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KINEMATIC PROPERTIES OF STAR CLUSTERS IN M33

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RESUMEN

Los cúmulos de estrellas son herramienta únicas y muy eficaces para el estudio de la formación de las galaxias. En particular, la edad, la metalicidad y la cinemática de estos objetos llevan impresa la huella del proceso de formación de su propia galaxia. M33 es la galaxia espiral tardía más cercana y nos proporciona una importante conexión entre los cúmulos de galaxias espirales más tempranas y las numerosas galaxias enanas tardías. GTC/OSIRIS nos ofrece, por primera vez, velocidades con precisión adecuada para alcanzar la region débil de la función de luminosidad y realizar así un estudio espectroscópico detallado. Presentaremos velocidades de alta precisión de cúmulos estelares débiles observados con el GTC/OSIRIS, así como objetos más brillantes observados con el WHT/WYFFOS. En combinación con nuestro estudio fotométrico, así como del análisis de los parámetros estructurales, proporcionaremos información relevante de la historia de formación estelar y la evolución de la galaxia.

ABSTRACT

Star clusters provide a unique and powerful probe useful for studying the star formation histories of galaxies. In particular, the ages, metallicities and kinematics of star clusters bear the imprint of the galaxy formation process. M33 is the only nearby late-type spiral galaxy and it provides a notable connection between the cluster populations of earlier-type spirals and the numerous, nearby later-type dwarf galaxies. GTC/OSIRIS provides us, for the first time, with adequate velocity precision to reach the faint end of the luminosity function and to perform a detailed spectroscopic study. We will present here high velocity precision of faint star clusters using GTC/OSIRIS as well as brighter star clusters using WHT/WYFFOS. In combination with our photometric study as well as structural parameter analysis, we will provide relevant information of the star formation history and evolution of the galaxy.

Key Words: galaxies: individual (M33) — galaxies: spiral — galaxies: star clusters: general — galaxies: stellar content

1. INTRODUCTION

The process of galaxy formation and evolution is one of the most active research areas in modern astrophysics. It is widely accepted that galaxy evolution occurs in the framework of the Λ-Cold Dark Matter (Λ-CDM) model. In the context of hierarchical clustering theory, large disk galaxies like the Milky Way (MW) and M31 derive from the merger and accretion of many smaller subsystems. It is less clear how accurate this theory is at low-mass galaxies, and if we should expect tidal tails of disrupted galaxies in the vicinity of a dwarf spiral galaxy. With these questions in mind, we have focused on studying the nearest example of a dwarf spiral galaxy, M33. As unique and powerful tracers of a galaxy star formation history, we have made use of the star clusters to uncover the formation and evolution of M33.

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2. KINEMATIC PROPERTIES

We have extensively studied the star cluster system in M33 and its relation with the star formation and evolution of the galaxy, performing the deepest and widest-field photometric catalog for M33 to-date (San Roman et al. 2009, 2010, 2011). As a result, we have identified numerous guaranteed and candidate star clusters in a wide region centered in M33. This result has mitigated the incompleteness present in previous catalogs of star clusters in M33, especially in the outskirts of this galaxy. Photometric analysis suggests a large epoch of M33 formation. Analysis of the radial density distribution suggests that the cluster system of M33 has suffered from significant depletion, possibly due to interactions with M31. The position angles of the clusters show a strong peak pointing toward M31. This evidence supports tidal forces as the reason for cluster elongation.

However, positions and magnitudes of star clusters are not sufficient by themselves to characterize the properties of M33. Information on the galaxy's kinematics and chemical composition is also re-

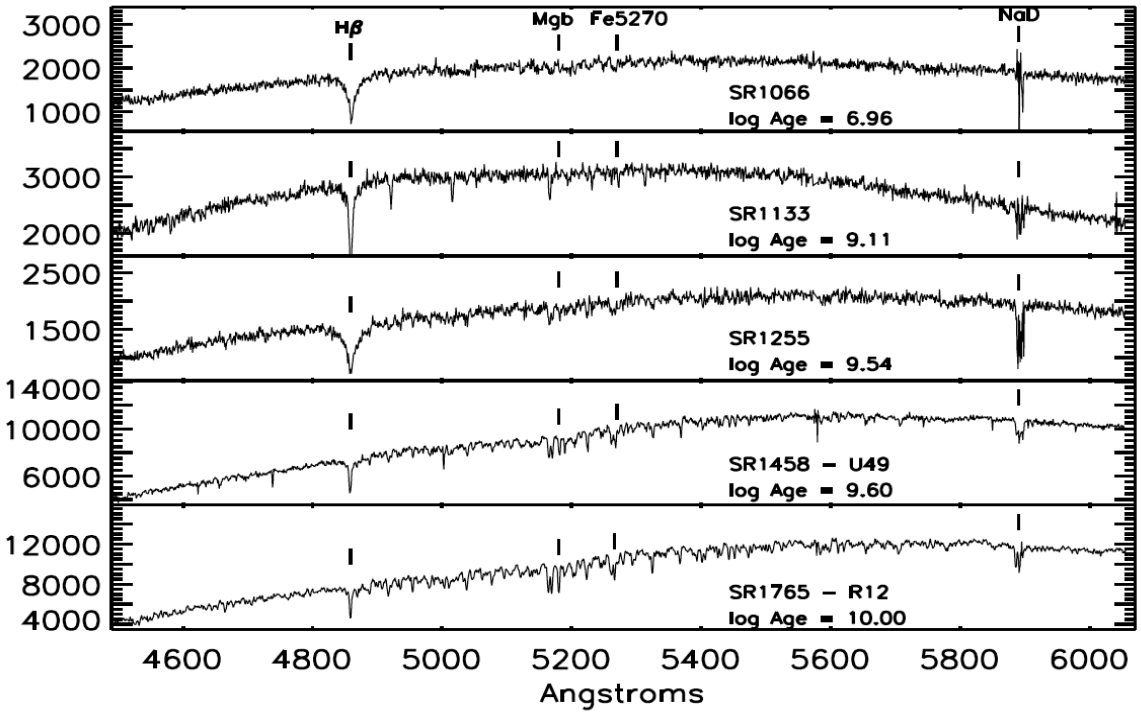

Fig. 1. GTC/OSIRIS spectra for several clusters from our sample. The identification number of each cluster corresponds with San Roman et al. (2010).

quired. We are currently performing a spectroscopic study of star clusters in the aforementioned M33 catalog. We are interested in using spectroscopic data to identify kinematical components in M33 such as disk, halo, and potentially stellar streams. The observing plan has been divided in two parts: a first part using the William Herschel Telescope (WHT) focusing on the brightest clusters, and a second part using the Gran Telescopio de Canarias (GTC) covering the fainter end of the luminosity function.

Examples of cluster spectra obtained with GTC/OSIRIS are shown in Figure 1. Starting with the top panel and moving down, these data illustrate typical line strengths found in each age division. The strength of metal lines increases with cluster age while broad Balmer lines are present in younger clusters.

Two techniques have been used to measure cluster velocities. The first consists of fitting the centers of absorption lines, measuring the wavelenght shift and converting to heliocentric velocity. Preliminary analysis show promising results. Even with this inferior technique, we are obtaining velocities in good agreement with those from previous studies. The second technique uses Fourier cross-correlation between the object spectrum and a template to calculate the relative shift between the two. Different templates are used to optimize the results. The M33 nucleus and an A-type stellar spectrum are used as templates for young clusters while more approprite templates such as early-type stars and the spectrum of R12 are used for older objects.

This project will improve the previous spectroscopic studies in a number of ways. First, the sample size of clusters with measured kinematics and abundances will rival those existing in the MW and M31. This sample size will allow us to perform statistically solid intercomparisons of these galaxies. Second, we will have, for the first time, enough clusters with adequate velocity precision to search for the existence of a thick disk in M33. Both of these factors together promise to reveal essential information about the process of galaxy formation and evolution. In addition, our proposed study will yield chemical compositions and ages for a large number of star clusters, helping to break the age-metallicity degeneracy.

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