Estimating the Distance to a Galaxy Using the Tip of the Red-Giant Branch

PROJECT PROPOSAL FOR **PH556 — Astrophysics**

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1. Introduction

The Hertzsprung–Russell (HR) diagram is a fundamental tool in stellar astrophysics that plots stars according to their luminosity and temperature, revealing clear patterns that trace stellar evolution. By comparing a star's position on the diagram to theoretical models, astronomers can infer its age, composition, and evolutionary stage. Of particular interest is the red giant branch (RGB), where evolved, low-mass stars exhibit predictable luminosity behavior. The distinct "tip" of the RGB and the helium flash event serve as reliable standard candles, making the HR diagram invaluable for estimating the distances to star clusters and galaxies with high precision and minimal assumptions.
TRGB, or the Tip of the Red Giant Branch, is a primary astronomical method for measuring distances to galaxies. It identifies the brightest stars on a galaxy's red giant branch and uses their standard luminosity as a "standard candle" to determine distances. Out objectives are to observe 2 galaxies, plot their color-magnitude diagram, identify the TRGB magnitude and determine the distance of the galaxies.

Additional goals for the project are to further study:

- Isochrone fitting to determine the age and metallicity of the galaxies.
- Prepare and study H-R diagrams

2. Methodology

2.1 H-R diagram

2.2 Distance computation using the Tip of the Red Giant Branch (TRGB)

We determine the distance by exploiting the near-constant i-band luminosity of the TRGB in old, metal-poor populations.

1. **Data & Photometry.** Obtain deep images in i and g . Perform PSF photometry, and transform to a standard system using the zero-points magnitude. Remove crowded/foreground objects.
2. **Construct Color-Magnitude Diagram & Luminosity Function.** Build the CMD (i vs. $i-g$) and the RGB luminosity function (LF) of stars within a color window bracketing the RGB. Identify the TRGB with an edge detector by visual inspection and/or statistical methods. The TRGB is the sharp break at the bright end. The TRGB color at the break, $(i-g)_{\mathrm{TRGB}}$, is measured from stars in a narrow magnitude slice just below the tip.
3. **Distance Modulus & Distance.**

$$\mu = m_{i,\mathrm{TRGB}} - M_i^{\mathrm{TRGB}}, \qquad d\,[\mathrm{pc}] = 10^{(\mu+5)/5}.$$

Notes/Assumptions:

- We will use PanSTARRS catelog to identify the fields within the target objects for observation.
- We will use object which can be comfortabily observed from GIT location and can be resolved within GIT's resolving power and sensitivity.

3. Observational Strategy and Technical Justification

Target Name	RA (J2000)	Dec (J2000)	Apparent Magnitude (V)	Size
Draco Dwarf	17:20:12.4	+57:54:55	10.9	$35.5' \times 24.5'$
IC 1613	01:04:47.8	+02:07:04	9.9	$16.2' \times 14.5'$

We have selected two galaxies for our TRGB (Tip of the Red Giant Branch) measurements. These targets were chosen based on the telescope's ability to resolve individual stars, the presence of a measurable TRGB population, and their visibility from the GIT observatory site. Figures 1 and 3 show Pan-STARRS images of the galaxies, while Figures 2 and 4 present their corresponding visibility plots.

Tiled observations are required because the galaxies are large enough that they cannot fit entirely within a single GIT field of view (approximately $10'$ by $7'$). The apparent magnitudes listed in the target table refer to surface brightness values and not to the magnitude range of the individual stars.

Observations are planned in at least two filters: SDSS g' and i'. For each galaxy, we aim to obtain three non-overlapping tiles outside the central core region in both filters, resulting in a total of 12 exposures. Preliminary estimates indicate an exposure time of approximately 360 seconds per frame. The exact exposure time will be adjusted during the observing session in coordination with the on-site observer, based on the quality of the initial images.

Table 1: List of planned observations. Each row corresponds to an individual exposure.

Exposure Name	Target Name	Tile No.	Filter	Exposure Time (s)
Exp1	Draco Dwarf	1	SDSS g'	360
Exp2	Draco Dwarf	2	SDSS g'	360
Exp3	Draco Dwarf	3	SDSS g'	360
Exp4	Draco Dwarf	1	SDSS i'	360
Exp5	Draco Dwarf	2	SDSS i'	360
Exp6	Draco Dwarf	3	SDSS i'	360
Exp7	IC 1613	1	SDSS g'	360
Exp8	IC 1613	2	SDSS g'	360
Exp9	IC 1613	3	SDSS g'	360
Exp10	IC 1613	1	SDSS i'	360
Exp11	IC 1613	2	SDSS i'	360
Exp12	IC 1613	3	SDSS i'	360

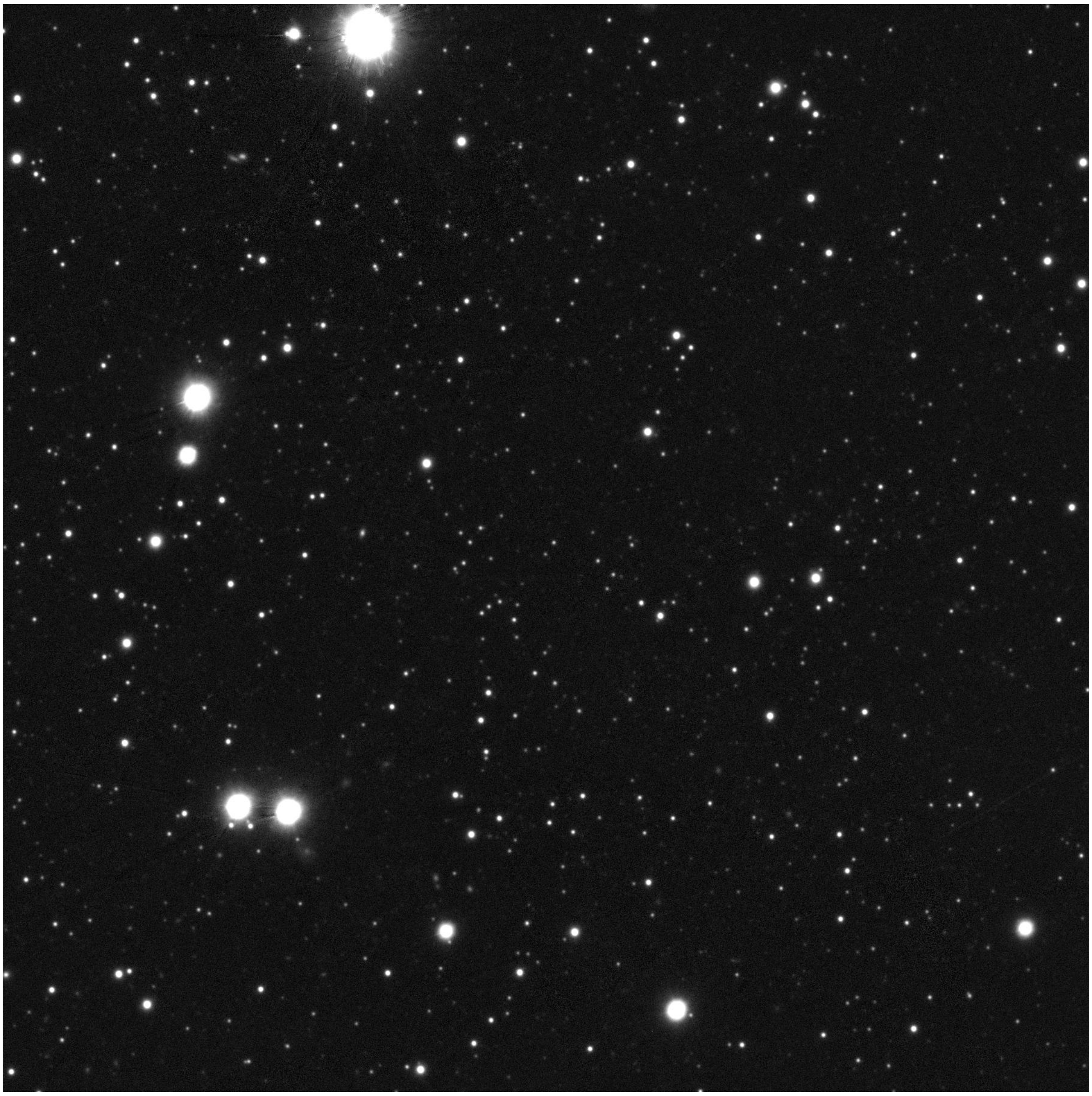

Figure 1: Pan-STARRS image of the Draco Dwarf Galaxy in the SDSS i' filter.

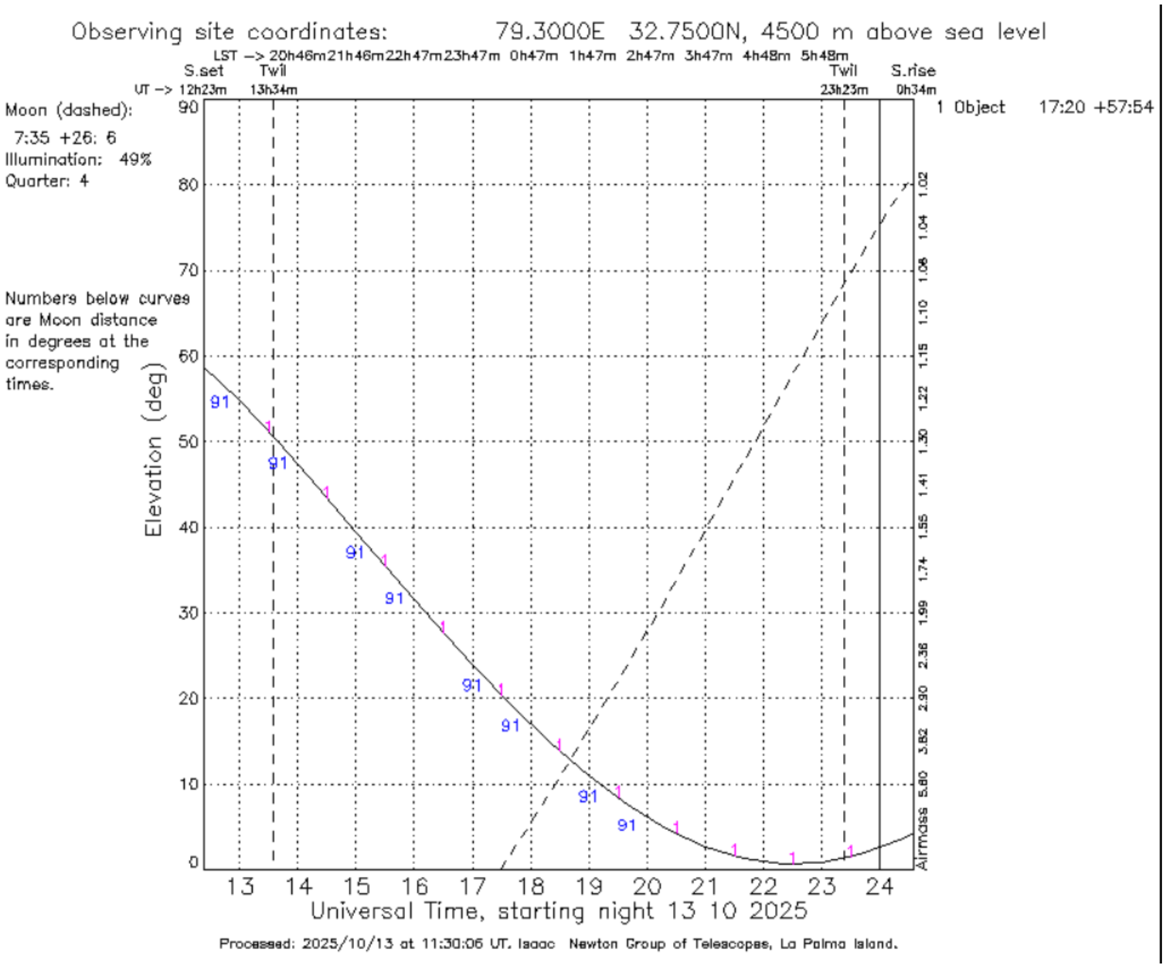

Figure 2: Visibility plot of the Draco Dwarf Galaxy.

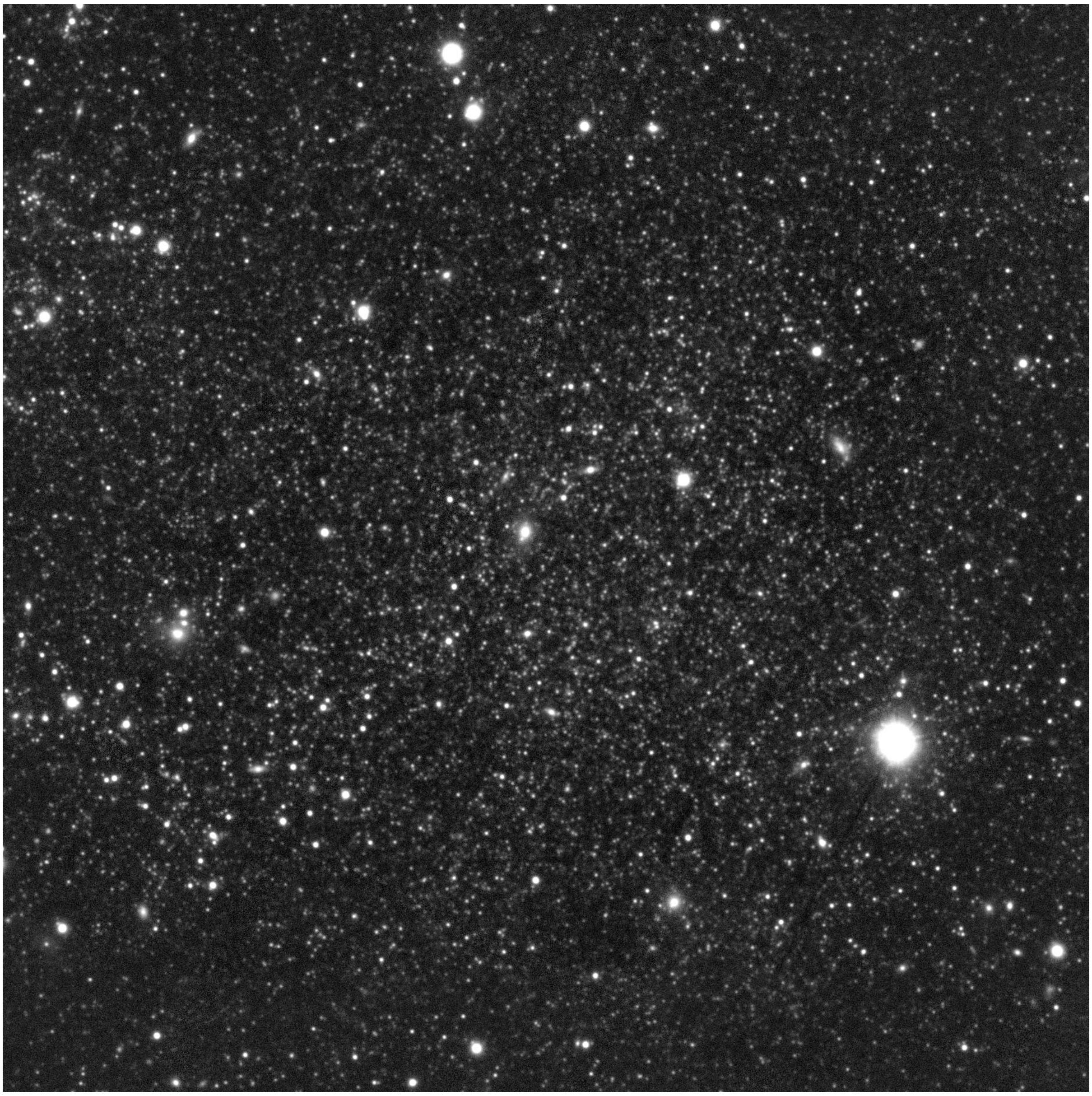

Figure 3: Pan-STARRS image of the IC 1613 Galaxy in the SDSS i' filter.

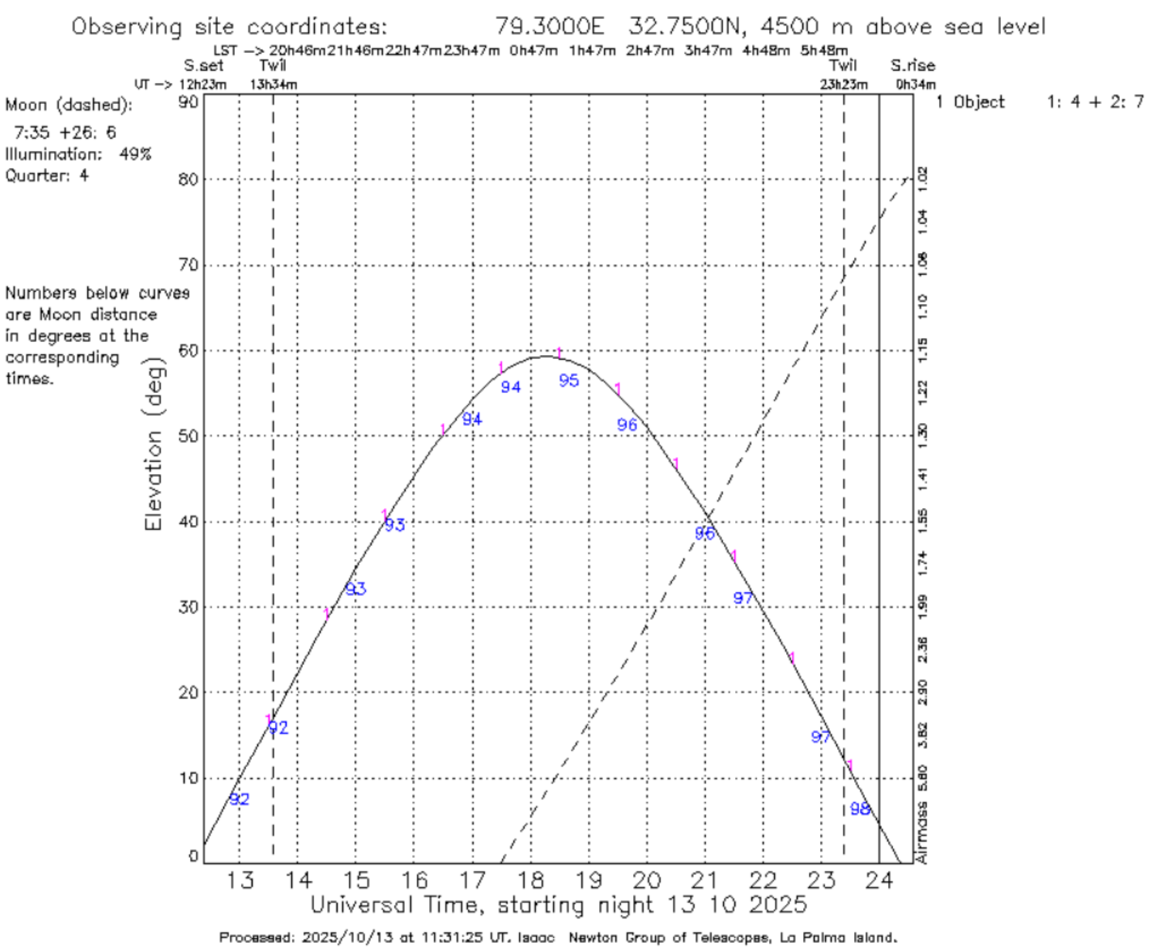

Figure 4: Visibility plot of the IC 1613 Galaxy.

References

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