Studying nearby disk galaxies with the CALIFA survey

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Abstract

The survey CALIFA, Calar Alto Legacy Integral Field Area Survey, will provide the largest and most comprehensive wide-field IFU survey of galaxies carried out to date, addressing several fundamental issues in galactic structure and evolution. We will observe a statistically well-defined sample of ~600 galaxies in the local universe using 210 observing nights (awarded) with the PMAS/PPAK integral field spectrophotometer, mounted on the Calar Alto 3.5m telescope. The science drivers for the project are:

✓ Model the stellar population and constrain the star formation histories.

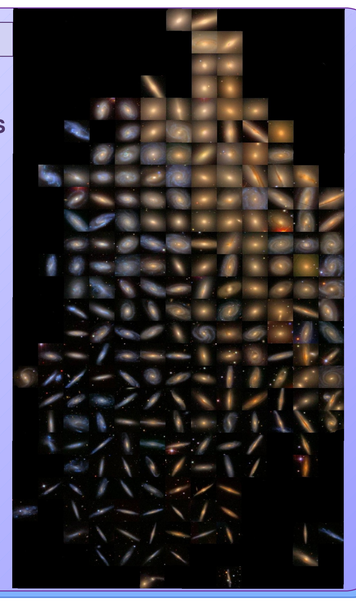
✓ Trace the distribution of ionized gas and estimate chemical abundances for the gas phase.

✓ 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.

The CALIFA project comprises researchers from a large number of institutions worldwide: 8 instution in Spain, 4 in Germany (CAHA funding countries) and 11 elsewhere for a total of 56 researchers. CALIFA will provide a valuable bridge between large single-aperture surveys such as SDSS and more detailed studies of individual galaxies with PPAK (e.g. PINGS), SAURON, VIRUS-P, and other instruments.

Science drivers for CALIFA

CALIFA galaxies



~ GALAXY MASS DISTRIBUTION

~ STELLAR POPULATIONS
- Star formation in green valley galaxies
- Early-type galaxies
- Star formation history of disk galaxies
- Stellar populations and environment

~ PROPERTIES OF THE IONIZED GAS

~ NUCLEAR ACTIVITY IN GALAXIES (AGN)

~ STELLAR AND GAS KINEMATICS
- Kinematic substructures
- Fast and slow rotators
- Chemodynamics
- Scaling relations

Our interests at UCM

STELLAR POPULATIONS DISK GALAXIES

The formation and evolution of galaxy disks is a complex process as many are the mechanisms that might alter their photometric, chemical, and kinematical properties. Many important questions remain unanswered: How old are the disks seen in the spiral galaxies today? How did they chemically evolve? Are they growing inside-out, as proposed to explain the color and metallicity gradients in our own Milky Way? Do they have an edge? How efficient is the stellar radial diffusion? To well understand the mechanisms governing the evolution of spiral galaxies, and to known precisely the SF and chemical history of these objects is needed. Our effort is committed to add another dimension to the study of nearby disk galaxies thanks to the use of 3D data and to take advantage of large number of *spaxels* provided by these CALIFA observations.

PROPERTIES OF IONIZED GAS DISK GALAXIES

The few studies on the chemical composition of HII regions (that trace the sites of massive SF) at large galactocentric distances suggest that the extended disks are relatively unevolved systems. The study of nebular abundances is therefore crucial for understanding the chemical evolution of galaxies. Our aim is to determine metal abundances at different radii using strong-line methods in order to establish the chemical evolution of disks as a function of galaxy mass and environment. In those cases where T_e measurements would be available we will also improve the empirical calibration of the strong-line methods, again, as a function of radii, galaxy mass, and environment.

Observations

The observations will be performed using PMAS at the Calar Alto (CAHA, Spain) observatory 3.5m telescope in the PPAK mode (efective FWHM ~1.6" when the 3 dithered pointing are combinate). The spectra will be covering the range 3700–7000Å in 2 overlapping setups, the red zone 4300–7000Å @ R~850 and blue one 3700–5000Å @ R~1650. PPAK offers a combination extremely wide field-of-view > 1" with a high filling factor in one single pointing (65%), good spectral resolution, and sensitivity across the optical spectrum.

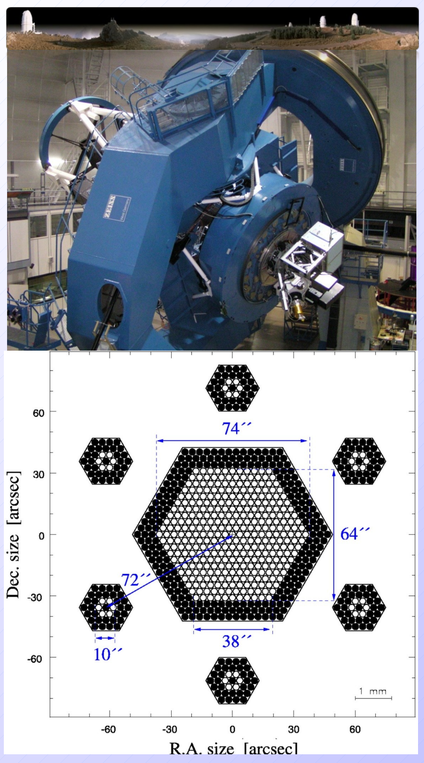


Fig.3 *Cassegrain focus of the 3.5-m telescope on Calar Alto and Layout and dimensions of the PPak-IFU.*

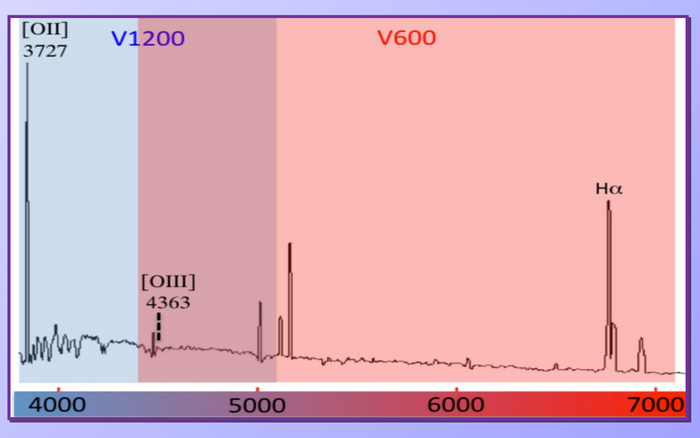


Fig.4 *The overlap region of the blue and red setups includes the two Balmer lines where the decomposition of emission and absorption is most critical, Hα and Hβ and the faint [OIII]4363 Á line used for obtaining direct, T_e-based oxygen abundance measurements.*

The sample

The CALIFA sample (600 objects) has been selected from the photometric catalog of the SDSS as a sample limited in apparent isophotal diameter. An additional restriction is the covered redshift range, that is set $0.005 < z < 0.03$ which ensures that all galaxies can be observed with the same grating settings. We chose diameter limits of $45" < D_{25} < 80"$ which allows covering the entire galaxy in one single PPAK field. This parent sample covers a substantial fraction of the galaxy LF at this redshift.

The CMD is also well covered and well-sampled with enough galaxies to perform proper statistical analysis. We will cover a range of ~7 mag in luminosity and ~2 mag in color, with about ~40 objects in each box of 1 × 0.5 mag. We estimate that there are over 200 early-type galaxies in our sample. On the other hand, 2/3 of the galaxies in the CALIFA sample are disk-dominated. The sample is dominated by field galaxies, but will effectively include galaxy populations in groups, low-density clusters, and even dense environments such as the Coma cluster which is fully covered by the CALIFA footprint and redshift range.

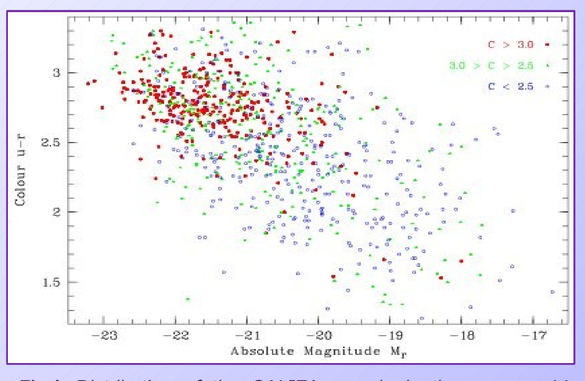


Fig.1 *Distribution of the CALIFA sample in the u−r vs. M, color-magnitude diagram. The symbol/color coding represents the concentration index $C \equiv r_{90}/r_{50}$, with $C \sim 2.8$ as the typical separation between disk- and bulge-dominated galaxies.*

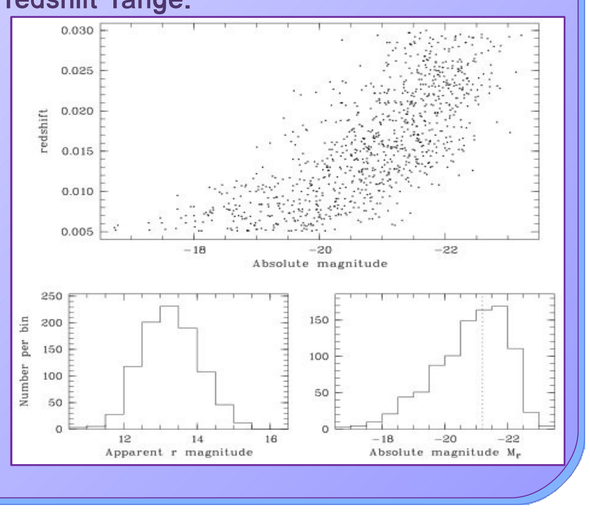
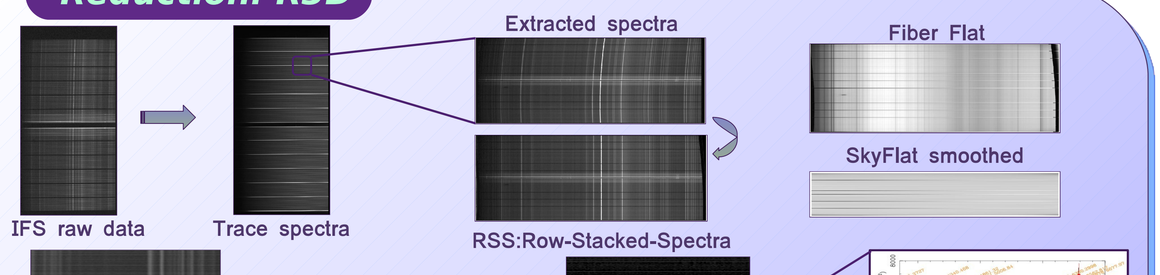
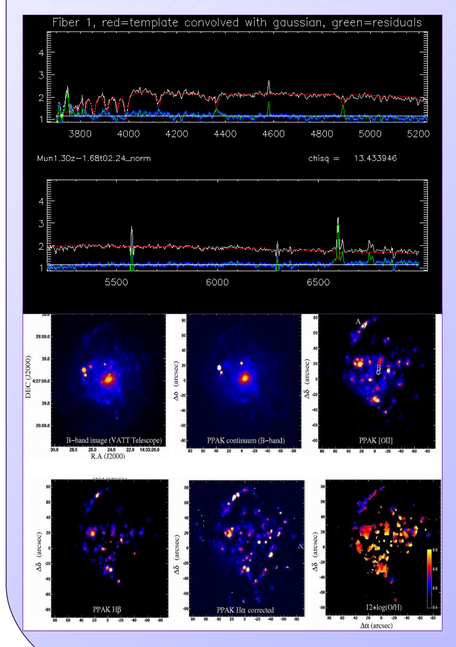


Fig.2 *Top: Distribution of the CALIFA sample in absolute magnitude (Mr) vs. redshift. Bottom left: Histogram of apparent magnitudes. Bottom right: Histogram of SDSS r-band absolute magnitudes; the dotted vertical line represents L.*

Reduction: R3D



Analysis



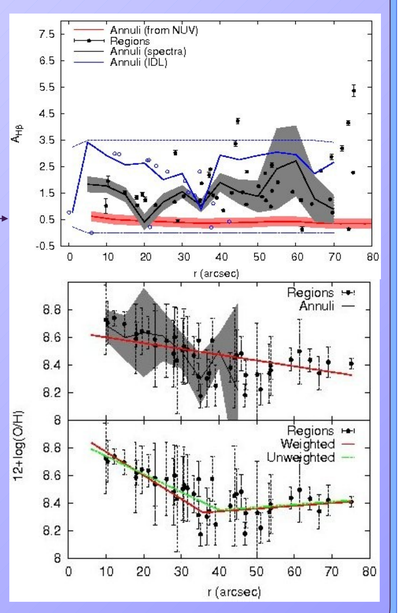
← Extraction
Decomposing the integrated spectra
Underlying absorption spectra

Extinction →
Stellar continuum and ionized-gas attenuations

← Line Maps
Optical emission lines
Synthetic Broad-Band Image
Metal Abundance

Metallicity Gradient →
Strong-line methods
Kewley & Dopita 2002

Results for NGC5668



... and all this for 600 galaxies

Pilot observations

Pilot study campaign in April 2009:

21 galaxies observed

First run in June 2010

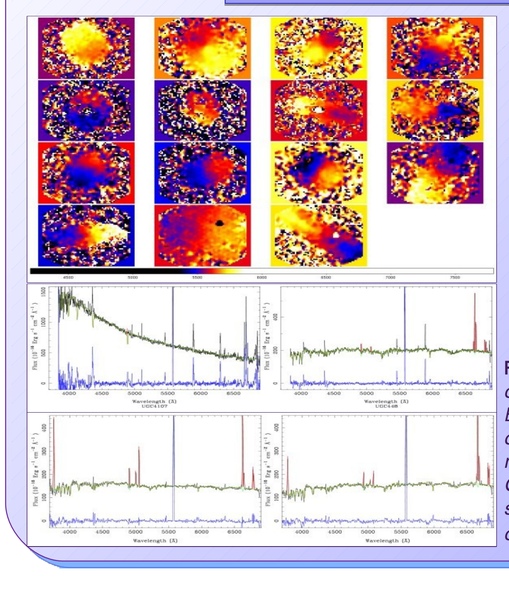


Fig.5 *Top: Hα velocity map derived from a selected sample of objects.*
Bottom: Integrated spectra of each of the objects observed as part of our pilot study (black solid line). The green line shows the best fitted multi-stellar component model, while the red line shows the best fitted Gaussian model for the considered emission lines. The blue line shows the residuals derived after subtraction both models to the original data.

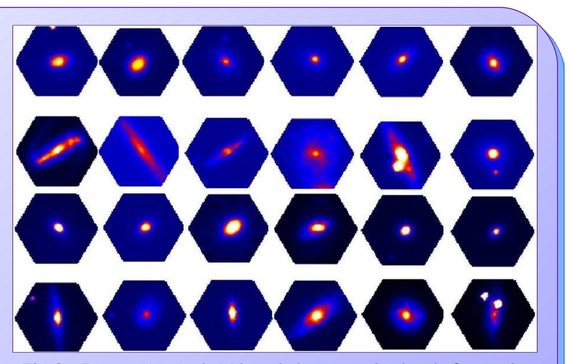


Fig.6 *Reconstructed V-band image obtained from the reduced datacubes of the 24 objects observed during the pilot study of the legacy survey. By construction of the sample, there is variety of galaxies of different morphologies. The reduced data fulfill the expectations in terms of S/N and spectrophotometric accuracy.*