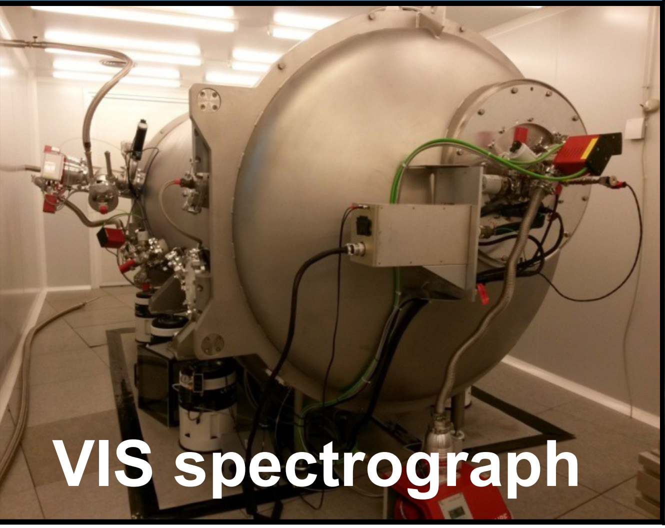
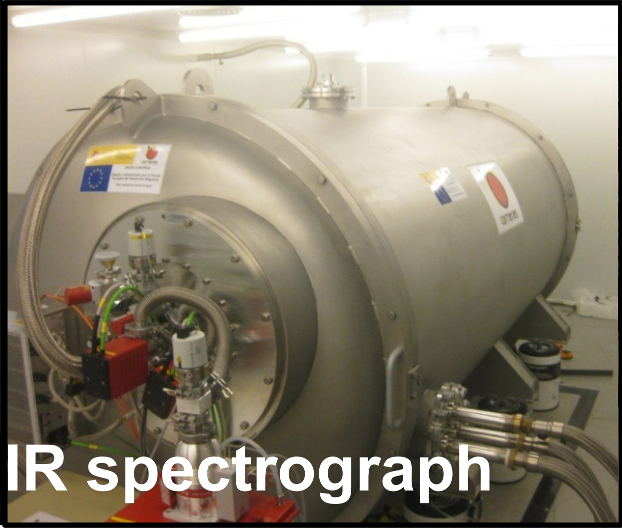
News from CARMENES

Calar Alto high-Resolution search for M dwarfs with Exoearths using Near-infrared and optical Échelle Spectrographs

carmenes



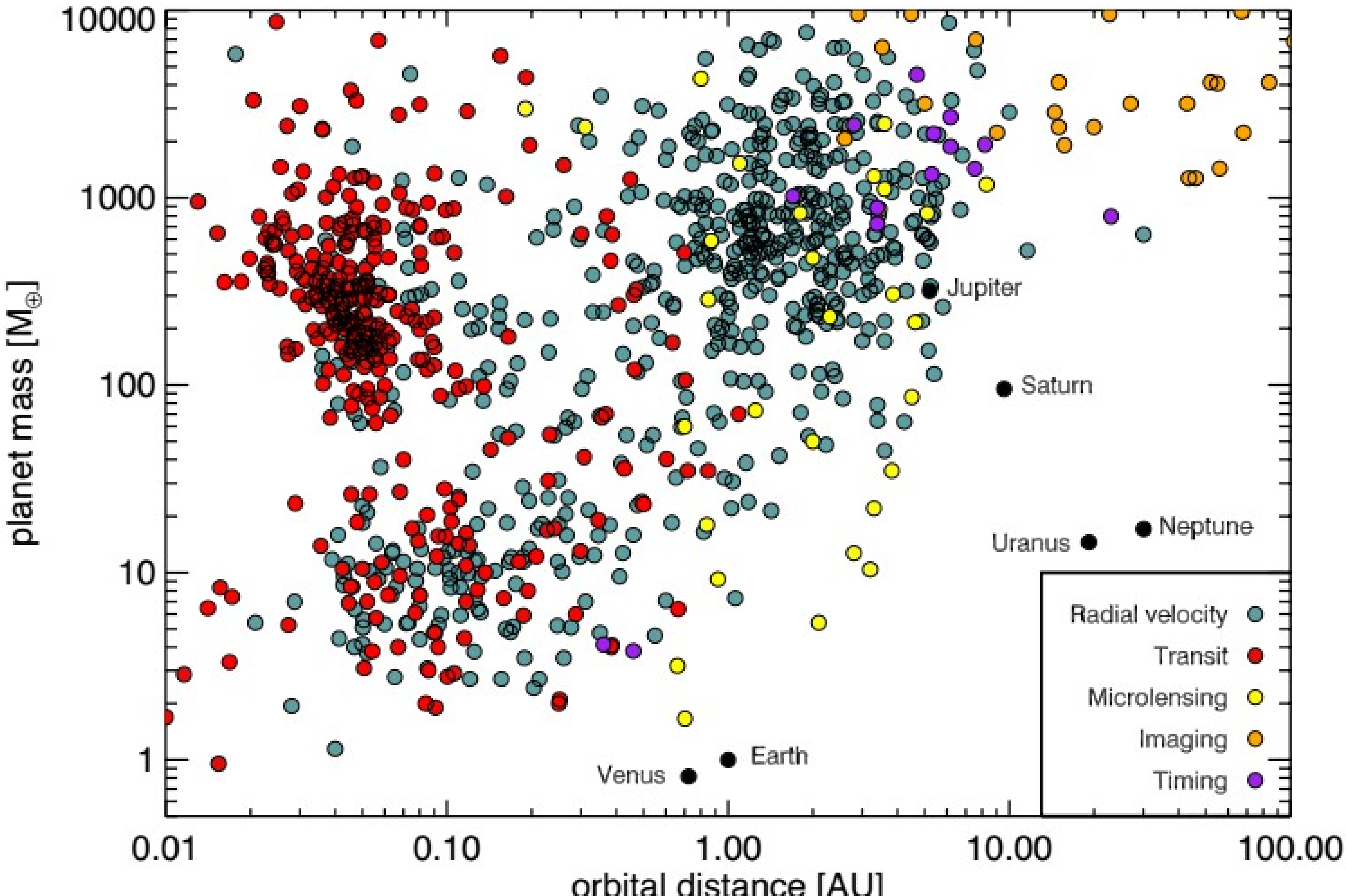


INSTITUT FÜR ASTROPHYSIK GÖTTINGEN

Lev Tal-Or
Ariel University
SAO-RAN 08.10.2019

אוניברסיטת אריאל בשומרון

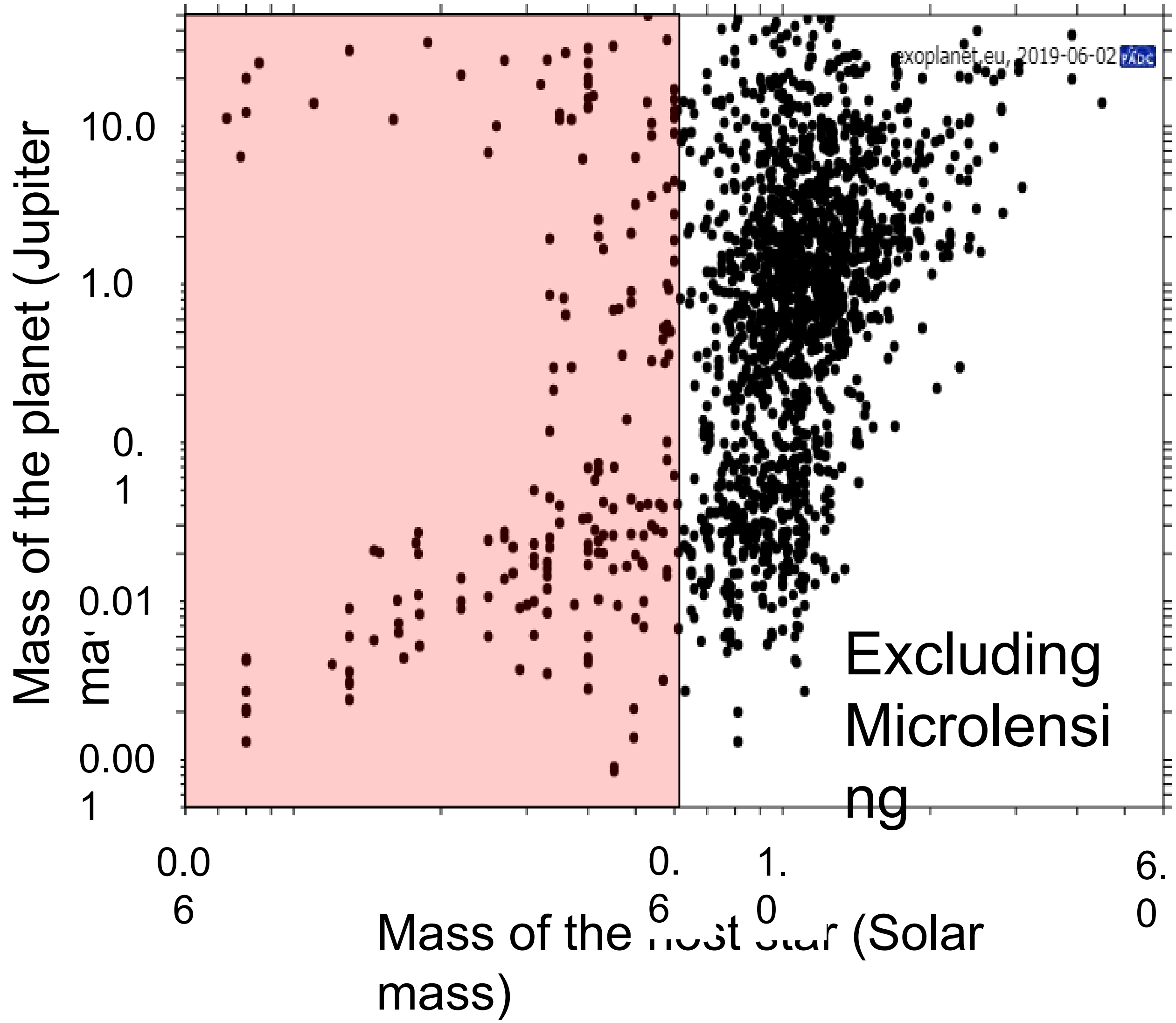
Exoplanets: current status



Winn & Fabrycky (2015)

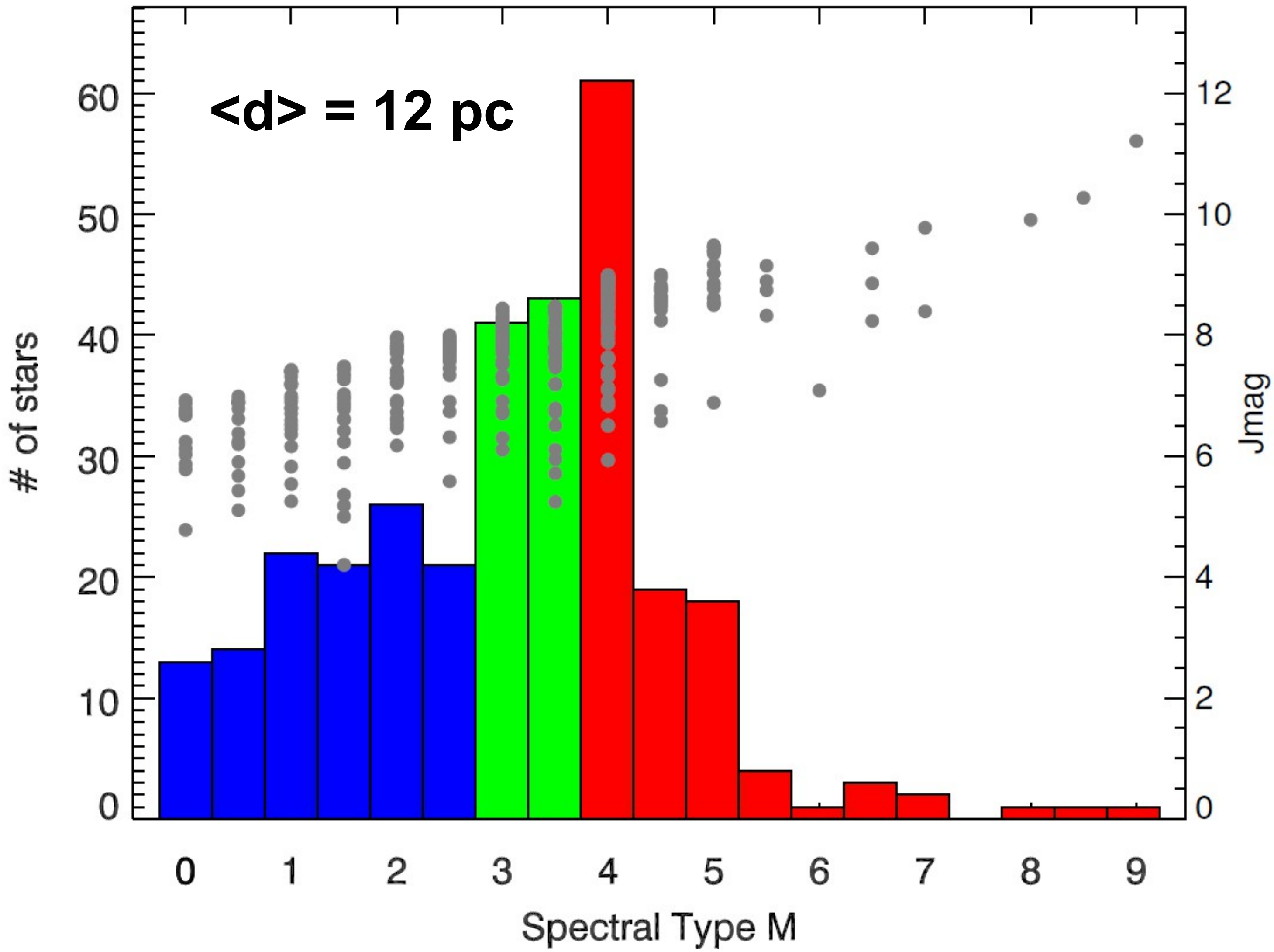
Don’t we have good-enough statistics of inner planets?

CARMENES: motivation I



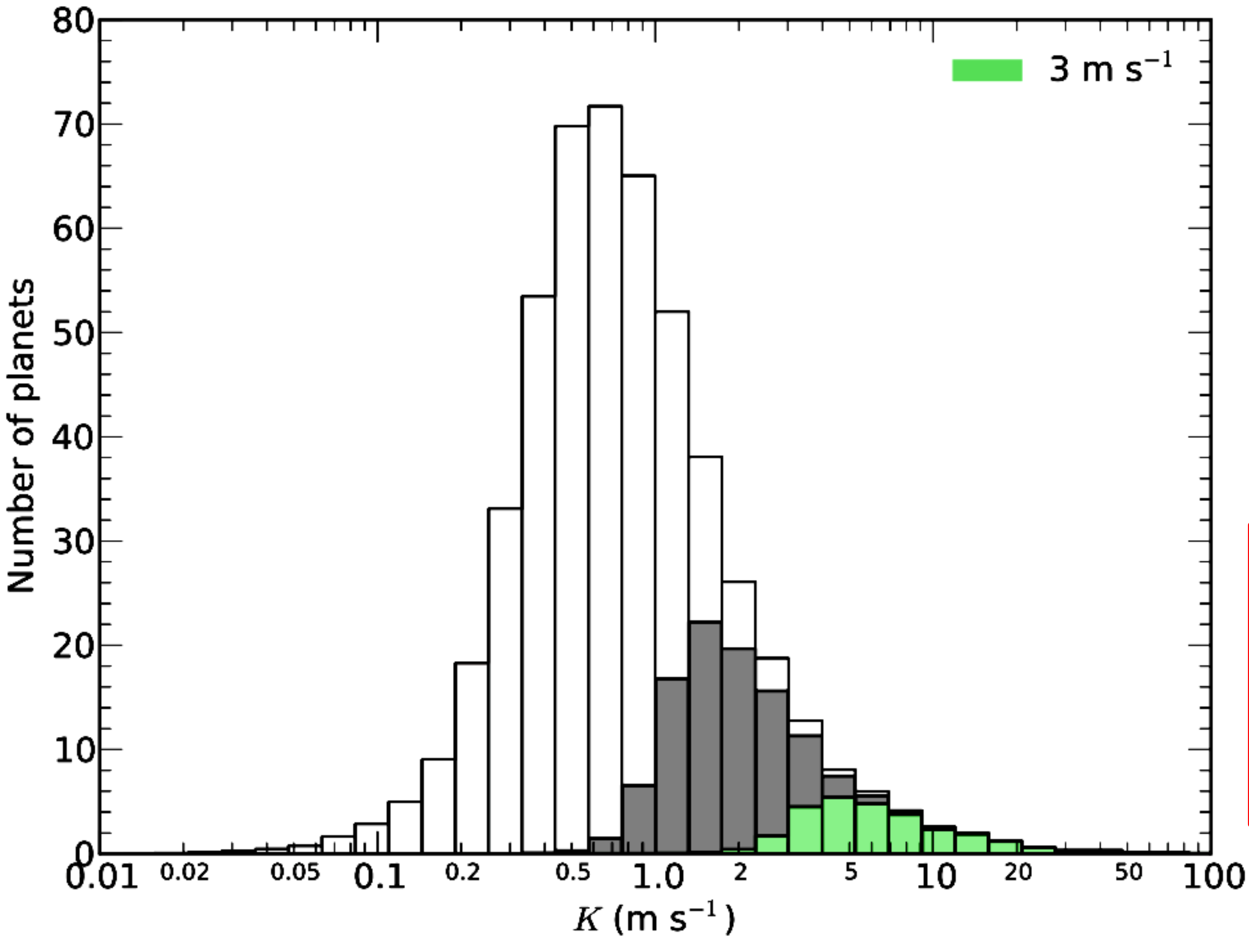
Good statistics only for FGK-star inner-planetary systems!

CARMENES: the survey sample



Since Jan 2016: observing ~325 single M0.0V – M9.0V stars

CARMENES: the expectations



Assumptions

- 750 clear nights.
- 5 years.
- ~60 obs. per star.
- ~1m/s precision.
- ~3m/s RV jitter.

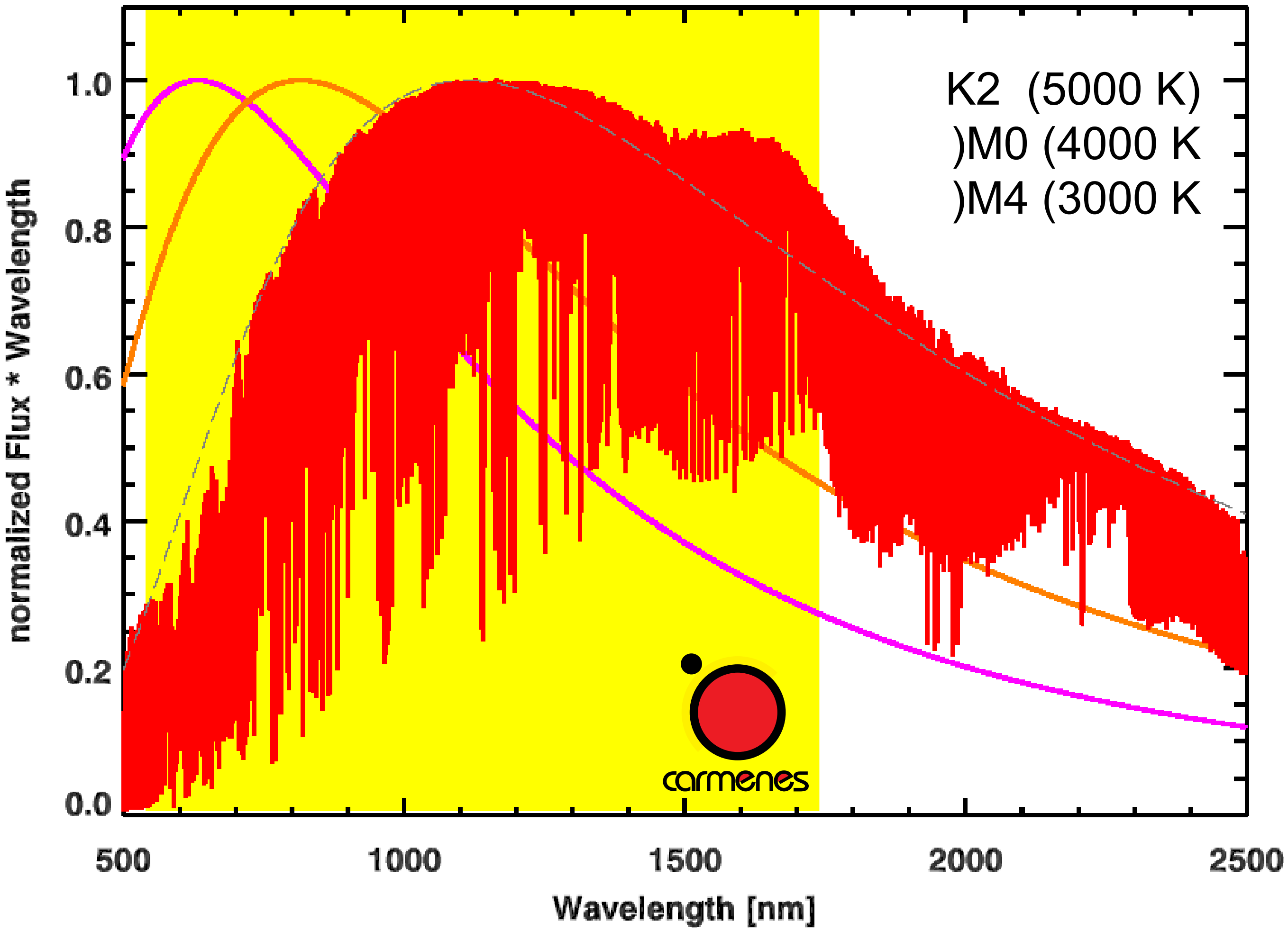
$\sigma_{\rm activity}$ [m s^{-1}]	Generated planets	Detected planets
All planets		
0	505^{+16}_{-17}	118^{+10}_{-9}
3	505^{+16}_{-17}	28^{+5}_{-5}

Garcia-Piquer (2017)

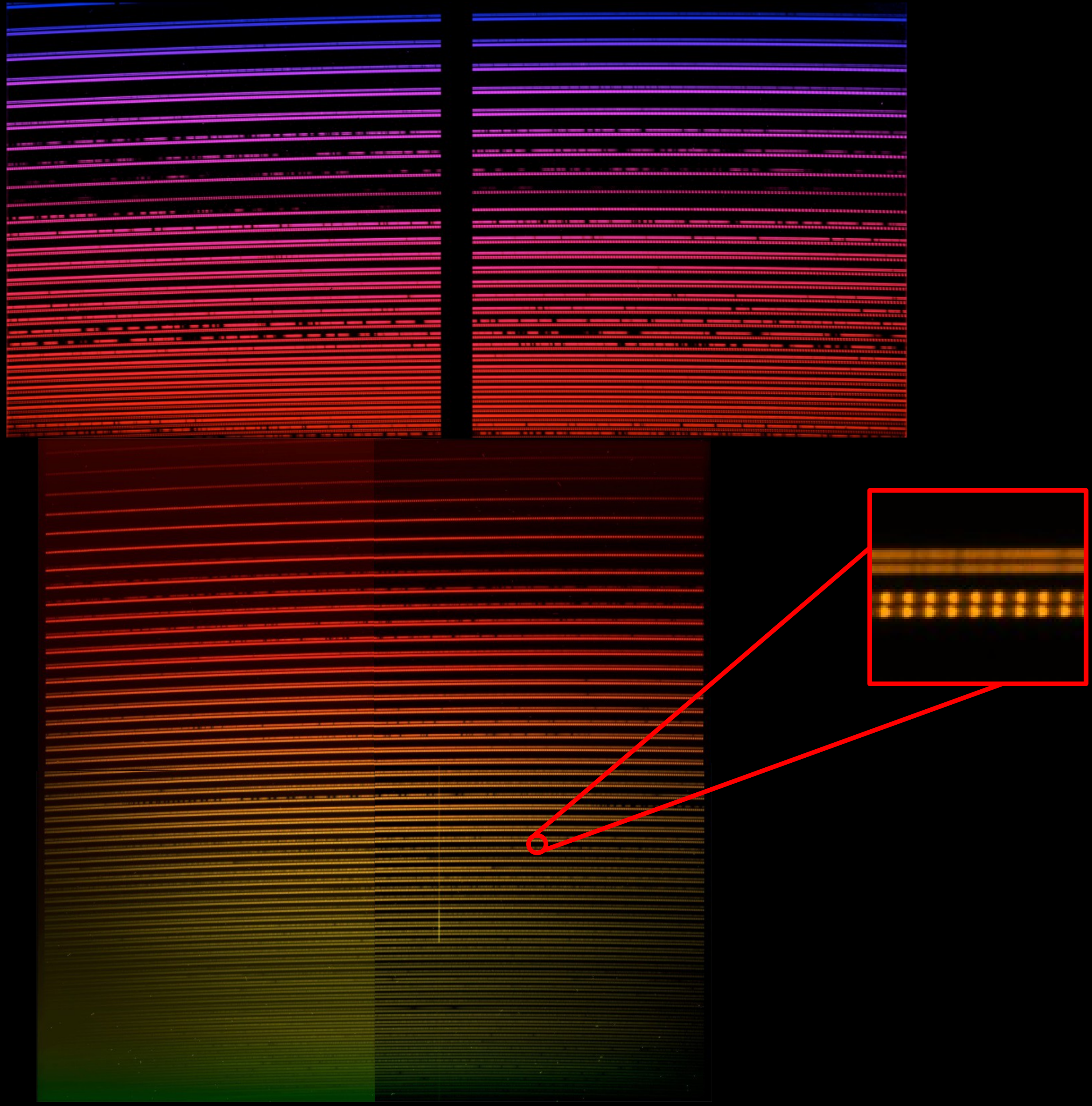
Exoplanet yield will highly depend on our ability to model simultaneously planetary- and activity-induced RV signals.

CARMENES is most sensitive to planets of >1 MEarth on orbits of <1 Year.

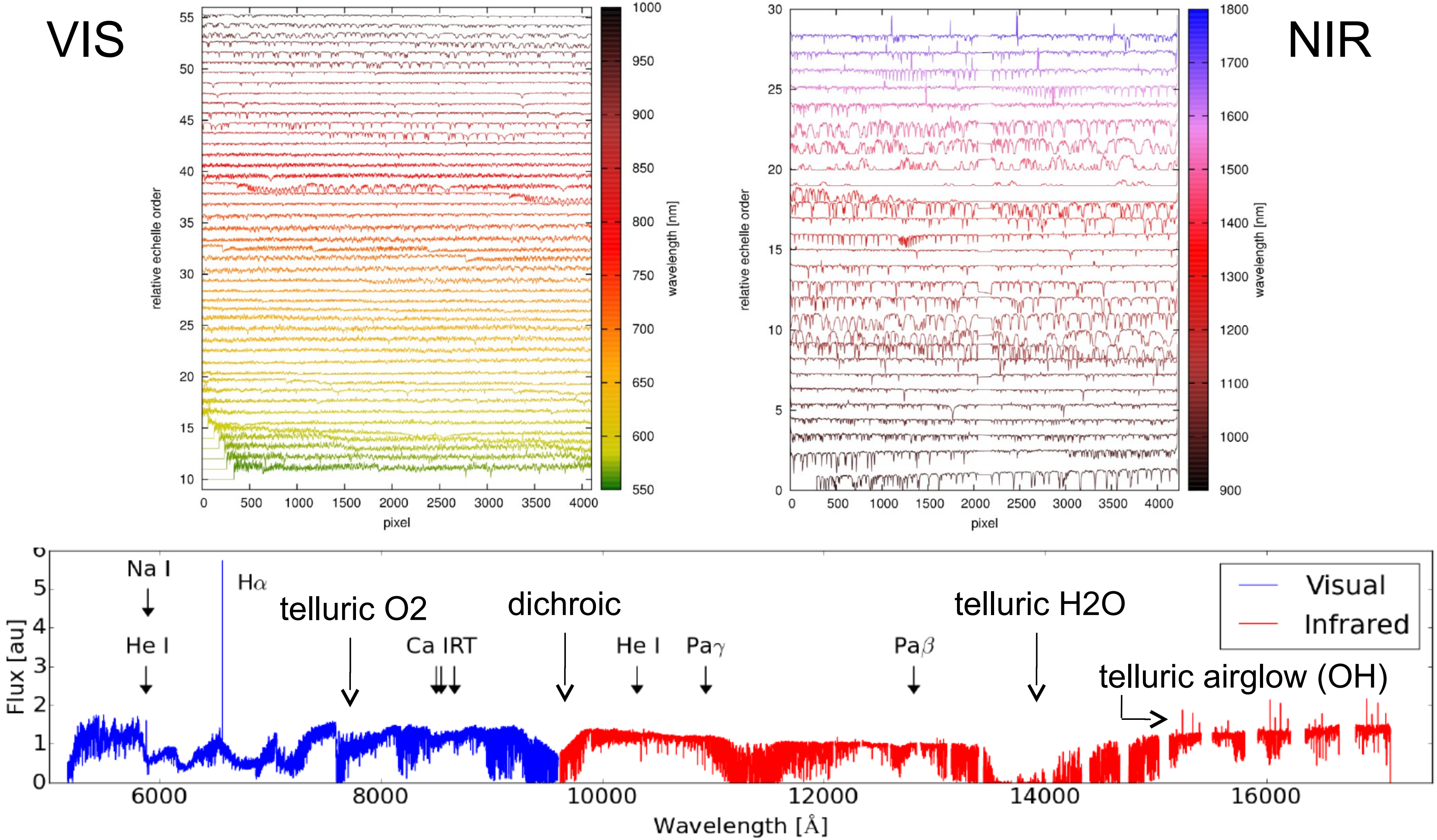
Optimal wavelength range for M dwarfs



Most of the **flux and RV information** of M stars
are in the red-visible and NIR wavelength regime.



CARMENES: the spectra



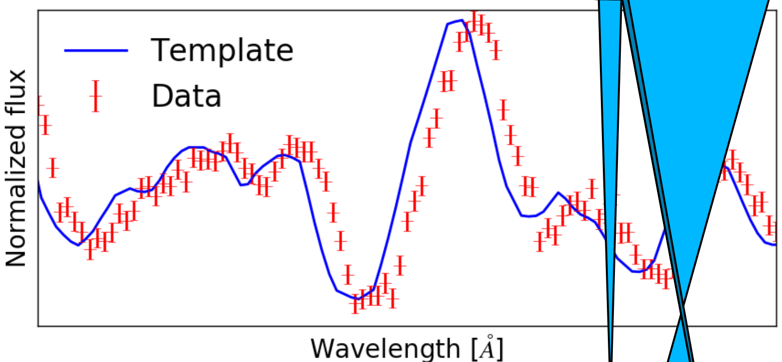
Example CARMENES spectrum of an active M dwarf:
Unpresedented spectral coverage at R~105

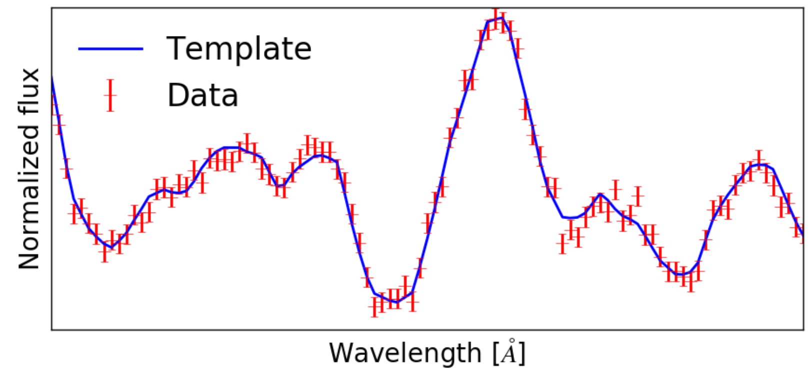
Spectrum radial velocity analyser (SERVAL)

High-precision radial velocities and two alternative spectral indicators

M. Zechmeister[1], A. Reiners[1], P. J. Amado[2], M. Azzaro[3], F. F. Bauer[1], V. J. S. Béjar[4,5], J. A. Caballero[6], E. W. Guenther[7], H.-J. Hagen[8], S. V. Jeffers[1], A. Kaminski[9], M. Kürster[10], R. Launhardt[10], D. Montes[11], J. C. Morales[12], A. Quirrenbach[9], S. Reffert[9], I. Ribas[12], W. Seifert[9], L. Tal-Or[1], and V. Wolthoff[9]

(2018A&A...609A..12Z).





Stellar templa

tart: Highest SNR sp

Shift & co-add spectra

$\chi 2$ fit

adial velocity

The CARMENES search for exoplanets around M dwarfs

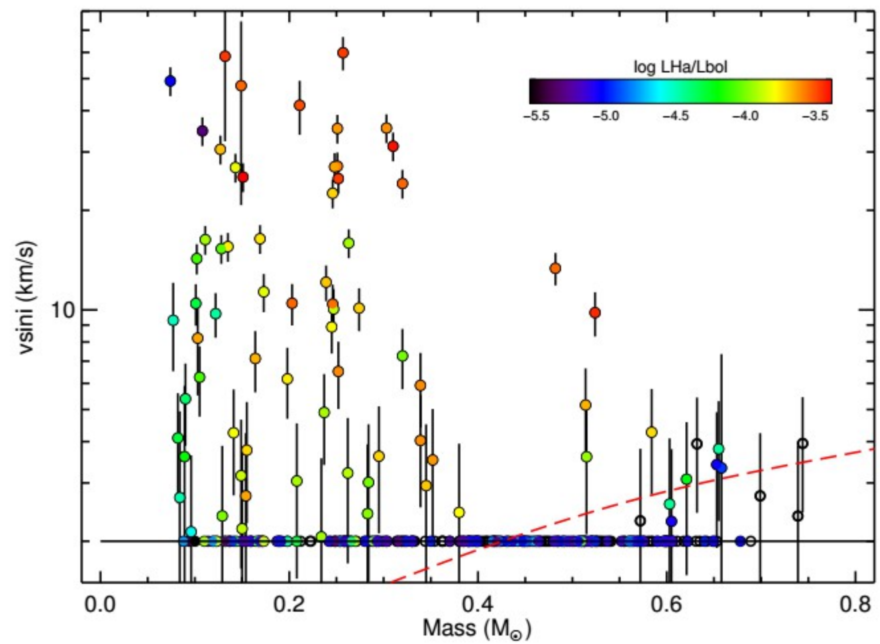
High-resolution optical and near-infrared spectroscopy of 324 survey stars

A. Reiners[1], M. Zechmeister[1], J.A. Caballero[2,3], I. Ribas[4], J.C. Morales[4], S.V. Jeffers[1], P. Schöfer[1], L. Tal-Or[1],

+ additional ~150 coauthors.(2018A&A...612A..49R).

- The CARMENES sample + average activity indicators: many fast rotating stars with Hα in emission.
- Estimates of achievable RV precision: VIS~1.2 m/s; NIR~5.0 m/s.

"We find that for all M-type dwarfs, the highest RV precision can be reached in the wavelength range 700 –900 nm."



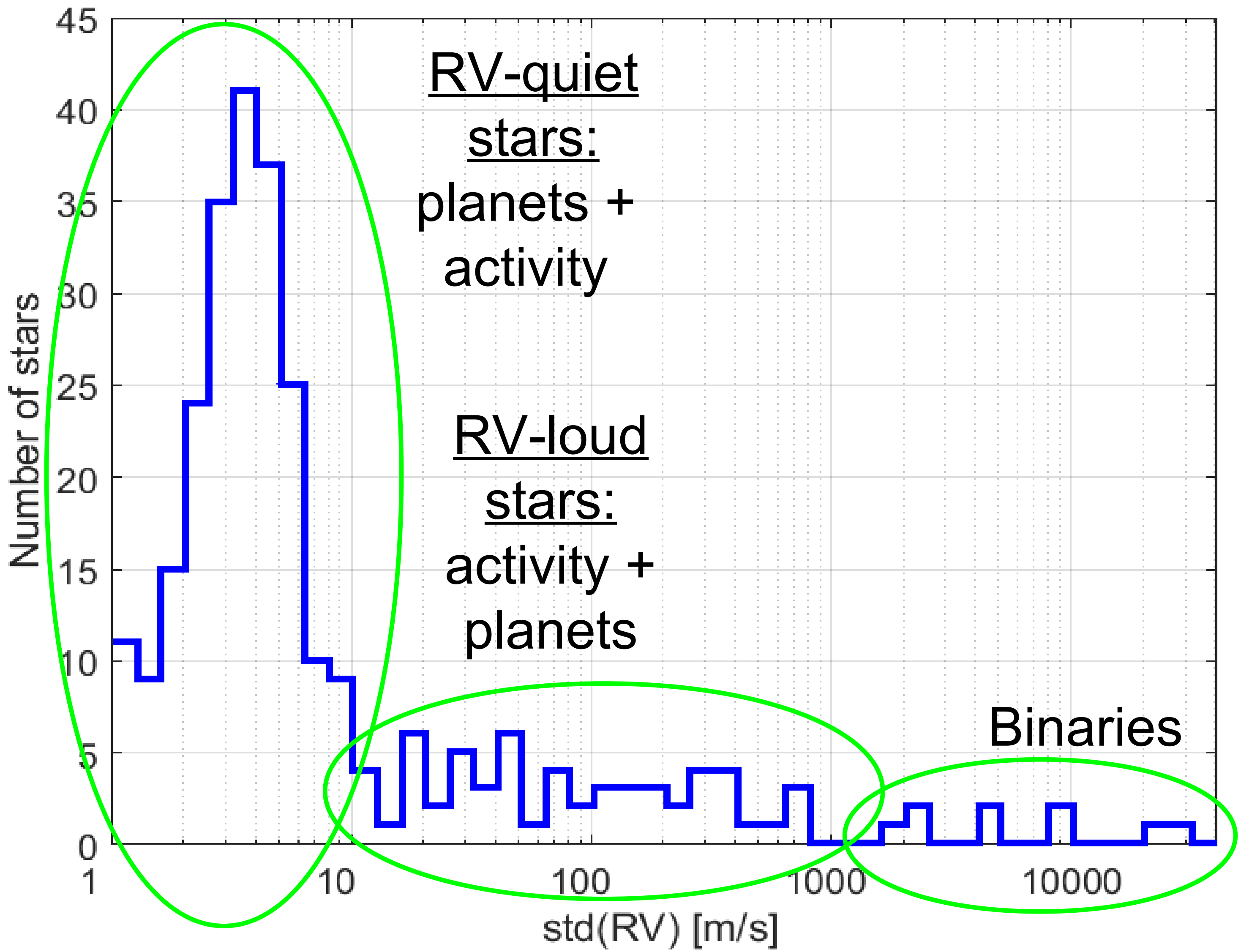
The CARMENES search for exoplanets around M dwarfs

Radial-velocity variations of active stars in visual-channel spectra★

L. Tal-Or[1], M. Zechmeister[1], A. Reiners[1], S. V. Jeffers[1], P. Schöfer[1], A. Quirrenbach[2], P. J. Amado[3], I. Ribas[4,5],

+ 17 coauthors

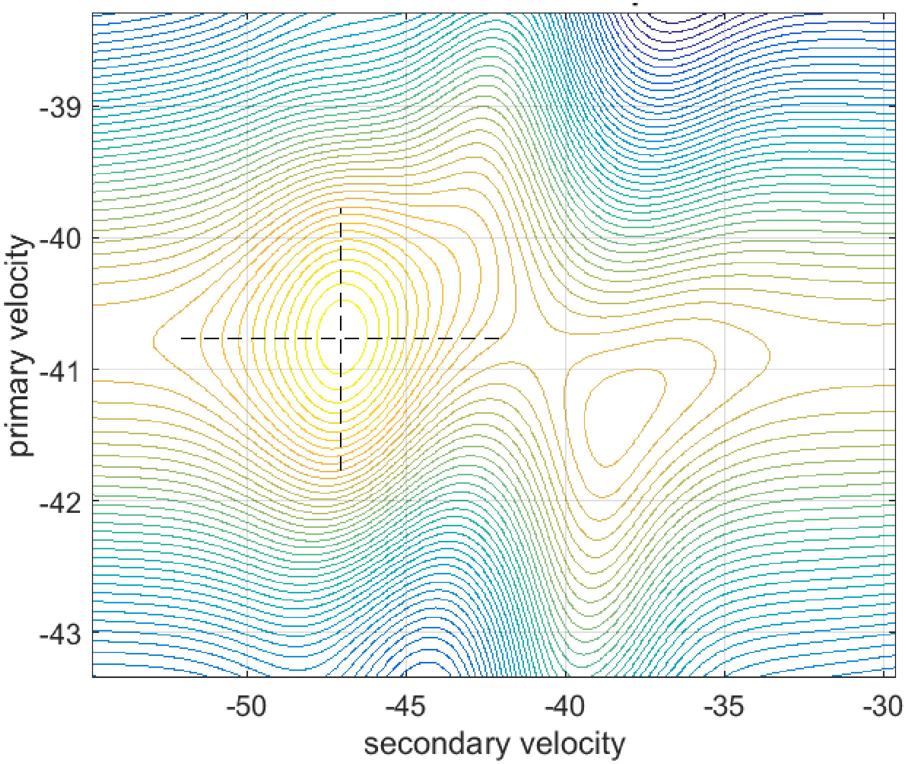
2018A&A
614A.122T

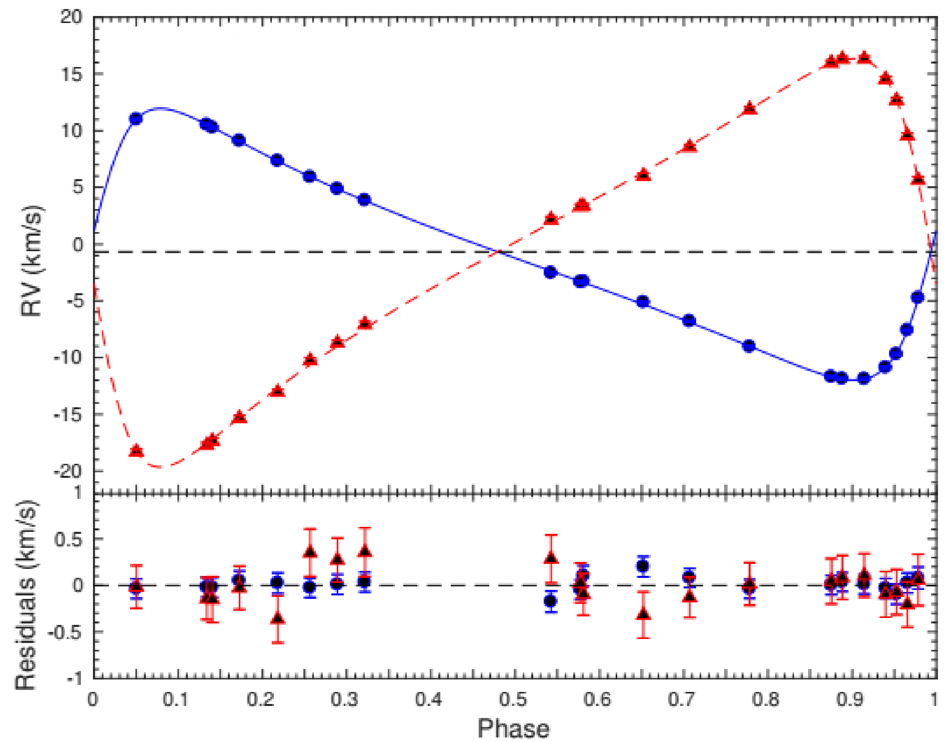


The CARMENES search for exoplanets around M dwarfs

Nine new double-line spectroscopic binary stars

D. Baroch[1,2], J. C. Morales[1,2], I. Ribas[1,2], L. Tal-Or[3,4], M. Zechmeister[3], A. Reiners[3], J. A. Caballero[5],
+ additional 23 coauthors.(2018A&A...619A..32B).



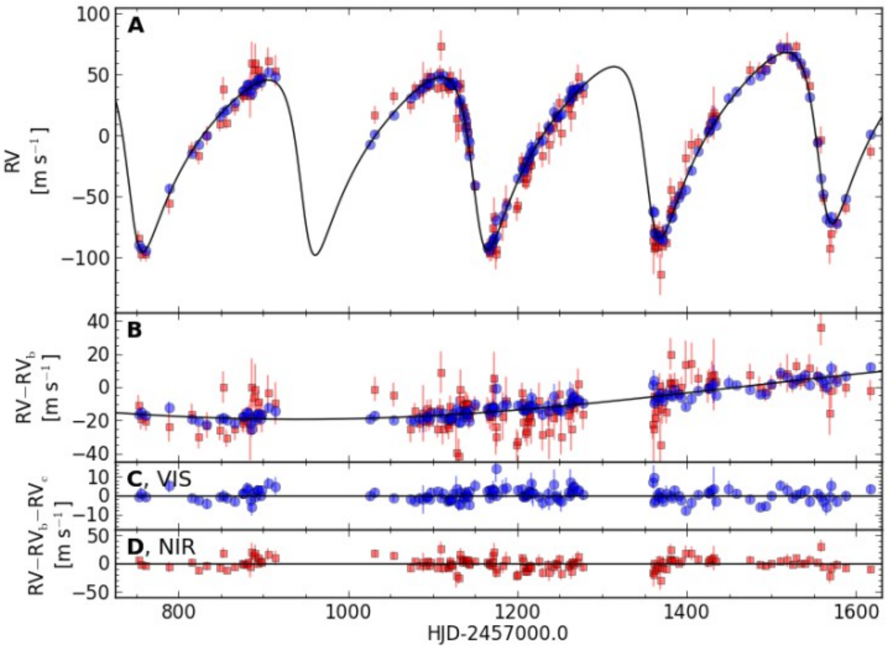


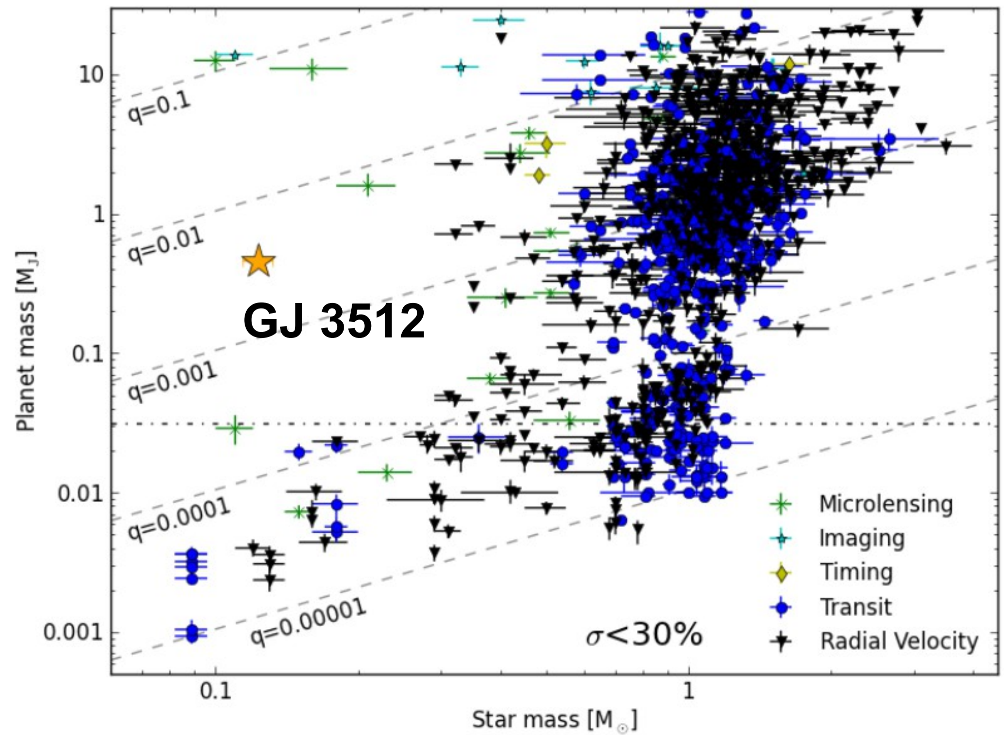
Two-dimensional correlation (todcor, Zucker & Mazeh 1994). → Orbital solution → M1,2 sin3 *i*

Will become astrometric binaries in Gaia DR4 (2022)

A giant exoplanet around a very low-mass star challenging planet formation models

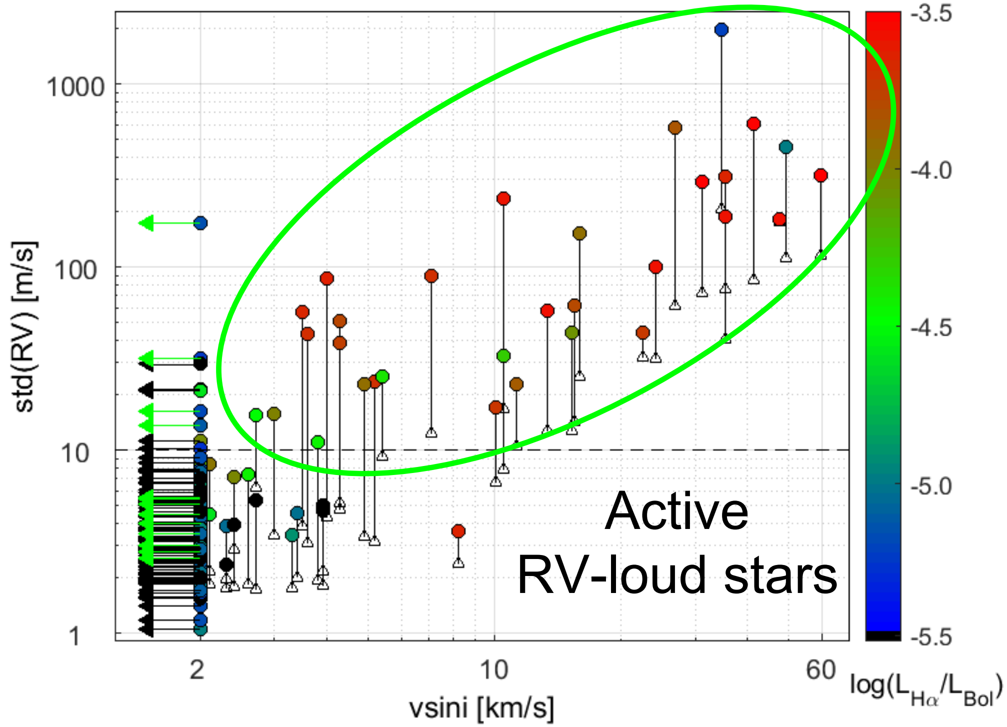
Morales+19 (Science, Sep 27, 2019)



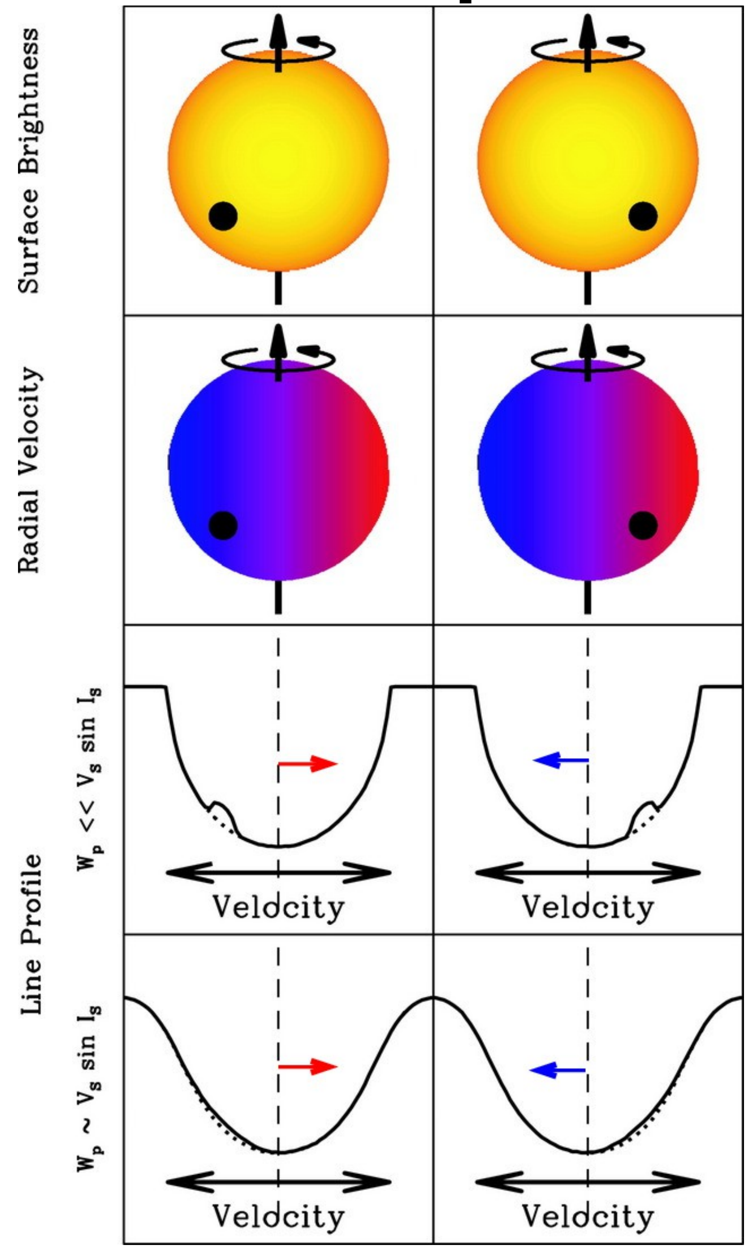


- Second planet with a longer period in the system.
- Favors formation via disk instability + planet-planet scattering over pebble accretion.

CARMENES: active RV-loud sample



- significant std(RV)-vsini, and marginal std(RV)-Hα correlations.
- Expected signature of active regions on rotating M stars.



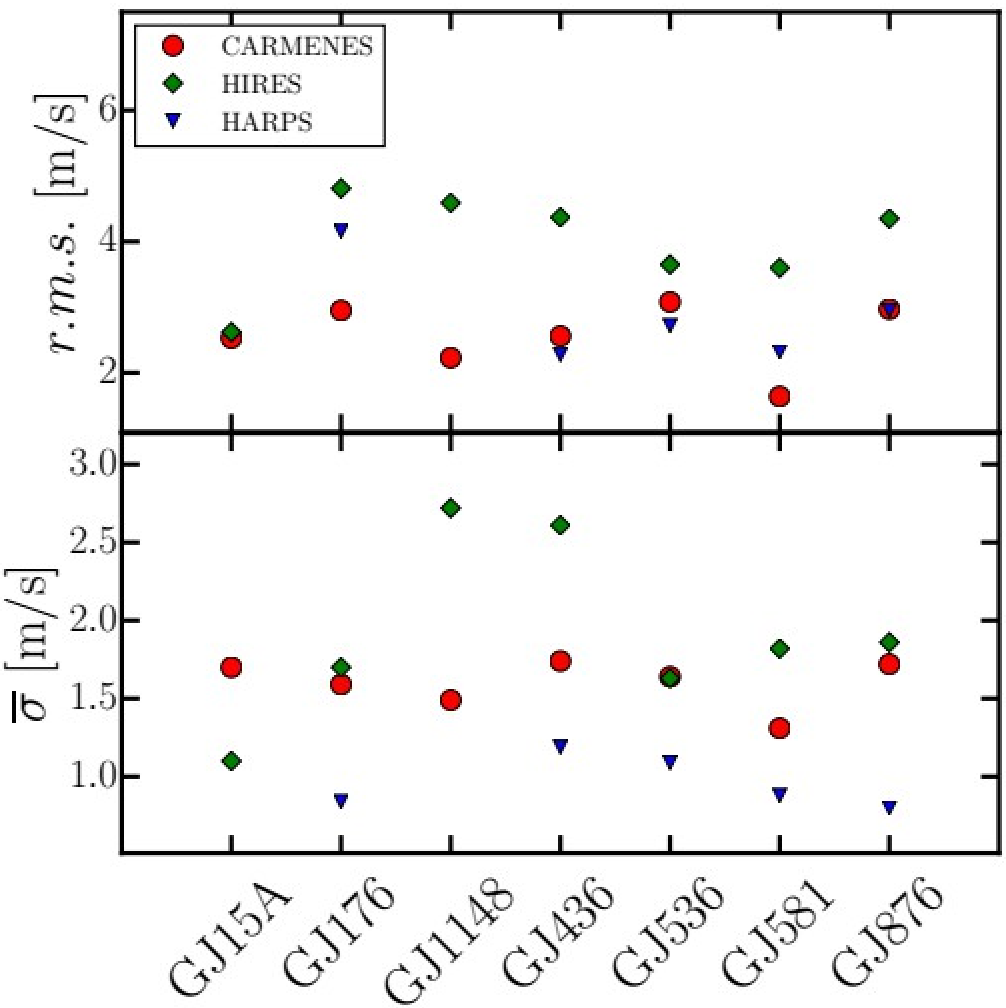
Tal-Or et al. (2018)

The CARMENES search for exoplanets around M dwarfs

First visual-channel radial-velocity measurements and orbital parameter updates of seven M-dwarf planetary systems*

T. Trifonov[1], M. Kürster[1], M. Zechmeister[2], L. Tal-Or[2], J. A. Caballero[3,5], A. Quirrenbach[5], P.J. Amado[6], I. Ribas[7],

+ additional ~150 coauthors.(2018A&A...609A.117T).

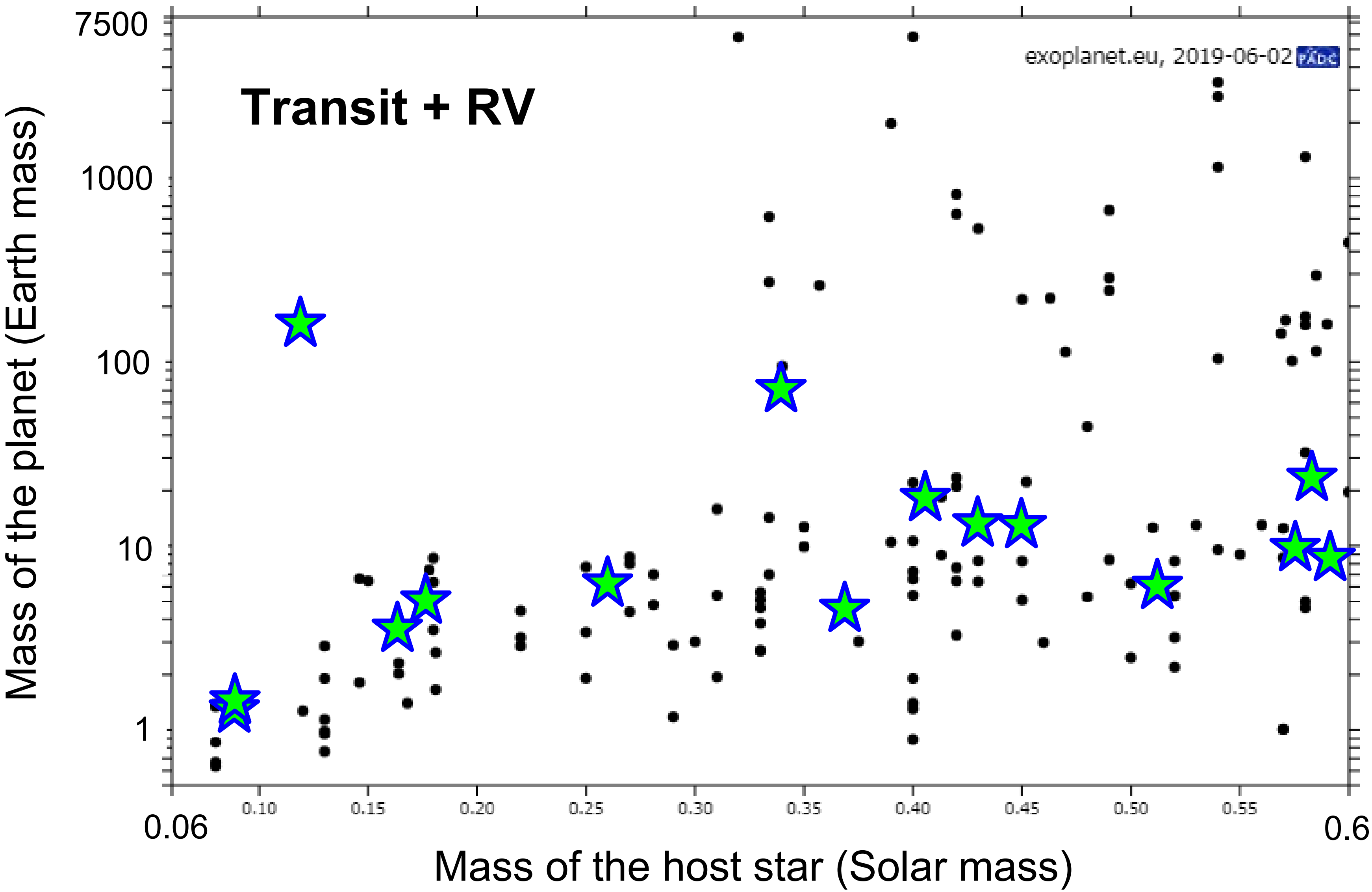


For M1.0 – M4.0 stars CARMENES VIS RV accuracy is comparable to HARPS.

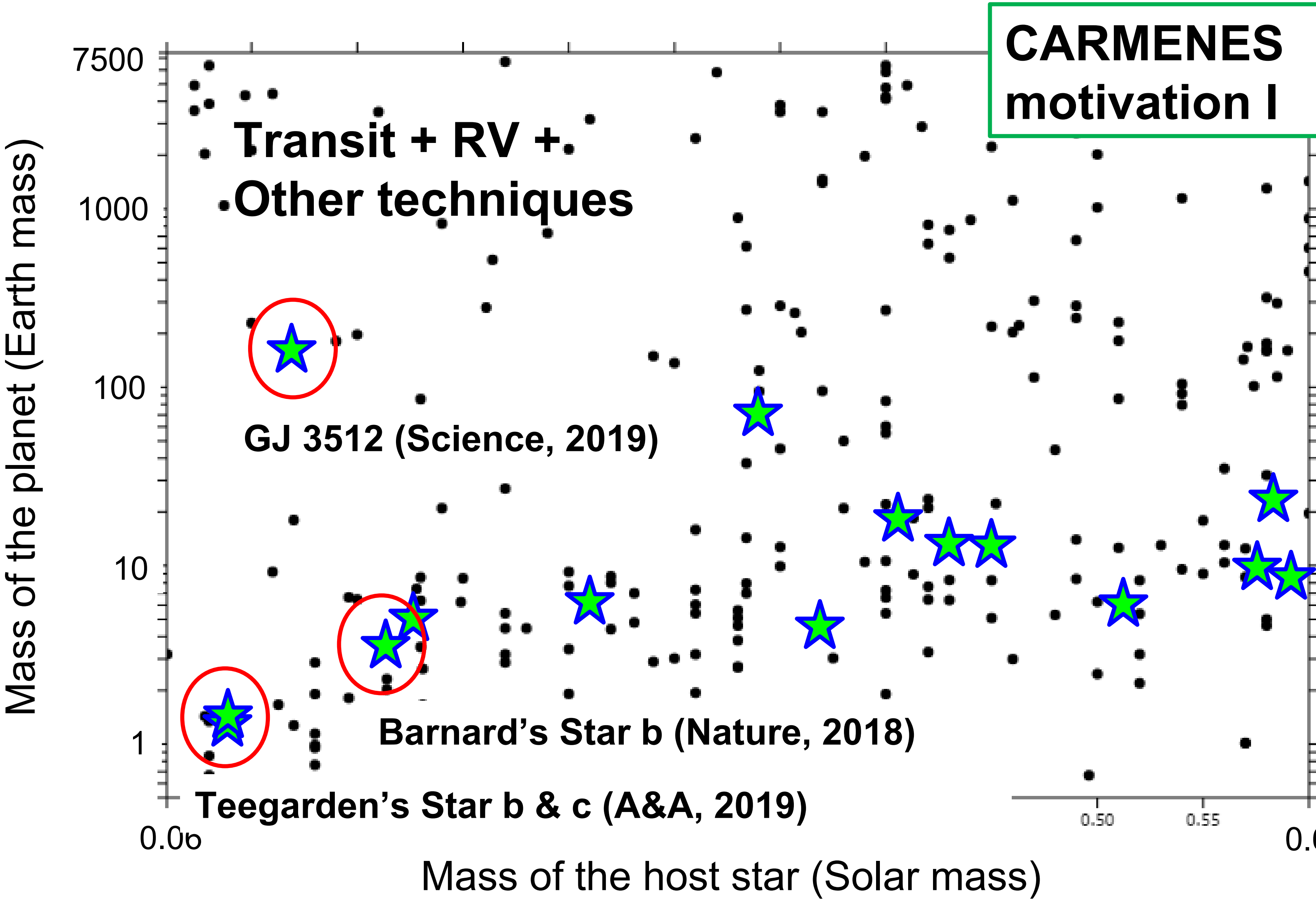
<u>Expectation:</u>
For later than M4.0 stars CARMENES should do better than any other instrument.

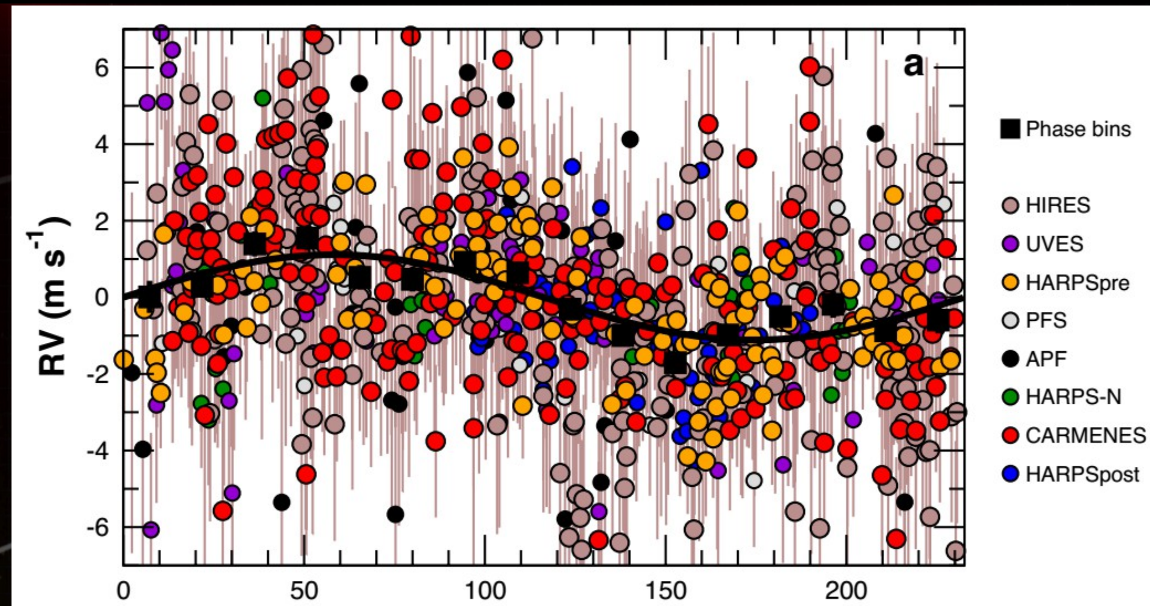
CONFIRMED

CARMENES: the first 15 planets in context

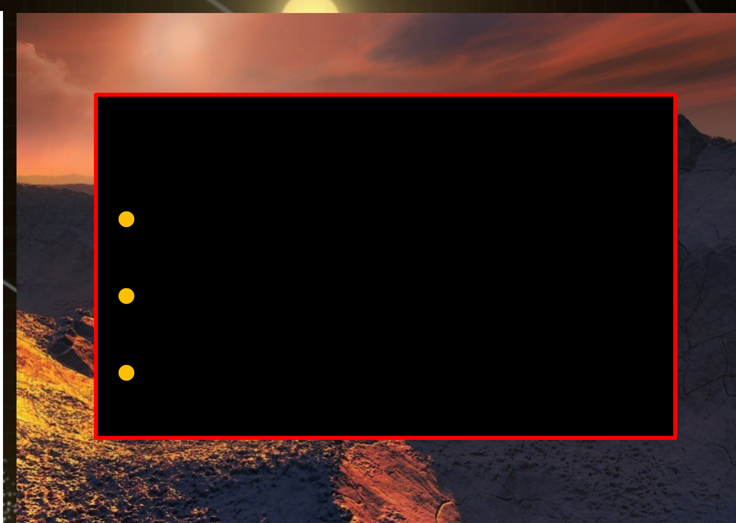


CARMENES: the first 15 planets in context

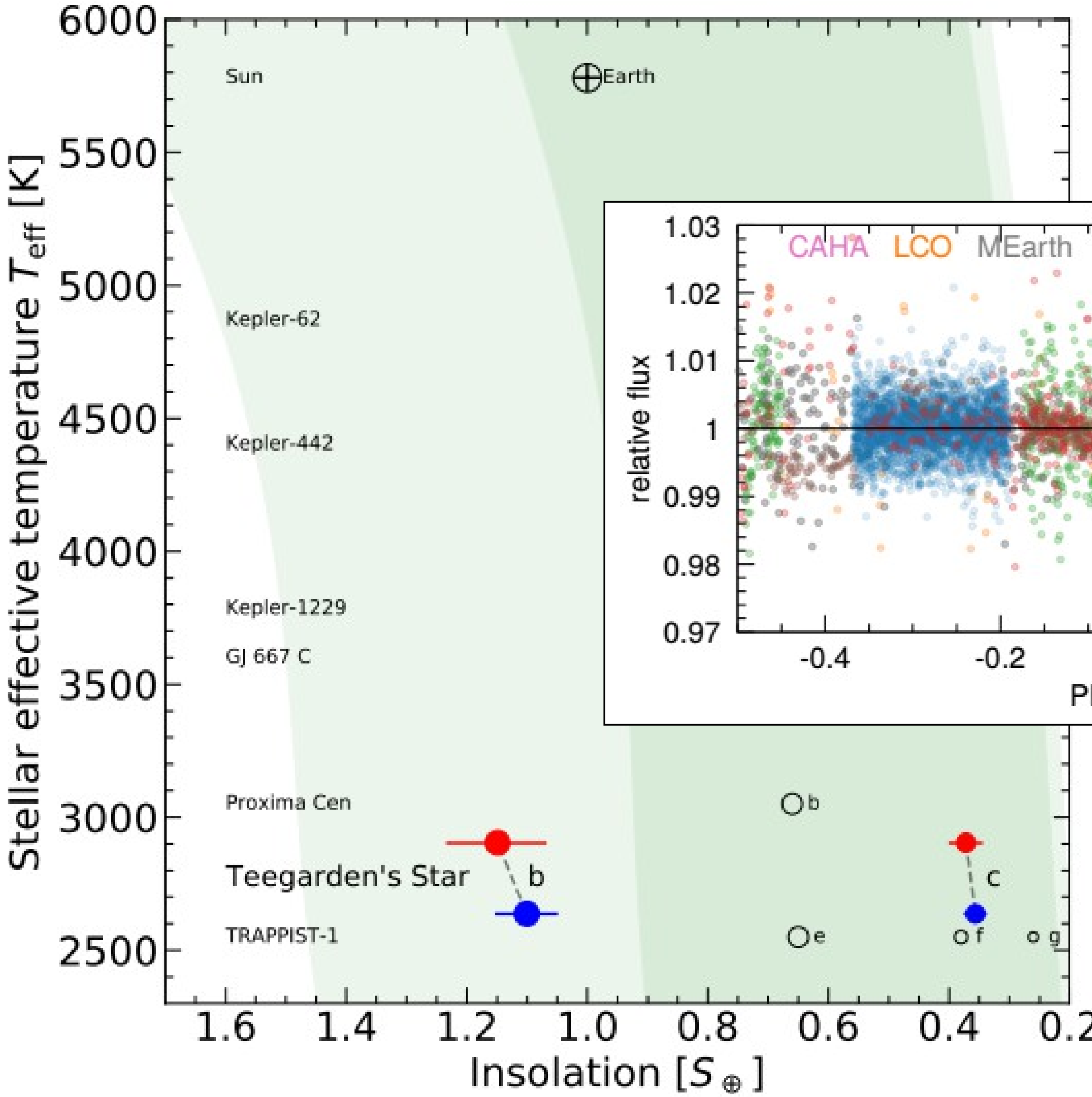




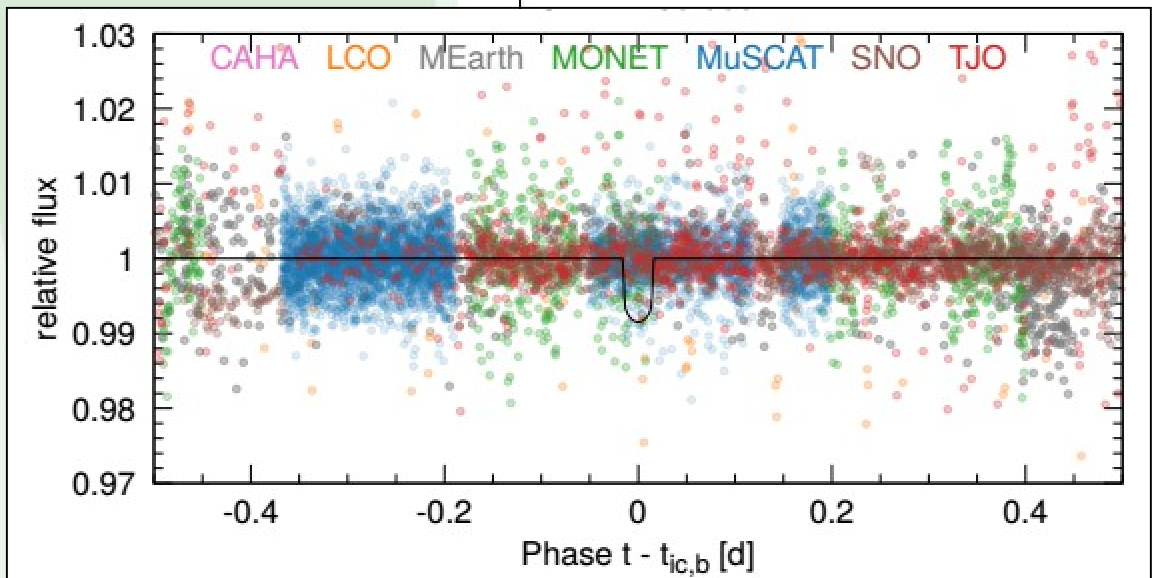
Orbital period (d)	$232.80^{+0.38}_{-0.41}$
Radial velocity semi-amplitude (m s^{-1})	1.20 ± 0.12
Eccentricity	$0.32^{+0.10}_{-0.15}$
Argument of periastron (deg)	107^{+19}_{-22}
Mean longitude at BJD2455000.0 (deg)	203 ± 7
Minimum mass ($M \sin i$; $M_\oplus$)	3.23 ± 0.44
Orbital semi-major axis (au)	0.404 ± 0.018
Irradiance (Earth units)	0.0203 ± 0.0023
Equilibrium temperature (K)	$\lesssim 105 \pm 3$
Minimum astrometric semi-amplitude ($\alpha \sin i$; mas)	0.0133 ± 0.0013
Angular separation (mas)	221 ± 10



Teegarden's Star b & c: two HZ Earths?



Unfortunately, no transit of planet b:



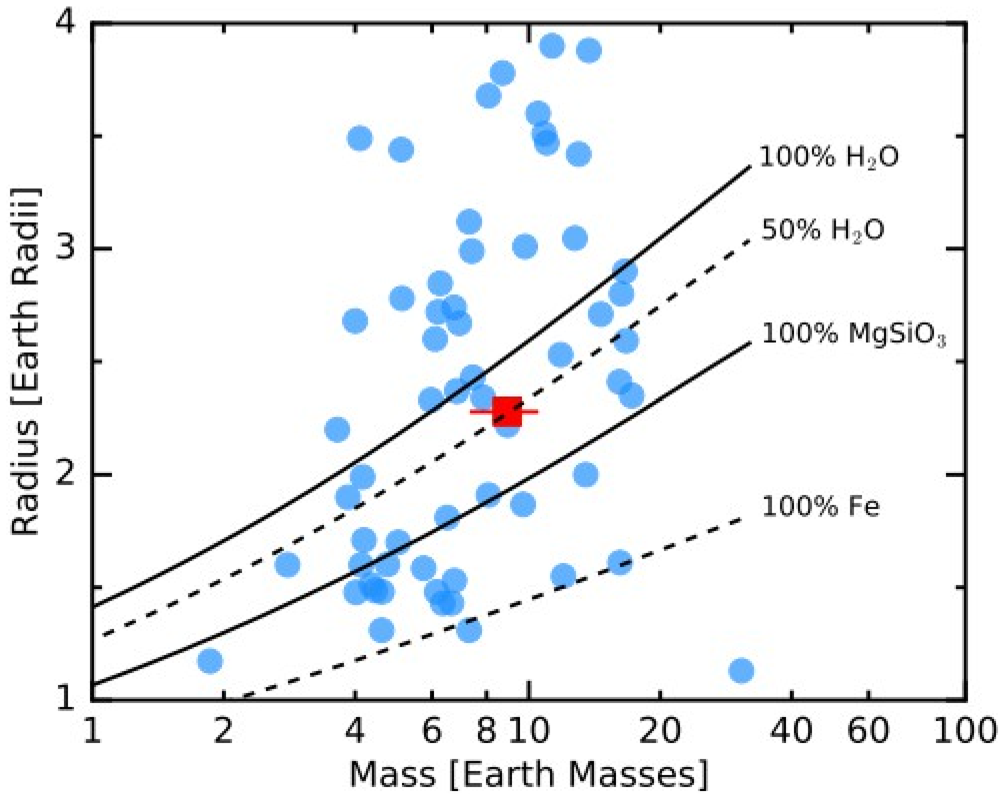
Zechmeister+19 (A&A, 2019)

CARMENES: transiting-planet confirmation

THE CARMENES SEARCH FOR EXOPLANETS AROUND M DWARFS:
A LOW-MASS PLANET IN THE TEMPERATE ZONE OF THE NEARBY K2-18

PAULA SARKIS,[1] THOMAS HENNING,[1] MARTIN KÜRSTER,[1] TRIFON TRIFONOV,[1] MATHIAS ZECHMEISTER,[2] LEV TAL-OR,[2]

+ additional ~19 coauthors.(2018AJ....155..257S).

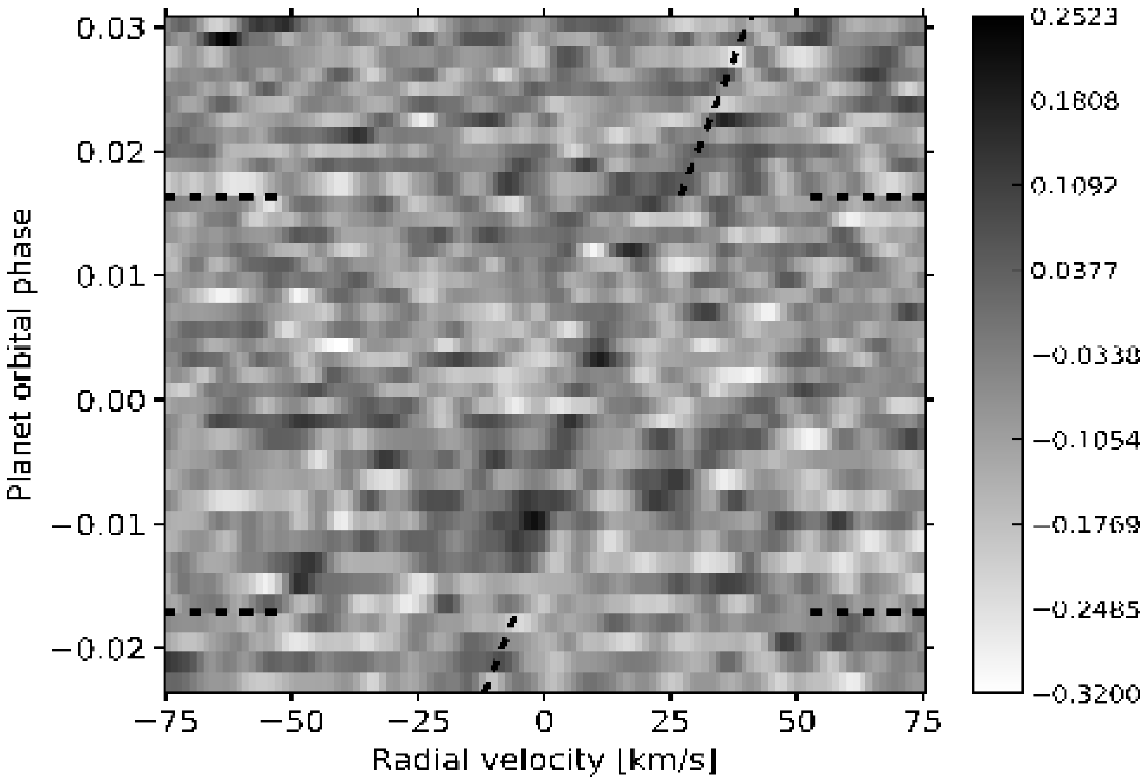


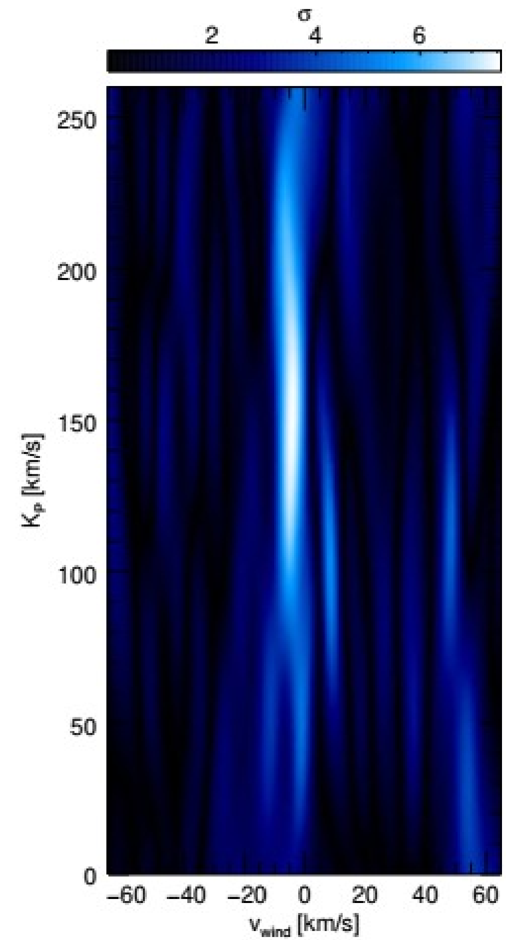
ρplanet ~ 4 g/cm3

TESS: almost full-sky survey for short-period transiting planets

CARMENES: exoplanet atmospheric study

Multiple water band detections in the CARMENES near-infrared transmission spectrum of HD 189733 b

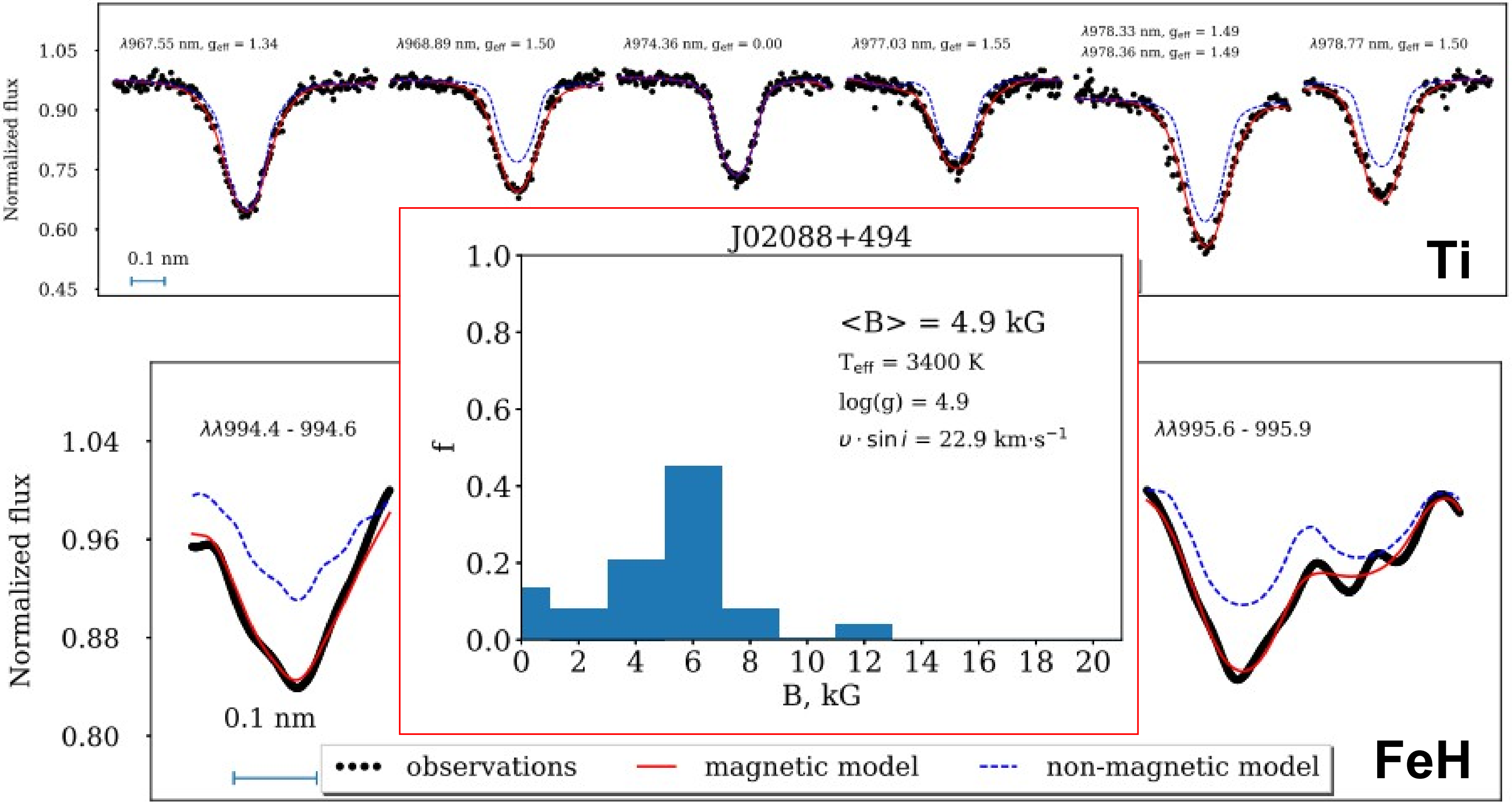




Transit spectroscopy via CCF:
cross-correlating the observed spectra, after correcting for tellurics and the star light, with a model of H2O in the planet's atmosphere

Alonso-Floriano et al. (2019A&A...621A..74A)

CARMENES: magnetic fields in M dwarfs



Modeling magnetically-sensitive lines with a radiative transfer code to measure **magnetic flux density distributions**.

Shulyak et al. (A&A, 2019)

3.5 years of CARMENES' M-dwarf RV survey

- Excellent tool for spectroscopic and RV study of M dwarfs: **confirming transiting planets and detecting new ones.**
- The first 15 planets agree with previous observations: **rocky planets are more abundant than gas/ice giants.**
- Progress in M-dwarf's activity research: **magnetic fields**.
- Excellent tool for **atmospheric characterization** of transiting planets (mainly in the NIR: **He I**, H2O, CH4, …).
- Next challenges:
  - Detecting many new planets by **simultaneous modeling of planetary orbits and activity**.
  - Better atmospheric characterization.

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