Galaxies are one of the main observable constituents of the Universe we live in. Understanding their formation and evolution throughout cosmic time will lead us to learn about the history of the Universe itself and, therefore, it is one of the most important disciplines in modern astronomy.

Galaxies are enormous gravitationally bound systems composed of billions of stars, gas and dust. They were first classified by Hubble (1926) according to their morphology into two main groups: spirals and ellipticals (see Fig. 1). Spiral galaxies have bright and dusty spiral arms winding toward a bright bulge at their center. Our own Milky Way is an example of a typical spiral galaxy. Elliptical galaxies, on the other hand, have an ellipsoidal shape and appear on the sky as smooth, almost featureless systems. These two types of galaxies differ not only morphologically but also in their stellar and gas content as well as in the physical processes involved in their formation and evolution. Ellipticals have very little gas and dust. Since the stars are formed from gas, only few young stars are present in these galaxies. They are basically made of old populations of stars. Spiral galaxies have both very young and old stars. Their spiral arms have large amounts of gas and dust. As a consequence, new stars are constantly forming in different areas. The central bulge of a spiral galaxy is primarily composed of old stars.

Elliptical galaxies, the subject of study in this thesis, are particularly interesting because they contain a predominant fraction of the total stellar mass in the local Universe. Although they appear as simple objects on the sky, ellipticals are in fact very complex systems. They are found in a variety of different sizes, ranging from the largest to the smallest known galaxies, and present different structural properties, such as brightnesses and kinematics (velocity dispersions). Interestingly, some of their properties correlate with each other following several scaling relations. This suggests that the formation and evolution of elliptical galaxies involved some common physical processes now reflected in their observable properties. These observables can be used as a profitable way to study galaxy formation and to test the available models.

The current cosmological model of galaxy formation, known as the “hierarchical paradigm”, predicts that galaxies form hierarchically through the accretion of
smaller objects that, due to gravity, merge together and form larger systems as we see them today (e.g. White & Rees 1978). One of the best approaches to test this model and decipher the star formation history (SFH) of these galaxies is to study in detail their stellar content.

Just like paleontologists study the prehistoric life on earth from the fossil record, we can reconstruct the history of a galaxy from its constituent stars. Stars have imprinted in their properties information about the chemical composition of the intergalactic gas from where they formed, and also about their ages.

The radiation emitted by a star is produced in its interior and released to the outer space through its stellar atmosphere. This radiation provides detailed information about the intrinsic properties of the emitting star. Stars are then classified according to the wavelength at which the radiation peaks, which also indicates their surface temperatures. On the other side, the magnitude of a star is a measure of its brightness and its color is defined as the difference in magnitudes between two different range of wavelengths. The color and is directly related to the surface temperature of the star. In the 1910s, two astronomers, E. Hertzsprung and H. Russell, noticed independently that some distinct and unexpected patterns can be observed when plotting the magnitudes of stars against their surface temperature (or color). This type of diagram is called HR-diagram or color-magnitude diagram (CMD). It was later learnt that concentrations of stars in such diagrams represent different stellar evolutionary stages. Moreover, the location of any star in a CMD is
Figure 2: The Hubble Space Telescope (HST) is a space-based observatory operational since 1990. Because of HST’s location above the Earth’s atmosphere, HST can produce high-resolution images of astronomical objects. Ground-based telescopes are limited in their resolution by the Earth’s atmosphere, which causes a variable distortion in the images. In this thesis, we have made use of HST observations of the elliptical galaxy M32. Credit: NASA and STScI.

uniquely related to its mass, age and chemical composition. By constructing CMDs with a sample of stars of a given galaxy, and by applying stellar evolution theory to them, we can disentangle directly the ages and chemical compositions of its different stellar populations, and thus its SFH. Thanks to the advent of the Hubble Space Telescope (HST, ver Fig. 2), in 1990, it was possible to resolve individual stars in many galaxies to unprecedented (and still unequalled) levels of faintness and distance. It is now possible to study the star formation and evolution of nearby galaxies in great detail (see e.g., Brown et al. 2006; Barker et al. 2007; Monelli et al. 2010). These works have shown that the SFHs not only differs significantly from one galaxy to another, but also within the same galaxy, according to the spatial location of the stellar sample under study (see review by Tolstoy et al. 2009).

Unfortunately, most of the elliptical galaxies in the Universe are at rather large distances from us and, in general, it is currently not possible to resolve their individual stars. On the contrary, we can observe the integrated light emitted from these galaxies, which is a combination of the light coming from all its constituent stars formed at different times with different chemical compositions. It is therefore important to disentangle, from its integrated light, the different stellar populations present in a galaxy. However, this is not trivial since several combinations of stellar populations can produce an indistinguishable integrated light. Models of stellar populations have been developed to understand the integrated light of galaxies and have become very sophisticated in disentangling these population degenera-
Figure 3: The nearest major galaxy Andromeda (M31) with two of its companions M32, the subject of this thesis, and M101. M32, projected onto the disk of M31, is the nearest elliptical galaxy for which we can compare predictions from the analysis of its integrated light with its resolved stellar content. Credit and Copyright: Robert Gendler.

cies (e.g. [Worthey 1994] [Bruzual & Charlot 2003] [Thomas et al. 2003] [Vazdekis et al. 2010]). Nonetheless, they still suffer from several uncertainties and there is an urgent need to test these models direct observations of stars in an elliptical galaxy.

In this thesis, we study the stellar populations of the elliptical galaxy Messier 32 (M32). M32 is a small galaxy, companion of our neighbor Andromeda galaxy, M31 (see Fig 3), projected onto its disk, and only 24 arcmin from its nucleus. Due to its low luminosity, compactness and high surface brightness (Bender et al. 1992), M32 is classified as a compact elliptical (cE) galaxy. The advantage of studying this particular elliptical galaxy is that, due to its proximity, we can observe its resolved individual stars as well as its integrated light. Thus it provides a unique window on the stellar composition of elliptical galaxies. M32 is therefore a vital laboratory to test the applicability of the stellar population models to more distant galaxies, by comparing predictions from the analysis of integrated light with the resolved stellar content. To date, there has not been a consistent comparison between those techniques. Moreover, the SFH of M32 is still a matter of debate. In this thesis, we investigate the resolved stellar populations of M32 with the primary goal of reconstructing a complete SFH of this galaxy. We have made use of very high resolution HST images that allowed us to disentangle the different populations present in M32.

In Chapter 2 we introduce our new set of observations of M32 and explain in
detail how we obtained the most detailed CMD of this galaxy yet constructed to date. Our field has an extent of $29'' \times 26''$ and it is located at $2'$ from the galactic center. We find that this CMD has a wealth of features that reveal the different stellar populations present in M32. With the aid of evolutionary models of stars at a fixed age and chemical composition for different ranges of masses, we can qualitatively analyze the CMD. We find from this analysis that M32 is dominated by intermediate-age and old (8–10 Gyr old), metal-rich ([Fe/H] $\sim -0.2$) stars and it contains some old (> 10 Gyr), metal-poor stars ([Fe/H] $\sim -1.6$) as well as possible young populations (0.5 – 2 Gyr old stars).

The analysis presented in Chapter 2 helped to constrain the ages and metallicities of M32 at our field location. However, a quantitative determination of the mix of ages and metallicities, which would provide more detailed information about its SFH, requires a deeper analysis. This is done in Chapter 3. We compare our observed CMD with a synthetic CMD, built from theoretical evolutionary models for a wide range of stellar masses, ages and metallicities. This comparison, together with the aid of statistical tools, can provide a reliable SFH of the galaxy under study. It is important to note that some of the regions in a CMD, i.e. some evolutionary phases, are specifically sensitive to the age and/or metallicity of the stellar system. The main-sequence, for example, is the evolutionary phase in which stars are burning hydrogen in their cores. When stars exhaust their hydrogen in their cores, they start to evolve. This particular point in a CMD is called the main-sequence turn off (MSTO). Since stars live most of their lives in the MS phase, there is a direct conversion of the MSTO’s information into the stellar ages of a galaxy. However, the MSTO fades as a stellar system ages, and thus it is often difficult to observe the oldest, faint stars in galaxies. This was the case in our study. The oldest MSTO of M32 was not reached in our observations and thus we were not be able to obtain a complete SFH from this CMD. Nonetheless, we did derive a detailed young and intermediate-age SFH of M32 at our field’s position. We find that M32 has a substantial population of 2–5 Gyr old stars contributing to $\sim 42\%$ of its mass at our field’s location, which is unexpectedly large population of young stars for an elliptical galaxy at such a large distance from its center.

In Chapter 4 we search in our observations for the presence of a particular kind of variable stars, called RR Lyrae. These stars show regular light variations which occur because they pulsate radially, i.e. periodic variations in the radius of RR Lyrae stars produce changes in their brightnesses. Due to the fact that these stars pulsate regularly, their light curve (light variation as a function of time) are easy to characterize and therefore the presence of RR Lyrae stars in a stellar system can be easily determined. The RR Lyrae stars, moreover, provide important information on their parent stellar populations: their mere presence is indicative of a ancient stellar population, as ages older than $\sim 10$ Gyr are required to produce RR Lyrae variables. This important property becomes even more relevant since RR Lyrae stars are quite bright, and therefore they can be observed at large distances. It

* In Astronomy we call ‘metals’ to any element heavier than H and He. The notation [M/H] indicates the metal abundance of the star with respect to that of the Sun. In this notation, metallicity [M/H] $> 0, = 0, < 0$ are higher, equal and lower than the solar metallicity, respectively.
is possible then to confirm the presence of an ancient population in a galaxy just by detecting RR Lyra stars, without observations of the much fainter MSTOs. We detected RR Lyrae variables in our field of study that belong to M32 and therefore found evidence for an ancient stellar population in this galaxy.