Neil Gehrels Memorial Meeting

Vicky Kalogera

May 20-21, 2018

National Academy of Sciences

LIGO-Virgo/Nick Gertonson - Daniel Schwen/Northwestern

Dept of Physics & Astronomy

and CIERA

Near-term GW detection expectations

and

Neil’s connection to GW170817
Neil's Interface with the GW Community

Thanks to Peter Shawhan & Gabby Gonzalez

2011: Joined the LIGO Scientific Collaboration

2015 - 2017: Co-chair of LVC Diversity Committee

2013 - 2014: LVC GW-EM MOU Committee

— Anti-Harassment Guidelines
— LSC Statement on Diversity

2012 - 2015: LVC Diversity Committee

— Early efforts of Swift follow-up of LIGO triggers
— "Search for GW Bursts from Soft Gamma Repeaters"
— LSC First LSC Paper: and deep LIGO triggers
— Joint search for sub-prime GRB candidates

2008:

2006 - 2008: LIGO PAC (Program Advisory Committee)

2006 - 2008: LIGO PAC (Program Advisory Committee)
Collaboration focused on X-ray follow-up of GW triggers


MOU with the LVC

Daryl Haggard, as PI
co-Is: Neil G and VK

McGill University

X-ray follow-up of GW triggers

Collaboration focused on
Around January 2017

Dealing with a BH-BH trigger ...

Around January 2017
Around January 2017

Dealing with a BH-BH trigger...

Neil

I am happy to stay in the loop on this interesting object, but don’t have a strong opinion one way or the other. I would hate to miss the big big detection. However, the odds are so small for it if it IS the BH-BH LIGO counterpart as you point out. I am slightly opposed.

Neil

On Jan 7, 2017, at 1:00 PM, Vicky Kalogera <vicky@northwestern.edu> wrote:

Neil, any opinions? should we go ahead without your input? do we want to trigger - it is definitely a BH-BH, so I am not sure whether I buy the validity of the counterparts reported as LIGO source counterparts …

On Jan 7, 2017, at 11:57 AM, Daryl Haggard <daryl.haggard@mcgill.ca> wrote:

Thanks Belinda,
The visibility looks good in ProVis, as do the roll and pitch angles — I know your team will do a more thorough assessment. Coordinates are proprietary, so I’ll wait to share those only if we officially trigger. I am waiting to touch base with the Swift team, but will follow up soon, -Daryl

On 1/7/17 12:48 PM, Wilkes, Belinda wrote:

Hi Daryl,
Thank you for the heads-up.
Did you already check the visibility with ProVis?
Are you awaiting a confirmation by Swift?
Your trigger window is 1-4 days.
We will need the coordinates to be able to tell you if there is a chance we can observe this in the next 4 days. Fine to wait until you decide whether/not to submit, if they are proprietary, just be aware that it takes time to make the assessment.

Belinda

On Sat, Jan 7, 2017 at 12:16 PM, Daryl Haggard <daryl.haggard@mcgill.ca> wrote:

Hello Belinda, Harvey, and Andrea,
Thanks to Daryl Haggard for finding this.
When GW170817 came...
Once GW170817 was localized...
Timeline of early EM follow-up:

The first 72 hours:
- 12 hr: First optical discovery
- 13.7 hr: First radio observations
- 2.4 days: First, deep X-ray observations
- 1.5 days: First optical and near-infrared spectra

GW trigger

The first 72 hours of early EM follow-up:

Courtesy Margutti & Fong
Timeline of early EM follow-up:

- **9-15 days:** X-rays come into view!
- **15 days:** Radio comes into view!

The first two weeks: The Early EM follow-up

Courtesy Margutti & Fong
HUBBLE
GW170817
COUNTERPART
CHANDRA

Day 160
Day 109
Day 16
Day 260

Courtesy D. Haggard
Jet and/or cocoon afterglows supported by recent data.

- X-ray and radio turn-over currently underway...
- Upper limits from Swift & NuSTAR.
- X-ray and radio initially pointed to off-axis GRB.
- Swift & NuSTAR.
- 2. Structured jet.
- Viewed off-axis.
- 1. Cocoon afterglow with choked jet.
- Days after Fermi GBM trigger.
- 10°, 10°-15°.
- CHANDRA non-det.
- SUNBLOCK.
- Chandra.
- 109, 160, 8, 260 days.
- 2 days; det. 9, 15°.
- Upper limits.
- 10.3 - 8 keV.
- F$_{0.3-8}$ keV [erg s$^{-1}$ cm$^{-2}$].
- Upper limits.
- $\sim$2 days; det. 9, 15°.
- Swift & NuSTAR.
- X-ray and radio initially pointed to off-axis GRB.
- Upper limits.
- CHANDRA non-det.
- CHANDRA non-det.
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Ultra-relativistic jet viewed from the side

Off-axis Jet predictions:

Margutti et al. 2018
Margutti +2018
updated with new data from Alexander +2018

Synchrotron Cooling frequency > X-rays at all times

SAME spectrum (no spectral evolution)
Lack of evolution in spectral index disfavors passing of synchrotron cooling break.

Absorbed power-law spectral models w/ absorbed power-law spectral models w/ $N_{H} = 7.5 \times 10^{20}$ cm$^{-2}$ $N_{H} = 7.5 \times 10^{20}$ cm$^{-2}$

260 days: $\Gamma_X = 1.57^{+0.39}_{-0.39}$
160 days: $\Gamma_X = 1.58^{+0.23}_{-0.22}$
109 days: $\Gamma_X = 1.55^{+0.24}_{-0.23}$

Chandra X-ray Spectral Fits

X-ray emission models

- Quasi-spherical model
- Jetted models

[Courtesy: Margutti, Fong, & Haggard]
How many more NS mergers in O3?

Always looking into the future
### Table IV: Compact binary coalescence rates per Mpc$^3$ per Myr

<table>
<thead>
<tr>
<th>Source</th>
<th>BH-BH (Mpc$^{-3}$ Myr$^{-1}$)</th>
<th>NS-BH (Mpc$^{-3}$ Myr$^{-1}$)</th>
<th>NS-NS (Mpc$^{-3}$ Myr$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>$1 \times 10^{-4}$</td>
<td>$9 \times 10^{-4}$</td>
<td>$3 \times 10^{-4}$</td>
</tr>
<tr>
<td>Low</td>
<td>$1 \times 10^{-4}$</td>
<td>$6 \times 10^{-4}$</td>
<td>$1 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

**GW paper, LVC, PRD, 2017**

- The Cosmic Coalescence Rates for Double Neutron Star Binaries
- "GW paper, LVC, PRD, 2017"

**GW paper, LVC, CQG, 2010**

- Rates Review Paper, LVC, CQG, 2010

**GW170817: Most Accurate NS-NS Merger Rate Measurement**

**Rates Predictions:**

- 161$\times$10, 2187$\times$10
- 70$\times$10, 927$\times$10

**TABLE IV: Compact binary coalescence rates per Mpc$^3$ per Myr.**

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**GW170817: Most Accurate NS-NS Merger Rate Measurement**

**Rates Predictions:**

- 161$\times$10, 2187$\times$10
- 70$\times$10, 927$\times$10
This rate distribution...
BH-BH rate will dominate, possibly by more than an order of magnitude, up to ~few/wk., at least ~few/mo.

VT has strong mass dependence but very mild dependence on assumed spin distribution.

NS-BH: N=0 not ruled out in any scenario, most give ∼50% N>0.

VT has mass dependence but very mild dependence on assumed spin distribution.

BH-BH rate will dominate, possibly by more than an order of magnitude, up to ~few/wk., at least ~few/mo.

SEE ALSO: Living Reviews in Relativity (in press)