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Spectroscopy with FLAMES: applications to GAIA RVS

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Abstract. The reduction of GAIA RVS instrument data can use applicable solutions defined for other spectrographs. The Data Reduction Software of the GIRAFFE spectrograph, part of the FLAMES facility at VLT, is developed in Geneva. Some reduction recipes can be adapted to GAIA RVS in terms of localization, extraction and calibration. On the other hand, the Argus mode of the instrument is described as a way to simulate GAIA observations for crowded fields.

1. Description of FLAMES and GIRAFFE

The FLAMES (Fiber Large Array Multi-Element Spectrograph) facility is mounted on Kueyen, the second Unit Telescope of the VLT. This instrument, soon available to the community (by Spring 2003), is described by Pasquini et al. (2000) and details can be found at http://www.eso.org/instruments/flames

VLT Unit Telescope #2 (Kueyen) feeds GIRAFFE, at the Nasmyth focus, through a set of optical fibers either deployed on individual objects (MEDUSA mode, 132 fibers) or grouped in for integral field observation (ARGUS/IFU modes, 320 fibers in all). The spectrograph produces on the 2k×4k detector a set of 137/320 spectra. Two spectral resolutions with set-ups covering all the wavelength range 360 – 940 nm are available; high resolution 15 000 – 45 000 (22 set-ups) and low resolution 5000 – 13 000 (8 set-ups). The GIRAFFE spectrograph offers three different observing modes:

1. In the MEDUSA mode 132 fibers are distributed in a field of 25′ diameter. Some of these have to be attributed to sky measurement.

2. In the IFU (Integral Field Units) mode, 15 fiber bundles are distributed in the same 25′ field, each bundle containing 20 fibers corresponding to an area of 3″ × 2″ on the sky (spatial sampling of 0.″52).
   In this mode the PSF on the detector is much more difficult to disentangle because it is less well sampled (the fiber size being smaller) and the spectra undergo significant cross-talk (being close-packed).

3. ARGUS, a single integral field unit containing 300 fibers covering a rectangular area of 11.″5 × 7.″3 (spatial sampling of 0.″52) or 6.″6 × 4.″2 (spatial sampling of 0.″3). As for the IFU mode, 15 sky fibers are available distributed anywhere around the Argus field (the microlens aperture on the sky is 0.″52 × 0.″52).

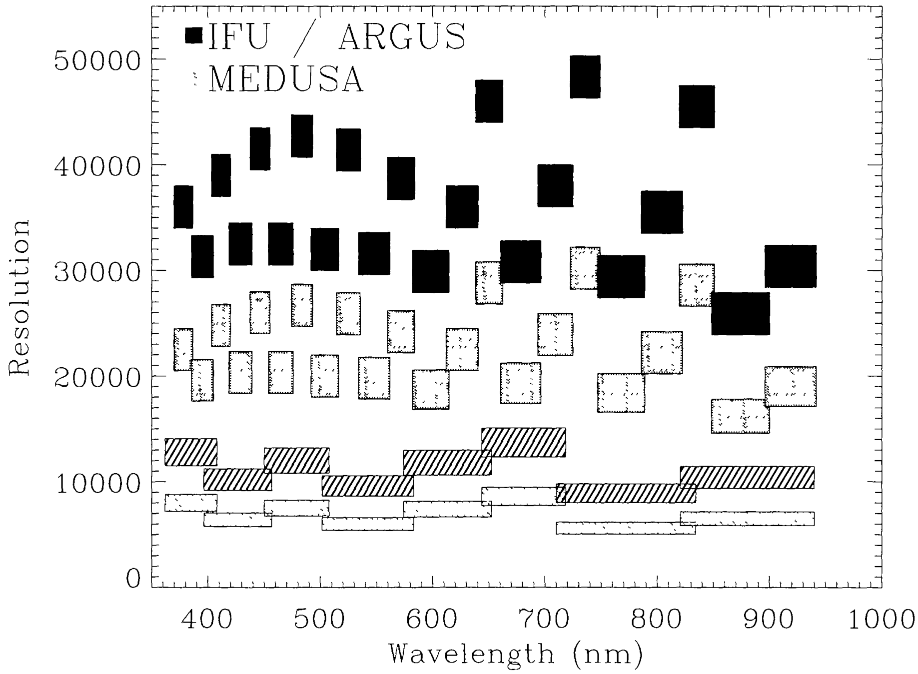

Figure 1. Every setups of GIRAFFE are displayed in the wavelength–resolution plane. Black and grey respectively stand for IFU/ARGUS and MEDUSA fibers, whereas plain and shaded boxes correspond to high and low resolution respectively.

The resolution is diplayed as a function of the wavelength in Fig. 1, for the whole set of available configurations. The better spectral resolution in the IFU/ARGUS mode is due to the better sampling on the sky (the smaller diameter of fibers).

2. Integral field observation and crowding

In the focal plane of the GAIA RVS instrument, the three dimensions α, δ (spatial coordinates) and λ (wavelength) are projected on two dimensions. An increasing crowding will rise from this projection effect. Integral field observation allows the measurement of (α, δ, λ) as a datacube, and can be useful to simulate GAIA RVS observations from real data. The ARGUS mode of GIRAFFE covers a rectangular area, with two available spatial sampling: $0\farcs52$ or $0\farcs3$. By using the spectral window 8484 – 9001 Å (on 4096 pixels, with $R \sim 25\,900$), covering the wavelength range of GAIA, the resulting extracted spectra can be injected in a simulation to study the same region as seen by GAIA.

The spatial resolution of GAIA RVS is $1\farcs0 \times 1\farcs5$ and the spectral resolution will be lower than 20 000, so that GIRAFFE ARGUS data can degraded in both spaces to simulate GAIA RVS data.

3. Data reduction software

The Data Reduction Software (DRS) of GIRAFFE, developed at Observatoire de Genève, Institut d'astronomie de l'Université de Lausanne and Observatoire de Paris (Blecha et al. 2000) is divided in two parts:

- the *BaseLine Data Reduction Software* (BLDRS), which aims at removing the instrumental signature from the observed data and calibrating the spectra in physical units.

- and the *Ancillary Data Analysis Software* (ADAS), dedicated to the analysis of the output spectra of the BLDRS.

3.1. Data reduction recipes

The BaseLine Data Reduction software does, among other things, the localization of the spectra on the detector and performs the extraction.

Localization The localization process carried out using the flat-field calibration frames is performed in two steps. First a localization mask is derived from scratch using threshold detection. And then the PSF perpendicular to the dispersion if fitted inside the localization lanes, along the centroids.

Extraction This function applies to any preprocessed science or calibration frame. The extraction of the spectra is carried out inside the localization lanes, and three options are offered: the first and the second ones can be applied in the MEDUSA mode because contamination should be negligible in this mode, while the third one should be adopted for the ARGUS/IFU. In this latter option, each spectral bin is described as a linear combination of the PSF multiplying the spectral elements which are to be extracted. This is Horne (1986) optimal extraction generalized to the case where the spectra are not strictly independent due to the cross-talk, and it is well adapted to any situation (including the case where the inter-spectra contamination is severe).

These localization and extraction processes have to be tested on real IFU/ARGUS data to see at which contamination level they are reliable, and then see if they are applicable to GAIA RVS.

4. Radial velocities

Computing the radial velocities of the observed targets is part of the ADAS package. The method and the CORAVEL templates used are described in Royer et al. (2002).

The accuracy of the measured radial velocity has been assessed in the GIRAFFE spectral range limited to the wavelength interval 8480 – 8740 Å, i.e. the GAIA RVS bandpass.

The correlation was done with classical binary masks of the CORAVEL type, optimized for each set-up, taking into account the nominal resolution of the GIRAFFE spectrum ($R \sim 16\,300$). The Solar Flux Atlas of Kurucz et al.

(1984) has been used to simulate observed data, with different signal-to-noise ratio, (SNR) and to create the mask. Thus there is no mismatch between the masks and the spectra.

Four different binary masks have been created, with different tolerances on the width of spectral lines to be retained. For *Mask1*, the tolerance is the lowest, there are 24 holes between 8480 and 8740 Å. In the other one, *Mask2*, there are 33 holes. And for both tolerances, a mask if built with and without the calcium triplet lines ('+Ca') among the holes. The results in the accuracy of the radial velocities are listed in Table 1, for the Sun.

Table 1. The expected accuracy in radial velocity (in $km\,s^{-1}$), for the solar spectrum, as a function of S/N and the templates.

	signal-to-noise ratio							
Template	1	2	5	10	20	40	100	200
Mask1	—	10.544	2.088	0.974	0.432	0.196	0.091	0.043
Mask2	31.734	6.997	2.429	1.134	0.517	0.271	0.098	0.052
Mask1+Ca	9.651	3.884	1.494	0.826	0.354	0.157	0.074	0.034
Mask2+Ca	12.034	5.289	1.823	0.914	0.402	0.210	0.078	0.041

One can notice that taking into account wider lines in the correlation improves the resulting accuracy for low signal-to-noise data, but spoiles it in the case of high signal-to-noise. In the case of the Sun, using the calcium triplet for the radial velocities of low SNR increases significantly the precision of the radial velocity, but for high SNR the gain factor is much lower. The optimzation of the templates should be investigated for other spectral types.

These results were computed from simulated spectra, but GIRAFFE will soon start producing data, which will be used to carry out further tests.

References

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