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LIMBO: A time-series Lucky Imaging survey of variability in Galactic globular clusters

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Abstract. We present a large observing project monitoring globular clusters (GC) over long time baselines, which will lead to a complete census of variable stars in those clusters down to several magnitudes below the horizontal branch (HB). The use of Lucky Imaging (LI) will allow us to obtain high-precision photometry for even faint objects, and long-term monitoring will also mean that observations are sensitive to detecting other slow transient phenomena, such as gravitational microlensing, the primary aim of this project.

Keywords. techniques: photometric, stars: variables, globular clusters: general

1. Introduction

The emergence of LI marks a significant advance in our ability to obtain high-resolution images from the ground, without the need for adaptive optics to correct for atmospheric turbulence. Carrying out complete variability censuses across entire clusters with conventional CCD observations is limited by our ability to obtain high-precision photometry in the crowded cores, where source blending often prevents the detection of low-amplitude variability, or of low-amplitude variability of stars much fainter than the HB.

In short, LI consists in taking a large number of very short (sub-second) exposures in order to "freeze" atmospheric turbulence. The best images are sorted according to a pre-determined criterion are then stacked to form a high signal-to-noise image with, in the best observing conditions, a resolution close to the diffraction limit. This then allows us to construct a high-resolution reference image, which we use to perform PSF difference imaging on all images and obtain very high-precision photometry of all sources.

In Fig. 1, we compare an image of the cluster NGC 6981 taken with a conventional CCD on a 2-m telescope (Bramich *et al.* 2011), with the same field observed with a LI camera on the Danish 1.54-m telescope (Skottfelt *et al.* 2013), in a similar seeing conditions. Using LI enabled us to detect two variables, V57 and V58, which were too close to a bright star on conventional CCD images to obtain high-precision photometry.

2. Observational set-up and cluster sample

Our sample consists of 30 clusters, observed using the 1.54-m Danish Telescope in La Silla, Chile. This programme is combined with microlensing monitoring of the Galactic Bulge by the MiNDSTEp consortium, making use of parts of the night when the Galactic Bulge is not observable. Our cluster sample was selected based on three main criteria:

- Each target should have a HB magnitude brighter than 18 in the V filter.
- No recent CCD time-series study of the target cluster has been conducted.
- The cluster has a dense core, i.e. a large density parameter ρ_0, which increases the probability of lensing by compact objects in the cluster core.

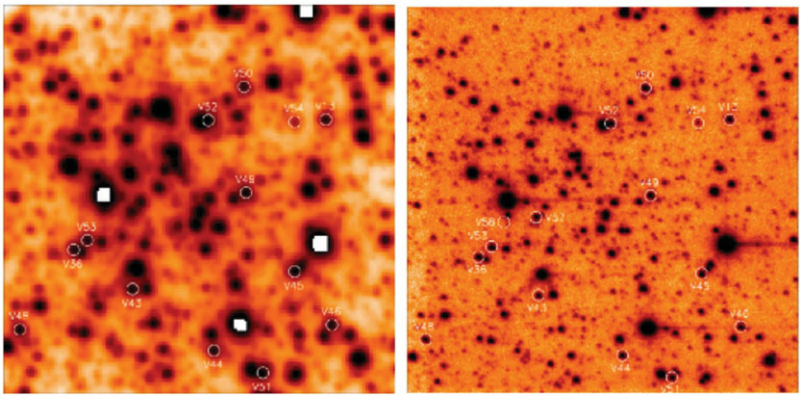

Figure 1. The core of globular cluster NGC 6981 observed with a conventional CCD mounted on the Hanle 2-meter telescope at the Indian Astrophysical Observatory, with a FWHM of $\sim 0.9''$ (Bramich *et al.* 2011, left), and a LI camera, mounted on the 1.54-m Danish Telescope in La Silla, with a FWHM of $\sim 0.4''$ (Skottfelt *et al.* 2013). LI photometry enabled us to detect variables V57 and V58, which were suffering from blending from a bright star on CCD images.

This set-up aims to maximise the potential of our survey, which will provide us with a complete census of variable stars in globular clusters, down to several magnitudes below the HB. This builds on our team's current work with conventional CCD camera (e.g. Figuera Jaimes *et al.* 2013, Kains *et al.* 2012, 2013, Arellano Ferro *et al.* 2013).

Furthermore, long-baseline high-precision photometry will allow us to detect changes and modulation to the variable signals due to effects like the Blazhko effect, as well as potential detection of rare objects, such as RR Lyrae in eclipsing binary systems. Finally, we also aim to detect transient phenomena such as gravitational microlensing by cluster members, which could enable us to detect objects such as stellar-mass or intermediate-mass black holes. The latter are predicted to reside in the cores of globular clusters, although there has not yet been any conclusive detection of these objects.

3. Conclusions

This survey will lead to a significant update of our knowledge of variable stars in our target clusters. Thanks to the large amount of observing time devoted to the project, this is also an excellent opportunity for systematic searches for gravitational microlensing in GC, including by stellar- and intermediate-mass black holes. In the coming years, the SONG (Stellar Observations Network Group) telescopes, which will also be equipped with LI cameras, may enable us to increase our sample of GC significantly, including clusters in the Northern Hemisphere.

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