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Detecting AGB stars in LG Dwarf Galaxies for Understanding Galaxy Formation and Evolution

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Abstract. Stars are the main ingredients of galaxies, and the sites of the creation of most chemical elements in our universe. The knowledge that we gain from studying nearby resolved stellar populations assists directly our ability to measure the properties of distant galaxies. The overall objective of this project is to study galaxy formation and evolution in a complete environment of the dwarf galaxies in the Local Group, by using the same methods for all of them. For that purpose, we used the INT to conduct a monitoring survey of the majority of Local-Group dwarf galaxies in order to identify the most evolved AGB stars that are long-period variables (LPV). LPV stars reach their maximum brightness amplitudes at optical wavelengths, owing to changes in temperature. They trace stellar populations as young as ∼30 Myr up to as old as ∼10 Gyr, and identifying them is one of the best ways of reconstructing star-formation history using a method that we have developed and applied successfully to other Local-Group galaxies. Since the luminosity variations span 100–1000 days, we planned observations over 10 epochs, spaced ∼3 months apart; 9 epochs of data have so far been obtained.

Keywords. Stars: evolution, stars: AGB, stars: variables: LPV, stars: mass loss, Galaxy: stellar content, (galaxies:) Local Group, galaxies: dwarf.

1. Introduction

Studies of stellar populations provide an excellent opportunity to understand galaxy formation and evolution.Owing to their close proximity to us, the dwarf galaxies in the Local Group (LG) can easily be resolved into individual stars, and studied in detail. Thay are also important because of the variety and wide range of metallicity (0.002 $Z_\odot$ to 0.08 $Z_\odot$; Boyer *et al.* 2015) which they exhibit. Almost all types of known dwarf galaxies – dwarf spheroidals (dSphs), dwarf irregulars (dIrrs), and transition galaxies (dTrans) – are present in the LG. They therefore offer a unique opportunity to study the structure and formation history of the member galaxies.

Since their luminosity depends on birth mass, stars evolving through AGB phase are powerful tracers of stellar populations. In this project we identify LPVs through an optical monitoring survey of the majority of the LG dwarf galaxies, and then use their luminosity distributions to reconstruct their star-formation history by employing a novel method that we have applied already to some of the LG galaxies (Javadi *et al.* 2011; Rezaiekh *et al.* 2014; Golshan *et al.* 2017; Javadi *et al.* 2017).

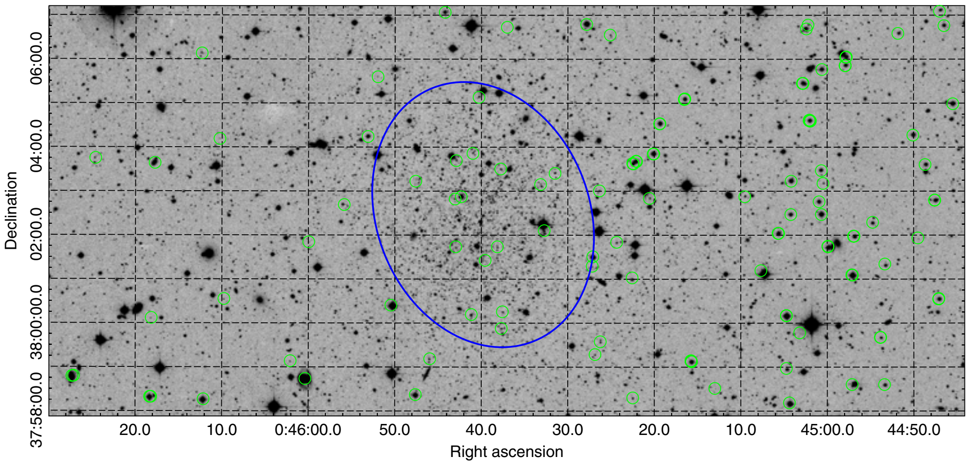

Figure 1. A master WFC image of the And I dwarf galaxy, showing the spatial location of our variable candidates. The half-light radius is marked by the blue ellipse.

The cool atmospheres of AGB stars encourage the formation of dust grains. During their evolution, the AGB stars lose mass at high rates, and return significant amounts of gas and dust to the interstellar medium (e.g., van Loon *et al.* 2005; Javadi *et al.* 2013). By using data from DUSTiNGS (DUST in Nearby Galaxies with Spitzer; Boyer *et al.* 2015), we plan to model the SEDs of the INT variable stars and calculate mass-loss rates in order to study the relation between pulsation amplitude and mass loss.

2. Description of Observations

The majority of dwarf galaxies in the LG have been resolved into stars with the Isaac Newton Telescope (INT)/Wide field Camera (WFC) in a monitoring survey for identifying the long-period variable (LPV) AGB stars. Our sample contains 43 dSph, 6 dIrr and 6 dTrans galaxies, all of which are visible in the Northern hemisphere. We have also observed four distant globular clusters to investigate the possibility that they are actually stripped nucleated dwarf galaxies (Saremi *et al.* 2017).

As LPV stars vary on time-scales from 100 days (for low-mass AGB stars) to 1300 days (for the dustiest massive AGB stars), we require monitoring over several epochs, spaced by a month or more. Nine epochs of data have been obtained already.

Owing to their changing temperatures, LPV stars reach their largest amplitudes in brightness variations at optical wavelengths. Observations were taken through the WFC Sloan i and Harris V filters. Since i-band amplitudes of pulsating AGB stars are > 0.1 mag, we aimed for S/N = 10 for the faintest stars, equivalent to the tip of the RGB.

3. Data Processing

We used the THELI (Transforming HEavenly Light into Image) pipeline, which is an image processing pipeline for optical images taken by multichip (mosaic) CCD cameras (Erben *et al.* 2005). This pipeline works on raw images and removes several instrumental effects, implements photometric calibration and astrometric alignment, and constructs a deep co-added mosaic image complemented by a weight map of the image pixels.

To perform photometry in a crowded stellar field, we used the DAOPHOT/ALLSTAR software developed by Stetson (1987). This package employs a Point Spread Function (PSF) method. The NEWTRIAL programme was used to find variable-star candidates (Stetson 1993). As an example, Fig. 1 shows the master WFC image of the And I dwarf

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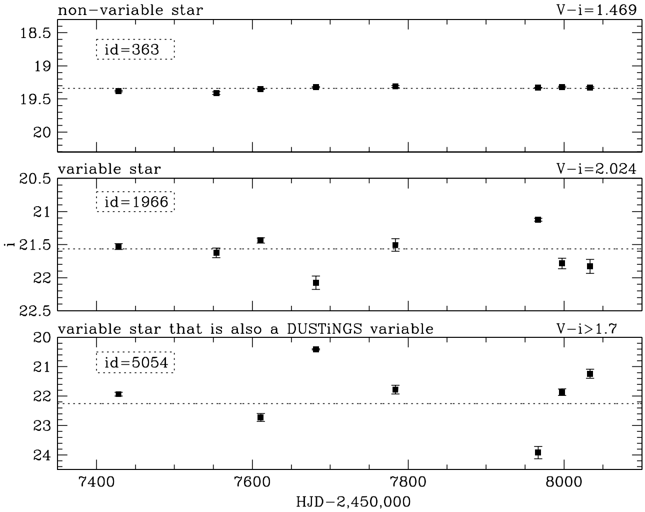

Figure 2. Sample light-curves of two variable stars of the And I dwarf galaxy; star #5054 is also a variable in the DUSTiNGS catalogue *Spitzer* sources (Boyer *et al.* 2015). The top panel shows a non-variable star for comparison.

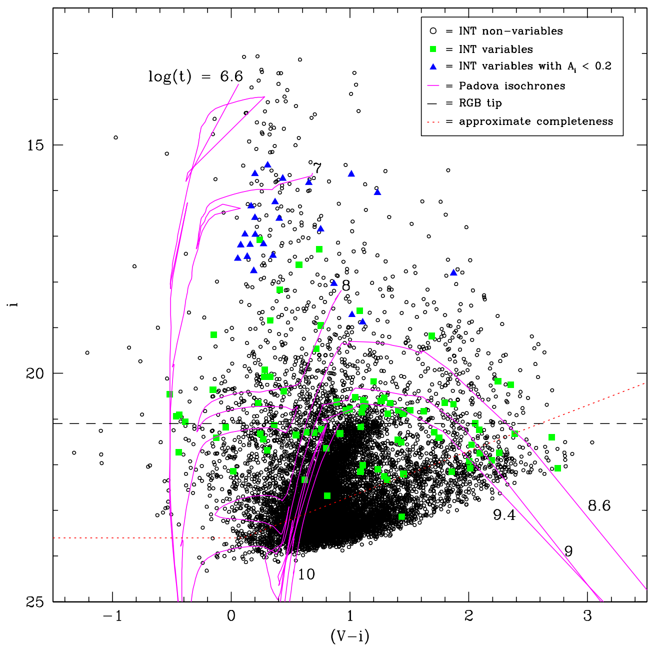

Figure 3. $(V-i)$ colour–magnitude diagram for And I, with variable stars marked as squares/green. The variable stars with amplitudes $A_{\rm i} < 0.2$ mag are indicated by triangles/blue. Overplotted are isochrones from Marigo *et al.* (2008) with a distance modulus of 24.49 mag.

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galaxy and marks the spatial locations of our variable candidates. The half-light radius is indicated by the ellipse. The density of variable stars for the regions inside and outside the ellipse are 0.68 and 0.43 number/arcmin^2, respectively.

4. Some Results

Two LPV stars were identified in the And I dwarf galaxy (see Fig. 2). One of them was also found to be variable at mid-IR wavelengths in the *Spitzer* monitoring survey DUSTiNGS (Boyer *et al.* 2015). Fig. 3 presents the $(V - i)$ colour–magnitude diagram for And I, with LPV stars marked as squares. Triangles indicate variables with $A_\mathrm{i} < 0.2$ mag. Overplotted are isochrones from Marigo *et al.* (2008) with a distance modulus of 24.49 mag and Z = 0.00069 (Kalirai *et al.* 2010). The 10 Gyr isochrone defines the location of tip of the RGB, which in this example is 21.1 mag for the i band. The dashed line marks the 50% completeness limit.

Acknowledgments

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