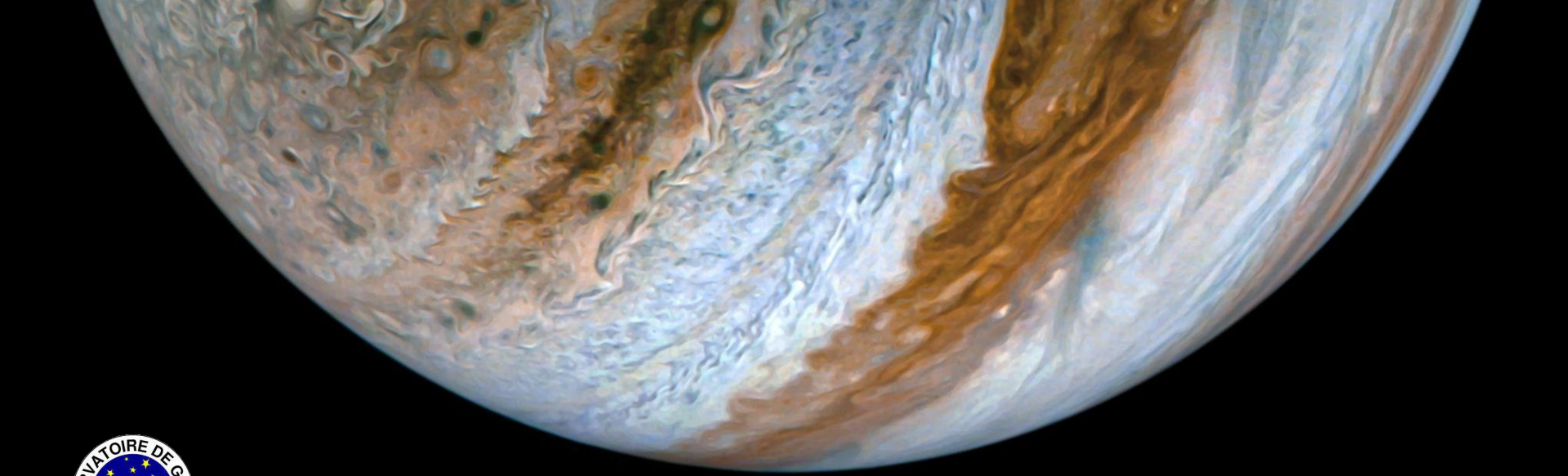


challenges in current and future radial-velocity surveys

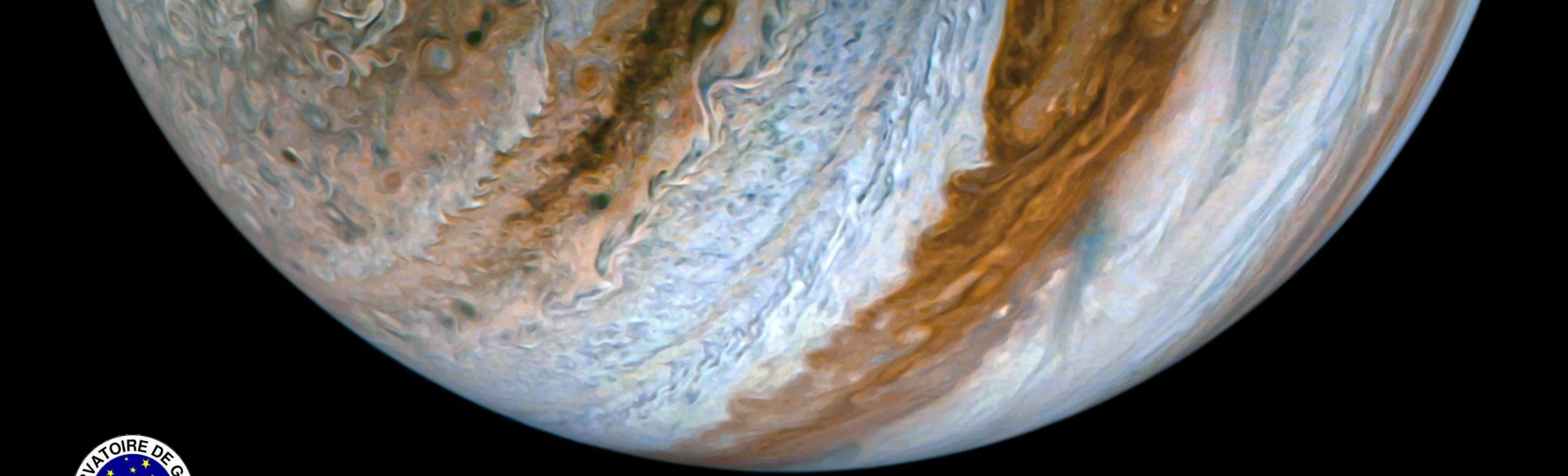
João Faria

OBSERVATOIRE DE GENÈVE
FONDÉ EN 1772

UNIVERSITÉ DE GENÈVE
FACULTY OF SCIENCE

Swiss National Science Foundation

PlanetS
National Centre of Competence in Research



probing the correlation between CJs and SPs

João Faria

with Jean-Baptiste Delisle, Damien Ségransan, Émile Fontanet, William Ceva

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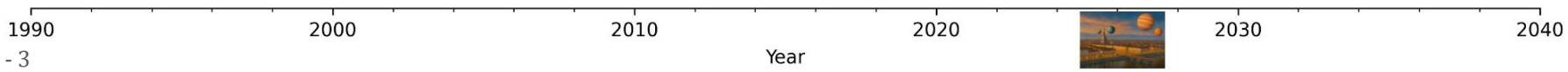
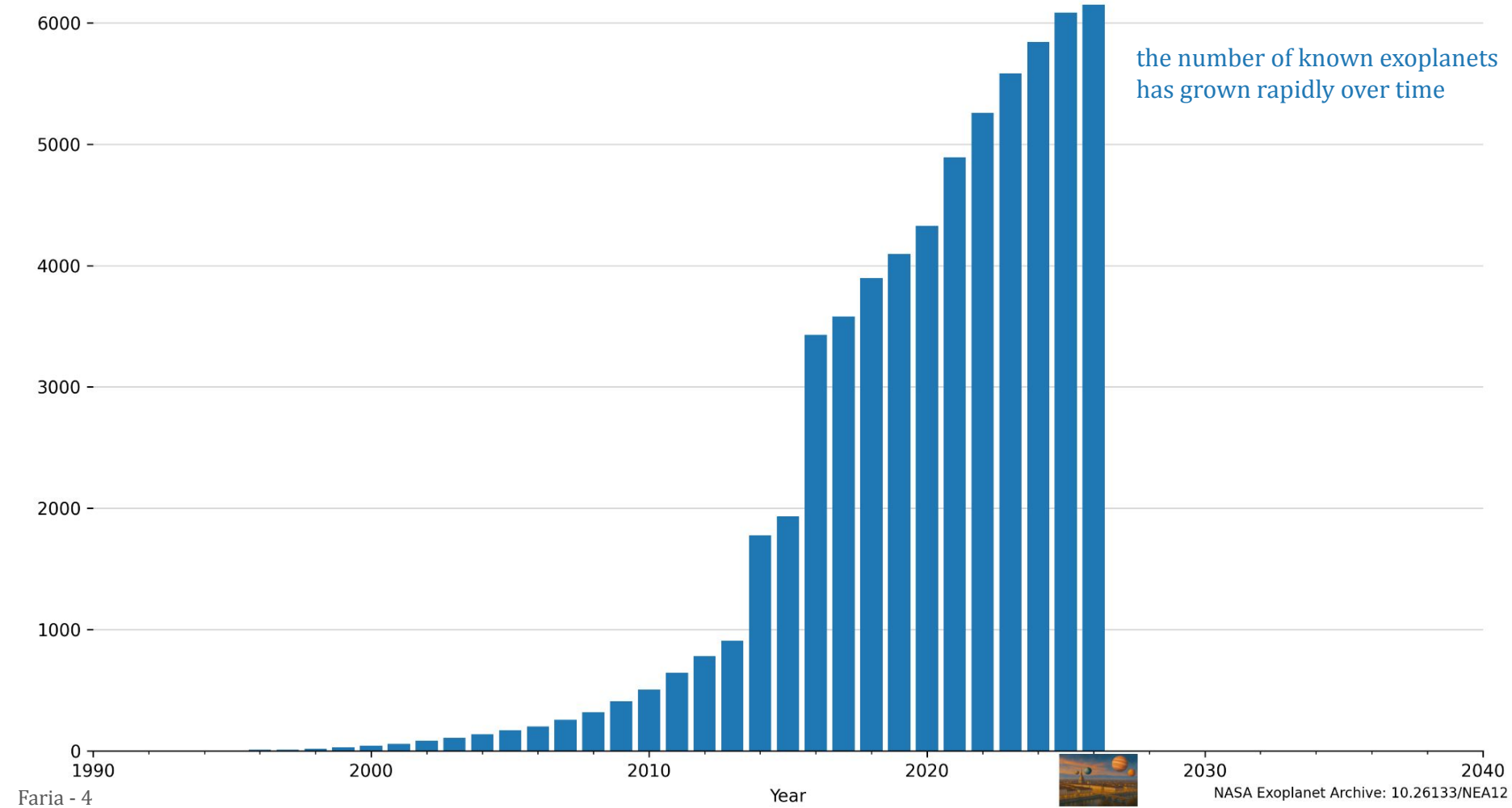

1990
2000
2010
2020
2030
2040
Year

cumulative number of known exoplanets



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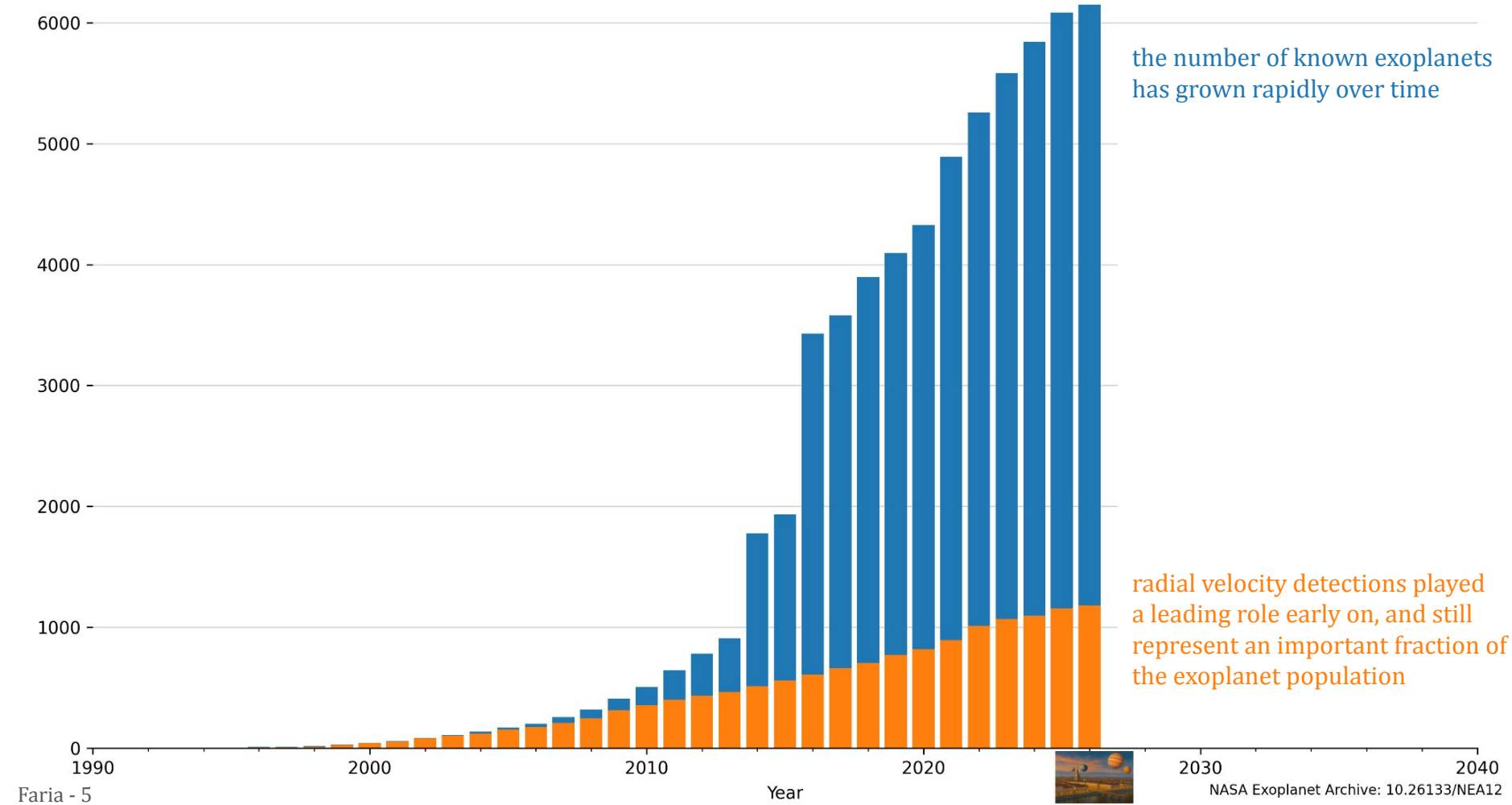
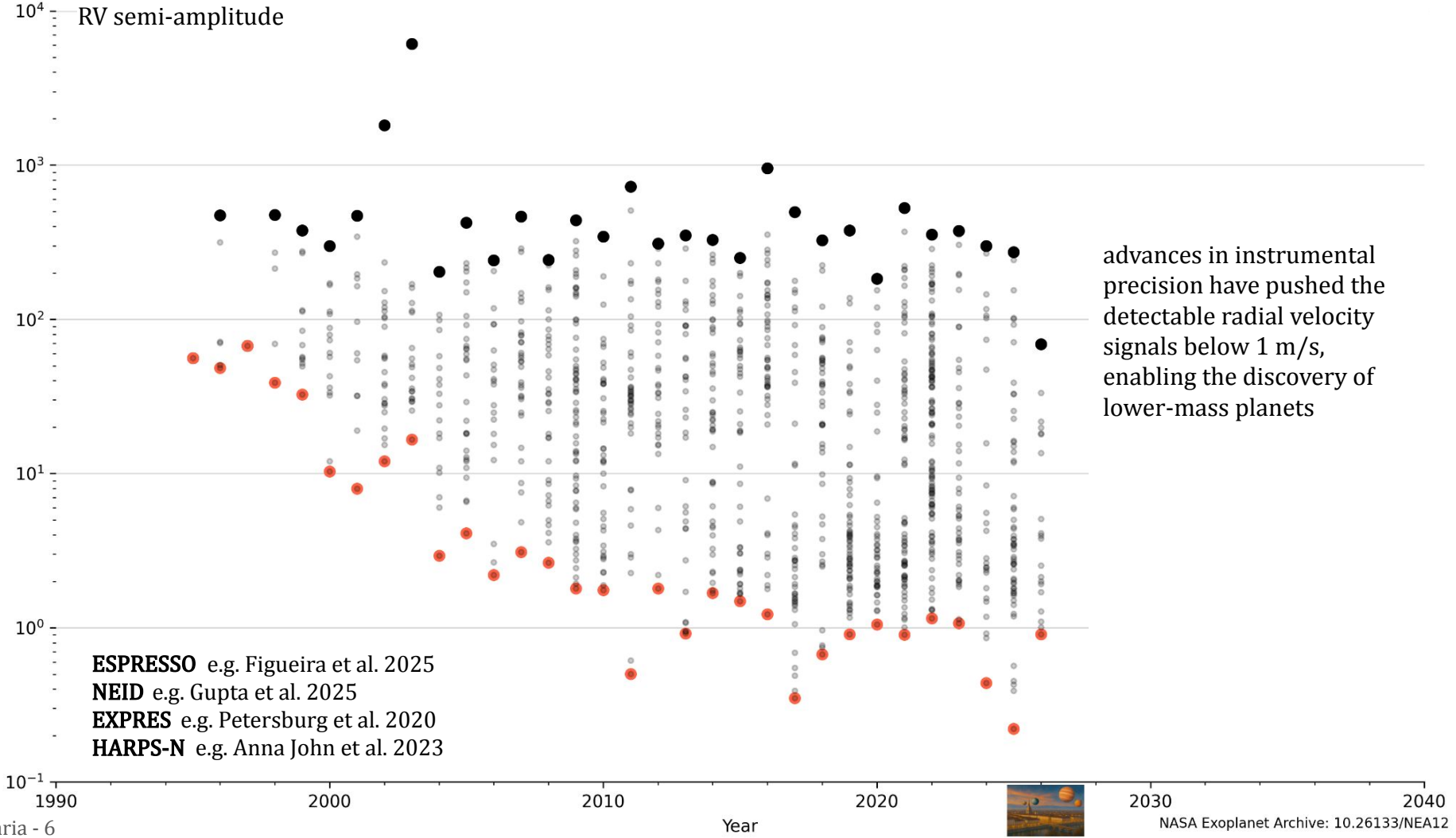
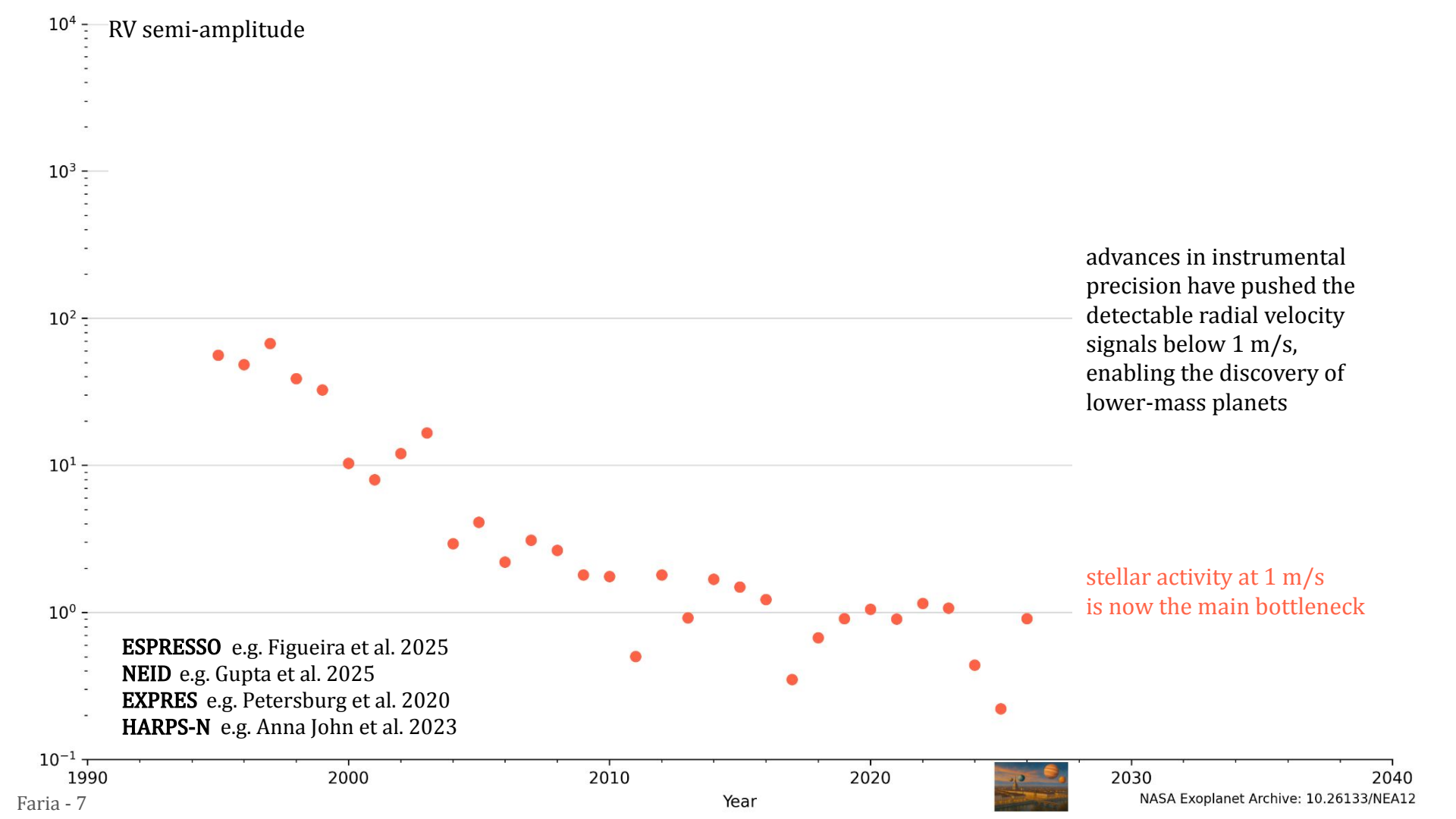


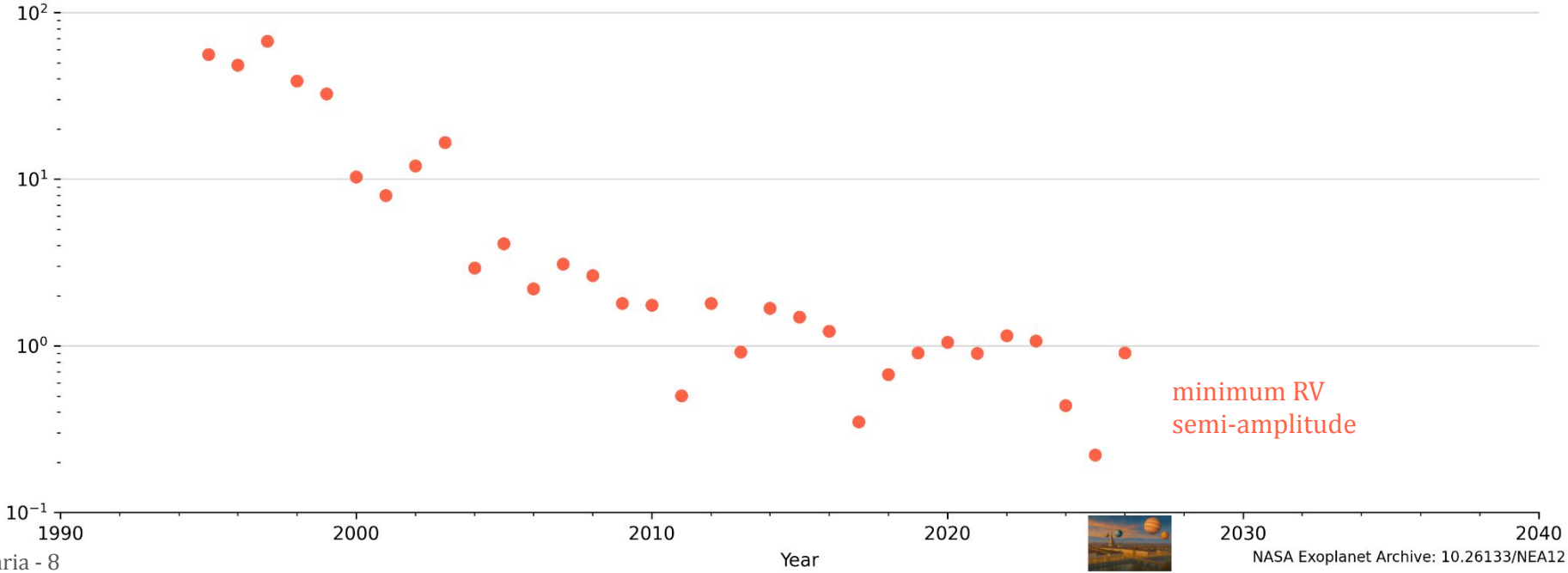
the number of known exoplanets has grown rapidly over time

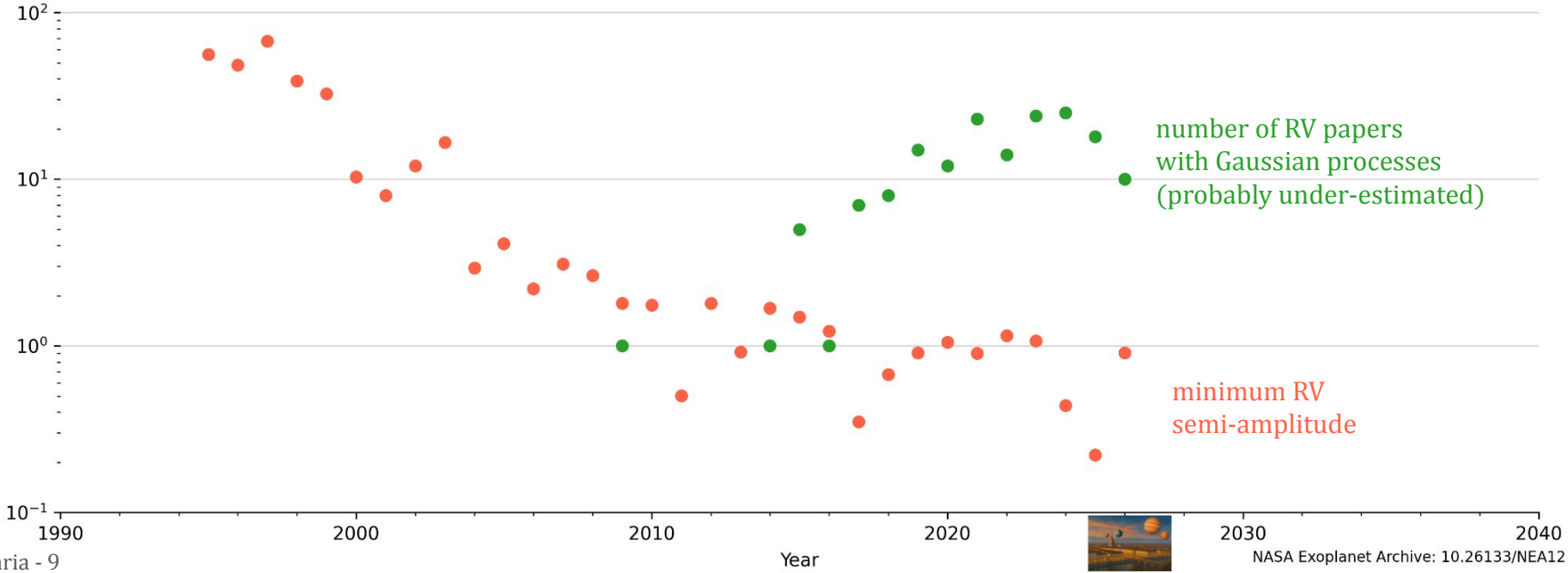
radial velocity detections played a leading role early on, and still represent an important fraction of the exoplanet population

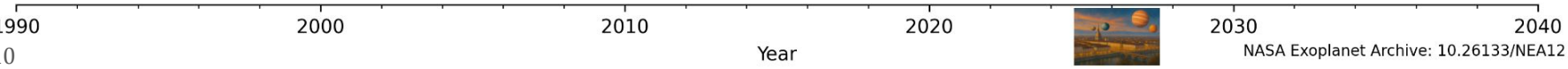


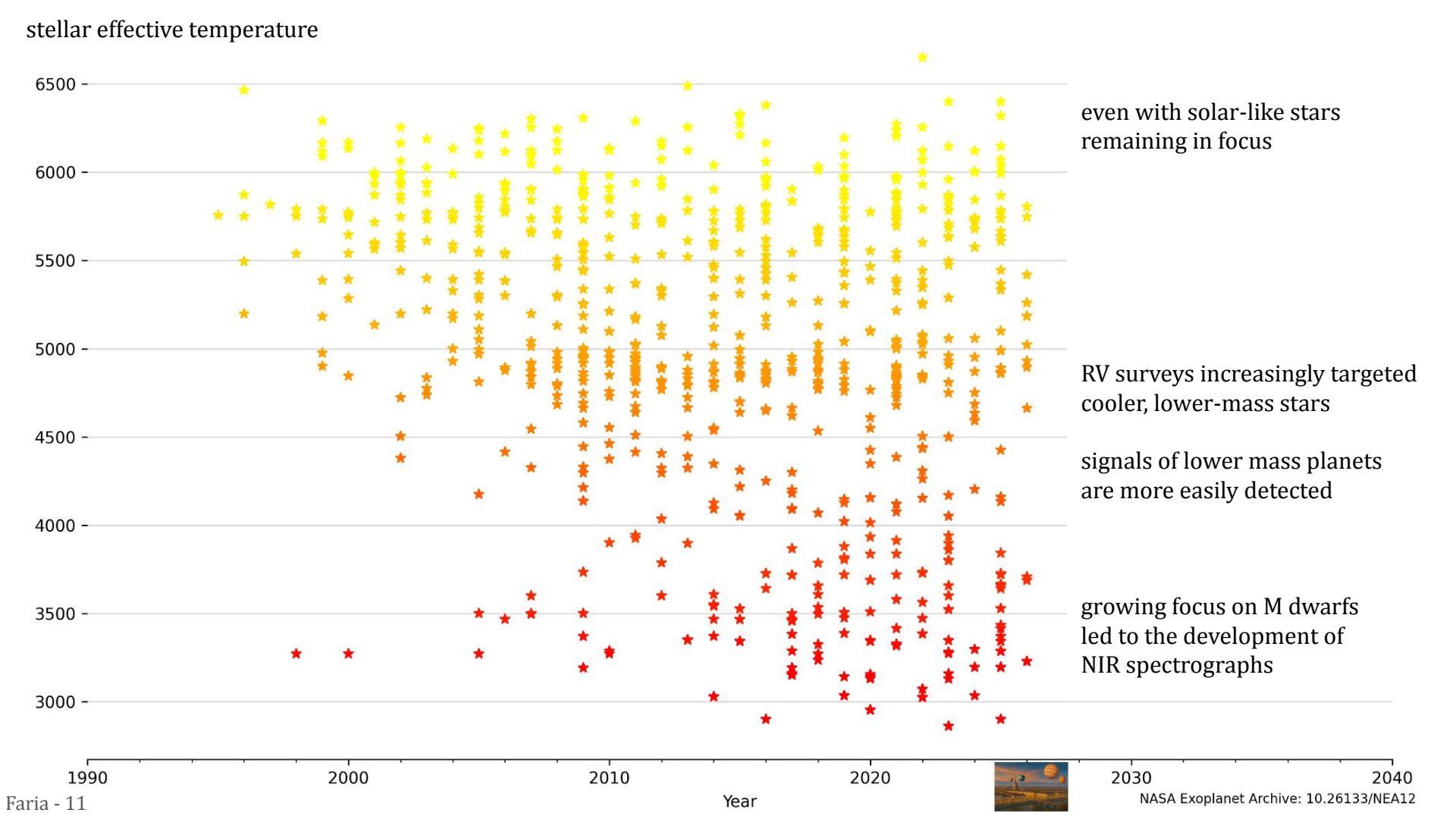
advances in instrumental precision have pushed the detectable radial velocity signals below 1 m/s, enabling the discovery of lower-mass planets


RV semi-amplitude
10^4
10^3
10^2
10^1
10^0
10^{-1}
1990
2000
2010
2020
2030
2040
Year
advances in instrumental precision have pushed the detectable radial velocity signals below 1 m/s, enabling the discovery of lower-mass planets
stellar activity at 1 m/s is now the main bottleneck
ESPRESSO e.g. Figueira et al. 2025
NEID e.g. Gupta et al. 2025
EXPRES e.g. Petersburg et al. 2020
HARPS-N e.g. Anna John et al. 2023
NASA Exoplanet Archive: 10.26133/NEA12


10^2
10^1
10^0
10^{-1}
1990
2000
2010
2020
2030
2040
Year
minimum RV
semi-amplitude
NASA Exoplanet Archive: 10.26133/NEA12


10^2
10^1
10^0
10^{-1}
1990
2000
2010
2020
2030
2040
Year
number of RV papers
with Gaussian processes
(probably under-estimated)
minimum RV
semi-amplitude
NASA Exoplanet Archive: 10.26133/NEA12


1990
2000
2010
2020
2030
2040
Year
NASA Exoplanet Archive: 10.26133/NEA12


stellar effective temperature
6500
6000
5500
5000
4500
4000
3500
3000
1990
2000
2010
2020
2030
2040
Year
even with solar-like stars remaining in focus
RV surveys increasingly targeted cooler, lower-mass stars
signals of lower mass planets are more easily detected
growing focus on M dwarfs led to the development of NIR spectrographs
NASA Exoplanet Archive: 10.26133/NEA12

challenges?
what do you mean?

55 Cnc in RVs


55 Cnc B b
55 Cnc B c
55 Cnc B
55 Cnc e
0.167 R_Jup
55 Cnc b
55 Cnc c
55 Cnc f
55 Cnc d
55 Cnc


1990
2000
2010
2020
2030
2040
Year
NASA Exoplanet Archive: 10.26133/NEA12

55 Cnc in RVs

the fourth exoplanet ever discovered with RVs from the Lick Observatory
Butler et al. 1997

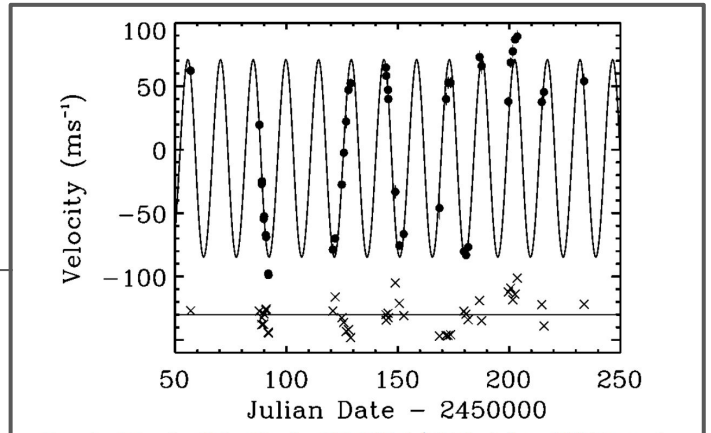
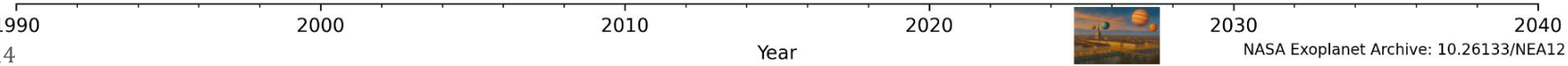


FIG. 1.—Doppler Velocities for HR 3522 (ρ^1 55 Cnc) from 1995 December through 1996 June. A Keplerian fit yields the orbital parameters P = 14.64 days and K = 77.5 m s^{-1}, indicating a companion having m sin i = 0.84M_{JUP} at 0.11 AU. The error bars are about the size of the points.



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two more planets discovered, one with a period
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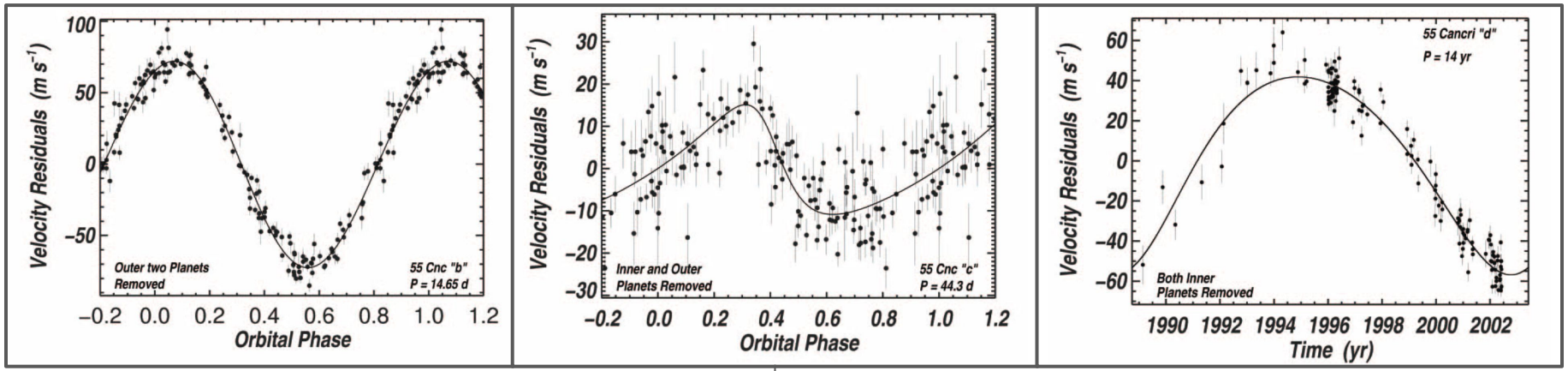
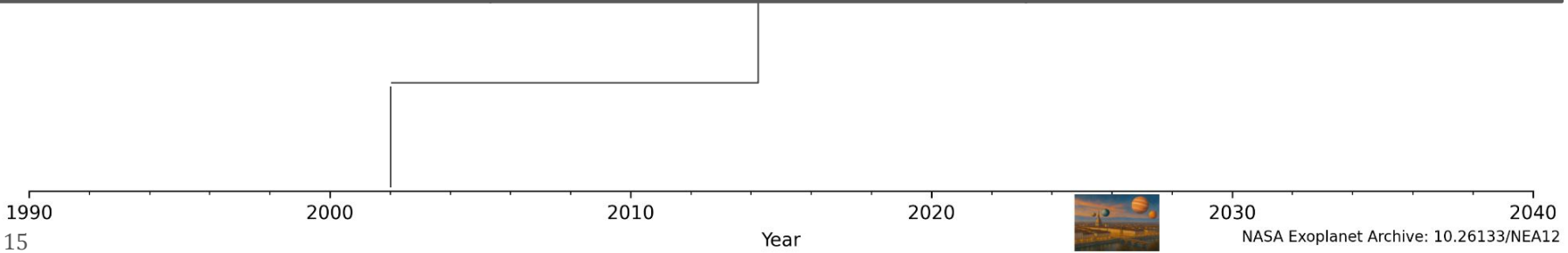
Marcy et al 2002





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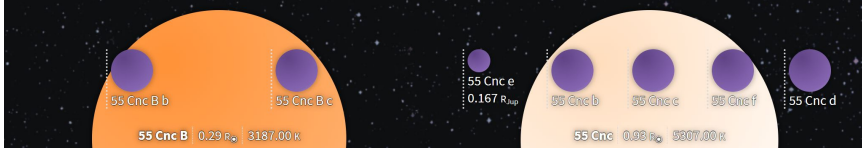

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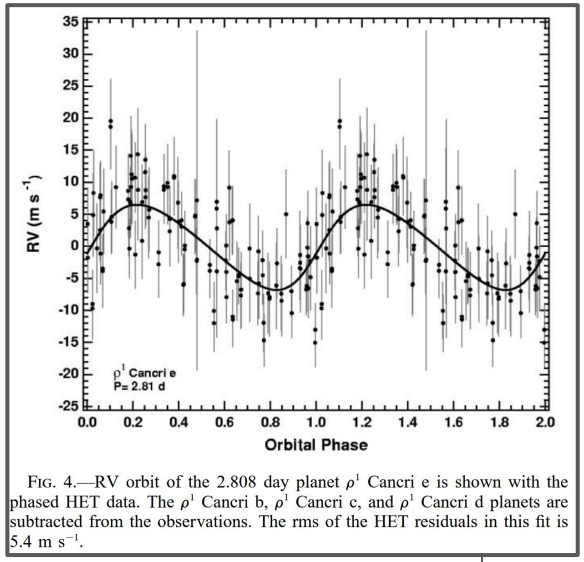

FIG. 4.—RV orbit of the 2.808 day planet ρ^1 Cancri e is shown with the phased HET data. The ρ^1 Cancri b, ρ^1 Cancri c, and ρ^1 Cancri d planets are subtracted from the observations. The rms of the HET residuals in this fit is 5.4 m s^{-1}.

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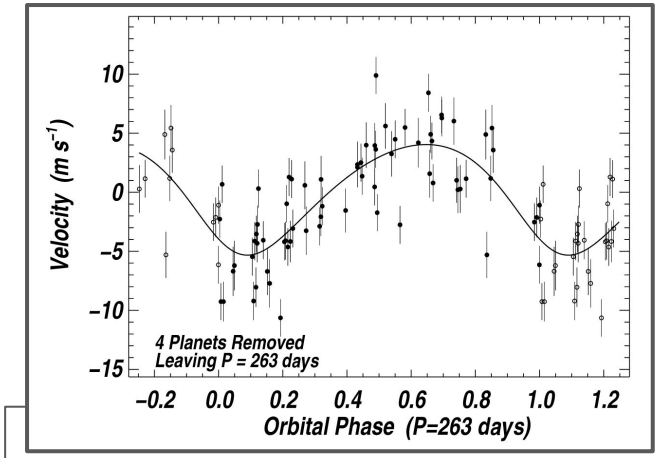
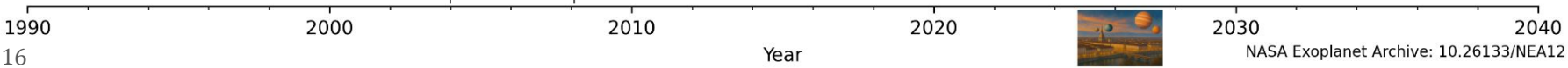


a fifth planet in "the large empty
zone between two other planets"
Fischer et al. 2008



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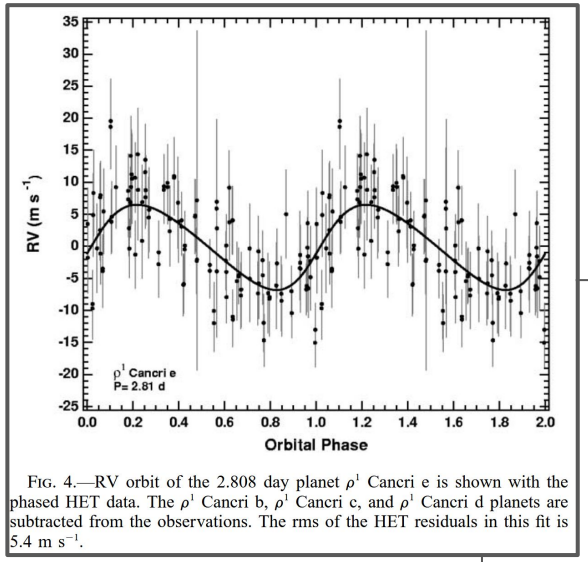

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1d alias of a less massive planet at 0.7365d
Dawson & Fabrycky 2010

1990 2000 2010 2020 2030 2040
Year

NASA Exoplanet Archive: 10.26133/NEA12

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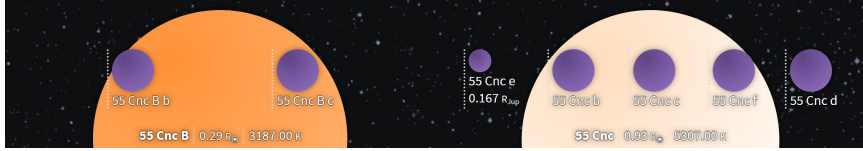

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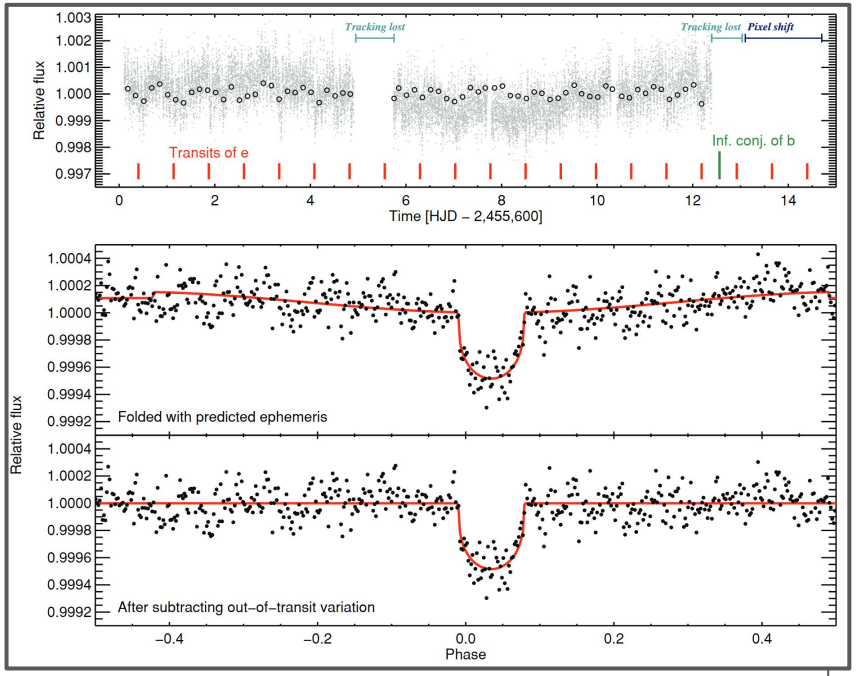

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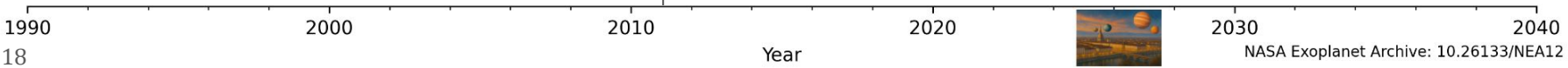

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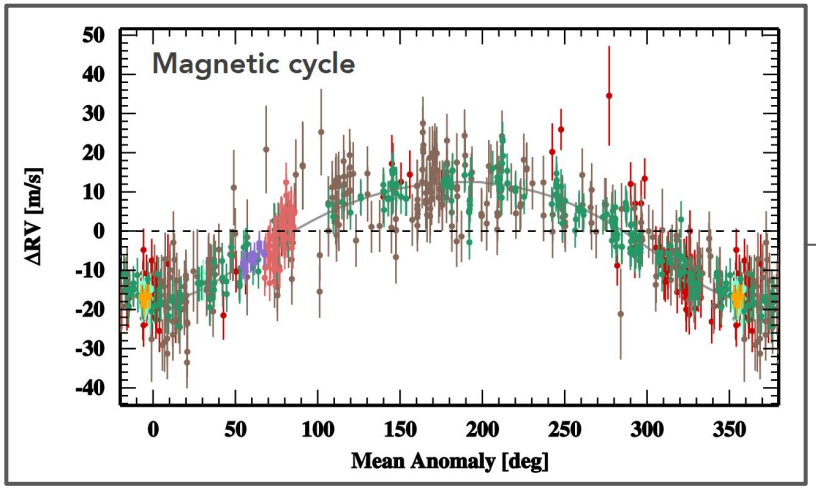

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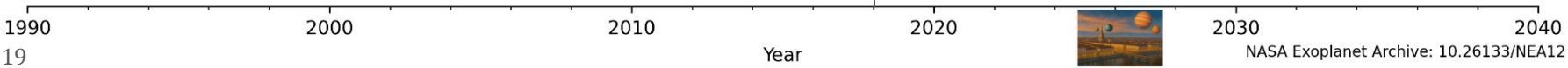

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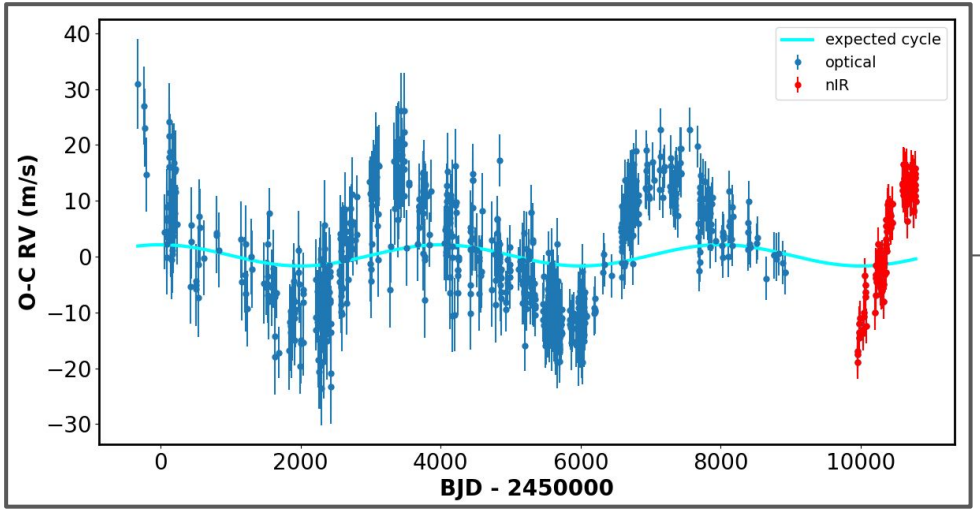

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nIR RVs (SPIRou)
point to a 6th
planet candidate
at 4800d

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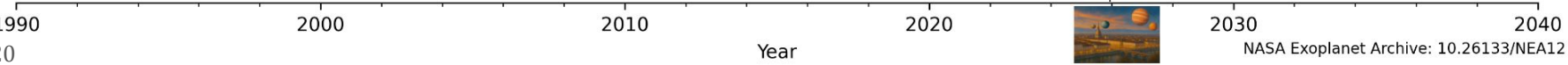

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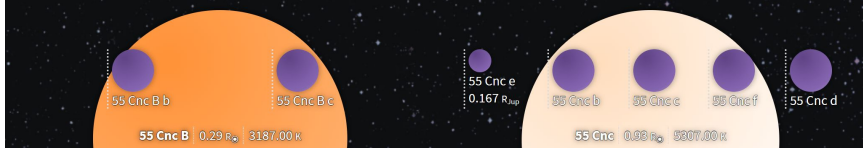

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not to mention all the offsets involved in
mixing data from multiple instruments

or the eccentricity of planet *b*
which is too high to be consistent with tidal
damping and absence of a 3:2 resonance
Ferraz-Mello & Beaugé (2025)

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all this around "a very quiet star",
mean log R'_{HK} over 21 years is -5

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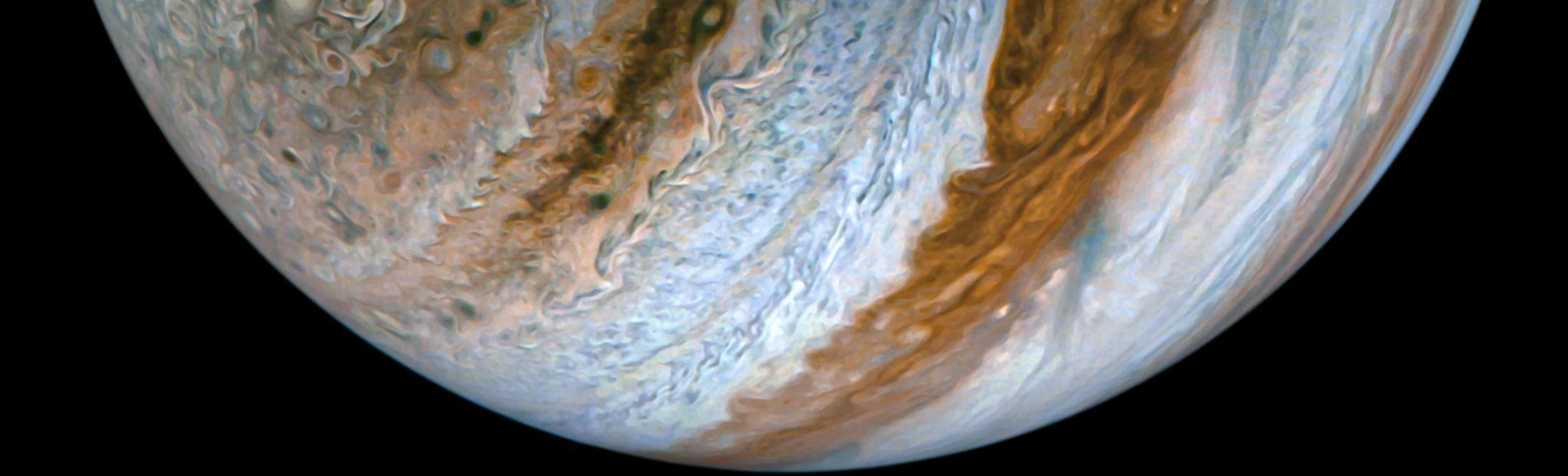
CHALLENGE ACCEPTED



probing the correlation between CJs and SPs

two comparative samples to
probe the occurrence of inner low-mass planets (SPs)
in systems with and without cold Jupiters

"giant" sample

at least one giant planet in outer region
$m \sin i > 100\ m_{\oplus}$, $a > 0.5$ AU
no giant planet in inner region
$a < 0.5$ AU
no highly eccentric orbits
$e < 0.7$
no high-mass companions from H-G PMA
$m < 30\ m_{Jup}$ at 5 AU

"flat" sample

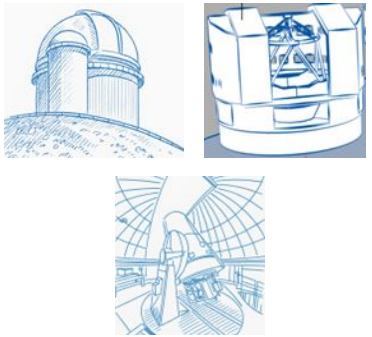
at least 25 HARPS and 25 CORALIE points

no detected giant planets in RVs

no high-mass companions from H-G PMA
$m < 30\ m_{Jup}$ at 5 AU

long-term RV monitoring with several high-resolution spectrographs

- historical CORALIE and HARPS surveys
- two ESO Large Programmes HARPS + ESPRESSO (PI: Delisle)
- NIRPS GTO programme (on a subsample out of "giant")



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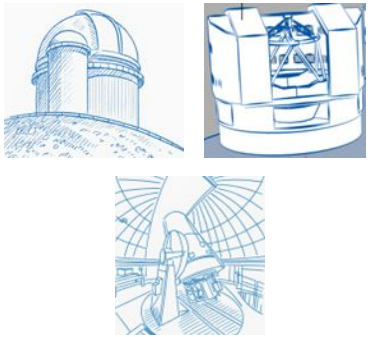
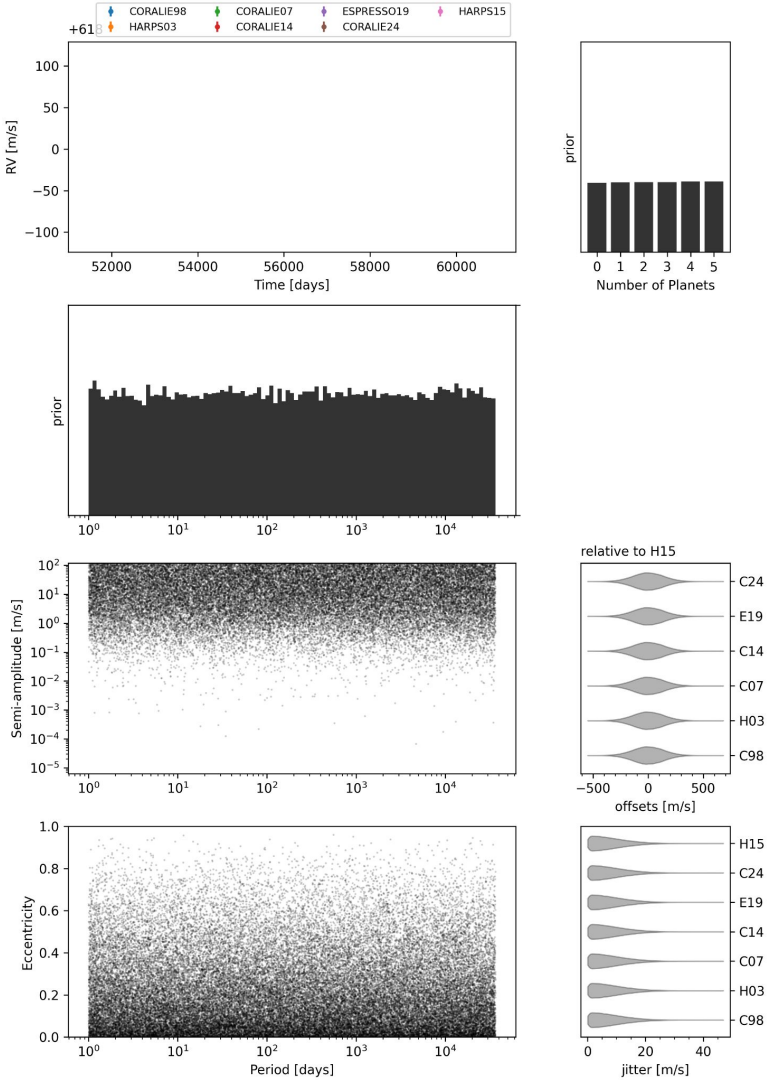
main goal: reach a uniform observing strategy, avoiding "observer-excitement" bias:
many more measurements for targets with planets than targets without planets

- low amplitude planets more likely to be detected in multi-planet systems
- systems with planets (and more points) have larger weight in occurrence estimates



consistent Bayesian approach to RV analysis

broad priors for all model parameters
and number of planets is also **free**



consistent Bayesian approach to RV analysis

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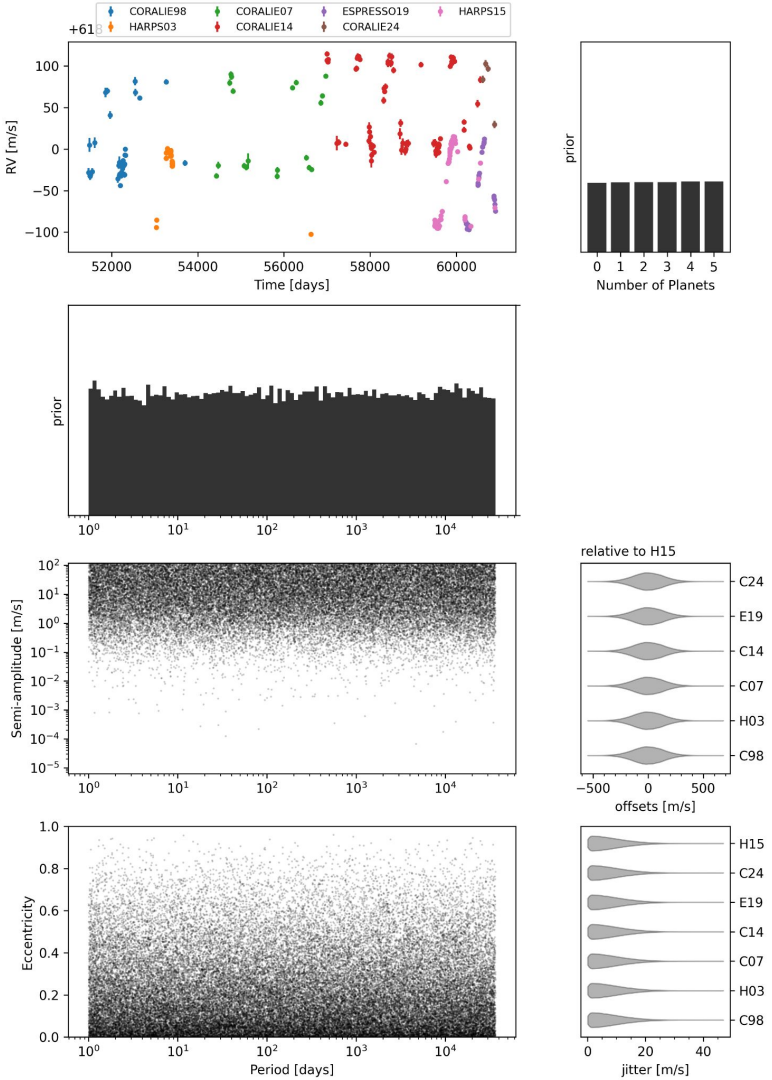
all stars analysed with the same model



consistent Bayesian approach to RV analysis

broad priors for all model parameters
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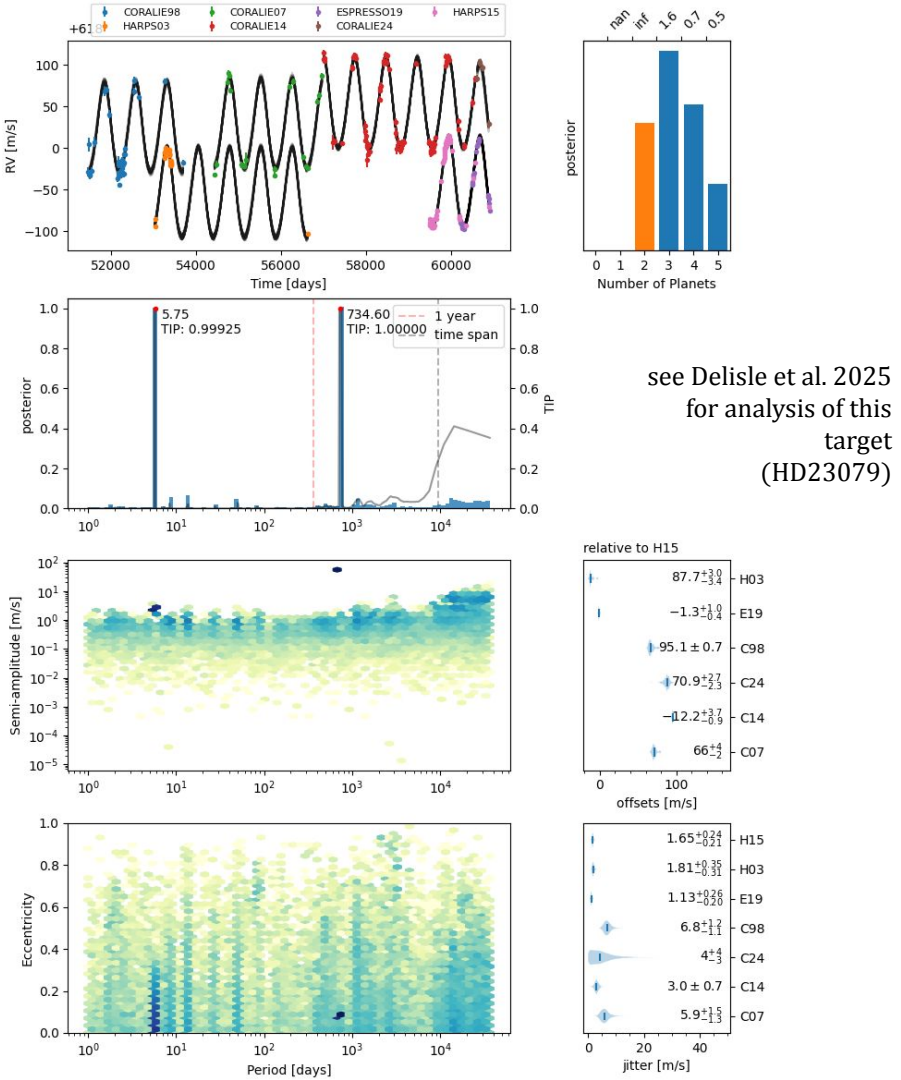
all stars analysed with the same model

posterior distributions for the number of planets
and each of their orbital parameters



see Delisle et al. 2025
for analysis of this
target
(HD23079)

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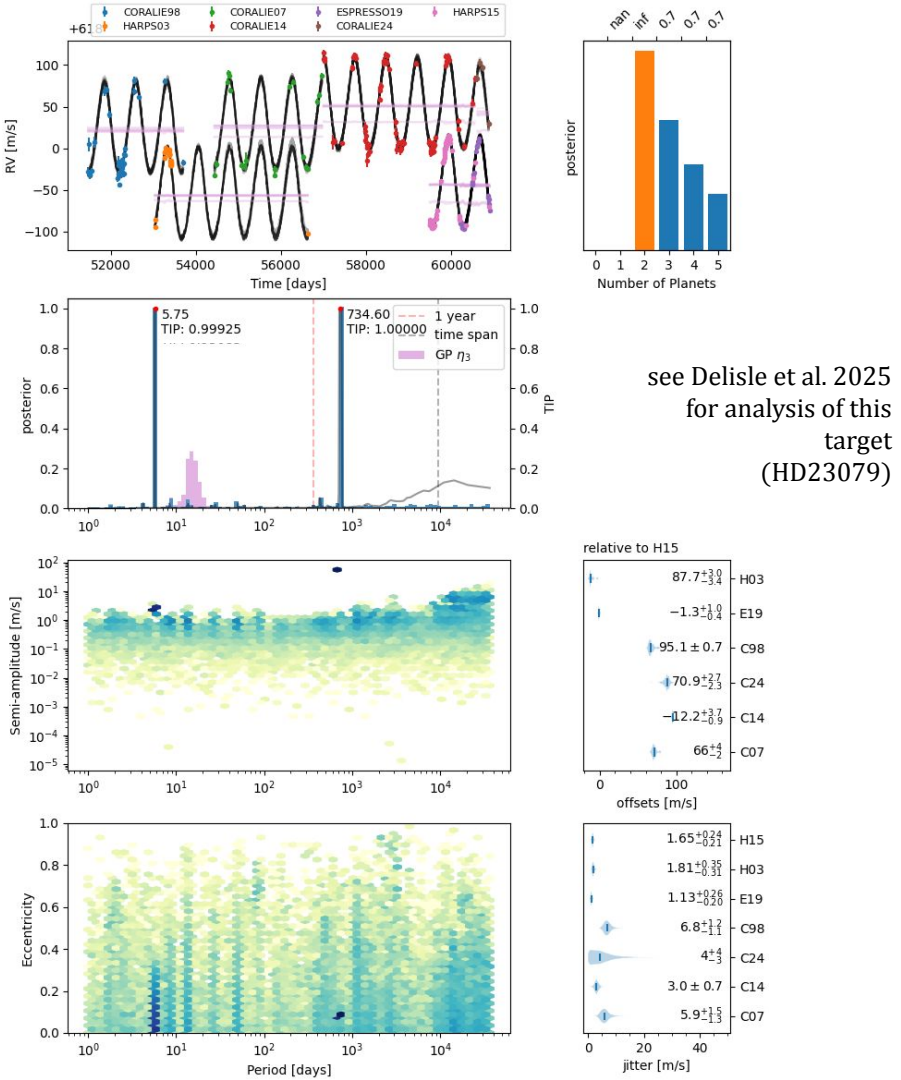
can use a GP to model stellar activity signals



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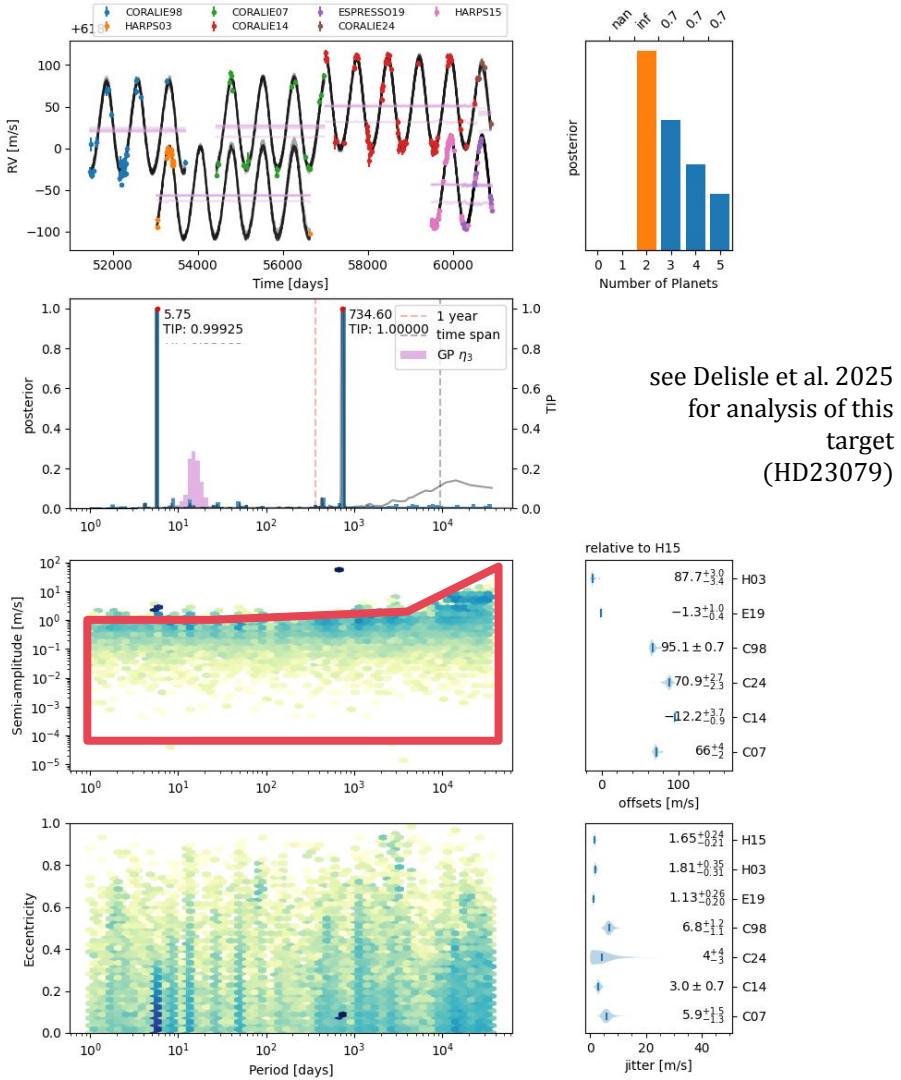
the posterior also provides the periods and amplitudes of signals that, while not detected, are still *compatible* with the available data

compatibility limits

- available for “free”, from one single run
- no subtraction of detected signals
- no injection-recovery
- naturally accommodate eccentricity

see also Figueira et al. 2025, Standing et al. 2022

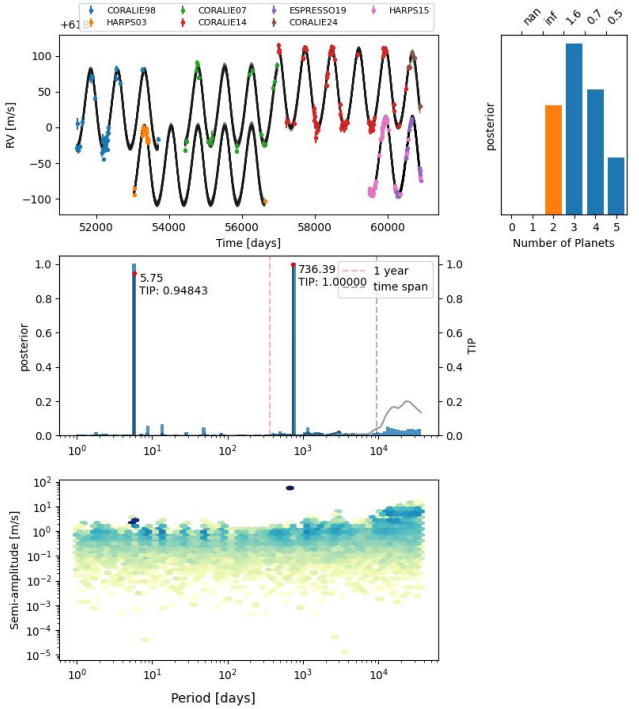


see Delisle et al. 2025
for analysis of this
target
(HD23079)

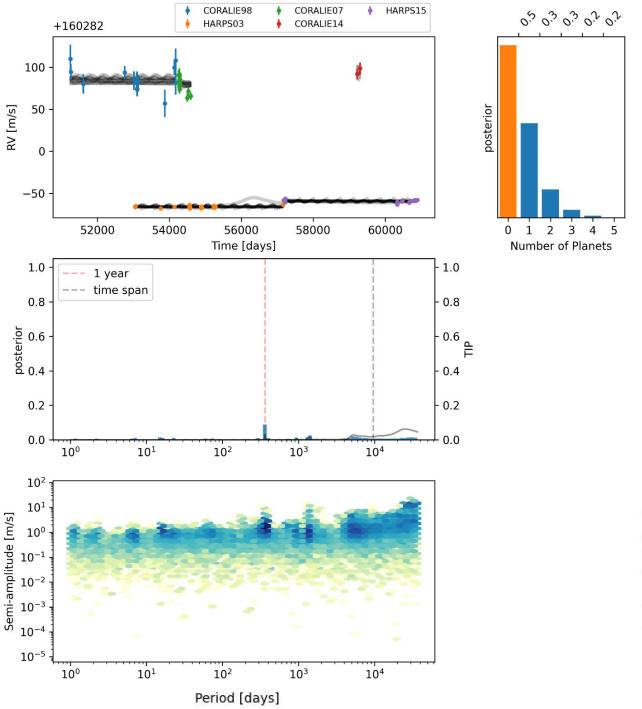
combining individual analysis for population inference

all stars analysed with the same model

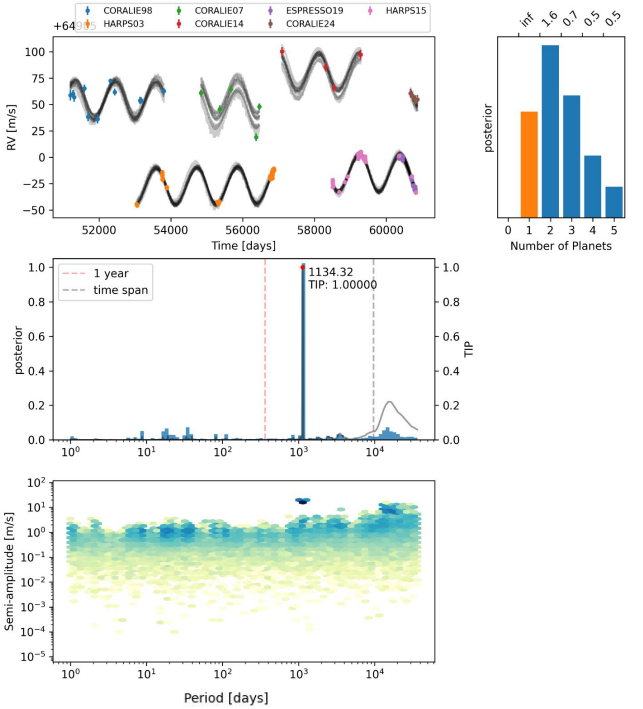
star 1



star 2



star 3



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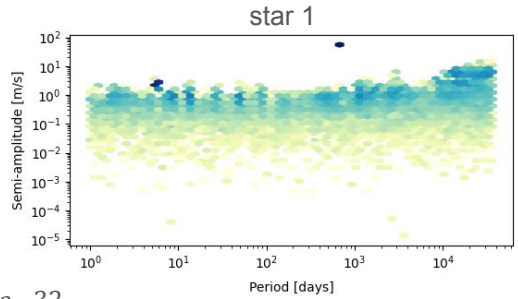

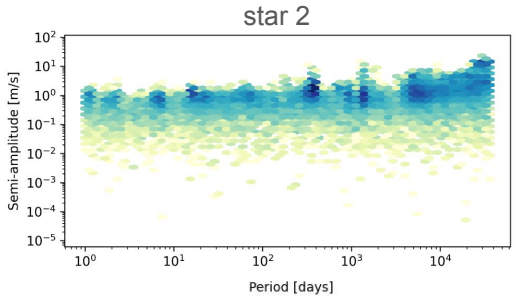

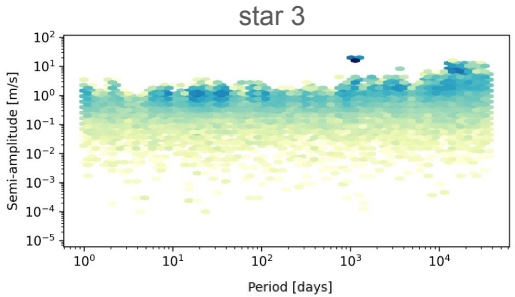

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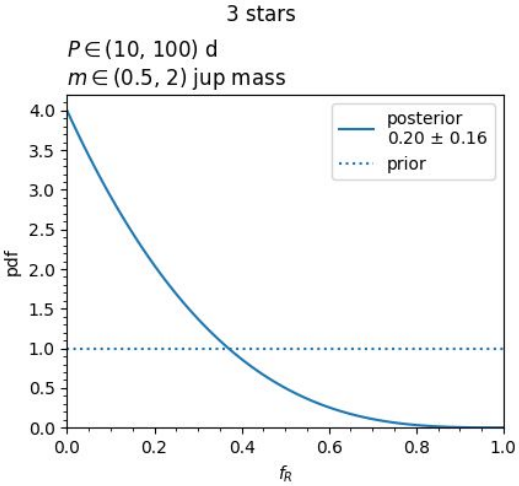
posteriors can be combined to infer the planet occurrence rate

see Faria, Delisle, Ségransan (2025)

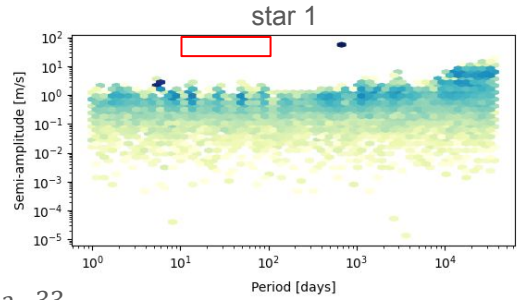
this approach

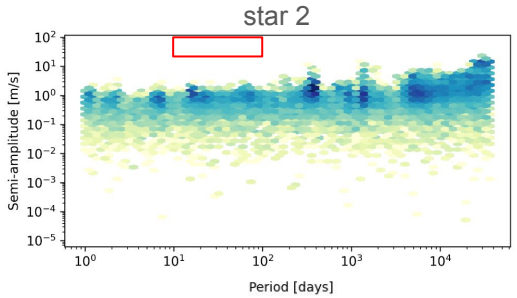
- relies only on existing posterior samples
- does not require injection-recovery tests
- no need to define an explicit detection threshold

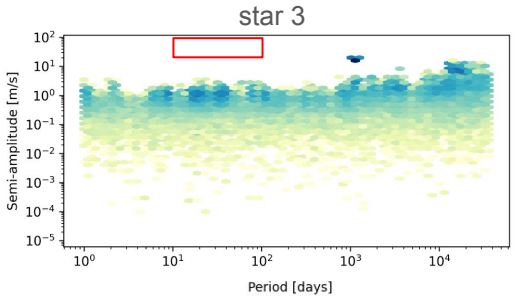
the same set of posterior samples can be reused to estimate occurrence rates for different regions or for different stellar subsamples



fraction of stars with at least one planet within a period-mass region







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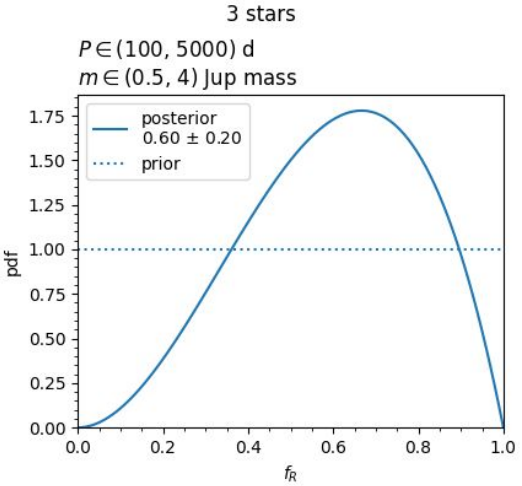

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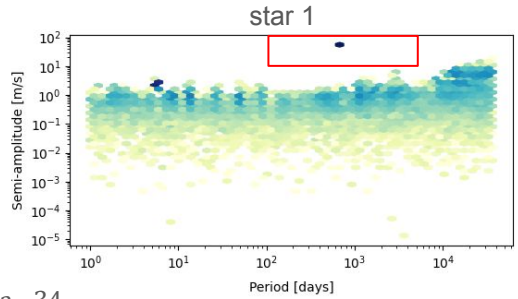

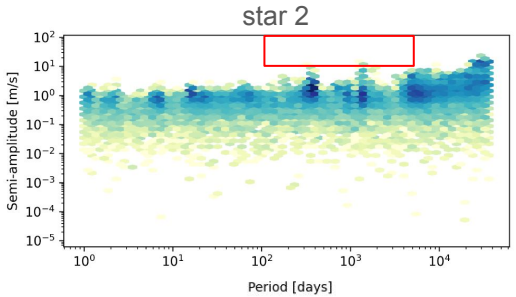

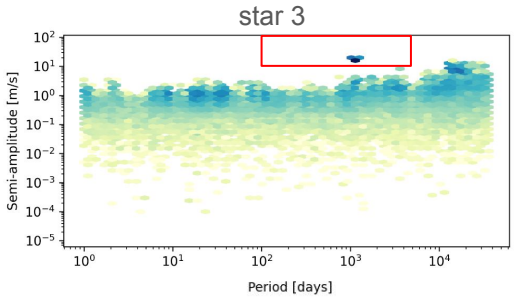

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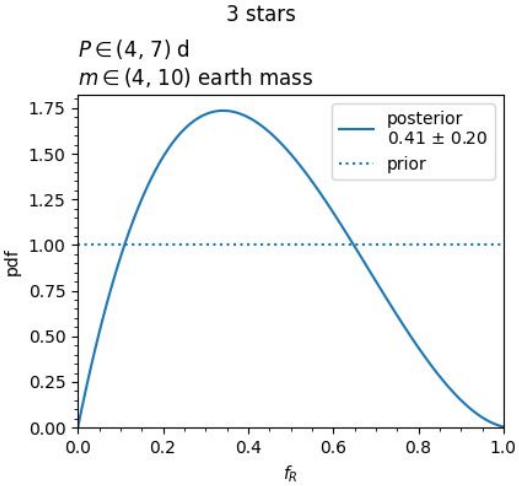

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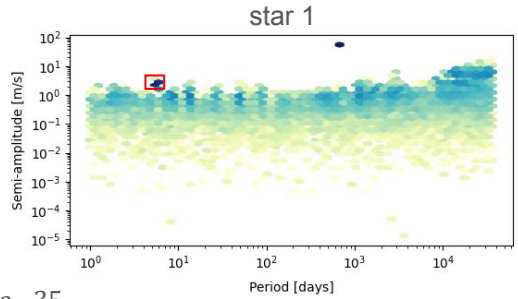

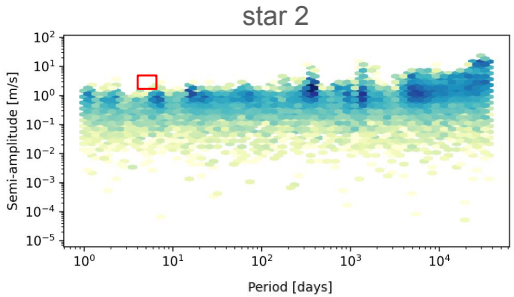

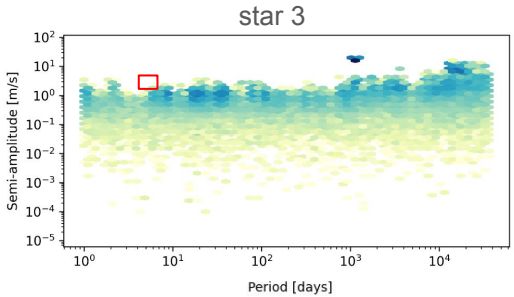

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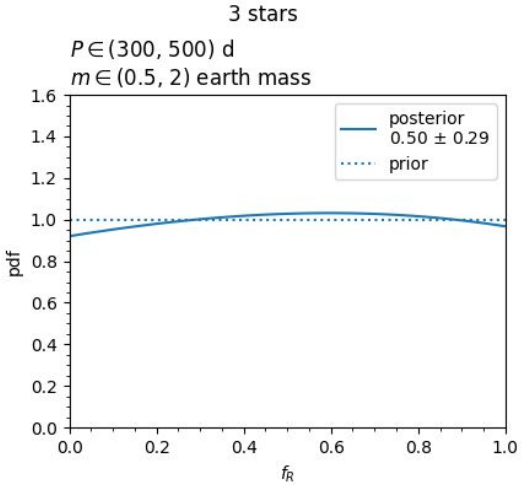

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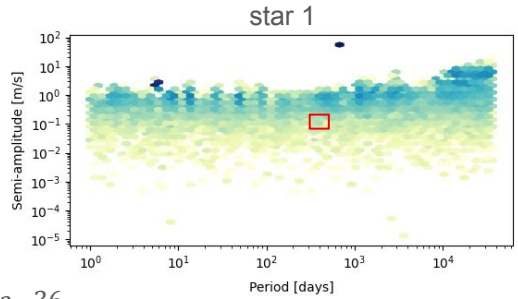
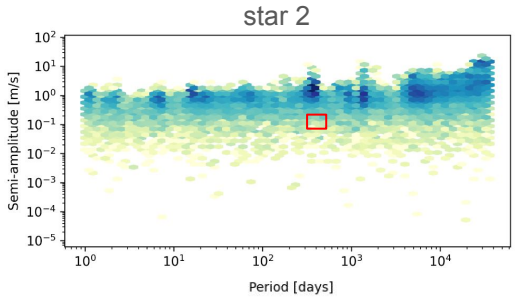
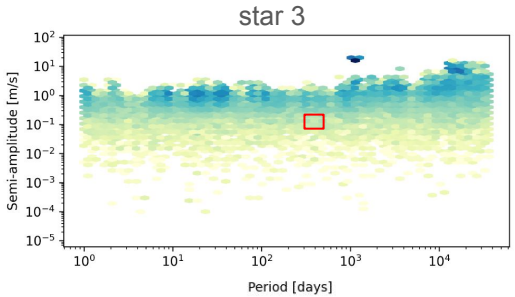
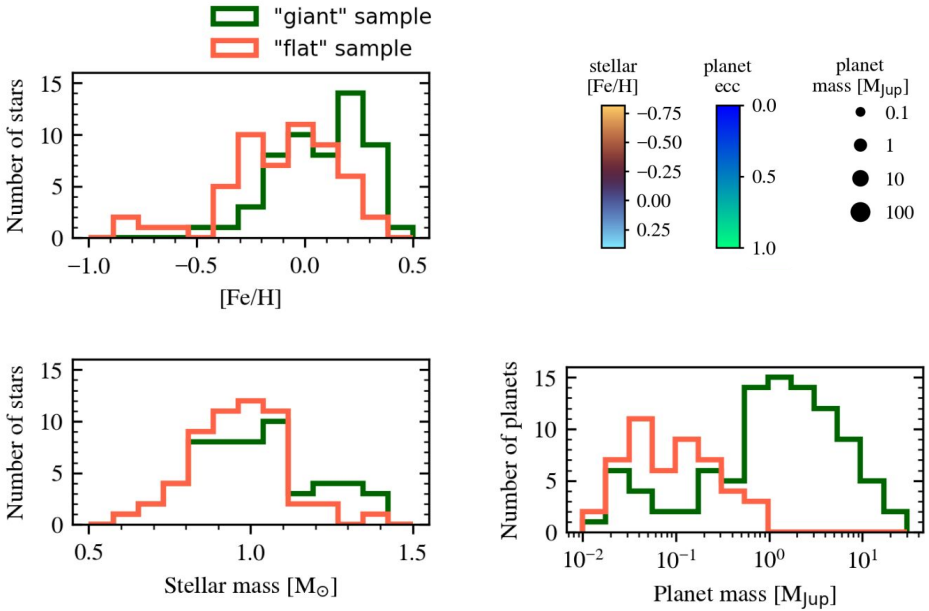




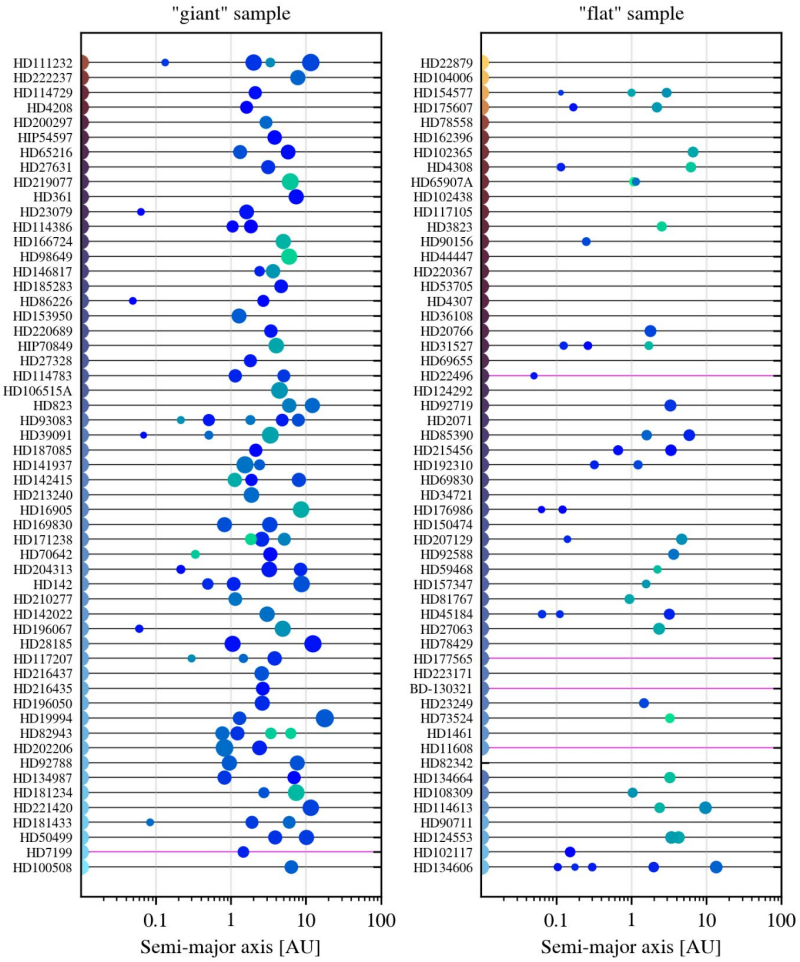


comparison of the two samples

*GP analysis



comparable mass and metallicity distributions
comparable detection sensitivities



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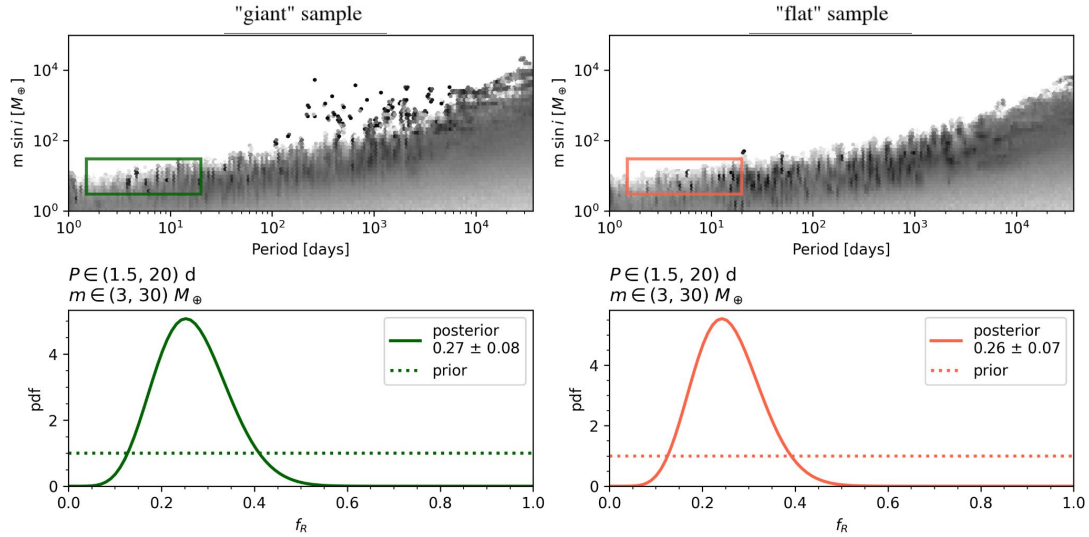
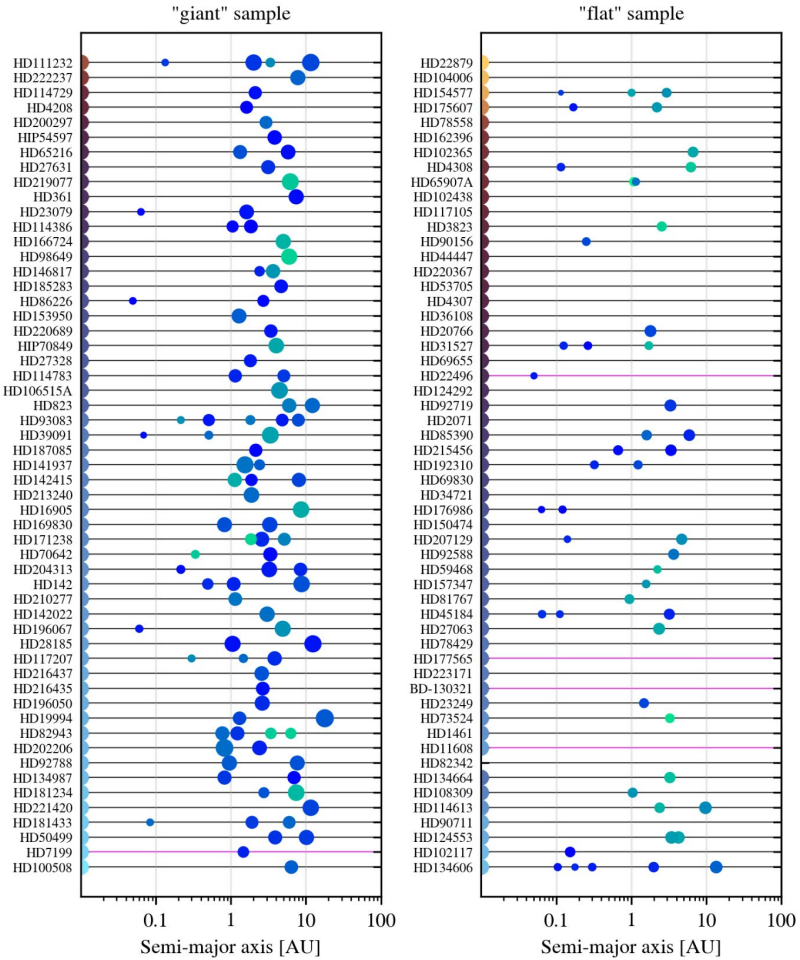
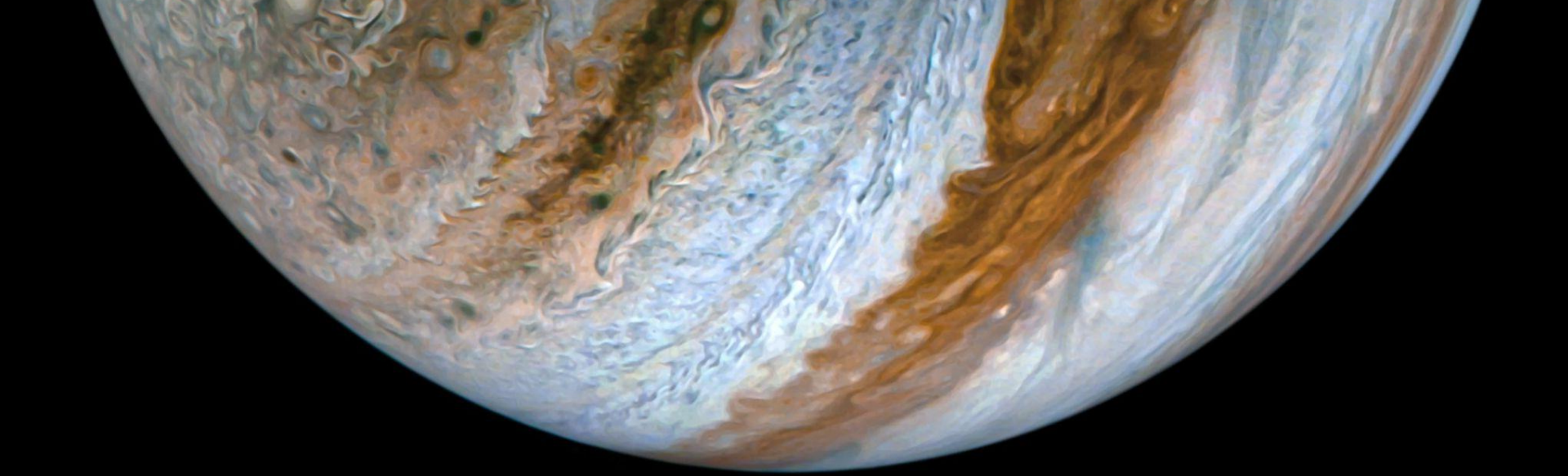




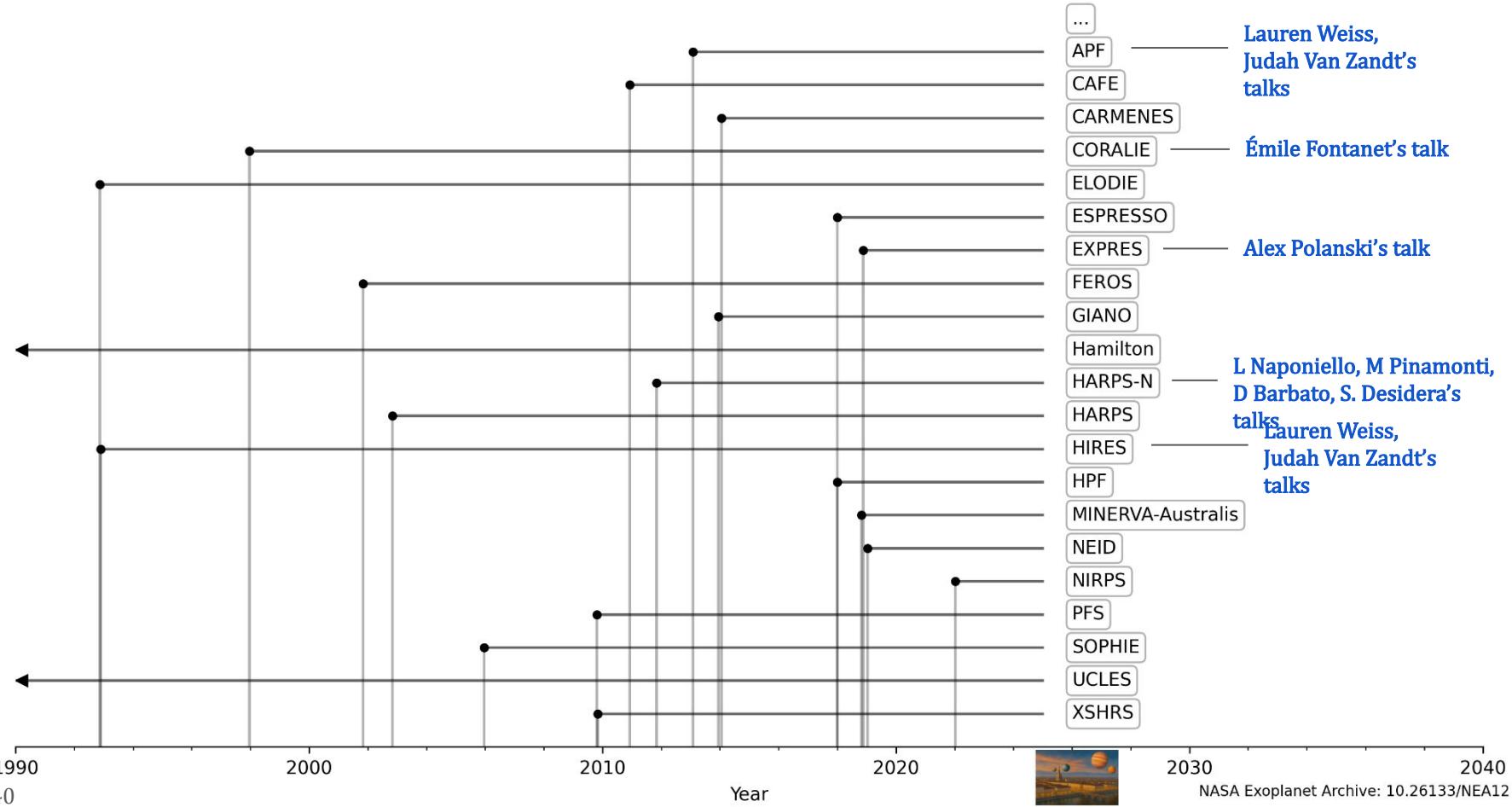
SP occurrence rates fully consistent
in the presence or absence of CJs

in agrement with Bonomo et al. 2025
also Alessandro Ruggieri's talk



challenges in current and future radial-velocity surveys

RVs in the past and near-future



RVs in the past and near-future

Follow-up of PLATO transiting candidates
remember Juan Cabrera's talk

x000 new giant planet systems
see Timothy Brandt's talk just next

Terra Hunting Experiment (THE) @ HARPS3, INT2.5m
10 yr nightly observations of ~40 bright Sun-like stars aiming to discover Earth twins
Hall et al. 2016, 2018; Thompson et al. 2016
see William Brilliant's poster!

Second Earth Spectrograph (2ES) @ MPG/ESO2.2m
5+ year observing program to discover temperate terrestrial Earth-mass planets
in the habitable zone around the brightest solar-type stars; Stürmer et al. 2024

NASA Exoplanet Archive: 10.26133/NEA12