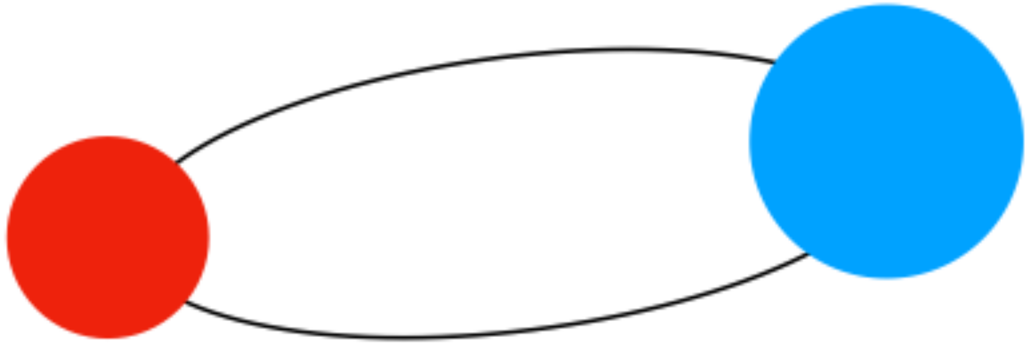
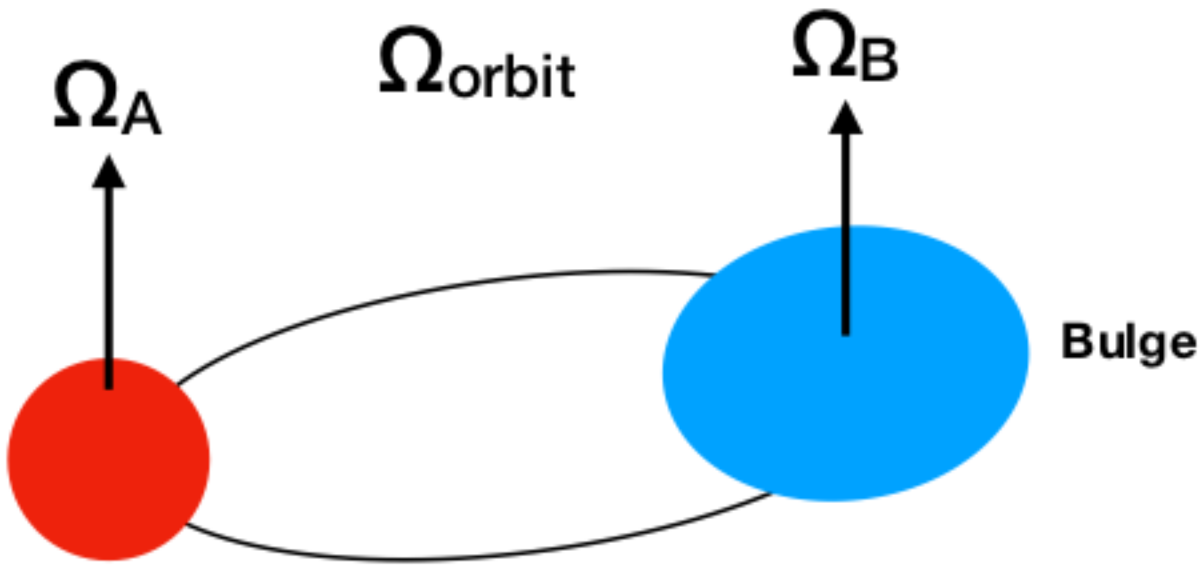


Tides, Differential Rotation, and Eclipsing Binaries

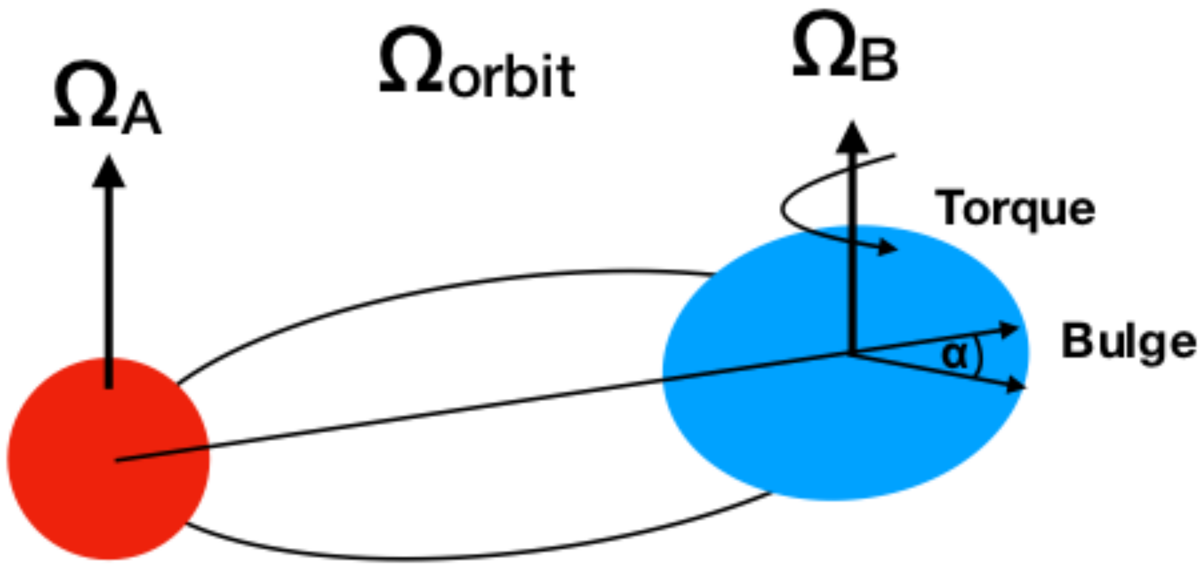
Adam Jermyn
with Jamie Tayar and Jim Fuller

arXiv:1911.01431

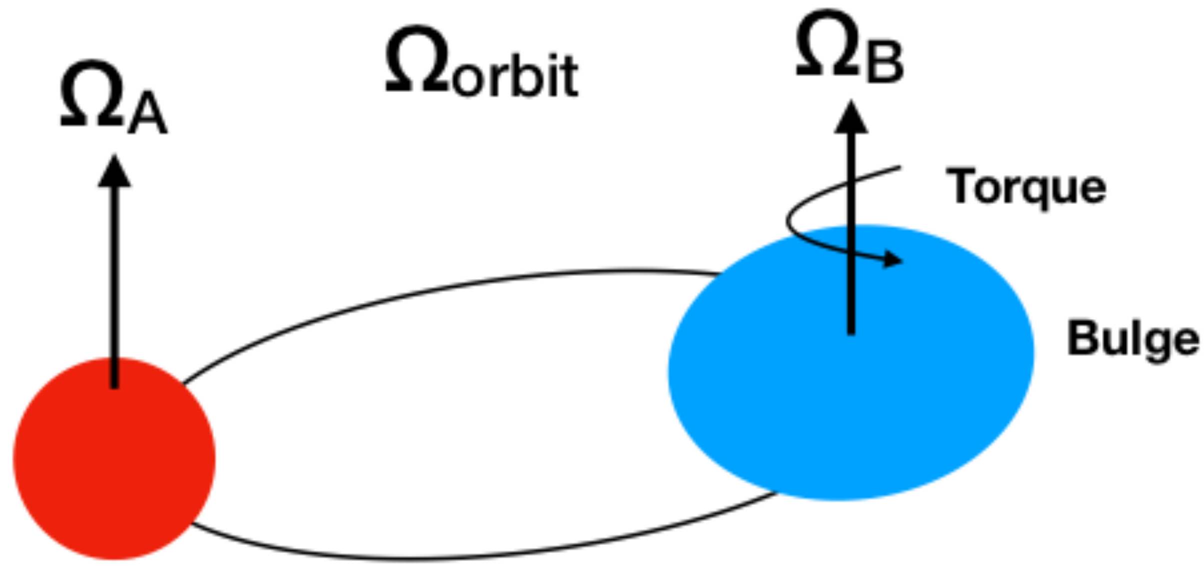
Tides



Tides

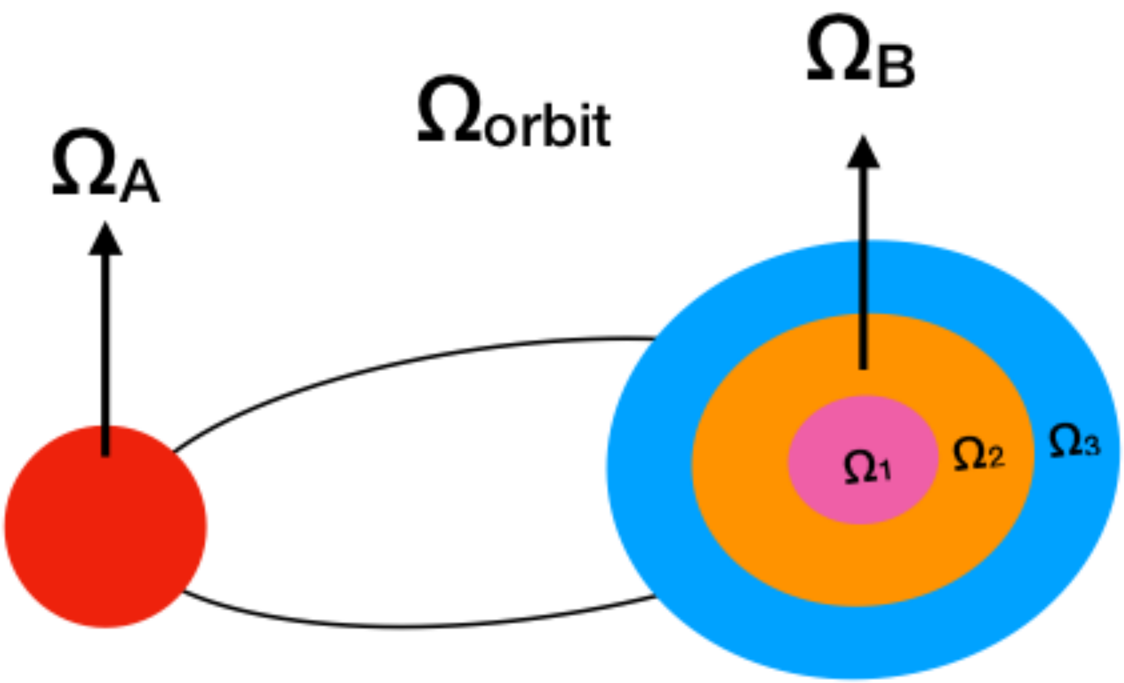


Tides



Over time, $\Omega_{A/B}$ synchronize to Ω_{orbit}

Now with differential rotation…



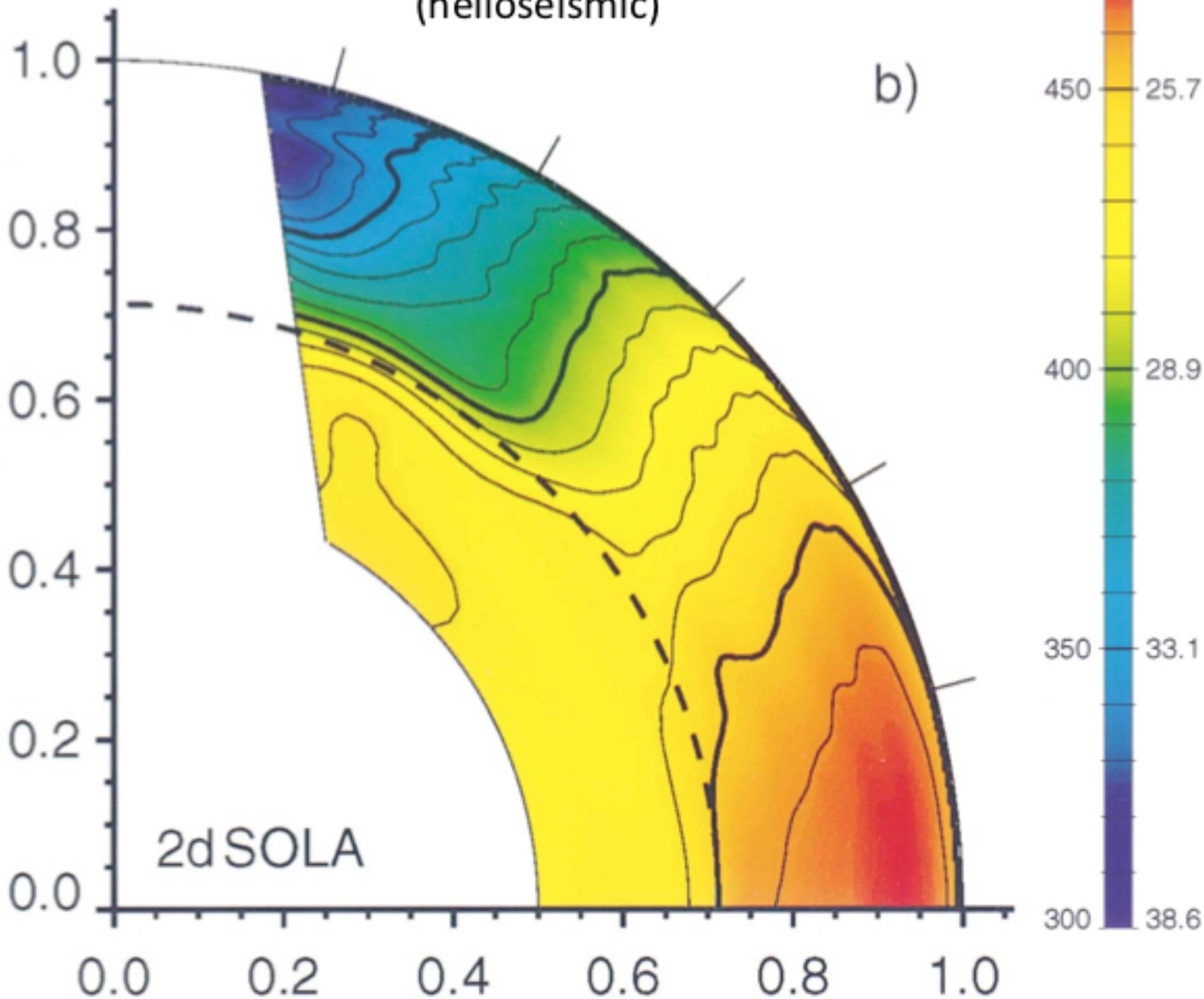
1. **Does differential rotation survive a tidal torque?**
2. **If it does, what does synchronizing mean?**

Solar Rotation Profile
(helioseismic)

Convection Zone

Tachocline

Radiative Zone



Schou et al. 1998

Does differential rotation survive?

$t_{transport} >> t_{tides}$: Tides control the shear

$t_{transport} << t_{tides}$: Intrinsic shear wins

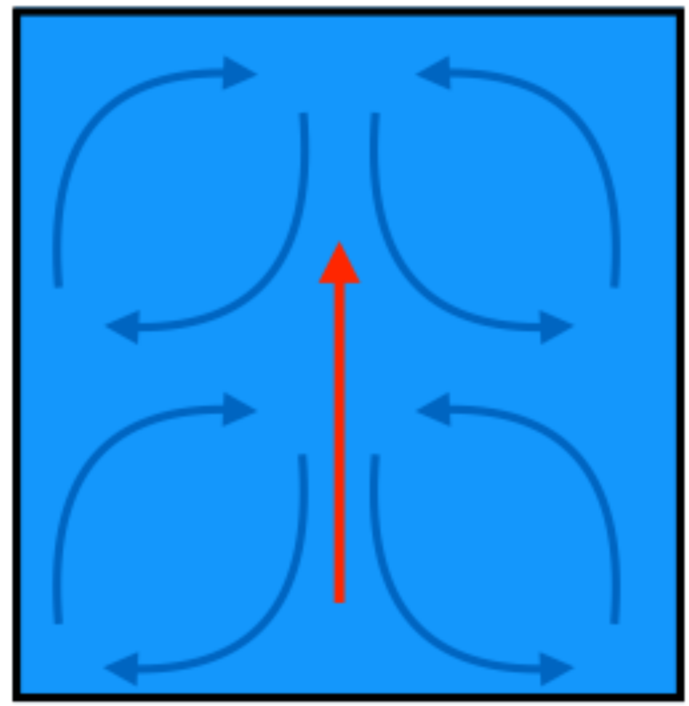
Depends on what transports angular momentum!

Does differential rotation survive?

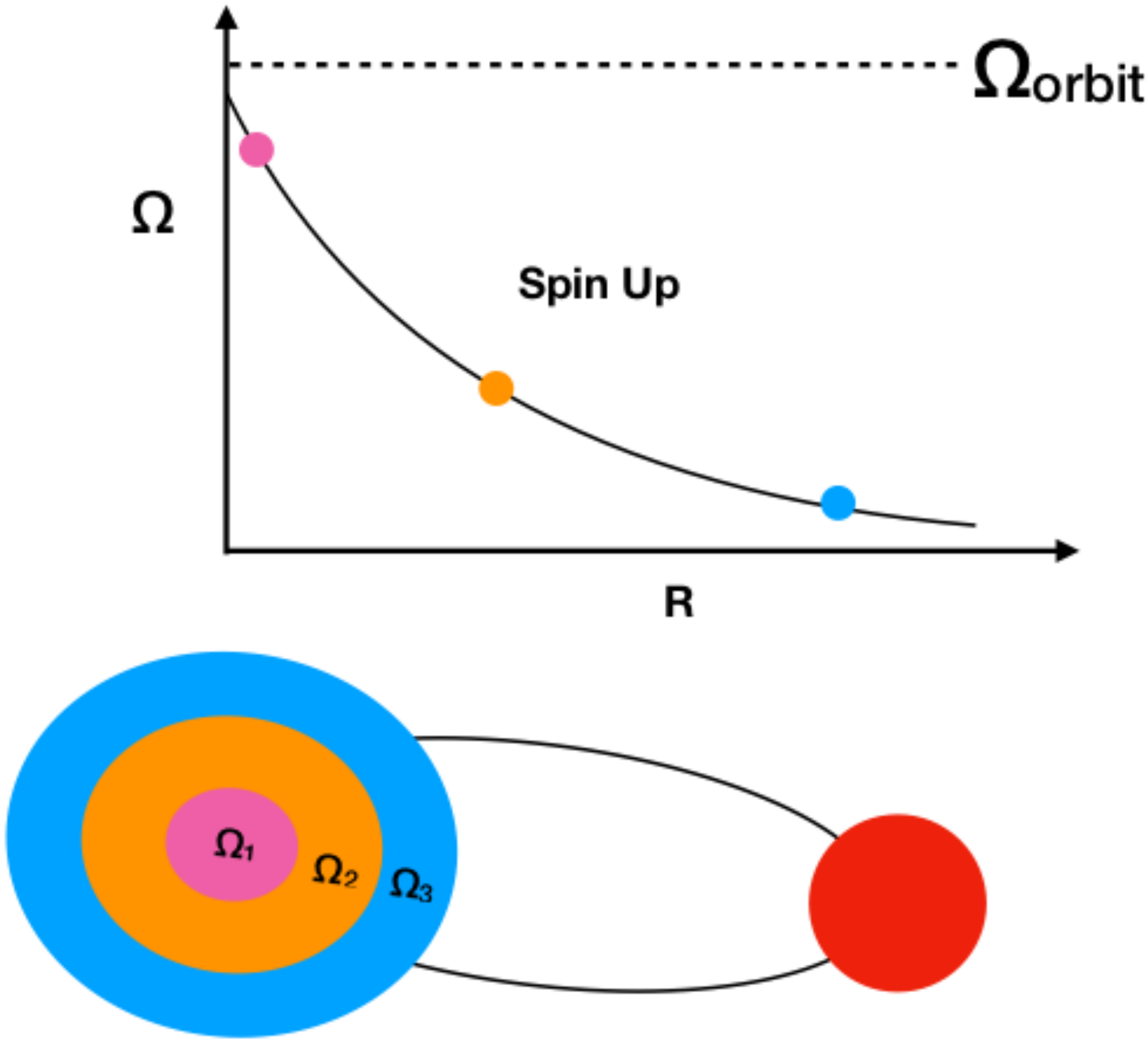
Depends on what transports angular momentum!

Radiative zones… unclear.

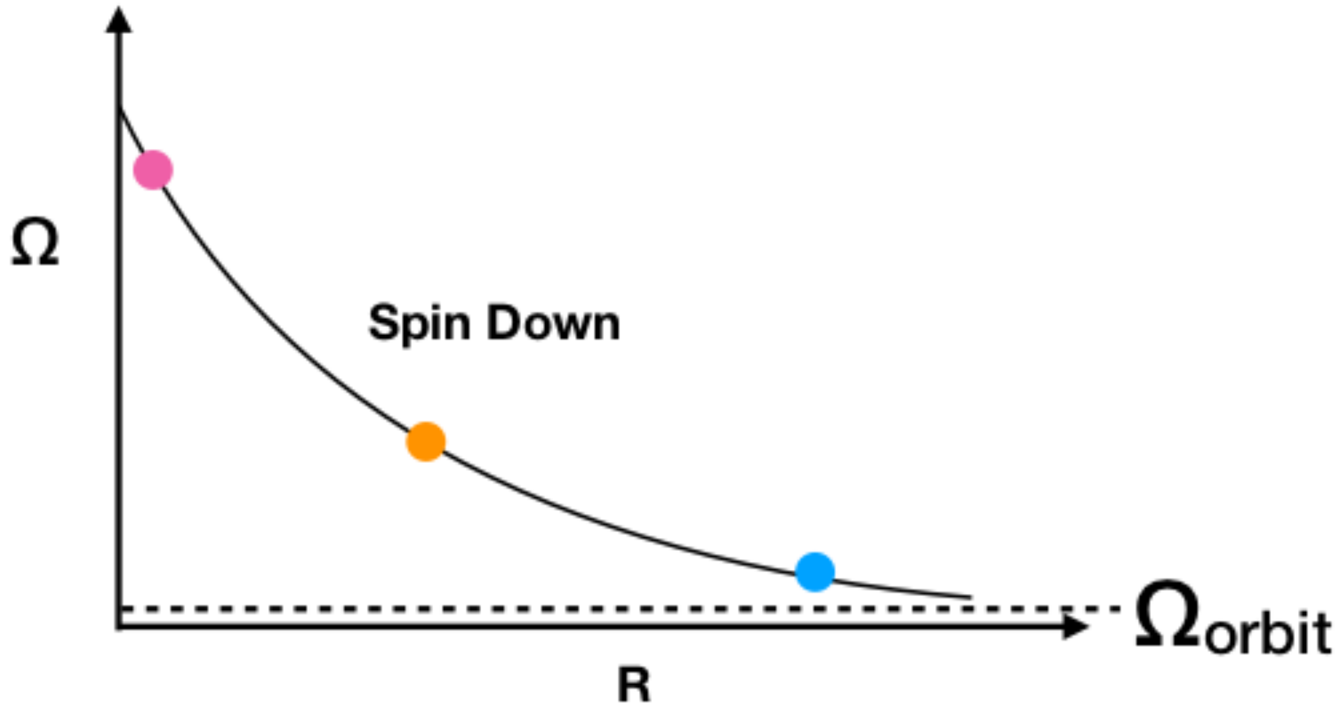
Convection zones… yes!
($t_{conv} << t_{tides}$)

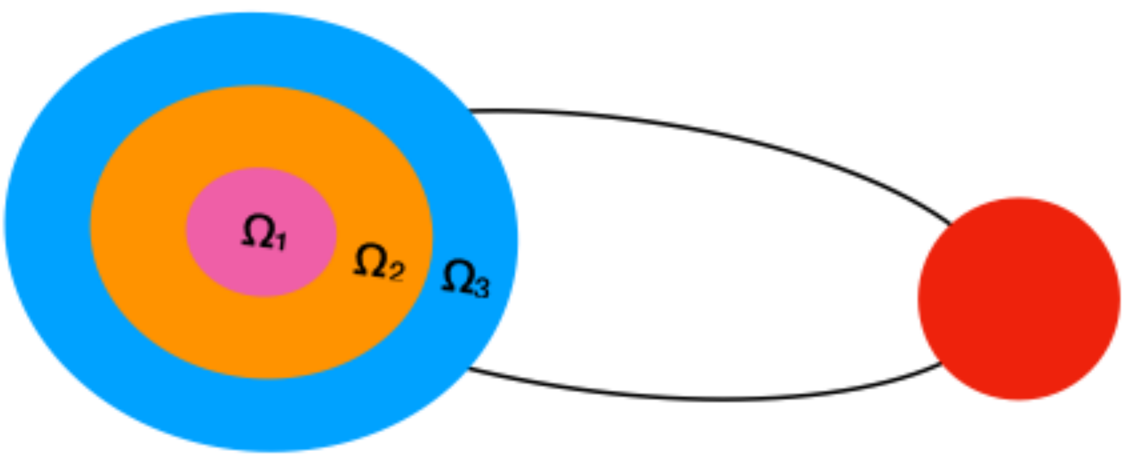


Tides in convecting stars

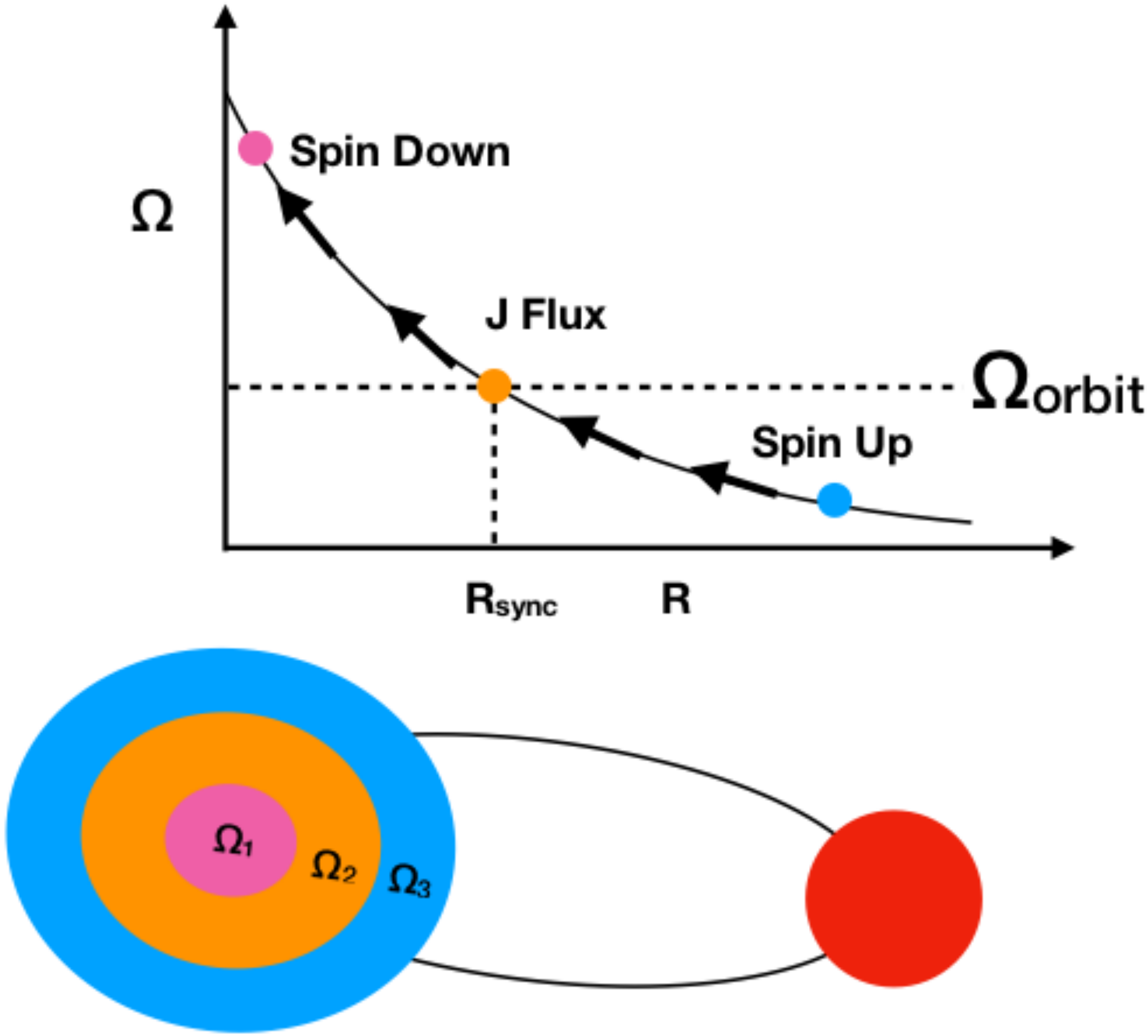


Tides in convecting stars

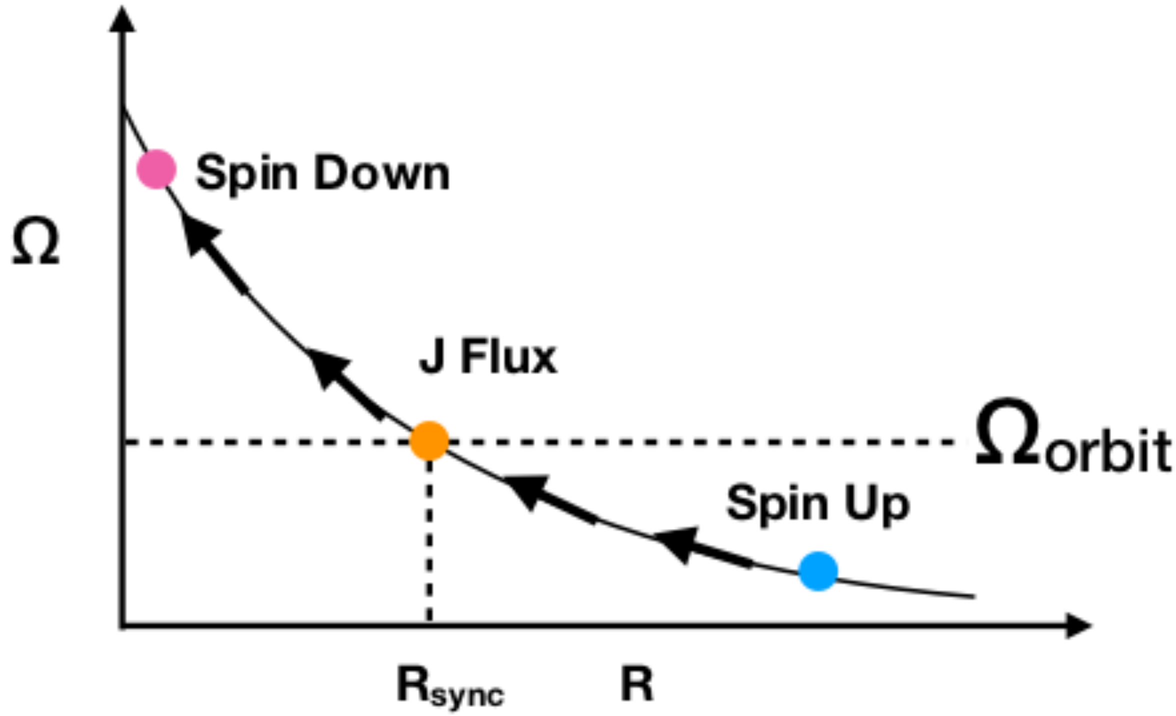


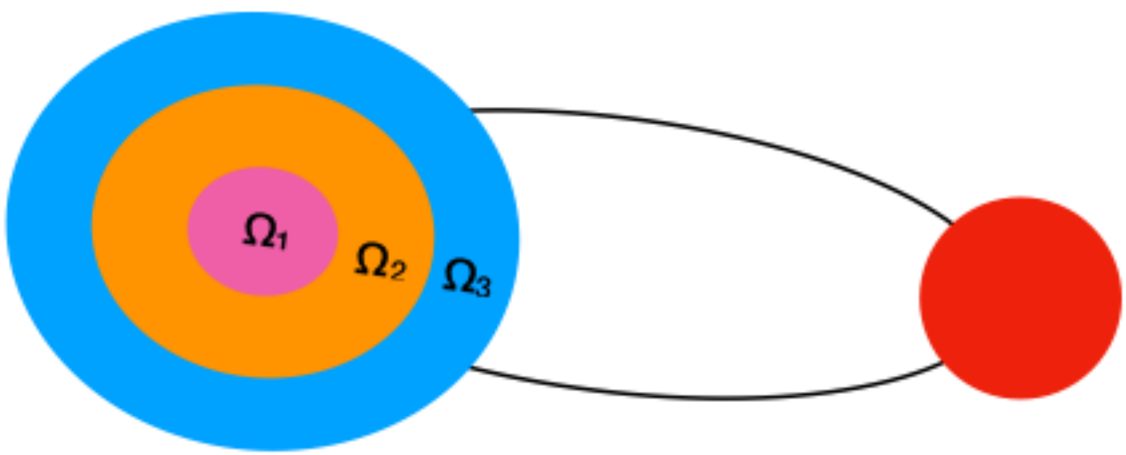


Tides in convecting stars



Tides in convecting stars

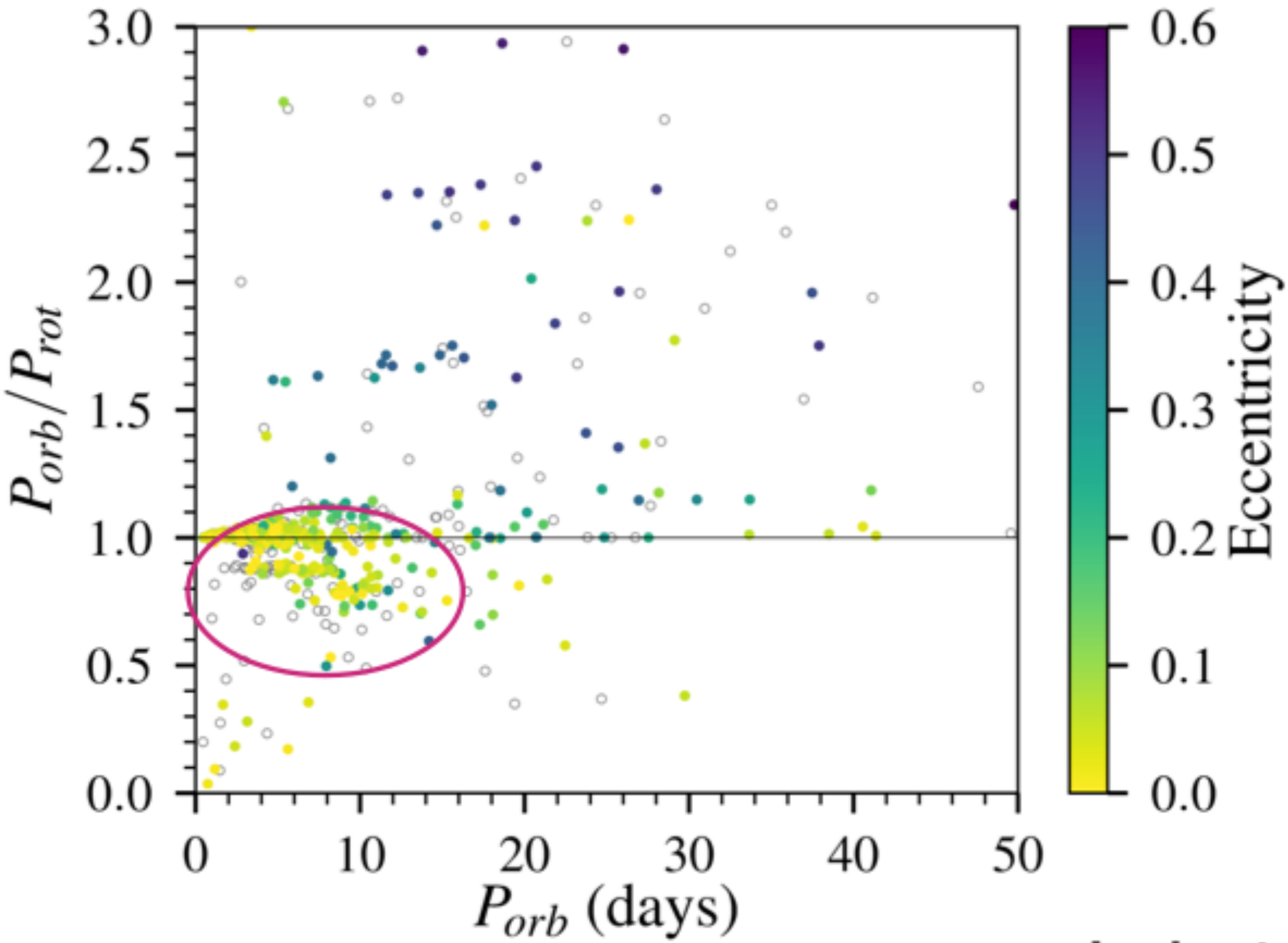




Synchronized:

- Net torque on each star is zero.
- Surface period may not equal orbital period!

Eclipsing Binaries



Lurie et al. 2017

Inference Problem

Toy Model: $$\Omega(r,\theta) = \Omega_0 \left(\frac{r}{R_\star}\right)^\beta \left(1 + \delta \ln \Omega P_2(\cos\theta)\right)$$

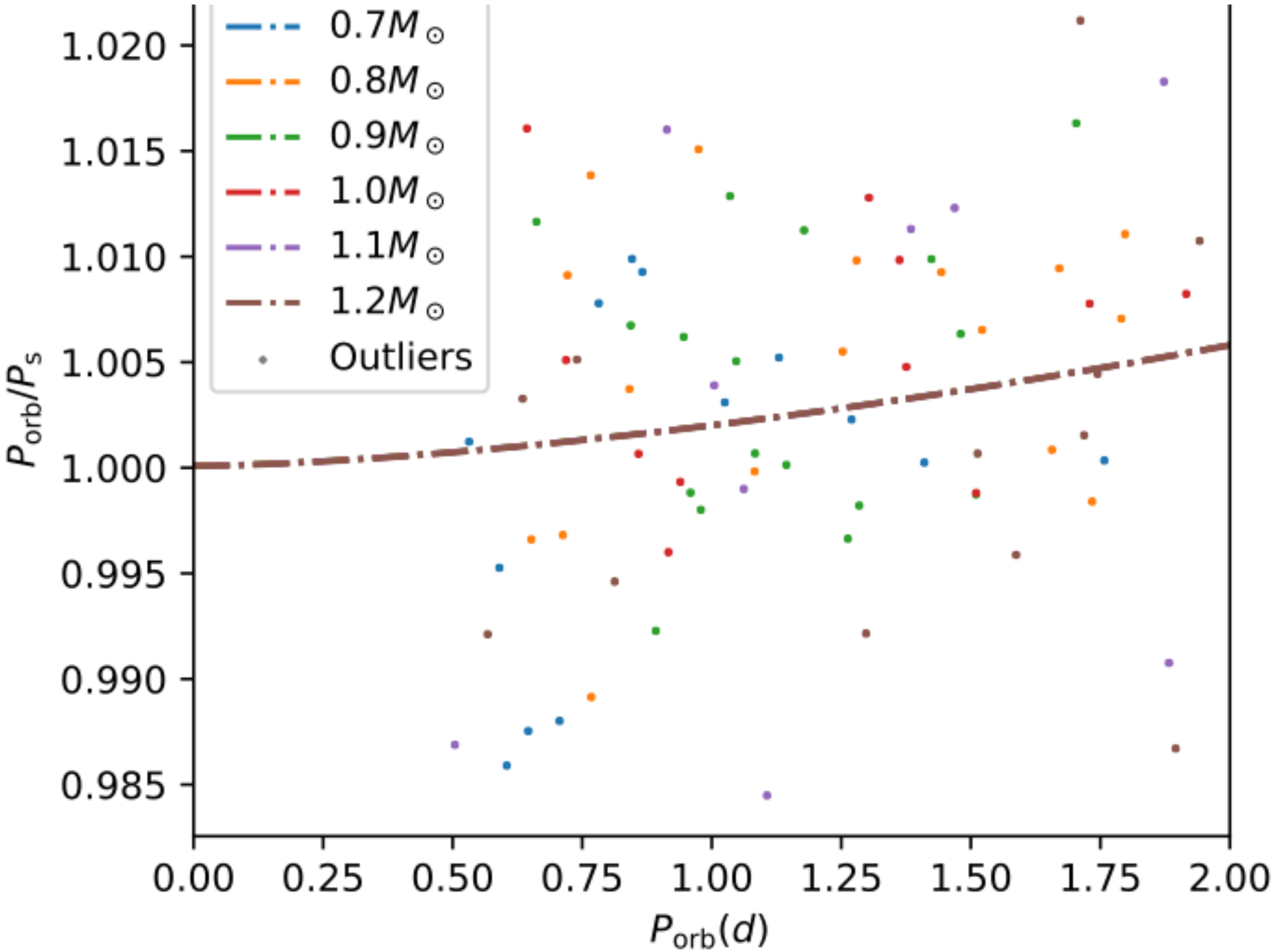
Two free parameters

Inference Problem

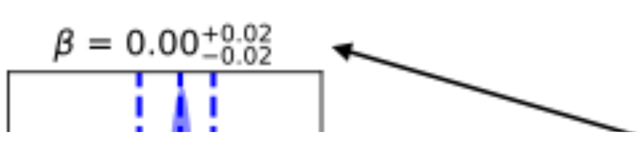
Toy Model: $$\Omega(r,\theta) = \Omega_0 \left(\frac{r}{R_\star}\right)^{\beta} \left(1 + \delta \ln \Omega P_2(\cos\theta)\right)$$

Prediction: $$\frac{P_{\rm orb}}{P_{\rm s}} \approx k_\star^{-1}(\beta) \frac{1 + \frac{5}{8}\delta \ln \Omega}{1 - \frac{2}{7}\delta \ln \Omega}$$ **(from tidal integrals)**

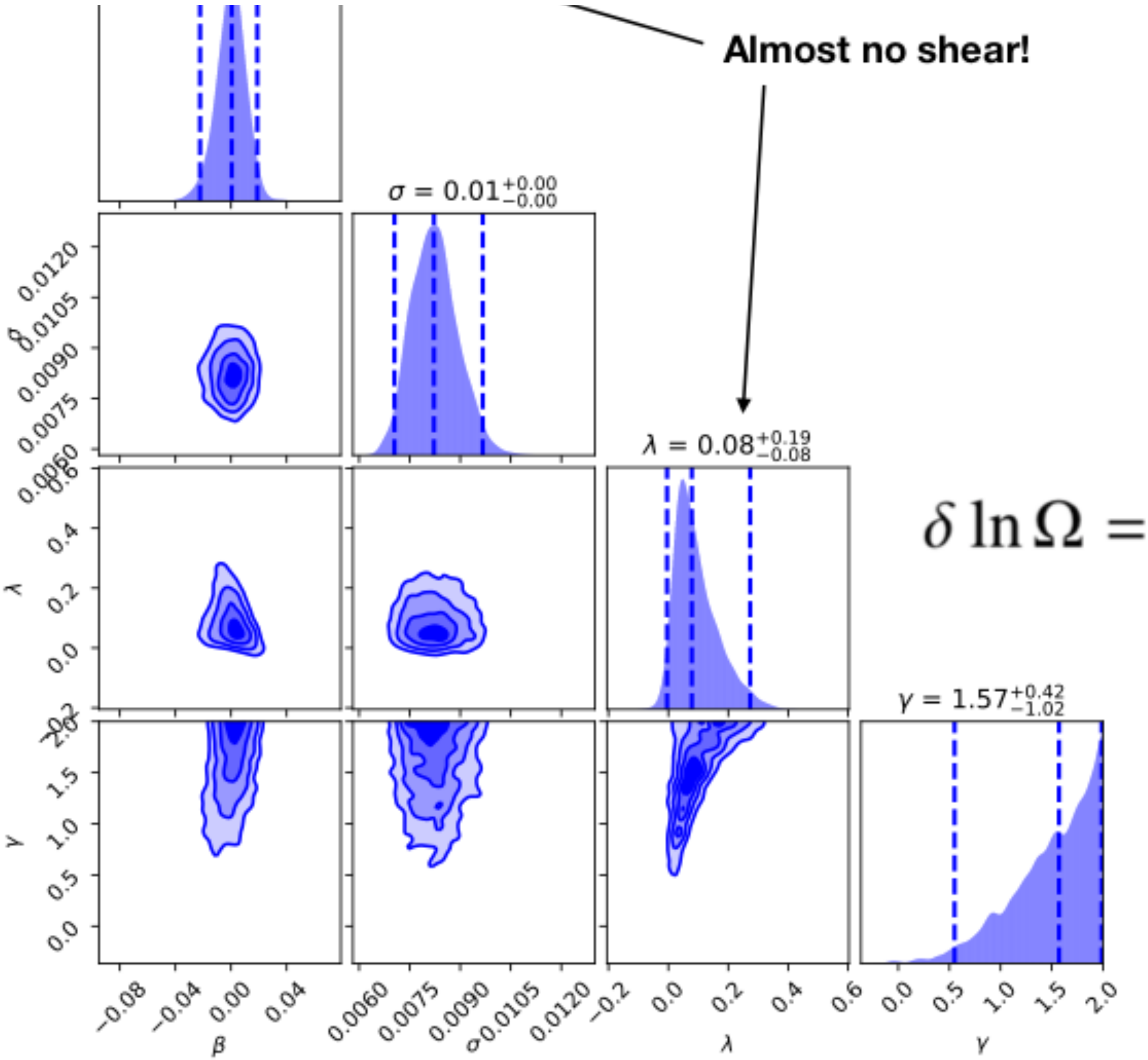
- **Depends on stellar structure and .**
- **Assume MS, pick mass to match Kepler temperature**



$0.7M_\odot$
$0.8M_\odot$
$0.9M_\odot$
$1.0M_\odot$
$1.1M_\odot$
$1.2M_\odot$
Outliers
P_{orb}/P_s
1.020
1.015
1.010
1.005
1.000
0.995
0.990
0.985
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
$P_{orb}(d)$

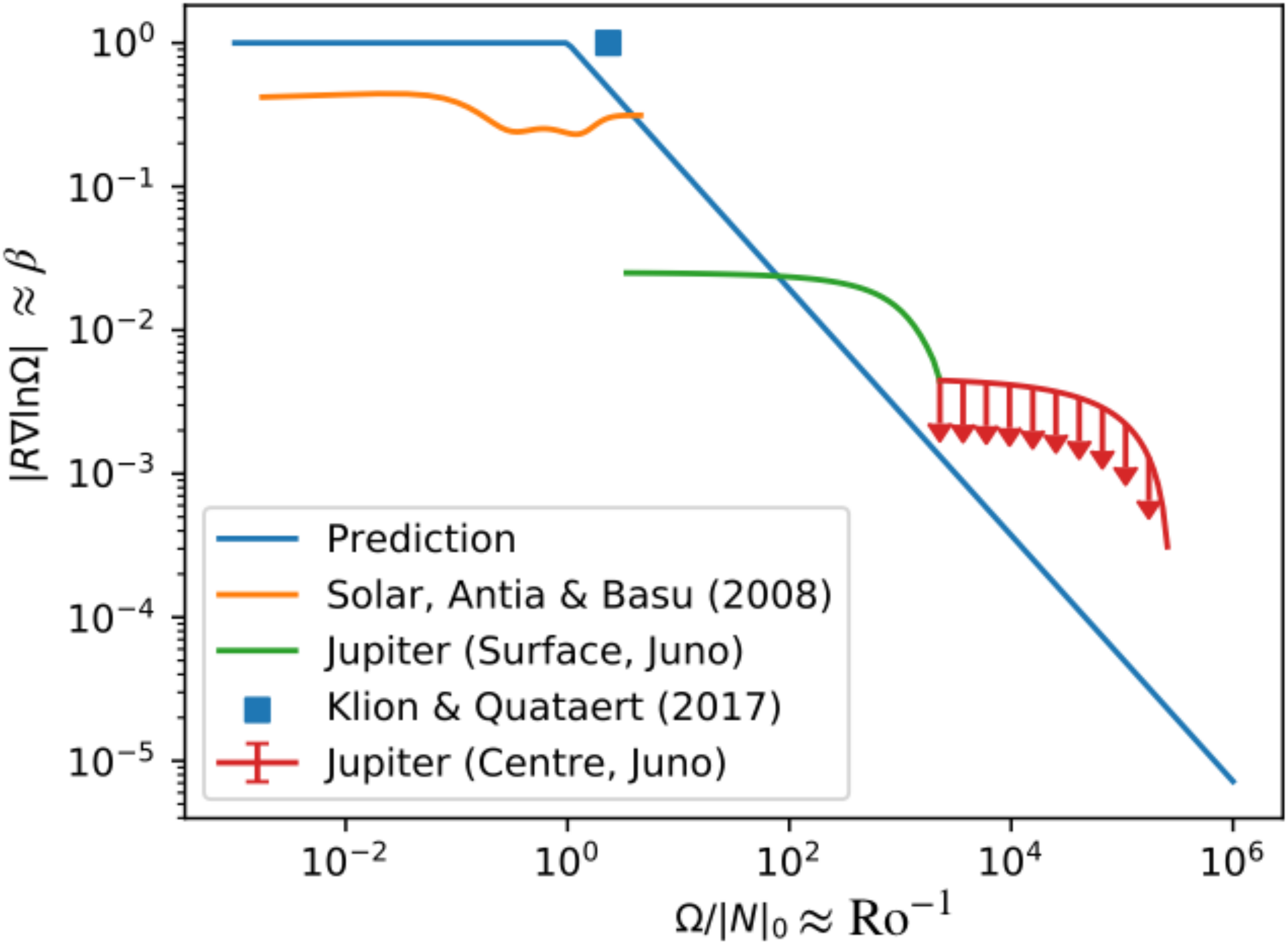


$\beta = 0.00^{+0.02}_{-0.02}$

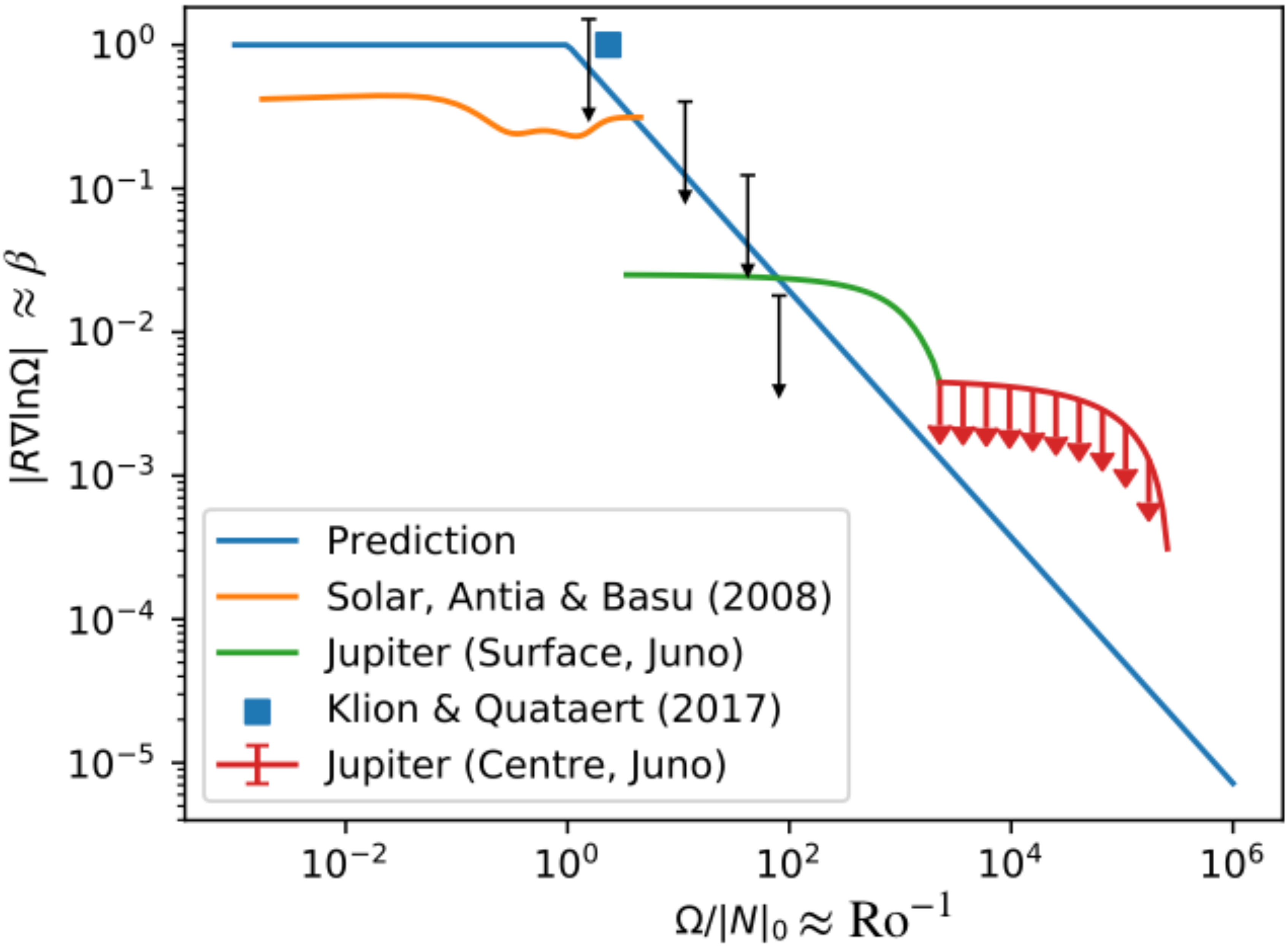


$$\delta \ln \Omega = \lambda \left(\frac{P_{\rm s}}{10{\rm d}} \right)^{\gamma}$$

$P_{orb,min}$	$P_{orb,max}$	β	$\beta_{1-\sigma}$	$\beta_{2-\sigma}$
		Radial Shear		
0	50	0.152	$^{0.251}_{-0.482}$	$^{0.337}_{-0.632}$
0	2	0.000	$^{0.010}_{-0.010}$	$^{0.019}_{-0.022}$
2	6	0.031	$^{0.091}_{-0.252}$	$^{0.139}_{-0.346}$
6	10	0.066	$^{0.373}_{-0.330}$	$^{0.677}_{-1.186}$
10	50	0.264	$^{1.329}_{-1.911}$	$^{2.267}_{-2.778}$

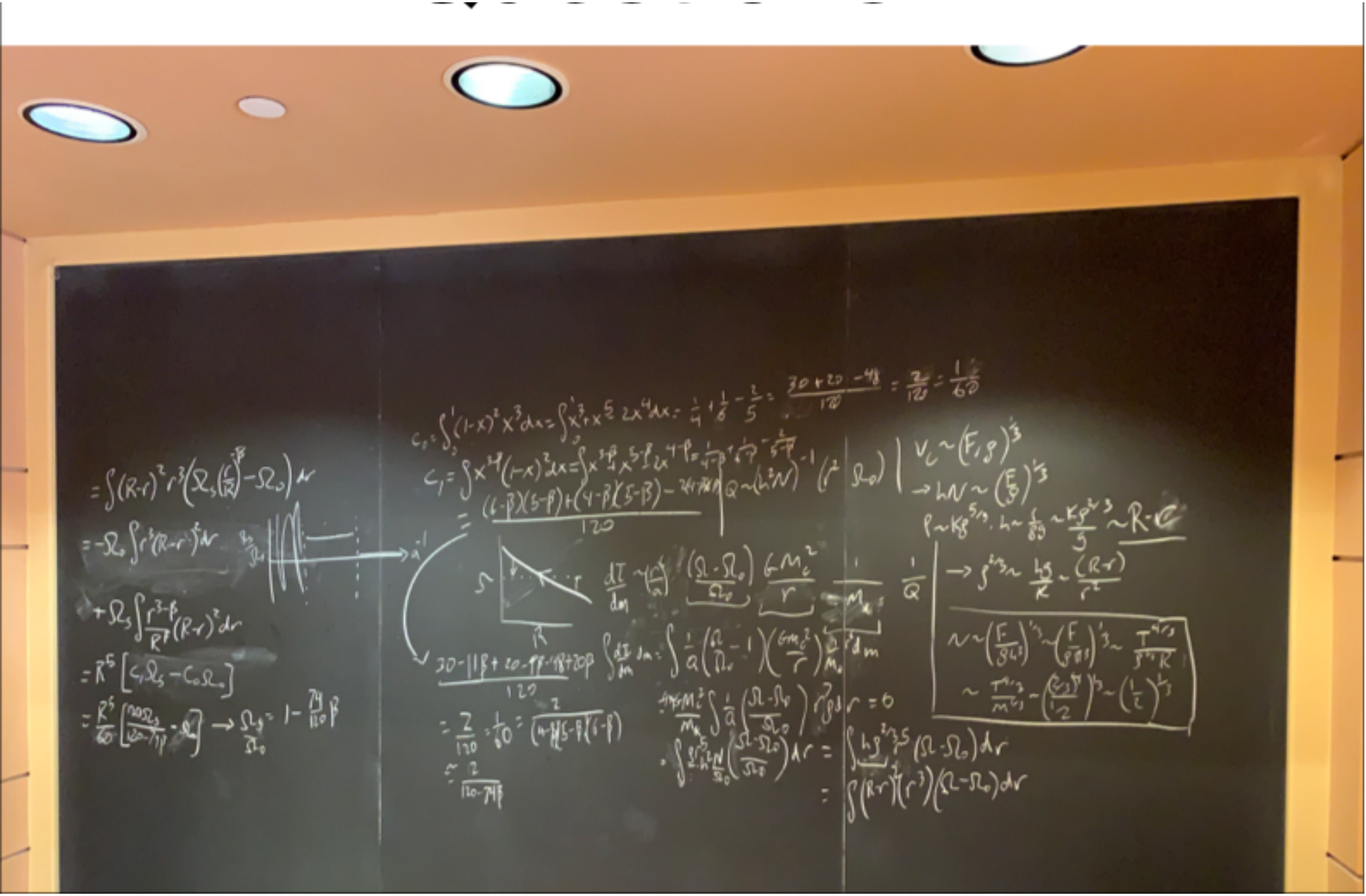


Jermyn+2020 arXiv:2008.09125



Jermyn+2020 arXiv:2008.09125

Questions?



$= R^5 \left[C_1 \Omega_s - C_0 \Omega_0 \right]$
$\sim \left(\frac{1}{2}\right)^{1/3}$
$= \frac{2}{120} = \frac{1}{60}$