## Properties of Anomalous and Type-II Cepheids in the Magellanic Clouds

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### **Overview Talk**

Introduction

Where and What ?

• T2C & AC in the MCs OGLE-III

 Groenewegen & Jurkovic, 2017, A&A 603, A70 and A&A 604, A29

• Conclusions & future work

## Where are they ?



### What are they ?

- Gingold (1976, 1985), Wallerstein (2002), Sandage & Tammann (2006)
- BL Her (1-4d), evolving of HB towards the AGB
- W Vir (4-20d), blue-loop off the AGB after a TP
- RV Tau (20-70d), Post-AGB, evolving off the AGB

Binarity ?

- MCs: peculiar W Vir (pWVir)
- MCs: T2C in EBs
- Known Galactic RV Tau that have discs and are known binaries

### **OGLE sample in the MCs**

LMC SMC				
BL Her	64	17		
W Vir	97	17		
RV Tau	42	9		
AC (F)	62	3		
AC (10)	21	3		
			335	
OGLE-III: Soszyński et al. (2008, 2010a, 2010b)				
OGLE-IV: AC: 141 in the LMC and 109 in the SMC				

## **SED** fitting

Construction of SED by collecting all available photometry Fitting model atmosphere (+ dust shell) For assumed distance (50, 61 kpc), get L,  $T_{\rm eff}$ , optical depth



30 of 51 RVT have IR emission (27/42 LMC; 3/9 SMC) **Surprise:** 11 of 114 W Vir have excess emission (8/97 LMC; 3/17 SMC; 3/24 pWVir) 0/81 BLH, 0/88 AC

#### **IR excess**



## dusty post-RGB stars



Stars with an SED expected for the P-AGB phase, based on optical & MIR colours. LR spectra of 2300 stars: remove interloopers, determine  $T_{\rm eff}$ ,  $\log g$ .

Sample of  $\sim$ 50 P-AGB, and  $\sim$ 160 stars with too low *L*.

A new class of dusty post-red giant branch stars (Kamath et al. 2016).

Binary pop. syn. models: have evolved off the RGB via binary interaction, and stored the dust in a circumbinary disc.



light-travel time (LTT) effect or light-time effect (LITE) in so-called *observed minus calculated* (O-C) diagrams

Method of templates by Hajdu et al. (2015) (template is constant; amplitude changes possible)

model for period change plus binary:

$$(O-C)(t) = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + (a \sin i) \frac{1 - e^2}{1 + e \cos(\nu)} \sin(\nu + \omega),$$







In total 23 systems show evidence for binarity, including three known eclipsing binaries (EBs). Other known EBs did not show the LITE.

known EBs:  $P_{\rm orb} = 172, 397, 609 \text{ d}$ New binaries:  $P_{\rm orb} = 1500-3000 \text{ d}$ 

(problem?: large orbits, large masses cf. Sodor et al. 2017)

#### **Period change**

About 40 systems showed evidence for period change.

Theoretical  $\dot{P}$  Wehlau & Bohlender (1982), models of Gingold (1976): BLH +20, -2, +1 d/Myr.

Galactic objects (Neilson et al. 2016): For periods below 8 days the period changes are small and positive (<20 d/Myr). For longer periods large changes are observed, from about -400 to +400 d/Myr.

HERE:

- (bias, but), when detected,  $\dot{P}$  is larger than predicted by standard evolution theory.
- Half of RVT show period increase
- Relation to BEP ?

### **PL-PR relations**



*PL*-, *PR*- relations for AC, T2C no difference between LMC and SMC BLH, WVir, RVT can be combined (with some restrictions)



Used published pulsation models for RR Lyrae (Marconi et al. 2015) and classical Cepheids (Bono et al. 2000)

 $P = f(L, M, T_{eff}, Z)$ to get the pulsation mass

#### **Pulsation masses**

BL Her and AC agree best, and agree with literature values: BL Her  $\sim 0.5~M_{\odot}$  ACs  $\sim 1.3~M_{\odot}$ 

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W Vir \sim 0.4-0.5 M_{\odot}
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RVT agree least: sometimes very low ( $\sim 0.3 \text{ M}_{\odot}$ ) or very large (> 1 M<sub> $\odot$ </sub>)

#### W Vir



FU (solid) and FO (dashed) blue (for Z = 0.004) and red edge (for Z = 0.008) classical Cepheids are indicated. BaSTI: light blue (Z = 0.001), magnenta (Z = 0.002), yellow (Z = 0.004), and brown (Z = 0.008). The dark blue line (Miller Bertolami): 0.60 M<sub>o</sub> at the ZAHB; and experiences a TP, crossing the IS. The evolution in that region is very fast.

#### SRD







SED and OGLE lightcurve for a period of 130 days. The star has a clear IR excess and appears in the sample of Kamath et al. (2014)

## **Conclusions & future work**

- SED fitting is powerfull tool
- LITE ⇒ P, Binary (OGLE-IV timeseries) meaning.. ? RV confirmation
- W Vir are unlikely to be related to TP on the AGB
- RVT more puzzling as a class ( $\dot{P}$ , mass)
- Galactic objects: thesis/poster by Joonas SAARIO
  - SED construction
  - GAIA parallax data
  - RV monitoring

# THE END