The role of PRVs to enable and support NASA discoveries

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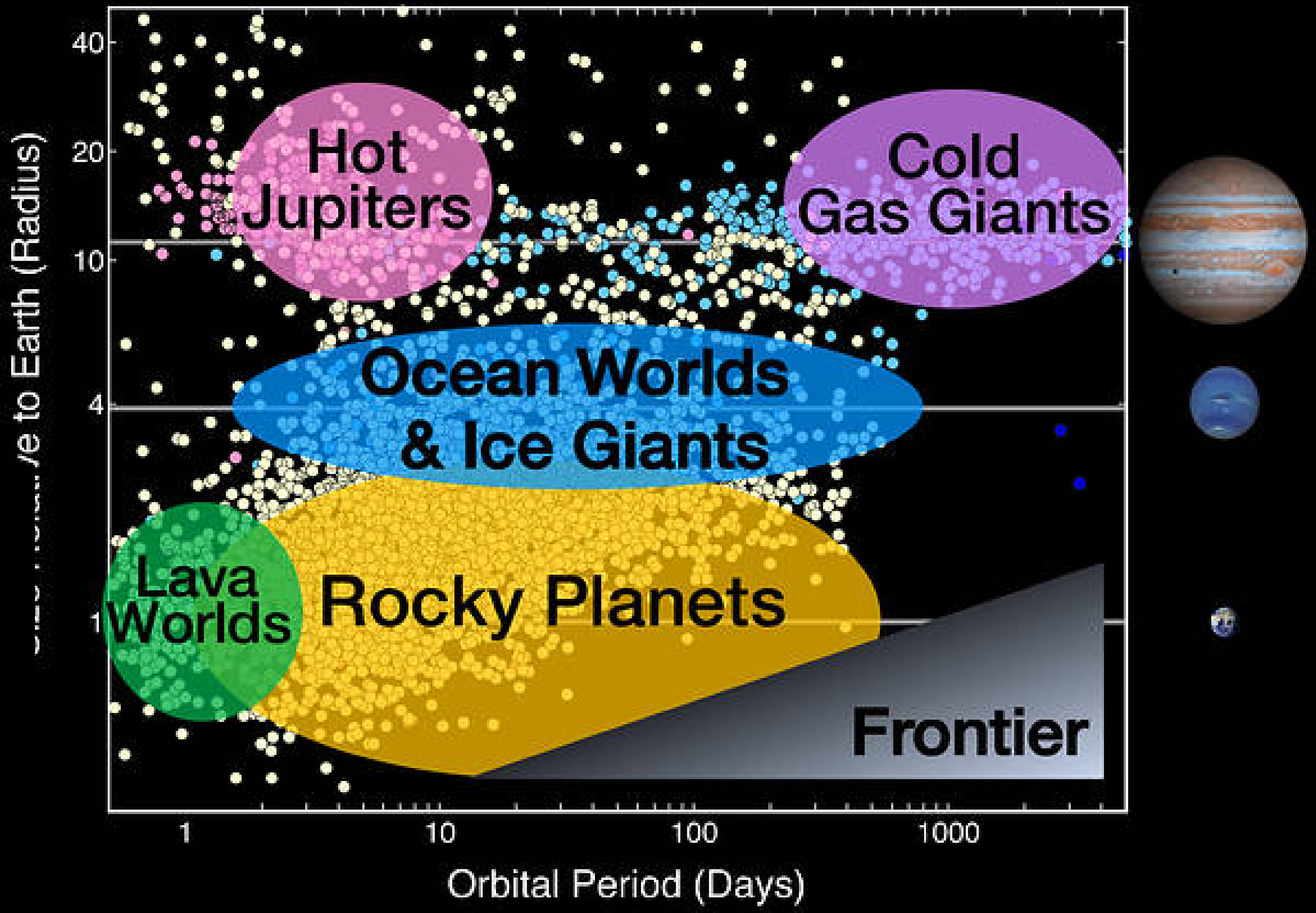
Exoplanet Populations - we are after biosignatures. How to get from here to there?

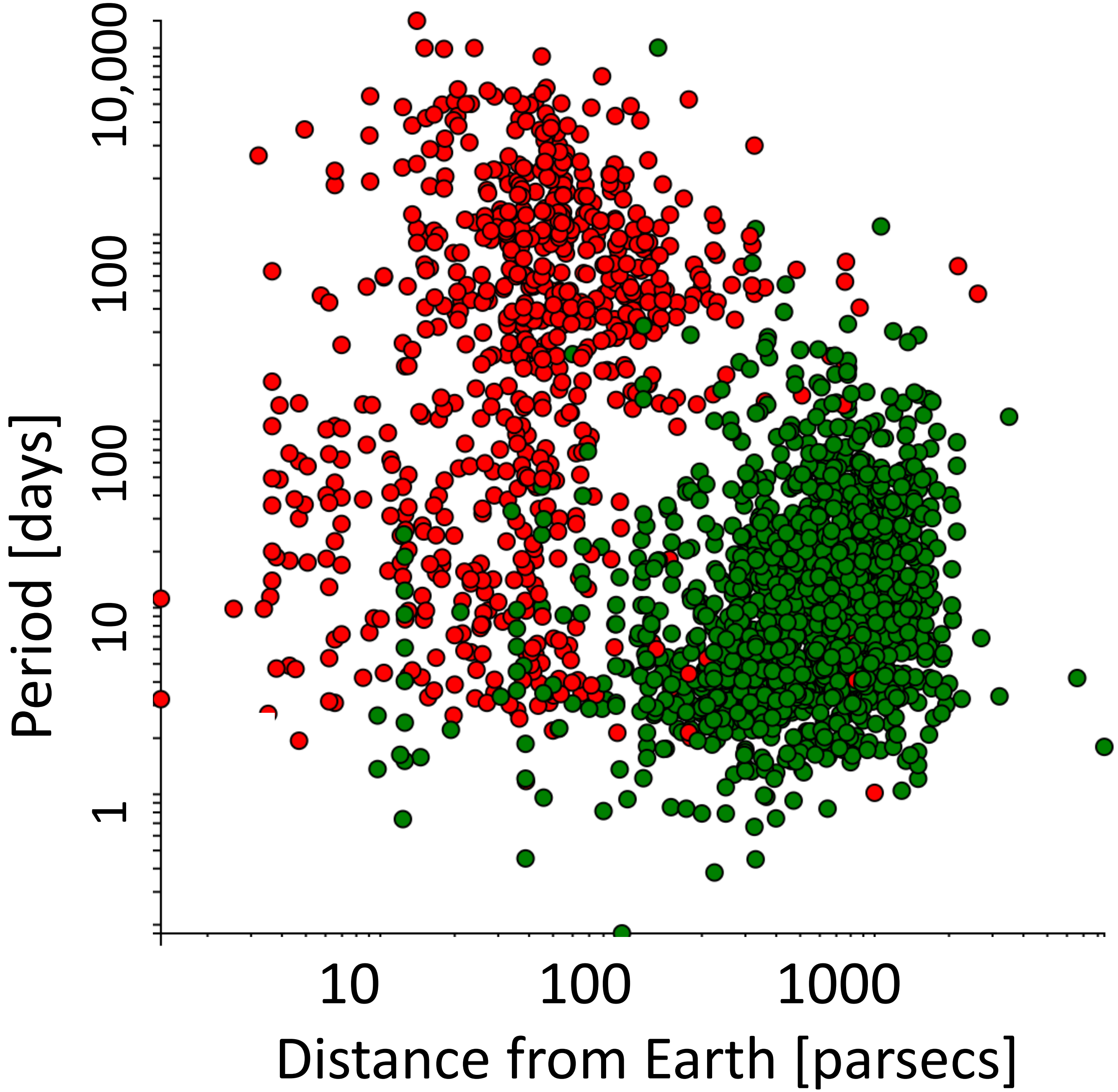
https://exoplanetarchive.ipac.caltech.edu/docs/exobib.html



Hot Jupiters ~1%
Cold Jupiters ~10-15%
Ocean Worlds ~20%
Lava Worlds ~1%
Rocky planets (P<100d) >25%

Microlensing: 36% of [Mdwarfs] have Neptune mass planets beyond 1AU. (Gould et al. 2010, Clanton & Gaudi 2014)

Image credit: NASA Kepler



Distances

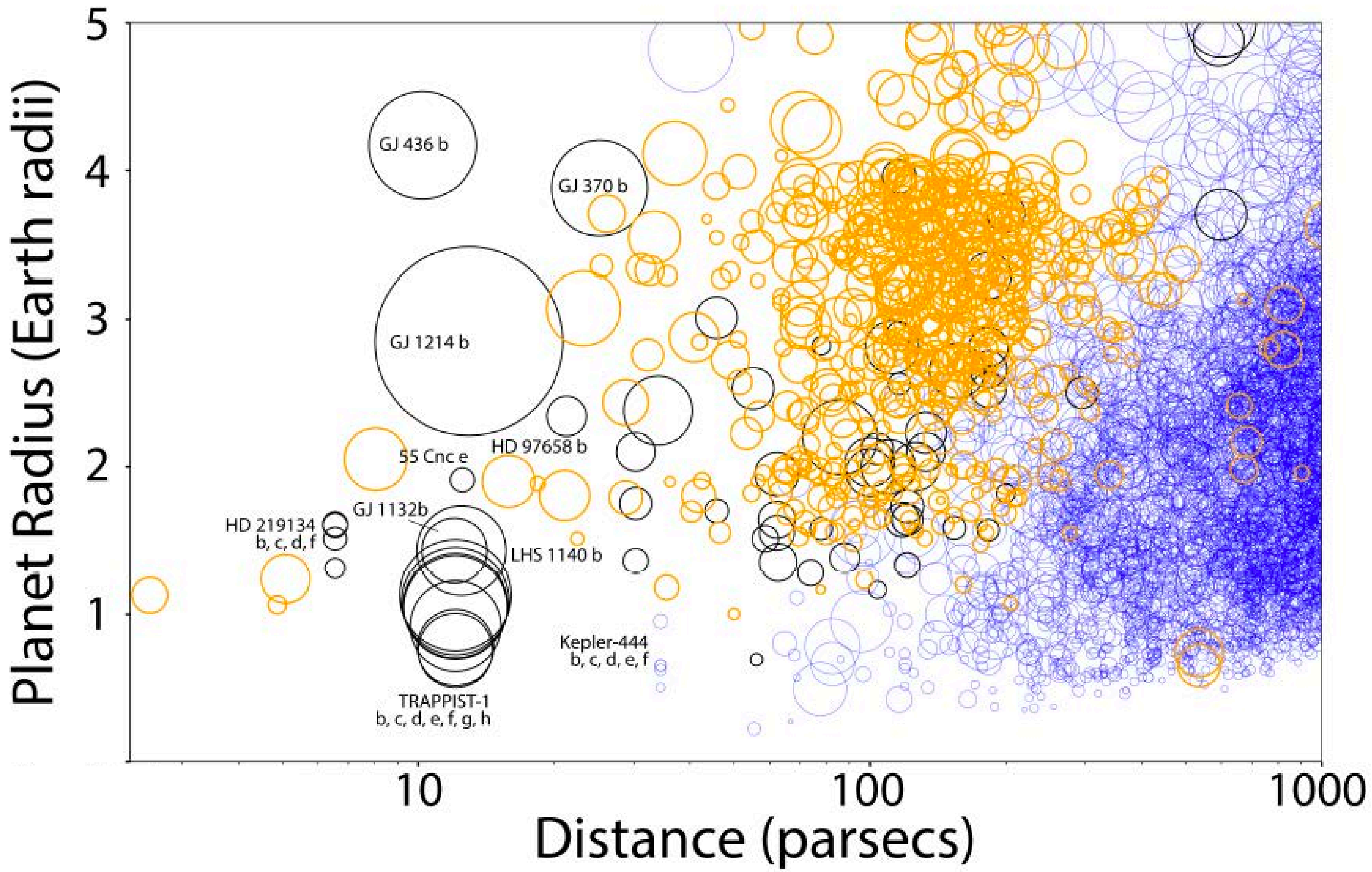
RV – detected exoplanets

Transiting exoplanets

It will always be true that transiting planets are statistically farther away ...and distance matters!

Image credit: Hanno Rein
Open Exoplanet Catalog

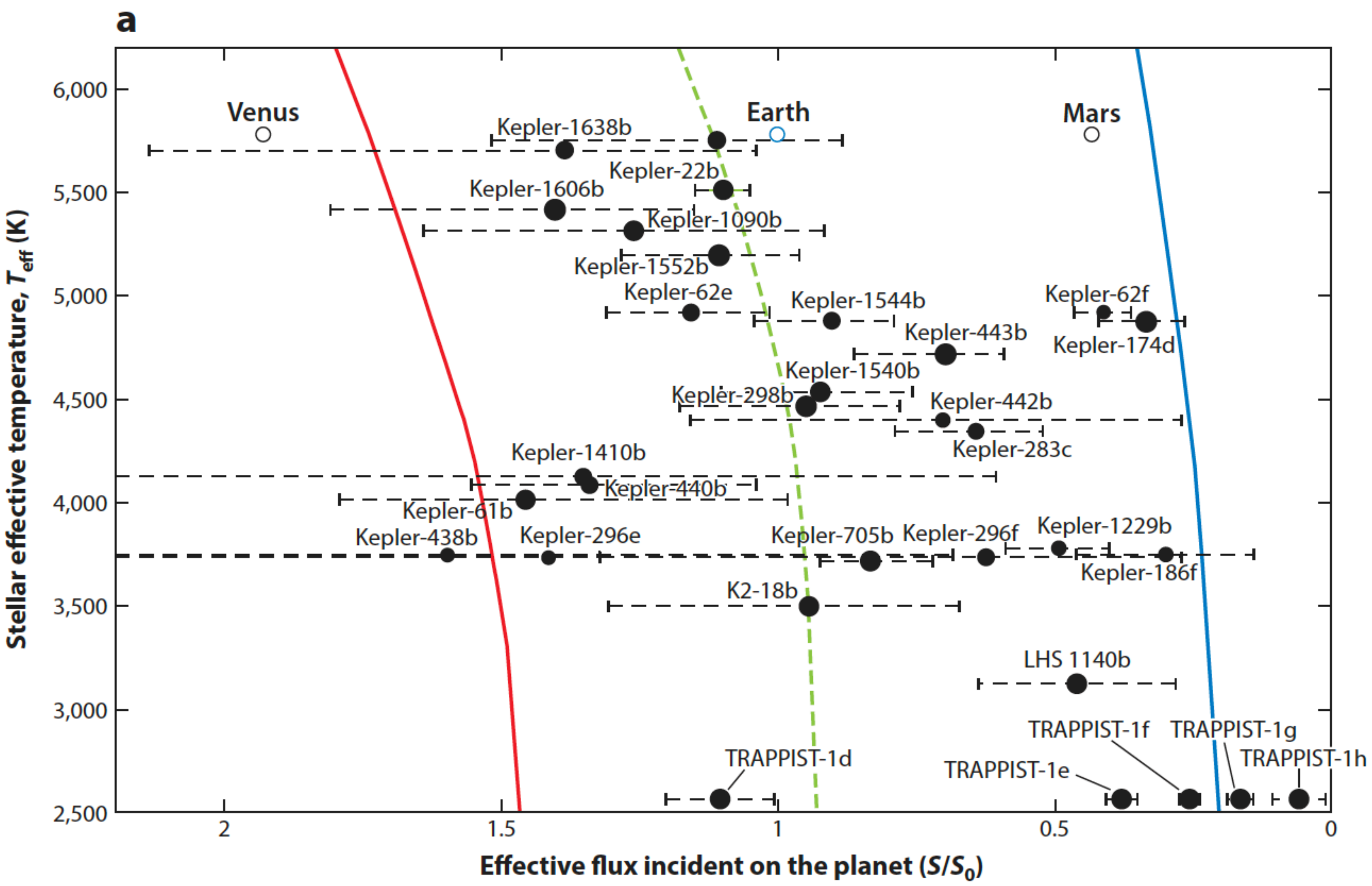
Transiting Planets – the TESS difference



Non-Kepler
Kepler
TESS
(simulated)

Barclay, Pepper, Quintana 2018
(image credit to Z. Berta-Thompson)

Transiting Planets in the HZ
(dots scale to 0-1, 1-1.5, 1.5-2 R_E)

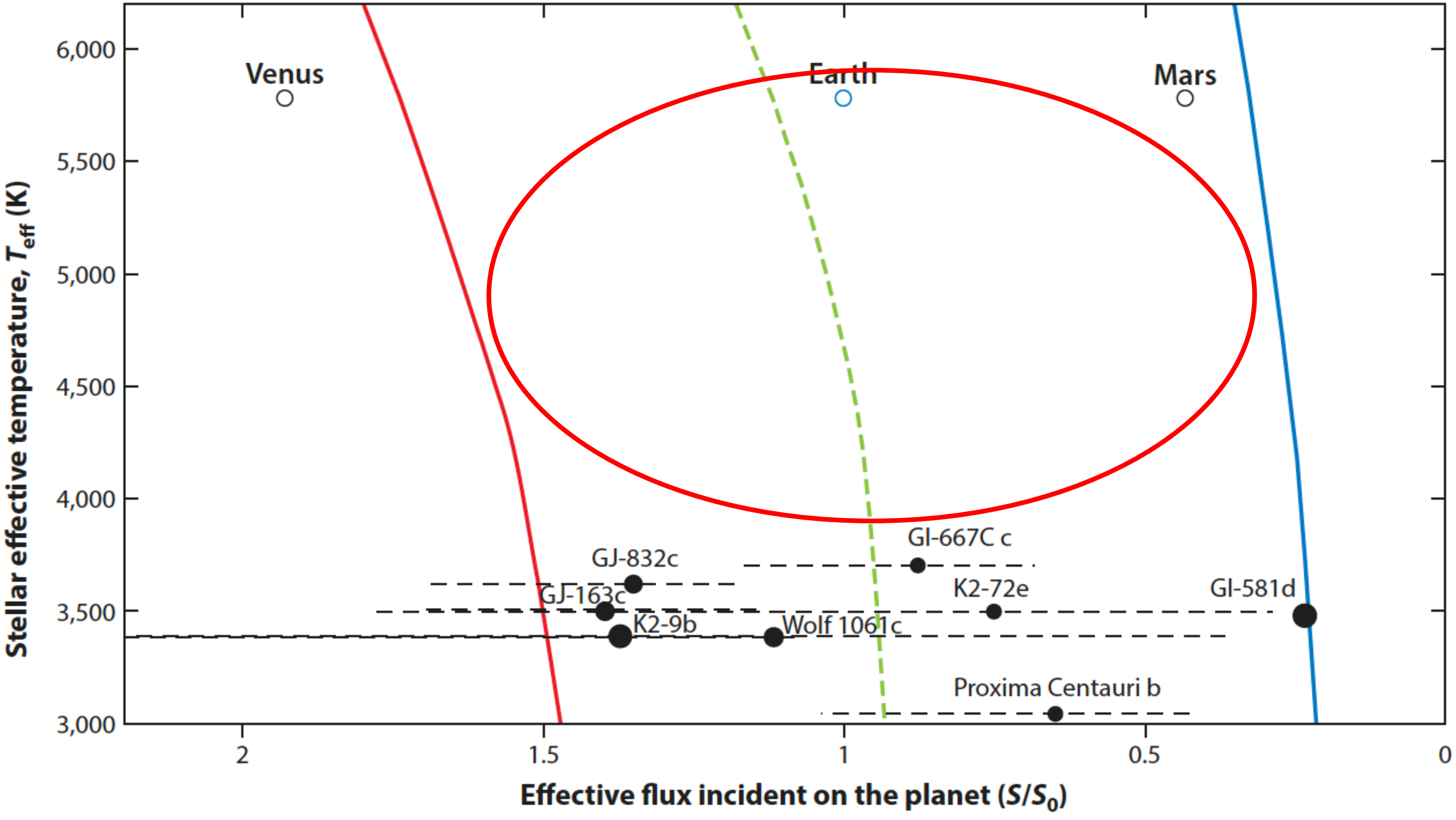


(Kaltenegger 2017)

No masses.
Difficult to get biosignatures with transit spectroscopy.

Poor candidates for coronographic follow-up and direct atmospheric spectroscopy.

RV-detected Planets in the HZ (dots scale to 0-5, 5-10 M_E)

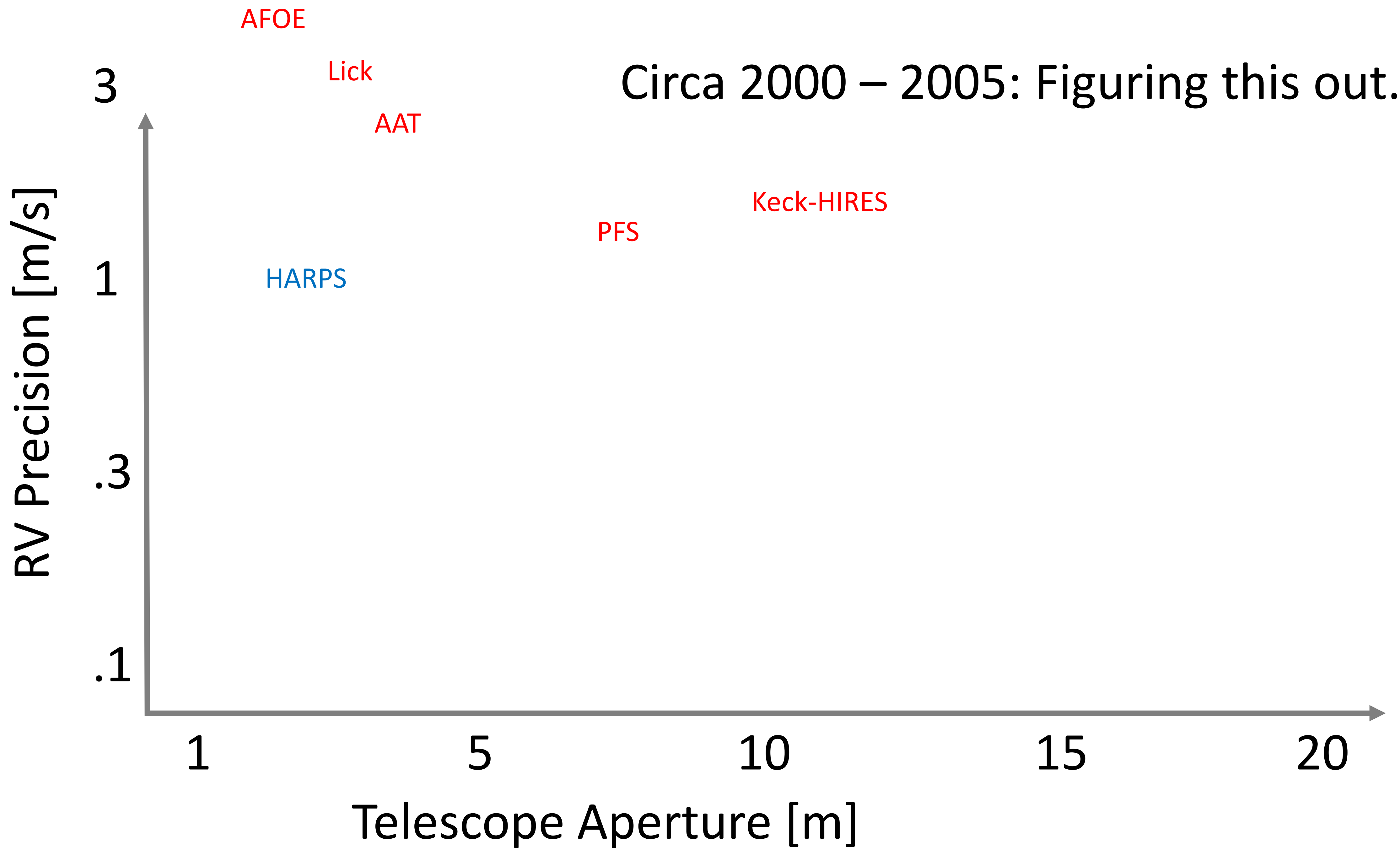


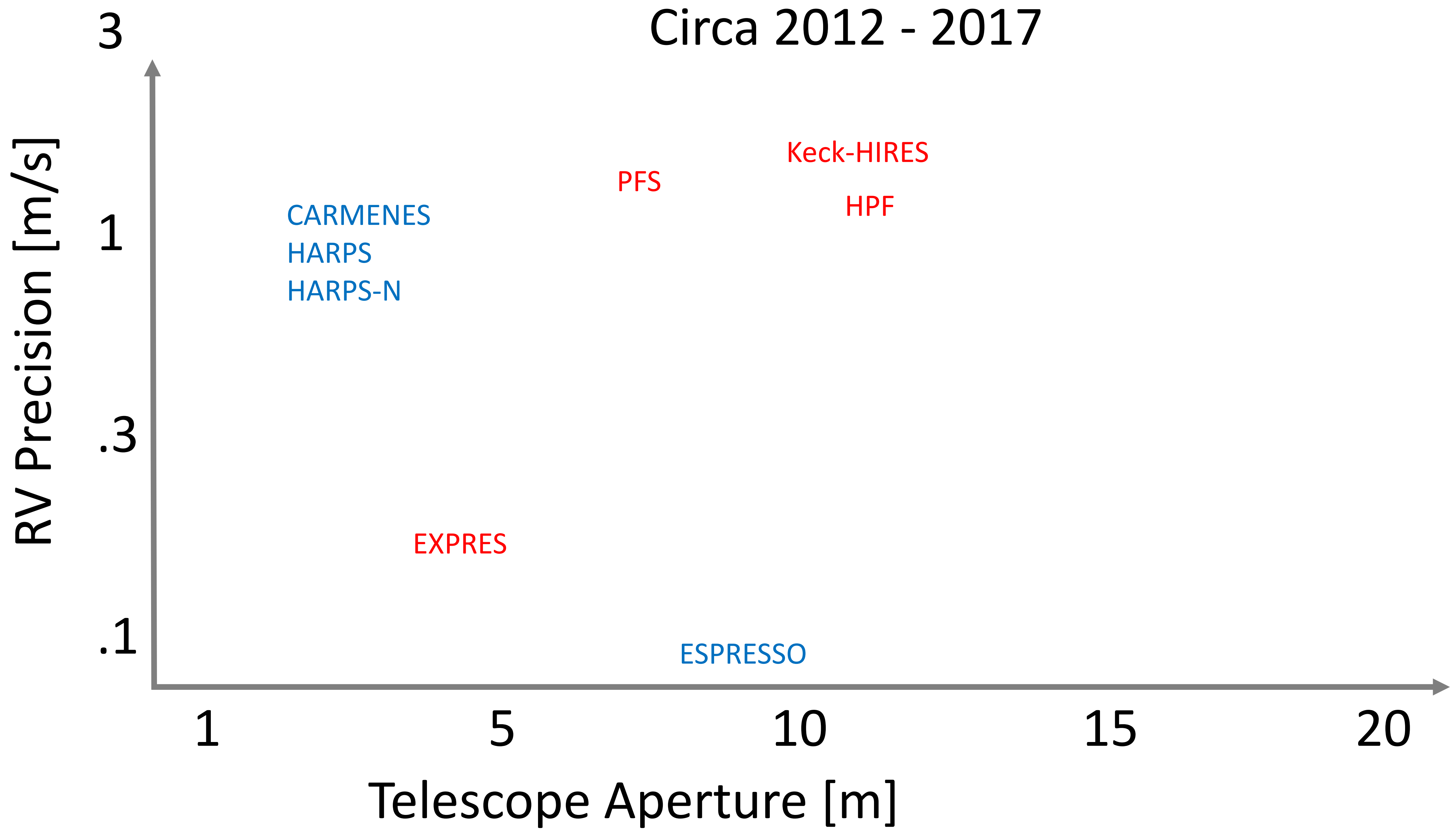
All are currently orbiting low-mass stars. This picture is about to change.

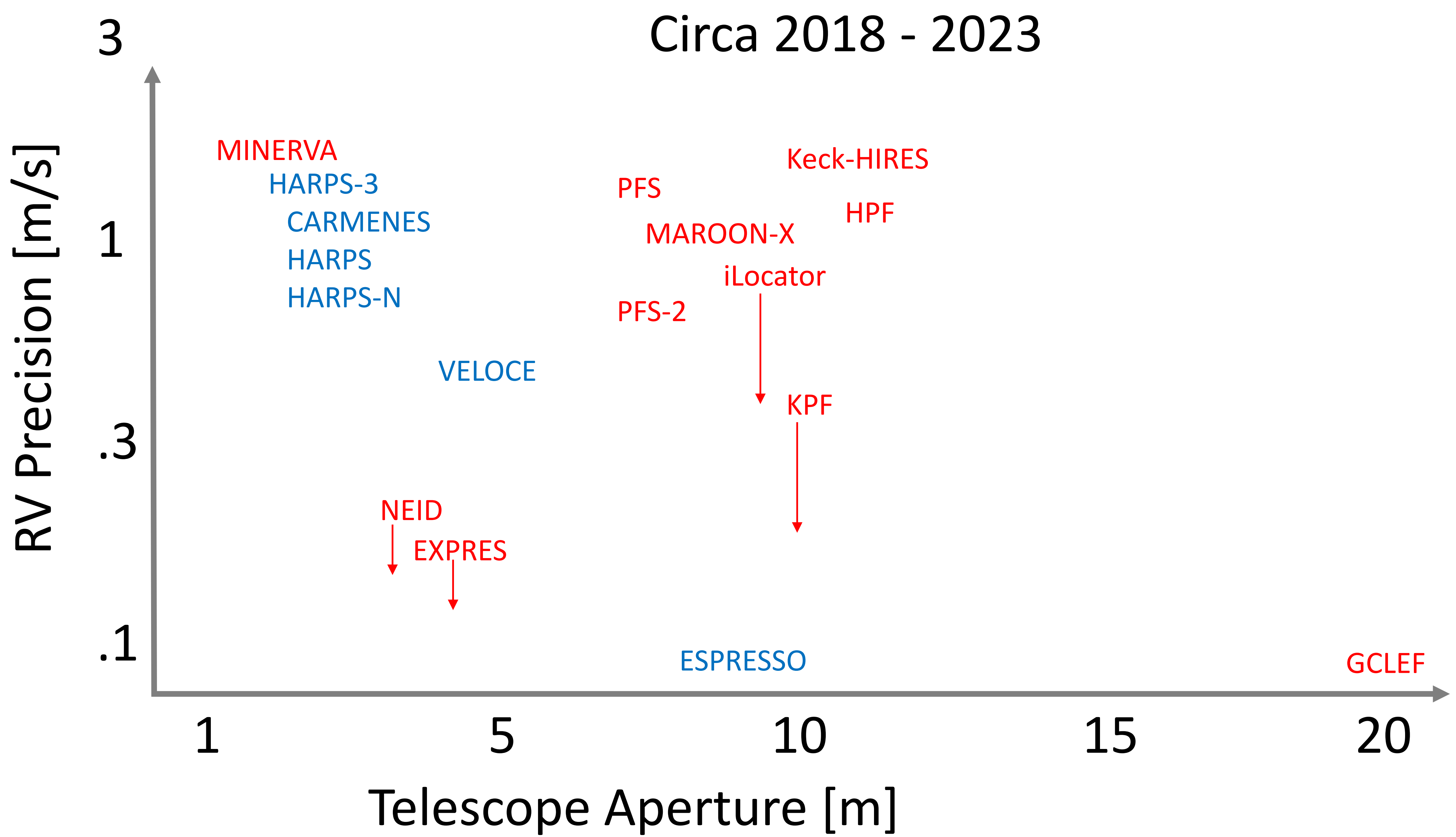
Nearby planetary systems are ideal for imaging and atmospheric spectroscopy.

(Kaltenegger 2017)

Circa 2000 – 2005: Figuring this out...




Circa 2012 - 2017
RV Precision [m/s]
3
1
.3
.1
Telescope Aperture [m]
1
5
10
15
20
CARMENES
HARPS
HARPS-N
PFS
Keck-HIRES
HPF
EXPRES
ESPRESSO

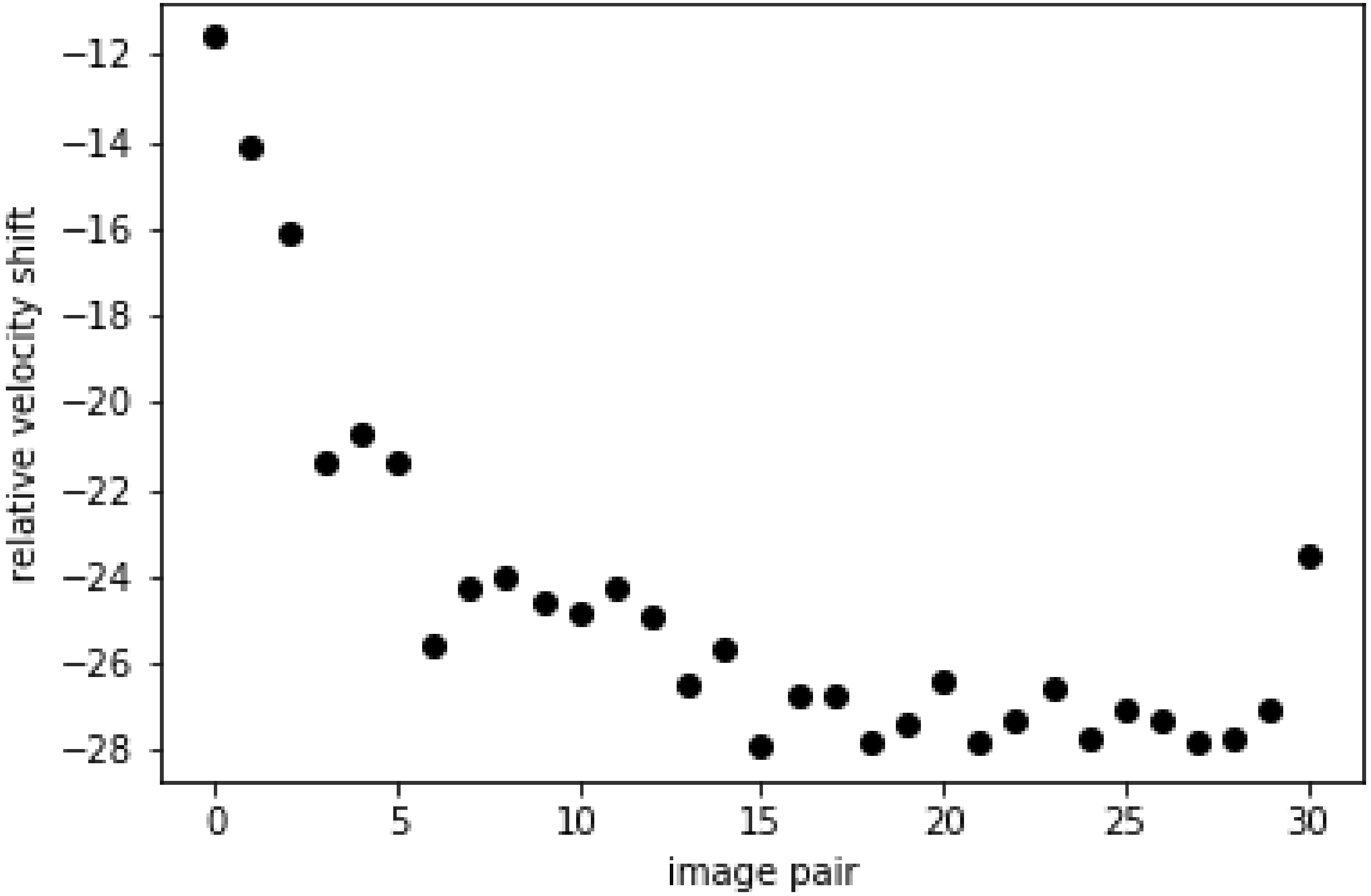

Circa 2018 - 2023
RV Precision [m/s]
3
1
.3
.1
MINERVA
HARPS-3
CARMENES
HARPS
HARPS-N
VELOCE
NEID
EXPRES
PFS
MAROON-X
PFS-2
iLocator
Keck-HIRES
HPF
KPF
ESPRESSO
GCLEF
1
5
10
15
20
Telescope Aperture [m]

Guaranteed of success if we reach high enough RV precision. What is stopping us?

1. ~~Instrumental errors~~
2. ~~telluric contamination~~
3. ~~Radial velocities from stellar photospheres~~

EXPRES was designed to disentangle photospheric velocities: high fidelity, high resolution, high-cadence observations at the DCT.

Guaranteed of success if we reach high enough RV precision.



Calibrated instrumental stability with LFC – RMS ~ 5 cm/s over 10 hours.

On stars? We think we have a path for disentangling photospheric noise – should have first published results by end of 2018.

These new instruments are a great start but not enough to meet the need for discovery & mission support. In general, 1-m telescopes will deliver 1-2 m/s RV precision. Need moderate (3-m) to large (10-m) telescopes for ~10 cm/s precision.

The RV niche: Earths around nearby stars. Not sure how you touch these with any other method except astrometry, which will require technology development.

ESPRESSO, EXPRES and NEID could lead the next wave, toward 10 cm/s. Statistical techniques developed by these teams will enable unexpected progress by others.

What's coming up next for exoplanets?

Gaia, TESS, CHEOPS, JWST, WFIRST, PLATO

These missions represent an eco-system – pull out one of them and the strategic path forward is stressed. All will need ground-based RV support.

Measuring RVs is time intensive. Longitudinal coverage and high cadence needed. Also need spectrographs for characterizing the star (abundances, p-modes for interiors) as well as RV detections and turning radii into densities.

U.S. Public access? NEID (WIYN), MAROON-X (Gemini, 2019-2020), KPF (Keck,2020-2021).