

Long Period Variables as tracers of Galactic Structure

Martin Groenewegen

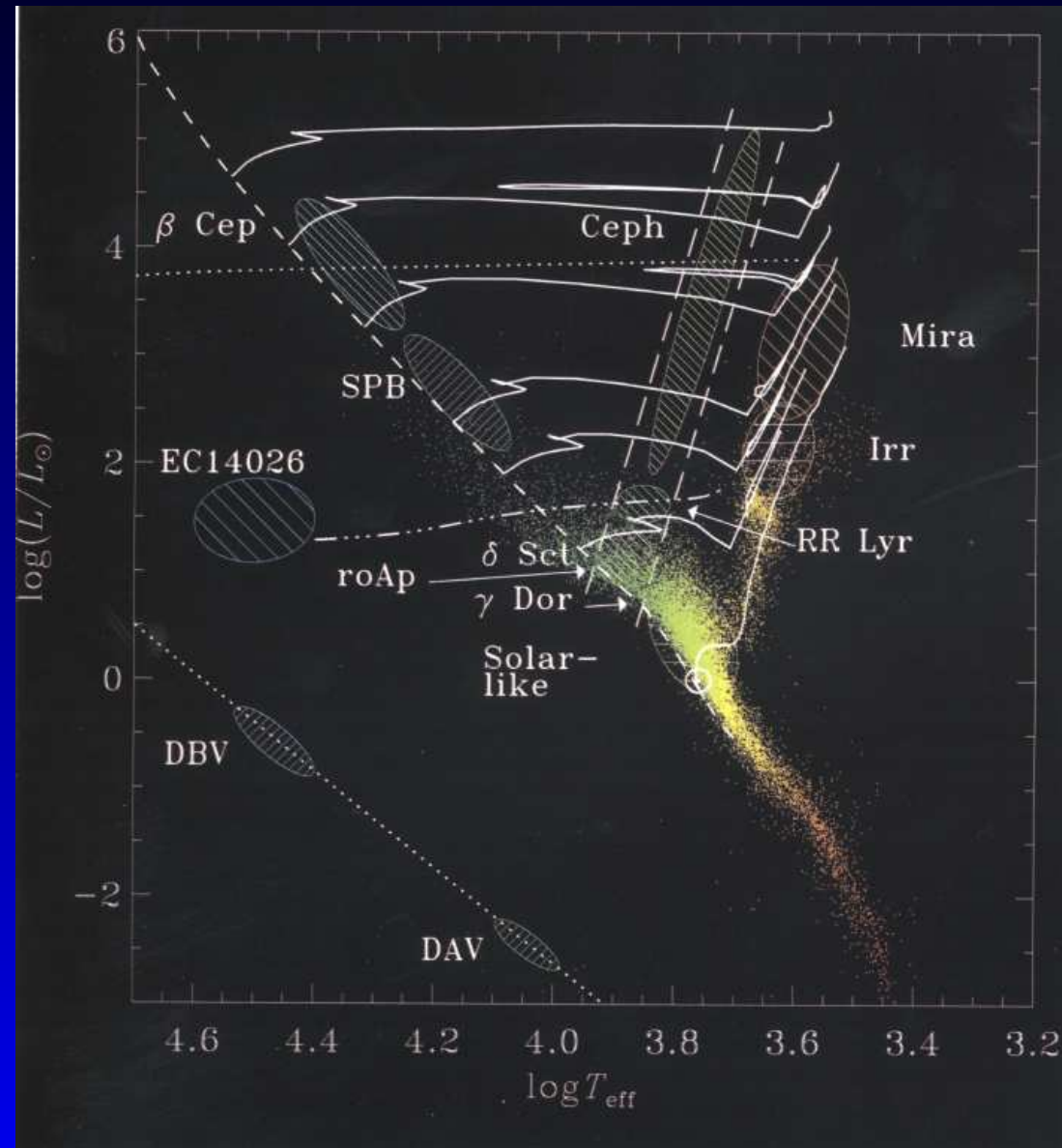
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Overview Talk

- Introduction to AGB stars, Miras, Long Period Variables (LPVs)
 - Period-Luminosity relation
- Tracers of Galactic Structure (?)
- The Galactic Centre
- Perspectives

AGB stars



Late-type stars

- All stars $\lesssim 7-8 M_{\odot}$ go through the AGB phase
- Alternate H and He shell-burning
- Exact $M \rightarrow S \rightarrow C$ sequence is uncertain

Depends on:

- initial mass
- metallicity
- mass loss
- dredge-up
- Hot Bottom Burning

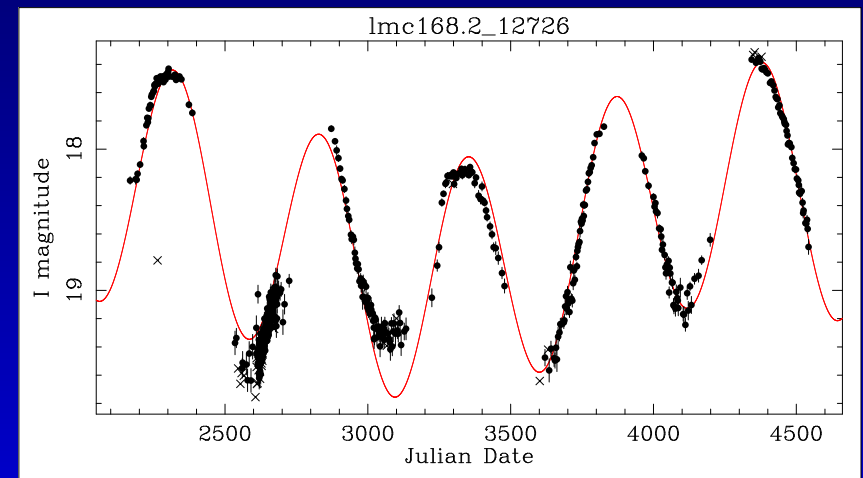
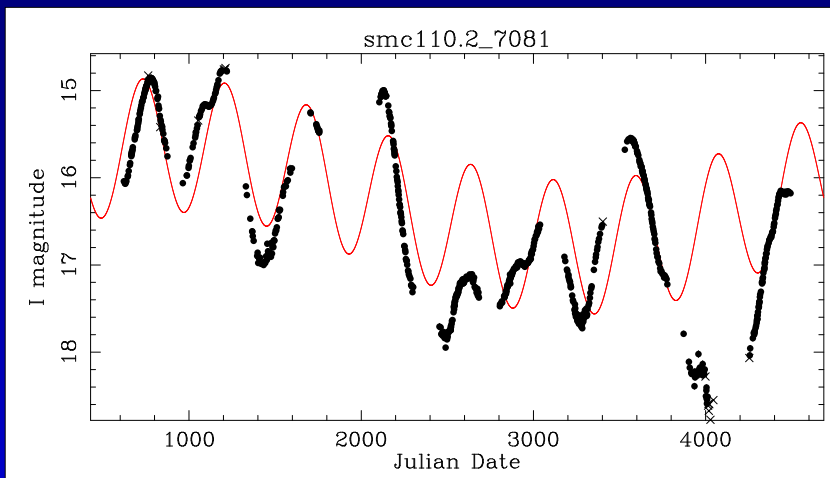
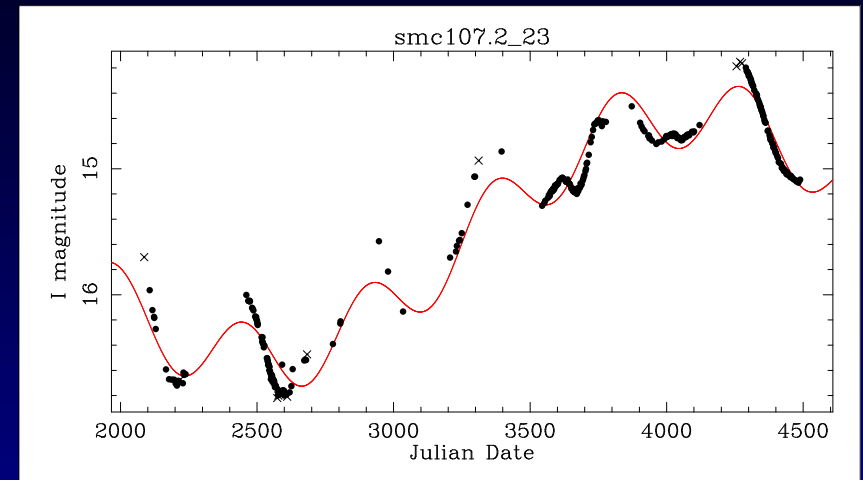
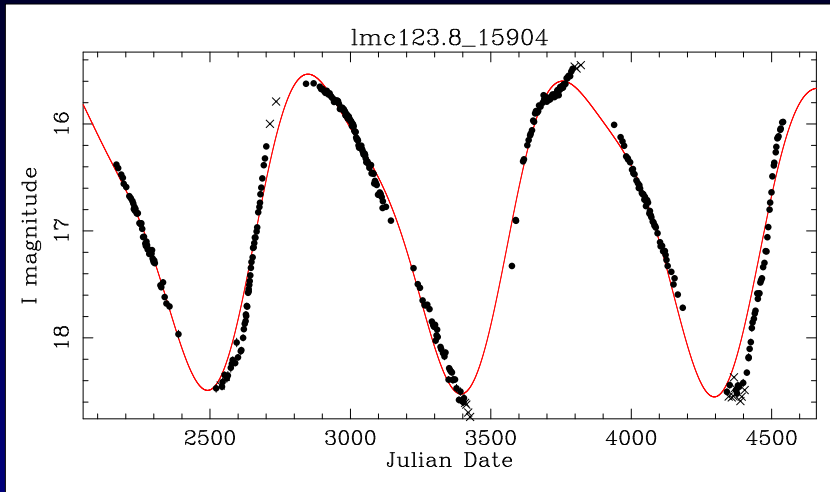
C-star formation:

$M_{\text{initial}} \gtrsim 1.5 M_{\odot}$ (solar), $\gtrsim 1.3 M_{\odot}$ (LMC)

AGB characteristics

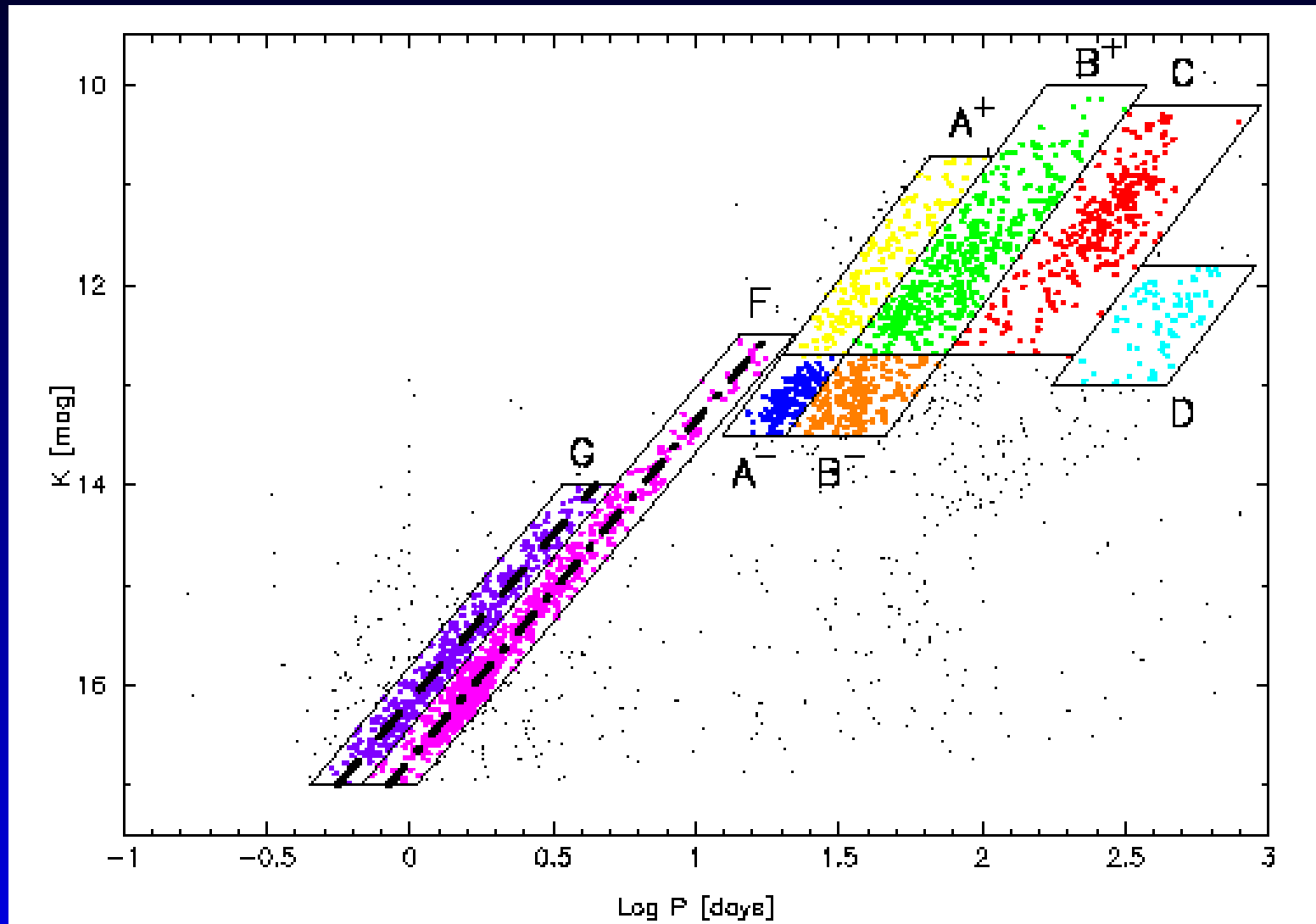
- Chemical type: M, S, C
- Pulsate: Irr, SR, Miras (LPVs)
- Mass-loss (effect on colours)

Pulsation

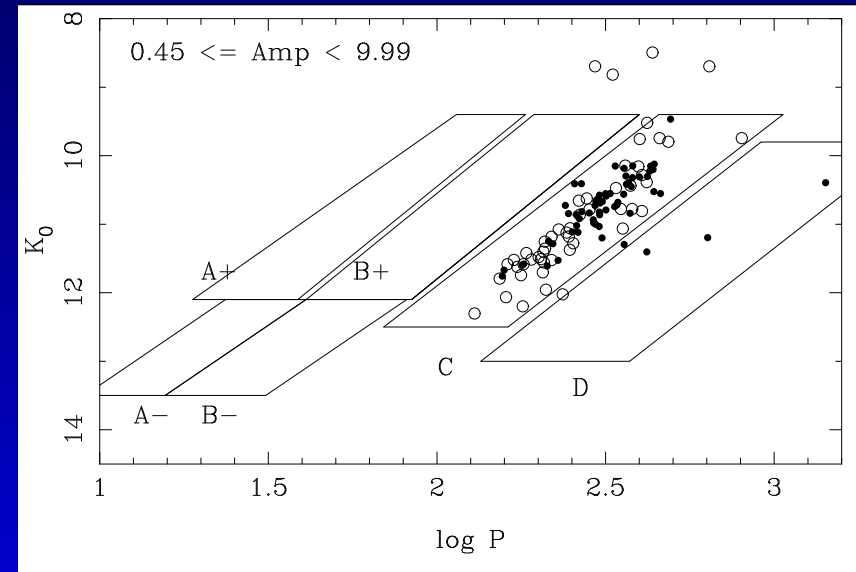
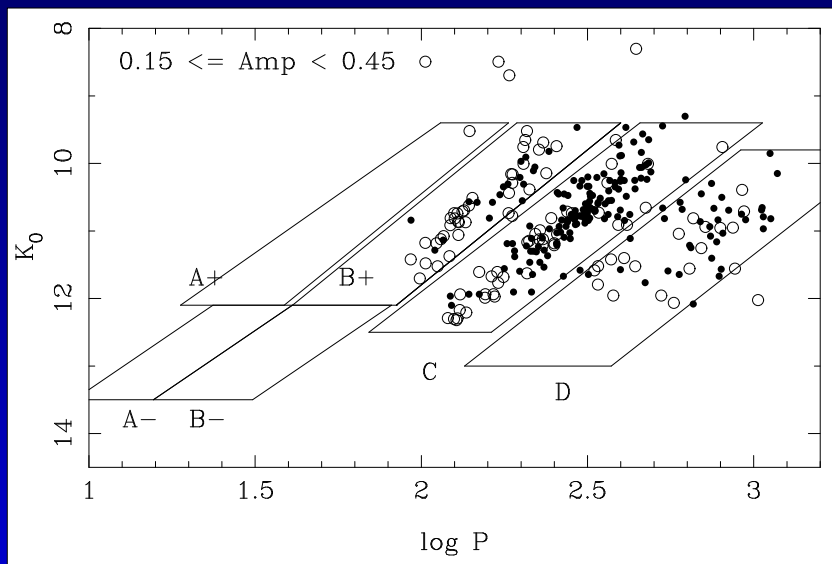
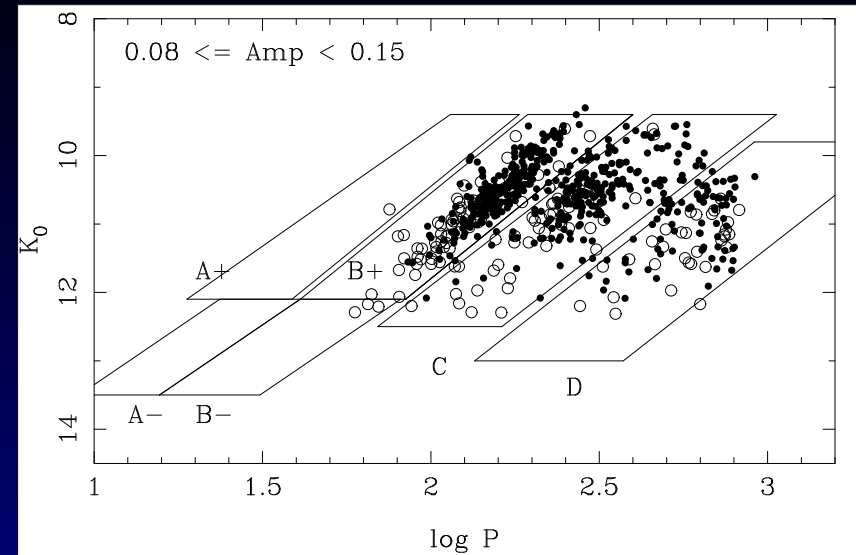
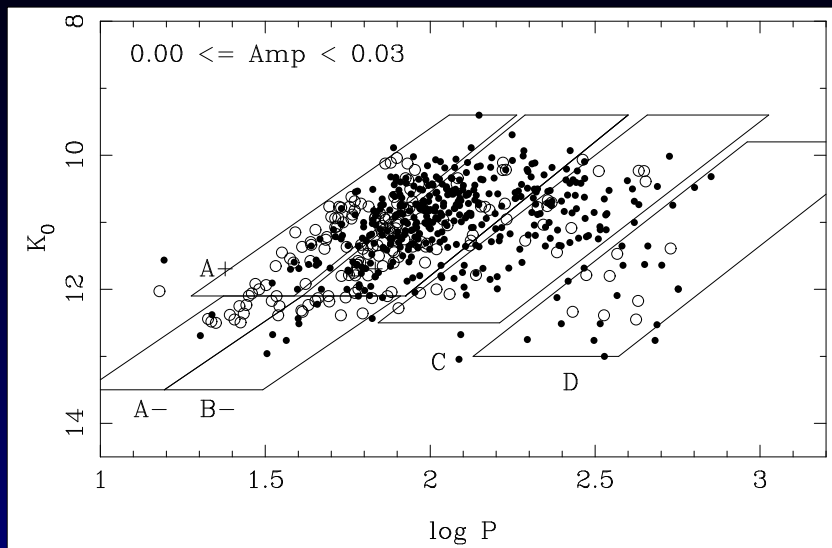


Example of OGLE II + III *I*-band lightcurves
-Main Period (50-2000 days)
-Long Secondary Period (LSP)

Pulsation



Ita et al. (2003)



LMC LPVs from Groenewegen (2004)
PL(K)-relation for different cuts in amplitudes

PL-relations

M_{bol} and M_{K}

- Feast et al. (1989, MN 241, 375)

$$M_{\text{bol}} = -3.00 \log P + 21.35 \text{ (29 LMC O-Miras, rms=0.16)}$$

$$M_{\text{bol}} = -1.86 \log P + 18.73 \text{ (20 LMC C-Miras, rms=0.13)}$$

$$M_{\text{K}} = -3.47 \log P + 19.48 \text{ (29 LMC O-Miras, rms=0.13)}$$

$$M_{\text{K}} = -3.30 \log P + 18.98 \text{ (20 LMC C-Miras, rms=0.18)}$$

- Groenewegen & Whitelock (1996, MN 281, 1347)

$$M_{\text{bol}} = -2.59 \log P + 20.52 \text{ (54 LMC C-Miras, rms=0.26)}$$

$$M_{\text{K}} = -3.56 \log P + 19.64 \text{ (54 LMC O-Miras, rms=0.25)}$$

PL-relations

- Using microlensing data:

Groenewegen et al. (2004, A&A 425, 595), Ita et al. (2004, MN 353, 705), Fraser et al. (2008, AJ 136, 1242).

But, SINGLE Epoch IR data

- Whitelock et al. (2008, MN 386, 313)

$M_K = -3.51 \log P + 19.59$ (31 LMC O-Miras, rms=0.14)

$M_K = -3.52 \log P + 19.53$ (22 LMC C-Miras, rms=0.15)

(ZP at $\log P = 2.39$) $\delta = -7.15 \pm 0.06$ (O-rich),

-7.24 ± 0.07 (C-rich), for DM= 18.39

Assuming same slope, determine ZP for Galactic stars.

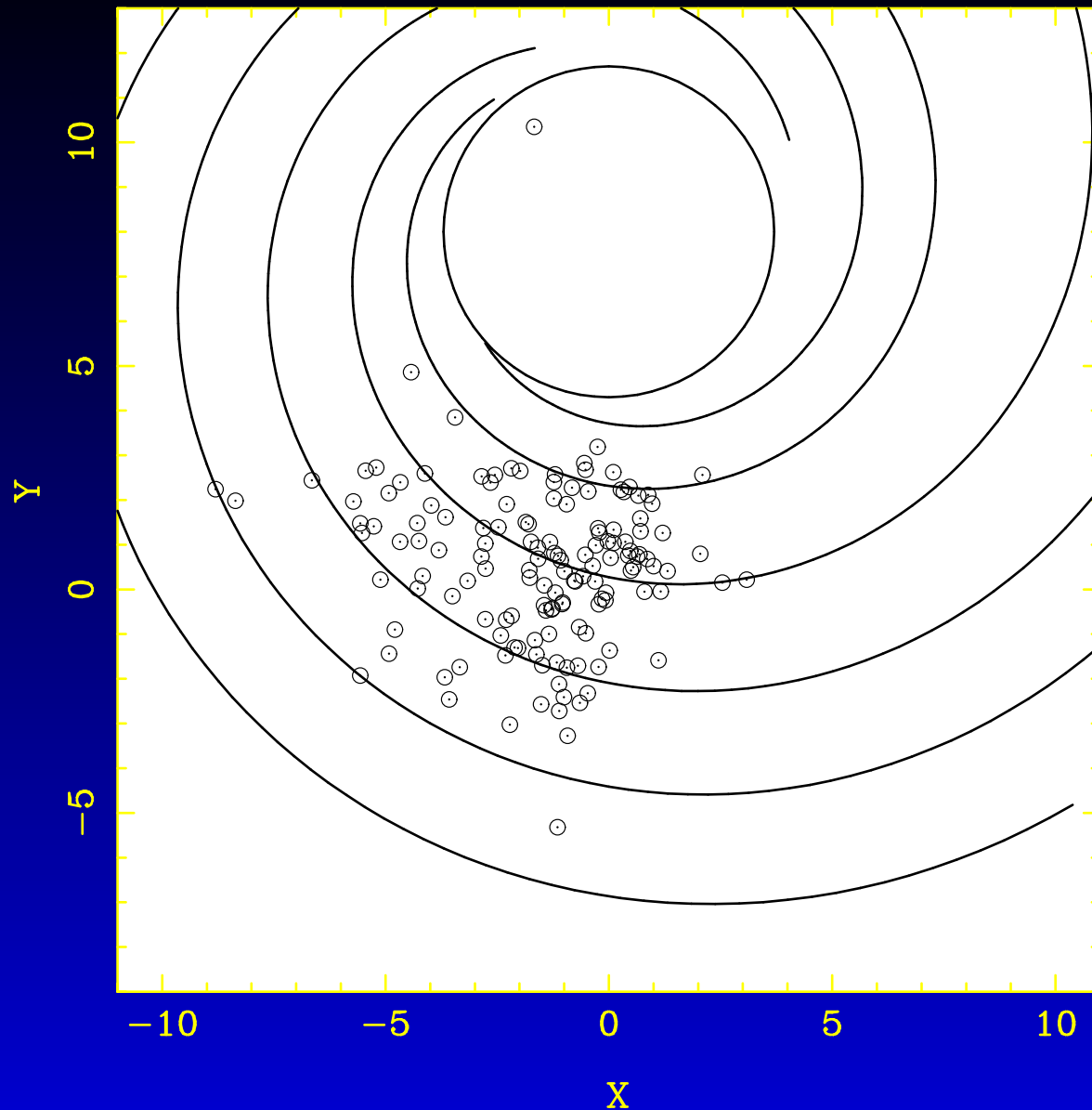
Hipparcos data: -7.32 ± 0.10 (42 O), -7.18 ± 0.37 (16 C)

GC -7.34 ± 0.13 ; VLBI parallaxes (OH/IR) -7.08 ± 0.17 ;

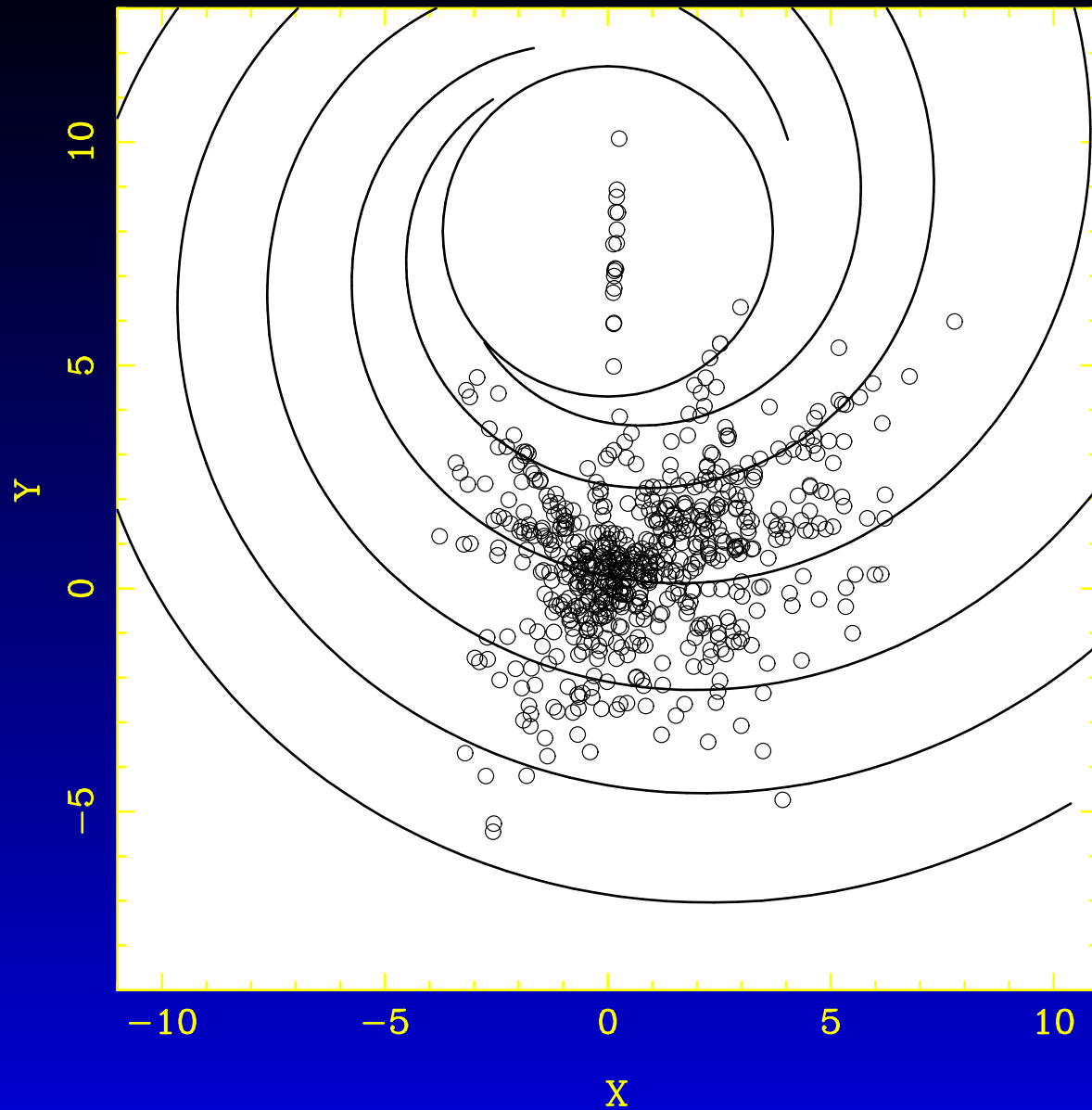
GB -7.04 ± 0.11 (Eisenhauer et 2005)

Galactic Structure

- Whitelock et al. (2006 MN 369, 751)
Collected IR lightcurves for 144 C-stars, and derived distances
- GCVS, Mira, $50 < P < 400$ days \Rightarrow 4520
Using SIMBAD script tool, looked for K -band
 \Rightarrow 1251
Used PL -relation + 3D reddening model to get distances



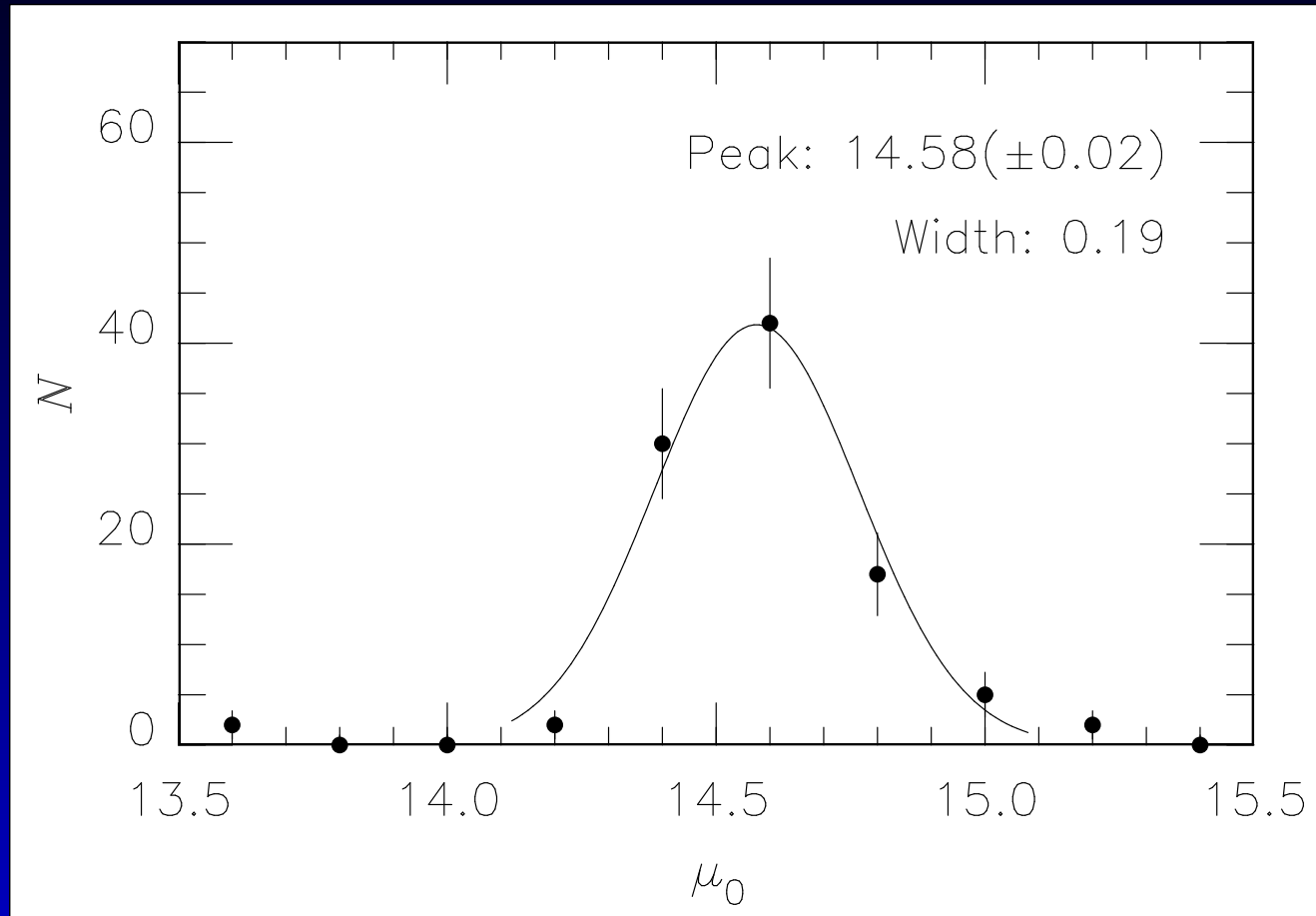
Whitelock et al., C-stars, IR lightcurves
4-spiral arm model from Hou et al. (2009, A&A 473,
473)



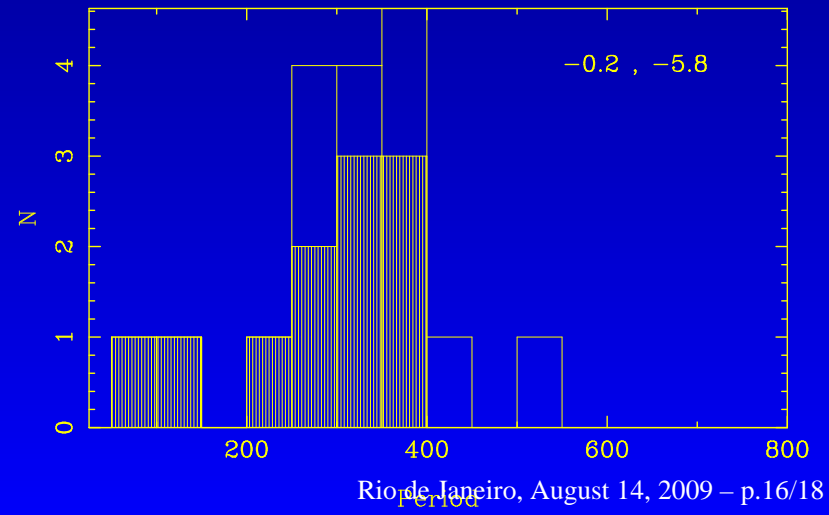
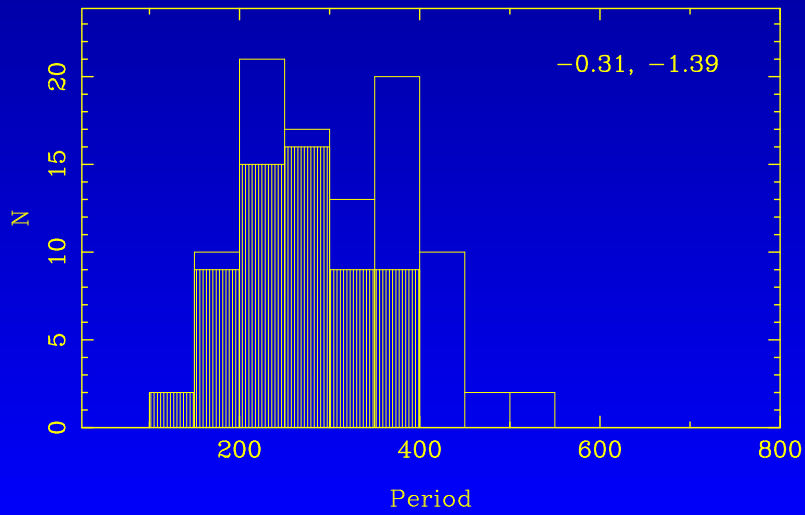
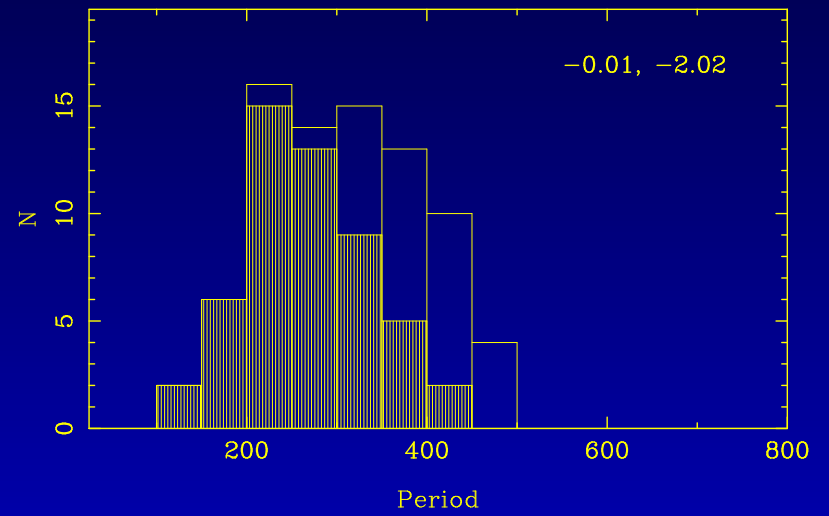
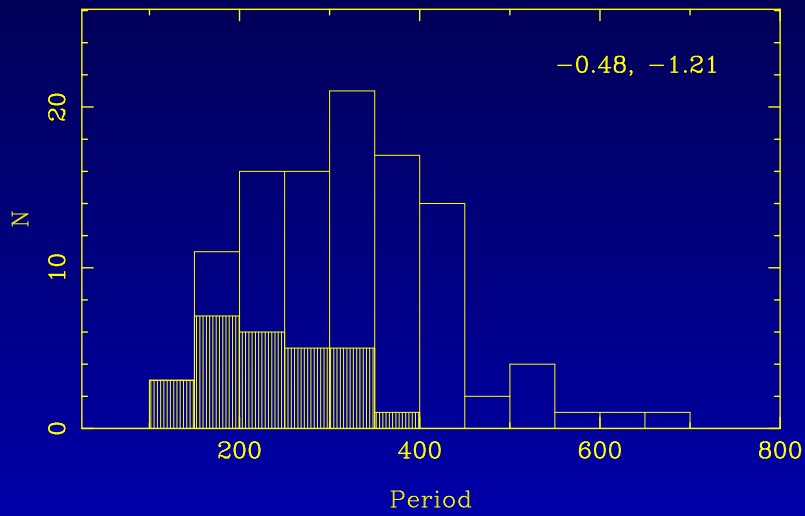
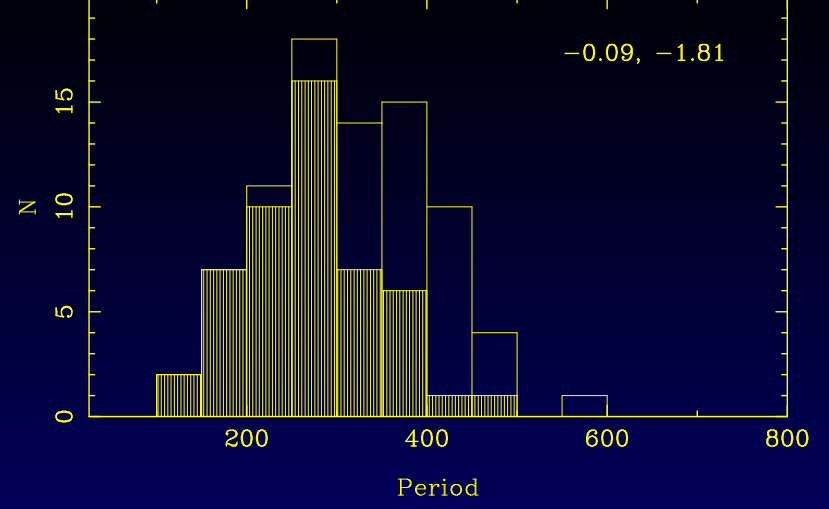
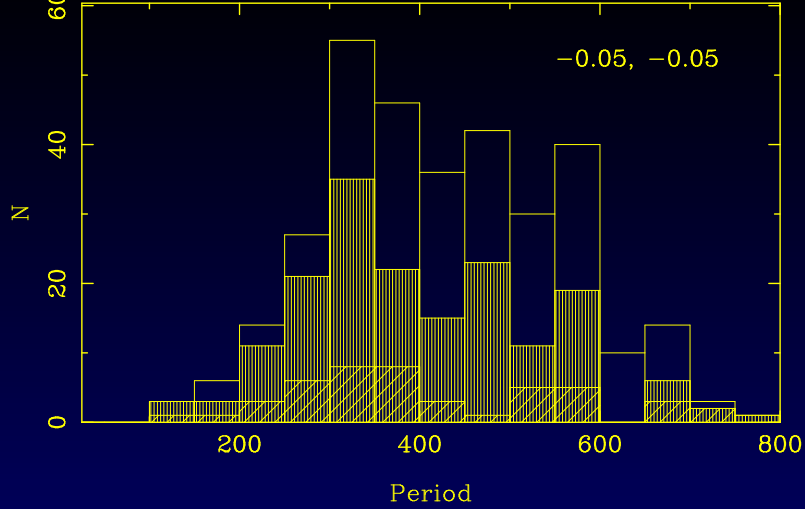
GCVS, single-epoch, $|z| < 500$ pc

Galactic Centre

- Groenewegen & Blommaert
(2005, A&A 443, 143)
Analysed OGLE-II
2691 Miras, correlated with 2MASS
Slope -3.37 ± 0.09
 8.6 ± 0.7 kpc (LMC DM= 18.50)
- Matsunaga et al. (astro-ph 0907.4019)
134 Miras in inner 20x30 arcmin
 8.2 ± 0.4 kpc (LMC DM= 18.45)



Matsunaga et al. 2009



Summary / The Future

- Find them in the optical, get few epochs in NIR.
 - LPVs select on amplitude
 - Effect of mass-loss: select on period ($P \lesssim 400$) or colour ($(J - K)_0 < 2$)
- IRSF/SIRIUS survey of MCs
Y. Ita (astro-ph 0907.5244)
3 + 1 sq. deg, $K = 15.5$ (SN=3)
- VMC (VISTA Magellanic Cloud survey)
M.-R. Cioni
180 sq deg; 12 epochs/6 mon; $K = 20.3$ (SN=10)
- Tracers of Galactic Structure: unclear
OGLE / LSST / skymapper
VISTA Hemisphere Survey+ UKIDSS

THE END