SARG EXTRA SOLAR PLANET SEARCH

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Abstract

SARG (Spettrografo Alta Risoluzione Galileo) is the high resolution spectrograph of TNG (Telescopio Nazionale Galileo), the Italian National Telescope in operation at La Palma (Canary Island, Spain). The spectrograph is equipped with an iodine cell in order to perform high precision radial velocity measurements. It is used by the SARG Extra Solar Planet Search: this quest (started from September 2000) is devoted to find planets around individual components of wide binary systems with a parallax larger than 10.0 mas and declination greater than 20 degree. In this contribute we describe the spectrograph, the survey criterion and some preliminary results.

Key words: Stars: asteroseismology; Planets: exoplanets

1. Introduction

SARG (Spettrografo Alta Risoluzione Galileo) is the high resolution optical spectrograph for the Italian Telescopio Nazionale Galileo (TNG). Instrument characteristics include a high spectral resolution (maximum about 150 000), high efficiency (peak at about 13%), rather large spectral coverage in a single shot. SARG was designed as a multipurpose instrument, in order to satisfy the scientific needs of a rather wide community. However, emphasis in the design was put to have a high resolution, stable instrument, while not sacrificing efficiency; such an instrument is particularly suited for precise radial velocity programs, such as planet search and asteroseismology. To this purpose, SARG is equipped with an iodine cell (Marcy & Butler 1992). The choice of the iodine cell technique is ideal for SARG, because it allows to achieve the best radial velocity precision maintaining at the same time the flexibility required by the multi-purpose nature of the instrument. For a more exaustive description of the spectrograph the reader is invited to consult the SARG WEB site[1].

The determination of differential radial velocities with very high precision (errors ± 5 m/s) is one of the main scientific aim of SARG. This goal is achieved by means of the iodine cell. The wavelength reference is directly superimposed on the stellar spectrum, allowing to remove the instrumental shifts. Fig. 1 shows some SARG spectra used for the radial velocity study of 51 Peg, that hosts a planet in close-in orbit (Mayor & Queloz 1995).

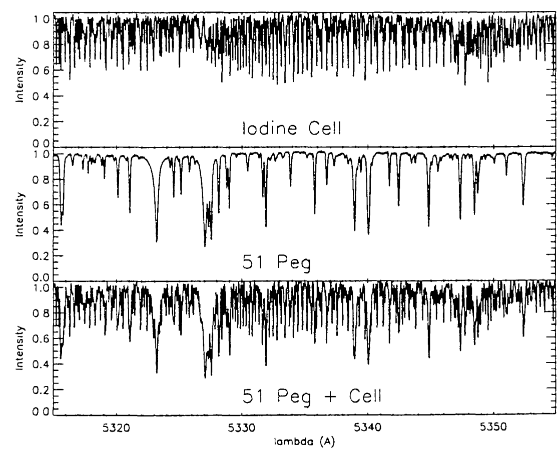

Figure 1. Spectra on 51 Peg obtained on 16 July 2000. Top panel: Iodine Cell spectrum with FF lamp; Central panel: star spectrum; Bottom panel: star + cell spectrum.

2. Results from SARG Commissioning

We are analyzing the iodine cell data using the code developed at ESO (Endl et al. 2000), that was already tested for ESO-CES planet search and led to the discoveries of the planets around the stars ι Hor (Kürster et al. 2000) and ϵ Eri (Hatzes et al 2000). From a partial (only five orders out 22 with iodine lines) and preliminary analysis of the data acquired during the SARG commissioning time, we have already achieved a medium-term (a few months baseline) radial velocity precision of 5 m/s on the constant radial velocity star τ Ceti (Fig. 2) and we have measured velocties for 51 Peg that fit very well the known orbit (Fig. 3 and Fig. 4). The analysis of the full spectral

[1] `http://www.pd.astro.it/Sarg`

Proc. 1st *Eddington* workshop *"Stellar Structure and Habitable Planet Finding"*, Córdoba, 11–15 June 2001 (ESA SP-485, January 2002, F. Favata, I. W. Roxburgh & D. Galadí-Enríquez eds.)

format and the fine tuning of the instrument profile modeling parameters could yield further improvements. Thus we think that SARG will match the best instruments in this field (3 m/s at Keck, Butler et al. 2000).

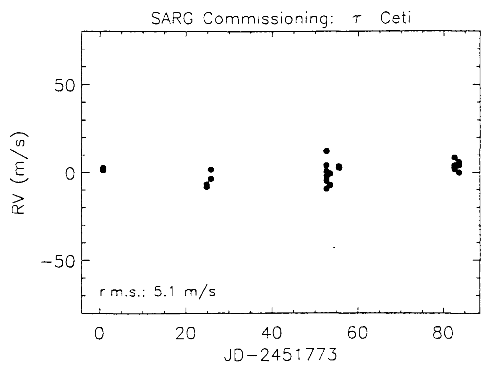

Figure 2. Radial velocities measurement of the star τ Cet obtained during SARG commissioning

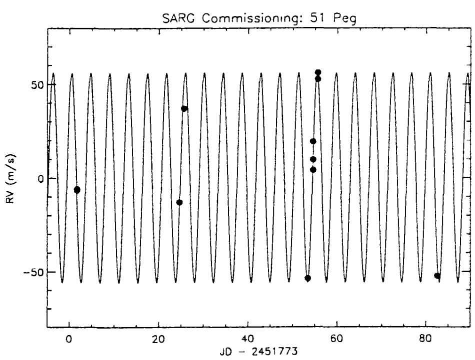

Figure 3. Radial velocity curve of 51 Peg phased to the known orbit (Marcy et al. 1997 with the updating from http://www.exoplanets.org).

3. The SARG Planets Search

Binary systems are ideal laboratories to study the dynamical effects on planetary systems due to the presence of the stellar companion, providing basic data about the minimum binary separation for planet formation and possible perturbations of planetary orbits. Furthermore, the discovery of planets in binary systems may allow to identify possible chemical anomalies of the star with the planet, by comparing the chemical composition of the component. If the high metallicity of the parent stars of planets (see

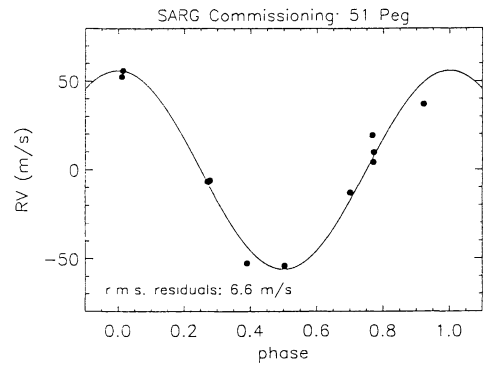

Figure 4. Radial velocities of the planet-harbouring star 51 Peg from SARG Commissioning observations (August-November 2000). The known orbit (Marcy et al. 1997 with the updating from http://www.exoplanets.org) is overplotted.

Fig. 5) is the result of planets or planetesimal ingestion (Gonzalez 1997) some systematic differences are expected between members of a binary system with and without planetary companions.

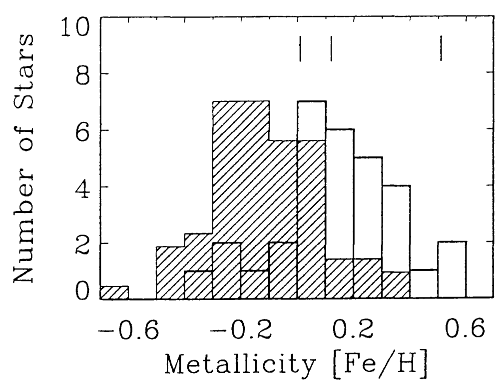

Figure 5. Histogram of metallicities of stars bearing planets (solid line) compared to a volume limited sample of 77 G dwarfs within 20 pc (dashed area). From Butler et al. (2000).

With these two aims in mind, we selected from Hipparcos Multiple Stars Catalog a sample of binary systems with separations larger than 2 arcsec (to avoid contamination of the spectra), magnitude difference less than 1.0 mag (a small magnitude difference is useful in comparison of chemical composition of the components, avoiding systematic effects due to different temperatures and gravities), colors in the range $0.45 < (B-V) < 1.1$, parallaxes larger than 10.0 mas (with errors smaller than 5 mas) and declination $\delta > -20$. Typical projected separations are in the range 100–1000 AU. Dynamical stability for a planet up to 20–30 AU from the star is possible in most cases, according to the simulations of Holman & Wiegert (1999). Among the planets already discovered, one orbits around a star in a binary system with projected separation 150 AU (HD 195019, Fischer et al. 1999).

The final sample of the survey is being selected using the SARG observations obtained during commissioning time and the first nights assigned to this project. We are checking for undetected double line binaries, rotational broadening and activity indicators. After the May 2001 run, we have already obtained first epoch spectra for 55 pairs (only one still missing). We identified 2 double lines and 1 single line spectroscopic binaries and two stars with velocity difference incompatible with the orbital motion of the wide binary (e.g. see Fig. 6). These stars were excluded from the sample. The final sample would be composed of about 100 stars (50 pairs). A smaller sample will likely lead to a number of detections insufficient to draw any significant conclusion.

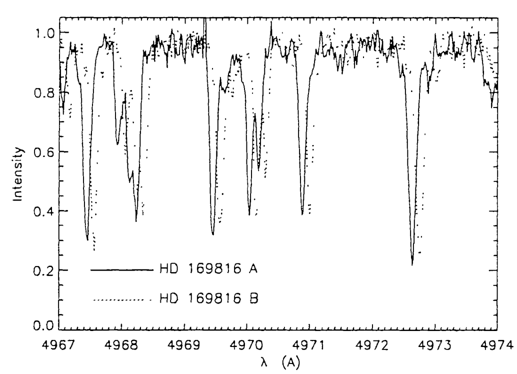

Figure 6. The two components of the visual pair HD 169816 have a velocity difference of 7 km/s. This is incompatible with the orbital motion of the visual pair, so that we argue that one the components should be itself a binary.

Moreover we are starting a photometric monitoring of the sample at Teramo Observatory, aimed to determine the rotational period of the stars, useful to disentangle the origin of observed radial velocity variations (keplerian motion, rotational modulations, activity), to constrain the inclination of the system (when coupled with the measured v sin i), and to check for possible transiting systems.

For more information consult the SARG exoplanet search site[2].

[2] `http://www.pd.astro.it/new_sites/ESP`

4. Preliminary Results

Together with the radial velocities measurements we are performing a careful differential abundance analysis of individual components of several main sequence binaries of our sample. This analysis is performed using the high resolution and S/N of the SARG stellar templates (i.e. the star spectra taken without the iodine cell).

We limited our analysis to spectral lines with EW< 50 mÅ to avoid lines that are saturated and are then more sensitive to velocity fields than to abundances; or have well developed damping wings, not well fitted by our gaussian fitting routine. We took full advantage of the wide spectral range and high resolution offered by SARG, so that our line lists include several hundreds of lines for each star, ensuring very small statistical error bars.

Table 1. HD 30101 Basic Parameters

	A	B
M_V	5.53	5.68
Mass	0.81	0.80
V−I	0.873	0.921
T_{eff}	5080	4990
log g	4.30	4.26
[A/H]	−0.17	−0.17

In Table 1 we report the basic parameters of HD 30101 (a binary system of the sample): the first row lists the absolute magnitudes M_V, obtained from the absolute magnitudes listed in the Hipparcos Catalogue; in the second row the masses are shown as they were calculated from M_V magnitudes and $B - V$ colours using Gray (1992) tables. The $V - I$ colours (third row) are from Cuypers & Seggewiss (1999) corrected to Johnson bands as in Bessel (1983). Last two rows show the effective temperatures and the surface gravities used in our analysis. The former were derived from the Fe ionization equilibrium, the latter were derived from the definition of the effective temperature and from the basic relation between masses, radii and gravities. The last row gives the overall metal abundance used in the abundance analysis.

In Table 2 different values of the individual component temperature difference, as evaluated from different indipendent methods, are listed.

Table 3 list the average Fe abundance obtained for HD 30101, along with the r.m.s. scatter around the mean (typically about 60 Fe I lines were used). We note that while the scatter for individual lines in the abundance analysis of each component are those typically encountered in abundance analysis of solar-type stars with good S/N spectra ($\sim$ 0.1 dex), the r.m.s. scatter for the difference is generally lower. This is because we are performing a strictly

Table 2. Temperature differences between components obtained using various methods: First row: ionization equilibrium for Fe; Second row: excitation equilibrium for Fe I; Third row: temperatures from $V-I$ colours using the calibration by Alonso et al. 1996; Fourth row: from difference in magnitude between the two components times the slope of the main sequence.

	$T_A - T_B$
Ion. eq.	90 ± 13
Exc. eq.	117 ± 27
$V-I$	121
ΔV	83

differential analysis, so that several sources of errors cancel out. The error given in the last row of Table 3 only take into account the line to line scatter.

Table 3. Best Fe abundance difference for the components of HD 30101 binary system.

	[Fe/H]	(r.m.s.)
A	-0.172 ± 0.011	0.091
B	-0.167 ± 0.011	0.095
A–B	0.005 ± 0.005	0.040

The real error bars should also consider the effects of errors in the adopted atmospheric parameters due to errors in the effective temperature. This was done by multiplying the expected errors in the temperature difference between the two stars for the sensitivity of abundances on temperatures, and summing quadratically this term to that due to the line–to–line scatter. The result for HD 30101 is:

$$[\mathrm{Fe/H}]_{\mathrm{A}} - [\mathrm{Fe/H}]_{\mathrm{B}} = 0.005 \pm 0.009$$

In Fig. 7 we report the differences in abundance between the two components of the HD 30101 binary system. The open simbols are related to one line evaluation while filled ones are based on two or more lines.

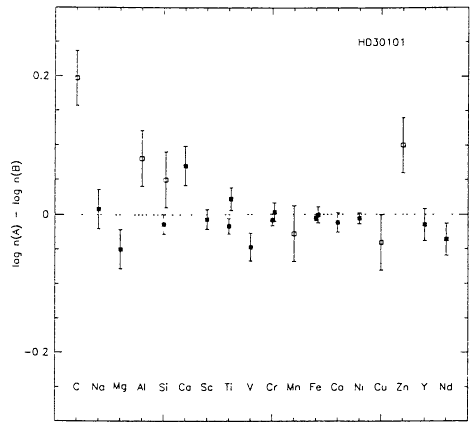

Figure 7. Differences in abundance between the two components of the HD 30101 binary system. The open simbols are related to one line evaluation while filled ones are based on two or more lines.

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