Calibration of the Gaia RVS with candidate standard stars observed from the ground

L. Chemin[1,2], C. Soubiran[1], F. Crifo[2], G. Jasniewicz[3], D. Katz[2], D.. Hestroffer[4], S. Udry[5]

L. A. Bordeaux (1), OBSPM-GEPI (2), GRAAL (3), OBSPM-IMCCE (4), Observatoire de Genève (5)

Contact : chemin@obs.u-bordeaux1.fr

Credit (Gaia): http://sci.esa.int/science-e/www/area/index.cfm?fareaid=26

Abstract

The Radial Velocity Spectrometer (RVS) on board of Gaia will perform a large spectroscopic survey to determine the radial velocities of some 2.10^8 stars. We present the status of ground-based observations of the 1420 candidate standard stars, performed with the SOPHIE, NARVAL and CORALIE spectrographs. Each candidate star has to be observed several times before Gaia launch (and at least once during the mission) to ensure that its radial velocity (RV) remains stable during the whole mission. The analysis shows that about 7-8% of the current catalogue exhibits variations larger than the adopted threshold of 300 m/s during an average elapsed time of 3 years. Consequently, those stars should be rejected as reference targets, due to the expected accuracy of the Gaia RVS (1 km/s at best). Emphasis is also put here on our observations of bright asteroids to calibrate our ground-based RVs by a direct comparison with velocities predicted by celestial mechanics. It is shown that the zero points of Sophie, Narval and Coralie are consistent with each other within the uncertainties. Despite some scatter, their temporal variations remain small with respect to our adopted stability criterion.

Gaia Radial Velocity Spectrometer

RVS is a slitless spectrograph whose spectral domain is 847- 874 nm and resolving power R~11500. The expected accuracy is 1 km/s for F0 to K0 stars brighter than V=13, and for K1 to K4 stars brighter than V=14.

The main scientific objectives of RVS are the chemistry and dynamics of the Milky Way, the detection and characterisation of multiple systems and variable stars (for more details, see Wilkinson, et al., 2005, MNRAS, 359, 1306)

Those objectives will be achieved from a spectroscopic survey of

- Radial velocities (~ 150.10^6 stars, V ≤ 17)
- Rotational velocities (~ 5.10^6 stars, V ≤ 13)
- Atmospheric parameters (~ 5.10^6 stars, V ≤ 13)
- Abundances (~ 2.10^6 stars, V ≤ 12)

Each star will be observed ~40 times by RVS over the 5 years of the mission.

Calibration of RVS

RVS has no calibration module on board. Ground-based observations are thus absolutely needed to determine the zero point of the radial velocities from a large sample of well-known, stable reference stars.

Two measurements per star are needed before Gaia is launched (or one, depending on already available archived data), and one during the mission. Both measurements will ensure the temporal stability of radial velocities, the rejection of any targets with significant RV variation and consequently the best calibration law for the RVS.

Spectral observations of stars

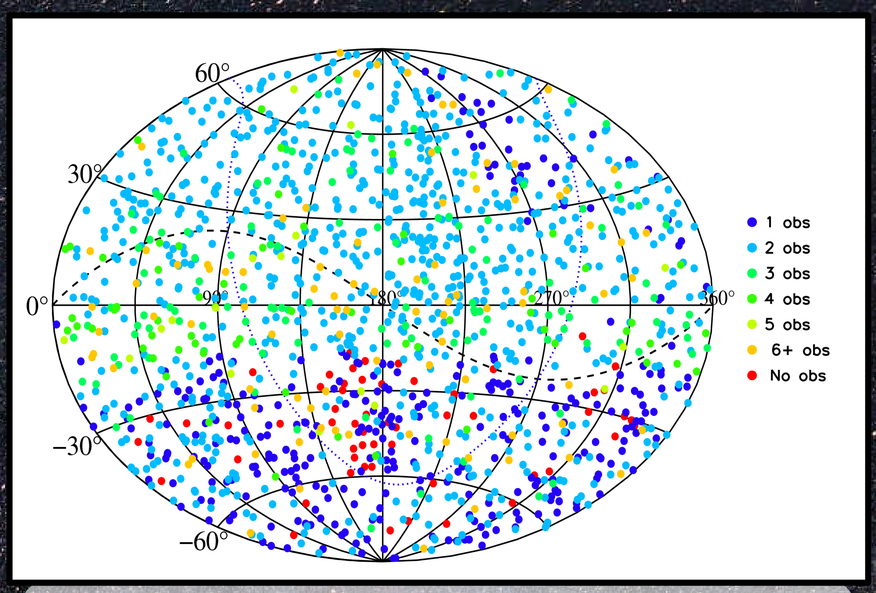


***Figure 1**: Current status of the number of observations available per candidate standard star, including archival data (equatorial coordinates). Ecliptic plane = dashed line; Galactic plane = dotted line.*

The selection of 1420 candidate standard stars described in Crifo et al. (2010, A&A, 524, A10). The ongoing observations are performed with

- SOPHIE on the 1.93-m telescope at Observatoire de Haute-Provence,
- NARVAL on the Télescope Bernard Lyot at Observatoire Pic-du-Midi,
- CORALIE at the Euler swiss telescope at La Silla.

As of June 2011 we have observed:

- 691 stars (1165 velocities) with SOPHIE
- 669 stars (945 velocities) with CORALIE
- 93 stars (98 velocities) with NARVAL

In addition to these new observations, we use previous ones available from the spectroscopic archives of ELODIE (former OHP spectrograph) and HARPS (currently at the ESO La Silla 3.6m telescope), which allow us to recover 1057 velocities for 292 stars (with ELODIE) and 1289 velocities for 113 stars (with HARPS). Figure 1 represents the spatial distribution in the equatorial frame of the number of measurements already obtained for the 1420 candidate standard stars and Figure 2 displays the velocity field of the sample.

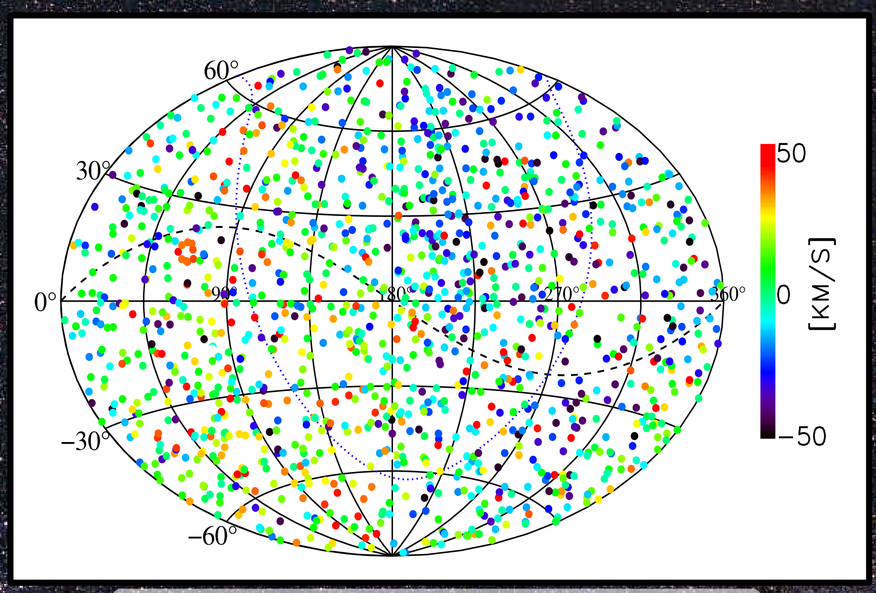
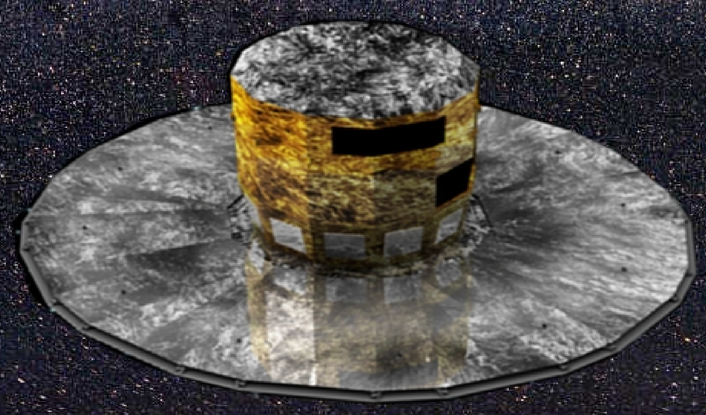


***Figure 2**: Velocity field of the candidate standard stars.*



How stable are the radial velocities?

We have derived the variation of radial velocity for each star that has at least two RV measurements (1051 among 1420 stars). This variation is defined as the difference between the maximum and minimum velocities (in the SOPHIE frame) distribution is displayed in Figure 3. A candidate is considered as a reference star for the RVS calibration when its radial velocity does not vary by more than an adopted threshold of 300 m/s as a function of time. Such a threshold has been defined so that it must be well smaller the maximum expected accuracy of the RVS (1 km/s for the brightest stars).
It turns out that 75.4% of the stars have very stable RV at a level of less than 100 m/s (as derived from all available measurements as of 2011). 7.1% of stars exhibit a variation of more than 300 m/s. Those variable stars will have to be rejected from the list of standard stars.

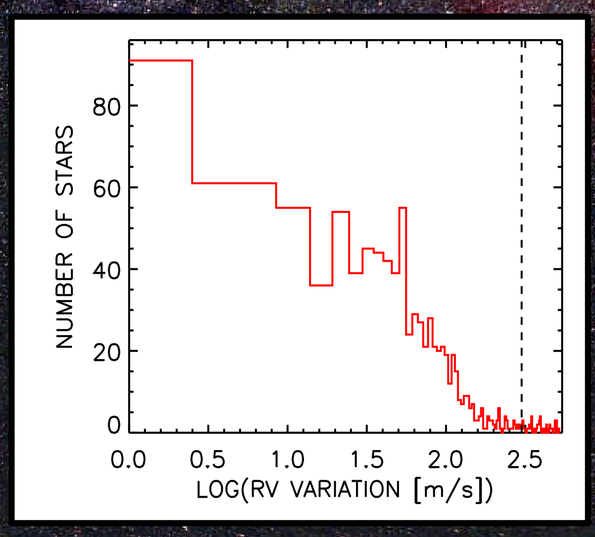


***Figure 3**: Distribution of variations of radial velocities of candidate standard stars. A dashed line shows the adopted 300 m/s stability threshold.*

Spectral observations of asteroids

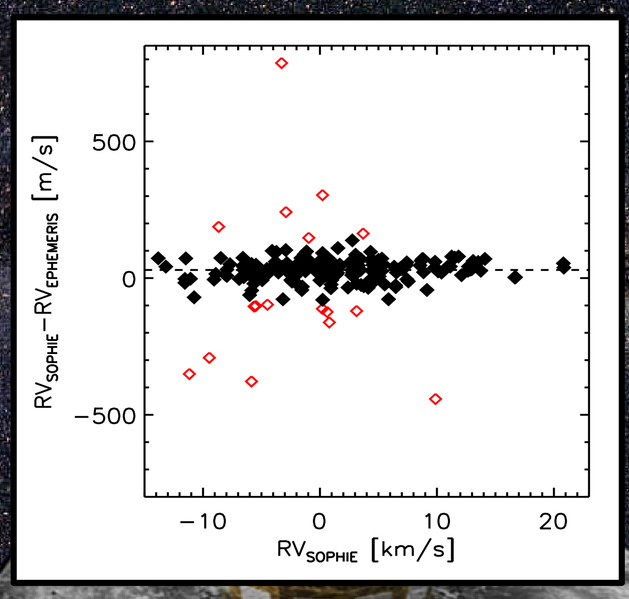


***Figure 4**: Residual velocities (observed-calculated) of asteroids as a function of their observed velocities (Sophie observations only). Red symbols are points deviant by more than 3σ.*

Observations of asteroids are very important for the calibration. Indeed they will allow the derivation of the zero point of the RVs for SOPHIE, CORALIE and NARVAL. This point will be achieved by comparing our ground-based measurements of RVs of asteroids with theoretical RVs, which are known from celestial mechanics with an accuracy better than 1 m/s. The theoretical RVs are derived using the using the ephemerides from IMCCE (http://www.imcce.fr). About 280 measurements of 90 asteroids have been done so far.

As an illustration, Figure 4 displays the residual velocity (observed minus theoretical RVs) of asteroids observed by the SOPHIE instrument as a function of the observed RVs. The average residual of asteroids observed with SOPHIE is 30 m/s and the scatter is 38 m/s.

In Figure 5 we show the variation of the residual RVs as a function of time. The graph nicely shows how stable are the instruments as a function of time. The error-bars represent the dispersion of all measurements performed at each observational session. Their amplitude is mainly related to the conditions of observation, that differ from one session to another (like e.g., the contamination by moonlight). Though significant (between 10 and 50 m/s) those error-bars remain well smaller than our target stability criterion of 300 m/s, which will enable us to determine the RV zero point of each instrument.

Notice we have furthermore verified that intrinsic properties of asteroids (e.g. their size, shape, rotation velocity, albedo, etc...) have negligible systematic impacts on the determination of RVs zero points for the spectrographs.

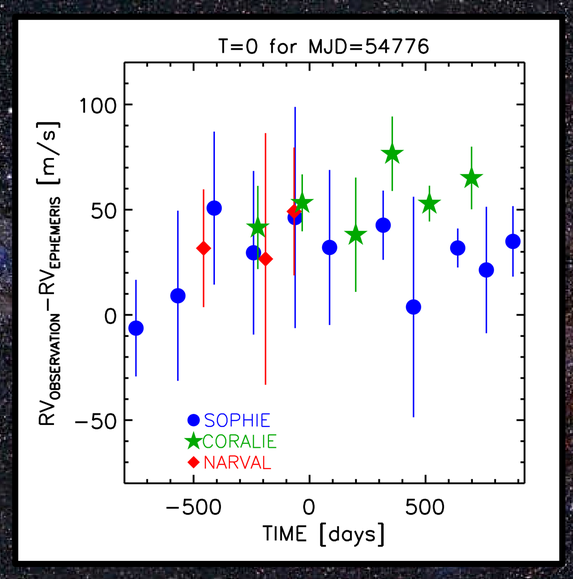


***Figure 5**: Comparison of residual velocities of asteroids for SOPHIE, CORALIE and NARVAL as a function of time.*