Gaia Science-Alerts potential for the discovery of intermediate mass black holes

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End goals to keep in mind

Do IMBHs exist?

How do supermassive black holes form?
Intermediate-mass BHs

IMBHs could harbor ~ the same baryonic fraction as SMBH (Madau & Rees 2001)

Black hole mass density; Merloni & Heinz 2012
Formation of IMBHs:

Direct collapse gas cloud
(Begelman, Volonteri, Rees 2006)

IMBH formation in globular clusters
(Miller & Hamilton 2002)

Collapse of Pop III stars
(Madau & Rees 01)
Crowther et al. 2010 observed M_ZAMS>200 Msun in the LMC R136 cluster

Runaway collisions in dense young star clusters
(Portegies Zwart & McMillan 2002; Portegies Zwart et al. 2004)
Stellar-mass black holes

How do ultra-luminous X-ray sources fit-in?

Casares 2005, Casares & Jonker 2013
see also Farr et al. 2011, Ozel et al. 2010

Compact Object Mass ($M_\odot$)
ULXs: high-mass end of stellar-mass BHs or IMBHs? Optical counterparts exist, e.g. Gladstone et al. 2013, but often too faint for direct mass measurements.
NIR observations of ULXs red super-giant mass donor?

out of 65 observed, 19 have a counterpart with abs magnitude consistent with red supergiant

NIR observations of ULXs red super-giant mass donor!

\[ V_{\text{radial}} = 170 \pm 10 \text{ km/s} \]

Heida, Jonker, et al. in prep.
NIR observations of ULXs
RGS+BH systemic velocity (radial!)

Heida, Jonker, et al. in prep.

Simulation by Serena Repetto

Heida, Jonker, et al. in prep.
NIR observations of ULXs intermediate-mass BH

Heida, Jonker, et al. in prep.
IMBH candidates?

ESO 243-49 HLX-1, a candidate intermediate mass black hole

composite, embellished, HST image
Tidal disruption events & IMBHs

Y-axis ($r_{\text{tidal}}$ in km)

X-axis ($M_{\text{BH}}$ in $M_{\odot}$)

- 10 $M_{\odot}$ MS star
- 1 $M_{\odot}$ MS star
- 0.1 $M_{\odot}$ MS star
- 1 $M_{\odot}$ WD
- Schwarzschild radius

Schwarzschild radius
Tidal disruption of a WD by an IMBH

<table>
<thead>
<tr>
<th>WD–BH encounter</th>
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<tbody>
<tr>
<td>masses (sol.)</td>
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<tr>
<td>in. separation</td>
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<tr>
<td>hydrodynamics</td>
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<tr>
<td>EOS, gravity</td>
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<tr>
<td>nucl. burning</td>
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<tr>
<td>simul. time</td>
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<tr>
<td>color coded</td>
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<tr>
<td>penet. factor</td>
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Coding, simulation, visualisation: S. Rosswog

Rosswog, Ramirez-Ruiz, Hix 2009
Tidal disruption events & IMBHs

Macleod et al. 2014 (and refs therein)

\[ M_{bh} = 10^5 M_\odot \]
Tidal disruption events & IMBHs

TDF by a $10^4 \, M_\odot$ BH

$L$ (erg/s)

Time (days)

figure from Thomas Wevers
Tidal disruption events & IMBHs

Alerts for Gaia-detected galaxies: $\Delta m < -0.3$, $G < 20$

Figure courtesy Sjoert van Velzen
Detection of a fast X-ray transient

XRT000519

Precursors to the transient

Transient: archival optical images

INT 999s i’-band; 2001-3-22

M_i’ = -6.7 for a Distance Modulus of 31 for M 86

Interpretations: peak luminosity?

$F_{\text{peak}} (0.5-10 \text{ keV}) = 2 \times 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1}$

$d_{\text{M86}} = 16.2 \text{ Mpc}$

$\mathcal{L}_{\text{Edd}}$?
More fast X-ray flashes:

Glennie, Jonker, Fender et al. to be submitted
Evryscope complement of Gaia?

Law et al. 2014 arXiv1407.0026

see & http://evryscope.astro.unc.edu/
Conclusion:

Gaia-discovered tidal disruption events will be a great tool to search for intermediate-mass black holes.

See talks by Thomas Wevers & Sjoert van Velzen!
Transients with expected optical/X-ray/radio emissions

- Absolute peak magnitude $M_V$
- Peak X-ray luminosity (erg s$^{-1}$)
- Time scale (seconds)

Types of transients:
- $\gamma$-ray bursts
- X-ray flashes & sub-luminous
- SN Ia break out
- SGR Giant flares
- SGR Intermediate flares
- SN IIbc break out
- Classical novae
- SGR Giant flares
- Flare stars
- Tidal disruption
- SGR Intermediate flares

Jonker, O’Brien et al. ArXiv 1306.2336