Highlights of Spanish Astrophysics XI, Proceedings of the XV Scientific Meeting of the Spanish Astronomical Society held on September 4–9, 2022, in La Laguna, Spain. M. Manteiga, L. Bellot, P. Benavidez, A. de Lorenzo-Cáceres, M. A. Fuente, M. J. Martínez, M. Vázquez- Acosta, C. Dafonte (eds.), 2023

MEGADES: MEGARA Galaxy Disc Evolution Survey.

Chamorro-Cazorla, M.[1,2], Gil de Paz, A.[1,2], Castillo-Morales, Á.[1,2], Gallego, J.[1,2], Carrasco, E.[3], Iglesias-Páramo, J.[4], García-Vargas; M.L.[5], Pascual, S.[1,2], Cardiel, N.[1,2], Catalán-Torrecilla, C.[1,2], Zamorano, J.[1,2], Sánchez-Blázquez, P.[1,2], Pérez-Calpena, A.[5], Gómez-Álvarez, P.[5], and Jiménez-Vicente, J.[6,7]

[1] Departamento de Física de la Tierra y Astrofísica, Fac. CC. Físicas, Universidad Complutense de Madrid, Plaza de las Ciencias, 1, Madrid, E-28040, Spain
[2] Instituto de Física de Partículas y del Cosmos, IPARCOS-UCM, Fac. CC. Físicas, Universidad Complutense de Madrid, Plaza de las Ciencias 1, Madrid, E-28040, Spain
[3] Instituto Nacional de Astrofísica, Óptica y Electrónica, Luis Enrique Erro No.1, C.P. 72840, Tonantzintla, Puebla, Mexico
[4] Instituto de Astrofísica de Andalucía-CSIC, Glorieta de la Astronomía s/n, 18008, Granada, Spain
[5] FRACTAL S.L.N.E.. C/ Tulipán 2, p13, 1A. E-28231, Las Rozas de Madrid, Spain
[6] Departamento de Física Teórica y del Cosmos, Universidad de Granada, Campus de Fuentenueva, 18071, Granada, Spain
[7] Instituto Carlos I de Física Teórica y Computacional, Universidad de Granada, 18071, Granada, Spain

Abstract

The main interest of the science team for the exploitation of the MEGARA instrument at the 10.4m Gran Telescopio Canarias (GTC hereafter) is devoted to the study of nearby galaxies. The focus lies on researching the history of star formation, and the chemical and kinematical properties of disc systems. We refer to this project as MEGADES: the MEGARA galaxy disc evolution survey. The initial goal of MEGADES is to provide a detailed study of the inner regions of nearby disc galaxies in terms of their spectrophotometric and chemical evolution, and to provide a dynamical characterisation by distinguishing the contribution of in situ and ex situ processes to the history of star formation and effective chemical enrichment of these regions. In addition, the dynamical analysis of these inner regions naturally includes the identification and characterisation of galactic winds that might be present in these regions. At a later stage, we will extend this study farther out in galactocentric distance. The first stage of this project encompasses the analysis of the central regions of 43 nearby galaxies observed with the MEGARA integral field unit for $\sim$ 114 hours, including both guaranteed time and open time observations.

1 Introduction

Given the wide variety of processes and variables that affect the evolution of galaxies and, therefore, their appearance and properties throughout their history, it is clear that understanding the mechanisms that may have influenced the galaxy to reach the state in which we can observe it today requires the collection of as much information as possible. Fortunately, different processes have a different impact in the spectro-photometric, chemical and dynamical evolution of the stars and gas in galaxies.

In an effort to improve our understanding of the universe, with the advent of CCDs in the last 1990s, the idea of large surveys of galaxies became popular. The aim of these surveys has been to provide as much observational information as possible in the observational field in which they are designed. Initially, these surveys mainly relied on photometric observations and long-slit spectroscopy. However, in recent years, the development of instruments with observational capabilities based on Integral Field Spectroscopy (IFS) has represented a technical breakthrough that has led to a better understanding of the mechanisms involved in the evolution of galaxies.

One of the latest advances in astronomical instrumentation is MEGARA (*Multi-Espectrógrafo en GTC de Alta Resolución para Astronomía*). This instrument, capable of observing in both Integral Field Spectroscopy (IFS) and Multi-Object spectroscopy (MOS) modes, has a combination of spatial and spectral resolution unprecedented in this type of device. The fundamental nature of the open questions on galaxy evolution together with the availability of MEGARA@GTC led us to pursue MEGADES (MEgara GAlaxy Discs Evolution Survey), the scientific legacy project associated with the exploitation of the MEGARA instrument Guaranteed Time in the Large Compact Bundle (LCB) Integral Field Unit (IFU) mode.

2 Survey

2.1 MEGADES goals

The long-term objective of MEGADES is to understand the impact of secular processes on disc evolution. Our primary goal is to test whether gas infall is one of the main mechanisms in the evolution of galaxies, and whether it drives the inside-out formation of discs. Therefore, we will test the model predictions for this scenario against our MEGADES observations by analysing the secular and external causes of the differences, that is, nuclear activity, stellar migration, minor mergers, intense star formation, and so on. We will use MEGARA high spatial and spectral resolution 2D spectroscopy to analyse the kinematic properties of the stellar component in order to detect different structures such as bars or inner discs in the central regions of MEGADES galaxies. We will also analyse line indices sensitive to age and metallicity [1], and for the detected HII regions, the gas emission line spectrum, from which we will produce diagnostic diagrams and determine chemical abundances. Finally, we will study the presence and frequency of GWs in the MEGADES sample, both in its warm and cold phases. We will examine the kinematic properties and the shape of the Hα emission line to distinguish different kinematic components to study the warm phase, and we will use the

NaI D absorption doublet to analyse the cold phase.

With this first data release, we will be able to perform all these studies in the central regions of the galaxies in the sample and then place them in context with analyses of the outer emission disc when these observations become available. We will study the stellar populations that make up the bulges of the MEGADES galaxies together with their kinematical properties. With this information, we will be able to determine whether classical bulges dominate the galaxies in our sample or if there are more galaxies with pseudo-bulges [2]. We will also study the possible presence of outflows associated with nuclear starbursts and AGN, considering the existence of different kinematic components in the neutral or warm phase, and the differences that may exist between the two phases. In addition to all of this, we will be able to generate different diagnostic diagrams with the information contained in the different lines we will study.

2.2 MEGADES sample

The original MEGADES sample was extracted from the Spitzer survey of stellar structure in galaxies (S4G) sample [3]). The S4G was designed as a volume- ($d < 40$ Mpc, $|b| > 30°$), magnitude- ($m_{B,corr} < 15.5$ mag), and diameter-limited ($D25 > 1'$) survey. The use of the MEGARA IFU to carry out all observations makes a diameter-limited sample a reasonable idea, as has been the case for the CALIFA sample [4] or PHANGS-MUSE [5].

In addition to the limitations of the S4G sample, we imposed further constraints to fit the sample to our scientific goals. We wished to avoid dwarf systems and elliptical galaxies because in most cases, they are not supported by rotation. We also removed galaxies with inclinations higher than 70° to be able to analyse the metallicity and have the possibility of deriving velocity ellipsoids.

Taking into account all the previous considerations, and because it is not practical to observe the entire S4G sample (2331 galaxies) because of the required telescope time, we must consider further selection criteria in our sample: We limited the diameter to a range in which on the lower side, we removed the smallest galaxies, and on the upper side, we limited the diameter to approximately the field of view of the MEGARA MOS ($2.5' < D25 < 4'$)[1]. We also limited the declination ($Dec(J2000) > -20°$). Summarising all the above selection criteria, the galaxies in our sample are selected by distance $d < 40$ Mpc ($z \sim 0.0092$), galactic latitude $|b| > 30°$, declination $Dec(J2000) > -20°$, apparent magnitude $m_{B,corr} < 15.5$ mag, apparent diameter $2.5' < D25 < 4'$ and inclination $i < 70°$.

This contribution includes a random subsample of 30 out of the 215 galaxies that meet the selection criteria of the MEGADES-S4G sample. However, to enrich our sample, we added 13 galaxies from the CALIFA sample (Calar Alto Legacy Integral Field Area Survey) that show signs of containing interstellar NaI D and are candidates for hosting galactic winds in their neutral phase because their $EW_{ISM-NaID} > 1.5$ Å. The CALIFA survey, with SDSS DR7[2] [6] as the parent sample, is limited in diameter ($45'' < D25 < 80''$), redshift ($0.005 < z < 0.03$),

[1]Note that as part of the outer-disc extension of MEGADES we plan to obtain MOS spectra of HII regions over the whole galaxies extension.

[2]Sloan Digital Sky Survey Data Release 7

galactic latitude above 20°, and declination above +7°.

3 Data release I

3.1 Observations

We release the reduced observations of all galaxies in the sample with all available setups. We observed the central regions of the MEGADES galaxies using three different VPHs, VPH480-LR (LR-B), VPH570-LR (LR-V), and VPH675-LR (LR-R). This produces a combined spectrum covering the spectral range from 4350 to 7288 Åwith a spectral resolution of R $\sim$ 6000. This range includes spectral features such as Hβ, [OIII]λ5007, NaI D, Hα, [NII]λ6584, [SII]λ6717 and [SII]λ6731, as well as absorption features needed for the stellar populations analysis [1]. For the 13 CALIFA galaxies, we only have LR-V and LR-R observations. They suffice for studying the possible presence of outflows in the neutral (NaI D) and the warm (Hα) components. Figure 1 shows an RGB image of the galaxy NGC 3982 created from the LR-B, LR-V and LR-R observations.

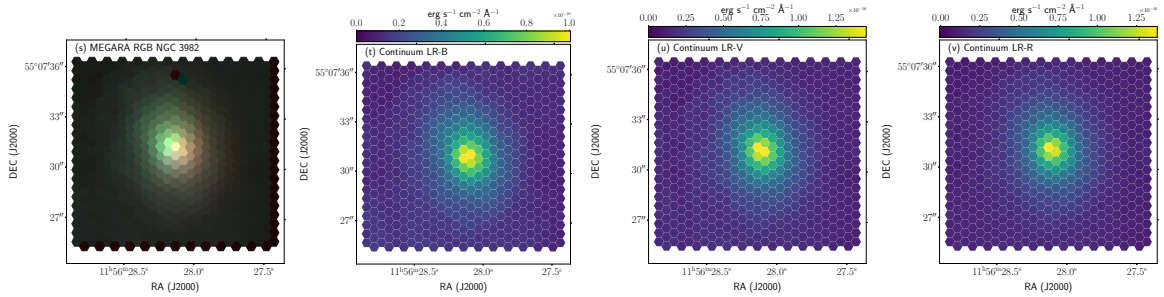

Figure 1: Left subfigure shows a continuum RGB image of NGC 3982 obtained from the MEGARA observations performed with LR-B, LR-V and LR-R (shown in the three following subfigures, respectively).

3.2 Stellar kinematics

We have performed an analysis of the stellar kinematics in the galaxies of the entire sample using the pPXF software based on observations made with the VPH LR-V (5165.57 Å-6176.18 Å). This analysis has been performed on the observations with a Voronoi binning so that all analysed regions reach a signal-to-noise ratio of 10. Figure 2 shows the stellar kinematic analyses performed on NGC 0023. Among the results obtained from this analysis we have velocity, velocity dispersion, skewness (h3) and kurtosis (h4) maps of the stellar component of all the galaxies in the sample.

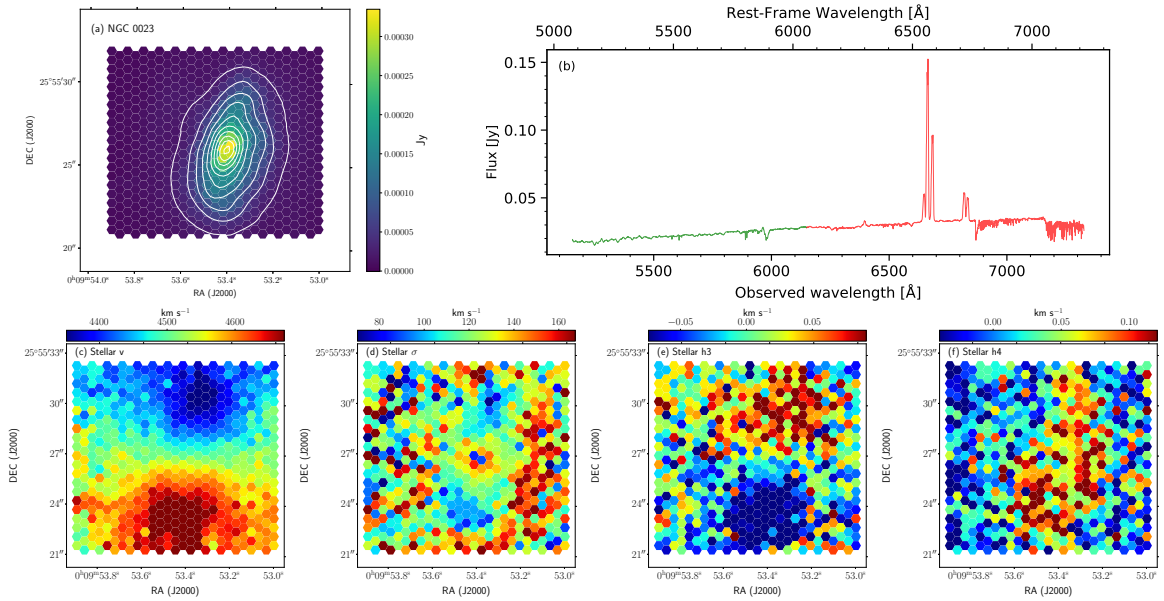

Figure 2: Subfigure (a) shows a continuum image of NGC 0023 obtained with the LR-V VPH (5165 Å- 6150 Å) with the isophotes of the PanSTARRS r-band image overplotted in white. Subfigure (b) shows the integrated spectrum of the separate observations made at different wavelengths. In subfigures (c), (d), (e) and (f) we show the stellar velocity, velocity dispersion, asymmetry and kurtosis maps, respectively, for each galaxy.

3.3 Spectral lines

We have carried out measurements on the emission lines of the ionised gas such as Hβ, [OIII]λ5007, Hα, [NII]λ6584, [SII]λ6717 and [SII]λ6731, and measurements on the neutral gas using the sodium doublet lines NaI D. All lines with a signal to noise ratio measured at the peak of the line higher than 3 were analysed individually using Gauss- Hermite models, except for NaI D, for which we used an an- chored double-Gaussian model. We also fitted the continuum emission around the lines using the information available on both sides of the line. For this task, we made use of one of the tools developed for the analysis of MEGARA observations, the *analyze_rss* megaratool. In Figure 3 we show maps of some of the properties measured for the lines mentioned above for the Hα and [NII]λ6584 lines using observations of NGC 0023.

4 Conclusions

We present the MEGADES survey together with the observations ready for scientific use. We carried out the first studies on the data from the inner regions of the galaxies in the MEGADES sample. We performed an analysis of the stellar kinematics in the galaxies of the entire sample using the pPXF software based on observations made with the VPH LR-

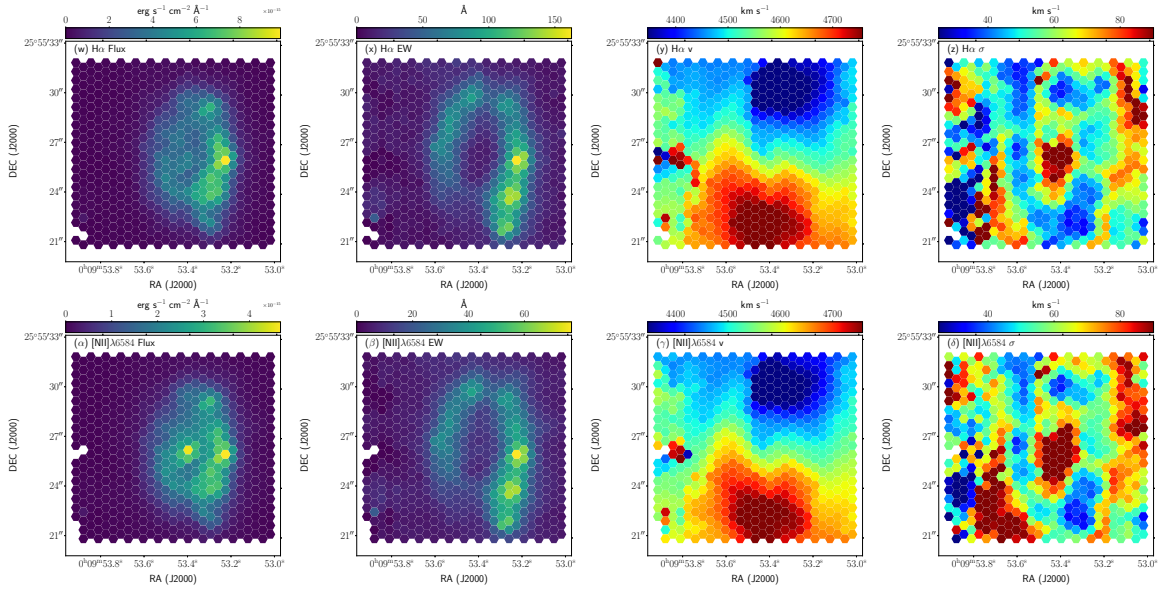

Figure 3: In the top panels, from left to right respectively, we show our measurements of flux, equivalent width, velocity and velocity dispersion from the Hα line in NGC 0023. In the bottom panels we show the same properties measured on the [NII]λ6584 line.

V (5165.6 Å- 6176.2 Å). We present all maps of the kinematic components, that is, radial velocity, velocity dispersion, skewness, and kurtosis. We also carried out measurements on the emission lines of the ionised gas such as Hβ, [OIII]λ5007, Hα, [NII]λ6584, [SII]λ6717, and [SII]λ6731, and measurements on the neutral gas using the sodium doublet lines NaI D. We also present some of the features measured on these lines in maps.

All the observations together with the results of the analyses carried out in this work are available to the community on the MEGADES website (https://www.megades.es). To access the public data, one can log in with the username "public" and the password "6BRLukU55E".

References

[1] Chamorro-Cazorla, M., Gil de Paz, A., Castillo-Morales, A., et al. 2022, A&A 657, A95

[2] Kormendy, J. & Kennicutt, Robert C., J. 2004, ARA&A 42(1), 603

[3] Sheth, K., Regan, M., Hinz, J. L., et al. 2010, PASP 122(898), 1397

[4] Sánchez, S. F., Kennicutt, R. C., Gil de Paz, A., et al. 2012, A&A 538, A8

[5] Emsellem, E., Schinnerer, E., Santoro, et al. 2022, A&A 659, A191

[6] Abazajian, K. N., Adelman-McCarthy, J. K., Agüeros, M. A., et al. 2009, ApJS 182(2), 543