# The period – luminosity and period – radius relations of Type II and anomalous Cepheids in the Large and Small Magellanic Clouds

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#### ABSTRACT

Context. Type II Cepheids (T2Cs) and anomalous Cepheids (ACs) are pulsating stars that follow separate period-luminosity relations. Aims. We study the period-luminosity (PL) and period-radius (PR) relations for T2Cs and ACs in the Magellanic Clouds. Methods. In an accompanying paper we determined luminosity and effective temperature for the 335 T2Cs and ACs in the LMC and SMC discovered in the OGLE-III survey, by constructing the spectral energy distribution (SED) and fitting this with model atmospheres and a dust radiative transfer model (in the case of dust excess). Building on these results we study the PL- and PR

relations. Using existing pulsation models for RR Lyrae and classical Cepheids we derive the period-luminosity-mass-temperature-Results. The PL relation for the T2Cs does not appear to depend on metallicity, and, excluding the dusty RV Tau stars, is  $M_{\rm bol}$  =  $+0.12 - 1.78 \log P$  (for P < 50 days). Relations for fundamental and first overtone LMC ACs are also presented. The PR relation

for T2C also shows little or no dependence on metallicity or period. Our preferred relation combines SMC and LMC stars and all T2C subclasses, and is  $\log R = 0.846 + 0.521 \log P$ . Relations for fundamental and first overtone LMC ACs are also presented. The pulsation masses from the RR Lyrae and classical Cepheid pulsation models agree well for the short period T2Cs, the BL Her subtype, and ACs, and are consistent with estimates in the literature, i.e.  $M_{BLH} \sim 0.49 M_{\odot}$  and  $M_{AC} \sim 1.3 M_{\odot}$ , respectively. The masses of the W Vir appear similar to the BL Her. The situation for the pWVir and RV Tau stars is less clear. For many RV Tau the masses are in conflict with the standard picture of (single-star) post-AGB evolution, the masses being either too large ( $\gtrsim 1 M_{\odot}$ ) or too small ( $\lesssim 0.4$ 

Key words. stars: variables: Cepheids: Type II Cepheids — stars: variables: Cepheids: Anomalous Cepheids — stars: fundamental

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**ABST Context.** Type II Cepheids (T2Cs) and anomalous Cepheids (ACs) Aims. We study the period-luminosity (*PL*) and period-radius (*PR* Methods. In an accompanying paper we determined luminosity and SMC discovered in the OGLE-III survey, by constructing that atmospheres and a dust radiative transfer model (in the case of relations. Using existing pulsation models for RR Lyrae and class metallicity relations, and then estimate the pulsation mass. *Results.* The *PL* relation for the T2Cs does not appear to depend +0.12 – 1.78 log *P* (for *P* < 50 days). Relations for fundamental for T2C also shows little or no dependence on metallicity or peri T2C subclasses, and is log *R* = 0.846 + 0.521 log *P*. Relations for pulsation masses from the RR Lyrae and classical Cepheid pulsatio and ACs, and are consistent with estimates in the literature, i.e. *M*<sub>F</sub> W Vir appear similar to the BL Her. The situation for the PWirt conflict with the standard picture of (single-star) post-AGB evolut *M*<sub>☉</sub>).
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**1. Introduction** Type II Cepheids (T2Cs) and anomalous Cepheids (ACs) are pulsating stars located in the instability strip (IS) of the Hertzsprung-Russell diagram (HRD) also occupied by the classical Cepheids (CCs) and RR Lyrae (RRL) variables. T2C are classically divided into subgroups based on their period, and, following Soszyński et al. (2008b) and Soszyński et al. (2010b), they are the BL Herculis (BLH) (1–4 days), the (peculiar) W Virginis ((p)WVir) (4 – 20 days), and the RV Tauri ginis ((p)WVir) (4 - 20 days), and the RV Tauris (RVT) (20 - 70days). The pulsation period of the ACs (from  $\sim 0.9$  to  $\sim 2$  days) overlaps with the short period T2Cs. T2Cs are known to pulsate in fundamental mode (FU) only, while the ACs pulsate in the first overtone (FO) and fundamental mode (FU).

An important characteristic of T2Cs and ACs is that they follow a period-luminosity (PL) relation, and that these objects can be found in globular clusters, and galaxies (Catelan & Smith 2015). They can therefore be used in the calibration of the distance scale. T2Cs in particular are useful where CCs are too few and RRL too faint (see for example the review by Sandage & Tammann (2006) and Wallerstein (2002)). ACs fill a space on the *PL*-diagram above the RRL and T2Cs by  $\sim 0.5$  to  $\sim 2$  magnitudes (as the period increases), but do not reach into the CC region. Caputo et al. (2004) investigated the possibility that they do continue to the PL relation of CCs, but Fiorentino & Monelli (2012) concluded that they are metal-poor stars that would not evolve into the CC IS region.

Period - luminosity relations have been discussed in several papers over the past decades. Nemec et al. (1994) is a rare example were P - L-[Fe/H] relations are derived for T2Cs and ACs (as well as RRL and SX Phe stars) in (B, V, K) colours based on objects in globular clusters. Recently, Clementini et al. (2016) presented PL relations for T2Cs and FU and FO ACs in the Gaia G-band. Marconi et al. (2004) provided a theoretical mass-dependent Period-Magnitude-Colour (PMC), Period-Wesenheit (PW) and Period-Magnitude-Amplitude relations for ACs in the metallicity range Z = 0.0001 - 0.0004. They also give the empirical PW(VI) relation based on ACs observed in 7 dwarf spheroidal galaxies. Ripepi et al. (2014), as a part of the VISTA Magellanic Cloud (VMC) Survey (Cioni et al. 2011), provided the *PL* relation in the  $K_s$  band, and the PW(V, K) relation for FU and FO ACs in the LMC, as well as the PL relation in the V and I band, a *PMC* and the PW(V, I) relation based on the original OGLE-data.

Di Criscienzo et al. (2007) derived theoretical periodmagnitude (*PM*) in the NIR and period-Wesenheit (*PW*) for various optical and NIR colour combinations relations combining pulsation models and evolutionary tracks for stars with periods up to 8 days, i.e. BLHs. Matsunaga et al. (2011) present NIR *PL* relations and Wesenheit relations for T2C in the SMC, and compare the results to their earlier work on the LMC (Matsunaga et al. 2009) and Galactic Centre (GC) (Matsunaga et al. 2006). The *K*-band *PL* relation for T2C in the GC was also presented by Groenewegen et al. (2008), and the absolute calibration was considered by Feast et al. (2008). More recently, Manick et al. (2017) used the OGLE-III LMC T2Cs to derive the Wesenheit *PW* relation.

Recent survey work in the NIR allowed a reappraisal of the *PL* relations, notably, Ripepi et al. (2015) considered VMC data (Cioni et al. 2011) to present several *PL*, *PLC* and *PW* relations, while Bhardwaj et al. (2017) did a similar study using NIR data from the LMC Synoptic Survey (Macri et al. 2015).

Apparently, there has been little recent work done on the radii of T2Cs. Burki & Meylan (1986) give a period-radius (PR) relation based on older data, and Balog et al. (1997) derived the radii for 17 Galactic T2Cs using the Baade-Wesselink method. Figure 5 in their article displays a PR relation, but they did not give an equation for their fit.

Masses for the T2Cs were estimated by Bono et al. (1997a) to be in a range between 0.52 and 0.59  $M_{\odot}$  (for Z < 0.001) for stars with periods below 15 days. Quoting the results of Vassiliadis & Wood (1993), Wallerstein (2002) gives the initial mass of the brighter T2Cs (the RVT) to be around 1  $M_{\odot}$ . In the case of ACs pulsation models have been considered by various authors to find masses in the range 1.3-2.2  $M_{\odot}$  (for Z = 0.0001 and 0.0004, Bono et al. (1997b), Marconi et al. (2004)), or, specifically  $1.2 \pm 0.2 M_{\odot}$  for the ACs in the LMC (Fiorentino & Monelli 2012). Recently, Martínez-Vázquez et al. (2016) find ~ 1.5  $M_{\odot}$  for four ACs in the Sculptor dSph galaxy.

In the accompanying paper, (Groenewegen & Jurkovic (2017), hereafter GJ17) studied all 335 T2C and AC in the Small and Large Magellanic Clouds (MCs) detected in the OGLE-III data (Soszyński et al. (2008b), Soszyński et al. (2010b), Soszyński et al.  $(2010a)^{1}$ ). The spectral energy distributions (SEDs) were constructed using photometry from the literature and fitted with the dust radiative transfer code "More of DUSTY" (MoD, Groenewegen (2012)), an extension of the DUSTY radiative transfer code DUSTY (Ivezić et al. 1999). Luminosities and effective temperatures were derived and are given in the Appendix in GJ17. The resulting Hertzsprung-Russell diagram was compared in a qualitative way to modern evolutionary tracks. In agreement with the findings cited above the BL Her can be explained by stars in the mass range  $\sim 0.5 - 0.6 M_{\odot}$  and the ACs by stars in the mass range ~  $1.1 - 2.3 M_{\odot}$ . The origin of the (p)WVir is unclear however: tracks of  $\sim 2.5 - 4 M_{\odot}$ cross the IS at the correct luminosity, as well as (some) lower mass stars on the AGB that undergo a thermal pulse when the envelope mass is small, but the timescales make these unlikely scenarios.

For ~ 60% of the RVT and ~ 10% of the W Vir (including the pWVir) objects an infrared excess was detected from the SED fitting. The results of Kamath et al. (2016) were con-

firmed that there exist stars with luminosities below that predicted from single-star evolution that show a clear infrared excess. The light curves of more than 130 systems were investigated to look for the light-travel time (LTT) effect or light-time effect (LITE) (Irwin 1952) in so-called *observed minus calculated*, (O-C)-diagrams. Twenty possible new binaries were identified, and about 40 stars that show a significant period change.

Previous work concentrated almost exclusively on deriving the *PL* relation in the NIR bands or using the Wesenheit index, the main aim of this paper is to use the stellar luminosity as parameter and in that way study the properties of these stars in a more fundamental way. We used the results published in GJ17 to derive the period-luminosity and *PR* relations of T2Cs and ACs. In addition, we derive estimates of the masses of these stars, based on theoretical pulsation models of RRL and CCs.

In Section 2 we discuss the derived PL relations for T2Cs and ACs. In Section 3 the period-radius relation is presented, and in Section 4 we estimate the masses. In the Section 5 we discuss and summarise our findings.

#### 2. Period – Luminosity relation

Figure 1 first shows the classical *PL* relation using the Wesenheit magnitude,  $W = I - 1.55 \cdot (V - I)$ , combining Fig. 1 in Soszyński et al. (2008b) and Fig. 1 in Soszyński et al. (2010b). In GJ17 we used distances to the LMC and SMC of 50 and 61 kpc in the SED modelling, and therefore we shifted the magnitudes of the SMC objects by 0.432 mag (distance moduli, DM, 18.927-18.495) to put them on the magnitude scale of the LMC. The most prominent outliers are marked with their identifier.

Wesenheit *PL* relations have been derived for various combinations of subclasses of T2Cs and ACs for both the LMC and SMC, and combined ("@LMC", meaning the SMC objects have been placed at the distance of the LMC) and the results are listed in Table 1. Stars showing eclipsing or ellipsoidal variation (as identified by OGLE; the blue crosses in Figure 1) have been excluded in the fitting and iterative  $3\sigma$  clipping has been applied to remove outliers.

Table 1, in addition, includes other determinations of the Wesenheit *PL* relation from the literature, both observational as theoretical. The Wesenheit *PL* relation does not not seem to depend on metallicity. At characteristic periods of log P = 0.5 (BLH), 1.5 (RVT) and 1.0 (WVir, and the solutions that include BLH and/or RVT) the magnitude difference between the solutions for the SMC and LMC are within the errors consistent with the expected difference of 0.43 mag.

The derived relations are also in agreement with those listed in the literature although this is not so surprising as there are all based on the same OGLE-III data and only differ in details. The RVT stars that show IR excess are brighter in W than those without (also remarked by Manick et al. (2017)), but excluding those there is well defined W(VI) relation for BLH, WVIR and non-dusty RVT, as illustrated in Figure 1.

The agreement with theoretical models is good for the BLH. The comparison with observations requires an adopted distance to the LMC, and an assumed metallicity for the models. For [Fe/H] = -1 and DM= 18.50 theory and observations agree within the error. The agreement is less good for the ACs, in particular the theoretical slope differs by almost  $3\sigma$  from the empirically derived one.

Figure 2 shows the bolometric version of the PL relation, using the luminosities derived in GJ17. The bottom part of Table 1 gives the corresponding fits to the PL relation. What is immediately noticeable is that the scatter in the bolometric PL

<sup>&</sup>lt;sup>1</sup> Soszyński et al. (2010a) originally listed the 6 SMC ACs with a classical Cepheid identification number. In the OGLE-III Variable Stars Database (http://ogledb.astrouw.edu.pl/~ogle/CVS/ they were subsequently listed under the names that we use in GJ17 and the present paper, OGLE-SMC-ACEP 01...06.

Table 1. Wesenheit and bolometric period-luminosity relations.

Sample	Galaxy <sup>a</sup>	Mag	Mag= a	$+b \log P$	dispersion	$\chi_r^{2b}$	Ν	Ν	Ref.
					(mag)			outliers	
BL Her	LMC	W	$17.359 \pm 0.022$	$-2.576 \pm 0.080$	0.089	9.18	55	6	
BL Her	SMC	W	$17.558 \pm 0.134$	$-2.429 \pm 0.480$	0.241	76.0	17	0	
BL Her	@LMC	W	$17.347 \pm 0.038$	$-2.669 \pm 0.137$	0.170	32.8	74	4	
W Vir	LMC	W	$17.402 \pm 0.064$	$-2.558 \pm 0.063$	0.093	9.91	76	2	
W Vir	SMC	W	$18.329 \pm 0.168$	$-3.009 \pm 0.158$	0.091	11.5	10	0	
W Vir	@LMC	W	$17.471 \pm 0.061$	$-2.624 \pm 0.060$	0.098	10.8	86	2	
RV Tau	LMC	W	$18.101 \pm 0.557$	$-3.142 \pm 0.352$	0.249	72.6	41	1	
RV Tau	SMC	W	$17.707 \pm 1.049$	$-2.585 \pm 0.674$	0.164	42.1	7	0	
RV Tau	@LMC	W	$18.004 \pm 0.494$	$-3.077 \pm 0.313$	0.240	66.9	48	1	
BL Her + W Vir	LMC	W	$17.363 \pm 0.017$	$-2.522 \pm 0.021$	0.102	11.6	133	6	
BL Her + W Vir	SMC	W	$17.597 \pm 0.072$	$-2.356 \pm 0.103$	0.209	53.0	26	1	
BL Her + W Vir	@LMC	W	$17.335 \pm 0.017$	$-2.496 \pm 0.021$	0.108	13.2	153	13	
BL Her + W Vir + RV Tau <sup><math>c</math></sup>	LMC	W	$17.358 \pm 0.014$	$-2.530 \pm 0.017$	0.089	9.00	136	10	
BL Her + W Vir + RV Tau <sup><math>c</math></sup>	SMC	W	$17.577 \pm 0.073$	$-2.388 \pm 0.097$	0.232	64.9	28	0	
BL Her + W Vir + RV Tau <sup><math>c</math></sup>	@LMC	W	$17.355 \pm 0.017$	$-2.526 \pm 0.020$	0.118	15.8	162	12	
AC FU	LMC	W	$16.612 \pm 0.020$	$-3.158 \pm 0.141$	0.150	25.7	62	0	
AC FO	LMC	W	$16.029 \pm 0.058$	$-3.373 \pm 0.247$	0.140	24.2	19	0	
BL Her + W Vir	LMC	W	$17.364 \pm 0.015$	$-2.521 \pm 0.022$	0.105		131		1
BL Her + W Vir	SMC	W	$17.554 \pm 0.083$	$-2.304 \pm 0.107$	0.230		27		2
BL Her + W Vir + RV Tau <sup><math>d</math></sup>	LMC	W	$17.33 \pm 0.03$	$-2.53 \pm 0.03$					3
BL Her	Theory	W	$17.30\pm0.07$	$-2.43 \pm 0.02$					4
AC FU	LMC	W	$16.59\pm0.02$	$-3.41 \pm 0.16$	0.15				5
AC FO	LMC	W	$16.05 \pm 0.05$	$-3.44 \pm 0.22$	0.13				5
AC FU	Theory	W	16.55	-2.94					6
BL Her	LMC	$M_{\rm bol}$	$+0.141 \pm 0.051$	$-1.749 \pm 0.200$	0.274	33.0	57	4	
BL Her	SMC	$M_{\rm bol}$	$-0.250 \pm 0.176$	$-0.691 \pm 0.717$	0.302	64.9	15	2	
BL Her	MCs	$M_{\rm bol}$	$-0.027 \pm 0.065$	$-1.326 \pm 0.257$	0.282	89.5	72	6	
W Vir	LMC	$M_{\rm bol}$	$0.723 \pm 0.115$	$-2.358 \pm 0.119$	0.186	36.8	74	5	
W Vir	SMC	$M_{\rm bol}$	$0.965 \pm 0.318$	$-2.589 \pm 0.319$	0.210	33.2	10	0	
W Vir	MCs	$M_{\rm bol}$	$0.743 \pm 0.109$	$-2.379 \pm 0.112$	0.201	37.1	85	4	
RV Tau <sup>d</sup>	LMC	$M_{\rm hol}$	$+1.442 \pm 1.146$	$-2.919 \pm 0.750$	0.301	91.1	15	0	
RV Tau <sup><math>d</math></sup>	SMC	$M_{\rm hol}$	$-1.088 \pm 0.433$	$-1.367 \pm 0.290$	0.041	4.6	4	0	
RV Tau <sup><math>d</math></sup>	MCs	$M_{\rm hol}$	$+0.951 \pm 0.974$	$-2.620 \pm 0.639$	0.298	78.4	19	0	
BL Her $+$ W Vir	LMC	$M_{\rm hol}$	$+0.199 \pm 0.035$	$-1.827 \pm 0.042$	0.230	40.6	130	10	
BL Her $+$ W Vir	SMC	$M_{\rm hol}$	$-0.087 \pm 0.100$	$-1.561 \pm 0.182$	0 349	256	26	1	
BL Her $+$ W Vir	MCs	$M_{hol}$	$+0.068 \pm 0.037$	$-1.704 \pm 0.049$	0.267	83.1	159	8	
BL Her + W Vir + RV Tau <sup><math>c</math></sup>	LMC	$M_{hol}$	$+0.226 \pm 0.033$	$-1.870 \pm 0.039$	0.233	40.5	136	11	
BL Her + W Vir + RV Tau <sup><math>c</math></sup>	SMC	$M_{hol}$	$-0.048 \pm 0.101$	$-1.686 \pm 0.172$	0.370	275	27	1	
BL Her + W Vir + RV Tau <sup><math>c, e</math></sup>	MCs	$M_{1}$	$+0.119 \pm 0.036$	$-1.787 \pm 0.044$	0.276	81.8	166	9	
AC FU	IMC	$M_1$	$-0.436 \pm 0.033$	$-3.122 \pm 0.044$	0.255	71 3	61	1	
ACFO	LMC	$M_{\rm tot}$	$-1.126 \pm 0.033$	$-3.248 \pm 0.215$	0.233	53.2	20	0	
ACTO	LIVIC	1v1 bol	$1.120 \pm 0.074$	$5.2+0 \pm 0.505$	0.244	55.2	20	U	

**References.** (1) Matsunaga et al. (2009); (2) Matsunaga et al. (2011); (3) Manick et al. (2017); (4) Di Criscienzo et al. (2007) for [Fe/H] = -1,  $l/H_p = 1.5$ , and LMC distance modulus 18.50; (5) Ripepi et al. (2014) ; (6) Marconi et al. (2004) for  $M = 1.3 M_{\odot}$  and LMC distance modulus 18.50.

**Notes.** <sup>(a)</sup> For the *PL* relations in the Wesenheit index "@LMC" means the stars in the LMC plus the stars in the SMC placed at the distance of the LMC by a shift of 0.432 magnitude. <sup>(b)</sup> The reduced  $\chi^2$  is based on an assumed "error" in the Wesenheit index and bolometric magnitude of 0.03 mag. <sup>(c)</sup> Excluding RVTs with dust excess and for *P* < 50 days. <sup>(d)</sup> Excluding RVTs with dust excess. <sup>(e)</sup> The preferred solution.

relations is significantly larger than in the corresponding Wesenheit relations. There could be several reasons for this. First, the Wesenheit relations are based on two intensity-mean magnitudes, while the luminosities are derived based on a fit to the entire SED, that is based on non-contemporaneous photometry. Second, if there are issues related to blending or binarity then certain combinations of the parameters involved may still yield a Wesenheit index close to the mean relation, but the fitting of the entire SED will more likely yield deviant results.

For comparison we will refer to two other systems throughout the discussion, namely the best studied of the known CCs in an eclipsing binary in the LMC (OGLE-LMC-CEP-0227), and one of the best studied T2C in our Galaxy,  $\kappa$  Pav (WVir type, P = 9.09 days). The latter has a HST-based distance of  $180 \pm 9$  pc (Benedict et al. 2011) and a metallicity of [Fe/H]=



Fig. 1. The Wesenheit *PL* relation. Stars in the SMC are plotted in red, and shifted to the distance of the LMC. Some outliers are marked with their identifier. Stars with an IR excess according to GJ17 are marked by a green plus sign. Stars that show eclipsing or ellipsoidal variations according to OGLE are marked by a blue cross. Stars plotted as a blue diamond are OGLE-LMC-CEP-0227 (the classical Cepheid in an eclipsing binary system, at P = 3.79 days), and the Galactic T2C  $\kappa$  Pav (at P = 9.08 days), scaled to the distance of the LMC, see text. For -0227 both the system value is plotted (the smaller, brighter point), and the Wesenheit magnitude of the Cepheid in the system (from Pilecki et al. (2013)). The black solid line is the relation derived from the BLH + WVIR + non-dusty RVTs with periods below 50 days in the LMC (see Table 1), plotted over the entire period range. The blue lines indicate the Wesenheit relation for CC in the LMC from Soszyński et al. (2008a) for FU (solid line) and FU (dashed line) pulsators, and the relation for RRab stars (at  $\log P < -0.08$ ) from Soszynski et al. (2003).

0.0 (Luck & Bond 1989). It is not listed in the 1st *Gaia* data release (Gaia Collaboration et al. 2016). Time-series photometry in *V*, *I* is available from Berdnikov (2008), from which we derived the mean magnitudes. In Figure 1 it is plotted as if it were located at the adopted distance to the LMC. Breitfelder et al. (2015) quote an effective temperature of  $T_{\rm eff} = 5739 \pm 107$  K, implying  $L = 508 \pm 65 L_{\odot}$ . Pilecki et al. (2013) have derived the *V*, *I* magnitudes of the two components in OGLE-LMC-CEP-0227, and the Wesenheit magnitude of the Cepheid in the system and of the total binary system are plotted in Figure 1 (at P = 3.79d), together with the Wesenheit relation for FU and FO CCs in the LMC from Soszyński et al. (2008a). Pilecki et al. (2013) also derived log  $L = 3.158 \pm 0.049 L_{\odot}$  and  $T_{\rm eff} = 6050 \pm 160$  K, in agreement with Marconi et al. (2013) (log  $L = 3.16 \pm 0.02 L_{\odot}$ ,  $T_{\rm eff} = 6100 \pm 50$  K).

 $\kappa$  Pav, that is close to the estimated *PL* relation in the Wesenheit index, is brighter than the relation in bolometric magnitude. The derived radius and effective temperature (Breitfelder et al. 2015) imply  $M_{bol} = -2.01 \pm 0.13$  while the various *PL* relations gives values in the range -1.53 to -1.59. This could be due to the intrinsic width of the IS, the assumed distance (although the HST-based distance is accurate to 5%), a metallicity dependence of the *PL* relation (this is not obvious from a comparison of LMC and SMC objects), or the fact that it has a binary companion. In fact, Matsunaga et al. (2009) discusses  $\kappa$  Pav in detail, and suggests that it should be classified as a pWVir object.

The outliers that are marked in both figures are mostly pWVir type stars, some of which have been classified as binaries by the OGLE team: OGLE-LMC-T2CEP-098, and -023, OGLE-SMC-T2CEP-007, -010, -028, or where the LITE was tentatively detected in GJ17, OGLE-SMC-T2CEP-001, and -029. The other outliers are mostly dusty objects with infrared excess detected in GJ17 namely some pWVir objects (OGLE-LMC-T2CEP-201



**Fig. 2.** Bolometric *PL*-relation. Stars in the SMC are plotted in red. The error in  $M_{bol}$  is smaller than the plot symbol. Some outliers are plotted with their identifier. Stars with an IR excess according to GJ17 are marked by a green plus sign. Stars that show eclipsing or ellipsoidal variations according to OGLE are marked by a blue cross. The classical Cepheid in the eclipsing binary OGLE-LMC-CEP-0227 (at P = 3.79 days) and the Galactic T2C  $\kappa$  Pav (at P = 9.08 days) are plotted as blue diamonds. The black solid line is the relation derived from the BLH + WVIR + non-dusty RVTs with periods below 50 days in the LMC (see Table 1), plotted over the entire period range.

and OGLE-SMC-T2CEP-011) and mostly RVT (OGLE-LMC-T2CEP-016, -067, -147, -174, -199).

### 3. Period – Radius relation

Figure 3 shows the *PR* relation based on the derived effective temperatures and luminosities in GJ17. The resulting radii with error bars are given in Table A.

*PR* relations have been derived for various combinations of the T2C subclasses in the SMC, LMC, and both, and for the FU and FO ACs in the LMC and the results are listed in Tab. 2. Stars showing eclipsing or ellipsoidal variation have been excluded in the fitting and iterative  $3\sigma$  clipping has been applied to remove outliers. Contrary to the *PL* relations where the dusty RVT stars deviated significantly and where excluded this is not the case here.

Marconi et al. (2015) present the latest nonlinear, timedependent convective hydrodynamical models of RRL stars for different metallicites and masses. Specifically they present Period-Mass-Radius-Metallicity (PMRZ) relations for fundamental and first-overtone pulsators (Their Eqs. 7 and 8). As they were concerned with RRL they excluded "the sequence D models" (see Marconi et al. (2015) for details) in their fitting procedure, since these luminosity levels were considered too bright for typical RRLs. However, these luminosities are typical for T2C, and therefore we re-derived the PMRZ relation for all models with log  $L > 1.65 L_{\odot}$  (and that reach up to log  $L \sim 2.0$ , and periods up to  $\sim 2.4$  days) using their dataset. We find:

$$\log R = (0.763 \pm 0.003) - (0.037 \pm 0.001) \log Z + (0.560 \pm 0.004) \log P \text{ (N = 195)} (1)$$

for FU pulsators, and

$$\log R = (0.855 \pm 0.005) - (0.034 \pm 0.001) \log Z + (0.585 \pm 0.007) \log P \text{ (N = 63)}$$
(2)

for FO pulsators. These relations are plotted in Fig. 3 at the average metallicity of RRL in the LMC (Gratton et al. 2004) of [Fe/H] = -1.5 (or  $\log Z = -3.23$ ). The theoretical relation lies

above the observed one. The slope agrees within the error bar with the observed relation for BLH (see Table. 2), but the zero point is slightly larger.

In a similar way, Bono et al. (2000) present non-linear pulsation models for CCs for various masses and metallicities. Period-Radius relations for FU pulsators at three different metallicities were already presented in Bono et al. (1998). Here we have rederived the PMRZ relations for FU and FO pulsators from the Bono et al. (2000) dataset, combining the "canonical" and "noncanonical" models (like they did), and find

$$\log R = (1.115 \pm 0.012) - (0.039 \pm 0.005) \log Z + (0.653 \pm 0.003) \log P \text{ (N = 202)} (3)$$

for FU pulsators, and

$$\log R = (1.257 \pm 0.028) - (0.003 \pm 0.014) \log Z + (0.706 \pm 0.016) \log P \text{ (N = 27)}$$
(4)

for FO pulsators. These relations are plotted in Fig. 3 at the average metallicity of Cepheids in the LMC (Romaniello et al. 2008) of [Fe/H] = -0.33 (or log Z = -2.06).

For comparison we have plotted objects with known radii. The values for the Cepheid in OGLE-LMC-CEP-0227 and Galactic T2C  $\kappa$  Pav are plotted as blue diamonds. Based on a Baade-Wesselink type analysis. Breitfelder et al. (2015) derived a projection factor of  $p = 1.26 \pm 0.04 \pm 0.06$ , and a radius of  $R = 22.83 \pm 1.14 R_{\odot}$ . Big light-blue stars represent Galactic Type II Cepheids that had their radii derived by Balog et al. (1997) using the Baade-Wesselink method. In case of  $\kappa$  Pav ( $R = 19 \pm 5 R_{\odot}$ ) their result is in good agreement with Breitfelder et al. (2015). It must be noted that since the article was published in 1997, some of the objects have been reclassified. That explains why they scatter so much. Looking at the classification by the General Catalog of Variable Stars (GCVS)<sup>2</sup> and the International Variable Star Index  $(VSX)^3$  it appears that KL Aql (P= 6.1 day), V733 Aql (P= 6.2), BB Her (P= 7.5) and DR Cep (P= 19.1) are CCs. DQ And (P= 3.2) has a questionable classification, but it is more likely than not that is a CCs, too. The cases of TX Del (P= 6.2) and IX Cas (P= 9.1) are different, because their radius from the Baade-Wesselink analysis might have been influenced with the fact that they are in binary systems. AU Peg (P= 2.4) is hard to interpret, because it was suggested that it might not be a T2C, and the radius of  $19 \pm 4 R_{\odot}$  puts it above the *PR* relation for T2Cs. It is also a binary, so, again, that could have had an influence on the determined radius. BL Her (P= 7.5), XX Vir (P= 1.3), SW Tau (P=1.6), NW Lyr (P=1.6), V553 Cen (P= 2.1, a C-rich object),  $\kappa$  Pav, AL Vir (P= 10.3), W Vir (P= 17.3) and V1181 Sgr (P=21.3) are T2Cs, and they follow our *PR* relation.

There is no obvious dependence of the *PR* relation on metallicity, or on subclass. Within the error bars, all T2C can be represented by a single *PR* relation (solutions 13-15). For this type of relation the slope between the solution for SMC and LMC stars differ by  $2\sigma$ , but slope and zero point are not independent. At the characteristic period of 10 days the predicted radii for an SMC and LMC T2C are identical. Combining both galaxies and all periods, solution (15) becomes our preferred *PR* relation for T2Cs.

Table 2 also includes the old relation presented in Burki & Meylan (1986). They did not give error bars, but at face value the relation is similar to the preferred relation we derive for the MC T2Cs. Together with the T2C from Balog et al. (1997)



**Fig. 3.** The Period-radius relation. Stars in the SMC are plotted in red. The black solid line is a fit to the BL Her, W Vir and RV Tau stars in the LMC (excluding  $3\sigma$  outliers). The blue solid and dashed lines are the theoretical *PR* relations for FU and FO RRL (shorter periods) and CC in the LMC, respectively (see text). The values for the Cepheid in the eclipsing binary system OGLE-LMC-CEP-0227 (at *P* = 3.79 days) and the Galactic T2C  $\kappa$  Pav (at *P* = 9.08 days) are plotted as blue diamonds. Light blue stars are represent the stars from Balog et al. (1997). Details about these stars are given in the text.

this supports the suggestion that there is no strong dependence of the PR relation on metallicity.

#### 4. Masses from evolutionary models

Following Section 3 we derived the following equation for FU pulsators from the models in Marconi et al. (2015) with  $\log L > 1.65$ ,

$$\log P = (11.468 \pm 0.049) + (0.8627 \pm 0.0028) \log L - (0.617 \pm 0.015) \log M - (3.463 \pm 0.012) \log T_{\text{eff}} + (0.0207 \pm 0.0013) \log Z \quad (N = 195, \sigma = 0.0044). \quad (5)$$

Similarly, we used the models in Bono et al. (2000) to find for FU pulsators (cf. their Table 6),

 $\log P = (10.649 \pm 0.085) + (0.9325 \pm 0.0053) \log L$ 

$$- (0.799 \pm 0.020) \log M - (3.282 \pm 0.022) \log T_{\text{eff}} + (0.0393 \pm 0.0026) \log Z \quad (N = 202, \sigma = 0.0085) \quad (6)$$

Equations 5 and 6 allow us to derive the current mass if we know period, luminosity, effective temperature and metallicity. The procedure seems to give sensible results. For the stellar parameters derived for the CC -0227 (Pilecki et al. 2013), and its metallicity of Z = 0.004 (Marconi et al. 2013), the equation based on the Cepheid models gives a mass of  $4.41 \pm 0.44 M_{\odot}$ , in agreement with the masses found by Pilecki et al. (2013) ( $4.165 \pm 0.032 M_{\odot}$ ) and Marconi et al. (2013) ( $4.14 \pm 0.06 M_{\odot}$ ). However, the equation from the RRL pulsation modes also gives an estimate that is correct within the error bar, namely  $5.86 \pm 1.18 M_{\odot}$ .

We used Equations 5 and 6 with Z = 0.004 (for both LMC and SMC) to estimate the masses. For the overtone AC the equations were evaluated at their fundamental period log  $P_{\rm FU} =$ log  $P_{\rm FO} + 0.127$ . Errors were estimated from the error in  $T_{\rm eff}$  and L, and the intrinsic scatter in the relation. The results are given in Table A.1. The Cepheid and RRL-based masses agree within 3× the combined error bars (marked as "OK" in Table A.1) or within 15% irrespective of the error bars (marked as "ok" in Table A.1) in 90% for the BLH (72/80), 82% for the FU ACs (53/65), 74% for the FO ACs (17/23), 58% for the pWVir (17/24), but only 22% for the WVir (20/90) and 18% (9/51) for the RVT.

<sup>&</sup>lt;sup>2</sup> http://www.sai.msu.su/gcvs/gcvs/

<sup>&</sup>lt;sup>3</sup> https://www.aavso.org/vsx/

Sample	Galaxy	$\log R = a$	$+b \log P$	dispersion	$\chi^2_r$	Ν	Ν	Solution	Ref.
		$(R_{\odot})$					outliers		
BL Her	LMC	$0.830 \pm 0.013$	$0.564 \pm 0.049$	0.047	2.60	57	4	(1)	
BL Her	SMC	$0.852 \pm 0.028$	$0.574 \pm 0.117$	0.056	12.4	17	0	(2)	
BL Her	MCs	$0.847 \pm 0.013$	$0.551 \pm 0.052$	0.058	5.43	76	2	(3)	
W Vir	LMC	$0.823 \pm 0.020$	$0.541 \pm 0.021$	0.037	1.74	77	2	(4)	
W Vir	SMC	$0.709 \pm 0.079$	$0.620 \pm 0.071$	0.038	4.11	10	0	(5)	
W Vir	MCs	$0.828 \pm 0.020$	$0.531 \pm 0.020$	0.037	2.25	87	2	(6)	
RV Tau	LMC	$0.848 \pm 0.141$	$0.528 \pm 0.088$	0.076	5.72	41	1	(7)	
RV Tau	SMC	$0.977 \pm 0.188$	$0.440 \pm 0.124$	0.039	2.54	7	0	(8)	
RV Tau	MCs	$0.864 \pm 0.112$	$0.517 \pm 0.071$	0.072	5.16	48	1	(9)	
BL Her + W Vir	LMC	$0.837 \pm 0.007$	$0.528 \pm 0.008$	0.041	2.09	134	6	(10)	
BL Her + W Vir	SMC	$0.869 \pm 0.015$	$0.480 \pm 0.022$	0.050	9.81	27	0	(11)	
BL Her + W Vir	MCs	$0.852 \pm 0.006$	$0.508 \pm 0.008$	0.044	3.46	161	6	(12)	
BL Her + W Vir + RV Tau	LMC	$0.833 \pm 0.007$	$0.535 \pm 0.007$	0.050	2.82	174	8	(13)	
BL Her + W Vir + RV Tau	SMC	$0.861 \pm 0.013$	$0.501 \pm 0.016$	0.050	8.75	34	0	(14)	
BL Her + W Vir + RV Tau <sup><math>a</math></sup>	MCs	$0.846 \pm 0.006$	$0.521 \pm 0.006$	0.053	3.91	209	7	(15)	
AC FU	LMC	$0.972 \pm 0.005$	$0.692 \pm 0.034$	0.045	2.39	61	1	(16)	
AC FO	LMC	$1.113 \pm 0.016$	$0.733 \pm 0.073$	0.054	3.65	20	0	(17)	
T2C	Galactic	0.87	0.54						(1)

Table 2. Period-Radius relations.

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References. (1) Burki & Meylan (1986).

Notes. <sup>(a)</sup> The preferred solution.

The effect of changing the metallicity was investigated. As a test it was lowered to Z = 0.0012 that would give a mass for the Cepheid -0227 from the Cepheid models in agreement with the observations (see above). This improved the agreement between the two mass estimates for the BLH and WVir, slightly reduced the agreement for the FU ACs and left the other percentages unchanged.

For the estimates based on Z = 0.004 the geometric mean of the two estimates was taken. For the various pulsation classes we find the following range in masses (listed are the 10,50,90% percentiles), where known eclipsing and ellipsoidal variables were excluded: BL Her (0.36, 0.49, 0.87  $M_{\odot}$ ), W Vir (0.31, 0.41, 0.57  $M_{\odot}$ ), pW Vir (0.37, 0.74, 1.29  $M_{\odot}$ ), RV Tau (0.25, 0.43, 0.82  $M_{\odot}$ ), and ACs (0.89, 1.29, 1.90  $M_{\odot}$ ), with the same range for FU and FO pulsators. Assuming Z = 0.0012 would lower these mass estimates by about 5%. For the RVT it does not matter significantly whether one separates them into the dusty or non-dusty ones.

Taking only the stars where the two mass estimates agree (the "OK" and "ok" from Table A.1) leaves these ranges essentially unchanged for the BLH and the ACs. For the WVir the range becomes (0.43, 0.50, 0.66  $M_{\odot}$  based on 20 stars). The pWVir have been suggested to be in binary systems. Including eclips-ing/ellipsoidal stars, and taking the stars where the two mass estimates agree the mass range is increased significantly to (0.72, 1.22, 1.77  $M_{\odot}$ , for 14 stars). The number of RVT where the two mass estimates agree (and are non-eclipsing/ellipsoidal) is only 7, and the median mass is 0.82  $M_{\odot}$ .

The classes of objects where the mass estimates agree best and most are the BLH and ACs. For these classes the estimates also agree with previous estimates in the literature. For the WVir the situation is slightly less clear but the mass estimates are similar to those of the BLH. The most confusing picture is presented by the pWVir and the RVT. The mass estimate for the former classes is definitely larger than for the BLH and WVir.

Some of the known binaries have a (spurious) large mass assigned: LMC -098 (3  $M_{\odot}$ , pWVir), SMC -007 (1.9  $M_{\odot}$ , RVT),

 $-010 (2.3 M_{\odot}, \text{pWVir}), -028 (1.6 M_{\odot}, \text{pWVir}), \text{ and } -029 (2.5 M_{\odot}, \text{pWVir})$ RVT). Based on this, the following stars (non ACs) could also be binaries: The LMC objects -032 (RVT, 1.9  $M_{\odot}$ ), -123 (BL-Her, 2.2  $M_{\odot}$ ), -136 (BLHer, 2.0  $M_{\odot}$ ), -153 (BLHer, 1.6  $M_{\odot}$ ), -185 (WVir, 4.5  $M_{\odot}$ ), and SMC objects -001 (pWVir, 1.7  $M_{\odot}$ ), and -011 (pWVir, 1.8  $M_{\odot}$ ). The first 5 stars listed were also removed as outliers in the PR relation, and -153 and -185 were also removed as outliers in the  $P - M_{bol}$  relation. -185 was an outlier in the amplitude-magnitude diagram (Fig. 10 in GJ17). None of these stars were marked as possible binaries based on the LTT effect in GJ17 however. -153 has been indicated by the OGLE team as blended, and the finding chart for -156 on the OGLE-III Variable Stars Database (http://ogledb.astrouw.edu.pl/~ogle/CVS/) suggests it is blended as well, so for those stars that could easily be the cause of their brighter appearance. On the other hand, based on the mass estimate, period, and the fact that it is brighter and larger than the other BLH, -123 could be classified as an FU AC.

During the refereeing process Pilecki et al. (2017) appeared that analysed this system in detail and derived a mass of 1.51  $\pm 0.09 \ M_{\odot}, T_{\rm eff} = 5300 \pm 100 \ {\rm K}, \text{ and } L = 450 \pm 40 \ L_{\odot} \text{ for}$ the pulsating star, and  $6.8 \pm 0.4 M_{\odot}$ ,  $T_{\text{eff}} = 9500 \pm 500$  K, and  $L = 5000 \pm 1100 L_{\odot}$  for the secondary. Fitting the SED as a single object GJ17 found  $T_{\text{eff}} = 7375 \pm 312$  K and  $L = 2857 \pm 169 L_{\odot}$ . Using the luminosity and effective temperature (and errors) from Pilecki et al. (2017) the mass estimate based on the Cepheid, respectively, RRL pulsation models is  $1.37 \pm 0.04 M_{\odot}$ , respectively,  $1.52 \pm 0.07 M_{\odot}$ , in agreement with Pilecki et al. (2017). The parameters they derived, in particular the mass, depend on the adopted, so-called, projection factor, p. We find that the geometric mean of the Cepheid and RRL pulsation mass, and their derived mass agrees best for  $p = 1.32 \pm 0.03$ , in excellent agreement with their adopted  $p = 1.30 \pm 0.04$ . Interestingly, their derived values of  $M_{\rm bol}$  = -1.88 ± 0.09 and R = 25.2 ± 0.4  $R_{\odot}$ (and that do not depend very much on the adopted value of p) still make the Cepheid overluminous and oversized with respect to our preferred solutions of Tables 1 and 2 that give  $M_{\text{bol}} = -1.12 \pm 0.05$ , and  $R = 16.2 \pm 0.3 R_{\odot}$ .

The mass estimates for the RVT show both very large and very small values. As indicated above, many RVT have mass estimates that are well above that expected for a post-AGB object (0.55 - 1.1  $M_{\odot}$ ). In addition, of the about 30 stars that have a mass estimate below 0.35  $M_{\odot}$ , 10 are RVT and 6 of those have a dust excess. Such low masses are also not expected from single-star evolution and, as remarked in in GJ17, the shape of the dust excess in these SEDs points to a disk-like structure that is thought to result from binary evolution. Possibly some are related to the so called binary evolutionary pulsators (BEP), binary stars that appear in the IS after significant mass transfer. Recently, Karczmarek et al. (2017) did extensive simulations to find contaminations of genuine RRL and classical Cepheids of respectively, 0.8 and 5% by BEP. In GJ17 we estimated that a contamination of several percent is plausible for T2C as well.

## 5. Summary and conclusions

The luminosities and effective temperatures derived in GJ17 for 335 T2Cs and ACs in the SMC and LMC were used to study the period-Wesenheit, and for the first time to our knowledge in the 21st Century, the period-bolometric luminosity and *PR* relations for these classes of stars.

The  $P - M_{bol}$  relation shows more scatter than the *PW* relation. This is likely due to the fact that the fits to the SEDs presented in GJ17 are based on non-contemporaneous photometry over a large wavelength region. This will introduce some "natural scatter", but will likely reveal the effect of binarity or blending more easily than when using only the OGLE mean *V*, *I* magnitudes. The period-bolometric luminosity and *PR* relations do not significantly depend on metallicity (as probed by the T2C in the SMC and LMC, and supported by the limited data for Galactic T2Cs), and excluding the dusty RVTs, the T2C can be described by single relationships.

We used the published results of theoretical pulsation models for classical Cepheids and RRL to derive period-luminositymass-temperature-metallicity relations. Assuming a metallicity these relations allow us to derive the pulsation mass for all objects based on both types of models. The RRL and CC models agree well and most for the BLH and ACs. The masses agree with those in the literature, respectively, ~ 0.5  $M_{\odot}$  and ~ 1.3  $M_{\odot}$ . For the RVT the agreement with the two mass estimates is poorest, and often indicates masses that are inconsistent with singlestar evolution of a post-AGB star: either above ~ 1  $M_{\odot}$  or well below ~ 0.5  $M_{\odot}$ .

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#### References

- Balog, Z., Vinko, J., & Kaszas, G. 1997, AJ, 113, 1833
- Benedict, G. F., McArthur, B. E., Feast, M. W., et al. 2011, AJ, 142, 187
- Berdnikov, L. N. 2008, VizieR Online Data Catalog, 2285, 0
- Bhardwaj, A., Macri, L. M., Rejkuba, M., et al. 2017, AJ, 153, 154
- Bono, G., Caputo, F., & Marconi, M. 1998, ApJ, 497, L43
- Bono, G., Caputo, F., & Santolamazza, P. 1997a, A&A, 317, 171
- Bono, G., Caputo, F., Santolamazza, P., Cassisi, S., & Piersimoni, A. 1997b, AJ, 113, 2209
- Bono, G., Castellani, V., & Marconi, M. 2000, ApJ, 529, 293

- Breitfelder, J., Kervella, P., Mérand, A., et al. 2015, A&A, 576, A64
- Burki, G. & Meylan, G. 1986, A&A, 159, 261
- Caputo, F., Castellani, V., Degl'Innocenti, S., Fiorentino, G., & Marconi, M. 2004, A&A, 424, 927
- Catelan, M. & Smith, H. A. 2015, Pulsating Stars
- Cioni, M.-R. L., Clementini, G., Girardi, L., et al. 2011, A&A, 527, A116
- Clementini, G., Ripepi, V., Leccia, S., et al. 2016, A&A, 595, A133
- Di Criscienzo, M., Caputo, F., Marconi, M., & Cassisi, S. 2007, A&A, 471, 893
- Feast, M. W., Laney, C. D., Kinman, T. D., van Leeuwen, F., & Whitelock, P. A. 2008, MNRAS, 386, 2115
- Fiorentino, G. & Monelli, M. 2012, A&A, 540, A102
- Gaia Collaboration, Prusti, T., de Bruijne, J. H. J., et al. 2016, A&A, 595, A1
- Gratton, R. G., Bragaglia, A., Clementini, G., et al. 2004, A&A, 421, 937
- Groenewegen, M. A. T. 2012, A&A, 543, A36
- Groenewegen, M. A. T. & Jurkovic, M. 2017, ArXiv e-prints [arXiv:1705.00886]
- Groenewegen, M. A. T., Udalski, A., & Bono, G. 2008, A&A, 481, 441
- Irwin, J. B. 1952, ApJ, 116, 211
- Ivezić, Ž., Nenkova, M., & Elitzur, M. 1999, DUSTY: Radiation transport in a dusty environment, Astrophysics Source Code Library

Kamath, D., Wood, P. R., Van Winckel, H., & Nie, J. D. 2016, A&A, 586, L5 Karczmarek, P., Wiktorowicz, G., Iłkiewicz, K., et al. 2017, MNRAS, 466, 2842 Luck, R. E. & Bond, H. E. 1989, ApJ, 342, 476

- Macri, L. M., Ngeow, C.-C., Kanbur, S. M., Mahzooni, S., & Smitka, M. T. 2015, AJ, 149, 117
- Manick, R., Van Winckel, H., Kamath, D., Hillen, M., & Escorza, A. 2017, A&A, 597, A129
- Marconi, M., Coppola, G., Bono, G., et al. 2015, ApJ, 808, 50
- Marconi, M., Fiorentino, G., & Caputo, F. 2004, A&A, 417, 1101
- Marconi, M., Molinaro, R., Bono, G., et al. 2013, ApJ, 768, L6
- Martínez-Vázquez, C. E., Stetson, P. B., Monelli, M., et al. 2016, MNRAS, 462, 4349
- Matsunaga, N., Feast, M. W., & Menzies, J. W. 2009, MNRAS, 397, 933
- Matsunaga, N., Feast, M. W., & Soszyński, I. 2011, MNRAS, 413, 223
- Matsunaga, N., Fukushi, H., Nakada, Y., et al. 2006, MNRAS, 370, 1979
- Nemec, J. M., Nemec, A. F. L., & Lutz, T. E. 1994, AJ, 108, 222
- Pilecki, B., Gieren, W., Smolec, R., et al. 2017, ArXiv e-prints [arXiv:1704.07782]
- Pilecki, B., Graczyk, D., Pietrzyński, G., et al. 2013, MNRAS, 436, 953
- Ripepi, V., Marconi, M., Moretti, M. I., et al. 2014, MNRAS, 437, 2307
- Ripepi, V., Moretti, M. I., Marconi, M., et al. 2015, MNRAS, 446, 3034
- Romaniello, M., Primas, F., Mottini, M., et al. 2008, A&A, 488, 731
- Sandage, A. & Tammann, G. A. 2006, ARA&A, 44, 93
- Soszyński, I., Poleski, R., Udalski, A., et al. 2008a, Acta Astron., 58, 163
- Soszyński, I., Poleski, R., Udalski, A., et al. 2010a, Acta Astron., 60, 17
- Soszynski, I., Udalski, A., Szymanski, M., et al. 2003, Acta Astron., 53, 93
- Soszyński, I., Udalski, A., Szymański, M. K., et al. 2010b, Acta Astron., 60, 91
- Soszyński, I., Udalski, A., Szymański, M. K., et al. 2008b, Acta Astron., 58, 293
- Vassiliadis, E. & Wood, P. R. 1993, ApJ, 413, 641
- Wallerstein, G. 2002, PASP, 114, 689

# **Appendix A: Mass estimates**

Table A.1 contains the radii with error bars, and the mass estimates and error bars for individual object based on the Cepheid and RRL pulsation models (Eqs. 5 and 6). For reference it is also indicated if the star has an IR excess (Dusty=1), or is a known binary (Binary=1). If the two mass estimates agree within  $3\times$  the combined error bars the last column has an "OK" listed, and else, if the two mass estimates still agree within 15% (without considering the errors) the last column has an "ok" listed.

Table A.1. Mass estimates

Name	Type	Period	Radius	Mass <sub>Cep</sub>	Mass <sub>RRL</sub>	Dusty?	Binary?	Agree?
	51	(d)	$(R_{\odot})$	$(M_{\odot})$	$(M_{\odot})$	5		C
OGLE-LMC-ACEP-001	F	0.85	$7.86 \pm 0.48$	$0.891 \pm 0.016$	$1.023 \pm 0.029$	0	0	ok
OGLE-LMC-ACEP-002	F	0.98	$9.32 \pm 0.56$	$1.127 \pm 0.022$	$1.314 \pm 0.045$	0	0	ok
OGLE-LMC-ACEP-003	10	0.51	$5.94 \pm 0.43$	$0.925 \pm 0.020$	$1.063 \pm 0.041$	0	Õ	ok
OGLE-LMC-ACEP-004	F	1.86	13.12 + 2.99	$1.091 \pm 0.202$	$1.202 \pm 0.383$	Ő	Ő	OK
OGLE-LMC-ACEP-005	F	0.93	$853 \pm 050$	$0.960 \pm 0.017$	$1.106 \pm 0.032$	Ő	Ő	ok
OGLE-LMC-ACEP-006	10	1 14	$12.07 \pm 0.00$	$1.703 \pm 0.042$	$2115 \pm 0.032$	Ő	Ő	OR
OGLE LINC ACEP-007	F	0.90	$8.75 \pm 0.66$	$1.705 \pm 0.012$ $1.096 \pm 0.029$	$1.267 \pm 0.064$	0	0	OK
OGLE-LMC-ACEP 007	10	1.00	$10.64 \pm 0.44$	$1.000 \pm 0.020$ $1.500 \pm 0.020$	$1.207 \pm 0.004$ $1.820 \pm 0.043$	0	0	OK
OGLE-LMC-ACEP 000	10	1.00	$10.04 \pm 0.44$ $10.56 \pm 0.42$	$1.300 \pm 0.020$ $1.344 \pm 0.016$	$1.620 \pm 0.043$ $1.605 \pm 0.032$	0	0	
OGLE-LMC-ACEP 010	E	0.83	$10.30 \pm 0.42$ 7.60 ± 0.73	$1.344 \pm 0.010$ 0.878 ± 0.020	$1.003 \pm 0.032$	0	0	OK
OGLE-LMC-ACEP-010	Г Б	1.00	$11.09 \pm 0.73$	$0.678 \pm 0.029$ 1.667 + 0.025	$0.993 \pm 0.039$	0	0	OK
OGLE-LMC-ACEP-011	Г	1.00	$11.44 \pm 1.01$	$1.007 \pm 0.003$ $1.571 \pm 0.610$	$2.233 \pm 0.200$	0	0	OK
OGLE-LMC-ACEP-012	Г 10	0.65	$9.99 \pm 2.00$ 7.51 + 1.09	$1.371 \pm 0.019$ $1.000 \pm 0.000$	$2.065 \pm 1.025$ 1 221 + 0.218	0	0	OK
OGLE-LMC-ACEP-013		0.07	$7.31 \pm 1.08$	$1.090 \pm 0.090$ 1.222 + 0.015	$1.321 \pm 0.218$ $1.220 \pm 0.025$	0	0	
OGLE-LMC-ACEP-014	Г 10	2.29	$13.37 \pm 0.03$	$1.233 \pm 0.013$	$1.339 \pm 0.023$	0	0	OK
OGLE-LMC-ACEP-015		1.58	$12.12 \pm 0.09$	$1.150 \pm 0.020$ $1.261 \pm 0.026$	$1.252 \pm 0.058$ $1.422 \pm 0.052$	0	0	OK
OGLE-LMC-ACEP-010	Г	1.55	$12.51 \pm 0.70$	$1.201 \pm 0.020$	$1.422 \pm 0.055$	0	0	ÛK
OGLE-LMC-ACEP-01/	F T	0.93	$9.64 \pm 0.39$	$1.298 \pm 0.016$	$1.505 \pm 0.031$	0	0	OV
OGLE-LMC-ACEP-018	F	1.02	$8.80 \pm 0.80$	$0.957 \pm 0.031$	$1.046 \pm 0.061$	0	0	UK
OGLE-LMC-ACEP-019	F	0.91	$9.23 \pm 0.50$	$1.259 \pm 0.022$	$1.435 \pm 0.045$	0	0	ok
OGLE-LMC-ACEP-020	10	0.51	$6.14 \pm 0.50$	$1.047 \pm 0.031$	$1.161 \pm 0.062$	0	0	OK
OGLE-LMC-ACEP-021	F	1.30	$11.22 \pm 1.83$	$1.206 \pm 0.136$	$1.396 \pm 0.299$	0	0	OK
OGLE-LMC-ACEP-023	10	0.97	$11.32 \pm 0.69$	$1.811 \pm 0.052$	$2.291 \pm 0.137$	0	0	
OGLE-LMC-ACEP-024	F	0.79	$6.98 \pm 0.24$	$0.825 \pm 0.011$	$0.817 \pm 0.012$	0	0	OK
OGLE-LMC-ACEP-025	10	0.64	$6.82 \pm 0.90$	$0.991 \pm 0.064$	$1.097 \pm 0.129$	0	0	OK
OGLE-LMC-ACEP-026	F	1.74	$14.61 \pm 0.61$	$1.509 \pm 0.020$	$1.815 \pm 0.044$	0	0	
OGLE-LMC-ACEP-027	F	1.27	$11.76 \pm 1.09$	$1.430 \pm 0.069$	$1.649 \pm 0.154$	0	0	OK
OGLE-LMC-ACEP-028	10	0.80	$12.17 \pm 1.33$	$2.467 \pm 0.276$	$3.821 \pm 1.117$	0	0	OK
OGLE-LMC-ACEP-029	F	0.80	$6.69 \pm 0.48$	$0.688 \pm 0.014$	$0.715 \pm 0.021$	0	0	OK
OGLE-LMC-ACEP-030	10	0.89	$10.40 \pm 0.78$	$1.662 \pm 0.063$	$2.060 \pm 0.163$	0	0	OK
OGLE-LMC-ACEP-031	10	1.12	$10.61 \pm 1.34$	$1.293 \pm 0.099$	$1.502 \pm 0.223$	0	0	OK
OGLE-LMC-ACEP-032	F	1.32	$12.24 \pm 0.52$	$1.432 \pm 0.019$	$1.737 \pm 0.041$	0	0	
OGLE-LMC-ACEP-033	F	2.35	$15.90 \pm 0.66$	$1.278 \pm 0.016$	$1.414 \pm 0.027$	0	0	ok
OGLE-LMC-ACEP-034	F	0.73	$8.05 \pm 1.75$	$1.156 \pm 0.209$	$1.383 \pm 0.469$	0	0	OK
OGLE-LMC-ACEP-035	10	0.60	$6.64 \pm 0.25$	$0.977 \pm 0.012$	$1.129 \pm 0.017$	0	0	ok
OGLE-LMC-ACEP-036	F	1.26	$12.09 \pm 0.50$	$1.473 \pm 0.019$	$1.807 \pm 0.042$	0	0	
OGLE-LMC-ACEP-037	F	1.26	$20.42 \pm 2.77$	$4.582 \pm 1.417$	$7.854 \pm 6.898$	0	0	OK
OGLE-LMC-ACEP-038	F	1.34	$10.51 \pm 0.61$	$1.019 \pm 0.017$	$1.107 \pm 0.031$	0	0	OK
OGLE-LMC-ACEP-039	F	0.99	$8.81 \pm 0.18$	$0.981 \pm 0.010$	$1.095 \pm 0.011$	Ő	Ő	ok
OGLE-LMC-ACEP-040	F	0.96	$10.81 \pm 1.25$	$1.589 \pm 0.128$	$2.044 \pm 0.356$	Ő	Ő	OK
OGLE-LMC-ACEP-041	F	0.88	8.57 + 1.64	$1.058 \pm 0.141$	$1.235 \pm 0.306$	Ő	Ő	OK
OGLE-I MC-ACEP-042	F	1.08	$12.10 \pm 0.63$	$1.600 \pm 0.011$	$2329 \pm 0.000$	Ő	0	011
OGLE LINE ACEP-043	10	0.68	$853 \pm 0.35$	$1.013 \pm 0.032$ $1.414 \pm 0.018$	$1.854 \pm 0.044$	0	0	
OGLE LINE ACEP-044	F	1 31	$11.09 \pm 0.99$	$1.111 \pm 0.010$ $1.224 \pm 0.048$	$1.037 \pm 0.091$ $1.327 \pm 0.094$	0	0	OK
OGLE EMC ACEP-045	F	0.68	$6.83 \pm 0.53$	$0.851 \pm 0.020$	$0.994 \pm 0.042$	0	0	ok
OGLE LMC ACEP 046	F	1.26	$11.00 \pm 1.58$	$1.214 \pm 0.110$	$1.374 \pm 0.042$	0	0	OK
OGLE-LMC-ACEP 040	Г Б	1.20 2.18	$11.00 \pm 1.30$ $12.63 \pm 0.74$	$1.214 \pm 0.110$ 0.840 ± 0.014	$1.374 \pm 0.233$	0	0	OK
OGLE-LMC-ACEP 047	Г Б	1.55	$12.05 \pm 0.74$ $14.07 \pm 1.88$	$0.049 \pm 0.014$ $1.622 \pm 0.173$	$0.038 \pm 0.020$ 1 078 ± 0.428	0	0	OK
OGLE-LMC-ACEP-048	Г Б	0.64	$14.07 \pm 1.00$	$1.022 \pm 0.173$	$1.978 \pm 0.428$ $1.008 \pm 0.124$	0	0	OK
OCLE LMC ACEP 050	Г 10	1.40	$0.07 \pm 0.99$	$0.913 \pm 0.008$ 1.750 ± 0.022	$1.000 \pm 0.134$	0	0	
OGLE-LMC-ACEP-030	10	1.40	$15.40 \pm 0.31$	$1.730 \pm 0.023$	$2.022 \pm 0.040$	0	0	OK
OGLE-LMC-ACEP-051	Г	0.71	$7.32 \pm 0.15$	$0.949 \pm 0.010$	$1.128 \pm 0.011$	0	0	OV
OGLE-LMC-ACEP-052		1.20	$12.30 \pm 1.20$	$1.544 \pm 0.088$	$1.885 \pm 0.222$	0	0	OK
OGLE-LMC-ACEP-053		1.89	$10.49 \pm 1.99$	$1.785 \pm 0.174$	$2.231 \pm 0.436$	0	0	OK
OGLE-LMC-ACEP-054	F	0.98	$10.45 \pm 0.70$	$1.346 \pm 0.035$	$1.804 \pm 0.103$	0	0	0.17
OGLE-LMC-ACEP-055	F _	1.61	$13.24 \pm 1.58$	$1.326 \pm 0.094$	$1.569 \pm 0.220$	0	0	OK
OGLE-LMC-ACEP-056	F	1.12	$10.68 \pm 1.57$	$1.284 \pm 0.129$	$1.532 \pm 0.304$	0	0	OK
OGLE-LMC-ACEP-057	F	1.71	$14.65 \pm 0.89$	$1.572 \pm 0.039$	$1.882 \pm 0.094$	0	0	_
OGLE-LMC-ACEP-058	10	0.65	$6.40 \pm 1.16$	$0.889 \pm 0.090$	$0.885 \pm 0.143$	0	0	OK
OGLE-LMC-ACEP-059	F	0.83	$10.67 \pm 0.86$	$1.564 \pm 0.064$	$2.490 \pm 0.274$	0	0	
OGLE-LMC-ACEP-060	F	1.28	$12.21 \pm 0.91$	$1.532 \pm 0.053$	$1.814\pm0.127$	0	0	OK

Name	Туре	Period	Radius	Mass <sub>Cep</sub>	Mass <sub>RRL</sub>	Dusty?	Binary?	Agree?
	Г	(d)	$(R_{\odot})$	$(M_{\odot})$	$(M_{\odot})$	0	0	
OGLE-LMC-ACEP-001	Г Г	0.85	$8.84 \pm 0.52$	$1.175 \pm 0.022$	$1.425 \pm 0.052$	0	0	OV
OGLE-LMC-ACEP-062	Г Г	1.00	$10.02 \pm 1.33$	$1.284 \pm 0.107$	$1.407 \pm 0.213$ $1.220 \pm 0.085$	0	0	
OGLE-LMC-ACEP-005	Г	0.89	$8.80 \pm 0.73$	$1.033 \pm 0.033$	$1.520 \pm 0.083$ $1.627 \pm 0.106$	0	0	
OGLE-LMC-ACEP-004	Г	1.30	$12.17 \pm 0.93$ 11.02 + 1.28	$1.392 \pm 0.040$	$1.027 \pm 0.100$ $1.280 \pm 0.161$	0	0	
OGLE-LMC-ACEP-003	Г Г	1.52	$11.05 \pm 1.38$	$1.109 \pm 0.080$ $1.080 \pm 0.020$	$1.269 \pm 0.101$ $1.252 \pm 0.063$	0	0	OK
OGLE-LMC-ACEP-000	Г	1.04	$9.30 \pm 0.72$	$1.069 \pm 0.029$ 1.625 ± 0.725	$1.232 \pm 0.003$	0	0	
OGLE-LMC-ACEP-007	Г Г	0.62	$10.10 \pm 3.10$ 5.69 ± 0.85	$1.033 \pm 0.733$	$2.221 \pm 2.000$	0	0	OK
OGLE-LMC-ACEP-008	Г Г	0.05	$5.00 \pm 0.03$	$0.032 \pm 0.030$	$0.074 \pm 0.001$ 2.567 ± 0.205	0	0	OK
OGLE-LMC-ACEF-009	10	0.84	$13.40 \pm 1.23$ 7.82 ± 0.71	$1.991 \pm 0.104$ 0.018 ± 0.020	$2.307 \pm 0.293$ 1 010 ± 0.058	0	0	OK
OGLE-LMC-ACEP-070	10	0.04	$7.62 \pm 0.71$ 8 50 ± 0.88	$0.918 \pm 0.029$ 1 102 ± 0.040	$1.019 \pm 0.038$ 1.180 ± 0.004	0	0	OK
OGLE-LMC-ACEP-0/1	IU E	1.05	$0.39 \pm 0.00$ 11 21 $\pm$ 1 21	$1.102 \pm 0.049$ $1.622 \pm 0.117$	$1.160 \pm 0.094$ $1.061 \pm 0.280$	0	0	OK
OGLE-LMC-ACEF-072	Г Е	1.05	$11.21 \pm 1.21$ $13.12 \pm 1.65$	$1.022 \pm 0.117$ $1.523 \pm 0.137$	$1.901 \pm 0.289$ $1.770 \pm 0.310$	0	0	OK
OGLE-LINC-ACEI-073	F	1.47	$13.12 \pm 1.03$ $12.69 \pm 0.74$	$1.323 \pm 0.137$ $1.317 \pm 0.026$	$1.770 \pm 0.010$ $1.500 \pm 0.055$	0	0	ok
OGLE I MC ACEP 075	F	0.60	$12.09 \pm 0.74$ $7.40 \pm 0.67$	$1.317 \pm 0.020$ $1.034 \pm 0.036$	$1.300 \pm 0.033$ $1.203 \pm 0.080$	0	0	OK
OGLE-LINC-ACEP-075	F	1.58	$11.87 \pm 1.11$	$1.034 \pm 0.030$ $1.083 \pm 0.041$	$1.205 \pm 0.000$ $1.182 \pm 0.082$	0	0	OK
OGLE-LINC-ACEP-070	F	1.50	$10.98 \pm 0.50$	$1.003 \pm 0.041$ $1.342 \pm 0.019$	$1.102 \pm 0.002$ $1.662 \pm 0.043$	0	0	OR
OGLE LINC ACEP-078	10	1.12	$10.90 \pm 0.50$ $10.84 \pm 0.58$	$1.342 \pm 0.019$ $1.383 \pm 0.025$	$1.002 \pm 0.049$ $1.542 \pm 0.050$	0	0	OK
OGLE LINC ACEP-079	F	1.15	$10.04 \pm 0.00$ $10.80 \pm 0.82$	$1.305 \pm 0.025$ $1.330 \pm 0.042$	$1.542 \pm 0.050$ $1.509 \pm 0.089$	0	0	OK
OGLE-LINC-ACEP-080	F	1.10	$9.83 \pm 0.02$	$1.550 \pm 0.042$ 1 169 + 0.032	$1.307 \pm 0.007$ $1.342 \pm 0.070$	0	0	OK
OGLE-LINC-ACEP-080	F	0.80	$7.05 \pm 0.74$ 7.75 + 0.45	$0.949 \pm 0.032$	$1.942 \pm 0.070$ $1.081 \pm 0.030$	0	0	ok
OGLE LINC ACEP-082	10	1.04	$13.07 \pm 0.43$	$2166 \pm 0.041$	$3.070 \pm 0.137$	0	0	UK
OGLE LINC ACEL 002	BLHer	1.04	$9.31 \pm 0.20$	$0.507 \pm 0.041$	$0.481 \pm 0.010$	0	0	OK
OGLE LINE TZCEP-002	WVir	18 32	$30.37 \pm 3.39$	$0.507 \pm 0.010$ $0.411 \pm 0.013$	$0.101 \pm 0.010$ $0.310 \pm 0.013$	0	0	OR
OGLE LINC T2CEP-002	RVTau	35.66	$60.28 \pm 8.03$	$0.953 \pm 0.060$	$0.510 \pm 0.015$ $0.714 \pm 0.056$	1	0	OK
OGLE-LMC-T2CEP-004	BLHer	1.92	$12.62 \pm 0.05$	$0.928 \pm 0.000$	$1.032 \pm 0.134$	0	0	OK
OGLE-LMC-T2CEP-005	RVTau	33 19	$50.18 \pm 6.41$	$0.520 \pm 0.000$ $0.605 \pm 0.024$	$0.483 \pm 0.025$	Ő	Ő	011
OGLE-LMC-T2CEP-006	BLHer	1.09	$6.26 \pm 0.54$	$0.414 \pm 0.011$	$0.361 \pm 0.012$	Ő	0 0	ok
OGLE-LMC-T2CEP-007	BLHer	1.24	$6.82 \pm 0.49$	$0.421 \pm 0.011$	$0.372 \pm 0.011$	Ő	Ő	ok
OGLE-LMC-T2CEP-008	BLHer	1.75	$9.19 \pm 0.39$	$0.509 \pm 0.010$	$0.493 \pm 0.011$	Ő	Ő	OK
OGLE-LMC-T2CEP-009	BLHer	1.76	$8.71 \pm 0.35$	$0.460 \pm 0.010$	$0.418 \pm 0.010$	Ő	Ő	OK
OGLE-LMC-T2CEP-010	BLHer	1.50	$7.35 \pm 0.54$	$0.386 \pm 0.011$	$0.336 \pm 0.011$	0	Õ	ok
OGLE-LMC-T2CEP-011	RVTau	39.26	$52.01 \pm 2.21$	$0.592 \pm 0.010$	$0.405 \pm 0.010$	1	Õ	
OGLE-LMC-T2CEP-012	WVir	11.58	$24.80 \pm 2.23$	$0.454 \pm 0.012$	$0.370 \pm 0.012$	0	0	
OGLE-LMC-T2CEP-013	WVir	11.54	$23.84 \pm 1.12$	$0.416 \pm 0.010$	$0.333 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-014	RVTau	61.88	$48.67 \pm 2.12$	$0.283 \pm 0.010$	$0.161 \pm 0.010$	1	0	
OGLE-LMC-T2CEP-015	RVTau	56.52	$72.01 \pm 3.53$	$0.732 \pm 0.011$	$0.559 \pm 0.011$	1	0	
OGLE-LMC-T2CEP-016	RVTau	20.30	$23.45 \pm 2.12$	$0.228 \pm 0.010$	$0.127 \pm 0.010$	1	0	
OGLE-LMC-T2CEP-017	WVir	14.45	$30.64 \pm 2.31$	$0.541 \pm 0.012$	$0.467 \pm 0.013$	0	0	
OGLE-LMC-T2CEP-018	BLHer	1.38	$7.70 \pm 0.30$	$0.474 \pm 0.010$	$0.440 \pm 0.010$	0	0	OK
OGLE-LMC-T2CEP-019	pWVir	8.67	$27.86 \pm 6.88$	$0.833 \pm 0.135$	$0.819 \pm 0.201$	0	0	OK
OGLE-LMC-T2CEP-020	BLHer	1.11	$7.60\pm0.70$	$0.611 \pm 0.016$	$0.605 \pm 0.023$	0	0	OK
OGLE-LMC-T2CEP-021	pWVir	9.76	$23.72 \pm 1.04$	$0.534 \pm 0.010$	$0.430 \pm 0.010$	0	1	
OGLE-LMC-T2CEP-022	WVir	10.72	$23.70 \pm 1.62$	$0.450\pm0.011$	$0.369 \pm 0.011$	0	0	
OGLE-LMC-T2CEP-023	pWVir	5.23	$24.72 \pm 1.90$	$1.343 \pm 0.044$	$1.323 \pm 0.072$	0	1	OK
OGLE-LMC-T2CEP-024	BLHer	1.25	$6.85 \pm 0.74$	$0.413 \pm 0.012$	$0.373 \pm 0.014$	0	0	OK
OGLE-LMC-T2CEP-025	RVTau	67.97	$75.77 \pm 9.15$	$0.645 \pm 0.025$	$0.478 \pm 0.023$	0	0	
OGLE-LMC-T2CEP-026	WVir	13.58	$28.09 \pm 1.39$	$0.485 \pm 0.010$	$0.406 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-027	WVir	17.13	$27.46 \pm 3.44$	$0.362 \pm 0.013$	$0.260 \pm 0.012$	0	0	
OGLE-LMC-T2CEP-028	pWVir	8.78	$23.71 \pm 2.61$	$0.645 \pm 0.022$	$0.508 \pm 0.022$	0	0	
OGLE-LMC-T2CEP-029	RVTau	31.25	$53.89 \pm 3.43$	$0.845 \pm 0.015$	$0.648 \pm 0.016$	1	0	
OGLE-LMC-T2CEP-030	BLHer	3.94	$14.34 \pm 0.63$	$0.514 \pm 0.010$	$0.459 \pm 0.010$	0	0	ok
OGLE-LMC-T2CEP-031	WVir	6.71	$18.38 \pm 0.84$	$0.454 \pm 0.010$	$0.388 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-032	RVTau	44.56	$96.44 \pm 32.06$	$1.865 \pm 1.092$	$1.863 \pm 1.571$	1	0	OK
OGLE-LMC-T2CEP-033	pWVir	9.39	$23.79 \pm 1.92$	$0.571 \pm 0.013$	$0.461 \pm 0.014$	0	0	
OGLE-LMC-T2CEP-034	WVir	14.91	$29.99 \pm 1.60$	$0.488 \pm 0.010$	$0.419 \pm 0.011$	0	0	
OGLE-LMC-T2CEP-035	WVir	9.87	$26.15 \pm 2.49$	$0.612 \pm 0.017$	$0.557 \pm 0.021$	0	0	OK

Name	Type	Period	Radius	MassCan	Masspri	Dusty?	Binary?	Agree?
	-71-5	(d)	$(R_{\odot})$	$(M_{\odot})$	$(M_{\odot})$			8
OGLE-LMC-T2CEP-036	WVir	14.88	$23.60 \pm 1.55$	$0.308 \pm 0.010$	$0.214 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-037	WVir	6.90	$17.20 \pm 0.75$	$0.385 \pm 0.010$	$0.308 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-038	WVir	4.01	$14.72 \pm 1.46$	$0.607 \pm 0.017$	$0.476 \pm 0.018$	0	0	
OGLE-LMC-T2CEP-039	WVir	8.72	$20.20 \pm 1.72$	$0.418 \pm 0.011$	$0.330 \pm 0.011$	0	0	
OGLE-LMC-T2CEP-040	pWVir	9.63	$33.74 \pm 4.61$	$1.143 \pm 0.090$	$1.182 \pm 0.159$	0	0	OK
OGLE-LMC-T2CEP-041	BLHer	2.48	$10.81 \pm 1.53$	$0.541 \pm 0.023$	$0.440 \pm 0.025$	0	0	OK
OGLE-LMC-T2CEP-042	pWVir	4.92	$14.36 \pm 2.17$	$0.427 \pm 0.018$	$0.320 \pm 0.017$	0	0	
OGLE-LMC-T2CEP-043	WVir	6.56	$16.79 \pm 1.13$	$0.378 \pm 0.010$	$0.312\pm0.010$	0	0	
OGLE-LMC-T2CEP-044	WVir	13.27	$25.38 \pm 1.74$	$0.405 \pm 0.010$	$0.316 \pm 0.011$	0	0	
OGLE-LMC-T2CEP-045	RVTau	63.39	$74.94 \pm 3.79$	$0.706 \pm 0.011$	$0.519 \pm 0.011$	0	0	
OGLE-LMC-T2CEP-046	WVir	14.74	$35.90 \pm 1.70$	$0.797 \pm 0.012$	$0.704 \pm 0.013$	1	0	ok
OGLE-LMC-T2CEP-047	WVir	7.29	$18.63 \pm 1.60$	$0.427 \pm 0.011$	$0.352\pm0.012$	0	0	
OGLE-LMC-T2CEP-048	BLHer	1.45	$7.89 \pm 1.71$	$0.473 \pm 0.036$	$0.436 \pm 0.048$	0	0	OK
OGLE-LMC-T2CEP-049	BLHer	3.24	$12.47 \pm 2.71$	$0.503 \pm 0.041$	$0.426 \pm 0.045$	0	0	OK
OGLE-LMC-T2CEP-050	RVTau	34.75	$36.52 \pm 1.57$	$0.302 \pm 0.010$	$0.184 \pm 0.010$	1	0	
OGLE-LMC-T2CEP-051	RVTau	40.61	$47.45 \pm 3.14$	$0.441 \pm 0.011$	$0.297 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-052	pWVir	4.69	$14.41 \pm 1.91$	$0.466 \pm 0.017$	$0.349 \pm 0.016$	0	1	
OGLE-LMC-T2CEP-053	BLHer	1.04	$6.84 \pm 0.38$	$0.520 \pm 0.011$	$0.496 \pm 0.011$	0	0	OK
OGLE-LMC-T2CEP-054	WVir	9.93	$23.35 \pm 0.57$	$0.473 \pm 0.010$	$0.401 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-055	RVTau	41.01	$50.93 \pm 3.26$	$0.527 \pm 0.011$	$0.356 \pm 0.011$	1	0	
OGLE-LMC-T2CEP-056	WVir	7.29	$19.92 \pm 0.49$	$0.480 \pm 0.010$	$0.425 \pm 0.010$	0	0	ok
OGLE-LMC-T2CEP-057	WVir	16.63	$30.31 \pm 3.42$	$0.456 \pm 0.014$	$0.361 \pm 0.015$	0	0	
OGLE-LMC-T2CEP-058	RVTau	21.48	$33.97 \pm 3.83$	$0.431 \pm 0.013$	$0.328 \pm 0.013$	0	0	
OGLE-LMC-T2CEP-059	WVir	16.74	$34.09 \pm 3.16$	$0.595 \pm 0.015$	$0.496 \pm 0.017$	0	0	
OGLE-LMC-T2CEP-060	BLHer	1.24	$7.30 \pm 1.39$	$0.474 \pm 0.030$	$0.453 \pm 0.042$	0	Õ	OK
OGLE-LMC-T2CEP-061	BLHer	1.18	$5.96 \pm 0.86$	$0.336 \pm 0.013$	$0.275 \pm 0.014$	0	Õ	
OGLE-LMC-T2CEP-062	WVir	6.05	$20.36 \pm 3.43$	$0.612 \pm 0.039$	$0.612 \pm 0.061$	0	Õ	OK
OGLE-LMC-T2CEP-063	WVir	6.92	$17.59 \pm 1.49$	$0.403 \pm 0.011$	$0.325 \pm 0.011$	Ő	Ő	011
OGLE-LMC-T2CEP-064	BLHer	2.13	$9.80 \pm 2.05$	$0.473 \pm 0.034$	$0.429 \pm 0.044$	Õ	Õ	OK
OGLE-LMC-T2CEP-065	RVTau	35.05	$45.67 \pm 2.07$	$0.479 \pm 0.010$	$0.339 \pm 0.010$	1	Ő	011
OGLE-LMC-T2CEP-066	WVir	13.11	$25.80 \pm 0.64$	$0.421 \pm 0.010$	$0.338 \pm 0.010$	0	Õ	
OGLE-LMC-T2CEP-067	RVTau	48.23	71.33 + 10.49	$0.978 \pm 0.075$	$0.701 \pm 0.064$	1	Ő	OK
OGLE-LMC-T2CEP-068	BLHer	1 61	$814 \pm 0.60$	$0.970 \pm 0.073$ $0.449 \pm 0.011$	$0.400 \pm 0.0012$	0	Ő	ok
OGLE-LMC-T2CEP-069	BLHer	1.02	7.34 + 1.96	$0.630 \pm 0.088$	$0.626 \pm 0.130$	Ő	Ő	OK
OGLE-LMC-T2CEP-070	WVir	15.44	25.12 + 2.56	$0.348 \pm 0.011$	$0.240 \pm 0.011$	Ő	Ő	011
OGLE-LMC-T2CEP-071	BLHer	1.15	$7.14 \pm 1.67$	$0.497 \pm 0.045$	$0.476 \pm 0.063$	Ő	Ő	OK
OGLE-LMC-T2CEP-072	WVir	14 51	$2670 \pm 123$	$0.412 \pm 0.010$	$0.315 \pm 0.010$	Ő	Ő	011
OGLE-LMC-T2CEP-073	BLHer	3 09	$12.58 \pm 1.02$	$0.519 \pm 0.012$	$0.313 \pm 0.010$ $0.471 \pm 0.014$	Ő	Ő	OK
OGLE-LMC-T2CEP-074	WVir	8 99	$22.53 \pm 1.02$	$0.519 \pm 0.012$ $0.519 \pm 0.011$	$0.426 \pm 0.011$	Ő	Ő	011
OGLE-LMC-T2CEP-075	RVTau	50.19	54.91 + 2.77	$0.458 \pm 0.010$	$0.317 \pm 0.010$	1	Ő	
OGLE-LMC-T2CEP-076	BLHer	2.10	$10.40 \pm 1.10$	$0.519 \pm 0.015$	$0.516 \pm 0.022$	0	Ő	OK
OGLE-LMC-T2CEP-077	BLHer	1 21	$6.82 \pm 0.65$	$0.019 \pm 0.012$ $0.460 \pm 0.012$	$0.385 \pm 0.013$	Ő	1	011
OGLE-LMC-T2CEP-078	pWVir	6.72	$28.22 \pm 0.03$	$1.165 \pm 0.012$	$1.285 \pm 0.019$	Ő	0	ok
OGLE-LMC-T2CEP-079	WVir	14 85	$26.02 \pm 1.10$ $26.06 \pm 2.02$	$0.359 \pm 0.010$	$0.285 \pm 0.0011$	Ő	Ő	on
OGLE-LMC-T2CEP-080	RVTau	40.92	$51.62 \pm 2.02$	$0.539 \pm 0.013$ $0.539 \pm 0.013$	$0.203 \pm 0.011$ $0.371 \pm 0.012$	1	0	
OGLE-LMC-T2CEP-081	WVir	9.48	$22.20 \pm 1.02$	$0.557 \pm 0.019$ $0.457 \pm 0.010$	$0.371 \pm 0.012$ $0.375 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-082	RVTau	35.12	$42.20 \pm 1.02$ $42.65 \pm 4.96$	$0.197 \pm 0.010$ $0.397 \pm 0.013$	$0.379 \pm 0.010$ $0.279 \pm 0.012$	0	0	
OGLE-LMC-T2CEP-083	nWVir	5 97	$12.03 \pm 0.79$ 17.78 + 0.79	$0.397 \pm 0.019$ $0.498 \pm 0.010$	$0.277 \pm 0.012$ $0.427 \pm 0.010$	Ő	Ő	
OGLE-LMC-T2CEP-084	BLHer	1 77	$8.96 \pm 2.84$	$0.190 \pm 0.010$ $0.551 \pm 0.089$	$0.127 \pm 0.010$ $0.447 \pm 0.085$	0	1	OK
OGLE-LMC-T2CEP-085	BLHer	3 41	$11.36 \pm 1.04$	$0.375 \pm 0.007$	$0.302 \pm 0.003$	0	0	UI
OGLE-LMC-T2CEP-086	WVir	15.85	$28.45 \pm 1.27$	$0.373 \pm 0.012$ $0.434 \pm 0.011$	$0.326 \pm 0.012$	0	0	
OGLE-LMC-T2CEP-087	WVir	5 18	1611 + 231	$0.466 \pm 0.019$	$0.407 \pm 0.011$	0	0	OK
OGLE-LMC-T2CEP-088	BLHer	1 95	$779 \pm 0.71$	$0.358 \pm 0.011$	$0.258 \pm 0.023$	0	0	01
OGLE-LMC-T2CEP-080	BLHer	1.75	$6.87 \pm 0.71$	$0.462 \pm 0.011$	$0.230 \pm 0.011$ $0.419 \pm 0.011$	0	0	OK
OGLE-LMC-T2CEP-090	BLHer	1.48	$8.38 \pm 0.64$	$0.524 \pm 0.012$	0.499 + 0.014	0	0	OK
						5	~	<u> </u>

Name	Туре	Period	Radius	Mass <sub>Cep</sub>	Mass <sub>RRL</sub>	Dusty?	Binary?	Agree?
		(d)	$(R_{\odot})$	$(M_{\odot})$	$(M_{\odot})$			
OGLE-LMC-T2CEP-091	RVTau	35.75	$47.36 \pm 8.04$	$0.572 \pm 0.034$	$0.362 \pm 0.024$	1	0	
OGLE-LMC-T2CEP-092	BLHer	2.62	$10.68 \pm 1.94$	$0.441 \pm 0.024$	$0.390 \pm 0.030$	0	0	OK
OGLE-LMC-T2CEP-093	WVir	17.59	$33.65 \pm 2.77$	$0.585 \pm 0.014$	$0.440 \pm 0.013$	0	1	
OGLE-LMC-T2CEP-094	WVir	8.47	$22.54 \pm 1.13$	$0.524 \pm 0.010$	$0.471 \pm 0.011$	0	0	ok
OGLE-LMC-T2CEP-095	WVir	5.00	$15.79 \pm 0.38$	$0.460\pm0.010$	$0.408 \pm 0.010$	0	0	ok
OGLE-LMC-T2CEP-096	WVir	13.93	$25.78 \pm 2.78$	$0.400 \pm 0.012$	$0.306 \pm 0.012$	0	0	
OGLE-LMC-T2CEP-097	WVir	10.51	$22.69 \pm 1.95$	$0.428 \pm 0.011$	$0.338 \pm 0.011$	0	0	
OGLE-LMC-T2CEP-098	pWVir	4.97	$32.80 \pm 2.78$	$3.038 \pm 0.263$	$3.159 \pm 0.478$	0	1	OK
OGLE-LMC-T2CEP-099	WVir	15.49	$35.43 \pm 2.77$	$0.677 \pm 0.015$	$0.628 \pm 0.019$	0	0	OK
OGLE-LMC-T2CEP-100	WVir	7.43	$15.73 \pm 0.97$	$0.292 \pm 0.010$	$0.212 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-101	WVir	11.42	$21.60 \pm 2.54$	$0.357 \pm 0.012$	$0.257 \pm 0.012$	0	0	
OGLE-LMC-T2CEP-102	BLHer	1.27	$7.57 \pm 0.90$	$0.528 \pm 0.018$	$0.481 \pm 0.023$	0	0	OK
OGLE-LMC-T2CEP-103	WVir	12.91	$24.61 \pm 2.16$	$0.395 \pm 0.011$	$0.304 \pm 0.011$	0	0	
OGLE-LMC-T2CEP-104	RVTau	24.88	$47.95 \pm 6.84$	$0.835 \pm 0.052$	$0.676 \pm 0.057$	1	0	OK
OGLE-LMC-T2CEP-105	BLHer	1.49	$8.54 \pm 1.45$	$0.555 \pm 0.033$	$0.520 \pm 0.046$	0	0	OK
OGLE-LMC-T2CEP-106	WVir	6.71	$18.21 \pm 1.20$	$0.450 \pm 0.011$	$0.378 \pm 0.011$	0	0	
OGLE-LMC-T2CEP-107	BLHer	1.21	$9.91 \pm 1.67$	$0.962 \pm 0.093$	$1.106 \pm 0.200$	0	0	OK
OGLE-LMC-T2CEP-108	RVTau	30.01	$41.06 \pm 1.79$	$0.471 \pm 0.010$	$0.323 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-109	BLHer	1.41	$8.23 \pm 0.50$	$0.420 \pm 0.010$	$0.513 \pm 0.012$	0	0	
OGLE-LMC-T2CEP-110	WVir	7.08	$18.84 \pm 1.70$	$0.443 \pm 0.012$	$0.381 \pm 0.013$	Ő	Ő	
OGLE-LMC-T2CEP-111	WVir	7 50	$18.76 \pm 0.84$	$0.419 \pm 0.012$	$0.343 \pm 0.010$	Ő	Ő	
OGLE-LMC-T2CEP-112	RVTau	39.40	52.33 + 3.32	$0.605 \pm 0.012$	$0.409 \pm 0.011$	1	Ő	
OGLE-LMC-T2CEP-113	BLHer	3.09	12.43 + 2.30	$0.540 \pm 0.036$	$0.455 \pm 0.040$	0	Ő	OK
OGLE-LMC-T2CEP-114	F	1.09	$10.01 \pm 0.69$	$1.051 \pm 0.023$	$1.345 \pm 0.060$	Ő	Ő	011
OGLE-LMC-T2CEP-115	RVTau	24 97	$37.00 \pm 2.71$	$0.430 \pm 0.023$	$0.326 \pm 0.000$	0	0	
OGLE-LMC-T2CEP-116	BLHer	1 97	$9.80 \pm 1.04$	$0.190 \pm 0.011$ $0.491 \pm 0.014$	$0.320 \pm 0.011$ $0.488 \pm 0.020$	0	0	OK
OGLE-LMC-T2CEP-117	WVir	6.63	$17.74 \pm 0.80$	$0.191 \pm 0.011$ $0.429 \pm 0.010$	$0.358 \pm 0.020$	0	0	OR
OGLE-LMC-T2CEP-118	WVir	12.70	$26.27 \pm 1.86$	$0.129 \pm 0.010$ $0.457 \pm 0.011$	$0.375 \pm 0.010$	0	0	
OGLE LINC T2CEP-119	RVTau	33.83	$49.26 \pm 8.80$	$0.157 \pm 0.011$ $0.650 \pm 0.048$	$0.373 \pm 0.011$ $0.442 \pm 0.036$	1	0	
OGLE LINC T2CEP 119	WVir	4 56	$15.01 \pm 0.00$	$0.050 \pm 0.040$ $0.464 \pm 0.011$	$0.442 \pm 0.030$ $0.412 \pm 0.011$	0	0	ok
OGLE LINC T2CEP 120	BLHer	2.06	$9.87 \pm 1.67$	$0.489 \pm 0.011$	$0.412 \pm 0.011$ $0.461 \pm 0.036$	0	0	OK
OGLE LINE TZCEP-121	BL Her	1 54	$8.00 \pm 0.81$	$0.109 \pm 0.020$ $0.427 \pm 0.012$	$0.101 \pm 0.000$ $0.411 \pm 0.015$	0	0	OK
OGLE LINC T2CEP 122	BI Her	1.00	$12.26 \pm 1.07$	$1.824 \pm 0.012$	$2.722 \pm 1.103$	0	0	OK
OGLE LINC T2CEP 125	BI Her	1.00	$8.44 \pm 1.17$	$0.426 \pm 0.015$	$0.393 \pm 0.020$	0	0	OK
OGLE LINC T2CEP-125	RVTau	33.03	$44.16 \pm 4.13$	$0.120 \pm 0.013$ $0.464 \pm 0.012$	$0.340 \pm 0.020$	0	0	OR
OGLE LINC T2CEP-126	WVir	16 33	$31.95 \pm 1.84$	$0.101 \pm 0.012$ $0.505 \pm 0.011$	$0.370 \pm 0.012$ $0.432 \pm 0.011$	1	0	
OGLE LINE TZCEP-120	WVir	12.67	$25.53 \pm 4.32$	$0.305 \pm 0.011$ $0.446 \pm 0.022$	$0.132 \pm 0.011$ $0.347 \pm 0.022$	1	0	
OGLE LINC T2CEP 127	WVir	18.49	$36.69 \pm 3.43$	$0.440 \pm 0.022$ $0.623 \pm 0.017$	$0.547 \pm 0.022$ $0.519 \pm 0.018$	0	0	
OGLE LINC T2CEP 120	RVTau	62 51	$50.09 \pm 3.49$ $51.88 \pm 2.20$	$0.023 \pm 0.017$ $0.333 \pm 0.010$	$0.519 \pm 0.010$ $0.189 \pm 0.010$	1	0	
OGLE LINC T2CEP-130	RI Her	1 94	$9.09 \pm 1.71$	$0.555 \pm 0.010$ $0.455 \pm 0.027$	$0.109 \pm 0.010$ $0.402 \pm 0.033$	0	0	OK
OGLE LINE TZCEP-131	BL Her	1.21	$7.09 \pm 0.01$ $7.49 \pm 0.31$	$0.135 \pm 0.027$ $0.416 \pm 0.010$	$0.391 \pm 0.000$	0	0	OK
OGLE LINC T2CEP-131	nWVir	10.02	2452 + 254	$0.552 \pm 0.016$	$0.351 \pm 0.010$ $0.453 \pm 0.017$	0	0	OR
OGLE LINC T2CEP-132	WVir	6.28	$1655 \pm 1.37$	$0.332 \pm 0.010$ $0.400 \pm 0.011$	$0.133 \pm 0.011$ $0.321 \pm 0.011$	0	0	
OGLE LINC T2CEP-134	nWVir	4.08	$17.91 \pm 1.37$	$0.100 \pm 0.011$ $0.857 \pm 0.020$	$0.321 \pm 0.011$ $0.807 \pm 0.029$	0	0	OK
OGLE-LMC-T2CEP-135	RVTau	26.52	$43.20 \pm 3.11$	$0.037 \pm 0.020$ $0.573 \pm 0.012$	$0.007 \pm 0.029$ $0.457 \pm 0.012$	Ő	0	011
OGLE LINC T2CEP-136	RV Iau RI Her	1 32	$13.20 \pm 5.11$ $13.48 \pm 4.37$	$1.719 \pm 0.895$	$2.457 \pm 0.012$ 2.260 + 2.246	0	0	OK
OGLE LINC T2CEP-137	WVir	6.36	$17.18 \pm 2.10$	$0.425 \pm 0.014$	$0.350 \pm 0.015$	0	0	OR
OGLE LINC T2CEP-137	BI Her	1 39	$10.25 \pm 3.71$	$0.425 \pm 0.014$ $0.830 \pm 0.247$	$0.968 \pm 0.015$	0	0	OK
OGLE-LINC-T2CEP-130	WVir	14 78	$10.25 \pm 5.71$ 29.36 + 1.46	$0.030 \pm 0.247$ $0.483 \pm 0.010$	$0.900 \pm 0.479$ $0.400 \pm 0.010$	0	0	OR
OGLE-LINC-T2CEP 140	RI Her	1 8/	$27.30 \pm 1.40$ $0.43 \pm 0.02$	$0.403 \pm 0.010$ $0.512 \pm 0.014$	$0.400 \pm 0.010$ $0.486 \pm 0.018$	0	0	OK
OGLE-LMC-T2CEP 1/1	BL Her	1.04	$9.43 \pm 0.92$ $8.24 \pm 1.12$	$0.312 \pm 0.014$ 0.374 ± 0.014	$0.480 \pm 0.018$ 0.330 $\pm 0.016$	0	0	OK
OGLE-LWC-12CEF-141 OGLE-I MC T2CEP $1/2$	BI Hor	1.02	$0.24 \pm 1.12$ 11 48 $\pm$ 0.27	$0.37 \pm 0.014$ 0.817 ± 0.010	$0.009 \pm 0.010$ 0 000 $\pm 0.011$	0	0	ok
$\begin{array}{c} \text{OGLE-LWC-12CEF-142} \\ \text{OGLE-LWC-12CEF-142} \\ \end{array}$	WA	1/ 57	$11.70 \pm 0.27$ $23.64 \pm 2.40$	$0.017 \pm 0.010$ 0.321 $\pm 0.011$	$0.202 \pm 0.011$	0	0	UK
OGLE-LWC-12CEP-143 OGLE I MC T2CED $144$		14.37	$23.04 \pm 2.40$ 11 72 $\pm 4.20$	$0.321 \pm 0.011$ 0.752 ± 0.200	$0.223 \pm 0.011$ 0.826 $\pm 0.252$	0	0	OV
OGLE-LIVIC-12CEP-144 OGLE I MC T2CED 145	BI Uar	1.94	$11.73 \pm 4.38$ $12.01 \pm 2.40$	$0.732 \pm 0.209$ 0.530 ± 0.025	$0.020 \pm 0.0020$	0	0	OV OV
OCLE-LWC-12CEP-143 OCLE I MC T2CED 144	WA	3.34 10.09	$12.71 \pm 2.40$	$0.330 \pm 0.033$ 0.443 - 0.011	$0.440 \pm 0.039$	0	0	0K
OCLE-LWC-12CEP-140 OCLE I MC T2CED $147$		10.00	$23.03 \pm 1.09$ 60.48 ± 6.46	$0.443 \pm 0.011$ 0.077 $\pm 0.024$	$0.377 \pm 0.011$ 0.684 ± 0.020	1	0	
OCLE-LWC-12CEP-149 OCLE I MC T2CED 149		40.80 2 47	$0.02 \pm 0.40$	$0.777 \pm 0.034$	$0.00+ \pm 0.029$ 0.206 ± 0.011	1	0	
OGLE-LIVIC-12CEP-148 OGLE I MC T2CEP 140	DUT	2.0/ 12.10	$9.92 \pm 0.70$ 52.85 + 4.45	$0.370 \pm 0.011$	$0.300 \pm 0.011$ 0.372 ± 0.012	0	0	
OOLE-LIVIC-12CEP-149	IX V TAU	42.40	$52.05 \pm 4.43$	$0.550 \pm 0.015$	$0.373 \pm 0.012$	U	U	

Name	Type	Period	Radius	MassCen	Massrri	Dusty?	Binary?	Agree?
	<i>J</i> 1	(d)	$(R_{\odot})$	$(M_{\odot})$	$(M_{\odot})$			0
OGLE-LMC-T2CEP-150	WVir	5.49	$17.60 \pm 0.67$	$0.585 \pm 0.010$	$0.473 \pm 0.010$	1	0	
OGLE-LMC-T2CEP-151	WVir	7.89	$19.46 \pm 1.67$	$0.428 \pm 0.011$	$0.350 \pm 0.012$	0	0	
OGLE-LMC-T2CEP-152	WVir	9.31	$22.84 \pm 2.52$	$0.493 \pm 0.015$	$0.418 \pm 0.017$	0	0	
OGLE-LMC-T2CEP-153	BLHer	1.18	$11.24 \pm 0.71$	$1.591 \pm 0.042$	$1.638 \pm 0.075$	0	0	OK
OGLE-LMC-T2CEP-154	pWVir	7.58	$23.97 \pm 0.92$	$0.822 \pm 0.011$	$0.666 \pm 0.011$	0	0	
OGLE-LMC-T2CEP-155	WVir	6.90	$22.43 \pm 3.50$	$0.669 \pm 0.040$	$0.647 \pm 0.061$	0	0	OK
OGLE-LMC-T2CEP-156	WVir	15.39	$33.84 \pm 3.31$	$0.631 \pm 0.018$	$0.558 \pm 0.021$	1	0	OK
OGLE-LMC-T2CEP-157	WVir	14.33	$27.71 \pm 1.38$	$0.439 \pm 0.010$	$0.358 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-158	WVir	7.14	$18.13 \pm 1.22$	$0.412 \pm 0.010$	$0.337 \pm 0.011$	1	Õ	
OGLE-LMC-T2CEP-159	WVir	6.63	$18.90 \pm 0.47$	$0.478 \pm 0.010$	$0.428 \pm 0.010$	0	Ő	ok
OGLE-LMC-T2CEP-160	BLHer	1.76	$9.15 \pm 1.08$	$0.500 \pm 0.016$	$0.482 \pm 0.023$	0	Õ	OK
OGLE-LMC-T2CEP-161	WVir	8.53	29.73 + 3.39	1.004 + 0.050	$1.009 \pm 0.085$	Ő	Ő	OK
OGLE-LMC-T2CEP-162	RVTau	30.39	44.46 + 3.27	$0.516 \pm 0.012$	$0.397 \pm 0.012$	1	Ő	011
OGLE-LMC-T2CEP-163	BLHer	1.69	10.11 + 2.40	$0.684 \pm 0.085$	$0.676 \pm 0.128$	0	Ő	OK
OGLE-LMC-T2CEP-164	pWVir	8.50	25.88 + 2.23	$0.759 \pm 0.019$	$0.688 \pm 0.026$	1	Ő	OK
OGLE-LMC-T2CEP-165	BLHer	1 24	$830 \pm 0.43$	$0.554 \pm 0.011$	$0.647 \pm 0.013$	0	Ő	ok
OGLE-LMC-T2CEP-166	BLHer	2.11	$1533 \pm 1.19$	$1293 \pm 0.070$	$1.518 \pm 0.162$	Ő	Ő	OK
OGLE-LMC-T2CEP-167	BLHer	2.11	$11.49 \pm 1.69$	$0.574 \pm 0.027$	$0.586 \pm 0.045$	0	0	OK
OGLE LINE TZCEP-168	WVir	15 70	$2851 \pm 1.00$	$0.371 \pm 0.027$ $0.430 \pm 0.010$	$0.334 \pm 0.010$	0	0	OR
OGLE LINC T2CEP-169	RVTau	30.96	$20.31 \pm 1.30$ $37.17 \pm 7.37$	$0.430 \pm 0.010$ $0.377 \pm 0.021$	$0.334 \pm 0.010$ $0.232 \pm 0.015$	1	0	
OGLE-LINC-T2CEP-170	WVir	7.68	$10.64 \pm 0.49$	$0.377 \pm 0.021$ $0.435 \pm 0.010$	$0.232 \pm 0.013$ $0.375 \pm 0.010$	0	0	
OGLE-LINC-T2CEP-170	RI Her	1.55	$856 \pm 135$	$0.433 \pm 0.010$ $0.523 \pm 0.026$	$0.373 \pm 0.010$ $0.488 \pm 0.036$	0	0	OK
OGLE-LMC-T2CEP 177	WVir	11.55	$0.50 \pm 1.55$ 25.68 $\pm$ 2.57	$0.323 \pm 0.020$ $0.492 \pm 0.014$	$0.430 \pm 0.030$	0	0	OK
OGLE-LMC-T2CEP 172	W VII W/Vir	11.22	$25.00 \pm 2.57$ 16.30 ± 0.00	$0.492 \pm 0.014$ 0.523 $\pm 0.011$	$0.430 \pm 0.010$ 0.608 ± 0.014	0	0	ok
OGLE-LWC-T2CEF-175	DVTou	4.15	$10.30 \pm 0.99$ 75.02 $\pm 10.04$	$0.323 \pm 0.011$ 1 1 20 $\pm 0.084$	$0.008 \pm 0.014$ 0.848 ± 0.070	1	0	
OGLE-LWC-T2CEP-174	WVir	40.82	$73.02 \pm 10.04$ 22.04 ± 1.03	$1.129 \pm 0.004$ 0.453 ± 0.010	$0.848 \pm 0.079$ 0.378 ± 0.010	1	0	0K
OGLE-LMC-T2CEP 175	W VII W/Vir	7.00	$22.04 \pm 1.03$ 20.40 ± 0.03	$0.433 \pm 0.010$ $0.470 \pm 0.010$	$0.376 \pm 0.010$ 0.306 ± 0.010	0	0	
OGLE-LWC-T2CEP-170	W VII W/Vir	15.04	$20.49 \pm 0.93$	$0.470 \pm 0.010$ $0.424 \pm 0.011$	$0.390 \pm 0.010$ 0.341 ± 0.011	0	0	
OCLE-LWC-T2CEP-177	W VII W/V/in	12.04	$28.00 \pm 2.04$	$0.424 \pm 0.011$ 0.278 ± 0.010	$0.341 \pm 0.011$ 0.204 + 0.011	0	0	
OGLE-LWC-T2CEF-178	W VII W/Vir	8.05	$23.04 \pm 1.74$ 20.25 ± 0.53	$0.378 \pm 0.010$ $0.434 \pm 0.010$	$0.304 \pm 0.011$ 0.370 ± 0.010	0	0	ok
OGLE-LWIC-T2CEP-179	W VII DVTou	0.05 21.00	$20.23 \pm 0.33$	$0.434 \pm 0.010$ 1 1 47 + 0 1 22	$0.379 \pm 0.010$	1	0	OK
OCLE I MC T2CEP 181		7 21	$01.01 \pm 10.03$	$1.147 \pm 0.123$ 0.762 ± 0.020	$0.904 \pm 0.142$ 0.716 + 0.041	1	0	
OGLE-LMC-T2CEP-181		/.21 0.22	$23.87 \pm 2.03$	$0.702 \pm 0.029$	$0.710 \pm 0.041$ 0.544 + 0.011	0	0	UK
OGLE-LMC-T2CEP-182	W VII W/V/m	0.23 6 5 1	$23.33 \pm 1.11$	$0.000 \pm 0.011$	$0.344 \pm 0.011$	0	0	
OGLE-LMC-T2CEP-185	W VII W/V/m	0.31	$10.70 \pm 1.11$	$0.433 \pm 0.010$ 0.202 + 0.011	$0.434 \pm 0.011$	0	0	ÛK
OGLE-LWIC-12CEF-184	W VII W/Vir	14.04	$27.43 \pm 2.21$	$0.393 \pm 0.011$	$0.329 \pm 0.011$ 5 142 + 0.160	0	0	
OCLE LMC T2CEP 186		16.26	$00.93 \pm 1.67$	$3.632 \pm 0.037$	$5.145 \pm 0.100$	0	0	
OGLE-LMC-T2CEP-180		2.40	$51.99 \pm 1.00$	$0.313 \pm 0.010$ 0.482 ± 0.017	$0.451 \pm 0.011$	0	0	OV
OGLE-LWIC-12CEF-187	DL Hor	2.40	$10.62 \pm 1.30$	$0.462 \pm 0.017$ 0.775 ± 0.021	$0.403 \pm 0.023$	0	0	OK
OGLE-LWC-T2CEP-180 OGLE LMC T2CEP 180	DL Hor	1.05	$0.29 \pm 0.93$	$0.773 \pm 0.031$ $0.493 \pm 0.010$	$0.643 \pm 0.000$	0	0	OK
OCLE I MC T2CEP 100	DUTau	20.26	$7.30 \pm 0.30$	$0.463 \pm 0.010$	$0.439 \pm 0.010$	1	0	ÛK
OGLE-LMC-T2CEP-190	KV Tau DV/Tau	24.24	$52.21 \pm 5.57$	$0.000 \pm 0.012$	$0.423 \pm 0.011$	1	0	
OCLE I MC T2CEP 102	KV Iau DVTau	24.24 26.10	$03.39 \pm 3.29$	$1.103 \pm 0.033$	$0.003 \pm 0.030$	1	0	
OGLE-LMC-T2CEP-192	Kv Tau WWin	20.19	$34.90 \pm 3.10$	$0.570 \pm 0.011$	$0.237 \pm 0.011$	0	0	alt
OGLE-LMC-T2CEP-195		1.00	$20.00 \pm 0.49$	$0.510 \pm 0.010$	$0.438 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-194	BLHer	1.31	$8.23 \pm 0.04$	$0.392 \pm 0.013$	$0.5/8 \pm 0.01/$	0	0	OK
OGLE-LMC-T2CEP-195	BLHer	2.75	$11.49 \pm 1.15$	$0.485 \pm 0.013$	$0.441 \pm 0.010$	0	0	ÛK
OGLE-LMC-T2CEP-190	W VII DI II	14.90	$32.84 \pm 2.33$	$0.027 \pm 0.013$	$0.530 \pm 0.014$	0	0	OV
OCLE LMC TOCED 100	<b>DLHer</b>	1.22	$\delta.0/\pm 1.04$	$0.013 \pm 0.023$	$0.008 \pm 0.039$	0	0	UK
OGLE-LWIC-12CEP-198	KV Iau	38.27	$49.05 \pm 2.79$	$0.472 \pm 0.010$	$0.3/3 \pm 0.010$	1	0	
OGLE-LMC TOCEP 199	KV Iau	57.20	$38.00 \pm 2.67$	$0.3/7 \pm 0.010$	$0.182 \pm 0.010$	1	0	017
OGLE-LMC-T2CEP-200	KV Iau	54.92	$5/.81 \pm 8.19$	$0.790 \pm 0.047$	$0.661 \pm 0.053$	1	0	OK
OGLE-LMC-T2CEP-201	pWV1r	11.01	$36.81 \pm 2.77$	$1.372 \pm 0.044$	$1.207 \pm 0.057$	1	0	OK
OGLE-LMC-T2CEP-202	RVTau	38.14	$50.01 \pm 2.66$	$0.490 \pm 0.010$	$0.382 \pm 0.010$	0	0	
OGLE-LMC-T2CEP-203	RVTau	37.13	$46.46 \pm 3.67$	$0.427 \pm 0.011$	$0.325 \pm 0.011$	0	0	

Name	Type	Period	Radius	Mass <sub>Cep</sub>	Massrri	Dusty?	Binary?	Agree?
	<b>J</b> 1	(d)	$(R_{\odot})$	$(M_{\odot})$	$(M_{\odot})$	5	5	0
OGLE-SMC-ACEP-01	10	0.83	$6.88 \pm 0.36$	$0.738 \pm 0.012$	$0.728 \pm 0.014$	0	0	OK
OGLE-SMC-ACEP-02	F	0.83	$7.87 \pm 0.17$	$0.923 \pm 0.010$	$1.070 \pm 0.011$	0	0	ok
OGLE-SMC-ACEP-03	10	0.76	$6.67 \pm 0.46$	$0.755 \pm 0.015$	$0.765 \pm 0.022$	0	0	OK
OGLE-SMC-ACEP-04	F	0.83	$8.23 \pm 0.32$	$1.046 \pm 0.012$	$1.210 \pm 0.019$	0	0	ok
OGLE-SMC-ACEP-05	10	0.70	$6.78 \pm 0.25$	$0.870 \pm 0.011$	$0.928 \pm 0.013$	0	0	ok
OGLE-SMC-ACEP-06	F	1.26	$9.12 \pm 0.68$	$0.824 \pm 0.018$	$0.820 \pm 0.027$	0	0	OK
OGLE-SMC-T2CEP-001	nWVir	11.87	$43.32 \pm 1.89$	$1.785 \pm 0.029$	$1.685 \pm 0.040$	0	Õ	OK
OGLE-SMC-T2CEP-002	BLHer	1.37	$7.64 \pm 0.67$	$0.484 \pm 0.012$	0.434 + 0.014	Ő	Ő	OK
OGLE-SMC-T2CEP-003	WVir	4.36	$12.73 \pm 1.28$	$0.347 \pm 0.011$	$0.278 \pm 0.011$	Ő	Ő	011
OGLE-SMC-T2CEP-004	WVir	6 53	19.98 + 2.56	$0.569 \pm 0.022$	$0.511 \pm 0.028$	Ő	Ő	OK
OGLE-SMC-T2CEP-005	WVir	8 21	$19.90 \pm 2.00$ $19.41 \pm 0.45$	$0.509 \pm 0.022$ $0.400 \pm 0.010$	$0.326 \pm 0.010$	Ő	Ő	011
OGLE-SMC-T2CEP-006	BLHer	1 24	$733 \pm 0.15$	$0.485 \pm 0.010$	$0.320 \pm 0.010$ $0.459 \pm 0.010$	0	0	OK
OGLE-SMC-T2CEP-007	RVTau	30.96	$7735 \pm 0.13$	$2.058 \pm 0.010$	$1.804 \pm 0.865$	0	1	OK
OGLE-SMC-T2CEP-008	RI Her	1 49	$10.45 \pm 0.44$	$0.838 \pm 0.011$	$0.913 \pm 0.005$	0	0	ok
OGLE SMC-T2CEP-009	BL Her	2 97	$12.07 \pm 0.11$	$0.030 \pm 0.011$ $0.572 \pm 0.010$	$0.547 \pm 0.013$	0	0	OK
OGLE-SMC-T2CEP-010	nWVir	17.48	$60.53 \pm 6.25$	$0.372 \pm 0.010$ 2 347 + 0 226	$2.296 \pm 0.360$	0	1	OK
OGLE-SMC-T2CEP-011	p W Vir	0.03	$38.92 \pm 2.65$	$1.891 \pm 0.068$	$2.290 \pm 0.300$ 1 665 ± 0.089	1	0	OK
OGLE-SMC-T2CEP-012	RVTau	29.25	$30.72 \pm 2.05$ $41.67 \pm 1.15$	$0.486 \pm 0.000$	$0.352 \pm 0.000$	0	0	OR
OGLE-SMC-T2CEP 012	W/Wir	13.81	$+1.07 \pm 1.13$ 25.27 $\pm 0.67$	$0.480 \pm 0.010$ 0.386 $\pm 0.010$	$0.352 \pm 0.010$ $0.203 \pm 0.010$	0	0	
OCLE-SMC-T2CEP-013	W VII W/Vir	13.01	$23.27 \pm 0.07$ 23.85 ± 0.50	$0.380 \pm 0.010$ 0.335 ± 0.010	$0.293 \pm 0.010$ $0.247 \pm 0.010$	0	0	
OCLE-SMC-T2CEP-014		2 57	$23.83 \pm 0.39$ 12 70 ± 1.04	$0.333 \pm 0.010$ 0.767 ± 0.018	$0.247 \pm 0.010$ $0.640 \pm 0.021$	0	0	
OCLE-SMC-T2CEP-015	DLIICI DI Uor	2.57 2.11	$12.70 \pm 1.04$ $10.22 \pm 0.63$	$0.707 \pm 0.013$ 0.520 ± 0.011	$0.049 \pm 0.021$ $0.487 \pm 0.012$	0	0	OK
OCLE-SMC-T2CEP-010	DLIICI DI Uar	1 20	$10.22 \pm 0.03$ 8 70 ± 0.07	$0.520 \pm 0.011$ 0.607 ± 0.024	$0.487 \pm 0.012$ 0.703 + 0.040	0	0	OK
OCLE-SMC-T2CEP-017	DUTau	20.52	$0.19 \pm 0.91$	$0.097 \pm 0.024$ 0.742 + 0.021	$0.703 \pm 0.040$	1	0	ÛK
OGLE-SMC-T2CEP-018	KV Tau DV/Tau	39.32 40.01	$57.32 \pm 0.83$	$0.742 \pm 0.051$	$0.331 \pm 0.027$ 0.247 + 0.010	1	0	
OGLE-SMC-12CEP-019	KV Tau DV/Tau	40.91	$50.40 \pm 2.09$	$0.341 \pm 0.010$ 0.276 ± 0.010	$0.347 \pm 0.010$ 0.242 + 0.010	1	0	
OGLE-SMC-T2CEP-020	RV Iau DI Han	2 2 1	$30.13 \pm 3.30$	$0.370 \pm 0.010$	$0.243 \pm 0.010$	0	0	
OGLE-SMC-12CEP-021	BLHer	2.31	$8.99 \pm 0.57$	$0.344 \pm 0.010$	$0.294 \pm 0.010$	0	0	OV
OGLE-SMC-T2CEP-022	BLHer	1.4/	$7.22 \pm 0.57$	$0.304 \pm 0.011$	$0.531 \pm 0.011$	0	0	ÛK
OGLE-SMC-12CEP-023	pw vir	17.08	$39.21 \pm 1.69$	$0.820 \pm 0.011$	$0.6/0 \pm 0.012$	0	1	
OGLE-SMC-12CEP-024	KV Iau	43.96	$51.41 \pm 3.24$	$0.506 \pm 0.011$	$0.326 \pm 0.010$	1	0	
OGLE-SMC-12CEP-025	pw vir	14.17	$30.97 \pm 1.42$	$0.624 \pm 0.011$	$0.496 \pm 0.011$	0	1	017
OGLE-SMC-T2CEP-026	BLHer	1.70	$10.17 \pm 0.39$	$0.696 \pm 0.011$	$0.680 \pm 0.011$	0	0	OK
OGLE-SMC-T2CEP-027	BLHer	1.54	$7.70 \pm 0.31$	$0.408 \pm 0.010$	$0.368 \pm 0.010$	0	0	OK
OGLE-SMC-T2CEP-028	pWV1r	15.26	$49.73 \pm 1.33$	$1.653 \pm 0.014$	$1.655 \pm 0.018$	0	1	OK
OGLE-SMC-T2CEP-029	RVTau	33.68	$91.49 \pm 2.38$	$2.547 \pm 0.025$	$2.524 \pm 0.035$	0	1	OK
OGLE-SMC-T2CEP-030	BLHer	3.39	$14.97 \pm 0.81$	$0.750 \pm 0.012$	$0.658 \pm 0.014$	0	0	ok
OGLE-SMC-T2CEP-031	W Vır	7.90	$20.76 \pm 2.32$	$0.491 \pm 0.015$	$0.419 \pm 0.017$	0	0	
OGLE-SMC-T2CEP-032	W V1r	14.25	$26.57 \pm 1.75$	$0.434 \pm 0.011$	$0.320 \pm 0.010$	l	0	
OGLE-SMC-T2CEP-033	BLHer	1.88	$11.56 \pm 0.67$	$0.831 \pm 0.014$	$0.831 \pm 0.019$	0	0	OK
OGLE-SMC-T2CEP-034	WVir	20.12	$36.42 \pm 1.09$	$0.566 \pm 0.010$	$0.442 \pm 0.010$	0	0	
OGLE-SMC-T2CEP-035	WVir	17.18	$29.80 \pm 3.18$	$0.437 \pm 0.013$	$0.326 \pm 0.013$	1	0	
OGLE-SMC-T2CEP-036	BLHer	1.09	$9.38 \pm 0.36$	$1.018 \pm 0.012$	$1.117 \pm 0.017$	0	0	ok
OGLE-SMC-T2CEP-037	BLHer	1.56	$10.03 \pm 0.41$	$0.737 \pm 0.011$	$0.757 \pm 0.012$	0	0	OK
OGLE-SMC-T2CEP-038	pWVir	4.44	$21.40 \pm 1.62$	$1.203 \pm 0.035$	$1.152 \pm 0.053$	0	0	OK
OGLE-SMC-T2CEP-039	BLHer	1.89	$11.52 \pm 0.25$	$0.783 \pm 0.010$	$0.818 \pm 0.010$	0	0	OK
OGLE-SMC-T2CEP-040	WVir	16.11	$29.73 \pm 3.47$	$0.465 \pm 0.015$	$0.360 \pm 0.015$	0	0	
OGLE-SMC-T2CEP-041	RVTau	29.12	$37.67 \pm 1.72$	$0.400\pm0.010$	$0.267 \pm 0.010$	0	0	
OGLE-SMC-T2CEP-042	BLHer	1.49	$8.54 \pm 0.18$	$0.544 \pm 0.010$	$0.521 \pm 0.010$	0	0	OK
OGLE-SMC-T2CEP-043	RVTau	23.74	$41.40 \pm 2.07$	$0.620 \pm 0.011$	$0.484 \pm 0.011$	0	0	