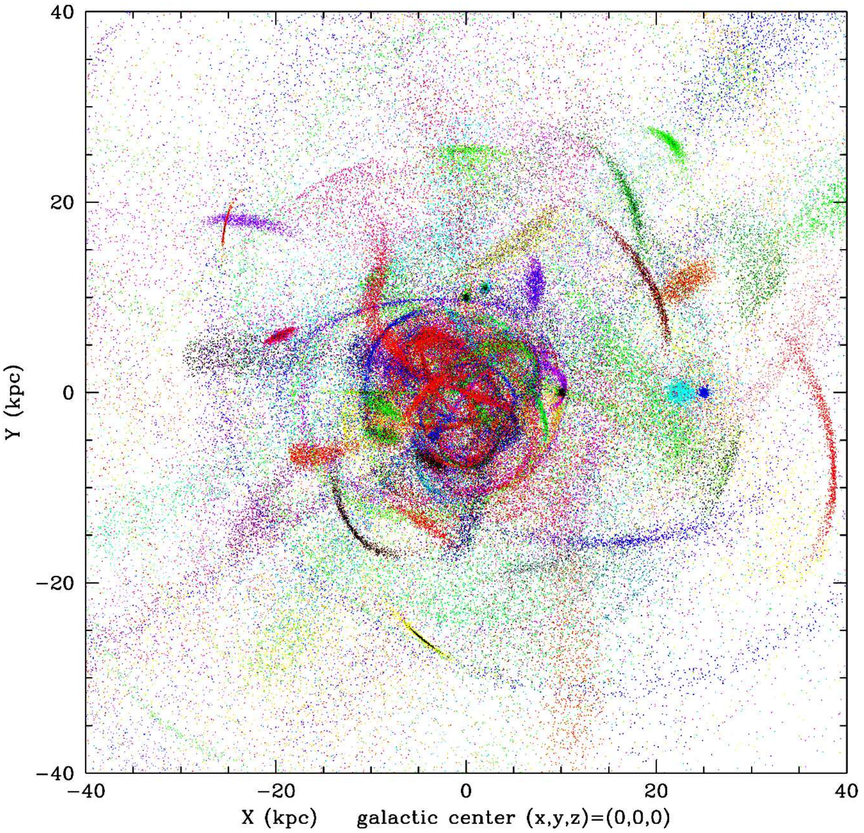


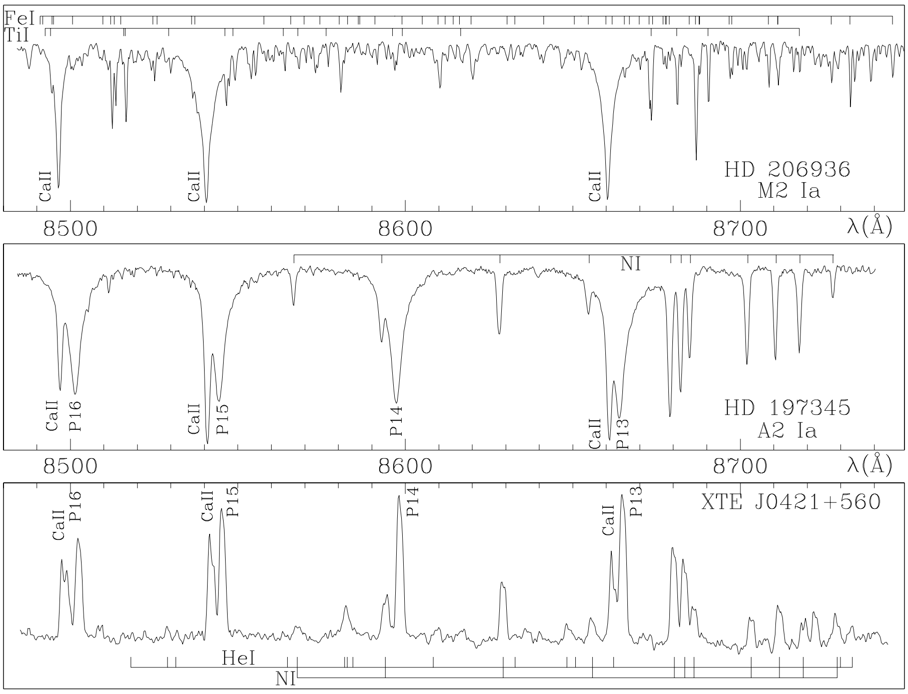
Simulation of a galactic halo formed by accretion of 50 dwarf galaxies over a period of 10 Gyr. Each colour represents an accreted satellite galaxy. Gaia's data will allow astronomers to identify and characterise the accretion events that have taken place in the halo of the Milky Way. Image courtesy of A. Helmi and the 'Spaghetti Project Survey' team.

The primary objective of the Gaia's Radial Velocity Spectrometer (RVS) instrument is the acquisition of radial velocities. These line-of-sight velocities complement the proper-motion measurements provided by the astrometric instrument. Together, these data provide the means to decipher the kinematical state and dynamical history of our Galaxy.

The RVS will provide the radial velocities of about 100-150 million stars up to 17-th magnitude with precisions ranging from 15 km s^{-1} at the faint end to 1 km s^{-1} or better at the bright end. Gaia's data will radically improve our understanding of the Milky Way. It will allow us to probe the gravitational potential and the distribution of dark matter throughout the Galaxy, to map the spiral structure of the Galactic disc, to disentangle, characterise, and constrain the origin and evolution of the stellar populations of the Galaxy, to recover the history of the halo accretion events, and to test the paradigm of the hierarchical formation of galaxies.

The RVS will collect, on average, $\sim$40 (transit) spectra per star over the 5 years of the mission. The associated multi-epoch radial-velocity information will be ideally suited for identification and characterisation of double and multiple systems. In particular, Gaia will provide masses and radii accurate to a few per cent for thousands of eclipsing binaries. The RVS will also monitor the radial motions of the outer layers of pulsating stars. It will provide pulsation curves for RR Lyrae stars, Cepheids and Miras up to $\sim$14-th magnitude. Radial velocities will also be used to correct the astrometric data of nearby, fast-moving stars for the effects of 'perspective acceleration'.

The RVS wavelength range, 847–874 nm, is a rich domain. It will not only provide radial velocities, but also many stellar and interstellar diagnostics. The RVS data will effectively complement the astrometric and photometric observations of Gaia's targets, improving object classification. RVS data will also contribute to the derivation of stellar atmosphere parameters, in particular effective temperature, surface gravity, and overall metal abundances. Individual abundances of key chemical elements, e.g. Ca, Mg and Si, will be derived for millions of stars up to $\sim$12-th magnitude, bringing major improvement in our knowledge of the chemical history and the enrichment processes of the Galaxy. Information on many facets of stellar physics will be extracted from the spectroscopic observations, for example, stellar rotation, chromospheric activity, and mass loss. Finally, from the 862-nm Diffuse Interstellar Band (DIB), RVS data will allow astronomers to derive a 3-dimensional map of interstellar reddening.



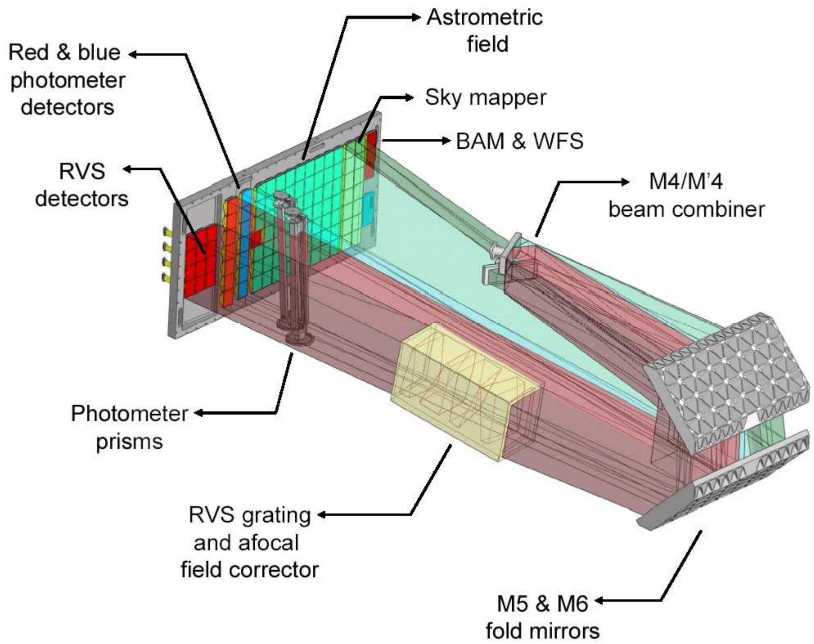
Spectra of the late-type star HD 206936 (top), of the early-type star HD 197345 (middle), and of the X-ray-transient star XTE J0421+560 (bottom), obtained with the echelle spectrograph mounted on the Asiago 1.82-m telescope. The different morphologies of the spectra outline the classification potential of the RVS wavelength range. Figure courtesy of U. Munari.

The Radial Velocity Spectrometer (RVS) is an integral-field spectrograph dispersing the light of the field of view with a resolving power R $\sim$ 11,500. The RVS instrument, like the astrometric and photometric instruments, operates in TDI (time-delayed integration) mode, observing each source about 40 times during the 5 years of the mission. The RVS wavelength range, 847–874 nm, has been selected to coincide with the energy-distribution peaks of G- and K-type stars which are the most abundant RVS targets. For these late-type stars, the RVS wavelength interval displays, besides numerous weak lines mainly due to Fe, Si, and Mg, three strong ionised Calcium lines (at around 849.8, 854.2, and 855.2 nm). The lines in this triplet allow radial velocities to be derived, even at modest signal-to-noise ratios. In early-type stars, RVS spectra may contain weak lines such as Ca II, He I, He II, and N I, although they will generally be dominated by Hydrogen Paschen lines.

Over the 5 years of the mission, the RVS will observe $\sim$5 billion (transit) spectra of the brightest 100–150 million stars on the sky. The on-ground analysis of this spectroscopic data set will be a complex and challenging task, not only because of the data volume but also because the spectroscopic data analysis relies on the multi-epoch photometric and astrometric data. As a consequence, the extraction of radial velocities and astrophysical parameters from Gaia's observations will be performed in a fully automated fashion. Automated methods will also be used to analyse the RVS spectra to extract, for example, chemical-element abundances, rotational velocities, and interstellar reddening.

Radial velocities will be obtained by cross-correlating observed spectra with either a template or a mask. An initial estimate of the source atmospheric parameters derived from the astrometric and photometric data will be used to select the most appropriate template or mask. Iterative improvements of this procedure are foreseen. For stars brighter than $\sim$15-th magnitude, it will be possible to derive radial velocities from spectra obtained during a single field-of-view transit. For fainter stars, down to $\sim$17-th magnitude, accurate summation of the $\sim$40 transit spectra collected during the mission will allow the determination of mean radial velocities.

Atmospheric parameters will be extracted from observed spectra by comparison of the latter to a library of reference-star spectra using, e.g., minimum-distance methods, principal-component analyses, or neural-network approaches. The determination of the source parameters will also rely on the information collected by the other two instruments: astrometric data will constrain surface gravities, while photometric observations will provide information on many astrophysical parameters. Details of the procedures with which to optimally 'combine' Gaia's astrometric, photometric, and spectroscopic data are currently being studied.



Schematic figure illustrating the location of the RVS optical module and CCDs. Figure courtesy of EADS Astrium.

The primary aim of the Radial Velocity Spectrometer (RVS) instrument is the acquisition of spectra for the brightest 100–150 million stars on the sky, down to 17-th magnitude. These spectra, mainly through extracted radial-velocity information, are crucial for the study of the kinematical and dynamical history of the Milky Way.

The RVS instrument is a near-infrared (847–874 nm), medium-resolution ($R = \lambda/\Delta\lambda \sim 11{,}500$), integral-field spectrograph dispersing all the light entering the field of view. The RVS instrument is integrated with the astrometric and photometric instruments and telescopes; the RVS CCDs are located in the Gaia focal plane. RVS uses the (astrometric) Sky Mapper function for object detection and confirmation. Objects will be selected for RVS observation based on measurements made slightly earlier in the Red Photometer. Light from objects coming from the two viewing directions of the two telescopes is superimposed on the RVS CCDs.

The spectral dispersion of objects in the field of view is materialised by means of an optical module physically located between the last telescope mirror (M6) and the focal plane. This module contains a grating plate, a filter plate, and four fused-silica lenses which correct the main aberrations of the off-axis field of the telescope. The RVS module has unit magnification which means that the effective focal length of the RVS equals 35 m. Spectral dispersion is oriented in the along-scan direction. A dedicated passband filter restricts the throughput of the RVS to the desired wavelength range. The total throughput of the telescope (6 Silver reflections), the grating plate, the four dioptric elements, and the bandpass rejection filter is $\sim$30% at the central wavelength of the spectrograph (this value includes the CCD quantum efficiency).

The RVS-part of the Gaia focal plane contains 3 CCD strips and 4 CCD rows. With an assumed dead time of 20%, each source will thus typically be observed during $\sim$40 field-of-view transits throughout the 5-year mission. On the sky, the RVS CCD rows are aligned with the astrometric and photometric CCD rows; the resulting semi-simultaneity of the astrometric, photometric, and spectroscopic transit data will be advantageous for variability analyses, scientific alerts, spectroscopic binaries, etc. All RVS CCDs are operated in TDI (time-delayed integration) mode. The RVS CCDs have 4500 TDI lines and 1966 pixel columns ($10 \times 30\ \mu m^2$ pixels) and are red enhanced with high resistivity.

RVS spectra will be binned on-chip in the across-scan direction. All single-CCD spectra are transmitted to the ground without any further on-board (pre-)processing. For bright stars, single-pixel-resolution windows will be used. The RVS will be able to reach object densities on the sky of at least 36,000 objects deg^{-2}.