INSPIRE:
Investigating Stellar Population In RElics
Final Data Release (DR3)

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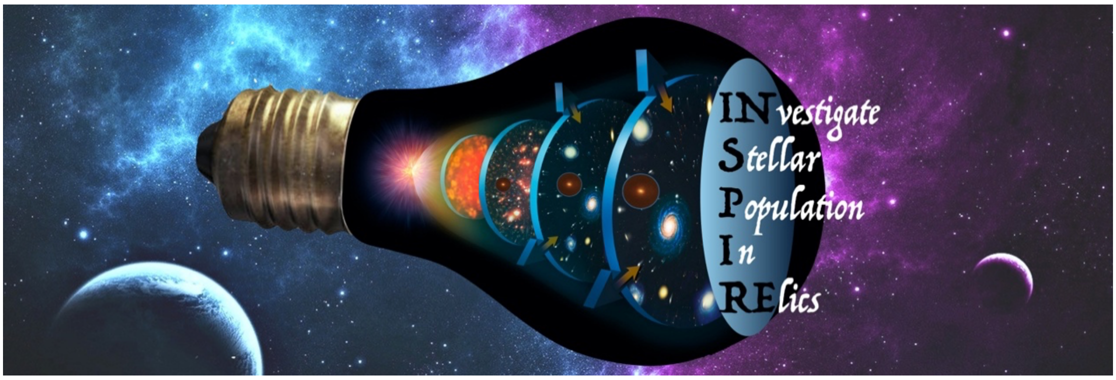


Abstract

This document describes the third and final public data release (DR3) of the X-Shooter ESO Large Program 1104.B-0370, "INvestigating Stellar Population In Relics (INSPIRE), which is firstly introduced in the INSPIRE pilot project (Spiniello et al., 2021a, A&A, 646, A28, hereafter S21a). Scientific results associated to this DR3 are presented in Spiniello et al., 2023, arXiv:2309.12966, hereafter S23).
The first data release, published in March 2021, and described in the accompanying paper (Spiniello et al. 2021b, A&A, 654, A136, hereafter S21b), comprised of 19 ultra-compact massive galaxies (UCMGs) for which integrated stellar velocity dispersion, as well as mass-weighted age and metallicity and light-weighted [Mg/Fe] had been precisely measured. In the DR2, we release one-dimensional (1D) spectra in the UVB and VIS and NIR arms, of 21 additional systems, for which ESO observation have been completed before March 2022. Also in this case, we accompanied the DR with a scientific paper (D'Ago et al., 2023, A&A, 672, A17, hereafter DA23) that focusses on measuring the velocity dispersion from 1D spectra and assessing the systematics on it. In addition, we release again the spectra for the 19 objects described in DR1 and S21b, adding this time also the NIR arm.
In this third and final data release we complete the INSPIRE sample, making publicly available the UVB, VIS and NIR 1D spectra of all the remaining objects, and replacing all the already released ones, hence bringing the total sample to 52 UCMGs. Finally, we add a catalogue with the morpho-photometric characteristics (from optical multi-band images) as well as spectroscopic and stellar populations information on each of the galaxy in the INSPIRE sample.

Scientific Context

The first generation of extremely massive Early-Type Galaxies (ETGs) is already in place at $z \geq 3$ (Guo et al., 2013); their number density dramatically increases between $3 < z < 1$ (Trujillo et al. 2007) and then only mildly evolves at $z < 1$ (Bell et al. 2003). Interestingly, at higher redshift, massive red objects are found to have 3–5 times smaller sizes than in the local Universe, and thus they are 30–100 times denser (van Dokkum et al., 2008).

To reconcile these observations, a *two-phase formation scenario* (Oser et al., 2010) has been proposed to explain the mass assembly and evolution across cosmic time of very massive galaxies. A first intense and fast dissipative series of processes form their central "bulk" mass (at z>2) generating, after star formation quenches, a massive, passive, and very compact galaxy with size a factor of ~4 smaller than local massive galaxies (the so-called "red nuggets", Daddi et al. 2005). Then a second, more time-extended phase, dominated by mergers and gas inflows, is responsible for the dramatic structural evolution and size growth from z~1 to today (Buitrago et al., 2008). Unfortunately, this "accreted" material overlaps, along the line-of-sight, with the spatial and orbital distributions of the "in-situ" light, that encodes the information about high-z baryonic processes, irreversibly limiting our resolving power. Luckily, since merging is believed to be stochastic, a small fraction of red nuggets survives intact until the local Universe, without experiencing any further interaction: **Relic Galaxies**. *Relics are the perfect local "laboratories" to study the processes that shaped the mass assembly of massive galaxies in the high-z Universe and disentangle between possible formation scenarios for massive galaxies*.

In the local Universe, only three relics have been confirmed and studied in great details (Trujillo et al. 2014, Ferré-Mateu et al., 2017, hereafter F17). They have large rotation velocities (~200-300 km/s) and high central stellar velocity dispersions (>300 km/s). From a stellar population point of view, these three objects have a single stellar population with super-solar metallicities and old ages out to several effective radii. Their stars are also characterized by a large [Mg/Fe] over-abundance, which is consistent with early and short star formation episodes (within timescales < 1 Gyr, Thomas et al. 2005). Finally, the three relics also have a bottom-heavy stellar initial mass function (IMF), with the fraction of low-mass stars being at least a factor of 2 larger than that found in the Milky Way (F17).

The goal of INSPIRE is to build the first catalogue of spectroscopically confirmed relics at 0.1<z<0.5, bridging the gap between the three local confirmed relics and the high-z red nuggets, to understand the discrepancy between the observational results and to put a stringent constraint on the predictions from simulations. A more detailed descriptions of the scientific aims and goal of INSPIRE is provided in S21a and S21b, where we also present results obtained using data released here.

According to the definition given in Tortora et al. (2016, hereafter T16), a galaxy is defined as UCMG if it has an effective radius $R_{eff} < 1.5$ kpc and a stellar mass $M_* > 8 \times 10^{10}$ M_{sun}. However, since different studies have adopted different thresholds for size and masses, and since we aim at finding a large number of relics, we slightly relax these criteria and consider as confirmed UCMGs all objects with $R_{eff} < 2$kpc and stellar masses $M_* > 6 \times 10^{10}$ M_{sun}.

Overview on INSPIRE

INSPIRE is based on data obtained as part of the ESO Large Programme ID: 1104.B-0370, PI: C. Spiniello, which has been awarded 154 hrs of observations on X-Shooter to spectroscopically follow up 52 UCMGs with redshift $0.1<z<0.5$, which are part of a dedicated KiDS project (Tortora et al. 2018, Scognamiglio et al. 2020, hereafter T18 and S20 respectively). The observations have been completed in March 2023, and all data have been reduced and analysed.

Five refereed publications have been already produced by the Survey. Three of them are associated to the three ESO data releases (S21b, DA23, S23). The first paper, S21a, was meant to be a pilot to demonstrate the validity of the observation and data reduction and analysis strategies. Finally, in INSPIRE IV (Martín-Navarro et al. 2023), we give a first hint for the possibility that relics have a bottom-heavy (i.e., dwarf richer) Initial Mass Function. Two more papers of the INSPIRE series are already in preparation.

Details on the target selections, observation strategy for the whole INSPIRE Programme were already given in the release description of the first DR. We summarise the most important ones here below.

Selection of the targets

The targets have been selected from multi-band imaging from the Kilo Degree Survey (KiDS) project, thanks to a project specifically dedicated to the search for Ultra-Compact Massive Galaxies (UCMGs) at redshift $z<0.5$ (T16, T18, S20).

About 100 of the photometrically selected candidates were also spectroscopically confirmed. Among these, INSPIRE targets the 52 objects with *g-i* broad band colour compatible with that of a stellar population with integrated age larger than 8 Gyrs, considering a solar, super-solar and a sub-solar metallicity (Fig. 1, in S21b).

Each galaxy has structural parameters computed from *gri* KiDS images (Roy et al. 2018) and stellar masses retrieved from T18 and S20. These quantities are released in the master catalogue associated to this DR3.

Observation Strategy

The observation strategy has been optimized to capitalize on relatively sub-standard observing conditions (seeing up to 1.2, CLR nights, grey lunar phase with Moon FLI<0.5), allowing for an easy schedulability of the objects into the observation queue. Moreover, the selected targets span a very wide range in right ascension (RA) and declination (DEC), as can be seen from the histograms below, with an optimum observing time spread over the full year. This makes service mode observations, under a LP highly efficient. We note also that we have many systems with declination <-30, perfect as "fillers" in nights with strong wind coming from the North.

The slit widths are 1.6 arcsec in the UVB and 1.5 in VIS and NIR to ensure minimal slit loss. A dithering scheme (NODDING MODE) with multiple frames where the galaxy is offset by a small amount from the center of the slit is used to facilitate a proper sky subtraction. Finally, we also implement a sigma clipping routine to further clean the 2D spectra from cosmic ray and sky residuals. Similarly to DR1, the seeing during the observations ranged between 0.85 to 1.2 arcsec, with a median value of ~1". We note that the spectra are fully seeing-dominated, as the effective radii of all objects in arcseconds (apparent sizes, on average Reff~0.3-0.4") are much smaller than the median seeing of the observations.

The final integration time on target has been driven by the high SNR ratio we need to reach to precisely constrain the stellar population parameters (SNR >15 per Angstrom). More details are given in S21b.

Data reduction, 1D extraction and spectra analysis

The data reduction and analysis follows the same steps and procedures already extensively described in previous INSPIRE data releases and papers, briefly described here.

1. We reduce the data using the ESO XSH pipeline (v3.5.3) under the ESO Reflex Workflow (Freudling et al., 13, version 2.11.3 only up to the creation of the 2-dimentional (2D) spectral frames (one for each arm). We cannot use ESO Internal Data Products (IDPs), as they only comprise the already extracted 1D spectra and we need to perform an ad-hoc extraction of the one 1D spectra, to take into account the fact that these galaxies are not spatially resolved and the spectra are seeing-dominated, as the effective radii of all objects on the sky are much smaller than the median seeing of the observations.
2. We use our own Python routines, developed for S21a and already used in S21b to extract a 1D spectrum that encapsulates the same fraction of light for the different objects (R50, containing ~50% of the total light, but a mix from inside and outside the real effective radius).
3. For the VIS and NIR arms, we correct all the spectra from telluric absorption lines using the code 'molecfit' (Smette et al. 2015, version 4.2) run with its interactive ESO Reflex workflow. The telluric correction has been performed with the recipe "molecfit_model" that fits telluric absorption features on telluric standard observed the same night and with the same instrument set-up of the galaxies. Once we determined the column densities of the various molecules in the spectrum, we constructed the telluric correction considering the difference in airmass between the observations of the telluric standard and the galaxy. For this purpose, we use the recipe "molecfit_calctrans".
4. We analyse the spectra in three arms separately with the Penalised Pixel-fitting software (ppxf, Cappellari & Emsellem, 2004, Cappellari, 2017), getting their redshift and an integrated stellar velocity dispersion measurement. We re-fit all the spectra for all the 52 INSPIRE target using an uniform ppxf configuration.
5. We restframe, combine and smooth to a final resolution of FWHM=2.51Å the spectra for each object. We use line-indices analysis to estimate the [Mg/Fe] of the UCMGs and then we re-run ppxf on these to constrain the stellar population parameters (age, metallicity) using as input the MIUSCAT single stellar population models (SSP) by Vazdekis et al. (2015).
6. We build star formation histories and infer from these the fraction of stellar mass formed by z=2, the cosmic time at which each galaxy had formed 75% of its stellar mass and the time of final assembly (100% of the stellar mass assembled). This allows us to define the *degree of relicness (DoR),* a dimensionless number that quantifies how ``extreme" the SFH is. This enables an operative definition of relics, but it also serves to quantify the relative contribution of very old and lately formed (or accreted) stars. The DoR varies from 1, for the most extreme case: a galaxy that has fully assembled its stellar mass 700 Myrs after the Big Bang, to 0, for a galaxy that is still forming stars today. More details are given in S23.

INSPIRE Third Data Release – the final sample

In this third data release, in addition to the spectra for the 10 newly released sources, we replace all the spectra provided before for the 40 UCMGs previously released in DR1 (19) and DR2 (21). In this way, we provide the users with an homogeneous set of data obtained with the same data reduction pipelines and extraction routines. The spectra provided here are identical to the ones analysed in S23, from which kinematics and stellar populations have been derived and presented in the catalogue, also released as part of this DR3.

The entire INSPIRE dataset comprised 52 UCMGs. These are listed, along with their coordinates, *r*-band magnitudes (MAG_AUTO) and morpho-photometric quantities in Table 1. We list in the same table also the the DR in which the systems appeared for the first time, and the paper reporting their discovery. Effective radii in arcsecond and kpc, were computed computed as median of the quantities obtained from *g,r,i* bands, while stellar masses were inferred from optical SED fitting.

In this DR3, we release 52 spectra for each arm, totalling 156 1D spectra, at their original resolution. In addition, we also provide a catalogue with optical photometry from the Kilo Degree Survey, structural parameters derived in Roy et al. (2018), stellar masses inferred from SED fitting in the *ugri* bands (Tortora et al. 2018, Scognamiglio et al. 2020, T18 and S20 respectively), as well as redshifts, kinematical and stellar populations results from the INSPIRE Survey.
The formats of the resulting 1D spectra and of the catalogue are described in the next Section.

Release Content

The complete INSPIRE collection targets 52 ultra-compact massive galaxies, observed with the XSH spectrograph. For each object, three 1D spectra are produced, one for each arm of the instrument (UVB, VIS and NIR). Hence, in total, the ESO Phase 3 INSPIRE data comprise 156 spectra. Of these, 120 spectra on 40 galaxies were already previously released (19 in DR1 and 21 in DR2), while 36 are new and added with this DR3. Each spectrum, in each arm and for each galaxy, is the sum of different products at the Observation Block (OB) level (from 1 to 4 OBs per system) and is released as a binary table in the FITS standard data format.
The spectra are all given at the restframed wavelength, and the redshift used is reported in the corresponding headers. We do not join together the spectra from different arm of the same system since these have different resolution (R~3200 in UVB, R~5000 in VIS, R~4300 in NIR). However, we note that the kinematics and/or stellar population results presented in INSPIRE papers are obtained from a joint spectrum which was brought to the final resolution of FWHM = 2.52 Å, that of the single stellar population models used to perform the full-spectral fitting and to derive the stellar population parameters. More details on the joining procedure and the spectroscopic analysis are given in the accompanying papers. The combined and restframed version of the spectra are attached to each corresponding final science product as ancillary file, as explained below. The master catalogue listing the morphological, photometrical, and spectroscopic characteristics of the 52 ultra-compact galaxies is released as a single table and it is querable from the ESO catalogue interface.

Table 1: The INSPIRE final sample. For each galaxy, we list the ID, coordinates, the ESO DR in which this system was firstly presented, the origin paper reporting the discovery (or the public survey from which they were taken) and a number of morpho-photometric quantities all derived from from KiDS images (from left to right: gri magnitudes in the AB system, median effective radii (<R_e>) in arcseconds and kpc, median Sérsic indices (n), median axis ratios (q) and stellar masses.

ID KiDS	RA (deg)	DEC (deg)	DR	SAMPLE	mag_g (AB)	mag_r (AB)	mag_i (AB)	$\langle R_e \rangle$ ($''$)	$\langle R_e \rangle$ (kpc)	$\langle n \rangle$	$\langle q \rangle$	$M_\star$ ($10^{11} M_\odot$)
J0211-3155	32.8962202	-31.9279437	1	T18	21.28	19.78	19.28	0.24	1.07	8.10	0.48	0.88
J0224-3143	36.0902655	-31.7244923	1	T18	20.91	19.25	18.62	0.29	1.55	6.06	0.39	2.71
J0226-3158	36.5109217	-31.9810149	1	T18	20.63	19.25	18.76	0.35	1.32	3.65	0.60	0.69
J0240-3141	40.0080971	-31.6950406	1	T18	20.58	19.05	18.59	0.19	0.81	8.10	0.27	0.98
J0314-3215	48.5942558	-32.2632678	1	T18	21.00	19.57	19.07	0.15	0.66	5.54	0.39	1.00
J0316-2953	49.1896388	-29.8835868	1	T18	21.19	19.66	19.13	0.20	1.02	3.52	0.31	0.87
J0317-2957	49.4141028	-29.9561748	1	T18	20.51	19.10	18.63	0.26	1.05	5.01	0.21	0.87
J0321-3213	50.2954390	-32.2221290	1	T18	20.67	19.23	18.74	0.31	1.37	4.93	0.39	1.23
J0326-3303	51.5140585	-33.0540443	1	T18	20.94	19.48	18.99	0.32	1.43	3.66	0.35	0.93
J0838+0052	129.5304520	0.8823841	1	S20	20.65	19.29	18.75	0.31	1.28	4.02	0.41	0.87
J0842+0059	130.6665506	0.9899186	1	S20	21.12	19.60	19.06	0.23	1.01	3.27	0.29	0.91
J0844+0148	131.0553886	1.8132204	2	S20	21.25	19.78	19.26	0.26	1.14	6.56	0.49	0.71
J0847+0112	131.9112386	1.2057129	1	SDSS-GAMA	19.67	18.41	17.98	0.46	1.37	3.33	0.27	0.99
J0857-0108	134.2512185	-1.1457077	1	S20	20.72	19.21	18.70	0.34	1.40	2.94	0.33	1.00
J0904-0018	136.0518949	-0.3054848	2	S20	20.59	19.11	18.64	0.26	1.16	4.82	0.32	1.30
J0909+0147	137.3989150	1.7880025	2	SDSS-GAMA	20.06	18.68	18.16	0.30	1.05	9.97	0.77	1.05
J0917-0123	139.2701850	-1.3887918	2	S20	20.86	19.21	18.66	0.27	1.37	3.05	0.41	2.19
J0918+0122	139.6446428	1.3794780	1	T18	20.67	19.13	18.57	0.33	1.71	6.06	0.51	2.26
J0920+0126	140.1291393	1.4431610	2	S20	20.97	19.52	19.05	0.33	1.51	6.92	0.68	0.98
J0920+0212	140.2320835	2.2126831	1	SDSS-GAMA	20.35	18.87	18.43	0.34	1.48	1.99	0.32	1.03
J1026+0033	156.7231818	0.5580980	2	SDSS-GAMA	18.45	17.39	16.97	0.34	1.02	3.18	0.29	1.48
J1040+0056	160.2152308	0.9407580	2	S20	20.95	19.52	18.49	0.31	1.29	4.57	0.36	0.93
J1114+0039	168.6994335	0.6510299	2	S20	20.45	19.00	18.55	0.34	1.52	4.93	0.25	1.62
J1128-0153	172.0885023	-1.8890642	2	T18	19.87	18.56	18.07	0.35	1.27	6.69	0.31	1.30
J1142+0012	175.7023296	0.2043419	2	SDSS-GAMA	17.80	17.02	16.57	0.71	1.40	3.60	0.23	0.84
J1154-0016	178.6922829	-0.2779248	2	T18	20.90	19.52	18.73	0.22	1.06	4.36	0.19	0.64
J1156-0023	179.2186145	-0.3946596	2	SDSS-GAMA	20.06	18.83	18.08	0.26	1.04	6.53	0.38	1.39
J1202+0251	180.5132277	2.8515451	2	S20	20.97	19.43	18.96	0.31	1.49	6.47	0.89	0.68
J1218+0232	184.7355807	2.5449139	2	S20	20.78	19.23	18.71	0.31	1.40	2.75	0.26	0.93
J1228-0153	187.0640987	-1.8989049	2	S20	20.27	18.85	18.37	0.36	1.61	2.87	0.54	1.15
J1402+0117	210.7400749	1.2917747	3	S20	21.34	19.96	19.44	0.17	0.68	6.43	0.46	0.66
J1411+0233	212.8336012	2.5618381	2	S20	20.49	18.86	18.41	0.21	1.07	2.83	0.30	1.55
J1412-0020	213.0038281	-0.3440699	3	SDSS-GAMA	20.74	19.19	18.67	0.33	1.42	6.13	0.39	1.20
J1414+0004	213.5646898	0.0809744	3	SDSS-GAMA	20.41	18.99	18.50	0.31	1.42	4.26	0.42	1.18
J1417+0106	214.3685124	1.1073909	3	SDSS-GAMA	18.97	17.90	17.51	0.49	1.48	3.92	0.33	0.91
J1420-0035	215.1715599	-0.5864629	3	SDSS-GAMA	20.30	18.95	18.45	0.34	1.35	5.67	0.62	0.99
J1436+0007	219.0481314	0.1217459	2	SDSS-GAMA	19.55	18.27	17.85	0.39	1.40	2.65	0.19	1.15
J1438-0127	219.5218882	-1.4582727	3	SDSS-GAMA	20.65	19.29	18.74	0.28	1.20	4.11	0.38	0.88
J1447-0149	221.9657402	-1.8242806	3	SDSS-GAMA	19.86	18.61	18.16	0.44	1.51	3.06	0.45	0.86
J1449-0138	222.3504660	-1.6459975	3	SDSS-GAMA	20.86	19.40	18.92	0.35	1.44	5.81	0.33	1.03
J1456+0020	224.2361596	0.3353906	3	S20	20.88	19.46	18.97	0.12	0.50	5.53	0.20	0.71
J1457-0140	224.3397592	-1.6691725	3	S20	20.99	19.43	18.93	0.34	1.66	4.60	0.53	1.51
J1527-0012	231.7772381	-0.2065670	3	S20	21.37	19.67	19.08	0.23	1.26	5.77	0.23	1.74
J1527-0023	231.7522351	-0.3997483	3	S20	21.21	19.64	19.14	0.22	1.12	9.16	0.75	1.15
J2202-3101	330.5472803	-31.018381	2	T18	20.93	19.43	18.93	0.31	1.45	4.24	0.39	1.10
J2204-3112	331.2228147	-31.200261	2	SDSS-GAMA	20.84	19.32	18.86	0.35	1.39	6.36	0.31	0.90
J2257-3306	344.3966471	-33.114445	2	T18	20.80	19.42	18.95	0.29	1.18	4.31	0.41	0.93
J2305-3436	346.3356634	-34.603091	1	T18	21.26	19.69	19.12	0.31	1.29	3.89	0.40	0.86
J2312-3438	348.2389042	-34.648591	1	T18	20.90	19.32	18.79	0.24	1.25	2.25	0.43	1.34
J2327-3312	351.9910156	-33.200760	1	T18	20.99	19.35	18.80	0.28	1.51	5.94	0.67	1.57
J2356-3332	359.1261248	-33.533475	2	T18	21.31	19.81	19.27	0.22	1.06	4.28	0.34	0.98
J2359-3320	359.9851685	-33.333583	1	T18	21.11	19.59	19.05	0.24	1.04	4.49	0.39	1.07

Data Format

1D Spectra

The spectra are stored in a FITS table which is made of a primary header (NAXIS=0) and one single extension. They all have PRODCATG=SCIENCE.SPECTRUM and are phase3 and VO compliant, they are expressed in unit of wavelength in Angstrom and Flux in erg cm^{-2} s^{-1} $Å^{-1}$. The wavelength is always measured in air for all three arms.

Naming convention

The names of the files all follow the same convention. They are all in the format:

"INSPIRE_<id-galaxy>_<xsh-arm>_<extraction-method>.fits"

where the id-galaxy is the one given in Table 1, but without the KiDS suffix, the xsh-arm is equal to UVB or VIS, depending on the spectrograph arm and the extraction-method is equal to R50 in this DR.

1D Ancillary spectra

To constrain the stellar population parameters with via full-spectral fitting it is desirable to a wavelength range that is large enough to break the age-metallicity Worthey et al. 1994). This is also necessary to carefully assess whether the stellar velocity dispersion measurements depend on the resolution and wavelength coverage of the spectrum used to constrain it (D'Ago et al. 2022). Thus, we first restframed and logarithmically rebinned the UVB, VIS and NIR original spectra of each object and then combined them together, also degrading their final resolution to that of the SSP models that we use in the stellar population analysis (with fix full width half maximum, FWHM = 2.52 Å). To perform the convolution, we use a Gaussian function with a variable sigma (following the prescription of Cappellari et al. 2017). More details on the procedure can be found in the papers.

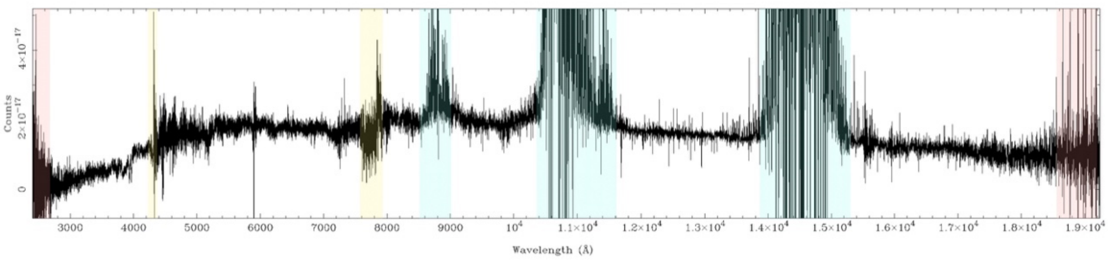
The ancillary files are given as single FITS files; their naming convention is very similar to that of the main science files:

"INSPIRE_<id-galaxy>_<xsh-arm>_<resolution>_<extraction-method>.fits"

where the xsh-arm is equal to "UVB+VIS+NIR" and the resolution is "FWHM2.52".

Each ancillary spectrum is connected to three main products (the spectra of each arm, for the corresponding galaxy), via the keyword "ASSON1" present in the primary header of each single arm spectrum.

Here below we show a typical case (J0844+0148) where we highlight the regions where the arms have been joined with yellow vertical shaded boxes, the three regions between the NIR bands with cyan boxes and the regions at the edges of the detector with orange boxes. A large value has been artificially attributed to these pixels to highlight that the data there is not trustable.



Master catalogue

In this third data release, we provide to the astronomical community, in addition to the single-galaxy spectra, a master catalogue listing the coordinates, the source paper, magnitudes in *gri* bands (from KiDS), stellar masses, effective radii, Sersic indices and axis ratios (from T18 and S20, also derived from KiDS images), and a number of spectroscopic quantities derived by INSPIRE (S21, DA23,S23). These last spectroscopic quantities are the main legacy results of the INSPIRE Survey.

In particular we give:

- The spectroscopic redshift and the age of the Universe at it,
- The integrate signal-to-noise ratio per Ang in the three arms separately,
- The integrated velocity dispersion values (computed from the R50 aperture spectra) with its associated uncertainty (see DR2 for more details),
- The SSP-equivalent [Mg/Fe] abundances derived by line-indices analysys (see DR1 and DR3 for more info),
- The mass-weighted ages and metallicities with their uncertainties. We provide two different values for each measurements, corresponding to two different configurations of the full-spectral fitting code used for the analysis (Penalised Pixel-fitting software, Cappellari, 2017. We refer the reader to the DR3 paper, S23, for more details.),
- The fraction of stellar mass formed during the first phase of the formation scenario (assumed to be at z~2) and the associated uncertainty,
- The cosmic time at which the galaxies had assembled 75% of their stellar mass and the associated uncertainty,
- The cosmic time at which the galaxies had formed all their stellar mass and the associated uncertainty,
- The degree of relicness (DoR). As already mentioned, this is a dimensionless number that can vary from 0 to 1 and has been defined to quantify how ``extreme'' the SFH of each of the UCMGs is, enabling an operative definition of relics, but it also serves as a means to quantify the relative contribution of very old and lately formed (or accreted) stars (see S23 for more details). Relics are objects with DoR>0.34.

Acknowledgements

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