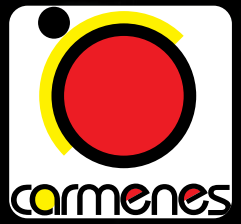
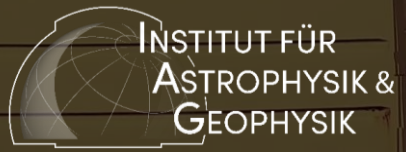
# A decade of CARMENES:
# Unveiling Planetary Systems around M Dwarfs

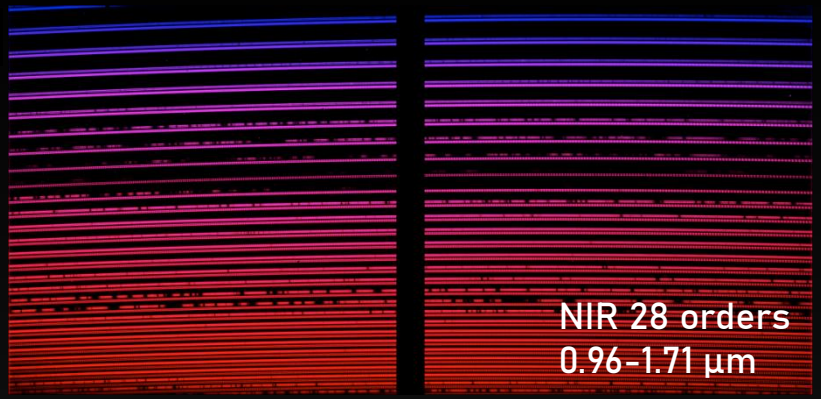


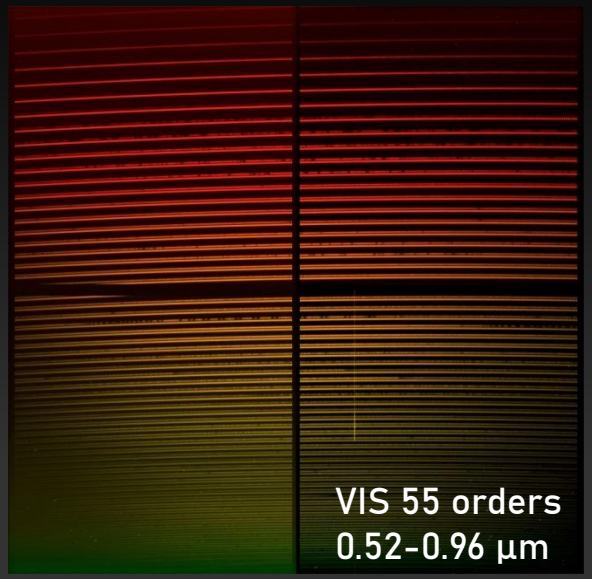

Ansgar Reiners

Georg-August Universität Göttingen

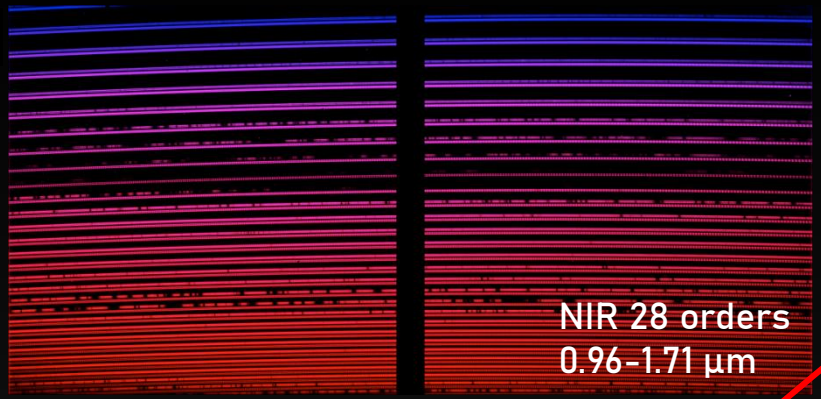


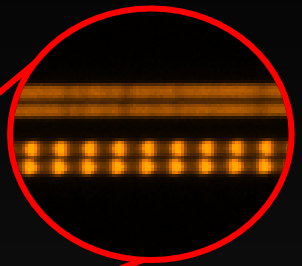
# The (two) CARMENES instruments

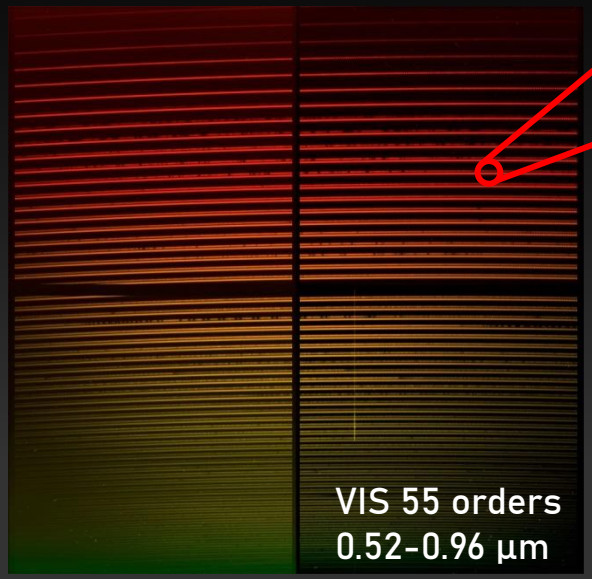


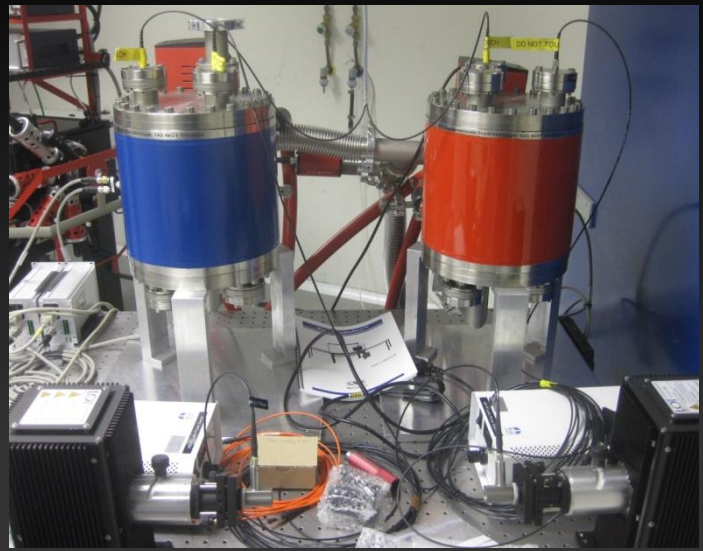

two spectrographs (VIS + NIR)




Fabry-Pérot
Interferometers



# Broad wavelength coverage, high resolution, and long time series: Science with CARMENES

Blue Planets around Red Stars

DFG

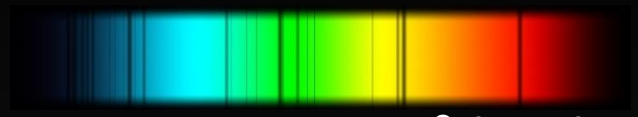
carmenes

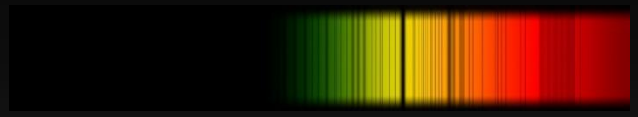
| Extrasolar Planet Discoveries |
| --- |
| >45 planet discoveries |
| >35 transiting planet mass measurements |
| including several of the most Earth-like exoplanets known |
| **Stellar Parameters** |
| Atmospheric parameters for 300 stars from VIS and NIR, radii and masses |
| **Planetary Atmospheres** |
| Ground based detections of extended helium atmospheres, water, Ca, and other |

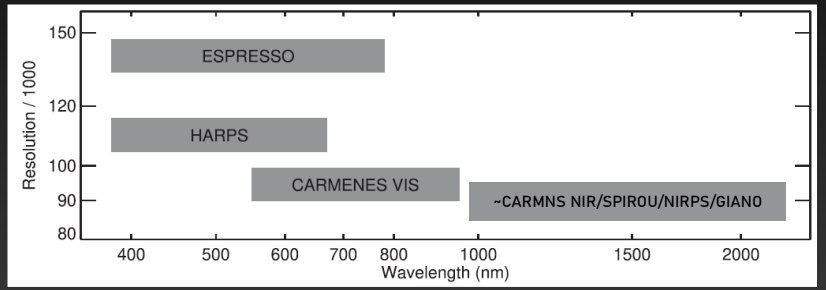
| Methdodology and known planets |
| --- |
| Data analysis, spectroscopic indicators, target characterization |
| radial velocities, photon limits, dynamical characterization |
| **Stellar Activity and Rotation** |
| activity indicators, line profiles, period search |
| magnetic fields, phometric rotation periods, HeI triplet |

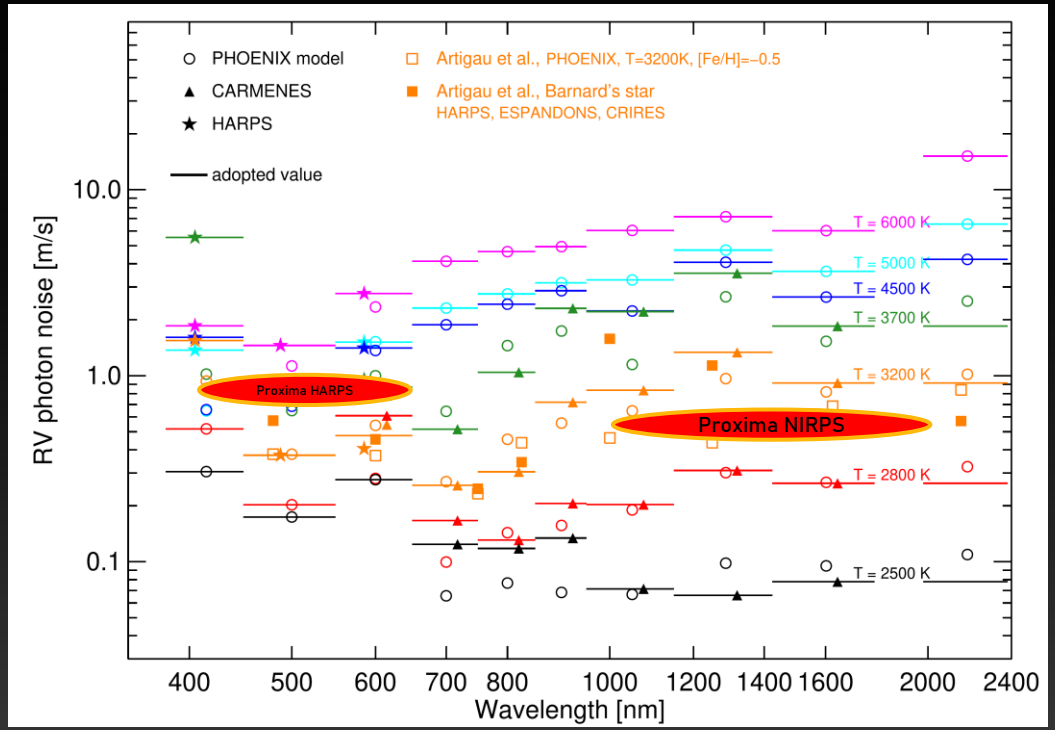
MAX-PLANCK-GESELLSCHAFT CSIC ICE Institut für Astrophysik Göttingen TLS hs Unión Europea Fondo Europeo de Desarrollo Regional "Una manera de hacer Europa" Calar Alto KTS DFG DLR

# CARMENES and HARPS reveal spectroscopic radial velocity (RV) information content



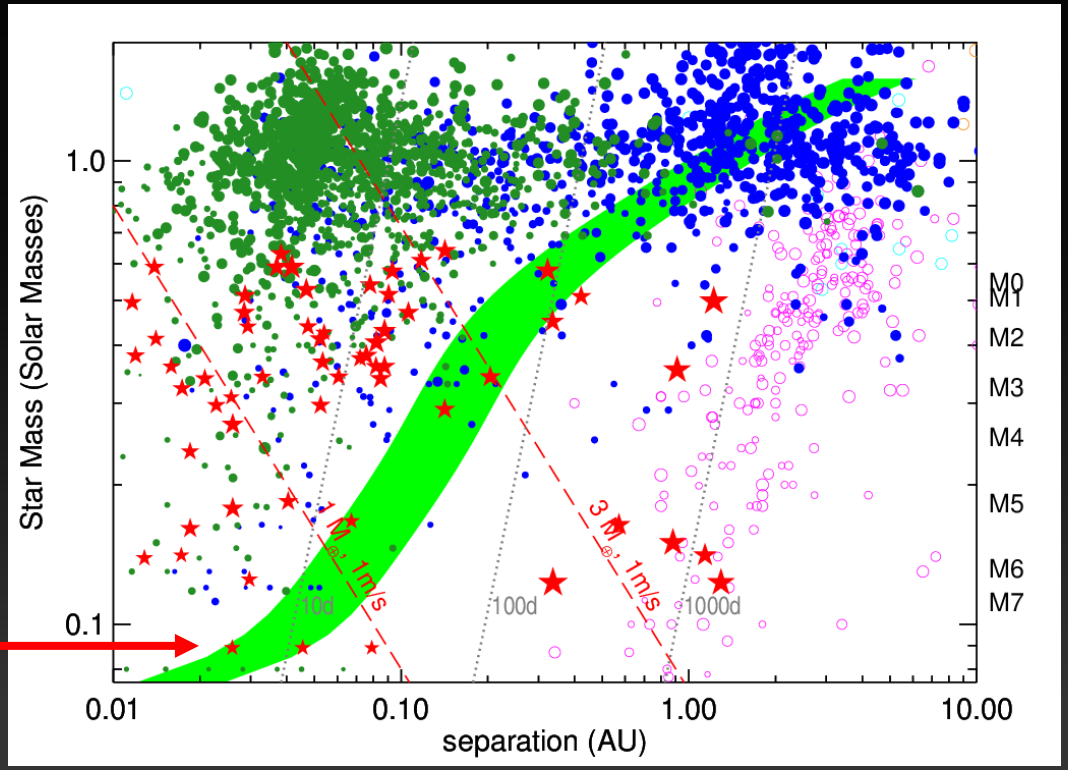




Suarez-Mascareno et al., 2025

Reiners & Zechmeister, 2020

# With CARMENES, we discovered 48 new planets and confirmed 37 transit candidates (so far…)




Imaging

Transits

Microlensing

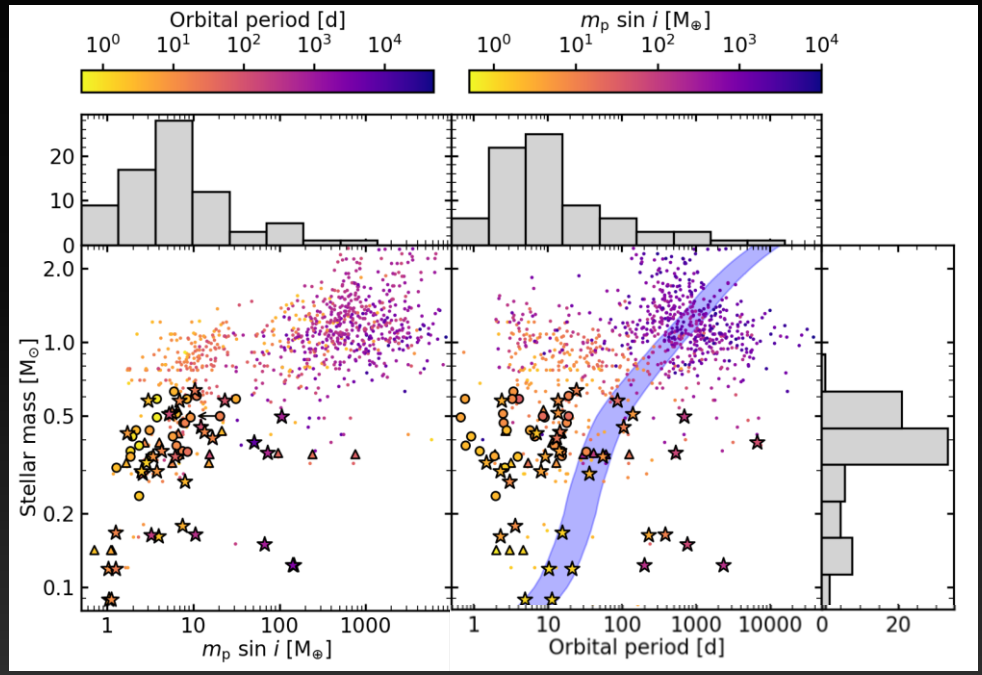
Radial Velocities

Transit Timing

CARMENES discoveries

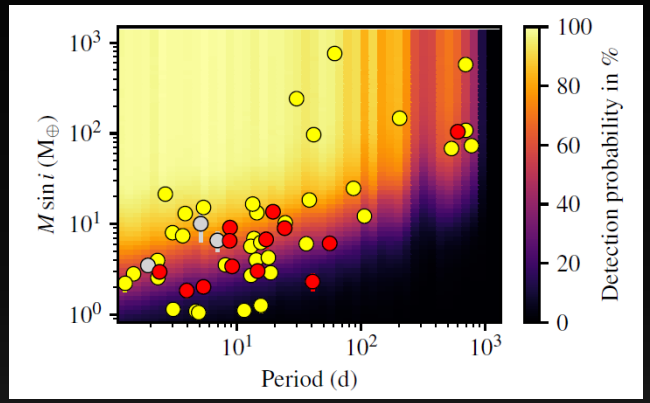
data from exoplanet.eu

# CARMENES discovered planets around very-low-mass stars including several close-in small as well as cold giant planets




Ribas, Reiners et al., 2023

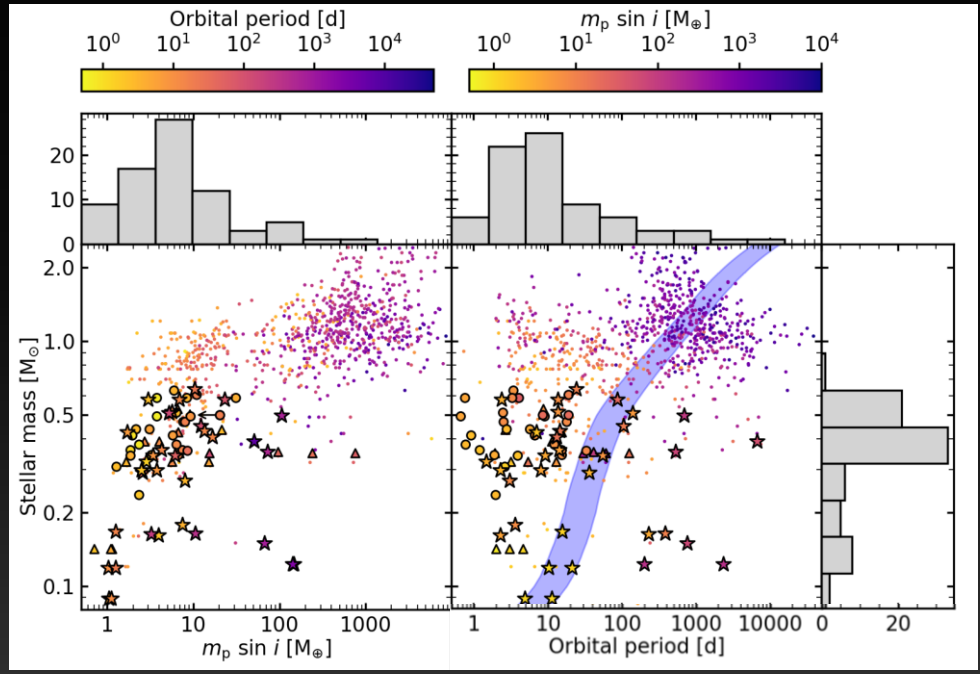
# With CARMENES, we estimated planet occurrence rates from a sample of 238 M dwarfs




$$\bar{n}_{pl} = 1.44 \pm 0.20$$

**average number of planets**

with masses 1 – 1000 $M_\oplus$,
periods 1 – 1000 days,
around stars 0.3–0.5 $M_\odot$




Ribas, Reiners et al., 2023

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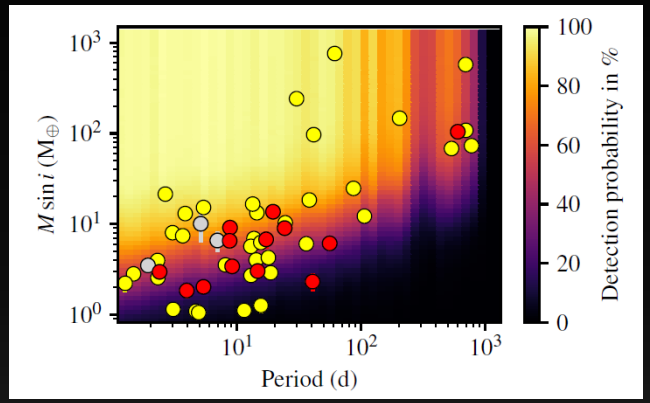


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Ribas, Reiners et al., 2023

with

$$\bar{n}_{pl} = 1.37 \pm 0.24$$

average number of planets
with masses 1 – 10 $M_\oplus$

$$\bar{n}_{pl} = 0.03^{+0.02}_{-0.01}$$

average number of planets
with masses 100 – 1000 $M_\oplus$

compare:

$$\bar{n}_{pl} = 0.23 \pm 0.02$$

planets with masses 30 – 6000 $M_\oplus$, beyond 2 AU,
around stars 0.5 – 1.5 $M_\odot$
(California Legacy Survey; Fulton et al., 2021)