A. Suárez Mascareño

RV searches with high-resolution spectrographs

From CORAVEL to ESPRESSO

Doppler cross-correlation spectroscopy as a path to the detection of Earth-like planets. - From CORAVEL to ESPRESSO via ELODIE -

Plenary Session

Monday, June 27th 2022   15:30 - 16:00   AUDITORIUM 1

Michel Mayor[1]

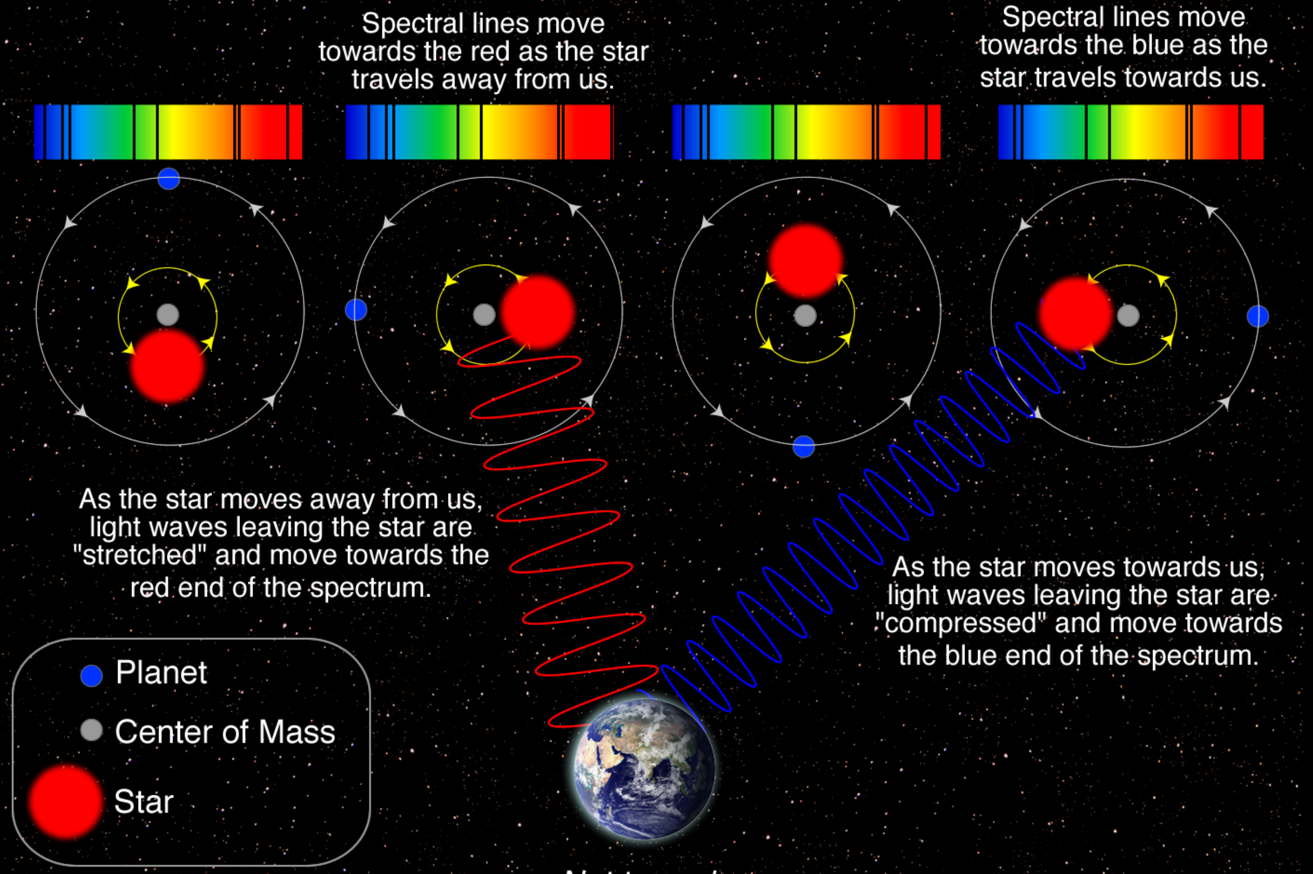
- **Alejandro Suárez-Mascareño** (IAC, Tenerife):
  "RV searches with high-resolution spectrographs: from CORAVEL to ESPRESSO"

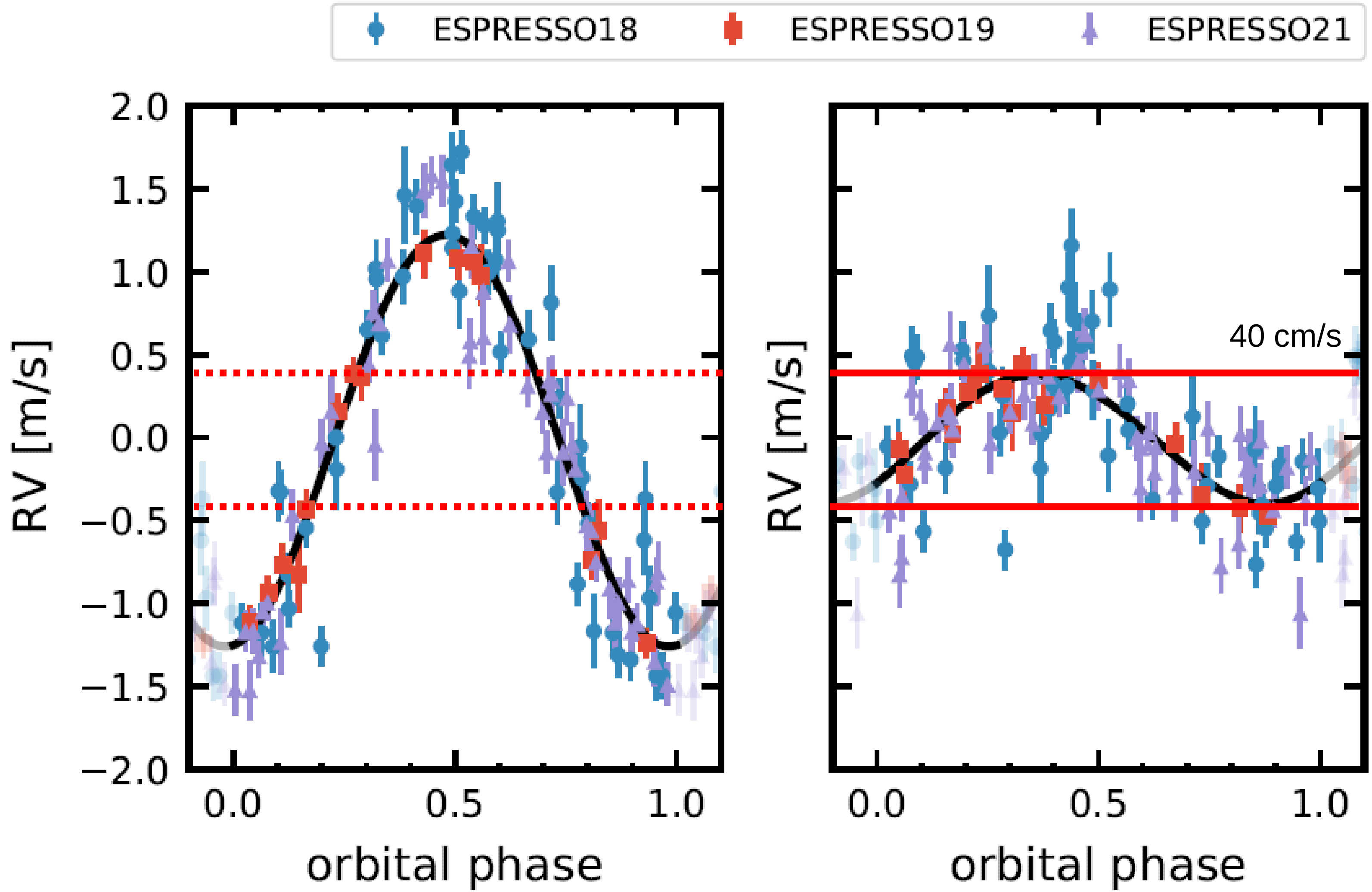
DON'T PANIC

The Hitchhikers Guide to the Galaxy

Radial Velocity Method

The star and planet orbit their common center of mass.





ESPRESSO18
ESPRESSO19
ESPRESSO21
RV [m/s]
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0.0
0.5
1.0
orbital phase
RV [m/s]
40 cm/s
0.0
0.5
1.0
orbital phase

1952 – RVs are over!

With the completion of the great radial-velocity programmes of the major observatories, the impression seems to have gained ground that the measurement of Doppler displacements in stellar spectra is less important at the present time than it was prior to the completion of R. E. Wilson's new radial-velocity catalogue.

Struve, O. 1952

Maybe there's still something...

With the completion of the great radial-velocity programmes of the major observatories, the impression seems to have gained ground that the measurement of Doppler displacements in stellar spectra is less important at the present time than it was prior to the completion of R. E. Wilson's new radial-velocity catalogue.

I believe that this impression is incorrect, and I should like to support my contention by presenting a proposal for the solution of a characteristic astrophysical problem.

Struve, O. 1952

PROPOSAL FOR A PROJECT OF HIGH-PRECISION STELLAR RADIAL VELOCITY WORK

By Otto Struve

Question: Statistics of planet-like bodies

Hypothesis: Loss of angular momentum in stars suggests formation of planetary systems → Many planetary systems!

Method: High precisión radial velocity

Shortcut: Close-in Jupiter-like planets (Hot Jupiters!)

Cross Correlation

Peter Fellgett; 1953

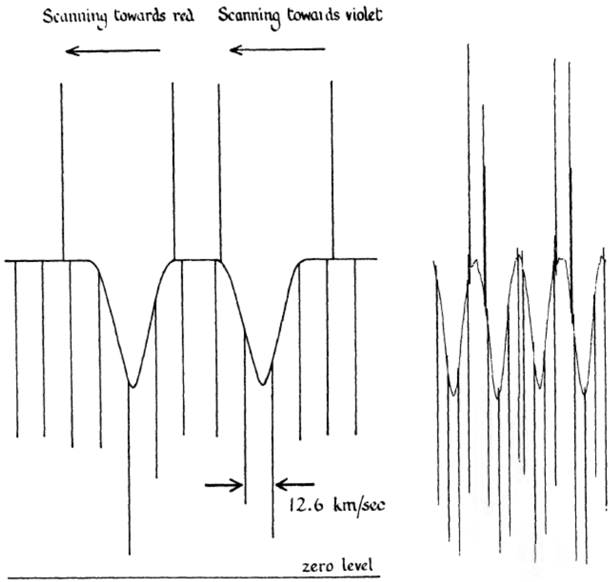


FIG. 2.—*Left:* diagrammatic representation of a radial-velocity observation. *Right:* actual record of an observation of 41 Comae.

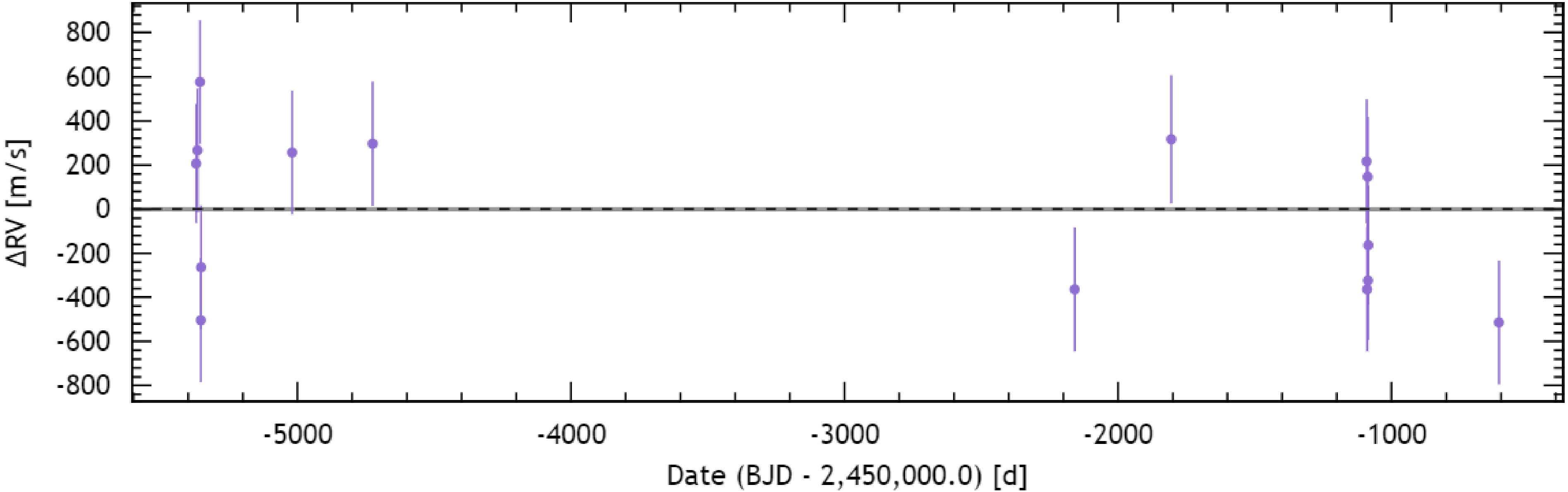
A photoelectric radial velocity spectrometer

R. F. Griffin 1967

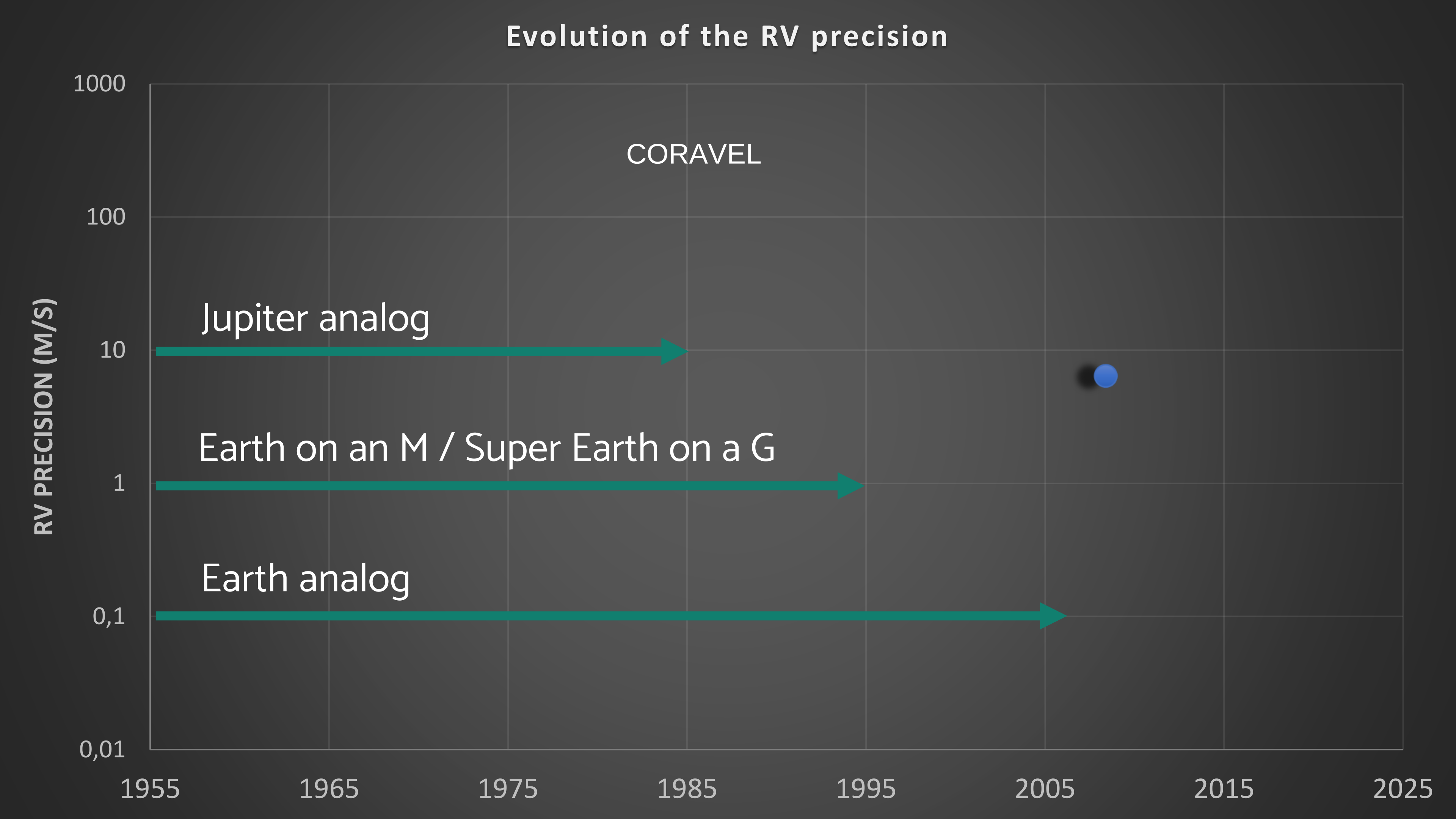
~500 m/s

The first of the modern RV spectrograph

CORAVEL – A. Baranne, M. Mayor and J. L. Poncet; 1979



~300 m/s


Evolution of the RV precision
1000
100
10
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0,1
0,01
RV PRECISION (M/S)
CORAVEL
Jupiter analog
Earth on an M / Super Earth on a G
Earth analog
1955
1965
1975
1985
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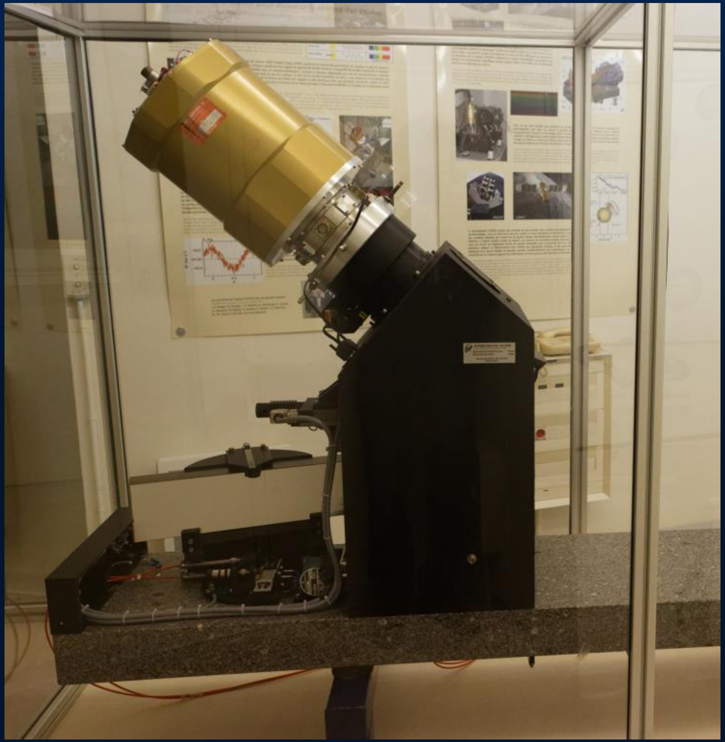
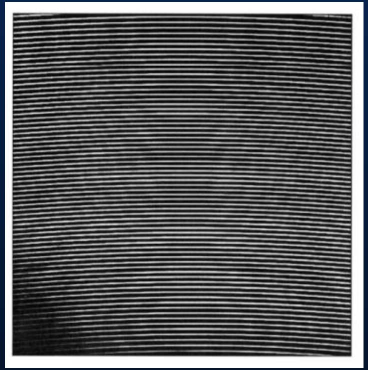
The dawn of the era of exoplanets



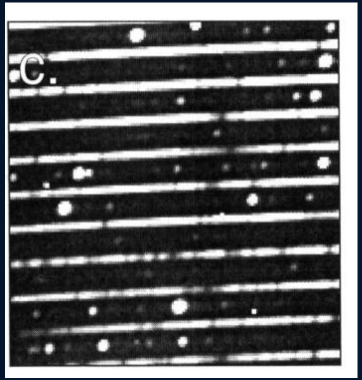
ELODIE

Baranne, A. et al. 1996

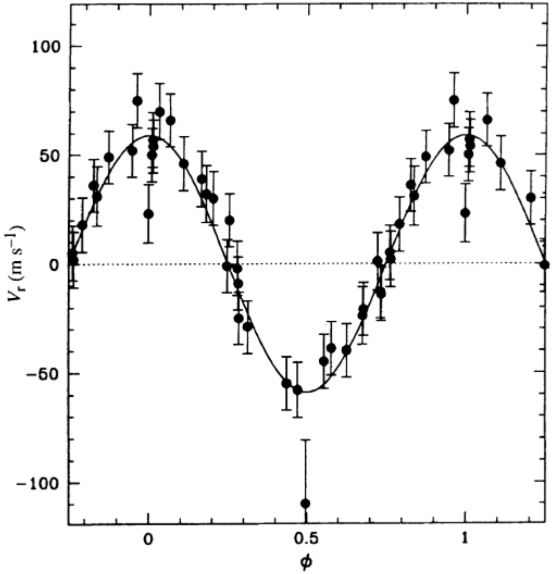
CCD



Simultaneous ThAr



10-15 m/s



A Jupiter-mass companion to a solar-type star

Michel Mayor & Didier Queloz

Geneva Observatory, 51 Chemin des Maillettes, CH-1290 Sauverny, Switzerland

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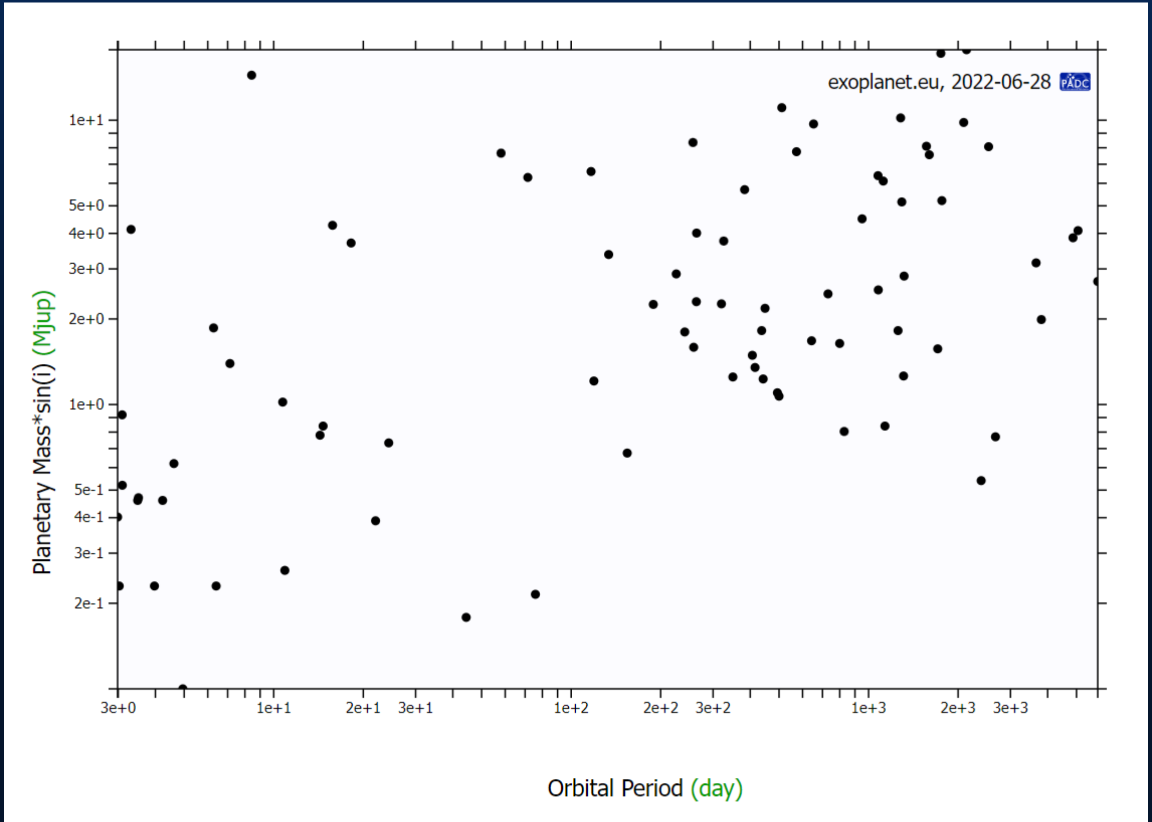
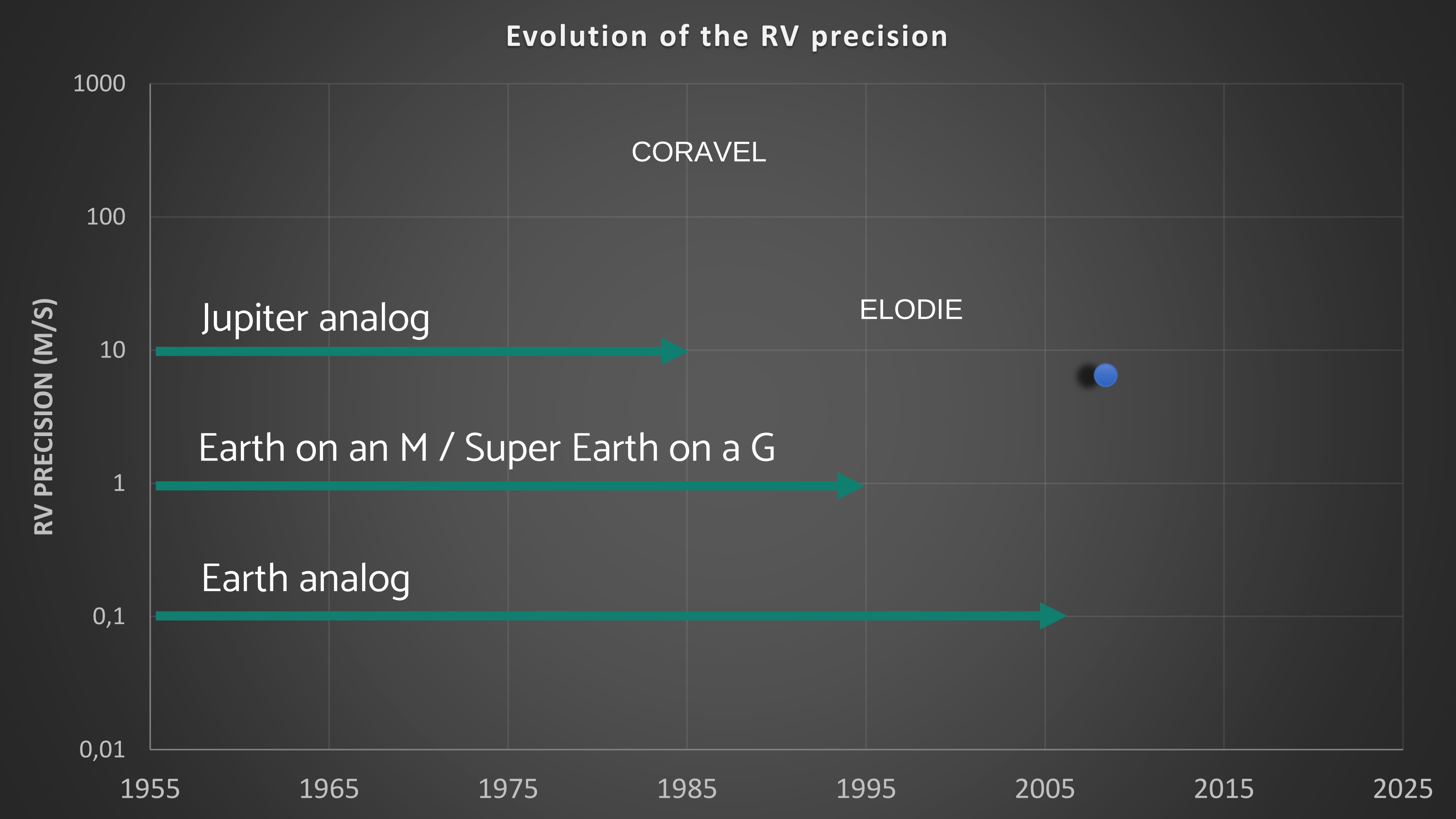
The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System.

Planets Everywhere



85 planetary discoveries in the years after 51 Pegasi b

Most with masses over 1 Jupiter mass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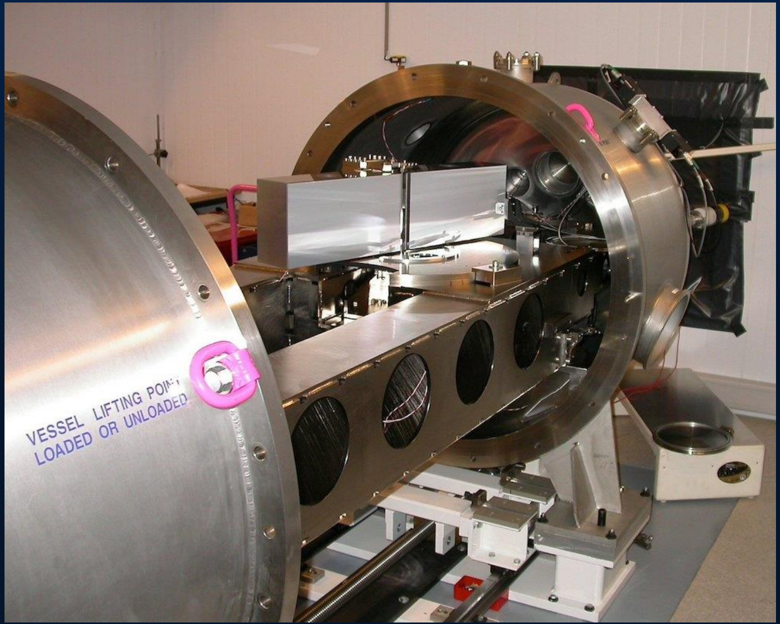
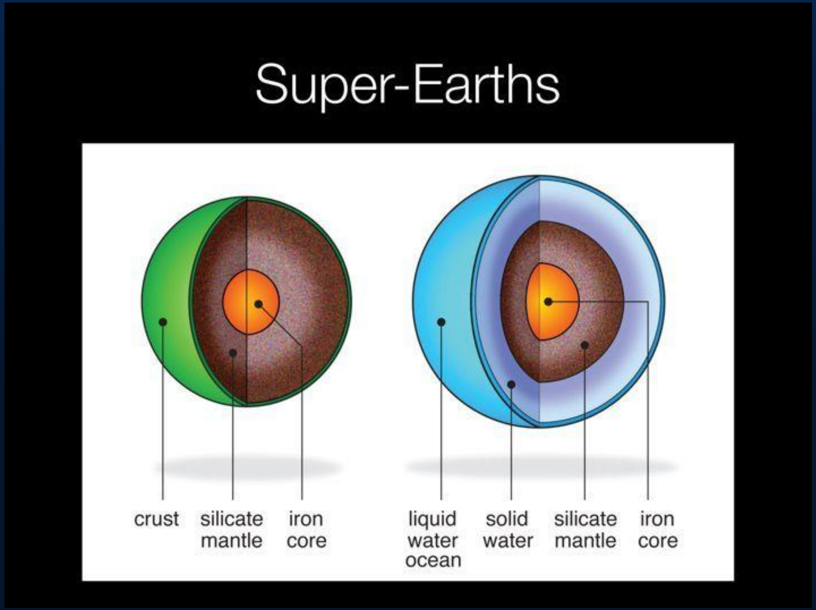
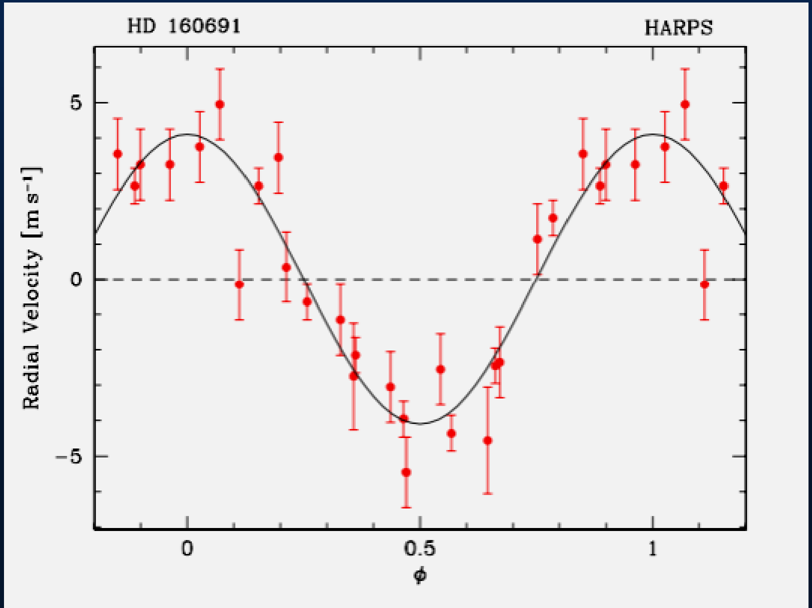
Breaking the 1 m/s barrier



A New Population

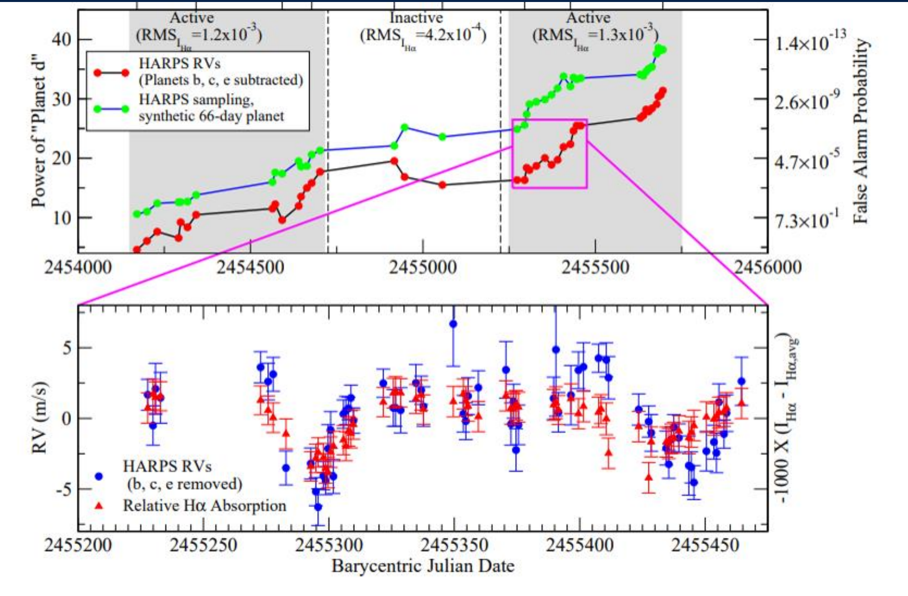




A 14 Earth-masses exoplanet around mu-Arae

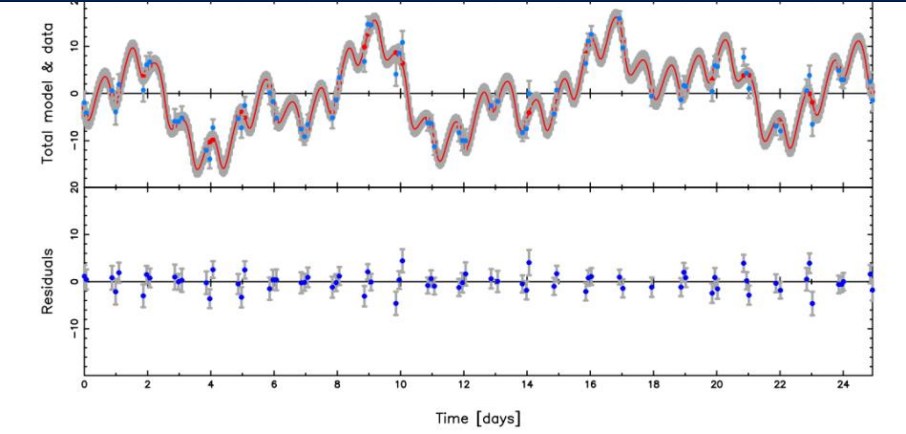
Santos, N. C. et al. 2004

Public Enemy number 1: Stellar Activity



Stellar Activity Maskerading as Planets in the Habitable Zone of the M-dwarf Gliese 581

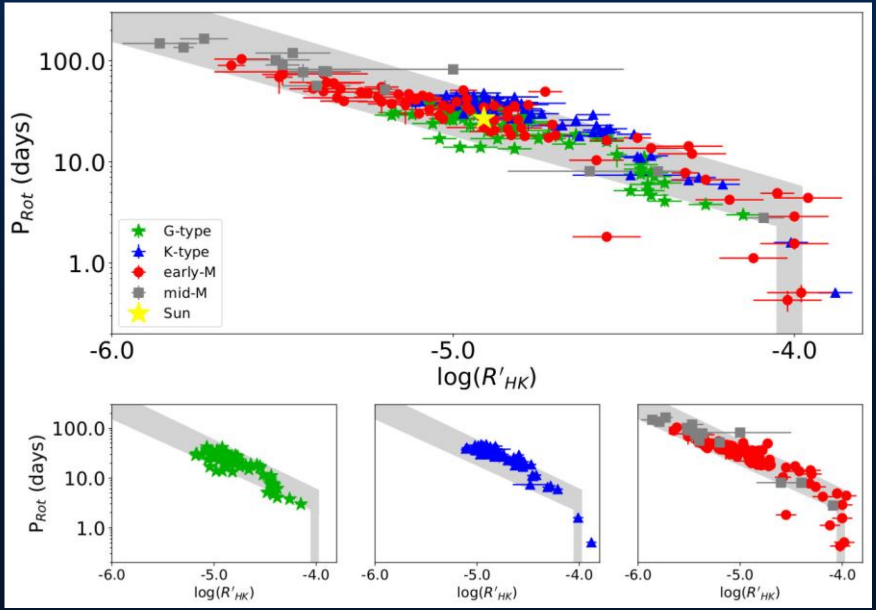
Robertson, P. et al. 2014

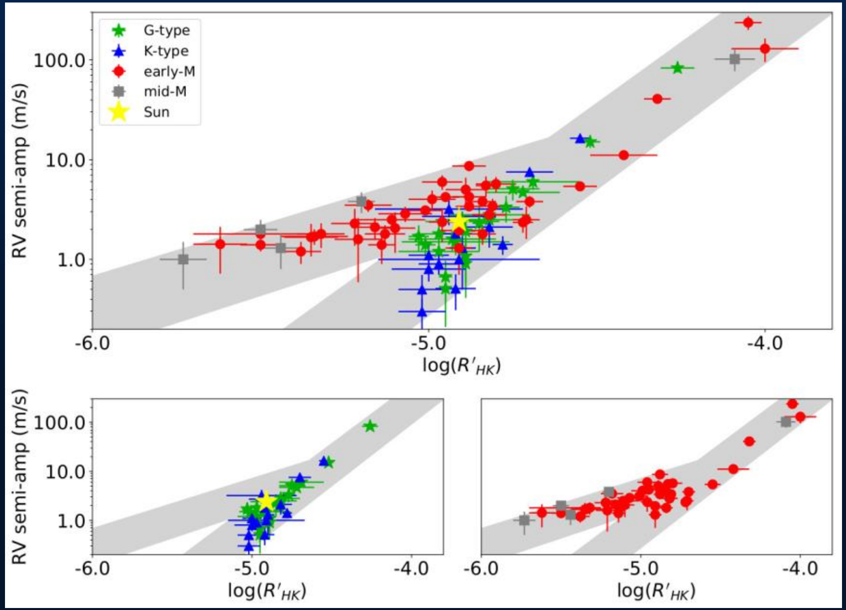


Planets and Stellar Activity: Hide and Seek in the CoRoT-7 system

Haywood, R. D. et al. 2014

Public Enemy number 1: Stellar Activity

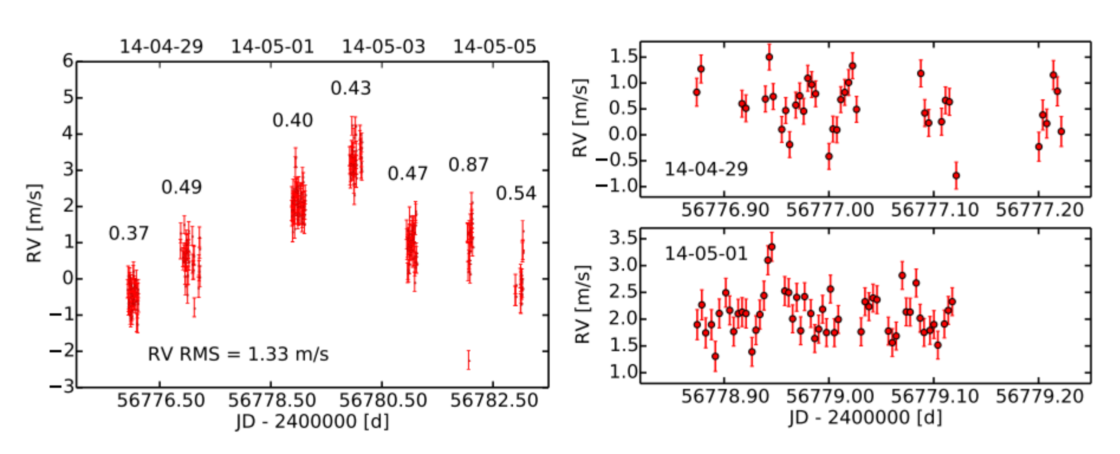




Combined data of Suárez Mascareño et al. 2015, 2016, 2017 and 2018

Solar feeds

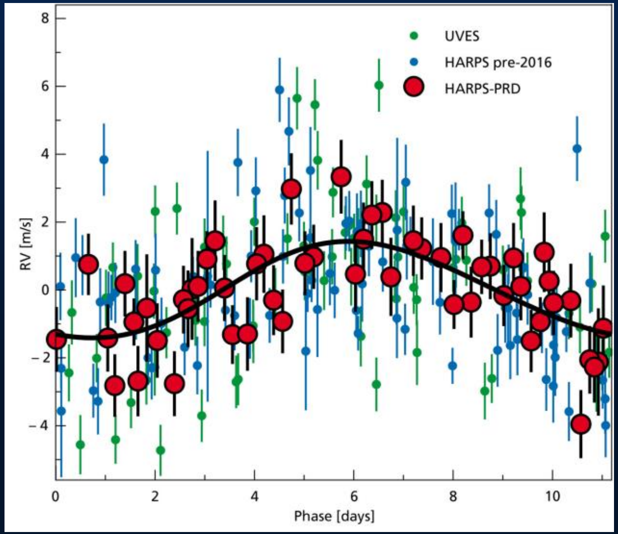
Installing the solar telescope at the TNG



HARPS-N observes the Sun as a star

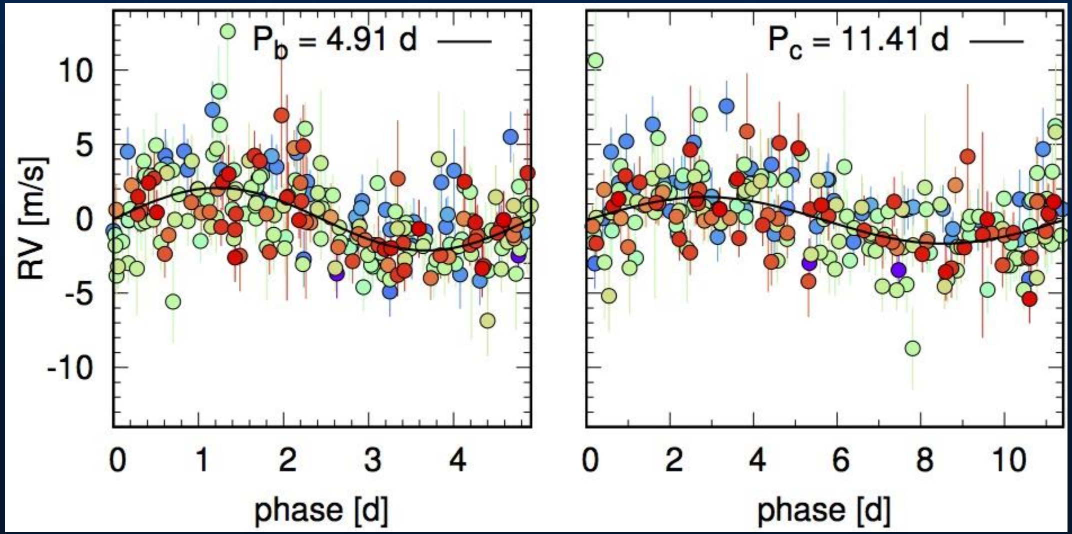
Dumusque, X et al. 2015

Earth-mass planets orbiting M-dwarfs



A terrestrial planet candidate in a temperate orbit around Proxima Centauri

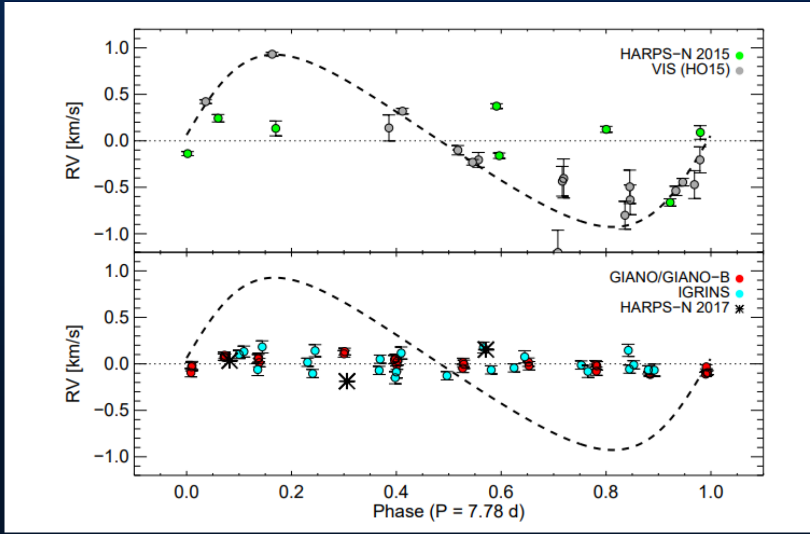
Anglada-Escudé et al. 2016

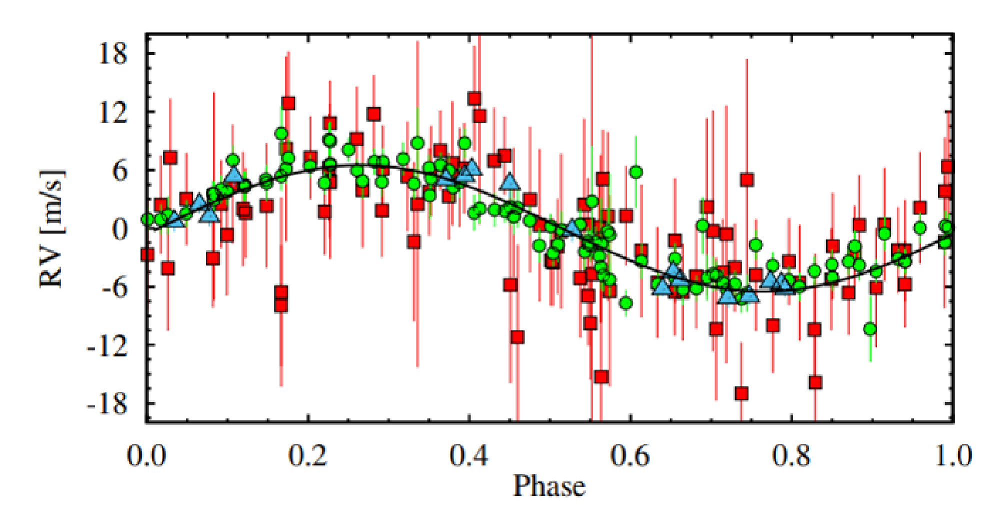


Two temperate Earth-mass planet candidates around Teegarden's Star

Zechmeister et al. 2019

Precise RVs in the NIR





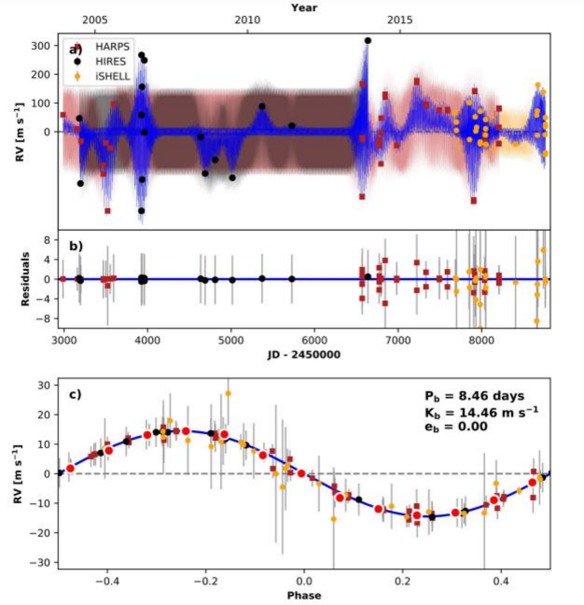
Multi-band high resolution spectroscopy rules out the hot Jupiter BD+20 1790b

Carleo et al. 2021

Measuring precise radial velocities in the near infrared: the example of the super-Earth CD Cet b

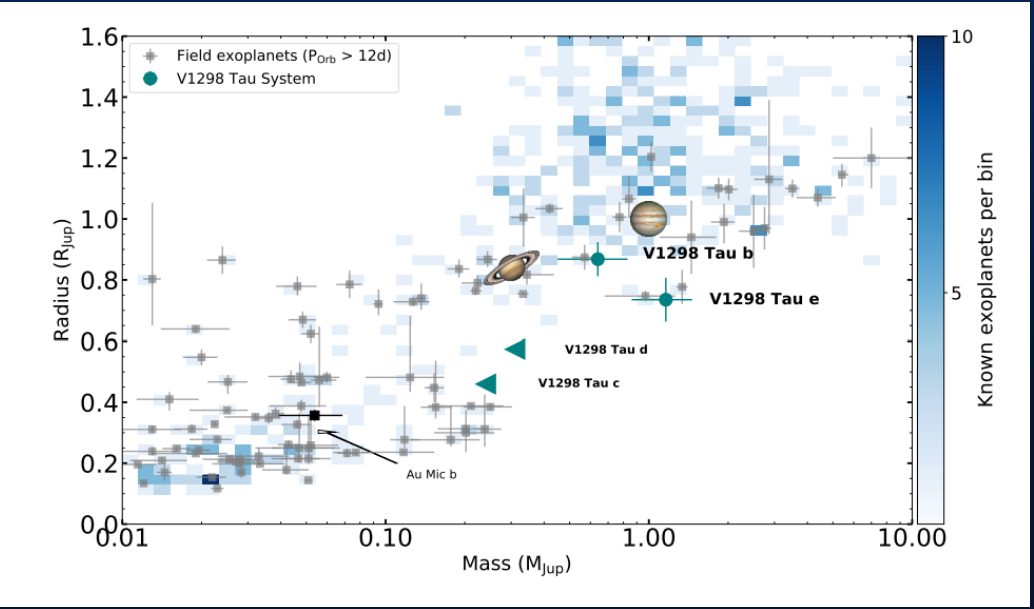
Bauer, F. F. et al. 2020

Insights on Young Planets



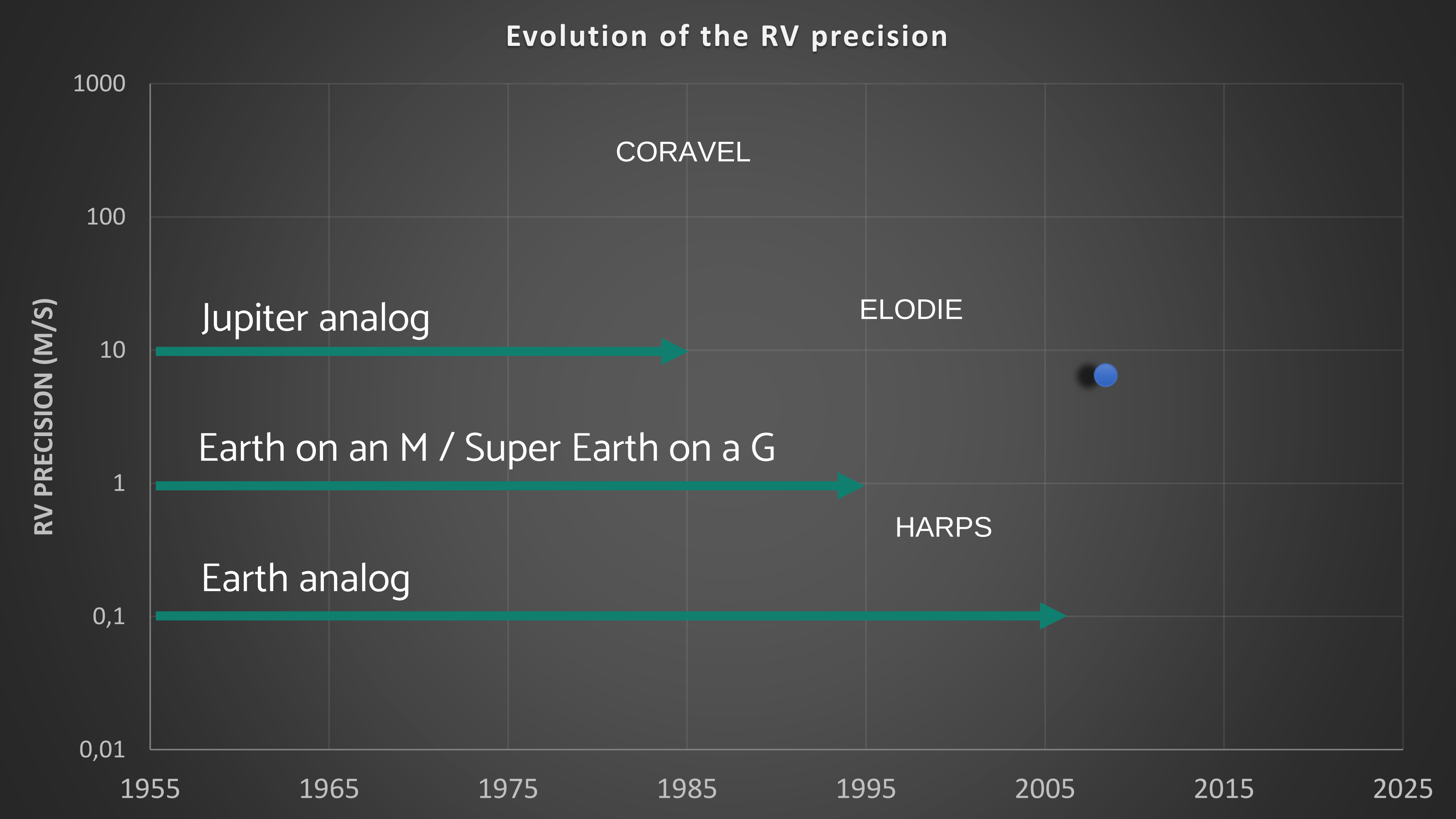
A planet within the debris disk around the pre-main-sequence star AU Microscopii

Plavchan et al. 2020



Rapid Contraction of Infant Giant Planets

Suárez Mascareño et al. 2021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ESPRESSO@VLT

Installed at the VLT array (4x8.2 meter telescopes)

R ~140 000

Wavelength 390-780 nm

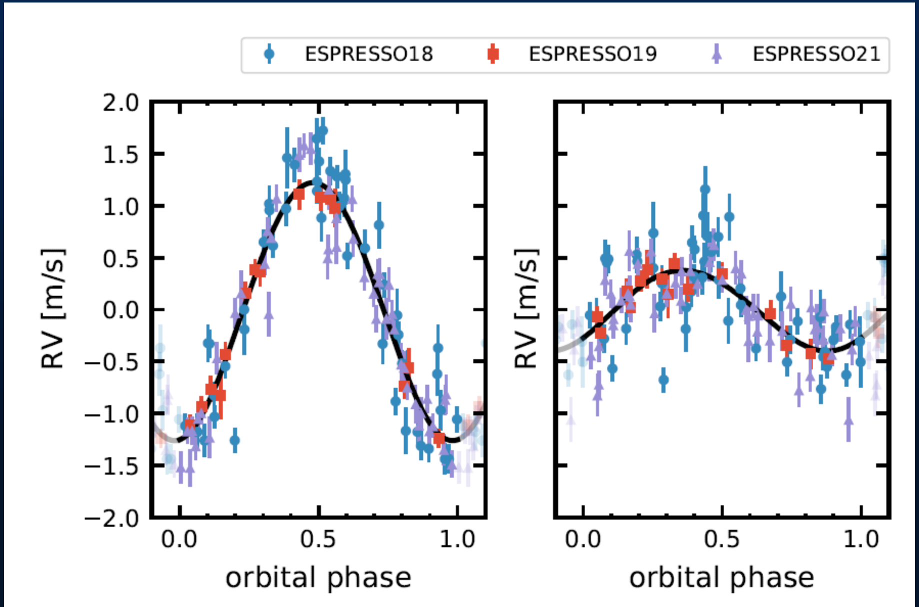
Ultra-stabilized

Simultaneous calibration (FP, Laser Comb)

Designed to obtain RV precisión of 10 cm/s

Pepe et al. 2021

Beyond Earth-mass

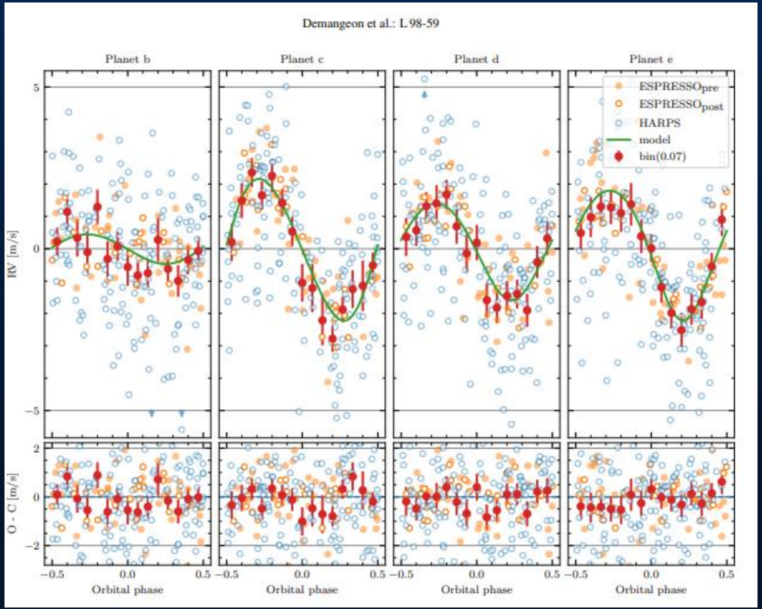


Revisiting Proxima with ESPRESSO

Suárez Mascareño et al. 2020

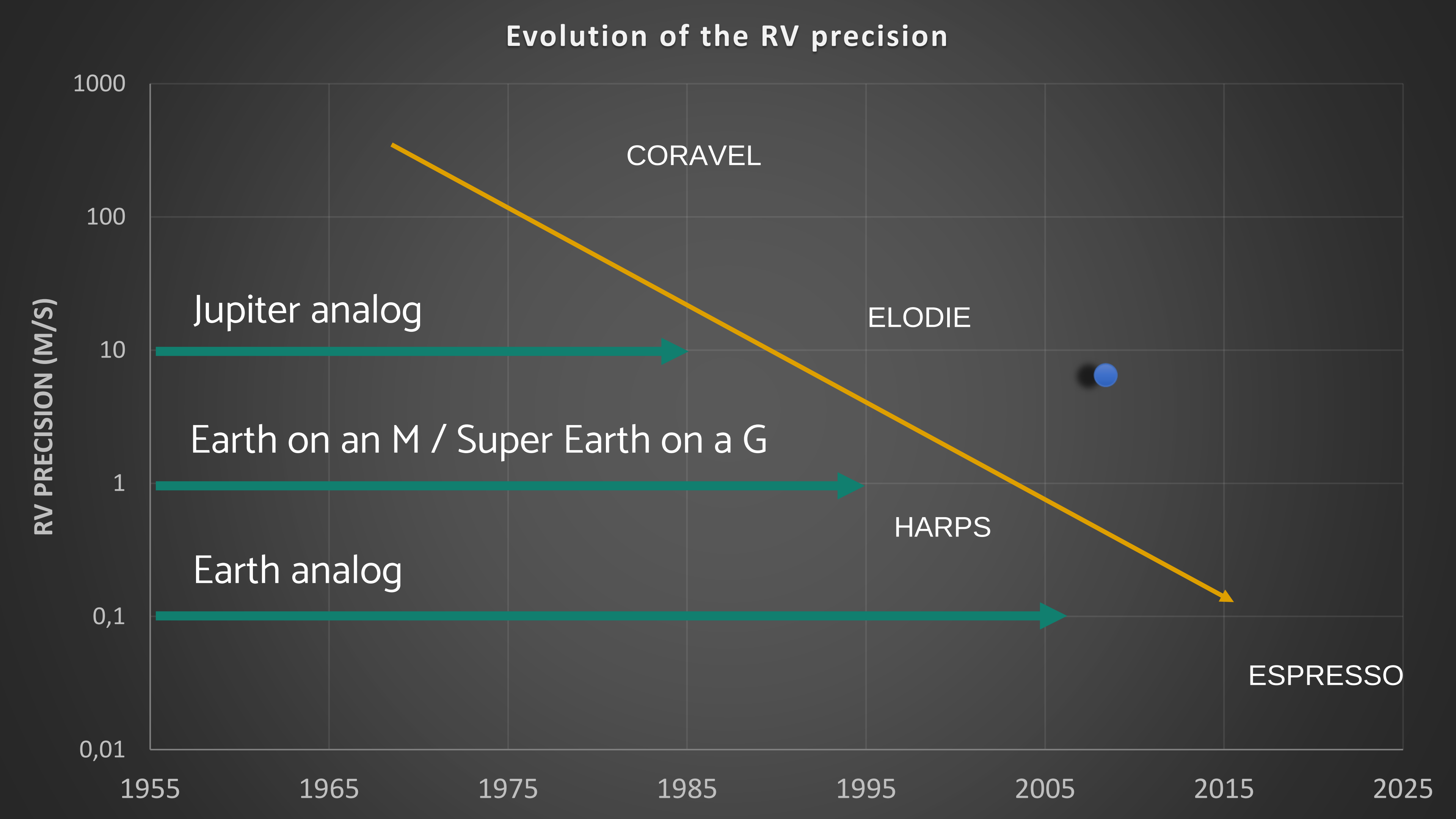
A candidate short-period sub-Earth orbiting Proxima Centauri

Faria et al. 2022



Warm terrestrial planet with half the mass of Venus transiting a nearby star

Demangeon et al. 2021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2022 – Still a long way to go!

Improve wavelength calibration

Laser Comb

Improve velocity extraction

Line by line

Better correction of stellar activity

Apply insight from the solar feeds

We are mostly “good” at rotation

Reach 1 m/s in the NIR (and beyond!)

Reach long term 10 cm/s precisión

Improve telluric correction (VIS and NIR)

Improve termal/pressure stability

Earth-analogs

Long-period low-mass planets

Complete planetary systems

Young planets

Systems orbiting very-low mass stars

Systems orbiting Brown dwarfs

The population of neighbouring planets remains unknown