The M2K Planet Search:

Spectroscopic Screening and Transit Photometry

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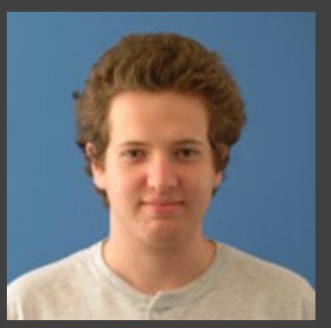

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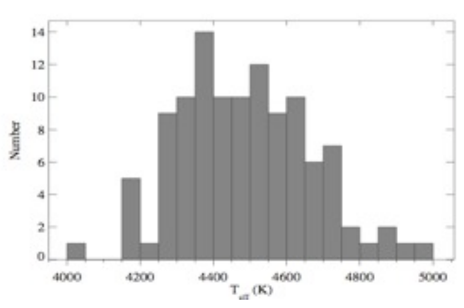
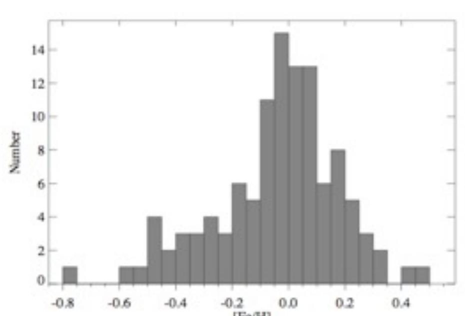
Abstract/Motivation:

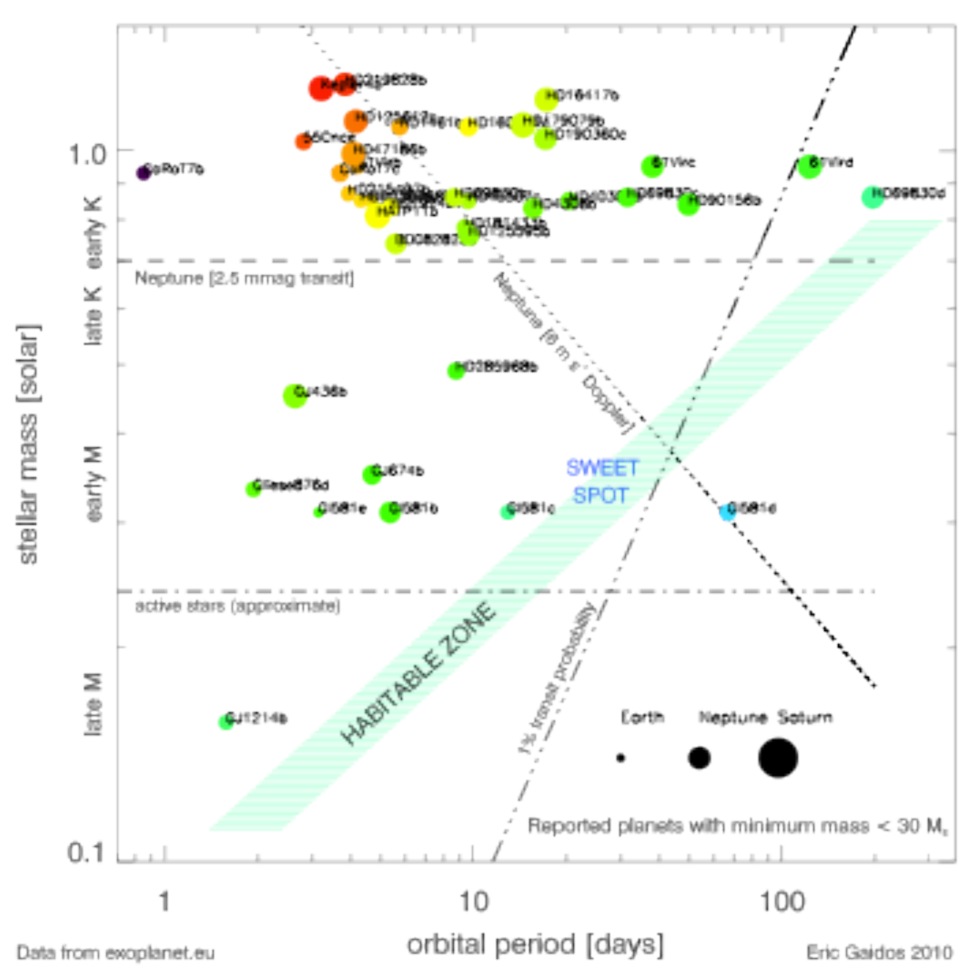
The M2K project is a search for planets orbiting nearby early M and late K main sequence stars drawn from the SUPERBLINK catalog. M and K dwarfs are attractive targets for finding low-mass and habitable planets because (1) close-in planets are more likely to orbit within their habitable zone, (2) planets orbiting them induce a larger Doppler signal and have deeper transits than similar planets around F, G, and early K type stars, (3) planet formation models predict they hold an abundance of super-Earth sized planets, and (4) they represent the vast majority of the stars close enough for direct imaging techniques. In spite of this, only ~10% of late K and early M dwarfs are being monitored by current Doppler surveys. We have obtained low-resolution spectra for more than 2000 of our sample of ~10,000 M and K dwarfs. We further screen these stars for high metallicity and low chromospheric activity. We search for transits on targets showing high RMS Doppler signal and candidates provided by SuperWASP project. By using "snapshot" photometry have been able to achieve sub-millimag photometry on numerous transit targets in the same night. With further follow-up observations we will be able to detect planets smaller than Neptune mass.

M and K Dwarf Targets

Stellar candidates are selected from SUPERBLINK, which identifies stars with proper motion larger than 40 *mas/yr*. Stars are identified as M and K dwarfs based on an empirical V, V-J color relationship (Lepine 2005), then the list is narrowed down by visual magnitude (V < 12.5) and distance (d < 50 pc). Targets are further vetted using low resolution spectra (next panel). Shown below is the [Fe/H] (left) and temperature (right) distributions of target stars.





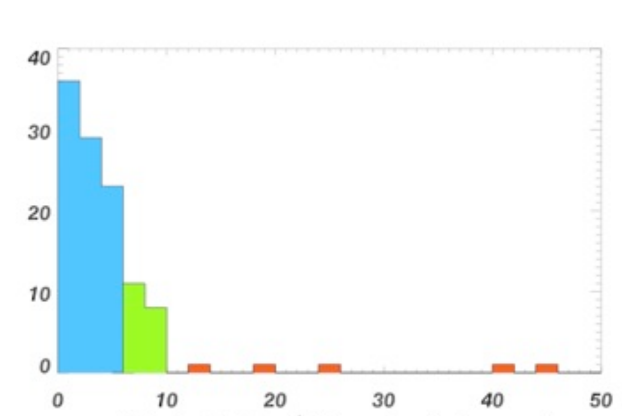


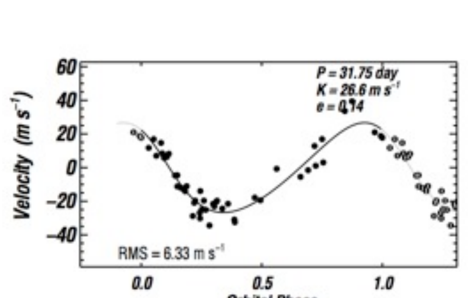
The search is bounded by detection of a Neptune mass planet with ~6 m/s Doppler amplitude and 2.5 mmag photometry, a ~1% transit probability, and avoidance of active stars. This leaves a small "sweet spot" in the habitable zone shown in the Figure on the left along with most published planets with mass < 30 M_{earth}.

Doppler Measurements

Based on the technique of the N2K program (Fischer et al 2005), we start with 3-4 "quick look" observations. Stars with very high radial velocity scatter are likely spectroscopic binaries and are rejected, and stars with constant RV likely have no companion are observed sparingly for long term trends.

Keck I HIRESr RV measurements are shown to the right for M + K targets observed for Doppler motions. So far there are 5 clear planet candidates (orange), as well as at least 17 targets which have RMS > 3 times the noise level (green), but need more data to confirm or deny the existence of a planet. High RMS (>50 m/s) is not shown.

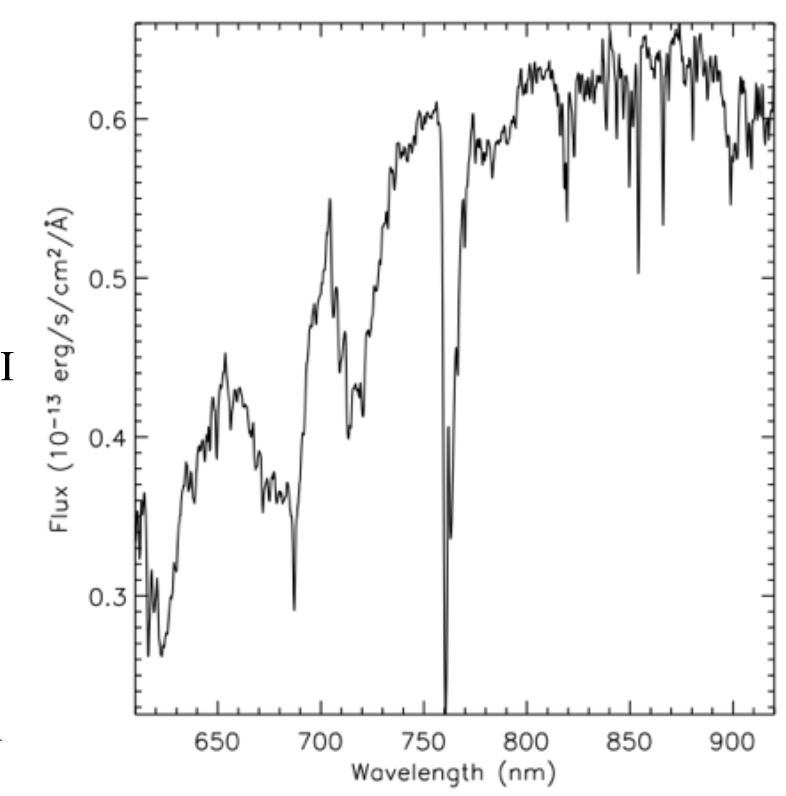




Shown to the left is the phase-folded RV of the star HIP57274 (Fischer et al. 2010). The planet has *msin(i)* = 1.07 Saturn masses. The high dispersion around the fit may be due to a second planet.

Spectroscopic Screening

The SUPERBLINK survey provides us with more than 10,000 stars fitting our color, distance, and magnitude requirements. To get a more reasonable list of targets, we screen candidates using low-resolution spectra from the Mark III spectrograph at 1.3m MDM telescope on Kitt Peak and the SNIFS (SuperNova Integral Field Spectrograph) at the UH2.2m telescope on Mauna Kea. To the right is a sample spectra from SNIFS of metal rich M and K main sequence stars.

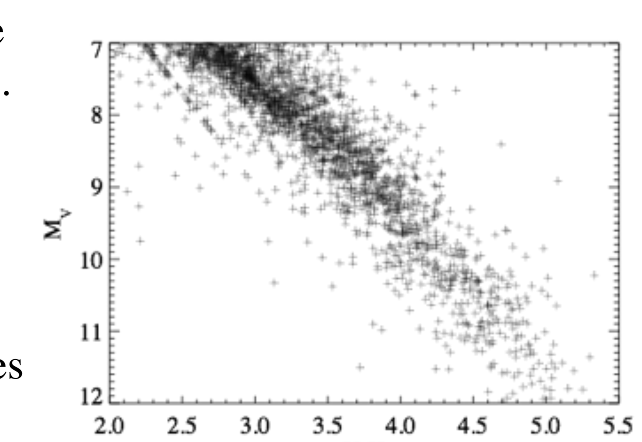


Stars are screened for:

High metallicity: metal rich targets are more likely to harbor planets (Johnson & Apps 2009).

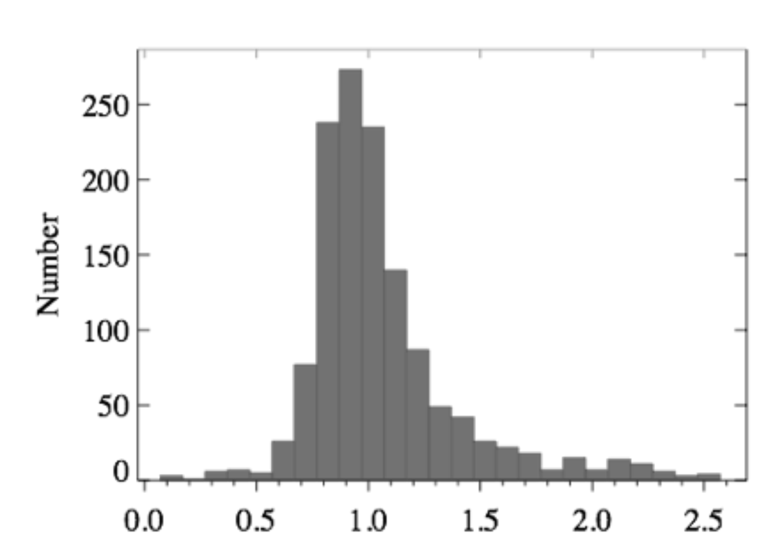
Low Chromospheric Activity: high Chromospheric activity is associated with random and quasi-periodic velocities that can mimic the reflex velocities from exoplanets (Bonfils et al. 2007).

Spectral Type: Color selection of stars can be inaccurate due to metallicity variations. Color-magnitude diagram for those targets with parallax determined distances are shown on the right.



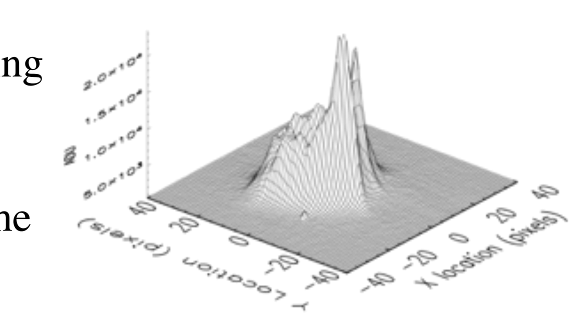
Screening stars in this manner is far more efficient than a blind planet search, and reduces the need for highly sought after telescope resources (i.e. Keck, Subaru).

We use a ζ parameter for characterizing metallicity. ζ is correlated to, but not the same as [Fe/H]. This gives an idea of relative metallicity. So far more than 1500 of our > 13000 database of photometric selected stars have been screened spectroscopically. Shown below is the distribution of ζ values for most of these stars.



Photometric Transit Search

Stars with modest RV signal (orange and green in the bottom plot of the leftmost panel) are monitored photometrically for transit signals using the SNIFS instrument at the UH2.2m telescope on Mauna Kea. We employ a combination of telescope defocusing and "snapshot" photometry to achieve consistent sub-millimag photometry. Defocusing the telescope enables us to get the necessary flux (> 10^7 electrons) for low shot noise (< 10^{-3}) while keeping the exposure length long enough to avoid scintillation noise. A sample defocused image is shown to the right. In snapshot mode, we slew the telescope between target and comparison star.



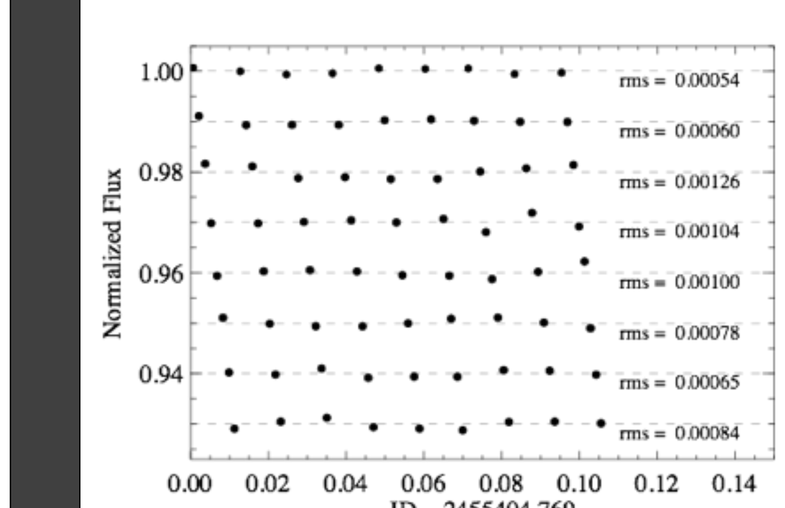
This lets us:

Place both target and comparison star on the same part of the chip.

Select a comparison star with similar magnitude to the target star.

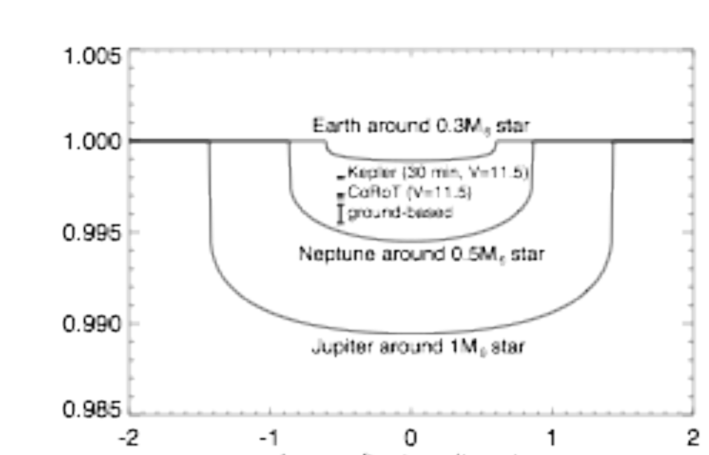
Adjust the exposure length to get similar flux levels from both the target and comparison star.

Select a comparison star of similar spectral type as the target star.



With this technique we can also observe a large number of targets quasi-simultaneously, using each target as a comparison star for the others. Shown to the left is differential photometry of 8 stars observed in this way, all within ~10 degrees of each other on the sky. Each integration + slew takes only ~2 minutes, giving us a 16-17 minute cadence on each of the 8 stars. This is more than sufficient to locate a ~1 hour duration transit.

Planetary transit depth scales as $(R_{planet}/R_{star})^2$. As a result, with the levels of precision we have demonstrated so far (as good as 5×10^{-4} RMS) is sufficient to detect Neptune mass and larger planets around K dwarfs and even super-Earth mass planets around smaller M dwarf stars.



References/Acknowledgements:

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