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Asteroseismology of solar–type stars with SARG@TNG

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Abstract

Since 1995, the extra-solar planet search has driven the high resolution spectroscopy community to build more and more stable spectrographs in order to reach the photon statistics limit in radial velocity measurements. This situation opened the possibility of asteroseismic observations of stellar p mode pulsations in solar-like stars. In this contribution we summarize the high precision radial velocity measurements of two solar type stars (α CMi and μ Her) using the SARG spectrograph at TNG equipped with an iodine cell. The analyzed spectra show individual measurement errors of about 1.0 m/s (very close to the theoretical photon noise limit). Further we discuss the synergy between high precision radial velocity asteroseismology campaigns and the search for Super Earths.

Individual Objects: Procyon, μ Her

Radial velocity uncertainties with SARG

SARG (Spettrografo Alta Risoluzione Galileo) is the high resolution optical spectrograph of the Italian Telescopio Nazionale Galileo (TNG). Instrument characteristics include a high spectral resolution (maximum about 160 000), high efficiency (peak at about 13%), rather large spectral coverage in a single shot. SARG was designed as a multipurpose instrument. The instrument, which mounts an iodine absorbing cell, is particularly suited for precise radial velocity programs, such as planet search and asteroseismology (Gratton et al. 2001). Radial velocities are obtained by means of the AUSTRAL code (Endl et al. 2000). We evaluate radial velocity uncertainties for SARG using the appropriate quality factor (see Bouchy et al. 2001) for spectrograph resolution, spectral type and rotational broadening. For stars brighter than 3.5 magnitude the resulting RV uncertainties range between 0.9 to 3 m/s depending on magnitude and spectral type of the star. This result affects also the efficiency of the instrument in detecting oscillations maintaining the number of spectra confined inside a reasonable number necessary to detect oscillation of amplitude ν_{osc} over a 4 σ threshold. We are aware that the limits of RV measurements are also set by spectrograph instabilities, but analyzing the results obtained with the subgiant star Procyon and μ Her we can limit the instrumental contribution to RV uncertainty lower than 1 m/s.

Procyon

Procyon A has been observed twice with SARG. The first time was in January 2001 (6 nights, 950 spectra) and the second was in January 2007 during a multisite campaign involving 11 Telescopes (Arentoft et al. 2008). In both campaigns a single the Doppler shift measurement has an rms internal error of 1.38 m/s. Sometimes, as shown by Claudi et al. (2005), the pulsation of the star is clearly visible in the RVs time series when there is no negative interference with other pulsation modes.

During the coordinated campaign, a coverage of Procyon lasting about 10 days without interruption was obtained. The resulting time series shows slow variations on a time scale of days. The good agreement between the measurements of the different telescopes lets one suspect that this is a variation that has a stellar origin, even if some contribution from instrumental drift could not be excluded. Nevertheless it could be interpreted as being due to rotational modulation from an active region on the stellar surface. The period is 10 days and could match the rotational period of this star or half of it (Arentoft et al. 2008). As far as the uncertainties of the RV measurements are concerned, HARPS is surely the best spectrograph. It is worth to mention that SARG has very similar RV uncertainties, as it is possible to see in Figure 1d of Arentoft et al. (2008).

μ Her

A clear detection of excess of power, providing a substantial evidence for solar-like oscillations in the G5 subgiant μ Her, was obtained with seven nights of observation with the SARG echelle spectrograph. The amplitude spectrum shows a clear excess of power centred at 1.2 mHz, with peak amplitudes of about 0.9 m/s. Successively, fitting the asymptotic relation to the power spectrum, a mode identification for the l=0,1,2,3 modes in the frequency range 900 – 1600 μHz is derived. The most likely value for the large separation turns out to be 56.5 μHz, consistent with theoretical expectations. The mean amplitude per mode (l=0 or 1) at peak power is 0.63 m/s, almost 3 times larger than the solar one. Results on this star are fully described by Bonanno et al. (2008).

Synergy with searches for Super Earths

The extension of the domain of radial velocity planet searches towards planets of masses significantly lower than Saturn is one of the most relevant results of the past years. The main difficulty is to strive for smaller radial velocity amplitude against the limits imposed by the star itself. It was shown that averaging consecutive radial velocity measurements it is possible to limit these effects (Santos et al. 2004).

In the search for solar-like oscillations targets are monitored for several contiguous nights. The data acquired are then very well suited to reach the limits of radial velocity precision.

To estimate the sensitivity of the our data to low-mass short-period planets we use the MULO code by M. Barbieri (described by Desidera et al. 2003). This allows us to constrain the masses of planets in circular as well as in eccentric orbits that are compatible or excluded by the data. Planets with masses larger than the derived limit are excluded because their presence would have created a detectable excess of variability with respect to the observed one. For both stars observed with SARG in asteroseismology campaigns (Procyon and μ Her) the nightly averages of the time series show an rms of about or less than 20 cm/s, that corresponds to limits on planetary masses in short period orbits of about 1.5 – 2.0 Earth masses. This result is based on only two targets (bright stars). Moreover each star has been observed in an optimal situation for what concerns the possible instrumental noise (only one target observed in successive nights for the whole run, keeping fixed the pointing and guiding). While we typically have a bit larger errors in normal planet-search survey operations (several targets per night over time scales of several years), nevertheless the result demonstrates that, at least on short temporal basis, a suitable observing strategy can push the intrinsic stellar limit of radial velocity measurements well below 1 m/s, allowing the detection of Earth-like planets in close orbits.

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