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CALIFA, the Calar Alto Legacy Integral Field Area survey: early report

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Abstract

We present here the Calar Alto Legacy Integral Field spectroscopy Area survey (CALIFA). CALIFA is large collaboration comprising more than 50 astronomers of 8 different countries, which main aim is to obtain detailed spatially resolved spectroscopic information of $\sim$ 600 galaxies of any type at the Local Universe ($0.005 < z < 0.03$). The defining science drivers for the project are: (a) model the stellar population and constrain the star formation histories; (b) trace the distribution of ionized gas and estimate chemical abundances for the gas phase; and (c) measure the kinematic properties of the galaxies, both from emission and from absorption lines; all these quantities will be recovered from maps covering the entire luminous extent of the galaxies in the sample. To achieve these goals CALIFA will sample the full optical extension of the selected galaxies (to a $3\,\sigma$ depth of $\mu \sim 23$ mag arcsec^{-2}), covering the wavelength range between 3700–7000 Å with two setups ($R \sim 850$, and ~ 1650), by using PPAK/PMAS at the 3.5 m telescope. The proposal was recently approved by the observatory, allocating $\sim$ 210 dark nights, distributed in 6 semesters and starting in July 2010. As a legacy survey, the fully reduced data will be delivered freely, once their quality has been verified. We report here on the results of the early analysis performed on the data taken so far (21 galaxies).

1 Introduction

Much of our recently acquired understanding of the architecture of the Universe and its constituents derives from large surveys (e.g., 2dFGRS, SDSS, GEMS, VVDS, COSMOS, to name but a few). Such surveys have not only constrained the evolution of global quantities such as the cosmic star formation rate, but also enabled us to link this with the properties of individual galaxies – morphological types, stellar masses, metallicities, etc. Compared to previous approaches, the major advantages of this recent generation of surveys are: (1) the large number of objects sampled, allowing for meaningful statistical analysis to be performed on an unprecedented scale; (2) the possibility to construct large comparison/control samples for each subset of galaxies; (3) a broad coverage of galaxy subtypes and environmental conditions, allowing for the derivation of universal conclusions; and (4) the homogeneity of the data acquisition, reduction and (in some cases) analysis.

An observational technique combining the advantages of imaging and spectroscopy (albeit with usually quite small field of view) is Integral Field Spectroscopy (IFS). However, so far this technique has rarely been used in a "survey mode" to investigate large samples, apart from notably exceptions (eg., SAURON [2]). A need for a detail understanding of the spatially resolved spectroscopic properties of a statistical sample of nearby galaxies has been identify in order to understand the final product of the evolution of galaxies. In order to address this requirement, we proposed the CALIFA survey. This survey has been granted with 210 dark nights of the 3.5 m telescope at Calar Alto Observatory (Spain), homogeneously distributed along 6 semesters, officially starting the 1st of July 2010. CALIFA will observe a well-defined sample of $\sim$ 600 galaxies in the local Universe with the PMAS/PPAK integral field spectrophotometer [7, 3], mounted on the 3.5 m telescope at the Calar Alto Observatory. The sample to be observed was selected to comprise most of the galaxy types, covering the full color-magnitude diagram down to $M_B < -18$ mag. The observations will cover the optical wavelength range between 3700 and 7000 Å, using two overlapping setups, with resolutions of $R \sim 1650$ and $R \sim 850$. Considering this spectral coverage, and the large field-of-view of PPAK (> 1 arcmin^2), CALIFA is thus the largest and the most comprehensive wide-field IFU survey of galaxies carried out to date.

2 Science goals

Using the CALIFA dataset we expect to: (i) model the stellar population and constrain the star formation histories; (ii) trace the distribution of ionized gas and estimate chemical abundances for the gas phase; and (iii) measure the kinematic properties of the galaxies, both from emission and from absorption lines. All these quantities will be reconstructed in maps covering the entire luminous extent of the galaxies in the sample. These spatially resolved information will be used to achieve the main science goals of the survey.

One of the most fundamental challenges in Astrophysics is to understand the origin for the observed diversity of galaxies, and the physical mechanisms – intrinsic and environmental – that are responsible for the differences as well as similarities between them. Detailed studies of nearby galaxies can help by revealing structural properties that can be interpreted as "fossil records" of the formation and evolution process. We have long known from our own Milky Way that there are intricate links between chemical and kinematic characterisations of stellar populations, as well as between stars and gas, and similar relations have been found in other galaxies. An old but still unanswered question is the problem of "nature vs. nurture", i.e. the relative importance of environmental processes such as merging and accretion, relative to intrinsic secular processes that inevitably occur in an evolving complex dynamical system. A more recently posed puzzle is the bimodality of the galaxy population: Why do galaxies tend to be either "red and dead" or blue and star forming, and in particular, what is happening to galaxies in the intermediate "green valley" of the color-magnitude diagram? In order to come close to answering these questions, major observational and theoretical efforts will be required. Spatially resolved spectroscopy of many galaxies, such as will be provided by the CALIFA Survey, will be of essential importance in this endeavour. In the following we summarize our plans for scientific exploitation of the CALIFA:

- The nature of the galaxies in the *green* valley.
- The differences between the slow and fast rotator early-type galaxies.
- The detail star formation history of disk galaxies: the origin of disk truncations.
- The environmental dependency of the stellar population in galaxies.
- The origin of the gas ionization in different families of galaxies.
- The origin of the scaling laws of gas metallicity.
- A detail classification of galaxies on the basis of the stellar and gas kinematics
- Chemodynamics: the relation between the kinematic properties and the star formation and chemical enrichment processes in galaxies.

3 Sample

The CALIFA mother sample has been selected to fulfill the main requirements of the science goals of the survey, ie., the characterization of the spatially resolved spectroscopic properties of galaxies in the Local Universe of any kind, on one hand, and to maximize spatial coverage of the IFU over the complete size of the galaxies, on the other. Based on these requirements, the mother sample has been selected from the SDSS DR7 photometric catalogue [1], to guarantee its photometric coverage, adopting a combination of angular isophotal diameter selection ($45'' < D_{25} < 80''$) with redshift one ($0.005 < z < 0.03$). The final sample comprises $\sim$1000 galaxies, being a representative subsample of the galaxies in the Local Universe [5]. The final observed sample by CALIFA will be selected from this mother sample, based on the visibility for each night. It is expected that this will produce a random subsample (of 600 galaxies).

Figure 1 shows post-stamp images of a random selection of galaxies within the mother sample distributed along the color-magnitude diagram, illustrating the diversity of galaxies

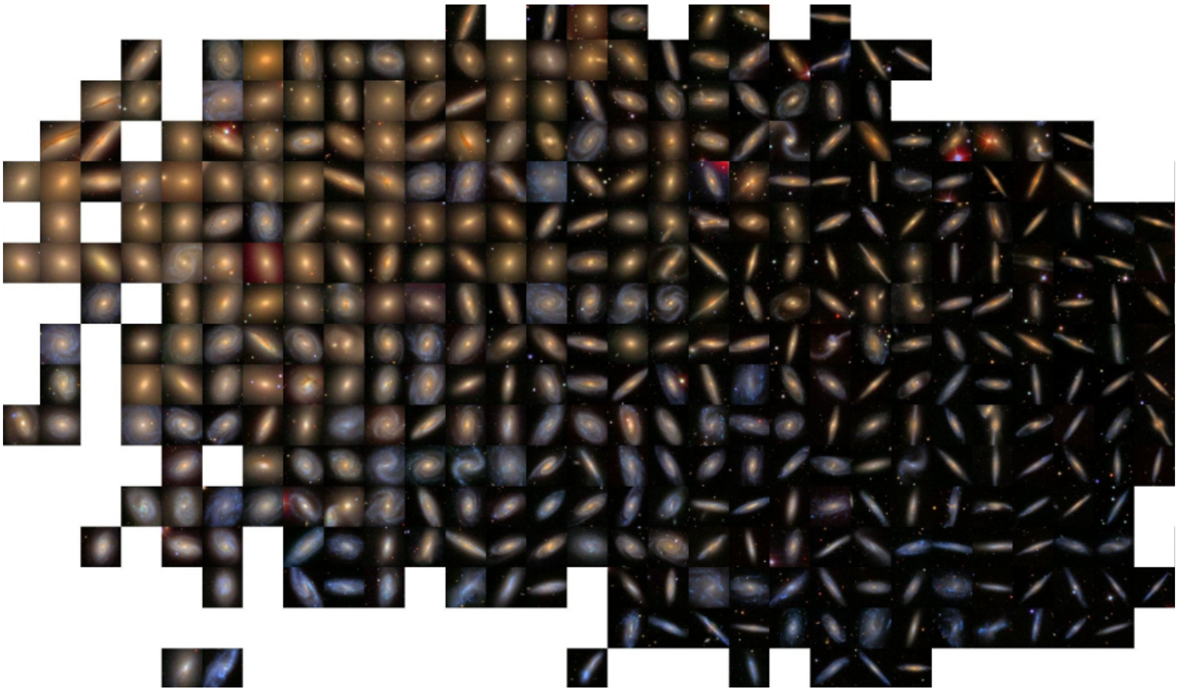

Figure 1: Poststamp true-color images of a set of galaxies within the CALIFA mother sample of $90'' \times 90''$ size, extracted from the SDSS dataset, ordered following the $u-r$ vs. r color-magnitud diagram. The figure spans from $M_r \sim -23$ mag from the left end, to $M_r \sim -18$ mag to the right end, and from $u-r \sim 3.5$ mag from the top end, to $u-r \sim 1.5$ mag to bottom end. The figure illustrate the large variety of galaxy types covered by the survey.

and the wide range of parameters covered by the survey ($\sim$ 5 magnitudes in luminosity and $\sim$ 3 in color).

4 State of the art of the survey

CALIFA has recently started. Its data acquisition phase will long for three years, and we have just got data for 21 galaxies (June–July 2010). However, our observing strategy and data reduction has been refined on the basis of early pilot studies [4, 12], and a wide previous experience with the instrument. The reduction of the CALIFA data is performed using a fully automatic pipeline, that operates without human intervention, producing both the scientific useful frames and a set of quality control measurements that help to estimate the accuracy of the reduced data. The pipeline uses the routines included in the R3D package [9] and the E3D visualization tool [8]. The reduction consists of the standard steps for fibre-based integral-field spectroscopy.

The first acquired data have been fully reduced using the implemented pipeline. To

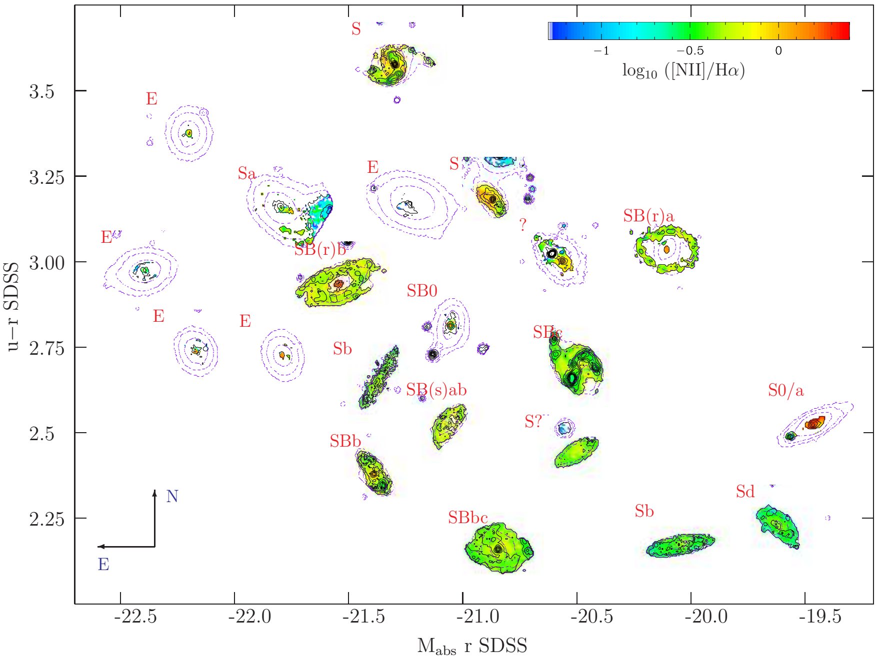

Figure 2: Similar color-magnitude diagram as presented in previous figure, with the color-maps showing the distribution of the emission line ratios between [NII]λ6583 and Hα, derived by the fitting procedure. In this case the solid-contours show the intensity of the Hα emission. The dashed-blue-contours show 3 intensity levels of the continuum emission at $\sim$ 6550 Å (starting at $3\times\ 10^{-16}$ erg s^{-1} cm^{-2}). They have been included to indicate the physical extension of the continuum emission in the galaxies.

determine their quality, a set of exploratory analysis were performed in order to derive the properties of the both the underlying stellar populations and ionized gas, spaxel-to-spaxel, together with the kinematics information of both components. The actual adopted procedure is based on FIT3D [10], and it was described in detail in [11], and used in previous surveys (eg., PINGS [6]).

Figure 2 shows one of the outputs of this analysis. In the figure it is shown the spatial distribution of the [NII]/Hα emission line ratio (a classical ionization diagnostic parameter), for the different observed galaxies, distributed along the the color-magnitude diagram. This figure illustrates the kind of comparative analysis that can be performed with CALIFA, where different spatially resolved spectroscopic properties of different families of galaxies can be compared in an homogenous way. In particular, in this figure it is seen: (i) red and dry galaxies, with little or no gas, most of them luminous early types; (ii) bluer and more gas rich galaxies, with a wider variety of morphologies, and with extended star forming regions, and (iii) galaxies clearly dominated by AGN activity, with gas ionization concentrated in the central regions ([NII]/Hα > 1).

We will progressively report on the development of the survey in subsequent articles, and through its webpage http://www.caha.es/sanchez/legacy/oa.

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