Asteroseismology of Solar-Type Stars with TESS

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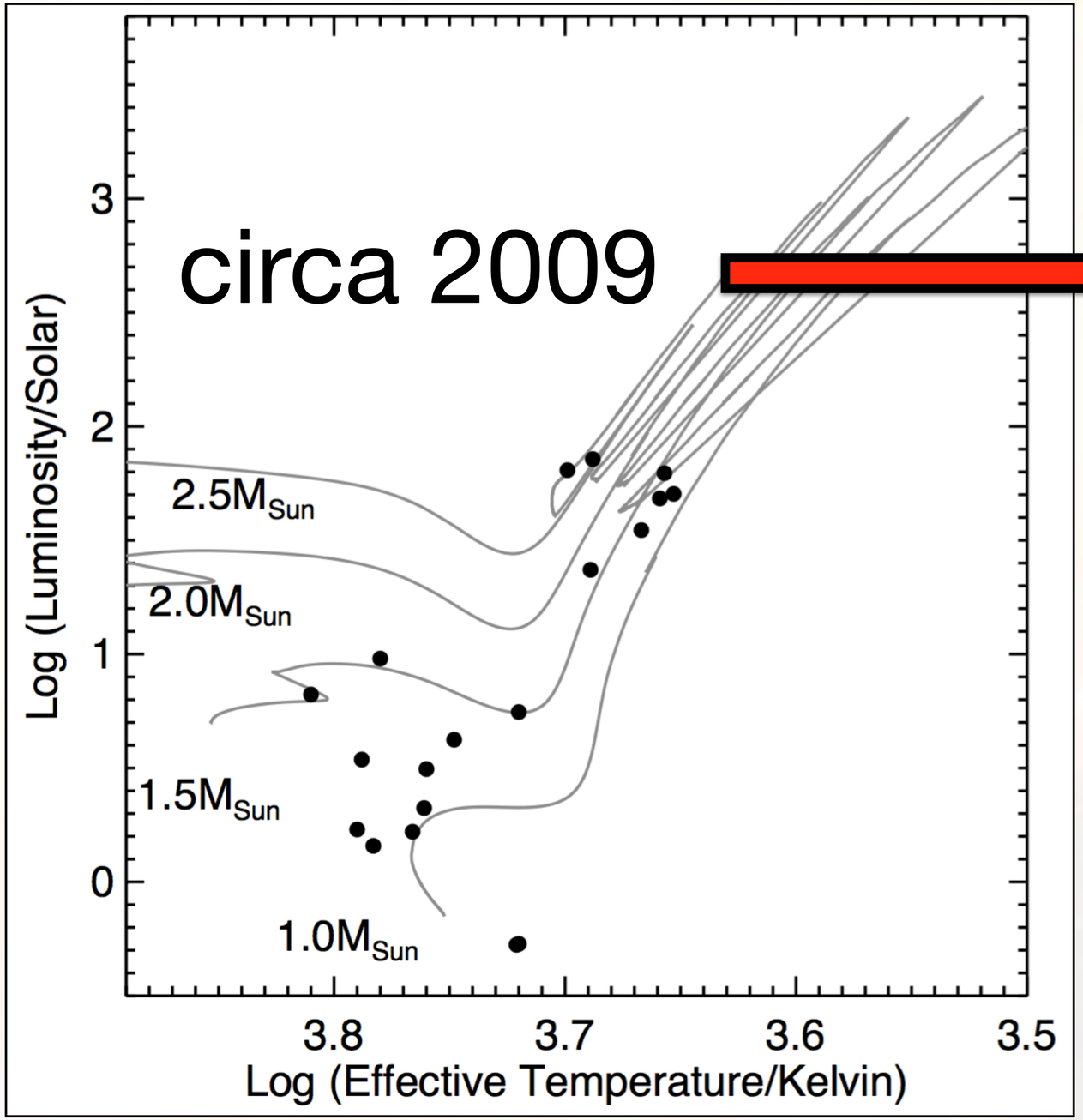
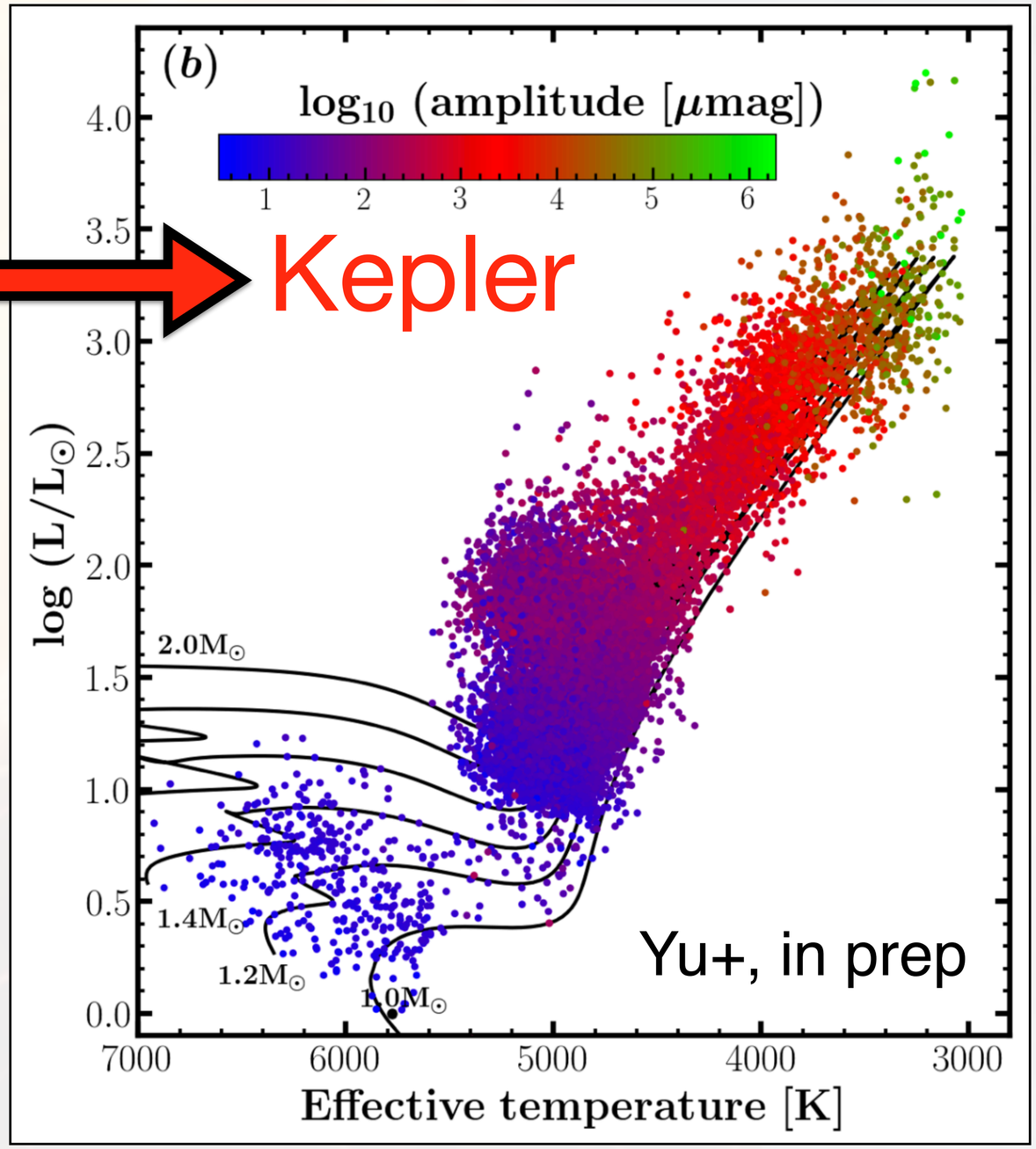
Bill Chaplin (Birmingham), Ashley Chontos (IfA Hawai‘i), Warrick Ball (Birmingham) and the members of TASC Working Groups 1 & 2

TESS Science Conference

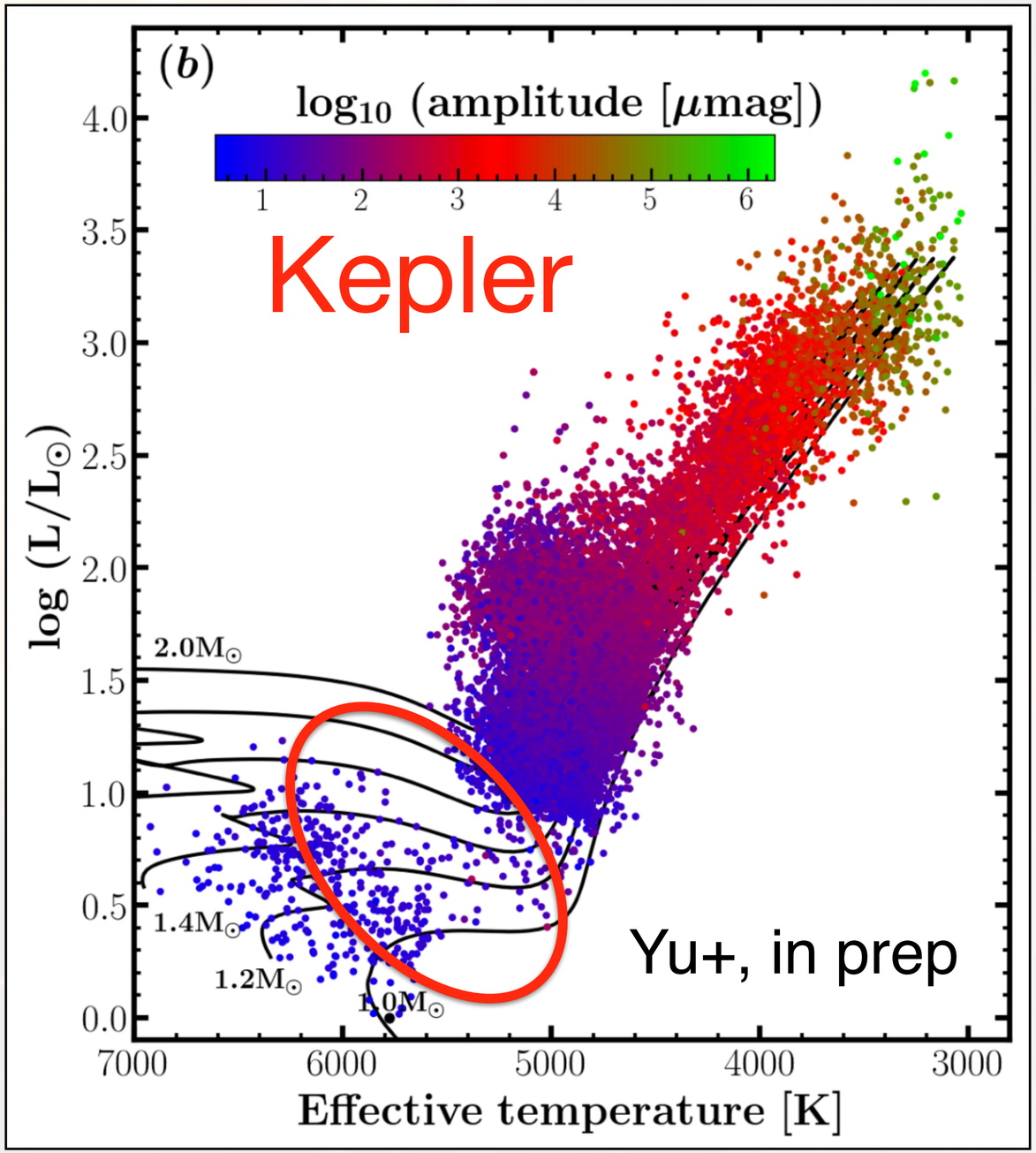
Cambridge, July 2019


circa 2009
Log (Luminosity/Solar)
Log (Effective Temperature/Kelvin)
2.5M$_{Sun}$
2.0M$_{Sun}$
1.5M$_{Sun}$
1.0M$_{Sun}$
3
2
1
0
3.8
3.7
3.6
3.5

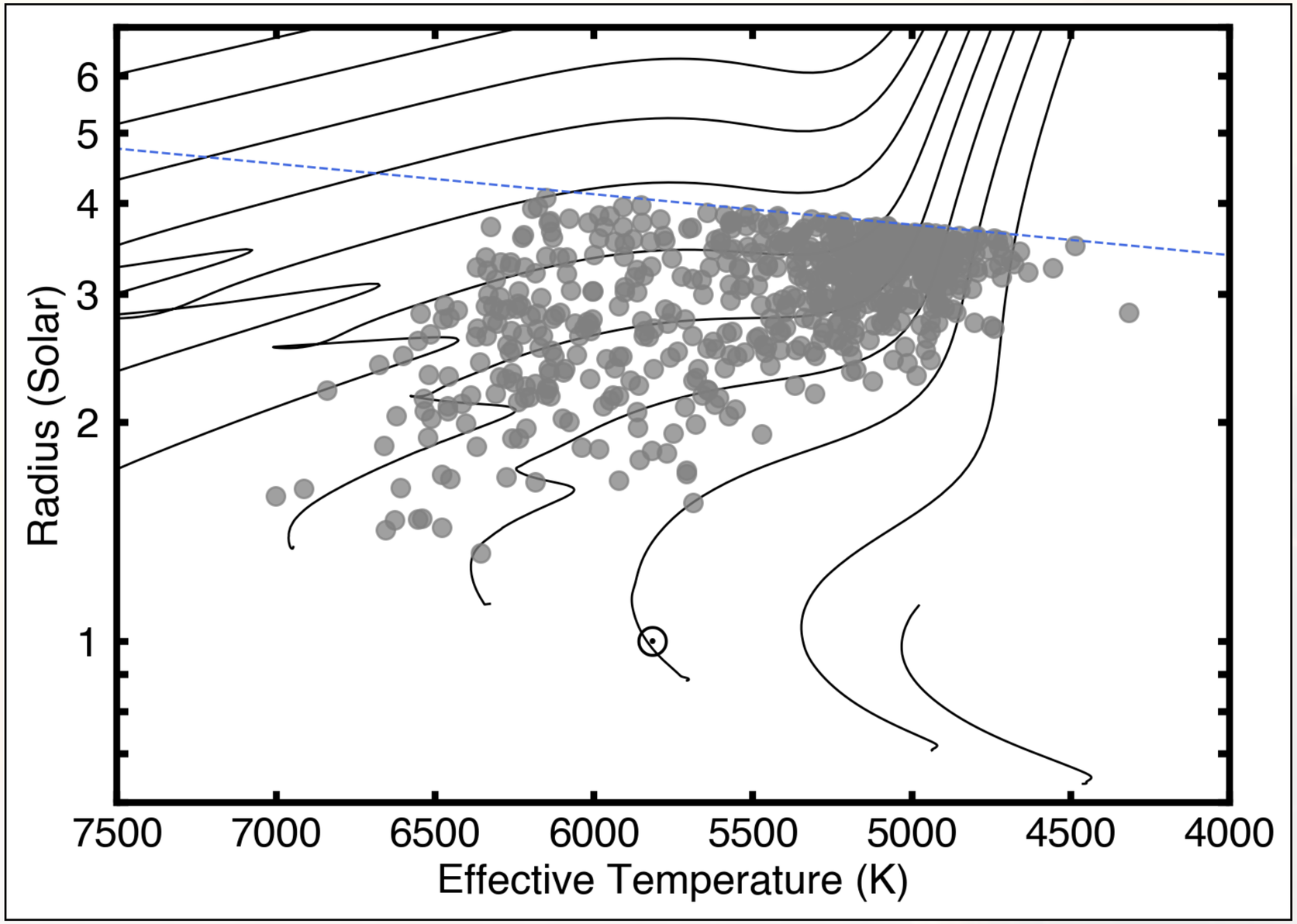

Kepler
(b)
log$_{10}$ (amplitude [μmag])
1
2
3
4
5
6
log (L/L$_\odot$)
Effective temperature [K]
2.0M$_\odot$
1.4M$_\odot$
1.2M$_\odot$
1.0M$_\odot$
Yu+, in prep
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
7000
6000
5000
4000
3000

Kepler/K2 was amazing, but we need more!

- Kepler observed only a small number of subgiants (rotation!)
- Kepler stars are mostly faint (e.g. no interferometry possible)
- Only in Kepler/K2 fields (need all-sky coverage for calibration of spectroscopic surveys)



Asteroseismic TESS Yield: First Results



- Asteroseismic Target List (ATL): solar-like oscillators for 2-minute cadence

Schofield, Chaplin, Huber+ 2019

- ~4000 ATL targets observed in TESS sectors 1-11
- Analyzed 630 stars ranked in the top 2000 stars in the ATL

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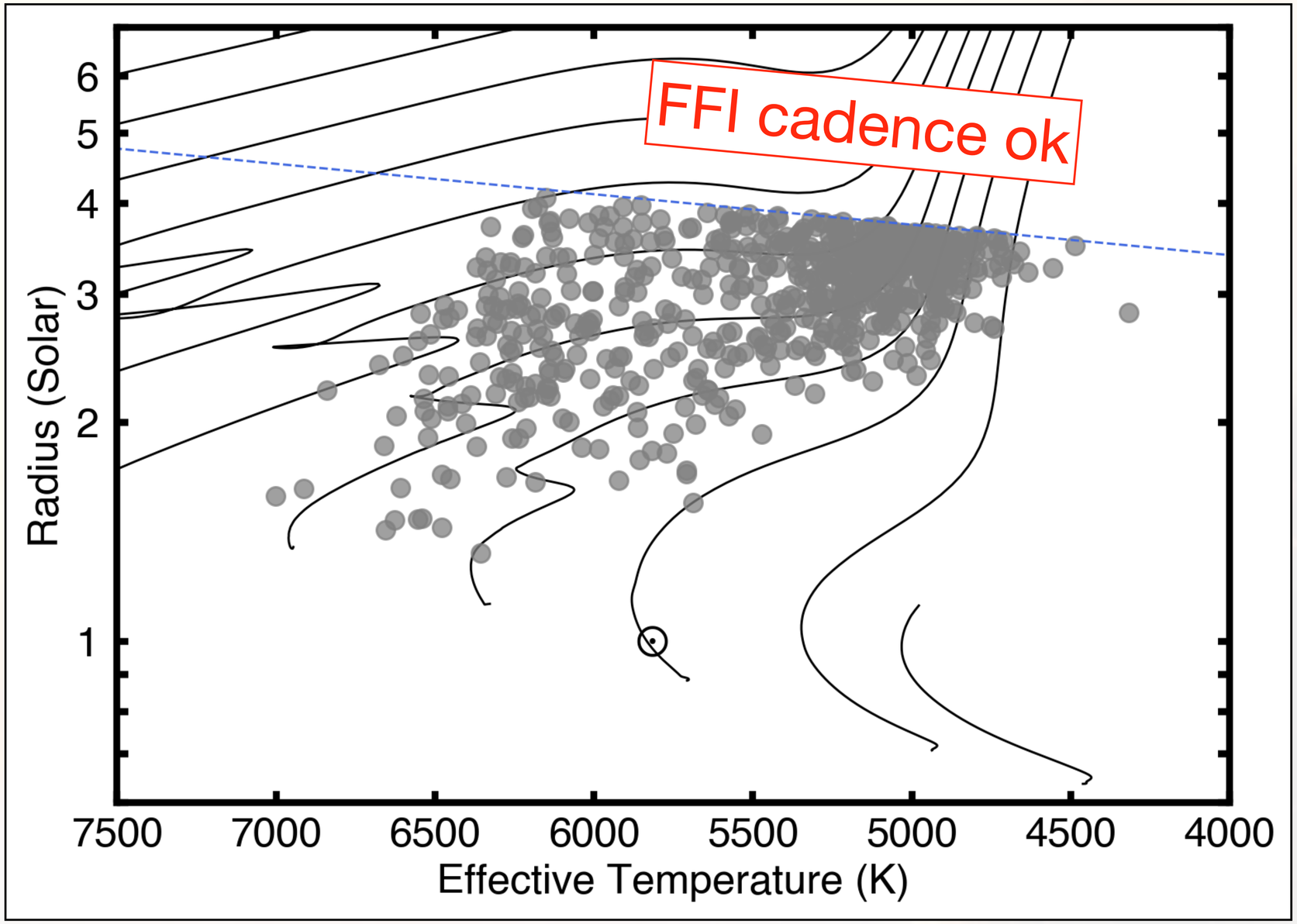

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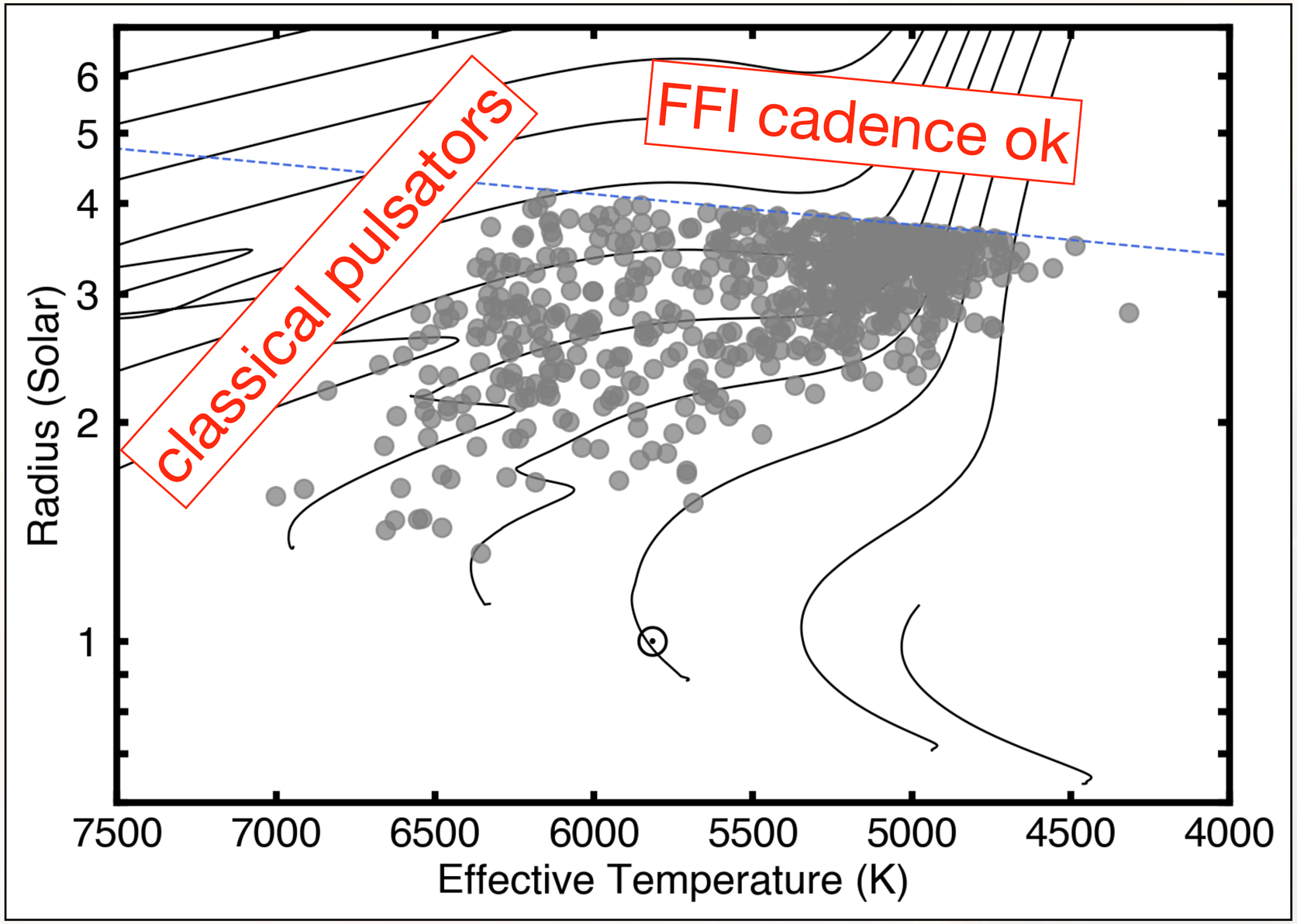

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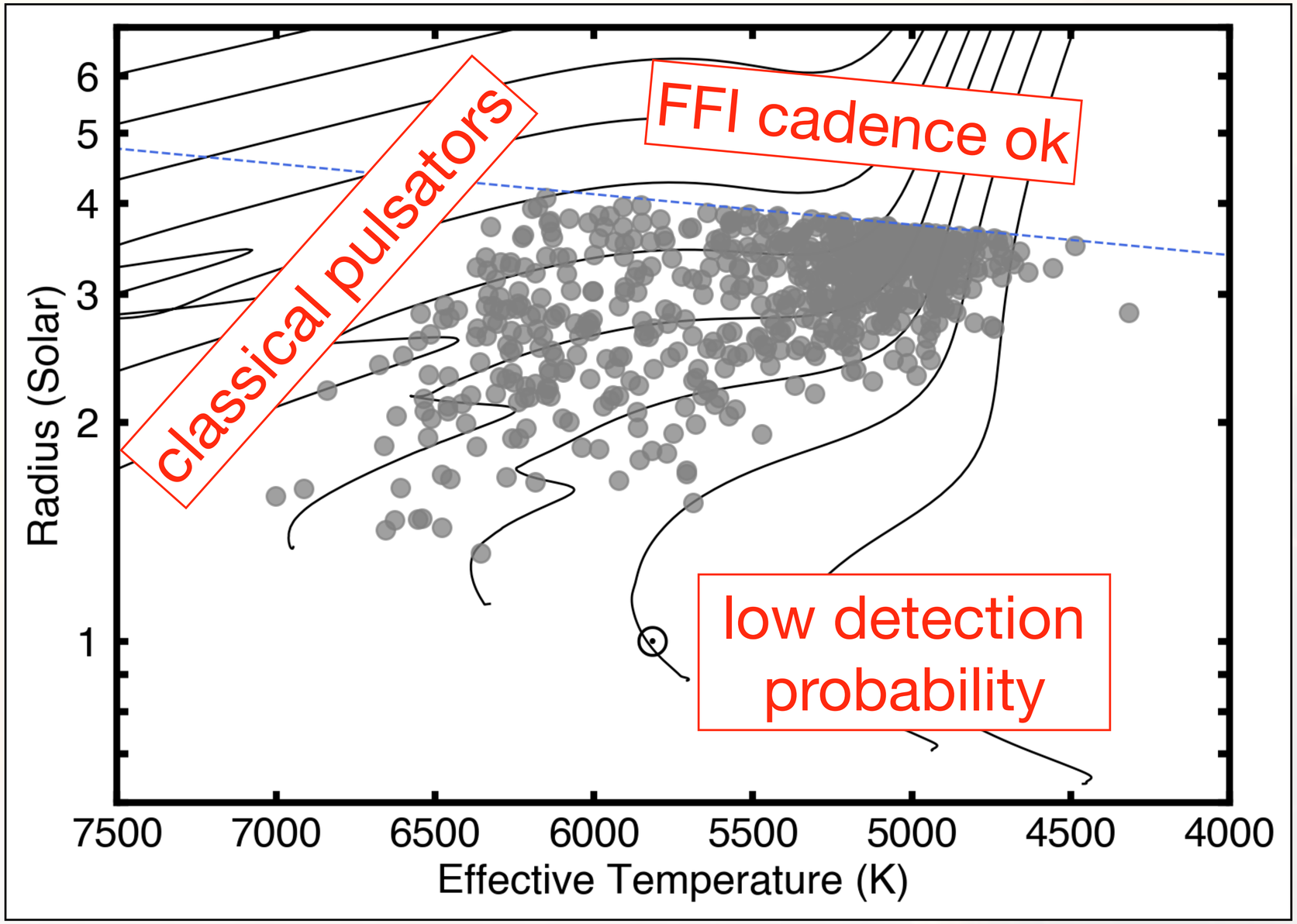

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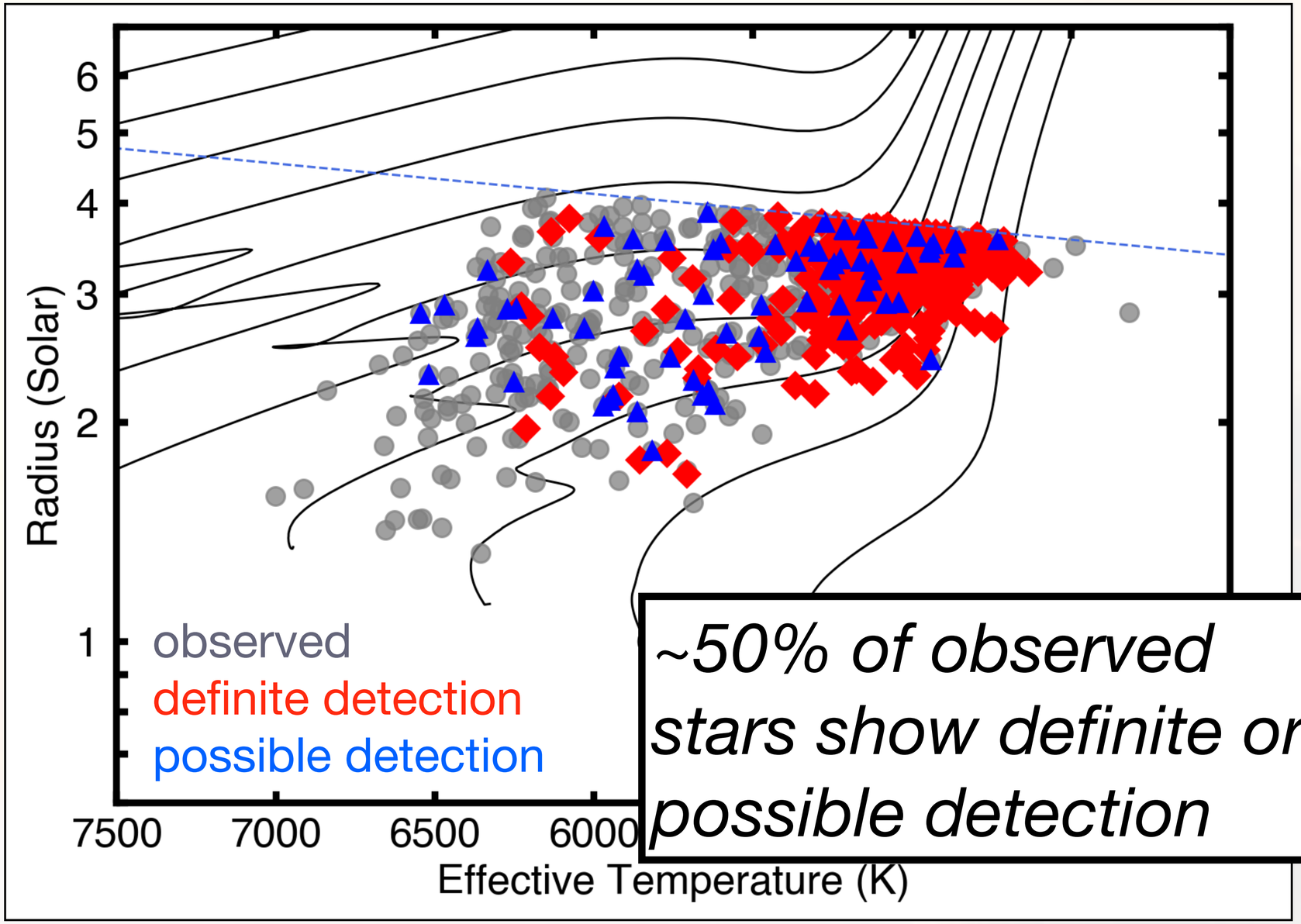

~50% of observed stars show definite or possible detection

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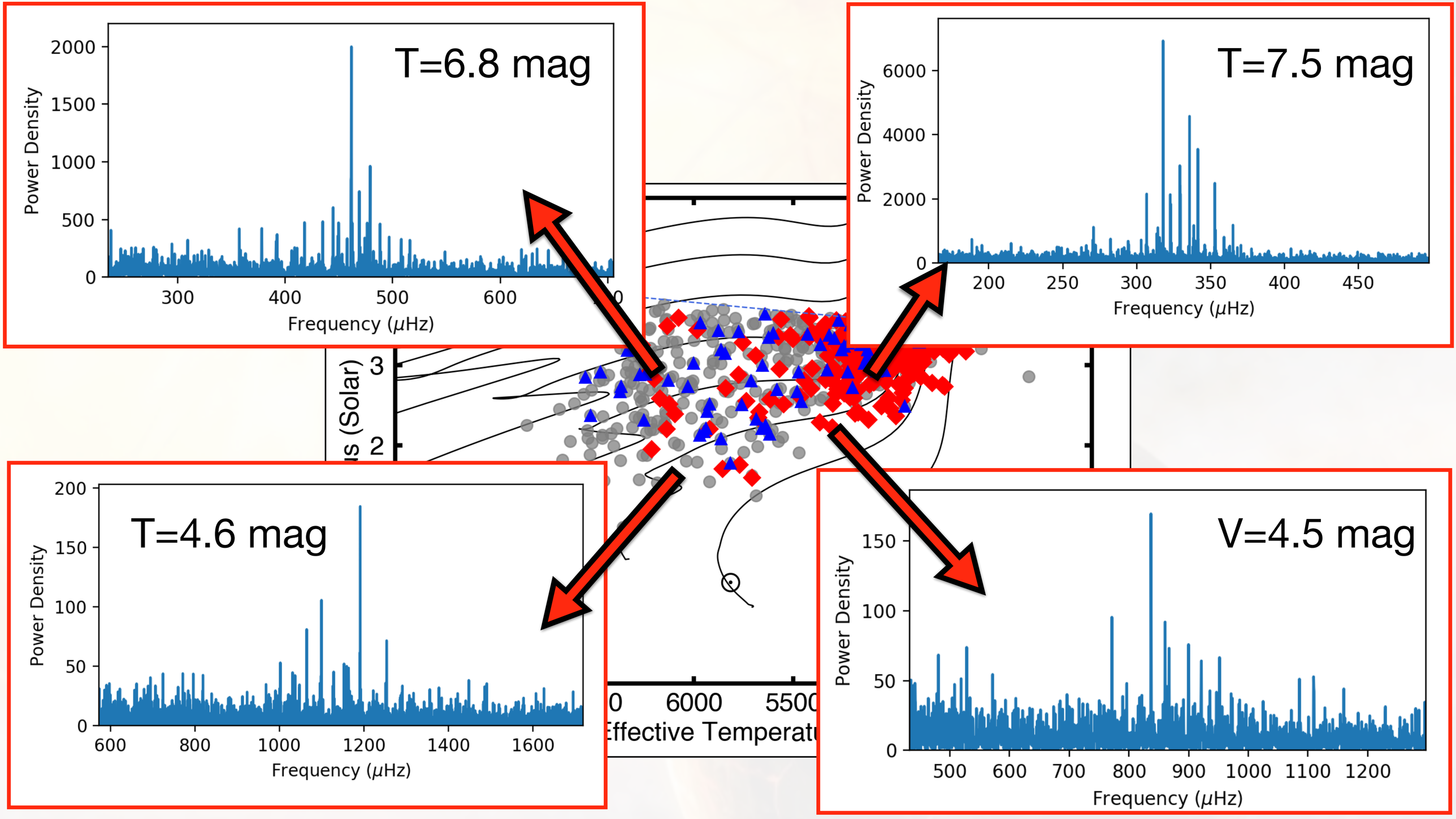
T=6.8 mag
Power Density
Frequency (μHz)
T=7.5 mag
Power Density
Frequency (μHz)
T=4.6 mag
Power Density
Frequency (μHz)
V=4.5 mag
Power Density
Frequency (μHz)
Effective Temperatu

Why is the Detection Fraction only ~50%?

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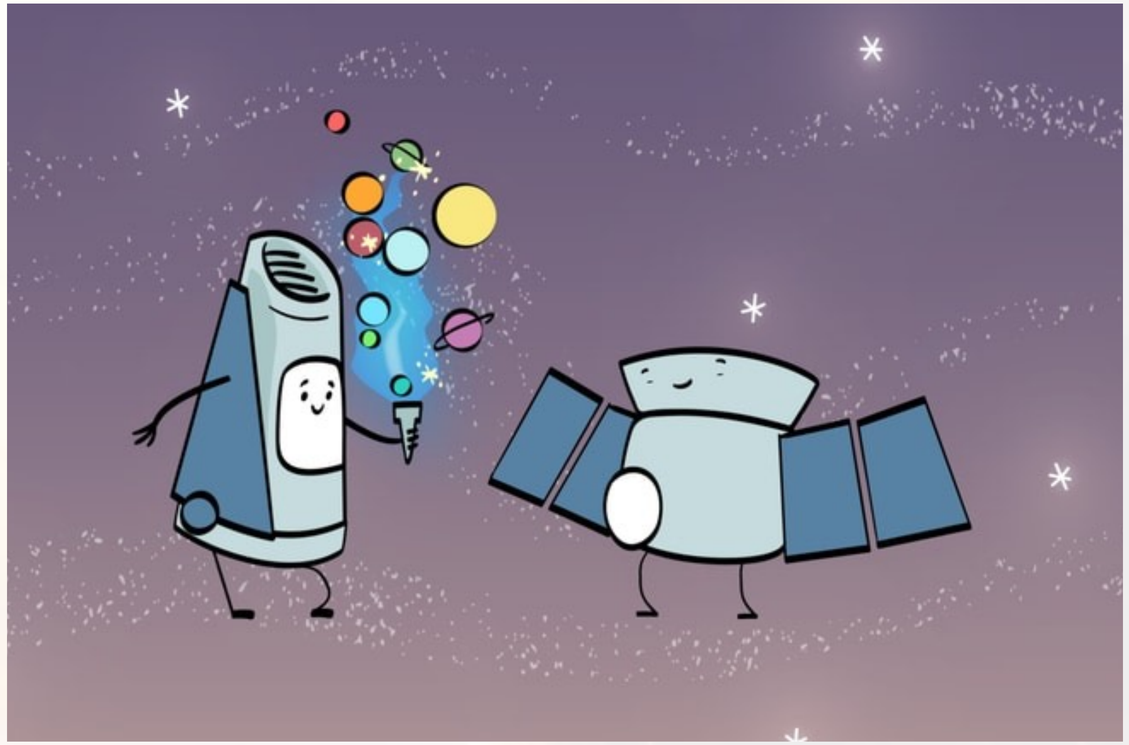
It's complicated, BUT: Kepler asteroseismic detection fraction was ~30%!



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extrapolating, we expect ~1000-2000 detections in the TESS prime mission (~2-4 x Kepler)

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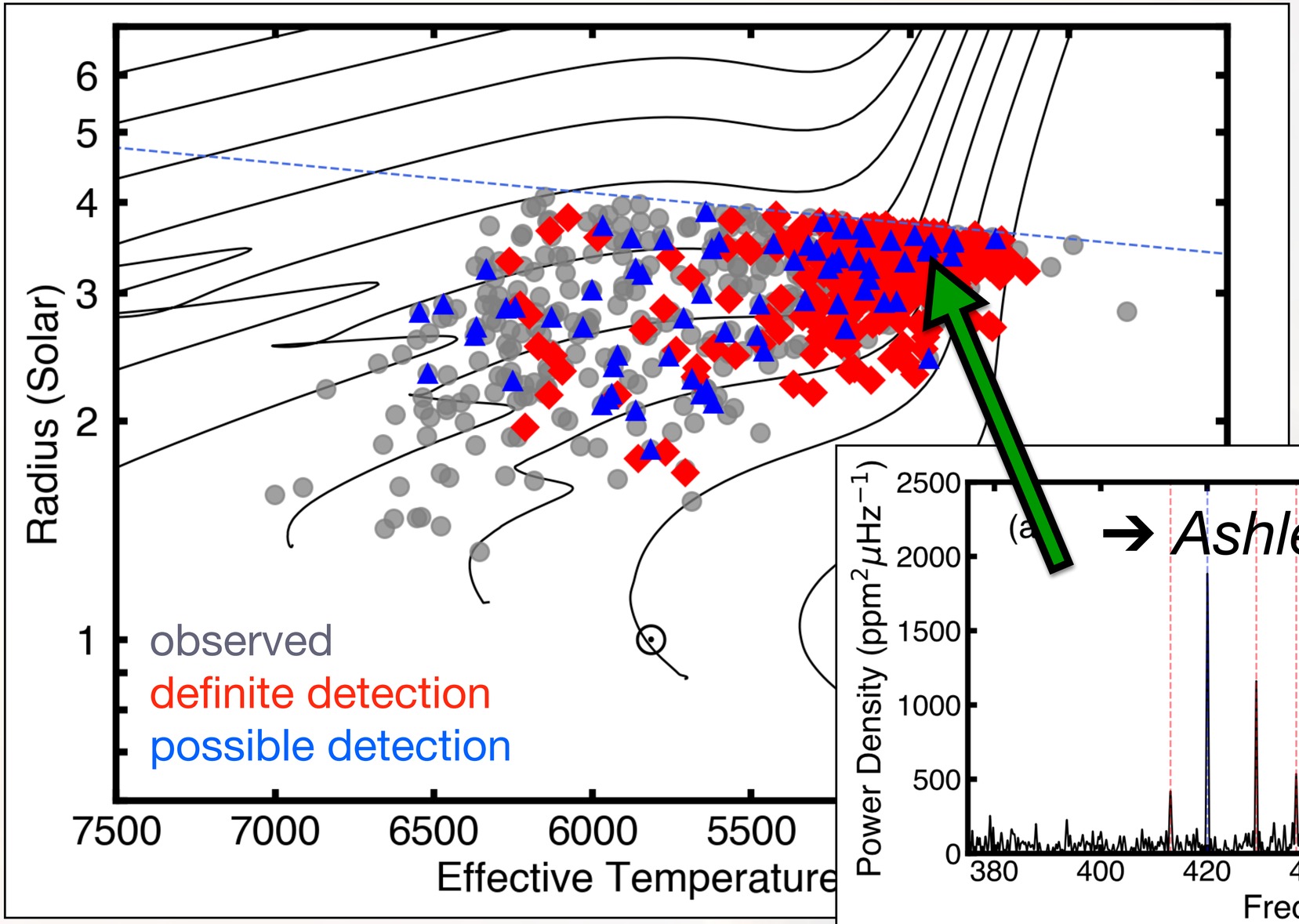
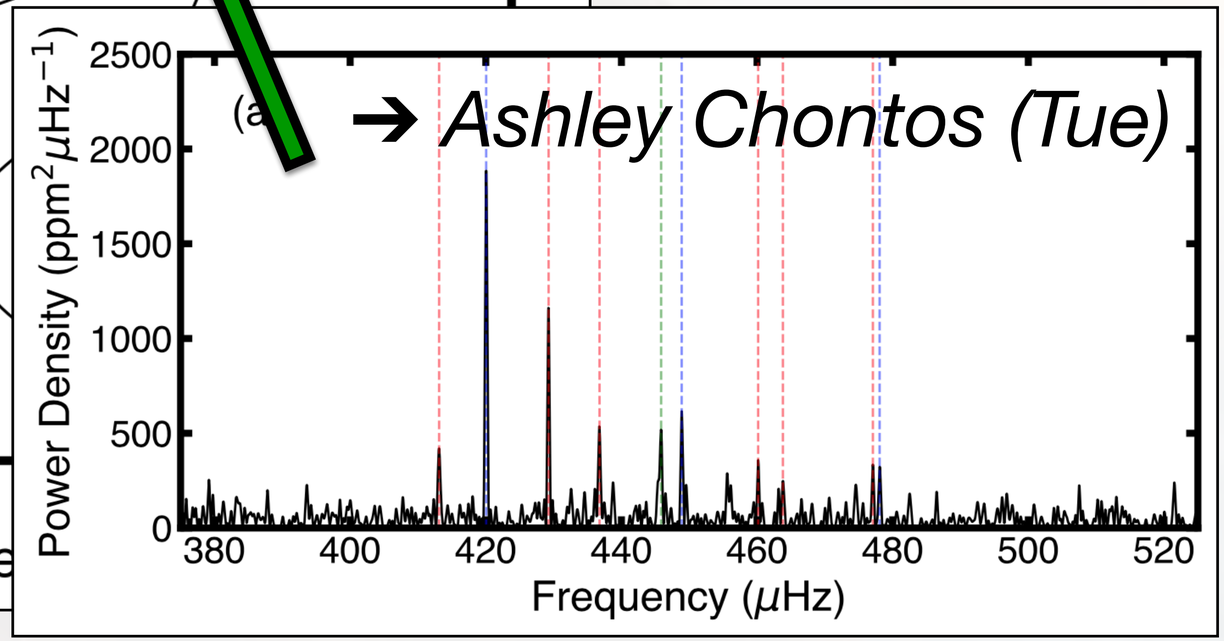


HD221416
TOI-197

Huber+ 2019



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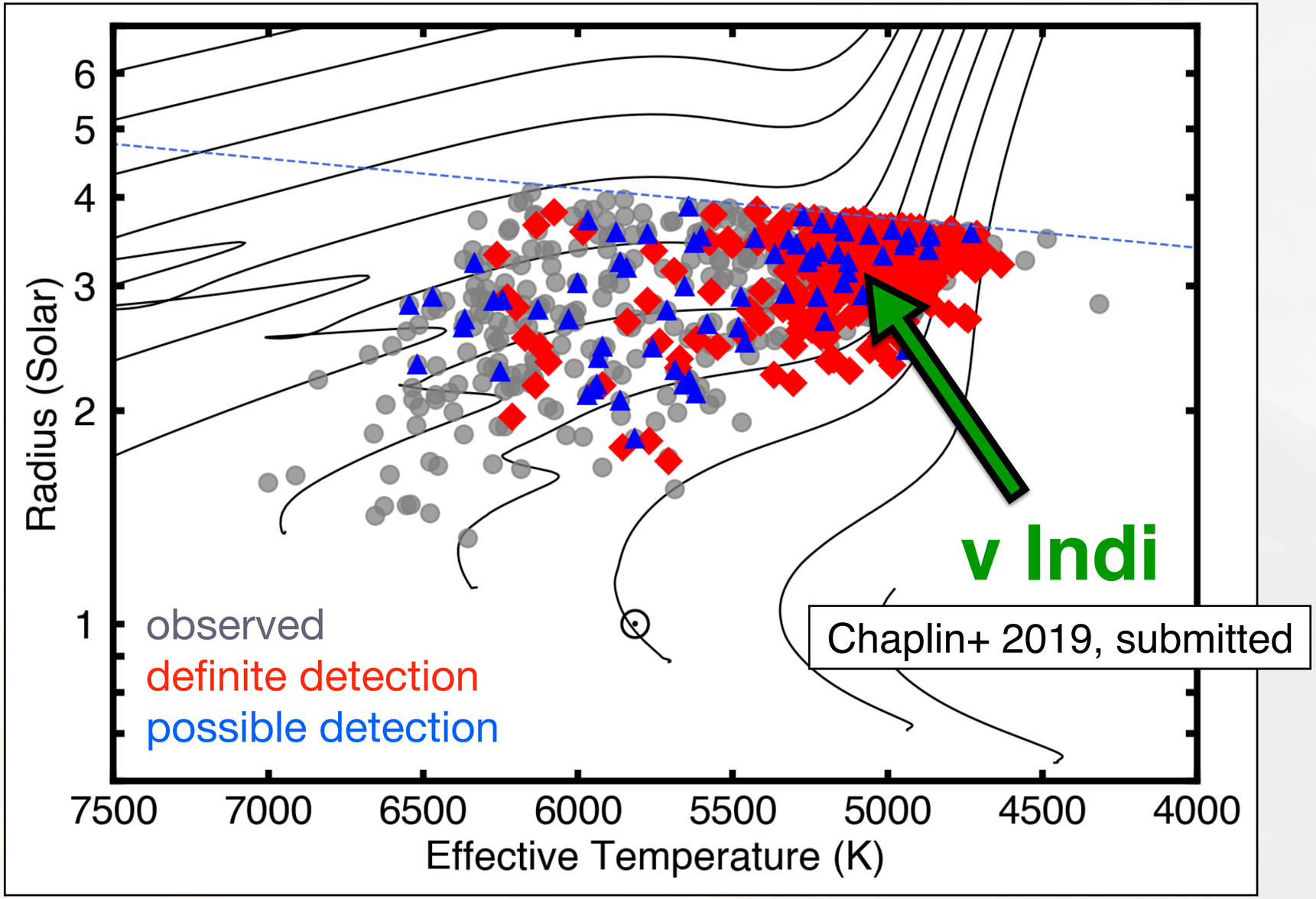

SOLAR-LIKE OSCILLATIONS IN THE METAL-POOR SUBGIANT ν INDI: CONSTRAINING THE MASS AND AGE USING ASTEROSEISMOLOGY

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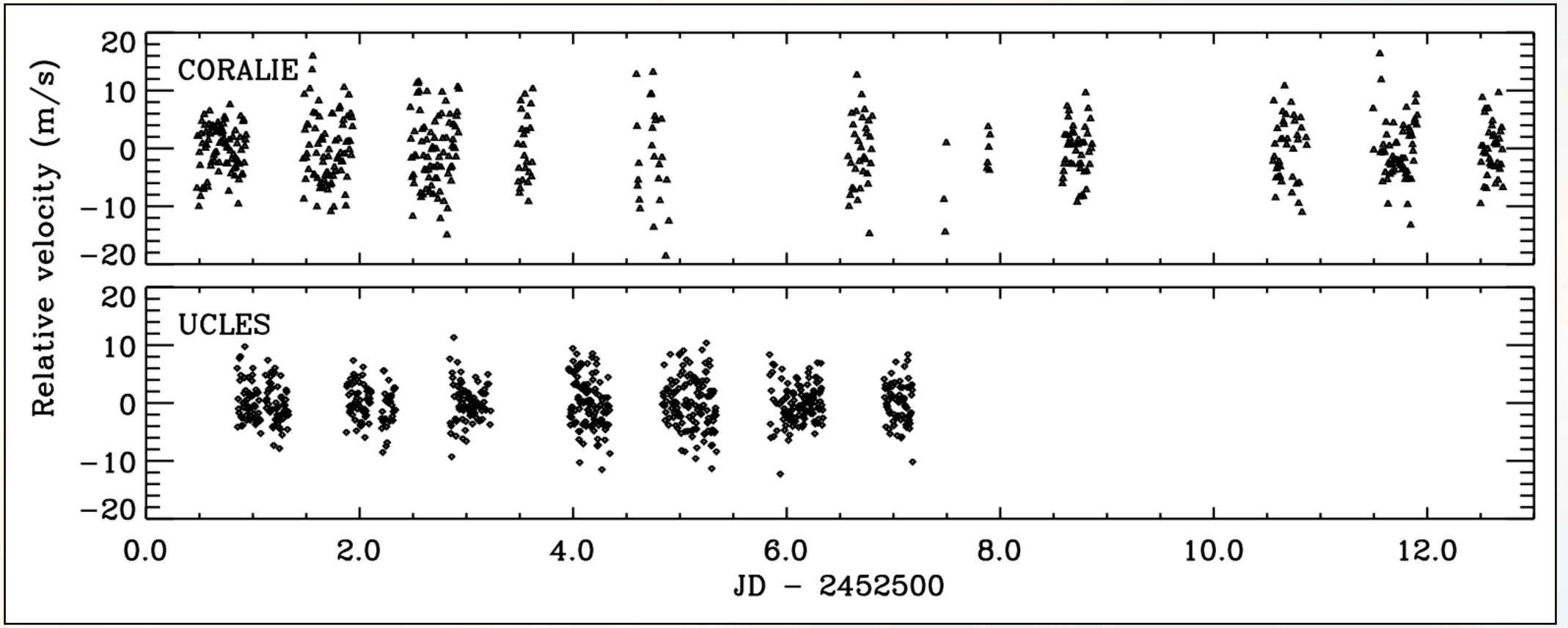
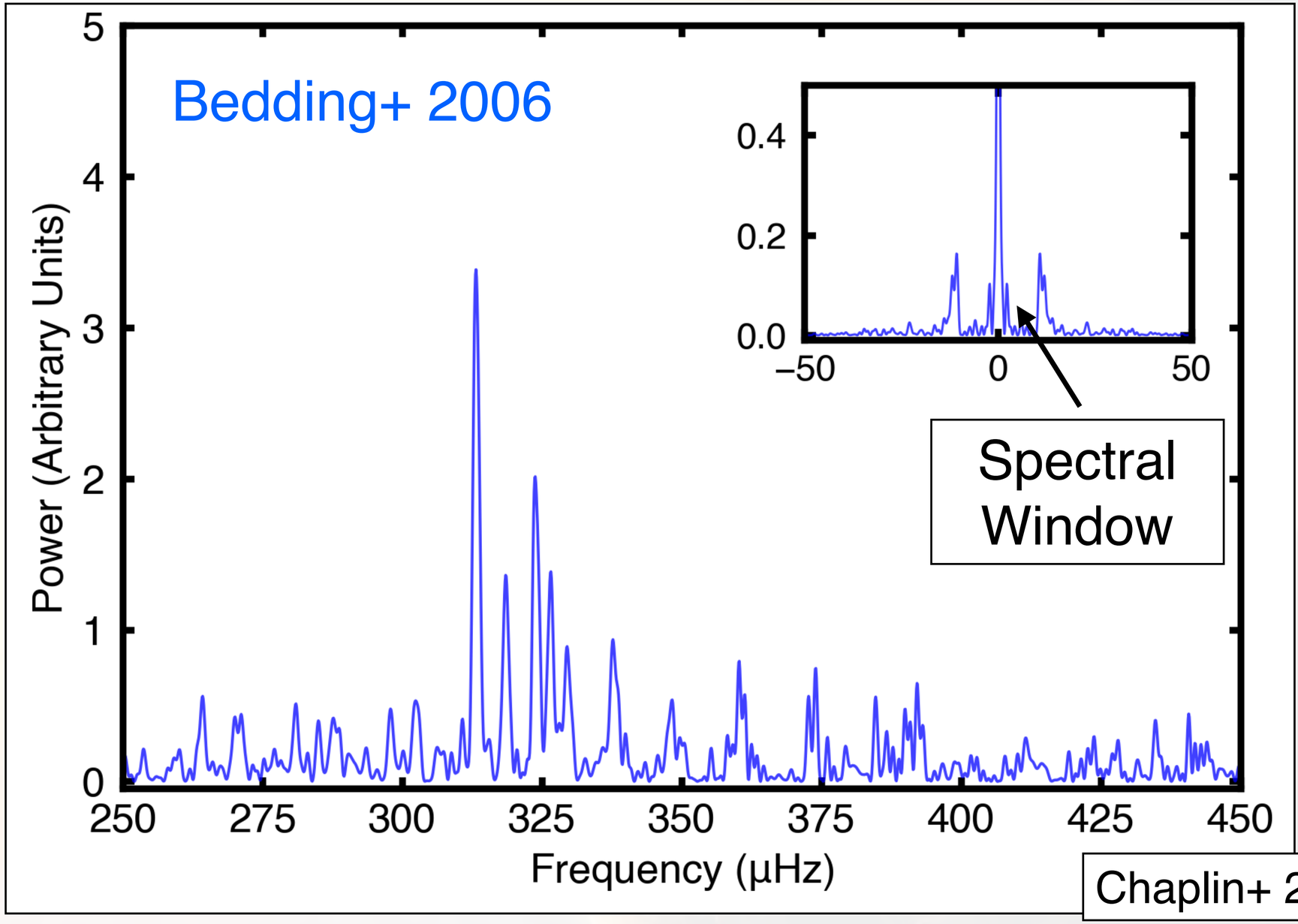
Received 2006 January 6; accepted 2006 April 19



Bright, metal-poor benchmark star (V=5.3, [Fe/H] ~ -1.5)

An asteroseismic Celebrity: ν Indi



Chaplin+ 2019, submitted

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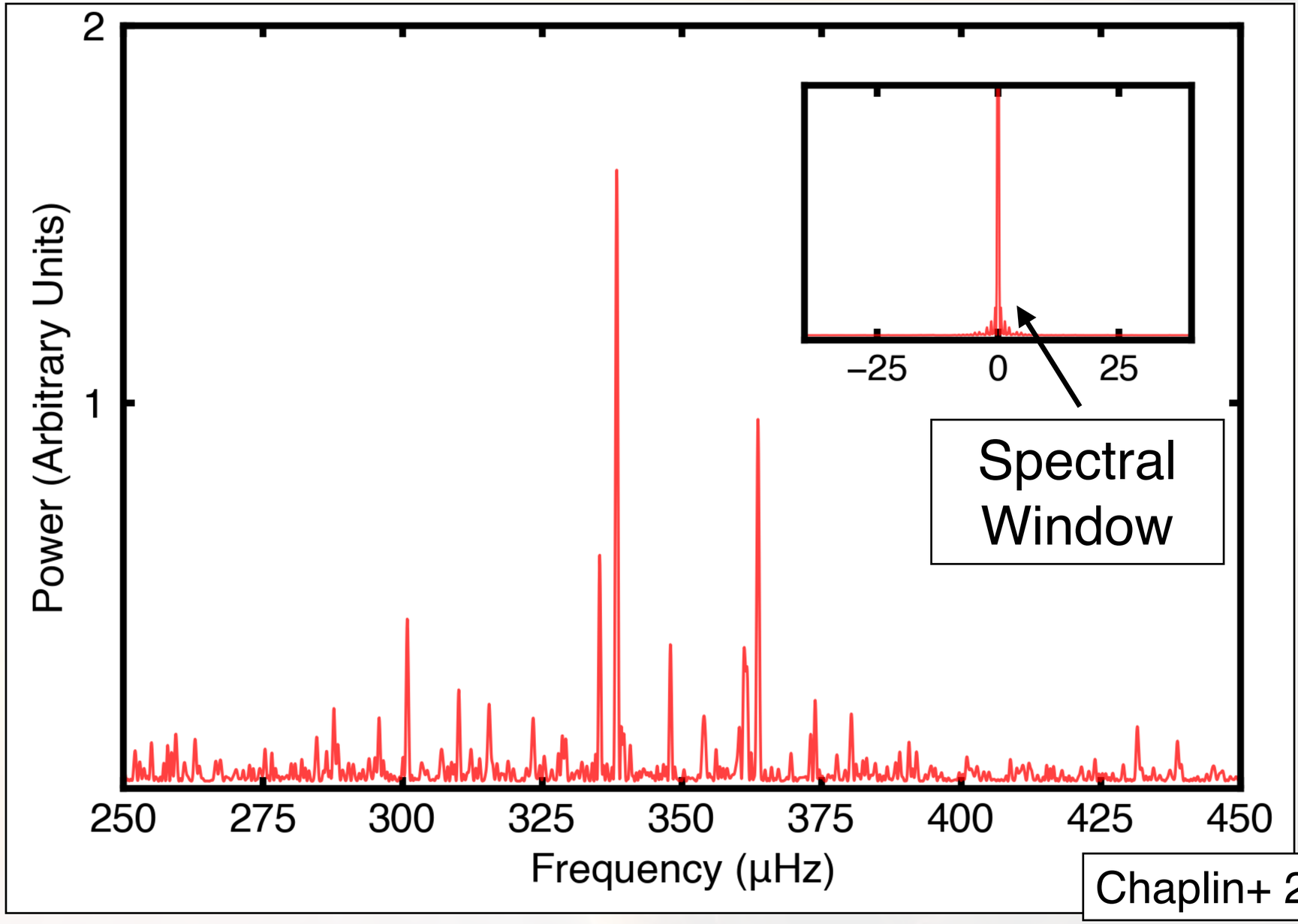
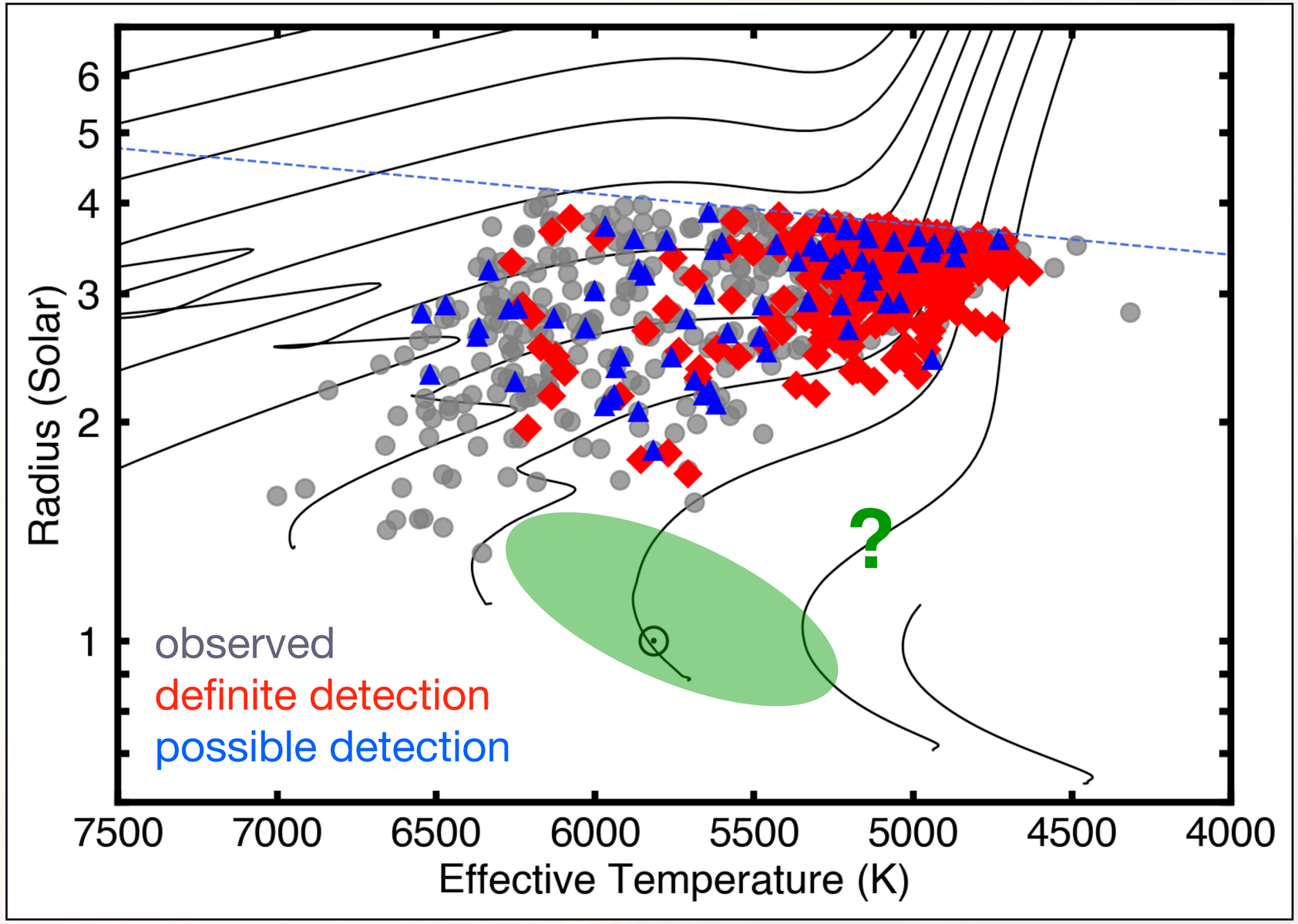


Chaplin+ 2019, submitted

Where are the "true" Solar-Type Stars?



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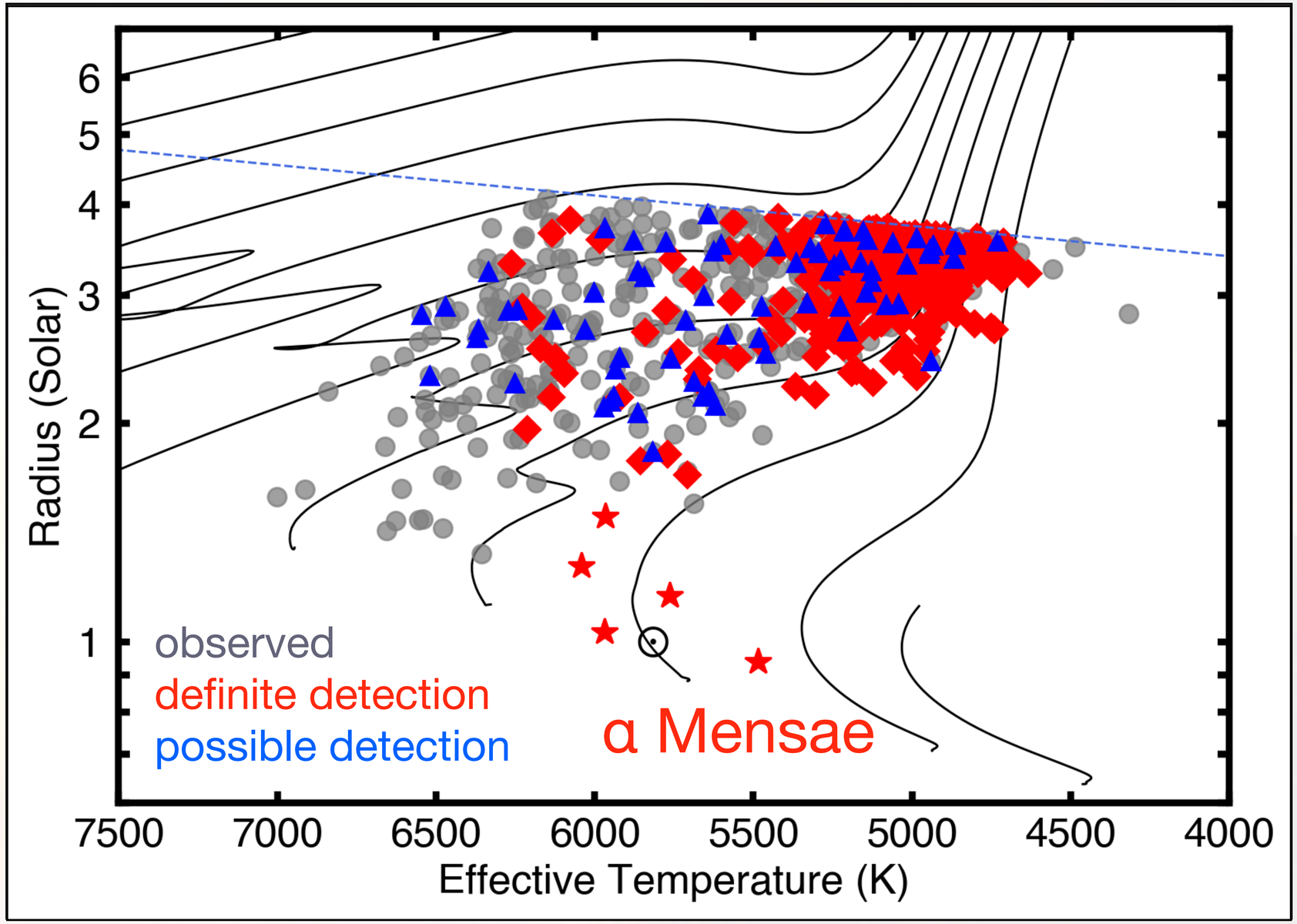
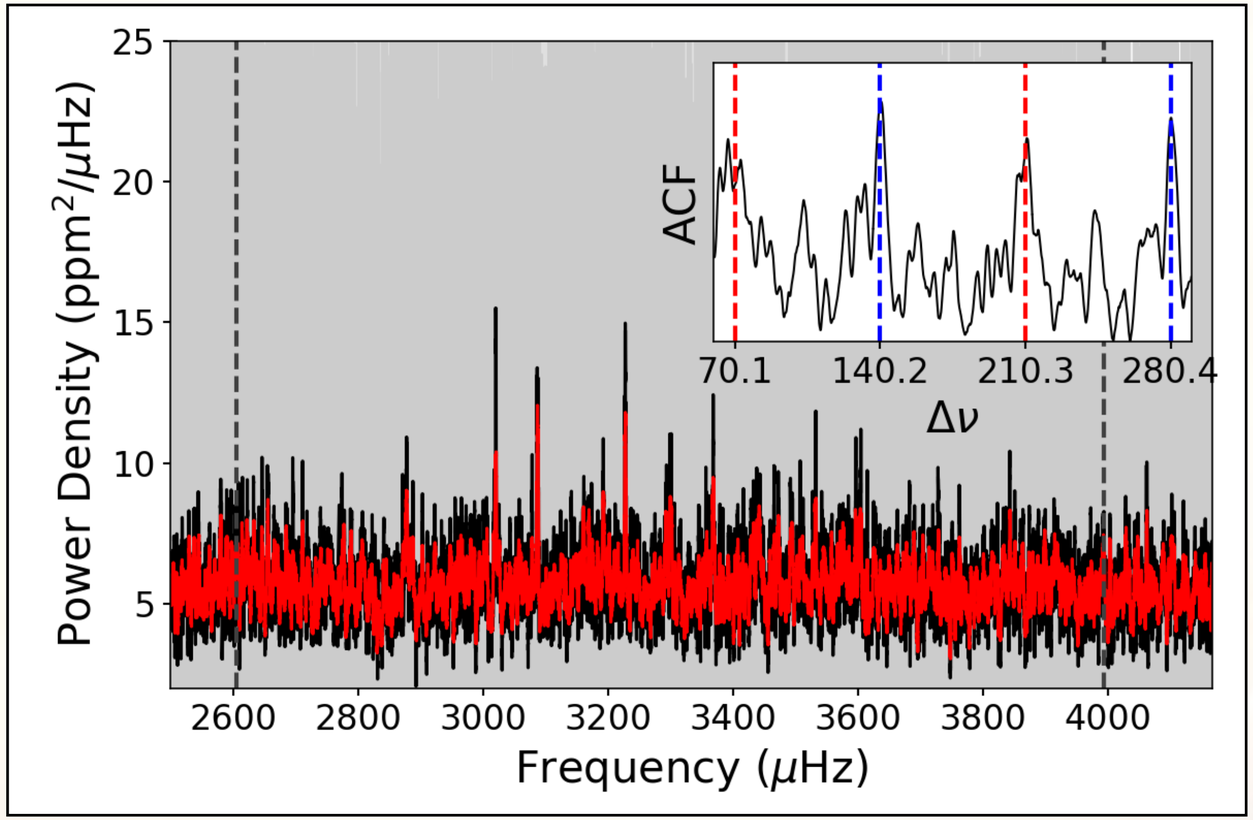
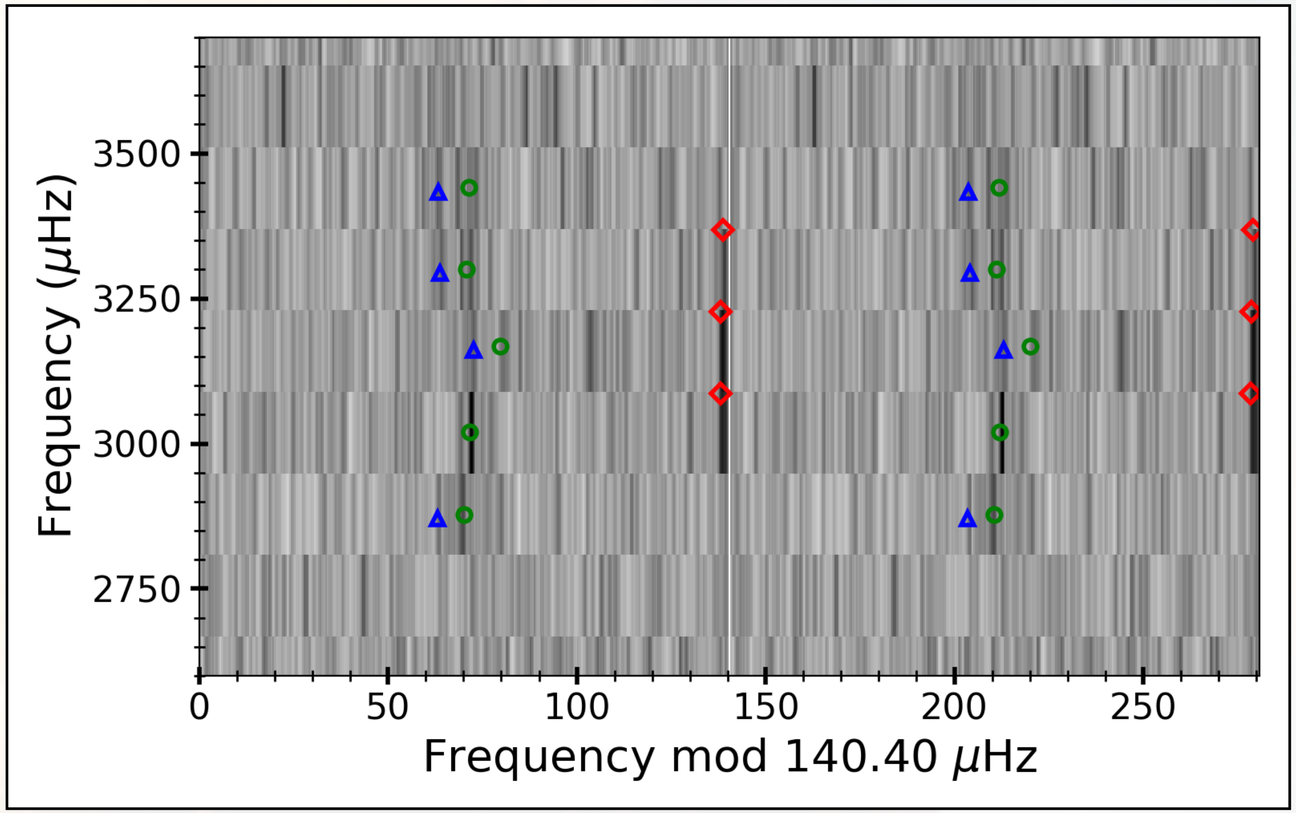


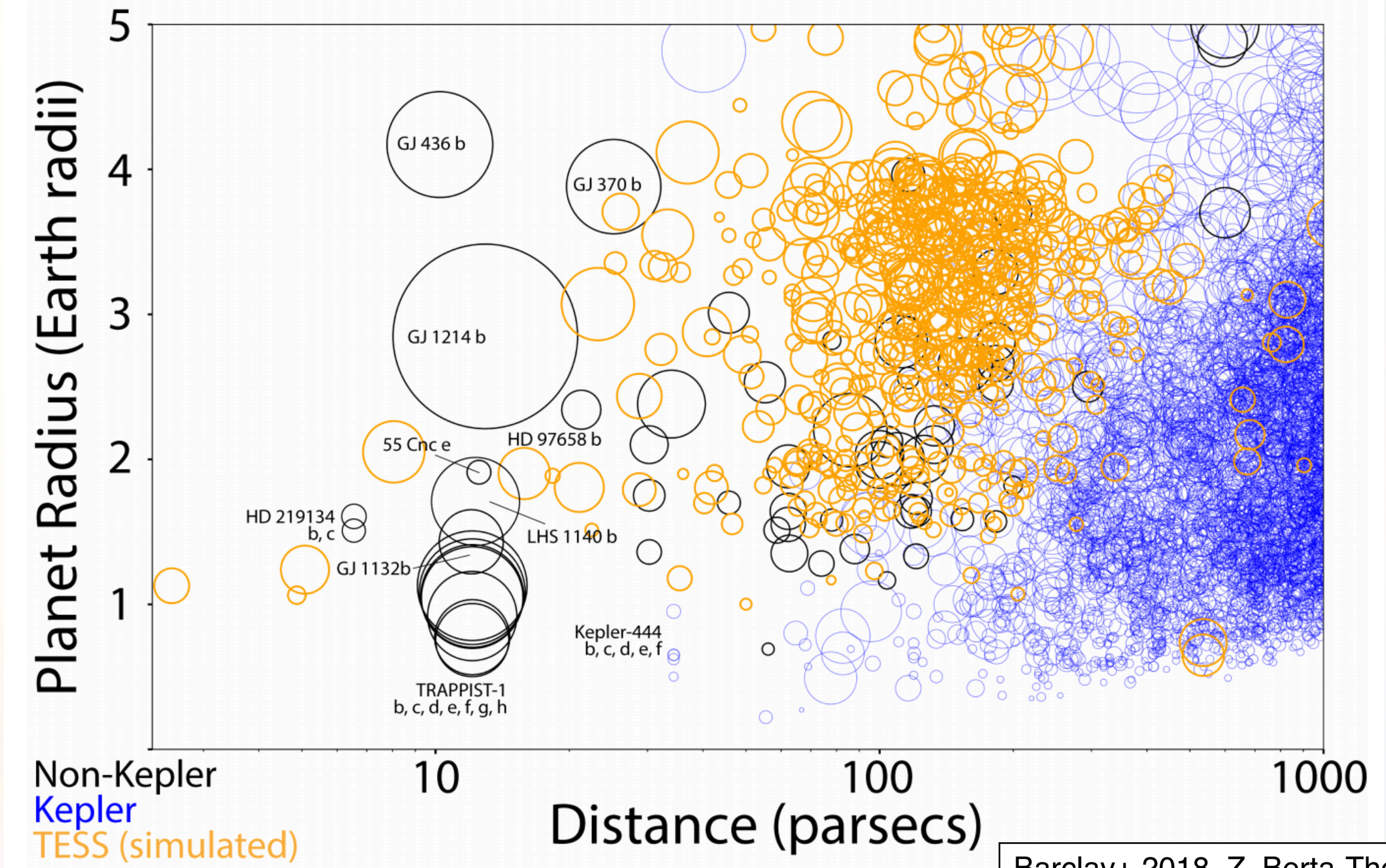
α Mensae: A Bright Solar Analog



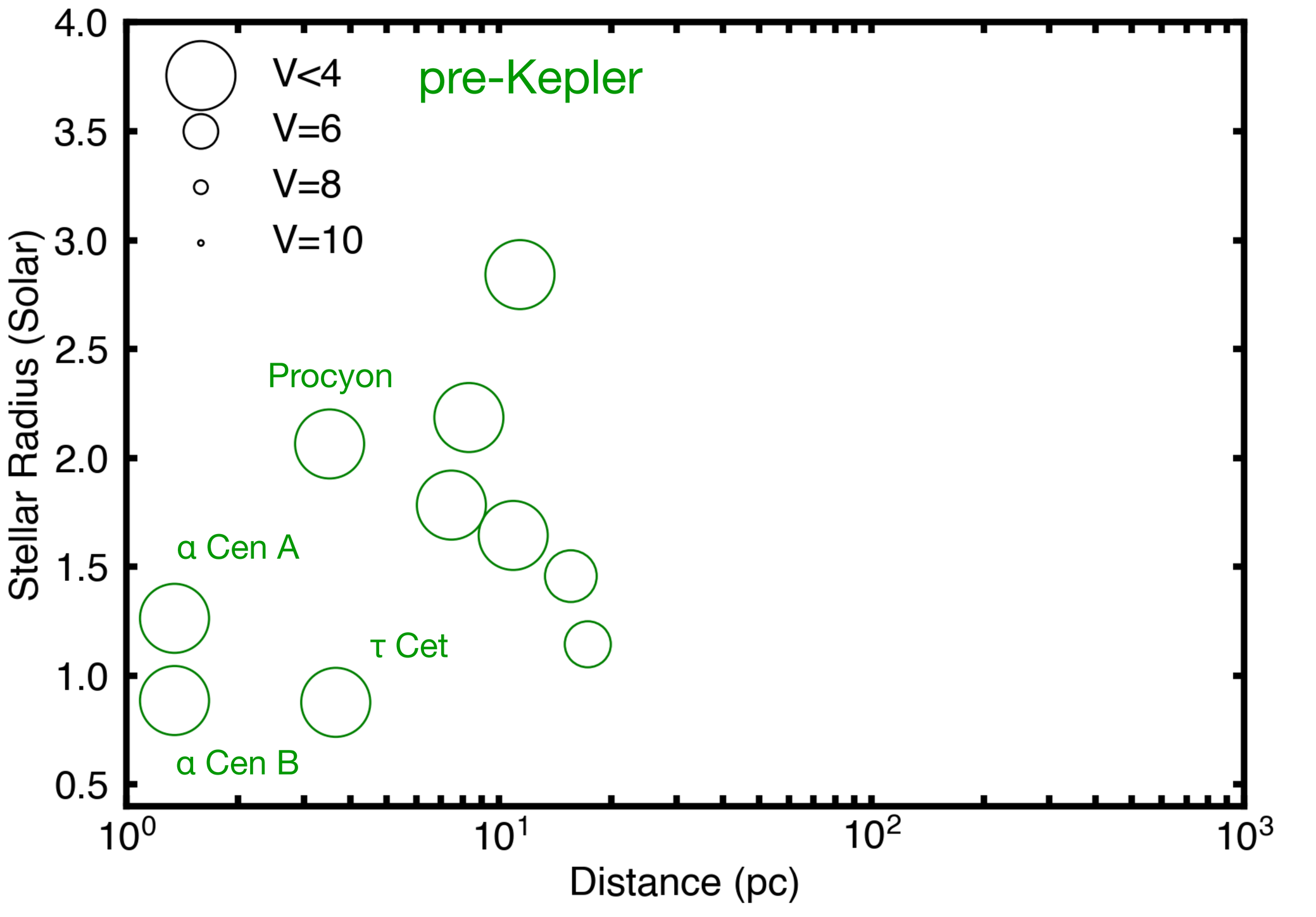


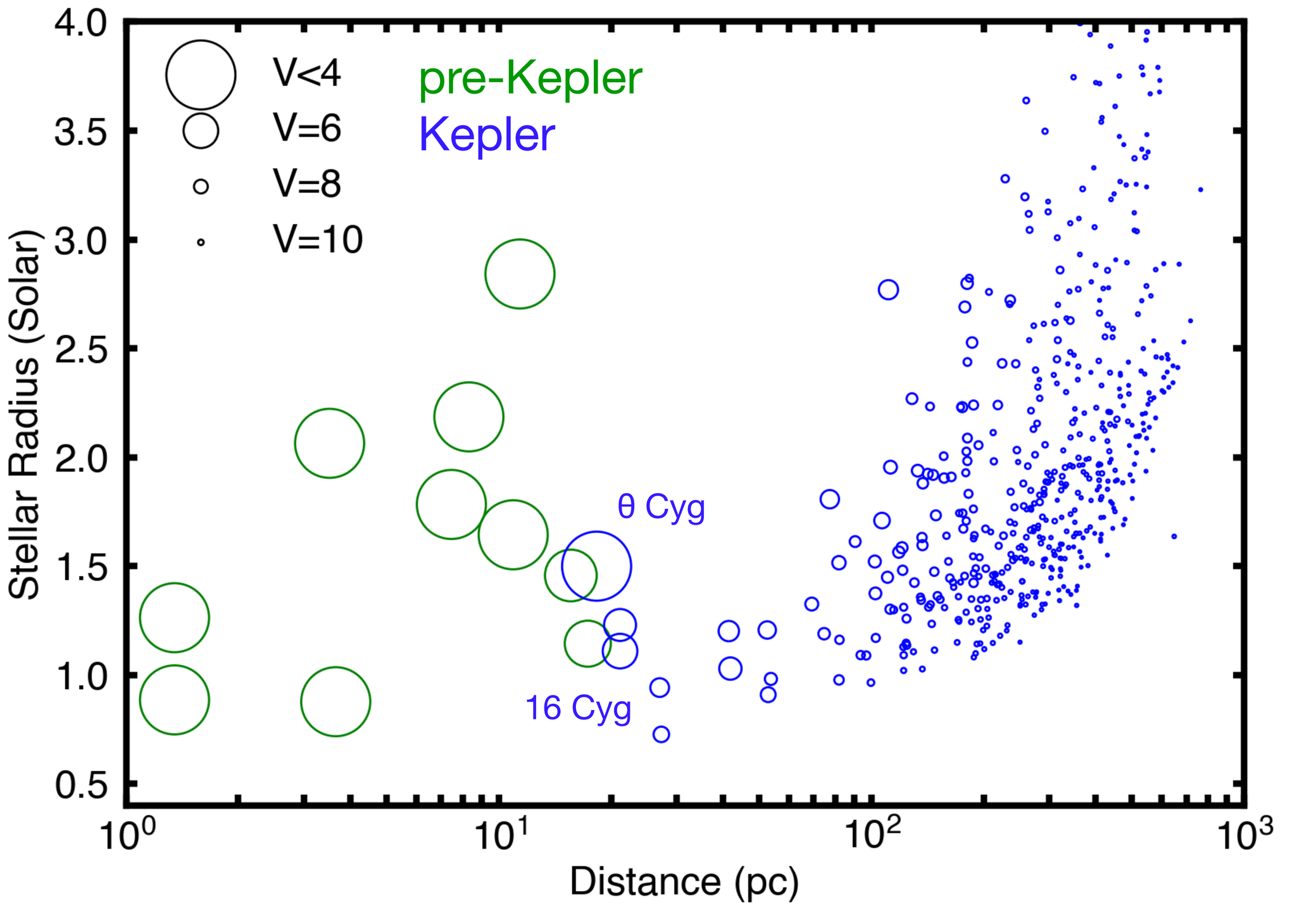
- Brightest star cooler than the Sun with space-based seismic detection
- M3V companion at ~30 AU → gyrochronology benchmark!

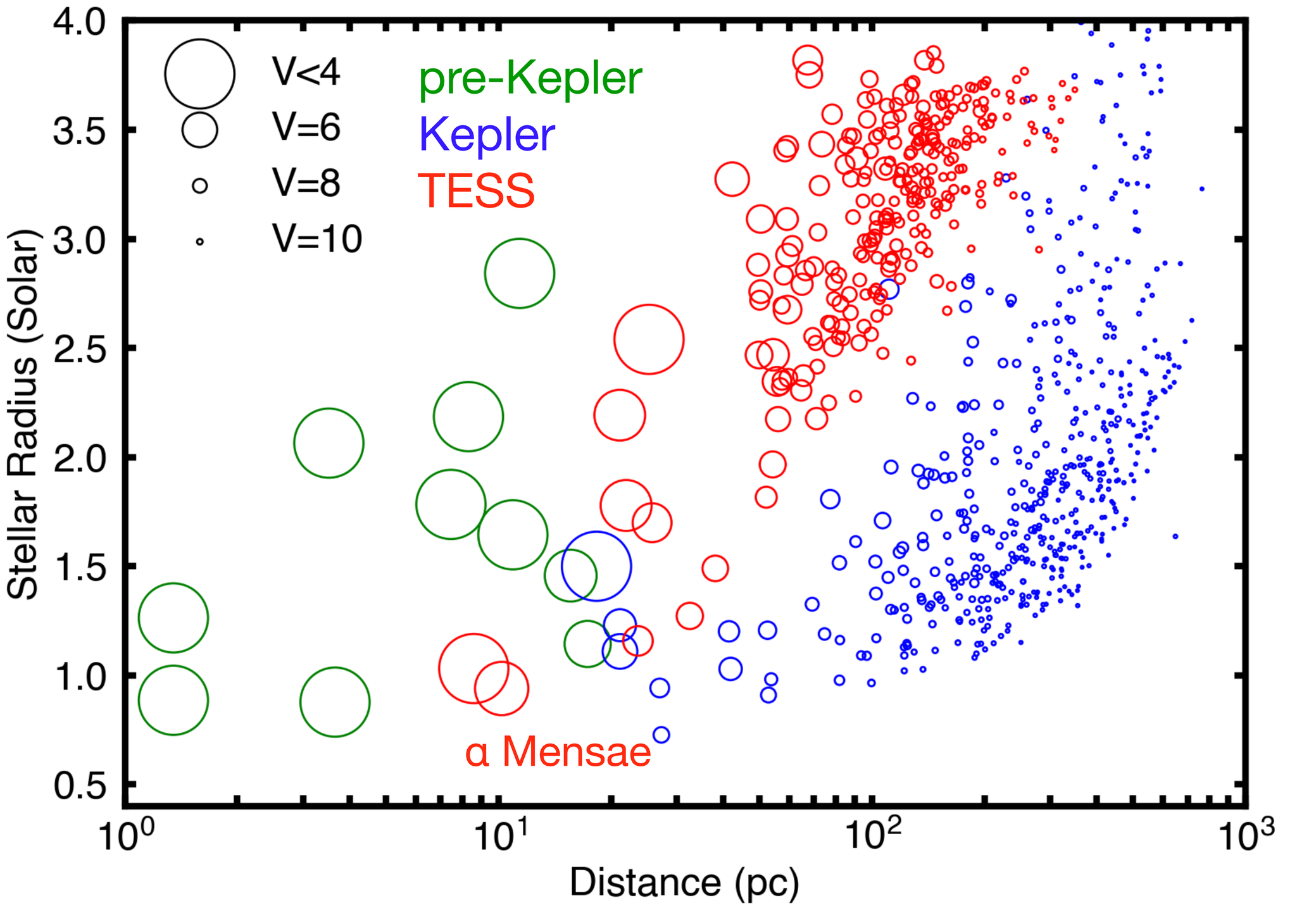
Chontos+ 2019, in prep

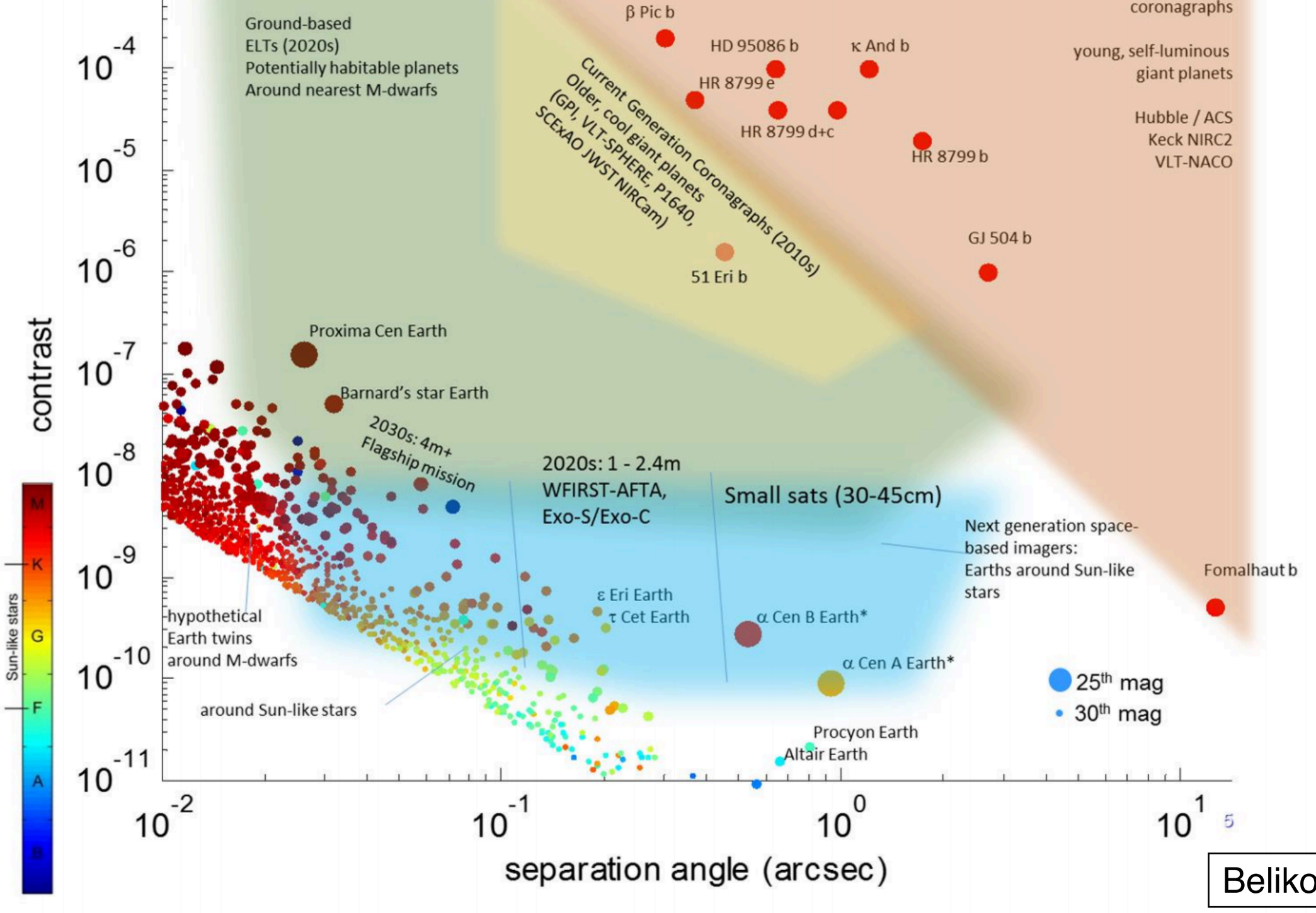


Barclay+ 2018, Z. Berta-Thompson

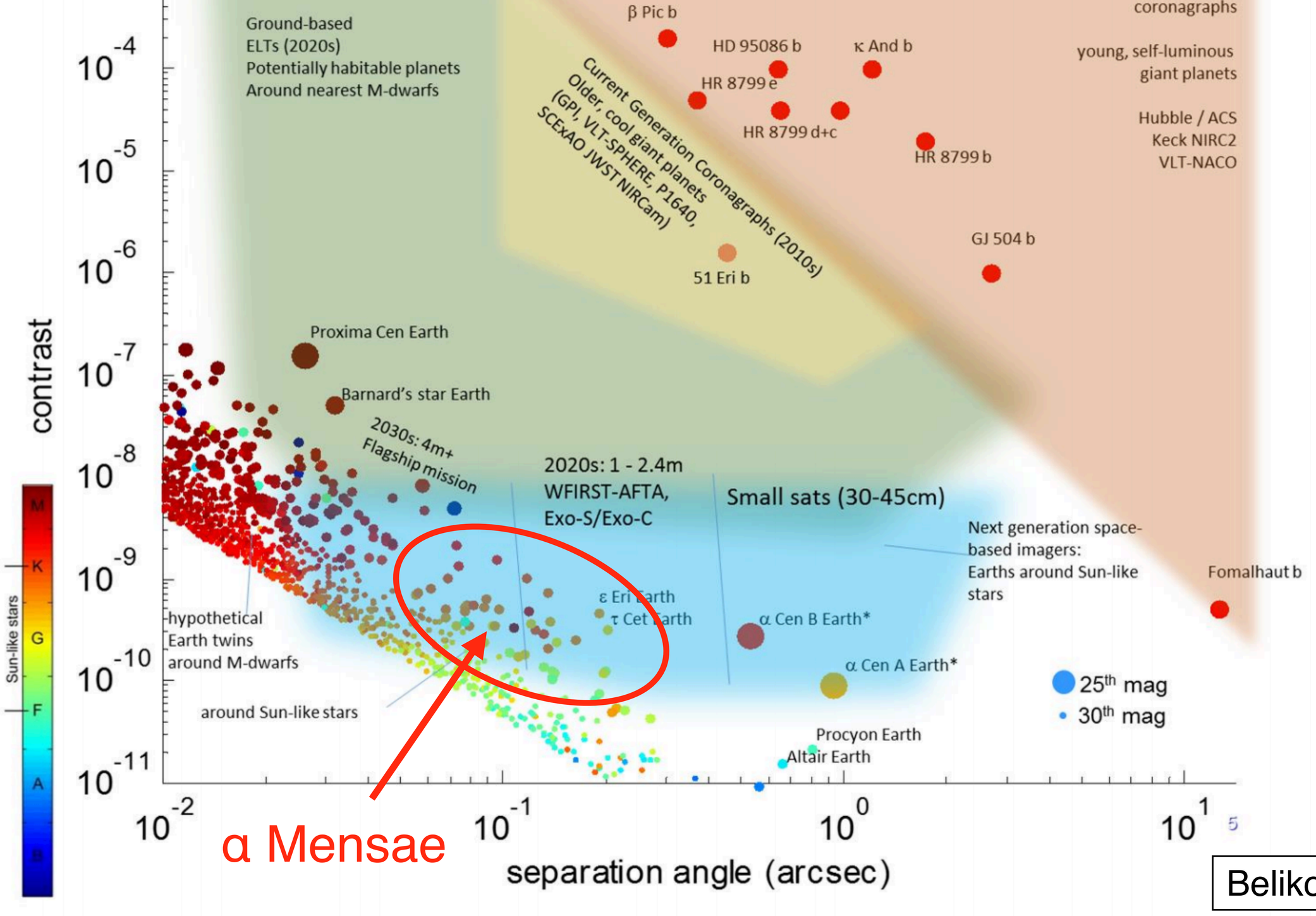

pre-Kepler
V<4
V=6
V=8
V=10
Procyon
α Cen A
τ Cet
α Cen B
Stellar Radius (Solar)
Distance (pc)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
10^0
10^1
10^2
10^3


V<4
V=6
V=8
V=10
pre-Kepler
Kepler
θ Cyg
16 Cyg
Stellar Radius (Solar)
Distance (pc)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
10^0
10^1
10^2
10^3


V<4
V=6
V=8
V=10
pre-Kepler
Kepler
TESS
α Mensae
Stellar Radius (Solar)
Distance (pc)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
10^0
10^1
10^2
10^3



Belikov+ 2015



Belikov+ 2015

Conclusions

- **Preliminary TESS Sector 1-11 yield of oscillating dwarfs & subgiants from 2-min cadence data is ~50%;** roughly implies ~1000-2000 detections over prime mission (2-4 x Kepler)

- **TESS complements Kepler with detections in nearby stars:** nu Indi (galactic archeology), alpha Mensae (solar analog), ...

- **Many other projects in progress:** gyrochronology benchmarks (94 Aqr, Metcalfe+ in prep), brown dwarf hosts & young stars (Warrick Ball, ZJ Zhang), ...

- **Extended mission:** projected to double the prime mission yield through 10-min FFI and longer timeseries. 20-second cadence very valuable!

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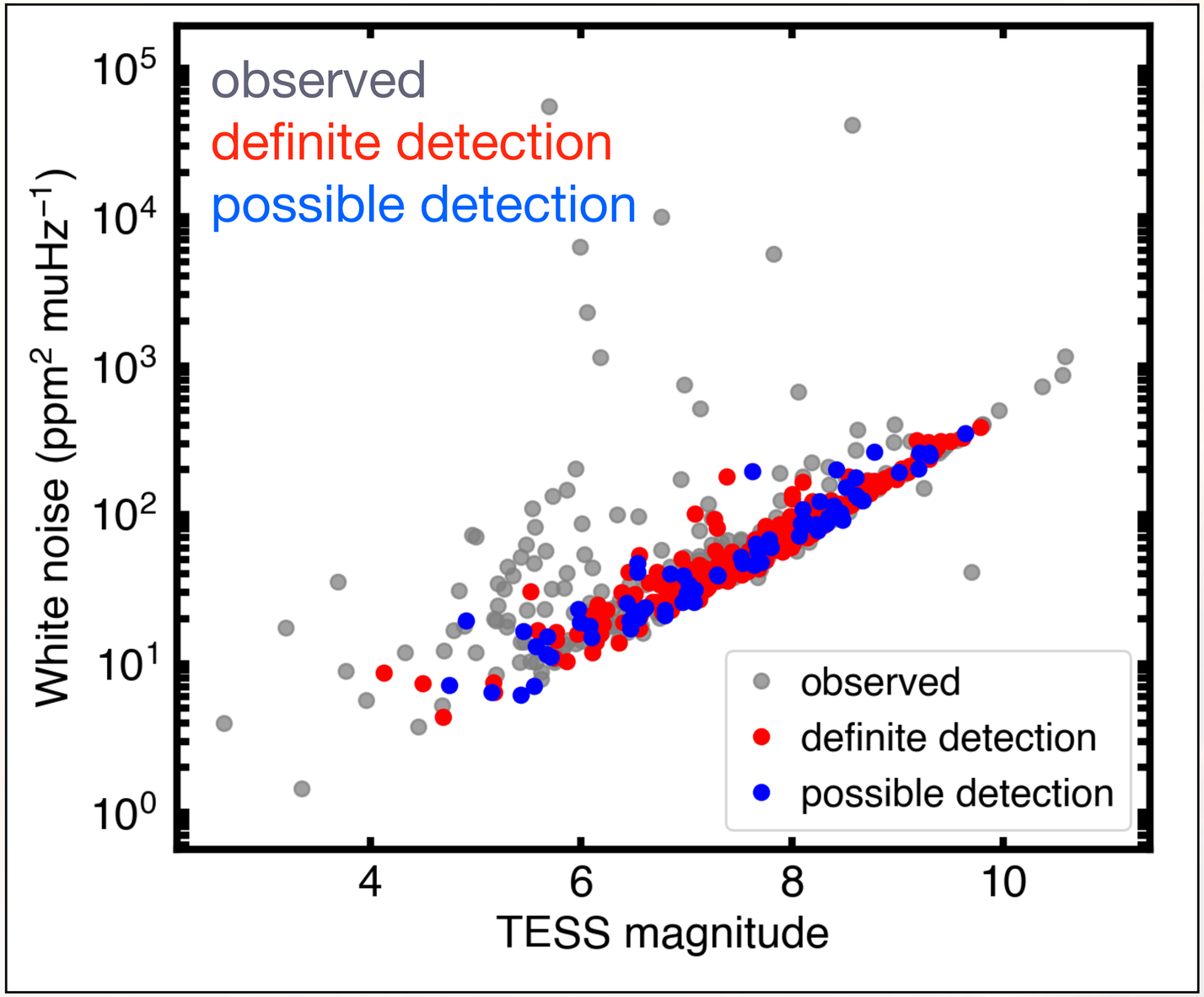
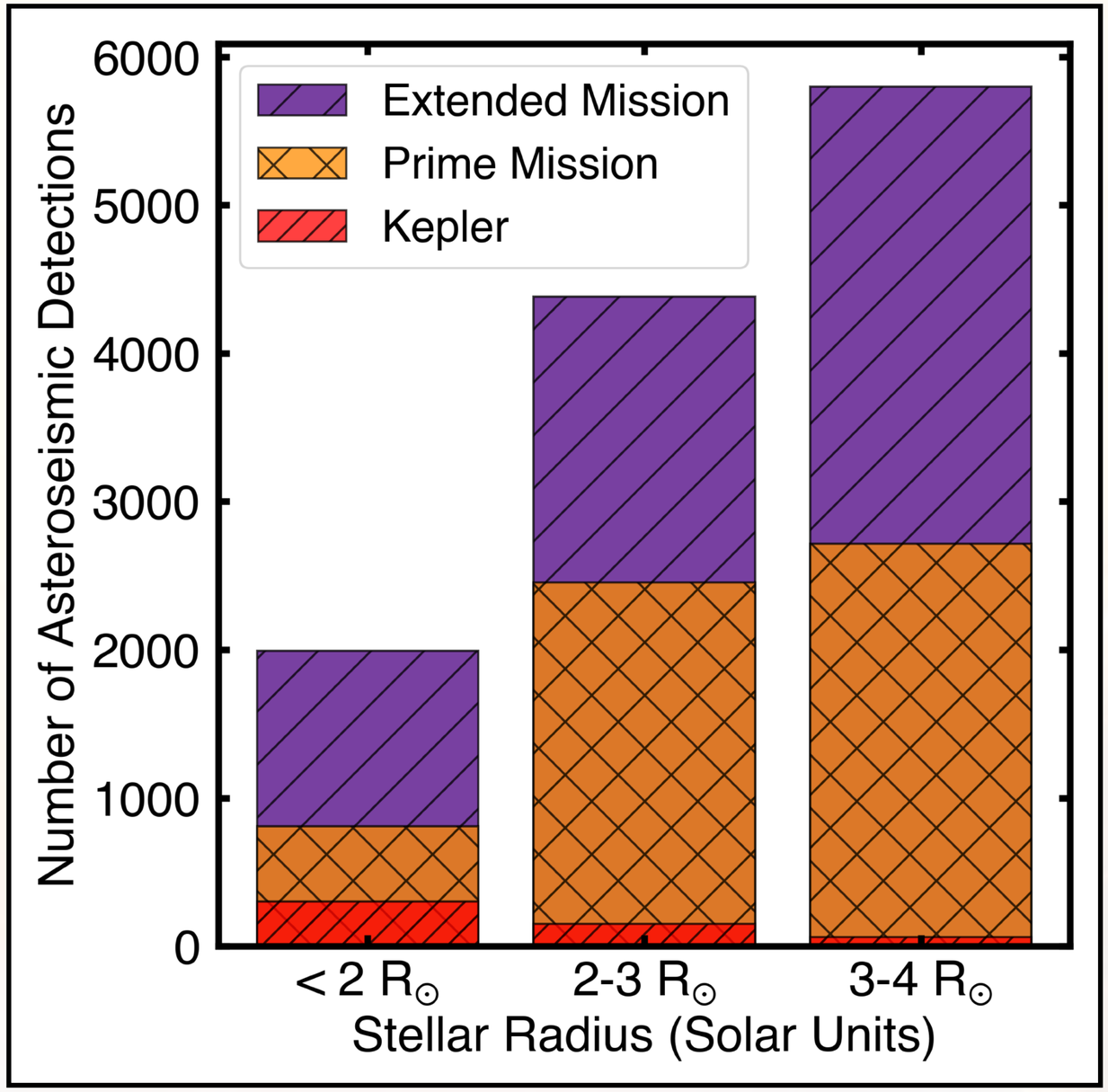


1) Stellar activity suppresses connvective driving of oscillations (not included in detection probabilities)

2) Inaccurate stellar parameters (needed to calculate oscillation amplitudes)

3) Precision for bright stars is worse than expected (non-optimal apertures?)

Solar-Like Oscillators in the Extended Mission



Asteroseismic yield will **double** due to:

- Essentially all subgiants being covered with 10-min FFI cadence
- Decreased noise for dwarfs with twice as much data in 2-min cadence