

# New Variable Stars in CMa Globular Cluster Candidates

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## Abstract

We present the preliminary results of an image-subtraction analysis of the Galactic globular cluster M79 (NGC 1904), as well as a new investigation of the variable star population in NGC 1851. Both M79 and NGC 1851 have been previously associated with the Canis Major overdensity, which has been suggested to have an extragalactic origin. We found 6 new RR Lyrae in M79, and also recovered 3 previously known RR Lyrae. The average period of the 5 ab-type RR Lyrae is 0.68 d, corresponding to an Oosterhoff II classification – which is unusual, though not unprecedented, for systems of extragalactic origin. We also report on the discovery of at least 4 previously unknown variables in NGC 1851.

## 1. Introduction

The leading scenario for the formation of the Galaxy envisages the accretion of smaller galaxies, disrupted and accreted over time (Searle & Zinn 1978). This originally largely qualitative scenario has received considerable support from simulations carried out within the framework of the  $\Lambda$ CDM cosmological paradigm, which clearly predict that large galaxies such as the Milky Way are formed in a hierarchical fashion (e.g., Diemand et al. 2007). In this scenario, dense, massive globular clusters could survive the accretion process (e.g., Forbes & Bridges 2010). The existence of the Sagittarius dwarf spheroidal galaxy and stream (Ibata et al. 1994), which is clear evidence of ongoing accretion, gives support to this scenario.

**TABLE 1**  
**Positions and periods for RR Lyrae in M79**

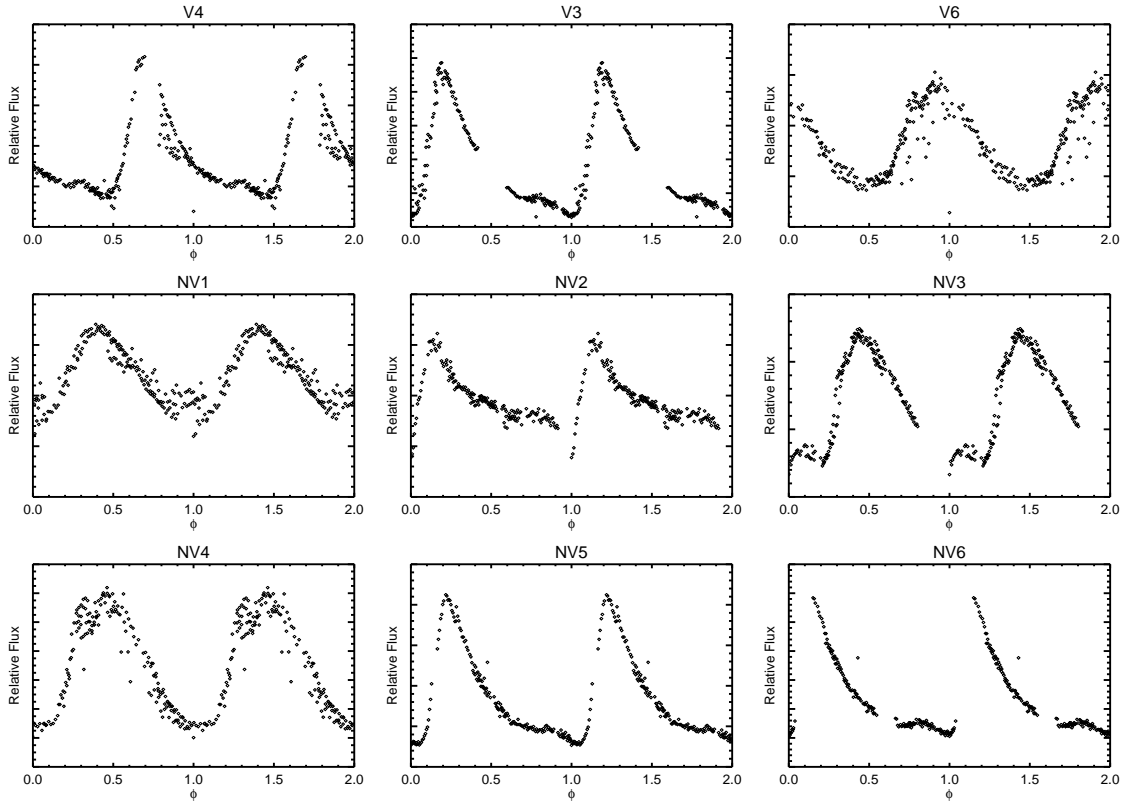
Variable ID	RA (J2000)	DEC (J2000)	Period (days)	Type
V4 <sup>a</sup>	05 24 17.76	-24 32 16.3	0.6341531	RRab
V3 <sup>a</sup>	05 24 13.52	-24 32 29.2	0.7350907	RRab
V6 <sup>a</sup>	05 24 06.01	-24 29 32.9	0.3387880	RRc
NV1	05 24 12.56	-24 31 52.8	0.3616000	RRc
NV2	05 24 12.10	-24 31 34.2	0.7279145	RRab
NV3	05 24 11.92	-24 31 34.5	0.8199846	RRab??
NV4	05 24 11.37	-24 31 28.4	0.3234196	RRc
NV5	05 24 10.57	-24 31 11.5	0.6906617	RRab
NV6	05 24 10.22	-24 31 03.7	0.6683208	RRab

<sup>a</sup> ID of previously known variables, according to Clement's catalogue

In this sense, another possible case of a dwarf galaxy being accreted by the Milky Way is provided by the Canis Major overdensity (Martin et al. 2004), which may be related to the Monoceros stream. In this case, it has been matter of considerable debate whether the CMa system represents a true extragalactic system or rather an extension of the warp of the outer Galactic disk. (see Sbordone et al, 2005; Momany et al., 2004; Bellazzini et al., 2004; Carraro et al., 2008 for more discussion on this topic)

One way to shed light on the possibility of an old star cluster being associated with an accreted dwarf galaxy may be provided by the so-called Oosterhoff (1939) dichotomy. This is a very interesting property of the RR Lyrae population in Galactic globular clusters, which divide into two classes according to their ab-type RR Lyrae pulsation properties: Oosterhoff type I (OoI), with  $\langle P_{ab} \rangle \sim 0.55$  d, and Oosterhoff type II (OoII), with  $\langle P_{ab} \rangle \sim 0.65$  d. The period range between 0.58 d and 0.62 d is poorly populated, and has been called the ‘‘Oosterhoff gap’’ (Catelan 2004). Field stars in the Milky Way halo also seem to display the Oosterhoff dichotomy (e.g., Miceli et al. 2008; Szczygiel et al. 2009). Intriguingly, the Oosterhoff dichotomy is observed only in the Milky Way: nearby extragalactic systems show instead a single-peaked  $\langle P_{ab} \rangle$  distribution, with the peak located inside the Oosterhoff gap. Thus, extragalactic systems are predominantly *Oosterhoff-intermediate*, and therefore an Oosterhoff-intermediate classification for a globular cluster may provide a hint of a possible extragalactic origin (see Catelan 2006, 2009 for recent reviews and additional discussion).

In this study we analyze time-series photometric data for the globular cluster (M79), which has been associated with the Canis Major overdensity (e.g., Forbes et al. 2004). In particular, we show the preliminary results of a new search for variable stars, and the periods obtained for the RR Lyrae stars found. We also present new time-series

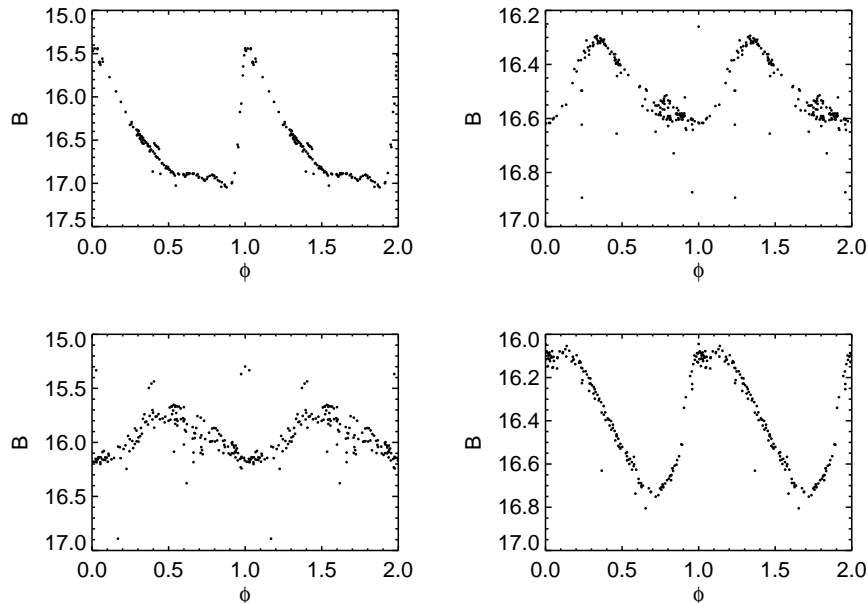


**Figure 1.**— Light curves of the M79 RR Lyrae stars found in this study. The light curves are given in relative fluxes in the  $B$  band.

photometry for NGC 1851, also associated with Canis Major, including the discovery of 10 previously unknown variables. The Oosterhoff types of the globular clusters found so far in CMa are then discussed within the framework of the potential extragalactic origin of this system.

## 2. Variable stars in M79

M79 ( $\alpha_{J2000}=05^h 24^m 10^s$ ,  $\delta_{J2000}= -24^\circ 31' 27''$ ) is a Galactic globular cluster with an extended blue horizontal branch morphology. It is one of the seven clusters which have been associated with the CMa overdensity (e.g., Forbes et al. 2004). The variable stars in this cluster have been poorly studied, with the most recent time-series analysis dating back to Rosino (1952). According to the Clement et al. (2001) online catalog, there are 8 known or suspected variable stars in M79, most of them in the outskirts of the cluster, and only 3 have well-determined periods. In this work, we used 174 images in the  $B$  filter, where the amplitude of RR Lyrae is enhanced, taken with the 1.54m Danish telescope in 2001. An image subtraction analysis was performed using ISIS v2.2 (Alard 2000), which is expected to unveil previously unknown variables, especially in



**Figure 2.**— Light curves of the new RR Lyraes in NGC1851.

the cluster core (see, e.g., Contreras et al. 2010 for a recent example of the technique’s impressive detection power, even in very crowded fields).

Table 1 displays the properties for the RR Lyrae stars found in this study. In Figure 1 we show the light curves (in relative fluxes) of the variables found in this study. V3, V4, and V6 are previously known variables, listed as in Clement’s catalogue. NV1 displays an odd light curve, that could correspond to a double period – but further analysis is needed to put this result in a firmer footing.

The average period for the ab-type RR Lyrae is  $\langle P_{ab} \rangle \simeq 0.68$  d, which corresponds to an OoII type. A future study will include the calibrated amplitudes obtained with DAOPHOT II/ALLFRAME (Stetson 1994).

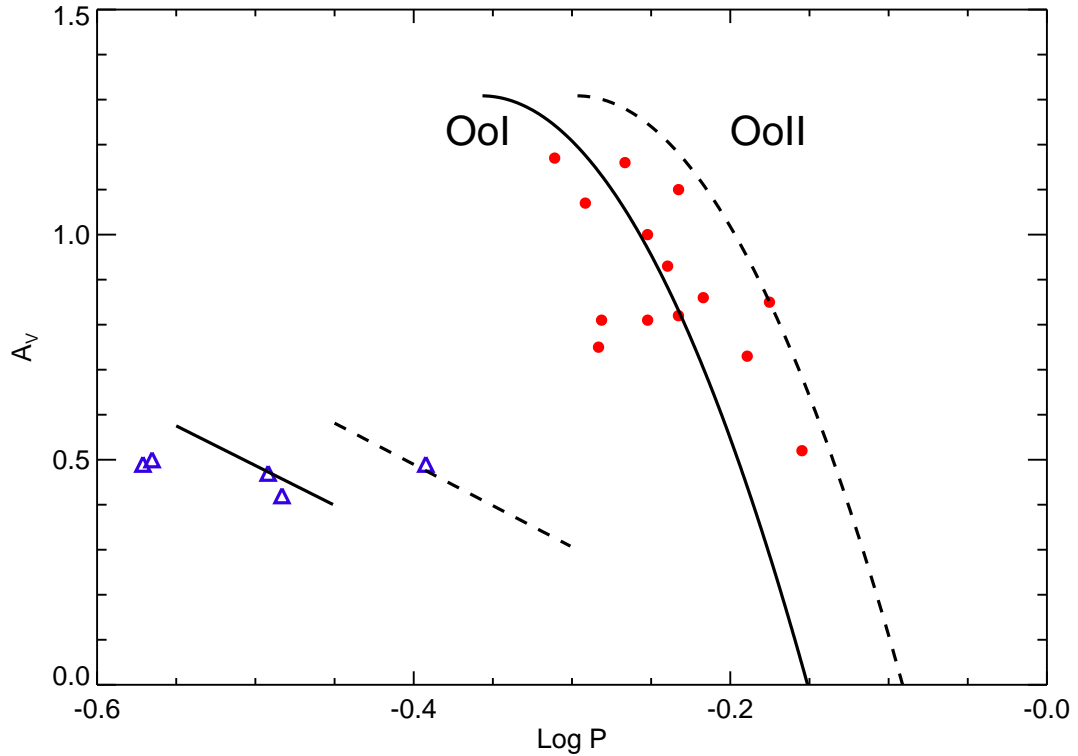
### 3. New photometry for NGC 1851

We present the result of a new photometric study of NGC 1851, another suggested member of the Canis Major system, based on more than 1000 images from archives, performed with DAOPHOT II/ALLFRAME (Stetson 1994). We discovered 4 variables with reasonably well-measured periods, as shown in Figure 2 (See Table 2 for details). We also recovered 29 of the previously known variables. For the RR Lyrae stars with reliable periods, we obtain in this study  $\langle P_{ab} \rangle \simeq 0.569$  d, consistent with an OoI type, as found also in previous studies of the cluster (e.g., Walker 1998).

The period-amplitude diagram for NGC 1851 (Fig. 3) gives additional evidence on

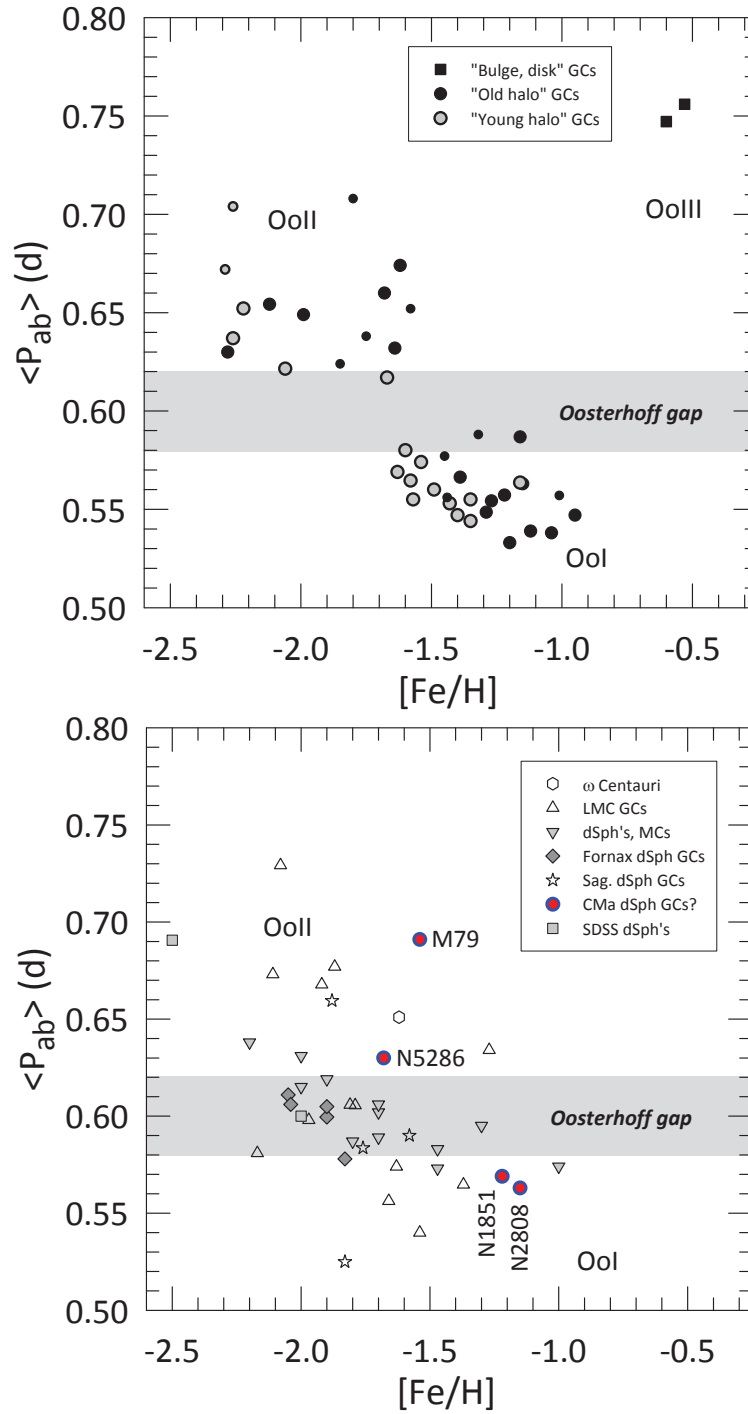
TABLE 2  
Details of four new RR Lyrae in NGC1851

Variable ID	RA(J2000)	DEC(J2000)	Period (days)	Type	$A_B$
NV1	05 14 02.43	-40 02 56.4	0.520589	RRab	1.60
NV2	05 14 01.14	-40 01 53.9	0.668266	RRab?	0.40
NV3	05 14 05.08	-40 02 40.2	0.279355	RRc	0.55
NV4	05 14 01.14	-40 01 53.9	0.268519	RRc	0.70



**Figure 3.**— Period-amplitude diagram for the NGC 1851 RR Lyrae found in this study. Filled red dots correspond to ab-type RR Lyrae, and empty blue triangles indicate RRC stars. Reference OoI and OoII lines are taken from Zorotovic et al. (2010), based on Cacciari et al. (2005).

the cluster’s Oosterhoff classification. We overplot reference lines corresponding to the different Oosterhoff types (from Zorotovic et al. 2010). Again, we find that the RRab variables (red dots) fall predominantly on the locus defined by OoI clusters. RRC-type variables (blue triangles) follow a similar trend.



**Figure 4.**— Mean ab-type RR Lyrae periods vs. metallicity diagram for Galactic (*upper panel*) and nearby extragalactic (*lower diagram*) systems. In the lower panel, a few globular clusters that have previously been suggested to be associated with the CMa overdensity are highlighted.

#### 4. On the Origin of the CMA Overdensity

Through the analysis of the RR Lyrae population of these two clusters and the Oosterhoff argument, we can add some constraints that may be of relevance to the CMA debate. In particular, the inferred Oosterhoff types (OoII for M79, and OoI for NGC 1851) suggest that these systems follow the Galactic trend. This is clearly shown in Figure 4, adapted from Catelan (2009), where the average periods of ab-type RR Lyrae in Galactic (upper panel) and nearby extragalactic (lower panel) systems are shown. Our new measurements for M79 and NGC 1851 are also shown in the lower panel of this figure, along with similar results for other CMA-related globular clusters, namely NGC 2808 (see Kunder et al. 2011, these proceedings) and NGC 5286 (Zorotovic et al. 2010). As can be seen, these four globular clusters conform to the Oosterhoff dichotomy. Even though this is not unprecedented for nearby extragalactic systems, it is certainly more common for systems of extragalactic origin to present Oosterhoff-intermediate types. This may represent additional evidence against an extragalactic origin for the CMA overdensity and its associated system of globular clusters.

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