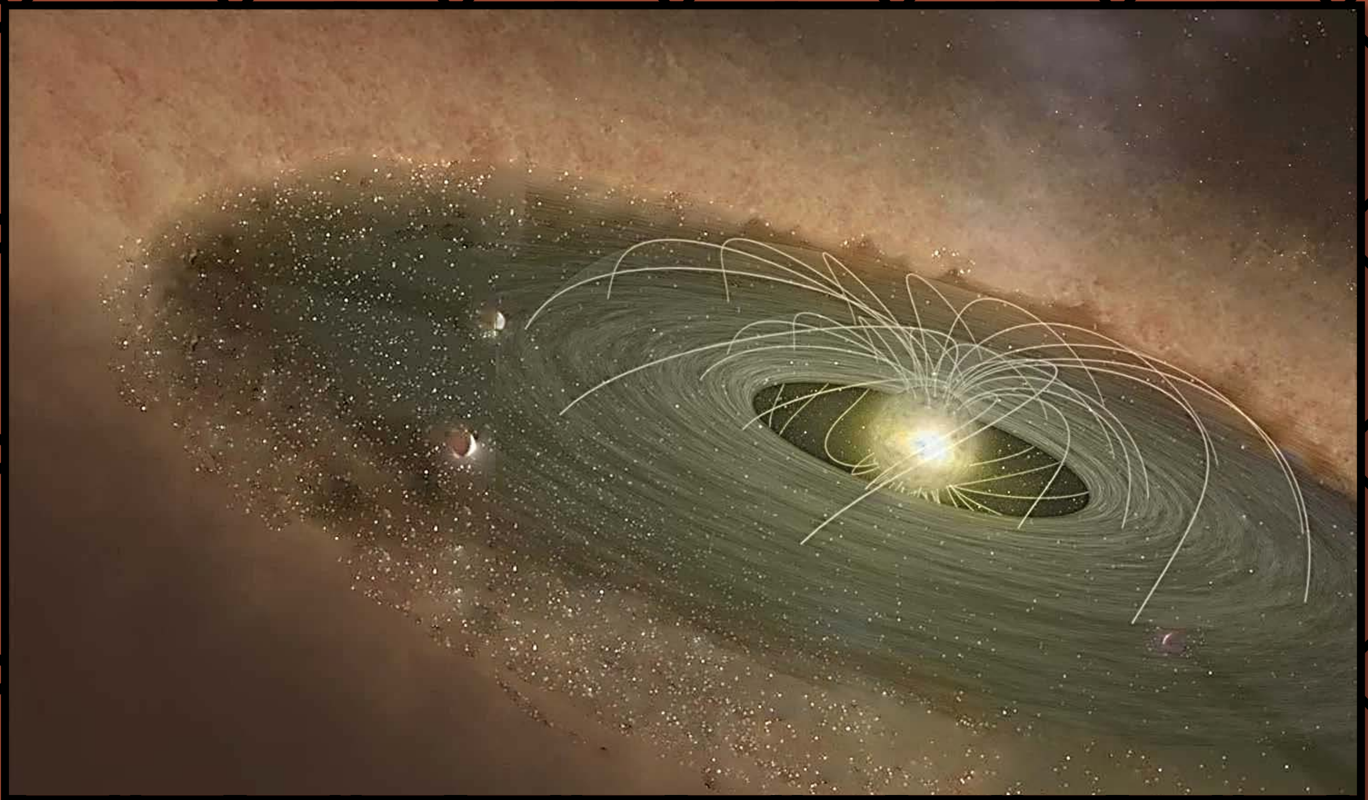
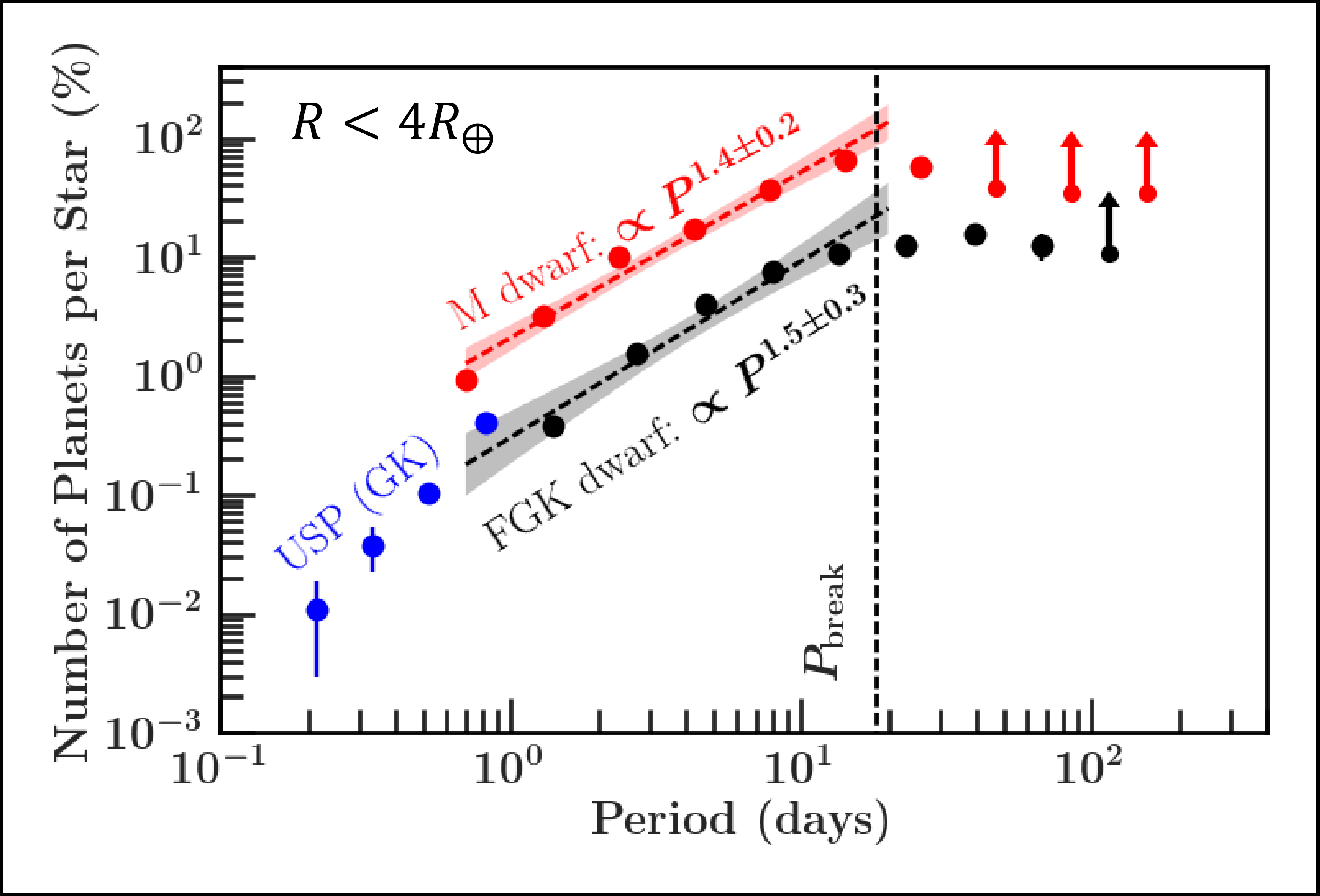


ULTRA-SHORT PERIOD PLANETS, MAGNETOSPHERIC TRUNCATION, AND TIDAL INSPIRAL

Eve J. Lee (Caltech-TAPIR)
Eugene Chiang (UC Berkeley)

OBSERVED OCCURRENCE RATE PROFILE

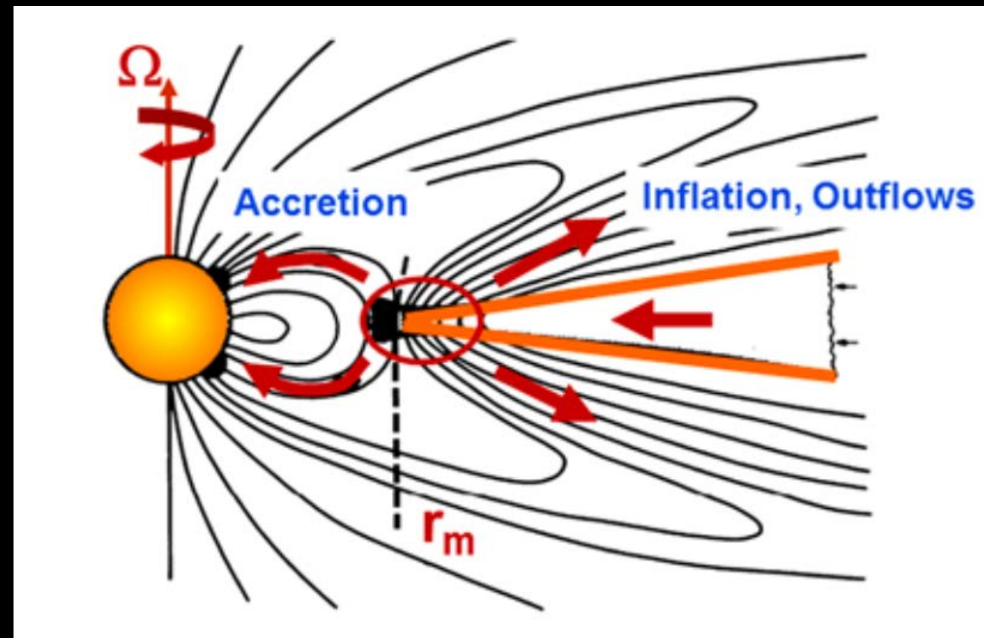


Fressin+2013, Sanchis-Ojeda+2014, Dressing & Charbonneau 2015

see also Petigura+2013, Mulders+2015

MAGNETOSPHERIC TRUNCATION

Romanova & Owocki 2016

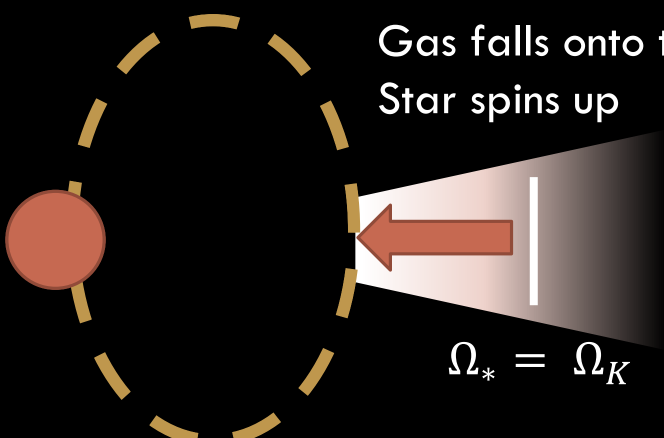


Truncation radius r_m:

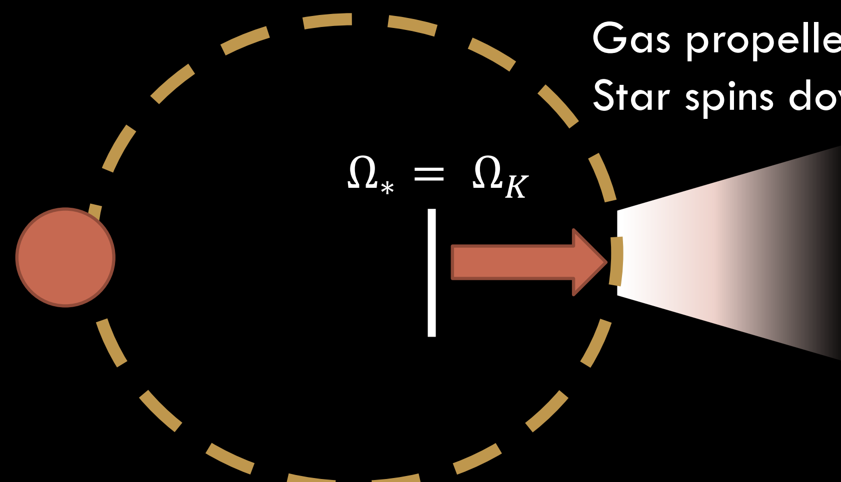
$$\frac{B^2}{8\pi} \sim \frac{\dot{M}\Omega}{r_m}$$

Stellar magnetic pressure

Disk accretion ram pressure

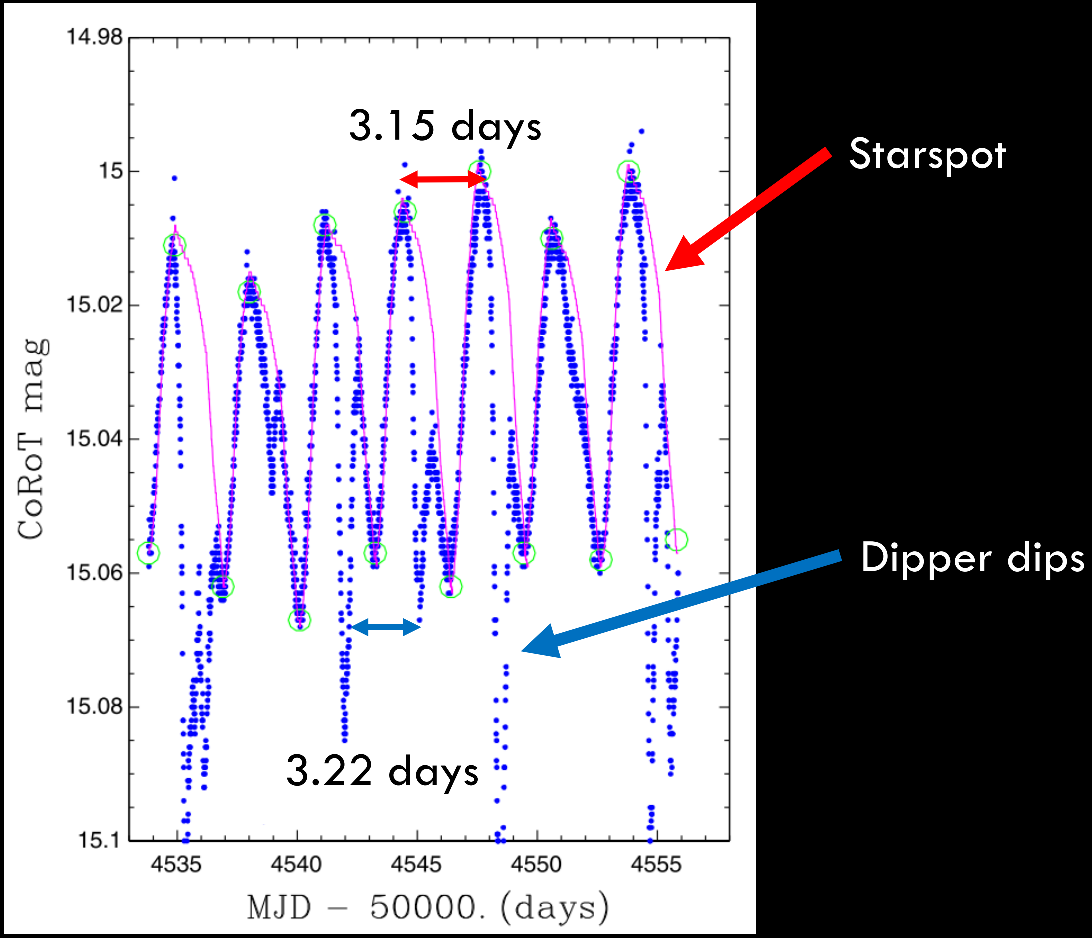


Gas falls onto the star,
Star spins up



Gas propelled away,
Star spins down

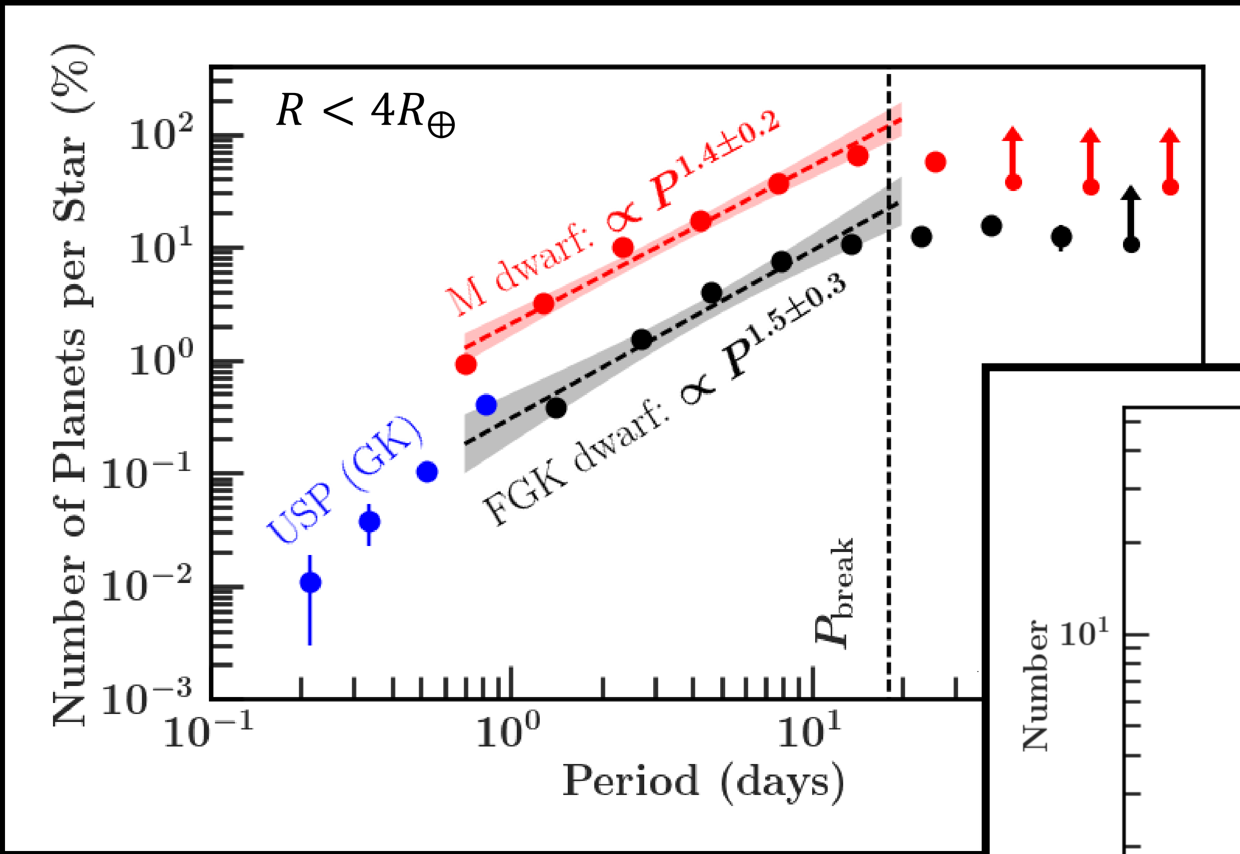
OBSERVATIONAL EVIDENCE OF TRUNCATION NEAR CO-ROTATION: DIPPERS



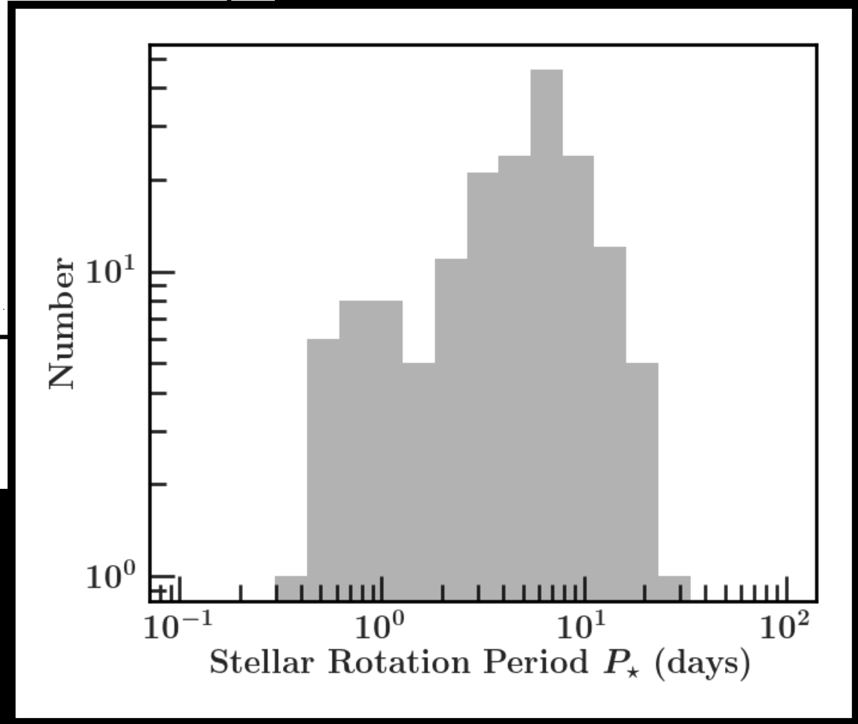
NGC 2264, Stauffer et al. (2015)
MON-21, CoRoT light curve

STELLAR ROTATION PERIOD DISTRIBUTION ALSO FALLS OFF AT SHORTER PERIODS

EJL & Chiang 2017
See also Mulders+ 2015

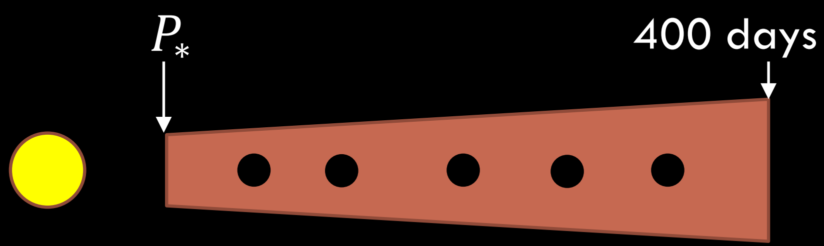


Fressin+2013, Sanchis-Ojeda+2014, Dressing & Charbonneau 2015



NGC 2362 (Irwin+2008)

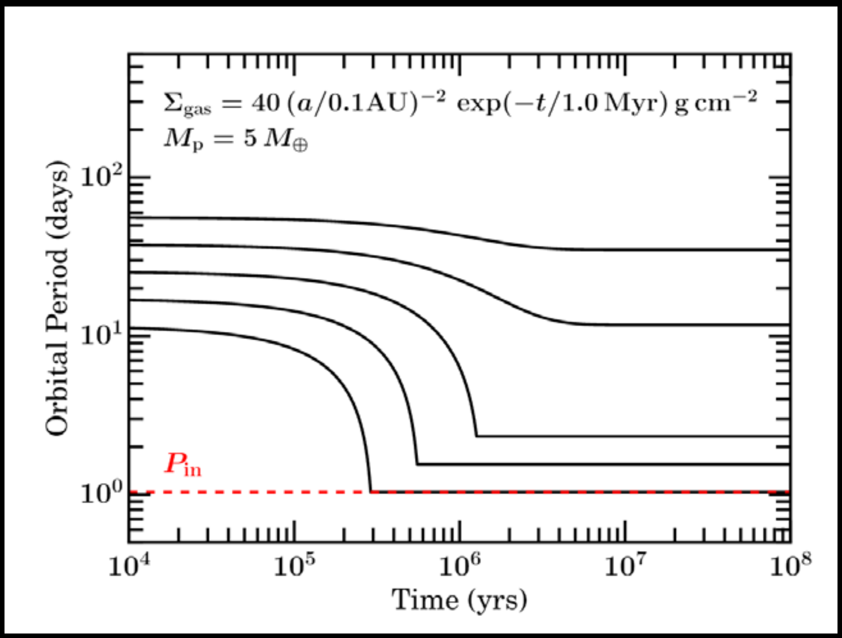
TWO CLASSES OF MODEL



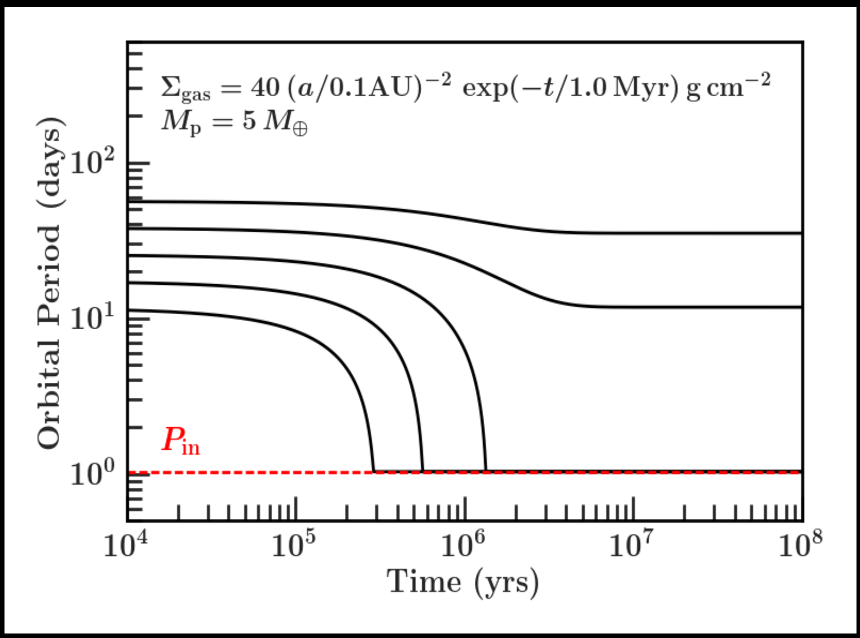
1. In-situ Randomly distributed in log period

2. Migration

a) Lock into resonance

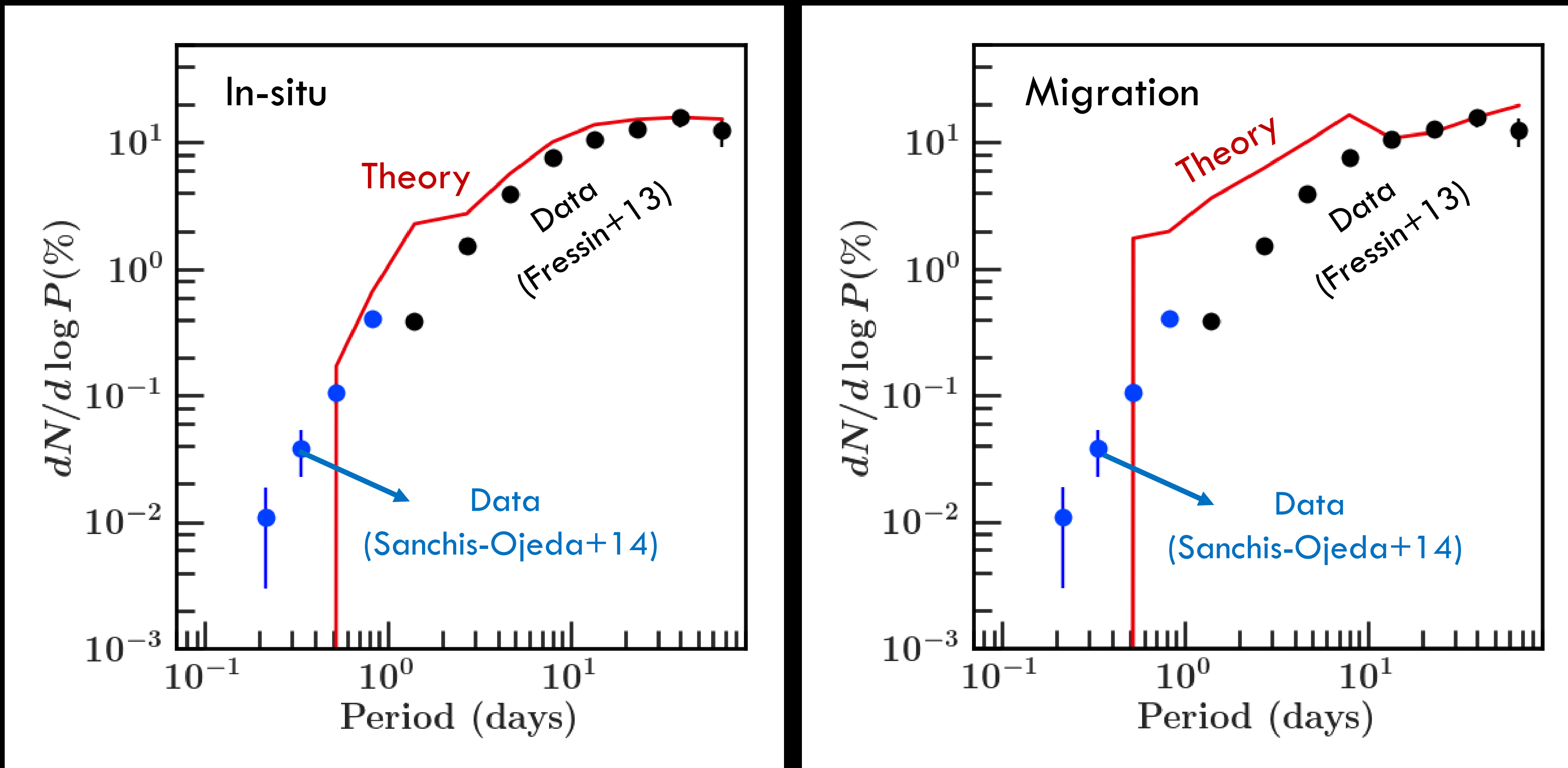


b) Merge at the disk edge



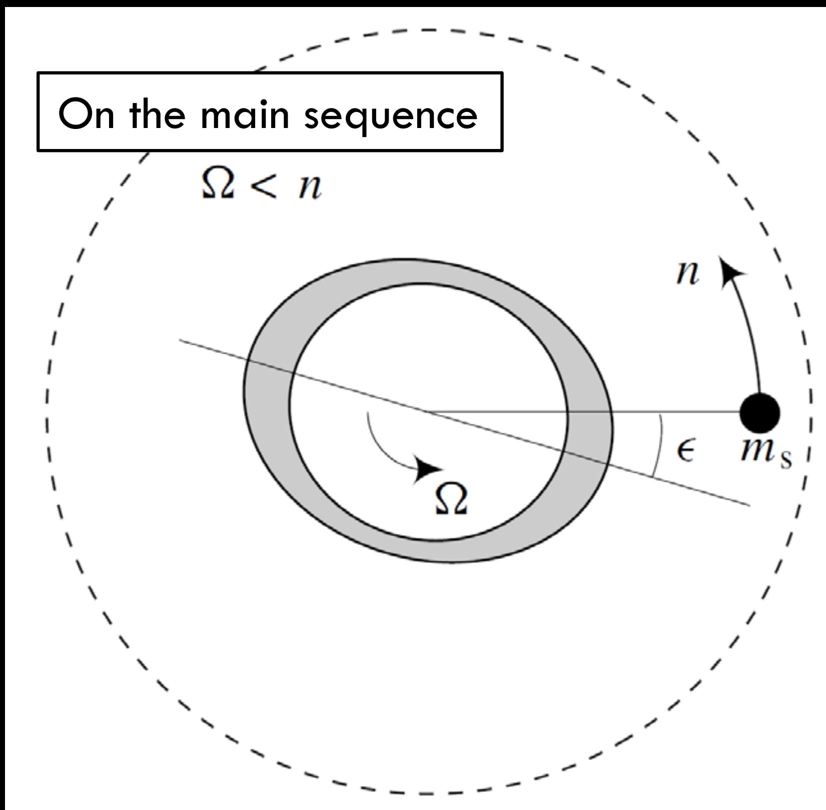
EJL & Chiang 2017

EJL & Chiang 2017



(merged at the edge;
resonance lock case looks similar)

ORBITAL DECAY BY ASYNCHRONOUS TIDES OVER GYRS



Murray & Dermott

Bulge lags behind because of “friction” in the star

For stellar spin and orbital motion to become synchronous:

$$L_{spin} < L_{orb}/3$$

For a typical $5M_\oplus$ planet orbiting a solar mass star:

$$L_{spin} \sim 100 L_{orb}$$

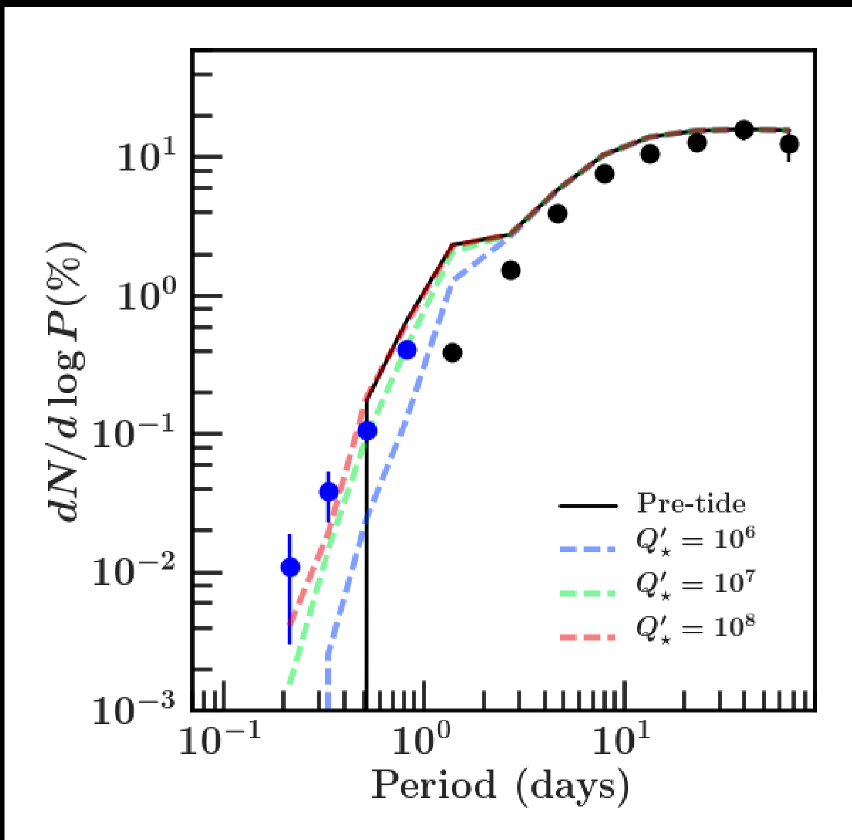
$$\dot{a} \propto -a^{-11/2} \frac{M_p}{M_*^{1/2}} \frac{R_*^5}{Q'_*}$$

Tidal quality factor: hiding all the physics of dissipation

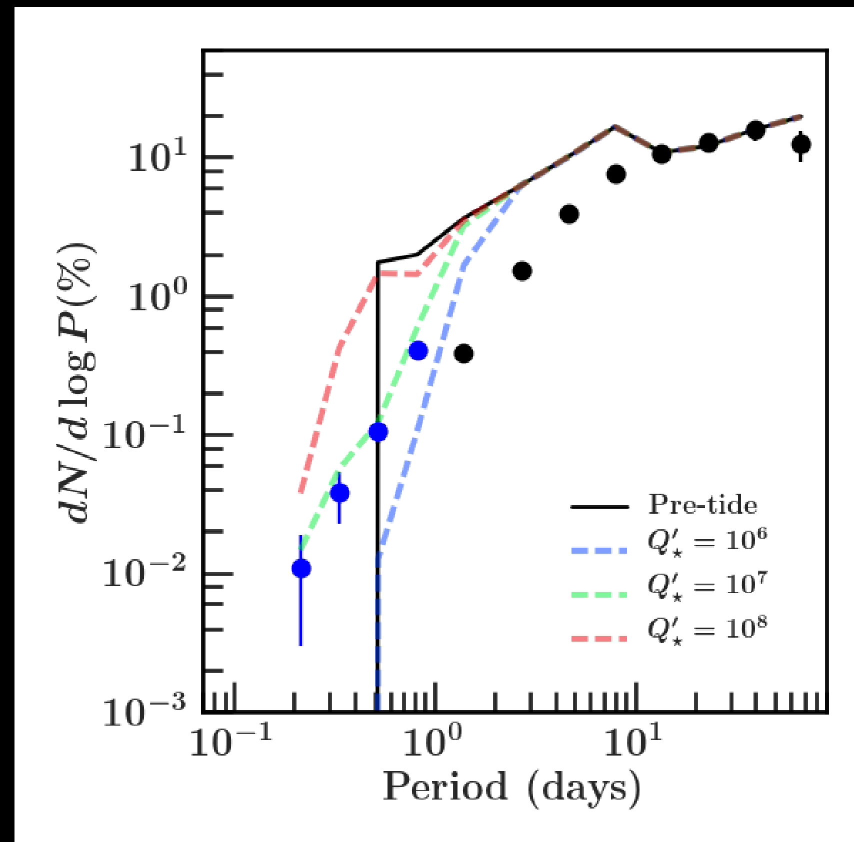
Q'_* is expected to range between 10^4 and 10^8 …but depends on frequency, stellar mass, age, and maybe metallicity

EJL & Chiang 2017

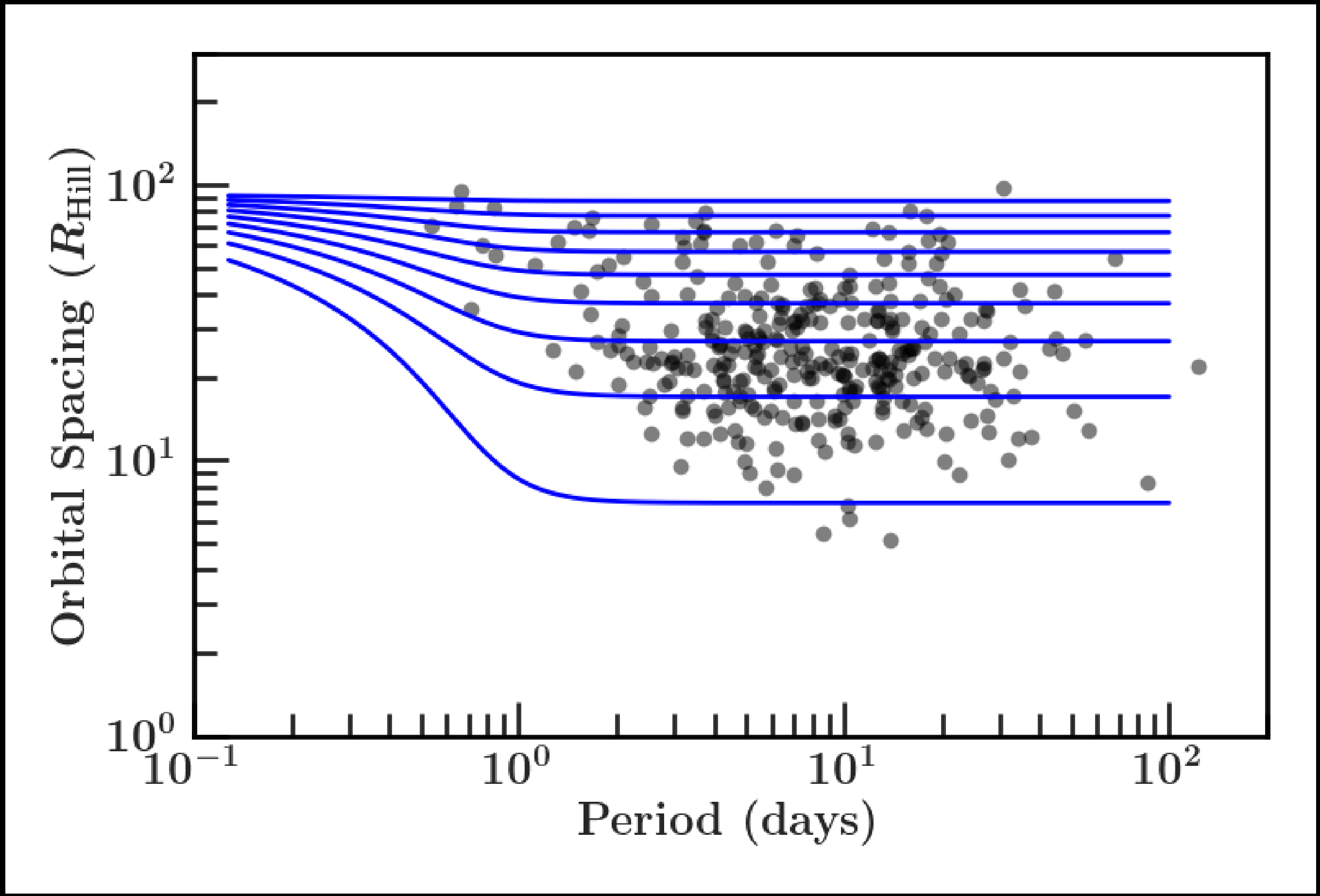
In-situ + tides



Migration + tides



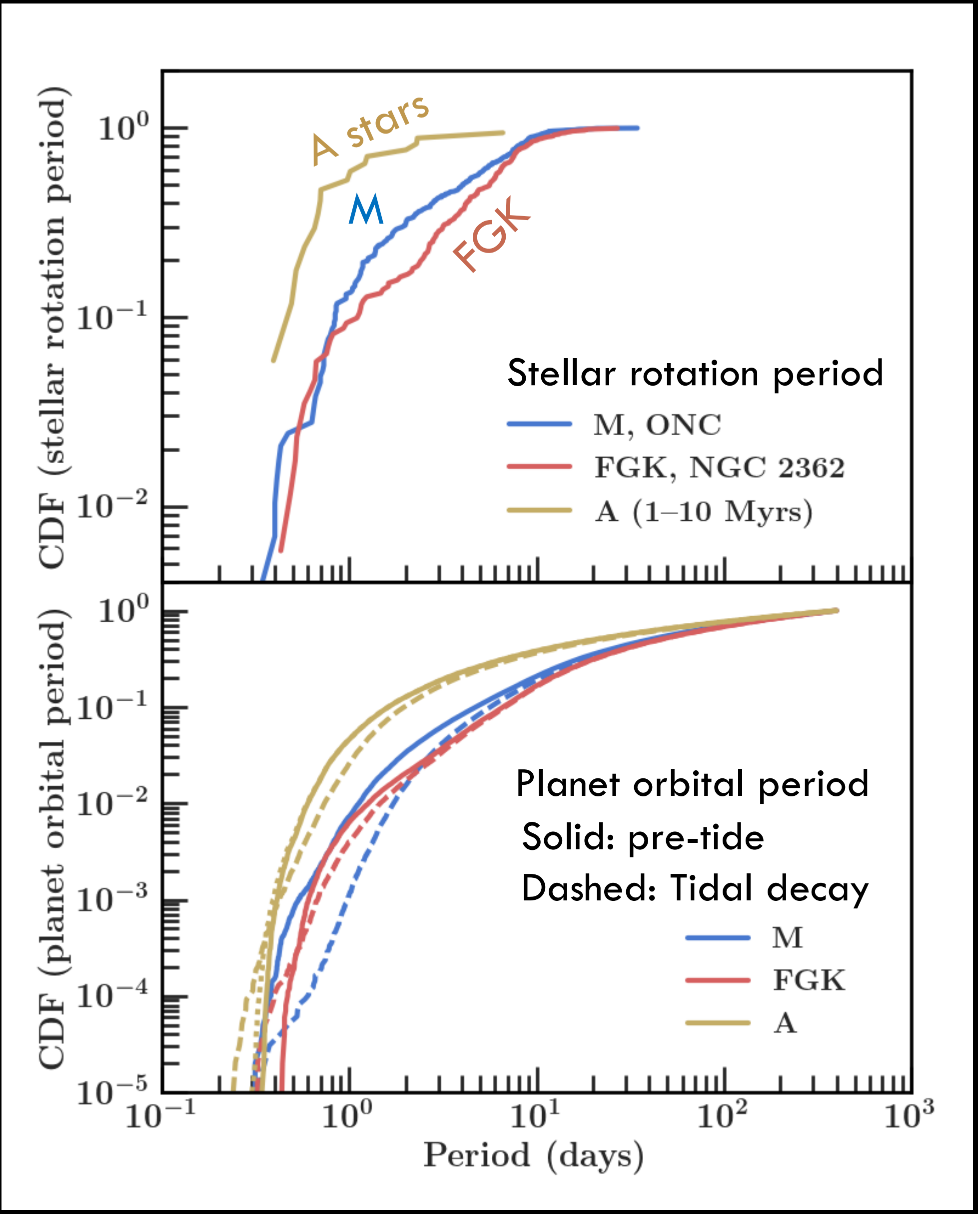
TIDAL DECAY COULD EXPLAIN WIDER SPACING AT SHORTER PERIODS



see also Steffen & Farr (2013) for period ratio vs. period

EJL & Chiang 2017

PREDICTION FOR PLANETS AROUND A STARS

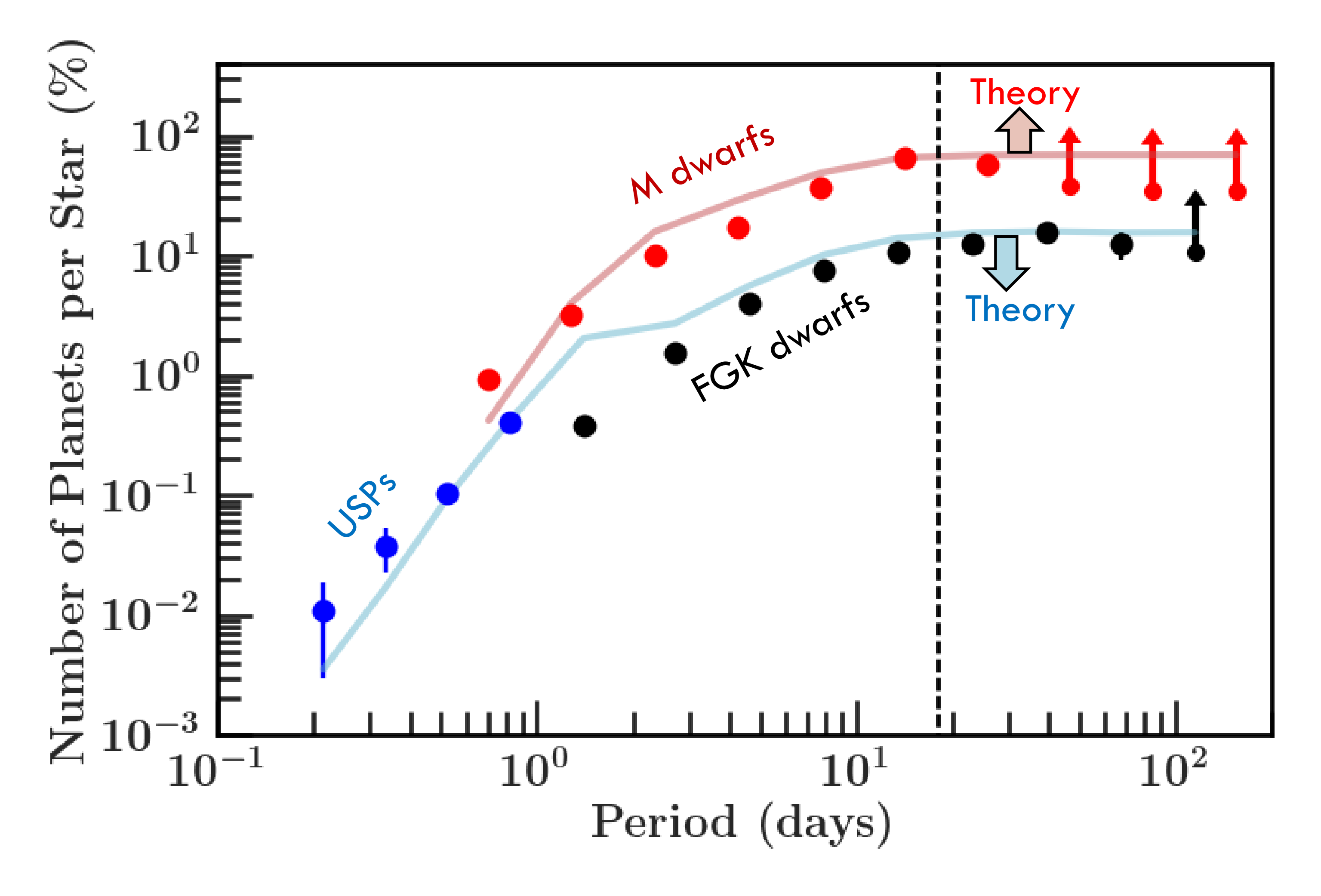


M, tides $Q_* = 10^5$

FGK, tides $Q_* = 10^7$

A, tides $Q_* = 10^7$

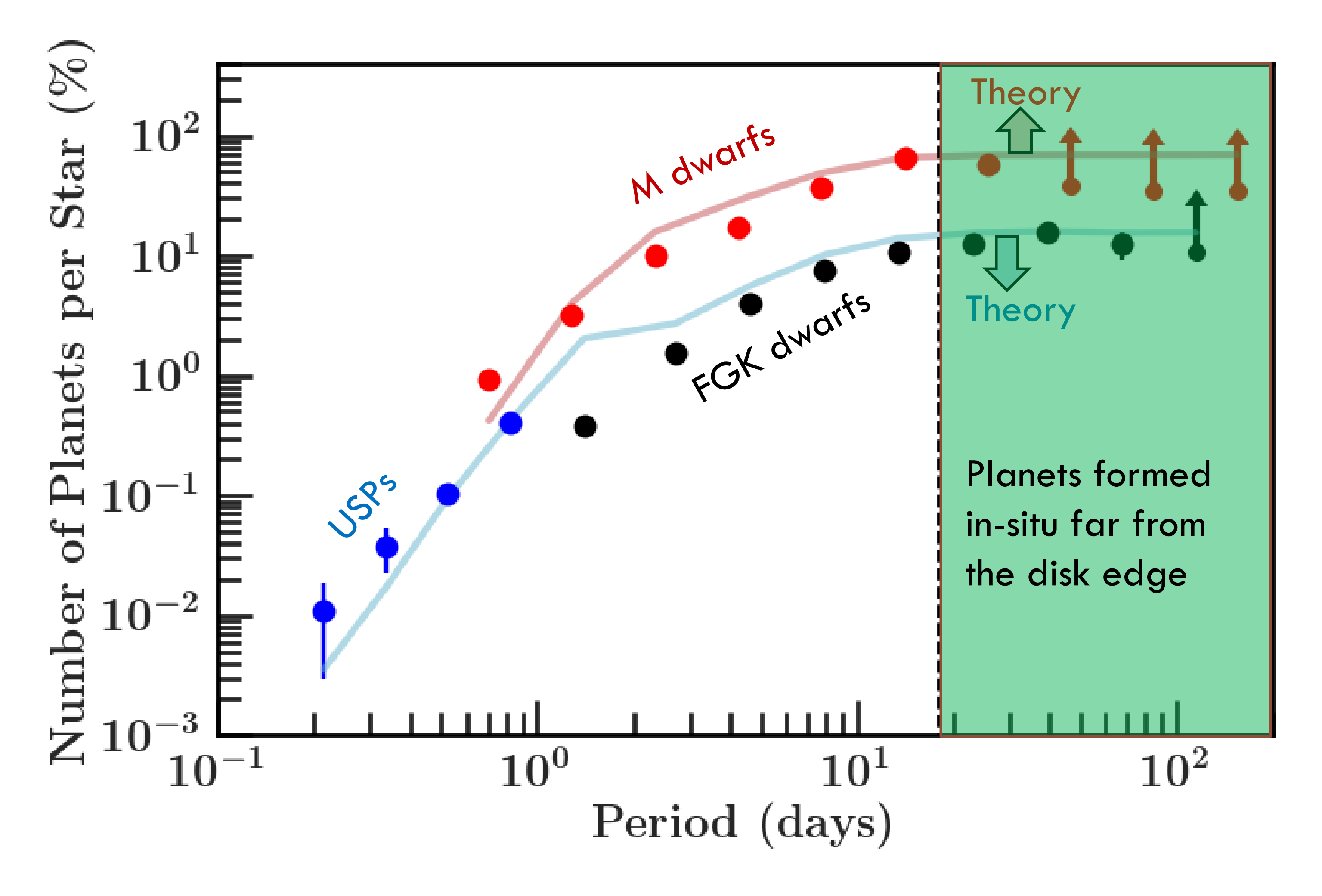
FGK: in-situ, $Q'_* = 10^7$, NGC 2362 (5 Myrs)
M: in-situ, $Q'_* = 10^5$, ONC (1 Myr)



Fressin+2013 (FGK), Sanchis-Ojeda+2014 (USPs),
Dressing & Charbonneau 2015 (M)

EJL & Chiang 2017

FGK: in-situ, $Q'_* = 10^7$, NGC 2362 (5 Myrs)
M: in-situ, $Q'_* = 10^5$, ONC (1 Myr)



Fressin+2013 (FGK), Sanchis-Ojeda+2014 (USPs),
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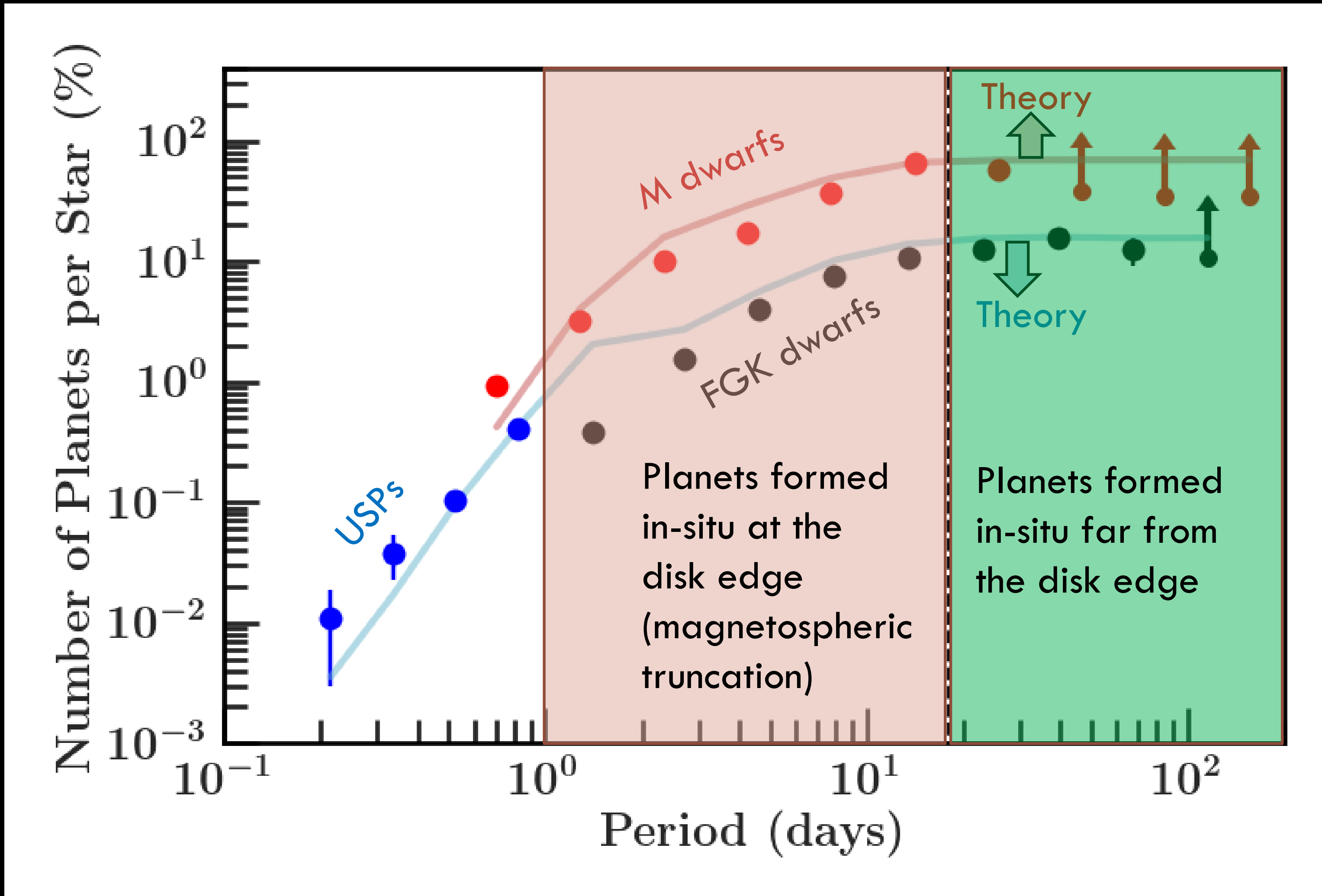

Fressin+2013 (FGK), Sanchis-Ojeda+2014 (USPs),
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EJL & Chiang 2017

FGK: in-situ, $Q'_* = 10^7$, NGC 2362 (5 Myrs)
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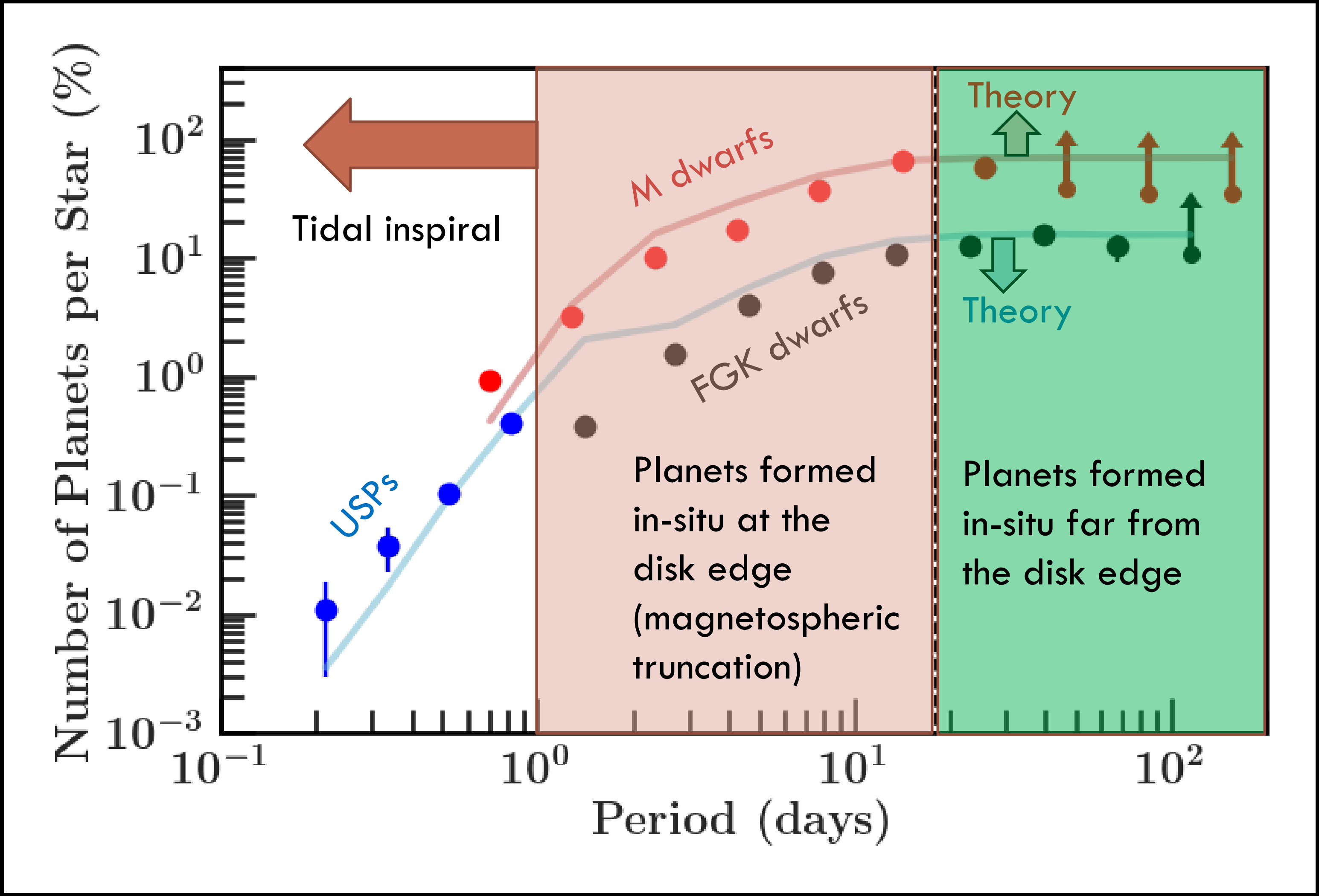
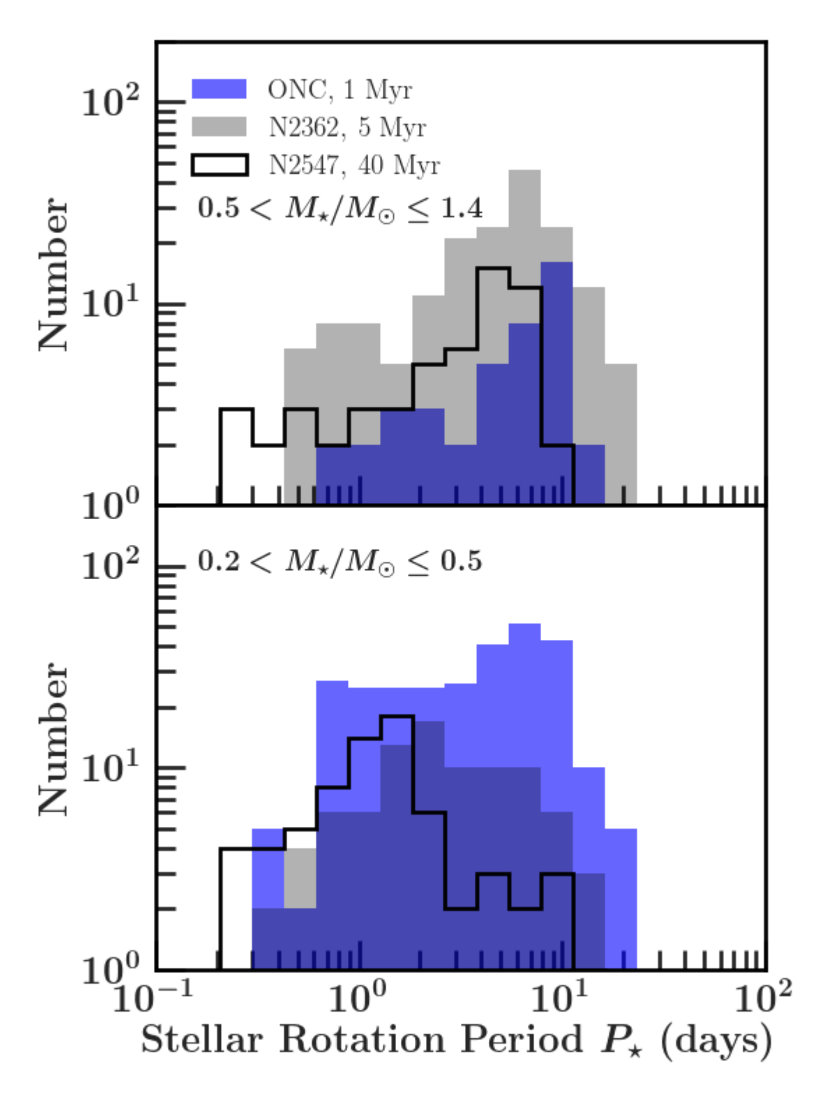


Fressin+2013 (FGK), Sanchis-Ojeda+2014 (USPs), Dressing & Charbonneau 2015 (M)



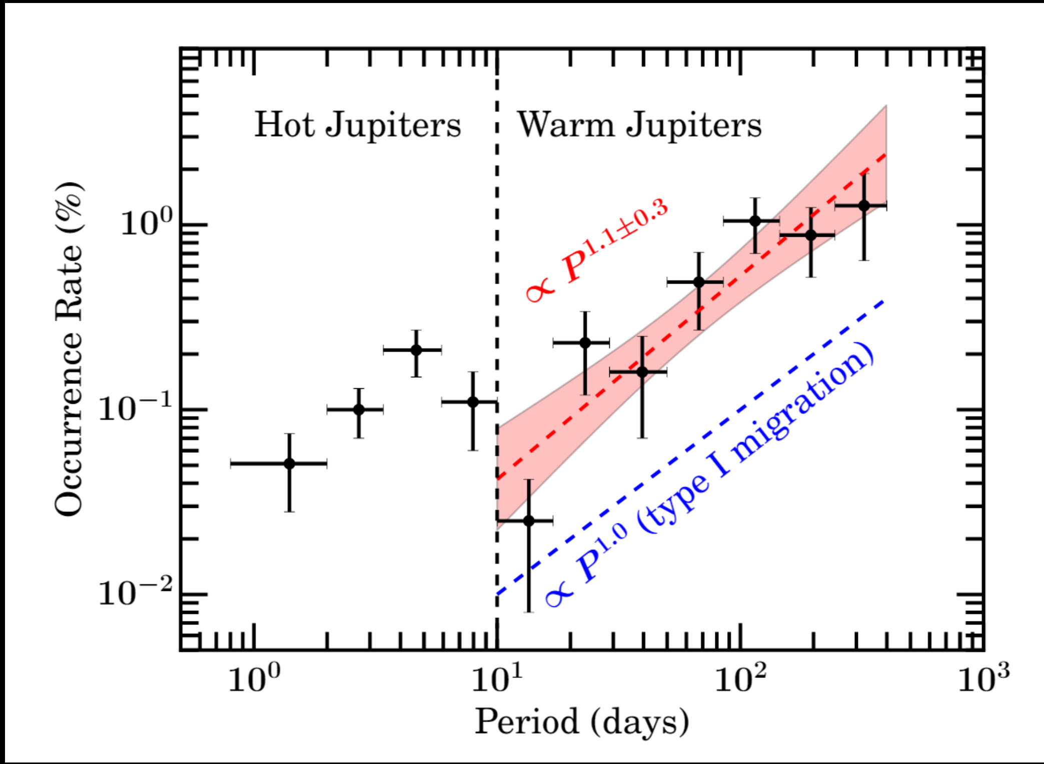
Herbst+2002, Rodriguez-Ledesma+2009, Irwin+2008ab

Pre-main sequence stellar spin & short-period planets

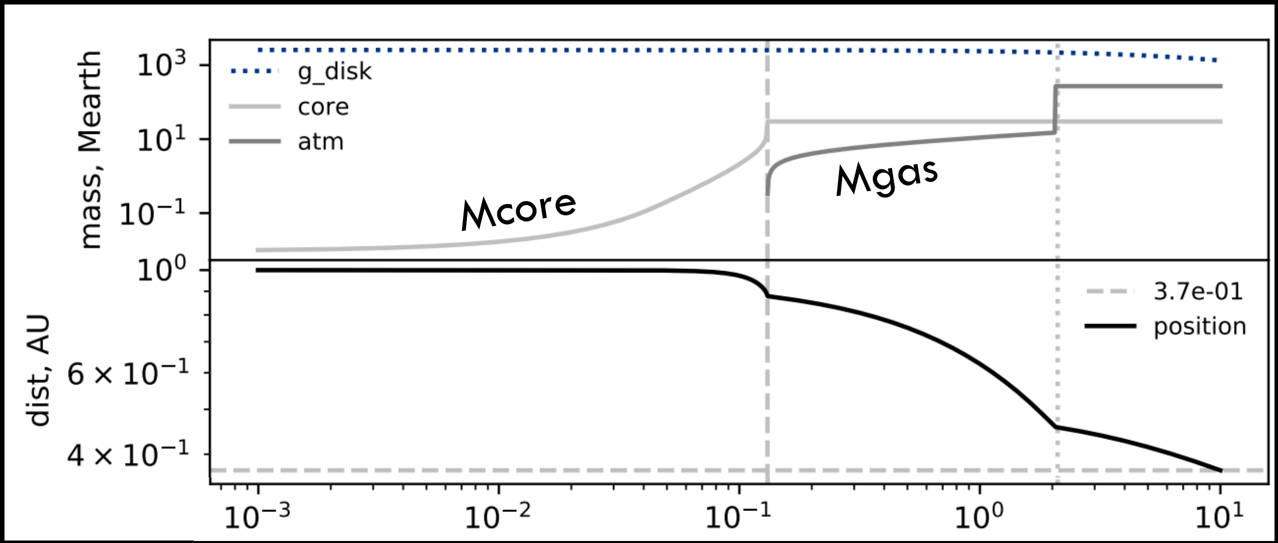
- Correlation with stellar metallicity?
- Effect of binaries?
- Initial spin period distribution?
- Cluster-to-cluster variations for a given age?

WARM JUPITER OCCURRENCE RATE

$$\frac{dN}{dlogP} \propto t_{mig}$$



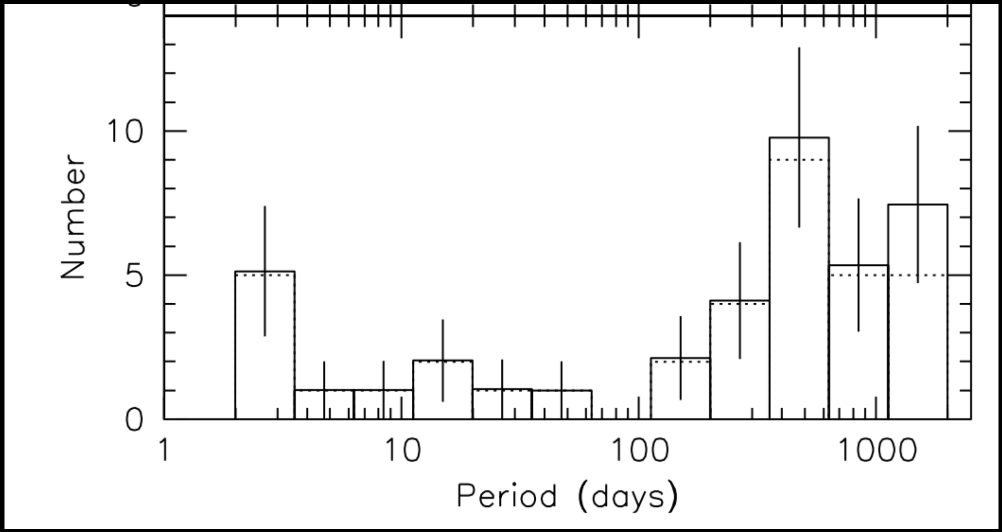
Data from Santerne+2012



On average, ~70% of distance travelled by Type I

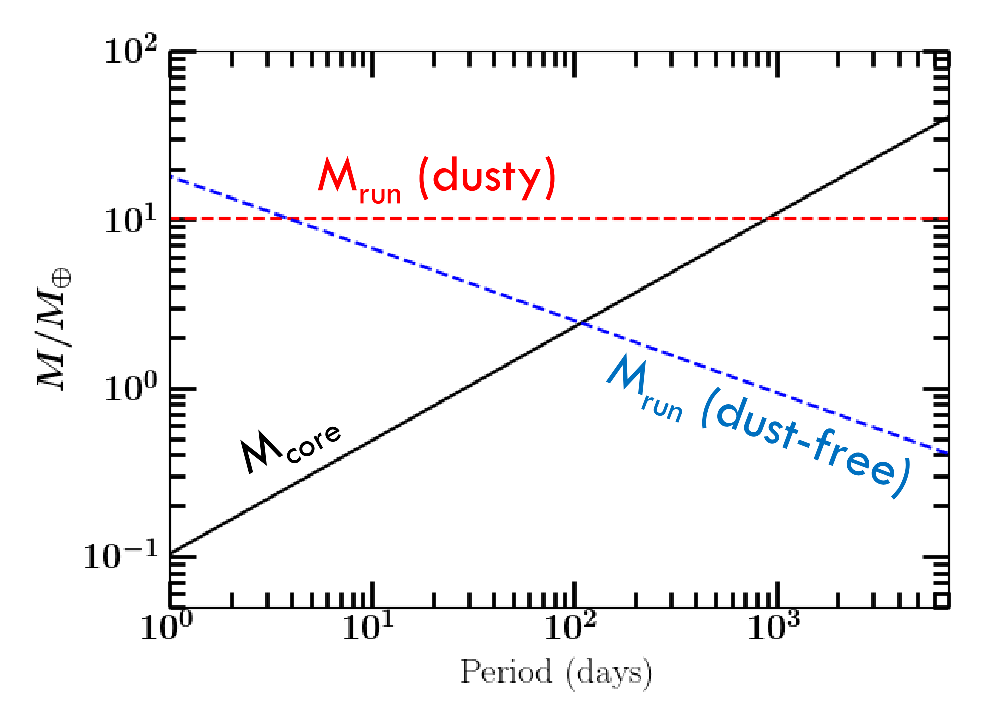
Jonathan Lin*, EJL & Chiang (in prep)

INNER SUPER-EARTHS, OUTER JUPITERS



Cumming et al. (2008)

- Core formation expects more massive cores at larger distances
- Gas accretion is more rapid farther away from the star (for dust-free accretion)



Run-away mass from Lee & Chiang (2015)
Stopping mass from Fung & Chiang (2017)

Fung & EJL (in prep)