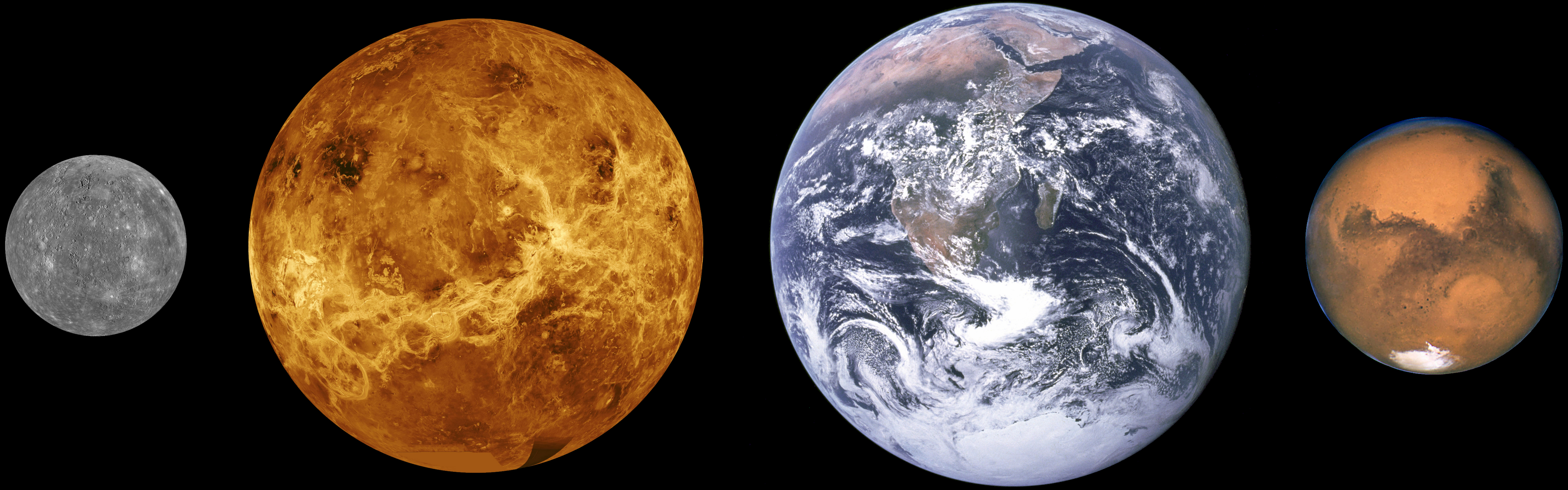
Low-mass M Dwarfs Lack Jupiter Analogs

and why you should care even if you are obsessed with small rocky worlds

David Charbonneau (Harvard)

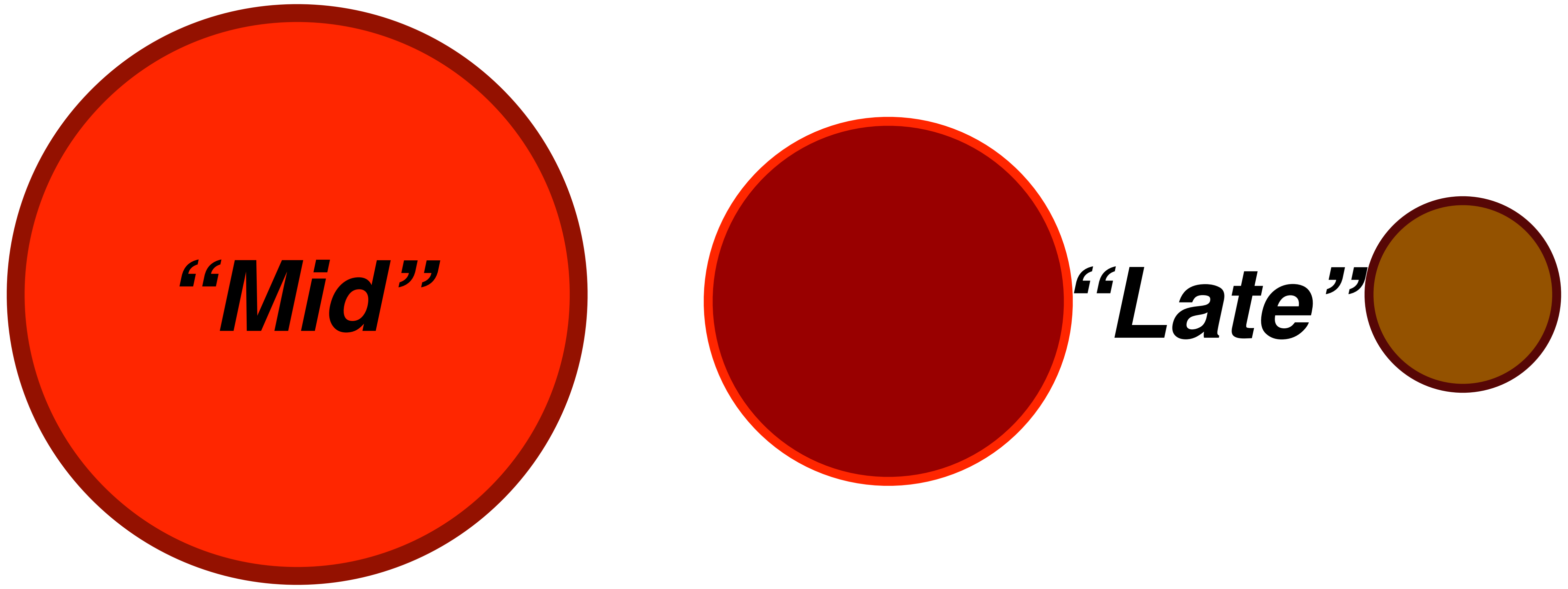


M Dwarf Properties
--sizes to scale--
0.075 M_{Sun} < mass < 0.60 M_{Sun}
Earth
"Early"
"Mid"
"Late"
G2V
M = 1 M_{sun}
R = 1 R_{sun}
T = 5800 K
M0V
M = 0.6 M_{sun}
R = 0.6 R_{sun}
T = 3800 K
M2V
M = 0.45 M_{sun}
R = 0.45 R_{sun}
T = 3400 K
M4V
M = 0.25 M_{sun}
R = 0.25 R_{sun}
T = 3100 K
M6V
M = 0.15 M_{sun}
R = 0.15 R_{sun}
T = 2800 K
M8V
M = 0.1 M_{sun}
R = 0.1 R_{sun}
T = 2600 K

M Dwarf Properties

--sizes to scale--

0.075 M_{Sun} < mass < 0.60 M_{Sun}



M4V

M = 0.25 M_{sun}

R = 0.25 R_{sun}

T = 3100 K

M6V

M = 0.15 M_{sun}

R = 0.15 R_{sun}

T = 2800 K

M8V

M = 0.1 M_{sun}

R = 0.1 R_{sun}

T = 2600 K

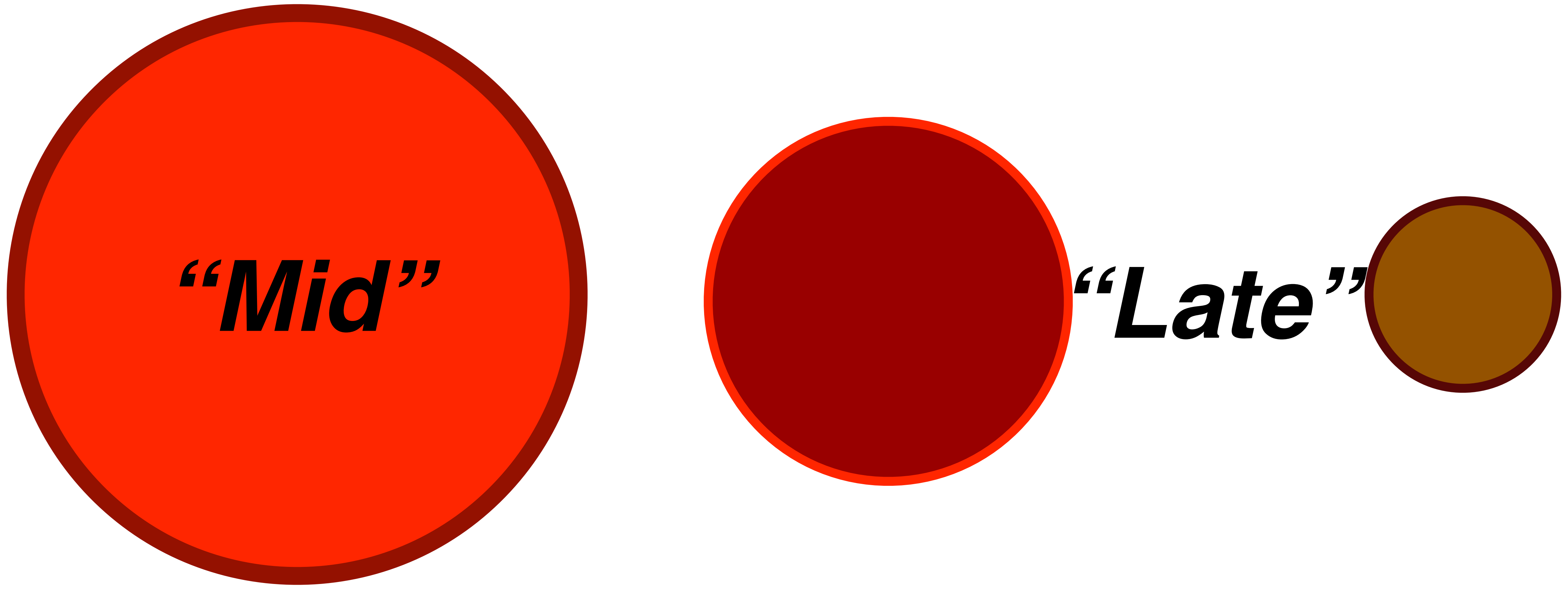
M Dwarf Properties

--sizes to scale--

$0.075\ M_{Sun} < \text{mass} < 0.60\ M_{Sun}$

By coincidence, the maximum stellar radius that permits spectroscopic studies of terrestrial atmospheres in transmission = the mass at which stars become fully convective.

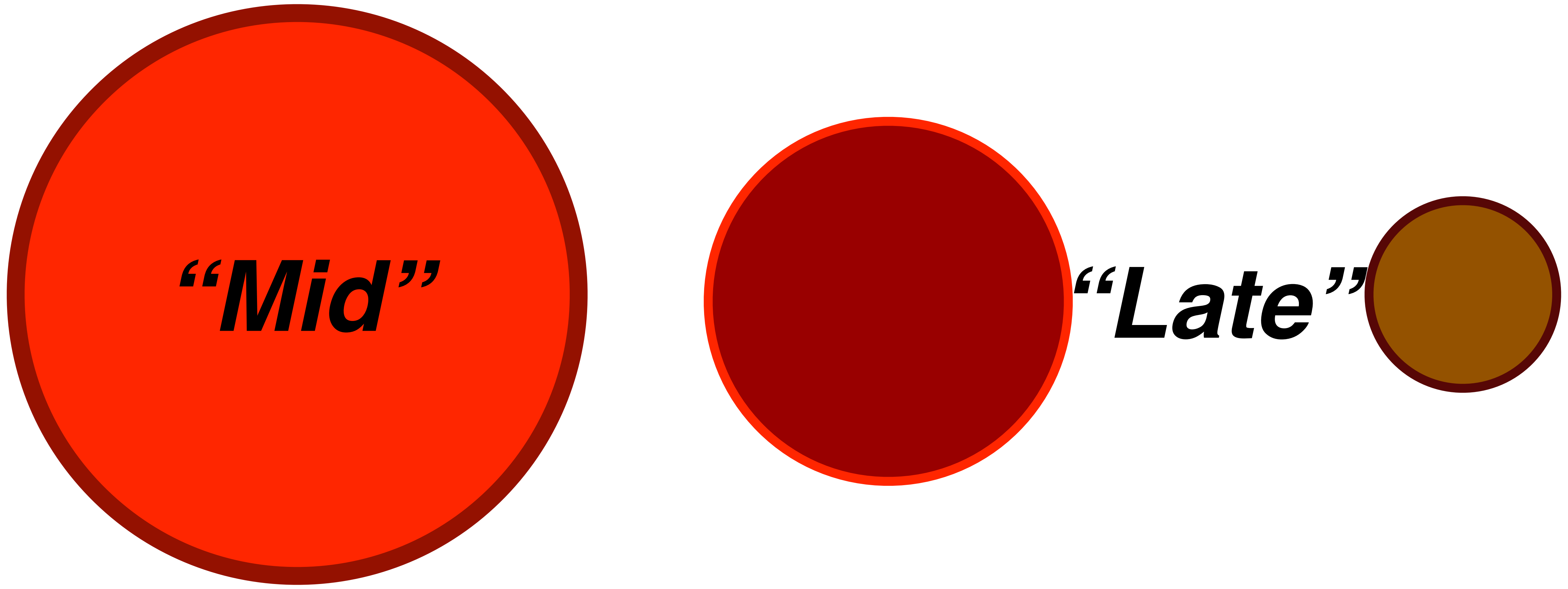
This has big implications for their magnetic activity, high-energy emission, and angular momentum evolution.



M4V	M6V	M8V
$M = 0.25\ M_{sun}$	$M = 0.15\ M_{sun}$	$M = 0.1\ M_{sun}$
$R = 0.25\ R_{sun}$	$R = 0.15\ R_{sun}$	$R = 0.1\ R_{sun}$
T = 3100 K	T = 2800 K	T = 2600 K

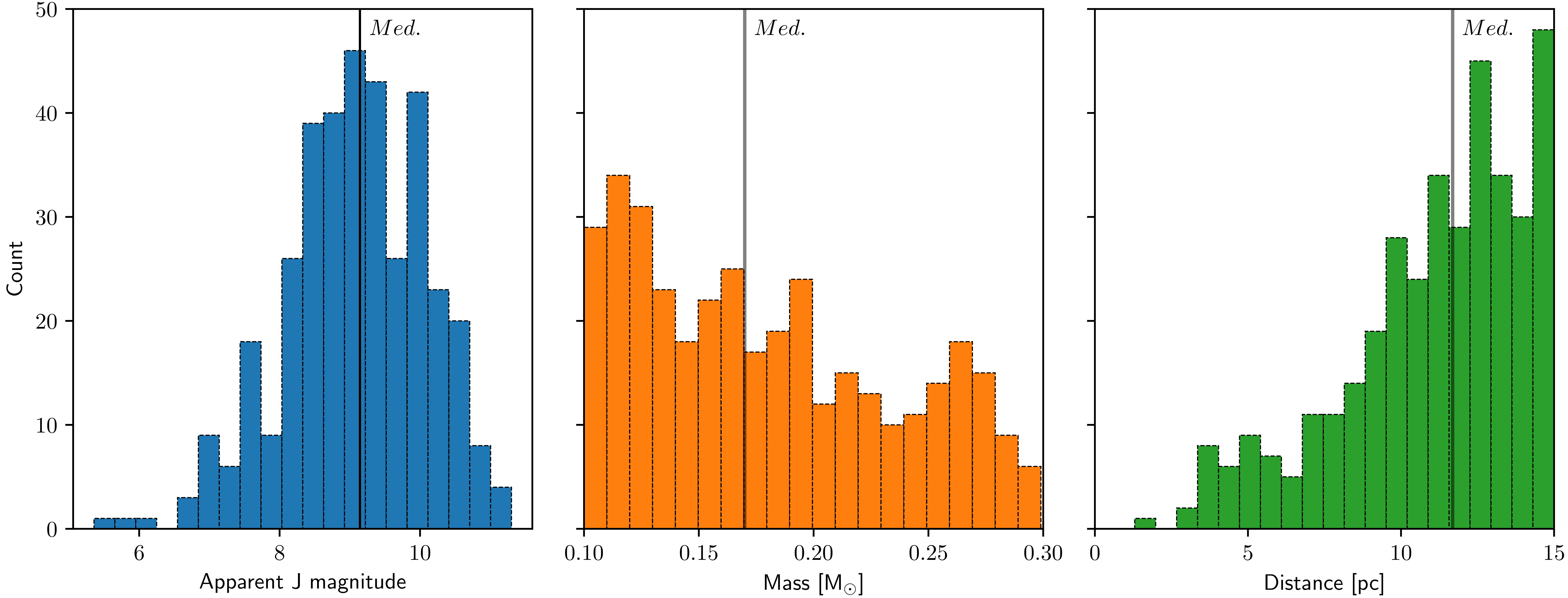
The 15 Parsec Survey

Stars with masses 0.1 - 0.3 M_{Sun}

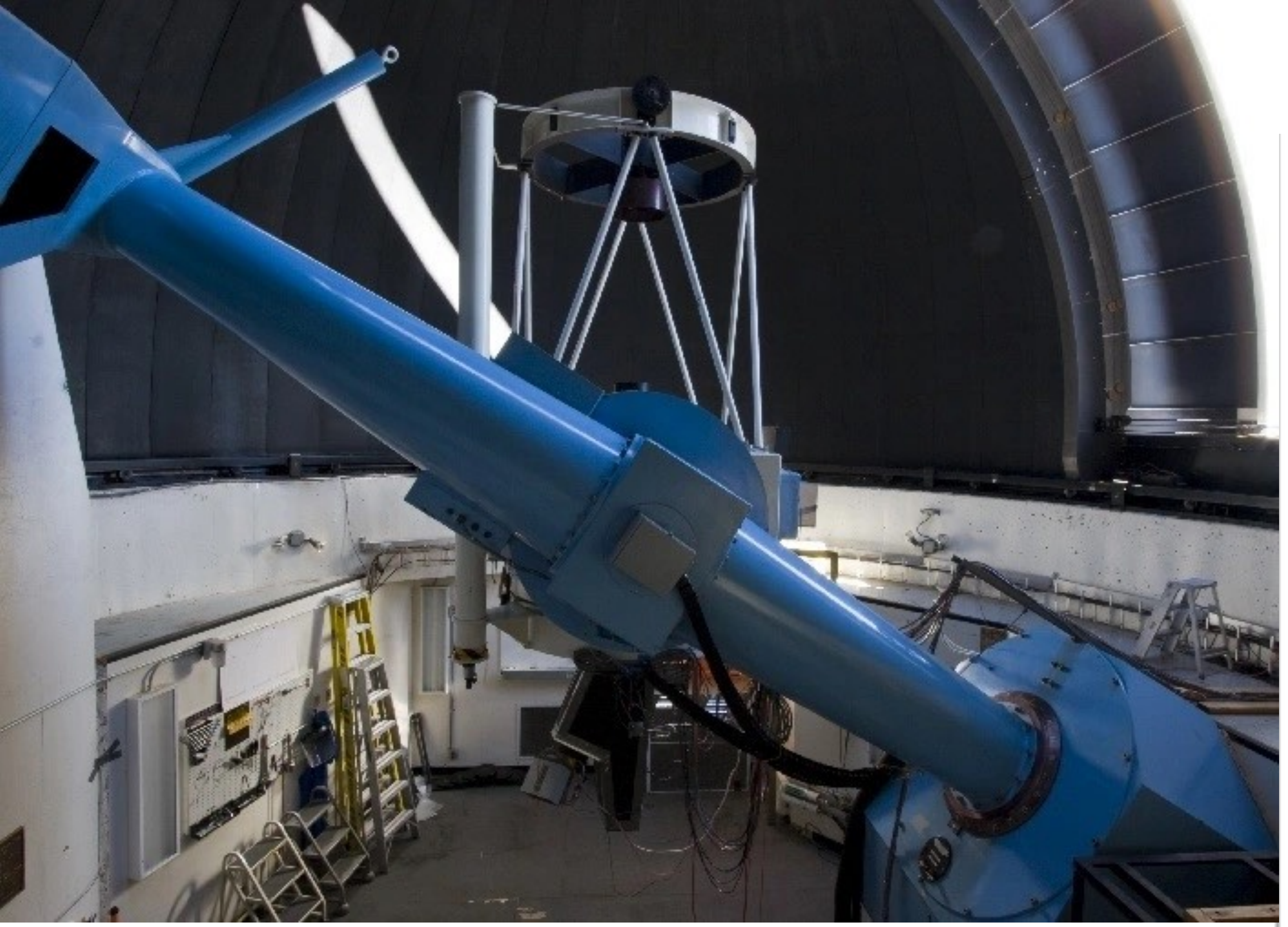


Volume Complete

There are 413 of them

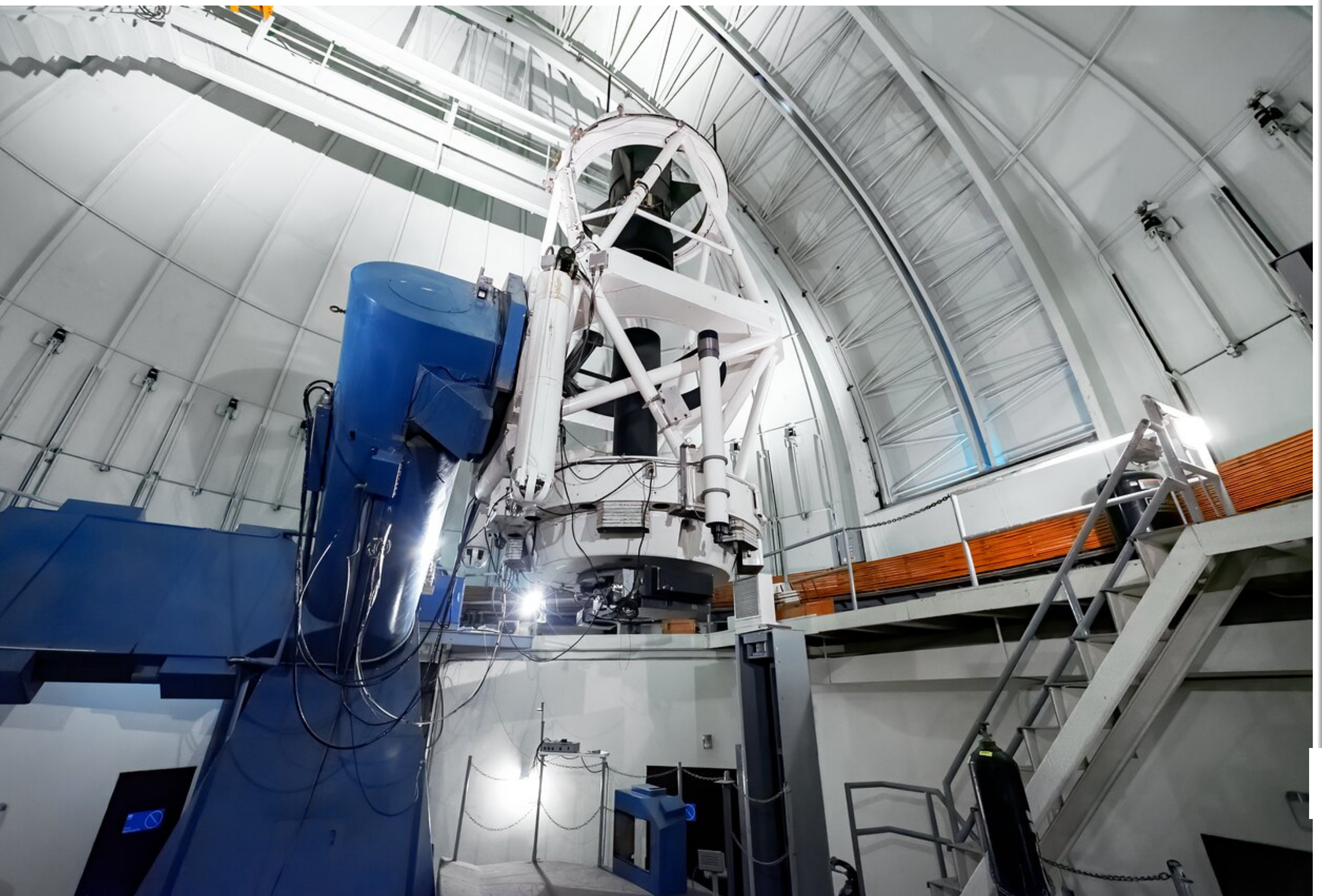


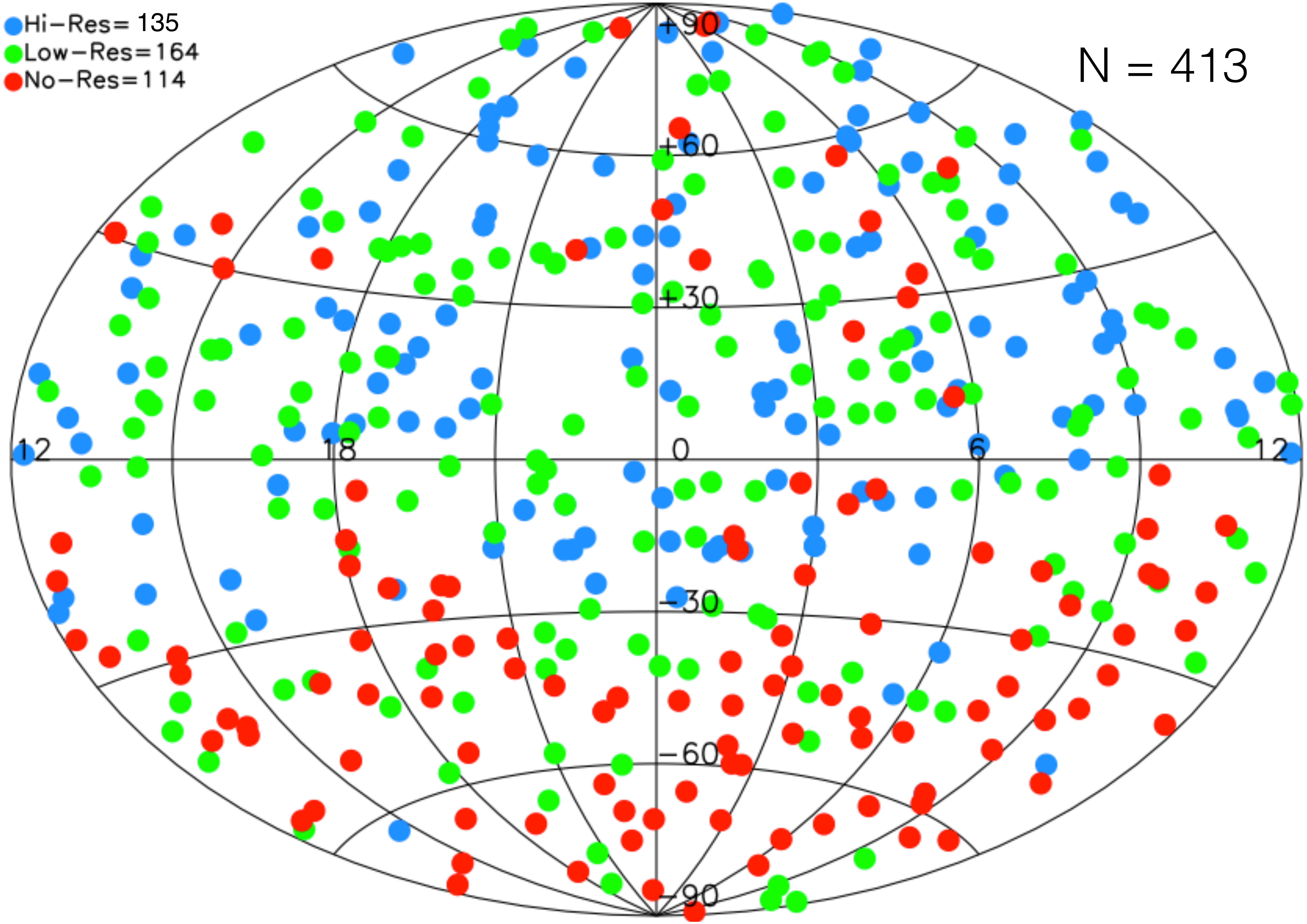
Winters, Charbonneau, Henry et al. (2021)



TRES Spectrograph
FLWO 1.5m Arizona

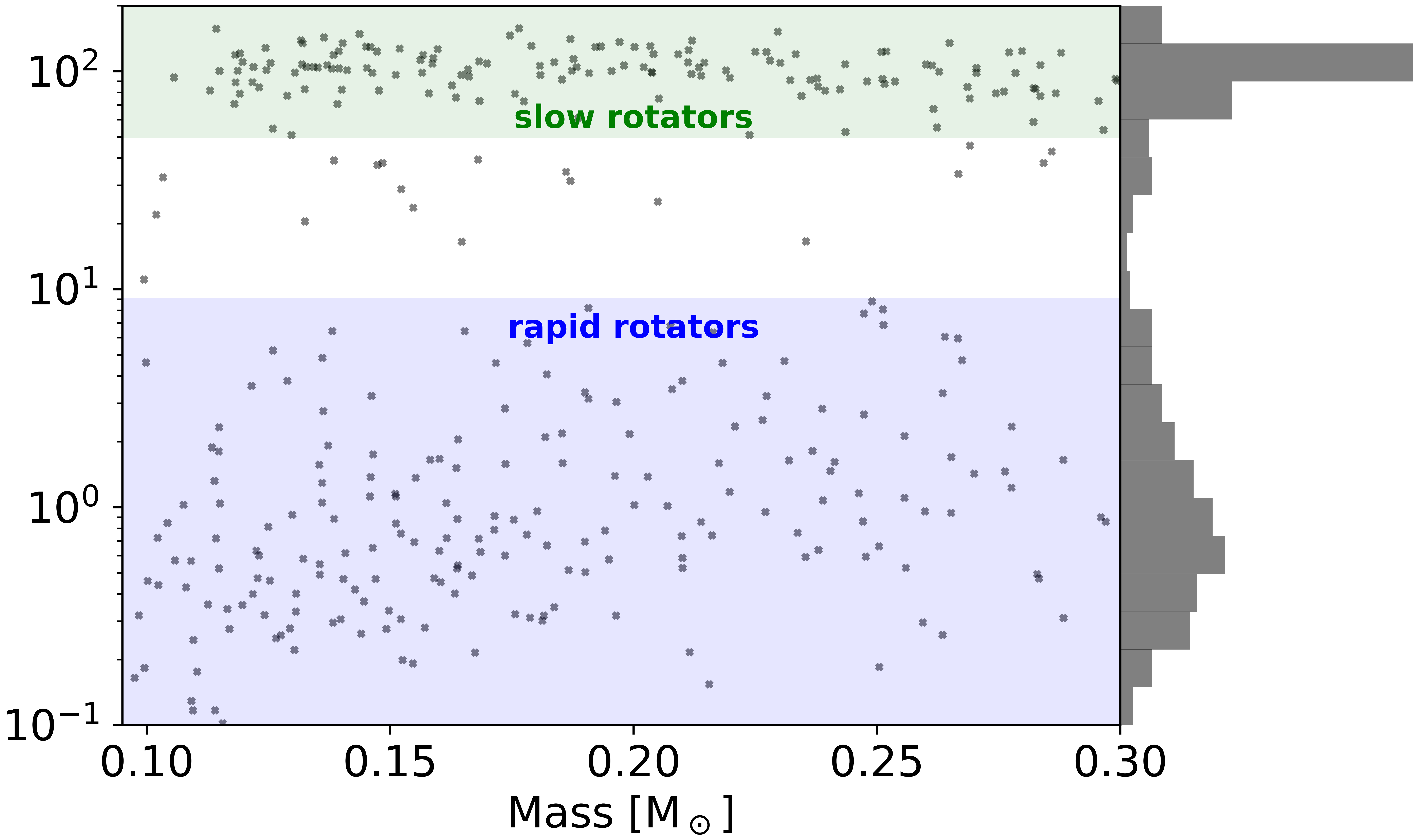
CHIRON Spectrograph
SMARTS 1.5m Chile





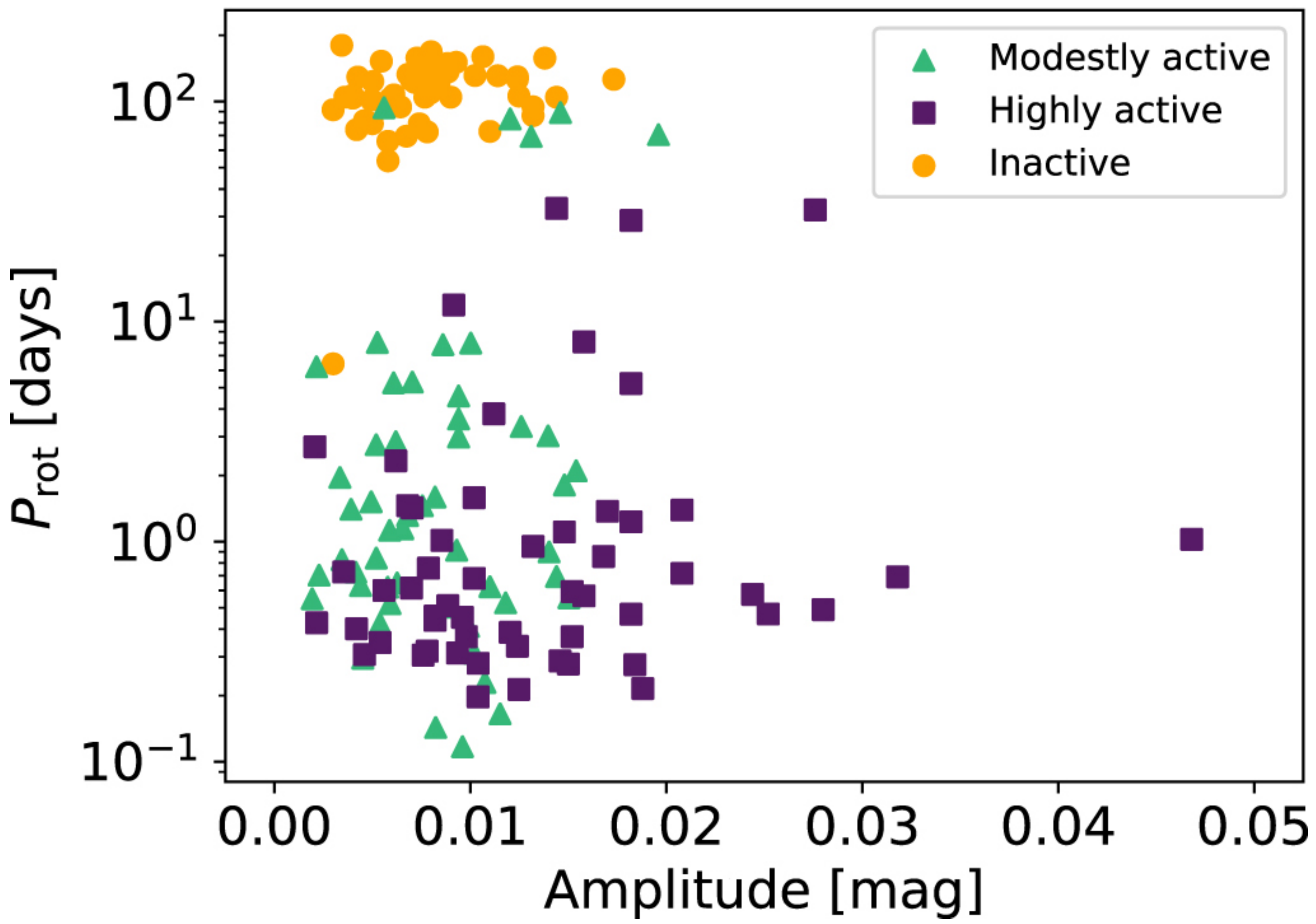

The MEarth Project

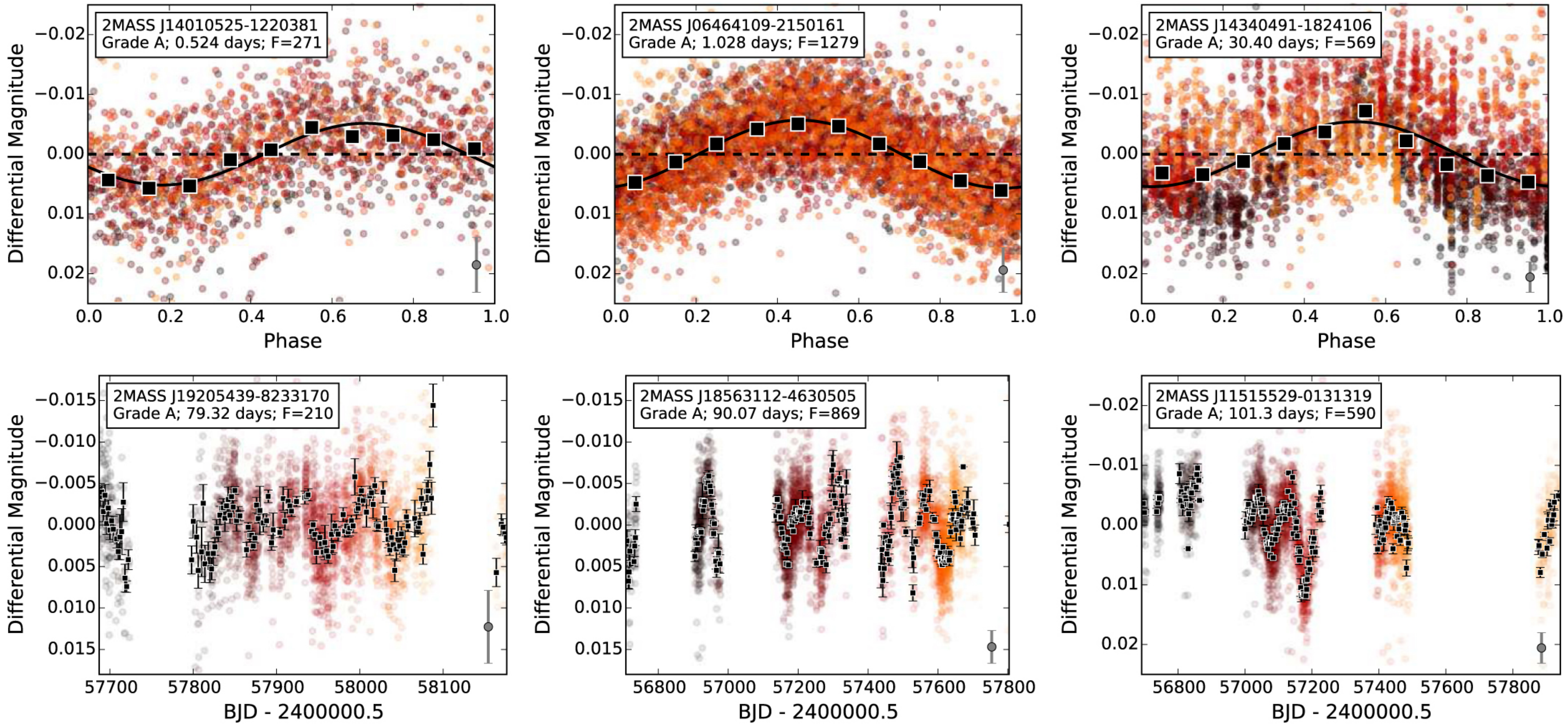
Dr. Elisabeth Newton

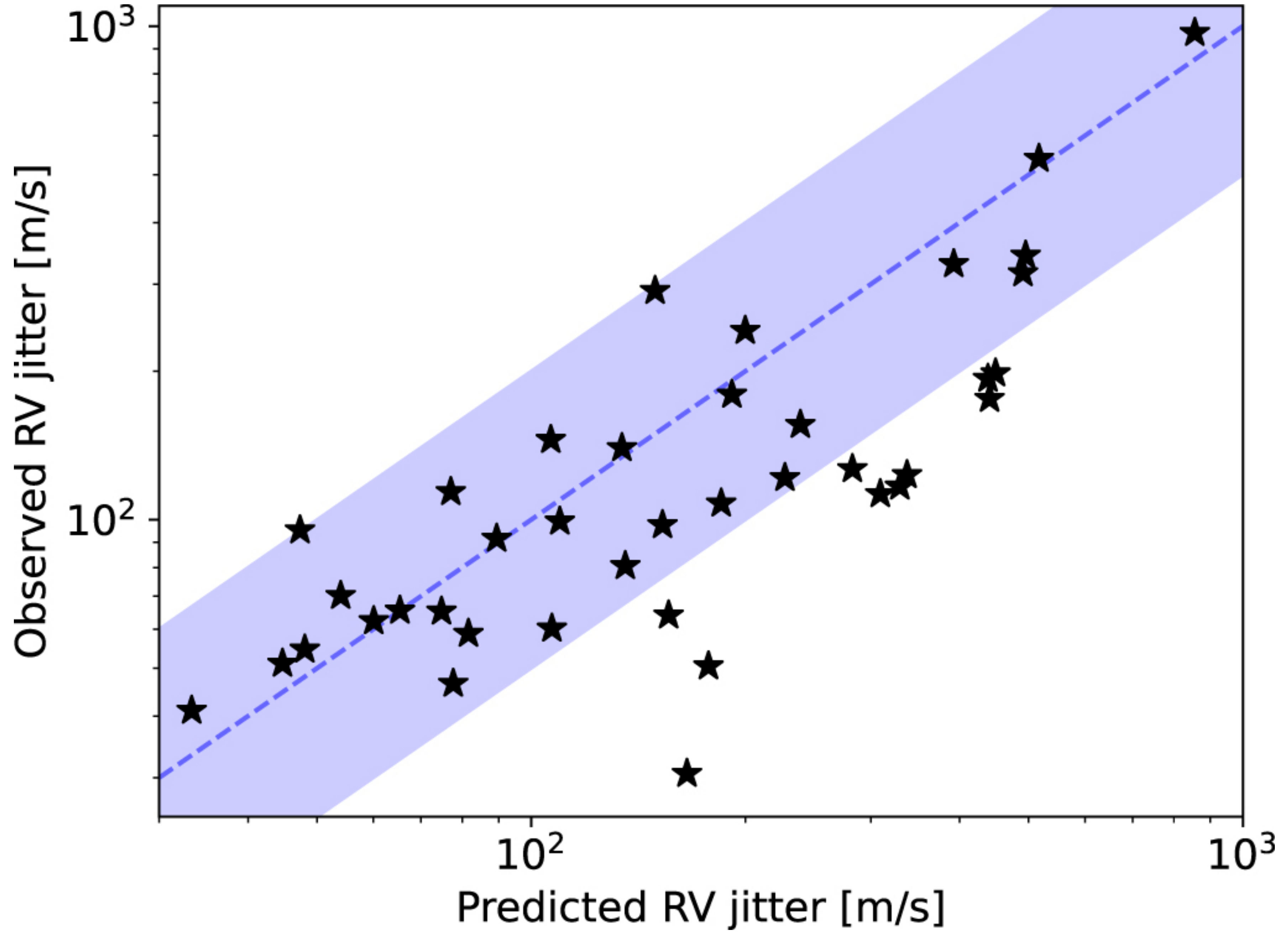


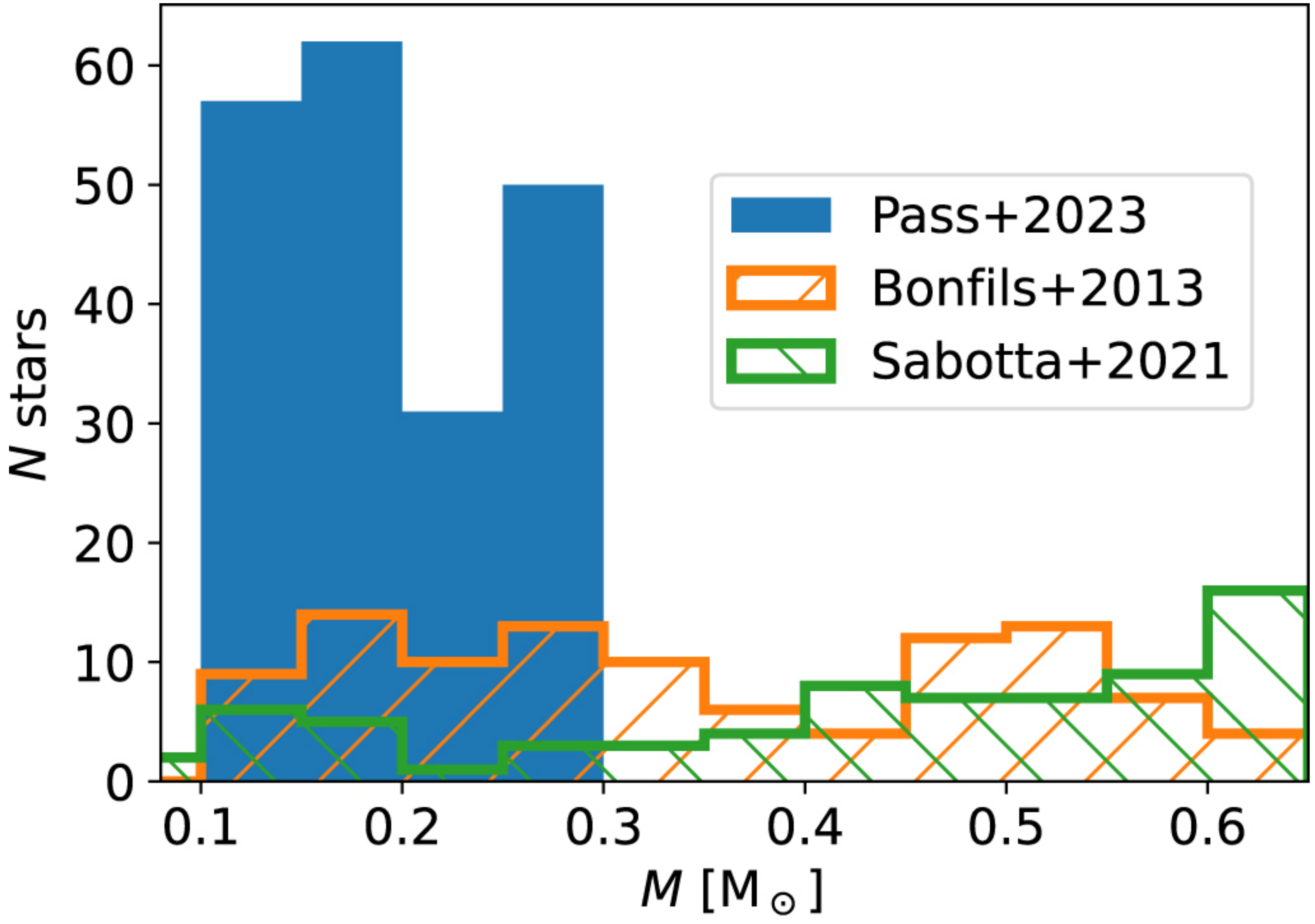
Newton, Irwin, Charbonneau et al. 2016, 2018
masses updated from GAIA (Emily Pass)

We must remove the active stars
(H-alpha equivalent width < -1 Å)
because we know they will
introduce spurious RV signals







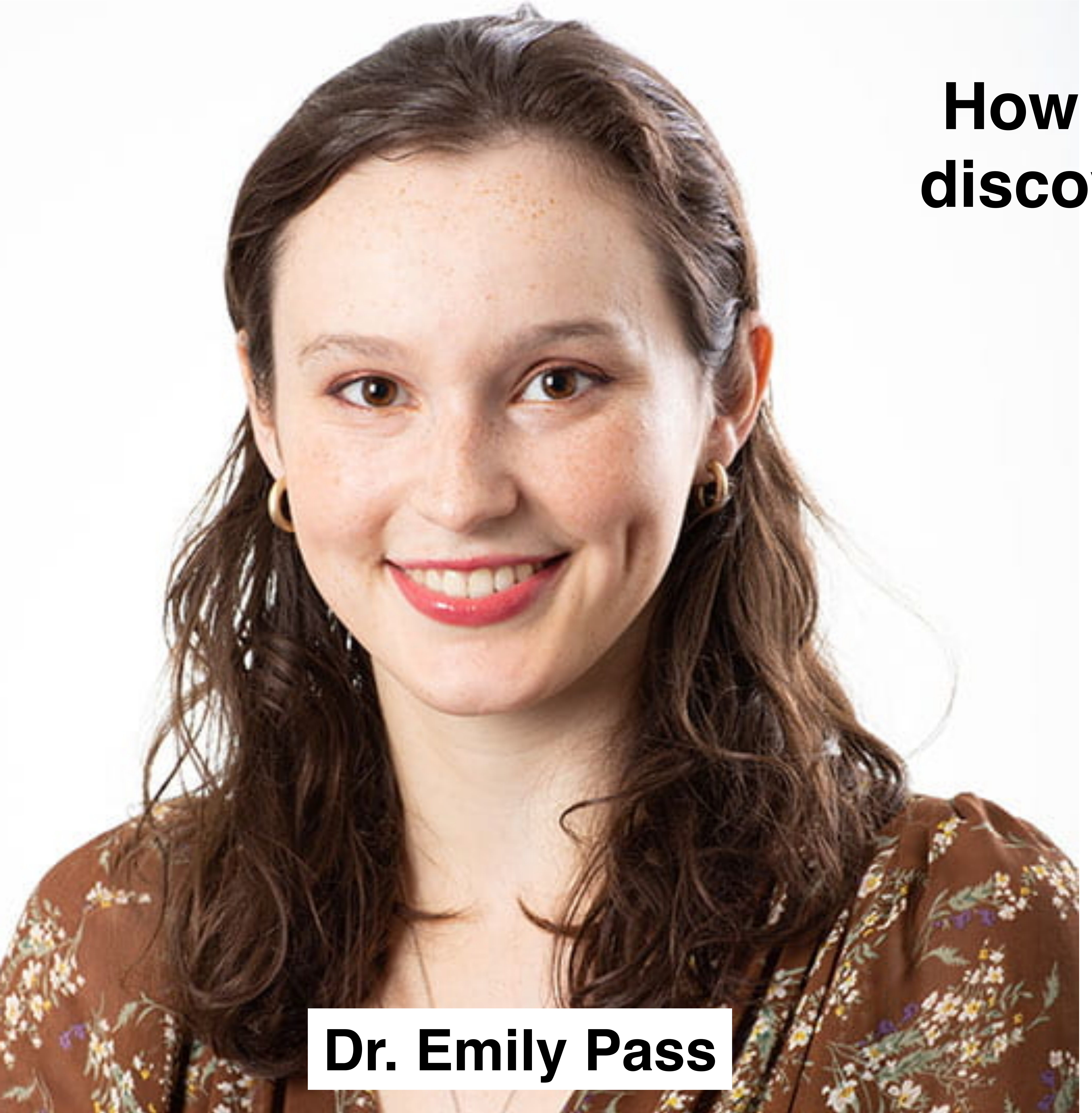


After we remove **active stars** and those in **multiple systems with a separation of less than 4 arcseconds**, we are left with a sample of

200 stars

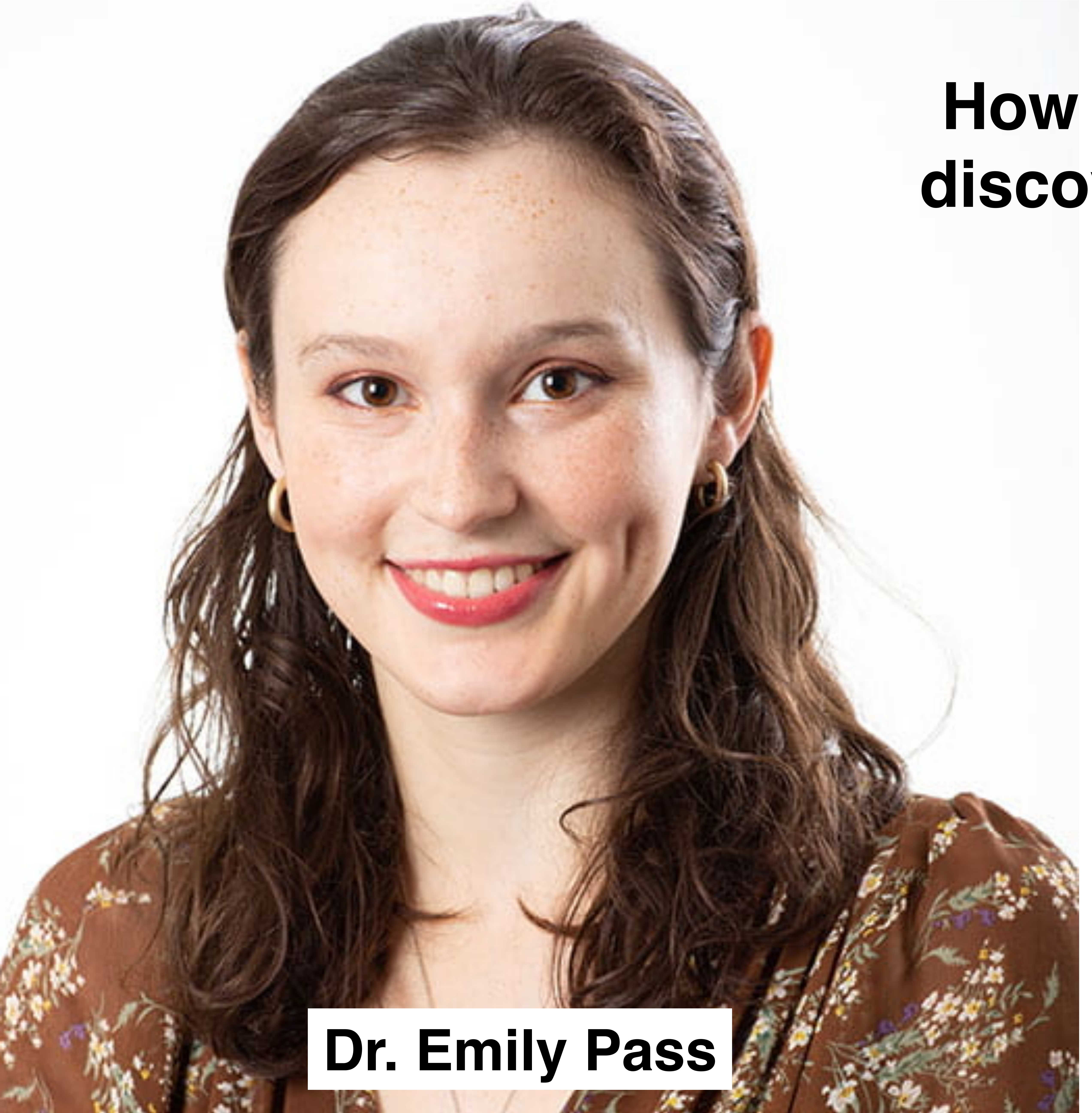
We analyzed **4 observations spanning 6 years** with a **typical precision of 20 m/s**

Do Low-mass Stars Have Jupiters?



How many Jupiters did Dr. Emily Pass discover around these low-mass stars?

Do Low-mass Stars Have Jupiters?



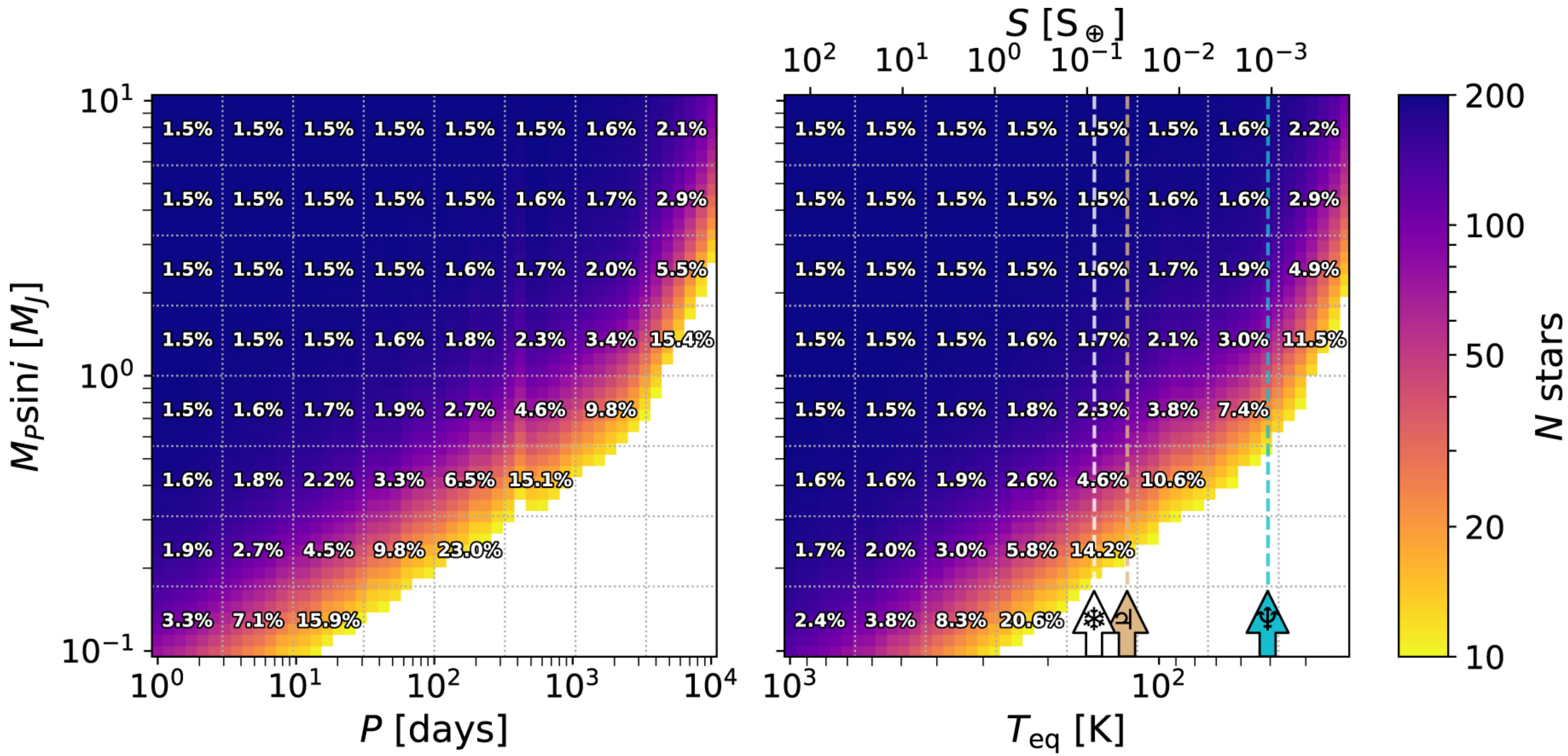
How many Jupiters did Dr. Emily Pass discover around these low-mass stars?

0

Pass, Winters, Charbonneau, et al. (2023)

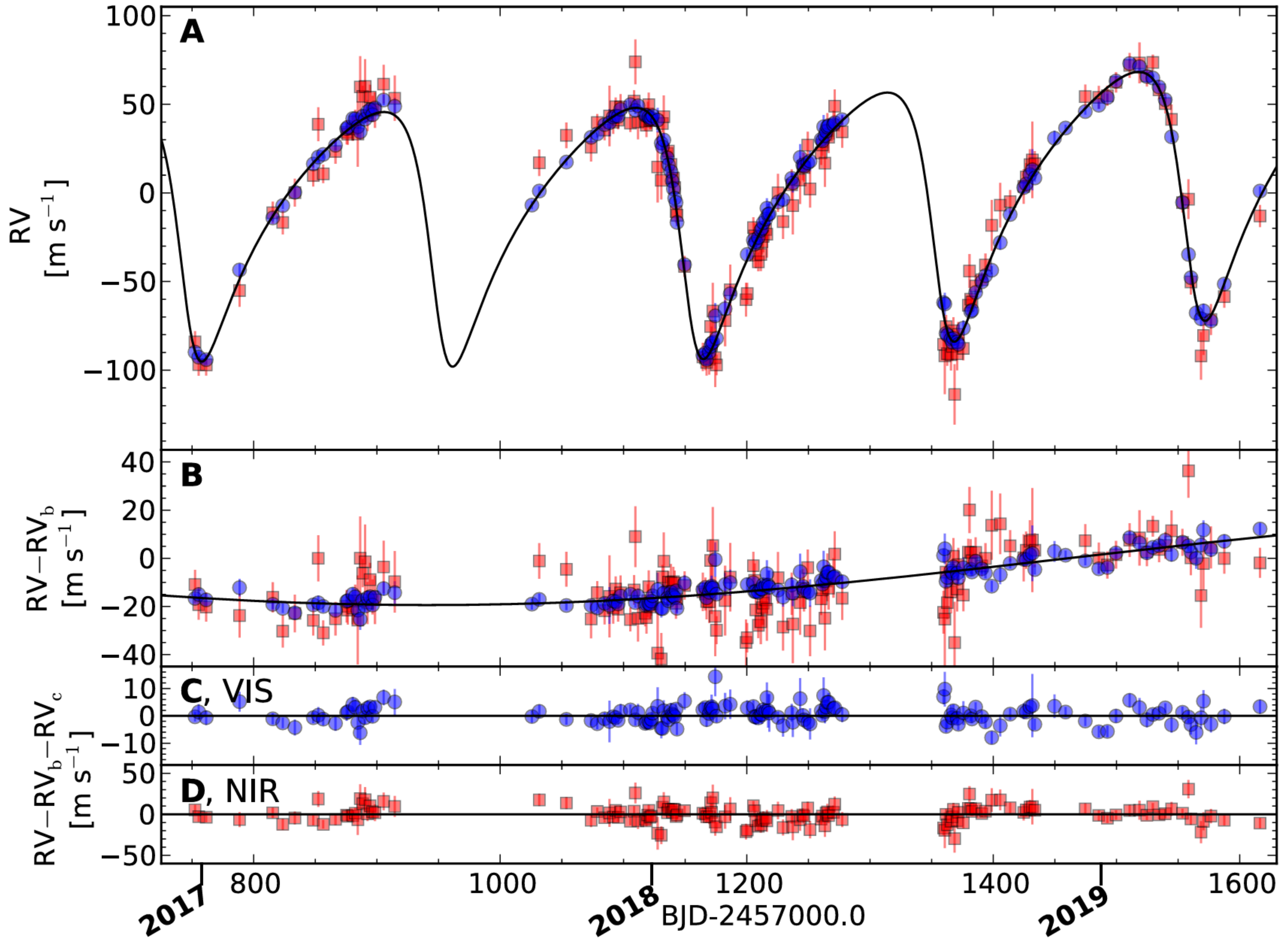
Low-mass Stars Lack Jupiter Analogs

(Shown are 95% confidence upper limits.)



Pass, Winters, Charbonneau, et al. (2023)

There are two gas giants known to orbit stars in our 15-parsec sample, but both stars are active so not in our RV subset

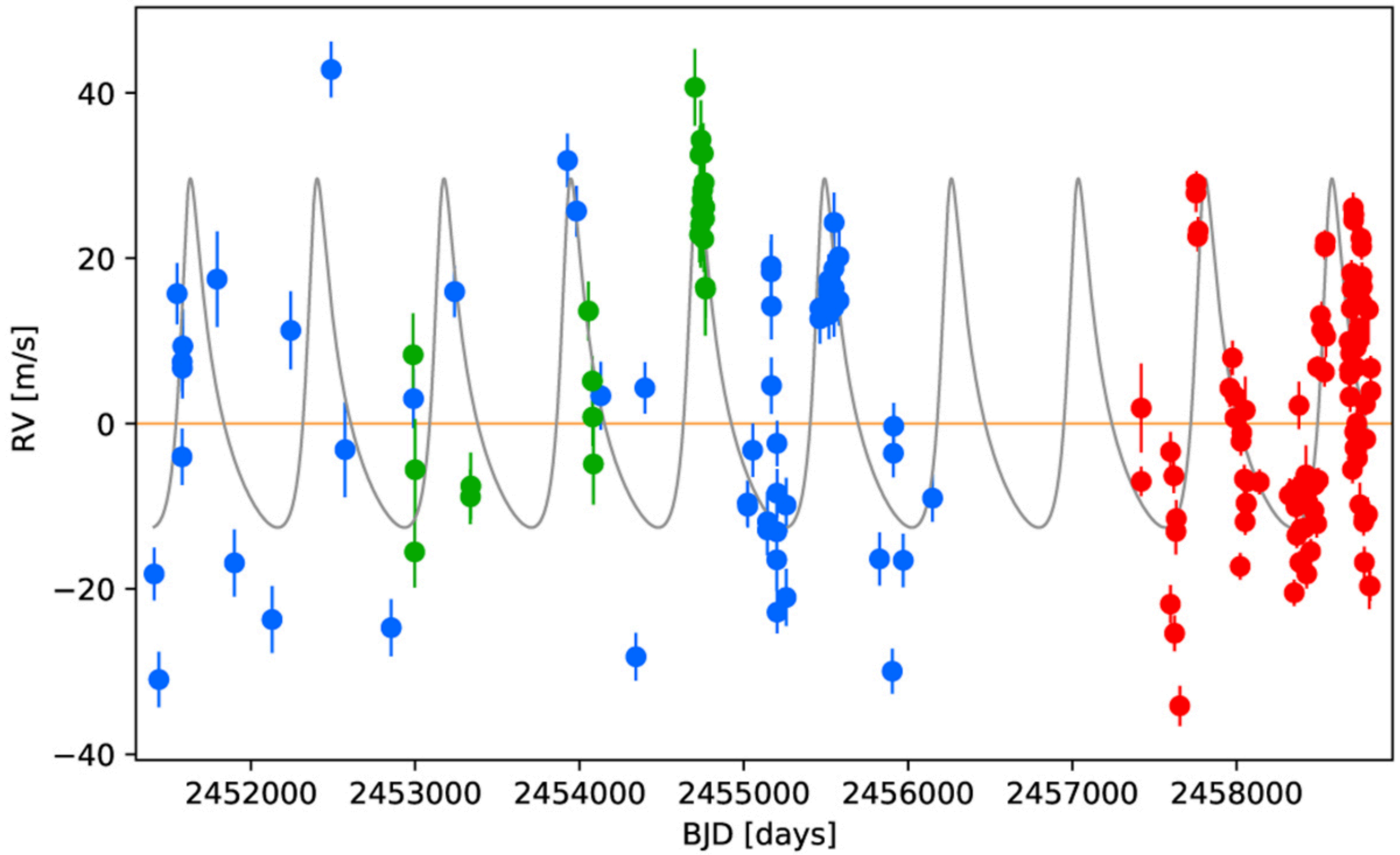


LHS 252 b (Hα EW =−1.8Å)

0.46 M_{Jup} planet

204 day period

(Morales et al. 2019)



GJ 83.1 b (Hα EW =−2.3Å)

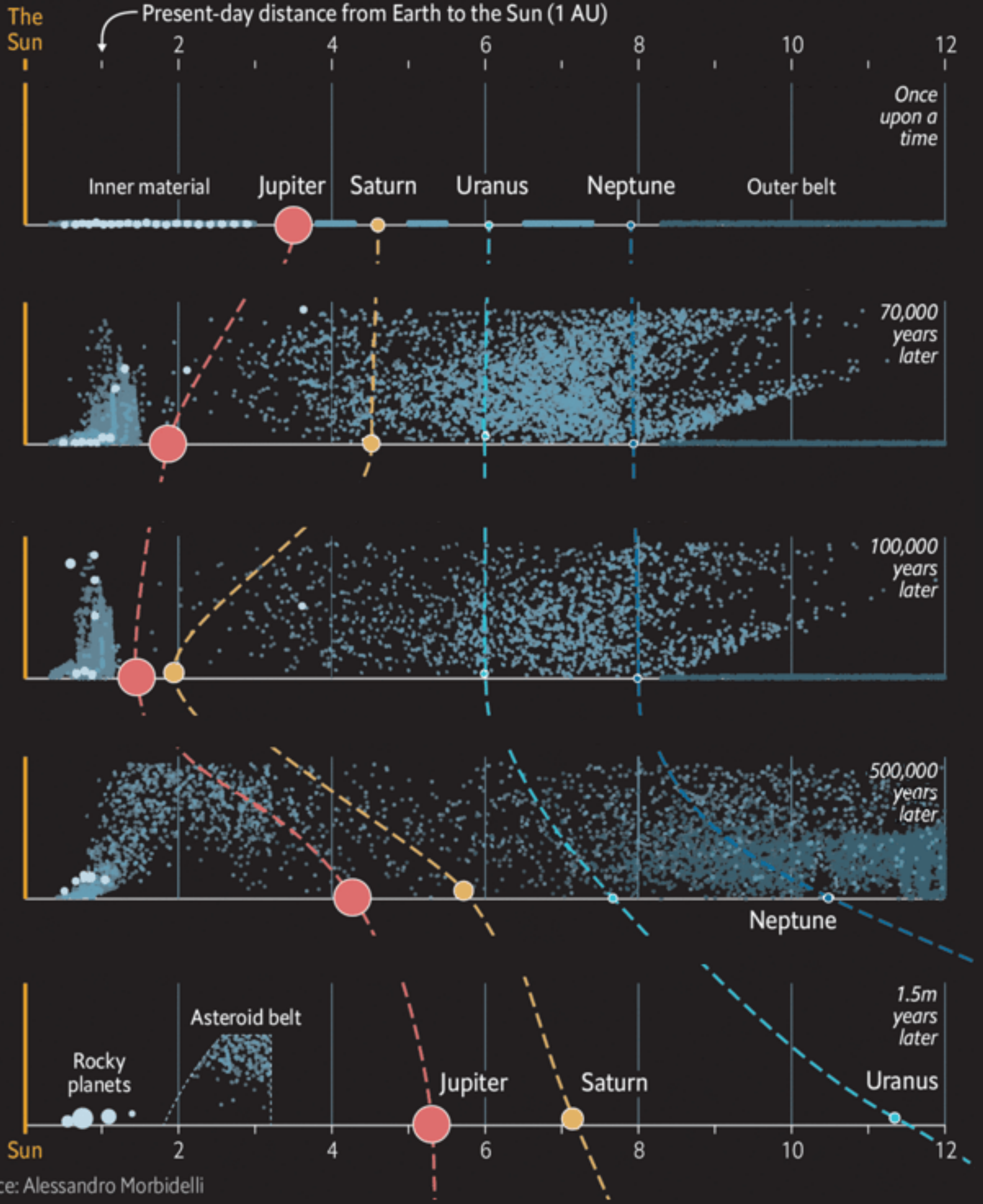
0.21 M_{Jup} planet

771 day period

(Feng et al. 2020; Quirrenbach et al. 2022).

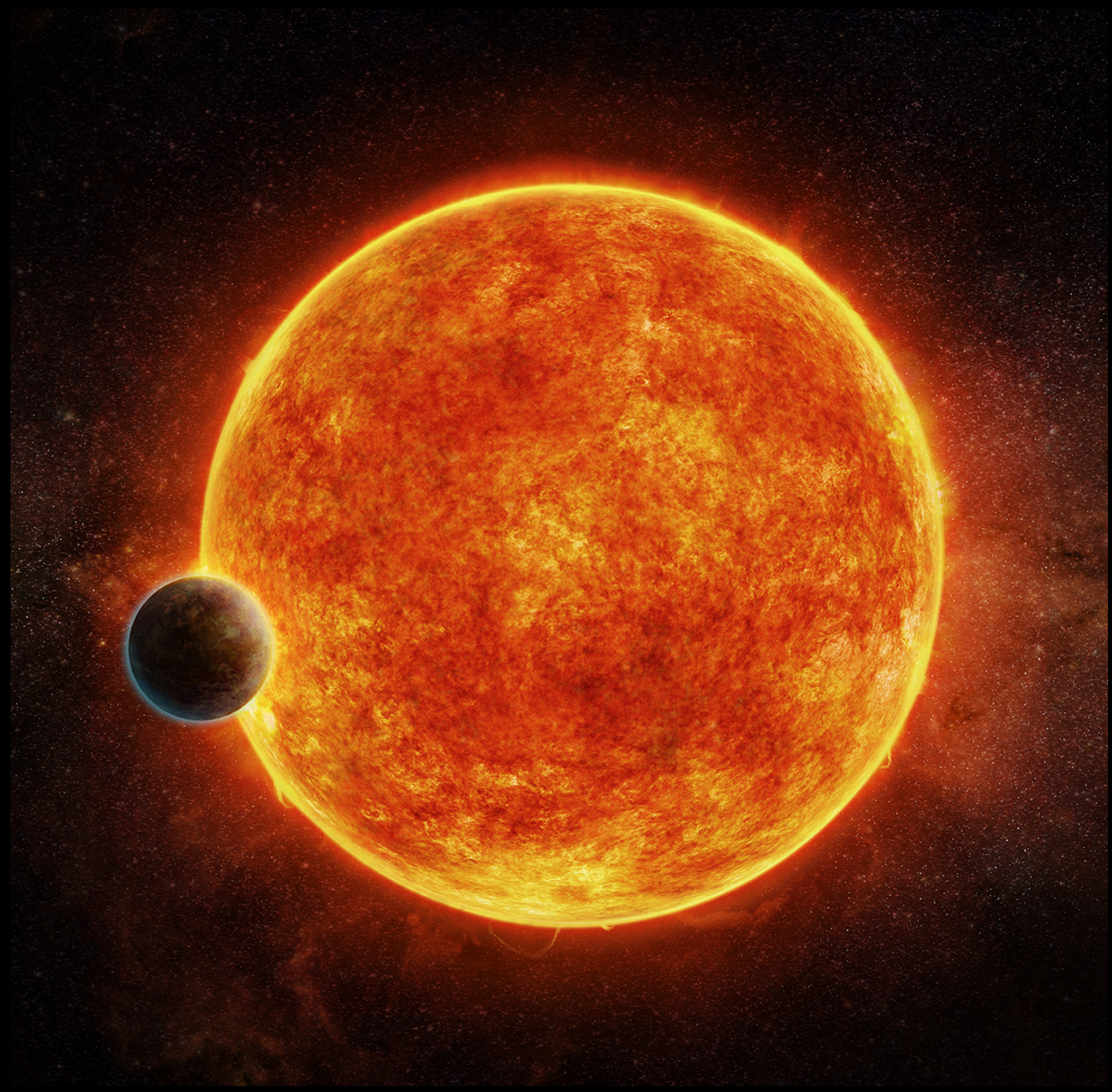
Jupiter sculpted the inner solar system

NASA



Source: Alessandro Morbidelli

Conclusions



We monitored a volume-complete, inactive sample of 200 stars with masses 0.1–0.3 $M_\odot$ and located within 15 pc, collecting four high-resolution spectra of each M dwarf over six years.

We place a 95% confidence upper limit of 1.5% on the occurrence of $M_P \sin i > 1\ M_{Jup}$ giant planets out to the water snow line.

Beyond the snow line ($100\ K < T_{eq} < 150\ K$),
we place 95% confidence upper limits of
1.5% for $3\ M_{Jup} < M_P \sin i < 10\ M_{Jup}$,
1.7% for $0.8\ M_{Jup} < M_P \sin i < 3\ M_{Jup}$, and,
4.4% for $0.3\ M_{Jup} < M_P \sin i < 0.8\ M_{Jup}$ giant planets

Without such Jovians, the compositions, dynamical histories, and water inventories of terrestrial planets of low-mass M dwarfs may be quite different than those of the Solar system.