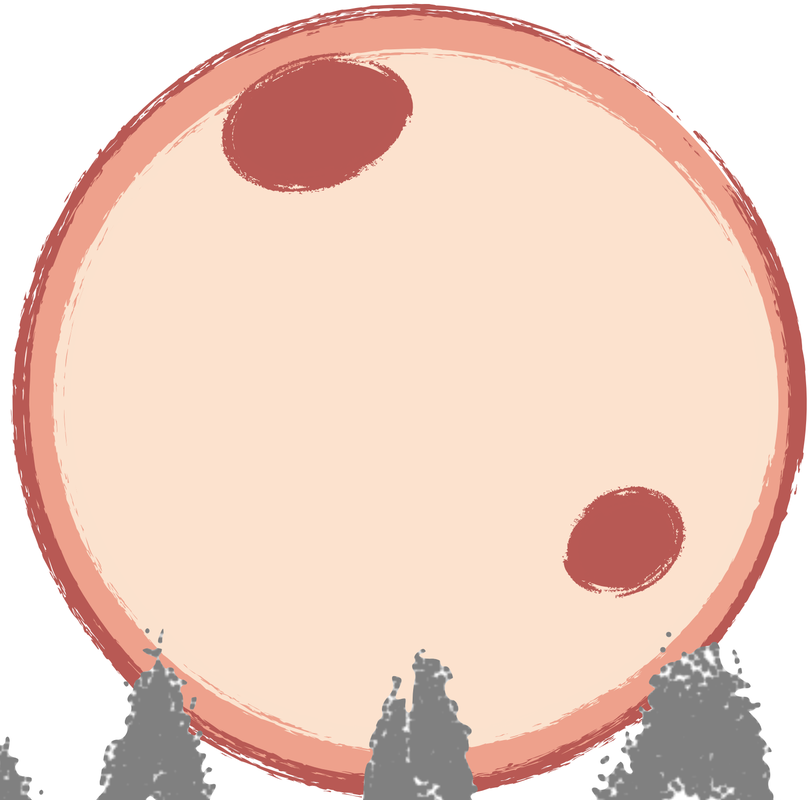
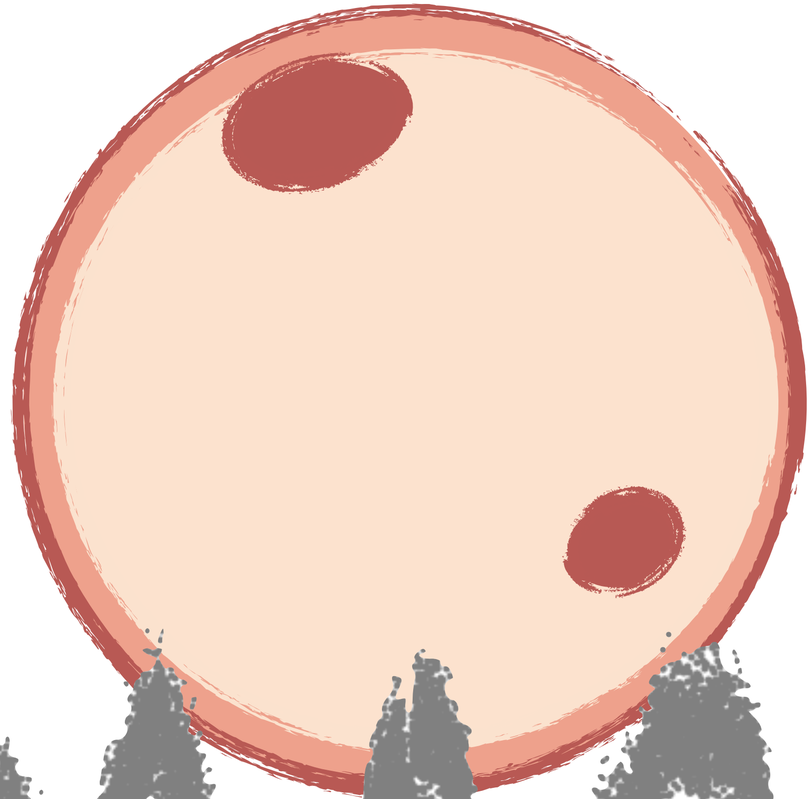
Planets around young, active stars



Elisabeth Newton
Dartmouth College

Planets around young, active stars

^and/or

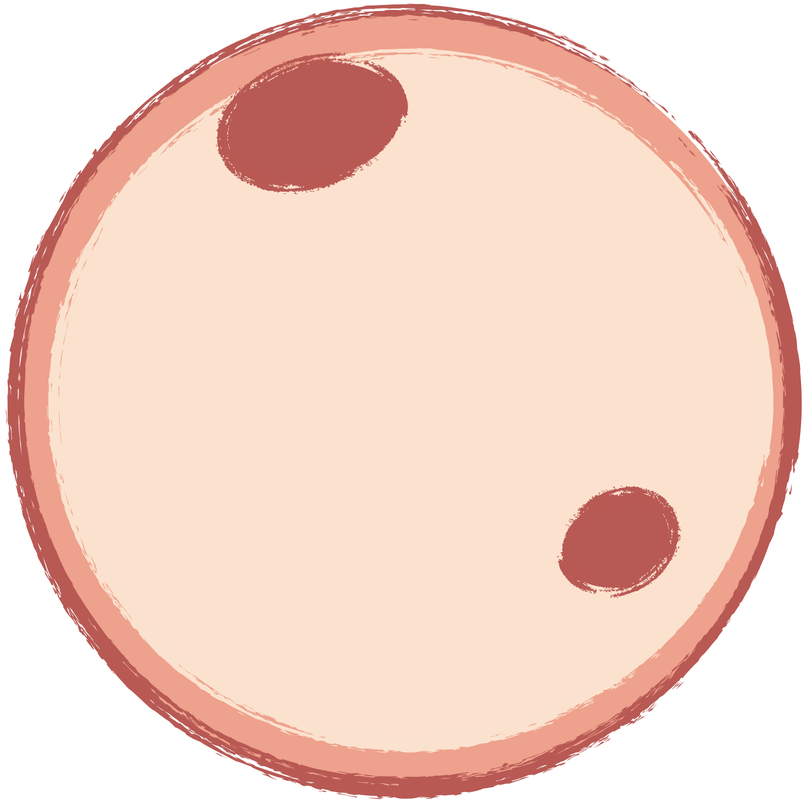


All young stars are active but not all active stars are young

(I’m talking about old M dwarfs)

Planets around young and/or active stars

An outline of this talk!

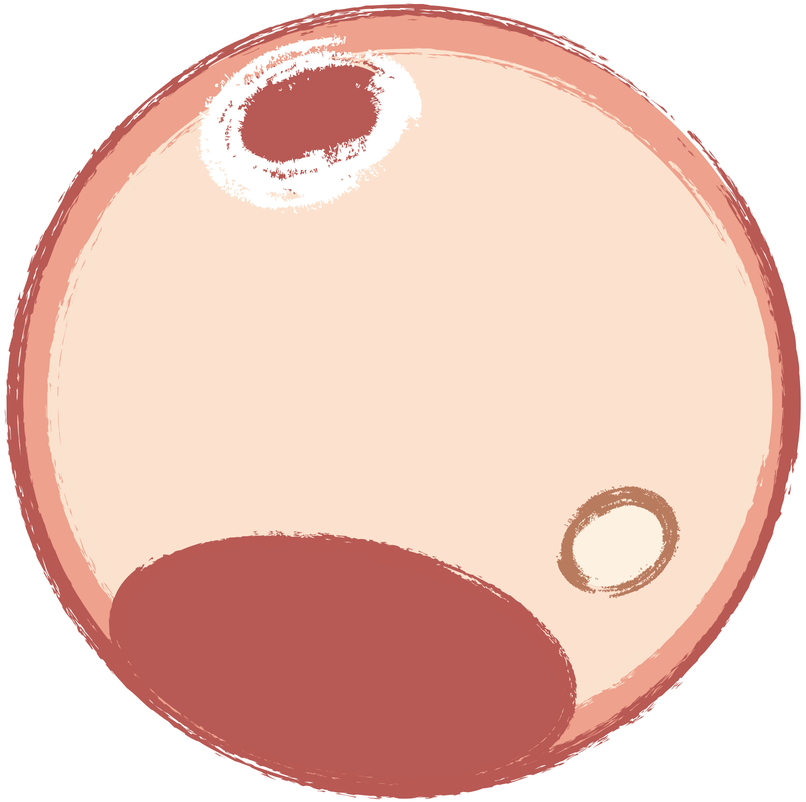


Age, activity, and rotation

Transit detection around active stars

Planet characterization around active stars

What I mean when I say starspots

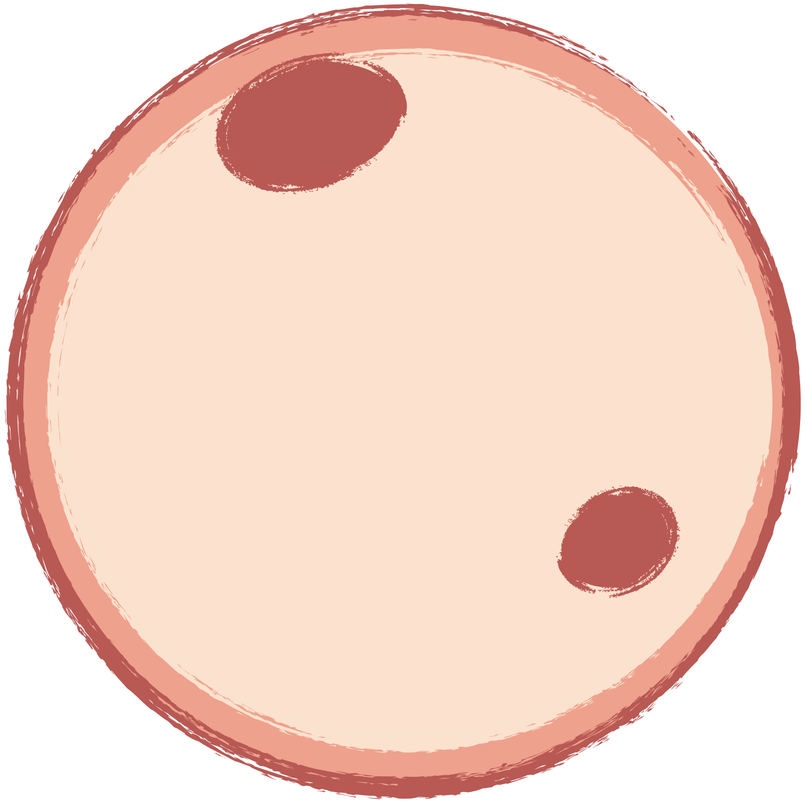


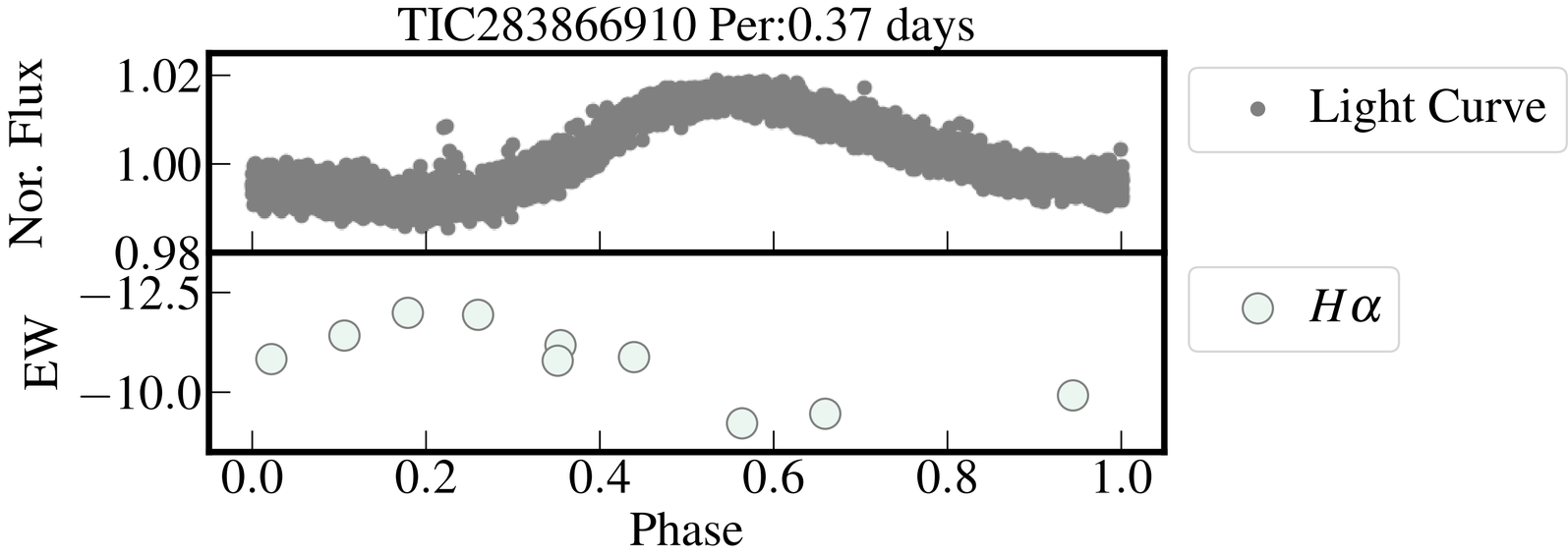
starspots ⇛

surface inhomogeneities

Bright faculae, dark faculae, bright spots, dark spots, granulation…

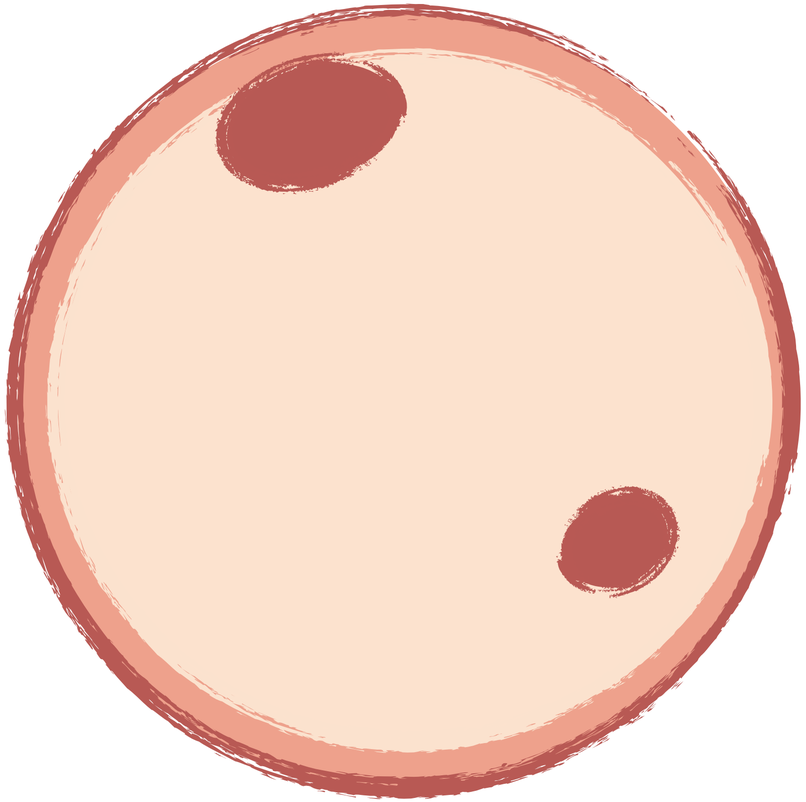
What I mean when I say starspots





Garcia Soto+25
Poster 2.09

Planets around young and/or active stars



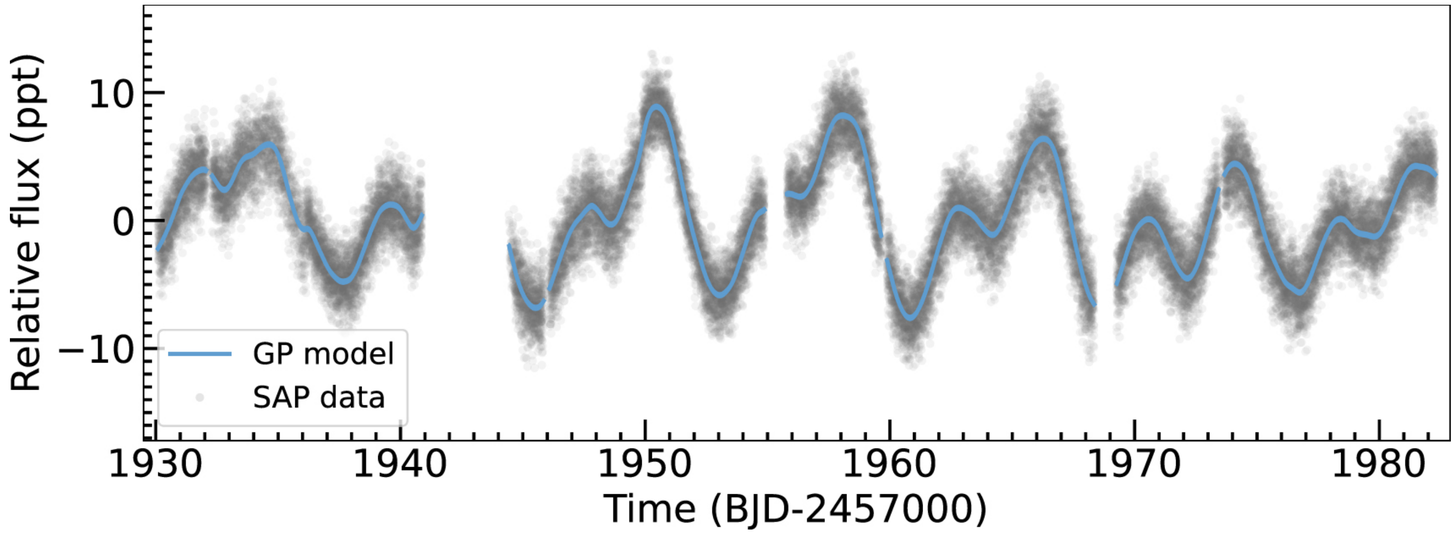
Age, rotation, and activity

Transit detection around active stars

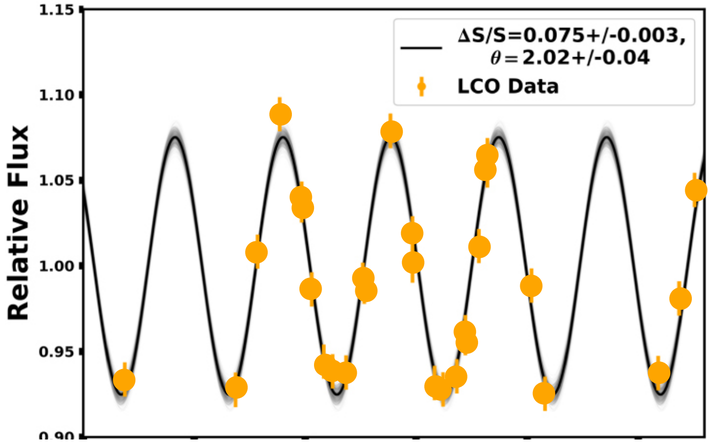
Planet characterization around active stars

Photometric rotation modulation

Changes in brightness due to starspots rotate in and out of view



TOI 2048 TESS broadband photometry | Newton+2022

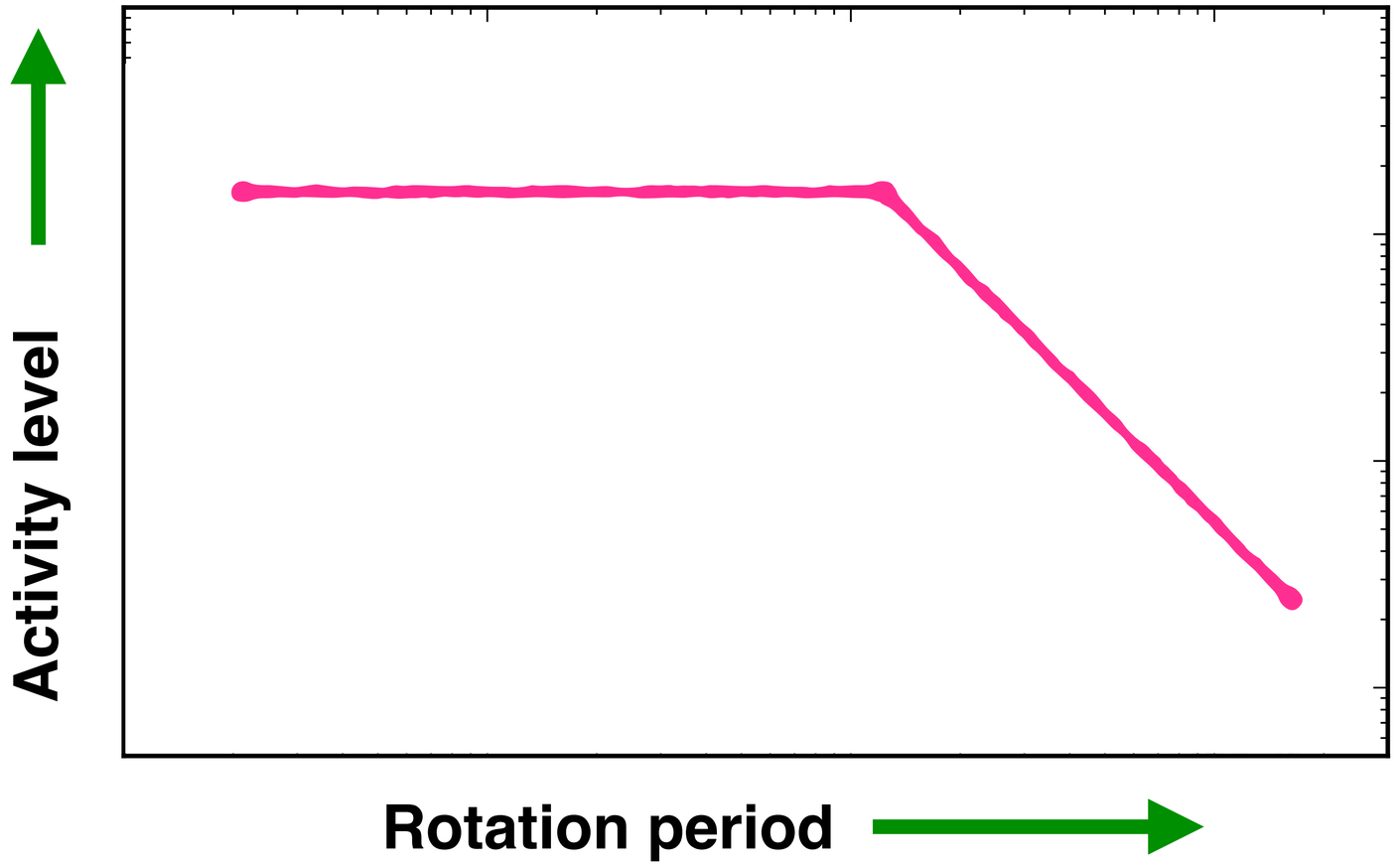


AU Mic ground-based *g*-band photometry | Waalkes+2024

See R Roettenbacher's talk for many more ways in which stars can be variable

Rotation drives other magnetic phenomena

This results from the stellar magnetic dynamo

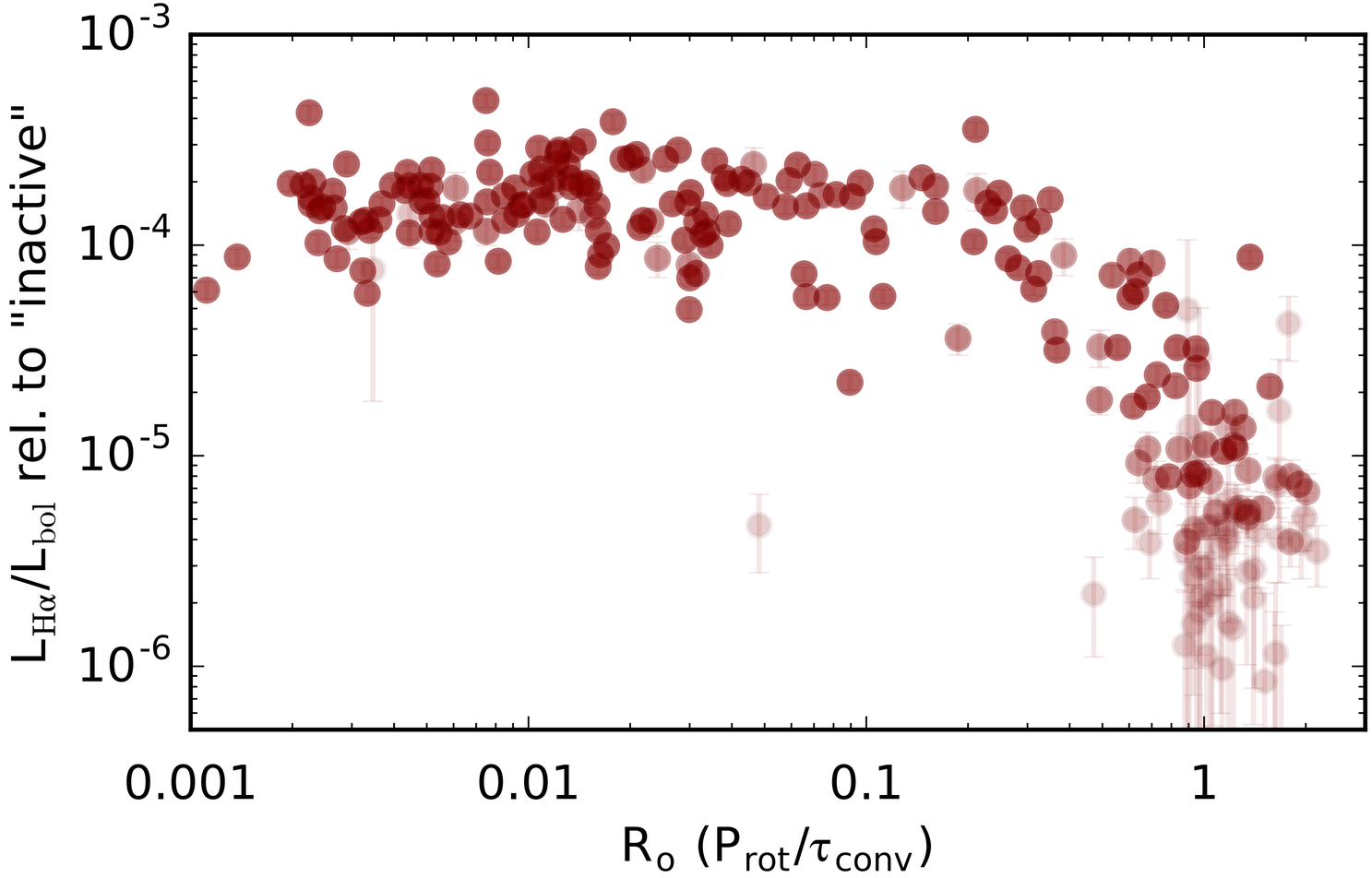


Activity can be…

- high-energy emission
  - chromospheric
  - coronal
- spot coverage
- flares rate

Rotation drives other magnetic phenomena

Example: chromospheric activity in M dwarfs

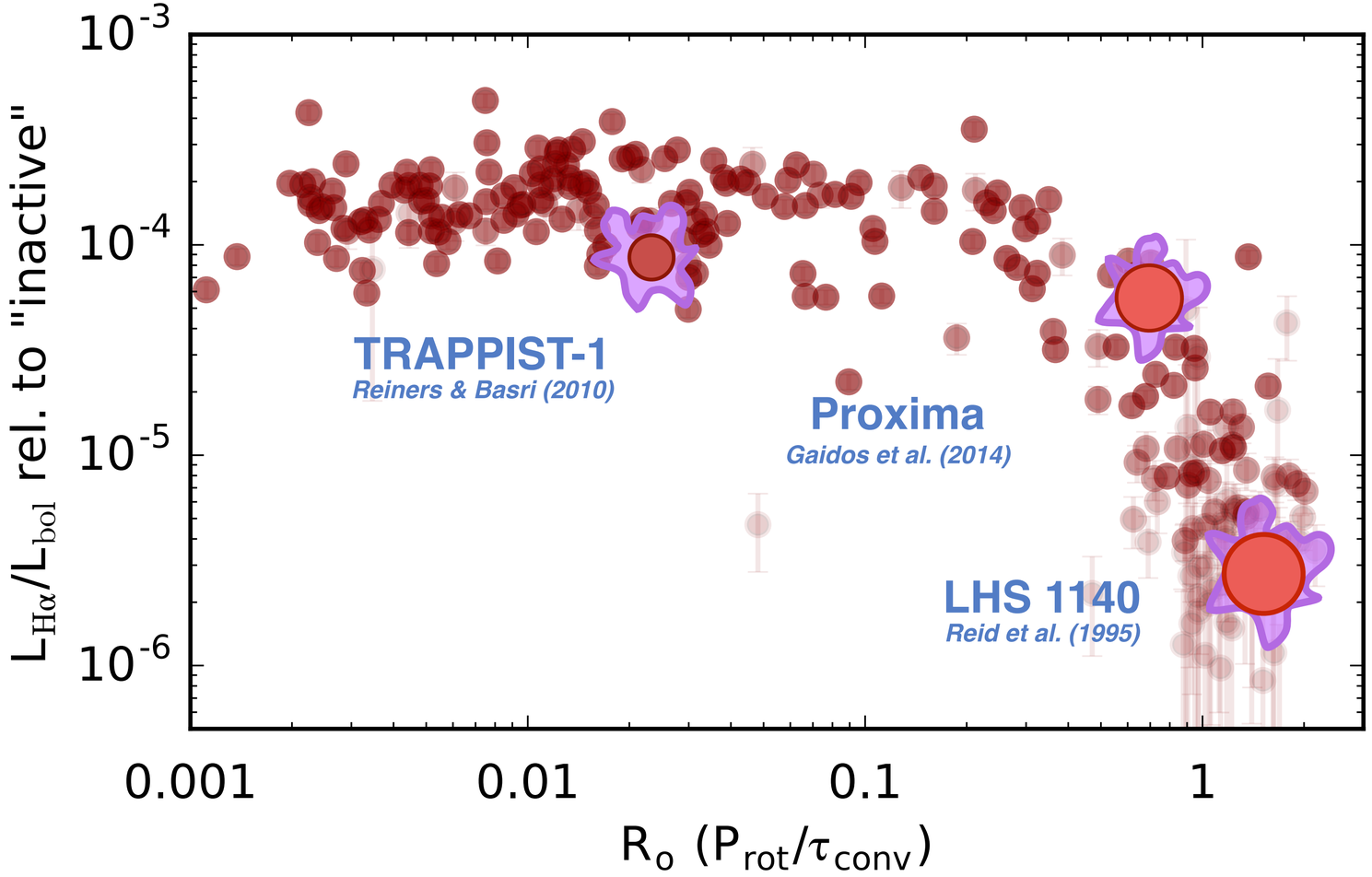


Nearby dMs

Newton+2017

Rotation drives other magnetic phenomena

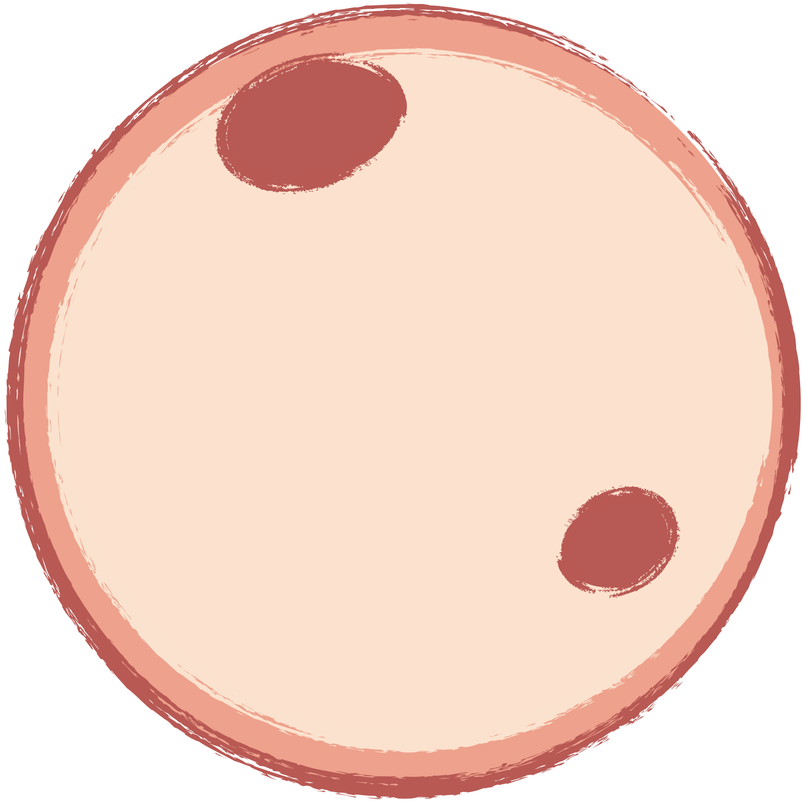
Example: chromospheric activity in M dwarfs

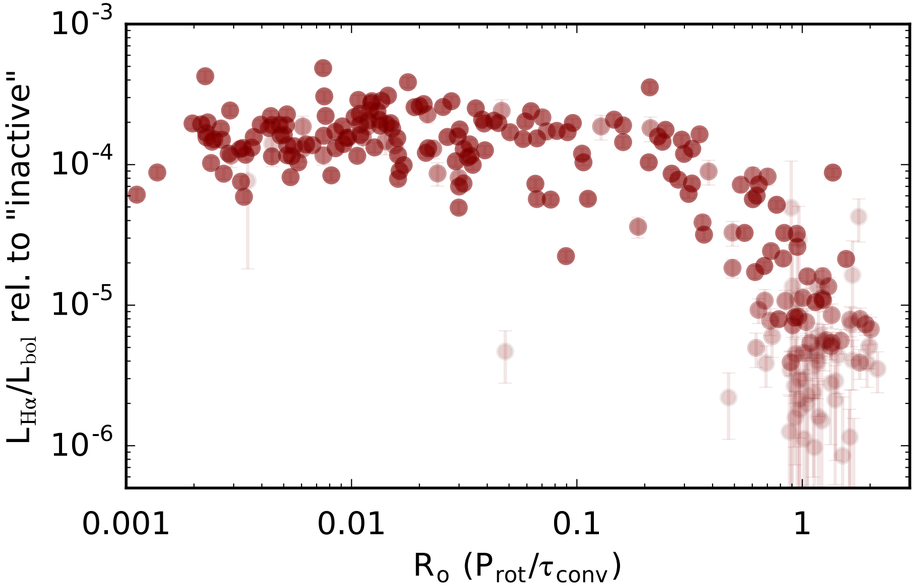


Nearby dMs

Newton+2017

Planets around young and/or active stars

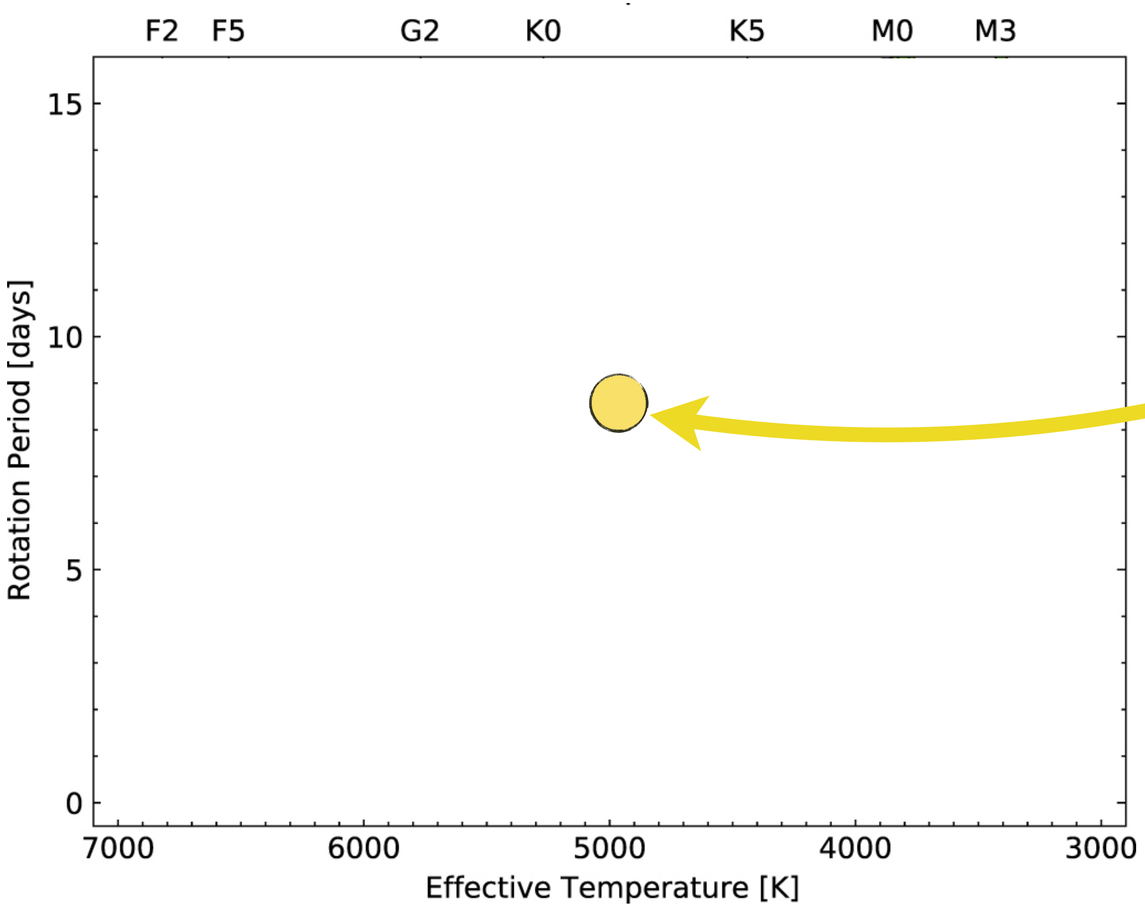


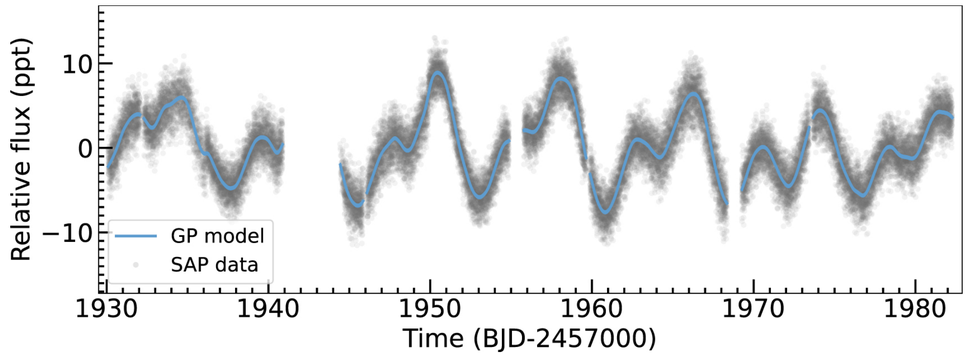


We now have a connection between rotation and activity.
How do these change with age?

What determines the rotation period of a star?

The temperature (or mass | spectral type | color) - rotation relation





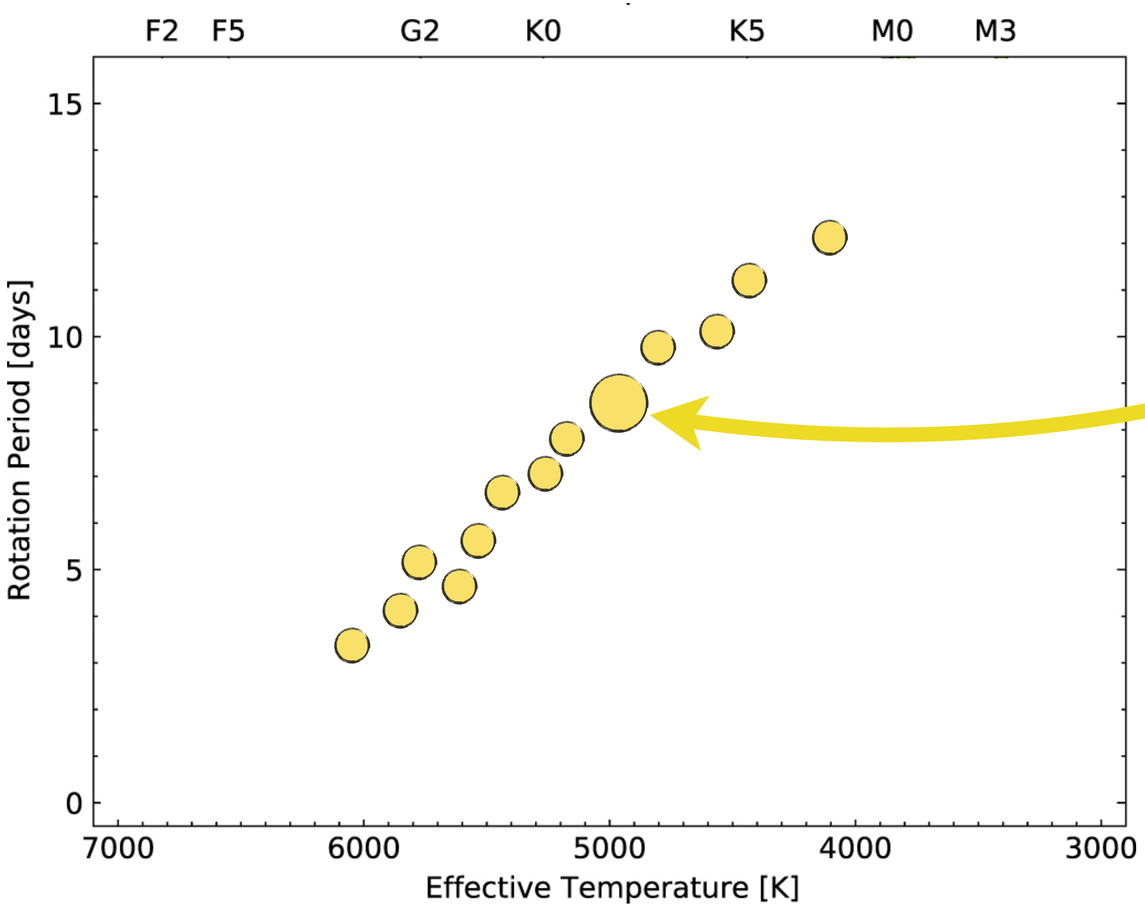
Newton+2022 (Group-X)

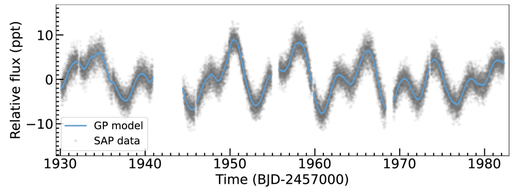
Each point is a photometric rotation period

See talk by L Bouma

Mass+age determines the rotation period of a star

The temperature (or mass | spectral type | color) - rotation relation



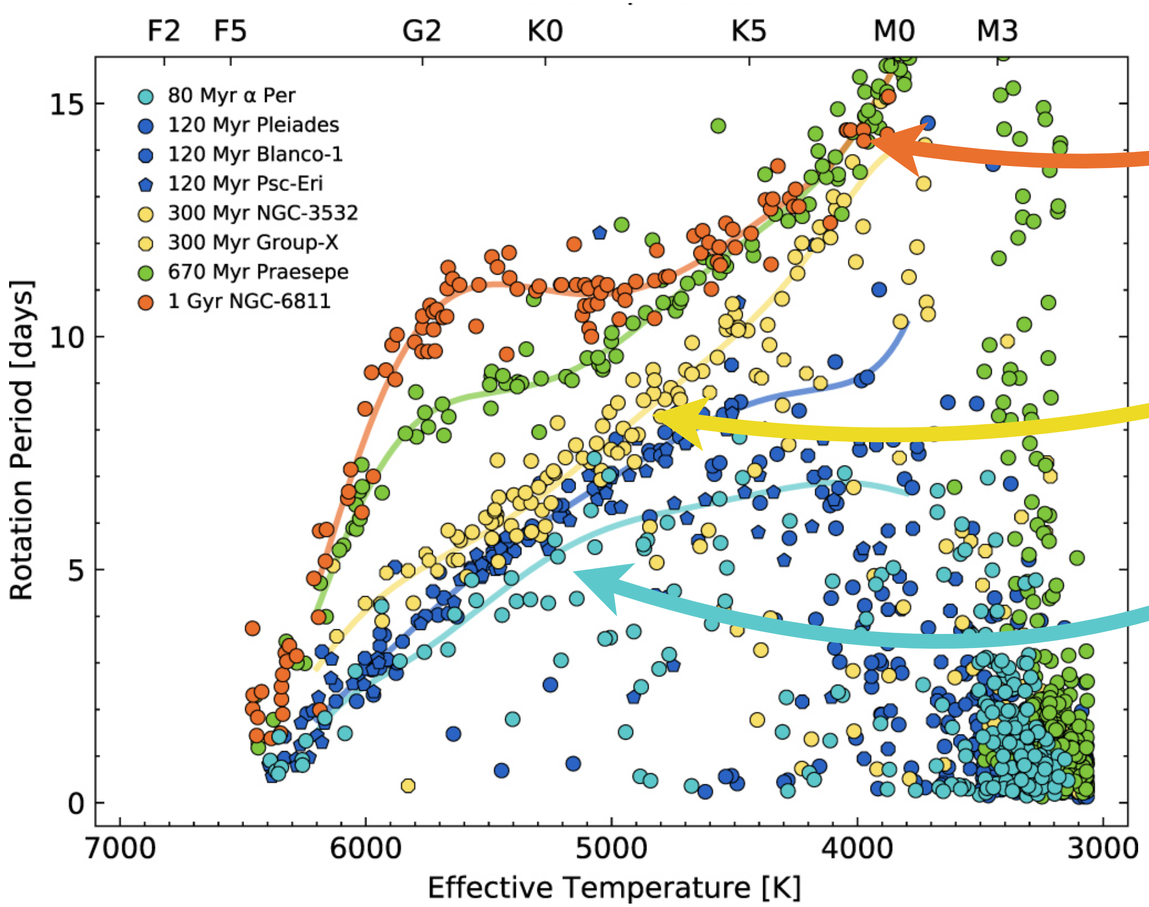


Group-X (300 Myr)

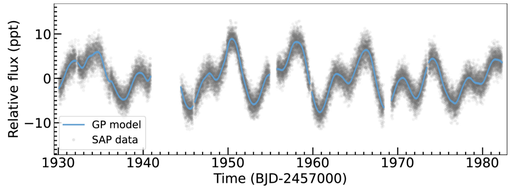
See talk by L Bouma

Mass+age determines the rotation period of a star

The temperature (or mass | spectral type | color) - rotation relation



Oldest



Group-X (300 Myr)

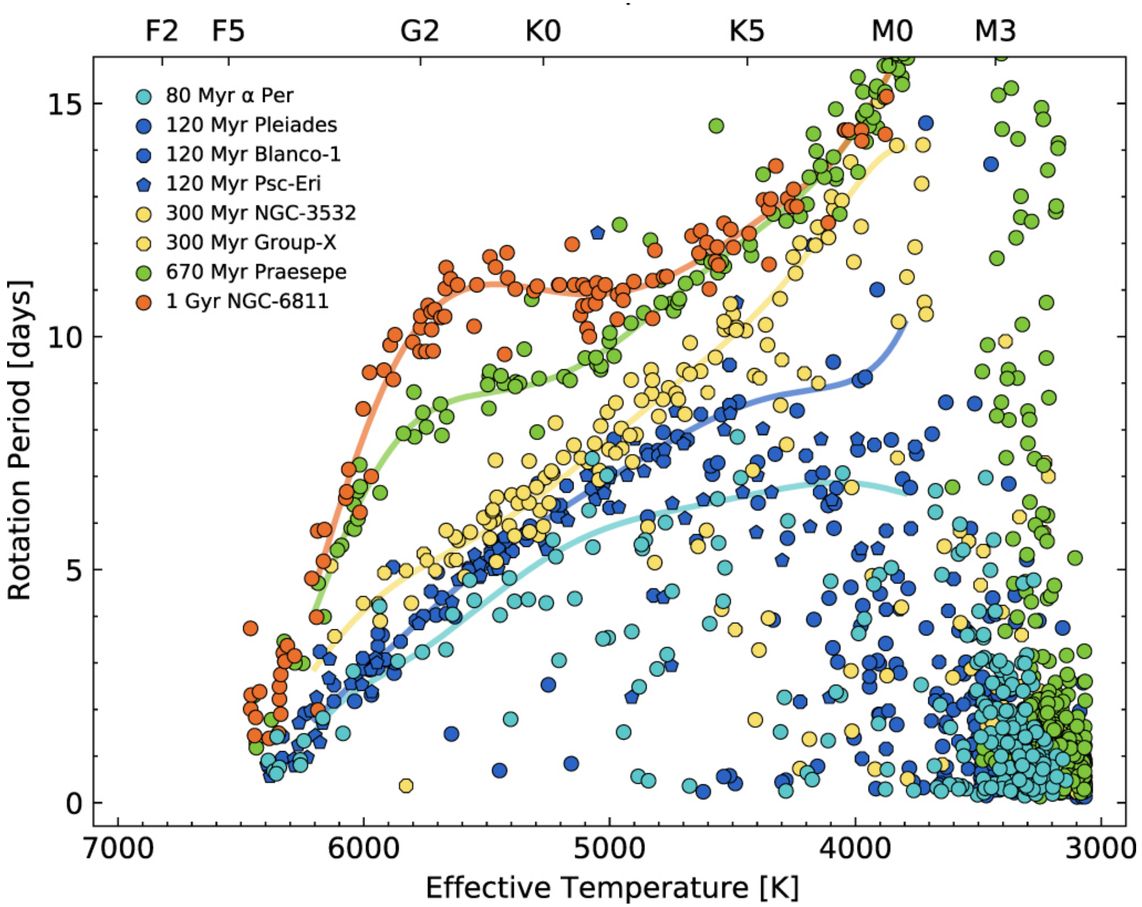
Youngest

Each color is a cluster of a different age

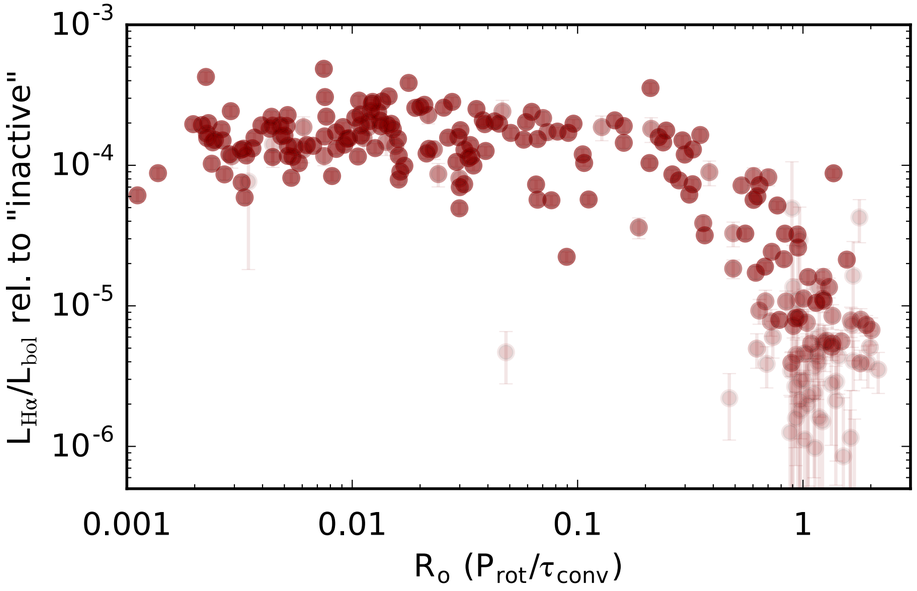
Bouma+2023

Young stars are magnetically active

As they age, stars spin down, and get less active



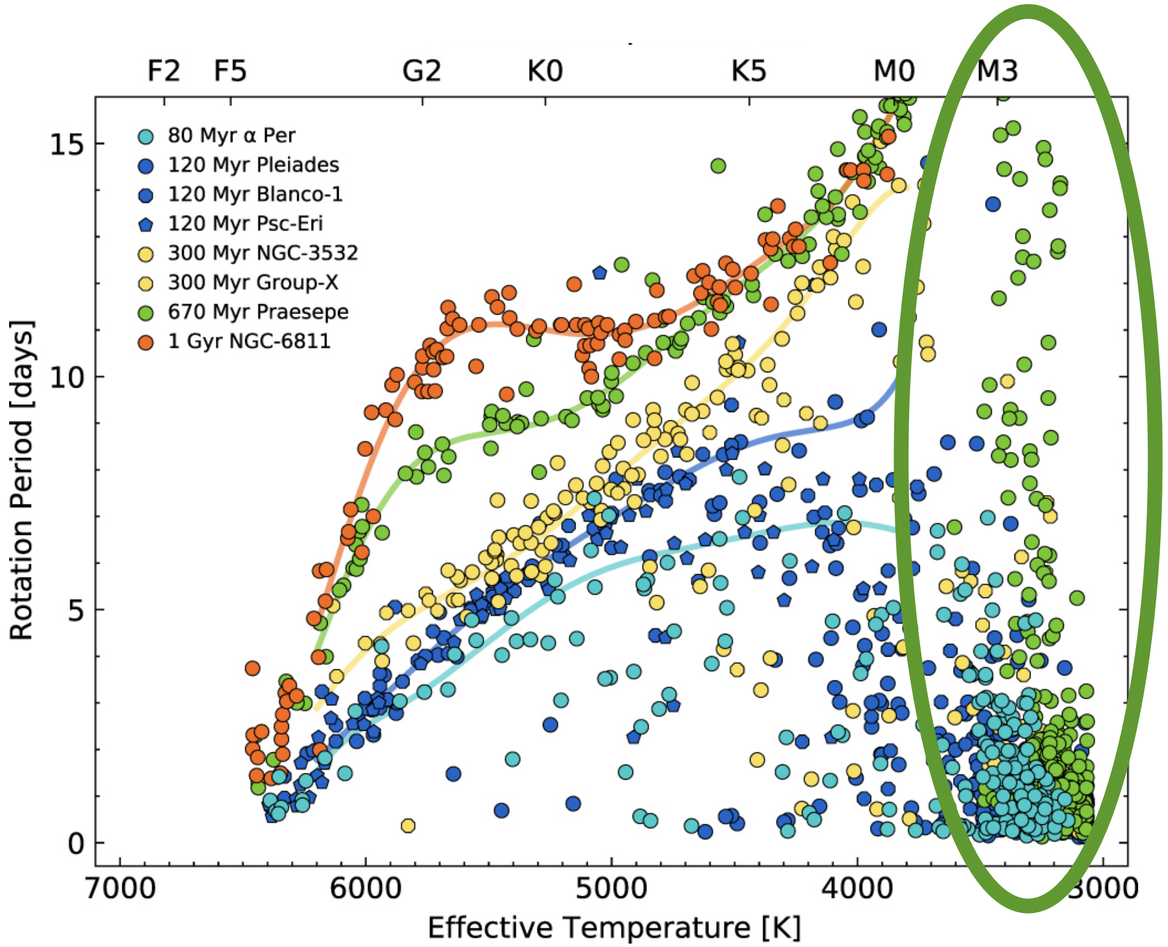
+



Bouma+2023

Newton+2017

M dwarfs are magnetically active

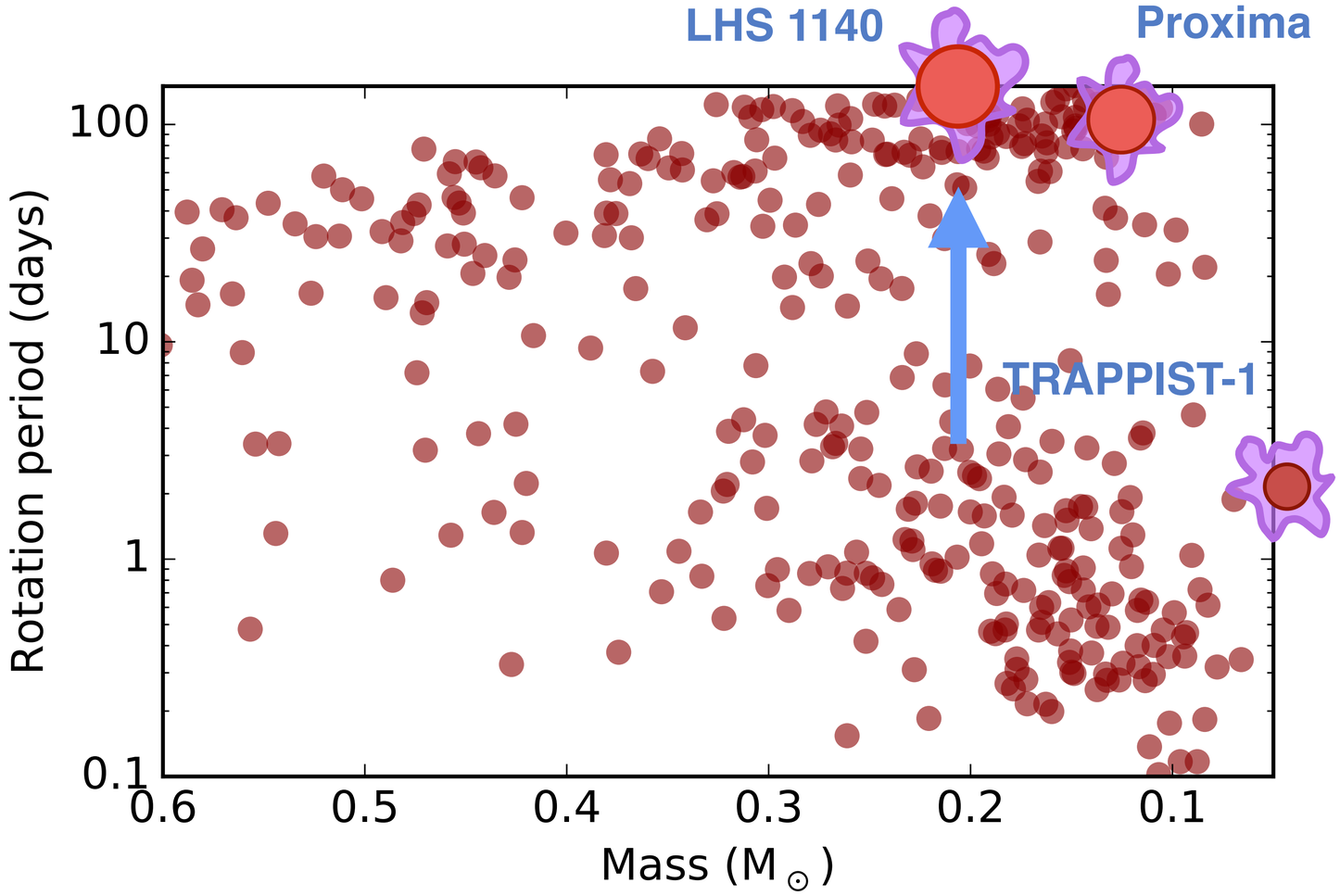


Low-mass M dwarfs are still rapidly rotating at the oldest cluster shown here

Bouma+2023

M dwarfs are magnetically active

It takes M dwarfs a few Gyr spin-down

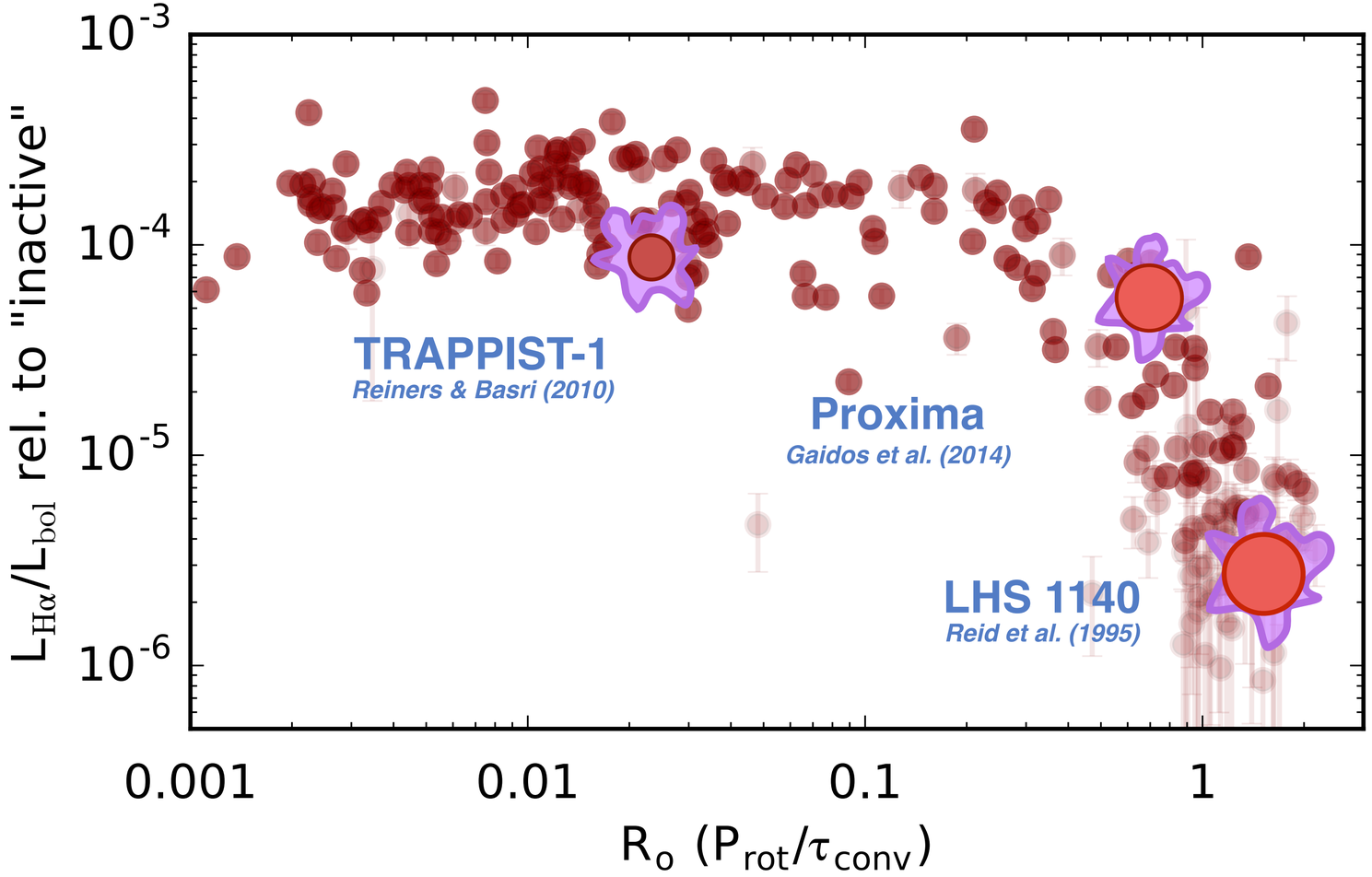


It takes a 0.2M⊙ star 2-3 Gyr to spin down

Newton+2016
Kiman+2021
Medina+2022
Pass+2024

M dwarfs are magnetically active

Proxima is 5 Gyr old and barely past the breakpoint/knee

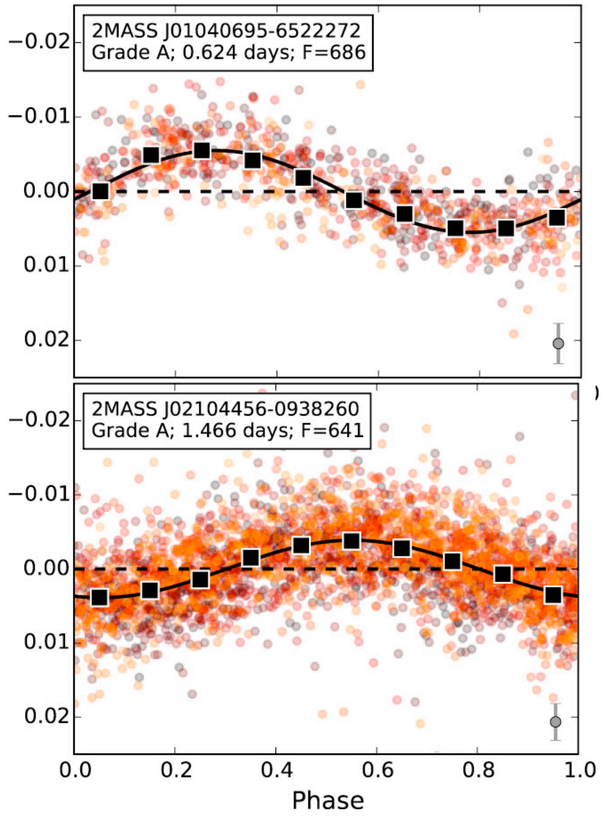


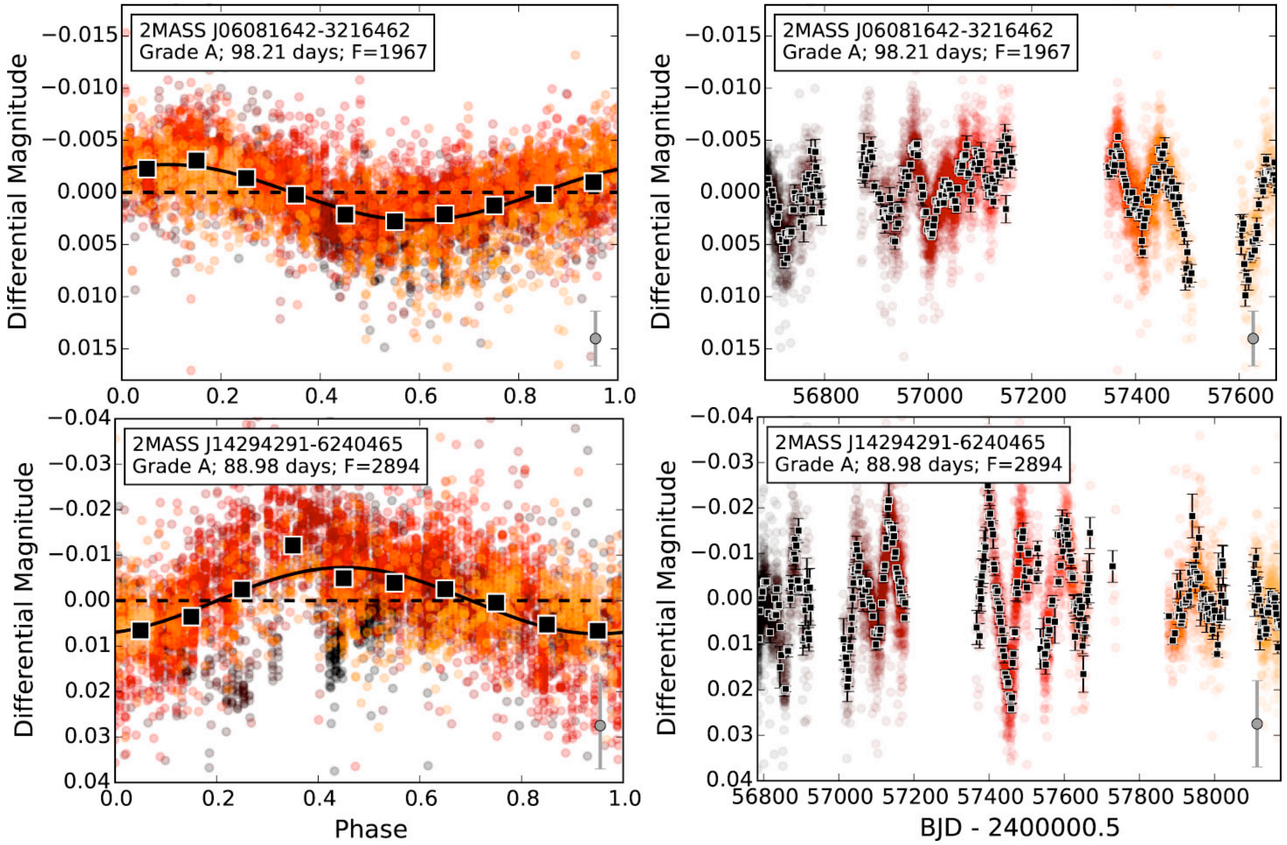
Nearby dMs

Newton+2017

M dwarfs are magnetically active

Large photometric variability even at long rotation periods

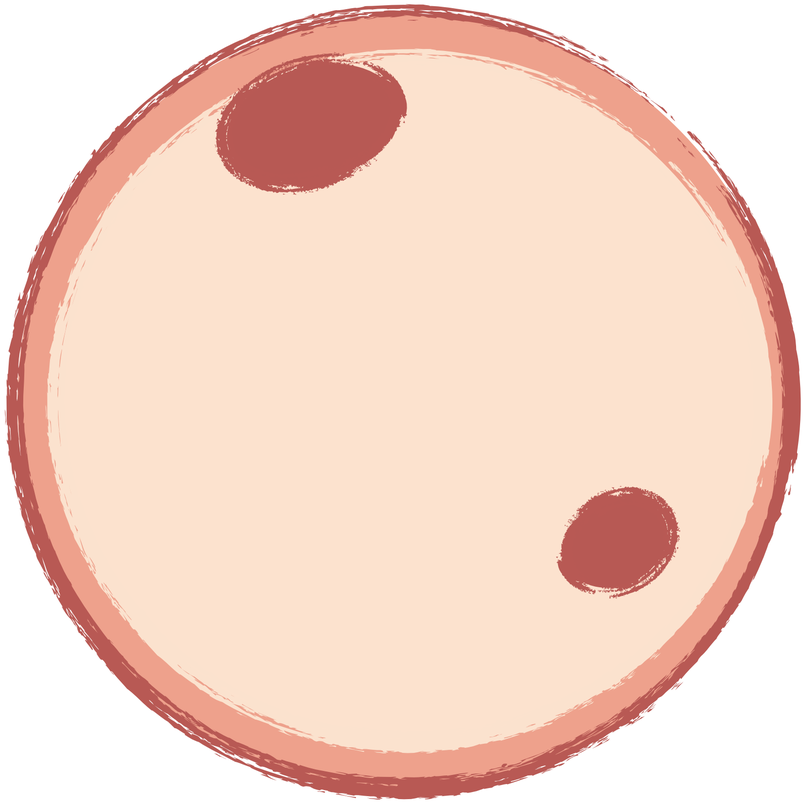




Short periods

Long periods

Planets around young and/or active stars



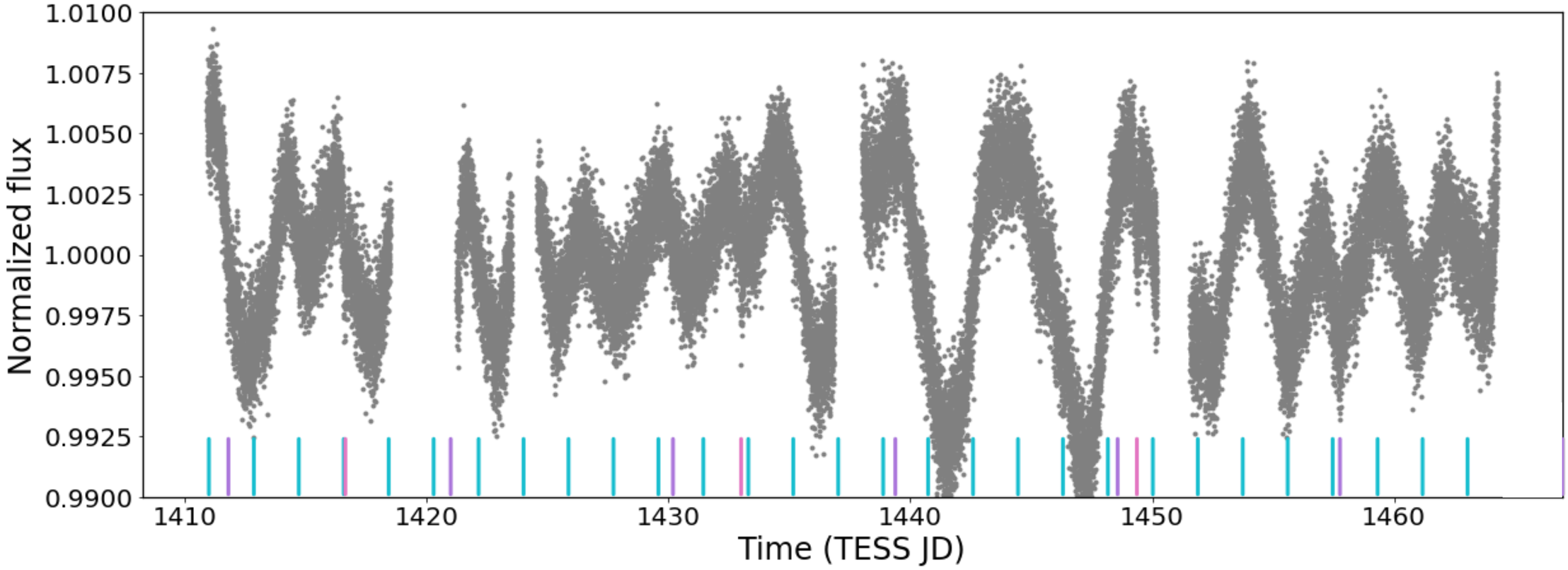
Age, rotation, and activity

Transit detection around active stars

Planet characterization around active stars

Transit signals in variable lightcurves

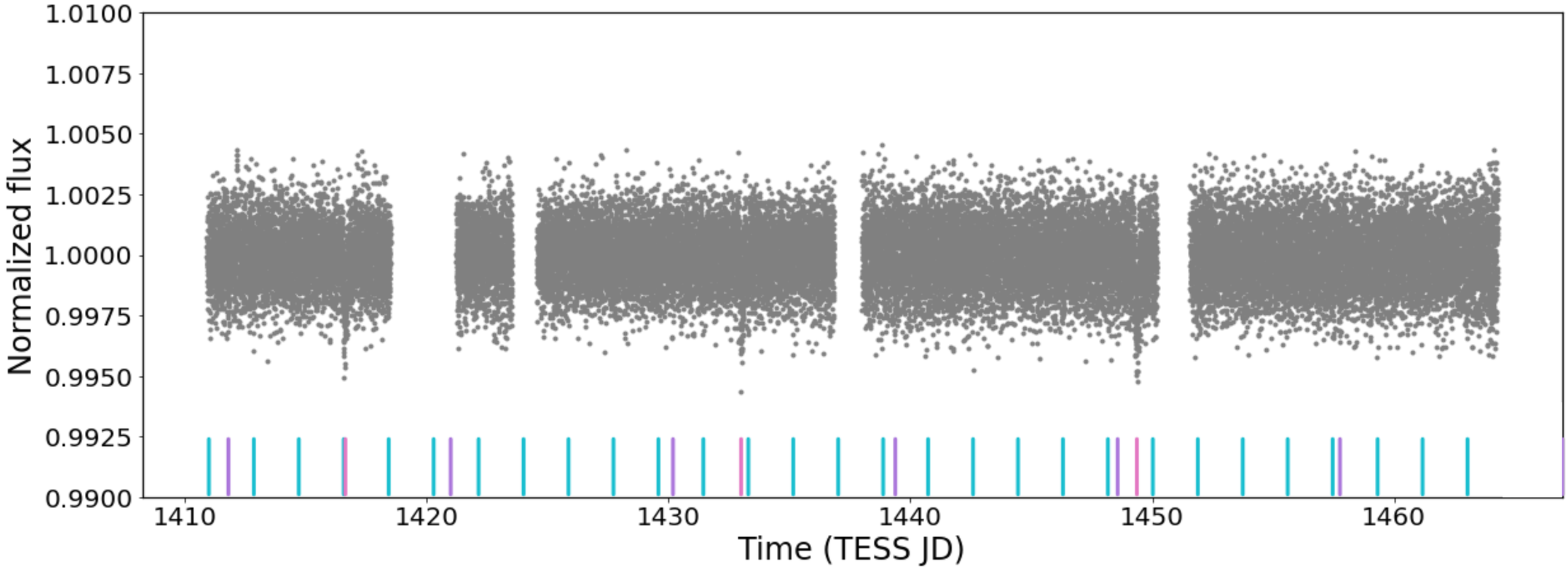
TESS lightcurve of 120 Myr-old TOI 451 with three planets



Newton+2021

Transit signals in variable lightcurves

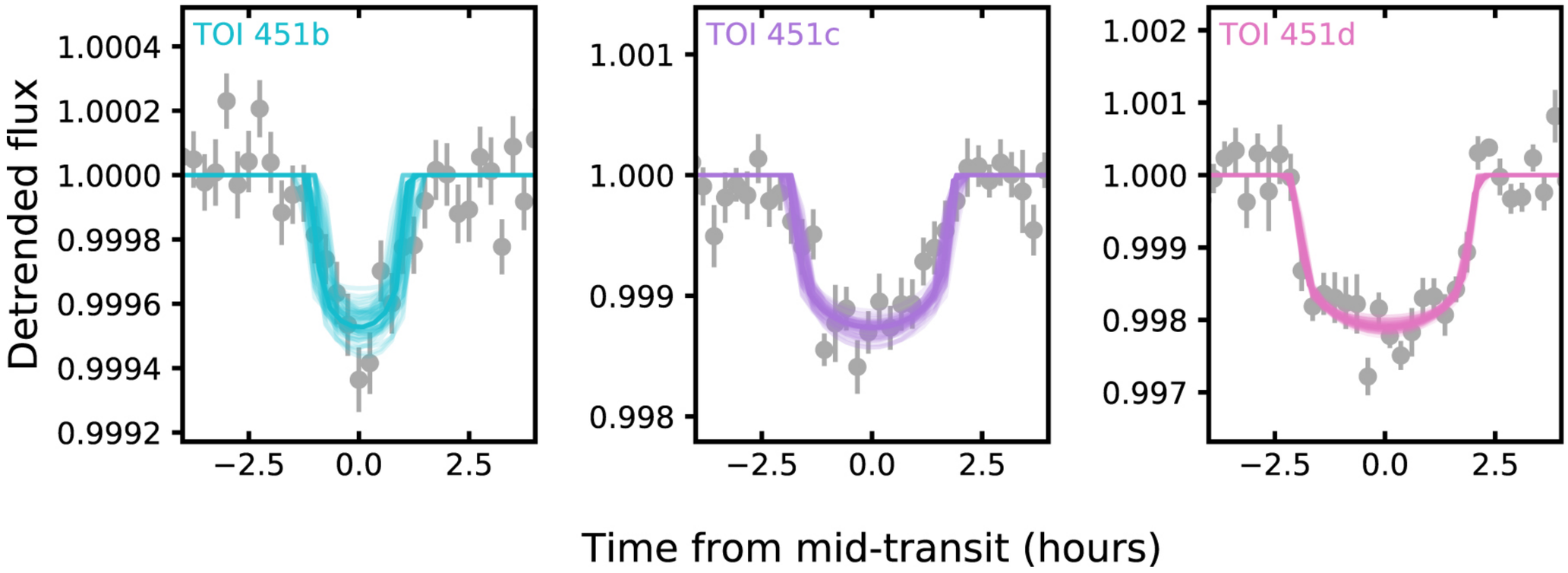
Detrended TESS lightcurve masking the known planets



Newton+2021

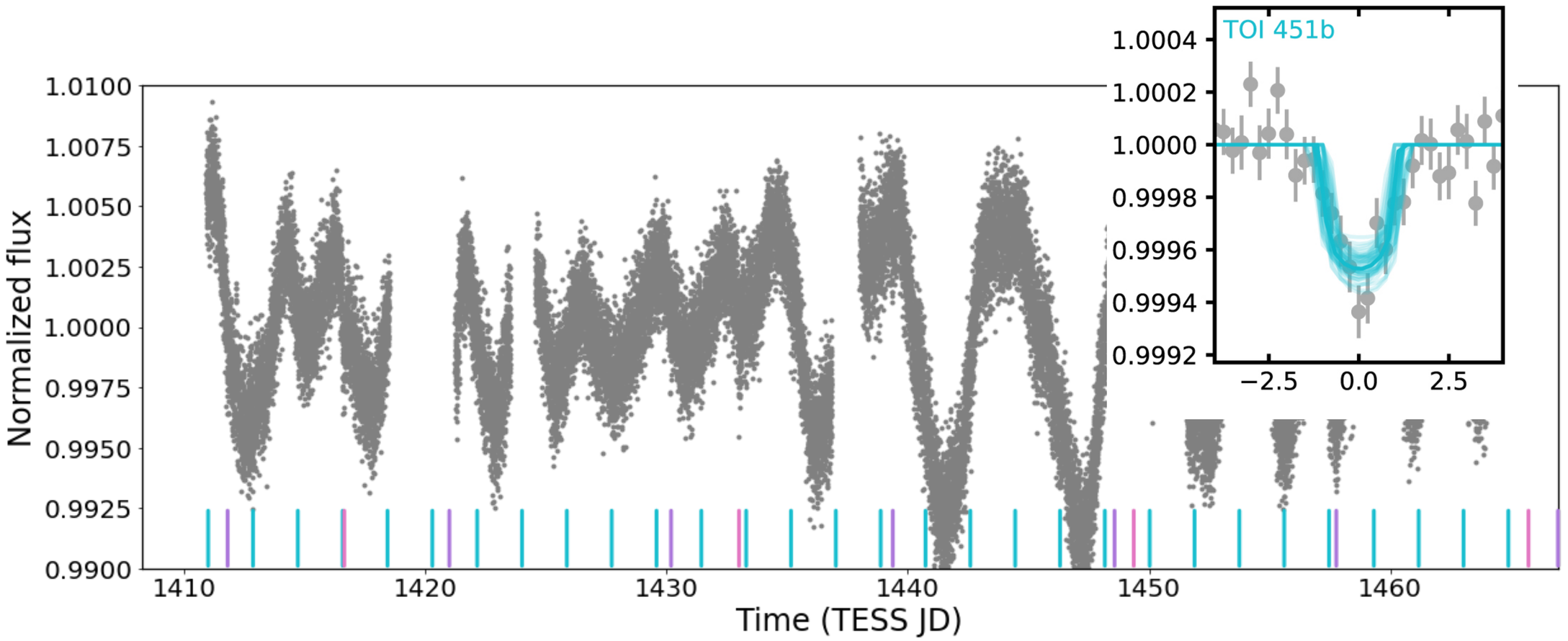
Transit signals in variable lightcurves

The planets: simultaneous fit of rotation+planet signals

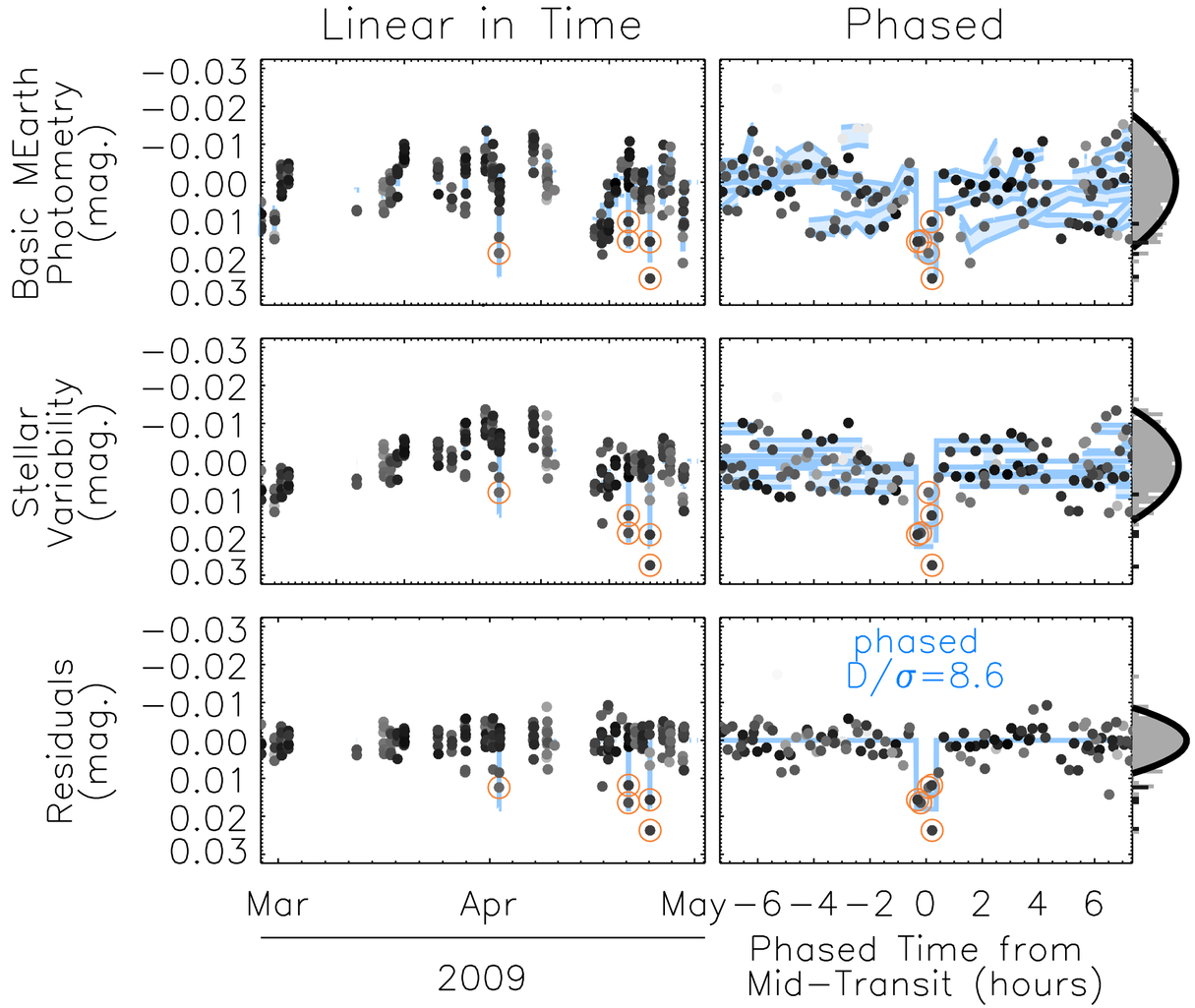


How do we actually find this planets in these data?

“Bridging the clean-first, search-later divide” - ZK Berta-Thompson



Finding transiting planets in a MEarth light curve

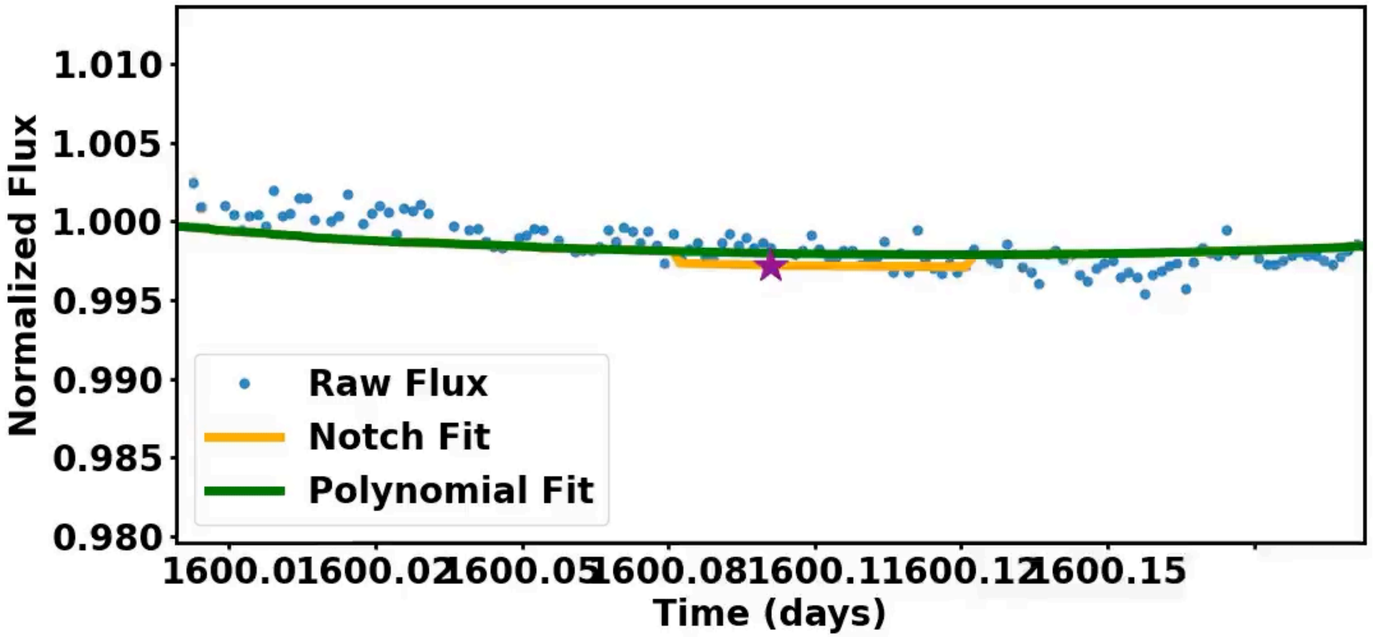


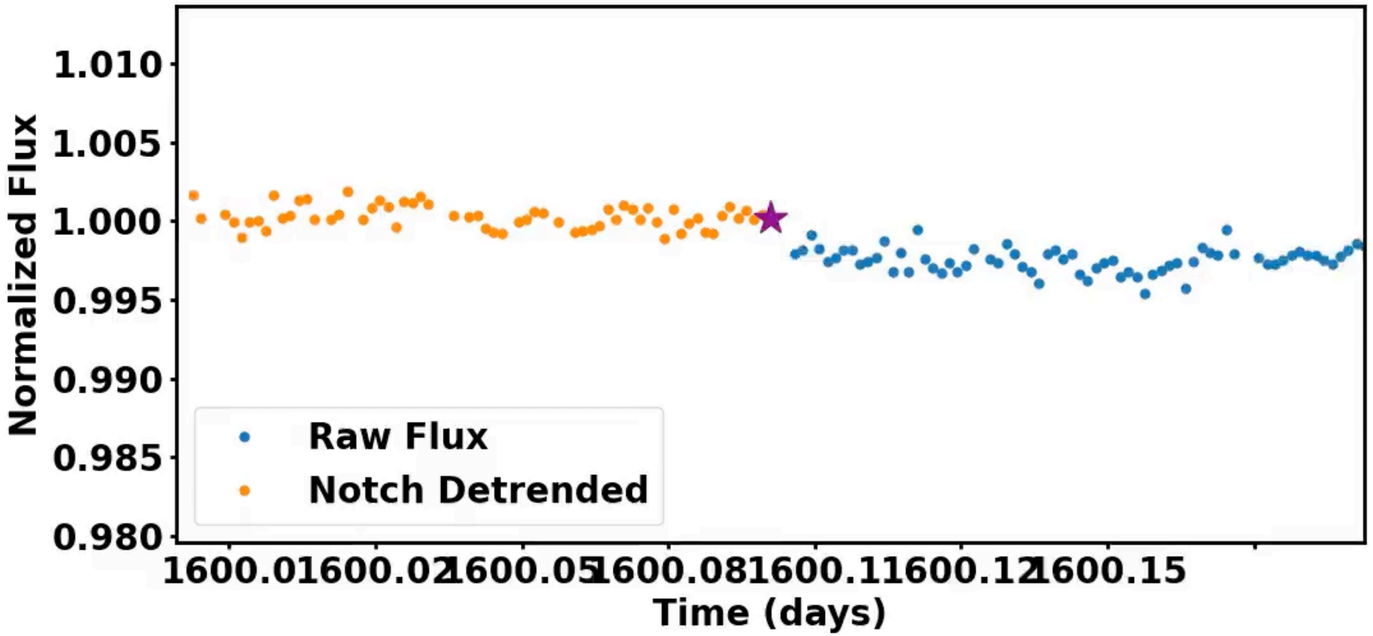
MEarth marginalizes over corrections for **systematics**

and **starspot variability**

when searching for **planetary transits**.

Charbonneau, Berta, et al. (2009), Berta et al. (2011), Berta et al. (2012b)



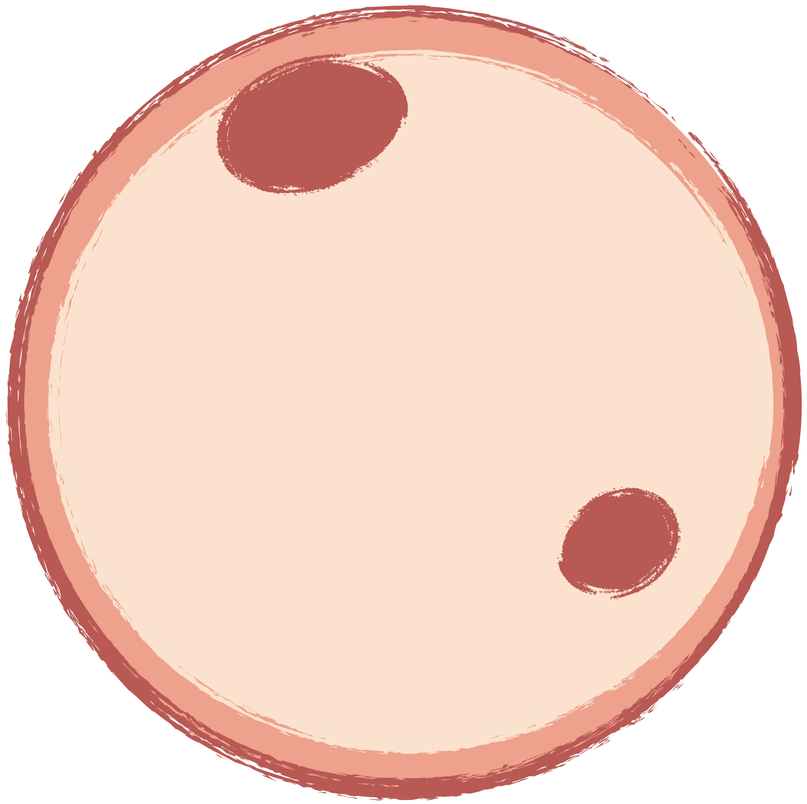


Finding transiting planets in K2 and TESS lightcurves

The Notch filter

Rizzuto+2017
Barber+2024

Planets around young and/or active stars



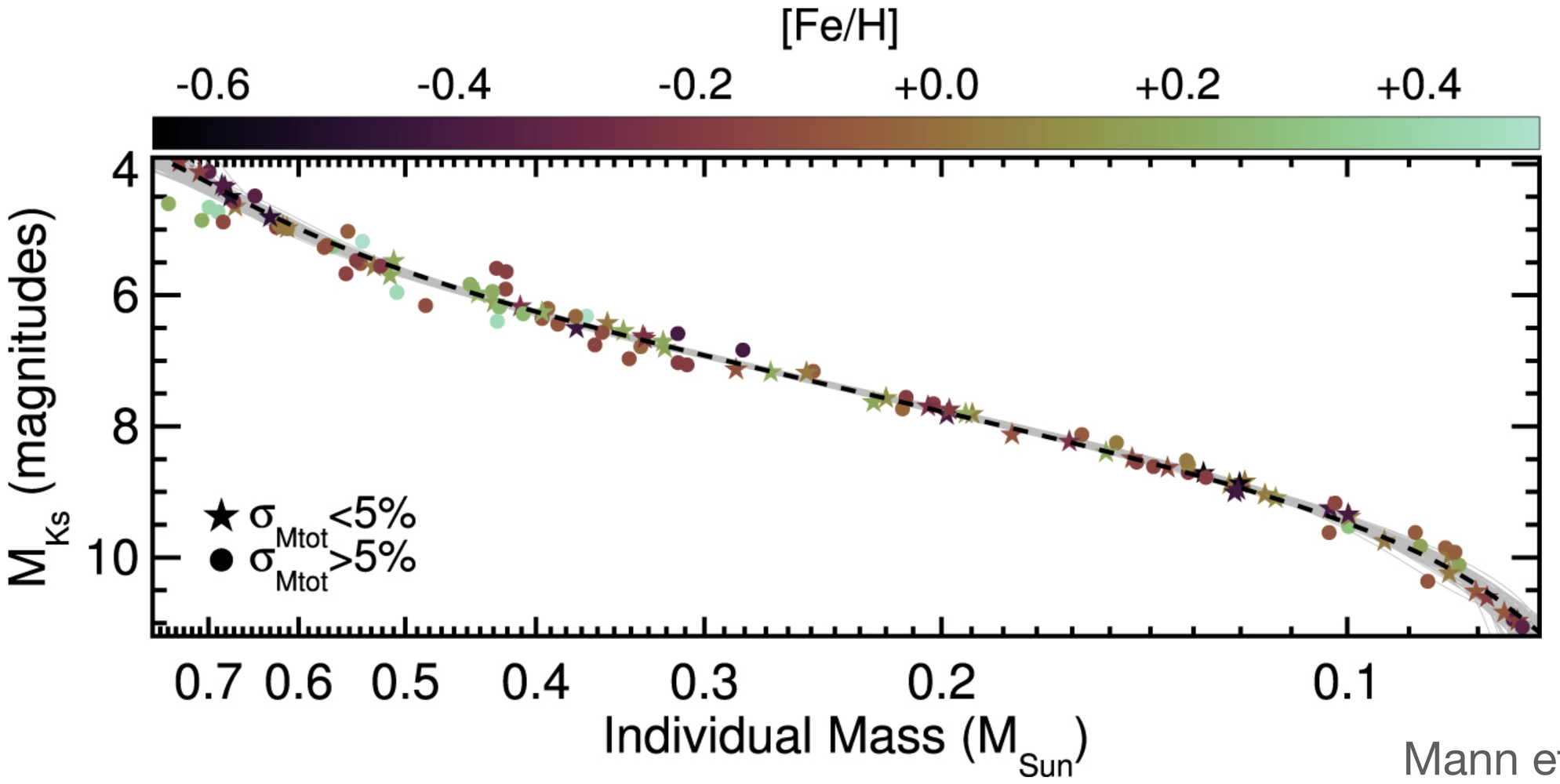
Age, rotation, and activity

Transit detection around active stars

Planet characterization around active stars

M dwarfs masses from the M_K-mass relation

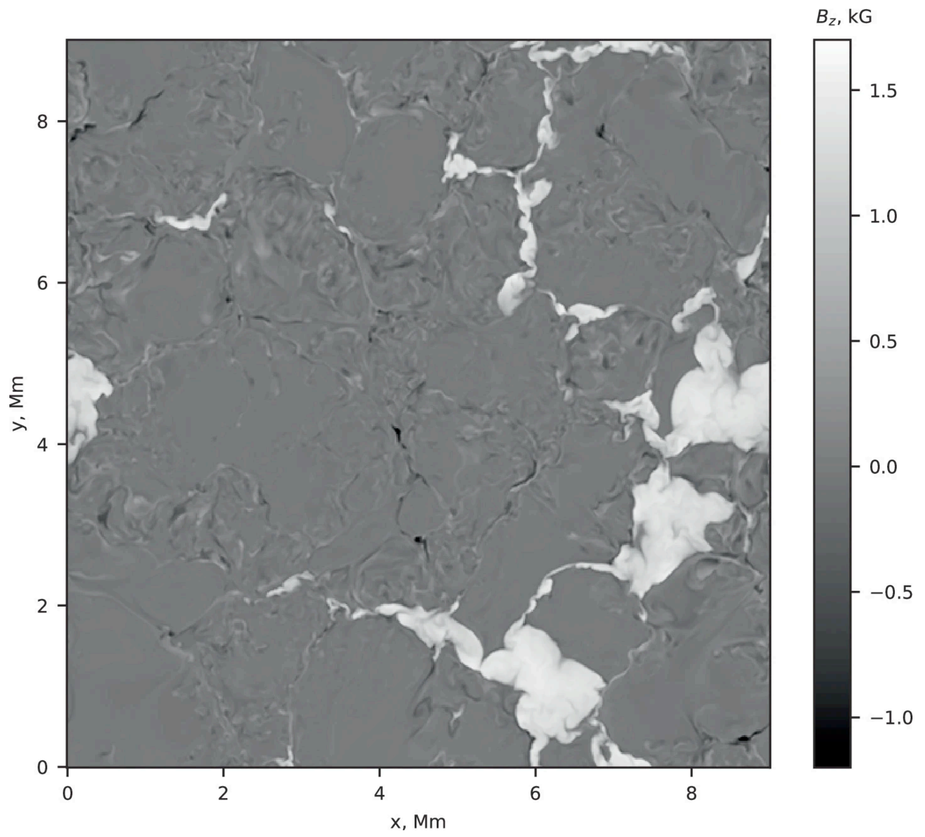
Mass measurements not really affected by activity!



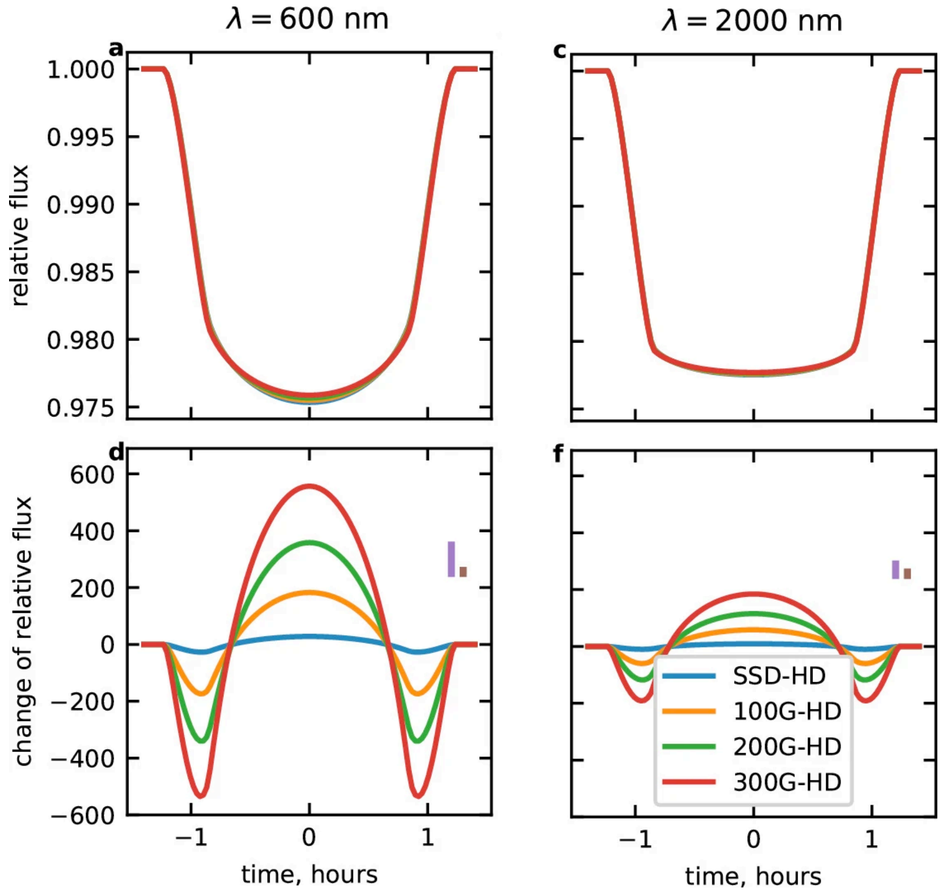
Mann et al. (2019)

Limb darkening impacts transit parameters

Magnetic field plays a role



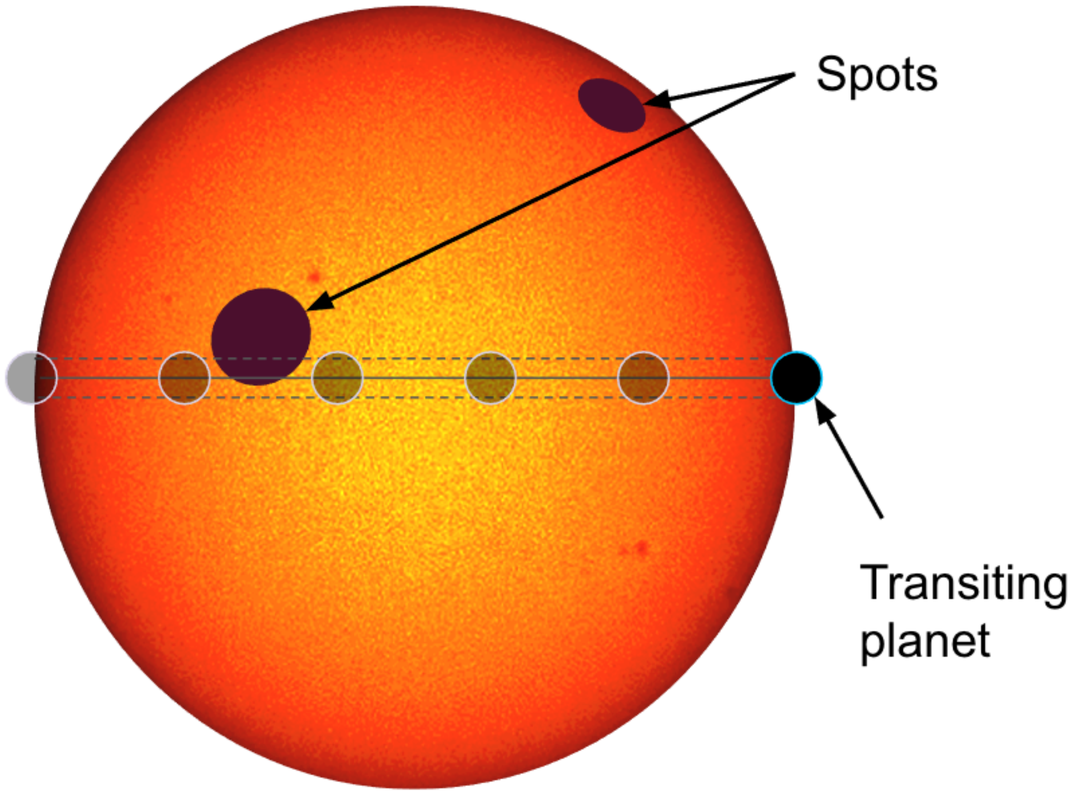
MURaM magnetic field simulation
(see also S Seager's talk)

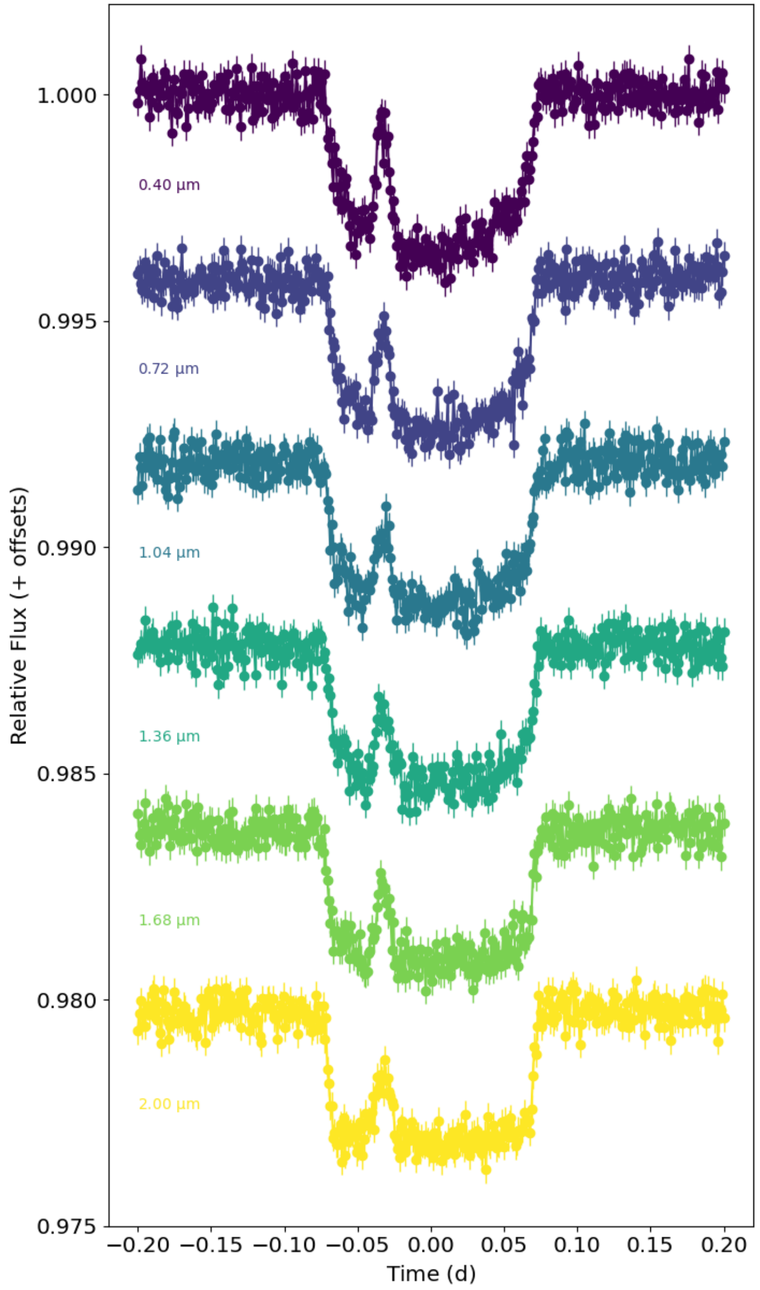


Simulated WASP-39 light curves

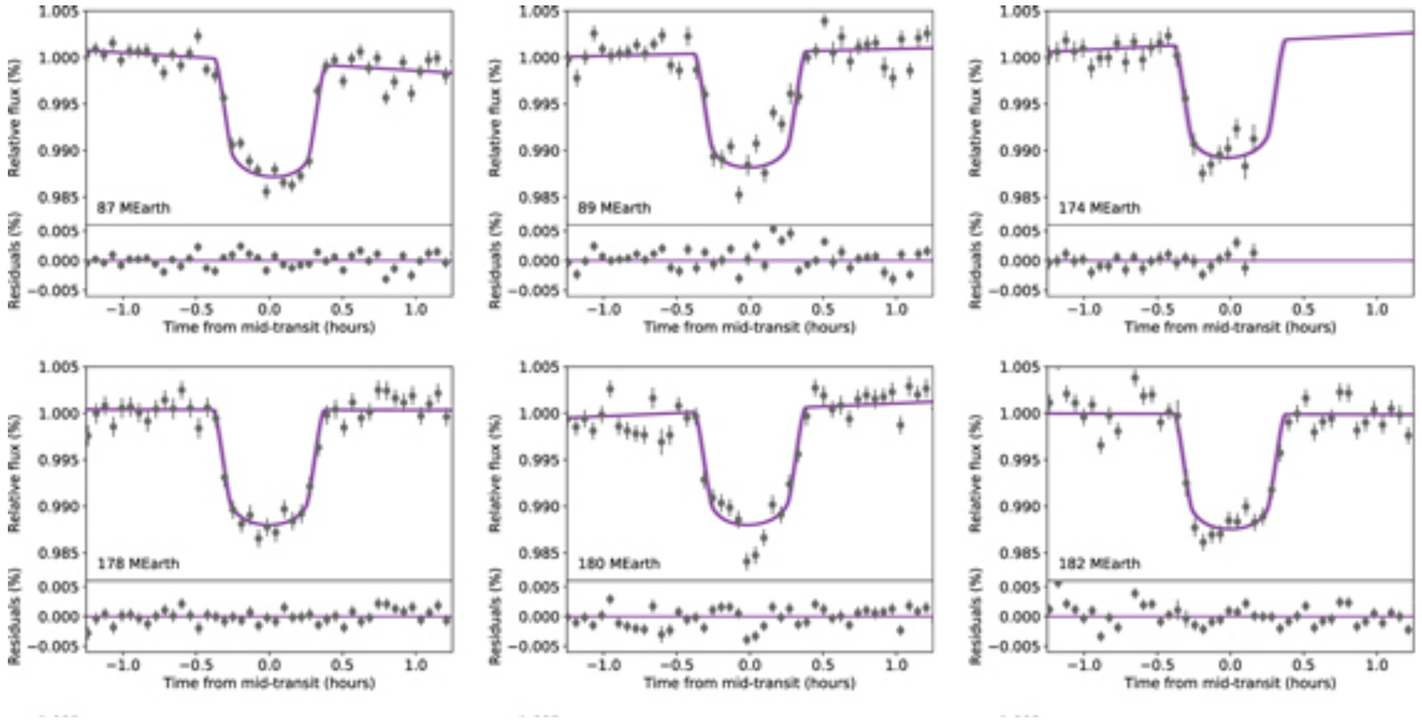
Kostogyrz+2024

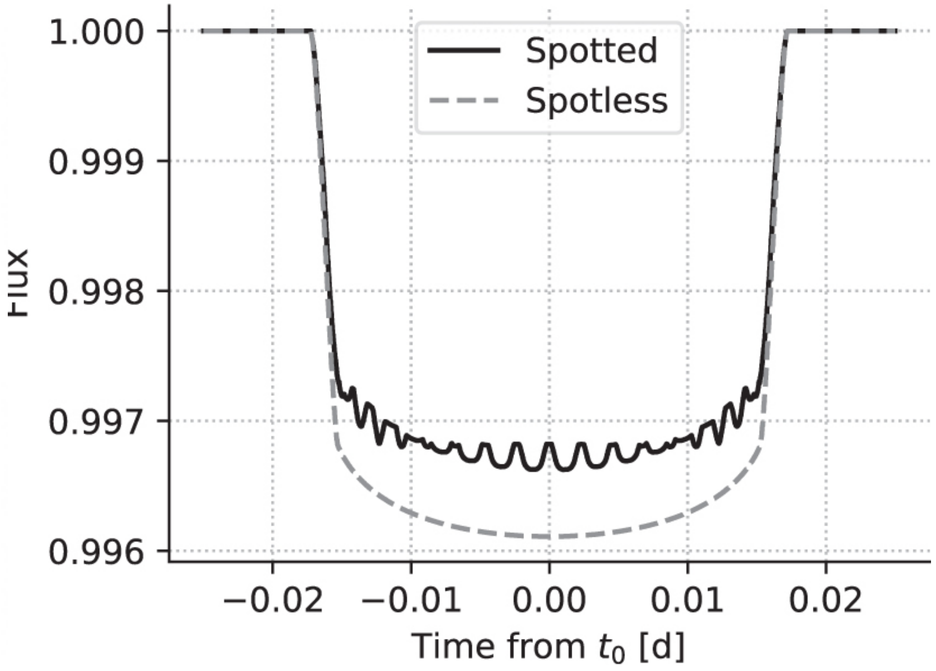
Resolved spot crossings





Unresolved spot crossings



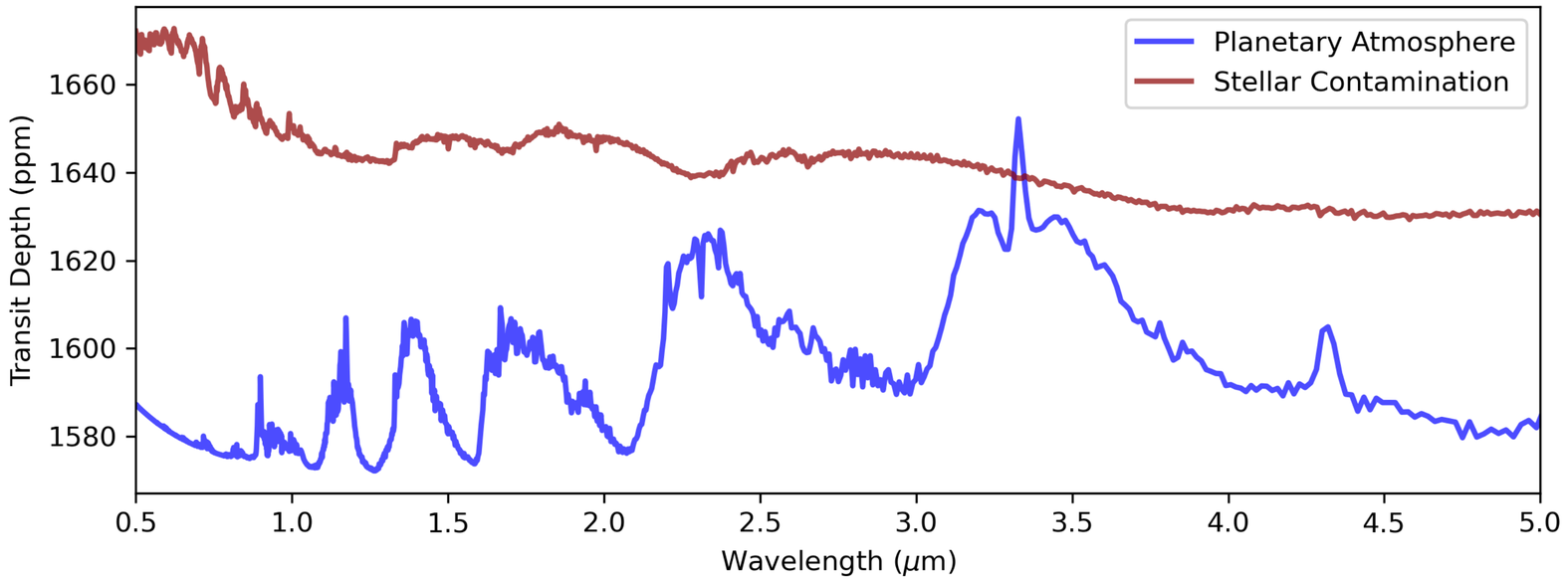


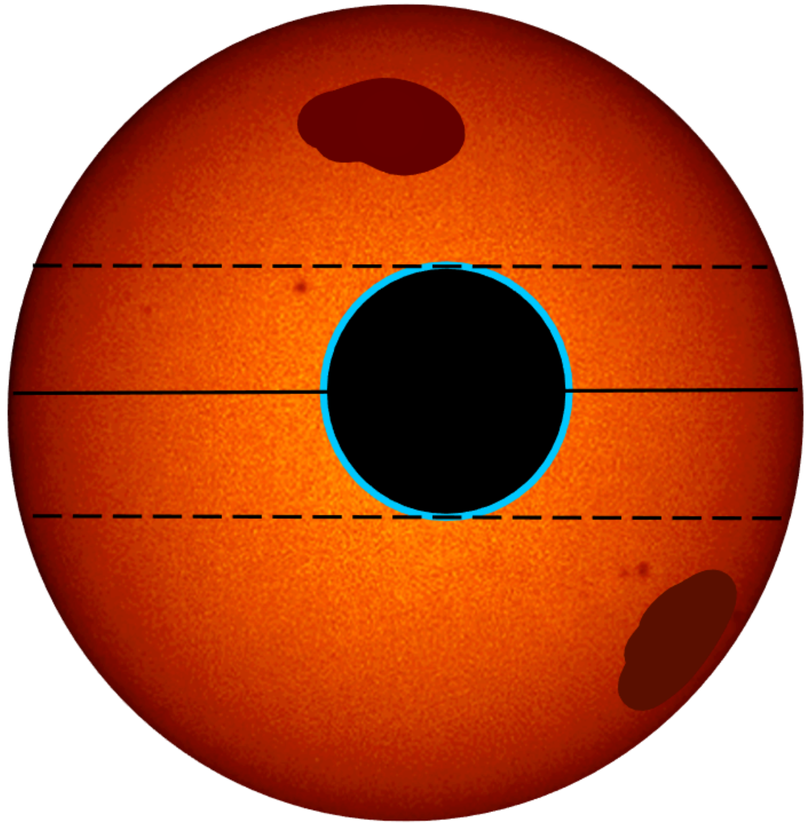
Morris+2018

Many transits of the young planet K2-25 | Kain+2020

Impact on transmission spectroscopy

“The transit light source effect” — B Rackham

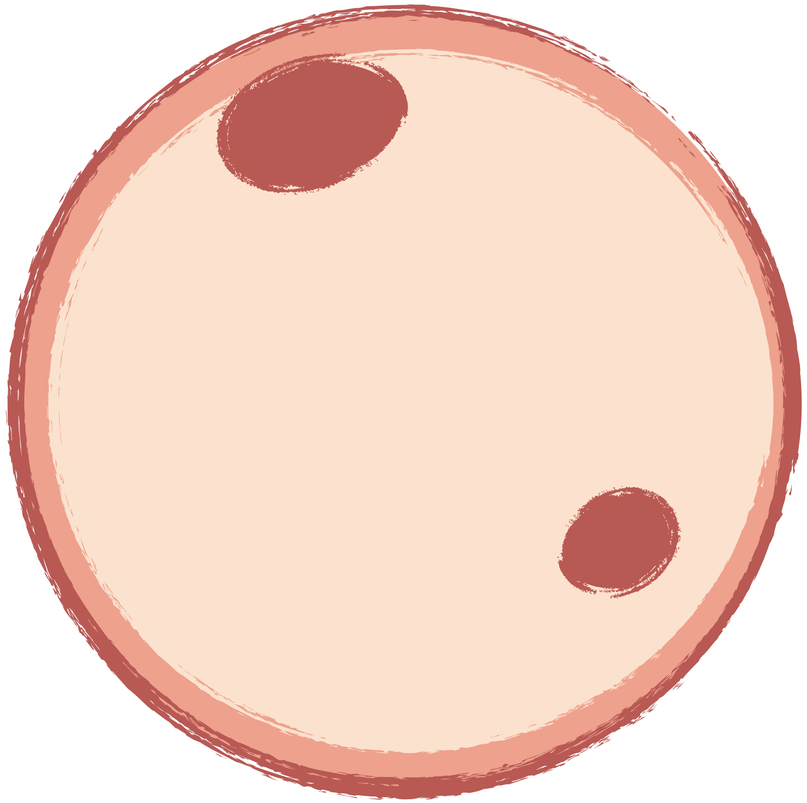




Simulation of a temperate sub-Neptune around an M0V star.

Planets around young and active stars

An outline of this talk!



Age, activity, and rotation

Transit detection around active stars

Planet characterization around active stars

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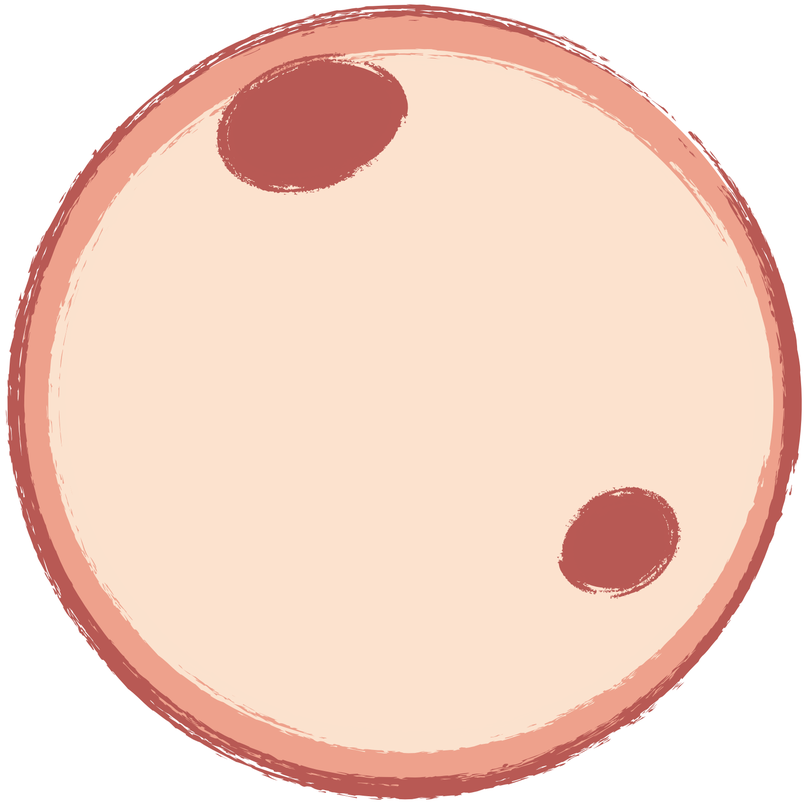
A summary of this talk!



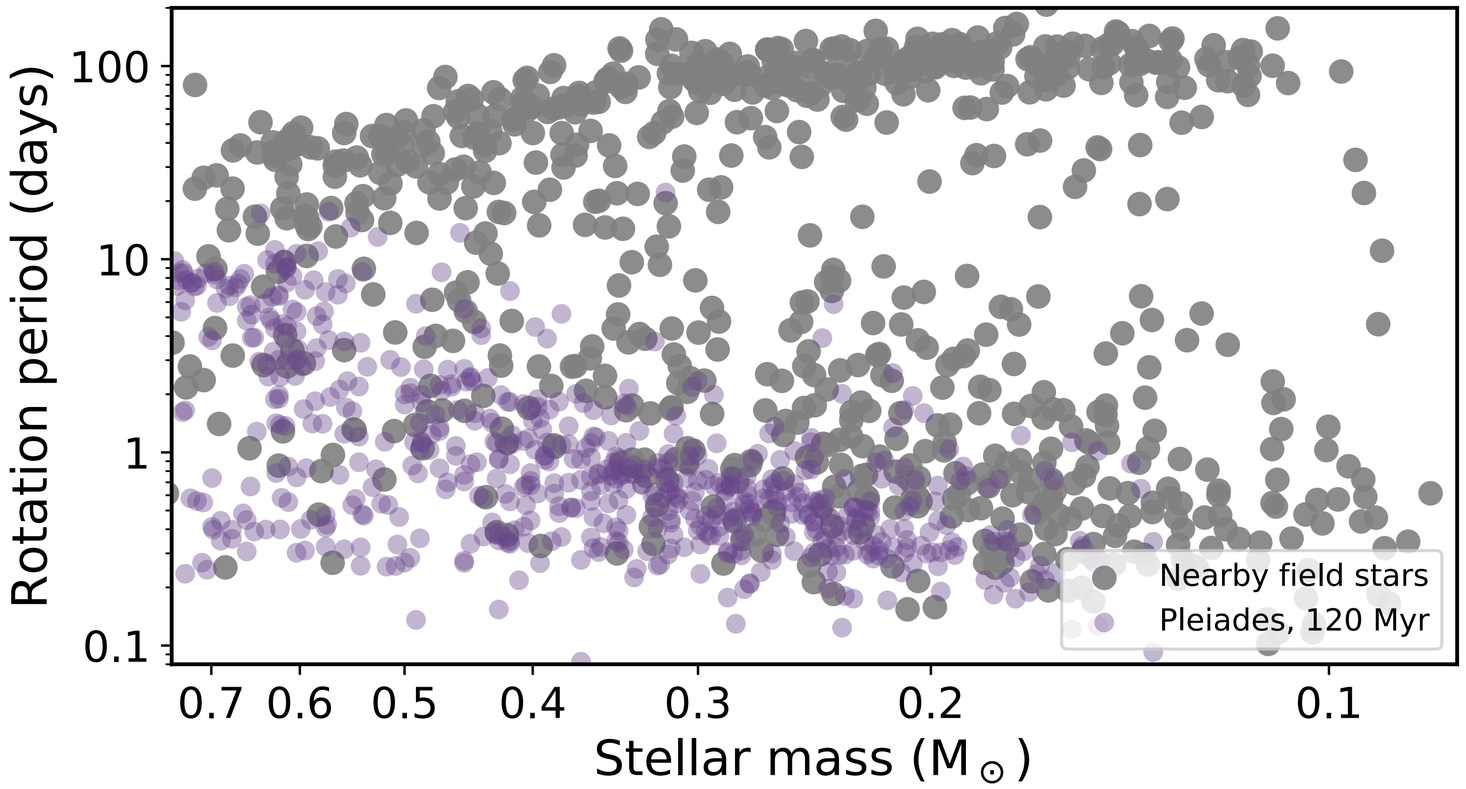
Young stars are photometrically variable due the combined age-rotation and rotation-activity relations

M dwarfs are highly variable because they take a long time to spin down and because they have lots of spots even at long rotation periods

Transit detection around active stars can be hard! Simultaneously fitting stellar variability will searching for planets can be necessary.

Starspots can have a wide variety of possible impacts both on transit white-light curves and in transmission spectroscopy.

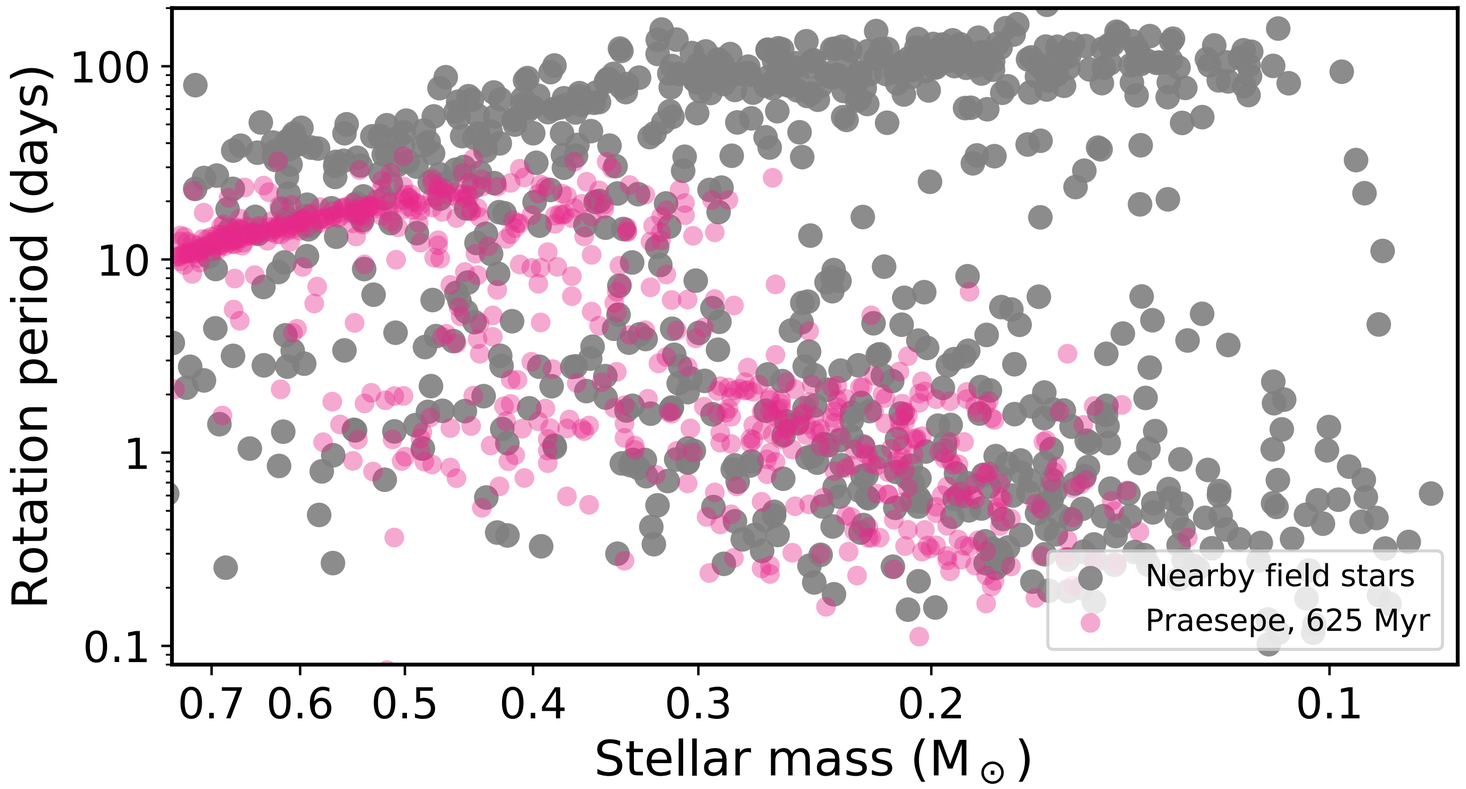
Spin-down of M dwarfs from clusters to the field



Field M dwarfs
Newton et al. (2019)

Pleiades 125 Myr
Rebull et al. (2016)

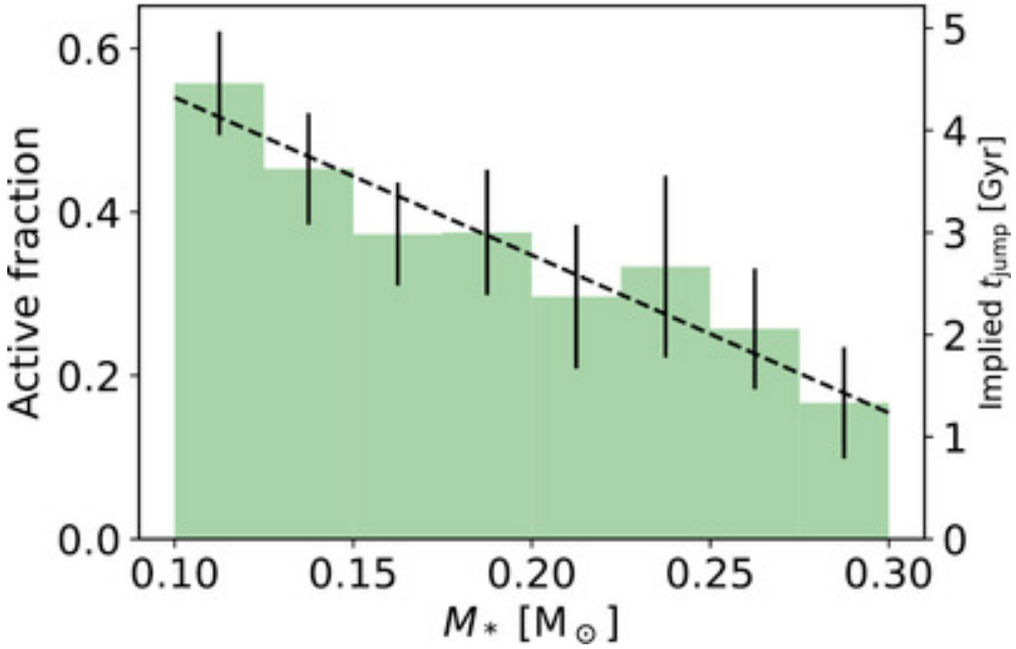
Spin-down of M dwarfs from clusters to the field



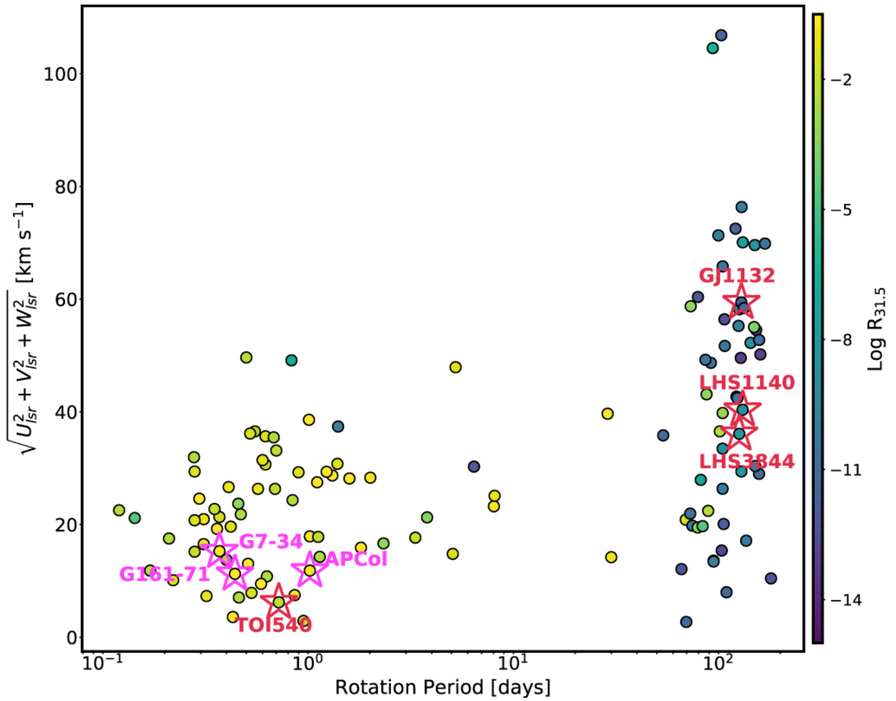
Field M dwarfs
Newton et al. (2019)

Praesepe 625 Myr
Rebull et al. (2017)
see also Douglas et al. (2017)

How to determine when spin-down occurs: active fraction and Galactic kinematics



Fraction of stars that are active
(Pass et al. 2024, Kiman et al. 2021, Medina et al. 2022)



Galactic kinematics
(Medina et al. 2022, Newton et al. 2016)