3rd GAIA space mission radial velocity spectrometer workshop

Ljubljana, 9-11 June 2002

Summary of the contributions

RVS-CoCo-005

(T. Zwitter, D. Katz, U. Munari)

Ulisse Munari:	Spectral works in progress at Asiago, Ljubljana and Trieste

A status report about the spectral works in progress within the Asiago-Ljubljana-Trieste group is presented and discussed. They are aimed to provide the widest observational and synthetic base for evaluating GAIA potential and to provide the inputs for simulation of GAIA spectral observations and strategies of data reading, compression, reduction and analysis.

- *Sordo, Munari: ADSD, the Asiago Database of Spectrophotometric Databases.*
  ADSD censes, documents and homogenizes 25 databases of ultraviolet real spectra (70$\leq \lambda \leq$ 3200 Å, 4165 spectra, IUE excluded), 120 databases of optical real spectra (3000$\leq \lambda \leq$ 10000 Å, 14024 spectra), and 18 databases of infrared real spectra (1$\leq \lambda \leq$ 22 μm, 6325 spectra). An interrogation web interface is provided.

- *Munari, Marrese, Pavlenko: An atlas of real and synthetic Carbon star spectra.*
  GAIA-like real spectra of Carbon stars have been secured to map the Keenan & Morgan 1941 (ApJ 94, 501) classification scheme, and a grid of GAIA-like synthetic Carbon star spectra have computed for $^{12}C/^{13}C$=3,10, C/O=1.1, 1.2, 1.3, $\log g$=0.0 and T_{eff}=2600, 2800, 3000, 3200, 3500, 4000, 4500 K in order to evaluate the diagnostic potential of GAIA spectroscopy of Carbon stars.

- *Marrese, Munari, Jorissen, Zwitter: An atlas of real S-type star spectra.*
  GAIA-like real spectra of S-type stars have been secured to map the Keenan & Boeshaar 1980 (ApJS 43, 379) classification scheme in order to evaluate the diagnostic potential of GAIA spectroscopy of S-type stars.

- *Munari, Zwitter, Marrese, Tomasella, Boschi:*
  An atlas of GAIA spectra of peculiar stars.
  GAIA-like real spectra of more than 110 peculiar stars have been obtain to evaluate their diagnostic and classification potential. The observed peculiar stars include objects from the classes of RR Lyr, Classical Cepheids, Pop II Cepheids, Dwarf Cepheids, δ Del, Mira, Semi-regular, RV Tau, β CMa, Be, MWC 560, LMXRB, HMXRB,

β Lyr, Flare, RS CVn, FK Com, BY Dra, Magnetic, V_{rot}, O runaway, WR, R CrB, post-AGB, VV Cep, Symbiotics, CVs, Novae, Old Novae, Recurrent Novae, M31-RedVar, Shell, A-shell, Am, Ap, Sr-Cr-Eu, λ Boo, H-deficient, J stars, Barium, CN, CH, DIBs-UIPs-ISM, pre-ZAMS, Herbig Ae/Be stars.

- *Marrese, Boschi, Munari:* *Additional spectral mapping of cool spectral types.*
  Following the publication by Munari and Tomasella (1999, A&AS 137, 521) of an atlas of 130 GAIA-like spectra mapping the MKK classification system, further observational effort has been put in extending the mapping toward the cooler spectral types (from F0 to M9) that will be the dominating ones for GAIA. Additional 105 stars have been observed in exactly the same fashion as for Munari and Tomasella's atlas, to the aim of filling in some gaps in the grid and including objects over a wide range of metallicities.

- *Zwitter, Castelli, Munari:* *A final synthetic GAIA database of 10^5 spectra.*
  Following the publication of the atlases of GAIA synthetic spectra by Munari and Castelli (2000, A&AS 141, 141) and Castelli and Munari (2001, A&A 366, 1003) comprising about 1000 spectra, we have almost completed the computation of a much larger grid (containing 10^5 individual spectra) by a finer mapping in surface gravity and metallicity, and by providing the same set of spectra for 5 different resolutions (spanning the range currently considered for GAIA) and 12 different rotational velocities. In a limited number of cases also varying [α/Fe] has been introduced in the grid. The range of explored parameters are: $3500 \leq T_{eff} \leq 50000$, $-4.0 \leq$[Z/Z$_\odot$]$\leq +1.0$, $0.0 \leq \log g \leq 5.0$, $8400 \leq \lambda \leq 8750$, 5000 $\leq$Resolution$\leq$ 20000, $0 \leq V_{rot} \leq 500$, [α/Fe]=0.0, 0.2, 0.4.

- *Zwitter, Munari:* *Building up a 2500-10500 Å synthetic spectral library.*
  For its interest to GAIA photometry and assessment of the photometric system, we are also computing an extended library of synthetic spectra with parameters similar to the above ones (even if at a reduced priority) for the much larger wavelength range $2500 \leq \lambda \leq 10500$ Å. So far the temperatures 6250, 6750, 7250, 7750, 8250, 9750, 9250, 9750 K have been completed.

David Katz: The RVS instrument simulator

The Radial Velocity Spectrometer is currently in definition phase : definition of the objectives and specifications, coordination with the GAIA simulator development and identification of the interfaces. The RVS simulator is intended to assess the generic performances of the instrument, to be a tool to optimize the instrument design (study instrumental effects) and to investigate the Galactic or time dependent issues (crowding, multiple systems, ...). Considering the wide scope of the simulator, its main specification is flexibility : on the output data (from single star to field, from 1 CCD to full mission), on the level of complexity of the background, design and satellite simulation and on the input data (local/simulator or external/user data). The RVS simulator will be developed as part of the more general GAIA simulator, thus using the same interfaces as the other instruments : Galaxy model, general satellite and payload characteristics.

M. Cropper, Smith, Brindle: Data Handling and Compression Issues

We reported on the constraints resulting from the limited bandwidth assigned to RVS, and what general principles and procedures should be followed to minimise information loss in reducing the data rate by a factor 75. In order to investigate the options, an RVS simulator was written to generate test images. The first step was to investigate lossless compression schemes. The compression factors with schemes such as LZW (in GIF) and SHA-1 (in PNG) were found to be extremely favourable, so that it could be envisaged that all of the data could be transmitted without loss. (However, this was later found to be incorrect, due to a reduction in the colour table used by the compression utility. The revised figures and conclusions are in RVS-MSC-003 on Livelink.) The consequences of coadding the data from the 6 CCDs and the transmission of only those pixels containing spectra (windowing) were also investigated.

Y. Viala, D. Morin,	GAIA-RVS : scanning, telemetry
F. Ochsenbein, D. Katz:	budget, transits

¿From the new version of the GAIA Nominal Scanning Law and the new RVS design (Position in GAIA and FOV dimensions) we computed the attitude of the satellitte versus time using the quaternion formalism (Lindegren : SAG-LL-14, SAG-LL-30 and SAG-LL-35). The matrix attitude is computed from J2000.0, every120 s (one RVS-FOV transit time) , during the 5 years mission assumed for GAIA. This allows us to determine, at every timestep of 120 s, the position of the RVS-FOV (centre and extremities) in celestial coordinates (equatorial, galactic and ecliptic) as well as its orientation on the sky given as the angle between the instantaneous scan direction and the galactic plane. With the adopted timestep, the sky is covered by nearly juxtapopsed (neglecting the drift across scan due to precession) RVS-FOV. Each day of scanning corresponds to 720 juxtaposed FOVs, leading to a total of 1296000 FOVs for the entire (1800 days) GAIA mission. To adress the problem of crowding and spectrum contamination between neighbouring stars a module has been developped which allows to determine, for any celestial position, all RVS-FOVs transits through that position during the whole GAIA mission, together with the FOVs position angles. Preliminary calculations for some selected positions along the galactic plane show that the distribution of position angles exhibits strong variation with position on the sky. A third module is devoted to the calculation of telemetric flows for RVS. As a first step, the total number of stars within each RVS-FOV (the possibility do divide the FOV in small areas has been taken into account) was computed using the "red book" (Table 6.6, p. 282) galaxy model. All stars up to the magnitude limit G = 17 have been counted. In this model, the total number of stars observed per day ranges from 5 to 21 millions. The largest number being reached at 7-8 epochs during the mission where the GAIA rotational axis points towards the galactic poles. To get telemetric flows (in MBbts/s) the number of stars per FOV has to be multiplied by the numer of bits per star spectrum and divided by the FOV transit time. The number of pixels per star spectrum depends on instrument parameters and on-board processing not yet fixed (resolution of the spectrometer, number of CCD in the FOV and number of rows per star spectrum, CCD and/or rows summing or not before sending data to the ground). Mean telemetric flows per day have been computed for the whole mission and for six RVS "parameter sets" (taking into account the fact that, in very crowded areas, full occupation of the CCD occurs : several stars can overlap on the same pixel, leading to a maximum value for the telemetry rate per FOV). Results are displayed in the form of curves giving telemetric flows per day as a function of time during the whole mission. Extreme values of the telemetric flow ranges from 0.4 Mbits/s (mean value, over the whole GAIA mission, of the number of stars counted per day, summing of rows and CCD before sending data to the ground, spectrometer resolution R = 5000) to 23 Mbits/s (maximum crowding, no summation of rows and CCD, spectrometer resolution R = 20000) : this corresponds to compression rates ranging from 2 to 90 assuming that 0.25 Mbits/s are allocated to RVS. All these calculations are undertaken by using a more realistic star distribution in the galaxy : the one determined from the GSC-II catalog. Results will be presented at the next RVS Workshop and compared to those obtained by using the "red book" galaxy model.

Frederic Royer:	Reduction recipes used with GIRAFFE, and applications to GAIA

GIRAFFE is the multi-object spectrograph, part of the FLAMES facility on the VLT (http://www.eso.org/instruments/flames/). Although this instrument is different in many points from GAIA RVS, there is some similarities:

- compatible wavelength range and resolution,
- multi-object observation,
- crowding on the CCD (overlaping in the direction perpendicular to the dispersion).

The data reduction software is developed in Geneva.
In the observational mode IFU/ARGUS, the PSF perpendicular to the dispersion has a FWHM of about 3 pixels. The high contamination between adjacent spectra makes that the threshold of localization must adopt a local value, to detect all the spectra. Once the spectra are localized and extracted, deconvolution can be carried out to recover the true spectra of individual sources, provided a good knowledge of the PSF :

$$O = A * C => C = A^{-1} * O$$

[O: matrix of extracted observed spectra; C: matrix of corrected spectra; A: matrix of mutual contamination between normalized PSF]

These procedures need to be tested on real observations, that are beeing done during the Commissioning phase at Paranal. The range of contamination in GAIA will be higher, and the sampling of the PSF will perhaps prevent a good knowledge of it, but these GIRAFE recipes may probably give hints in reducing GAIA data.

Frédéric Arenou, David Katz: Impact of some systematic effects

How faint can we go? This talk intended to give some hint on the debate between limiting magnitude and spectral resolution, not seen from the scientific point of view, but rather with the accuracy in mind. A basic fact is that, assuming the Gaia-2 design, a spectra at R=11500 will cover 666 lines large of 3 pixels height. Consequently the average continuum of a G=17 G3V star would be about 0.25e-/transit/CCD/TDIpixel and the spectral lines variations even smaller. With purely random errors, the average 100 observations per star would allow to get radial velocities at the end of the mission. The question is whether systematics could play a large role. Answering the accuracy question is not really easy at this step, so instead of evaluating all the possible effects, we see the question from the other side: down to which level will we be able to do the pixel calibrations. Although there may be no systematics below this level, this changes nothing for the accuracy, since we would not be able to prove that it is better. For each CCD, we thus compute what is the random error s on each pixel, and what is the degree of freedom d which will improve our knowledge down to the level of $s/\sqrt{d}$. One thing which reduces considerably d is for example the crowding since for calibrations we need spectra with no overlapping due to another star. We find that this level is comparable to the variations of the lines per pixel. Of course, this situation could be more favourable in term of radial velocity accuracy since the systematics would be reduced when combining the different transits. In terms of pixel, the situation would be improved by reintroducing the tilt mecanism (longer exposure time per CCD and smaller transverse motion) and degraded by increasing the resolution (smaller signal per pixel and larger crowding).

U.Munari, S.Desidera, F.Boschi, C.Pernechele:	Using absorption cells in $\lambda-$ calibration of GAIA spectra

The use of spectral markers in ground-based spectroscopy (telluric O_2 and H_2O lines, absorption cells) is put into historical perspective, and the documented accuracies in radial velocities compared. Hydrogen fluoride (HF) posses useful lines in the GAIA wavelength range, that would guarantee a $\lambda-$ calibration accuracy better than 1.0 km/sec for GAIA spectra of resolutions $\geq$15,000. However, it requires long optical path lengths (at least half a meter), high temperatures (T$\sim$100 Celsius) and significant pressure (at least 0.5 bar) to work properly. Identification of more suitable chemical compounds could open interesting alternative solutions to the $\lambda-$ calibration of GAIA spectra. Atomic resonant lines could play a role too. Resonant $6s1 - 6p3$ transition of Cs falls at 8521.10 Å, within the GAIA range and away from the CaII triplet, the Paschen series and the strongest Fe lines. Its implementation in an absorption cell and its utility in $\lambda-$ calibration of GAIA spectra has to be investigated.

David Katz:	RVS atmospheric parameters precision

We performed Monte-Carlo simulations to assess the RVS atmospheric parameters (effective temperature, surface gravity, metallicity) precision as function of magnitude. The atmospheric parameters were derived using a "minimum distance + gradient method (MDGM)". It is based on the assumption that similar spectra have similar parameters. Its principle is to (i) compare the target spectrum to a library of (synthetic) reference spectra, spanning a large volume in atmospheric parameters space, looking for the most "similar" in least square term (hereafter called pivot) and then (ii) to quantify the differences between the target and pivot spectra/parameters by comparing them to the differences between the pivot and its neighbours (in the library). A grid of 1000 Kurucz synthetic spectra, spanning the intervals $4750 \leq Teff \leq 7000$ K by step of 250 K, $0.5 \leq \log g \leq 5.0$ by step of 0.5 and 9 metallicity from 0.5 to -3.5, was used as reference library. Preliminary results were obtained for a Kurucz synthetic template of parameters : Teff = 5500 K, log g = 4.5, [Fe/H] = -0.1 (not a reference grid node). The precisions (accounting for the systematic and random errors) respectively for Teff, log g and [Fe/H] are : at V = 8 (full mission), R = 5 000 (79 K, 0.19, 0.02), R = 10 000 (51 K, 0.11, 0.01), R = 20 000 (31 K, 0.06, 0.01) and at V = 15 (full mission), R = 5 000 (146 K, 0.39, 0.07), R = 10 000 (152 K, 0.37, 0.08), R = 20 000 (173 K, 0.51, 0.09). Those numbers should be considered with caution. In this study, synthetic spectra were compared to other synthetic spectra computed with the same assumptions. Therefore, uncertainty on atomic data (log gf, ...) values as well as the present limit of our knowledge in the art of atmosphere modelling, have not been taken into account in the error budget.

Frédéric Thévenin: Stellar parameters for Late-Type stars

If we consider that the effective temperature will be derived by photometry with a precision of 80K, the surface gravity by the parallax and isochrones with a precision of 0.10 dex, one needs to derive abundances of peculiar elements like Ca, Fe, Si with a precision of 0.10 to 0.15 dex, to perform studies of the chemical evolution of the Galaxy with the use of [Ca/Fe] or [Si/Fe] versus [Fe/H] diagrams. Toy-models have been used to investigate how S/N or resolution of the spectrograph work in order to derive an estimate of the error on the determination of an equivalent width. As an example, for a small line of 0.1Å with a S/N=10 and a pixel of $\delta x = 0.75$Å the error is 0.18Å and the error on the abundance is 0.65 dex.

$$\delta W = \sqrt{2n}(S/N)^{-1}\delta x$$

with n the sampling (here n=3). **More we spread the spectrum, less is the error.** S/N=10 is probably an extreme limit. A more precise study of the different lines of Ca and Fe to be used for chemical studies will be involved in a future work.

Preliminary conclusion is that a resolution lower than 12000 is unacceptable for chemical studies of the Galaxy. A carefull demonstration has to be done.

In parallel, a new interpretation of the spectra in order to extract the information and for example to eliminate the strong structures like the continuum or the strongest lines of the spectra which gives systematic effects on the radial velocity measurements is now developed. We used the Wavelet concept and prepare this new approach on synthetic spectra to decide if this is useful or not for our spectral problem.

Frédéric Arenou, M. Haywood:	Perspective acceleration correction versus resolution

One of the use of the radial velocities is to correct the astrometry from the effect known as "perspective acceleration", a quadratic time effect on the stellar motion proportional to proper motion μ, parallax and radial velocity V_r. Not correcting this effect would bias the true proper motion and possibly misinterpret this secular change as a reflex motion due to a long-period stellar or sub-stellar companion. Using a Galaxy model by Haywood (1997), we find a simulated sample of about 81000 stars which would be concerned by a cumulative positional effect δ_p during the mission larger than 1/10 of the standard error on position. This sigma/10 assumption was chosen to get a negligible systematic effect, but a larger value could be taken. It turns out that most of the obtained stars would be from the thick disk, due to the effect of the asymetric drift on μ and V_r. Computing the perspective acceleration requires that V_r is known to a sufficient precision. A 100% relative error on δ_p would be enough since the sigma/10 assumption was very conservative. This translates to a requirement approximately identical for V_r. Since V_r is large in this sample by construction, the needed $\sigma(V_r)$ will be easily obtained, whatever the spectral resolution which will be chosen. So, the only requirement would be to get radial velocities for "faint" stars (11.6% of the sample is fainter than G=15, 1.3% fainter than 17). This does not represent large numbers, but the stars are not known in advance.

Andreja Gomboc:	RVS stellar rotation accuracy

To estimate the accuracy of the stellar rotation velocity determination, the synthetic stellar spectra, obtained with Kurucz model, are artificially noised (with S/N=10, 30, 100, 300) and fitted by spectra with different $v_{rot} \sin i$. Assuming precise radial velocity and stellar parameters (T, log g, $Z/Z_\odot$) the accuracy of $v_{rot} \sin i$ is about 5 km/s (S/N=10) and 2 km/s (S/N=30) for resolution 0.25 Å/pix and about 10-20 km/s (S/N=10) and 5-10 km/s (S/N=30) for resolution 0.75 Å/pix. Since stellar parameters are not precisely known, the accuracy of rotation velocity is degraded:

- due to the uncertainty of 0.5 in log g, by less than 2 km/s,

- due to the uncertainty of 250 K in temperature, by about 5 km/s,

- due to the uncertainty of 0.5 in metallicity, by up to 50 km/s for resolution 0.75 Å/pix (20 km/s for resolution 0.25 Å/pix)
- due to the uncertainty of 10 km/s in radial velocity, by up to 20 km/s.

Therefore, crucial parameters to achieve high stellar rotation accuracy are: high spectral resolution, high radial velocity accuracy and high accuracy in metallicity.

Tomaž Zwitter: RV accuracies and crowding in the new design

The proposed Astrium design changes the capabilities of the GAIA spectrograph: it collects only 78% of the photons per transit compared to the original (red-book) design. The number of photons from background is 3.5- or 1.6-times larger (depending on use of an active tilt mechanism). Also the read out noise per wavelength bin is 4-times larger (1.3-times with tilt). So one may ask what is the degradation of the radial velocity accuracy compared to the original design. We ran a set of simulations identical to the ones published in Zwitter (2002), but with the parameters of the Astrium design. It turned out that the Astrium design without de-rotation (and so a wider PSF profile) looses 1.0 magnitude in V compared to the original design. This means that an error corresponding to $V = 17$ in the original design now applies to $V = 16$. If the tilt mechanism is in place the width of stellar tracings is smaller and so the accuracy is less compromised: it turns out that one looses 0.5 in V compared to the original design. It was stressed that the achievable radial velocity accuracy cannot be traced to the signal to noise ratio within a given wavelength interval. The S/N per 1 Å bin is always higher for lower resolutions (due to smaller numebr of pixels and so a lower background and RON), but the accuracy is generaly better for higher resolution spectra (because higher resolution means also better sampling of the profiles of the spectral lines).

Finally a brief outline was given concerning the crowding issue. The free length L of the spectrum (distance between the spectral heads in the dispersion direction) is given by

$$L = (ns)^{-1} \ln[(1-p)^{-1}]$$

where n is star density (stars / degree^2), s is tracing width (4.5 arcsec for the Astrium design without tilt), and p is the probability for the free length L.

It was shown that we will never be able to avoid some degree of overlap of the spectra, even in moderately crowded regions. But the overlap itself does not make *per se* the spectrum unuseful for further analysis. For bright stars an overlap of the studied object with another star of equal brightness means that the S/N gets divided by $2^{1/2}$, i.e. the same S/N as for a non-overlapped target half as bright or 0.75 magnitude fainter. On the other hand we have vast experience with deconvolution of badly overlapped spectral tracings, i.e. those of spectroscopic binaries.

Everybody agreed that the problem of crowding could be important and so deserves further analysis with realistic simulations.

Giuseppe Bono: Odds and News on Radial Variables

We presented some recent results concerning the intrinsic accuracy of both classical Cepheids and RR Lyrae variables as distance indicators. In particular, we discussed pros and cons of first overtone Cepheids and the role that they play to determine the distance to the Magellanic Clouds. Moreover we presented new distance evaluations for field RR Lyrae stars based on the Period-Luminosity-Metallicity relation in the K band and compared the new estimates with the Baade-Wesselink distances.

We also discussed the impact that accurate radial velocity curves of RR Lyrae and Classical Cepheids can have to constrain the evolutionary and pulsation properties of these objects. Finally, we presented several empirical and theoretical circumstances, based on data available in the literature, supporting a high spatial resolution (15,000) and high signal to noise ratio (S/N$\geq$ 50) for the GAIA spectrograph.

Mark Wilkinson: Observing the halo, bulge, disk, stellar streams and bulge clusters with the new design

I presented an overview of the main dynamical components of the Milky Way galaxy which GAIA will be able to observe. I emphasised the importance of a large radial velocity data set for dynamical modelling. For example, Binney et al. (1997) showed that the incomplete ground-based radial velocity follow-up of stars with Hipparcos proper motions had resulted in a kinematically biased data set which could not be used in the building of dynamical models. Also, in their study of bulge models, Vauterin & Dejonghe (1998) showed that radial velocities are an essential discriminant between axisymmetric and triaxial bulge/bar models, as proper motions alone do not have sufficient discriminating power. The inclusion of the on-board RVS on GAIA is therefore an essential complement to the proper motion data set.

For each dynamical component of the Milky Way, I discussed the radial velocity accuracy and V-band magnitude limit required to allow meaningful discussion of the stellar dynamics involved. Based on a survey of the relevant literature, I concluded that radial velocities accurate to about 10 km/s down to a V-magnitude limit of about 17.5 will be necessary to ensure that the RVS radial velocity data set will be useful for discriminating between different Galaxy models. However, velocity errors smaller than 5 km/s are required to probe, for example, the internal dynamics of cold stellar streams and tidal tails in the solar neighbourhood.

A key outstanding issue to be investigated during the coming months is the extent to which crowding will affect the magnitude limits and radial velocity accuracies which are achievable. The final choice of resolution for the RVS must allow observations of fields in as many regions of the Galaxy as possible, in order to produce as complete as possible a picture of the stellar dynamics.

David Katz: Discussion summary

I. Context & short term objectives

The "Radial Velocity Spectrometer" instrument is currently in definition phase. Several options are considered/compared for the resolution, CCDs number and size, CCD read-out policy, tilt mechanism (...). Studies are under-way to select the "optimal" configuration : (i) definition/refine- ment of the scientific specifications, (ii) assessment of the different configurations performances, (iii) assessment of crowding impact at low Galactic latitudes, (iv) definition/selection of on-board compression and data-handling algorithms, and (v) assessment of telemetry budget. The RVS characteristics have to be fixed before the end of the year (see below) in order to allow the phase A industrial contracts to proceed/start.

Two industrial studies are particularly dependent upon well defined RVS characteristics :

The first one, starting in June, is the "CCD & focal plane assembly demonstrator". It will investigate the feasibility of the CCD and FPA manufacture and specifications implementation. In order to proceed, this study needs to know the number and size of CCDs. The discussions have converged on two scenarii for the RVS CCD & FPA (see the tilt mechanism section below).
The second industrial contract that require specifications from the RVS is the "Payload & Data-Handling Electronics (PDHE)". Its objective is to evaluate/size the electronics needed to handle the acquisition, on-board treatment and transmission of the Data (observations and house-keeping). The PDHE will start in September. At that time the RVS group will have to provide the following specifications :

- CCD read-out policy (binning and flushing strategy)
- data flow per star, i.e. resolution, width perpendicular to dispersion, CCD number (upper limit)
- number of stars observed, i.e. limiting magnitude as a function of Galactic coordinates (upper limit)
- foreseen on-board algorithms ("worst" case)

All characteristics for which upper limits have to be given in September, should be defined by December. Conclusions about CCD read-out policy and on-board algorithms are presented in the discussion section.

II. Discussions

1- CCD read-out policy

1.1- Binning

Because of the PSF width, random positionning of stars with respect to CCDs and possibly transverse motion (see tilt mechanism below), most of the spectra will cover several pixels across dispersion. It would be possible, during the read-out process, to read pixels by sets, only keeping the sum of the signals (i.e. binning the pixels). This option has two merits: reduce the read-out noise by about 10% and reduce the telemetry budget. On the other hand, information is lost in case of spectra partial overlap. This last point was considered a major drawback, since the rate of overlapping will be very significant in the Galactic disk and bulge. Therefore it has been decided not to bin the pixels.

1.2- Flushing

During the read-out process, it is possible to flush part of the pixels: i.e. to read sets of pixels at high frequency (therefore discarding the information between spectra). The read-out noise of the remaining pixels is reduced. In the case of the RVS, at 30 degree Galactic latitude (2100 stars/deg^2 - CTSR p242), one third of the CCDs is covered with spectra of G = 17 or brighter stars. As a consequence, the flushing was considered unapplicable to RVS CCDs.

2- Tilt mechanism

2.1- FoV rotation mechanism

The satellite precession induces a spectra sine transverse motion with respect to the detectors. The maximum intensity of this transverse motion is 0.17 arcsec/s or 2.81 arcsec (1.9 pixel) in the 16.5 s CCD crossing time (current baseline). A tilt mechanism, rotating the CCD plane, could compensate the transverse motion with the merits of : reduce spectra width (75% or more of the energy spread on 1 or 2 pixels instead of 2 or 3), reduce the crowding (95% or more of the energy spread on 2 or 3 pixels instead of 3 or 4), reduce the number of CCDs (thus increasing the signal per TDI pixel), reduce sky contamination and total read-out noise per transit. The mechanism also presents a drawback: the risk of failure. The merits of the tilt mechanism were considered significant, especially with respect to crowding. At the same time the mechanism failure risk is not quantified. It was therefore recommended that two parallel configurations being considered: one with tilt mecha- nism (with the goal of identifying solutions and quantify failure risk) and one without mechanism (to serve as backup in case no safe enough mechanism solution being found). The choice between the two options will be made, once the failure risk will be quantified.

2.2- Focal plane assembly scenarii

The number and size of the CCDs are dependent upon the compensation (or not) of the transverse motion. It was proposed to consider two scenarii (in particular for the purpose of the "CCD & FPA demonstrator contract") until a decision being taken about the tilt mechanism: (i) with tilt mechanism: 3 CCDs of 2020 by 3930 pixels. (ii) without tilt mechanism: 6 CCDs of 1010 by 3930 pixels.

3- on-board algorithm

Sending to the ground, all observations (6 CCDs per transit), all information (3 lines per spectra), for all stars up to apparent magnitude G=17 will require compression factor ranging from about 45 (R= 5 000) to 90 (R= 20 000), to fit in the 0.25 Mbit/s allowed to the RVS instrument. It was considered reasonable to "interpolate" and sum the successive CCD observations before downlinking the data. The possibility of collapsing the lines to further reduced the volume of data was also considered. It was decided to reexamine the question in September with new inputs from the compression study.

4- Resolution

Resolutions ranging from R = 5 000 to R = 20 000 are currently considered. High resolution spectra carry more spectral information, while lower resolution spectra, less degraded by the crowding allow to observe in denser areas. During the discussion it was strongly recommended by several participants to adopt R = 10 000 as the lowest foreseen resolution, emphasizing that below R = 10 000 the scientific output in term of double stars, variable stars or detail chemical composition will be strongly reduced. On the other hand, two important studies are still in progress: the Galactic structure scientific specifications are refined (i.e. how close to the Galactic plane should the satellite observe) and the impact of the crowding on the performances assessed (i.e. how close to the Galactic plane could the satellite observe). It was concluded that it was not possible to discard R = 5 000 resolution before being sure that higher resolution can observe close enough to the Galactic plane to satisfy the scientific requirements.

5- Calibration

5.1- Wavelength calibration

The baseline strategy to calibrate the spectra in wavelength, is to rely on RVS observations of RV standard. The importance to assess the performances of this approach has been stressed, as well as the interest to identify and study other/complementary technics.

5.2- Instrument and background calibration

With the current baseline, 0.25e- on the average will be integrated per transit, per CCD, per TDI pixel for a G=17 G3V star. The basic assumption is that the large number of observations (CCD times transit) will allow to recover the spectral information. This will be true, only if no "unca- librated systematics" arise at the level of (a significant fraction of) 0.25e- per transit, per CCD, per TDI pixel. This was identified as an important issue to be investigated carefully, as this may have a significant impact on the limiting magnitude.

III. Objectives

The main objective for the next 7 months is to converge on the RVS instrument design. In order to do so, the following topics should be investigated further on:

- Refinement of the scientific specifications and in particular the Galactic structure specifications: stellar tracers, needed accuracy, relevant Galactic direction (i.e. field density) ...

- Assessment of crowding impact: impact of one or several overlapping of similar or different magnitude stars; limiting magnitude as function of Galactic coordinates.

- Investigate calibration strategy and their accuracy.

- Identify/study/select on-board processing and compression strategy and assess telemetric budget.

- Assess/refine instrument performances: RV, v sin i, individual abundancies.

IV. Actions

List of agreed actions:
All: Express results with respect to I cousins photometric band.
F. Arenou: Continue to investigate calibrations versus random and systematic noises.
G. Bono: Assess GAIA performances with respect to pulsating stars using simulated photometric and spectroscopic data.
M. Cropper: Continue to investigate compression strategy.
A. Gomboc: Refine RVS v sin i (versus magnitude, resolution and source type) performances assessment.
D. Katz: Refine RVS simulator objectives and specifications. Implement UML model.
U. Munari: Investigate wavelength calibration techniques.
U. Munari: Investigate known systematic noises from existing very low photon counts experiments.
F. Royer: Investigate spectra deblending methods.
F. Thevenin: Assess RVS atmospheric parameters and individual abundances precisions versus magnitude, resolution and source type.

Y. Viala: Refine telemetric budget assessment (observed catalogs, impact of crowding).
M. Wilkinson: Refine Galactic structure scientific specifications.
T. Zwitter: Assess impact of crowding.

V. Web pages and Meetings

web:

RVS web page	:	http://wwwhip.obspm.fr/gaia/rvs
Ljubljana web page	:	http://www.fiz.uni-lj.si/astro/RVIII/
Ljubljana pictures	:	http://wwwhip.obspm.fr/gaia/rvs/workshop3
Monte-Rosa web page	:	http://ulisse.pd.astro.it/GAIA2002/

meetings:

9-12 September 2002	Monte Rosa	Monte Rosa Conference
13 September 2002	Monte Rosa	4th RVS Workshop
28-29 November 2002	Paris	5th RVS Workshop