



New Radial Velocity Standards for the RVS

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Abstract

This TN describes new lists of Radial Velocity Standard stars which have been compiled to extend the current catalogue of 1420 candidates.

Document History

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1 Introduction

The need of ~ 1000 radial velocity (RV) standard stars has been established several years ago by the CU6 management. The selection of 1420 appropriate candidates is described in Crifo et al. (2010). A large observing programme has taken place from 2006 to 2012, complemented by archival data, to verify the stability of these targets. The pre-launch version of the catalogue of RV standard stars for Gaia is described in Soubiran et al. (2013). At the 16th CU6 meeting in December 2013, it was stated that this sample is not large enough for the wavelength calibration

module at the beginning of the mission, when no internal RVS standards are yet available. In addition a request was recently made to identify stable stars at the Ecliptic Poles in order to verify some CU6 outputs during the commissioning. New standards are needed. Here we provide 568 such stars, found in the archives of the high resolution spectrographs ELODIE and SOPHIE at OHP, and in our GBOG observations at the NEP. In addition we provide a list of 1691 secondary stars, with high precision RV measurements but no guarantee of stability. Those can be used for some verification of the CU6 pipeline.

2 Criteria for selecting RV standards

The new primary RV standards verify the following conditions :

- $V_{\text{mag}} \leq 11$
- FGK stars : $0.35 \leq B-V \leq 1.25$
- no other star with $\Delta G_{\text{mag}} < 4$ within $80''$. This is performed with the UCAC4 catalogue, taking Johnson-Cousins magnitudes transformed into G magnitudes (Jordi et al., 2010).
- RV stability better than 300 m s^{-1} over several years. For that we consider stars with at least 4 RV measurements available, spanning a minimum of 2 years, and showing a standard deviation lower than 100 m s^{-1} .
- not part of the initial catalogue of 1420 candidates

As secondary stars, we selected all stars with at least 2 RV measurements available, spanning at least 10 days, and showing a standard deviation lower than 700 m s^{-1} . There is no constraint on V_{mag} and spectral type for the secondary stars, nor inspection of their neighbourhood. Such stars might be stable, but the data available is not sufficient to state about their stability.

3 The ELODIE and SOPHIE archives

ELODIE and SOPHIE are two velocimeters successively mounted on the T193 telescope at OHP, with resolving power of $R = \lambda/\Delta\lambda \simeq 42\,000$ and $75\,000$ respectively. SOPHIE has a high efficiency mode with a resolving power of $R = 40\,000$.

The ELODIE archive (Moultaka et al., 2004) includes 26 315 spectra with measured RV. All the RV measurements can be retrieved with relevant information (signal to noise ratio, date of observation,...) as a single file by a command of this type : `http://atlas.obs-hp.fr/`

elodie/E.cgi?n=501&a=t&d=objname,datenuit,imanum,sn,jdb,vfit,sigfit,ampfit,vfit2,sigfit2,ampfit2,masque,imatyp.

From this list, only stars which can be identified with a HIP, TYC or 2MASS number are kept. This is to ensure that the cross-match with the IGSL can be done. Observations of signal to noise ratio lower than 10 were rejected, as well as spurious RV measurements, or those obtained with private masks, or giving a double or enlarged correlation peak. Large series of observations of a single star within the same night (e.g. for asteroseismology follow-up) were reduced to one observation per night (the one with the highest precision). After this cleaning, 21 323 RV measurements remain, for 4 506 different stars.

As of early March 2014, there were more than 71 200 spectra for 5 230 distinct targets in the SOPHIE archive. Almost 37 500 spectra are fully public and more than 28 000 spectra are available with the exact time of observation masked (for a 5-year period), while nearly 4 900 spectra are under the standard 1-year embargo. Similar cleaning as for ELODIE gives 25 184 RV measurements for 4 391 different stars.

The trend between the ELODIE and SOPHIE measurements was determined by a linear regression as a function of the B-V colour (see Fig. 1). For this, only stars with at least 2 measurements in good agreement ($\sigma < 0.5 \text{ km s}^{-1}$) with each instrument were considered. The regression was performed iteratively, by rejecting outliers at the 3σ level. Then the ELODIE measurements were transformed into the SOPHIE scale, using the resulting function $RV_{SOPHIE} - RV_{ELODIE} = 0.301(B - V) - 0.128 \pm 0.05 \text{ km s}^{-1}$.

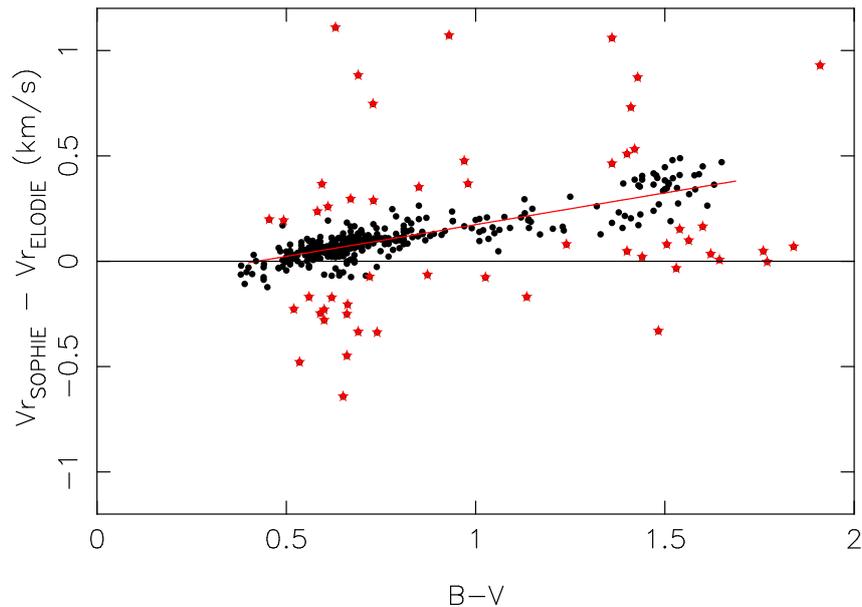


FIGURE 1: Comparison of RV measurements from SOPHIE and ELODIE for common stars. The resulting regression is shown. Outliers are indicated as red stars.

The combination of both lists from SOPHIE and ELODIE gives 7 512 different stars from which the primary RV standards and secondary stars were selected.

4 The NEP observations

A selection of 63 Tycho2 stars around the NEP was performed several years ago in order to prepare the commissioning of the RVS (Crifo et al., 2012). These stars cover a wider field than the EPC. They have been observed with the NARVAL spectrograph at TBL because the primary objective was to obtain spectra of these stars in the RVS range. In its spectroscopic mode, NARVAL has a resolving power of $R = 78\,000$ and covers the spectral range 375–1050 nm. Some NEP stars have been observed several times with NARVAL, and some also with SOPHIE. On those stars with multiple RV measurements, we made similar selections as described in Sect. 2.

5 New primary RV standards

More than 700 bright FGK stars were found to be stable enough to become primary RV standards but $\sim 25\%$ of them were rejected after inspection of their neighbourhood where other objects with $\Delta G_{\text{mag}} < 4$ were found. Those were added in the secondary sample. The remaining 568 primary stars are shown on the celestial sphere (Fig. 2), together with the previous 1420 candidates. Only one new primary standard is found at the NEP, TYC4212-00891-1.

Figure 3 shows the two histograms of the time span between the first and last measurement for the new and previous RV primary standards.

Figure 4 shows the two histograms of the RV variations for the new and previous RV primary standards.

6 Secondary stars

There are ~ 1691 stars with at least 2 consistent RV measurements (see Sect. 2), 37 of which at the NEP. Note that there exists two other compilations of RV measurements, with different criteria, described in Crifo & Sartoretti (FCO-002) and Zwitter et al. (TZ-002).

Figure 5 shows the two histograms of the V magnitudes and B-V colours for the secondary stars. Interestingly one can see a small peak around $B-V=1.5$ which corresponds to large follow-up programs on M dwarfs with ELODIE and SOPHIE.

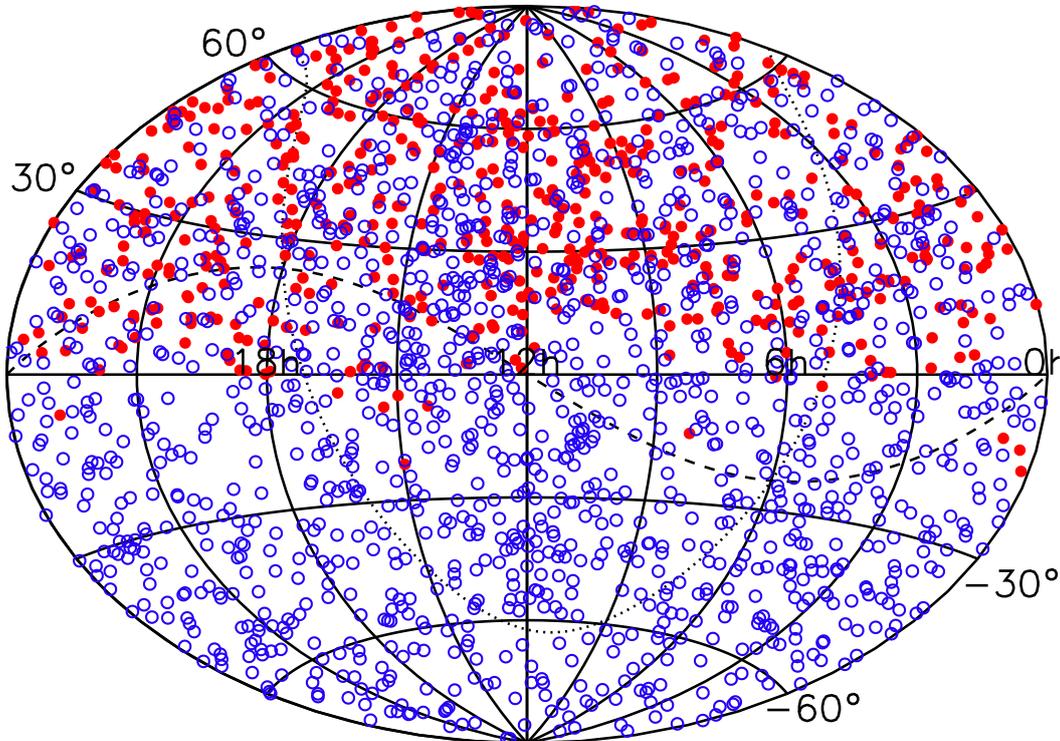


FIGURE 2: Distribution of the 568 new primary RV standards (red dots) and the previous 1420 ones (blue open circles) on the celestial sphere in equatorial coordinates. A dashed line indicates the projection of the Ecliptic plane, a dotted line that of the Galactic plane.

7 Format and distribution

The pre-launch release of the catalogue of 1420 primary standards (Soubiran et al., 2013) is distributed at the CDS <http://cdsarc.u-strasbg.fr/viz-bin/Cat?J/A&A/552/A64>.

The 2 two lists described in this TN are stored on the ESAC disk space created for the GBOG WG : `gbogcom` at `ssh.esac.esa.int, /gbog/cu6/RV-STANDARDS` (password given upon request). The ascii files, described in a ReadMe file, include the HIP, TYC or 2MASS identifier, J2000 equatorial coordinates, Vmag, B-V, spectral type (when known from Simbad), mean RV in SOPHIE scale, internal error of RV, standard deviation, uncertainty, maximum deviation, mean julian day of observations, julian day of last observation, time baseline of observations, number of RV measurements, of SOPHIE measurements, of ELODIE measurements and of rejected measurements.

A pdf file also provides plots of individual measurements for each of the new primary standards,

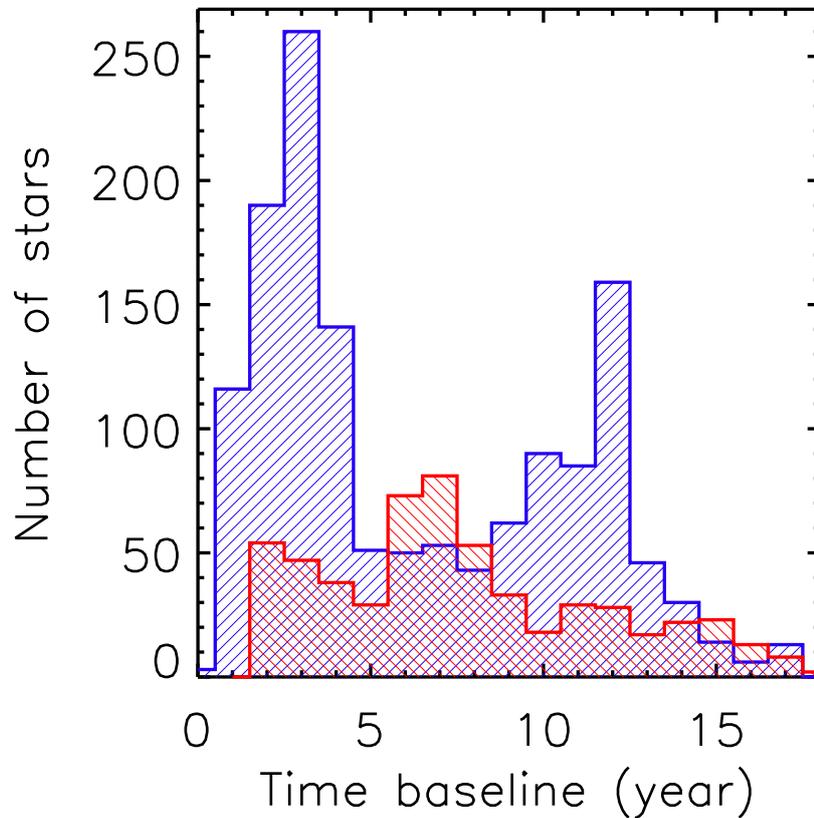


FIGURE 3: Distribution of time baselines of observations for the new and previous RV primary standards in red and blue respectively.

an excerpt of it being shown in Fig. 6.

8 Further improvements

Other primary RV standards should be searched in the southern hemisphere. Unfortunately the HARPS archive at ESO does not allow us to do similar queries than with the ELODIE and SOPHIE archives. However the AMBRE–HARPS catalogue is expected to be released soon (de Laverny, private communication), and the search of new standards will be possible from it.

A new observing program will be organised for the follow-up of the primary standards.

New secondary stars will be compiled from the following catalogues :

- The Geneva-Copenhagen Survey (Nordström et al., 2004)

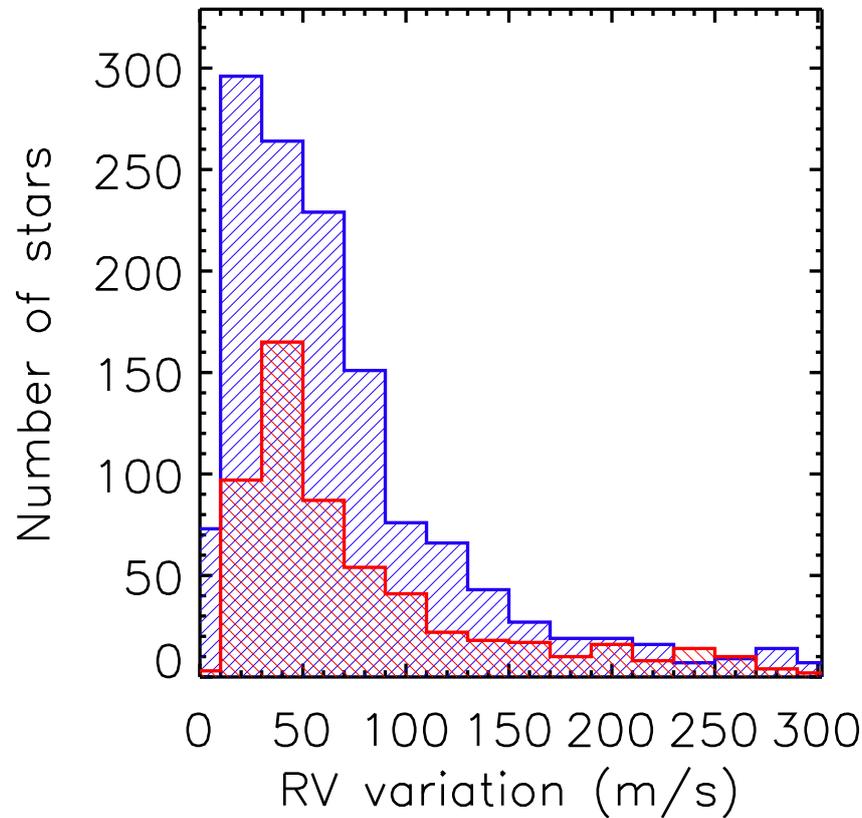


FIGURE 4: Distribution of RV variations of the new and previous RV standard stars in red open circles and blue dots respectively.

- The catalogue of Radial Velocities for 889 Late-Type Stars (Nidever et al., 2002)
- The catalogue of K and M giants from CORAVEL/Hipparcos/Tycho-2 data (Famaey et al., 2005)
- The catalogue of Precise Radial Velocities of 2046 Nearby FGKM Stars and 131 Standards (Chubak et al., 2012)
- The catalogue of Orbital Solutions for 171 Single-lined Spectroscopic Binaries (Latham et al., 2002)
- The AMBRE–FEROS catalogue (Worley et al., 2012)
- Our own RV measurements of the NARVAL–ESPADONS library described in Chemin et al. (LCH-001)

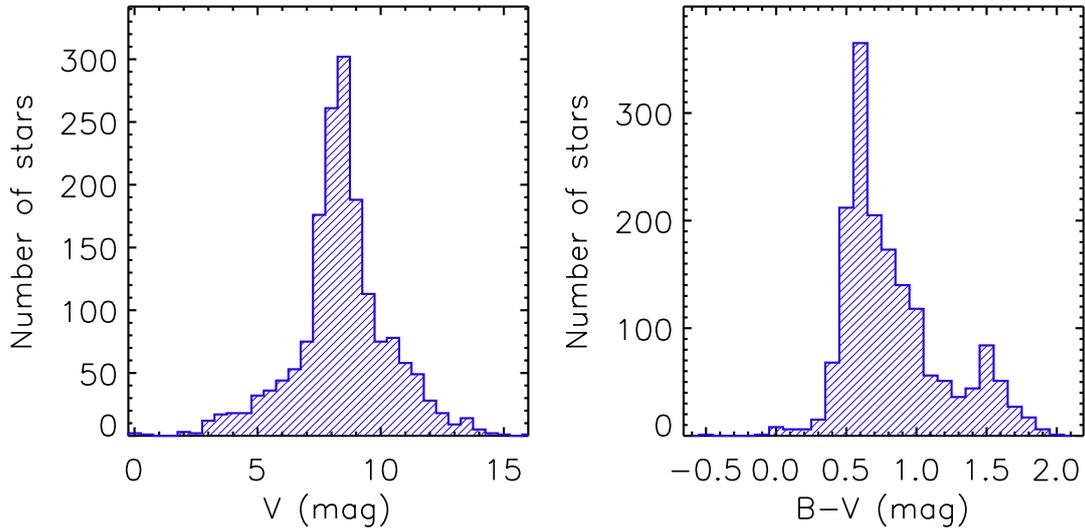


FIGURE 5: Histograms of the V magnitudes and B-V colours for the secondary stars.

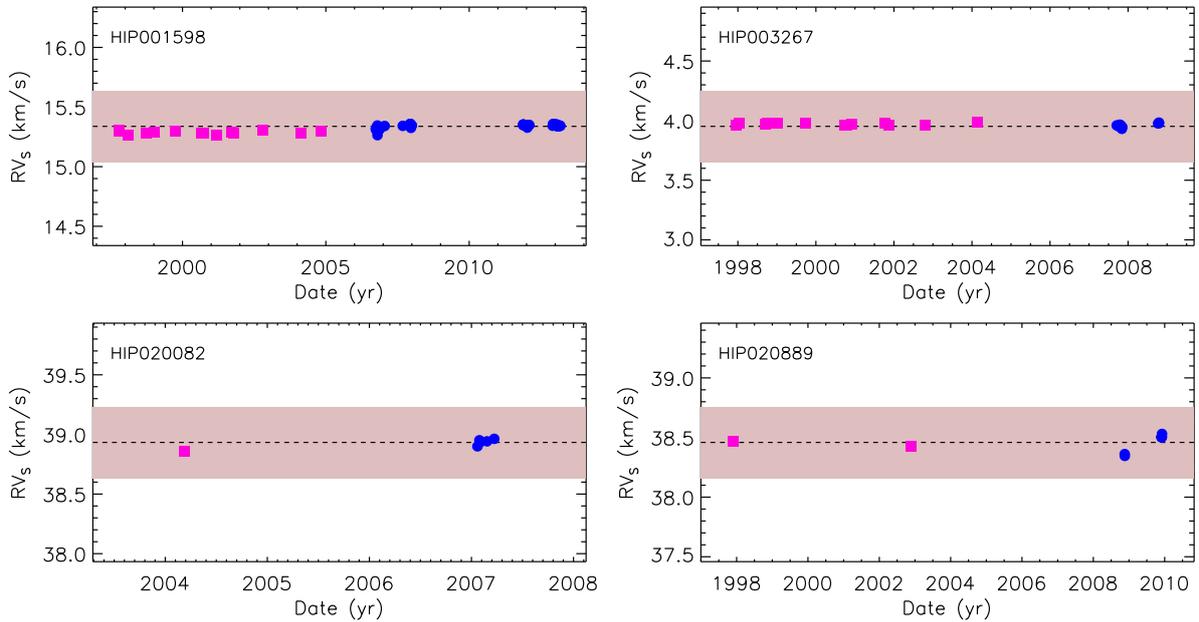


FIGURE 6: RV measurements for some of the new primary standards. The RV axis is centered on $\overline{RV_S}$ and spans 2 km s^{-1} . The shaded area represents the 300 m s^{-1} stability limit. Blue dots represent SOPHIE measurements and pink squares ELODIE measurements.

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Acronym List

The following table has been generated from the on-line Gaia acronym list:

Acronym	Description
2MASS	Two-Micron All Sky Survey
CDS	Centre de Données astronomiques de Strasbourg
EPC	Ecliptic Pole Catalogue
ESAC	European Space Astronomy Centre (VilSpa)
ESO	European Southern Observatory
GBOG	Ground-Based Observations for Gaia (DPAC)
IGSL	Initial Gaia Source List
NEP	North Ecliptic Pole
OHP	Observatoire de Haute Provence (France)
RV	Radial Velocity
RVS	Radial Velocity Spectrometer
TBL	Telescope Bernard Lyot (Pic du Midi, France)
TN	Technical Note
WG	Working Group