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GROUND-BASED FOLLOW-UP OF THE GAIA-RVS RADIAL VELOCITY STANDARDS

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Abstract. The RVS spectrograph on board of Gaia having no calibration device, radial velocity standards are needed to calibrate the zero-point of the instrument. We have prepared a list of 2798 such stars, well distributed over the sky, and compiled ∼25 000 individual RV measurements from ground-based velocimeters. For a fraction of these stars, their stability at the 300 m s^{-1} level during the Gaia mission has still to be assessed. The catalogue and follow-up programme are presented.

Keywords: stars, radial velocity, Gaia

1 Introduction

After a successful launch on 19 December 2013 and several months of commissioning activities, Gaia started its regular observations in July 2014. Gaia is currently continuously scanning the sky in TDI (Time Delay Integration) mode, observing all objects brighter than G = 20.7, including the bright objects down to magnitude 2-3. In addition to the position, parallax and proper motion being measured for one billion stars, radial velocity (RV) is also determined for the ∼100 million brightest stars (down to G ∼ 16) with the Radial Velocity Spectrometer (RVS, Katz et al. 2004; Cropper & Katz 2011). RV measurements will start to be published in the second Gaia Data Release expected end 2017. The RVS is an integral-field spectrograph with resolving power of ∼11 500 covering the near infra-red wavelength range 845 to 872 nm. The RVS will record 40 epochs on average per source during the 5 years of the mission. At the end of the mission in 2019, the RV precision is expected to be 1 km s^{-1} for GK stars down to G = 12-13. Fig. 1 shows the RVS spectrum of one of our targets compared to a NARVAL spectrum of the same star convolved at the RVS resolution. The latest news about Gaia can be found on the ESA website*, together with the science performances updated after the commissioning.

The RVS has no calibration device. The internal calibration uses all bright, well behaved and stable FGK stars to establish the wavelength scale. The zero-point of the RVs needs however to be calibrated with RV standards (RV-STDs) known in advance and proved to be stable during the Gaia observations at the level of 300 m s^{-1}. When we started to look for suitable RV-STDs in 2006, no catalogue was existing, fulfilling the RVS requirements in terms of number of stars, magnitude range, sky coverage and precision. Crifo et al. (2010) estabished a list of 1420 RV-STD candidates, all part of the Hipparcos catalogue and selected in 3 sources of RVs : 'Radial velocities of 889 late-type stars' (Nidever et al. 2002), 'Radial velocities for 6691 K and M giants' (Famaey et al. 2005), and 'The Geneva-Copenhagen Survey of Solar neighbourhood' (Nordström et al. 2004), complemented with IAU standards (Udry et al. 1999). All these stars were observed between 2006 and 2012 with ELODIE and SOPHIE at OHP, NARVAL at TBL and CORALIE at the Swiss Euler telescope at La Silla. The archives of these instruments, as well as the HARPS archive, have been queried to complement our observations. These velocimeters all use the same cross-correlation pipeline and masks, so their measurements are homogeneous. The resulting pre-launch version of the catalogue of RV-STDs for Gaia includes 10 214 RV measurements for 1 420 stars, and is presented in Soubiran et al. (2013). The catalogue is made of 2 tables available at the CDS, one with the basic information on the stars and mean RVs and errors, the other one displays the individual measurements.

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2 The updated catalogue of RV standards for Gaia

The need of additional RV-STDs was expressed in December 2013 by the scientists in charge of the RVS pipeline. In 2006, the first estimate of ∼1000 necessary stars was based on the fact that Gaia should observe one RV-STD per hour. Later studies showed that the RVS calibration needs at least twice more RV-STDs. Our group was in charge of finding these additional candidates. They were searched in the archives of ELODIE (Moultaka et al. 2004), of SOPHIE and of HARPS taking advantage of the large number of FGK stars followed-up in exoplanet programmes, the observations of which are now public. There are indeed many stable stars in the archives, nicely fulfilling the RVS requirements.

Briefly the RV-STDs must be FGK stars brighter than V = 11, with no other star within 20 arcsec (80 arcsec initially). The RV stability at the level of 300 m s^{-1} was assessed by considering stars with at least 2 consistent RV measurements over a minimum time baseline of 300 days. The potential binaries, identified as such in Simbad or XHIP (Anderson & Francis 2012), were eliminated. Then we considered the stars showing a standard deviation, $\sigma_{\rm RV}$, lower than 100 m s^{-1} (corresponding to the stability level of $3\sigma_{\rm RV} \leq 300$ m s^{-1}). Note that all the measurements were transformed into the SOPHIE scale, the small offsets between the different instruments being corrected as explained in Soubiran et al. (2013). As a consequence the RVS final RVs will be in the SOPHIE scale.

We have now a total of 2 798 RV-STD candidates, shown on the celestial sphere in Fig. 2 : 1209 are from the initial catalogue, 1589 are new ones. Fig. 3 shows typical examples of stable stars found in the combined archives.

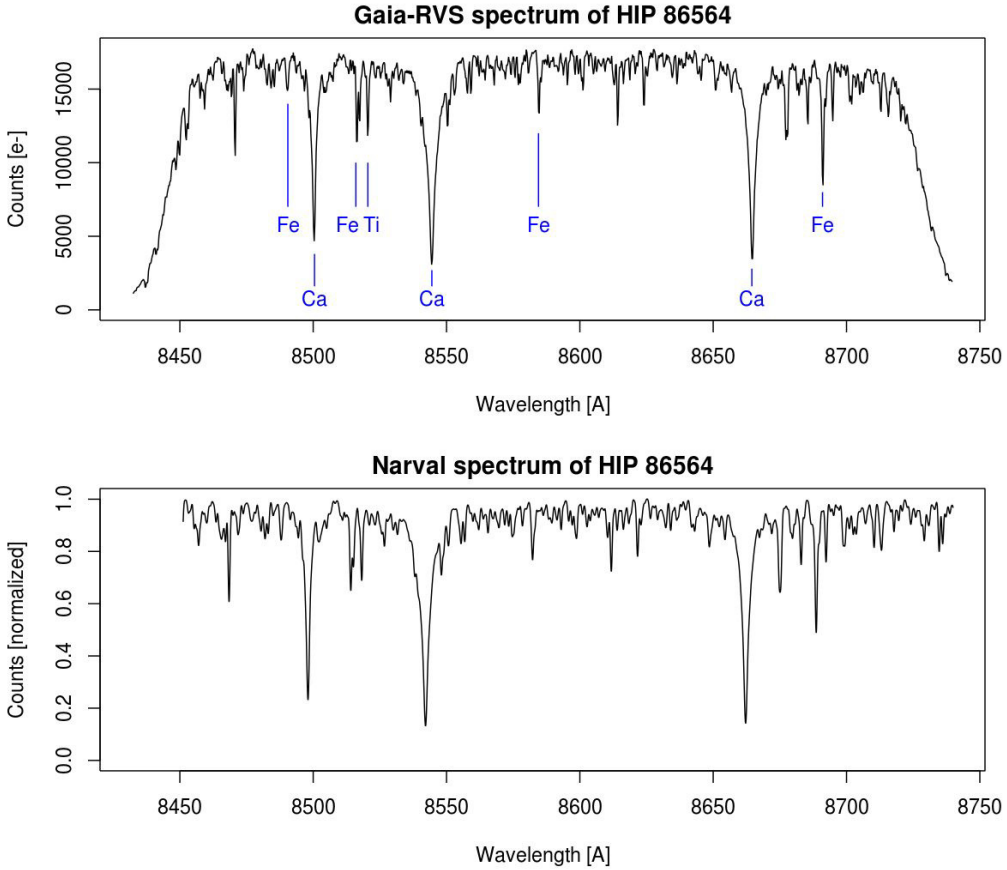

Fig. 1. HIP086564 is a bright V=6.64 K5 star observed by the RVS during the commissioning phase, and previously observed by us with NARVAL. This image has been published on the ESA web site as "Image of the Week" in June 2014.

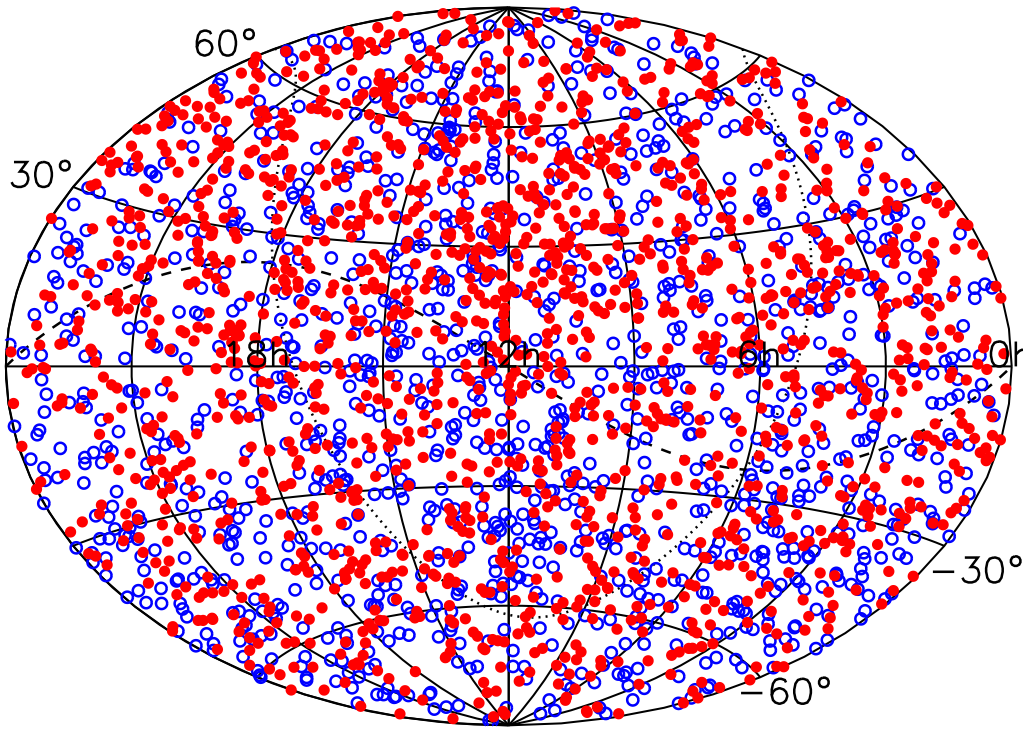

Fig. 2. Distribution of the RV-STD candidates on the celestial sphere in equatorial coordinates : blue open circles for the initial catalogue (Soubiran et al. 2013), red dots for the new ones. The dashed line indicates the projection of the Ecliptic plane, the dotted line that of the Galactic plane.

3 Follow-up programme

At this stage, most of the selected stars are only RV-STD candidates. Their stability at the level of 300 m s^{-1} during the Gaia mission (end in 2019) has still to be confirmed with new ground based observations (Crifo et al. 2015). There are 1 632 stars for the northern follow-up programme, already observed with ELODIE, SOPHIE, or NARVAL. We have already gathered a total of 24 865 individual RV measurements for these stars. However, not all the 1 632 stars have to be re-observed, depending on the number and time baseline of the already available RV measurements, and the date of the last observations. A total of 1072 northern stars have been selected to be re-observed with SOPHIE because they lack recent observations. This is a higher limit since the number of stars is revised each semester by querying the SOPHIE archive for public observations of our stars made by other groups. The follow-up of the 1072 northern stars started in September 2014, and is ongoing at a rate of 6 nights per semester. About 30% of the programme is achieved, with only one star found to exhibit variations larger than 300 m s^{-1}.

For the Southern programme we will use CORALIE. In addition, we will query again the HARPS archive to complement our own observations.

4 Conclusion

The catalogue of RV-STDs is mandatory for Gaia, for the RVS calibration, but it will also be useful for other projects. It is a unique dataset considering the number of stars, the homogeneity and precision of the RV measurements and their time baseline up to 20 years. For instance, the Gaia ESO survey (Gilmore et al. 2012) has already observed some of our RV- STDs for the validation of their Giraffe and UVES radial velocities. The USNO Astronomical Almanach lists our most stable stars in their section about Radial Velocity Standard Stars. This work is also an example of exploitation of the archives of spectrometers.

We thank the Programme National Cosmologie et Galaxies for supporting the observations at OHP.

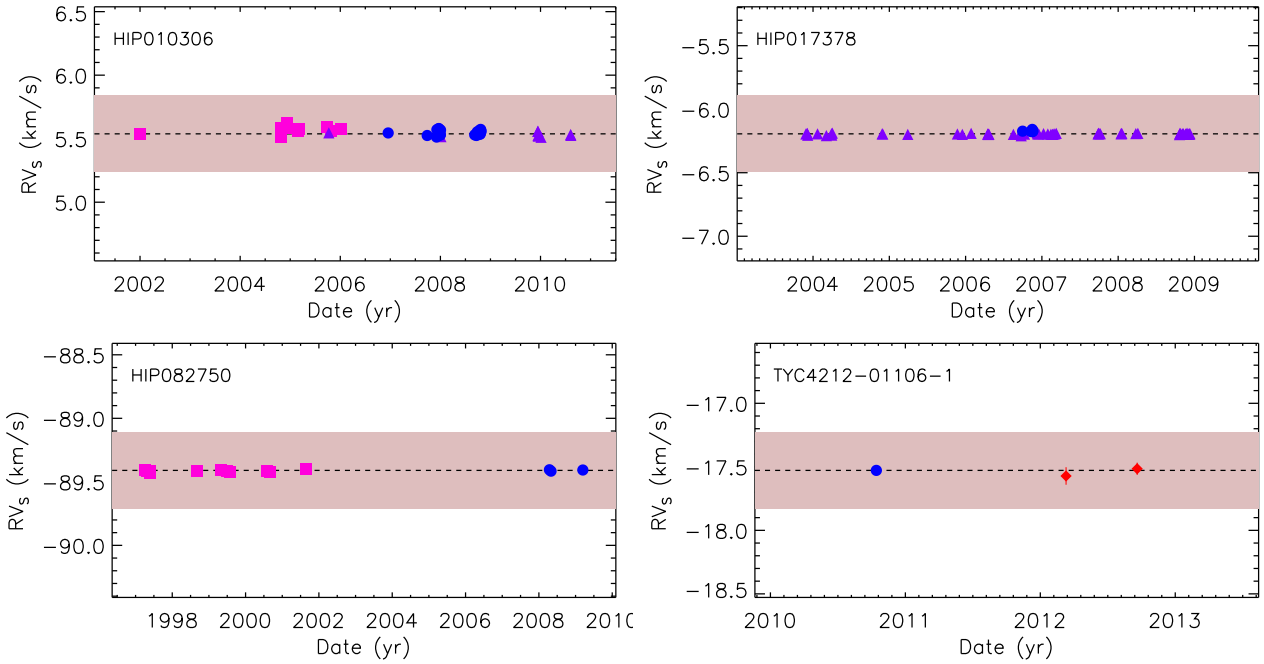

Fig. 3. RV measurements for some of the new RV-STD candidates. The pink squares, blue dots, red diamonds and purple triangles are respectively ELODIE, SOPHIE, NARVAL and HARPS measurements. The RV axis is centered on the mean RV and spans 2 km s^{-1}. The shaded area represents the 300 m s^{-1} stability limit.

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