The first confirmed microlensing event in a globular cluster

Pawel Pietrukowicz          Warsaw University Observatory, Poland
&
D. Minniti,   Ph. Jetzer,   J. Alonso-Garcia,   A. Udalski
The Paczyński's idea

Bohdan Paczyński (1940-2007)

Paczyński (1986) – microlensing by halo objects

Paczyński (1994) – microlensing in GCs
An episode in M22 in 2000

Probable lens:

M5 dwarf, $M = 0.14 \pm 0.10/0.02 \, M_{\odot}$

Pietrukowicz et al. (2005, Acta Astronomica, 55, 261)
An episode in M22 in 2000

*JHKs* combined image from VISTA Variables in the Via Lactea (VVV) survey
An episode in M22 in 2000

Probable lens:

M5 dwarf, $M = 0.14 \pm 0.10/-0.02 \, M_{\odot}$

Pietrukowicz et al. (2005, Acta Astronomica, 55, 261)
An episode in M22 in 2000

map from Churchwell et al. (2009)
Adaptive optics
VLT/NACO observations

Location: Cerro Paranal, Chile
Telescope: 8.2m UT4
Instrument: NAOS-CONICA
Mode: service
Date: 2011 July 17
Filter: $K_s$

V~14 mag star as the natural guide source
20 x 110 s exposures
FWHM = 0.11 arcsec
11 years after the event

Source-lens separation: 0.125"

Seeing: 0.7-1.0"

FWHM: 0.11"

Confirmation of the event: relative proper motion


M22-bulge relative pm from Chen et al. (2004)

11 years after the event

Source:
$K_s = 17.37\ \text{mag}$

Lens:
$K_s = 20.57\ \text{mag}$

Confirmation of the event: CMD

Geometry of the event

Lens:
\[ d = 3.2 \pm 0.2 \text{ kpc} \]
\[ M = 0.18 \pm 0.01 \text{ M}_{\odot} \]

Source:
\[ d = 6.0 \pm 1.5 \text{ kpc} \]
\[ M \sim 1 \text{ M}_{\odot} \]

models from Brocato et al. (1998)
Geometry of the event

Lens:
\[ d = 3.2 \pm 0.2 \text{ kpc} \]
\[ M = 0.18 \pm 0.01 \text{ Msun} \]

Source:
\[ d = 6.0 \pm 1.5 \text{ kpc} \]
\[ M \sim 1 \text{ Msun} \]
Confirmation of the event: OGLE-IV light curve

OGLE-IV – instrumentation

In operation since March 2010
1.3m Warsaw telescope at Las Campanas
32-chip mosaic camera
1.4 deg^2 field of view
Scale of 0.26 arcsec/pix
VI filters
Read-out time: 20 sec

http://ogle.astrouw.edu.pl
OGLE-IV – bulge coverage

Cadence (visits per night):
- Red: 10-30
- Yellow: 3-10
- Green: 1-3
- Blue: 0.5-1
- Cyan: < 0.5
- Transparent: occasionally

In 2011 bulge season:
- 1562 microlensing candidates
- 63 events with $t_E < 2$ days
- OGLE-IV covers 43 bulge GCs
OGLE-IV – disk coverage
OGLE-IV – bulge coverage

Cadence (visits per night):

Red: 10-30
Yellow: 3-10
Green: 1-3
Blue: 0.5-1
Cyan: < 0.5
Transparent: occasionally

In 2011 bulge season:

1562 microlensing candidates
63 events with $t_E < 2$ days

OGLE-IV covers 43 bulge GCs
OGLE-IV – likely events in bulge GCs

OGLE-2011-BLG-0123

I magnitude vs. HJD - 2450000

NGC 6522

OGLE-2011-BLG-1461

I magnitude vs. HJD - 2450000

NGC 6544
Summary

- For the first time from the ground we have resolved components of a microlensing event.

- For the first time we have confirmed that an object in a GC acted as a microlens.

- The detected microlens in M22 is a \( \sim 0.18 \, M_{\odot} \) dwarf.

- We show the capability of the microlensing technique in detection and mass measurement of objects in GCs.
Thank you!
Microlensing events in the fields of GCs

<table>
<thead>
<tr>
<th>Survey</th>
<th>Years</th>
<th>Total number of events</th>
<th>Events at ( r &lt; r_t )</th>
<th>Events at ( r \leq ) ( r_h )</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACHO</td>
<td>1992-1999</td>
<td>564</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>EROS-2</td>
<td>1996-2002</td>
<td>120</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>MOA</td>
<td>2000-2010</td>
<td>2818</td>
<td>98</td>
<td>1</td>
</tr>
<tr>
<td>OGLE-I</td>
<td>1992-1995</td>
<td>20</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>OGLE-II</td>
<td>1998-2000</td>
<td>164</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OGLE-III</td>
<td>2001-2009</td>
<td>4057</td>
<td>114</td>
<td>1</td>
</tr>
<tr>
<td>OGLE-IV</td>
<td>2011</td>
<td>1562</td>
<td>40</td>
<td>2</td>
</tr>
</tbody>
</table>

None of the event detected so far was observed in the core of a cluster!
Two GCs in Baade's Window

NGC 6522

NGC 6528

16'}