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Monitoring survey of pulsating giant stars in the Local Group galaxies: survey description, science goals, target selection

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Abstract. The population of nearby dwarf galaxies in the Local Group constitutes a complete galactic environment, perfect suited for studying the connection between stellar populations and galaxy evolution. In this study, we are conducting an optical monitoring survey of the majority of dwarf galaxies in the Local Group, with the Isaac Newton Telescope (INT), to identify long period variable stars (LPVs). These stars are at the end points of their evolution and therefore their luminosity can be directly translated into their birth masses; this enables us to reconstruct the star formation history. By the end of the monitoring survey, we will have performed observations over ten epochs, spaced approximately three months apart, and identified long-period, dust-producing AGB stars; five epochs of data have been obtained already. LPVs are also the main source of dust; in combination with Spitzer Space Telescope images at mid-IR wavelengths we will quantify the mass loss, and provide a detailed map of the mass feedback into the interstellar medium. We will also use the amplitudes in different optical passbands to determine the radius variations of the stars, and relate this to their mass loss.

1. Introduction

Dwarf galaxies are the most abundant type of galaxies in the Universe and so the study of them is of great importance. In this regard, the Local Group provides an excellent opportunity for understanding dwarf galaxies because of their proximity, variety, and wide range of metallicity (0.002 $Z_\odot$ to 0.08 $Z_\odot$) [1]. The Local Group dwarfs offer the chance for a complete inventory within a galactic environment. We set out to reconstruct their formation histories, and to probe their structure and evolution.

Asymptotic Giant Branch (AGB) stars have a strong influence on the global properties of a galaxy. DUSTiNGS (DUST in Nearby Galaxies with Spitzer) finds that AGB stars are efficient dust producers even down to 0.6% $Z_\odot$ [1]. Therefore, they are drivers of galaxy chemical enrichment and evolution via the return of significant amounts of gas and dust to the interstellar medium (ISM) [2]. Several efforts have been made in the last decade to characterize the AGB populations in nearby galaxies [1,3,4]. But only a small fraction of those stars were identified in optical surveys.

Furthermore, these stars are near the end-points of their evolution, and their luminosities directly reflect their birth masses – which is what makes AGB stars powerful probes of a galaxy's star formation history. They trace stellar populations as young as ~ 30 Myr to as old as the oldest globular clusters. The most evolved AGB stars are long period variables (LPVs), and identifying them is one of the best ways to reconstruct the star formation history [5]. LPVs reach the largest amplitudes of their brightness variations at optical wavelengths, due to the changing temperature. We will identify LPVs with an optical monitoring survey of the majority of the Local Group dwarf galaxies, and then will use their luminosity distribution to reconstruct their star formation history employing a method that we have developed and successfully applied in other Local Group galaxies [4,6,7].

2. Survey description

Observations are being made with the Wide Field Camera (WFC) – an optical mosaic camera at the prime focus of the 2.5m Isaac Newton Telescope (INT) in La Palma. The field of view of WFC is about 34’×34’ and it covers each galaxy in just one pointing, but dithering between repeated exposures is required to fill the gaps between the detectors. Still, even among the Andromeda system of satellites, none are near enough to one another to fit within one and the same field of view.

LPVs vary on timescales from ~100 days, for low-mass AGB stars to ~1300 days, for the dustiest massive AGB stars. Although we are not aiming to determine accurate periods, but to identify the LPVs and to determine their amplitude and mean brightness, we require monitoring over ten epochs, spaced approximately three months apart. Five epochs of data have been obtained already, and the majority of the targets have been observed more than twice.

We have selected the I-band for the monitoring survey because the spectral energy distribution (SED) of cool evolved stars peak around 1 μm, so they stand out in the I-band and the I-band is where the contrast between the LPVs and other stars is greatest. Also, the bolometric correction – needed to determine the luminosity – in this band is the smallest and the effects of attenuation by dust are minimal. However, we also observe in the V-band, as often as possible, to monitor the variations in temperature – and thus radius – and to further help constrain the SED modelling.

We have chosen exposure times that yield sufficient signal-to-noise (S/N) to detect small changes in magnitude at different epochs. The I-band amplitudes of pulsating AGB stars are > 0.1 mag. Therefore we aim for S/N = 10 for the faintest stars, equivalent to the RGB-tip.

3. Target selection

The main targets in this survey are the majority of dwarf galaxies in the Local Group that are visible in the Northern hemisphere, except some that have already been studied, such as NGC147 and NGC185 [8]. These targets contain 55 dwarf galaxies of which 22 are satellites of the Andromeda galaxy – others are satellites of the Milky Way or isolated dwarfs. Also, we have included four distant globular clusters (GC) to investigate the possibility that they are stripped nucleated dwarf galaxies.

We prioritise the targets, principally on the basis of their estimated number of AGB stars; some populous galaxies include IC10 (> 10^4 AGB stars) and Sextans A and B (> 10^3 AGB stars). Also, we are attempting to monitor the entire Andromeda system of satellites because these are all accessible to a Northern hemisphere survey. This survey benefits from the homogeneity in distances, completeness, and accuracy. The foreground populations and extinction are modest and similar between all Andromeda satellites. The main aim of this selection is to find out whether the Andromeda system could be a universal template for galaxy evolution, or just one particular case. Individual Milky Way satellites are observed as a comparison to the Andromeda system. Our targets are shown in table 1.

4. Data

4.1. Data reduction

We have used the THELI pipeline, which is an image processing pipeline with the ability to reduce multi-pointing optical images taken by a mosaic CCD camera. 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. In

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this pipeline more emphasis is put on precise astrometry, than precise photometry [9]. Two examples are shown in figure 1.

Table 1. Targets [10].

Dwarf galaxy	R.A (J2000)	Dec (J2000)	$(m\text{-}M)_0$ (mag)	V (mag)	type
Andromeda I	00 45 39.8	+38 02 28	24.36±0.07	12.7±0.1	dSph
Andromeda II	01 16 29.8	+33 25 09	24.07±0.06	11.7±0.2	dSph
Andromeda III	00 35 33.8	+36 29 52	24.37±0.07	14.4±0.3	dSph
Andromeda IX	00 52 53.0	+43 11 45	23.89±0.31	16.3±1.1	dSph
Andromeda V	01 10 17.1	+47 37 41	24.44±0.08	15.3±0.2	dSph
Andromeda VI	23 51 46.3	+24 34 57	24.47±0.07	13.2±0.2	dSph
Andromeda VII	23 26 31.7	+50 40 33	24.41±0.10	11.8±0.3	dSph
Andromeda X	01 06 33.7	+44 48 16	24.23±0.21	16.6±1.0	dSph
Andromeda XI	00 46 20.0	+33 48 05	24.40±0.50	17.5±1.2	dSph
Andromeda XII	00 47 27.0	+34 22 29	24.70±0.30	18.3±1.2	dSph
Andromeda XIII	00 51 51.0	+33 00 16	24.40±0.40	18.1±1.2	dSph
Andromeda XIV	00 51 35.0	+29 41 49	24.33±0.33	15.9±0.5	dSph
Andromeda XIX	00 19 32.1	+35 02 37	24.57±0.36	15.6±0.6	dSph
Andromeda XV	01 14 18.7	+38 07 03	24.00±0.20	14.6±0.3	dSph
Andromeda XVI	00 59 29.8	+32 22 36	23.60±0.20	15.9±0.5	dSph
Andromeda XVII	00 37 07.0	+44 19 20	24.50±0.10	15.8±0.4	dSph
Andromeda XVIII	00 02 14.5	+45 05 20	25.66±0.13	16.0±9.9	dSph
Andromeda XX	00 07 30.7	+35 07 56	24.35±0.15	18.2±0.8	dSph
Andromeda XXI	23 54 47.7	+42 28 15	24.67±0.13	14.8±0.6	dSph
Andromeda XXII	01 27 40.0	+28 05 25	24.82±0.31	18.0±0.8	dSph
NGC 205 (M110)	00 40 22.1	+41 41 07	24.58±0.07	08.1±0.1	dE
NGC 221 (M32)	00 42 41.8	+40 51 55	24.53±0.21	08.1±0.1	dE
Leo IV	11 32 57.0	-00 32 00	20.94±0.09	15.1±0.4	dSph
Leo V	11 31 09.6	+02 13 12	21.25±0.12	16.0±0.4	dSph
Ursa Major I	10 34 52.8	+51 55 12	19.93±0.10	14.4±0.3	dSph
Ursa Major II	08 51 30.0	+63 07 48	17.50±0.30	13.3±0.5	dSph
WILLMAN 1	10 49 21.0	+51 03 00	17.90±0.40	15.2±0.7	dSph
Coma Berenices	12 26 59.0	+23 54 15	18.20±0.20	14.1±0.5	dSph
Canes Venatici I	13 28 03.5	+33 33 21	21.69±0.10	13.1±0.2	dSph
Canes Venatici II	12 57 10.0	+34 19 15	21.02±0.06	16.1±0.5	dSph
Bootes I	14 00 06.0	+14 30 00	19.11±0.08	12.8±0.2	dSph
Bootes II	13 58 00.0	+12 51 00	18.10±0.06	15.4±0.9	dSph
Bootes III	13 57 12.0	+26 48 00	18.35±0.10	12.6±0.5	dSph?
Draco	17 20 12.4	+57 54 55	19.40±0.17	10.6±0.2	dSph
Sextans	10 13 02.9	-01 36 53	19.67±0.10	10.4±0.5	dSph
Ursa minor	15 09 08.5	+67 13 21	19.40±0.10	10.6±0.5	dSph
Hercules	16 31 02.0	+12 47 30	20.60±0.20	14.0±0.3	dSph
Leo I	10 08 28.1	+12 18 23	22.02±0.13	10.0±0.3	dSph
Leo II	11 13 28.8	+22 09 06	21.84±0.13	12.0±0.3	dSph
Segue 1	10 07 04.0	+16 04 55	16.80±0.20	15.3±0.8	dSph
Segue 2	02 19 16.0	+20 10 31	17.70±0.10	15.2±0.3	dSph
Pisces I	01 03 55.0	+21 53 06	24.43±0.07	14.3±0.1	dIrr/dSph
Pisces II	22 58 31.0	+05 57 09	21.31±0.18	16.3±0.5	dSph
Leo T	09 34 53.4	+17 03 05	23.10±0.10	15.1±0.5	dIrr/dSph
IC 10	00 20 17.3	+59 18 14	24.27±0.18	09.5±0.2	dIrr
Sagittarius	19 29 59.6	-17 40 51	25.14±0.18	13.6±0.2	dIrr
Cetus	00 26 11.0	-11 02 40	24.39±0.07	13.2±0.2	dSph
WLM	00 01 58.2	-15 27 39	24.95±0.03	10.6±0.1	dIrr
Aquarius	20 46 51.8	-12 50 53	25.15±0.08	14.5±0.1	dIrr/dSph
Leo P	10 21 45.1	+18 05 17	25.72±0.46	---	dIrr
Leo A	09 59 26.5	+30 44 47	24.51±0.12	12.4±0.2	dIrr
UGC 4879	09 16 02.2	+52 50 24	25.67±0.04	13.2±0.2	dIrr/dSph
Pegasus	23 28 36.3	+14 44 35	24.82±0.07	12.6±0.2	dIrr/dSph
Sextans A	10 11 00.8	-04 41 34	25.60±0.03	11.5±0.1	dIrr
Sextans B	10 00 00.1	+05 19 56	25.60±0.03	11.3±0.2	dIrr
Segue 3	21 21 31.1	+19 07 02	16.10±0.10	14.9±0.5	GC
Sextans C (PAL3)	10 05 31.8	+00 04 21	---	14.3±0.7	GC
NGC 2419	07 38 07.9	+38 52 48	19.75±0.06	---	GC
PAL 4	11 29 15.8	+28 58 23	20.20±0.01	---	GC

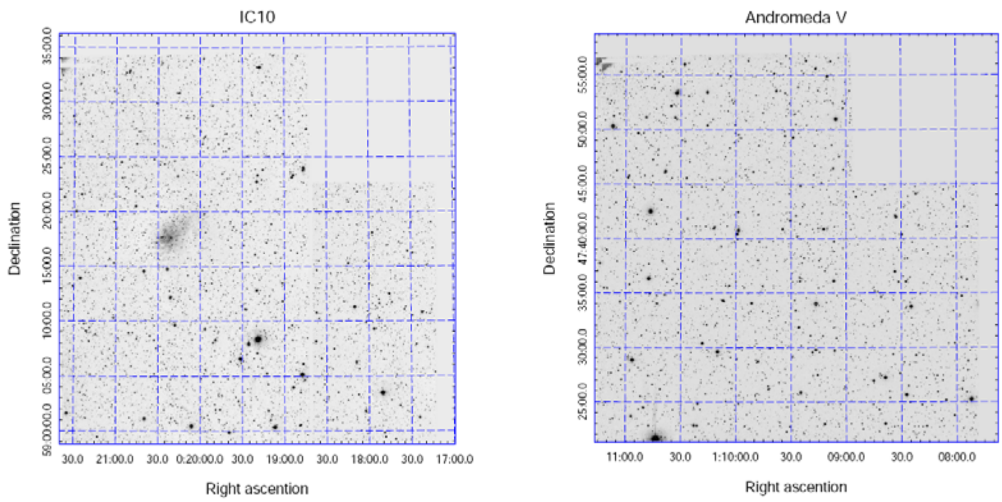

Figure 1. The IC10 dwarf galaxy and Andromeda V dwarf galaxy observed with the INT/WFC and processed with THELI.

4.2. Photometry
Photometry was obtained for all stars within each frame by automated fitting of a model of the Point Spread Function (PSF), using the DAOPHOT/ALLSTAR software suite [11]. The photometric calibration was performed using standard stars observed on some of the observing nights.

5. Science goals
The main objectives of the project are to: identify all LPVs in the dwarf galaxies of the Local Group; obtain accurate time-averaged photometry for all of them; obtain the pulsation amplitude of the LPVs; model their SEDs; study the relation between pulsation amplitude and mass loss (determined from mid-IR observations); reconstruct the star formation history.

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