Planets in the galactic bulge, globular clusters and in nearby Galaxies,

or what is the impact of the stellar environment on the formation and evolution of planets?

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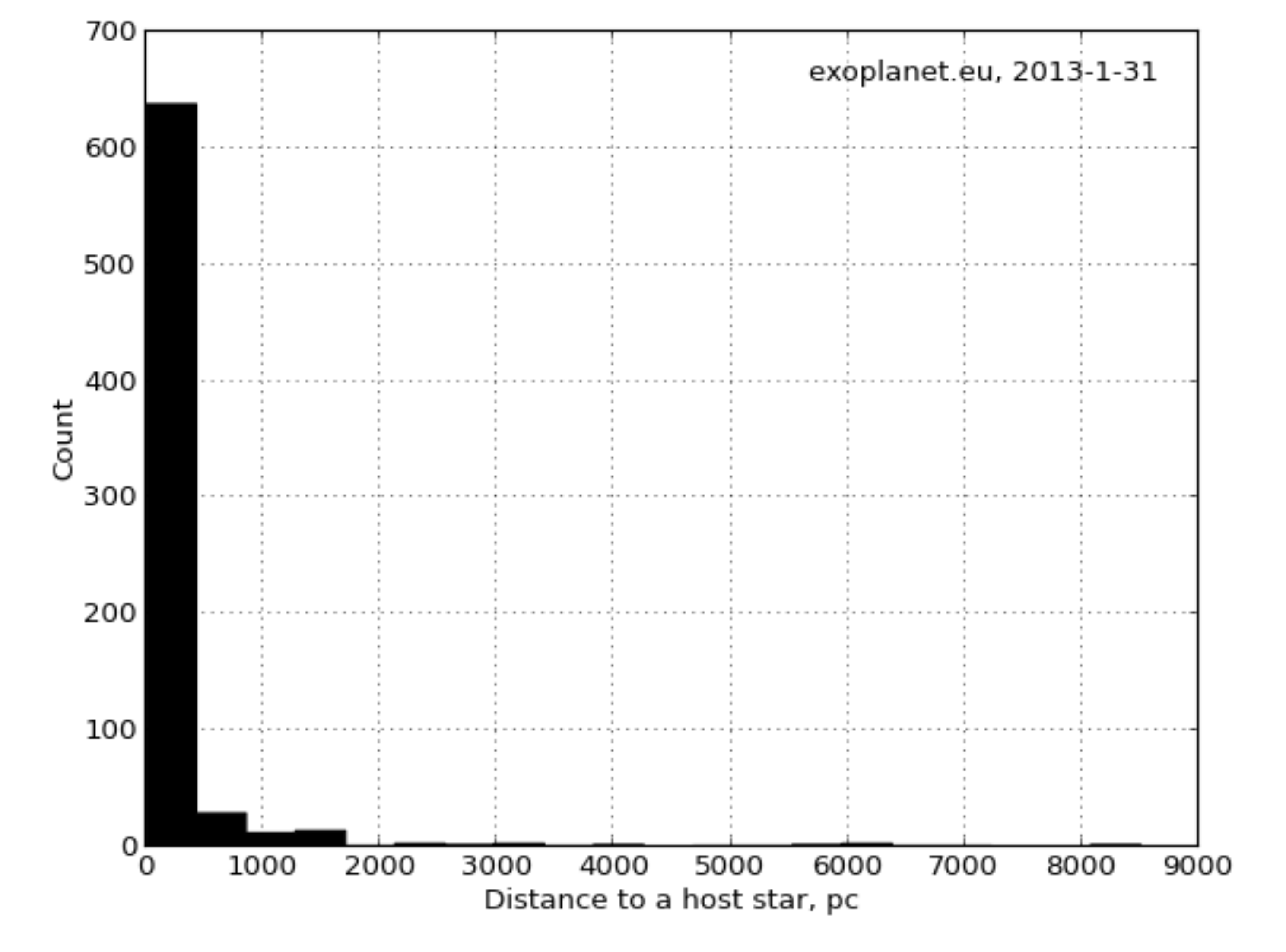
Almost all we know about extrasolar planets is based on stars (planets) in the local solar neighbourhood!

In this sense, know almost nothing about planetary systems in the universe!



The percentage of stars with planets increases with the mass and the metallicity of the host star

Metal rich host stars have more planets.

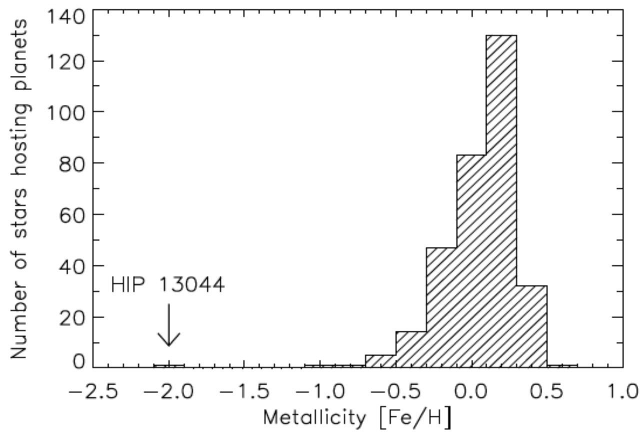
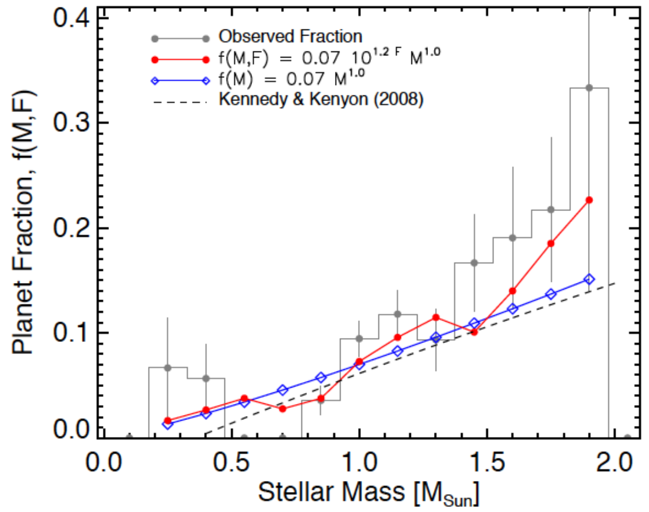


Fig. 3.— Distribution of the metallicity [Fe/H] of planet-hosting stars.

More massive stars have more planets.



Johnson et al 2010

The metallicity effect depends on the mass of the planet!

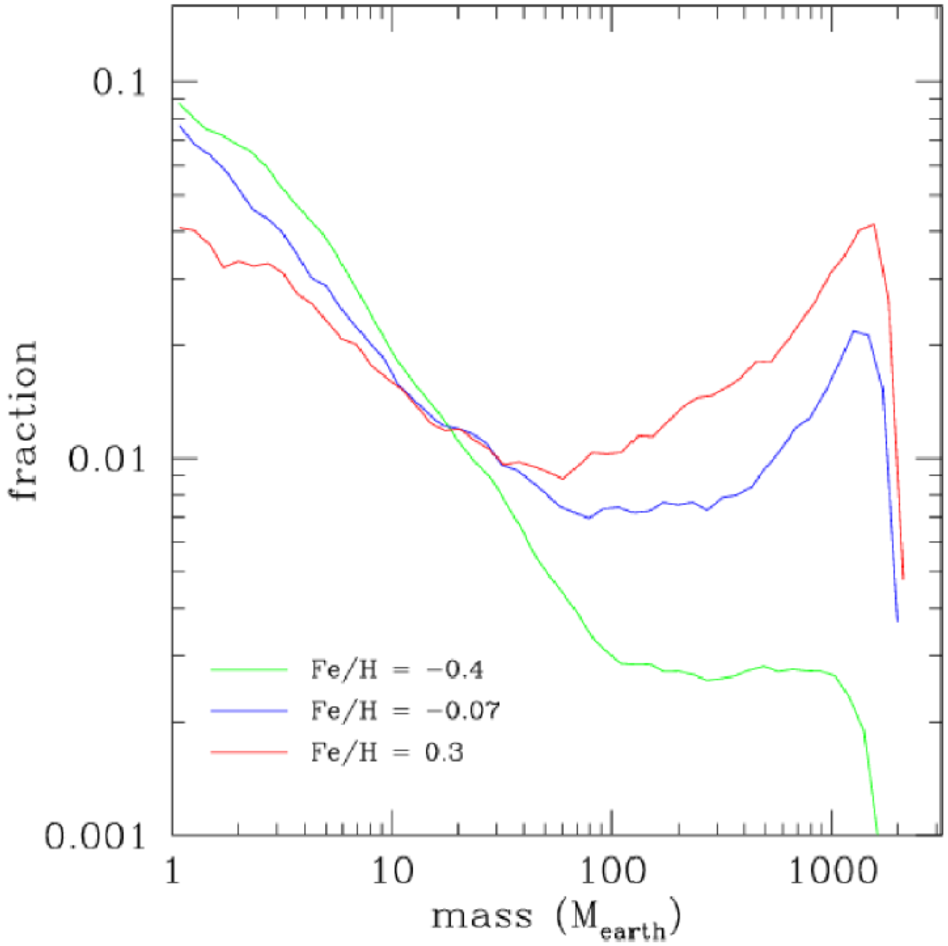


Fig. 2 Fraction of planets around a 1 $M_\odot$ star as a function of their mass (from simulations of Mordasini et al. 2006). Results are displayed for three different values of the metallicity of the star (and of the corresponding proto-planetary disk), as shown on the figure. It is seen that, high metallicities favour larger fractions of massive planets (in rough agreement with observations), while at low metallicities the presence of Earth-like planets is enhanced rather than suppressed. (Courtesy Y. Alibert).

Prantzos 2008, based on calculation from Mordasini et al 2006

Whether a massive, outer planet like Jupiter is necessary for the inner planets to be habitable is still an open issue.

Consequences of metallicity effect:

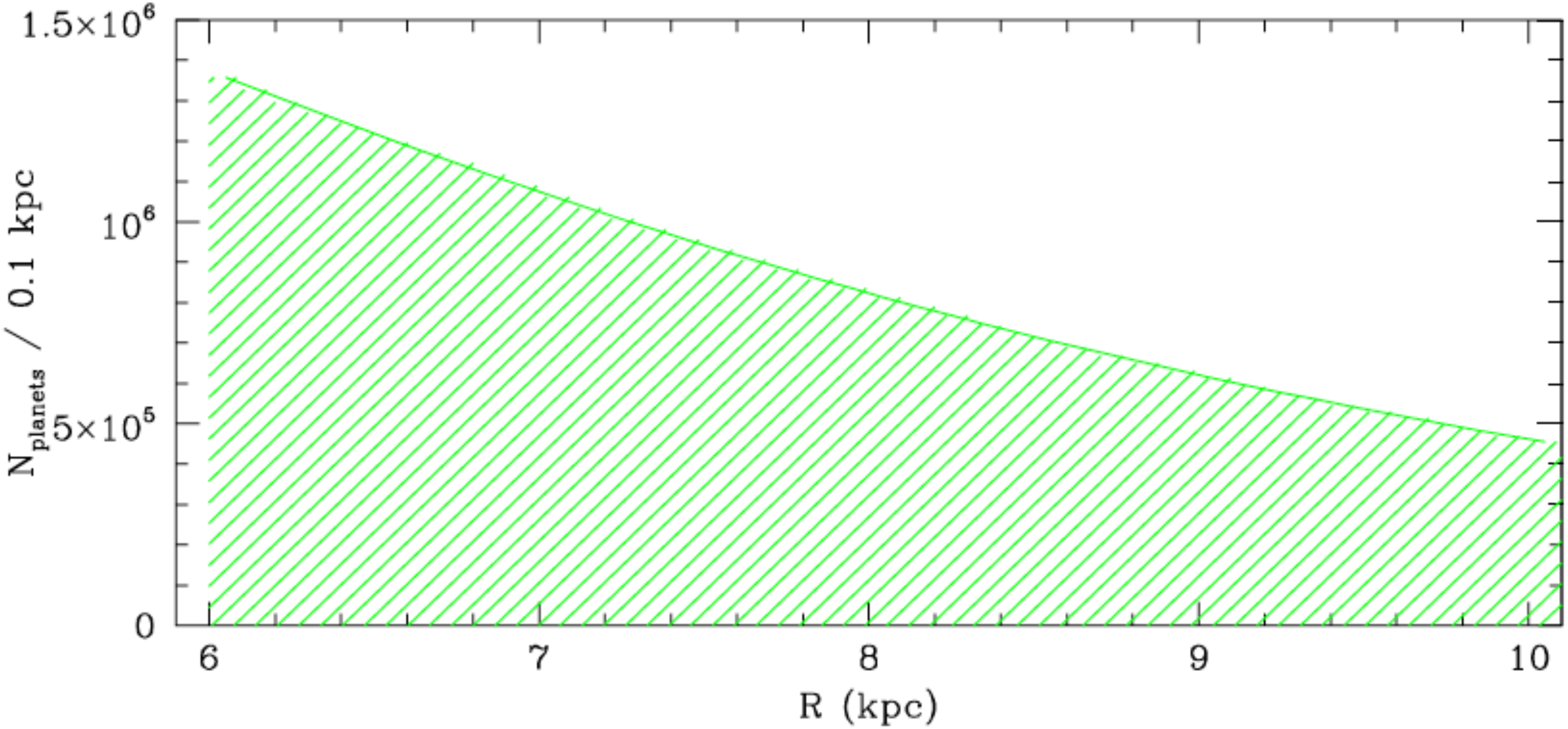
--> The frequency of (massive) planets should increase towards the inner galaxy.

--> Planets should be rare in dwarf galaxies.

However, we do not know if the metallicity and the mass of the host star are most important factors for planet formation.

What are effects of the stellar density, or the presence/absence of hot ionizing stars in the vicinity?

Expected number of extrasolar planet host stars as a function of Galactocentric distance for 6 < R < 10 kpc (Reid 2006).



Metallicity effect+ sterilization from Super Novae + 4 Gyrs needed for complex life to emerge --> Galactic habitable zone (Linewaever at al. 2004).

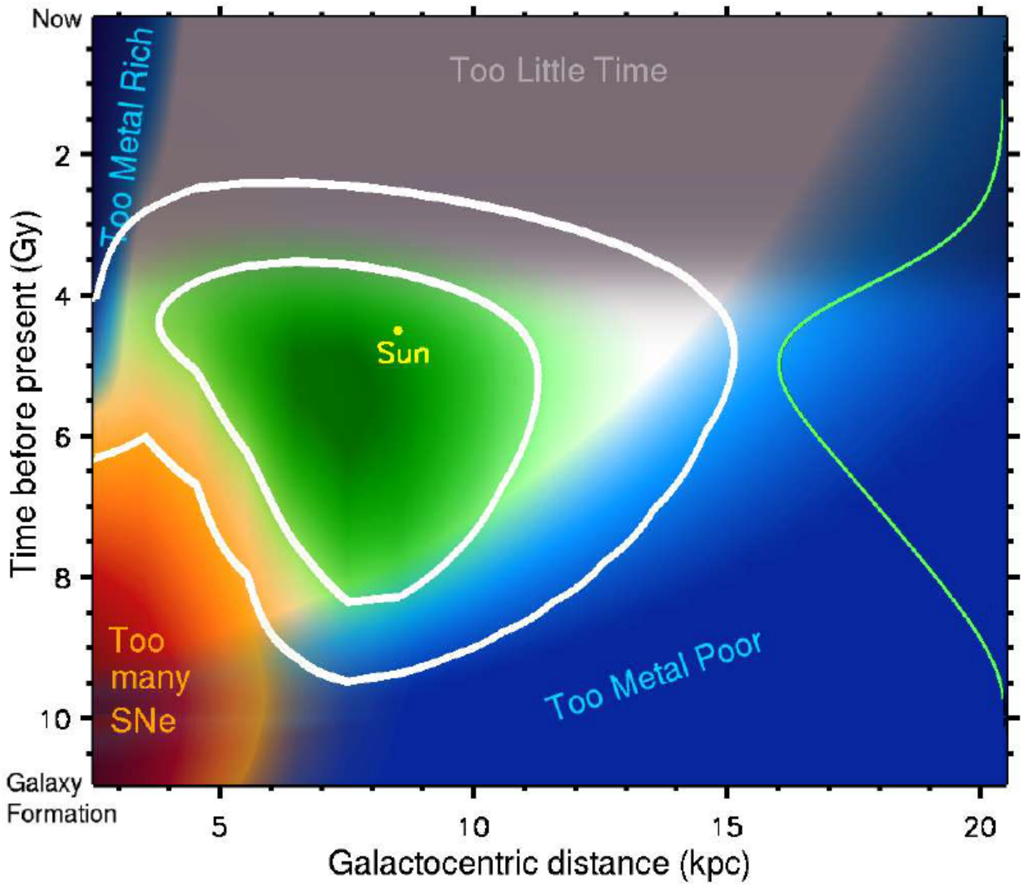


Fig. 3. The GHZ in the disk of the Milky Way based on the star formation rate, metallicity (blue), sufficient time for evolution (gray), and freedom from life-extinguishing supernova explosions (red). The white contours encompass 68% (inner) and 95% (outer) of the origins of stars with the highest potential to be harboring complex life today. The green line on the right is the age distribution of complex life and is obtained by integrating $P_{GHZ}(r, t)$ over r.

Key questions:

---> Is the metallicity and the mass of the host star really the main factors that determine how likely it is that a star has a planet or not?

---> What is the role that the environment plays in the formation and evolution of planets (encounters with other stars, presence of hot stars in the vicinity).

Counter examples:

--> Hyades cluster ([Fe/H]=0.13) RV 10 massive planets should have been found (Paulson et al. 2004) but only one planet found (Sato et al. 2007)

--> 9 planets (m_p>0.5 M_{jup}) orbiting stars with [Fe/H] = -2.5 to -0.5 have already been discovered.

Which factors are the important for the formation of planets (apart from mass/metallicity of the host?

- Does the frequency of (massive) planets increase towards the inner galaxy, as we expect?

- What is the frequency of planets in the galactic bulge (-1.5 < [Fe/H] < 0.5)? (A search for transiting planets in the GB has already been done).

- What is the effect of stellar density on the formation of stars?

  Thomson (2012): Frequency of planets in NGC 6366 and 47 Tuc. Both are GCs that have the same metallicity ([Fe/H]=-0.7..-0.9) but different stellar densities. Study planet population in relatively metal rich GCs (NGC 6440, NGC 6441, NGC 6388 [Fe/H]=-0.5...-0.4) (Searches for transiting planets in GC have already been done).

- Do stars in dwarf galaxies have planets?

Planet of HIP 13044 discovered: HIP 13044 belongs to a group of stars that have been accreted from a disrupted satellite galaxy of the Milky Way, the planet most likely has an extragalactic origin (Setiawan et al. 2010).

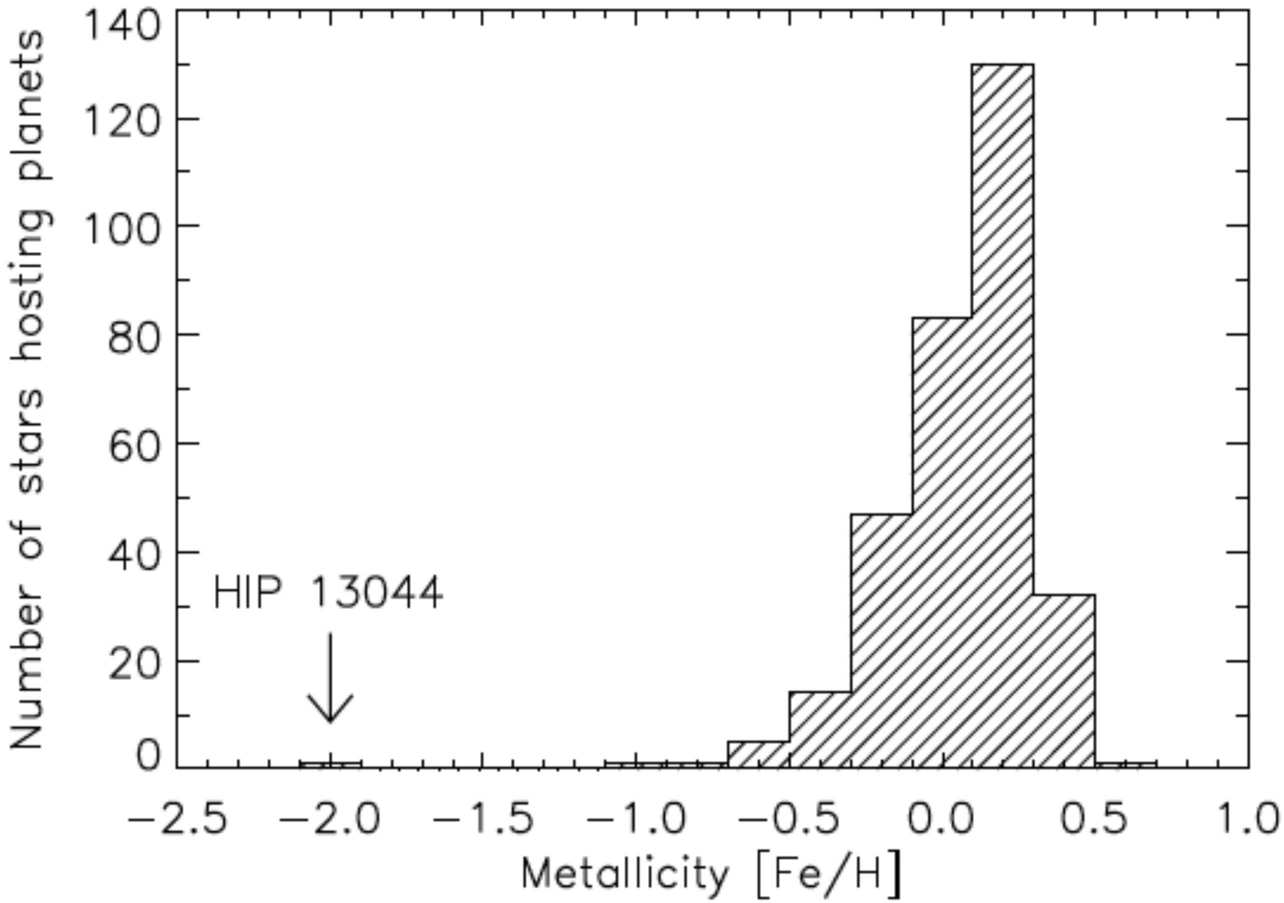
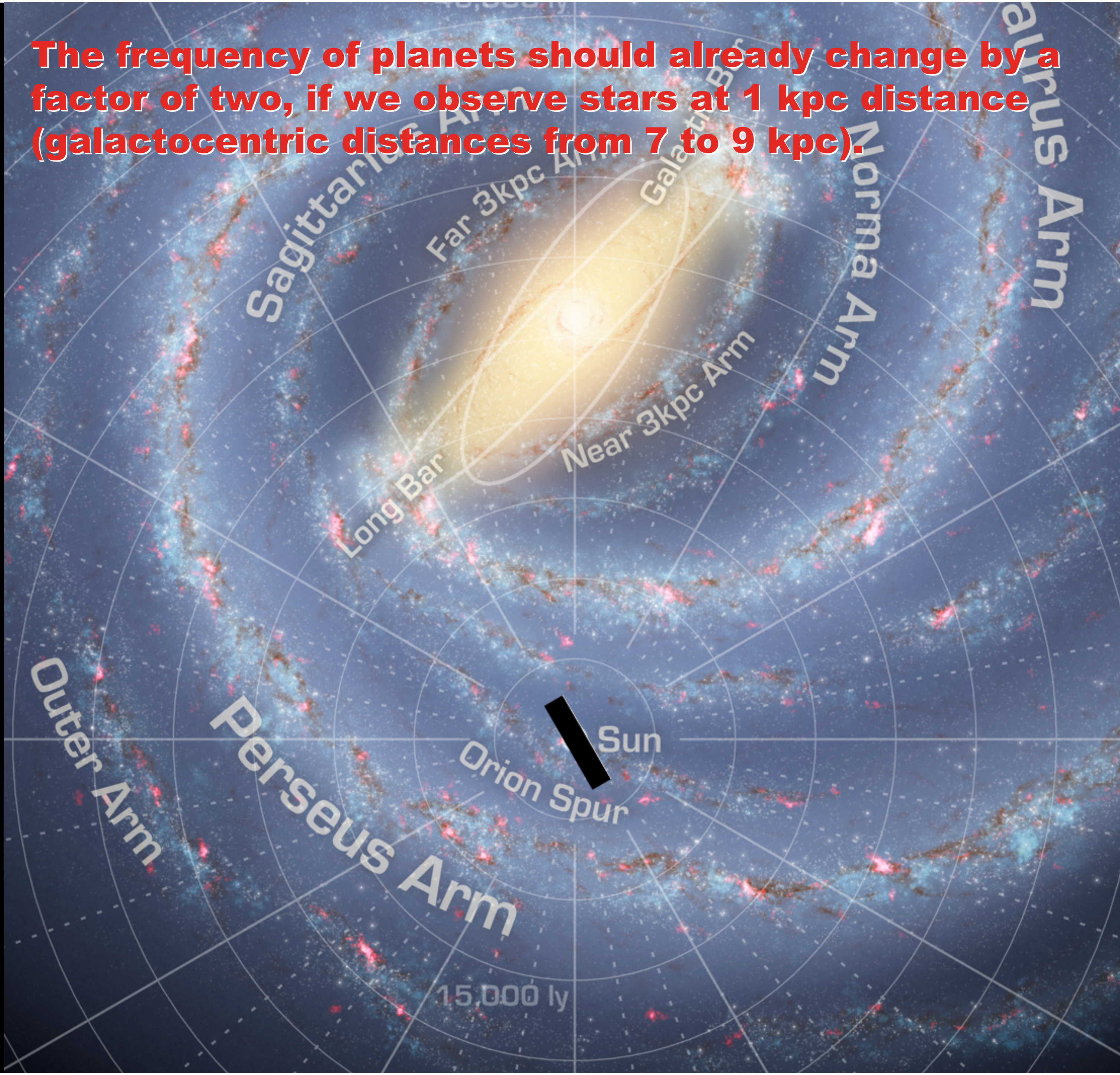


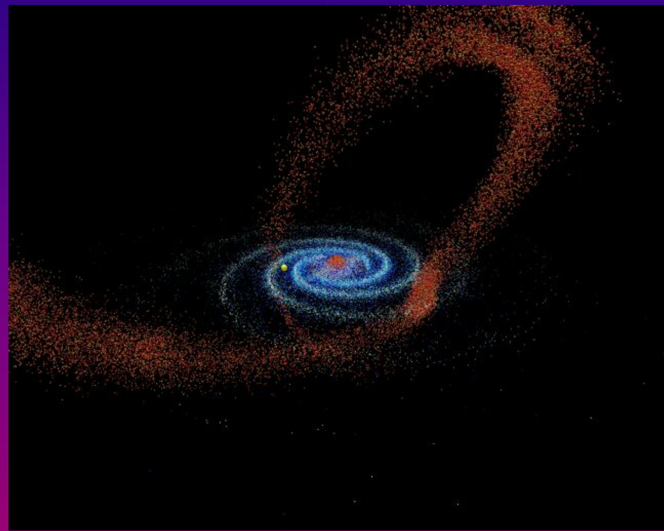
Fig. 3.— Distribution of the metallicity [Fe/H] of planet-hosting stars.

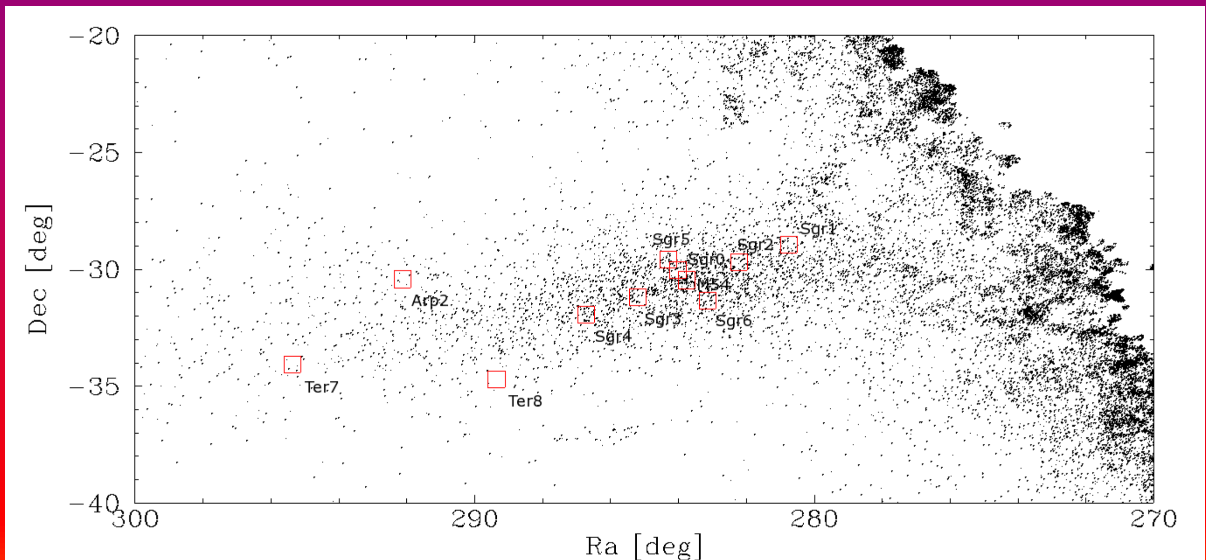
The frequency of planets should already change by a factor of two, if we observe stars at 1 kpc distance (galactocentric distances from 7 to 9 kpc).

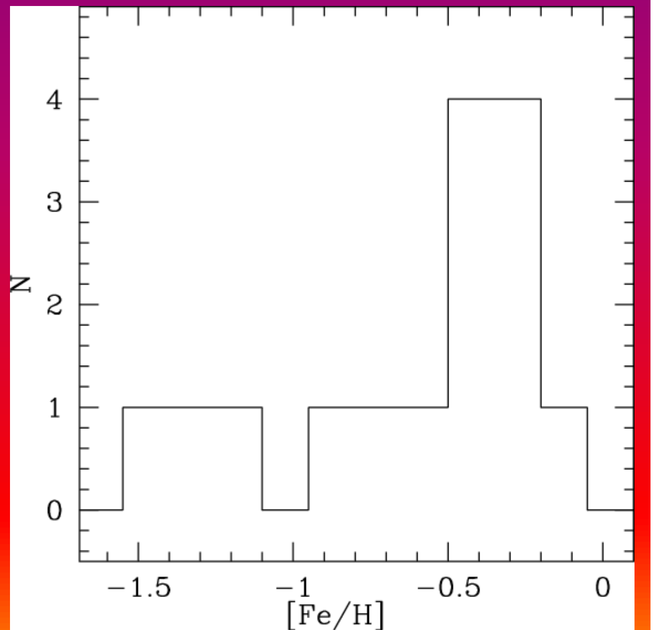


Sagittarius Dwarf Elliptical Galaxy

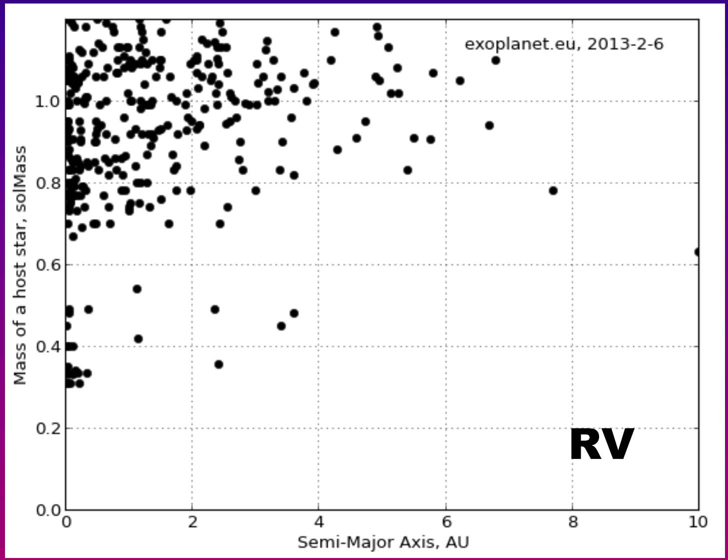
The Sagittarius dwarf elliptical galaxy is orbiting our galaxy at almost a right angle to the disk. It is currently passing through the disk; stars are being stripped off of it with each pass and joining the halo of our galaxy. Stars in this galaxy are metal poor.

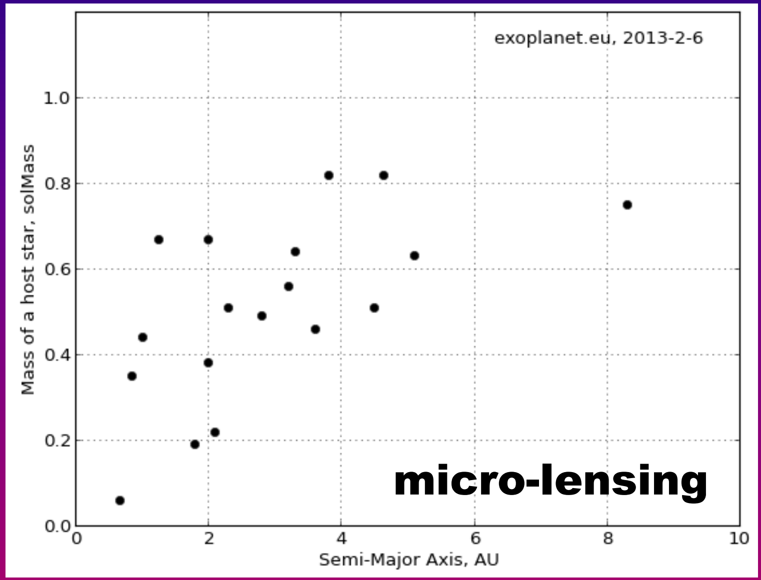




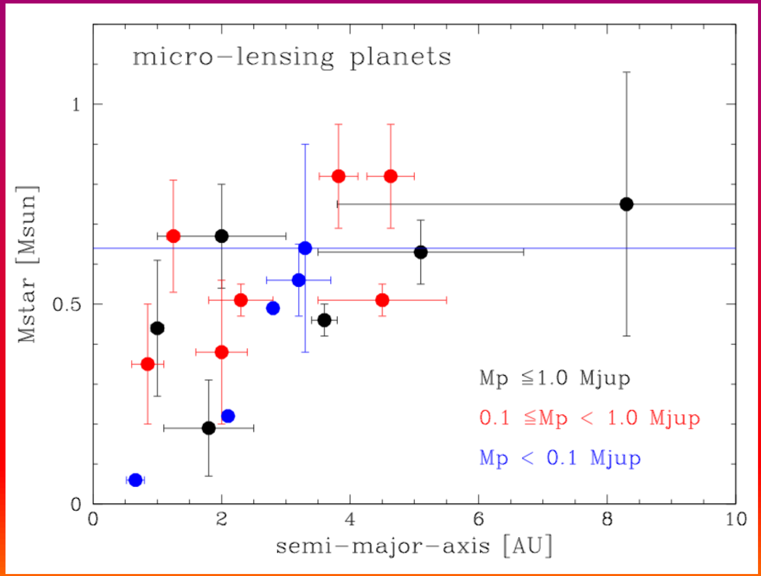


How about using micro-lensing?





Results of RV-searches and micro-lensing searches are difficult to compare.

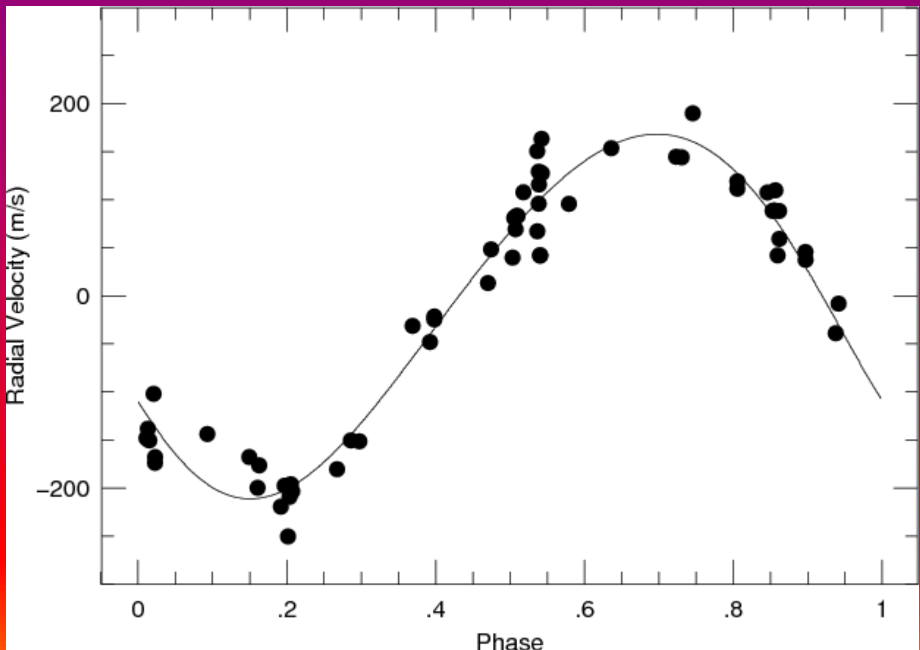


How about using radial velocity measurements?

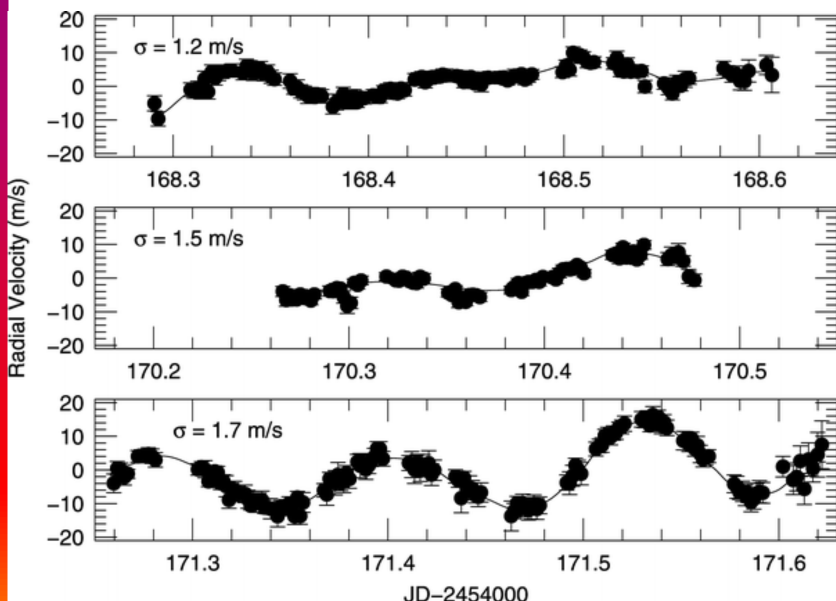
RV-accuracy required: ~8 m/s (better 3 m/s)

$$\sigma_{RV} \propto S^{-0.5} \cdot \Delta\lambda^{-0.5} \cdot R^{-1.5}$$

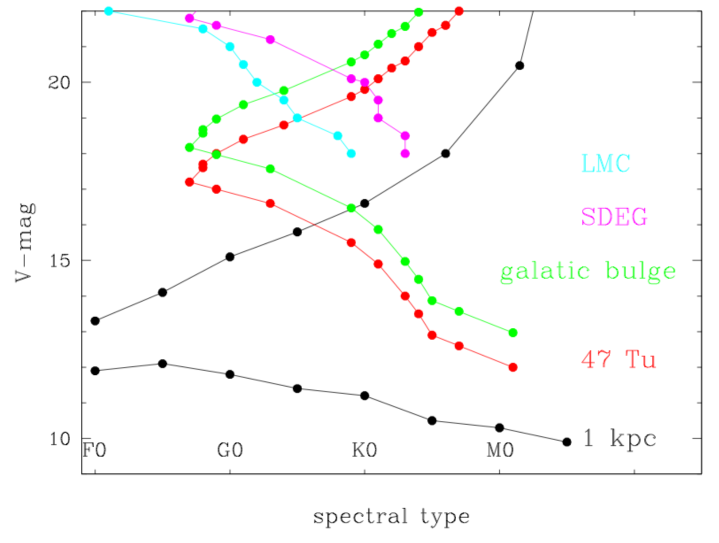
Example: planet of 10.50+/-2.57 Mjup orbs with a period of 516 days a K4III star of 1.80+/-0.25 Msun



$$\nu_{\max} = \frac{M/M_{\odot}}{(R/R_{\odot})^2\sqrt{T_{\mathrm{eff}}/5777\ \mathrm{K}}}\, 3.05\ \mathrm{mHz}.$$



Limiting magnitude and exposure times required:



Bulge:

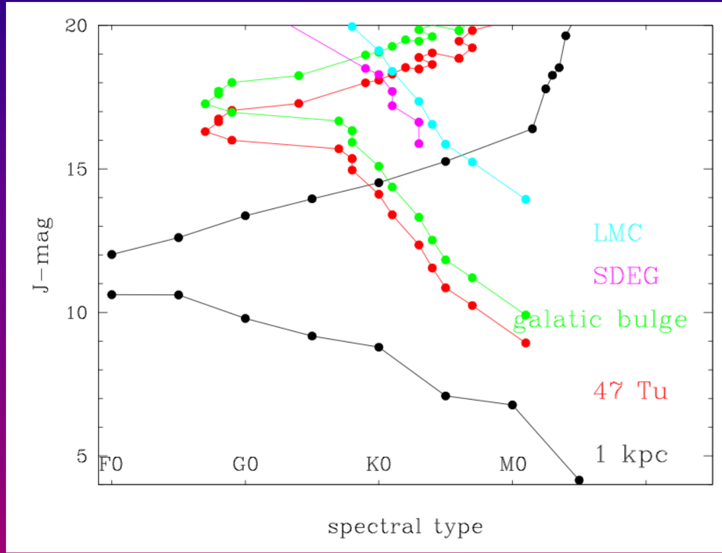
mV ≈ 17, mJ ≈ 15

47 Tuc:

mV=16, mJ ≈14

LMC:

mV≈18.5, mJ≈ 16.4



CODEX (like):

3(8) m/s V=19 mag

exp-time: 240s (44s)

OPTIMOS-EVE (like) (40 objects):

9 m/s V=18 mag

Exp-time: 400s

SIMPLE (like):

3(8) m/s H=16 mag

exp-time: 300s (70s)