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Variable stars in nearby galaxies[*]

II. Population I and II Cepheids in Field A of IC 1613

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Abstract. The light curves of Cepheids and other variable stars in Field A of IC 1613, obtained with a CCD and no filter (Wh photometry), have been analyzed. It is possible to separate first overtone from fundamental mode population I Cepheids taking into account the pulsation amplitude, the shape of the light curve and the period. The expected separation is verified in the period–luminosity PL diagram. Light curve Fourier parameters have been compared with those of Magellanic Clouds and galactic Cepheids, in order to point out the effects of the very low metallicity of IC 1613 on the light curve shape.

Population II Cepheids of IC 1613 can be discriminated from those of population I in the PL diagram, and, taking into account their color, from other red or blue variables. Their PL relation is consistent with that observed in globular clusters, nearby dwarf spheroidal galaxies and LMC. We have shown it is possible to apply the single-phase method for deriving standard photometry PL relations for population I and II Cepheids; therefore with just one accurate $BVRI$ observation it is possible to use the population I Cepheids for distance determinations.

Some unusual stars have been identified on the basis of periods, light curve shapes and colors; they appear to be pulsating stars laying on the extension of PL relation of known anomalous Cepheids. A firmer classification of these and other faint stars requires further deeper multicolor observations.

Key words: stars: oscillations – stars: variables: Cepheids – stars: variables: general – galaxies: individual: IC 1613 – galaxies: Local Group – galaxies: stellar content

1. Introduction

Cepheids are important stars not only as primary distance indicators but also as an essential tool for testing the theories on the internal constitution of stars and stellar evolution. The fact that resonances among the pulsation modes give rise to observable effects, i.e. structures in the Fourier decomposition coefficients, can be exploited to put constraints on the pulsational models and on the mass-luminosity relations. In the fundamental mode Cepheids a resonance occurs between the fundamental and the second overtone mode ($P_0/P_2 = 2$) in the vicinity of a period $P_0 = 10$ d and it is at the origin of the well known Hertzsprung progression of the bump Cepheids (e.g. Simon & Lee 1981). In the first overtone mode Cepheids, a resonance occurs between the first and the fourth pulsation modes ($P_1/P_4 = 2$; e.g. Antonello & Poretti 1986; Antonello et al. 1990). When these resonances observed in Cepheids of our Galaxy and Magellanic Clouds are used to constrain purely radiative models, one obtains stellar masses that are too small to be in agreement with stellar evolution calculations (e.g. Buchler 1998). It is therefore important to observe Cepheids in galaxies with very different metallicities. The MACHO, EROS and OGLE projects dedicated to the detection of microlensing events in the direction of Magellanic Clouds produced enormous amount of data on variable stars in these galaxies (e.g. Welch et al. 1997; Beaulieu & Sasselov 1997; Udalski et al. 1999). More recently, the project DIRECT was dedicated to the massive CCD photometry of M 31 (and M 33) with the purpose of detecting Cepheids and eclipsing binaries for direct distance determination of these galaxies (e.g. Kaluzny et al. 1998). In the previous paper of this series dedicated to the study of variable stars, and particularly Cepheids, in nearby galaxies (Antonello et al. 1999, hereinafter Paper I), we have illustrated the methods and strategy adopted for the detection of these stars in Field A of IC 1613, and we have shown the usefulness of the observations in white-light or Wh-band for obtaining the best light curves with relatively small telescopes.

The Cepheids of the irregular galaxy IC 1613 [$\alpha = 1^h04^m50^s$ (2000), $\delta = +2°08'$ (2000), l=130°, b=–61°], were studied by Baade, but his extensive results were never published. The data, reduced to a new photometric scale, were published by Sandage (1971), who discussed the apparently anomalous slope of the PL relation. Freedman (1988a), Sandage (1988) and Carlson & Sandage (1990) considered again this case and the conclusion was that there are no differences in the slope of the PL relation of Cepheids in IC 1613 with respect to that of other galaxies. From CCD $BVRI$ observations (Freedman, 1988a), Madore & Freedman (1991) derived a total mean reddening of $E(B-V)$=0.02 mag, and a true distance modulus of 24.42±0.13 mag, corresponding to a distance of 765 kpc; they suggest that IC 1613 is the best place for work on intrinsic calibration problems of the Cepheid distance scale, because

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[*] Based on observations collected at ESO-La Silla

Table 1. Population I Cepheids

Star	P [d]	Wh_0	V	R	ΔWh	mode
V2396	145.6	17.43	17.99	17.45	...	F
V1039	16.43	19.82	20.02	19.53	0.66	F
V2414	7.573	20.83	21.11	20.57	0.22	F
V1337	6.743	20.45	20.27	19.96	0.76	F
V0107	6.714	20.25	20.56	19.96	0.25	F
V1734	5.737	20.68	20.64	20.21	0.83	F
V2221	5.721	21.12	20.97	20.44	0.53	F
V0819	5.578	21.06	21.62	21.05	0.80	F
V1592	4.360	21.76	21.69	21.33	1.30	F
V1897	4.065	20.92	20.60	20.42	0.76	F
V2256	3.663	21.29	21.84	21.42	1.00	F
V1798	3.272	21.68	22.50	...	0.60	F
V1014	2.950	21.97	21.50	21.27	1.20	F
V0555	2.868	21.49	21.70	21.44	0.96	F
V0551	2.690	22.28	22.75	22.31	0.60	?
V2150	2.567	21.47	21.17	20.83	0.79	F
V0655	2.538	22.41	...	...	0.69	?
V0414	2.459	22.27	...	...	0.94	F
V1756	2.445	22.27	...	...	1.03	F
V2766	2.238	21.84	...	...	0.90	F
V2309	2.180	21.95	...	21.67	0.87	F
V0279	2.098	22.46	22.32	22.13	0.52	F
V2100	1.879	22.69	...	...	0.75	?
V2020	1.870	22.33	22.71	...	0.33	1-O
V0533	1.845	22.45	22.81	22.27	1.40	F
V0377	1.643	22.23	22.41	...	0.36	...
V1178	1.628	22.36	...	...	1.12	F
V0368	1.479	22.05	22.02	21.86	0.47	1-O
V2262	1.443	21.71	...	21.51	0.55	...
V0078	1.435	22.15	...	...	0.90	F
V2172	1.431	22.12	22.30	...	0.45	1-O
V0524	1.424	22.49	...	...	0.40	...
V0236	1.390	22.26	...	21.95	0.80	...
V1100	1.287	22.16	...	21.91	0.56	1-O
V0128	1.251	22.34	...	...	0.59	1-O
V1479	1.123	22.15	22.71	22.39	0.32	1-O
V1241	1.049	21.95	22.79	22.31	0.53	1-O
V1371	0.886	22.38	...	...	0.36	1-O
V1296	0.859	22.53	...	...	0.40	...
V0178	0.817	22.40	...	21.87	0.54	...
V1767	0.797	22.31	...	...	0.35	2-O?
V0479	0.663	22.35	...	...	0.50	...
V1289	0.646	22.33	...	...	0.35	...

the foreground reddening to this galaxy is very low and probably quite uniform, the extinction internal to IC 1613 appears to be quite small and the crowding of stellar images are relatively low. IC 1613 has probably a very low average metallicity, $[Fe/H] \sim -1.3$ (Freedman 1988b).

In the present paper we discuss the properties of population I Cepheids observed in Field A of IC 1613, and compare them with those in Galaxy and Magellanic Clouds, in a similar way to what done for these galaxies by MACHO, EROS and OGLE groups, and discuss the population II variables. Moreover, we show the utility of Wh light curves for deriving a standard PL relation.

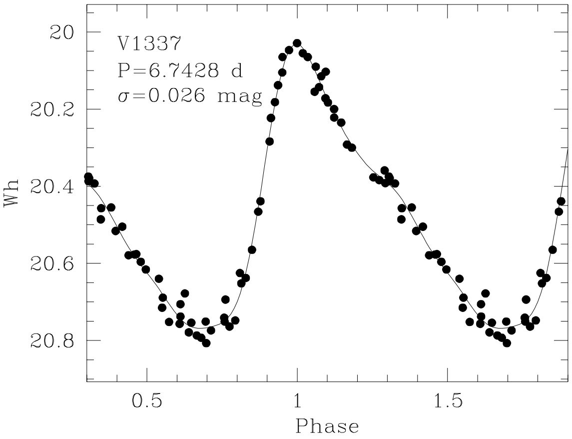

Fig. 1. Wh light curve of the Cepheid V1337 with a 5th order Fourier fit

2. Wh–photometry

As described in Paper I, the observations were performed at ESO LaSilla with the 0.9 m telescope and without filter, in order to collect the largest possible number of photons. The effective wavelength of Wh–band for a back–illuminated CCD detector is intermediate between that of Johnson V and R bands for F-G spectral types, therefore we expect that the photometric characteristics of pulsations such as amplitude and light curve shapes (or Fourier parameters) should be correspondingly intermediate between V and R. In general, the relation between V and R amplitudes of Cepheids is $\Delta R \sim 0.7\Delta V$, the amplitude ratios R_{i1} for bands R and V are similar, while the phase differences ϕ_{i1} are not the same, $\phi_{i1}(R) \sim \phi_{i1}(V) + a$, where $a \sim 0.2$–0.3 rad (Simon & Moffett 1985). Taking into account the approximate relation $V - Wh \sim 0.6(V - R)$ derived in Paper I and the relation between ΔR and ΔV, we obtain $\Delta Wh \sim 0.8\Delta V$. If we consider the uncertainties and the scatter of parameters from star to star, we can compare qualitatively the results of Wh photometry, as regards light curve characteristics, with those of V band. Similarly, we will compare our results with those of EROS survey (Beaulieu & Sasselov 1997), which were obtained with a nonstandard V-filter, whose effective wavelength was bluer than Johnson V-filter.

3. Population I Cepheids

3.1. Characteristics

The detected population I Cepheids are listed in Table 1, where the identification number, period, mean Wh_0, single-phase V and R values (see Paper I), amplitude ΔWh and pulsation mode have been reported. The Wh light curves were Fourier decomposed with the formula

$$Wh = Wh_0 + \sum A_i \cos[2\pi i f(t - T_0) + \phi_i], \qquad (1)$$

where $f = 1/P$; then the Fourier parameters, that is phase differences $\phi_{i1} = \phi_i - i\phi_1$ and amplitude ratios $R_{i1} = A_i/A_1$, were derived. The decomposition gave reliable results for many

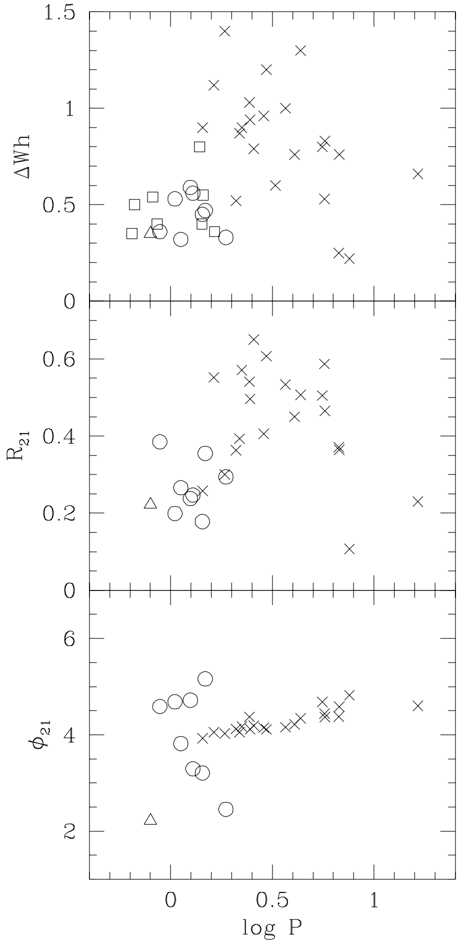

Fig. 2. Amplitude ΔWh, R_{21} and ϕ_{21} against period for population I Cepheids in Field A of IC 1613. *Crosses:* fundamental mode; *open circles:* first overtone mode; *open squares:* uncertain mode, but most of these stars should be first overtone mode pulsators; *open triangle:* second overtone mode candidate

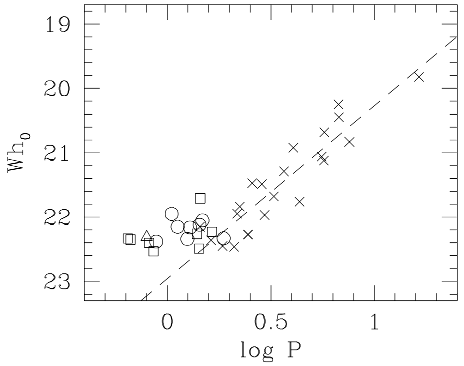

Fig. 3. Period–luminosity relation for population I Cepheids in Field A of IC 1613. Symbols as in Fig. 2. The dashed line is the statistical relation obtained for fundamental mode pulsators

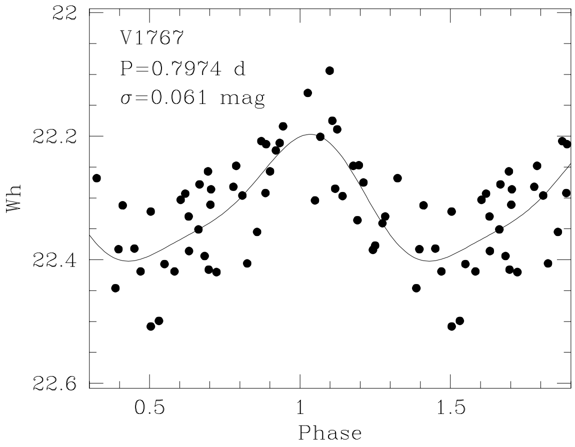

Fig. 4. Wh light curve of the second overtone candidate V1767 with a 2nd order Fourier fit; this figure illustrates also the present limiting capabilities of a 0.9 m telescope for discovering small amplitude faint Cepheids

Cepheids; the best example is shown in Fig. 1, where the light curve of V1337 is reported along with the 5th order fit, with a standard deviation of 0.026 mag. However, for several short period, faint Cepheids the Fourier decomposition is too uncertain, and on this basis their mode could not be identified; taking into account the amplitude and position in the PL diagram, most of them should be probable first overtone pulsators. The Fourier parameters R_{21}, ϕ_{21} and the amplitude ΔWh are plotted against P in Fig. 2. The trends of the parameters are qualitatively similar to those observed in other galaxies. Unfortunately there are no stars with P between 8 and 16 d, and therefore it is not possible to put a constrain with just these Cepheids on the location of $P_0/P_2 = 2$ resonance; this point will be discussed also in the next section. As regards first overtone mode Cepheids, we have to remark the apparent lack of stars with $P > 2$ d (log $P >$ 0.3). We have looked carefully at the data base, but we have not found convincing candidates with such periods. First overtone Cepheids are characterized by a scatter of ϕ_{21} values, which could be interpreted as the effect of the resonance $P_1/P_4 = 2$. The ϕ_{21} values are uncertain, with a formal error of about 0.5 rad, and therefore we cannot put much weight on this result.

First overtone mode pulsators are clearly discriminated also in the PL diagram shown in Fig. 3; indeed they are located roughly about half a magnitude above the PL relation of fundamental mode Cepheids,

$$Wh_0 = -2.69 \log P + 22.96. \qquad (2)$$

There is at least one second overtone candidate, V1767; the light curve, shown in Fig. 4, is different from that of other Cepheids, and we suspect it is the signature of the expected resonance $P_2/P_6 = 2$ for $P \lesssim 1$d. This result would be consistent with theoretical expectations (Antonello & Kanbur 1997) and with the observational results for LMC double-mode Cepheid pulsating in first and second overtone modes (Alcock et al. 1999). The search for pure second overtone mode Cepheids in SMC (e.g. Mantegazza & Antonello 1998) has yielded only recently the first positive results in the context of OGLE experiment (Udalski et al. 1999). According to the results of OGLE group, the SMC second overtone mode Cepheids have very small amplitudes (< 0.2 mag) and the light curves are almost

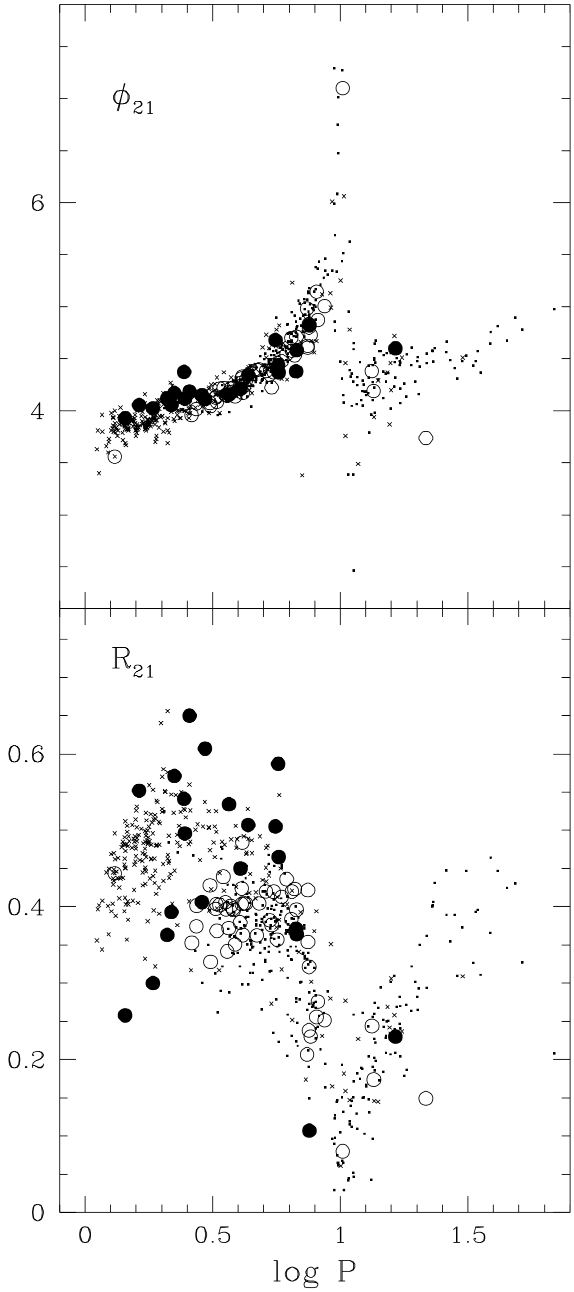

Fig. 5. Phase difference ϕ_{21} and amplitude ratio R_{21} against period for fundamental mode Cepheids in Galaxy (*dots*), LMC (*open circles*), SMC (*crosses*) and IC 1613 (*filled circles*)

sinusoidal; taking into account the scatter, V1767 has an amplitude of about 0.2–0.3 mag, but the shape is a bit different from that of a sinusoid.

Two warnings are in order: the first concerns the colors of the stars and the second the aliasing problem. Since Wh photometry is deeper than V and R ones made with the same telescope, presently we have no information on the colors of the faintest Cepheids. In particular, as noted by Udalski et al. (1999), small amplitude, almost sinusoidal light curves can be produced by several objects, such as ellipsoidal variables (which are usually

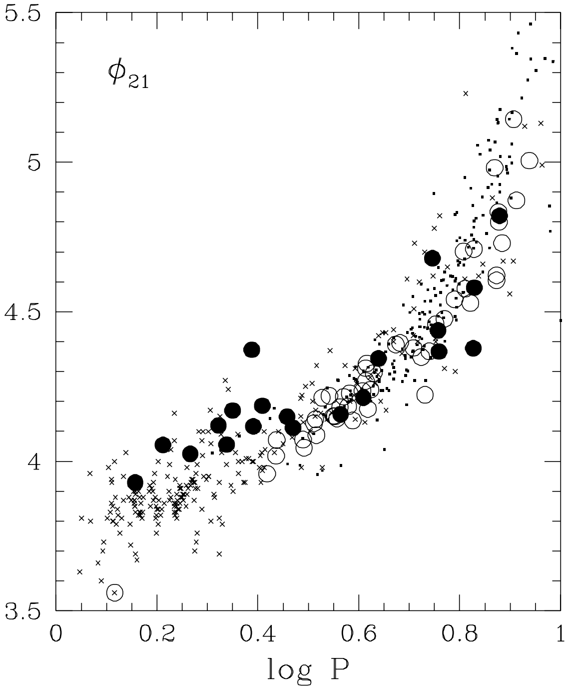

Fig. 6. Detail of the ϕ_{21}–P diagram shown in Fig. 5

hot stars) or spotted stars (which are usually cool stars). As remarked in Paper I, there are some difficulties in identifying the correct frequency for shorter period variables, because the peaks in the power spectrum at f and at the alias $f-1$ are similar; for example, a solution with $P = 3.9$d (but with a lower power spectrum peak) for V1767 is also reasonable, but it is too long a period for a population I Cepheid with the same luminosity, and the light curve keeps a non-sinusoidal shape. We conclude that shorter period Cepheids must be considered good candidates at least until a better information on their color is available.

The amplitudes as a function of P shown in Fig. 2 (upper panel) indicate a distribution similar to that observed in Galaxy. In particular, the first overtone mode pulsators have generally small amplitudes.

3.2. Comparison with other galaxies

Interesting results are obtained when we compare directly the Fourier parameters of Cepheids in IC 1613, Galaxy (data from Mantegazza & Poretti 1992, Antonello & Morelli 1996, and references therein) and Magellanic Clouds (EROS data; Beaulieu & Sasselov 1997). ϕ_{21} and R_{21} are plotted against the period in Fig. 5. It is quite evident that ϕ_{21} values of fundamental mode Cepheids are very similar in all the galaxies; this result, coupled with the evidence that R_{21} has a minimum for the same period range, confirms clearly that the resonance effects of $P_0/P_2 = 2$ do not depend much on the metallicity. Even if we noted previously that IC 1613 data alone cannot put a constraint, they tend to follow the same trend as that of the other galaxies. Fig. 6 shows a detail of the $\phi_{21} - P$ diagram. The fact that the phase difference appears to be not very sensitive to metallicity, and in a certain sense nor to the passband, is striking. The Cepheids of Galaxy have $[Fe/H] \sim 0.0$ and the Fourier parameters were obtained for V light curves; for LMC and SMC ($[Fe/H] \sim -0.2$ and $[Fe/H] \sim -0.5$, respectively; Feast 1991) the passband was bluer than V, while for IC 1613 ($[Fe/H] \sim -1.3$) the passband was redder. The uniformity of ϕ_{21} values is not likely to be due to curious combined effects. The clearest indication for a small difference is the trend of IC 1613 Cepheids with shorter P: the ϕ_{21} values tend to be slightly larger than those for the other galaxies. It may be possible that the $\phi_{21} - P$ relation in the range $1 \lesssim P \lesssim 8$ d ($0 \lesssim \log P \lesssim 0.9$) is a function of the metallicity.

One should note the systematic differences of R_{21} envelopes for shorter P among the various galaxies; as remarked in Sect. 2 this does not depend on the different photometric band, but it should reflect the sensitivity of this parameter to the metallicity. It may be possible that IC 1613 Cepheids have the largest R_{21} values because they are the metal poorest. Since the ϕ_{21} values do not change too much from galaxy to galaxy, increasing R_{21} values for a given period range are related to light curves with steeper rising branches and possibly also stronger humps and bumps. For the same reason the amplitudes of IC 1613 Cepheids should be quite larger than for example those of Galaxy.

The first overtone mode Cepheid case is shown in Fig. 7. R_{21} values appear to follow the same trend in Galaxy and Magellanic Clouds as in the fundamental mode case, and also IC 1613 data, even if uncertain, are roughly consistent with this picture. The P corresponding to the minimum of R_{21} values for Galaxy and Magellanic Clouds tends to differ slightly from galaxy to galaxy, that is it decreases with the metallicity. It is possible to identify approximately the following period of minimum: 3.2 d (Galaxy), 2.9 d (LMC) and 2.5 d (SMC). The ϕ_{21} values appear even more sensitive to the different metallicity. The so-called Z–shape of ϕ_{21} values in the Galaxy is progressively distorted for decreasing metallicity. The lowest ϕ_{21} values at $\log P \sim 0.5$ tend to coincide in Galaxy and Magellanic Clouds, while the highest ϕ_{21} values are displaced towards the shorter periods for decreasing metallicity. On the basis of this feature the EROS group (e.g. Beaulieu & Sasselov 1998) remarked a change of the center of the resonance effect $P_1/P_4 = 2$ as a function of metallicity. The intriguing question now is whether in IC 1613 the first overtone values indicate the resonance effect at much shorter period or it is just a matter of uncertain data. Could the large metallicity difference be responsible for this? Better data are needed to solve this problem.

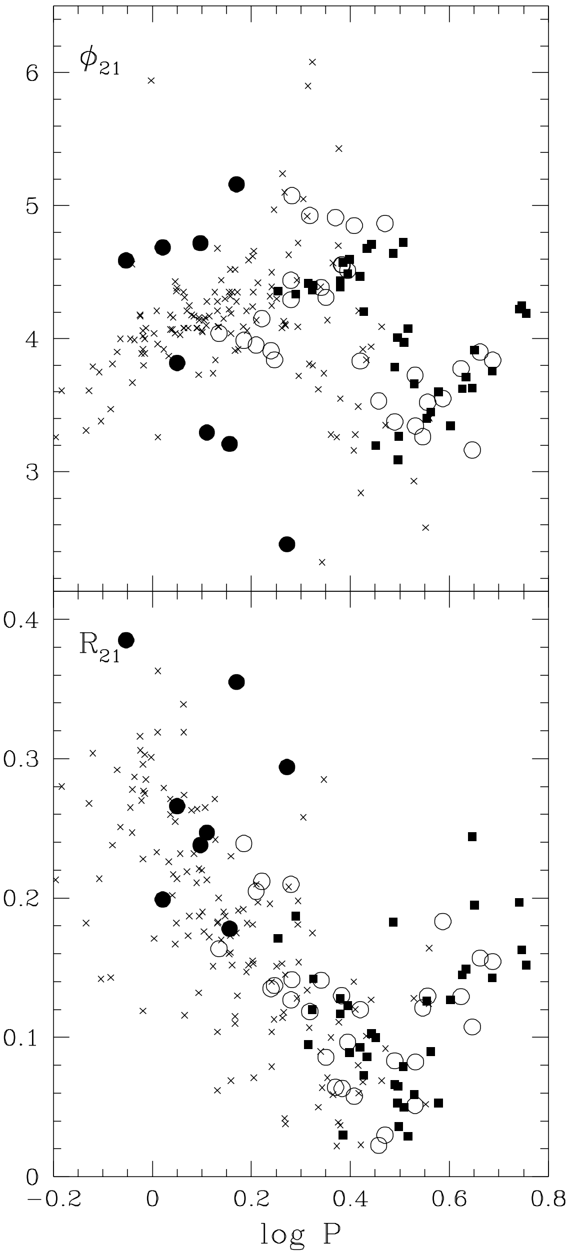

Fig. 7. Phase difference ϕ_{21} and amplitude ratio R_{21} against period for first overtone mode Cepheids in Galaxy (*filled squares*), LMC (*open circles*), SMC (*crosses*) and IC 1613 (*filled circles*)

4. Single-phase PL relation

In the present section we discuss the possibility of the application of the single-phase method devised by Freedman (1988a), that is we will use the only available V observation of the (brightest) Cepheids and the characteristics of Wh light curves. Cepheid light curve shapes and amplitudes depend on the color or passband as mentioned in Sect. 2. We take into account the ratio r=0.8 between Wh and V amplitudes and for the present we will ignore the presumably small phase shift of maximum between Wh and V light curves. In principle, simultaneous observations of a test Cepheid are needed in order to derive the accurate ratio between Wh and V amplitudes and the phase shift; however, considering the present precision of data, we think this is not a strict requirement. In particular, the error in the V measurement of faintest Cepheids estimated by DAOPHOT is large, $\gtrsim 0.18$ mag. A detailed study (also with simulations) of this topic will be made when all the observations of the four fields of IC 1613 will be reduced. For the present, we show

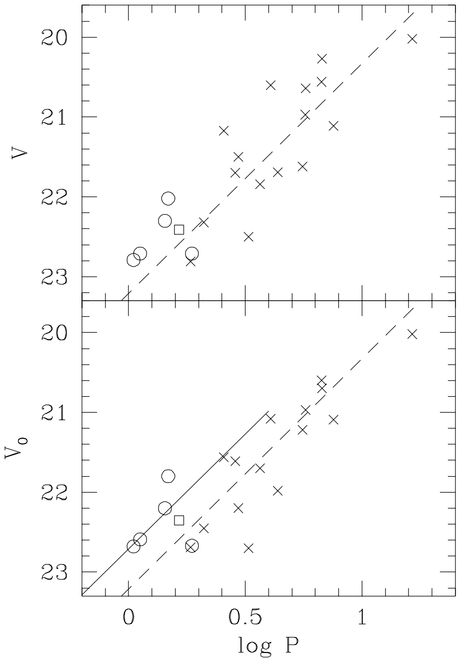

Fig. 8. PL relations with V data. Upper panel: random-phase single-value relation. Lower panel: converted to mean V light relation (see text). *Crosses:* fundamental mode Cepheids; *open circles:* first overtone mode Cepheids; *open square:* Cepheids with uncertain mode. *Dashed line:* PL relation for V band of 25 LMC stars (Madore & Freedman 1991) plotted assuming apparent values for distance modulus $\mu = 24.45$ for IC 1613 and relative distance $\delta\mu = 5.71$ between IC 1613 and LMC (Freedman 1988a). *Continuous line:* relation with the same slope and decreased zero-point by 0.5 mag, indicating approximatively the expected relation for first overtone mode Cepheids

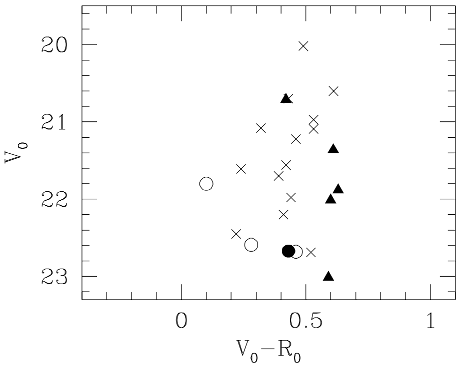

Fig. 9. Color–magnitude diagram for population I and II Cepheids. The V and R values are those converted to mean light. *Crosses:* fundamental mode pop I Cepheids; *open circles:* first overtone pop I Cepheids; *filled triangles:* W Vir stars; *filled circle:* possible anomalous Cepheid

Table 2. W Vir stars

Star	P [d]	Wh_0	V	R	ΔWh
V1935	61.7	20.54	20.90	20.43	0.8
V0971	31.15	21.39	21.94	21.30	0.2
V1598	23.01	20.94	21.36	20.75	0.5
V0130	22.99	21.61	21.93	21.35	0.3
V0881	8.353	22.17	22.74	22.23	0.8

the result of our exercise in Fig. 8; the mean V magnitude of Cepheids was estimated with the formula

$$V_0 = V(\phi) - [Wh(\phi) - Wh_0]/r, \quad (3)$$

where $V(\phi)$ is the single measurement, $Wh(\phi)$ the value of the fitted Wh curve for the same phase and r=0.8. Actually, V_0 is a converted single-phase V value to mean value. The comparison of the two panels in Fig. 8 shows the expected improvement of the converted value over the random single–phase relation mainly for the brighter Cepheids; the expected approximate relation for first overtone mode pulsators is also plotted. For deriving R_0 from the single-phase R value we have adopted the same procedure using $r = 0.6$; both V_0 and R_0 values are listed in Table 3.

We have planned to make observations in $BVRI$ bands of the four observed fields of the galaxy with a larger telescope in order to obtain *one* accurate photometric value in each of these bands for all of the Cepheids; this will allow us to derive statistically significant standard PL relations for fundamental and first overtone mode pulsators using the single–phase method.

5. W Vir stars and other population II Cepheids

W Vir stars can be discriminated from population I Cepheids in the PL diagram, because the former, for a given mean magnitude, have longer periods. In our Galaxy, W Vir stars are bluer than classical Cepheids, while in the very metal poor galaxy IC 1613 the color difference between the two populations presumably is small. Therefore we have identified the probable W Vir stars in the sample of the longer period variables with Cepheid–like light curve on the basis of their color; they are reported in Table 2 along with their mean Wh value and single-phase V and R values. Converted to mean light curve values were obtained with the same procedure adopted for population I Cepheids, and are listed in Table 3. Fig. 9 shows the color-magnitude diagram for Cepheids of both populations; the V–R color range is 0.10–0.63 mag, to be compared with the range indicated by the 11 population I Cepheids observed by Freedman (1988a), 0.15–0.66 mag.

The W Vir stars are reported in the PL diagram shown in Fig. 10. In the lower panel the two parallel dotted lines are the PL relations obtained by Nemec et al. (1994) for population II Cepheids in Galaxy and nearby spheroidal galaxies, corrected for the distance modulus 24.45; the lower line is for fundamental mode stars, and the upper line for first overtones. The relations take into account the metallicity of the galaxies. The continuous line is the relation for population II LMC stars, $M_V = 1.34–3.07 \log P$, obtained by Alcock et al. (1998). If we consider the various uncertainties in our derivations, there is a qualitative agreement. A quantitative analysis requires however a larger sample of stars of IC 1613. Carlson & Sandage (1990) suggested that the separation between population I and II Cepheid relations in IC 1613 is smaller than that in other galaxies; the suggestion was based on one Cepheid–like star

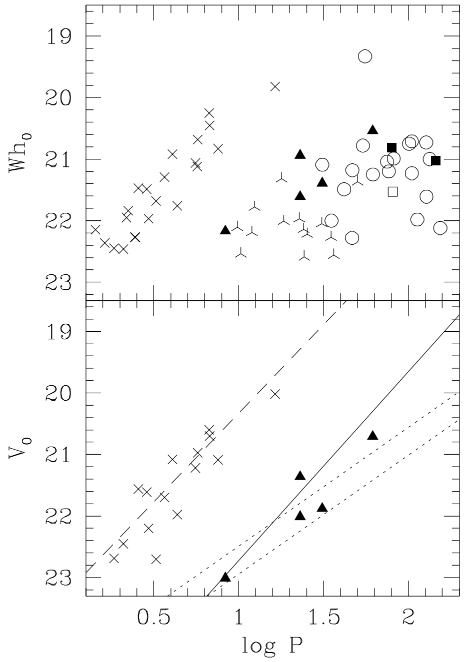

Fig. 10. PL relations. Upper panel: Wh_0 data. Lower panel: converted to mean V light relation. *Crosses:* fundamental mode Cepheids shown in Fig. 8; *filled triangles:* W Vir stars; *skeletal triangles:* other W Vir and periodic variables with unknown color; *filled squares:* possible RV Tau stars; *open circles:* semiregular and long period variables; *open squares:* variables with V–$R \lesssim 0.1$. *Dashed line:* PL relation for classical Cepheids shown in Fig. 8; *dotted lines:* PL relations for population II Cepheids pulsating in the fundamental (lower line) and first overtone mode (upper line) derived by Nemec et al. (1994); *continuous line:* relation obtained by Alcock et al. (1998) for LMC stars

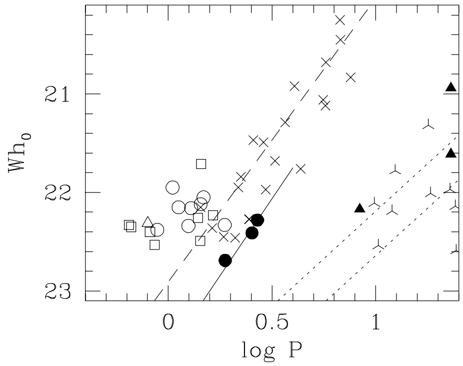

Fig. 11. Period–Wh_0 diagram for faint Cepheids. *Crosses:* fundamental mode population I Cepheids; *open circles:* first overtone population I Cepheids; *open squares:* population I Cepheids of uncertain mode; *open triangle:* possible second overtone population I Cepheid; *filled triangles:* W Vir stars; *skeletal triangles:* other periodic variables; *filled circles:* possible anomalous Cepheids. The lines are the PL relations for the V band corrected for the color difference $Wh = V - 0.3$ (rough mean value for Cepheids); the continuous line is the extension of the relation for fundamental mode anomalous Cepheids and the dotted lines for first and fundamental mode W Vir stars derived by Nemec et al. (1994)

Table 3. Converted to mean light curve V and R data for population I and II Cepheids

Star	V_0	R_0	Star	V_0	R_0
V1039	20.02	19.53	V2020	22.67	...
V2414	21.09	20.56	V0533	22.69	22.17
V1337	20.70	20.27	V0377	22.35	...
V0107	20.60	19.99	V0368	21.80	21.70
V1734	20.97	20.44	V2262	...	21.65
V0819	21.22	20.76	V2172	22.20	...
V1592	21.98	21.54	V0236	...	22.13
V1897	21.08	20.76	V1100	...	21.76
V2256	21.70	21.31	V1479	22.59	22.31
V1798	22.70	...	V1241	22.68	22.22
V1014	22.20	21.79	V0178	...	21.79
V0555	21.61	21.37			
V0551	22.67	22.24	V1935	20.71	20.29
V2150	21.56	21.14	V0971	21.88	21.25
V2309	...	21.73	V1598	21.36	20.75
V0279	22.45	22.23	V0130	22.01	21.41
			V0881	23.01	22.42

which was assumed to be a W Vir star. Our results show however that in IC 1613 such separation appears to be normal.

In Paper I we have mentioned three stars with relatively symmetric light curve, and with relatively low luminosity and long period. They are too faint for being first overtone pulsators, and cannot be fundamental mode pulsators owing to the different light curve shape. Only one of these stars has known V–R, which indicates a location in the instability strip (Fig. 9), and we suggested tentatively they are anomalous Cepheids. In Fig. 11 it is shown the PL diagram for faint Cepheids, which include these stars. Since the V measurement is lacking for several faint stars, we used the mean Wh magnitude. The PL relations for the V band adopted for classical Cepheids, and for the anomalous Cepheids and W Vir stars (Nemec et al. 1994) were corrected for the mean color of Cepheids, $Wh = V - 0.3$, and the adopted distance modulus was the same as before (24.45). The result for the anomalous Cepheids is intriguing indeed. However, there are some difficulties in accepting this interpretation, since there are not known anomalous Cepheids with $\log P > 0.2$ in galactic globular clusters and dwarf spheroidal galaxies. If existent, such 'long' period stars would have probably similar masses to the other pop I Cepheids, and it would be difficult to discriminate them. Another point is the lack of globular clusters in IC 1613 (e.g. Hodge 1978, 1988). The region of Cepheids with short P, say $\lesssim$ 3 d ($\log P \lesssim 0.5$), appears to be populated by interesting and yet unexplained stars: Alves et al. (MACHO group; 1998) found in LMC a sequence of pulsators which are fainter than that of fundamental mode population I Cepheids; our stars could be considered the first overtone analogue of such a sequence, assuming that the LMC faint stars are fundamental mode pulsators.

6. Conclusion

The analysis of the light curve of the Cepheids in Field A of IC 1613 has yielded the following results: a) a group of first overtone mode has been separated from fundamental mode Cepheids for the first time in a galaxy located beyond the Magellanic Clouds; b) a second overtone candidate has been identified taking into account its period and unusual light curve shape, which could be explained by the expected resonance $P_2/P_6 = 2$; c) conclusions on the effects of a very low metallicity on the light curve shape have been drawn from the comparison with Cepheids in other galaxies, i.e. Galaxy, LMC and SMC; d) there are no large metallicity effects on the resonance $P_0/P_2 = 2$ for fundamental mode stars, and there are probable differences in the resonance $P_1/P_4 = 2$ for first overtone mode pulsators; e) the Wh light curves can be confidently used for deriving a standard PL relation for the V band by applying the single-phase method; f) the position in the PL diagram of population II Cepheids is consistent with that of Cepheids in globular clusters, nearby dwarf spheroidal galaxies and LMC; g) some unusual stars have been identified on the basis of the period, light curve shape and color; they appear to be pulsating stars laying on the extension of PL relation of known anomalous Cepheids.

A firmer classification of the faint variable stars detected in the Wh band requires complementary deeper multicolor observations; these observations are needed also for applying the above quoted single-phase method to the faintest detected Cepheids.

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