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A Search for RR Lyrae Variables and Anomalous Cepheids in the Fornax Dwarf Galaxy

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Abstract.
We have started a search for variable stars in Fornax, covering a area of $40' \times 40'$. We have ~ 30 data points in both V and I. To detect variable stars, we use the variability index defined by Welch & Stetson (1993). We present here our first results.

1. Motivation

Anomalous Cepheids (ACs) are found in dwarf spheroidal galaxies and in a few globular clusters: they are thus associated with Population II objects. But pulsation theory predicts that they have masses of $\sim 1.5\,M_{\odot}$. There are two possible explanations for this: *i)* they are the result of a binary star merger, with both progenitors at or close to the turn-off ($M \sim 0.7 - 0.8\,M_{\odot}$), in which case they could be associated with blue stragglers, or *ii)* they are intermediate age objects (age of a few Gyr).

Following the discovery of $\sim$ 600 candidate ACs in the LMC (Alcock et al. 1999), it has been proposed that these ACs are merged binaries ($M \simeq 2.8\,M_{\odot}$), drawn from the intermediate-age population (age $\sim$ 3 Gyr, turn-off mass $\sim 1.5\,M_{\odot}$) of the LMC. Fornax having had continuous star formation until very recently (e.g. Stetson et al. 1998), this galaxy should contain many ACs. This could be a way to test the formation scenario of these objects (binary star coalescence). If this is true, we predict that Fornax will contain significantly more luminous ACs (because they are more massive) than other dSph.

There is also the puzzling relation between the specific frequency of ACs and the absolute magnitude of a galaxy (Mateo, Fisher & Krzeminski 1995). According to this relation, Fornax should have 10-15 ACs. If our interpretation is correct, Fornax should stand out in this relation and have 3-4 times more ACs.

Several studies have detected variable stars in Fornax (Light et al. 1986; Demers & Irwin 1987) or have suspected/demonstrated variability (e.g. Buonanno et al. 1985, Stetson et al. 1998). However, these studies suffer from several limitations. They cover a very small field (compared to the angular extent of Fornax) or have poor phase coverage or the photometry does not reach deep enough to allow detection of RR Lyrae variables and/or Anomalous Cepheids.

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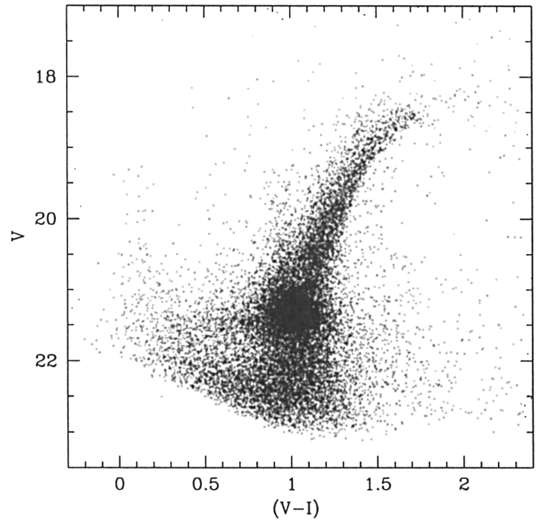

Figure 1. The colour-magnitude diagram for a $20' \times 20'$ field (based on a preliminary photometric calibration). We have stacked 6 images in each colour (10 min exposure each) to build a master frame, allowing us to go deeper in magnitude. One easily recognizes the broad red giant branch, the prominent red clump, the red horizontal branch and the main sequence.

2. Data

We have obtained data on the Mt Stromlo 1.3m MACHO telescope using the camera built for the MACHO microlensing experiment. We have 20 images in the MACHO passbands B and R covering $\sim$ 5 weeks. The field covered is $\sim 42' \times 42'$. We also obtained images on the 1m telescope (Siding Spring Observatory) during two runs of a few nights each, overlapping almost completely the field observed on the 1.3m. We have between 15 and 20 frames in V and I, depending on the position in the galaxy. Our time sampling is excellent for both short-period objects (RR Lyrae and ACs) and for longer-period variables (SR variables).

The data have been reduced in a standard way using IRAF. The photometry is performed with DoPHOT (Schechter, Mateo & Saha 1993). A preliminary colour-magnitude diagram is shown on Fig. 1. It covers only a quarter of the total area surveyed.

3. Search for Variables

We use the method proposed by Welch & Stetson (1993) to detect variable stars. It relies on the fact that the changes in brightness in two passbands are correlated. Defining $\delta V_k = (V_k - \overline{V})/(\sigma_{V,k})$ and $\delta I_k = (I_k - \overline{I})/(\sigma_{I,k})$, where V_k and I_k are individual measurements in two passbands (not necessarily V and I),

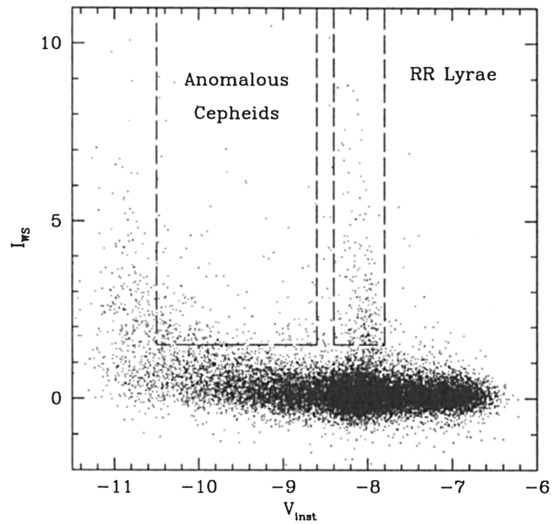

Figure 2. The variability index I_{WS} as a function of instrumental magnitude. Non-variable stars cluster around $I_{WS} = 0$, a large positive value is an indication of variability. The boxes indicate the magnitude ranges where RR Lyrae and Anomalous Cepheids are expected.

the variability index I_{WS} is

$$I_{WS} = \sqrt{\frac{1}{n(n-1)}} \sum_{k=1}^{n} (\delta V_k)(\delta I_k)$$

An advantage of this method is that the magnitudes can be in the instrumental system. Figure 2 illustrates this. In a plot of the variability index I_{WS} versus magnitude, non-variable stars cluster around 0. Figure 2 shows that, at the magnitude of the horizontal branch ($V_{inst} \sim -8$) there is large number of candidate variables. There are also quite a few candidate Anomalous Cepheids. The candidate variables with $V_{inst} < -10$ are on the red giant branch.

A period search has been made for only a few randomly selected candidate RR Lyrae and Anomalous Cepheids. Some light curves are shown on Fig. 3. These will be improved by calibrating the photometry and by using the whole data set. This is important given that the periods of the variables shown here are constrained by data obtained over a few consecutive nights only, the whole data set covers several months.

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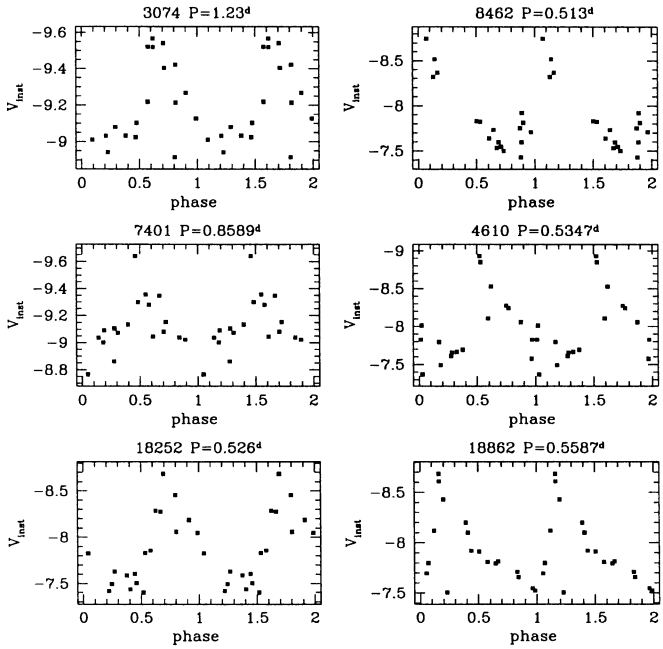

Figure 3. Light curves of a few selected variables. They are based on only half of the data. The periods are indicated. From their mean magnitudes and periods, these variables can be classified as ACs (3074, 7401) and RR Lyrae (4610, 8462, 18252, 18862).

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Discussion

Gallart: Where are the Anomalous Cepheids located in the CMD? What population do they belong to?

Bersier: Anomalous Cepheids are between 0.5 and 2 mag brighter than the RR Lyraes. They seem to be of intermediate age (a few Gyr) although they could be old objects ($M \sim 0.8 M_{\odot}$, age $\sim$ 12 Gyr) "rejuvenated" by merging with a star of similar mass.

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