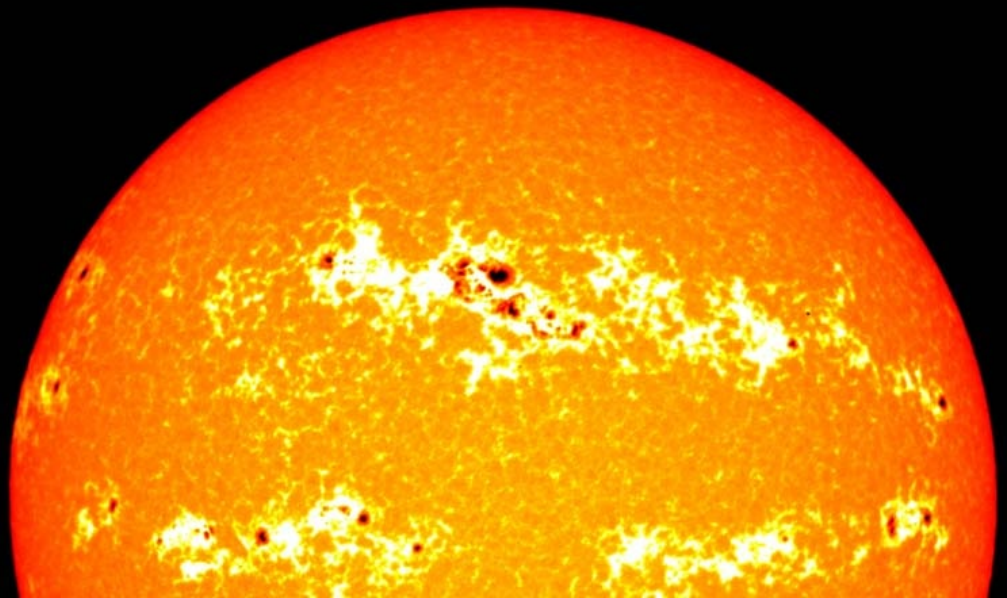
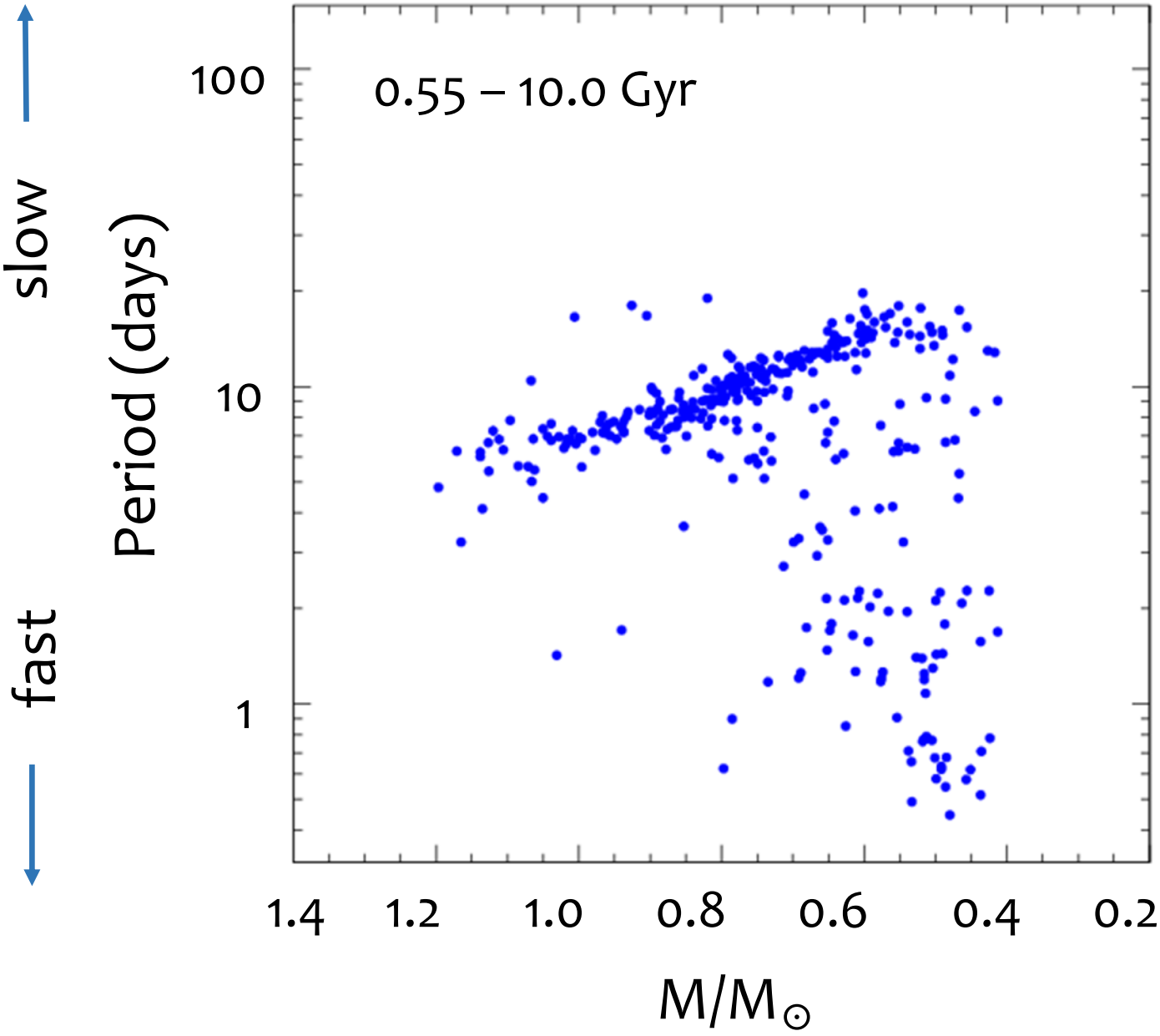
The Right Tool for the Job: Understanding the limits and potential of period-age relations

Jennifer van Saders
University of Hawai'i
Institute for Astronomy



Theoretical behavior in cool MS dwarfs



$$\frac{dJ}{dt} \propto \omega^3$$

Animation courtesy of Courtney Epstein (Epstein et al. 2014)

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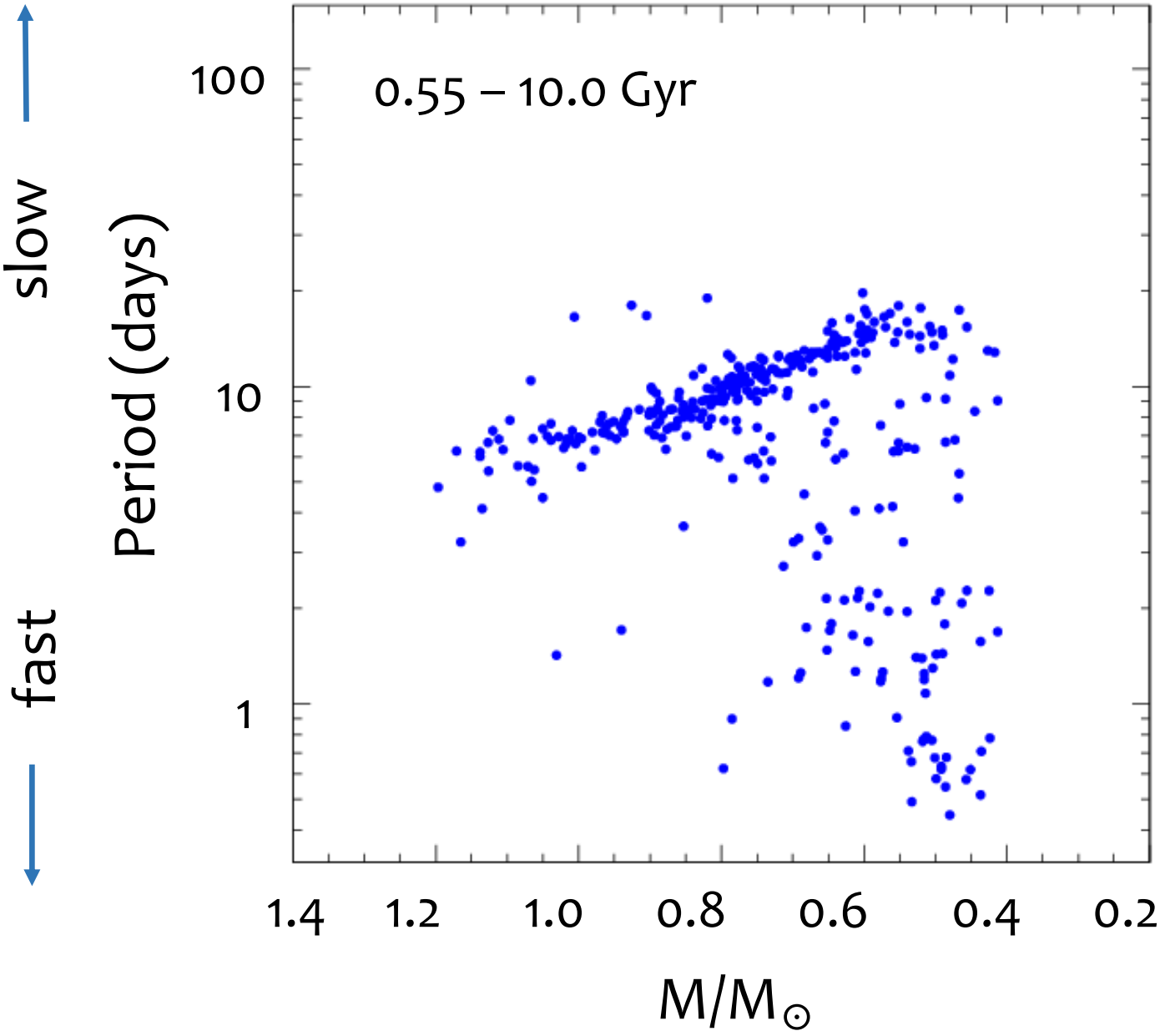

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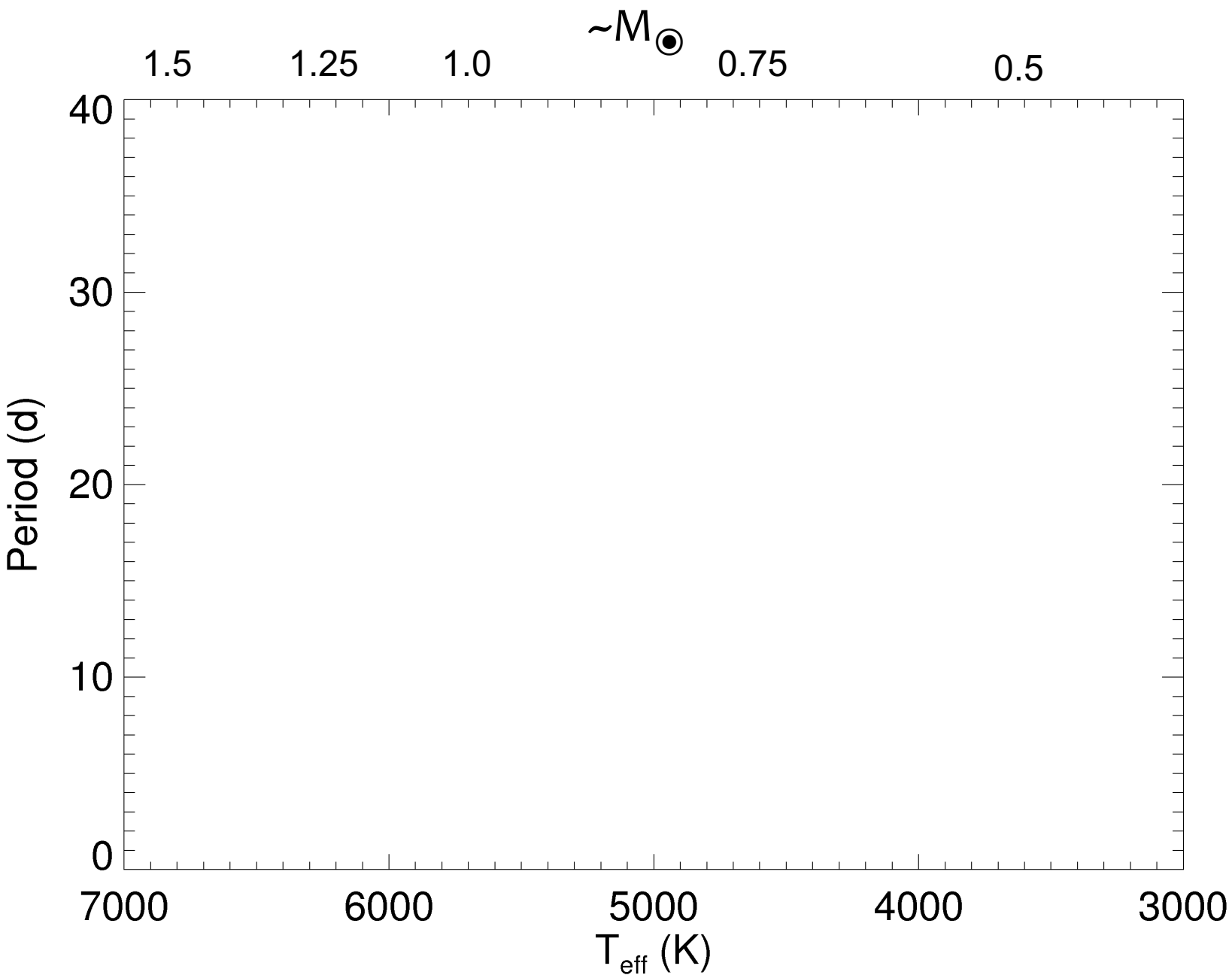
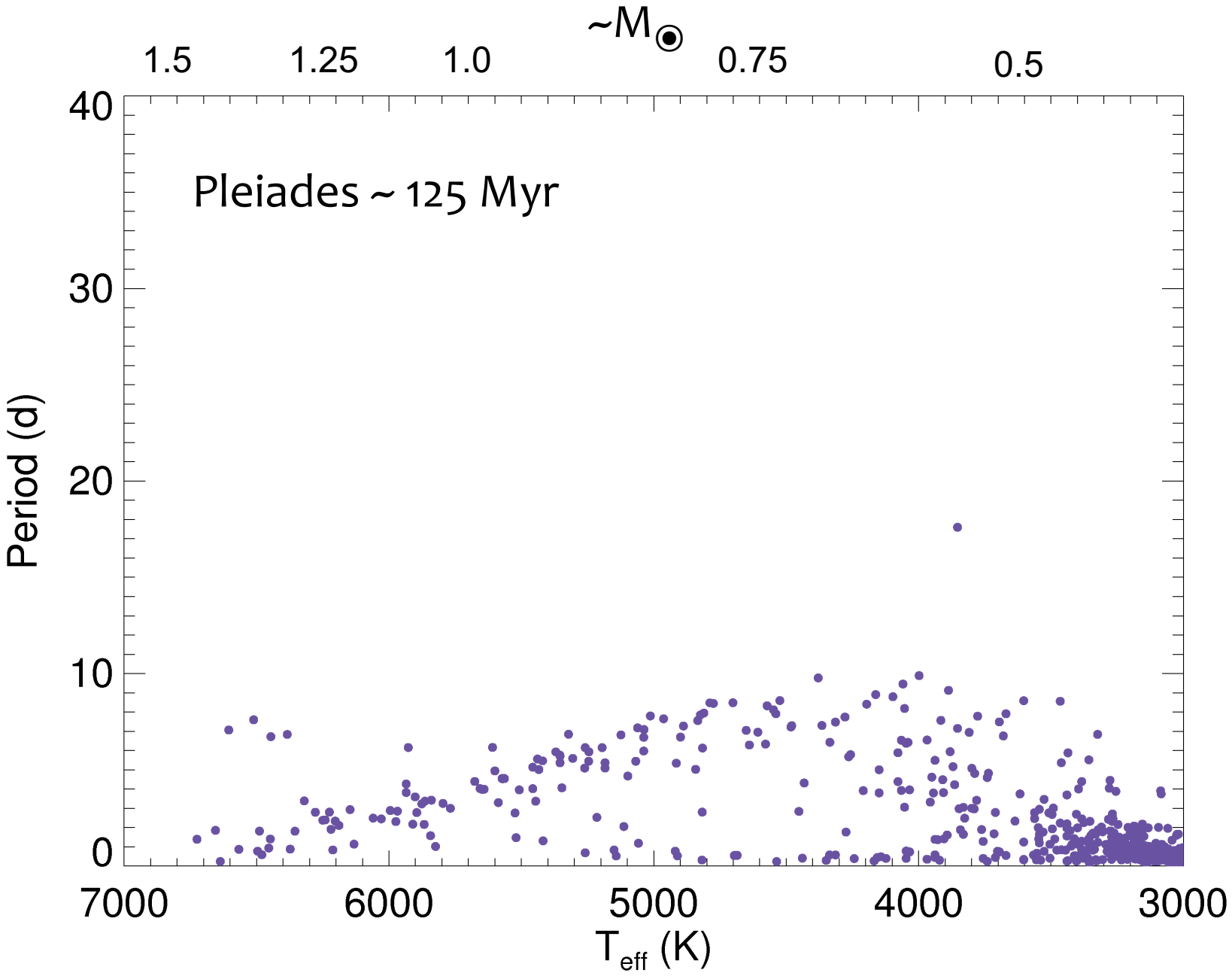
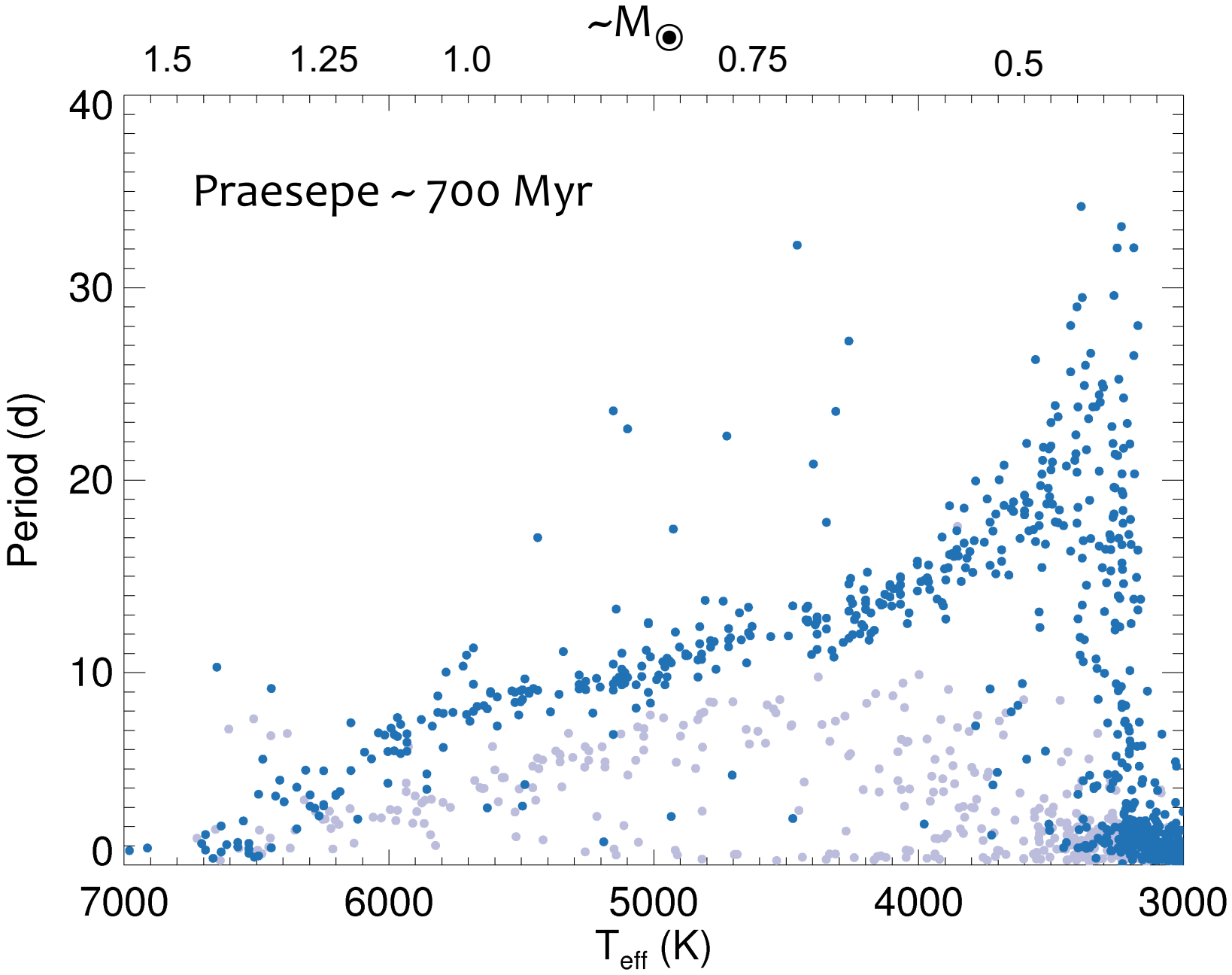
Animation courtesy of Courtney Epstein (Epstein et al. 2014)

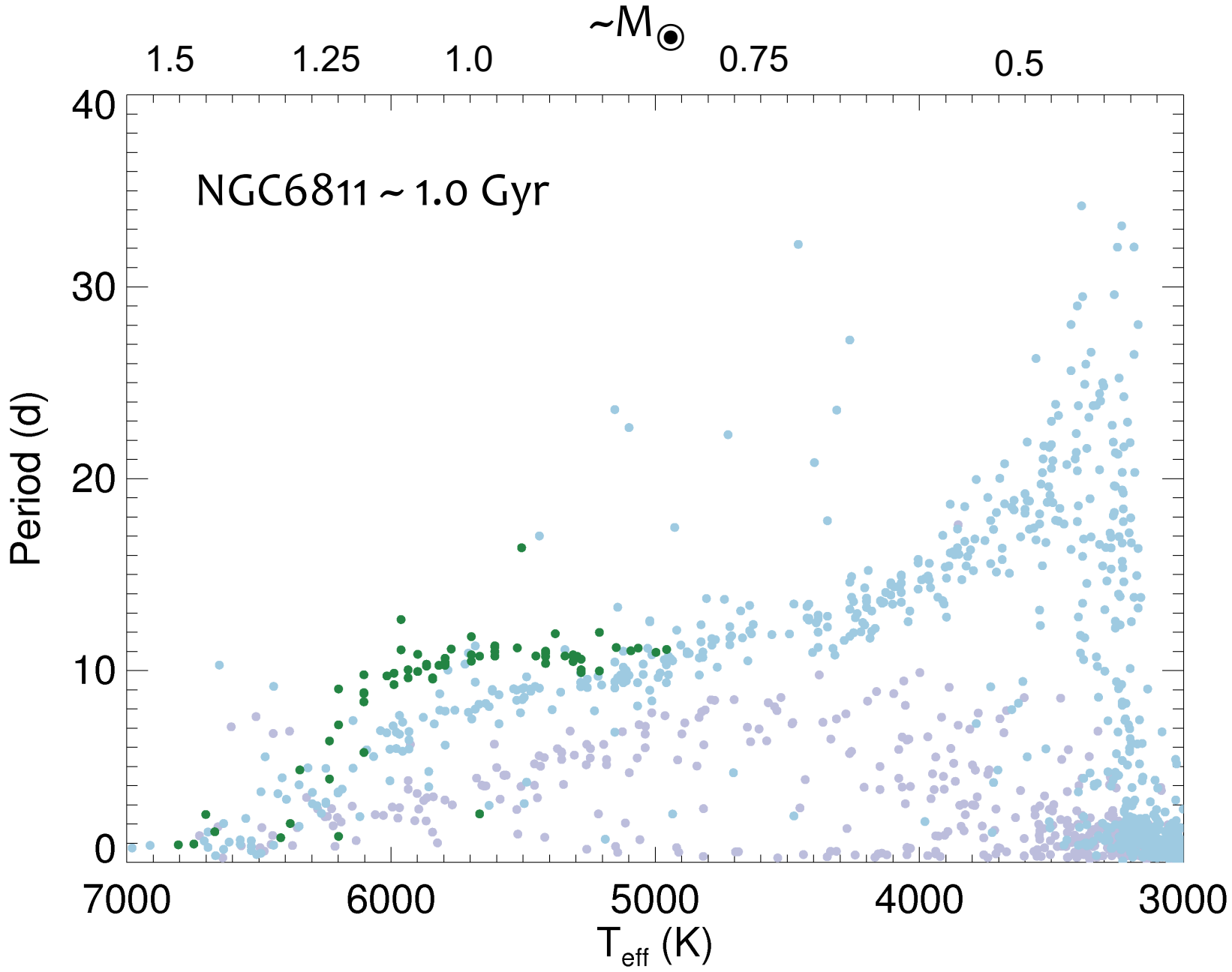

~M⊙
1.5
1.25
1.0
0.75
0.5
40
30
20
10
0
Period (d)
7000
6000
5000
4000
3000
T_eff (K)



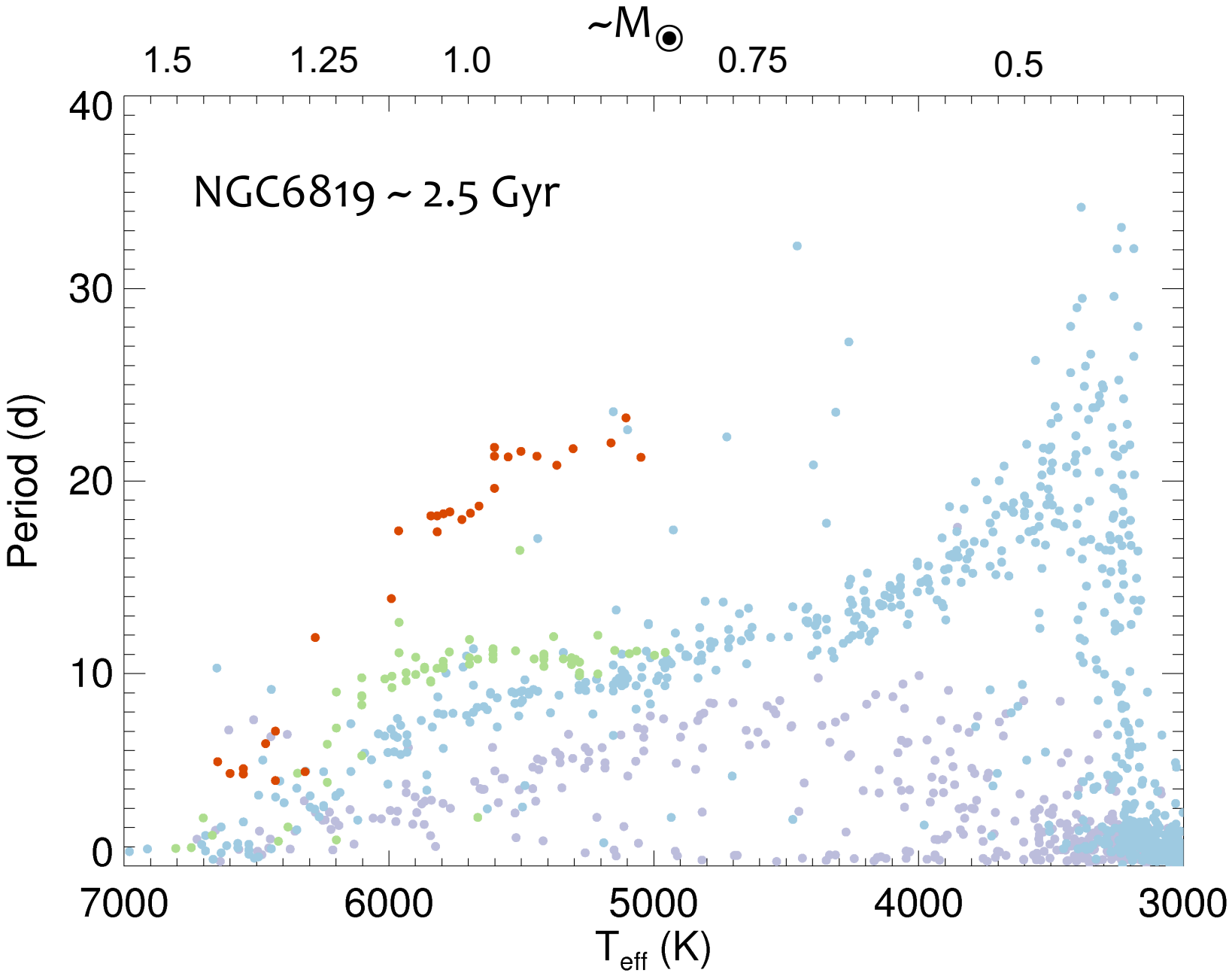
Rebull et al. 2016



Rebull et al. 2017 (see also Douglas et al. 2017 and the K2 Hyades, Douglas et al. 2016)



Meibom et al. 2011



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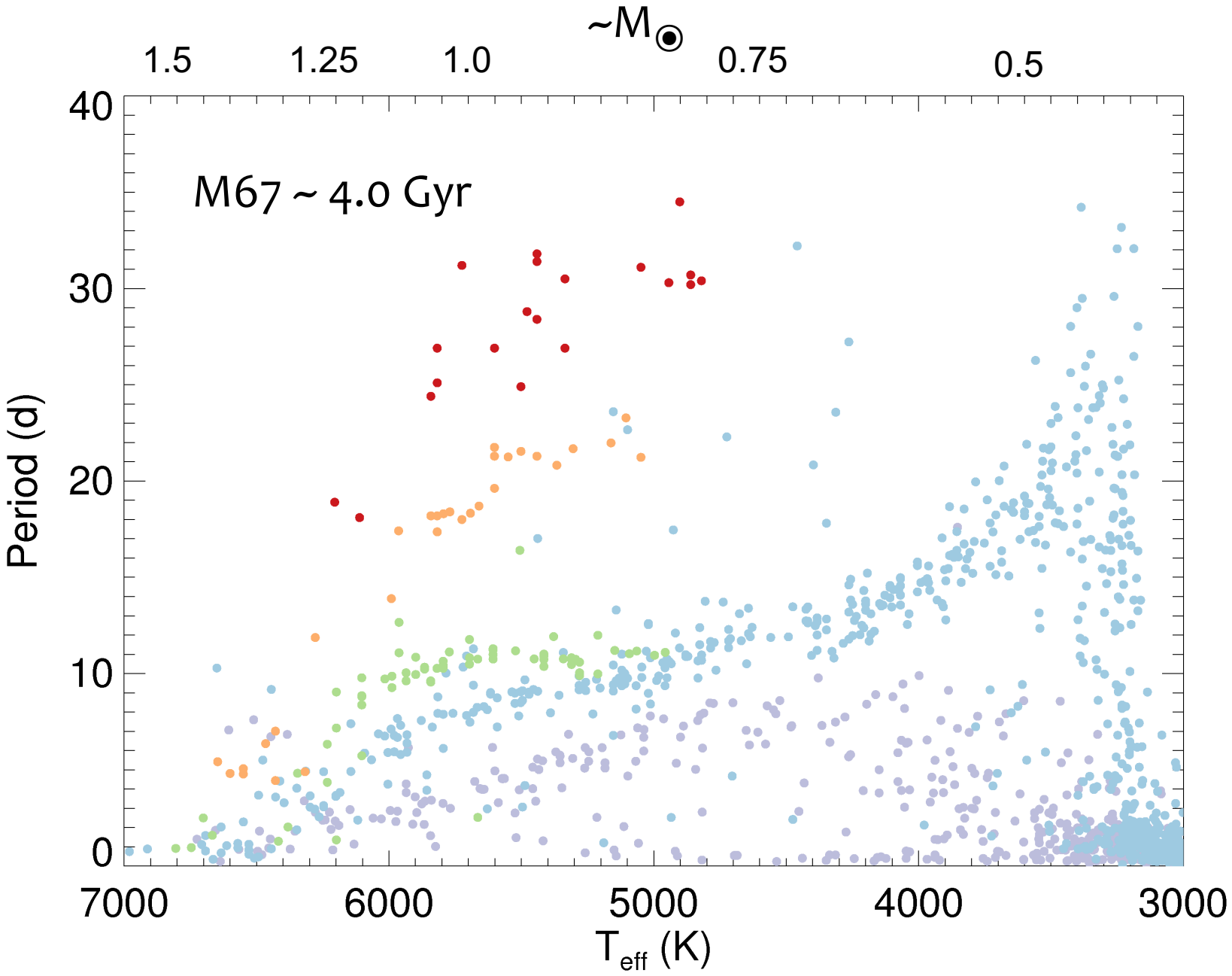
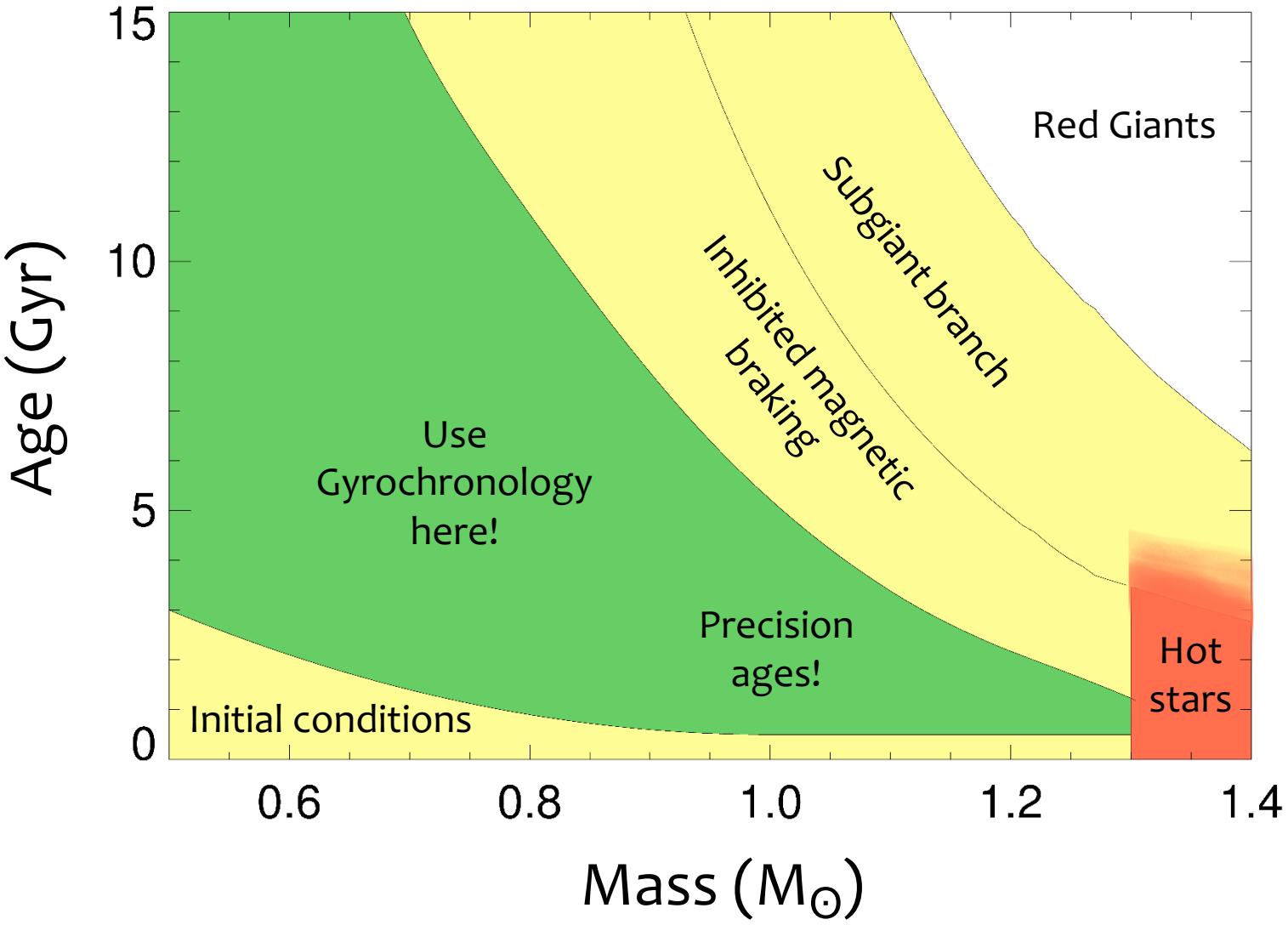


Barnes et al. 2016, but see also Esselstein et al. 2018

Gyrochronology Cheatsheet



Building a functional tool

Empirical

$$P = t^n \times \quad a(B - V - c)^b$$

Age
Skumanich:
n = 1/2

Mass dependence (B-V color)
a,b,c constants

Barnes 2007
Mamajek & Hillenbrand 2008
Barnes 2010 (Rossby relation)
Schlaufman 2010
Meibom et al. 2009
Angus et al. 2015
Angus et al. 2019 (submitted)
Douglas et al. 2019 (submitted)

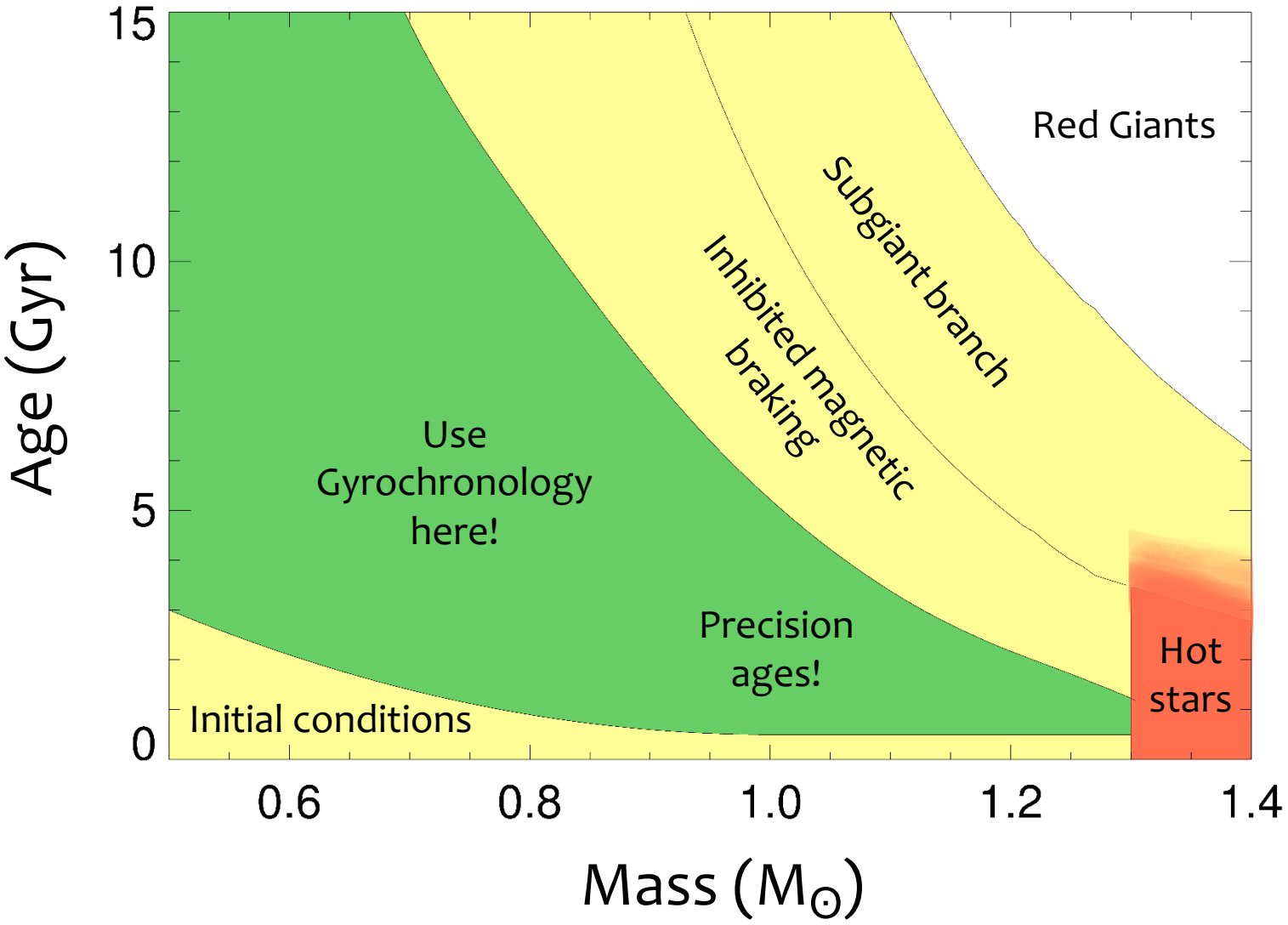
Semi-empirical

$$\frac{dJ}{dt} = f(\omega, M, R, \tau, \dot{M} \ \ldots)$$

Kawaler 1988
Matt & Pudritz 2009
Reiners & Mohanty 2012
van Saders & Pinsonneault 2013
Epstein & Pinsonneault 2014
Brown 2014
Matt et al. 2015
Gallet & Bouvier 2015
van Saders et al. (2016)

Challenges

The calibrator situation is still dire



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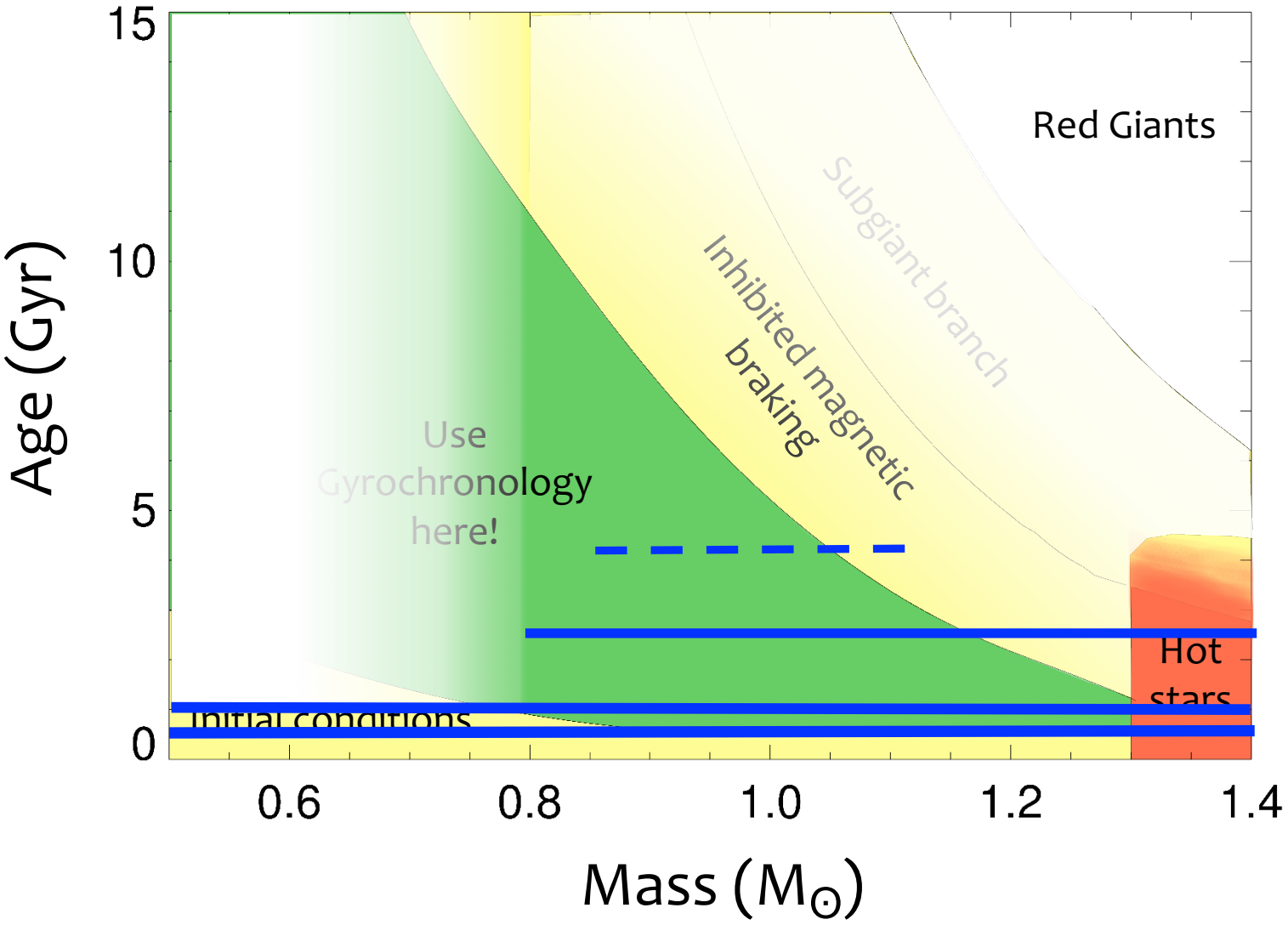
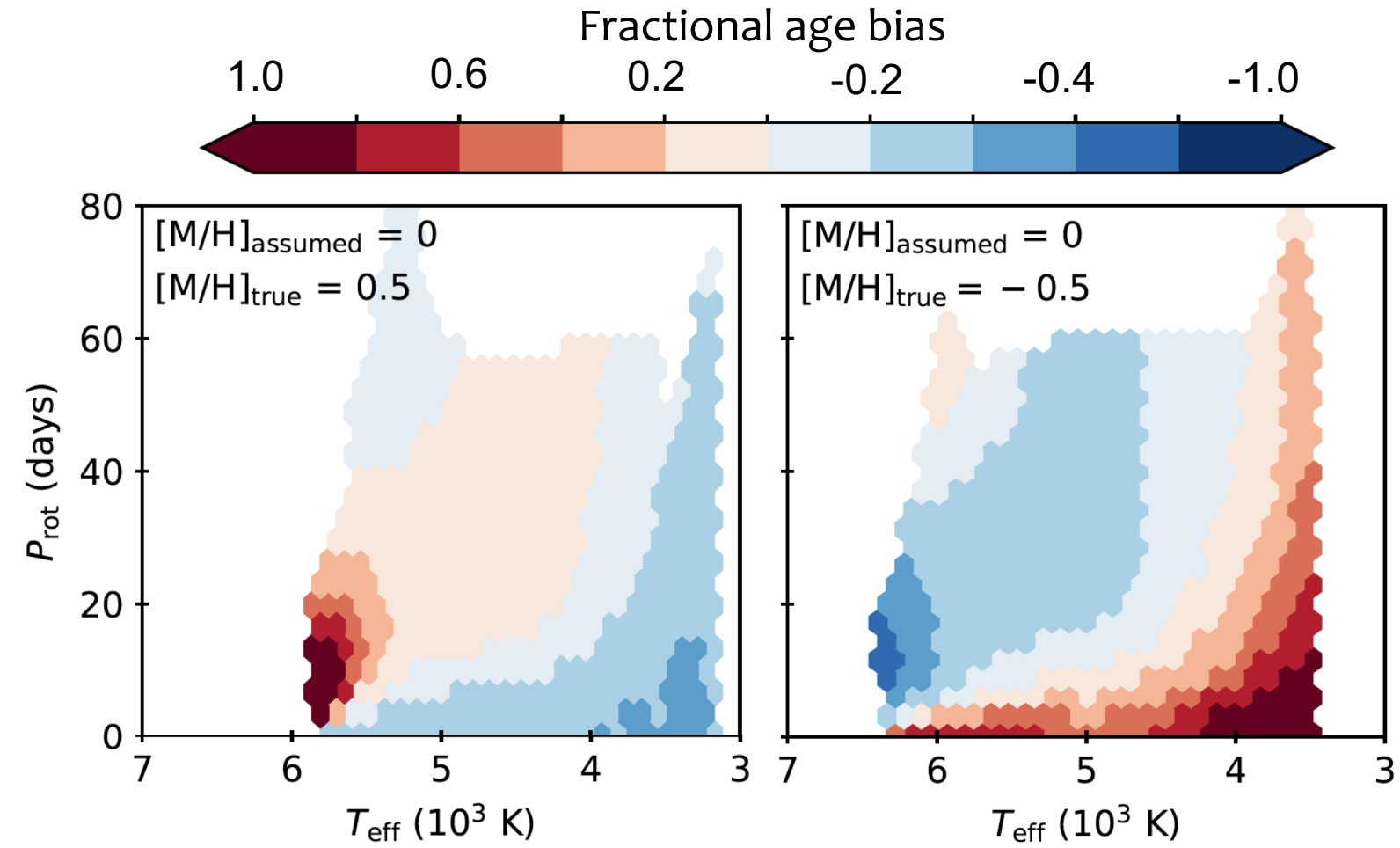


The impact of metallicity is an open question

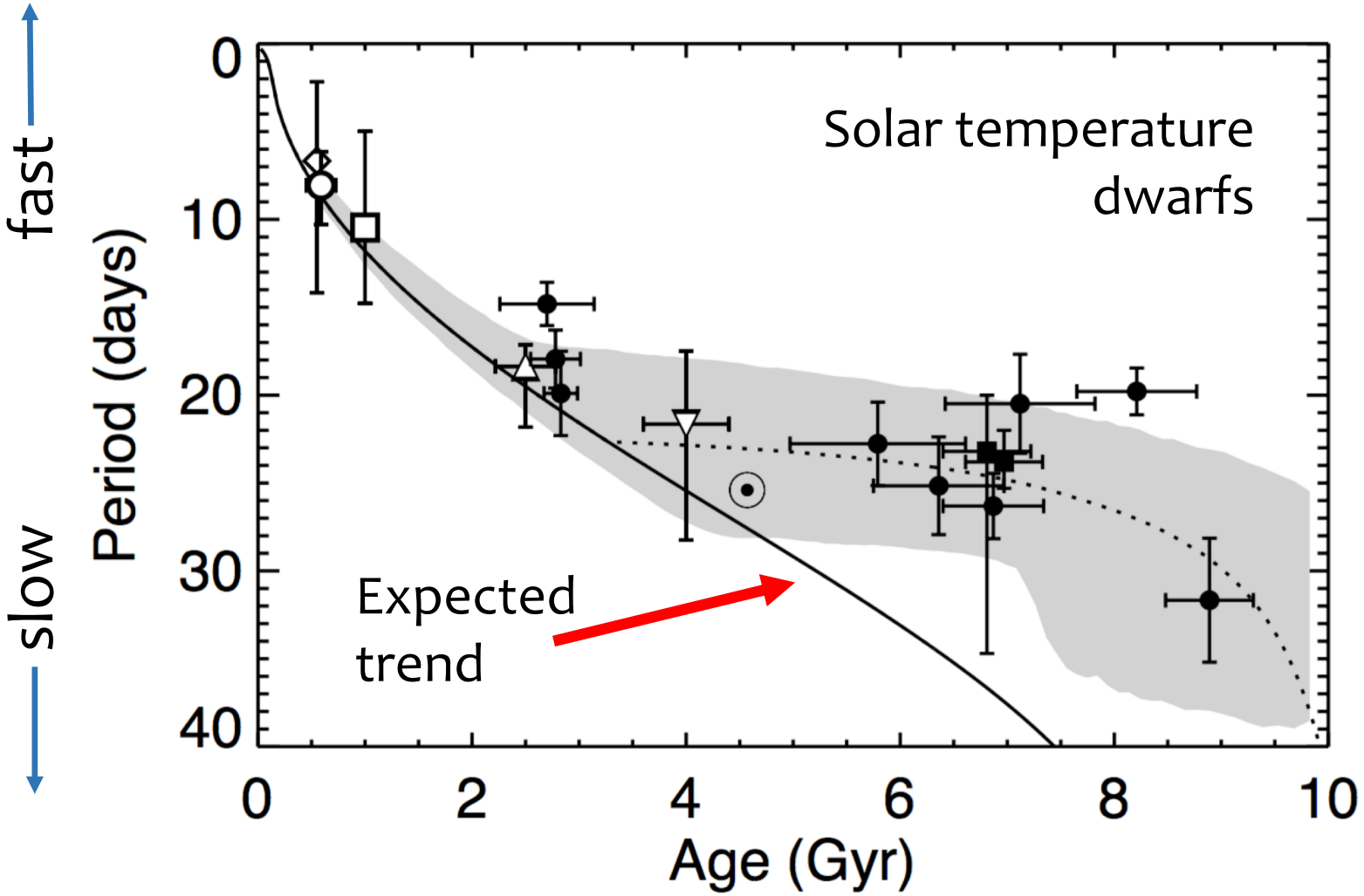
…but models suggest it's important



Claytor et al. (in prep). Check out the poster!

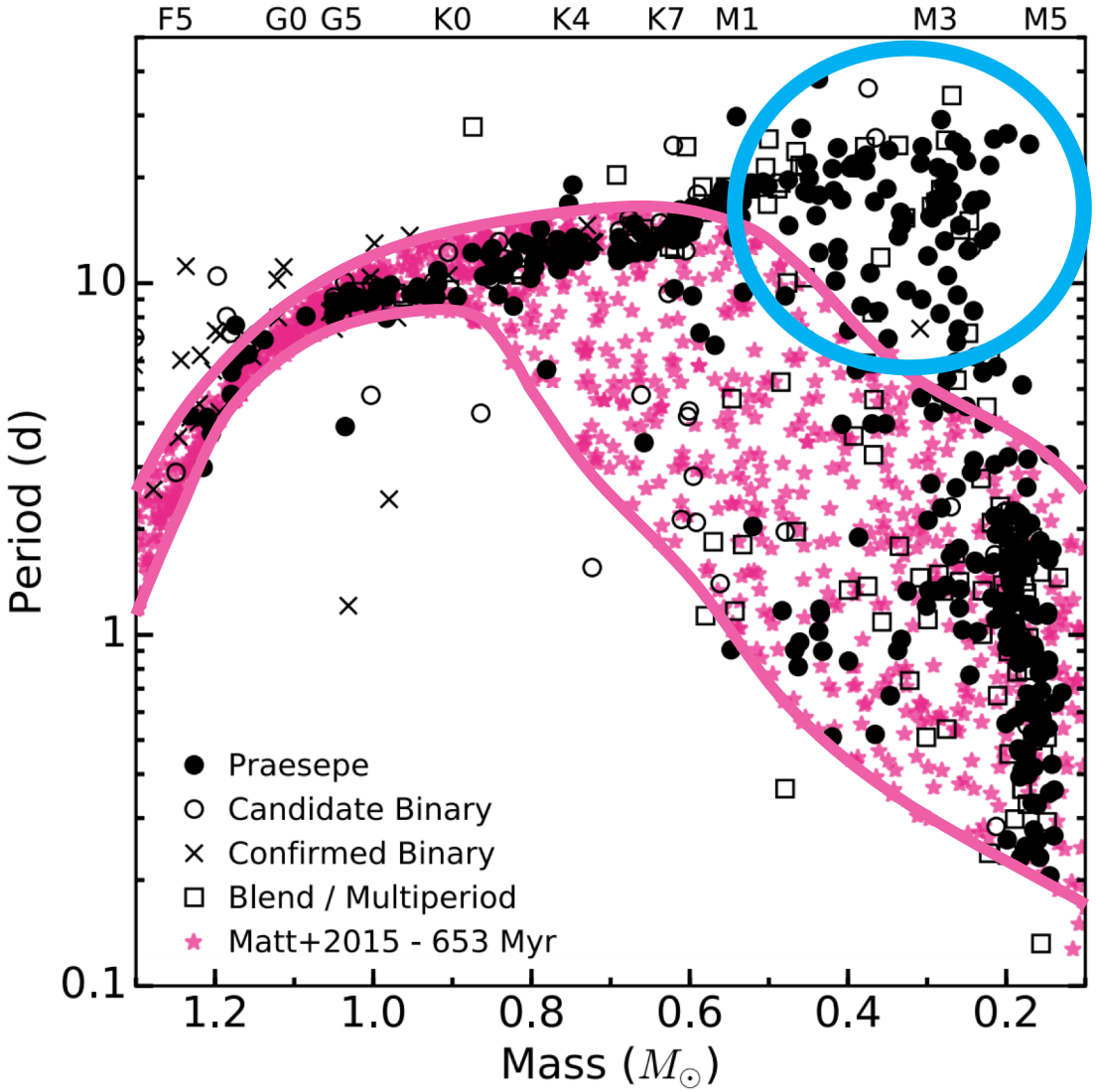
We're not really sure we understand the old stars

…in part because the calibrator situation is dire



van Saders et al. (2016), see also Angus et al. (2015)

We know we don't understand the M dwarfs

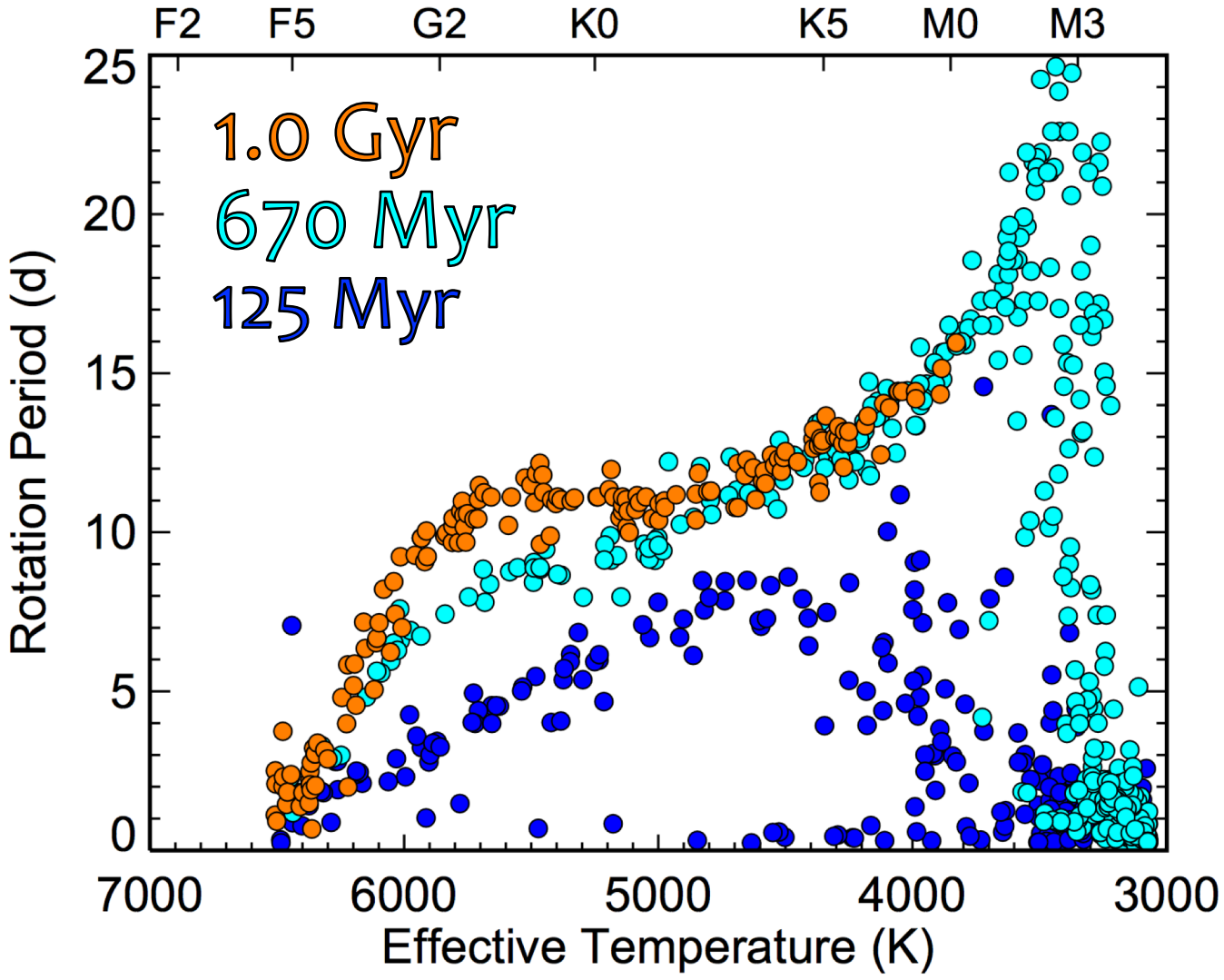


How do these stars reach long periods at this young age?

Model predictions (Matt et al. 2015)

Douglas et al. (2017)

And maybe K dwarfs are a problem too..



Curtis et al. 2019, see also Agueros et al. 2018, Douglas et al. (2019)

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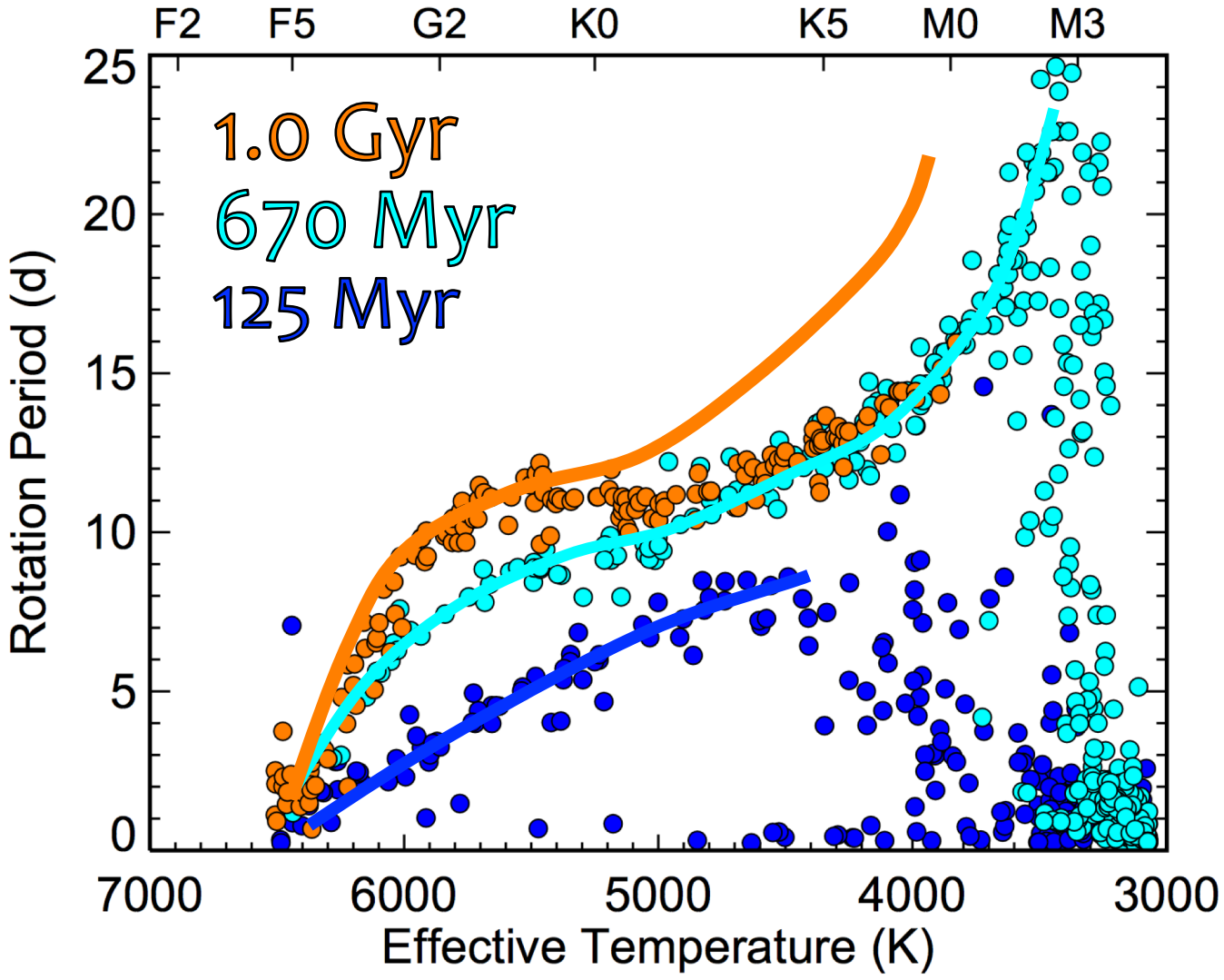

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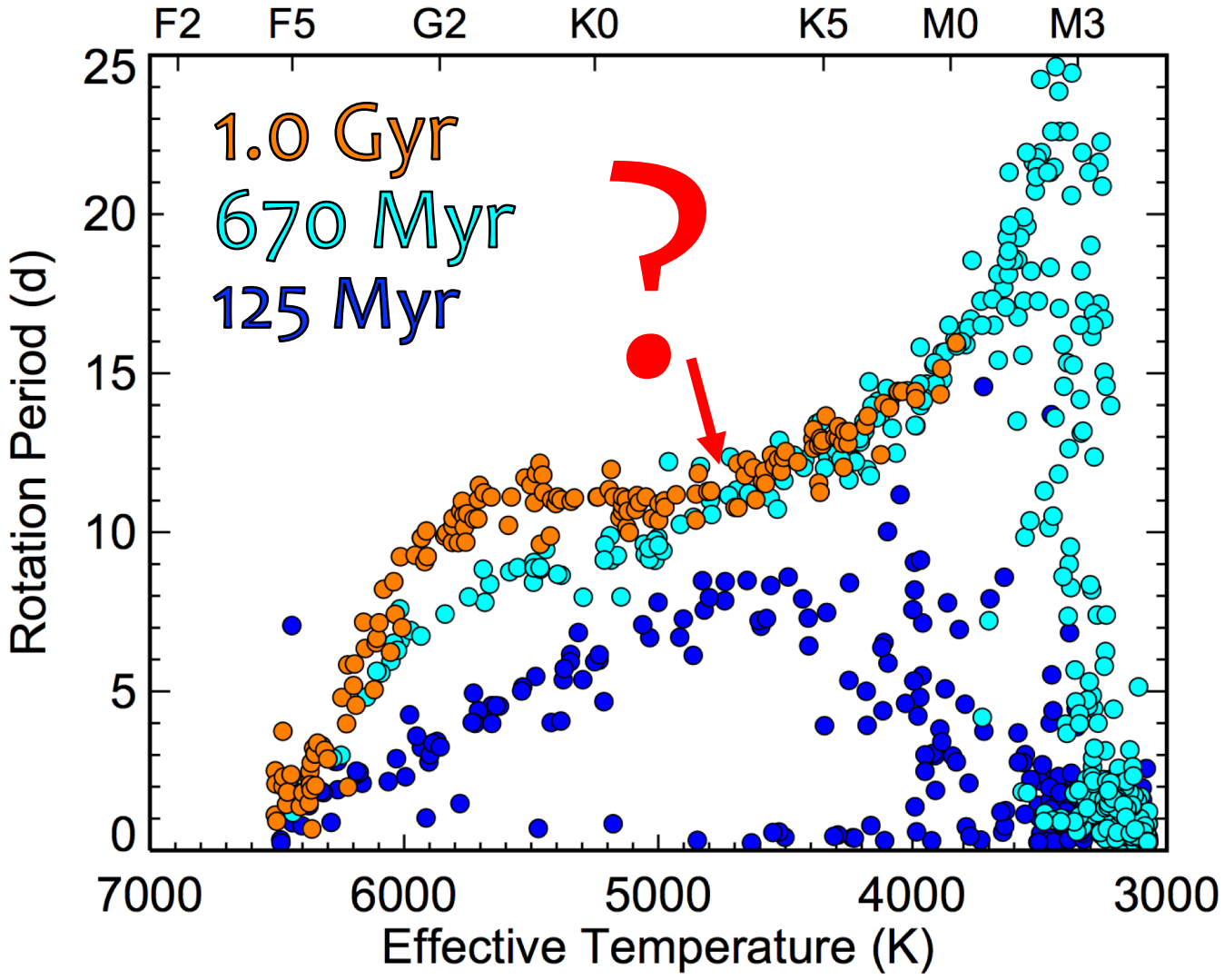

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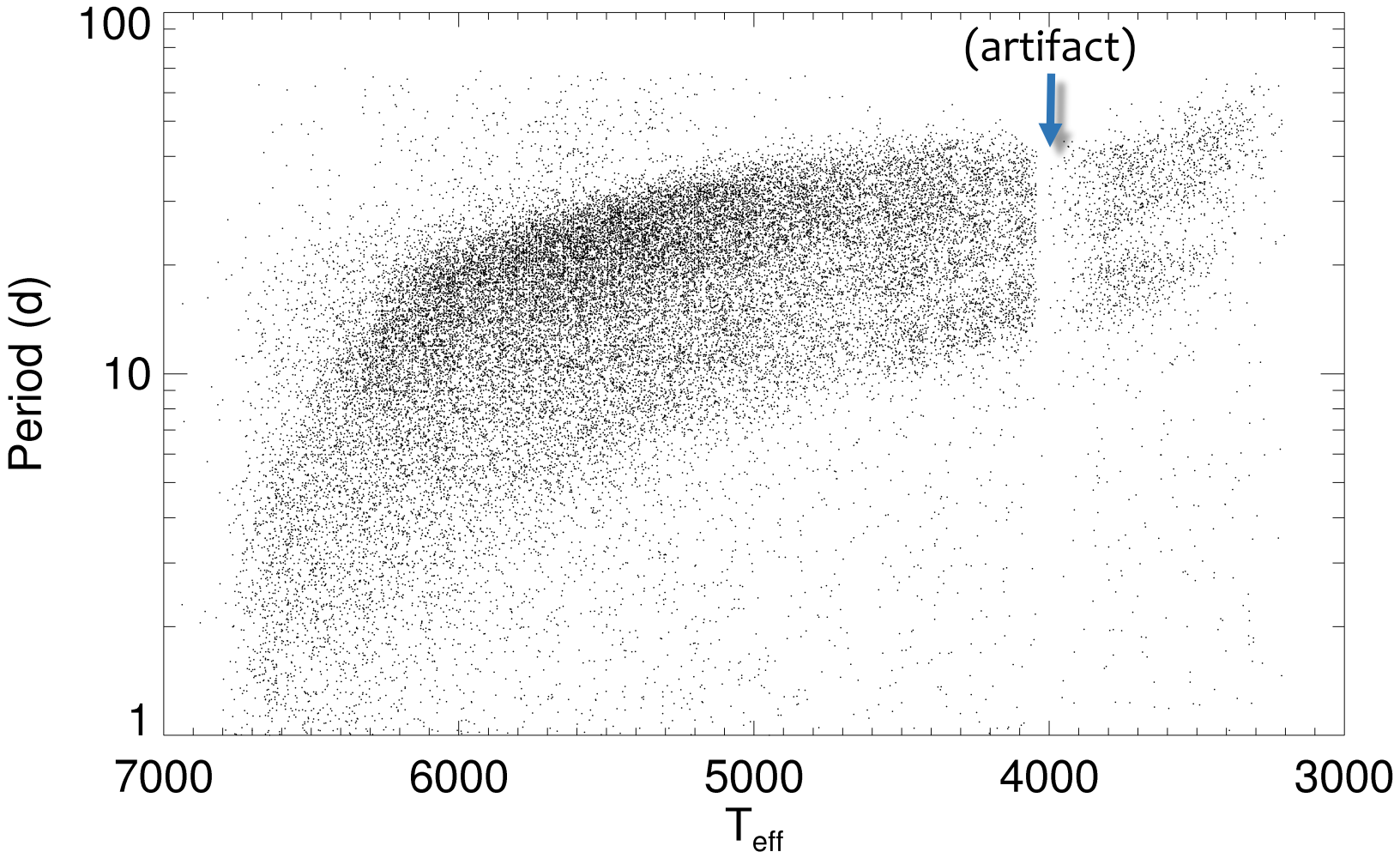
Field populations also show puzzling patterns



McQuillan et al. 2014

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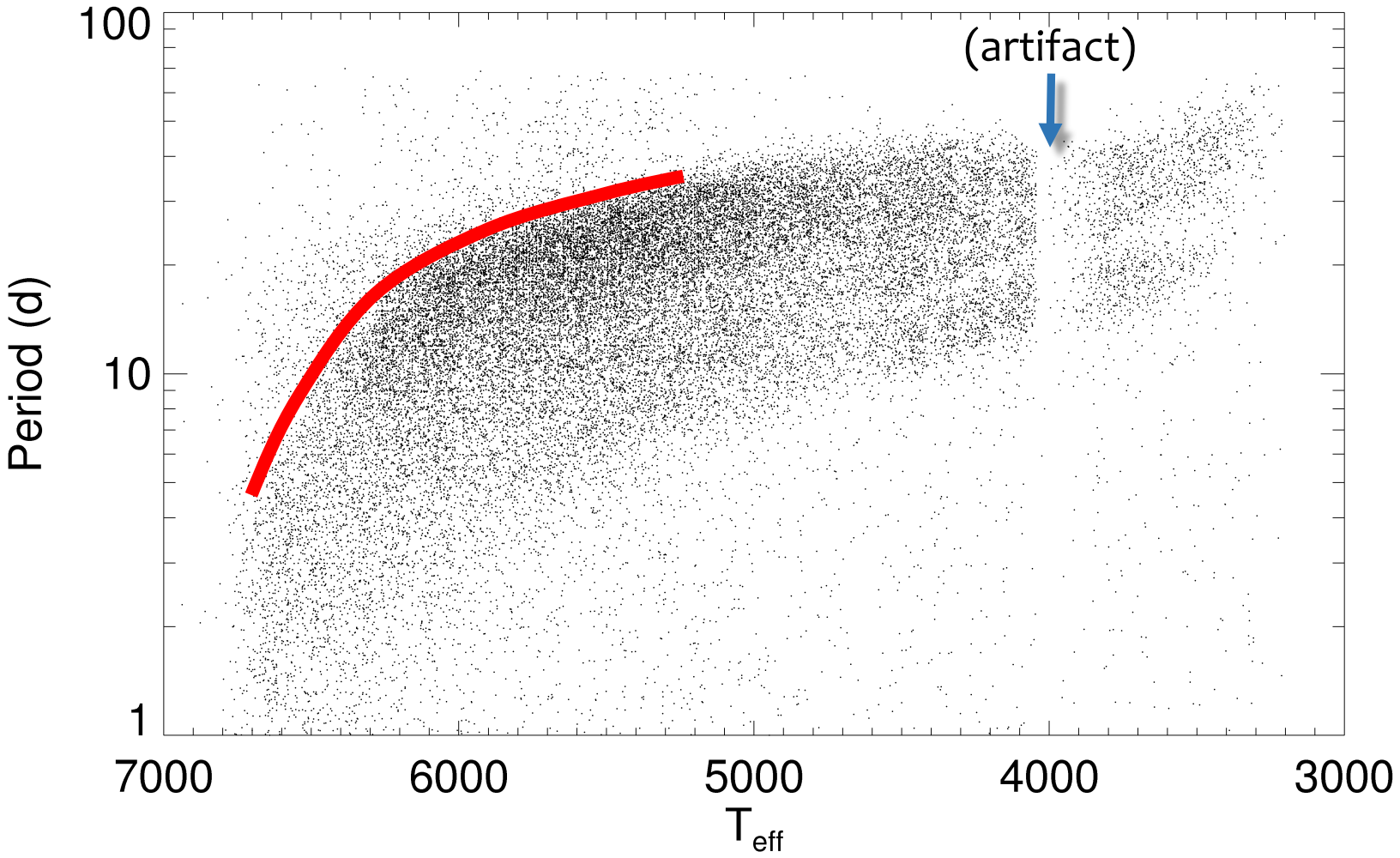

Detectability? Weakened braking? (van Saders et al. 2019)
Age distribution of the stellar population?
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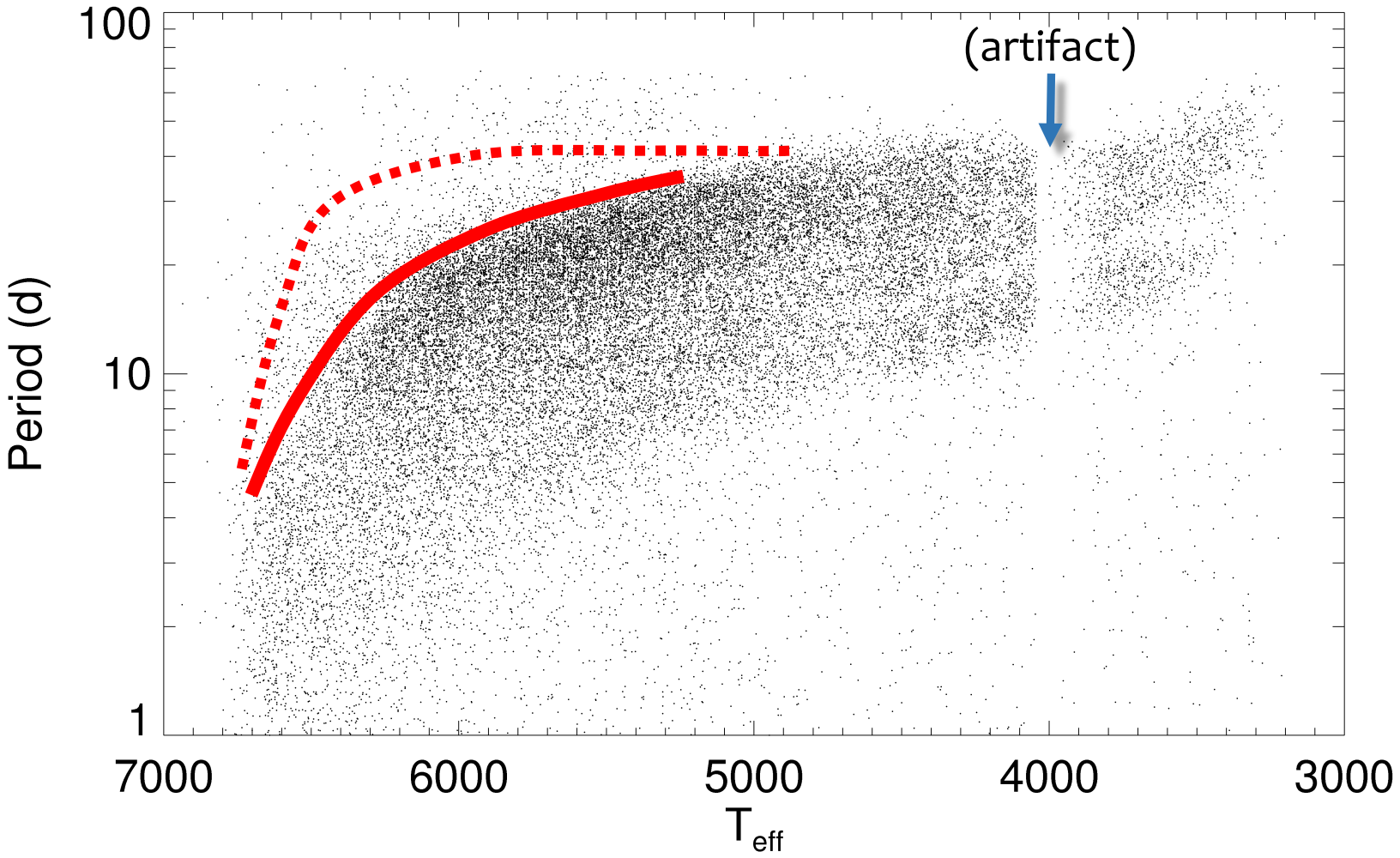

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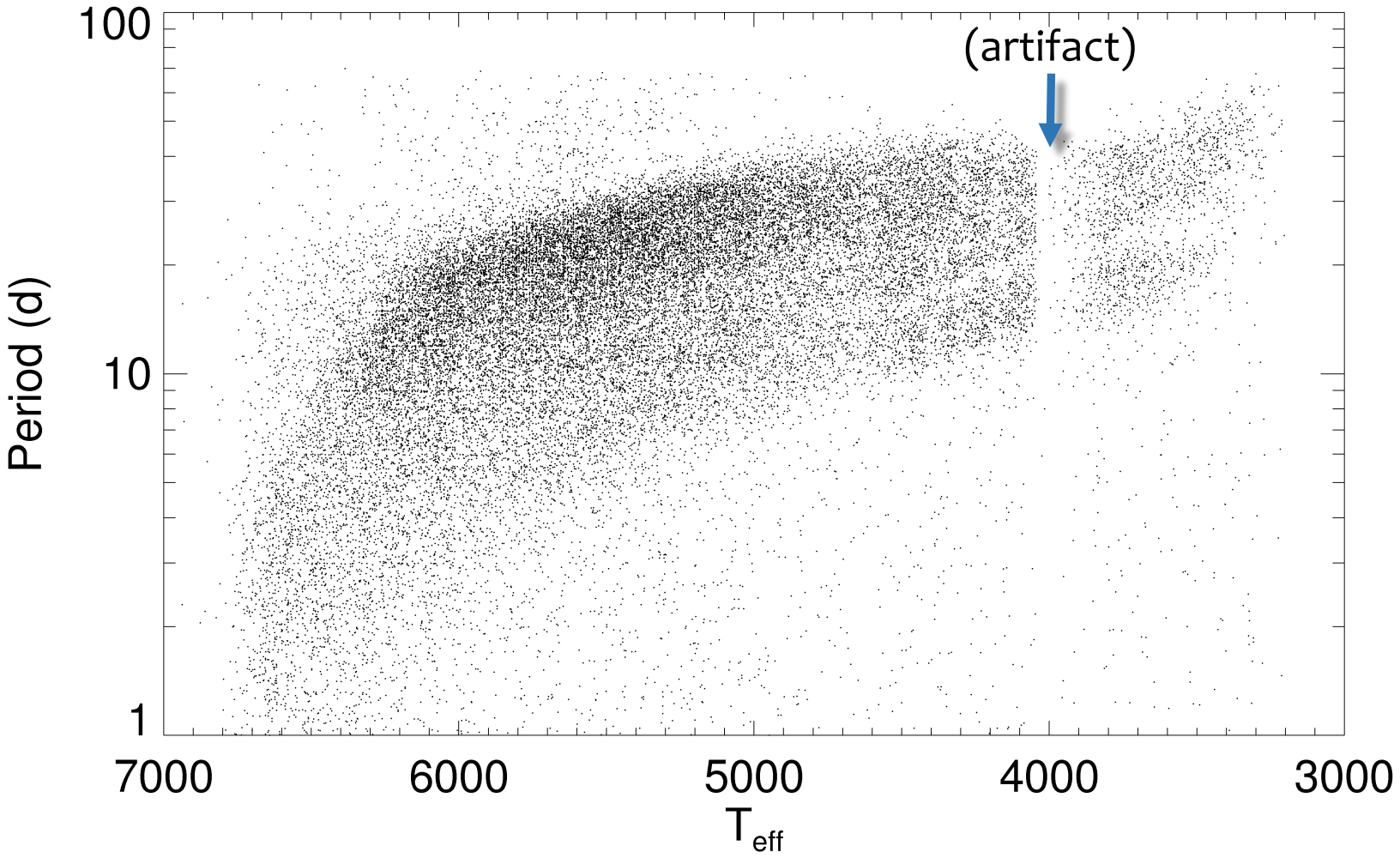

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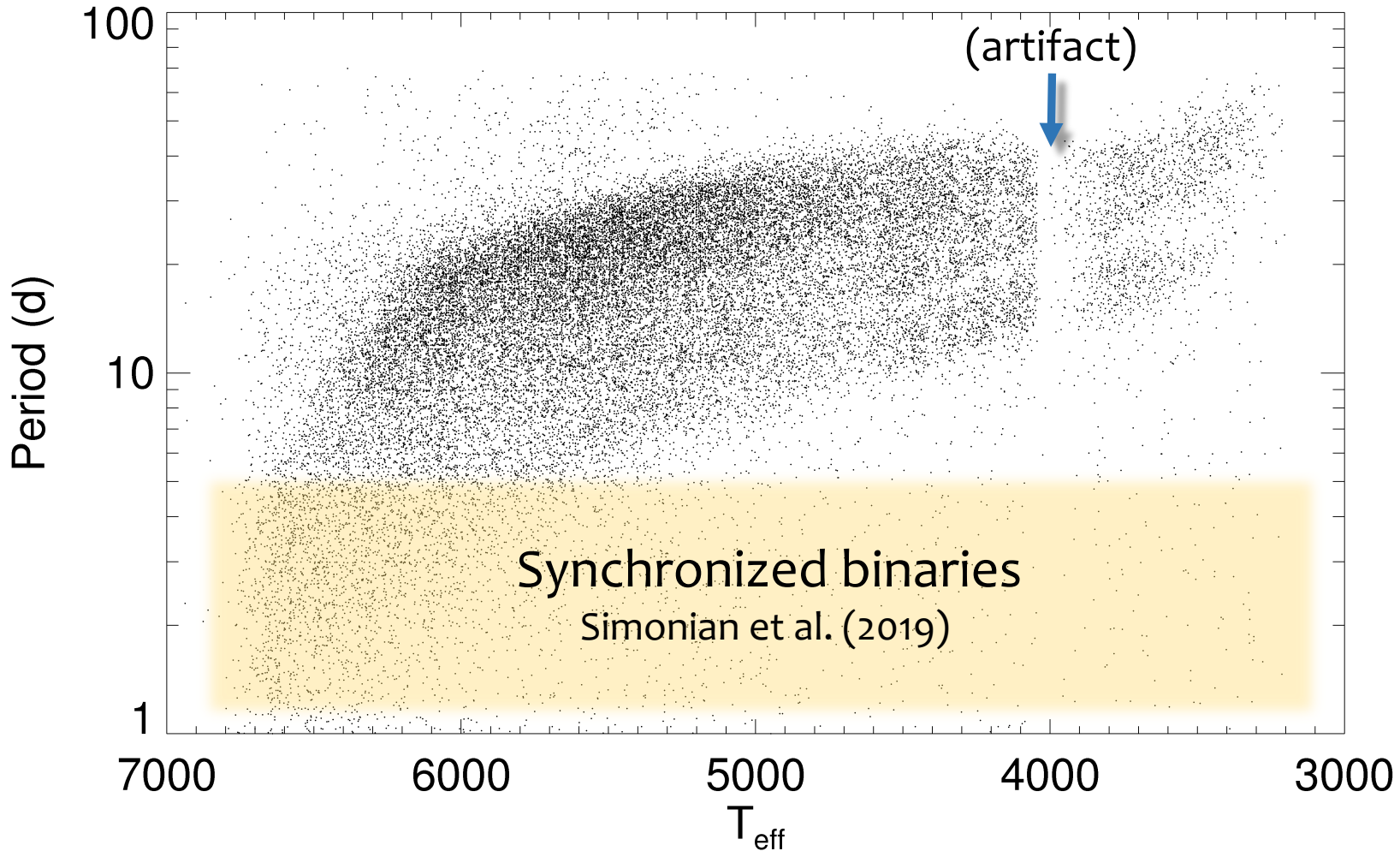

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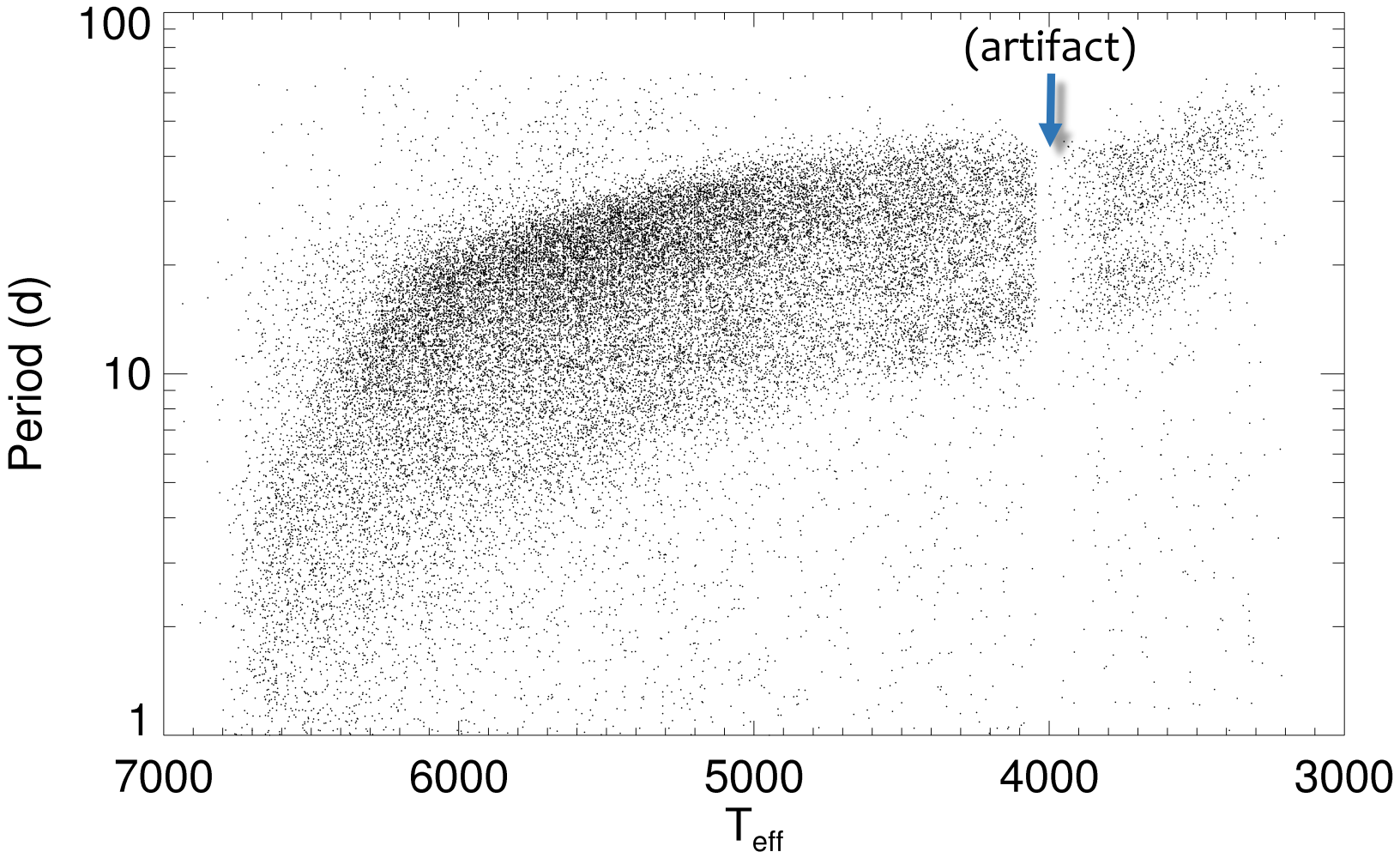

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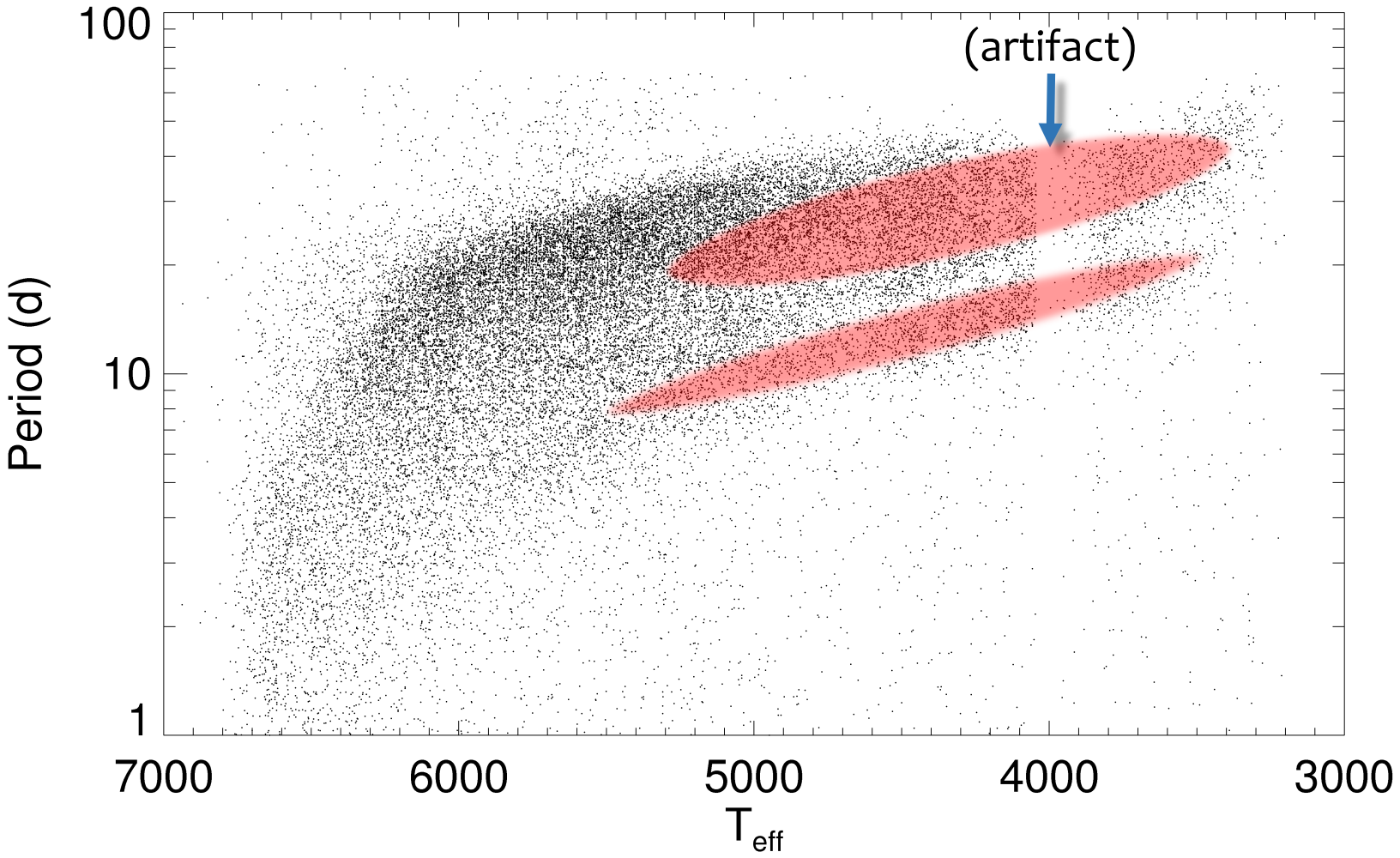

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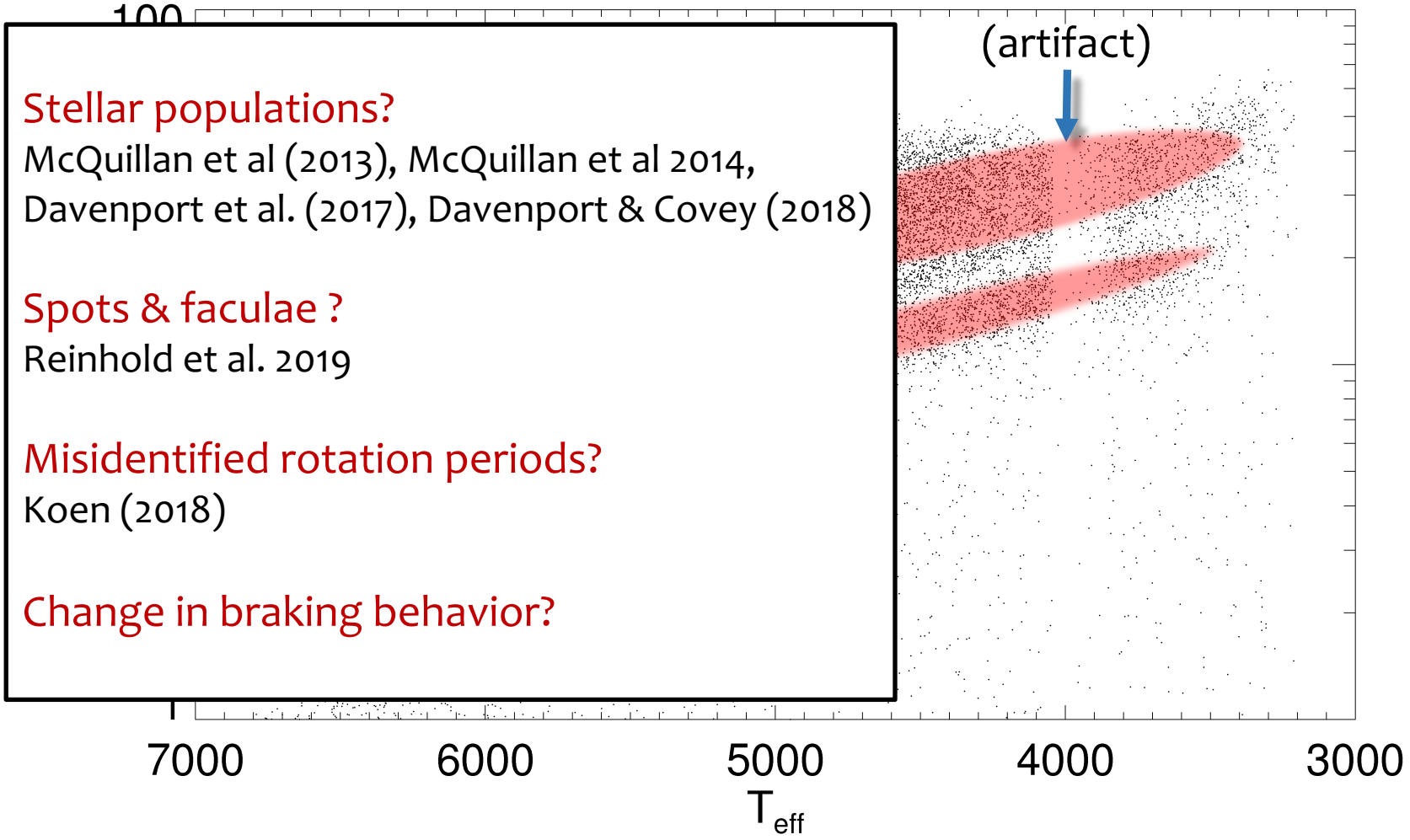

Stellar populations?
McQuillan et al (2013), McQuillan et al 2014,
Davenport et al. (2017), Davenport & Covey (2018)

Spots & faculae ?
Reinhold et al. 2019

Misidentified rotation periods?
Koen (2018)

Change in braking behavior?

McQuillan et al. 2014

Take-aways

The richness and complexity of these behaviors will offer deep insights into stellar magnetism and foster theoretical progress.

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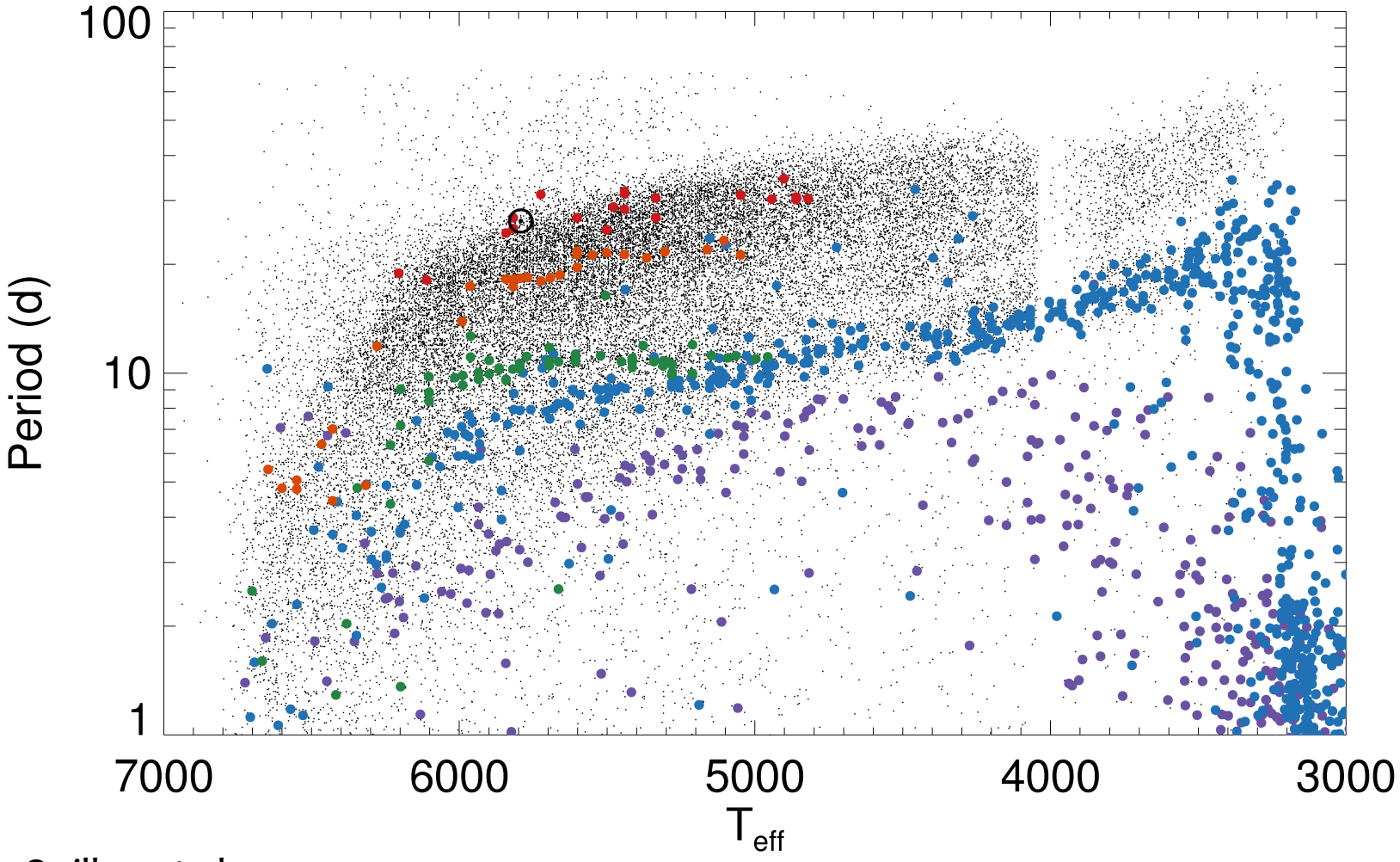
Where it's calibrated, it's a beautiful tool.
Just be sure to use it wisely!

Against the open clusters:



McQuillan et al. 2014
See also: Reinhold et al. 2015
Nielsen et al. 2013