Are the Ultra Long Period Cepheids cosmological standard candles?

Ilaria Musella
INAF - Capodimonte Astronomical Observatory

In collaboration with M. Marconi, F. Cusano, G. De Somma, R. Molinaro, G. Fiorentino

Ultra Long Period Cepheids

Properties:

- Light curves typical of Classical Cepheids
- P ≥ 80 days (Bird et al. 2009), firstly identified in LMC & SMC (Freedmann et al. 1985)
- much brighter (MI from -7 to -9 mag) than ‘short period’ Cepheids (M_I up to -5 mag)

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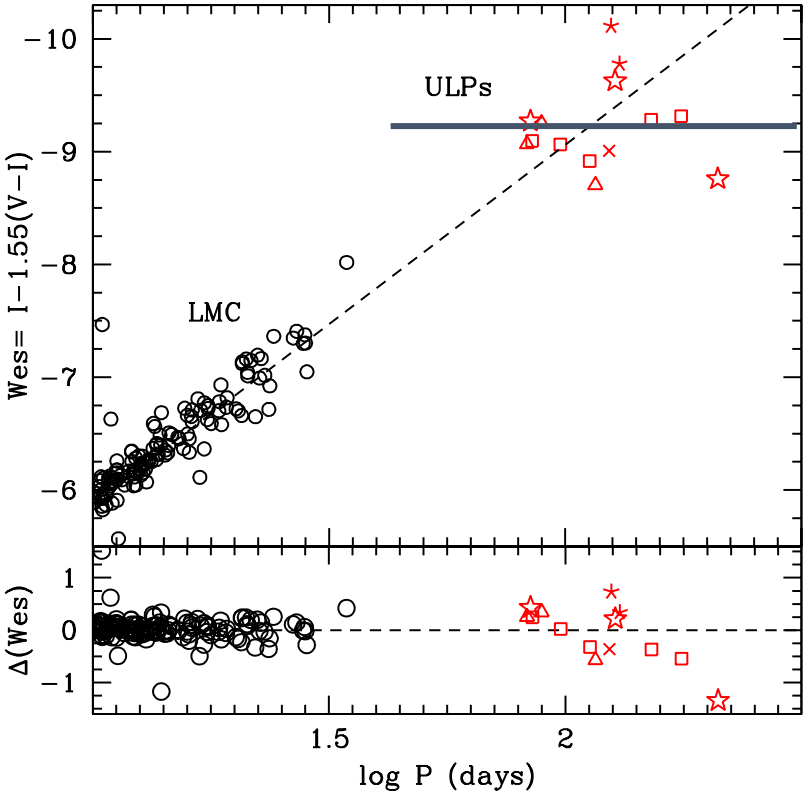
Work in progress (theory and observations) to

- Verify if they are the extension of Classical Cepheids to higher mass and luminosity or a different class of pulsators
- understand their role as “standards candles”

ULPs as Distance Indicators
Reddening Free Wesenheit



Bird+09

- 16 ULPs in nearby star forming galaxies: LMC, SMC, NGC6822, NGC55, NGC300
- 2 ULPs in the Blue compact dwarf galaxy IZw18 observed by HST: the most metal poor Z=0.0004 and the brightest ones

18 ULPs: rms=0.36

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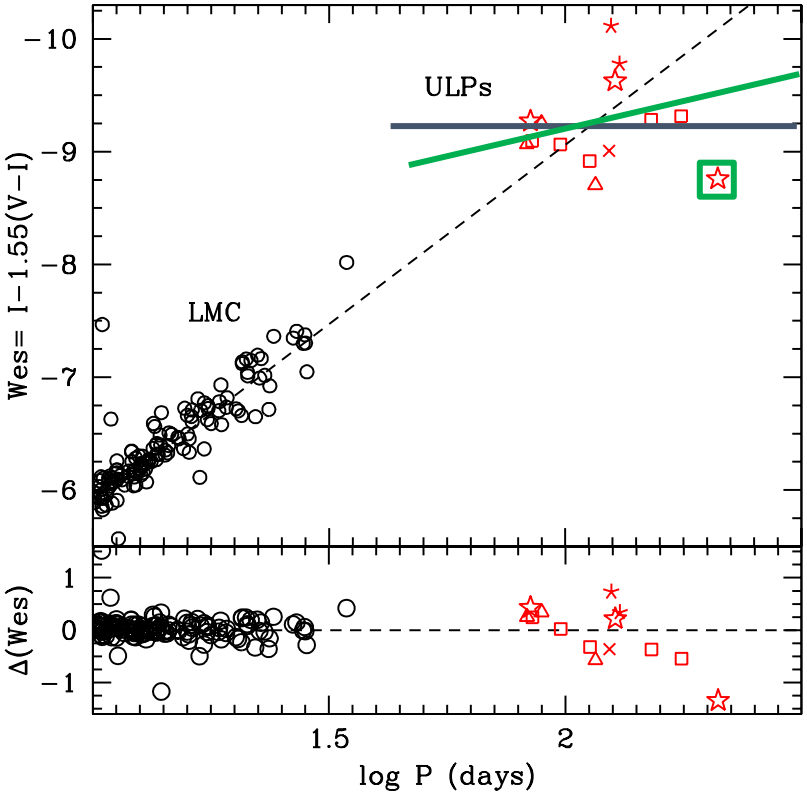

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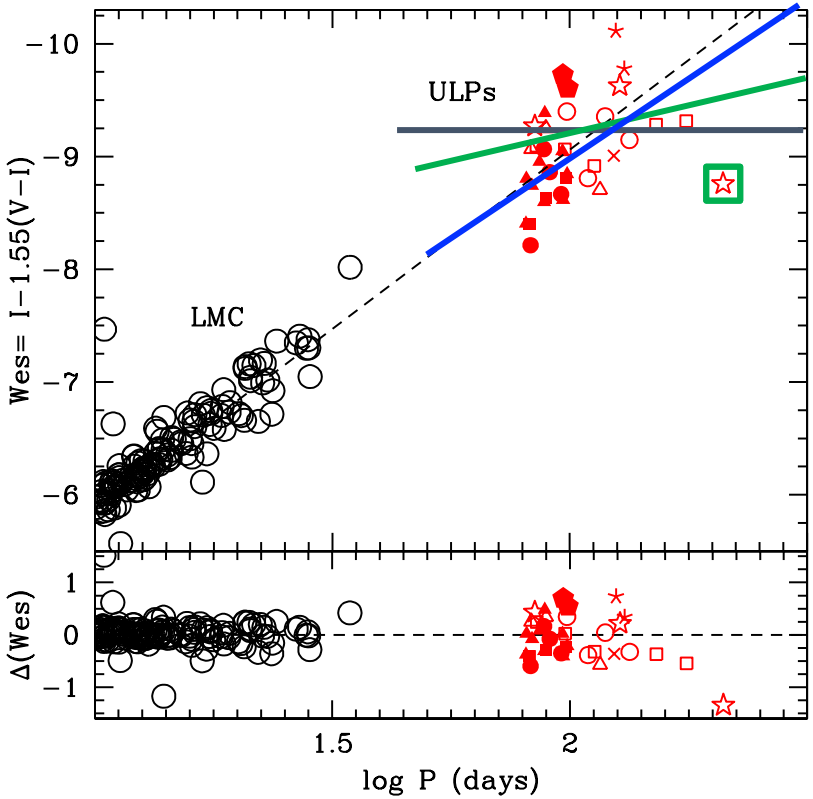

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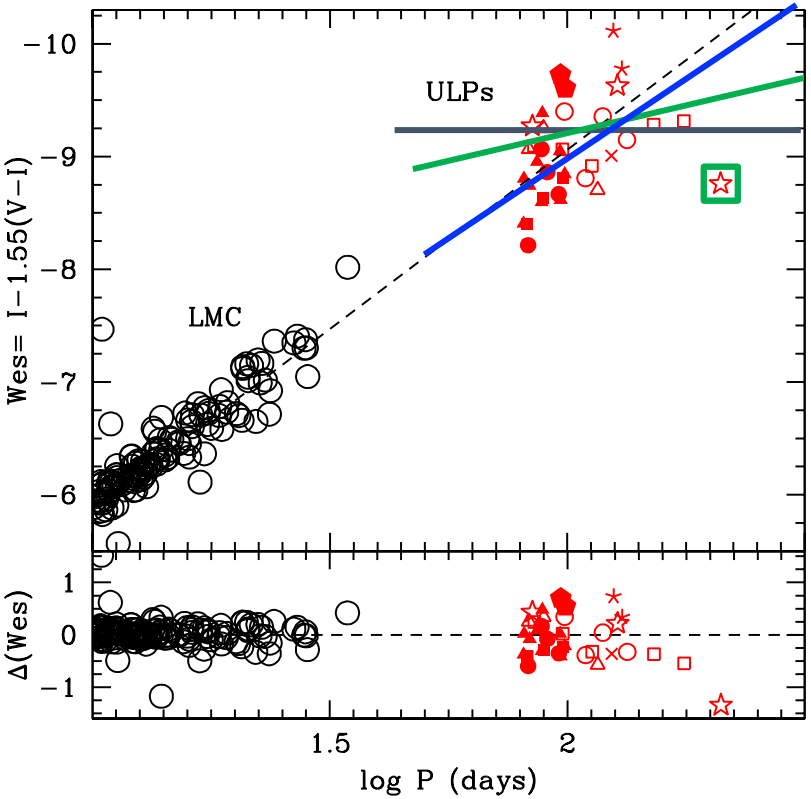
Fiorentino+12/13

- 2 ULPs in M81 (Gerke+11)
- 17 ULPs (SH0ES, Riess+09) in NGC 1309, NGC 3021, NGC 3370, NGC 4536, NGC 5584, NGC 4038 and NGC 4258

36 ULPs rms=0.38

ULPs as Distance Indicators
Reddening Free Wesenheit



Large dispersion rms >> 0.3

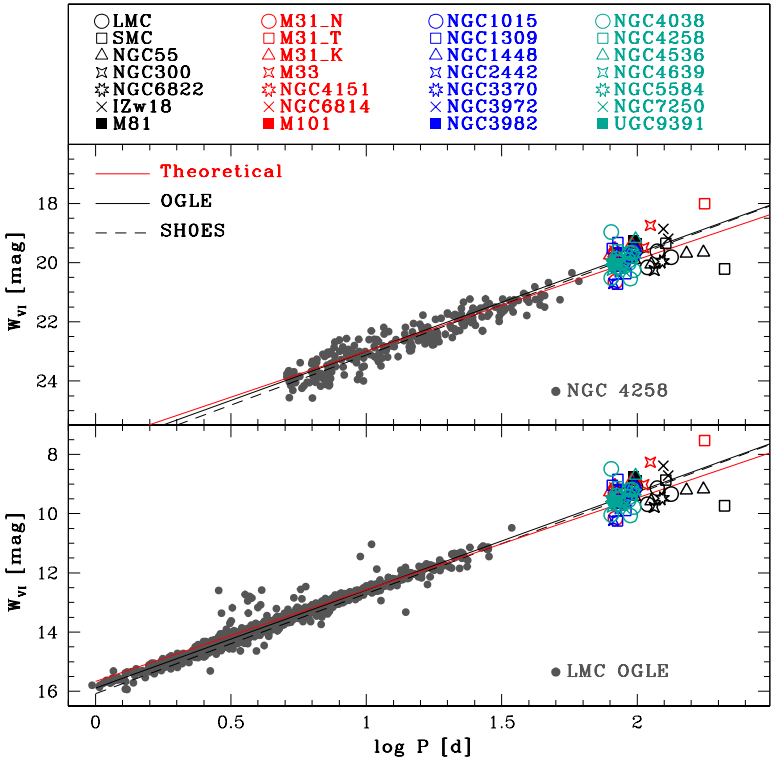
- ★ Intrinsic properties
- ★ Crowding/Blending (being CCs and ULPs observed in very dense environments)
- ★ Non homogeneous photometry
- ★ Poor statistics
  - long periods → long time baseline
  - Very bright → often saturated
  - Intrinsic → the crossing time of the IS much shorter than the classical cepheids one

New sample by Musella+21/22:

- Bird sample (18)
- 2 M81 ULPs (Gerke+11)
- New SH0ES sample (Riess+16 and Hoffman+16): 40 ULPs observed in 14 galaxies (all the Cepheid samples were reanalyzed to obtain a new and homogeneous photometric calibration. Not all the previous ULPs were confirmed and for many of them the new period was different then previous one)
- 6 M31 ULPs (Ngeow+15, Kodric+18, Taneva+20)
- 2 M33 (Pellerin and Macri 2011)
- 1 NGC4151 (Yuan+20)
- 2 NGC6814 (Bentz+19)

For a total of 72 ULPs

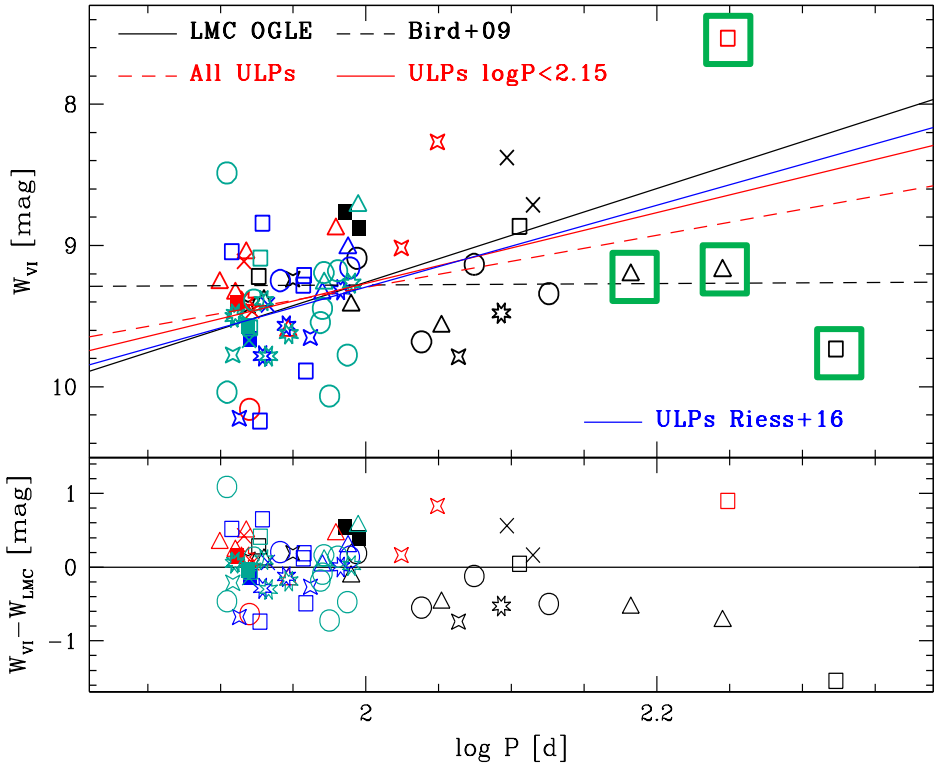
New sample: Wesenheit



NGC4258 is part of the SH0ES project and is adopted as anchor alternative to the LMC for the extragalactic distance scale

Dispersion much larger than LMC but more similar to NGC4258 shorter period Cepheids

New sample: Wesenheit



○LMC	○M31_N
□SMC	□M31_T
△NGC55	△M31_K
⋈NGC300	⋈M33
✡NGC6822	✡NGC4151
×IZw18	×NGC6814
■M81	■M101

○NGC1015	○NGC4038
□NGC1309	□NGC4258
△NGC1448	△NGC4536
⋈NGC2442	⋈NGC4639
✡NGC3370	✡NGC5584
×NGC3972	×NGC7250
■NGC3982	■UGC9391

All ULPs (red dashed line): RMS=0.42

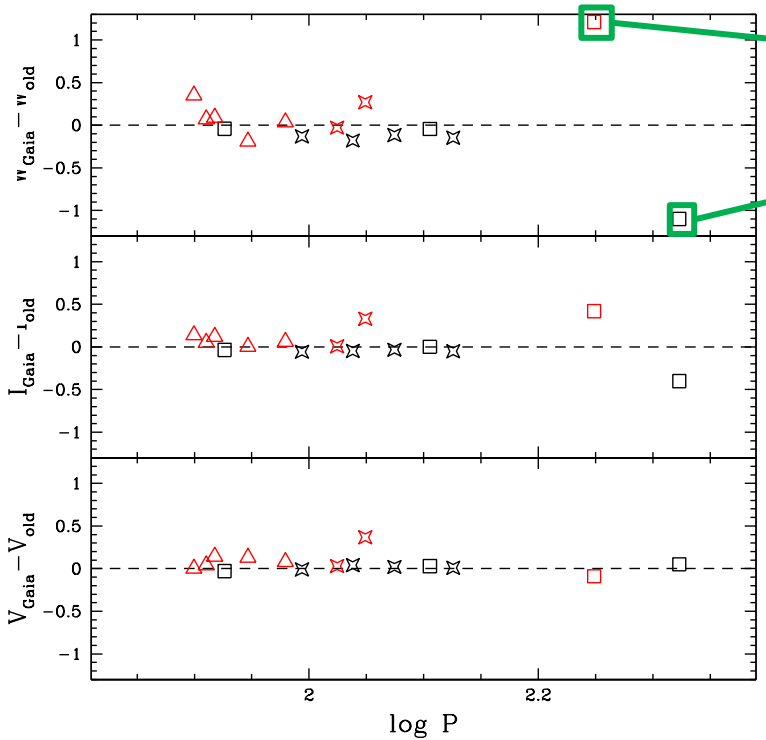
Log P < 2.15 (red line): RMS = 0.38 in better agreement with LMC

Riess (homogeneous photometry) RMS = 0.36 In still better agreement with LMC

Work in progress: Gaia DR3 data

14 ULPs with accurate and homogeneous photometry:

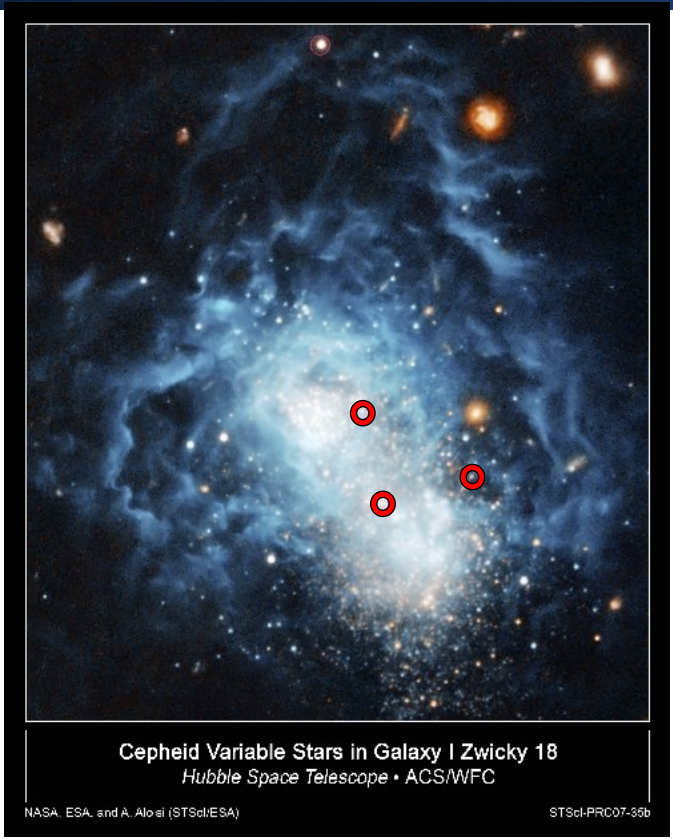
- All the known ULPs in LMC, SMC and M33
- 5 ULPs in M31



M31 H42 ULP

Largest period ULP

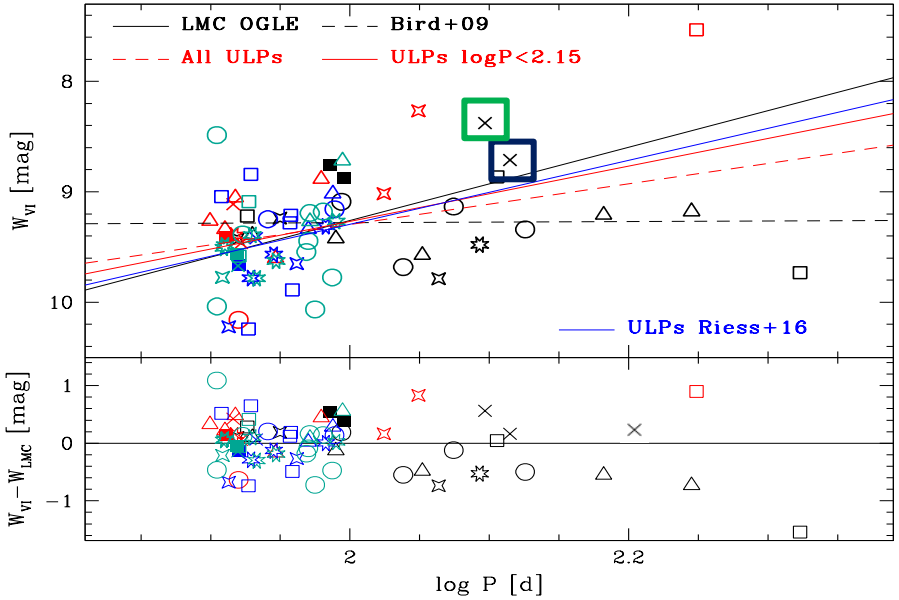
Work in progress: IZw18



WFPC + ACS: Aloisi+07; Fiorentino+10; Marconi, Musella+10

1 short period Cepheid

2 ULPs



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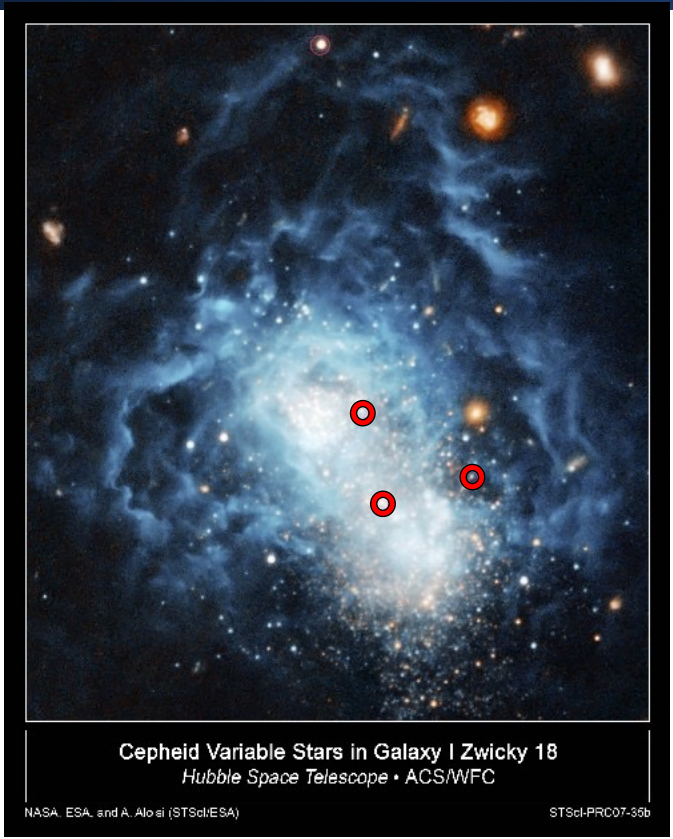
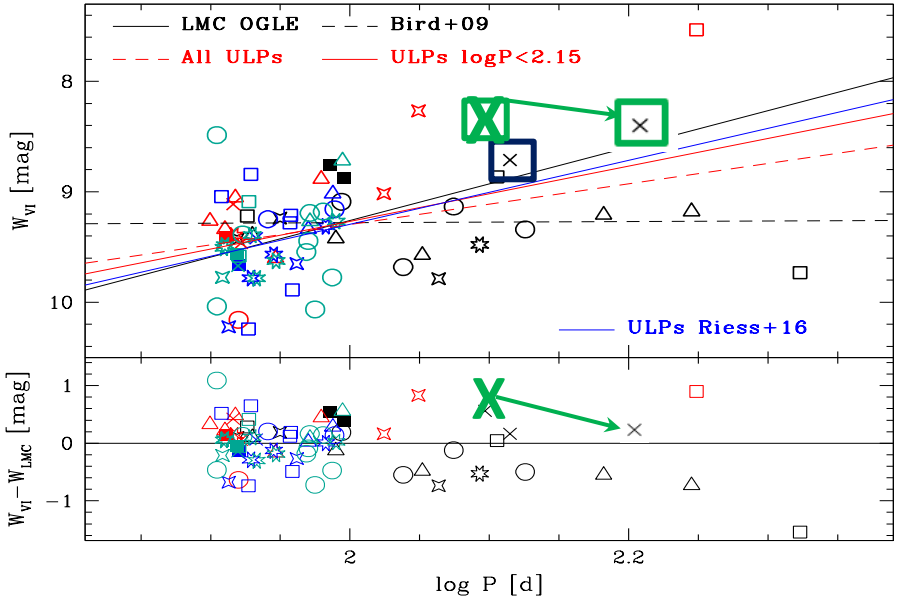
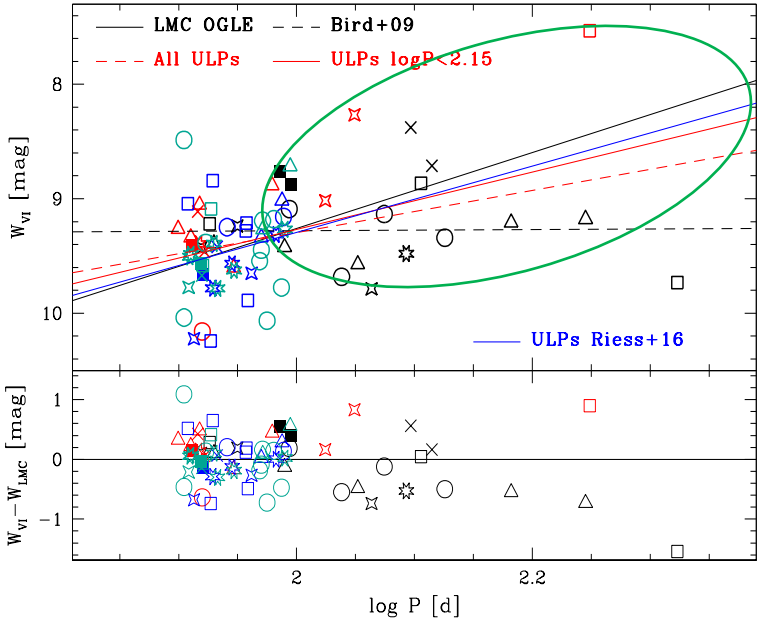


For the ULP less crowded: new TNG + LBT data

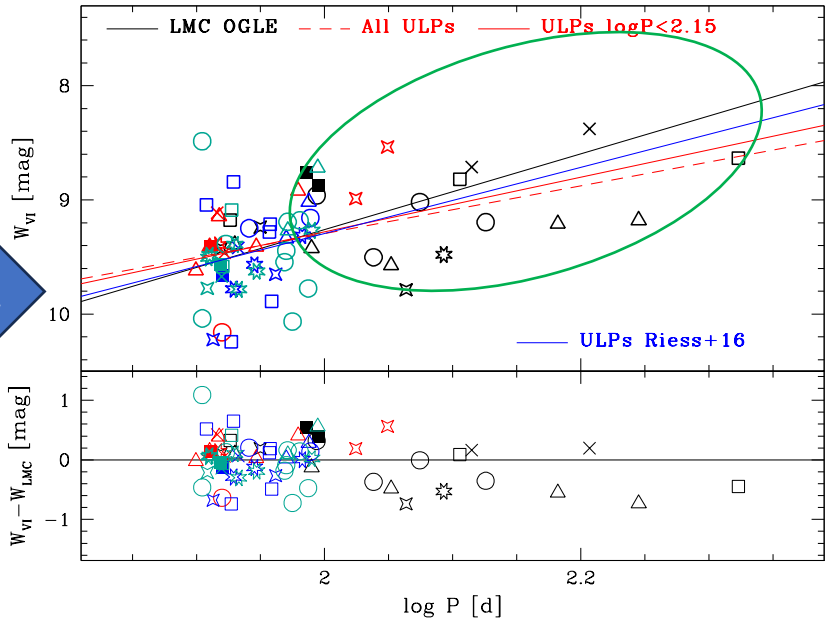
P: 125 d → 161 d



Updated ULP Wesenheit



Improved photometry



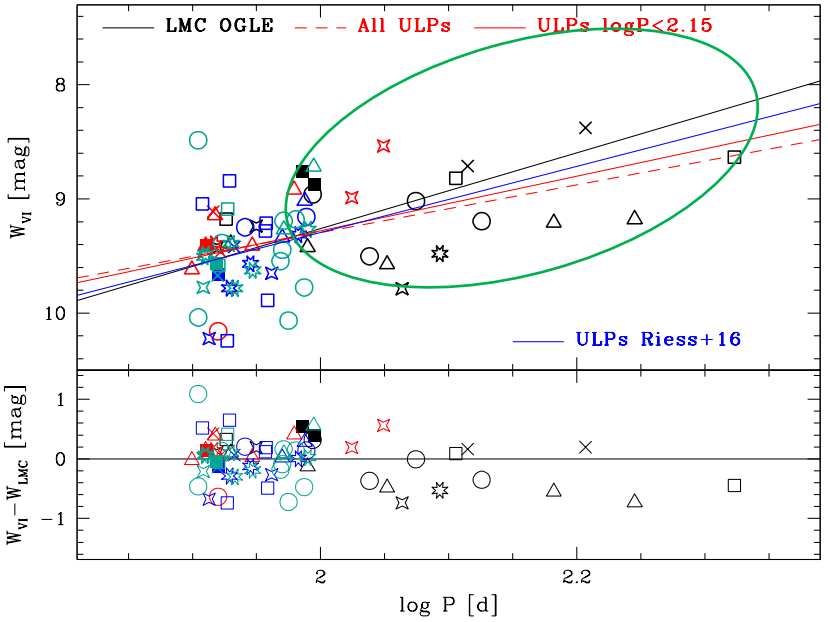
ULPs as distance indicators

Improving photometry

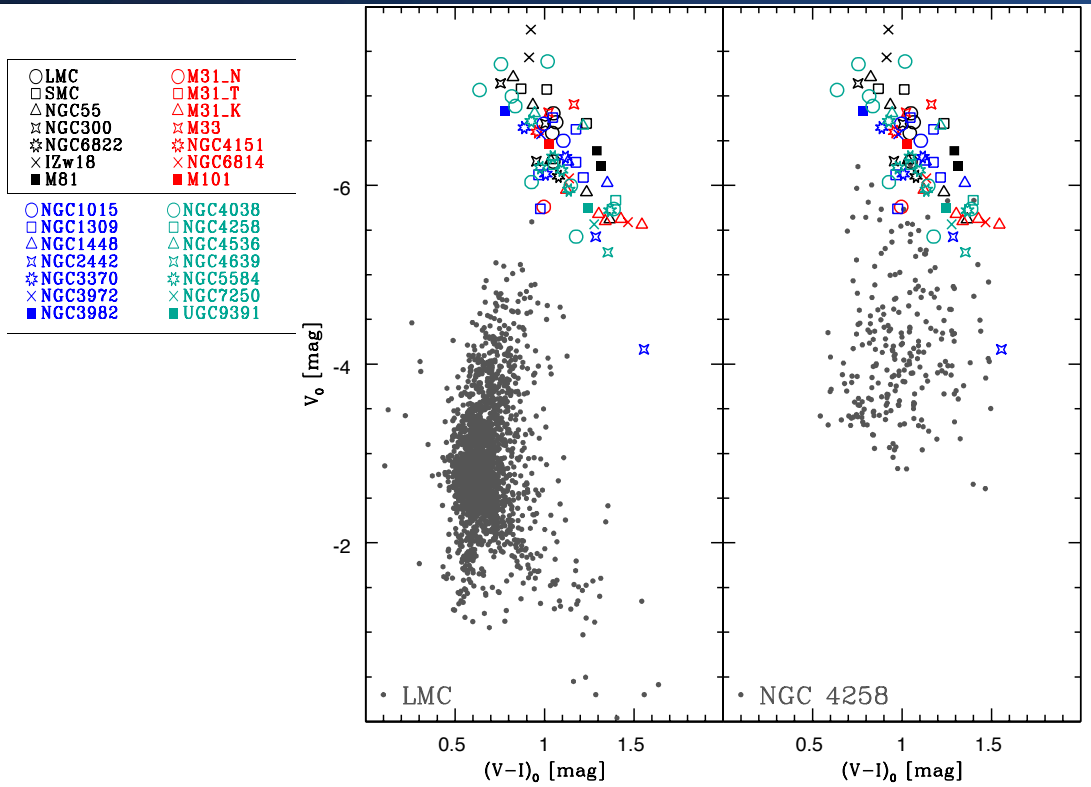
↓

improved agreement with CCs

Very good agreement with the LMC CCs for the *Gaia + Riess* sample (logP <2.15) RSM=0.34



ULPs Evolutionary phase: CMD



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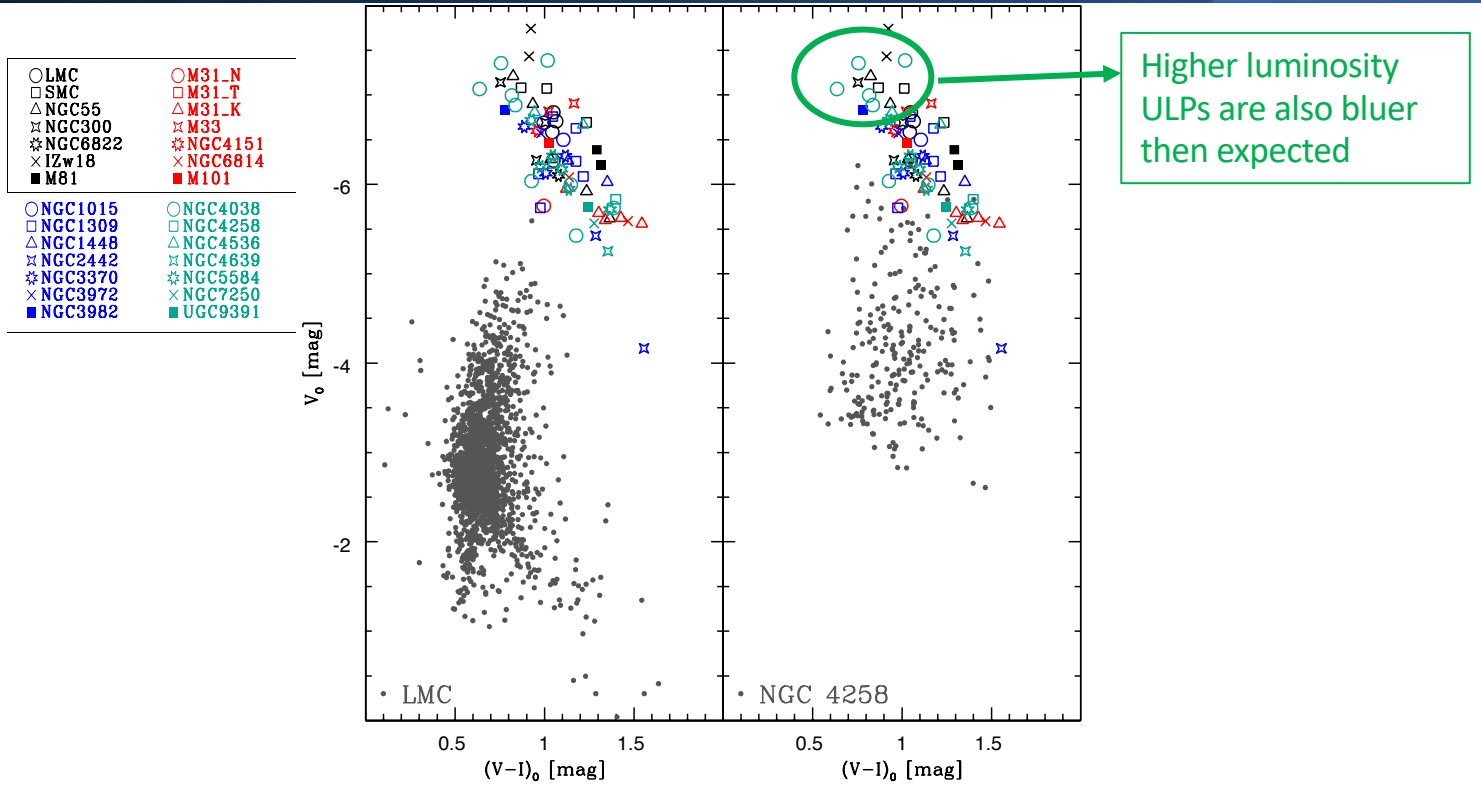

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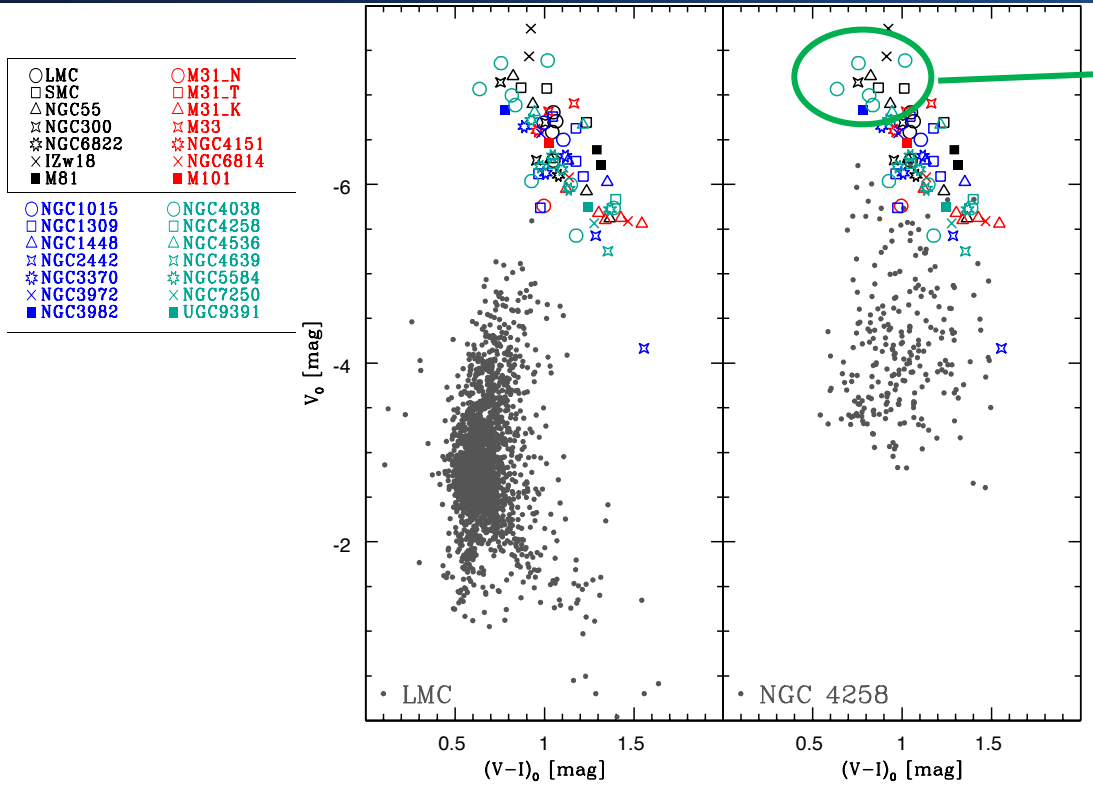

Higher luminosity ULPs are also bluer then expected

Large range in colour:

- Intrinsic property
- Crowding/Blending
- Unhomogeneity of photometries
- Dependence on metallicity
- Adopted reddenings and/or moduli

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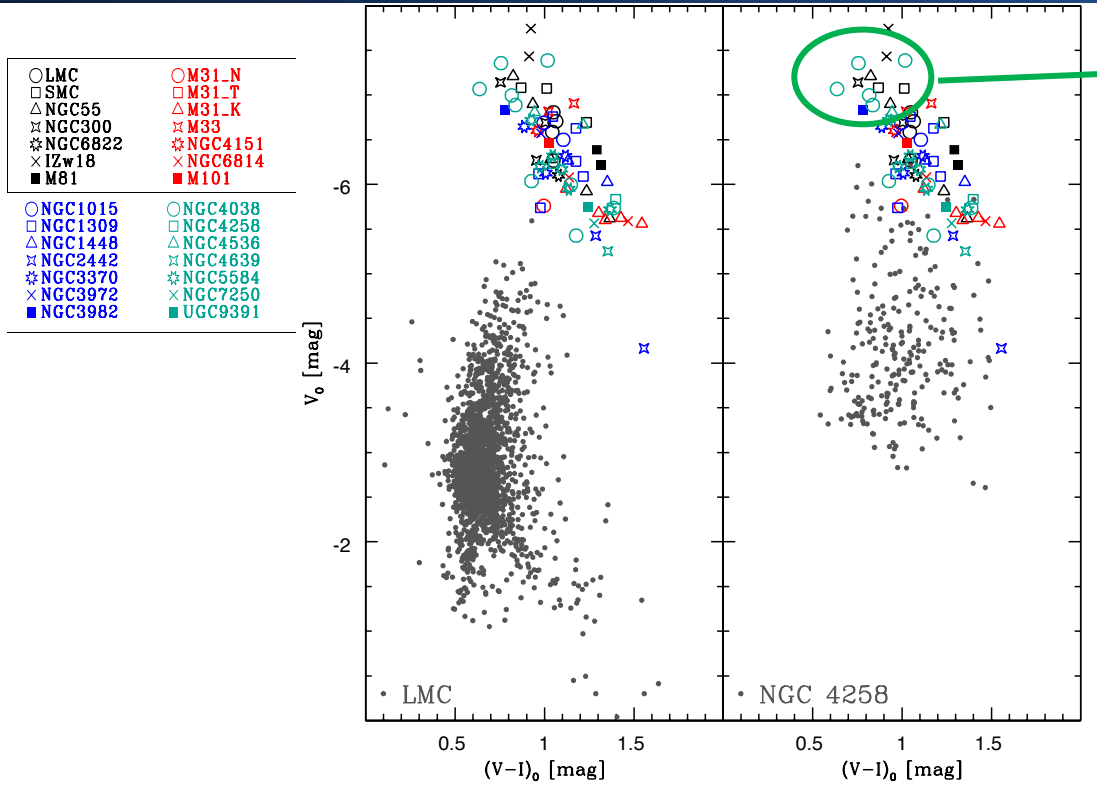

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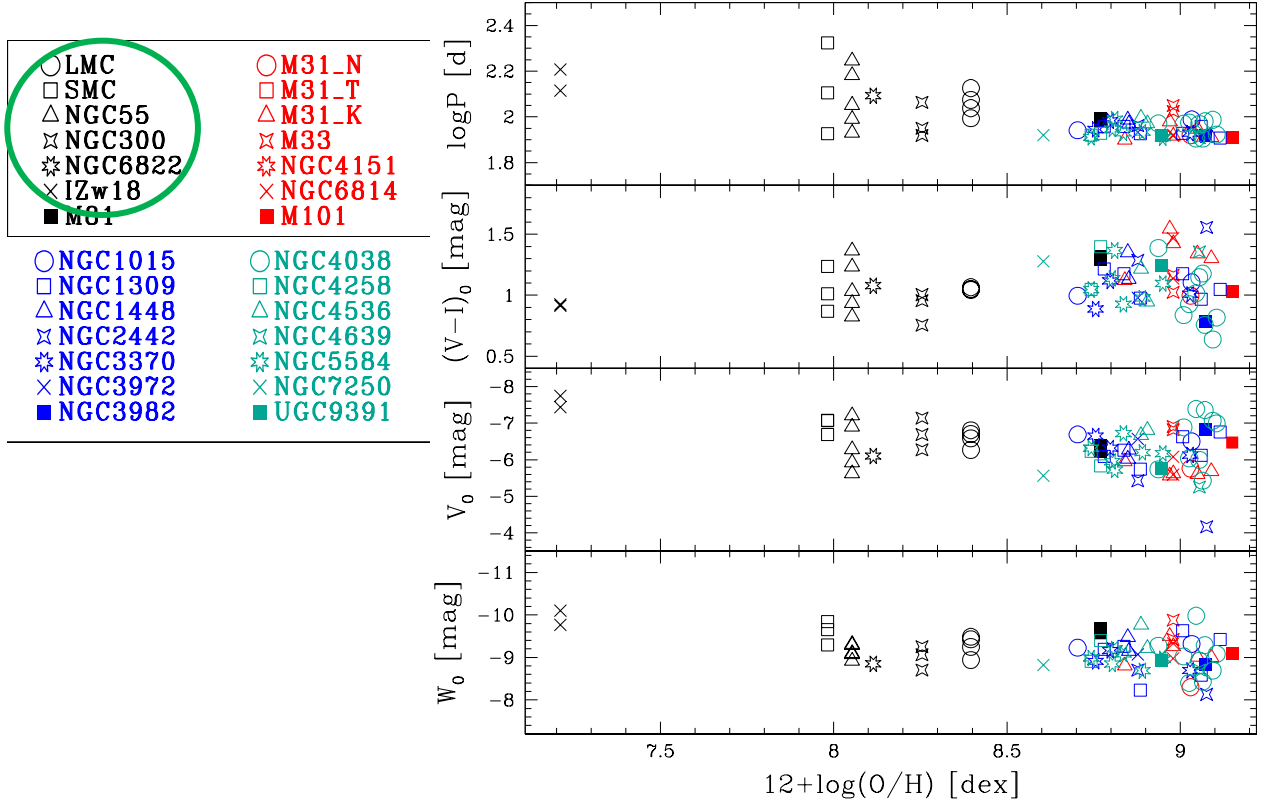
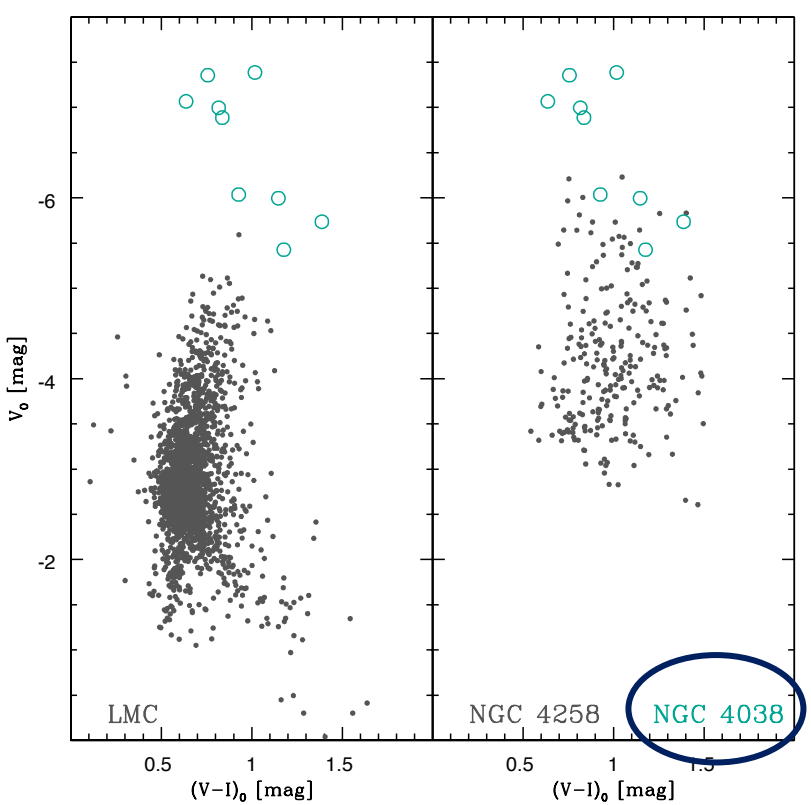
Dependence on the metallicity?



- Metal poor ULPs appear to be slightly brighter and bluer
- Also the photometrically homogeneous Gaia and Riess samples cover a large color range

Reddening, distance and metallicity effect?

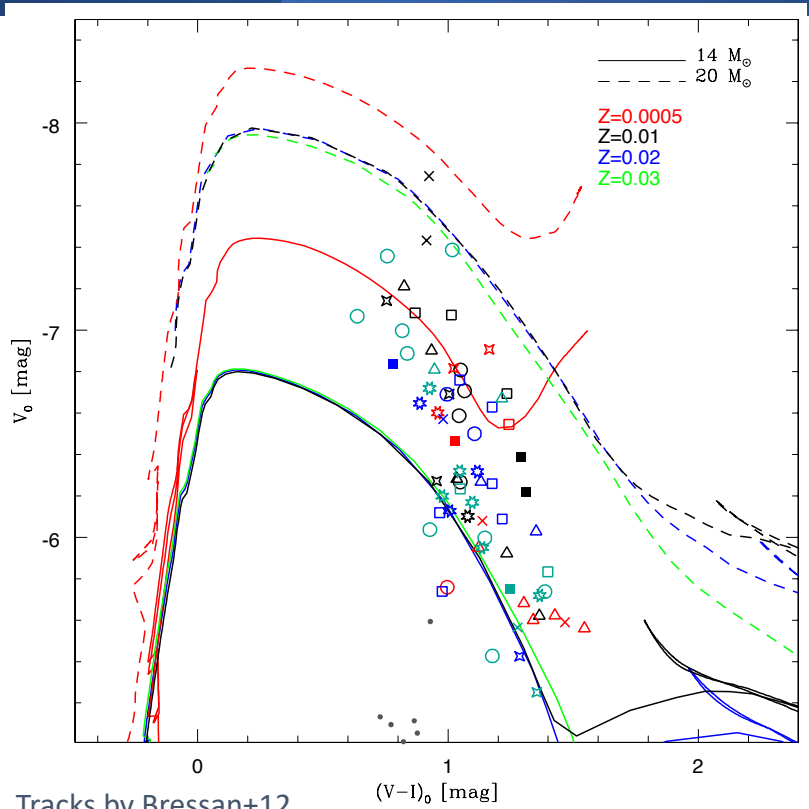


NGC 4038 (SH0ES projects) [9 ULPs]

- Large range in colour
- The 5 brightest NGC 4038 ULPs have solar metallicity confirmed by Lardo+15 → So they are bluer then expected but not metal poor

Comparison with evolutionary models

- At these higher masses, unlike what happens for the CCs, the evolutionary models do not predict the blue loop crossing the instability strip.



Tracks by Bressan+12

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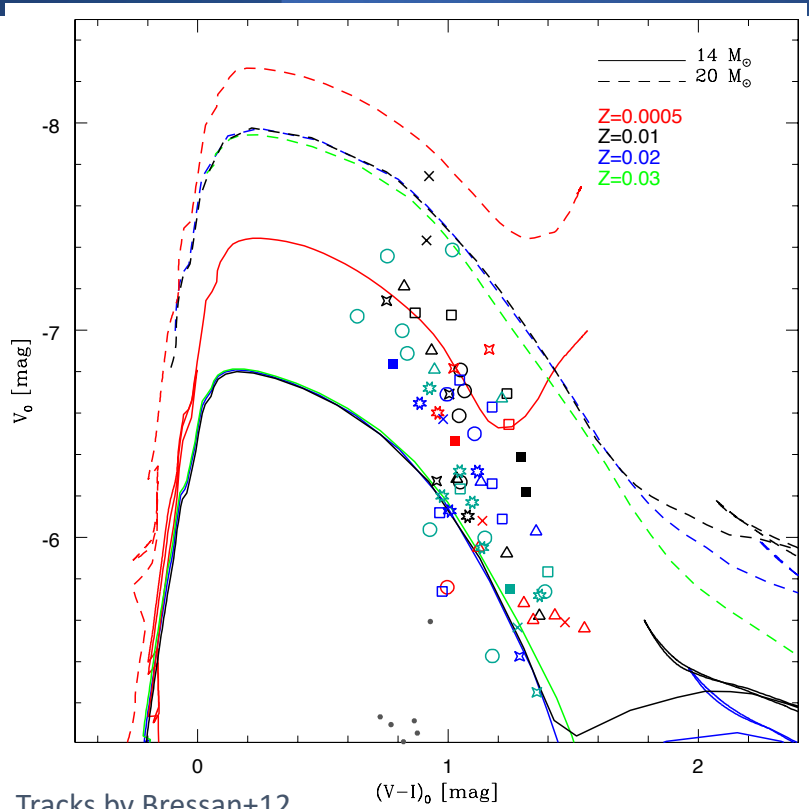
- In addition, if we apply a period-luminosity-color-mass relation, in many cases, we find inconsistent results



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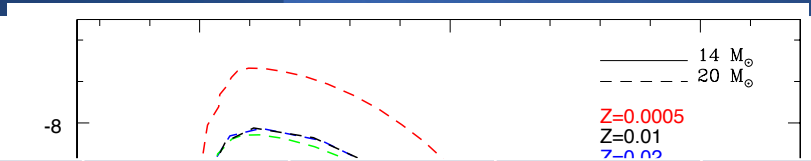


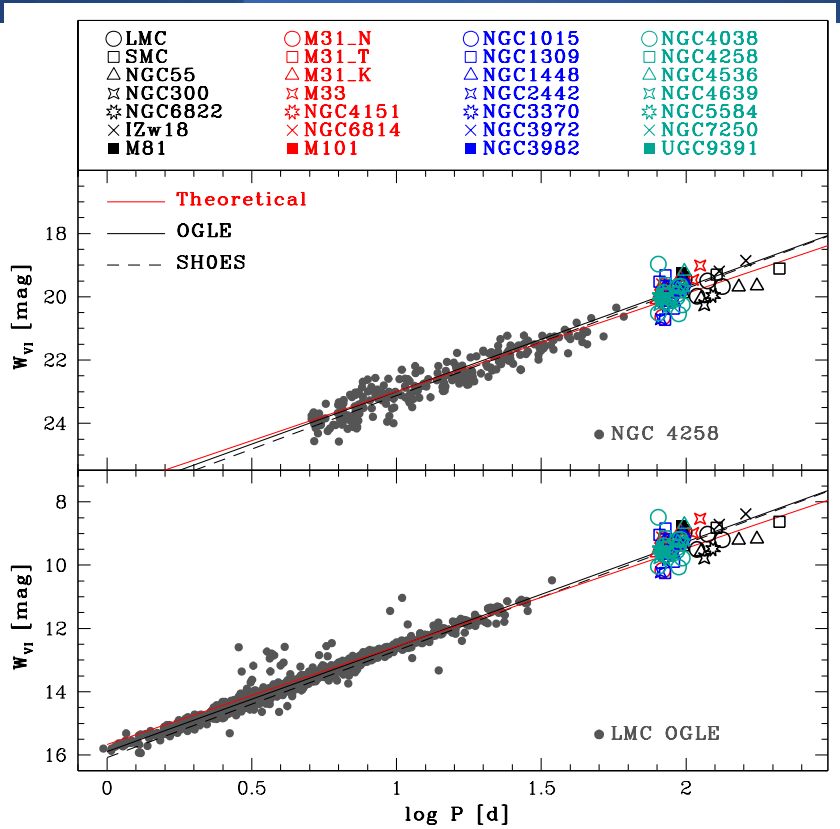
Galaxy	Period	Mass Track	Computed Mass	Computed period Assuming the computed mass
LMC	98.6	~15.6	~15.33	~97.29
LMC	133.6	~13.7	~8	~87
LMC	118.7	~15.6	~12.4	~97.29
M31	81.35	~14	~10	~62
M31	88.45	~14	~9	~62
M31	95.38	~15.6	~14.3	~88.9

Comparison with pulsation models

(non linear convective pulsation models: Marconi+ De Somma+, Fiorentino+)

These models reproduce all the observables (periods, mean magnitudes, light curves, amplitudes…):

- Good agreement with the mean statistical properties obtained for the CCs extended to higher luminosities and periods
- Difficult to perform the light curve fitting (to derive intrinsic stellar parameters and distance and reddenings) also due to the previous described inconsistencies in the PLMC.



Conclusions

These objects represent a challenge both from observational and theoretical point of view to define them as “standard candles”:

★ Theoretical Evolutionary Framework: evolutionary phase of ULPs

★ Theoretical Pulsation Models: extension of pulsation models to highest luminosities

★ Statistics and accuracy: improving and increasing the sample (e.g. Rubin-LSST, We are searching for ULPs in our Galaxy in Gaia Dr3 catalog. They are not present in the CC DR3 sample, but we are analyzing the LPV sample…)

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