
Completion of the GOYA Photometric Survey

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Summary. The Galaxy Origins and Young Assembly (GOYA) survey is designed to study the formation and evolution of $1 < z < 3$ galaxies with the aim of learning on the epoch and the mechanisms by which galaxies assembled the bulk of their stars and acquired their present structure and dynamics. In 1998 GOYA proposed, and has since been guiding, the construction of the most ambitious of the common-user instruments for GranTeCan —the EMIR near-infrared multi-object spectrograph. In preparation for the exploitation of EMIR, we have conducted a deep near-infrared photometric survey, for sample selection and characterisation. Now that this research has reached its final stages, we provide here details on its current status and its finalisation plans. Overall, this survey has images of 0.5 square degrees of high-latitude sky to limiting AB magnitude $K_s = 23.7$ ($5\text{-}\sigma$, $1''$ aperture) and corresponding depths at U, B, V, R, I and J . The sample of sources obtained is being extended to include fields available to Gemini-S, since a recent collaboration with the Flamingos-2 Early Science Survey Team grants GOYA privileged access to this pioneering near-infrared multi-object spectrograph.

1 Introduction

The search for the origins of the massive spiral and elliptical galaxies that populate the Universe today, and the understanding of the physical processes that drove their formation and evolution, will be a central theme in observational cosmology for the next decade. The evolution with redshift of quantities such as the dynamical mass, the stellar content of galaxies, the metallicity, the star formation rate density, and the super-massive black-hole accretion rates in the $1 < z < 3$ range will be prime drivers of progress. This comes as the natural continuation of the observations undertaken in the last decade with HST and 8-m class telescopes, which have shown that high- z galaxies were sensibly different to the present-day ones: they were smaller ([13]), less massive ([5]), of bluer colours ([8]), and formed stars at much superior rates

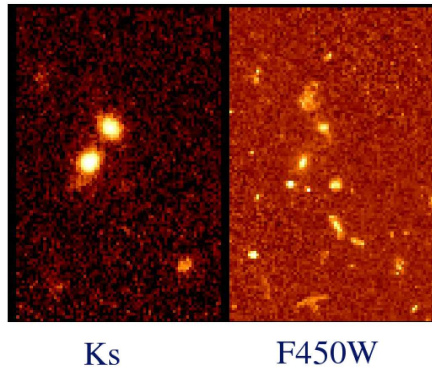


Fig. 1. Close-up images of the same field on GOODS-N. The image on the left is a near-infrared K_s -band picture obtained with LIRIS on the WHT, while the image on the right was taken with the HST under blue light.

([11]). However pioneering studies in the infrared domain have unveiled that the statistics obtained from optical samples, which map the UV spectrum of galaxies, are biased towards galaxies with high star-formation rates but with low masses ([9, 4, 1]). Hence, given the importance of massive galaxies as discriminants amongst different hierarchical structure-formation scenarios, mapping the rest-frame optical spectrum, which cosmological expansion shifts to the NIR, is the prime driver of the next generation of near-infrared, multi-object spectrographs on 10m-class telescopes.

With the Gran Telescopio Canarias (GTC), Spain has ensured a privileged access to first-class observational means in the optical and infrared astronomical ranges. In 1998 GOYA, led by four main nodes at IAC, UCM, LAOMP (Europe) and UFL (USA), proposed to Grantecan the commissioning of a multi-object spectrograph for the near-infrared range (0.9-2.5 microns), that has become known as EMIR. The instrument was then unique in its class, and today it keeps being so in many regards. Amongst the most relevant features we single out a robotic reconfigurable cryogenic multi-slit mask acting as field selector, and a set of dispersive elements formed by the combination of high quality diffraction grating and conventional prisms which allow resolutions of $R > 4000$ in $ZJHK$ (see [10] for further details). That the GOYA scientific aims drove the design of EMIR guarantees an immediate scientific production right at the onset of the spectrograph's operations. This return is granted by employing half of the EMIR Guaranteed Time during the initial years of EMIR operations.

In recent months, GOYA has established a close collaboration with the Flamingos-2 Early Science Survey team of the University of Florida and will benefit from a minimum of 7 nights of guaranteed time during 2007-08 with Flamingos-2. This is a fully cryogenic, 1 to 2.5 micron multi-object spectrometer and wide field imager for the Gemini-S, to start commissioning in 2007 ([6]). Apart from boosting the international promotion and visibility of the

Table 1. Extent of the goya Photometric Survey. Note that the limiting magnitude is the K_s band measured in the AB photometric system at S/N=3 and a fwhm=1". Also that the area is given in squared arcminutes. The fields targeted for the “deep” slice are the Groth Strip (175 arcsec²), Groth_O2k (750 arcsec²), goods-n (250 arcsec²; see Figure 1), and SA-68 (150 arcsec²)

Survey	Bands	Limiting Magnitude	Area
Ultra Deep (WHT / Groth-Westfall)	UBVIJK	23.7	20
Deep (WHT)	UBVRIJK	22.7	1300
Shallow (CAHA / Groth Flanking Fields) (J),K		~21.7	1000

GTC community, the Flamingos time will be highly valuable for it will allow to accelerate the generation of results for GOYA and polish the observational strategies for a more efficient exploitation of EMIR. Also, with ~ 500 NIR spectra of galaxies, we will be able to produce the first results as a proto-study for the complete GOYA Spectroscopic Survey to undertake with EMIR.

2 GOYA Photometric Survey: 2000-2007

All in all, GOYA has over 40 nights of guaranteed time with the top NIR MOS spectrographs. In preparation for a fruitful scientific exploitation, the GOYA Photometric Survey was undertaken to create a database of sources with near-infrared and optical photometry, photometric redshifts, and as much information as possible collected at other wavelengths, which could then be observed and characterised with EMIR and Flamingos-2.

Most of the effort of the Photometric Survey has been devoted to conduct a deep infrared imaging program (bands J, K) with correspondingly deep optical data. Undertaken by the GOYA nodes at IAC and UCM, it has used substantial allocations of observational resources at the ORM and Calar Alto. Due to bad weather throughout, the original plans to cover 1 square degree were downsized by a factor of two. We organised that survey area into “ultra deep”, “deep” and “shallow” levels of sensibility, roughly at decreasing steps of 1 magnitude starting at $K_s(AB) \simeq 22.7$ for the “ultra deep” slice (see Table 1 for details). As of today, the data-acquisition campaign is at a stage of being 80% complete, while the data reduction is completed at the 70% level. In terms of data-reduction we are currently reducing WHT and CAHA infrared data.

We are committed to publishing standardised photometric database catalogs of sources for public access. We are working in a timeline where a beta version of the photometric survey catalogs including all observed data in fields Groth-Westfall, Groth Strip, Groth Flanking Fields, GOODS-N, plus datamined info on CDFS and VIRMOS-2h, will be available by Jan 2007. This

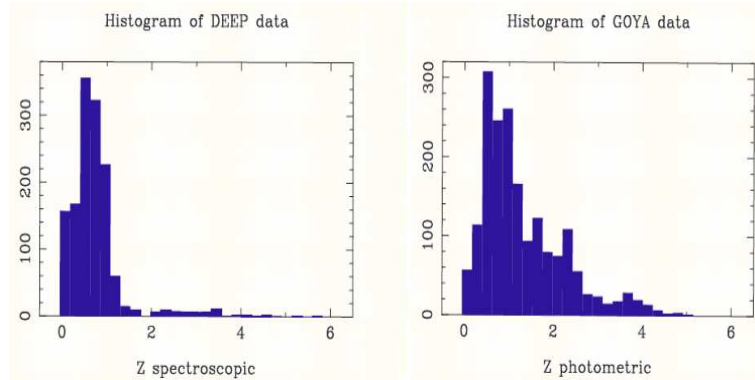


Fig. 2. The GOYA Photometric Survey has become a valuable scientific tool. Spawning from $K < 21.4$ and correspondingly deep $UBVIJK$ photometry over 175 sq. arc-min. on the Groth strip, several studies on early-type galaxy formation have been pursued: SED-based stellar mass estimates ([2]); B - and K -band population synthesis evolutionary models (Prieto et al 2006); bulge/disk relationships (Dominguez et al. in prep.); galaxy fusion rate *vs.* z ; extremely red objects; K -band luminosity function; photo- z distributions (depicted in picture); census of mergers; obscured X-ray AGN ([12]); *etc.*

catalogs will be debugged in the following months and an alpha version for internal use is planned for Jul 2007. Keeping on schedule, a public release of the data should follow as early as Jan 2008.

The GOYA photometric catalog combines data taken by our team with other data available in public databases, as well as through collaborations. The evolving calendars for the completion of GTC and the start of the GOYA spectroscopic survey with EMIR mean that we can now take advantage of public NIR surveys carried out with efficient, wide-field imagers such as UKIRT/WFCAM and CFHT/WIRCAM, for securing large datasets of NIR photometry of galaxies. Among those are space platforms of special interest for high- z galaxy studies, such as GALEX, and *Spitzer*. The GOODS and SWIRE surveys provide rest-frame K -band luminosities for galaxies at z up to ~ 3 , giving us ideal information for the selection of galaxy samples that avoid biases in star formation activity (see Perez-González’s talk in these proceedings).

3 Pre-EMIR science

We are exploiting the GOYA Photometric Survey in a wide range of scientific projects. We have obtained galaxy number counts in the NIR ([3]), and in blue bands ([7]). Using number count models that simultaneously fit blue and NIR counts we obtained constraints on the epoch of formation of galaxies in the red sequence (Prieto et al. 2006, these proceedings). We have obtained estimates

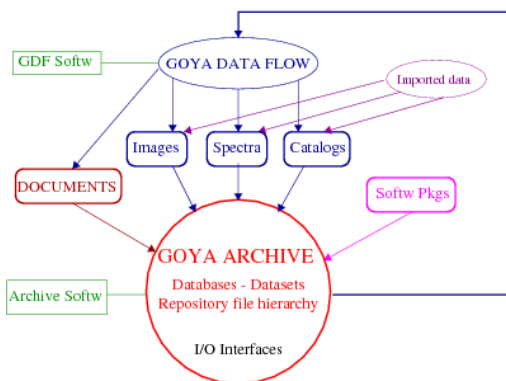


Fig. 3. The GOYA Data Flow specifies routines and algorithms for all the procedures involved in the acquisition of data, including data reduction pipelines, which are then stored in the Archive.

of the stellar mass in galaxies through SED-fitting methods ([2]). Currently ongoing projects include: the determination of the K -band luminosity function of galaxies and its evolution to $z = 1.5$; photometric and morphological characterisation of the sample of merger galaxies in the Groth and GOODS-N fields; evolution of the rate of mergers to $z = 1.5$; analysis of the ages of galactic bulges to $z = 0.8$, in Groth and GOODS-N (*Science with the GTC III Proceedings*, in prep.).

4 GOYA Data System

In order to manage the large amount of data produced in the survey, we have established the GOYA Data System (GDS), a prescription for a comprehensive organisation of information in the GOYA project (Figure 3). The GDS specifies what information is stored and how, specifies data formats, and provides for ways to access the data. Information consists of: the products of the GOYA Data Flow; data gathered from external sources; the documentation generated in the project; and, the software packages developed for the project. These components are organised into the GOYA Archive, which provides the relational functionality that fulfils the scientific needs of the project. User access interfaces to the archive include web interfaces as well as direct and ftp access.

The development of the GDS has been guided by the principles of: Standardisation, Integration, Modularity, Maintainability, Accessibility, Deployability. This shall make it easy to adapt to other surveys, and we will be happy to share this work with any interested parties. As Virtual Observatory (VO) standards become more unified, the GDS has the commitment to follow them.

5 Summary

The GOYA team has acknowledged the importance of measuring the dynamic and stellar mass, the star-formation rate, the abundances of heavy elements and the super-massive black-hole accretion rates in distant galaxies as the four main functions which will tell us how galaxies form and evolve. For these studies it has gathered over 40 nights of guaranteed time on two of the world's most advanced NIR spectrographs, EMIR on GTC (2008-10) and Flamingos-2 on Gemini-S (2007-08), and it is estimated that 10^4 near-infrared spectra will be obtained. In preparation for the exploitation of EMIR, the GOYA team has conducted a deep NIR photometric survey, for sample selection and characterisation, which covers over 0.5 deg^2 at typical magnitudes of $K_s < 22.5$ (AB). This survey is proving good for $0.5 < z < 2$ science and several lines of research have stemmed from it. Recently our source catalogs are being expanded to include sources available to Flamingos-2 and Spitzer infrared data.

We anticipate to release a working version of our catalogs for internal use around 2007 summer. A public release is planned for 2008, in the frame of the GOYA Archive. More information on the project can be obtained by contacting the authors or at <http://www.iac.es/project/GOYAiac/GOYAiac.html>.

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