Photometric microlensing observed by Gaia

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Gaia

- Launched on 19\textsuperscript{th} Dec 2013 from French Guiana
- Space satellite in L2 point (distance = 1\% AU)
- Main goal: astrometry for 1 billion sources in MW with precision down to 24 \(\mu\)as
- Whole sky covered 40-200 times over 5 years, cadence: 9x4s - 106min - 30 days
- BP-RP: low resolution spectra => easy to recognize obvious cataclysmic variables or Miras
- Gaia Science Alerts: operate since 2014, alerts based on rapid flux change of observed sources (new and old)
Why Gaia is important for microlensing?

- Gaia’s main goal is astrometry!!
- K. Rybicki: Possibility of detecting astrometric centroid shift on for stars with $G < 16\text{mag}$
- Possible way to detect single black holes!
- Soon: 1mas astrometry for all Gaia alerts!

V.A. Belokurov & N. A. Evans, 2001
Microlensing observed by Gaia

- Gaia Science Alerts: more than 4000 since 2014
  7 confirmed microlensing events, 20+candidates

- Most microlensing candidates occur in Bulge, but Gaia has low sampling there

- 9 events appears in OGLE EWS
- Follow-up is submitted to Cambridge Photometric Calibration Server (designed by Sergey Koposov and LW)
- Promising candidates get at least two spectra: one during amplification, second at baseline
Gaia16aua ‘Auala’

- Single source – single lens
- First confirmed microlensing event
- Towards Galactic Disk (South)
- Event observed by Gaia and OGLE
- Spectrum: 14\(^{th}\) Jul 2016 (SALT)
Gaia16aye ‘Ayers Rock*’

- Event with binary lens and single source
- Towards Galactic Disk (North)
- Follow-up obtained with OPTICON and many other collaborators; 24,000+ points!
- Multiple spectra obtained for various amplification factors

* Uluru
Gaia17aqu ‘Aqua’

- Single lens – single source
- Towards Galatic Disk (South)
- Observed by OGLE, follow-up with LCOGT
- Spectra with SALT amplified 28\textsuperscript{th} Mar, 19\textsuperscript{th} Apr 2017, baseline 8\textsuperscript{th} Jan 2018

<table>
<thead>
<tr>
<th>$T_0$ -24500000</th>
<th>$t_E$</th>
<th>$u_0$</th>
<th>$I_{0,OGLE}$</th>
<th>$f_{b1}$</th>
<th>$I_{Gaia}$</th>
<th>$f_{b2}$</th>
<th>$\chi^2$</th>
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<tbody>
<tr>
<td>7879.99</td>
<td>109.9</td>
<td>0.060</td>
<td>18.15</td>
<td>0.38</td>
<td>18.97</td>
<td>0.33</td>
<td>554.60</td>
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</tbody>
</table>
Gaia17bts ‘Bangtan Boys’

- Single lens – single source
- Towards Galactic Disk (North)
- Follow-up by OPTICON+others
- Spectra: 29\textsuperscript{th} Jul 2017 (Palomar)
  18\textsuperscript{th} Jan 2018 (Palomar)
- Best model: with parallax

\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|}
\hline
\textbf{t\textsubscript{0}} & \textbf{t\textsubscript{E}} & \textbf{u\textsubscript{0}} & \textbf{\pi\textsubscript{EN}} & \textbf{\pi\textsubscript{EE}} & \textbf{f\textsubscript{b,Gaia}} & \textbf{f\textsubscript{b,APASS,r}} & \textbf{f\textsubscript{b,APASS,i}} & \textbf{f\textsubscript{b,V}} & \textbf{t\textsubscript{0par}} & \textbf{\chi^2} \\
7950.49 & 47.20 & 0.238 & 0.32 & -0.93 & 0.69 & 0.73 & 0.71 & 0.70 & 7948.94 & 967.63 \\
\hline
\end{tabular}
Gaia17cad ‘Caddis Fly’

- Single lens – single source event
- Variable source!!! (visible in OGLE)
- Towards Galactic Bulge
- Ground-based observations by OGLE
- Spectrum: 7th Sept 2017

Gaia light curve

OGLE light curve
Towards Galactic Bulge
Detected when Bulge started to set
Gaia17ctl: spectrum on X-SHOOTER
No ground-based follow-up (yet)
Missed Events

- AlertPipe missed at least four microlensing events by now
- Three: discovered by ASAS-SN (ASASSN-16oe, ASASSN-V J044558.57+081444.6, ASASSN-V J182456.34-305816.7)
- One: Kojima event (TCP J05074264+2447555)
Summary and Future

- Gaia Science Alerts: interesting events found in Galactic Disk; spectral analysis helps to resolve the source and lens
- Soon: 1 mas astrometry for Gaia Science Alerts, Final Data Release planned for 2022
- Calibration Server will be doing automatic data reduction soon (not only calibration)
- Gaia Science Alerts will be refined for microlensing
- Future papers: Gaia16aye (two), Gaia17bts and all microlensing events found in GSA