SUPER: a SINFONI Survey for Unveiling the Physics and the Effect of Radiative feedback

Abstract

SUPER[1] is an ESO Large Programme (196.A-0377) using SINFONI in Seeing-Enhancer mode to study Active Galactic Nuclei at z=2-2.5. The AO assisted observations reach a PSF of 0.2 arcsec in H band. This first data release concerns the Type-1 AGN, which roughly corresponds to half of the survey sample (20/39). We release flux calibrated H (or H+K) band cubes, which at those redshifts cover the Hβ and [OIII]λ5007 lines.

Overview of Observations

SUPER observations were carried out both in service and visitor mode with the SINFONI spectrograph at the Cassegrain focus of Yepun (Unit Telescope 4) VLT. The observing constraints in the proposal were for clear conditions and seeing < 0.8 arcsec.

The AO-assisted observations gave an average image quality of up to 0.22" (median = 0.3") in H-band.

During science exposures, we used a dithering pattern where the target was moved within the SINFONI field of view so the sky for a particular frame was obtained from the subsequent frame and vice-versa. Each object exposures were limited to 10 minutes long to minimize the variation of the infrared sky. The total on-source exposure time for the targets ranges between 1 to 7 hours. To correct for atmospheric absorption and to flux calibrate the final co-added science cube, telluric stars were observed with the same setup as the science observations within 0.2 airmass and 2 hours of the science observations. Each telluric star exposure lasted 2-3 s with number of integration (NDIT) of 5 along with a sky observation of similar exposure time as that of the star. The stars were selected to have a K-band magnitude between 7 and 8.5 and a stellar type of B2V, B3V, B4V or B5V.

Details on the survey strategy can be found in Circosta et al. (2018; A&A, 620, A82) and on the data reduction in Kakkad et al. (2020; arXiv:2008.01728).

Release Content

This release includes the flux calibrated H (or H+K) band co-added cubes of 20 SUPER targets.

For 17 objects, we used a plate scale of 3"x3" with a spatial sampling of 0.05"x0.1", which gets resampled to 0.05"x0.05" in the final cube. The average spectral resolution in the H-band is ~300 which translates to a channel width of ~2 Å.
For 3 objects (labeled as noAO in the table below) the observations were conducted in seeing limited mode during visitor mode runs with weather conditions not suitable for AO observations. The plate scale in these cases was 8"x8" with a spatial sampling of 0.25"x0.25"in the final reduced cubes

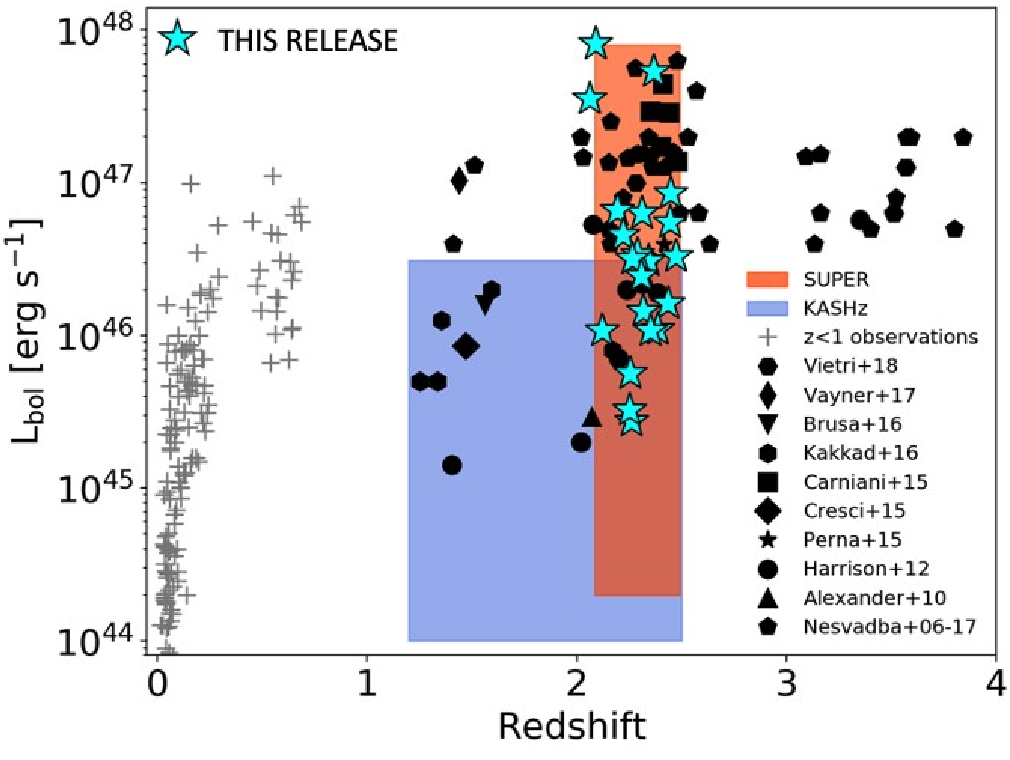
In the table below, we list the target name, its coordinates, the observing mode, the image quality and exposure time.

1 http://www.super-survey.org

Target	RA	DEC	z	H (AB)	Observ-ing mode	PSF (arcsec, kpc[a])	Expo-sure time (h)
X_N_160_22	02:04:53.81	-06:04:07.82	2.445	19.22	AO	0.31, 2.5	3.0
X_N_81_44	02:17:30.95	-04:18:23.66	2.311	18.78	AO	0.27, 2.2	7.0
X_N_53_3	02:20:29.84	-02:56:23.41	2.434	20.60	AO	0.47, 3.8	1.0
X_N_66_23	02:22:33.64	-05:49:02.73	2.386	20.56	AO	0.24, 1.9	1.0
X_N_35_20	02:24:02.71	-05:11:30.82	2.261	22.07	AO	0.27, 2.2	1.0
X_N_12_26	02:25:50.09	-03:06:41.16	2.471	19.83	AO	0.30, 2.4	6.0
X_N_44_64	02:27:01.46	-04:05:06.73	2.252	21.31	AO	0.66, 5.4	1.0
X_N_4_48	02:27:44.63	-03:42:05.46	2.317	19.57	AO	0.36, 2.9	3.0
X_N_102_35	02:29:05.94	-04:02:42.99	2.190	18.76	noAO	0.92, 7.6	1.0
X_N_115_23	02:30:05.66	-05:08:14.10	2.342	19.79	AO	0.30, 2.4	2.0
cid_166	09:58:58.68	+02:01:39.22	2.448	18.55	AO	0.29, 2.4	3.5
cid_1605	09:59:19.82	+02:42:38.73	2.121	20.63	noAO	0.7, 5.8	2.0
cid_346	09:59:43.41	+02:07:07.44	2.219	19.24	AO	0.30, 2.5	3.7
cid_467	10:00:24.48	+02:06:19.76	2.288	19.34	noAO	1.10, 9.0	2.0
J1333+1649	13:33:35.79	+16:49:03.96	2.089	15.72	AO	0.50, 4.2	1.0
J1441+0454	14:41:05.54	+04:54:54.96	2.059	17.15	AO	0.34, 2.8	1.0
J1549+1245	15:49:38.73	+12:45:09.20	2.365	15.92	AO	0.22, 1.8	1.0
S82X1905	23:28:56.35	-00:30:11.74	2.263	19.72	AO	0.34, 2.5	5.0
S82X1940	23:29:40.28	-00:17:51.68	2.351	20.80	AO	0.30, 2.4	4.3
S82X2058	23:31:58.62	-00:54:10.44	2.308	19.79	AO	0.27, 2.2	6.0

[a]The following ΛCDM cosmology parameters: H_0=70 km/s, Ω_M=0.3, Ω_Λ=0.7.

The figure below shows the past and on-going IFU surveys targeting the [OIII]λ5007 emission line to study the properties of outflows in AGN host galaxies in the L_{bol} vs. redshift plane. The red shaded area shows the parameter space covered from the overall SUPER survey, and the cyan stars indicate the objects of this data release.



Release Notes

The spectral reference system of our 3D SINFONI cubes is barycentric. The wavelength axis refers to wavelength measure in vacuum.

Data Reduction and Calibration

SUPER cubes have been reduced with the ESO SINFONI data reduction pipeline (Eisenhauer. et al. 2003, Bonnet et al. 2004). The pipeline corrects for the presence of non-linear and hot pixels, flags the pixels which have flat lamp intensities higher than a given threshold and performs a flat field correction, computes optical distortions and slitlet distances and performs wavelength calibration using exposures from xenon+argon arc lamp in the H-band and neon+argon arc lamp in the K-band. Science exposures, PSF and telluric star observations are reduced using the recipe sinfo_rec_jitter which outputs re-sampled data cubes of the individual exposures of the science frames as well as the PSF and telluric cubes corrected for the distortions, bad pixels and wavelength calibrated.

The sky subtraction was performed outside the ESO pipeline, using the improved sky subtraction procedure described in Davies (2007). During this procedure, 10-30% of the pixels from an object free region were used to create a model sky spectrum which was shifted in wavelength space to match the wavelength axis of the object frames. The processed sky spectrum was then subtracted from the object exposure across the FoV.

To remove the telluric absorption features and to flux calibrate the data cubes, first the hydrogen features were removed from the observed telluric star spectrum, and then divided by a black body spectrum and normalized to get the response function of the instrument. Both the science and the telluric cubes were divided by this response curve to correct for the telluric features. The spectrum extracted from the corrected telluric cube was then convoluted with the appropriate filter (H-band or K-band) from the 2MASS catalogue (Two Micron All-Sky Survey: Skrutskie et al. 2006) to get the required flux per unit count to be applied to the entire data cube.

The flux calibrated individual frames from multiple exposures were combined using the pipeline recipe sinfo_utl_cube_combine with a sigma clipping parameter (ks_clip=TRUE) and scaling the sky (using scale_sky=TRUE) within individual exposures. It has been verified that the sigma clipping does not remove signal from the original target itself. By setting the sky scaling parameter, the spatial median of each exposure is subtracted from the contributing exposure to remove sky background which might not have been removed in the previous steps of the reduction.

Data Quality

For observations within the same night, the offsets given by the header keywords CUMOFFSETX/Y are reliable as it has been verified comparing the stacked cube obtained with manually calculated offsets. Observations taken on different nights might have shifts in the centroid of the image. We performed a two-dimensional Gaussian fit to the combined cubes obtained from individual observing blocks during each night and the difference in the centroid of the Gaussian fits gave the relative offsets between the observations from different nights. After the determination of these offsets, each contributing cube is aligned and co-added such that the intensity of a pixel is given by the weighted mean of the intensity of the corresponding overlapping pixels from the individual cubes, where the weight depends on the exposure time of the individual frames. Any residual cosmic ray signal within the final co-added cube is then removed using a sigma clipping procedure.

The WCS coordinates of the co-added cube resulting from the SINFONI pipeline are inaccurate. We therefore applied an astrometric correction registering the peak of the continuum emission from the AGN with the optical/near-infrared coordinates reported in Circosta et al. (2018).

The absolute position of the SINFONI cubes, as provided in the header, is not sufficiently accurate for our purposes. Given the small field of view of the SINFONI images (3x3 arcsec^2), we cannot correct the astrometry using nearby stars, since usually the target is the only visible source in the field of view. Thus, we align our SINFONI data-cubes to broadband H-band images. To do this, we first align the H-band images to Gaia astrometry (Gaia Collaboration et al. 2016, 2018) using several stars across the fields. We then make broad-band images from the SINFONI data-cubes by collapsing them over the same wavelength range as the archival H-band images. We find the centroids of the images from the data-cubes and align these to the positions of the corresponding source in the near-infrared images. The final uncertainties on the astrometry in our SINFONI cubes are in the range 0.03-0.14".

Known issues

None.

Previous Releases

This is the first data release for SUPER.

Data Format

Files Types

For each of the 20 targets we release two files.
We use the AGN named cid_166 as an example to illustrate the data products and file naming convention.

- cube_cid_166_H_P3_updated.fits
  This is the aligned and combined data cubes obtained following the procedure described in Kakkad et al. (2020).
- cube_cid_166_H_whitelight_P3.fits
  White-light image obtained by integrating the datacube over the whole spectral range.

Catalogue Columns

No catalogues are released.

Acknowledgments

Any publication making use of this data, whether obtained from the ESO archive or via third parties, must include the following acknowledgment:

- “This paper uses data from the SUPER survey (Circosta et al. 2018, A&A, 620, A82)”

- "Based on data products created from observations collected at the European Organisation for Astronomical Research in the Southern Hemisphere under ESO programme 196.A-0377"

If the access to the ESO Science Archive Facility services was helpful for you research, please include the following acknowledgment:

- "This research has made use of the services of the ESO Science Archive Facility."