Gyrochronology

Here be dragons

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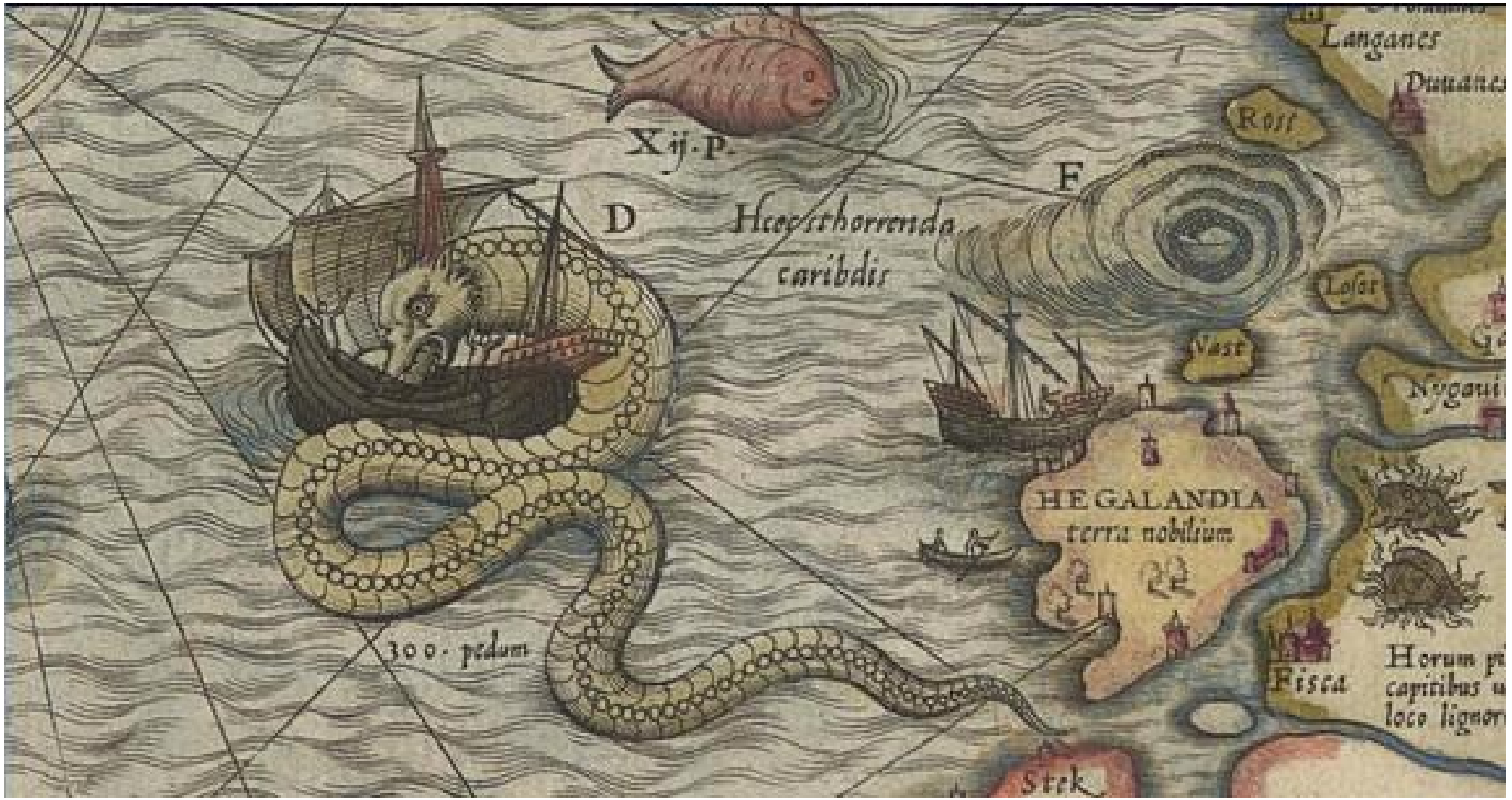

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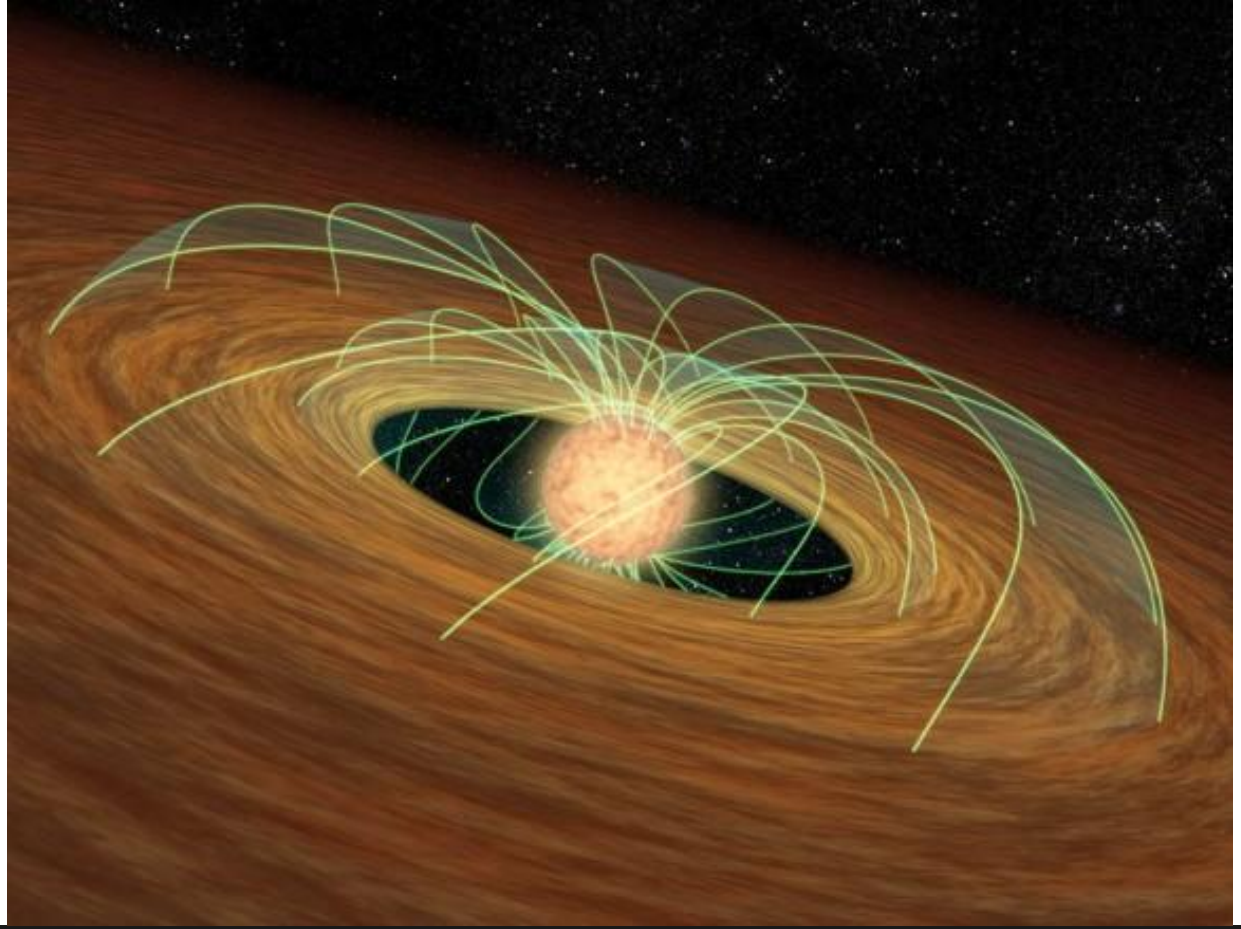
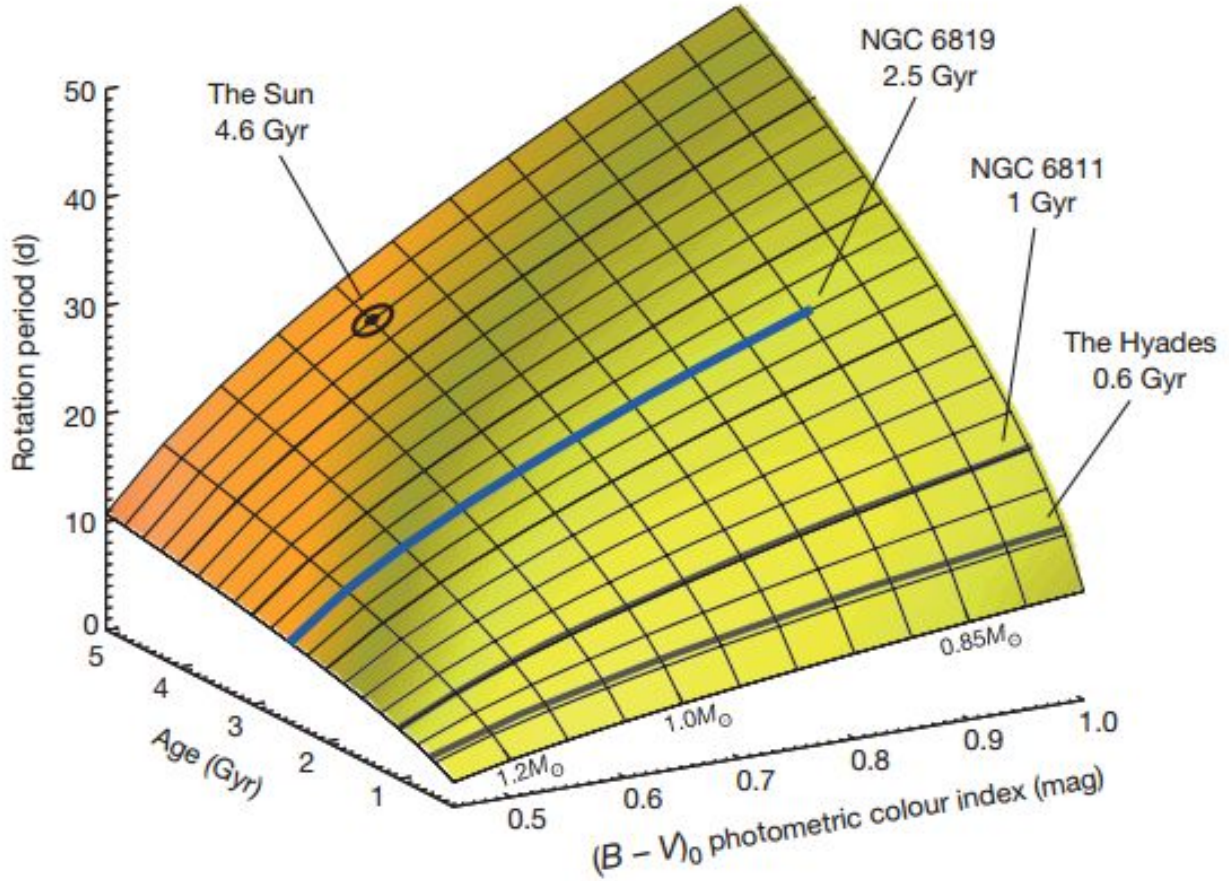


Credit: NASA/JPL-Caltech/R. Hurt (SSC).

Magnetic braking

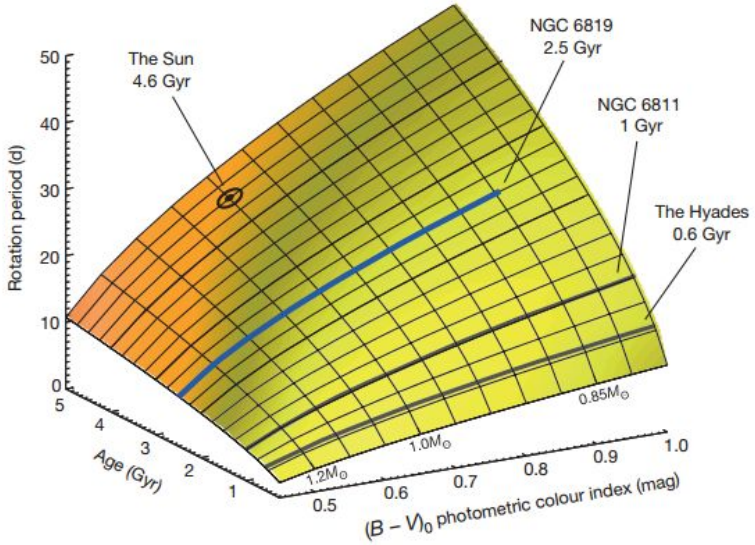


Meibom + 2015

Gyrochronology

A spin-down clock for cool stars from observations of a 2.5-billion-year-old cluster

Søren Meibom[1], Sydney A. Barnes[2], Imants Platais[3], Ronald L. Gilliland[4], David W. Latham[1], Robert D. Mathieu[5]



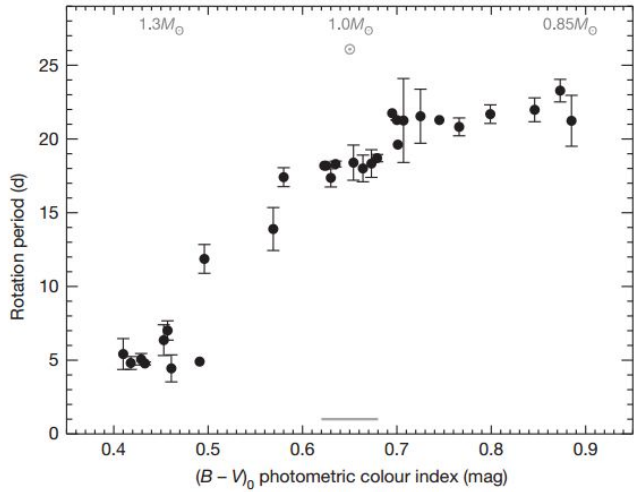


Figure 2 | The colour–period diagram for NGC 6819. The distribution of rotation periods as a function of de-reddened colour index $(B\text{-}V)_0$ for 30 cool photometric, proper-motion, and radial-velocity members of the 2.5 Gyr open star cluster NGC 6819. The measurements define a tight dependence of rotation period on colour (mass). The symbols and error bars respectively indicate the means and standard deviations of multiple measurements for the same star when available. The location of the Sun (4.56 Gyr) in the diagram is marked with a grey solar symbol. Stellar masses in solar units are given along the top horizontal axis at the corresponding colours. Solar-mass stars with $(B\text{-}V)_0$ between 0.62 and 0.68 mag (interval marked by grey line near the bottom horizontal axis) have a mean period of 18.2 d with a standard deviation of 0.4 d.

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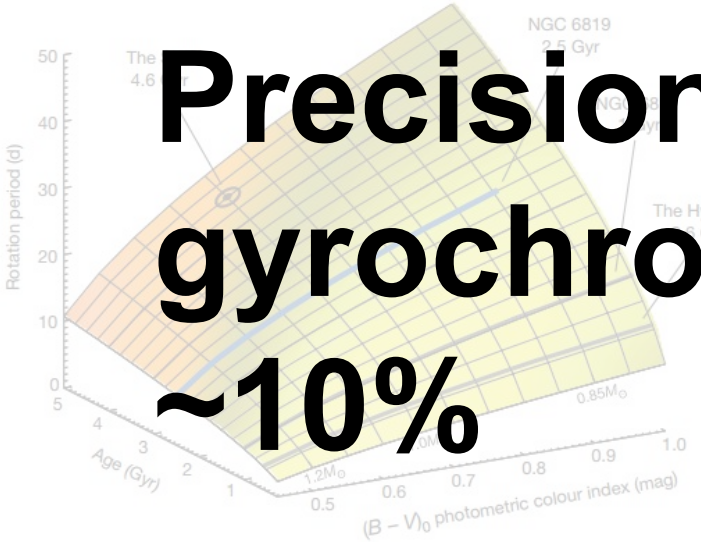
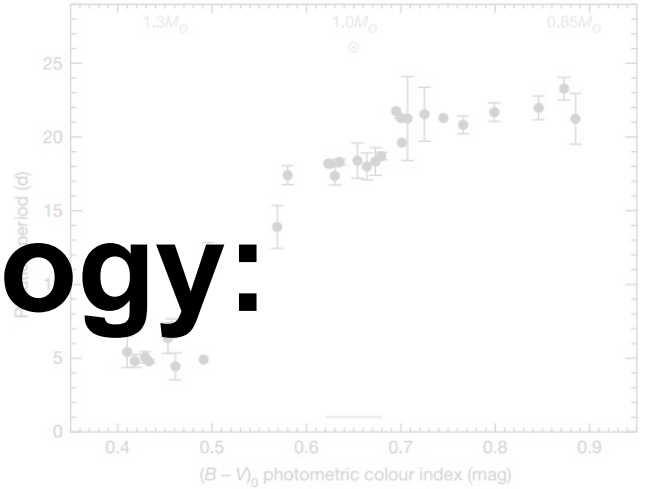


Precision of gyrochronology: ~10%



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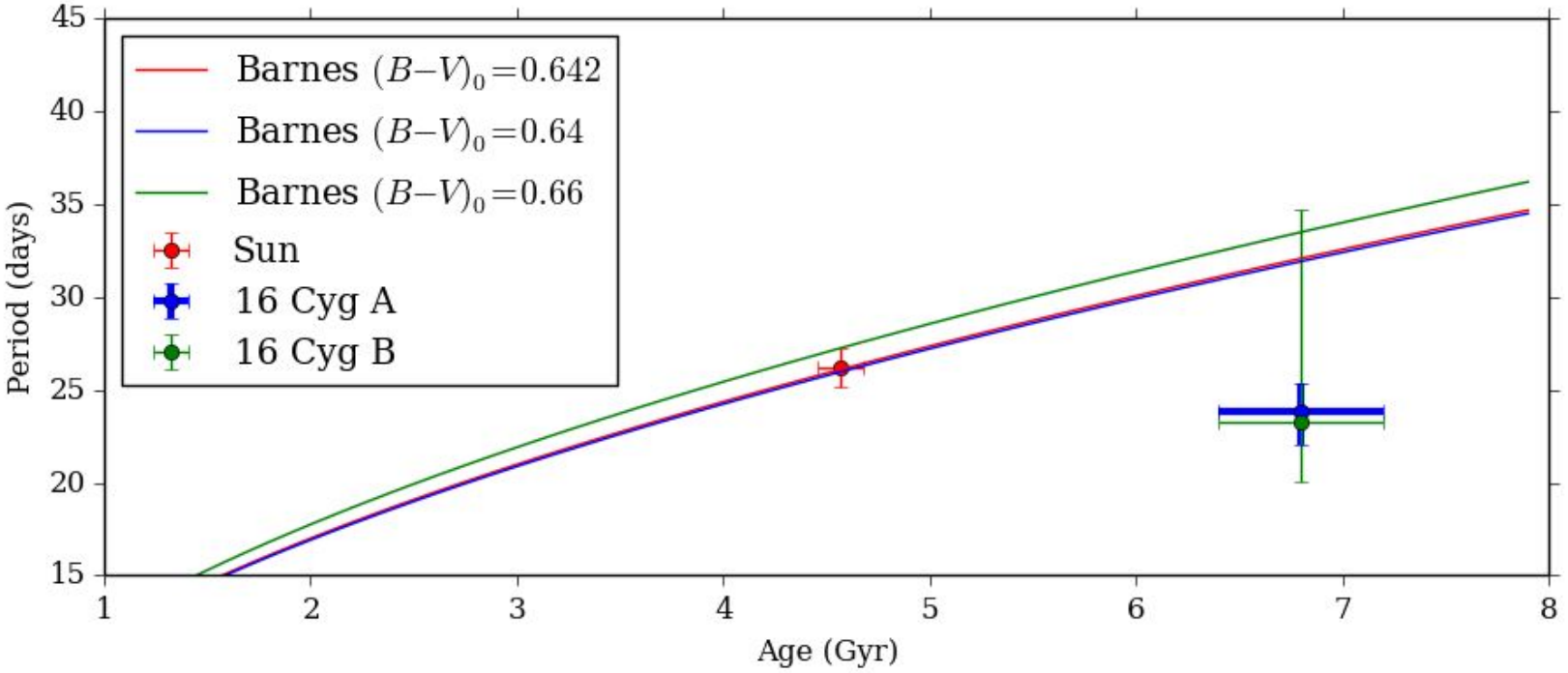

Davies + 2015

Gyrochronology on old stars

Calibrating Gyrochronology using Kepler Asteroseismic targets

Ruth Angus,[1⋆] Suzanne Aigrain,[1] Daniel Foreman-Mackey,[2] and Amy McQuillan[3]
[1] *Department of Physics, University of Oxford, UK*
[2] *Centre for Cosmology and Particle Physics, New York University, New York, NY, USA*
[3] *School of Physics and Astronomy, Raymond and Beverly Sackler, Faculty of Exact Sciences, Tel Aviv University, 69978, Tel Aviv, Israel*

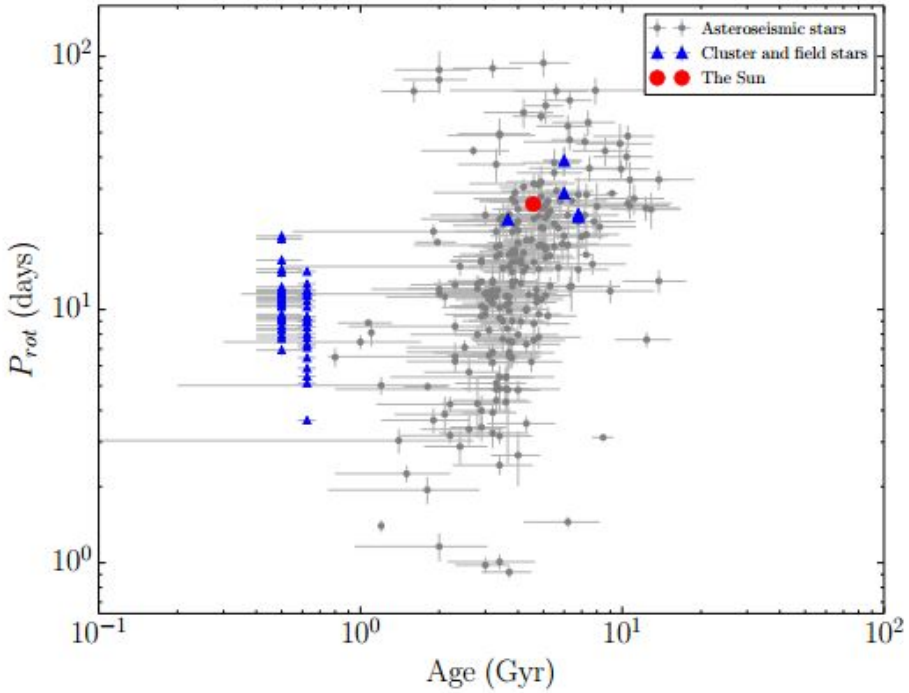

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Figure 1. Photometric rotation period vs age for 310 *Kepler* targets (grey circles) plus cluster and field stars (blue triangles). The Sun is shown as a red circle.

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Markov Chain Monte Carlo methods were used to explore the posterior probability distribution functions of the gyrochronology parameters and we carefully checked the effects of leaving out parts of our sample, leading us to find that no single relation beween rotation period, colour and age can adequately describe all the subsets of our data. The *Kepler* asteroseismic stars, cluster stars and local field stars [illegible] relation. The *Kepler* asteroseismic [illegible] clusters show unexpected deviations from the predicted behaviour, providing concerns for the overall reliability of gyrochro[illegible]

“leading us to find that no single relation between rotation period, colour and age can adequately describe all the subsets of our data”

Precision of gyrochronology: ?

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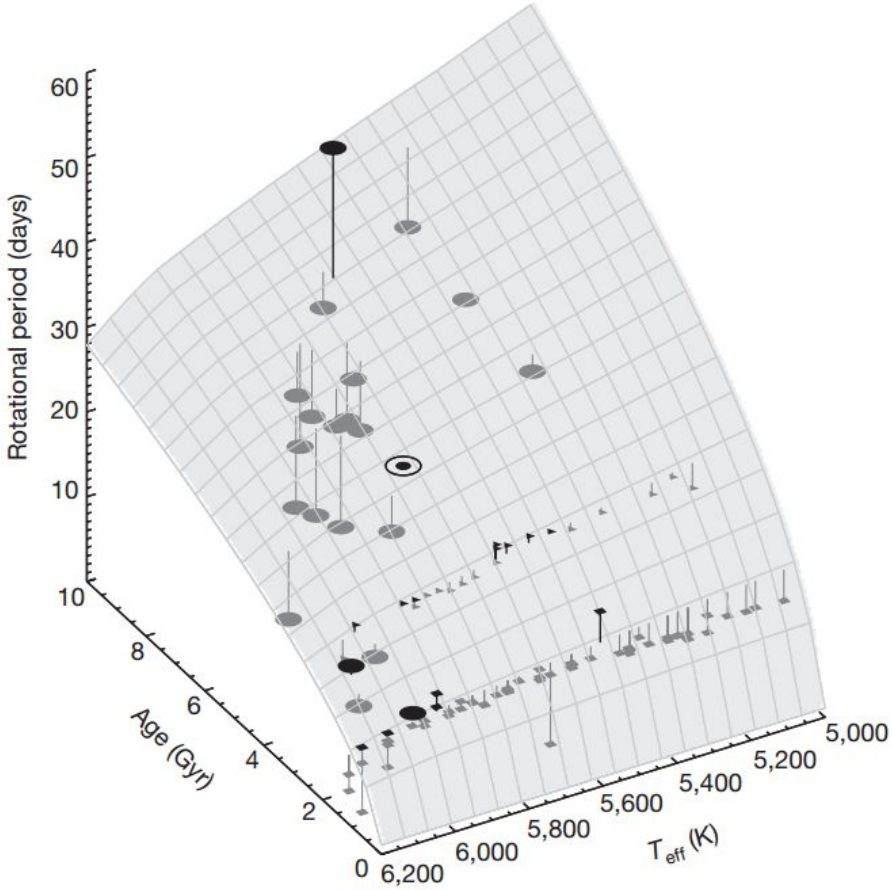

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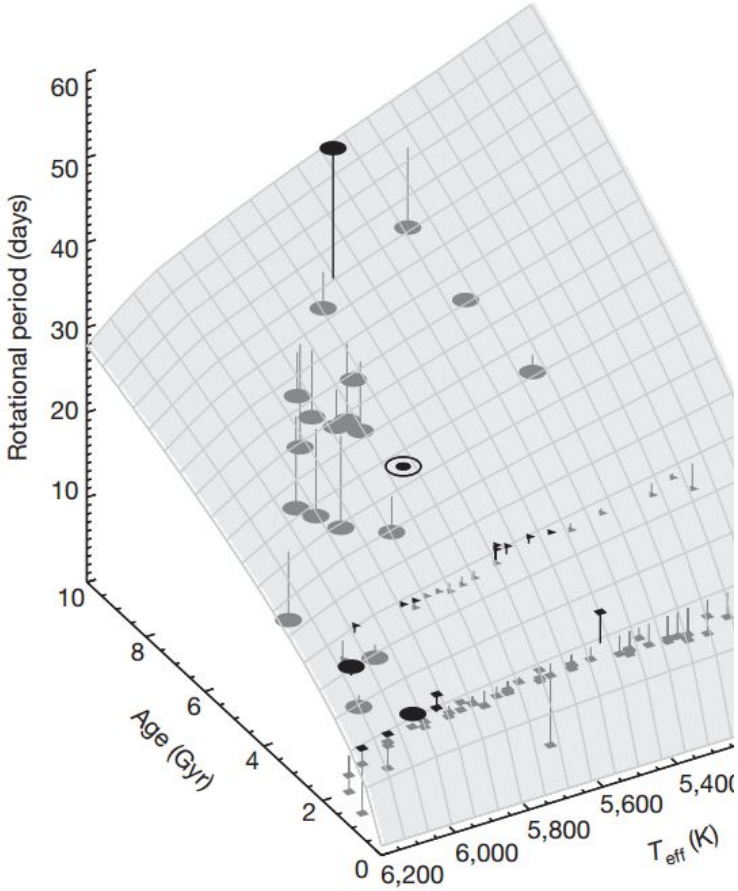
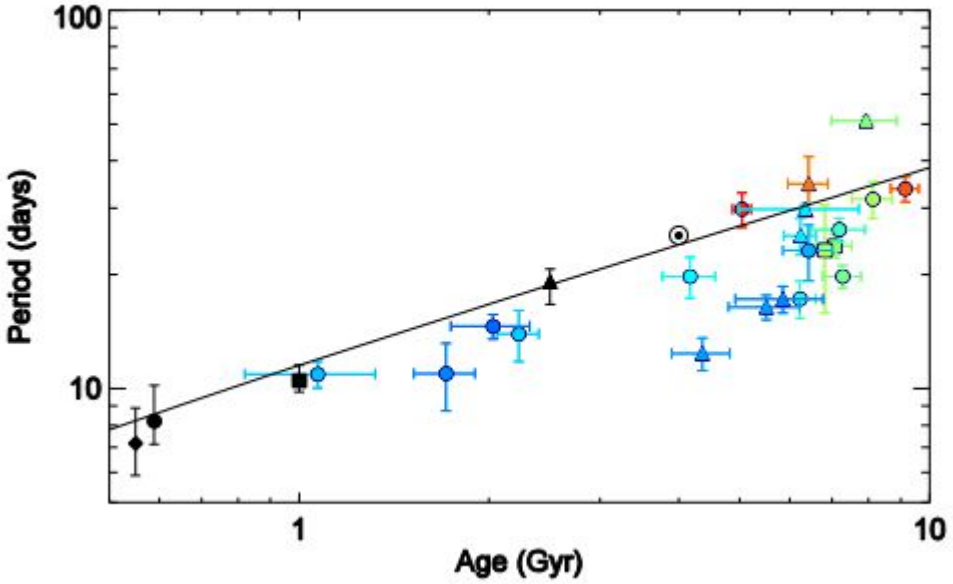
van Saders, Davies + Nature 2016





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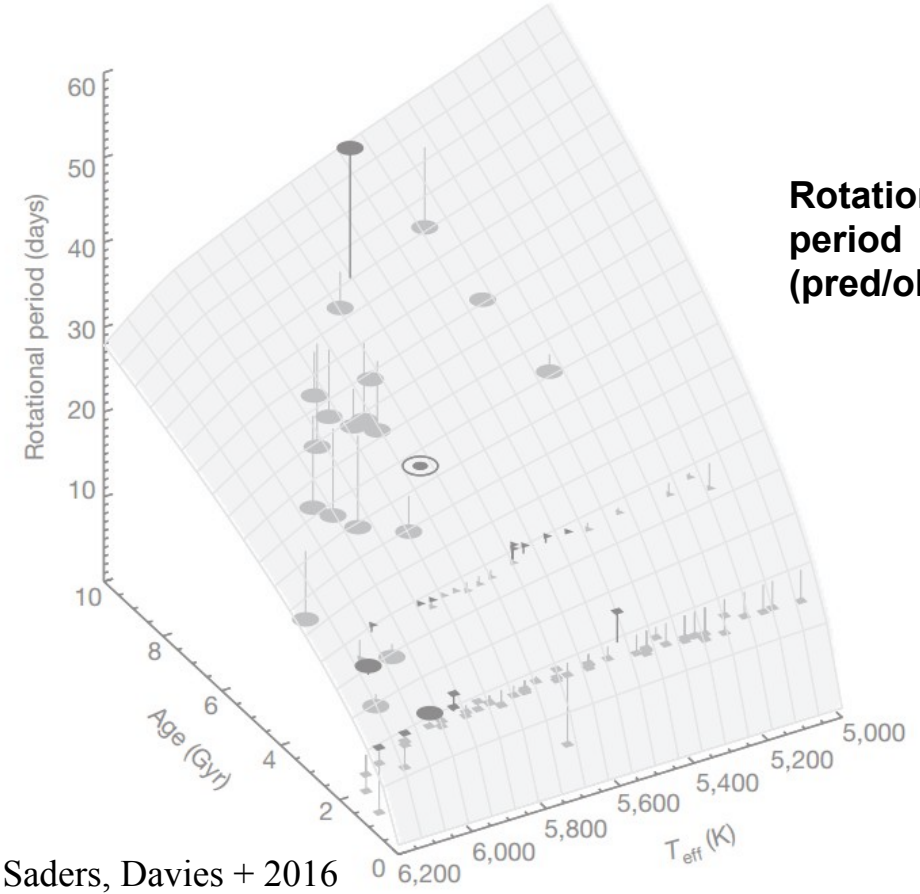
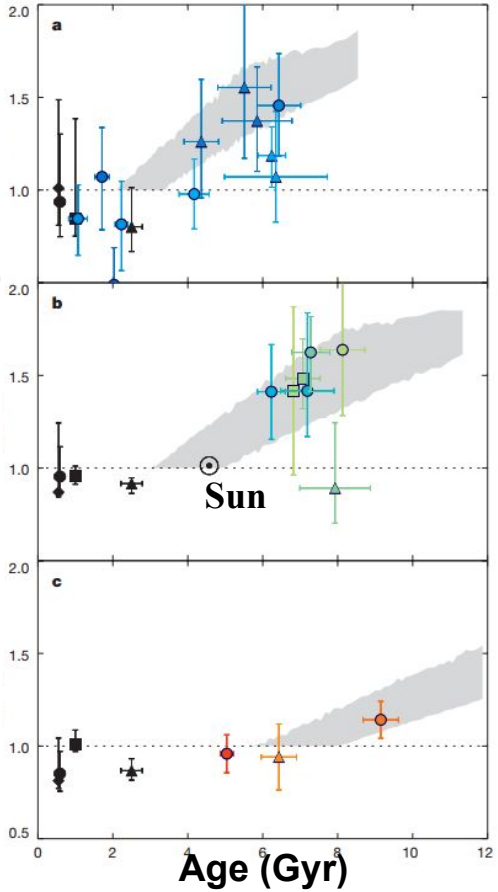
van Saders, Davies + Nature 2016



van Saders, Davies + 2016

Rotation period (pred/obs)



Stellar temperature or mass

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Rossby Number (Ro)

Definition: Period of rotation / convective turnover timescale

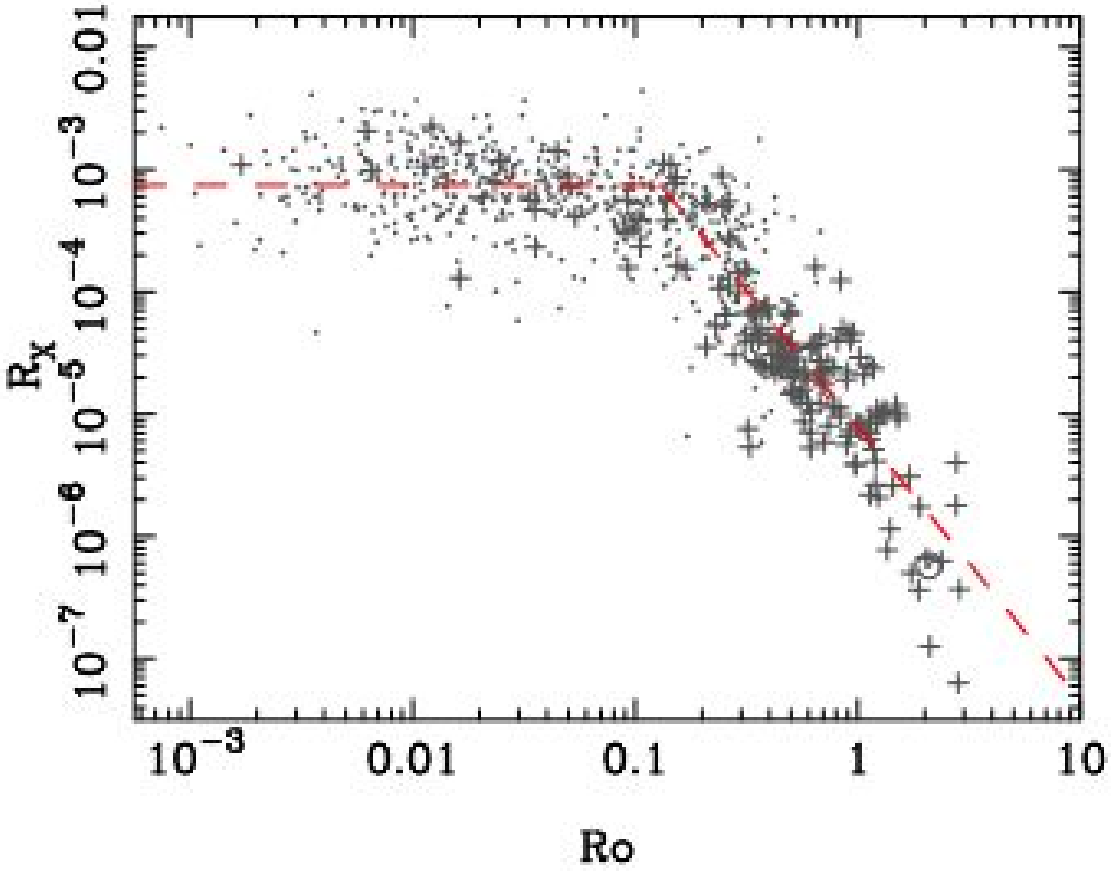
$$Ro = P_{\mathrm{rot}} / \tau_{\mathrm{c}}$$

Why use this?

It is *the* parameter of dynamo theory.

Links rotation and convection - important ingredients of solar dynamo theory.

Importantly linked to magnetic field strength.



Wright+ 2011

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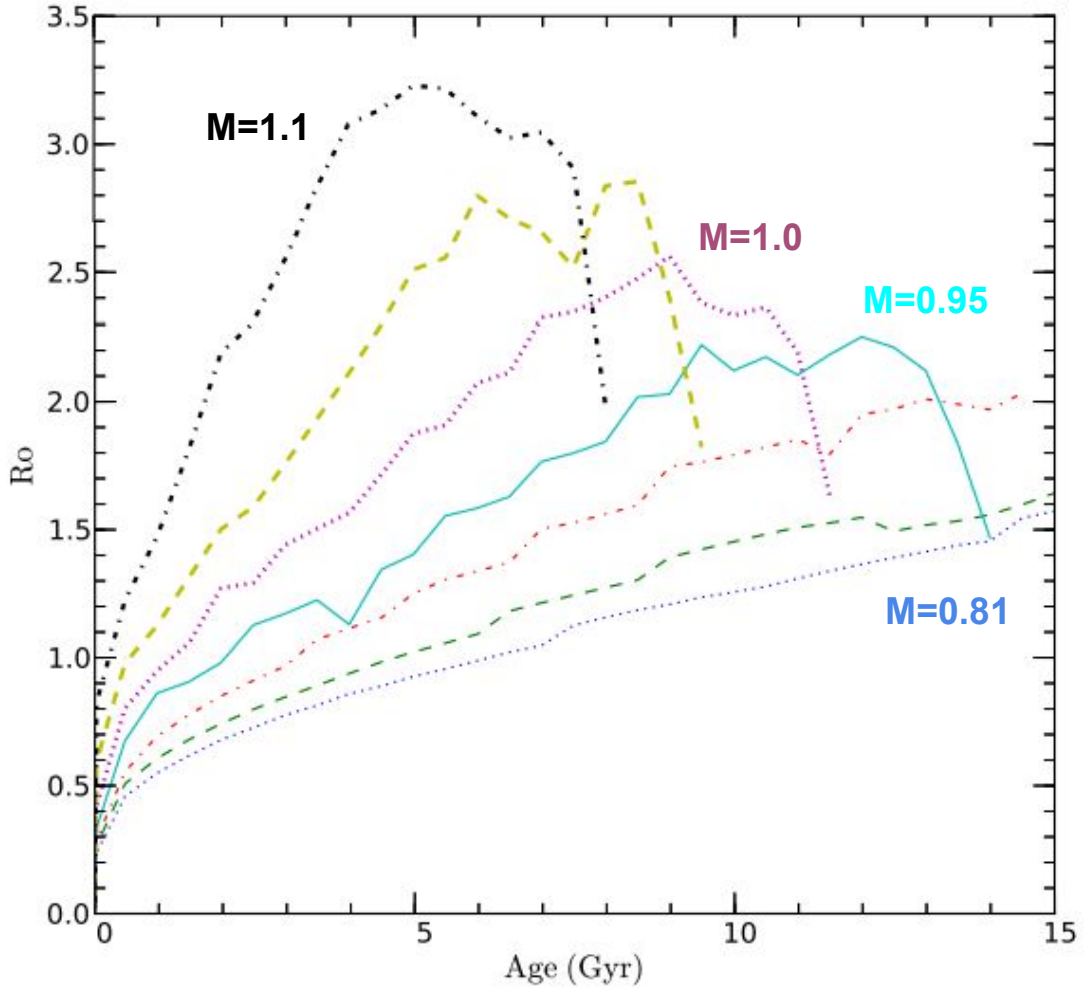
Rossby number evolution



Castro + 2013

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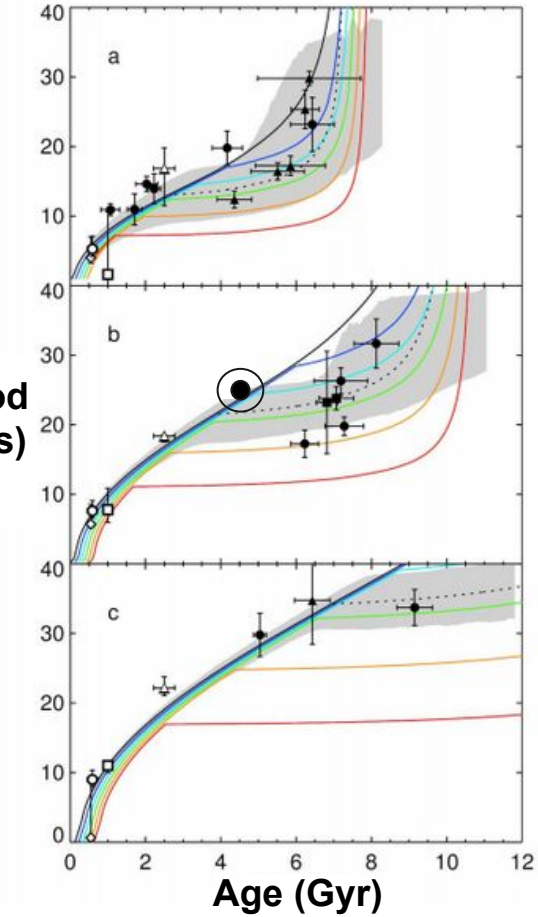
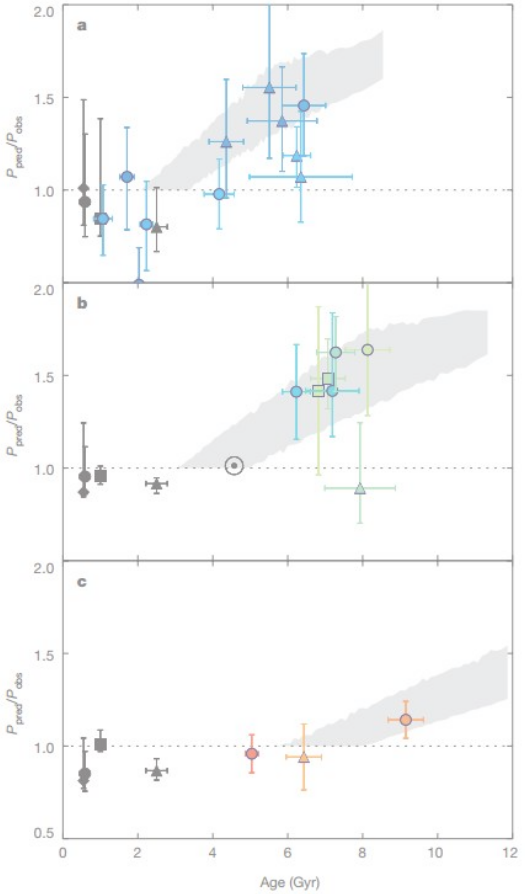
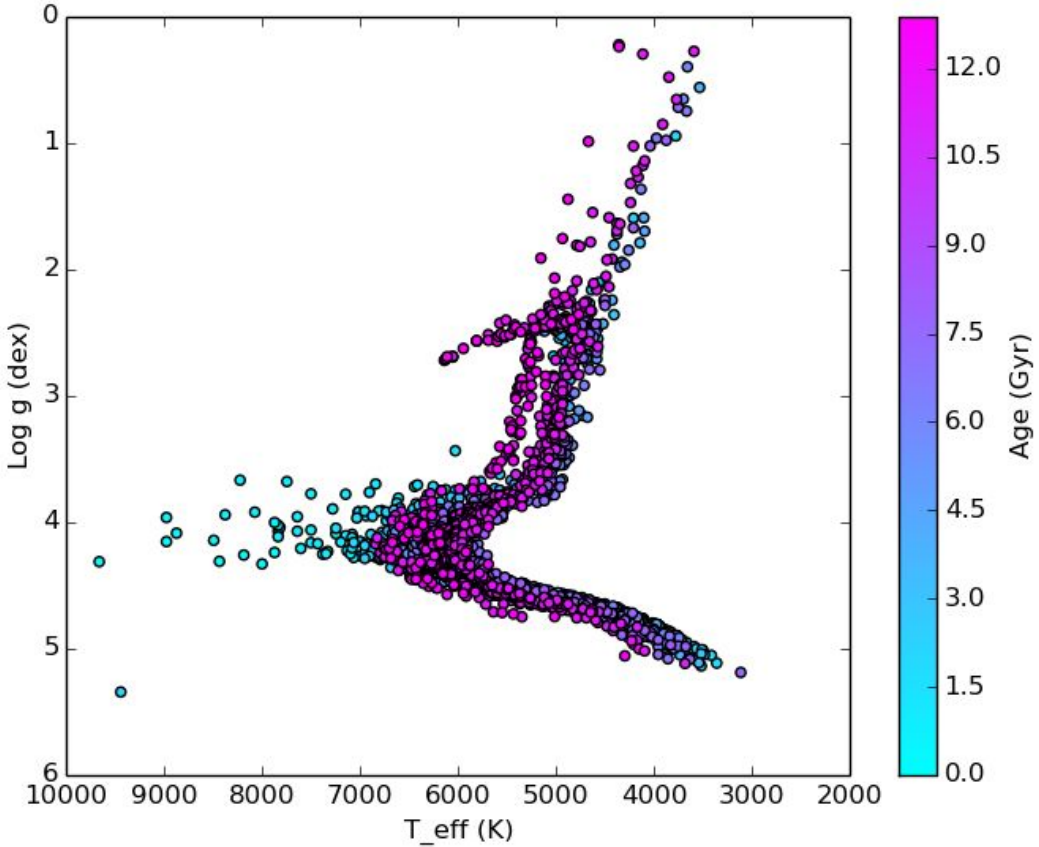




van Saders, Davies + Nature 2016

What does this mean for gyrochronology?



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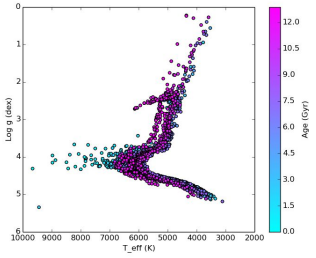

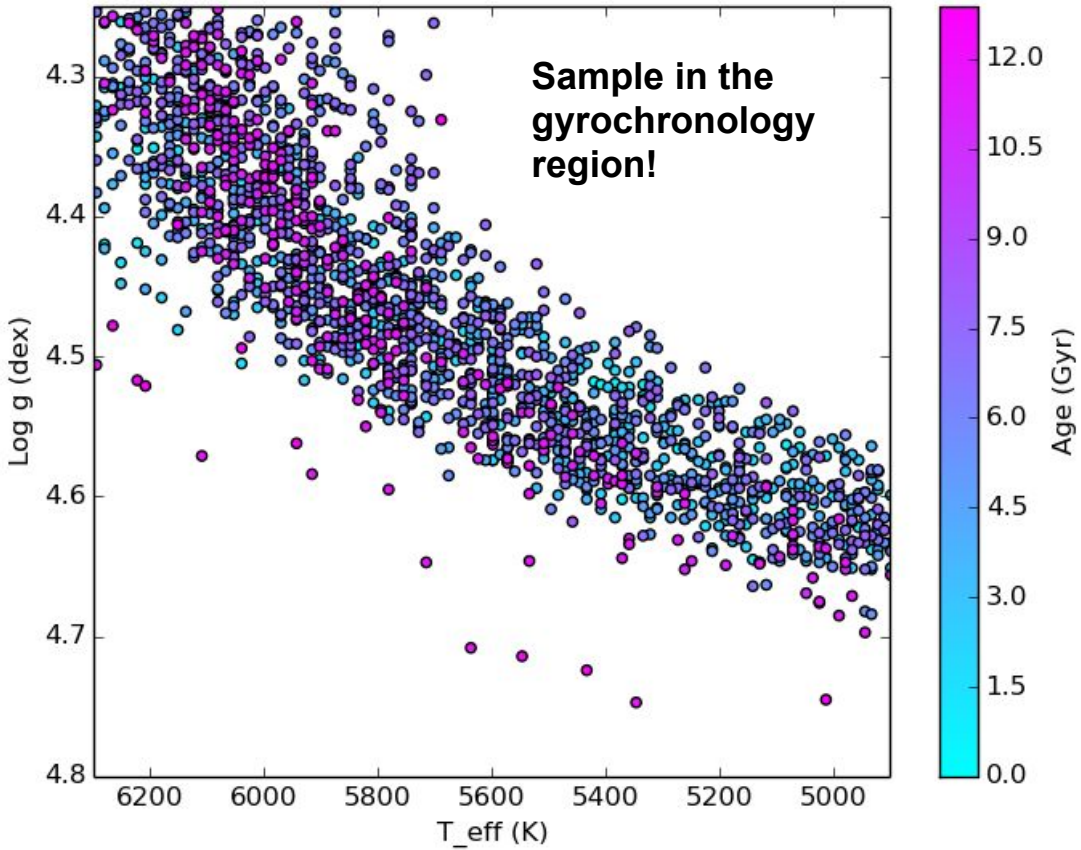

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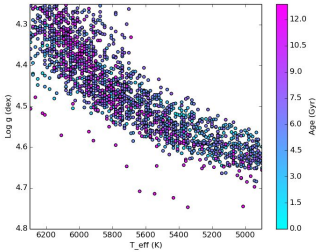

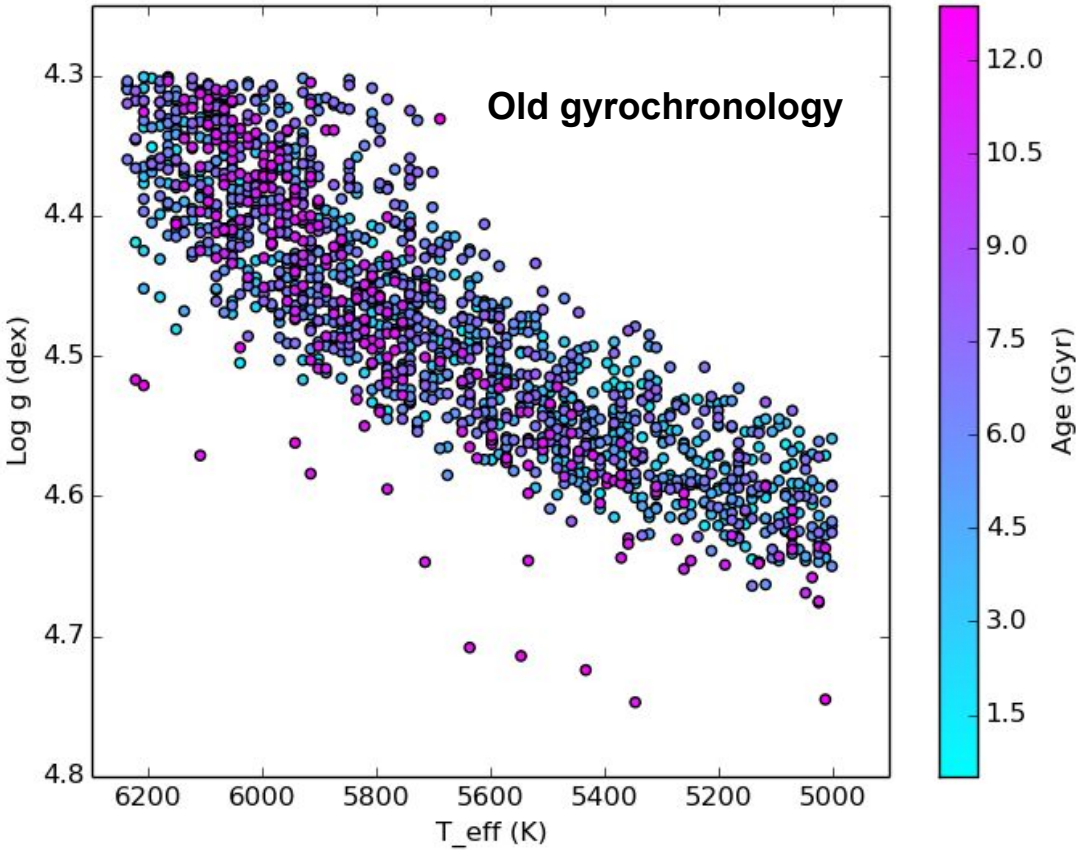

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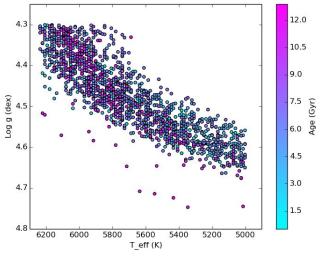

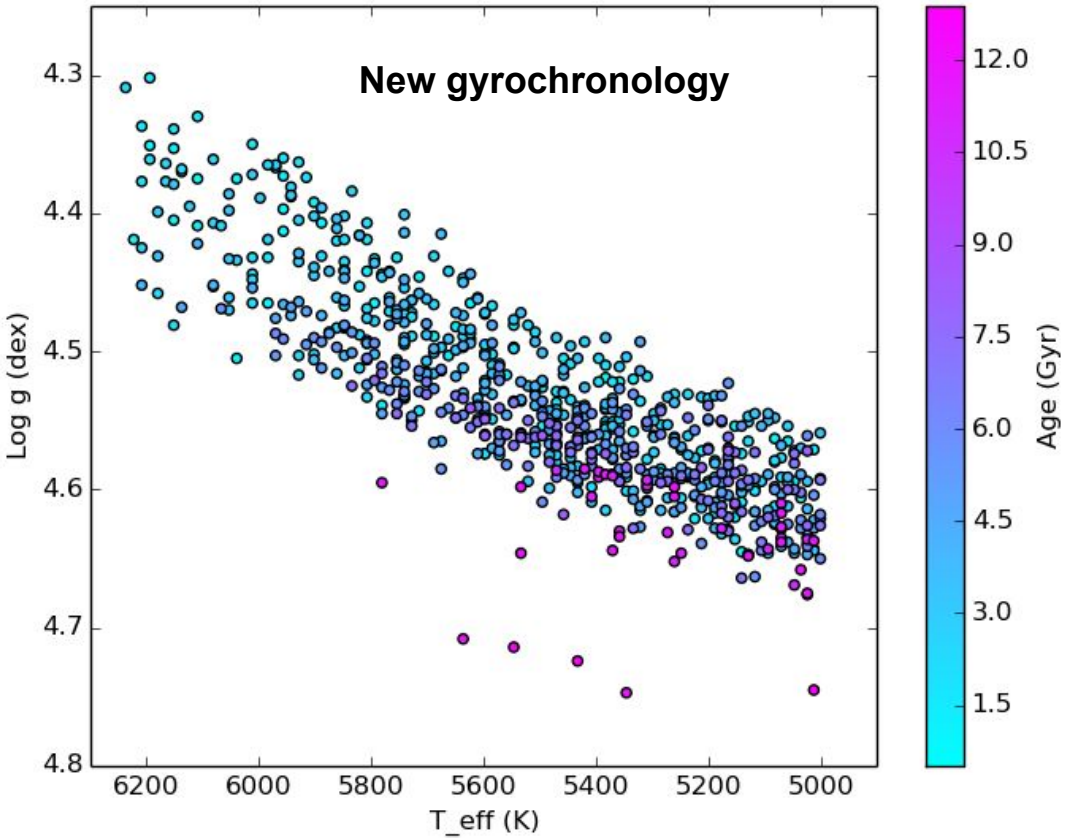

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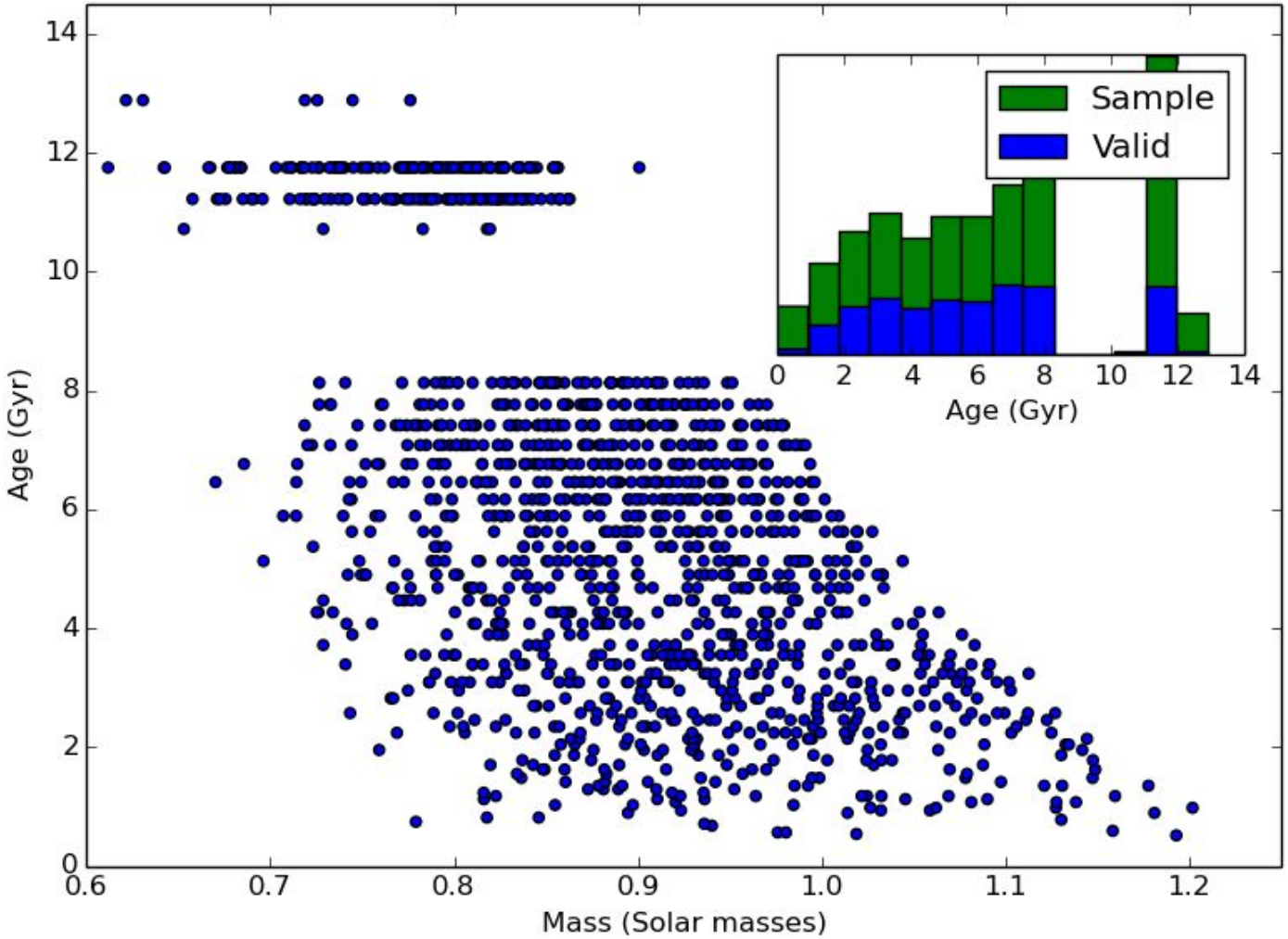
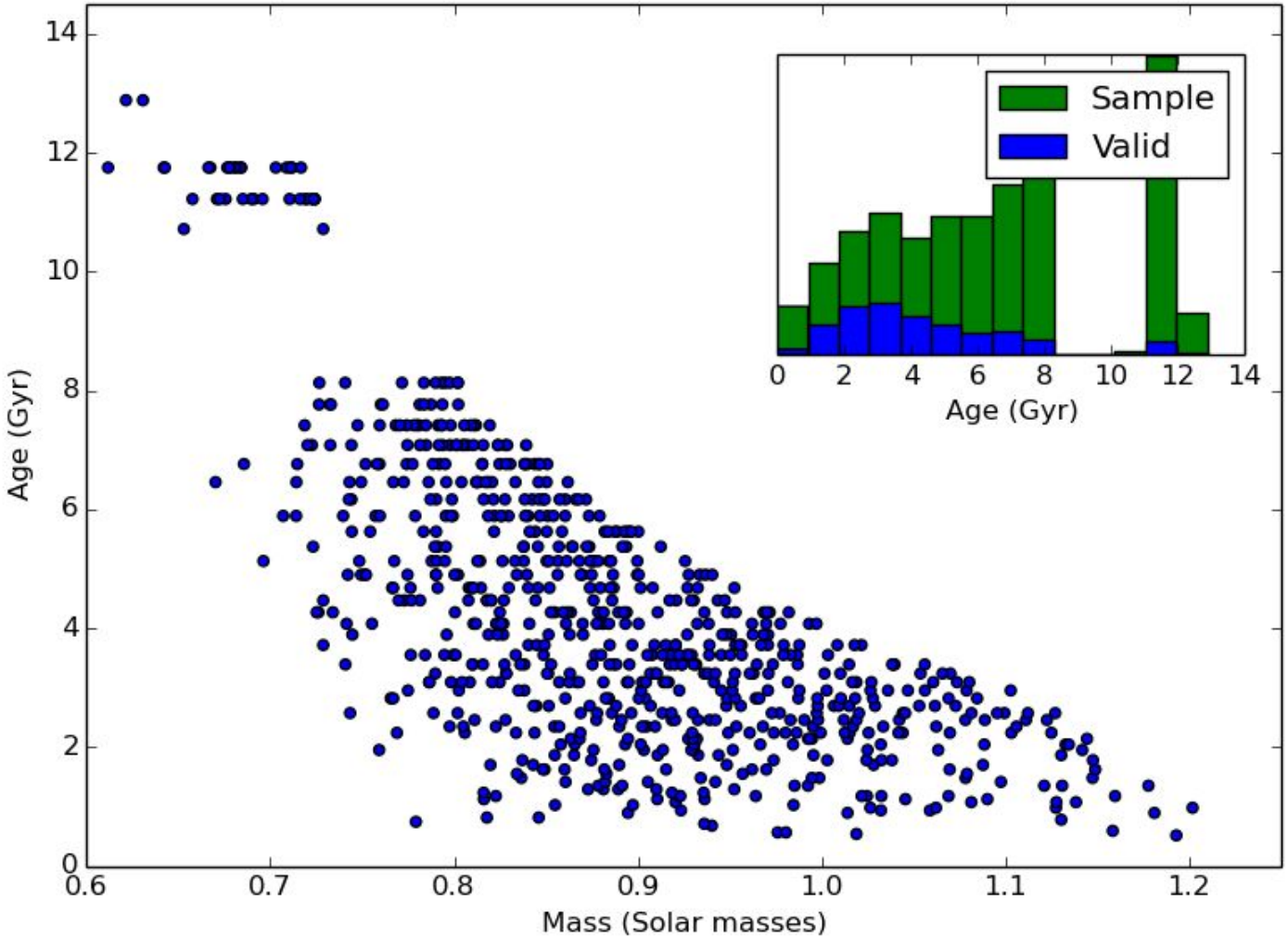

Age (Gyr)
Mass (Solar masses)
0
2
4
6
8
10
12
14
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Sample
Valid
0
2
4
6
8
10
12
14
Age (Gyr)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10
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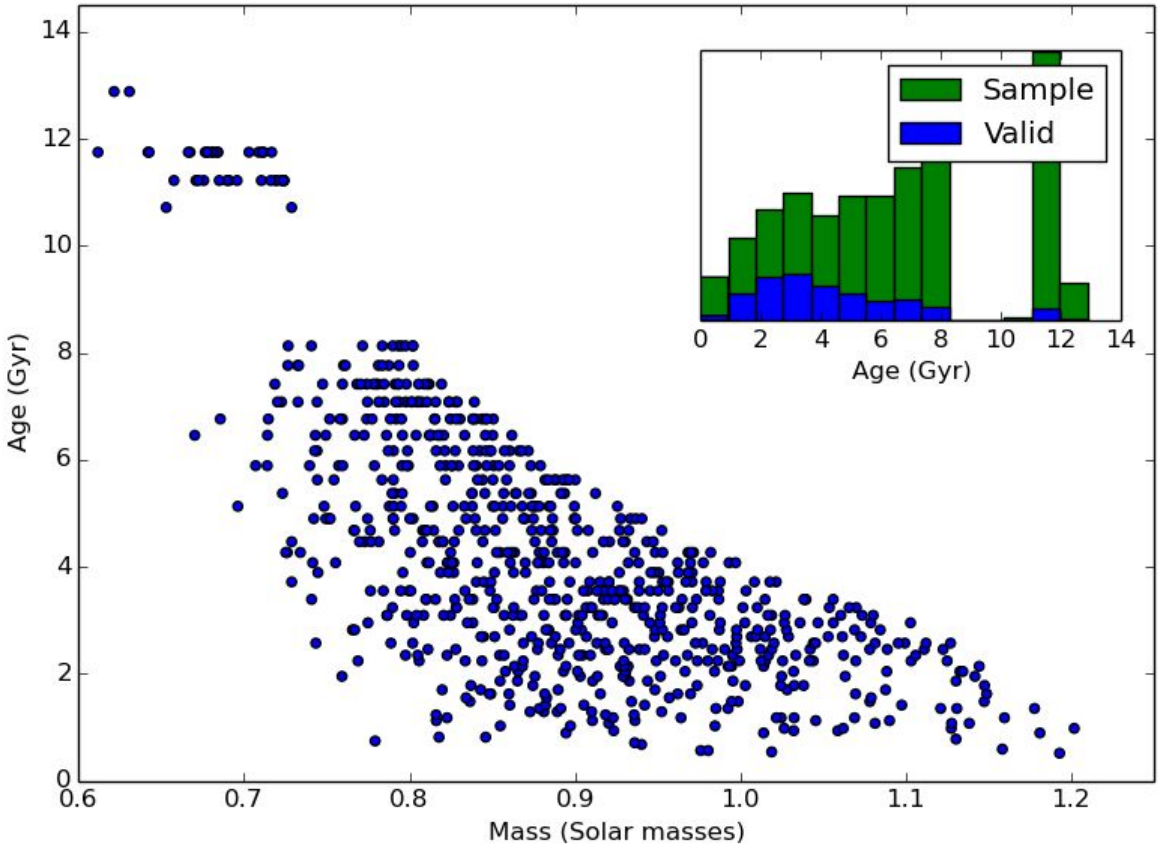
Age (Gyr)

Where do the dragons live?

- Too young
- Too massive
- Too small
- Too old
- Metallicity?



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