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The mass growth in galaxies: CALIFA's perspective

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Abstract

We report a few preliminary results from the analysis of the first 105 galaxies of the largest to date 3D spectroscopic survey of galaxies in the local universe (CALIFA). We apply the fossil record method of stellar population spectral synthesis by means of the STARLIGHT code to recover the spatially and time resolved star formation history of each galaxy. We describe the analysis pipeline we developed and some of its many products, that show the power of the combination of Integral Field Spectroscopy (IFS) data with spectral synthesis. As a preliminary result we show that, for massive galaxies, the inner parts of the galaxies grow faster than the outer ones, a clear signature of inside-out growth.

1 Introduction

The Calar Alto Legacy Integral Field Area (CALIFA) survey is obtaining spatially resolved spectroscopic information of a diameter selected sample of ~ 600 galaxies in the Local Universe ($0.005 < z < 0.03$). CALIFA has been designed to allow building two-dimensional maps of several quantities as stellar populations, ages and metallicities or kinematics, among others. CALIFA uses the PPAK Integral Field Unit (IFU), with a hexagonal field-of-view of $1.3\square'$, with a 100% covering factor by adopting a three-pointing dithering scheme. The optical wavelength range is covered from 3700 to 7000 AÅ, using two overlapping setups (V500 and V1200), with different resolutions: R850 and R1650, respectively. CALIFA is a legacy survey, intended for the community.

The CALIFA mother sample contains almost 1000 galaxies that were selected from the SDSS DR7 photometric catalog [1]. The main criteria selection, in addition to the restriction in declination to ensure good visibility from the Calar Alto Observatory (CAHA), are: a) Angular isophotal diameter in the SDSS r-band larger, 45 arcsec $\leqslant$ D25 $\leqslant$ 80 arcsec to ensure

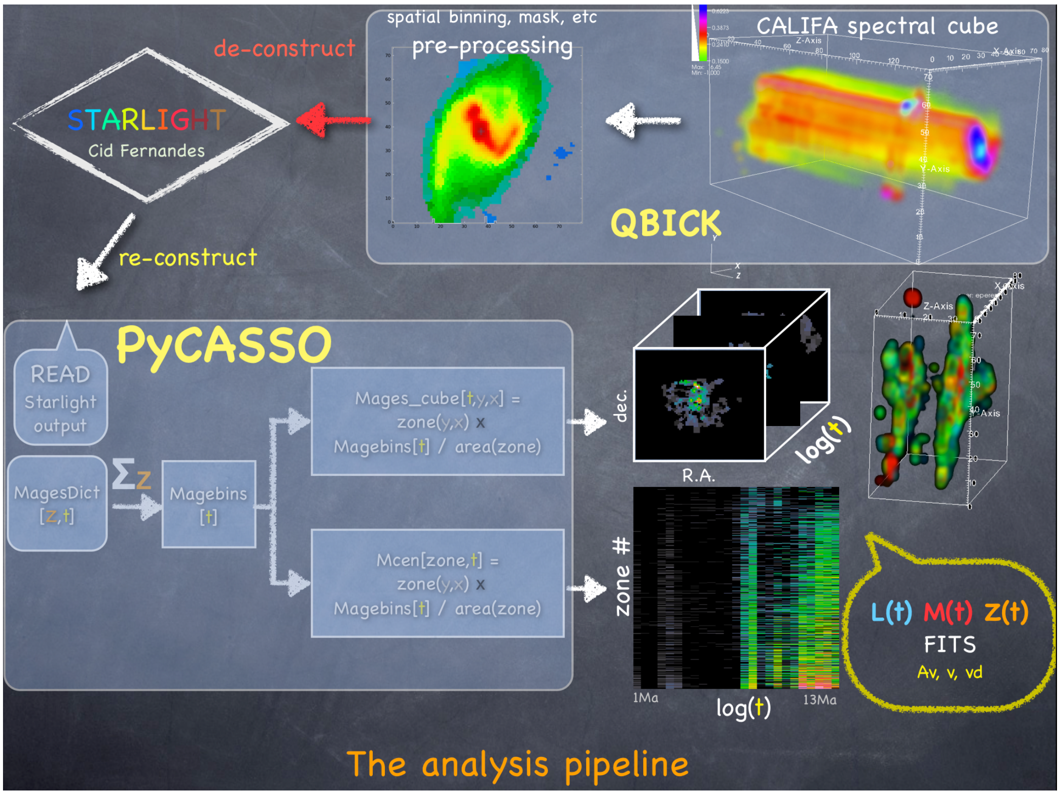

Figure 1: Flow chart of the pipeline analysis applied to CALIFA data.

that objects apparent size fill well the PPAK Field-of-View (FoV). b) The redshift range is $0.005 \leqslant z \leqslant 0.03$, to ensure that all the relevant emission lines at optical ranges are well covered.

In this paper we present a few preliminary results of the analysis of the first 105 galaxies observed by CALIFA. They were selected randomly from the parent sample but covering well the color-magnitude diagram and represents well a sub-sample of CALIFA mother sample. We used the first 105 galaxies observed by CALIFA in conjunction with the spectral synthesis code starlight [2], which recover the history of a stellar system out of the information encoded in its spectrum [3], to obtain the spatially resolved SFH of galaxies.

2 Analysis

The wide wavelength coverage of the V500 is ideal for the above outlined study, but the blue end of its spectra, which contains valuable stellar population tracers such as the 4000 Å break, is affected by vignetting over a part of the field of view. To make used of the whole available wavelenght range, we worked with a combination of the two gratings, whereby the data for $\lambda < 4600$ A comes from the V1200 and the rest from the V500. The spectra were homogenized to the resolution of the V500, as a part of the standard reduction included in

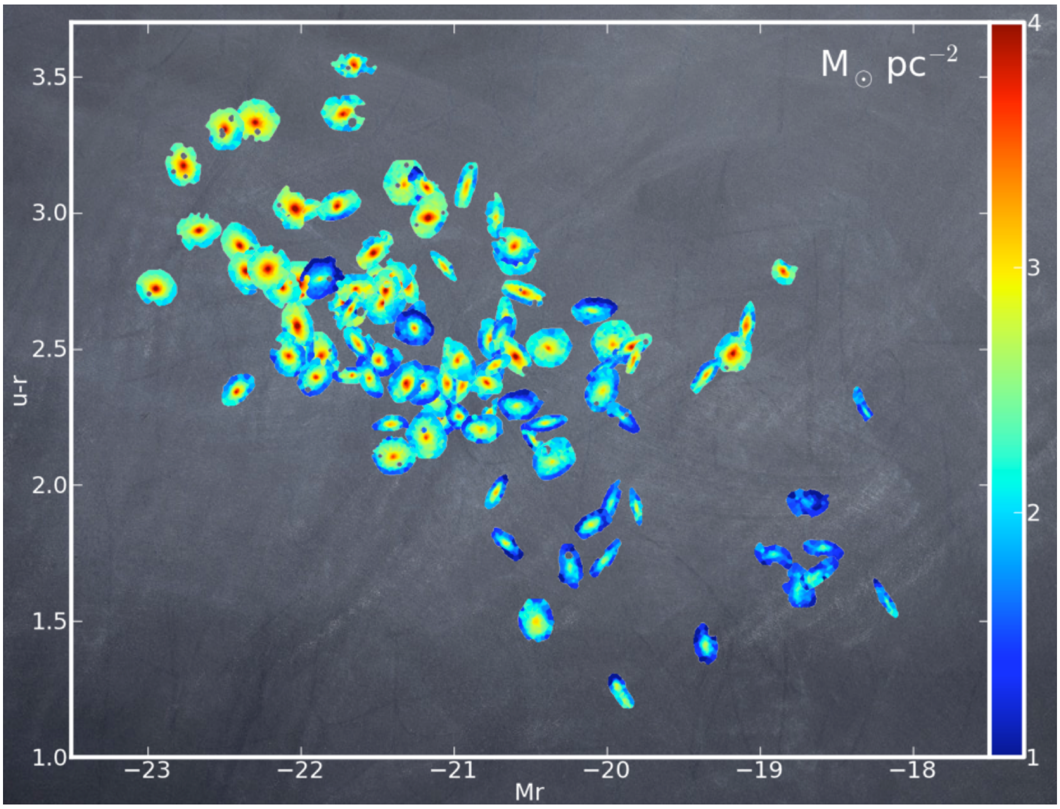

Figure 2: CMD with the density mass map for each of the 105 CALIFA analysed galaxies.

the CALIFA pipeline.

A series of pre-processing steps are applied to the reduced datacubes, with the general goal of extracting good quality spectra for a stellar population analysis with Starlight. These are: i) Definition of a spatial mask; ii) Refinements of the flag and error spectra; iii) Rest-framing; iv) Outer S/N mask; v) Spatial binning; vi) Resampling in λ. All these task have been packed in the fully automated package (QBICK) to prepare and pre-process datacubes for a 3D spectral fitting analysis.

STARLIGHT produces a large array of quantities, all stored in plain ASCII files, one for each spectrum fitted. Datacubes (IFS) require an efficient organization to handle all the data. We developed PYCASSO (Python Califa Starlight Synthesis Organizer), which comprises three parts: i) A writer module, which packs the output of all STARLIGHT files into a single FITS file per galaxy; ii) A reader module, which reads the produced FITS file and structures the data; iii) A post-processing module, which comprises a series of common operations for 3D data (mapping, resampling/smoothing population vectors, ...).

The whole sequence of analysis described in this section can be easily followed in the flow chart shown in Fig. 1.

3 Products

As a result of the many spectra that the CALIFA will obtain ($\sim 10^6$), a huge amount of data will be generated. This section is devoted to illustrating only some of the many products of our pipeline.

From the spectral synthesis analysis, there are many properties that can be visualised into 2D spatial maps for a galaxy: light converted to mass, extinction, kinematics (both $v_\star$ and σ_{star}), mean ages or metallicities among others. All this information can just be displayed in an individual basis, galaxy by galaxy. Or, more interestingly, we can provide a framework to obtain a general picture of the whole sample analysed. This is beautifully shown in Fig. 2, where the density map ($M_\odot$ pc^{-2}) for each individual galaxy is located in the Color-Magnitude Diagram (CMD). As clearly shown, some general trends can be easily seen, something that would be harder to grasp in an individual-basis analysis: more massive galaxies are located in the upper-left side of the CMD.

4 Mass growth

We can also pack all the galaxies to study general properties by groups. For example, in the CMD frame we can stack all the galaxies within a particular magnitude bin (which is a proxy for mass), so that we have enough statistics (number of galaxies) to derive general trends in that particular box. In order to sum up different types of galaxies, we scaled them in units of Half-Light-Radius (HLR).

One of the properties that can be studied is the mass growth along the lifetime of the galaxy. This can also be done for different regions of the galaxy and compare the rate for each zone and magnitude bin. Figure 3 shows this kind of stacking. The horizontal axis represents the logarithm of the lookback time and the vertical axis the relative mass of a galaxy component, being 1 the total mass. In the lower-left corner is written the central magnitude of the bin. The lines represent the mass growth along time for different regions of the galaxy. The white line stands for the nucleus, the green line for all spectra inside 0.5 HLR, the red one for all spectra contained in 1 HLR and the blue line for all spectra *outside* 1 HLR. The white horizontal line represents 80% of the total mass of the galaxy. Thus, we can easily see that for more massive galaxies (brighter magnitude bin), the slope of the curves are steeper, meaning that the rate of mass growth is faster. Regarding the comparison of different regions, it is also evident that the inner parts of the galaxies grow faster that the outer parts for the more massive bins. This is a clear evidence of inside-out growth.

5 Conclusions

We have described some of the many studies that can be obtained from the analysis of the CALIFA survey. By applying the spectral synthesis method (STARLIGHT code) integrated in an IFS pipeline analysis to the first observed 105 galaxies, we have shown the richness of this powerful combination.

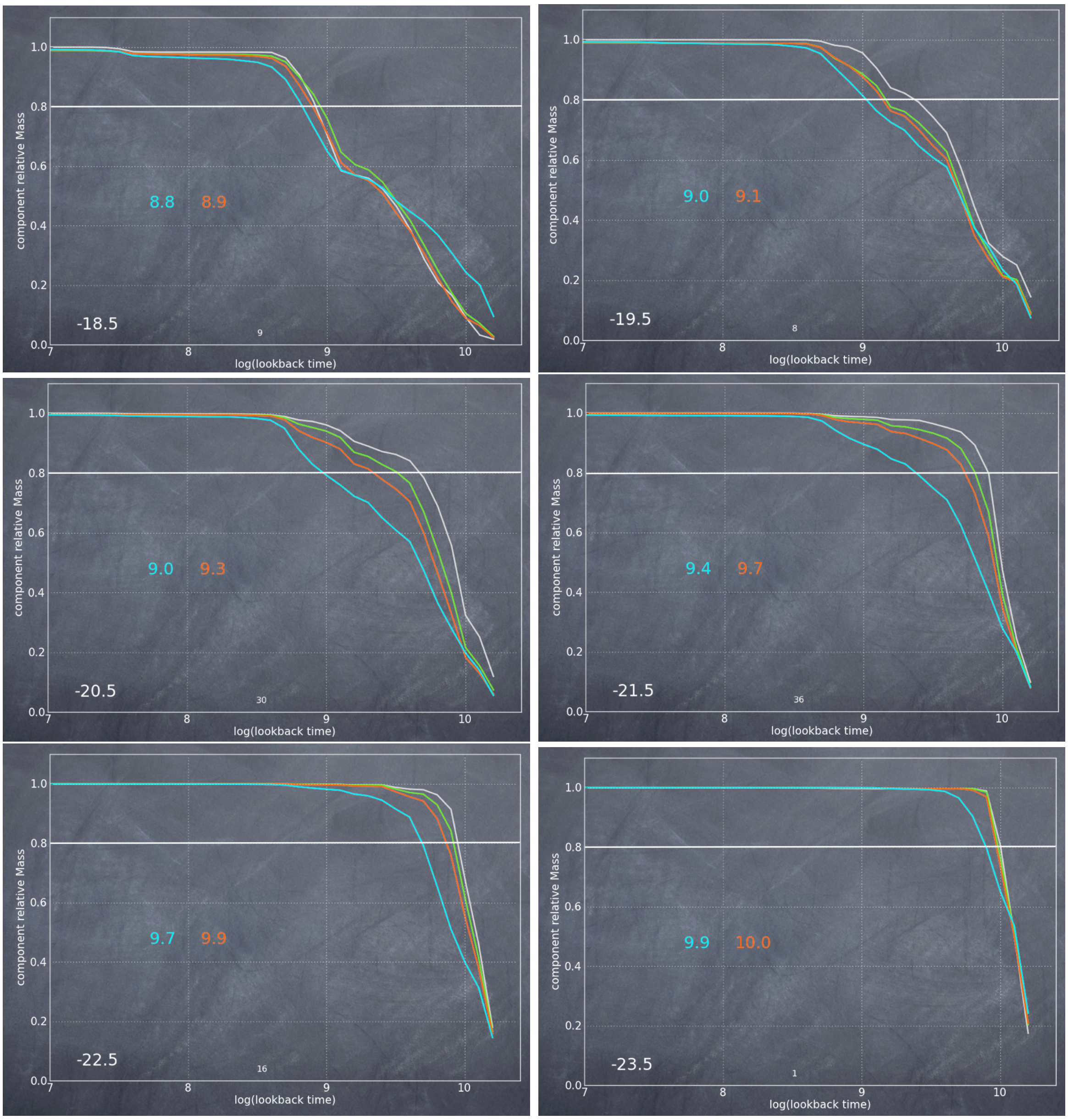

Figure 3: Mass growth by magnitude bin. See text for details.

As a preliminary result, we have reported how galaxies grow inside-out, being the mass build up faster for more massive galaxies. This is only one of many examples of exciting results to come from the analysis of the CALIFA survey.

Acknowledgments

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