Towards the frequency of planets around metal-poor stars

A. Mortier[1], N.C. Santos[1,2], A. Sozzetti[4], D. Latham[5], M. Mayor[3], S. Udry[3]

[1] Centro de Astrofísica, Universidade do Porto, Rua das Estrelas, 4150-762 Porto, Portugal
[2] Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto, Portugal
[3] Observatoire de Genve, Université de Genve, 51 Ch. des Maillettes, 1290 Sauverny, Switzerland
[4] INAF-Osservatorio Astronomico di Torino, strada dell'Osservatorio 20, 10025 Pino Torinese, Italy
[5] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

Introduction

The past 15 years, more than 500 planets were announced. Understanding the frequency of different types of planets around stars of different mass and metallicity is providing clues about the processes of planet formation and evolution. This has inspired the construction of specific samples to search for planets around different types of stars.
In this context, two metal-poor, solar-type samples were observed with the HARPS and Keck-HIRES spectrographs, respectively. These samples can be used to explore how frequently giant planets orbit metal-poor stars. This will determine the metallicity limit below which no giant planets can be observed.

The samples

The HIRES sample

- 160 metal-poor solar-type stars
- Instrument: HIRES @ Keck 1 Telescope
- Observed from early 2003 till early 2006
- Data reduction based on AFOE pipeline
- Most stars have 4 to 10 measurements
- RV rms of $\sim 9\ \mathrm{m\,s^{-1}}$

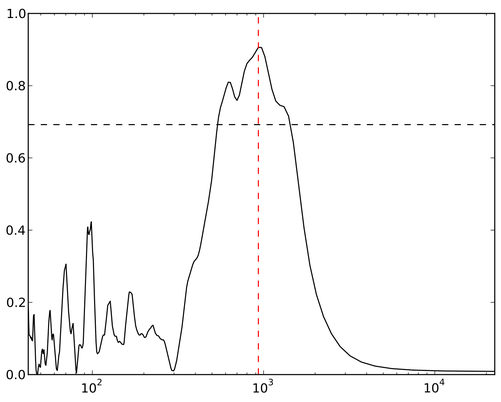
The HARPS sample

- 104 metal-poor or mild metal-poor solar-type stars
- Instrument: HARPS @ La Silla
- Observed from October 2003 till July 2010
- Data were reduced with HARPS pipeline
- 1301 precise radial velocity measurements
- Most stars have 5 or more measurements
- RV rms of $\sim 1 - 2.5\ \mathrm{m\,s^{-1}}$

Fourteen (14) stars are present in both samples. This increase in measurements for these objects reveals no extra planets when trying to fit a Keplerian orbit.

Generalized Lomb-Scargle periodogram

The Lomb-Scargle periodogram is used in the frequency analysis of unevenly sampled data (as is the case for our radial velocity measurements). The method is equivalent to a least-squares fitting of sine waves. Zechmeister et al. (2009) generalized the concept (GLS) to a full sine wave fit, including an offset and weights. We use this GLS method on the stars in our sample.



To know the significance of a peak in the periodogram, we use a bootstrapping method. Several time series of radial velocities are made by shuffling (with repetition) the radial velocities while preserving the original times. On each series, a GLS is performed to determine the highest peak. From these peaks, we determine the power a peak should have to have a 99.9% probability that the peak comes from a planet (false alarm probability level). The left figure shows the periodogram for *HD181720* with HARPS data (a previously announced planet was found). The x-axis represents the period in days. It shows a peak around 950 days. The black dotted line represents the FAP level.

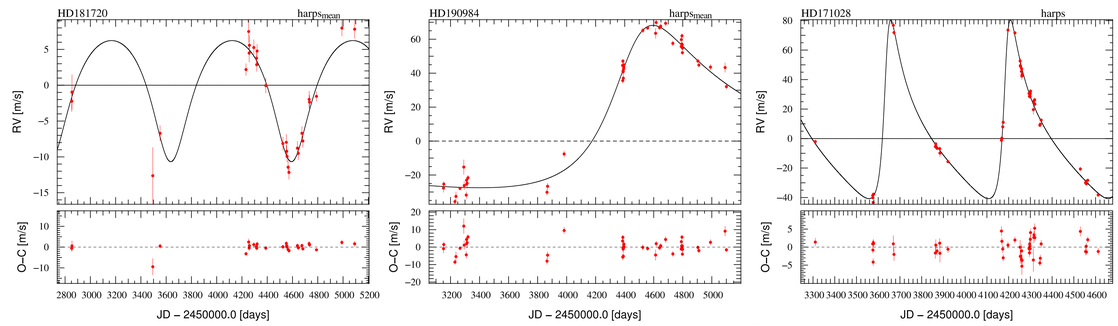
For the common stars in the samples, GLS periodograms are made with the combined data. As stated before, no significant peaks could be discovered in the new periodograms.

References

Santos, N. C., et al. 2011, A&A, 526, A112
Sozzetti, A., et al. 2009, ApJ, 697, 544
Zechmeister, M., Kürster, M. 2009, A&A, 496, 577

Previously announced planets in the HARPS sample

Three previously announced planets were found in the HARPS sample: *HD181720*, *HD190984* (Santos et al. 2010) and *HD171028* (Santos et al. 2007). All three are giant planets in long period orbits.



HD181720
Period: 956 days
Eccentricity: 0.26
Mass: $M \sin i = 0.37 M_{Jup}$

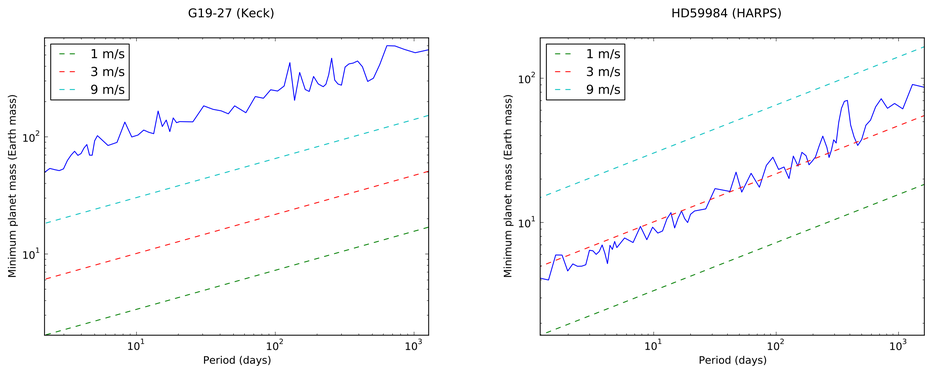
HD190984
Period: 4885 days
Eccentricity: 0.57
Mass: $M \sin i = 3.1 M_{Jup}$

HD190984
Period: 550 days
Eccentricity: 0.59
Mass: $M \sin i = 1.98 M_{Jup}$

Detection limits

To find out the detection limits, we first determine the FAP levels at each period in the periodogram of the data. Then, we insert a planetary signal in the data. With these new radial velocities, we look for the peak in the GLS periodogram. By changing the parameters of the planetary signal, the FAP levels can be reached. This gives you the limits on the planets that can be detected with these data. To transform an amplitude K (in m/s) in planetary mass (in Earth mass), we used the formula

$$M_p \sin i = 7.4 \cdot 10^{-24} K \sqrt{1 - e^2} \left(\frac{P M_*^2}{2\pi G} \right)^{1/3}$$



The figures show the detection limits (blue solid line). The left panel is a star from the HIRES sample, the right one is from the HARPS sample. For each period, we added a circular planetary signal with different amplitudes and phases. We took the maximum over all the phases. The dashed lines give the corresponding amplitudes of the signal.

✉amortier@astro.up.pt