Microlensing towards the Galactic Centre with OGLE

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Gravitational microlensing optical depth

- probably the best way to constrain the internal structure of the Milky Way
- the most recent models of the Galactic Bulge: Kerins, Robin, Marshall 2010
Gravitational microlensing optical depth

- review by Marc Moniez 2010

results so far:

<table>
<thead>
<tr>
<th>reference</th>
<th>seasons</th>
<th>field deg.$^2$</th>
<th>stars analyzed</th>
<th>events for $\tau$</th>
<th>$\bar{l}^\circ, \bar{b}^\circ$</th>
<th>$&lt;\tau&gt;_{bulge}$ $\times 10^6$</th>
<th>$&lt;t_E&gt;$ corrected</th>
</tr>
</thead>
<tbody>
<tr>
<td>OGLE [112]</td>
<td>2</td>
<td>0.81</td>
<td>all</td>
<td>9</td>
<td>±5, -3.5</td>
<td>3.3 ± 1.2</td>
<td></td>
</tr>
<tr>
<td>MACHO [11]</td>
<td>1</td>
<td>12.</td>
<td>all</td>
<td>45</td>
<td>2.55, 3.64</td>
<td>3.9 ± 1.8</td>
<td></td>
</tr>
<tr>
<td>MACHO [16]</td>
<td>3</td>
<td>4.</td>
<td>all/DIA</td>
<td>99</td>
<td>2.68, -3.35</td>
<td>3.23 ± 0.52</td>
<td></td>
</tr>
<tr>
<td>EROS [3]</td>
<td>3</td>
<td>15.</td>
<td>bright</td>
<td>16</td>
<td>2.5, -4.0</td>
<td>0.94 ± 0.29</td>
<td></td>
</tr>
<tr>
<td>MOA [104]</td>
<td>1</td>
<td>18.</td>
<td>all/DIA</td>
<td>28</td>
<td>4.2, -3.4</td>
<td>3.36 ± 0.81</td>
<td></td>
</tr>
<tr>
<td>MACHO [86]</td>
<td>7</td>
<td>4.5</td>
<td>bright</td>
<td>62</td>
<td>1.5, -2.68</td>
<td>2.17 ± 0.47</td>
<td>21.6 ± 3</td>
</tr>
<tr>
<td>OGLE [105]</td>
<td>4</td>
<td>5.</td>
<td>bright</td>
<td>32</td>
<td>1.16, -2.75</td>
<td>2.55 ± 0.57</td>
<td>28.1 ± 4.3</td>
</tr>
<tr>
<td>EROS [62]</td>
<td>7</td>
<td>66.</td>
<td>bright</td>
<td>120</td>
<td></td>
<td></td>
<td>28.3 ± 2.8</td>
</tr>
<tr>
<td>EROS [87]</td>
<td>7</td>
<td>20.1</td>
<td>all</td>
<td>22</td>
<td></td>
<td></td>
<td>48. ± 9.</td>
</tr>
</tbody>
</table>

- but number statistics way too low to recreate the full map
Optical Gravitational Lensing Experiment

OGLE-I
1992 – 1995
started by Paczyński (Princeton) and Udalski (Warsaw)
pilot program
Swope telescope in LCO, Chile

OGLE-II
1996 – 2000
dedicated 1.3m telescope in Las Campanas Observatory, Chile
2k x 2k single CCD
fov: 0.21 sq deg

OGLE-III
2001 – 2009
8 chip mosaic camera
2k x 4k 0.26”/pix each CCD
fov: 0.34 sq deg

OGLE-IV
2010 – ...
32 chip mosaic camera
2k x 4k 0.26”/pix each CCD
fov: 1.4 sq deg
data flow 8 times OGLE-III
OGLE-II Bulge fields
~49 fields
~10 square degrees
about 20 million objects
OGLE-III Bulge fields
~300 fields
~100 square degrees
about 200 million objects
OGLE-IV Bulge fields
233 fields
~330 square degrees

Colours indicate frequency of observations:
- red: 10-30 per night
- yellow: 3-10 per night
- green: 1-3 per night
- blue: 0.5-1 per night
- cyan: less than 0.5 per night
- transparent: observed occasionally

Interactive plots available at: ogle.astrouw.edu.pl
OGLE-III data search (2001-2004)

82 (out of 260) fields selected - frequently observed in 2001-2004 seasons
~27 sq. deg, ~50 million stars
Outline of the search procedure

I < 21.0 mag: ~50 million stars monitored for 4 years

significant brightening over baseline: ~12,000 objects

artefacts removed: 2290 candidates

standard microlensing fit ok: 610 standard events
Simplified blending distribution

- derived using standard events fits
- follows characteristic U shaped distribution (Sumi+2005)
- to be used in efficiency calculation

- in the full study the HST-OGLE comparison will be done
Optical depth towards the bulge from partial OGLE-III data (2001-2004)

the largest sample so far (OGLE-III): 610 events, 27 sq.deg, 50 million stars
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\[ \tau_{BW} = 1.9 \pm 0.3 \times 10^{-6} \]
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weak dependence of tau on b
- contamination with disk sources

Optical depth towards the bulge from full OGLE-III data (2001-2009)

**Preliminary results**

- Calculation for Baade’s Window fields with 13.8 million stars
- Only high quality events chosen
- 111 standard events found

\[ \tau_{BW} = 1.3 \pm 0.2 \times 10^{-6} \]

- In agreement with expected value
- Based on all stars down to 20.5 (not only bright) - and still in agreement with bright stars results
- 5,000 events expected - enough for detailed map of the optical depth for \(-7<l<+7\) and \(-5<b<-2\)

From D. Bennett
new long events, $t_E > 200\text{d}$

~450d

~400d

~300d

multi-peak

277d

~300d
very short events

$t_E=0.2d$

t$_E=6d +$ caustic crossing
other interesting events

- variable baseline

- new nova
Future of Galactic optical depth studies

- OGLE-III (2001-2009) events catalogue to be published soon
- next step: map of the optical depth towards the Galactic Bulge with OGLE-III events
- OGLE-IV (2010 - ...) is monitoring the Bulge and the Plane
- VVV NIR Bulge/Plane survey at low $b$ to complement OGLE I-band tau studies
- ESA’s Gaia mission (2013-2018) will detect microlensing events with $t_E > 30$ from all over the sky; Bulge not very well covered
Thank you!