The catalog of radial velocity standard stars for the RVS : status and progress of observations

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Abstract

A new full-sky catalog of Radial Velocity standard stars is being built for the determination of the Radial Velocity Zero Point of the RVS on board of Gaia. After a careful selection of 1420 candidates matching well defined criteria, we are now observing all of them to verify that they are stable enough over several years to be qualified as reference stars. We present the status of this long-term observing programme on three spectrographs : SOPHIE, NARVAL and CORALIE, complemented by the ELODIE and HARPS archives. Because each instrument has its own zero-point, we observe intensively IAU RV standards and asteroids to homogenize the radial velocity measurements. We can already estimate that ~8% of the candidates have to be rejected because of variations larger than the requested level of 300 m/s.

Gaia and the Radial Velocity Spectrometer (RVS)

Gaia RVS scientific objectives

- Dynamics and chemistry of the Milky Way
- Detection and characterisation of multiple systems and variable stars
- see Wilkinson, Vallenari, Turon, Munari, Katz et al., 2005, MNRAS, 359, 1306

The spectroscopic survey

- Radial velocities of $\sim 150 \cdot 10^6$ stars ($V \leq 17$)
- Rotational velocities $\sim 5 \cdot 10^6$ stars ($V \leq 13$)
- Atmospheric parameters $\sim 5 \cdot 10^6$ stars ($V \leq 13$)
- Abundances $\sim 2 \cdot 10^6$ stars ($V \leq 12$)

Gaia RVS basic characteristics

- Slitless spectrograph, no calibration module on board
- Grating + dioptric optics, light provided by the 2 astrometric telescopes (superimposed fields, f≒ 35m)
- Spectral domain = [847 nm - 874 nm]; Resolving power = 11500

The RVS will observe each star about 40 times.

Expected accuracy : 1 km/s for stars V~13 (G0V), 15 km/s for stars V~16 (G0V)

How to calibrate the RVS?

Need to initiate the calibration law and define the RV zero point from a large sample of well known and stable reference stars, observed from the ground in advance of the mission.

Observations of reference stars

Selection of candidates

The selection of 1420 star candidates, fully described in Crifo et al. (SF2A 2008, 2009), is performed from the following catalogues :

Nidever et al. 2002 (ApJ 141, 503) (based on échelle spectroscopy)
Nordström et al. 2004 (A&A 418, 989) (based on Coravel)
Famaey et al. 2005 (A&A430, 165) (based on Coravel)
IAU RV-standards (from website of IAU Commission 30)

Observations

The observations, combined with previous measurements in the above catalogues and spectroscopic archives, indicate whether a given candidate is enough stable to be qualified as a standard.

Used spectrographs: SOPHIE (OHP), NARVAL (TBL),
CORALIE (La Silla, Euler swiss telescope)
Spectroscopic archives : ELODIE (OHP), HARPS (ESO)

The candidate stars will be followed until 2017 (end of Gaia mission). One or two new measurements per star are needed BEFORE launch, depending on available data, and one more during the mission.

Number of ground–based observations of Gaia–RVS reference stars done as of June 2010

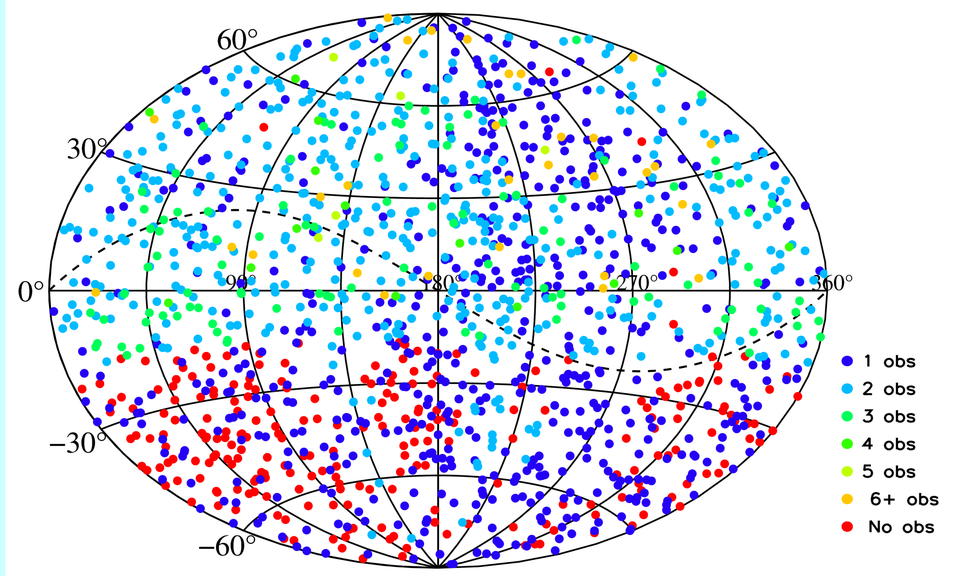

Figure 1: Current status of the survey. The ecliptic is shown as a dashed line.

Status of the observations

A total of 2569 measurements is available so far (new + archived observations).

- NARVAL: 98
- CORALIE: 512
- SOPHIE: 902
- ELODIE: 1057

Figure 1 represents the spatial distribution in the equatorial frame of the number of measurements already obtained for the 1420 candidates.

The majority of stars still lacking observations is located in the Southern part of the sky, because the Southern programme on CORALIE started later. Moreover the query of the ESO archive to retrieve HARPS measurements is still on-going. We already know that 1468 relevant spectra are available in the HARPS archive, but the RV could not yet be retrieved.

In the North (δ > -15°), ~200 stars are still lacking a second observation. The Northern programme should be completed in 2011.

Thanks to the ELODIE archive, we found 30 stars with more than 6 measurements. The most observed star has 83 measurements performed in more than 10 years.

Preliminary results

Because each instrument has its own zero-point, related to the wavelength range, resolution, mask, used software, etc, there are systematic differences in the measured RV. In order to study variations, we have adopted a common reference frame scale for all measured velocities, defined by the ELODIE scale. We found the following preliminary relations:

- VR (ELODIE) – VR (SOPHIE) = - 125 m/s
- VR (ELODIE) – VR (NARVAL) = - 75 m/s
- VR (ELODIE) – VR (CORALIE) = - 91 m/s.

We have compared our averaged RV with those given in Nidever et al. (2002). Figure 2 shows this comparison. The small offset (-40 m/s) illustrates the zero-point issue. Among the 320 points in common with Nidever, there are 27 (~8%) outliers (red symbols) that deviate more than ±300 m/s. Such discrepencies may be caused by variable objects to be rejected as standards.

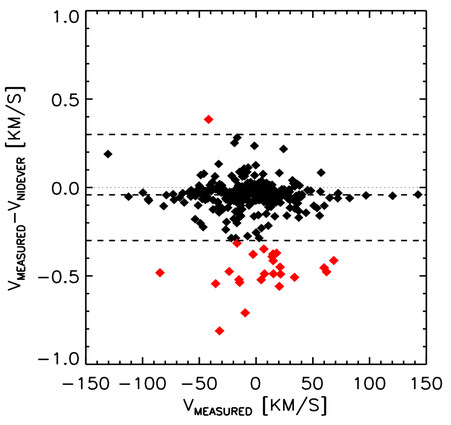

Figure 2: Comparison of RV with those published in Nidever et al. 2002.

Do RV vary significantly with time ?

We have derived the RV variation for each star that has at least two RV measurements. This variation is defined as the difference between the maximum and minimum velocities and its distribution is displayed in Figure 3. 75% of those stars present a scatter in radial velocity smaller than 100 m/s. About 8% of stars exhibit a variation of more than 300 m/s. This result is consistent with the fraction of possible variable stars found in Figure 2.

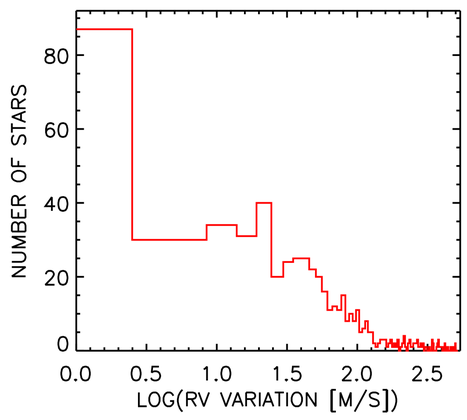

Figure 3: Distribution of RV variations.

For each star we have also derived the time baseline of the RV measurements from our observations and archives. Its distribution is displayed in Figure 4. It shows that most of the stars have been reobserved within 6 months to 2 years. Therefore, following the analysis of Figure 3, the radial velocity is very stable within that average period of 0.5-2 years. Notice the small peak around 10 years of observations, which corresponds to stars observed earlier with ELODIE. It is reassuring to see that RV have a small scatter over such a long elapsed time.

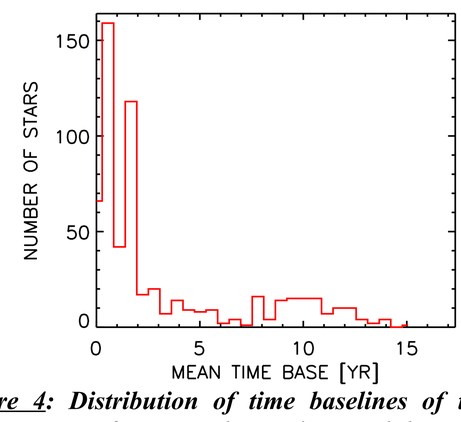

Figure 4: Distribution of time baselines of the RV measurements from our observations and the archives.

Observations of asteroids

Observations of asteroids are very important for this project because they will allow the derivation of the zero point of the radial velocities for all reference sources. Indeed radial velocity of asteroids are theoretically known from celestial mechanics with an accuracy of 1 m/s. 171 measurements of 70 asteroids have been performed until now with SOPHIE.

Figure 5 displays the residual velocity between the observed RV and the theoretical RV as a function of the observed one. The theoretical RV is derived using the INPOP theory and obtained from the MIRIADE webservice of the virtual observatory at IMCCE. The scatter of the residual RV is ~45 m/s and the mean offset between the observed and therotical distributions is ~ -20 m/s (displayed as a dashed line in Figure 5).

Points more deviant than 3σ (red symbols) correspond to low signal-to-noise observations due to bad transparency conditions, or to badly derived velocity centroids due to e.g. multiple peaks in the cross-correlation function. We are currently investigating the correlations of the observed and computed velocities with the physical properties of the asteroids (diameter, rotation, phase,…).

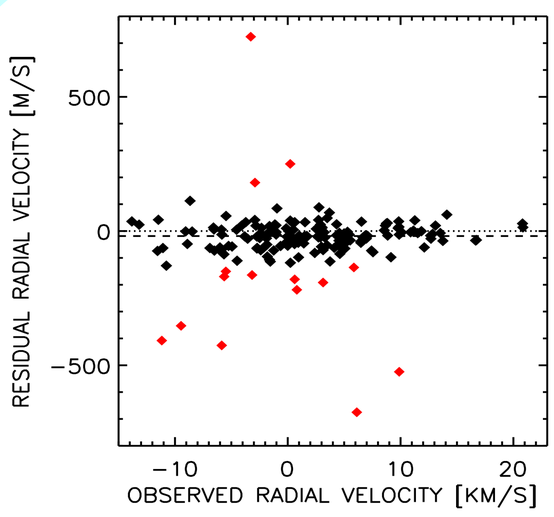

Figure 5: Residual velocities (observed - theoretical) as a function of observed velocities.

Conclusions

A new full-sky catalogue of radial velocities standards, much denser than the IAU standards, is in preparation. It will define the RV zero-point of the Gaia-RVS. It will also be used to initialize the iterative procedure of data reduction.

The follow-up of those 1420 star candidates (plus asteroids) has started in 2006 and will continue until the end of the mission in 2017.

2569 measurements are available so far from the ongoing ground-based Large Program on SOPHIE, CORALIE and NARVAL, complemented by the ELODIE and HARPS data archives.

A first version of the catalog will soon be made available.