UNIVERSITY OF HAWAII • INSTITUTE FOR ASTRONOMY
RESEARCH PROPOSAL – OBSERVING TIME REQUEST

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Program Title

A. Measuring the Milky Way

B.

C.

Abstract

Using various data reduction techniques, we will measure the size, shape, and age of the Milky Way galaxy's spiral arms.

TELESCOPE TIME REQUESTED

COLLABORATORS

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1 SCIENTIFIC JUSTIFICATION

1.1 Immediate Objective

To determine the size and shape of particular spiral arms, variable star distributions must be spatially mapped. In observed regions, the density of variable stars will give insight into the age (*and star formation epoch?*) of our galaxy. The distance to each star will be calculated using the distance modulus,

$$d = 10^{(m-M+5)/5}$$

where d is the distance in $parsecs$, m is the apparent magnitude, and M is the absolute magnitude.

Analyzing the gri data, in its entirety, is a cumbersome task. Subtraction of data collected by the gri project will cause transient objects to emerge. Light curves will be used in identification and categorization of desired variable stars. Variable stars comprising less than 1% of all observable stars Allen et al. (2016), significantly reduces the amount of data to analyze. Required computing time also decreases substantially.

1.2 Scientific Rationale

Of the different types of variable stars, we will focus on RR Lyrae, Type 1 Cephedis, and Type 2 Cephedis. These pulsating variables have well established absolute magnitudes B. et al. (2012). From this the luminosity is known, permitting the distance to each star to be calculated using Period-Luminosity (PL) relationship.

1.2.1 RR Lyrae

RR Lyrae have short periods, $1.5 - 24$ hours, and are generally classified as stars with spectral type A. On average, absolute magnitudes of RR Lyrae stars fall between 0.6-0.7 Tsujimoto et al. (1998). Using the distance modulus assuming no ISM extinction yields the upper limit on RR Lyrae distance measurements of 7.9 kpc with $m = 15$ (photometric accuracy of 4%). Figure 2a shows the PL relationship for variable stars classified as RR Lyrae Ngeow et al. (1998) (*how do we calibrate different band passes?*). Since the typical age of RR Lyrae is 10 Gyr, it can be used as the lower limit of the age of spiral arms.

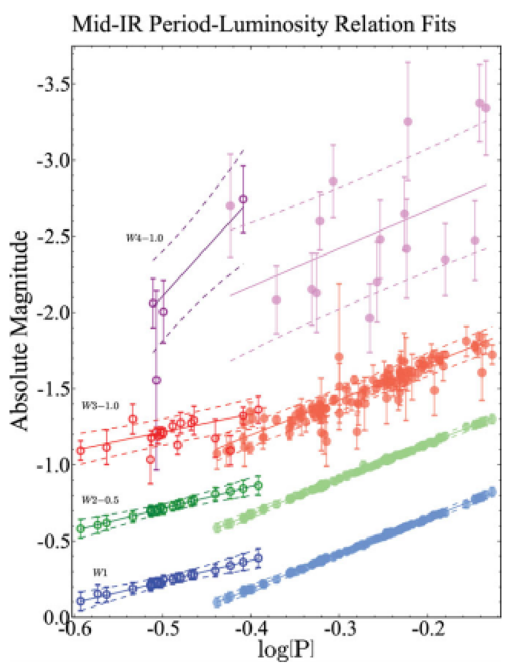

Figure 1: *Period-Luminosity relationship of RR Lyrae variable stars.*

1.2.2 Cephedis

Other variable stars that will be identified are Cephedis Type 1 and Cephedis Type 2. A typical pulsation period of Cephedis star is $1 - 50$ days Ryden et al. (2010). These sugergiants span the F, G, and K spectral classes, with average absolute magnitudes between $M = -0.5$ and $M = -6$ Ryden et al. (2010). The PL relation of Cephedis Type 1 and Cephedis Type 2 is shown in Figure **??**. From the PL relation we can extract distances Ngeow et al.

(2013). Using $m = 15$, 30 s exposures will allow for photometric accuracy of 4%. A Hertzsprung-Russell diagram of pulsating variable stars is shown by Figure 2b Turner et al. (2012). *Relatively young, star formation epoch?*

(a) Period-Luminosity relationship.

(b) HR-Diagram of pulsating variable stars.

Figure 2: Cephedis Type 1 and Cephedis Type 2 stars.

Near the galactic center, ISM is dense, and the number density of stars is high, which makes optical investigations quite difficult. Figure 3 shows the distribution of gasses in the Milky Way (Nakanishi and Sofue 2015). In order to determine the spiral arm structure of the Milky Way galaxy, we will avoid the galactic center. To take into account for the ISM extinction, we will use the ratio of total to selective extinction $R = \frac{1}{(\tau_1/\tau_2)-1} = \frac{1}{(\lambda_{eff,1}/\lambda_{eff,2})^{-1}-1}$ assuming the optical depth $\tau \propto \lambda^{-1}$ according to the Mie scattering.

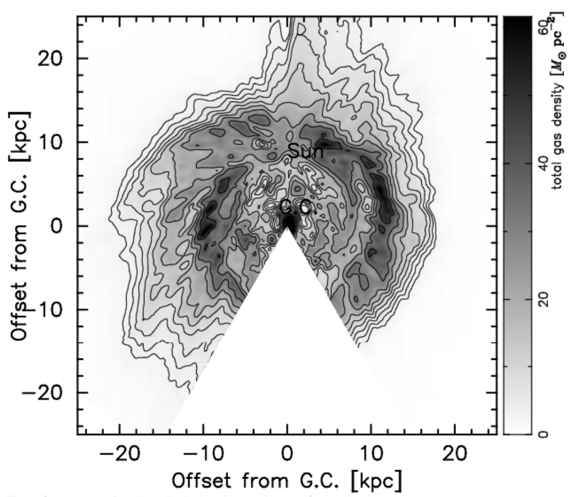

Figure 3: *Column density distribution of the sum of HI and H_2 gases.*

References

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Tsujimoto et al., 1998. The Absolute Magnitude of RR Lyrae Stars Derived from the [ITAL]Hipparcos[/ITAL] Catalogue. *The Astrophysical Journal, 492*(1). Retrieved February 15, 2016.

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TECHNICAL JUSTIFICATION

We request 10.3 hours using Pathfinder to obtain g, r, and i imaging for variable stars in the galactic plane.

The typical pulsation period of RR Lyrae is in a range of 1.5 hours to 24 hours. To sample a 1.5 hours period, we need to image a RR Lyrae at least twice in one period according to the sampling theorem (*sampling rate vs error?*). With the exposure time of 30 seconds and readout time of 8 seconds, the sky coverage rate is 948 deg^2/hour. To cover the galactic plane and avoid the galactic center, we choose a region with galactic latitude of $\pm 2°$ and galactic longitude of 70° to 290° (*from the gri project, we should be able to choose smaller patches with variable stars on the galactic plane; more points in one period*). The coverage rate and angular size of the field yield the one observation time of 1.14 hours. We want 3 band passes with 3 pulsation periods each to take into account the ISM extinction (*number of periods vs error?*), so we request the total observational time of 10.3 hours. Since Cepheid stars have longer pulsation periods, we should be able to sample data points well.

The SNRs of g, r, and i bands with $m_g = m_r = m_i = 15$ are 26.11, 26.31, and 20.67, respectively. We use relative intensity to measure pulsation periods, so this photometric accuracy of 4% should be enough (*photometric accuracy vs error?*).

Things to Discuss Further

- Determine deviation of variable stars from model
- Variations arise from gravitational effects from unknown sources
- Figure out dark matter distribution
- include - Plot of known var star distributions in spiral arms
- comment on knowing m from tying into pan-starrs
- difference in 3 variable stars light curves - show examples