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BN UMa AND CF Del : TWO NEW GALACTIC FIELD DOUBLE MODE RR LYRAE STARS

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BN UMa and CF Del have been found to be the 30^{th} and 31^{st} known galactic field double mode RR Lyrae variables. Analysis of the light curve of BN UMa reveals a fundamental frequency of 1.865924 ± 0.000019 and a first overtone of 2.5021805 ± 0.0000076. The deconvoluted light curves of BN UMa are shown in Figures 1 and 2. Successive prewhitening of the data (`Period04`) using both the fundamental and first overtone periods and their first three harmonics reveals several prominent combination bands, Table 1.

A similar analysis for CF Del indicates a fundamental frequency of 2.090090 ± 0.000020 and the first overtone at 2.808845 ± 0.000016. The deconvoluted light curves of CF Del are shown in Figures 3 and 4, and the combination bands are listed in Table 2.

The ratio of the first overtone period P1 to the primary period P0, P1/P0, for BN UMa is 0.74572 ± 0.00002 and for CF Del is 0.74411 ± 0.00003. These are typical values for RRd stars, Figure 5. It is interesting to note that the apparent outlier, GSC 3059-0636, is the only RRd in the galactic field known to have a much stronger fundamental mode pulsation than its overtone: $A1/A0 = 0.52$ (Oaster et al., 2006). In contrast to GSC 3059-0636, BN UMa and CF Del have typical amplitude ratios in which the first overtone has a larger amplitude than the fundamental: A1/A0 for BN UMa is 2.47, while that for CF Del is 1.24. Table 3 contains the characteristics of all 31 known galactic field RRd stars.

For BN UMa a total of 438 observations were obtained on 44 nights between JD 2454144 and 2454546, while for CF Del 239 observations were obtained on 34 nights between JD 2454349 and 2454576. Observations were taken approximately 20 minutes apart and were conducted with a robotic 0.45m f/4.5 Newtonian telescope located outside Seguin, Texas, USA using an unfiltered SBIG ST-10XME CCD camera. Stellar data were extracted from dark corrected and flat fielded images using Sextractor; magnitudes were derived differentially. For BN UMa GSC 3010-2100 was the comparison star and GSC 3010-2126 and GSC 3012-0837 were check stars. For CF Del USNO A2 0975-18805217 was the comparison star and USNO A2 0975-18802001, 0975-18808454, 0975-18802602 were check stars. The photometric accuracy varied by night, but was typically between 0.010 and 0.015 mag for both stars. Differential magnitudes of CF Del-comp and BN UMa-comp are available in the electronic form of this document (through the IBVS-website as `5825-t4.txt` and `5825-t5.txt`) and will also be submitted to the AAVSO database at `www.aavso.org`.

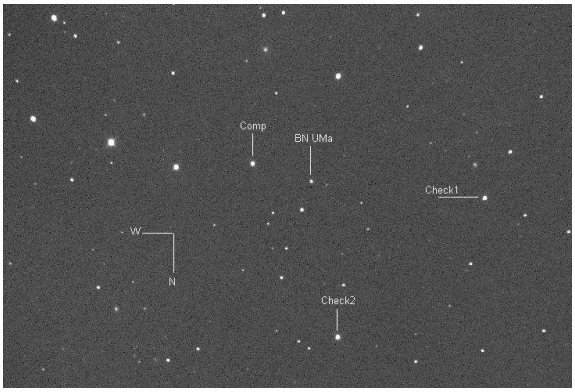

Figure 1. Finding chart for BN UMa identifying the variable, comparison and check stars. The field is 25.′0×16.′9. The R magnitude of the comparison star is 14.m1 according to the USNO A2 catalogue.

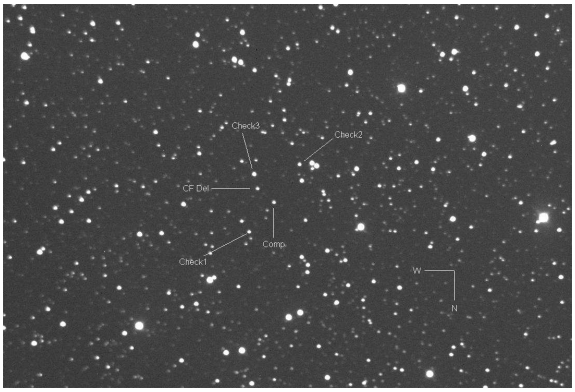

Figure 2. Finding chart for CF Del identifying the variable, comparison and check stars. The field is 25.′0×16.′9. The GSC 2.3 V magnitude of the comparison star GSC 3010.2100 is 12.m55.

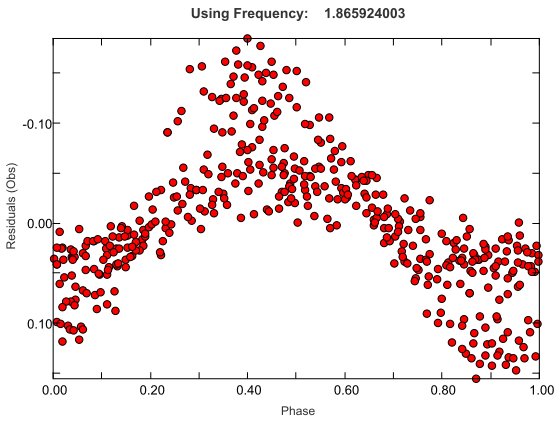

Figure 3. Fundamental mode of BN UMa after removing the first overtone and its first three harmonics.

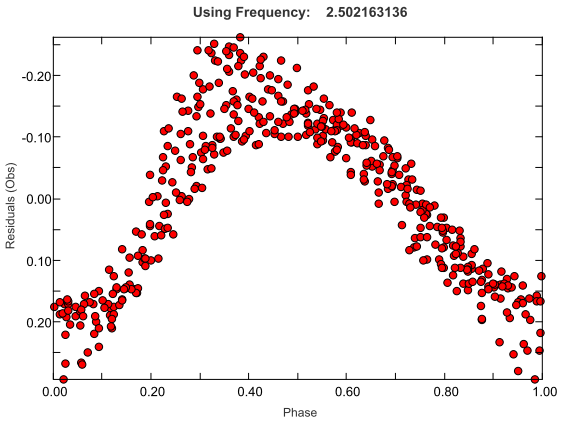

Figure 4. First overtone mode of BN UMa after removing the fundamental mode and its first three harmonics.

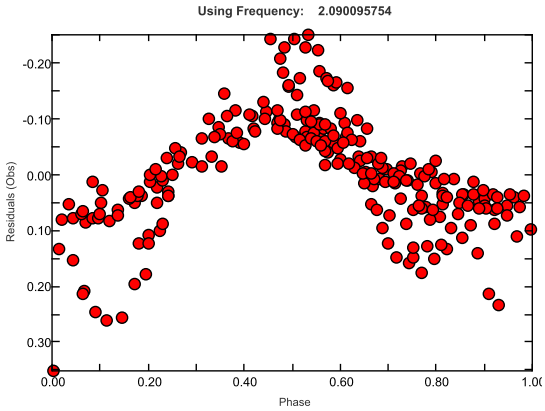

Figure 5. Fundamental mode of CF Del after removing the first overtone and its first four harmonics.

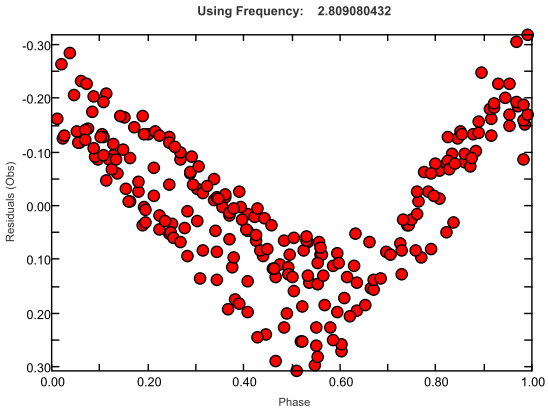

Figure 6. First overtone mode of CF Del after removing the fundamental mode and its first four harmonics.

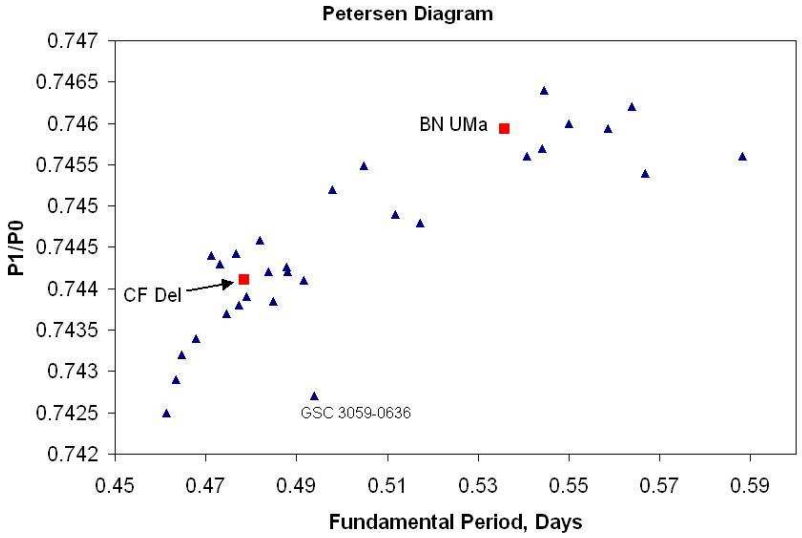

Figure 7. Petersen diagram of the 31 known RRd galactic field variables.

Table 3. All known galactic field double mode RR Lyrae stars excluding the galactic bulge

Star	Period F(d)	Period 1O(d)	Period ratio	Amplitude ratio 1O/F	ref
GSC 7411-1269	0.461255	0.342477	0.7425	0.98	Wils, 2006
V2493 Oph	0.463349	0.344234	0.7429	1.58	Wils, 2006
EM Dra	0.464727	0.345387	0.7432	1.18	Wils, 2006
GSC 8403-0647	0.467814	0.347778	0.7434	1.05	Wils, 2006
V372 Ser	0.471254	0.350791	0.7444	1.4	Wils, 2006
GSC 6368-0742	0.47302	0.35206	0.7443	1.5	Bernhard, 2006
GSC 3047-0176	0.474608	0.352983	0.7437	1.29	Wils, 2006
SW Ret	0.476624	0.354811	0.7444	2.73	Szczygiel, 2007
GSC 0526-0586	0.47722	0.35498	0.7438	1.3	Bernhard, 2006
CF Del	**0.478448**	**0.356018**	**0.7441**	**1.24**	**current work**
GSC 8758-1831	0.47907	0.35636	0.7439	1.5	Bernhard, 2006
ASAS 141539+0010.1	0.481932	0.358842	0.7446	1.57	Szczygiel, 2007
V458 Her	0.483723	0.359971	0.7442	2.17	Wils, 2006
ASAS122801-2328.4	0.48482	0.360634	0.7439	1.57	Pilecki, 2007
BS Com	0.487817	0.363066	0.7443	1.42	Dékány, 2007
Z Gru	0.487995	0.363187	0.7442	1.3	Wils, 2006
GSC 9092-1397	0.491521	0.365738	0.7441	1.17	Wils, 2006
GSC 3059-0636	0.4940	0.3669	0.7427	0.52	Oaster, 2005
GSC 7509-0299	0.49785	0.37102	0.7452	1.6	Bernhard, 2006
ASAS 211848-3430.4	0.50486	0.376366	0.7455	2.12	Szczygiel, 2007
EN Dra	0.511849	0.381272	0.7449	2.03	Wils, 2006
GSC 8936-2145	0.517197	0.385208	0.7448	1.37	Wils, 2006
BN Uma	**0.535786**	**0.39966**	**0.7459**	**2.48**	**current work**
GSC 4421-1234	0.540804	0.403193	0.7456	2.25	Wils, 2006
CU Com	0.544158	0.405762	0.7457	2.00	Wils, 2006
GSC 6108-0220	0.54452	0.40644	0.7464	6.0	Bernhard, 2006
AQ Leo	0.549995	0.410357	0.746	1.65	Wils, 2006
ASAS040054-4923.8	0.558588	0.416671	0.7459	1.61	Szczygiel, 2007
GSC 4868-0831	0.56392	0.420805	0.7462	2.45	Wils, 2006
GSC 8833-1048	0.5668	0.42249	0.7454	1.9	Bernhard, 2006
GSC 7019-0641	0.58823	0.4386	0.7456	2.2	Bernhard, 2006

Table 1. BN UMa Frequency Data

Assignment	Frequency	Amplitude (mag)
f_0	1.865924	0.0757
$2f_0$	3.731905	0.0055
$3f_0$	5.597857	0.0030
f_1	2.502180	0.1872
$2f_1$	5.004361	0.0362
$3f_1$	7.506544	0.0132
$4f_1$	10.008722	0.0045
$f_0 + f_1$	4.36809	0.0332
$f_1 - f_0$	0.63624	0.0259
$2f_1 - f_0$	3.13840	0.0106
$f_0 + 2f_1$	6.87025	0.0108
$f_0 + 3f_1$	9.37241	0.0036

Table 2. CF Del Frequency Data

Assignment	Frequency	Amplitude (mag)
f_0	2.090089	0.1424
$2f_0$	4.180179	0.0278
$3f_0$	6.270270	0.0061
$4f_0$	8.360359	0.0063
f_1	2.808845	0.1768
$2f_1$	5.617691	0.0241
$3f_1$	8.426536	0.0073
$4f_1$	11.235382	0.0044
$f_0 + f_1$	4.898935	0.0655
$f_1 - f_0$	0.718756	0.0345
$2f_0 + f_1$	6.989025	0.0165
$f_0 + 2f_1$	7.707781	0.0221
$2f_0 + 2f_1$	9.797871	0.0169
$2f_1 - 2f_0$	1.437511	0.0057
$3f_0 - 2f_1$	0.652579	0.0036

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