Mira Variables in the Galactic Bulge

Martin Groenewegen

K.U.Leuven

groen@ster.kuleuven.be
Overview

- History

  perspective of the micro-lensing surveys

- Groenewegen & Blommaert (2005)
  - Viewing angle of the Bar
  - Period distribution at various latitudes
  - Distance GC
LPVs in the Galactic Bulge

- Alard et al. (2001) MACHO, 332 ISOGAL sources in NGC 6522 and Sgr I Baades windows ($V, R$ and [7],[15])
- Schultheis & Glass (2001) extended Alard et al. by DENIS and 2MASS.
- Glass & Schultheis (2002) 174 M-giants in NGC 6522 Baades window; MACHO; DENIS + ISOGAL
- Glass & Schultheis (2003) MACHO, NGC 6522 Baades window, DENIS. 1085 of 1661 stars are variable.
- Wray et al. (2004) 13 000 small amplitude red giants variables in a sub-set of 33 OGLE fields.
LPVs in the Galactic Bulge

Groenewegen & Blommart (2005)

- All 49 OGLE-II fields GB 221 000 $I$-band lightcurves
- Fourier analysis + PDM at selected frequencies (Groenewegen 2004)
- $I$-band semi-amplitude larger than 0.45 mag
- Correlation with 2MASS database on position
Lightcurves of Bulge Miras
Galactic Bulge Mira $K$-band Period-Luminosity relation

$$m_K = (-3.37 \pm 0.09) \log P + (15.47 \pm 0.03)$$
ZP of $PL$-relation *versus* longitude
Modelling stars in the Bulge

Binney et al. (1997) model of COBE/DIRBE data.

\[ f_b = f_0 \exp\left(-a^2/a_m^2\right)/\left(1 + a/a_0\right)^\beta \]

\((f_0 = 624, a_m = 1.9 \text{ kpc}, a_0 = 0.10 \text{ kpc}, \beta = 1.8)\)

\[ a = \sqrt{x^2 + (y/\eta)^2 + (z/\eta)^2} \]

with the value of \(\eta = 0.5\)

\[ f_d = \left(\exp\left(-\left|z\right|/z_0\right) + \alpha \exp\left(-\left|z\right|/z_1\right)\right) \times \]

\[ R_d \left(\exp\left(-r/R_d\right) - f_h \exp\left(-r/R_h\right)\right) \]

\((z_0 = 210 \text{ pc}, z_1 = 42 \text{ pc}, \alpha = 0.27, R_d = 2.5 \text{ kpc})\)
Top view of Bulge (o) and Disc (●) stars for viewing angles of 43 and 79 degrees.
observed (□) and modelled (●) data
Both angles fit slope versus $l$ diagram, but only $\phi = 43^o$ fits the observed numbers
Synthetic AGB evolution

- Synthetic AGB evolution code of Wagenhuber & Groenewegen (1998)

- If a star is
  (a) inside the observed instability strip, and
  (b) optically visible, then
  \[ \log P = -2.07 + 1.94 \log R - 0.9 \log M \]

- Finetuned to give AGB and LPV lifetimes of \( Z = 0.016 \) stars in Vassiliadis & Wood (1993)
## Synthetic AGB evolution

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<th>Z</th>
<th>Mass</th>
<th>Vassiliadis &amp; Wood AGB</th>
<th>Vassiliadis &amp; Wood LPV</th>
<th>Wagenhuber &amp; Groenewegen AGB</th>
<th>Wagenhuber &amp; Groenewegen LPV</th>
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<td>282</td>
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- Finer grid in Initial Mass, mass loss on RGB
Theoretical period distribution of optically visible stars inside the observed instability strip for masses 1.1, 1.2, 1.5, 2.0 (1.2 Gyr), 2.5, 3.0M⊙ (200 Myr) (left to right, top to bottom)
Distance to Galactic Centre

- \( M_K = \alpha \log P + \beta \) (+ \( \gamma \log Z \))

**DM (LMC-GB) = 3.71 (for \( \gamma = 0 \))**

\[ \Rightarrow \text{IF } \text{DM}(\text{LMC}) \equiv 18.50 \text{ then } d(\text{GB}) = 9.0 \text{ kpc} \]

**Theory by Wood (1990):** \( \gamma = 0.25 \) (in \( K \)-band)

**DM (LMC-SMC) = 0.38; “rather small”**

\[ \Rightarrow \text{IF } \text{DM}(\text{LMC-SMC}) \equiv 0.50 \text{ THEN } \gamma = 0.40 \]

\[ \Rightarrow \text{IF } \text{DM}(\text{LMC}) \equiv 18.50 \text{ then } d(\text{GB}) = 8.6 \text{ kpc} \]

(DM(LMC) = -0.10 \( \iff \) \( d(\text{GB}) = -400 \text{pc} \))

**Using local calibration of Feast (2004):**

\( d(\text{GB}) = 8.8 \pm 0.4 \text{ kpc} \)
Conclusions

- Analysed the 221 000 $I$-band OGLE-II lightcurves to find 2691 Miras
  $m_K = (-3.37 \pm 0.09) \log P + (15.47 \pm 0.03)$
- Viewing angle of the Bar: 43 $\pm$ 17 degrees in agreement with previous work on Mira and OH/IR stars
- Period distribution at various latitudes indicate differences in population
  trace population of 0.2 Gyr (inner field) to 1.2 Gyr (up to $b = 6$)
- Distance GC: 8.6 - 9.0 kpc
  Longer than traditional
THE END