ESO Phase 3 Data Release Description

Data Collection	<GAIAESO/GaiaESO>
Release Number	<2>
Data Provider	<G.Gilmore, S.Randich>
Date	<19.06.2015>

Abstract

Gaia-ESO is a public spectroscopic survey[1] carried out with FLAMES, targeting ≥ 10^5 stars, systematically covering all major components of the Milky Way, from halo to star-forming regions, providing the first homogeneous overview of the distributions of kinematics and elemental abundances. This alone will revolutionise knowledge of Galactic and stellar evolution: when combined with *Gaia* astrometry the survey will quantify the formation history and evolution of young, mature and ancient Galactic populations. With well-defined samples, we will survey the bulge, thick and thin discs and halo components, and open star clusters of all ages and masses. The UVES and Giraffe spectra will: quantify individual elemental abundances in each star; yield precise radial velocities for a 4-D kinematic phase-space; map kinematic gradients and abundance - phase-space structure throughout the Galaxy; follow the formation, evolution and, dissolution of open clusters as they populate the disc, and provide a legacy dataset that adds enormous value to the *Gaia* mission and on-going ESO imaging surveys.

Overview of Observations

This release of the Gaia-ESO survey[2] covers observations obtained in the period 31.12.2011-31.12.2013. These include Milky Way (GE_MW) field observations, Open Cluster observations designated as Cluster fields (GE_CL), and calibration observations of different targets, such as radial velocity standard stars (GE_SD_RV), benchmark stars (GE_SD_BM), peculiar standard stars (GE_SD_PC), telluric standard stars (GE_SD_TL), open clusters (GE_SD_OC), globular clusters (GE_SD_GC) and COROT red giants (GE_SD_CR). See Figure 1 for the location of these fields in the sky.

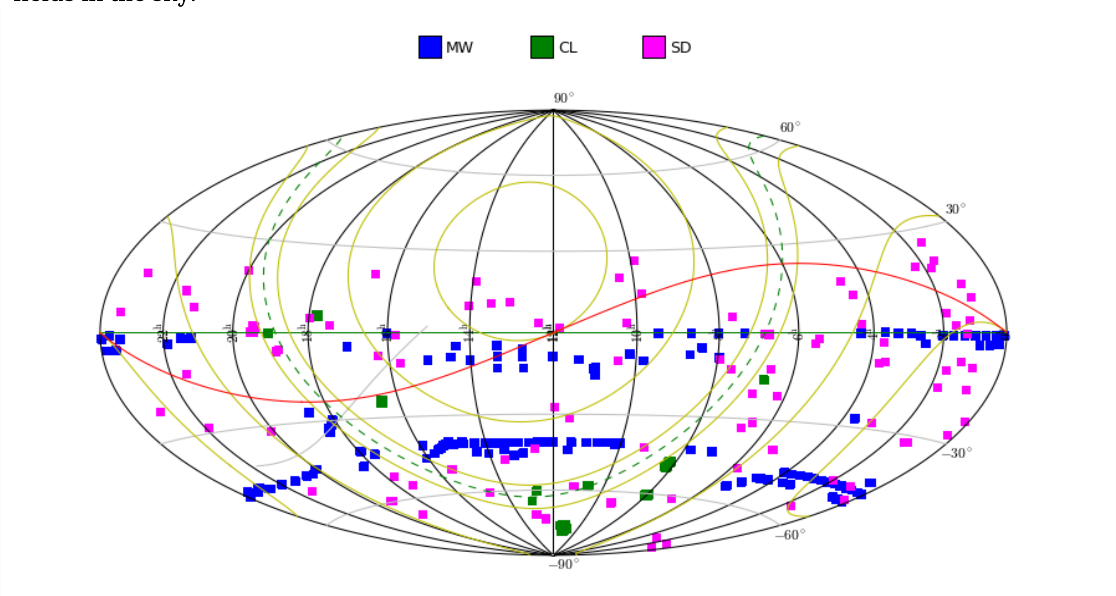

Figure 1: Location of target fields in the sky

The MW targets survey the Bulge, Halo, Thick Disc and Thin Disc populations of the Milky Way. Three primary instrumental setups were used for these observations: UVES 580 for brighter objects and Giraffe HR10 and HR21 for fainter ones.

1. ESO programmes 188.B-3002, 193.B-0936 described in 2012Msngr.147...25G
2. ESO programme 188.B-3002(A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,V,W)

For the Bulge survey observations of K giants were carried out for the brighter objects (GK stars) using UVES 580, otherwise Giraffe HR10 and/or HR21 were used. For the Halo/Thick disc survey, the primary targets are F+G stars, where bluer fainter F stars probe the halo, and brighter F/G stars probe the thick disc. The outer thick disc is probed using distant F/G stars, as well as K giants to sample the far outer disc. For the solar neighbourhood, G stars were observed using UVES 580 only.

The Standard fields included in this release are: calibration observations of stars in the globular clusters M15, NGC6752, NGC5927, NGC4833, NGC4372, NGC2808, NGC1851 which meet our selection threshold for inclusion (see **Data Quality** section), as well as *Gaia* benchmark stars, COROT giants, and radial velocity standards.

The open cluster survey aims to cover the age-metallicity-distance-mass parameter space. Depending on the stellar type, open cluster stars are observed with different Giraffe gratings (HR03/5A/6/9B/14A/15N), and two UVES settings (UVES520 and UVES580).
This data release includes spectra and advanced products for 13 science open clusters; for each of them different products are delivered, based on our quality control criteria (see below). The clusters along with information on the observations and delivered products are listed in Table 1. Normally, the faint cluster members ([pre-]main sequence or turn-off stars) are observed using Giraffe, while for the brighter stars (typically evolved giants or bright [pre-]main sequence cluster candidates) UVES parallels are employed. Limiting magnitudes for cool stars (later than A-type) are V=16.5 and V=19 for UVES and Giraffe respectively. Different magnitude ranges are covered in clusters where hot stars are observed with the blue gratings. An overlap in magnitude between the Giraffe and UVES samples is present normally and a number of stars were observed with both instruments for inter-calibration purposes.

Within each cluster, the target selection procedure was implemented slightly differently between Giraffe and UVES, but uniformly across clusters. Namely, for Giraffe, with which we aim to observe unbiased and inclusive samples, cluster candidates are selected on the basis of photometry. We used proper motions and other membership indicators (like e.g., X-ray emission) only to define the photometric sequences and the spatial extent of the clusters. In general, we did not use proper motions to select the targets, although in some cases they were employed to discard secure non-members. For UVES, with which we aim to target more secure cluster members, we instead employed membership information from the literature (e.g., v_{rad}, Li, Hα), when available. More details on the target selection within clusters can be found in Bragaglia et al. (2015, to be submitted).

For both MW and open clusters the range of observations are restricted to $+10° \geq$ Dec $\geq -60°$ whenever possible to minimise airmass limits (in practice a few target clusters are outside of this range). Figure 2 shows the seeing distribution, for the combined MW and CL dataset. Figure 3 shows instead the range of observing conditions during which the observations were taken.

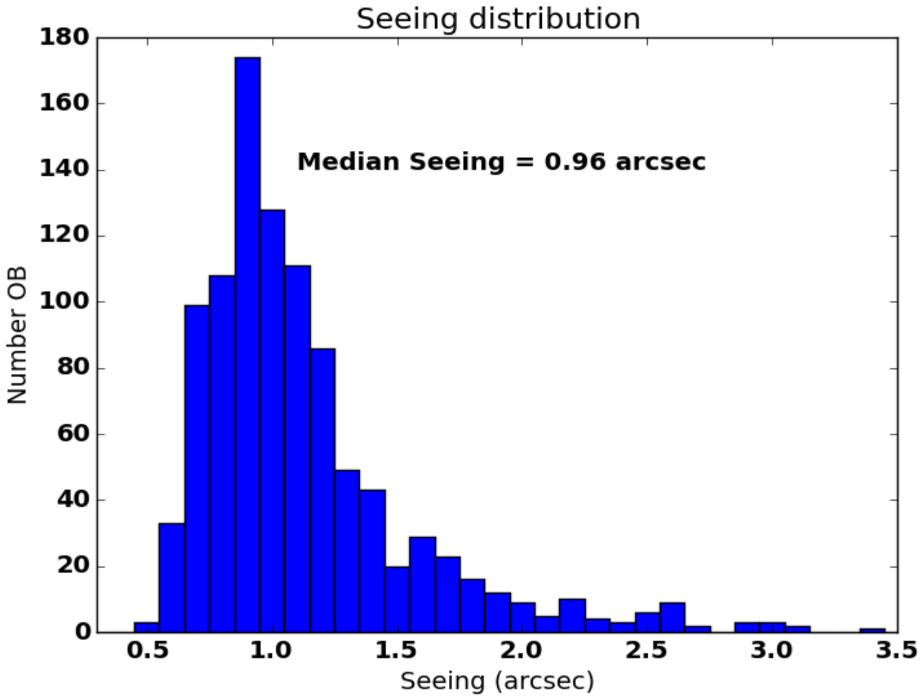

Figure 2: Histogram of seeing per exposure for MW, SD and CL fields and for all observations obtained up to December 2013.

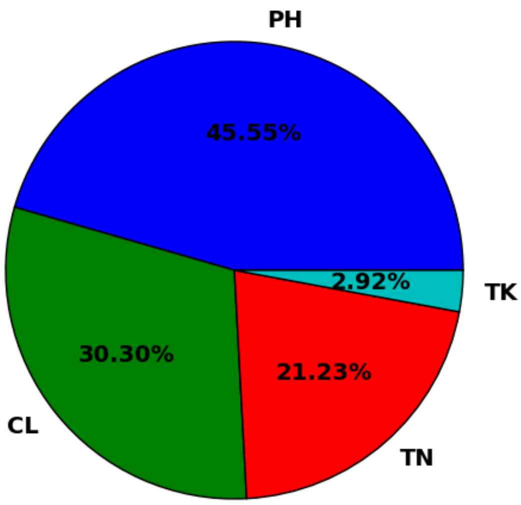

Figure 3: Percentages of observing conditions experienced during the observations: PH = Photometric, CL = Clear, CY = Cloudy, TN = Thin cirrus cloud, TK = Thick cirrus cloud.

The primary source catalogue for the Milky Way field stars is VISTA imaging, ensuring excellent recent astrometry, and adding maximal value to the VISTA surveys.

Photometry for the open clusters mainly comes from the literature and 2MASS. Astrometry is from 2MASS.

Release Content

The present data release includes spectra, as well as a catalogue containing photometry and advanced products (radial velocities, astrophysical parameters, lithium line strength, Hα emission) for a fraction of the stars for which spectra are delivered. The open cluster science targets for which products are delivered are listed in the table below.

Table 1: Open clusters included in the release and delivered products

Cluster	Setups	Radial Velocities (*)	Astrophysical Parameters (*)	Hα, Li
Gamma Velorum	U580, HR15N	Y	Y	Y
Rho Ophiucus	U580, HR15N	Y	N	Y
Chamaeleon I	U580, HR15N	Y	Y	Y
NGC2547	U520, U580, HR15N	Y	From U580, HR15N	Y
IC4665	U580, HR15N	Y	Y	Y
NGC2516	U520, U580, HR15N	Y	From U580	N
NGC6705	U580, U520, HR3/5A/6/14A/15N	From U580, U520,HR15N	From U580, HR15N	N
NGC4815	U580, HR9B/HR15N	Y	Y	N
Trumpler 20	U580, HR15N	Y	N	N
Berkeley 25	U580, HR9B	Y	From U580	N
Berkeley 81	U580, HR9B, HR15N	Y	Y	N
NGC3293	U520, HR3/5A/6/14A/15N	N	N	N/A

(*) When passing the quality threshold discussed below.

1. THE SPECTRA

The observations in this data release are summarised in Table 2. The total number of submitted data files is 27359 (size: 5.3 GB uncompressed) comprising spectra of 14947 unique targets. Figure 4 presents the histograms of the *J* magnitudes of the MW and CL targets.

2. THE CATALOGUE

For a fraction of the stars for which spectra are delivered, advanced products are also released. These include radial velocities, astrophysical parameters (APs: effective temperature, surface gravity, metallicity [Fe/H]), Lithium I 6707.8 À equivalent width, Hα emission information, and a gravity index (see Damiani et al. 2014, A&A, 566, 50). Parameters that passed the quality thresholds discussed below are included in the table. When a star has been observed with more than one setting and/or with multiple exposures, more than one spectrum is delivered per star (i.e., HR10 and HR21, or HR15N and UVES580). In such cases only one recommended set of parameters (one row of data) is written to the catalogue.

Table 2: Observations Summary (31/12/2011-31/12/2013)

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Field Type	Instru-ment	No. Objects	Grating	Spectral Range (Å)	Resolution	No. Spectra	Median S/N	No. Objects per field type
MW	Giraffe	3569	HR10	5339-5488	19800	3569	31	
		4691	HR21	8484-9001	16200	4691	68	
	UVES	484	580	4771-6785	47000	968	73	5289
SD	Giraffe	2084	HR10	5339-5619	19800	2327	48	
		1578	HR15N	6470-6750	17000	1807	80	
		2084	HR21	8484-9001	16200	2327	97	
	UVES	27	520			390	102	
	UVES	168	580	4771-6785	47000	676	120	2595
CL	Giraffe	6231	HR15N	6470-6790	17000	6231	50	
		756	HR9B	5143 - 5356	25900	756	27	
		692	HR3	4033-4201	24800	692	20	
		694	HR5A	4540-4587	18470	694	32	
		693	HR6	4538-4759	20350	693	25	
		684	HR14A	6308-6701	17740	684	37	
	UVES	74	520			148	147	
	UVES	353	580	4771-6785	47000	706	68	7445

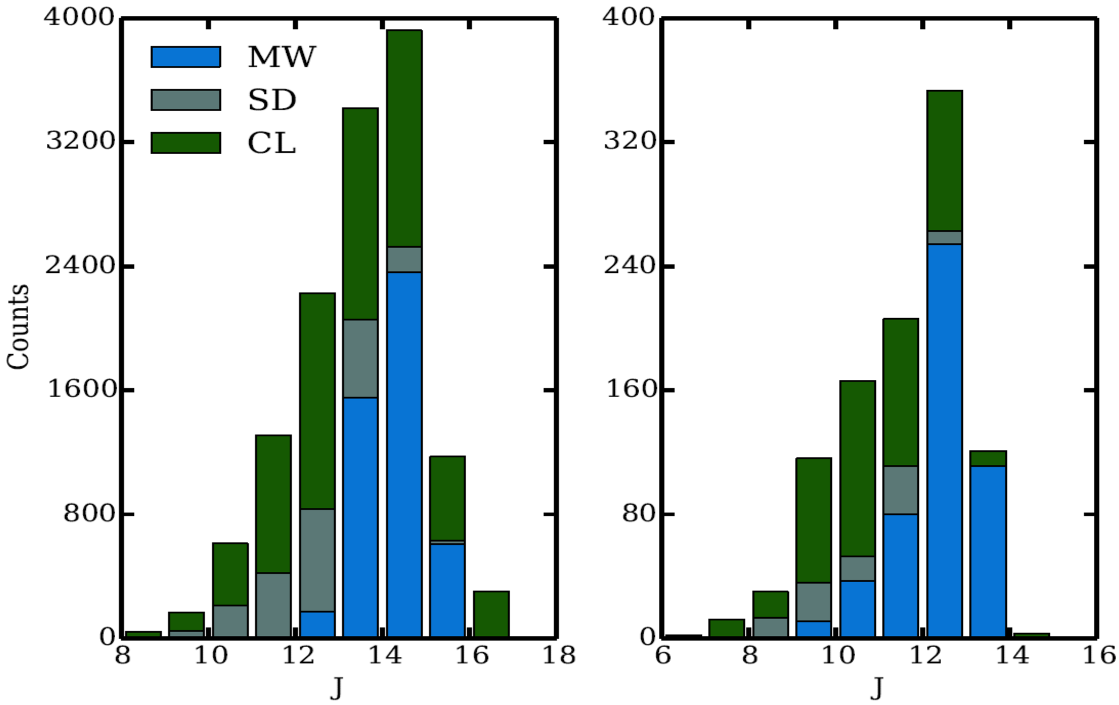


Figure 4: Histogram of magnitudes of targets (J_{VISTA} for MW fields, J_{2MASS} for clusters.) Left-hand panel: GIRAFFE; right-hand panel: UVES

Release Notes

Data Reduction and Calibration

The standard Gaia-ESO observing procedure is to divide each observing block into three exposures (except for Giraffe HR21 which is normally divided into two). Two long exposures which are then co-added to eliminate residual cosmic rays, and a short exposure (of a few seconds) which is taken for the purpose of obtaining a simultaneous arc lamp spectrum (SIMCAL) with Giraffe for the wavelength calibration. Spectra from the short exposures are not co-added when creating the final spectra.
Departures from this observing pattern exist – in the case, for example, of periods of poor seeing when additional exposures of a field have been obtained with the aim of increasing the signal-to-noise ratio (S/N). Conversely, during occasional periods of exceptionally good seeing, only one exposure of a field may be taken.

Multi-epoch exposures are defined to be those composed of individual exposures originating from more than one night. A night is defined as the 24-hour period from noon-noon local time (16:00-16:00 UT).

Reduction Pipeline: Giraffe
The Giraffe spectra were reduced by a pipeline that was specially written at the Cambridge Astronomical Survey Unit (CASU). It performs all of the following steps:

- *Bias correction and 2D flat fielding.* The latter is done using test dome flats that are taken periodically as part of the instrumental health checks. Although these are not dispersed flat fields and, of course, flat fields are wavelength dependent, using these does take out a large amount of the pixel-to-pixel variation. (Unfortunately dispersed flat fields without the fibre feed in the light path are not available);
- *Localisation and tracing of the fibre spectra using fibre flat field images.* The optimal extraction profile fits are also done at this point;
- *Extraction of arc spectra, identification of arc lines and wavelength-solution calculation;*
- *Removal of scattered light, extraction and wavelength calibration of object spectra.* The spectra are wavelength calibrated using the arc solution and also shifted to the solar rest frame. For all but the HR21 setting the SIMCAL lamp spectra are used to define a correction to the wavelength solution that is also applied here. For HR21 a similar correction is applied using a subset of well-studied night-sky lines;
- *Sky correction using combined sky fibres from the field.* For all but HR21 the combined sky spectrum is used as is and is subtracted from each object spectrum. For HR21, the sky spectrum is scaled by the relative fluxes of the sky lines to ensure cleaner sky removal;
- *Repeat exposures of the same objects are stacked and cosmic rays are removed.* These are then normalised by the fibre flat field to remove the large-scale wavelength-dependent variation in each fibre.

Reduction Pipeline: UVES
The UVES data were reduced at INAF-Arcetri, using the public ESO FLAMES-UVES pipeline (version 4.9.8 or later) for the standard steps of the data reduction process (e.g., bias subtraction, flat-fielding and wavelength calibration) and a pipeline written at INAF-Arcetri for the sky-subtraction, barycentric correction, co-addition. Details of the reduction process can be found in Sacco et al. 2014, A&A 565, 113). The main steps are summarized below.

The reduction is performed in a semi-automatic way, following a reduction cascade. Relevant raw data, including both calibration and science frames, are selected and inserted into the reduction path.

All acquired data are pipeline-reduced using the best possible master calibration products, which are produced starting from the best available day-time calibration frames. After quality checks, these are applied to the reduction of science data. The standard reduction steps followed are:

- *Bias subtraction*;
- *Flat-fielding;*
- *Tracing of the spectral order position*;
- *Wavelength calibration*;
- *Optimal extraction of science spectra* (spectra are de-convolved for fibre cross talk and intra-order background is subtracted);
- *Spectra are corrected for differences in fibre transparency*;
- *The orders are merged*;
- *The sky spectrum from the fibre allocated to the sky is subtracted from the target spectra.* This step is performed both on the individual orders, and on the merged spectra. When more than one fibre is allocated to the sky, the median of the sky spectra is subtracted;
- *Both single order and merged spectra are shifted to a Heliocentric reference system*;
- *Both single order and merged spectra of the same target are co-added*;
- *A median S/N ratio across the whole spectrum is calculated, for both CCDs*;
- *All co-added spectra are flagged for binarity*;
- *Final quality checks are performed on the spectra* (see **Data Quality** section);

Post-processing

The normalisation applied to the spectra depends on the particular science goal of the analysis. The choice of continuum level in particular is an individual one which is left as a scientific choice for the end user. As we did in the first release, we deliver here non-normalised spectra to ensure that no valuable information is lost from the spectra.

For the UVES echelle spectra, we have merged the spectral orders and deliver only the merged spectra.

Radial Velocity Pipeline: UVES

Radial velocities (RVs) are derived by cross-correlating each spectrum with a grid of synthetic template spectra. The grid is composed of 36 spectra convolved at the FLAMES-UVES spectral resolution. It covers seven effective temperatures ($T_{\rm eff}$ = 3100, 4000, 5000, 6000, 7000, 8000 K), three surface gravities (log(g) = 2.5, 4.0, 5.0), and two values of metallicity ([Fe/H] = 0.0, −1.0).

Each spectrum is cross-correlated with all the spectra of the grid, using the IRAF task FXCOR masking the Balmer lines (Hα and Hβ) and regions of the spectra with strong telluric lines. To derive the RV, the cross-correlation function (CCF) with the highest peak is selected and the peak is fitted with a Gaussian function to derive its centroid. This procedure fails for very early-type stars with an effective temperature above the highest temperature of our grid, which are characterised by the presence of no, or very few, absorption lines other than the Balmer lines. Radial velocities for these stars are not included in the present release.

To estimate the precision of the RVs, we used the differences between RVs measured from the lower ($RV_{\rm L}$) and upper ($RV_{\rm U}$) spectra, which are measured independently by the pipeline. Assuming identical uncertainties on RVs from the two wavelength ranges, and since there is no systematic offset between lower and upper spectra ($median(RV_{\rm U} - RV_{\rm L})$ = 0.007 km s^{-1}), the empirical error on the RVs derived by our pipeline is $\sigma_{\rm UL} = |RV_{\rm U} - RV_{\rm L}|/\sqrt{2}$; the statistical error on RV is equal to the 68th percentile rank of the distribution of these empirical errors, after outliers have been removed. (σ = 0.18 km s^{-1}).

Since the upper and the lower spectrum are calibrated using the same arc lamp, our approach for the error estimate does not take into account the error due to the variations of the zero point of the wavelength calibration. In order to estimate this source of uncertainty, we used spectra of targets observed multiple times in different epochs. Similarly to the above case, the empirical error is estimated as $\sigma = |\Delta RV|/\sqrt{2}$, where | ΔRV | is the difference between two observations of the same target performed in different nights. The distribution of this empirical error is much wider than the distribution of the errors $\sigma_{\rm UL}$; the 68th percentiles are $\sigma_{\rm U}$ = 0.38 km s^{-1} and $\sigma_{\rm L}$ = 0.40 km s^{-1} for the lower and upper ranges, respectively; this proves that the variations of the zero point of the wavelength calibration are the main source of uncertainty. Therefore, we adopt σ ~ 0.4 km

s^{-1} as the typical error for the RVs derived from the FLAMES-UVES spectra of the *Gaia*-ESO Survey.

Radial Velocity Pipeline: GIRAFFE

All spectra are iteratively matched against a range of templates to identify the most suitable object-specific templates, thus determining the output RV, and its probability distribution function. Errors are estimated from the curvature of the chi-square surface around the minimum and then empirically corrected to reflect the systematic error floor limit different for each instrument setup as further descibed in Koposov et al. 2011, ApJ,736,146.

Thanks to the observations of radial velocity standard stars, U580, HR10, HR15N, and HR21 RVs could be shifted to a common zero point. This was not possible for the bluer GIRAFFE grating and U520, due to the lack of enough standards observed with these settings at the time of data processing. Those standard stars were then observed later in the Survey.

Spectrum analysis

Five working groups (WGs) share this task, focusing on Giraffe and UVES spectra of FGK normal stars, of cool pre-main sequence stars, of OBA-type stars, and on unusual objects, respectively. Within each WG several nodes participate in the analyses. An early lesson from working with many analysis teams was the critical need to have a well-understood, common, suitable line-list for the analyses, a common set of model atmospheres, a common grid of synthetic spectra, and a common approach to data formats and standards. All of these have been made available to the analysis groups and are regularly updated thanks to the efforts of dedicated teams.
Once the node analysis within the different WGs has been completed, WG recommended parameters are derived using the calibrators (in particular the Gaia benchmark stars) to evaluate and weight node performances. Depending on the particular WG and on the number of nodes, the final recommended parameters are computed as weighted medians or mean values after outlier rejection and, when needed, offset correction. After this stage, parameter and abundance homogenisation across WGs is performed. This step involves putting the parameters and abundances derived by the different WGs for the different types of stars on the same scale. It is carried out based on common targets and calibrators analysed by all the spectrum analysis nodes and WGs (see Hourihane et al., 2015, in preparation).

The different node analyses are based on several complementary standard, as well as special-purpose, spectrum analysis methodologies. The structure of the WGs provides close coordination between the teams, ensuring the optimum range of analyses are applied to the various stellar and data types as appropriate. The methodologies are all established, all publicly well-documented, forming the basis of most modern spectrum analyses in the literature. Below we provide a general description of the strategy and methods followed by the spectrum analysis WGs. For the details, node value combination, and error estimate we refer to Smiljanic et al. (2014, A&A 570, 122), Lanzafame et al. (2015, in press - arXiv:1501.04450), Recio-Blanco et al. (2015, in preparation), Blomme et al. (2015, in preparation).

For the analysis of the spectra and the determination of the advanced product contained in this release, the five WGs in charge of the spectrum analysis follow a similar approach, summarized below:

- The data analysis has been duplicated among the nodes contributing to each WG. Specifically, more than one group has normally analysed and produced results for (nearly) all relevant Survey targets. This duplication of different methods has allowed, given performance comparison of the results, production of a set of recommended parameters. Also, through rigorous quality control, it has provided a quantitative estimate of both random and method-dependent uncertainties. When discordant results for a specific star, individual checks have been conducted;
- Depending on the star's spectral-type and characteristics, appropriate optimal tools, software, and model atmospheres have been used; however, some methodologies in common to all WGs have been identified. As mentioned, a common line list has been implemented (Heiter et al., 2015, in preparation); likewise, common model atmospheres,

covering the range from A to M spectral type (MARCS models), as well as a grid of synthetic spectra based on those models, have been used by most nodes, with exception of those analysing warm stars;

- The methods used to derive APs can be roughly divided in two broad categories. The first one, based on comparisons between observed spectra and a grid of templates (other synthetic or observed ones), includes the main types of parameterisation methodology, such as exhaustive search algorithms, global optimization methods, projection algorithms, pattern-recognition methods, and Bayesian parameterisation approaches (like e.g., MyGisFos, SME, ROTFIT, FASTWIND, etc.) ; the second one consists of more classical approaches, based on measurements of equivalent widths (EWs) of absorption lines and inversion codes (like e.g., MOOG) , or use of curves of growths (COGs) for particular lines/elements (e.g., Li). In these cases EWs are measured with (semi-) automatic codes by fitting Gaussian profiles to the lines. The available codes include: DAOSPEC, ARES, and SPECTRE.
- Additional methods to derive APs have been used in special subsets of the sample (e.g., Hα wings, line-depth-ratios). In most cases the codes are automatic, and proven to be able to handle Gaia-ESO scale data. An alternative approach for GIRAFFE/HR15N, proposed by Damiani_et al. (2014), is also used. This is based on spectral indices in different wavelength ranges of the spectrum. The derived spectral indices are calibrated against stars with known parameters, yielding quantitative estimates of APs;
- The width of Ha at 10% and Hα equivalent widths have been measured on the continuum-normalised spectra, using a semi-automatic procedure. After manually defining the wavelength range and level of continuum, the equivalent widths is calculated by a direct integration of the flux above the continuum, while the width at 10 % is derived by considering the level corresponding to 10% of the maximum flux above the continuum in the selected wavelength range. All measurements are visually checked and repeated in case of miscalculation (e.g. due to the presence of multiple peaks). Uncertainties are estimated using multi-epoch observations of the same star;
- Lithium equivalent widths released here (young cluster targets only) have been measured with three independent methods and then combined, after careful comparison (see Lanzafame et al. 2015). Namely, IRAF-splot (Gaussian fitting), DAOSPEC (Gaussian fitting), and a semi-automatic direct integration procedure in IDL, specifically developed for the Gaia-ESO Survey. As a conservative uncertainty estimate on the recommended equivalent width, we adopted the larger of the standard deviation and the mean of the individual method uncertainties;
- Finally, a special object-by-object analysis process has been applied to spectra that are not consistent with any of the stellar classes (e.g., binaries, carbon stars, etc.). A set of flag has been implemented and the dictionary is delivered in this release.

Data Quality

Spectra - general

The quality array ('QUAL') delivered along with the spectra in the data files codes data values as good quality (0) or bad quality (1). These code values are derived from weight maps where a value of '1' represents a bad pixel.

Further quality control that is applied to the spectra is described below.

Quality Control: UVES spectra

Quality control (QC) on the UVES data is performed in three steps:

- Check on the quality of the calibration frame by comparing the QC parameters, which are given as output by the ESO pipeline, with the typical values published on the ESO website. This approach allows us to verify the instrument stability (e.g. the stability of the bias frame or the precision of the wavelength calibration);
- Visual inspection of the final spectra aimed at discovering artifacts or other anomalies (e.g., in the wavelength calibration). If this analysis identifies anomalies in one or more spectra, the whole workflow, since fibre allocation, is investigated. Once the problem is

identified, the reduction is performed again to improve the quality of the spectra;
- Selection of S/N thresholds. (The S/N is the median value and is quoted per pixel.)

Quality Control: Giraffe spectra

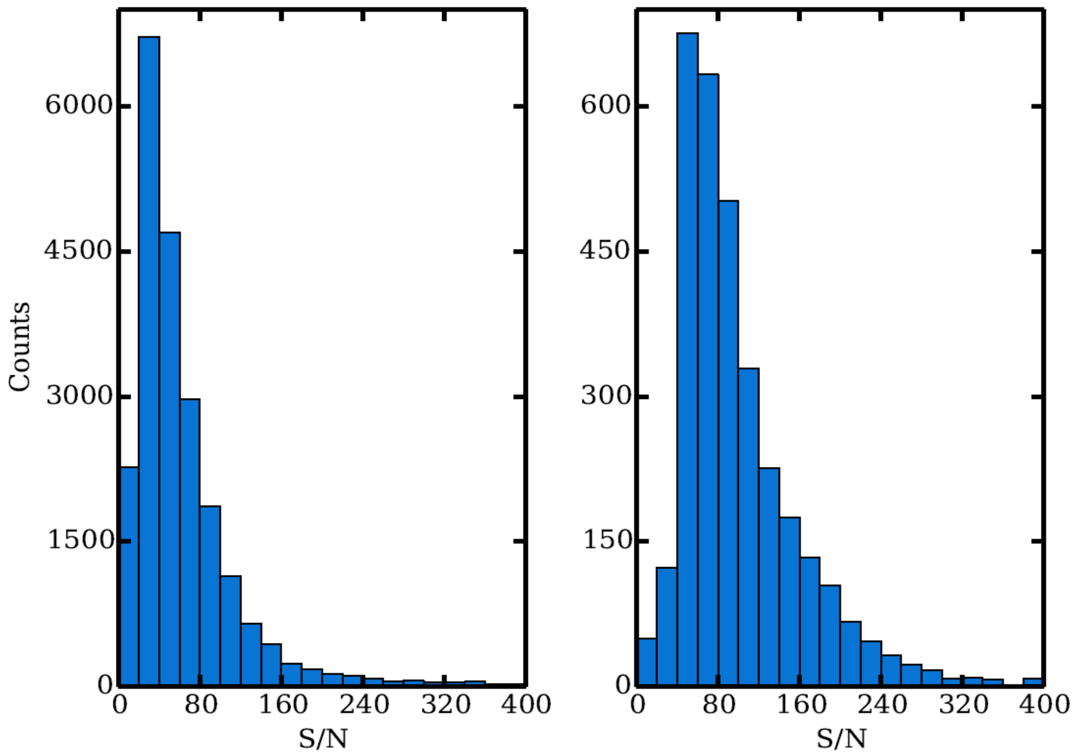
QC on the Giraffe data is carried out as part of the spectral template fitting which then assigns a basic classification.

The main criteria defining this classification are:

- the χ^2 of the fit;
- the S/N (calculated per pixel);
- the χ^2 of the pure continuum fit; and
- the distance to the best fit template.

The spectrum is marked as UNKNOWN instead of STAR when the continuum-only fit is better or almost as good as the template fit. The χ^2 and/or distance to the best-fit template are higher than a certain S/N-dependent threshold.

Figure 5: S/N ratio distributions for the released spectra; GIRAFFE and UVES are shown in the left- and right-hand panels, respectively.



Quality control: Radial velocities

The following set of figures shows quality diagnostics for the RVs and various instrumental set-ups. The radial velocity agreement for the same targets between instrumental set-ups is good (Figure 6). It can also be seen (Figure 7) that the radial velocity precision being achieved for the majority of survey targets is well within the required 1 km/s. Indeed it reaches below to 0.3 km/s (our requirement) for cool stars in clusters (see Figure 8 and Jeffries et al., 2014, A&A 563, 94). Similarly, very good precision is obtained for UVES (see Sacco et al. 2014).

Figure 6: comparison of the radial velocities obtained from the different Giraffe settings

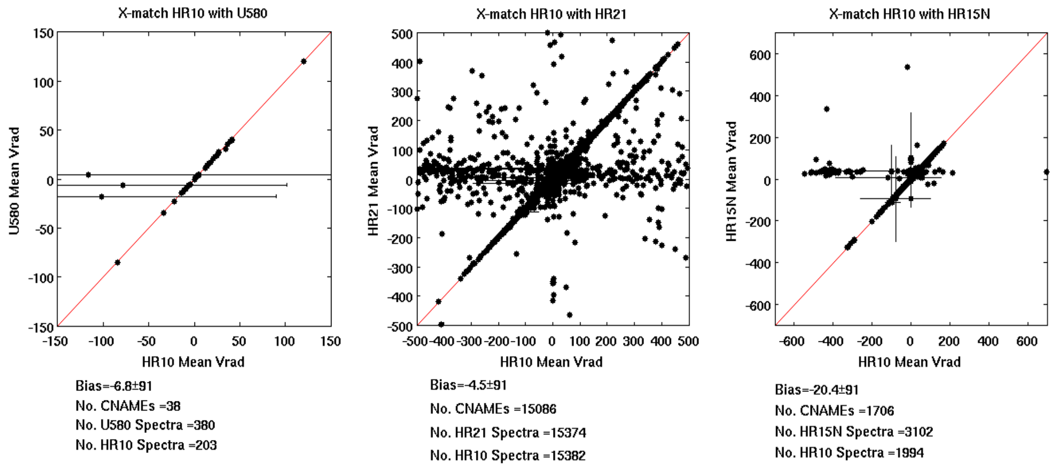


Figure 7: The radial velocity precision determined for GIRAFFE HR21 spectra.

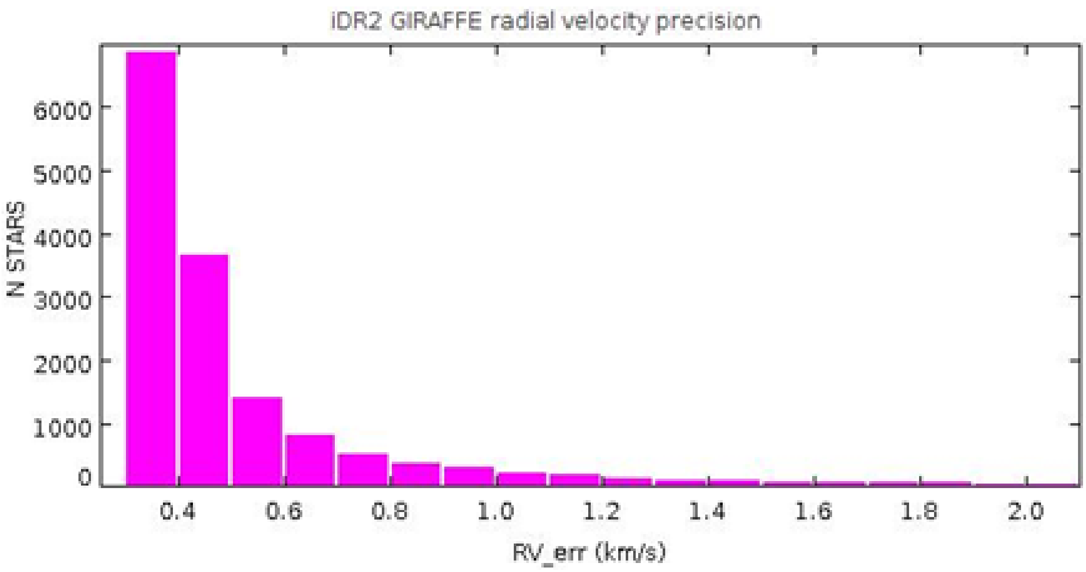
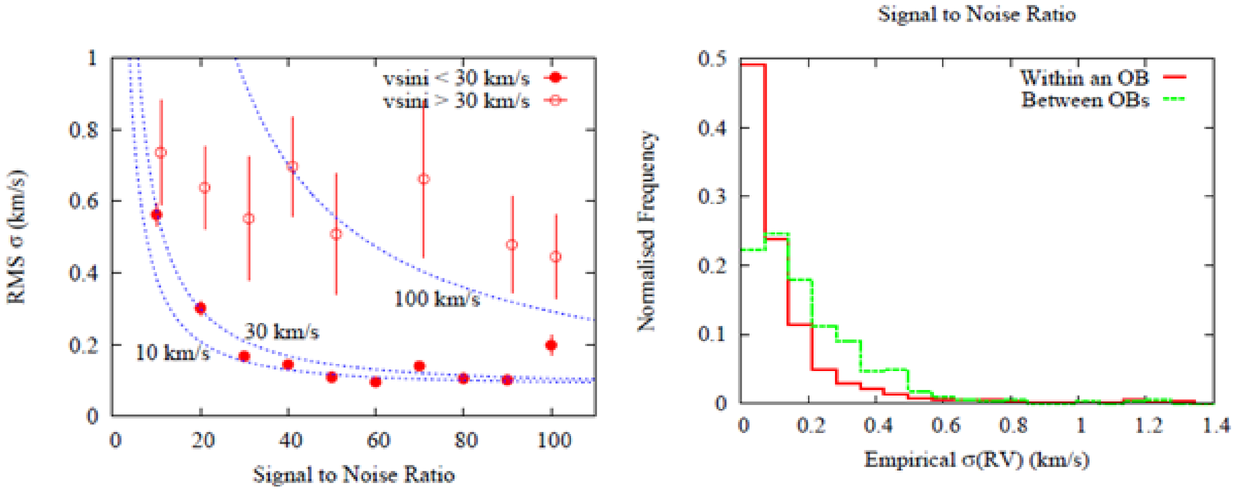


Figure 8. The empirically determined RV precision for Gamma Velorum measurements. Left panel: The RMS of the empirically estimated RV uncertainties (see text of Jeffries et al. 2014)) from pairs of observations within an OB, binned by SNR. A separate set of points is calculated for stars that have an estimated v sin i > 30 km s^{-1} to demonstrate their larger empirical uncertainties. The lines on the plot are loci determined from Equation 1 in Jeffries et al. (2014) using the coefficients A = 0.09 ± 0.01, B = 3.52 ± 0.23, C = 38 ± 8 for several labelled v sin i values. The fit is poorly constrained for large v sin i and there are some indications that the semi-empirical model underestimates the uncertainties for such stars at high SNR. Right panel: The frequency distribution of empirical RV un-

certainties determined from repeated observations within an OB and from repeated observations from separate OBs. The increase in the width of the latter distribution indicates additional uncertainties associated with wavelength calibration between OBs.



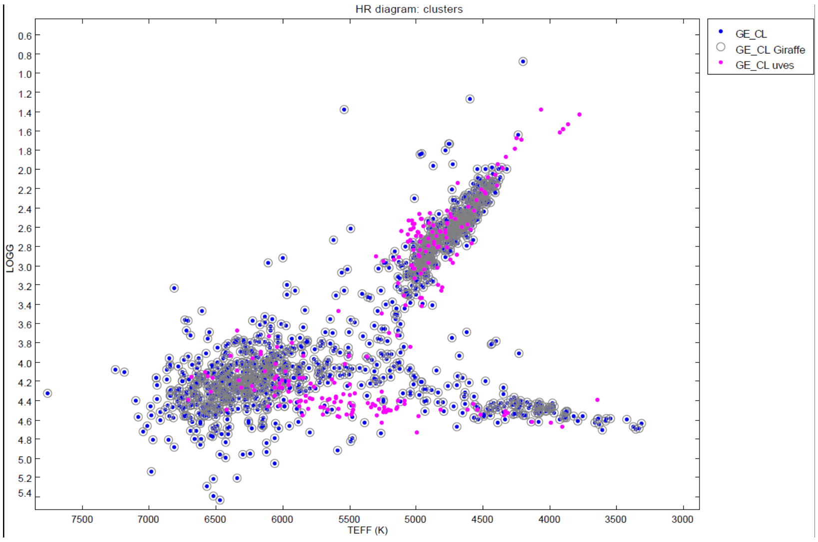
Quality control: astrophysical parameters

A variety of quality checks have been performed on the astrophysical parameters (see Smiljanic et al. 2014; Lanzafame et al. 2014; Recio Blanco et al. 2015; Hourihane et al. 2015); namely:

- the final recommended set of parameters for each benchmark star is compared with the literature values for these stars;
- HR diagrams of both field stars and clusters are produced. For the clusters comparison with the isochrones is performed (see Figure 9);
- Within the clusters checks for the homogeneity of metallicity and lack of trends with parameters are performed;
- For the MW fields we checked that the expected (from original selection) temperature and gravity distributions are recovered

A few quality plots are included below.

Figure 9: HR diagrams of the cluster fields (all clusters together) and MW fields. Stars observed with UVES and Giraffe are indicated with different colours.



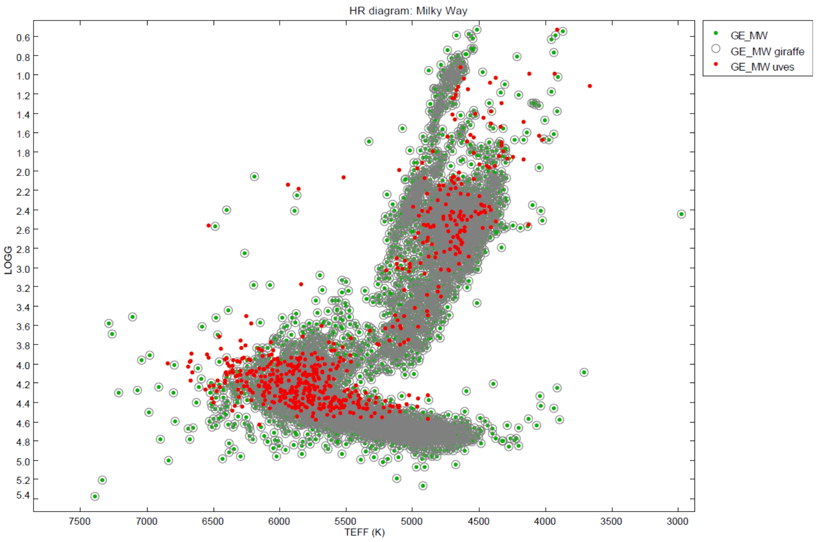


Figure 10: HR diagram of MW and cluster fields, Giraffe and UVES, colour coded by [Fe/H]

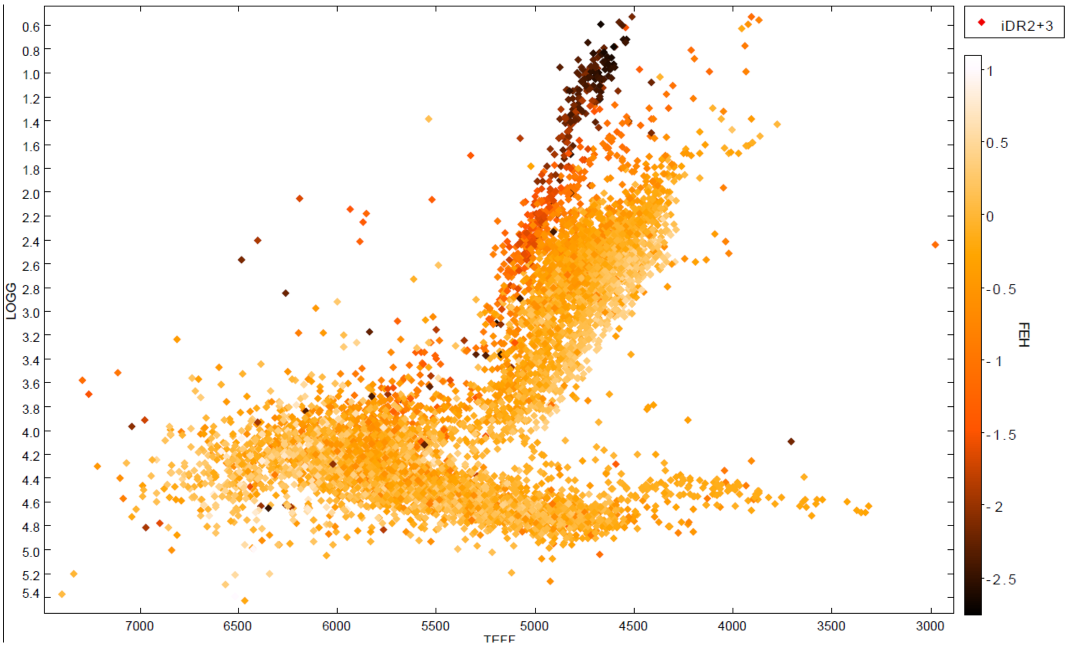
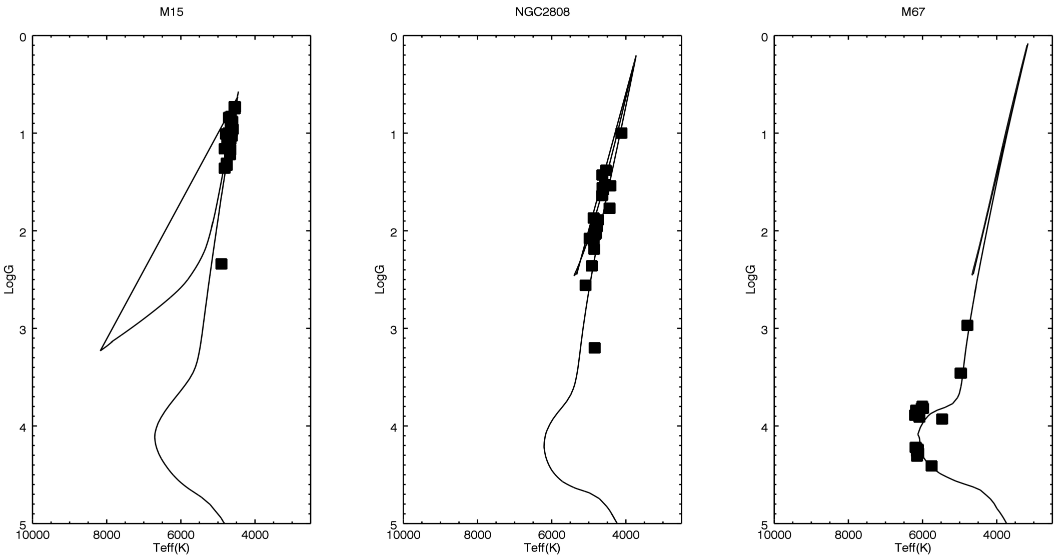


Figure 11: HR diagrams of three calibrator clusters with isochrones overimposed. Note that spectra for M67 were retrieved from the ESO archive and are not delivered in the present release



Quality Criteria:

The spectra included in this data release satisfy the following key criteria:

1. Observed prior to 31th December 2013;
2. Target observations are complete for the survey;
3. They are not characterized by reduction issues (e.g., sky emission subtraction)
4. They have all undergone a cycle of analysis (our internal iDR2 and iDR3), even if the resulting parameters are not released, because they do not match our selection criteria (see below)
5. Above S/N limit:
    1. MW and SD: UVES S/N > 40 in both lower and upper CCDS; Giraffe spectra exist for the target in both HR21 and HR10, achieving HR21 S/N>30 and HR10 S/N >20. MW bulge stars have a single setup (HR10 or HR21), and thus the requirement of spectra in both HR21 and HR10 is relaxed.
    2. CL: all of the clusters for which 70 % of the UVES targets have S/N > 40 in both lower and upper CCDs and 70% of the Giraffe HR15N spectra have S/N > 20. For each cluster, spectra with S/N ratios below those thresholds are also delivered. No SNR thresholds are imposed on the bluer gratings, since the current S/N ratios values for those spectra (with which warm stars are observed) may be underestimated. Since a great fraction of those spectra have been analysed, we believe they are of sufficient quality.
6. Preliminary Classification = STAR;
7. Observations are complete on all cluster targets, for all UVES and Giraffe settings during the required epoch;

The radial velocities included in this data release satisfy the following criteria:

1. For the clusters: -100 km/s < RV < 150 km/s
2. For the clusters: The error must have been determined
3. For the clusters: The error must be below 2 km/s
4. No cuts were applied for the MW

Based on the error distributions, the parameters included in this release satisfy the following criteria:

1. Relative error in effective temperature must be below 10%
2. Error in gravity must be below 0.4 dex
3. Error in [Fe/H] must be below 0.4 dex
4. No cuts were applied for Hα, lithium equivalent width, and gravity index
5. For the clusters: the position of the member stars in the HR diagram must be consistent with what expected given the cluster parameters and in good agreement with the theoretical isochrones
6. For the clusters: no spurious trend must be present between [Fe/H] and effective temperature and/or surface gravity

Known issues

N/A

Previous Releases

Previous release was number 1. The changes in the present release are as follows:

1. A larger set of spectra is included. In release #1 a subsample of the spectra obtained up to 30 June 2012 were delivered. Here we submit a fraction of the spectra obtained up to December 31, 2013. The spectra selection criteria have not changed. The spectra released here have been reduced with updated versions of the GIRAFFE and UVES pipe-

lines;
2. A catalogue is delivered, including ancillary information (i.e., target photometry), radial velocities, astrophysical parameters, Ha emission information, lithium equivalent widths, flags.

Data Format

Files Types

The files provided for this release are in the format as specified in issue 5 of document GEN-SPE-ESO-33000-5335. This consists of a FITS file with a primary header unit containing no data and a binary FITS table extension containing the data. The header cards in the header unit of each extension contain the information requested in the above document.[3] In addition, the primary and extension headers specify the type of the Gaia-ESO Survey field in the GES_TYPE keyword (values are listed in **Overview of Observations** Section). This keyword is intended to provide useful supplementary information on the field for the user – please note, however, that it is not currently a searchable field in the ESO archive. The wavelength array (WAVE), spectrum (FLUX), error array (ERR) and quality array (QUAL) are each provided in a single cell of the one row contained in the binary table.

The objects in each file have a name which is derived from the object's equatorial coordinates. This is formed by splicing the RA (in hours, minutes and seconds to two decimal places) and Declination (in degrees, minutes and seconds to one decimal place) as integers with the declination sign in the middle. Thus an object at 3h40m21.767s and -31°20'32.71" will have the name 03402177-3120327. The name of the file is of the form <prefix>_<name>_<expmode>.fits, or <prefix>_<name>_<expmode>_<index>.fits. The value of <prefix> will be either 'gir3' (Giraffe) ,'uvl3' (UVES lower) , or 'uvu3' (UVES upper). The value of <expmode> is derived from the central wavelength and grating for the instrument, e.g. H875.7. The value of the <index> suffix is an integer assigned to distinguish each individual exposure spectrum for the unstacked benchmark spectra (all spectra without an <index> are stacked from the available spectra).

Catalogue Columns

The catalogue comprises 38 columns with 14947 rows of data. The columns are described in the Table 3, and the flags used in columns PECULI, REMARK and TECH are defined in Table 4.

Table 3: Column names, data format, description and units contained within the Gaia-ESO Survey Catalogue.

Column	Data Format	Description	Units
CNAME	16A	GES object name from coordinates, corresponds to OBJECT in header of FITS spectrum	
GES_FLD	30A	GES field name from CASU	
OBJECT	30A	GES object name from OB	
GES_TYPE	8A	GES Classification System of Target Programmes	
SETUP	36A	Grating setups used for analysis	
RA	D	Object Right Ascension	Deg
DECLINATION	D	Object Declination	Deg
VRAD	E	Radial Velocity	km/s

3 Please note that the SPEC_RES keyword in the primary header denotes the spectral resolving power, $\lambda/\Delta\lambda$, rather than the FWHM resolution.

E_VRAD	E	Error on VRAD	km/s
TEFF	E	Effective Temperature	K
E_TEFF	E	Error on TEFF	K
LOGG	E	Log Surface Gravity (gravity in cms^{-2})	dex
E_LOGG	E	Error on LOGG	dex
FEH	E	Metallicity	dex
E_FEH	E	Error on FEH	dex
EW_LI	E	Li(6708A) equivalent width	mÅ
LIM_EW_LI	I	Flag on EW_LI	
E_EW_LI	E	Error on EW_LI	mÅ
EW_HA_ACC	E	Halpha EW: accretion	Å
E_EW_HA_ACC	E	Error on EW_HA_ACC	Å
HA10	E	Halpha EW at 10% of peak - accretion	km/s
E_HA10	E	Error on HA10	km/s
GAMMA	E	Gravity sensitive spectral index	
E_GAMMA	E	Error on GAMMA	
PECULI	36A	Peculiarity Flag(s): WG14 Dict.1000-2999	
REMARK	10A	Spec. Class. Flags(s): WG14 Dict.3000-8999	
TECH	11A	Technical Flag(s): WG14 Dict.9000-15000	
j_vista	D	J Band 4th aperture magnitude of VHS	mag
j_vista_err	D	J Band 4th aperture magnitude error of VHS	mag
h_vista	D	H Band 4th aperture magnitude of VHS	mag
h_vista_err	D	H Band 4th aperture magnitude error of VHS	mag
k_vista	D	K Band 4th aperture magnitude of VHS	mag
k_vista_err	D	K Band 4th aperture magnitude error of VHS	mag
dist_vista	D	Distance to VHS co-ordinate match	arcsec
BMAG	E	B Band magnitude from Cluster photometry compilation	mag
VMAG	E	V Band magnitude from Cluster photometry compilation	mag
RMAG	E	R Band magnitude from Cluster photometry compilation	mag
IMAG	E	I Band magnitude from Cluster photometry compilation	mag

Table 4: Definitions for the flags included in the PECULI, REMARK and TECH columns of the catalogue as stated in the WG14 Dictionary.

Flag	**WG14 Dictionary Definition**	**Confidence**
PECULI Flags		
1011A	Emission line detection (Hydrogen (01), ionization level)	A=probable
1011B	Emission line detection (Hydrogen (01), ionization level)	B=possible
1011C	Emission line detection (Hydrogen (01), ionization level)	C=tentative
1013A	Emission line detection (Balmer Halpha)	A=probable
1014A	Emission line detection (Balmer Halpha)	A=probable
1014C	Emission line detection (Balmer Halpha)	C=tentative
1021B	Emission line detection (Helium (02), ionization level I)	B=possible

2005A	Stars with large radial velocity variations, indicating either large jitter or binary motion	A=probable
2010A	SB1 (Stars with radial velocity variations larger than expected jitter for its type, indicating probable binary motion)	A=probable
2020A	SBn,n>2 (Spectroscopic Binary, Ncomponents >=2)	A=probable
2020B	SBn,n>=2	B=possible
2020C	SBn,n>=2	C=tentative
2030A	SBn,n>=3 (Spectroscopic Binary, Ncomponents >=3)	A=probable
2030B	SBn,n>=3	B=possible
2100A	Abnormal rotators	A=probable
2100B	Abnormal rotators	B=possible
2100C	Abnormal rotators	C=tentative
2462B	Enhanced 12CH	B=possible
2462C	Enhanced 12CH	C=tentative
REMARK Flags		
4400	Pre Main Sequence	
4410	Main sequence	
4420	Giant or supergiant	
4130A	T Tauri	A=probable
4140A	weak T Tauri	A=probable
TECH Flags		
14101	Single component emission - one intrinsic Halpha emission component	
14102	Single component emission - one intrinsic Halpha emission component	
14106	Sharp emission peaks - two intrinsic Halpha emission components with peak separations of less than 50 km/s, additional nebular emission component	
9020A	Radial velocity determination problem	A=probable
9030A	Data reduction issues	A=probable

Acknowledgements

Please use the following statement in your articles when using these data:
Based on data products from observations made with ESO Telescopes at the La Silla Paranal Observatory under programme ID 188.B-3002.