The COSMOS NIR Survey with INGRID

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Towards the end of the last decade, the international astronomical community realised that exploitation of the new generation of 8 – 10-m class telescopes would be hampered unless surveys of the sky with suitable depth were carried out. Spurred by this realisation, several observatories and research groups planned and established survey programs. Examples are the NOAO Deep Wide-Field Survey (`http://www.noao.edu/noao/noaodeep/`), the ING Wide Field Imaging Survey (`http://www.ing.iac.es/WFS/`), the DEEP project (`http://deep.ucolick.org/`), the CADIS survey (`http://www.mpia-hd.de/GALAXIES/CADIS/science_index.html`) and many others. Deep surveys aimed at the study of distant galaxies require NIR imaging in order to cope with the cosmological redshift of the galaxy spectral energy distributions (SEDs). In 2000 our group started a deep survey in the K_s-band using INGRID on the WHT and Omega Prime on the CAHA 3.5-m telescope. Our goal is to cover 0.5 square degrees of high-galactic latitude sky. Our target depth is $K_s = 22$ in AB magnitudes. Good La Palma seeing and better noise behaviour allows us to reach this depth in 2 hr exposures with INGRID, the CAHA/Omega data being about 1 mag. shallower for equal exposure times. On the other hand, the wider field of Omega allows a faster coverage of sky area. Our survey, deemed the COSMOS Survey, thus has two depth regimes, $K_{AB} = 21$ on a wide area and $K_{AB} = 22$ on the deeper areas mapped with INGRID. This depth allows us to map luminous blue compact galaxies (LBCGs) with $M_B = -21.4$ out to $z = 2.4$ ($H_0 = 70$) (Cristóbal et al., 2000).

Foremost in the science motivation for the COSMOS survey is to produce a database of distant galaxies for study with EMIR, the NIR multi-object spectrograph now in construction for the upcoming 10-m GTC on the ORM. EMIR is described in Balcells (1999 and 2000). Up-to-date information on the instrument is posted at `http://www.ucm.es/info/emir/`. Operating at cryogenic temperatures, EMIR will be one of the first spectrographs capable of performing multi-object spectroscopy in the 2.2-μm K-band. EMIR will allow us to efficiently obtain rest-frame visible spectra of large samples of galaxies at redshifts above 2, thus allowing the analysis of all the emission lines that have traditionally provided us with diagnostics on the excitation, extinction, star formation rates, metallicities, etc. of nearby galaxies.

Because of the $(1+z)^4$ cosmological surface brightness dimming, high-z sources in the COSMOS survey will predominantly be luminous, compact, i.e. high surface brightness galaxies. Best known among these are star-forming galaxies for the ease with which they can be identified via U-band dropout and related techniques (Steidel et al., 1996). Such galaxies at $z \sim 2$ will remain keys to understanding the rate of cosmic star formation when EMIR comes into operation. Of special interest is the possible connection of LBGs and other $z = 3$ compact galaxies (Lowenthal et al., 1997) to luminous blue compact galaxies (LBCGs) found at $0.5 < z < 1$ (Guzmán et al., 1997). The COSMOS survey should also break ground in cataloguing galaxies without the strong star formation rates of Lyman-break galaxies. At $2 < z < 3$, current surveys, selected in the visible, sample the UV continuum and are biased toward actively star-forming galaxies. COSMOS is mapping rest-frame R, which is sensitive not only to luminous star-forming galaxies but also to luminous, massive galaxies harbouring old populations.

For galaxy selection, photometric redshifts and photometric characterisation of the sources we plan to use complementary data at visible wavelengths, which we are gathering via our own parallel surveys and via collaborative agreements with other groups.

Survey fields were selected for their high-galactic latitude, low cirrus emission, lack of bright stars, and perhaps most importantly for the availability of complementary data from HST and at other wavelengths. Our fields now include: the Groth field, including a strip of 28 deep, two-band, HST/WFPC2 pointings and its flanking fields; the Coppi field, containing a deep exposure with the Chandra X-ray satellite; one of the SIRTF First-Look Survey fields, and the Koo-Kron SA68 field. COSMOS will also observe equatorial fields such as the NOAO Deep Survey 2-hr field, to make use of existing public multi-band databases, and to allow spectroscopic studies with VLT and Gemini-S in addition to the GTC.

To date, data was obtained on runs in April 2000, October 2000 and June 2001. Our first run was part of the first science run of INGRID, soon after the camera commissioning. We are pleased to acknowledge a lack of technical problems, a smooth camera operation, and the high cosmetic quality of the images — not to mention the 0.7" FWHM seeing we obtained in the first 2-hr coadded images. We were then operating with the temporary collimator which gave reduced throughput, and, in the excellent seeing, gave a slightly non-circular PSF. These problems disappeared in 2001 using the definitive INGRID collimator. We were pleased by the ease with which the camera operation could be programmed using UNIX scripts, allowing us to prepare custom-made dithering patterns tailored to the geometry of our fields, or to readily program and execute long linearity calibration exposure sets. We note a single technical problem, which was eventually clarified with the ING staff: an inaccuracy (an offset of a fraction of a second) in the exposure times recorded in the headers during the first months of operation.

Data reduction for the Survey was carried out using IRAF. For sky subtraction, we found the `dimsum` task (Stanford, Eisenhard & Dickinson, 1998) particularly adequate. Our pipeline, while not fully automated, allows now for streamlined reduction of long observing runs, reaching flat-field accuracies of 6×10^{-5} (peak-to-peak in the uniformly exposed areas). Our photometric calibration accuracy, in good atmospheric conditions, is typically 0.03 mag.

With INGRID, we have mapped the Groth strip, the Coppi field and a fraction of the SA68 field, for a total of 303 arcmin^2. Figure 1 shows a sample image from the Groth strip, together with the same field imaged in F606W with HST. The HST Groth images were obtained from the HST archive. We have performed source count and photometry using SExtractor (Bertin & Arnouts, 1996). Essential for deep galaxy photometry is to obtain reliable estimates of detection efficiency and spurious fraction (detection reliability). For the latter, we have developed a test, inspired on that used by Bershady et al. (1998), which we found more robust than tests based on injecting synthetic sources from eg. `artdata.mkobject` in IRAF. Our test relies on comparing photometry performed on two disjoint sets of co-added frames, each corresponding to half the total exposure time. Good detection of a given source in the two half-time images provides reliability that the source is real. A spurious source, in contrast, must come from a noise peak and therefore be detected on one of the two half-time images only. With this assumption, we deem spurious any detection in which the photometry in any one of the two half-time images is below a given SN_{lim}. To determine the value of SN_{lim} that isolates truly spurious sources, we construct the histogram of magnitude differences between the measurements in the two half images. Values of SN_{lim} that isolate spurious sources lead to a double-peaked histogram of magnitude differences, while values which do not, i.e. which include real sources, yield a histogram of magnitude differences with a single peak at $m_1 - m_2 = 0$. Examples of magnitude difference histograms are shown in Figure 2.

Differential number counts in a 71 arcmin^2 area of Groth are shown in Figure 3. The area comes from six INGRID pointings, from which the edge areas with lower exposure time have been excluded. Similar counts were obtained for the 47 arcmin^2 mapped in the Coppi field. Our Groth counts bridge over the magnitude range between shallow, wide- area surveys, eg. Martini (2001) and deeper, pencil-beam surveys such as the one by Bershady, Lowenthal & Koo (1998). There is good continuity between the three sets of counts. Our counts in Coppi and Groth are quite close to each other. The counts stress earlier results that no-evolution models are inconsistent with the counts. At these depths, and for this cosmology, pure luminosity evolution (PLE) models provide a good fit to the counts. We reproduce a moderate excess at intermediate magnitudes over the PLE models, as found by Martini (2001).

Subsequent work on the COSMOS Survey includes covering a wider area until the target 0.5 degree^2 is reached. Progress on COSMOS may be followed at the EMIR web site, `http://www.ucm.es/info/emir/`. ¤

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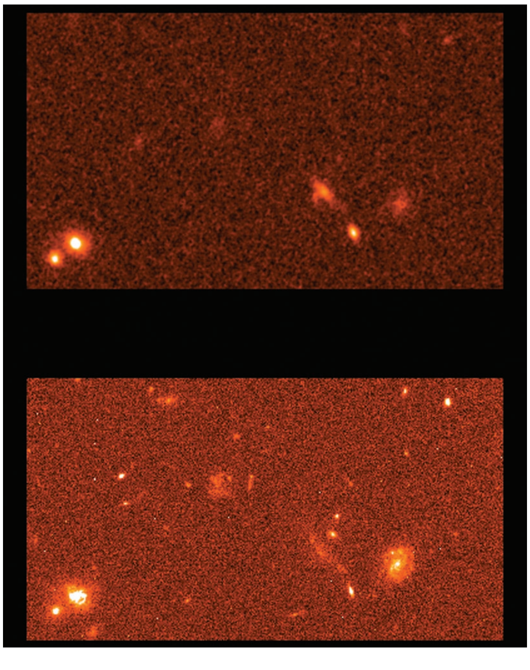

Figure 1. An 11.4"x 5" field in the Groth stirp, imaged in the K_s NIR band by INGRID (top) and in the F606W filter by HST/WFPC2. The INGRID exposure was 1.5 hr on-target integration. Seeing was 0.65" FWHM in the coadded image (pixel size 0.24 arcsec). On such images, we reach 50% detection efficiency at K~20.8. The low-inclination spiral in the lower left is clearly blue, while, next to it, an elongated object, seemingly another spiral, has pronounced redder colours.

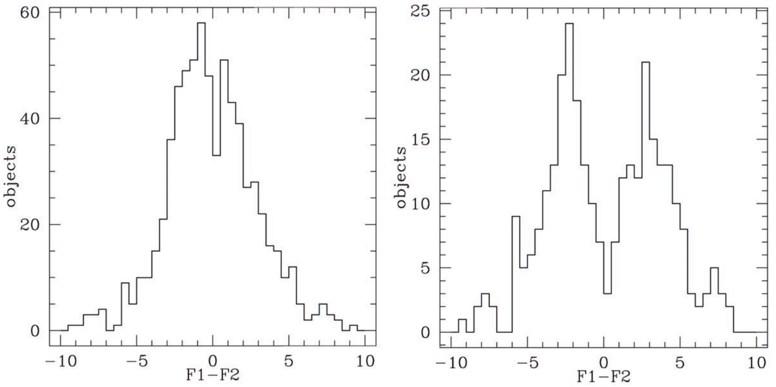

Figure 2. Histograms used in identifying spurious sources. After `SExtractor` has produced a source catalogue from the total-exposure image, we perform photometry at the same source positions on two independent images, each from a coadd totalling half the total exposure time. We select sources for which the SN in any one of the two half-time measurements is lower than a given SN_{lim}, and plot the histogram of magnitude differences $m_1 - m_2$. The first histogram used $SN_{lim}=2.8$; the single peak indicates that the $SN_{lim}=2.8$ cutoff selects many sources for which $m_1 - m_2 \sim 0$, two independent measurements consistent with each other which indicate that the sources are real. The second histogram used $SN_{lim}=1.6$; the double peak indicates that $SN_{lim}=1.6$ correctly isolates spurious sources.

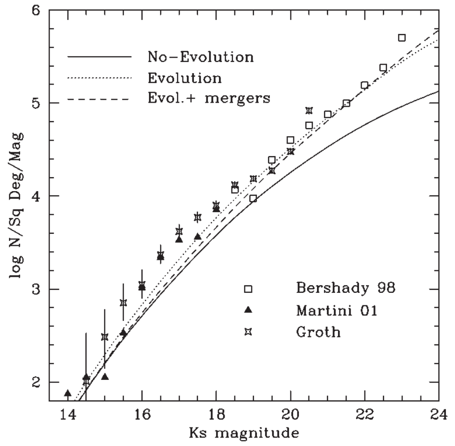

Figure 3. Number counts obtained on the Groth strip. The figure gives number of galaxies per square degree per magnitude interval. Counts are corrected for efficiency and for spurious sources. Efficiency correction is performed only for magnitude bins with a detection efficiency above 50%. Error bars are 1-σ upper- and lower-confidence intervals (84.13% confidence level). Superimposed on the counts are three reference number count predictions, which we derive using `ncmod` (Gardner, 1998).

Satellites and Tidal Streams Conference

We are pleased to announce the conference “Satellites and Tidal Streams”, organised by the Isaac Newton Group of Telescopes (ING) and the Instituto de Astrofísica de Canarias (IAC), to be held on the island of La Palma on May 26–30, 2003.

Current cosmological models predict that galaxies form through the merging of smaller substructures. Satellites and tidal streams might then represent the visible remains of the building blocks of giant galaxies. They therefore provide important information on the merging history and galaxy formation in the Universe. In this conference the observational evidence for substructures, their internal structure and their dynamical evolution and disruption within the tidal field of the host galaxy will be discussed and confronted with theoretical cosmological predictions of hierarchical merging and galaxy formation. Topics that will be discussed include: satellites of galaxies: bright and dark, the dark matter content of dSph and LSB galaxies, tidal streams: probes of the structure and formation of the Milky Way and other Nearby Large Galaxies, predictions of Cold Dark Matter models on small scales, compact HVCs and galactic substructure and mass substructure from gravitational lensing.

To achieve these goals, invited reviews and talks given by leading scientists in all the fields above are planned, as well as a number of contributed talks and posters presenting the recent results from the relevant fields. A preliminary list of invited speakers is: R. Braun (NFRA, The Netherlands), A. Burkert (MPIA, Germany), E. Grebel (MPIA, Germany), R. Ibata (Observatoire de Strasbourg, France), M. Irwin (IoA, UK), K. Johnston (Wesleyan University, USA), A. Klypin (NMSU, USA), D. Lynden-Bell (IoA, UK), S. Majewski (University of Virginia, USA), M. Mateo (University of Michigan, USA), B. Moore (University of Zurich, USA), J. Primack (University of California at Santa Cruz, USA), P. Schneider (Bonn University, Germany), S. White (MPA, Germany), R. Zinn (Yale University, USA).

You will find more information on the conference web site at: `http://www.iac.es/proyect/sattail/`

Registration opens on Thursday November 14th. The deadline for registration is April 1, 2003. The list of speakers, posters, etc. will be finalized after this deadline. Note that the total number of participants will be limited to 120. ¤

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