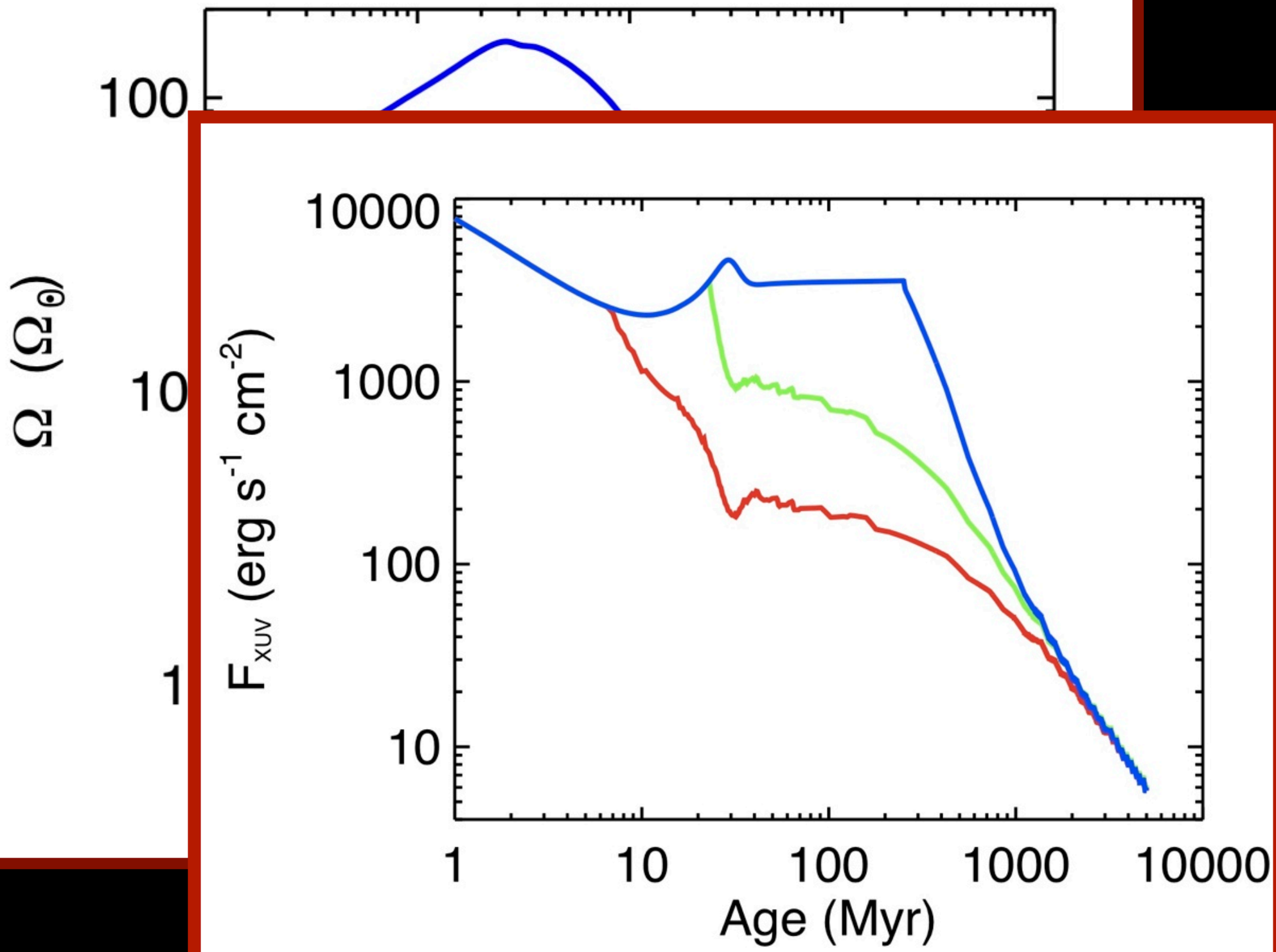
Total heating: 9.4×10^{20} erg s^{-1}

Kislyakova et al. (in prep)



Rotational evolution of a solar mass star

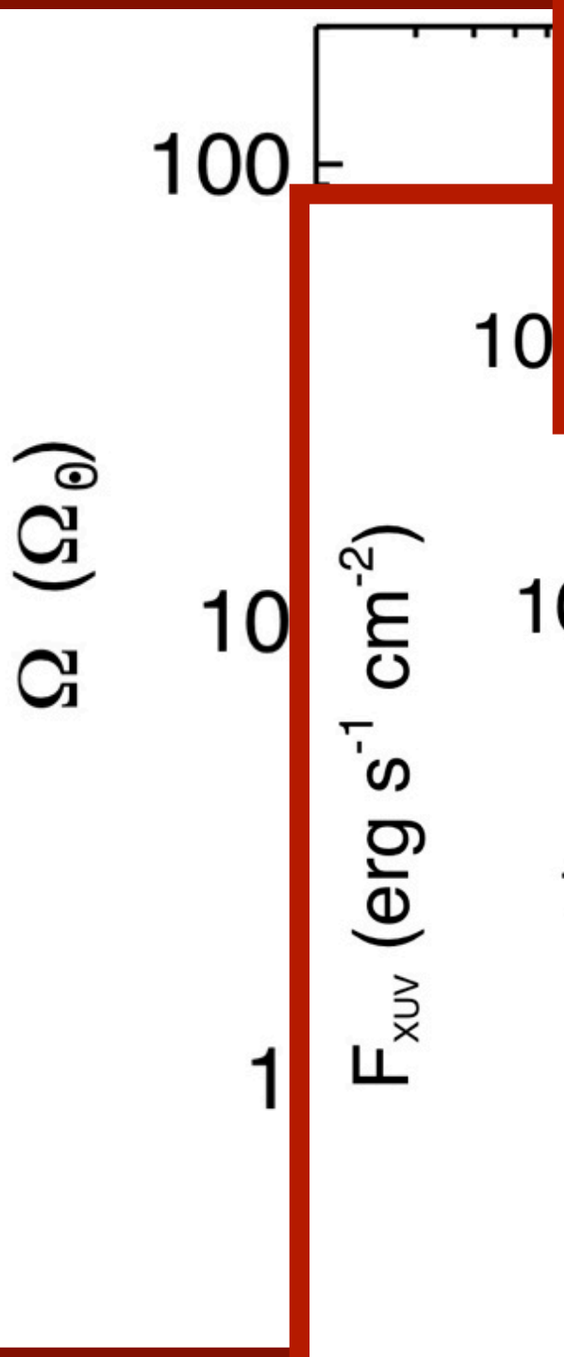
(Tu et al. 2015)

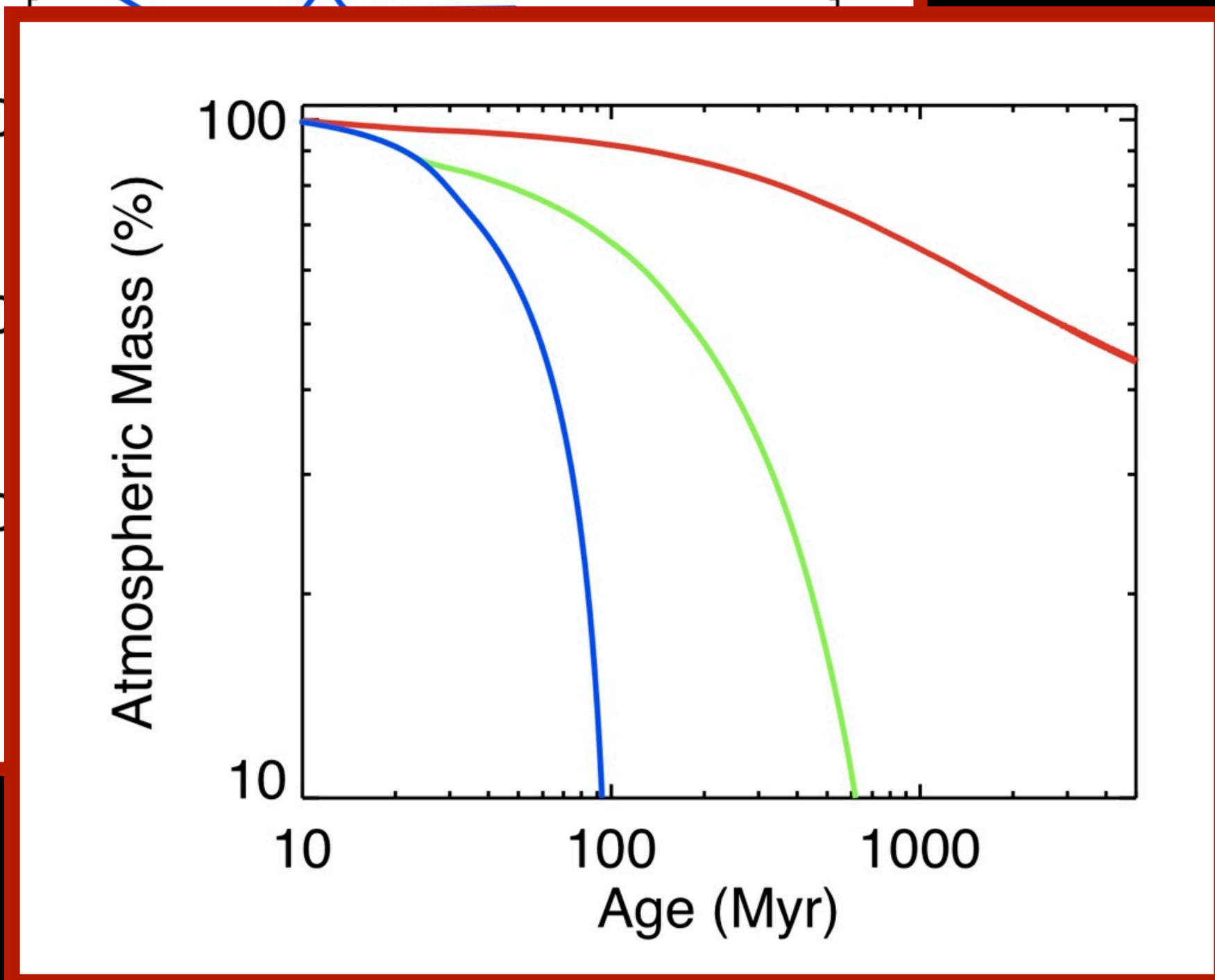


Resulting X-ray and EUV (XUV) evolution (Tu et al. 2015)

Non-unique evolution of planetary atmosphere

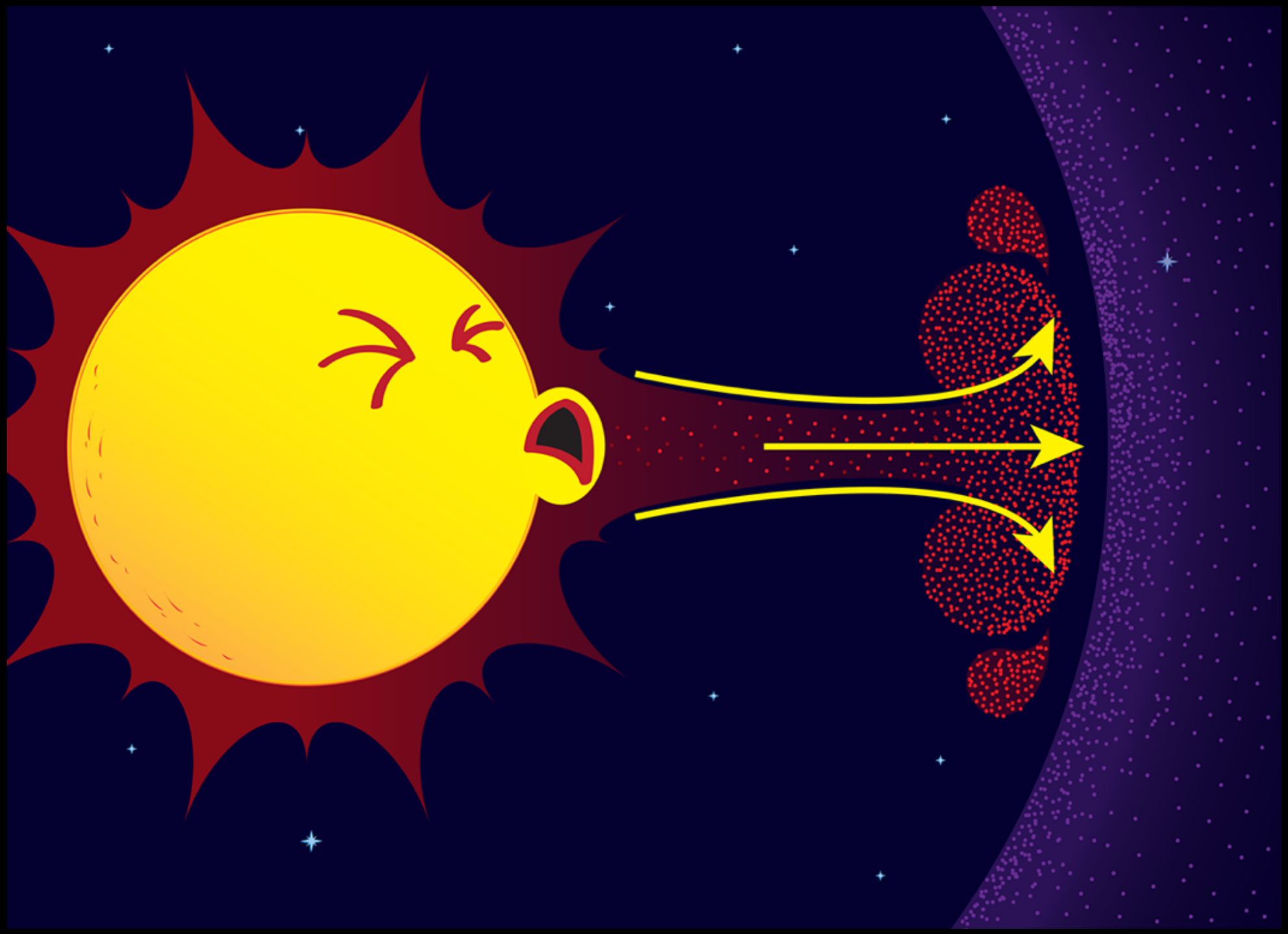
(Tu et al. 2015; Johnstone et al. 2015a)



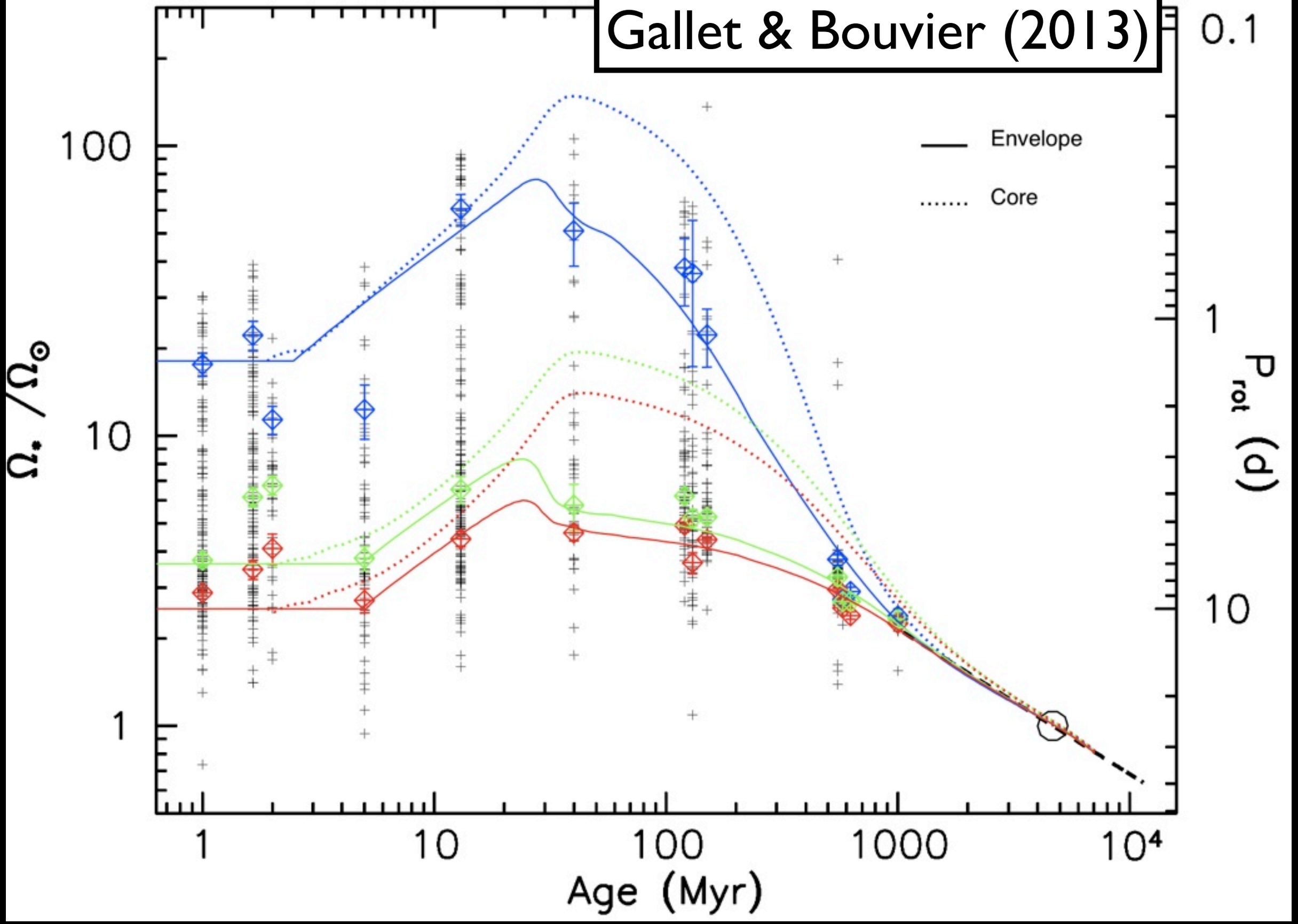


STELLAR WINDS

(...AND THE IMPORTANCE OF ROTATIONAL EVOLUTION)



Gallet & Bouvier (2013)



Using rotational evolution to observationally constrain winds

Matt et al. (2012), Reville et al. (2015)

Wind torque:

$$\frac{dJ_\star}{dt} \propto \left(\frac{dM_\star}{dt}\right)^{0.56} B_{\rm dip}^{0.87} \Omega_\star$$

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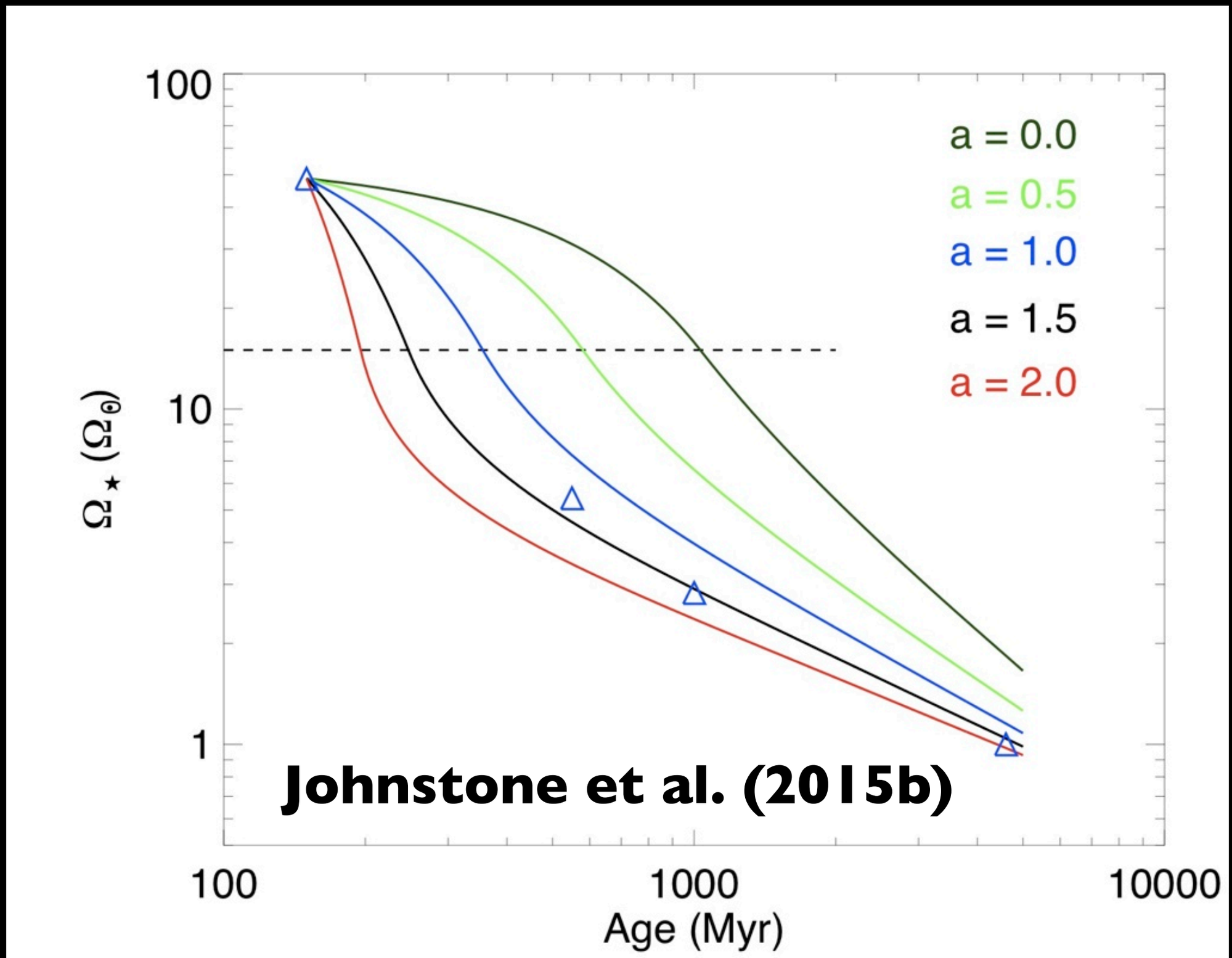
Get spin down law:

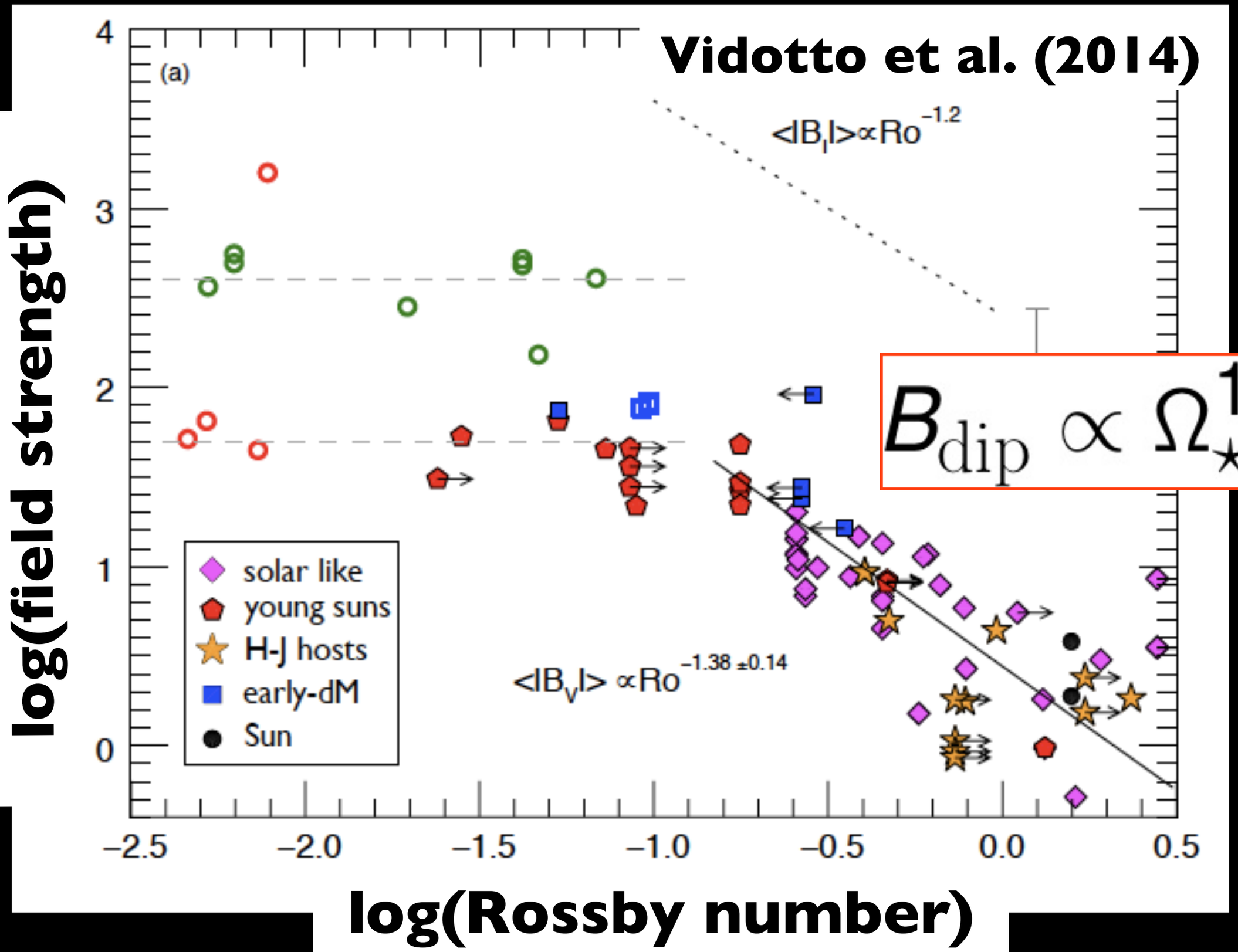
$$\frac{d\Omega_\star}{dt} \propto \Omega_\star^{0.56a+0.87b+1}$$

$$B_{\rm dip} \propto \Omega_\star^{1.32}$$

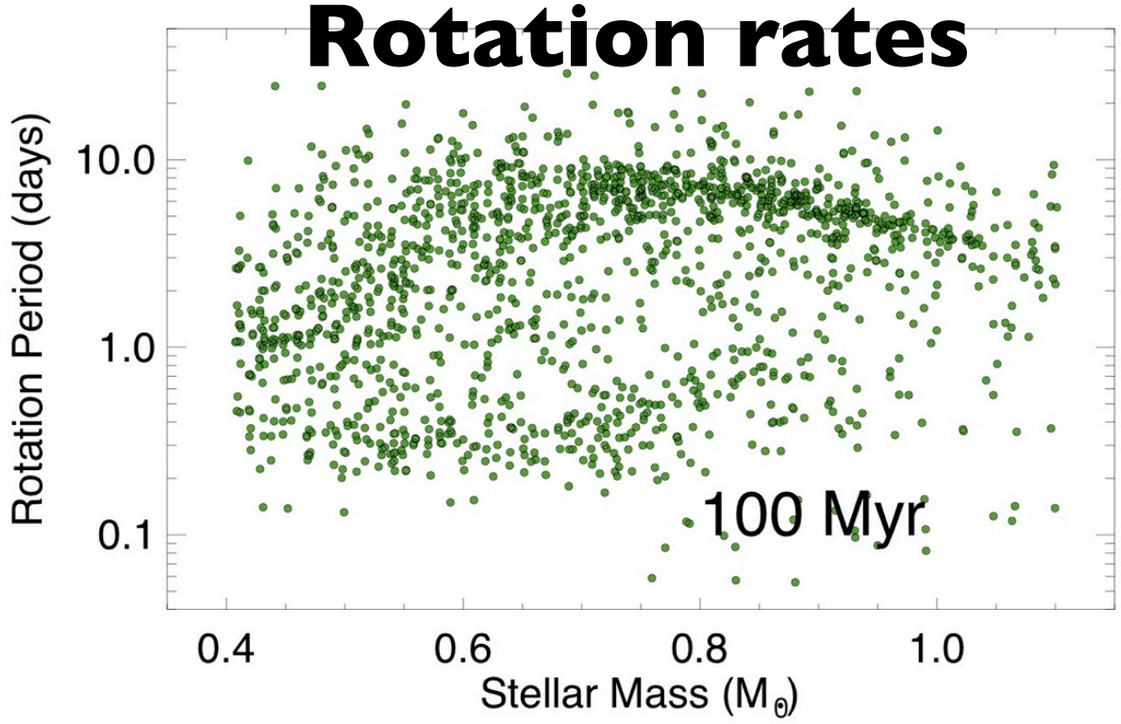
Vidotto et al. (2014)

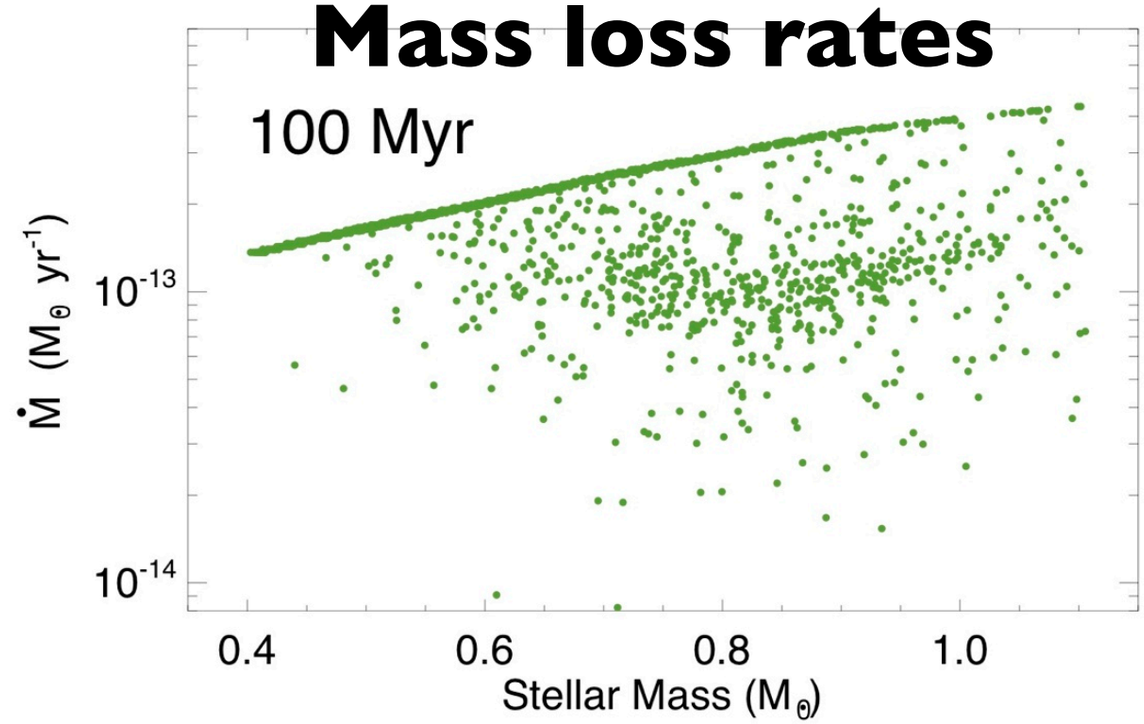


How do we scale large scale field strength? With Rossby number, age, or rotation rate?



Johnstone et al. (2015bc)





Assuming $B_{\rm dip} \propto Ro_\star^{-1.32}$ **gives us...**

$$\frac{dM_\star}{dt} \propto R_\star^2 \Omega_\star^{1.33} M_\star^{-3.36}$$

Johnstone et al. (2015c)

Johnstone et al. (2015bc)