1st production of public catalogues

The HUGS survey

INAF – OAR for the Astrodeep project

ASTRODEEP

"Unveiling the power of the deepest images of the Universe"

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ABSTRACT

In this document we present the analysis of the data foreseen by the plan and the relevant catalogues (including rest frame quantities). Theses catalogues have been made available on the ASTRODEEP website and this release represents the first generation of processed data.
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Goal

This document presents the first catalogues produced by the ASTRODEEP consortium. This release follows the plan (presented in the document D4.1) for the production and release of catalogues based on available data.
In this first release we have on a dataset available in the CANDELS fields and more specifically the UDS-CANDELS and GOODS-South. The survey is named HUGS: "Hawk-I UDS and GOODS Survey" and is an ultra–deep IR imaging survey executed with the Hawk-I imager at the VLT. Following the timeline for catalogue releases the CANDELS fields are the ones to be processed first, since most of the datasets are available.

Survey Strategy

The survey is a joint project between the Rome Observatory and the University of Edinburgh, and it is based on the data collected with a dedicated ESO Large Program (P.I. A. Fontana). It also includes all imaging data obtained with Hawk-I on the UDS and GOODS-S fields. Thanks to exquisite image quality and extremely long exposure times, HUGS delivers the deepest K-band images ever collected over areas of cosmological interest, and in general ideally complements the CANDELS dataset in terms of image quality and depth.
The HUGS survey was designed to cover the two CANDELS fields accessible from Paranal that do not have suitably deep K -band images: a sub-area of the UKIDSS Ultra Deep Survey (hereafter UDS) and GOODS-South (hereafter GOODS-S). The depth of the images in the K -band has been tuned in order to match the depth of the WFC3/IR images produced in the J_{125} and H_{160} filters. In practice, the target depth was chosen to be 0.5mag shallower than the one obtained with WFC3/IR in H_{160} to match the average $H - K$ colour of faint galaxies.
In both fields deep Y-band images have also been acquired. In the case of the UDS, these images provide an essential complement to the CANDELS data set, since neither Y_{098} nor Y_{105} imaging of this field has been obtained within CANDELS. In the case of GOODS-S, the Y-band images come from an earlier program designed to select $z\sim7$ galaxies with ground-based images (Castellano et al. 2010a,b). These images are slightly less deep than the Y_{105} images that have since been obtained within CANDELS, and cover only about 70% of the GOODS-S field, but have nevertheless been reduced and are made available here as part of HUGS. We describe below the details of the two fields, in terms of pointings, exposure time and expected depth.

The GOODS-S field

The coverage of the GOODS-S field with CANDELS is complex, forcing us to adopt

a complicated pattern for the HUGS observations. The WFC3 observations are deeper in a rectangular region (10x7 arcmin, named GOODS–Deep in CANDELS) that spans the entire width of the GOODS-S field, and is centred in the vertical direction. The Hubble Ultra Deep Field (UDF) is located close to the centre of this area. These deep images are complemented by shallower WFC3/IR images that cover the remaining area of the original ACS optical mosaic. The final layout was designed to deliver a deeper image over GOODS-Deep, while covering nearly the whole CANDELS area. In the deepest region, that includes most of the Hubble Ultra Deep Field, exposure times exceed 80 hours of integration, with a 1σ magnitude limit per square arcsec of about 28.0 mags (AB). The seeing is remarkably exceptional and constant across the various pointings, ranging between 0.38" and 0.43".

The UDS field

Three different Hawk-I pointings are able to cover 85% of the UDS field. These three pointings also provide two overlapping regions that have been used to cross-check the photometric and astrometric solutions in the three individual mosaics. The three pointings have been exposed with nearly identical exposure times, of 8 hours in the Y band and 13 hours in the Ks band, although final exposure times are slightly different because of discarding some images during reduction. In the UDS field the survey is about one magnitude shallower than GOODS-S, to match the correspondingly smaller depth of the CANDELS images, but includes also the Y band, where WFC3 is lacking. In the K band, with an average exposure time of 13 hours, and a seeing ranging from 0.37" to 0.43", the 1σ magnitudes limit per square arcsec is about 27.3mags. In the Y–band the average exposure time is of about 8 hours, and an average seeing of 0.45"-0.5", reaching 1σ magnitudes limit per square arcsec of about 28.3mags.

Data Release

Images

For each data set we made publicly available:

- The coadded image for each pointing (UDS1,2,3, GOODSD1, D2, W1, W2, W3 and W4) – these are all calibrated and rescaled to a standard zeropoint of 27.5 for the K –band images, and 27.0 for the Y -band;
- The relevant absolute r.m.s. images, with the same flux scale;
- A global mosaic of the two fields in each band, with the relevant absolute r.m.s., after homogenizing all images to the same PSF.
- A global mosaic of the two fields in each band, with the relevant absolute r.m.s., without any correction for the different PSFs.

The final images for the two fields are shown in Fig. 1 and Fig. 2., along with the r.m.s. images of the final mosaics.

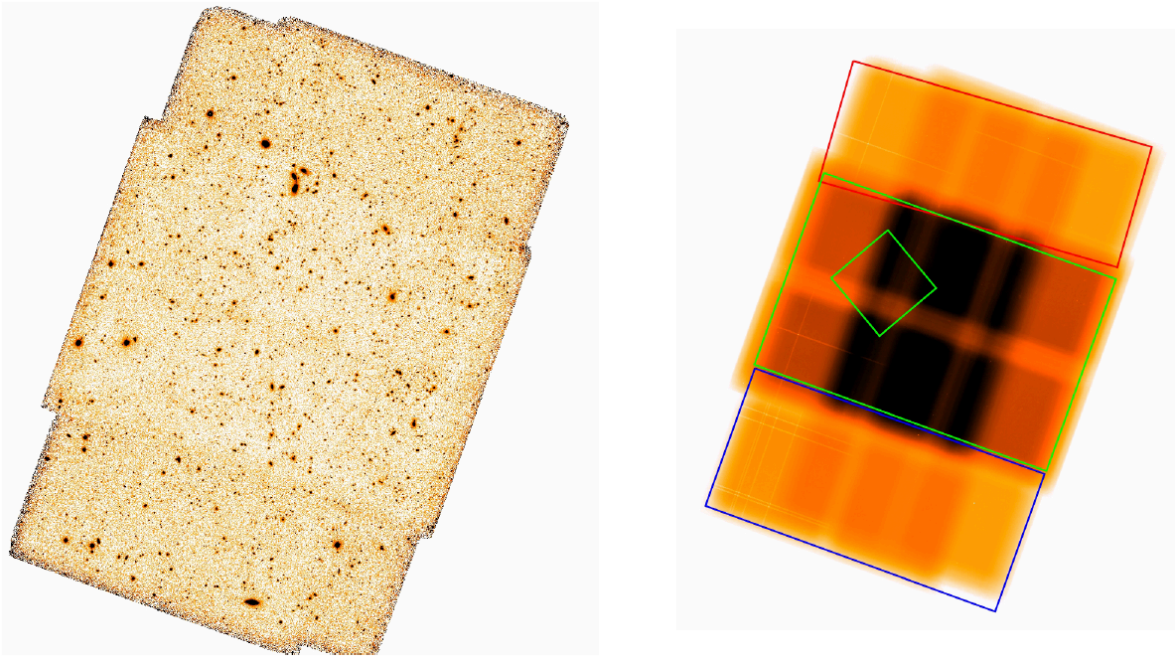

Fig.1: *Left:* The final image on the GOODS-South field, in the K band. *Right:* The weight image, computed as described in the text. Darker regions have higher weight - and hence correspond to deeper regions of the images. The grey scale (normalized to its maximum) of the weight map is shown at the bottom.

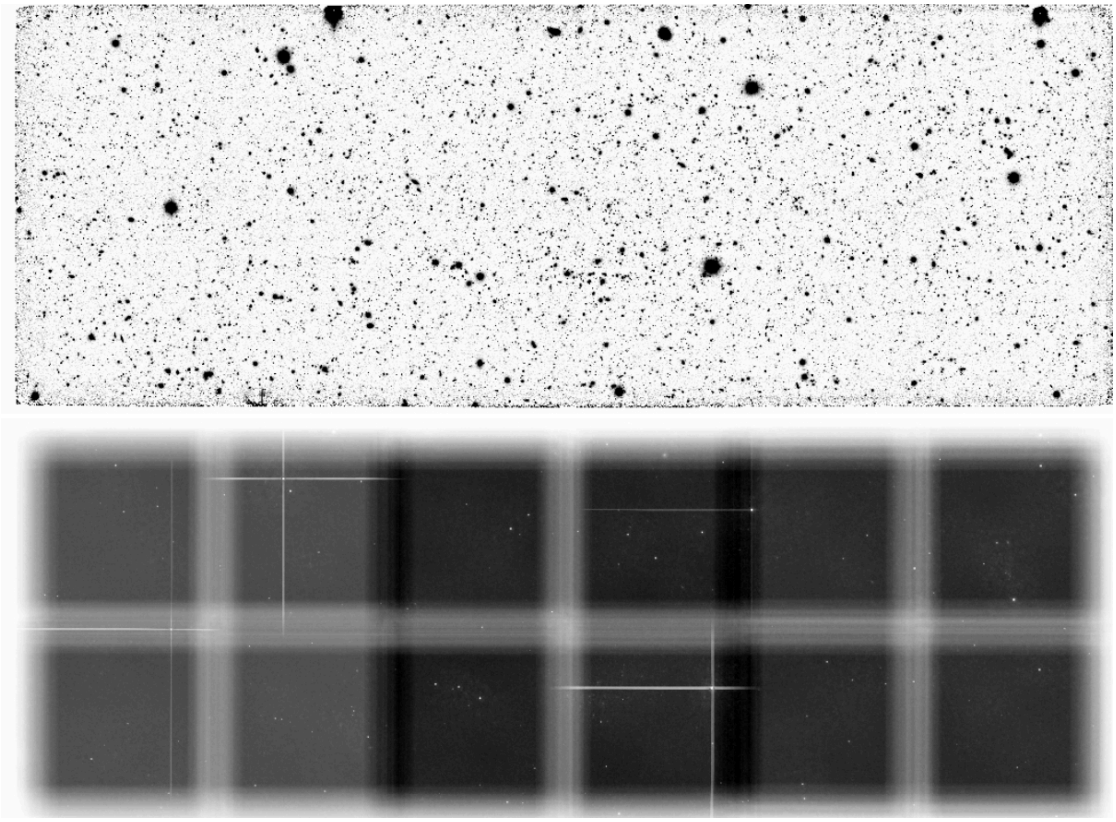

Fig. 2: *Top:* The final image of the UDS field in the Y band. *Bottom:* The weight image. The bottom scale represents the r.m.s., normalized to its peak value. Darker regions have lower r.m.s., or equivalently higher relative weight, and hence correspond to deeper regions of the images.

Catalogues

Catalogues from the HUGS images can be extracted in two different ways, either as "single band", i.e. using the HUGS images as detection image, or adding them to the full multi-wavelength suite of data in CANDELS.

Single-band catalogues: such catalogues are, in principle, straightforward to obtain. The two public catalogues that we derive have been obtained using SExtractor on the seeing–averaged mosaics of both the UDS and GOODS-S HUGS imaging. We applied a smoothing before detection (of the same size of the PSF), and used a minimal detection area of 9 pixels, requiring S/N> 3 in such an area.

Multi-wavelength catalogues: we included the photometry extracted from the HUGS images (both in K and in Y) in the UDS and GOODS multi-wavelength catalogues described in Galametz et al. (2013) and Guo et al. (2013) respectively. In both cases we detected the objects in the WFC3 H -band image from CANDELS, and performed PSF-matched photometry on the HUGS images. To deal with the different PSFs of the various images, we independently processed each of the final individual pointings, and thereafter weightaveraged the photometry of objects detected on multiple images to obtain the final photometry. Clearly, following this procedure, the ultimate depth of the catalogue is driven by the WFC3 H band image.

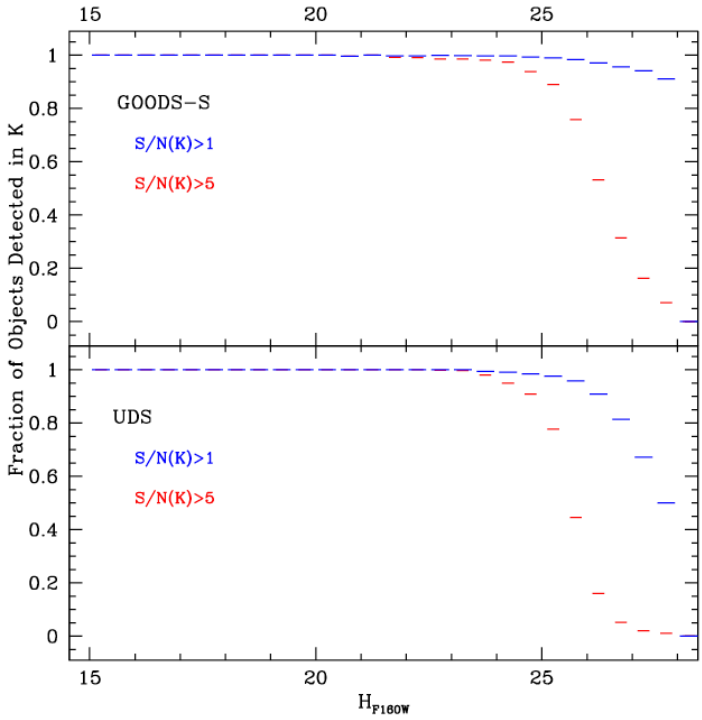

Fig. 3: Fractions of objects in the CANDELS catalogues that have a detected flux in the HUGS data, as a function of the H-band magnitude. Here the H-band is measured on the CANDELS F160W images, and the corresponding K-band flux is measured with the TFIT code on the final HUGS images. Results are shown for two different S/N ratios in the K-band, and for the two HUGS fields (as shown in the legends). Errors are computed assuming simple Poisson statistics.

It may be of some interest to show how effective the HUGS images are in providing us with useful information on the CANDELS-detected objects, since that is one of the main aims of the HUGS survey. This is shown in Fig.3, where we plot the fraction of objects that are detected at 5σ or 1σ in the K-band as a function of the H-band magnitude. In the case of GOODS-S, it is seen that as many as 90% of the H –detected galaxies have some flux measured at S/N>1 in the K-band, down to the faintest limits of the H-band catalogue, and that nearly 60% of the H ≈ 26 galaxies (and 15% of the H ≈ 27 galaxies) have a solid K-band detection with S/N>5. This result confirms that our original goal has been achieved, and in particular that our pointing strategy has been quite efficient in covering the inhomogeneous GOODS-S field at the required depth.

All the HUGS images and catalogues are made publicly available at the ASTRODEEP website:

http://www.astrodeep.eu

as well as from the ESO archive:

http://archive.eso.org/wdb/wdb/adp/phase3_main/form?phase3_program=HUGS

Full Catalogues are available at the CDS via anonymous ftp to:

http://cdsarc.u-strasbg.fr (ftp://130.79.128.5)

or via

http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/570/A11

Publications

There are two publications that describe the survey:

- An ESO Messenger paper (Fontana et al., 2014, Msngr, 155, 42), that can be used as a general introduction to the survey
- A full data paper (Fontana et al. 2014, A&A, 570, A11) where all technical details are fully described.