Earth-like planets around M-type stars

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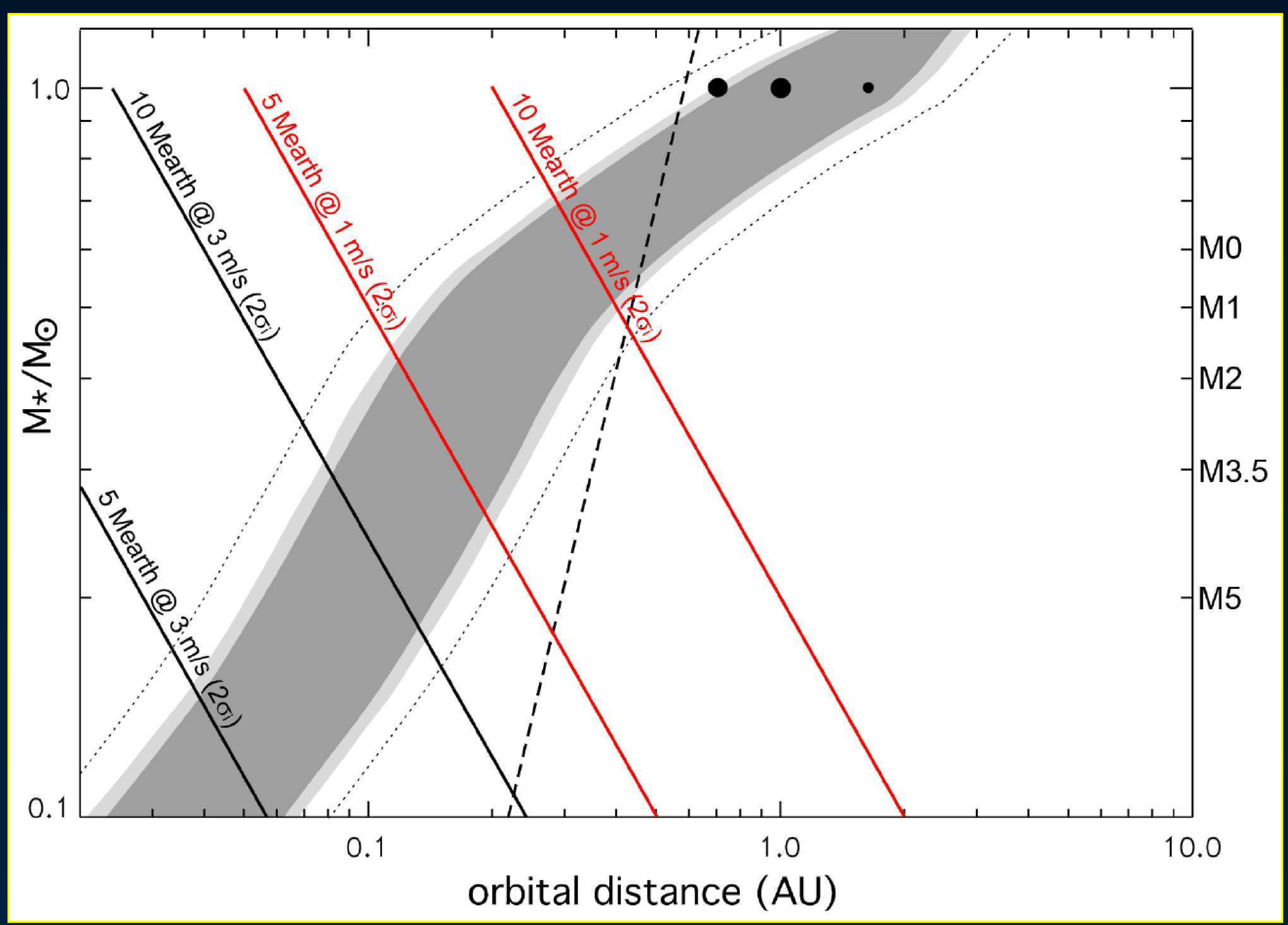
Abstract: Exoplanet research has made a great progress over the past decade. Since the first exoplanet discovered around a star in 1995 (Mayor & Queloz, 1995), more than 450 exoplanets have been identified and most of them with high-precision radial velocity measurements. The new challenge in this field is to detect Earth-like planets in the habitable zone of their host stars. Nowadays, the discovery of this kind of planets around solar type stars is out of the reach of the most precise spectrographs, but work is under progress to push the limits of optical spectroscopy towards the detection of small planets. On the other hand, late-type stars provide a good opportunity to detect small planets. A radial velocity accuracy of 3 m s^{-1} will permit the detection of super-Earths inside the habitable zone of stars later than M3 at 2σ significance. However, the spectroscopic discovery of planets around these stars is difficult due to their intrinsic faintness and the intrinsic stellar jitter. A viable alternative is to focus on the near IR spectral band, where these stars are brighter and the jitter is significantly smaller. We are developing a program to characterize the radial velocity jitter and the photometric variability of late-type stars, and this should produce a selection of the best candidates to be surveyed.

Exoplanets around late-type stars



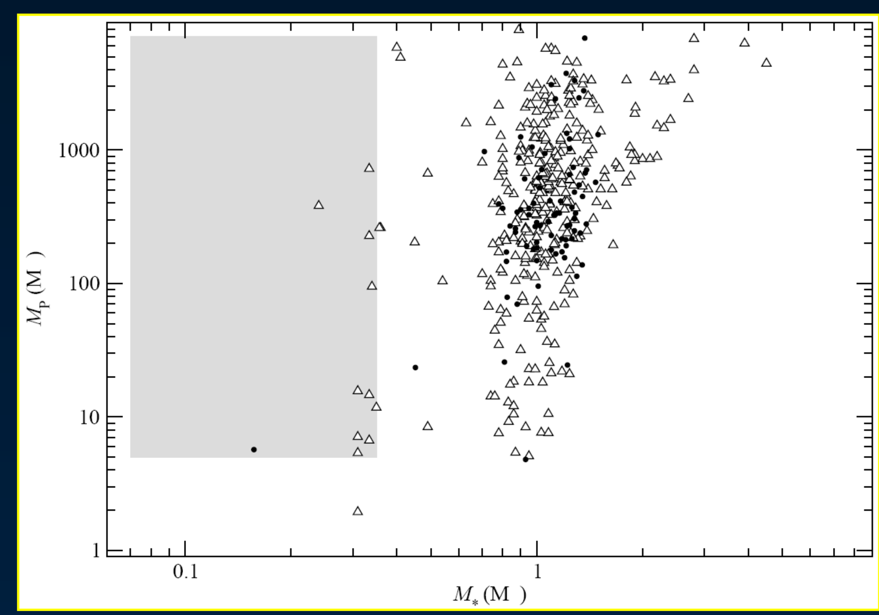
Habitable zone (shaded area) as a function of stellar mass. The dashed line indicates the tidal locking distance. Solid lines illustrate the limits for the detection of super-Earth type planets at different radial velocity accuracies.

Radial velocity semi-amplitude (in m s^{-1}) of a star of mass M_* hosting a planet with mass M_p:

$$\left[\frac{K}{\mathrm{m\ s^{-1}}}\right] = 0.0895\left[\frac{M_p}{\mathrm{M_\oplus}}\right]\left[\frac{a}{\mathrm{AU}}\right]^{-1/2}\left[\frac{M_*}{\mathrm{M}}\right]^{-1/2}\sin i$$

- 10 $\mathrm{M_\oplus}$ in the habitable zone of a 1 $\mathrm{M_\odot}$ star: $K_p \sim 1$ ms^{-1}
- 10 $\mathrm{M_\oplus}$ in the habitable zone of a 0.3 $\mathrm{M_\odot}$ star: $K_p \sim 5$ ms^{-1}

➢ Low-mass stars are potential candidates to search for super-Earths inside the habitable zone. Besides, the distribution of planets around M-type stars is yet poorly known and it would reveal the frequency of different kinds of planets around these stars and properties about its formation and evolution. But there are some difficulties that should be addressed.



Distribution of planet mass vs. host star mass of the exoplanets known till now. Transiting and spectroscopic planets ($M_p \sin i$) are plotted as dots and open triangles, respectively. The region of stars later than M3 with $M_p > 5\ \mathrm{M_\oplus}$ is marked.

Low-mass stars in the solar neighborhood

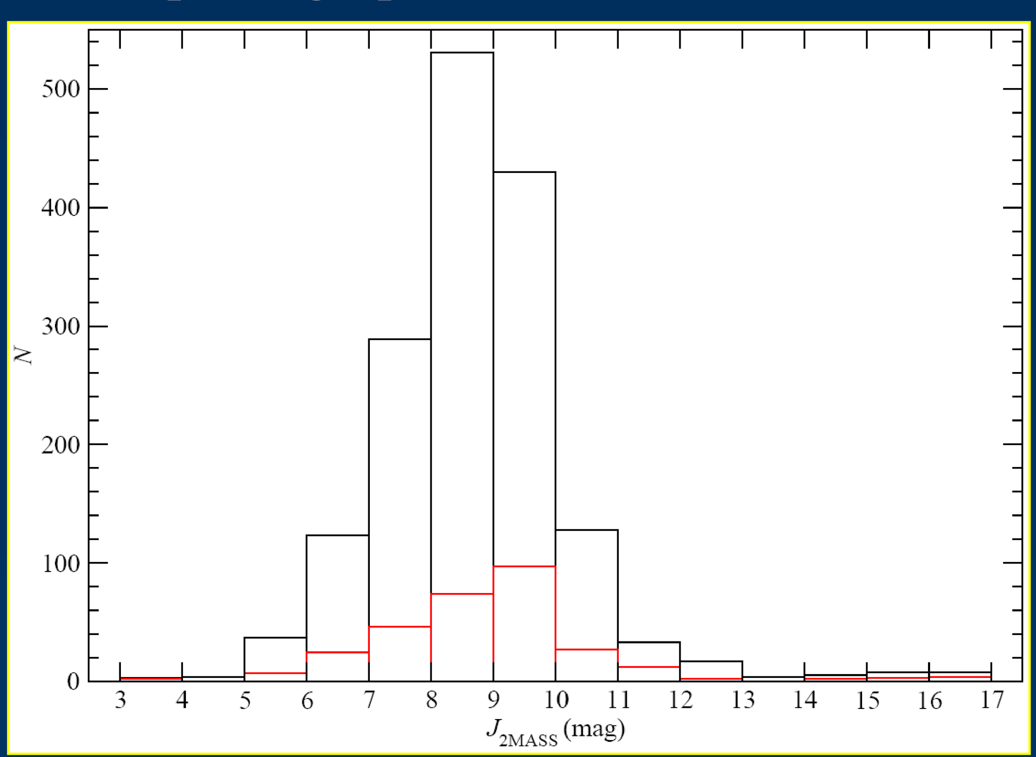
Spectroscopy of late-type stars is not an easy task:

- They are faint stars
- They are typically fast rotators ⟶ rotational broadening
- Stellar jitter: due to the magnetic activity of these stars. It can mimic the radial velocity signal of an exoplanet

Going to the IR region of the spectra could be a solution:

- Late-type stars are brighter in these bands
- Stellar jitter decreases towards IR wavelengths (Reiners et al. 2010)

The Palomar/Michigan State University Survey (PMSU) shows that only ~20% (~30% for $J < 9$) of the stars later than M3 are active stars (according to their Hα emission). A sample of these stars has been already selected to be surveyed with the CARMENES spectrograph (Quirrenbach et al. 2010).



Number of stars in the Palomar/Michigan State University Survey with spectral types later than M3 for different J-magnitude bins. The black histogram shows all the stars while the red includes only the active stars.

Characterizing the sample of low-mass stars

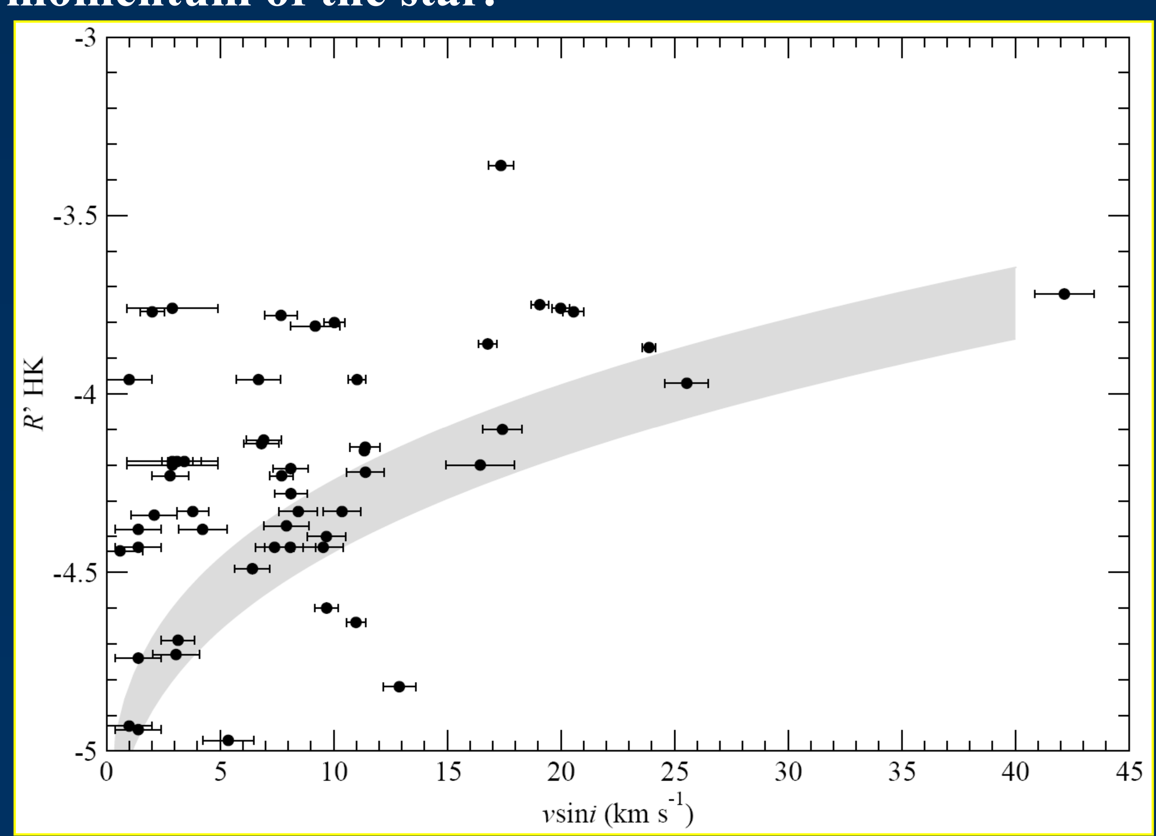
Goal: determine sin*i* to increase the probability of transit detection

1- *P* from photometry + *v*sin*i* from spectroscopy (*R* from models) ⟶ sin*i*

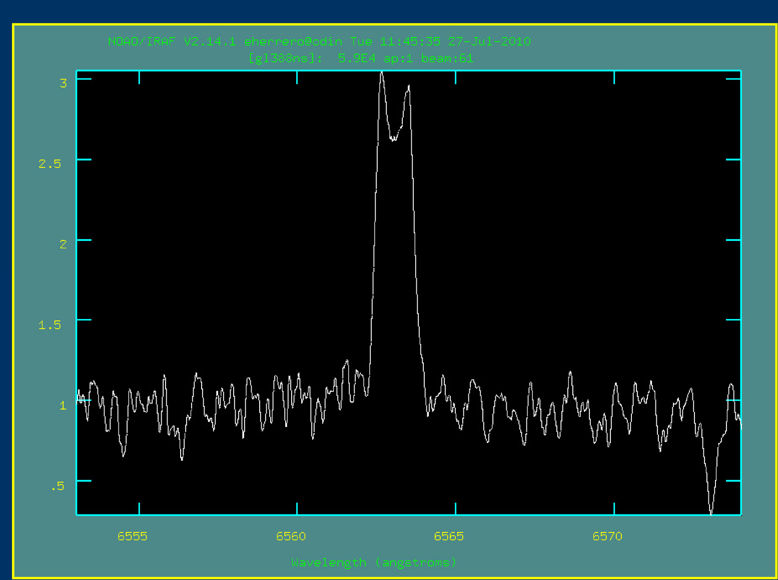
Problem: it is difficult to measure *P* in most cases, only a small sample is available (Kiraga & Stepien, 2007)

2- Activity indicator + *v*sin*i* from spectroscopy ⟶ sin*i*

Although the relation between chromospheric activity and rotation is not already well known for M-type stars, it is expected that larger *v*sin*i* for a specific activity level indicates sin*i*~1. Those stars are the most suitable for an exoplanet search by transits, assuming that the inclination of the planetary orbit is close to the angular momentum of the star.



Activity level vs. *v*sin*i* for a sample of F to M-type stars from López-Santiago et al. (2010). Grey area is a qualitative representation of the expected region of stars with inclination close to 90º.



The Hα line, seen in emission, for Gl388. This emission line is used as a chromospheric activity indicator.

Problem: depending on the used indicator, activity may saturate at relatively low *v*sin*i* values. High resolution spectra with good S/N ratios are needed to measure rotation velocities accurate below 2-3 km s^{-1}.

A sample of ~100 M-type stars with high-resolution spectra measured is now under study (data reduction) to analyze the relation between activity and the rotation velocity.

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