Survey of Variables with the ILMT

Baldeep Grewal[1], Bhavya Ailawadhi[2,4], Talat Akhunov[5,6], Ermanno Borra[7], Monalisa Dubey[2,8], Naveen Dukiya[2,8], Jiuyang Fu[1], Paul Hickson[1], Brajesh Kumar[2], Kuntal Misra[2], Vibhore Negi[2,4], Kumar Pranshu[2,3], Ethen Sun[1], Jean Surdej[9]

[1]University of British Columbia, Vancouver, Canada
[2]Aryabhatta Research Institute of Observational sciencES, Nainital, India
[3]University of Calcutta, Kolkata, India
[4]Deen Dayal Upadhyay Gorakhpur University, Gorakhpur, India
[5]National University of Uzbekistan, Tashkent, Uzbekistan
[6]Ulugh Beg Astronomical Institute, Tashkent, Uzbekistan
[7]Laval University, Quebec, Canada
[8]Mahatma Jyotiba Phule Rohilkhand University, Bareilly, India
[9]Liège University, Belgium

Abstract

The Hubble Tension is a discrepancy between the measurements of the Hubble constant, which describes the expansion rate of the Universe, derived from cosmological observations. This is an important tension because the value from the current model of cosmology Lambda Cold Dark Matter has a 5-sigma discrepancy compared to the latest type 1A supernovae measurements. One way to address the Hubble tension is by using Cepheid variable stars, which pulsate with a period that is related to their intrinsic luminosity. Cepheids are used as "standard candles" to measure distances to nearby galaxies, and their period-luminosity relation can be used to calibrate other distance indicators. Nestled in the mountains of Northern India and employing a 4-metre rotating liquid-mercury primary mirror, the international liquid mirror telescope (ILMT) is well-suited to study the photometric variability of Cepheids over a multi-year time span.

Introduction

The current model of cosmology, ΛCDM, does an excellent job of explaining many observed phenomena in the Universe. Although it is our best model for describing a wide range of astrophysical and cosmological data, it is by far from perfect. One of the biggest unresolved tensions in this model is the Hubble Tension. The Hubble Tension is a discrepancy between the measurements of the Hubble constant, which describes the expansion rate of the Universe, derived from cosmological observations. This is an important tension because the value from the current model of cosmology Lambda Cold Dark Matter has a 5-sigma discrepancy compared to the latest type 1A supernovae measurements [1]. The purpose of this poster is to talk about Cepheid Variables. As they are on the forefront of astronomy today.

The International Liquid-Mirror Telescope (ILMT) is a 4-m zenith-pointing optical telescope located at Devasthal Peak in India (29.36˚ N latitude) [2]. Its 16-MPixel CCD gives a 0.373 x 0.373-degree field of view. In order to compensate for image motion due to the Earth's rotation, the CCD is operated in time-delay integration mode in which it is continuously scanned at the sidereal rate. The telescope saw first light in April 2022 and began a period of commissioning in October.
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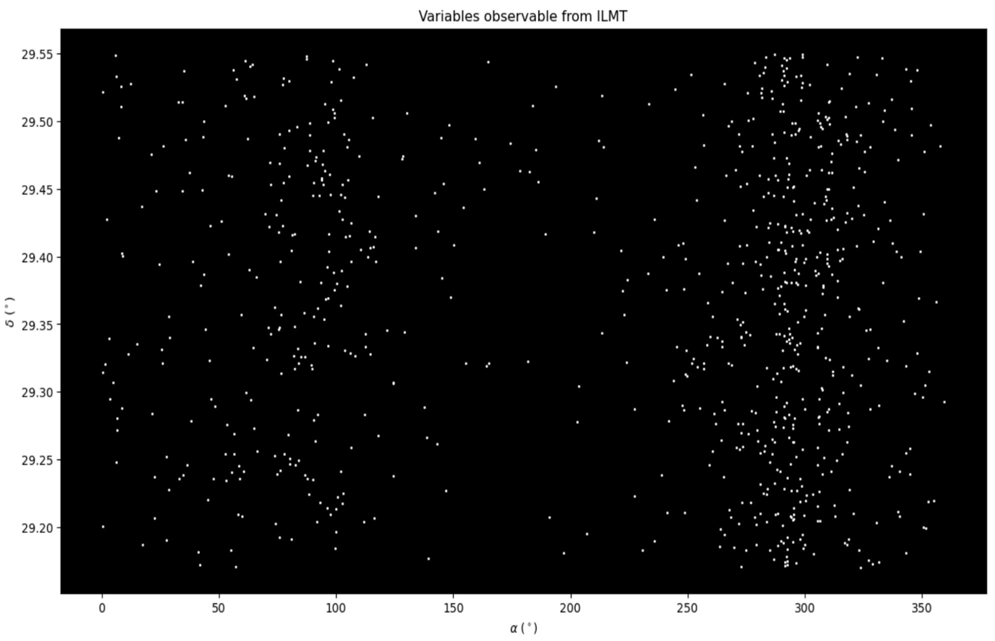

Figure 1: All the variables observable in the ILMT field of view. There are a total of 814 variables.

Observations and Analysis

Since the ILMT is a zenith pointing telescope, it is extremely useful for the study of variable stars. Each night the ILMT is pointed to the same patch of sky, observing the same targets. This would result in better signal to noise (SNR) ratios for such objects of interest. Cepheid variables pulsate within quite a large range, between 2-70 days [3]. Compared to conventional telescopes, it would be extremely difficult to request a telescope to point at a Cepheid for over 70 nights just to observe one pulsation period.

On clear nights, the ILMT will be able to take continuous data and observe the flux for such variable stars. Photometry will be performed on the images and the flux can be known for each Cepheid which shows up in the field of view. Another important fact about the ILMT is that I will be able to co-add images to improve on the SNR, which would improve the flux measurement. Over a five year span the ILMT would be able to collect enough data where the period luminosity relationship of Cepheids can be known to a high degree.

On the priority list for many astronomers' is trying to calibrate the precise period-luminosity (PL) relationship for such Cepheids. The relationship is known as the following

$$M_v = a_v(\log(P) - 1) + b_v$$

and it is about constraining the free parameters a_v and b_v [4].

Results

As of now, the processing of the data is still ongoing. What can be said about the ILMT ability to detect Cepheids is the expected SNR. For example, since the ILMT will only be able to resolve stars in our own galaxy, lets ask ourselves if it is possible to observe the fluctuations of a cepheid at the edge of the milky way (~ 15 kpc). Using the range of periods, a range of absolute magnitudes can be known and along with the distance modulus, the apparent magnitude can be known [5]. The signal to noise is summarized in figure 2.

Another important aspect of detecting such variables is the limiting magnitude of the ILMT. The ILMT utilizes the SDSS i', g', and r' bands with a limit of approximately 24 for each. We can now calculate the limiting absolute magnitudes and this results in magnitudes of 6.91, 6.42, 5.52 in the SDSS g', i', and r' bands, respectively.

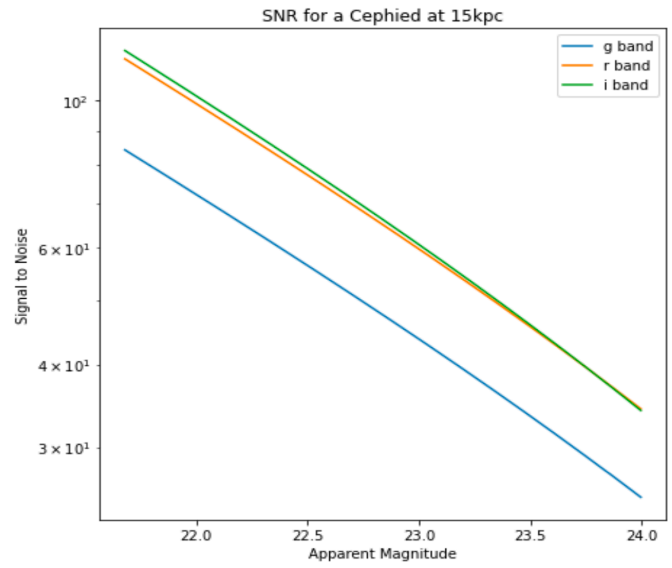

Figure 2: Shows The typical SNR For a cephied at the edge of the Milky way.

Discussion

Figure 2 gives the reader confidence in the abilities of the ILMT to detect such Cepheids. The reader also notes that on the top of the priority list for many astronomers to trying to resolve the Hubble Tension. The current model of cosmology has had many great triumphs, but this unresolved tension is of great importance. Calibrating the period-luminosity relationship and decreasing the uncertainty in the values for a_v and b_v is on the the major efforts in astronomy. With lower uncertainty in these values astronomers will be able to realize if there are errors in measurements of Cepheids or if Lambda Cold Dark Matter is incomplete.

The ILMT has the great advantage over conventional telescopes as it is zenith pointing. No detected time is required to observe such cepheids. In regular operation, the ILMT is expected to obtain on the order of 1500 clear dark hours of observations per year. Over a five-to-ten-year span, a precise PL relationship can be determined with very low uncertainties.

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