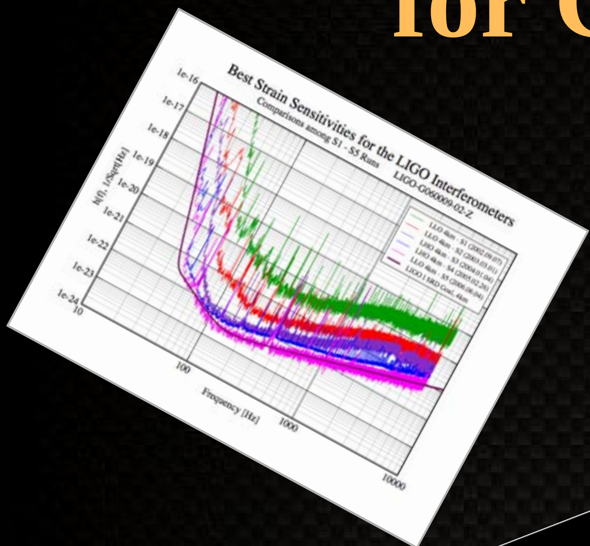
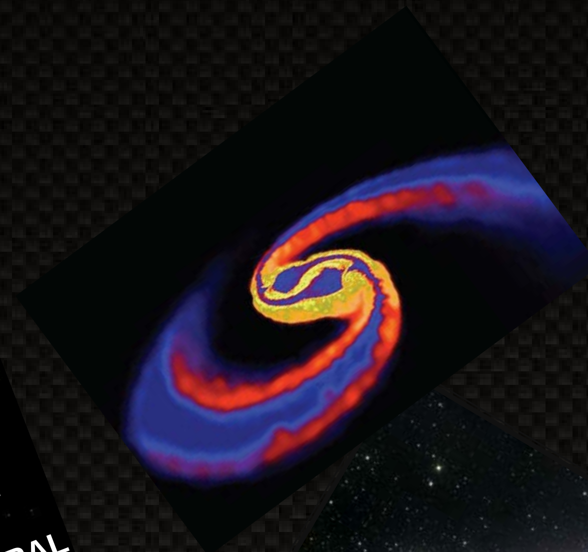
Astrophysically Triggered Searches for Gravitational Waves





Szabolcs Márka
for the LIGO Scientific Collaboration

AAS 211, Austin, TX, 2008

Astrophysical Event Triggered Searches

- Gamma-ray transients (GRBs, SGRs)
- Optical transients
- Neutrino events
- …

  - Correlation in time
  - Correlation in direction
  - Information on the source properties
  - …

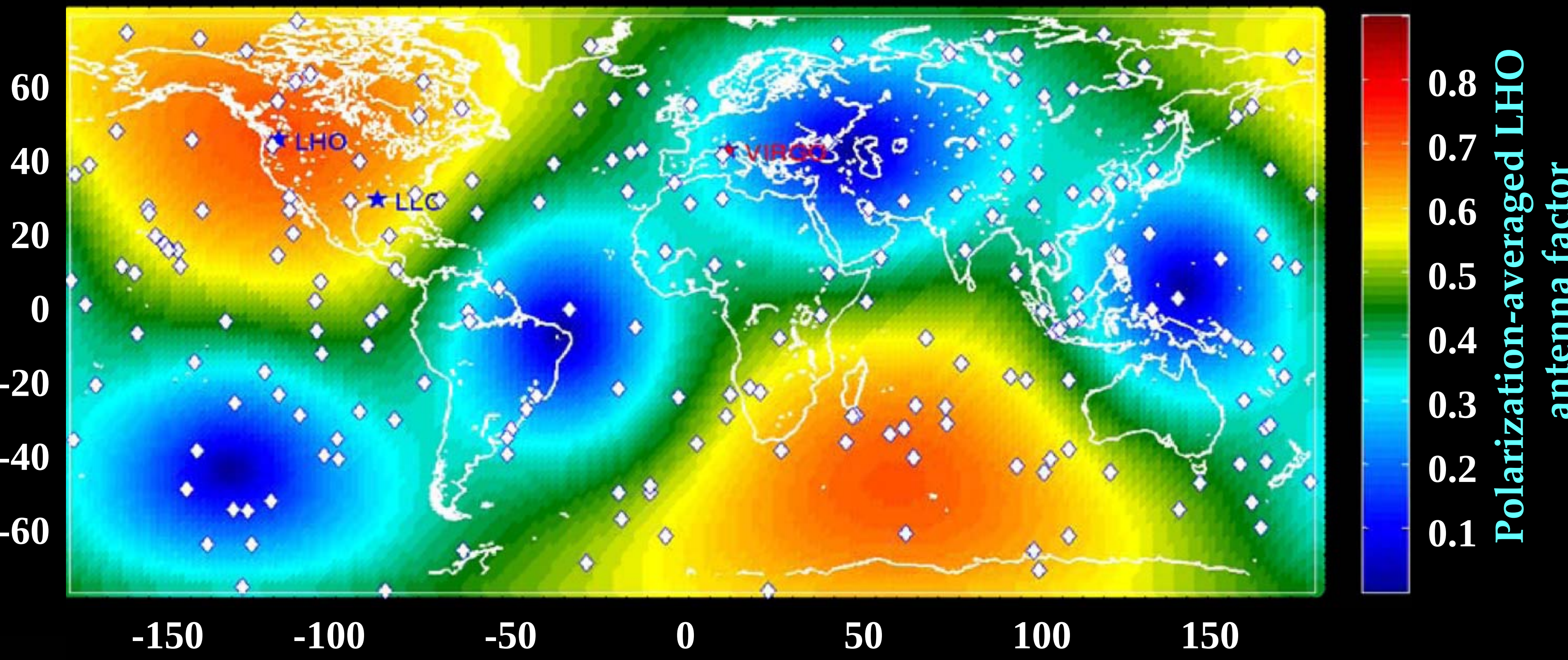
✓ Confident detection of GWs (eventually).

✓ Better background rejection ⇒ Higher sensitivity to GW signals.

✓ More information about the source/engine.

⚠ ✓ Even upper limits can have interesting implications. ⚠

213 GRB triggers from Nov. 4, 2005 to Sept. 30, 2007

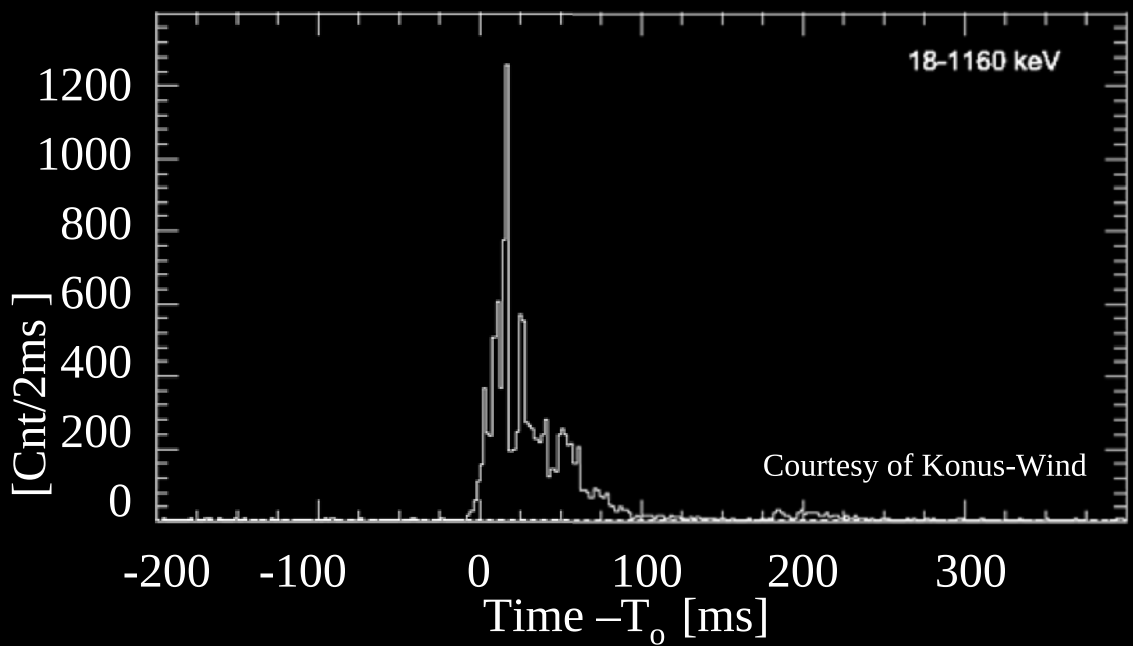


– **GRB triggers** (mostly from Swift, IPN, INTEGRAL, HETE-2)

- ~70% with double-IFO coincidence LIGO data ⚠
- ~40% with triple-IFO coincidence LIGO data
- ~25% with measured redshift
- ~15% short-duration GRBs

EM Observations - GRB 070201

Detected by Konus-Wind, INTEGRAL, Swift, MESSENGER



Described as an

"intense short hard GRB" (GCN 6088)

Duration ~0.15 seconds,
followed by a weaker, softer pulse
with duration ~0.08 seconds

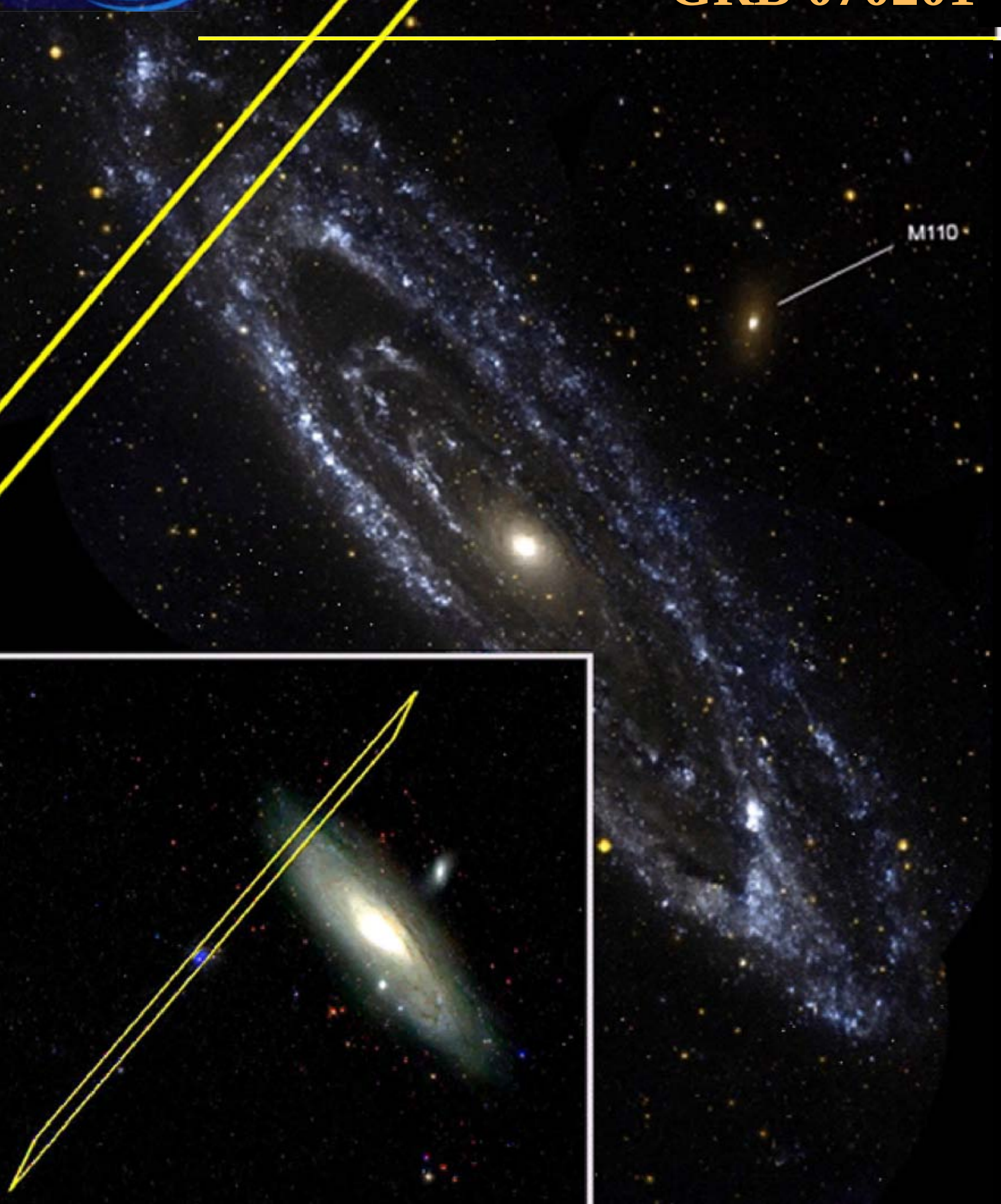
R.A. = 11.089 deg,
Dec = 42.308 deg

Antenna responses of LIGO Hanford:

$$F_{RMS} = \sqrt{F_+^2 + F_\times^2} / \sqrt{2} = 0.304$$

$$h(t) = F_+(\theta,\phi,\psi)h_+(t) + F_\times(\theta,\phi,\psi)h_\times(t)$$

GRB 070201 – Sky Location



R.A. = 11.089 deg,
Dec = 42.308 deg

$D_{M31} \approx 770$ kpc

Possible progenitors for short GRBs:

- **NS/NS or NS/BH mergers**
  Emits strong gravitational waves

- **SGR**
  May emit GW but weaker

$E_{iso} \sim 10^{45}$ ergs
if at M31 distance
(more similar to SGR than GRB energy)

Implications

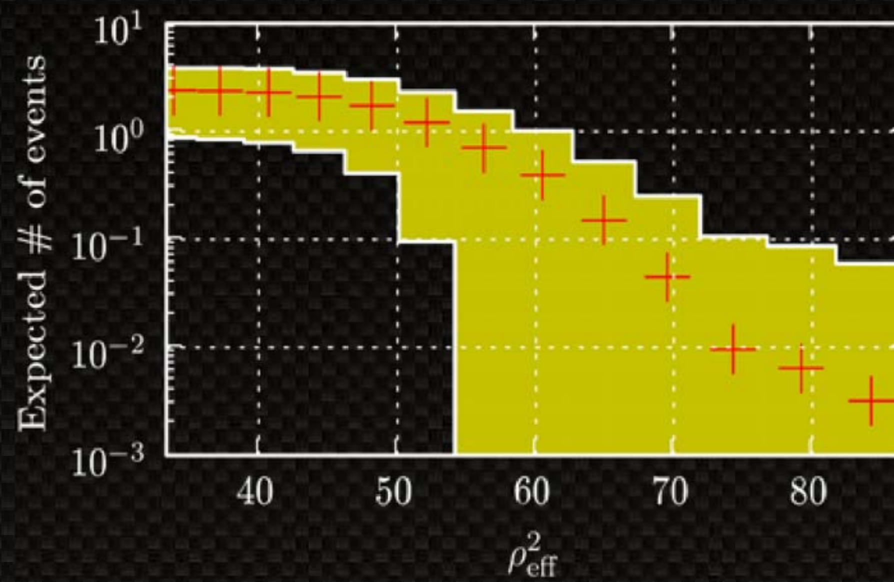
- **In case of a detection:**
  - Confirmation of a progenitor (e.g. coalescing binary system)
  - GW observation could determine the distance to the GRB

- **In case of non-detection:**
  - Exclude progenitor/model in mass-distance region
  - Assumed M31 distance to hypothetical GRB ⇒

    exclude binary progenitor
  - Bound the GW energy emitted by a source in M31
  - …

Background:

Compact Binary Inspiral Search

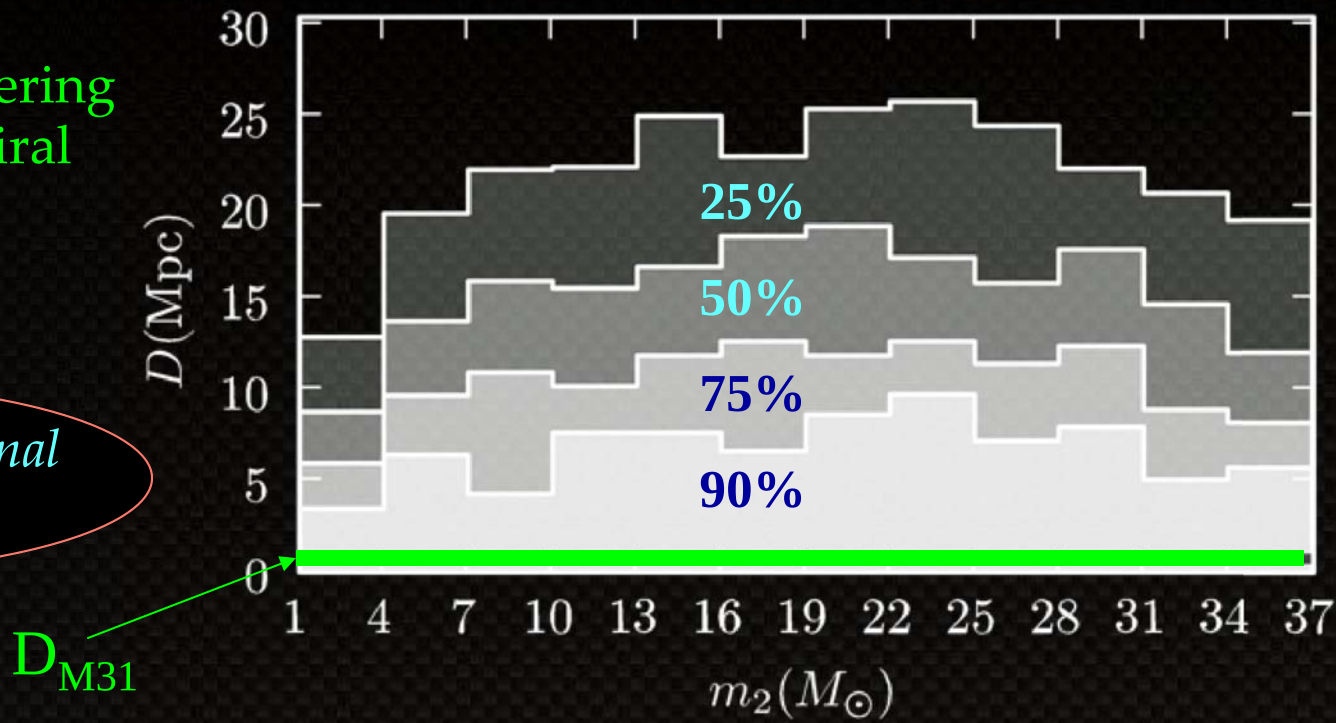


A cumulative histogram of the expected number of background triggers in 180 s based on the analysis of the off source times (+)

Results: Model Based Compact Binary Inspiral Search

Exercise matched filtering techniques for inspiral waveform search

No plausible gravitational waves identified



Exclude compact binary progenitor with masses

$1\ M_\odot < m_1 < 3\ M_\odot$ and $1\ M_\odot < m_2 < 40\ M_\odot$ with D < 3.5 Mpc away at 90% CL

Exclude any compact binary progenitor in our simulation space

at the distance of M31 at > 99% confidence level

Results: Model *Independent* Compact Binary Inspiral Search

Excess Power type search

No plausible gravitational waves identified

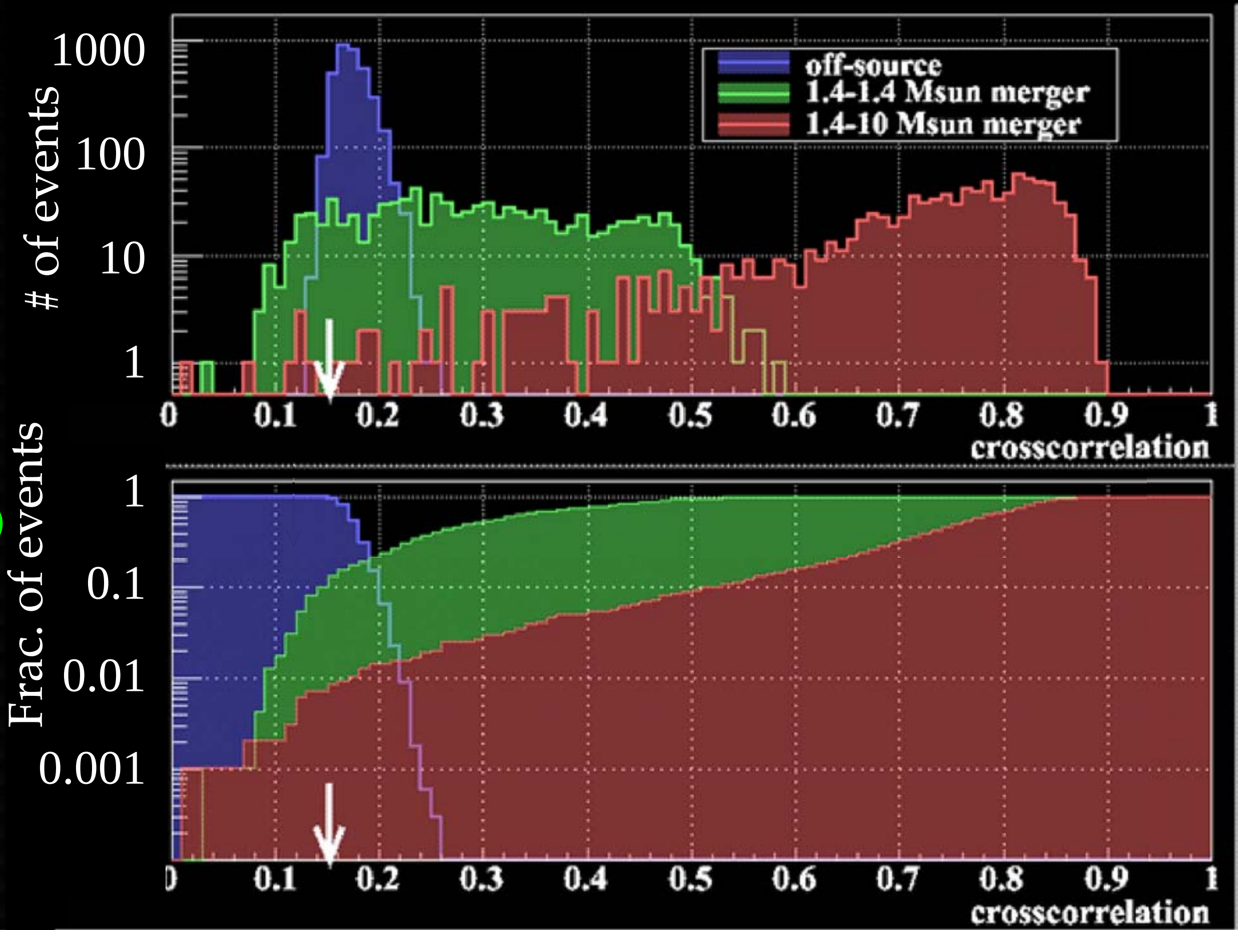
Injected simulated waveforms

- NS-NS inspirals (1.4-1.4 $M_\odot$)

and

- NS-BH inspirals (1.4-10 $M_\odot$)

at nominal M31 distance



Efficiency > 0.878, 1.4 - 1.4 $M_\odot$

Efficiency > 0.989, 1.4 - 10 $M_\odot$

These results give an independent way to reject hypothesis of a compact binary progenitor in M31

Soft Gamma-ray Repeater in M31 ?

SGR: highly magnetized neutron star;
can have giant flares (rare)
(arXiv:0712.1502)

Scientific American, February 2003

- Giant flare from an SGR:
  - a hypothesized explanation for 070201 burst
- Energy release in gamma rays consistent with SGR model
  - Measured gamma-ray fluence = 2 x 10^{-5} ergs/cm^2 (Konus-Wind)
- Corresponding gamma-ray energy, assuming isotropic emission, with source at D = 770 kpc (M31):

$$E_{\gamma,\mathrm{iso}} = \phi \times 4\pi D^2 \approx 10^{45}\ \mathrm{ergs}$$

- SGR models predict energy release in GW to be

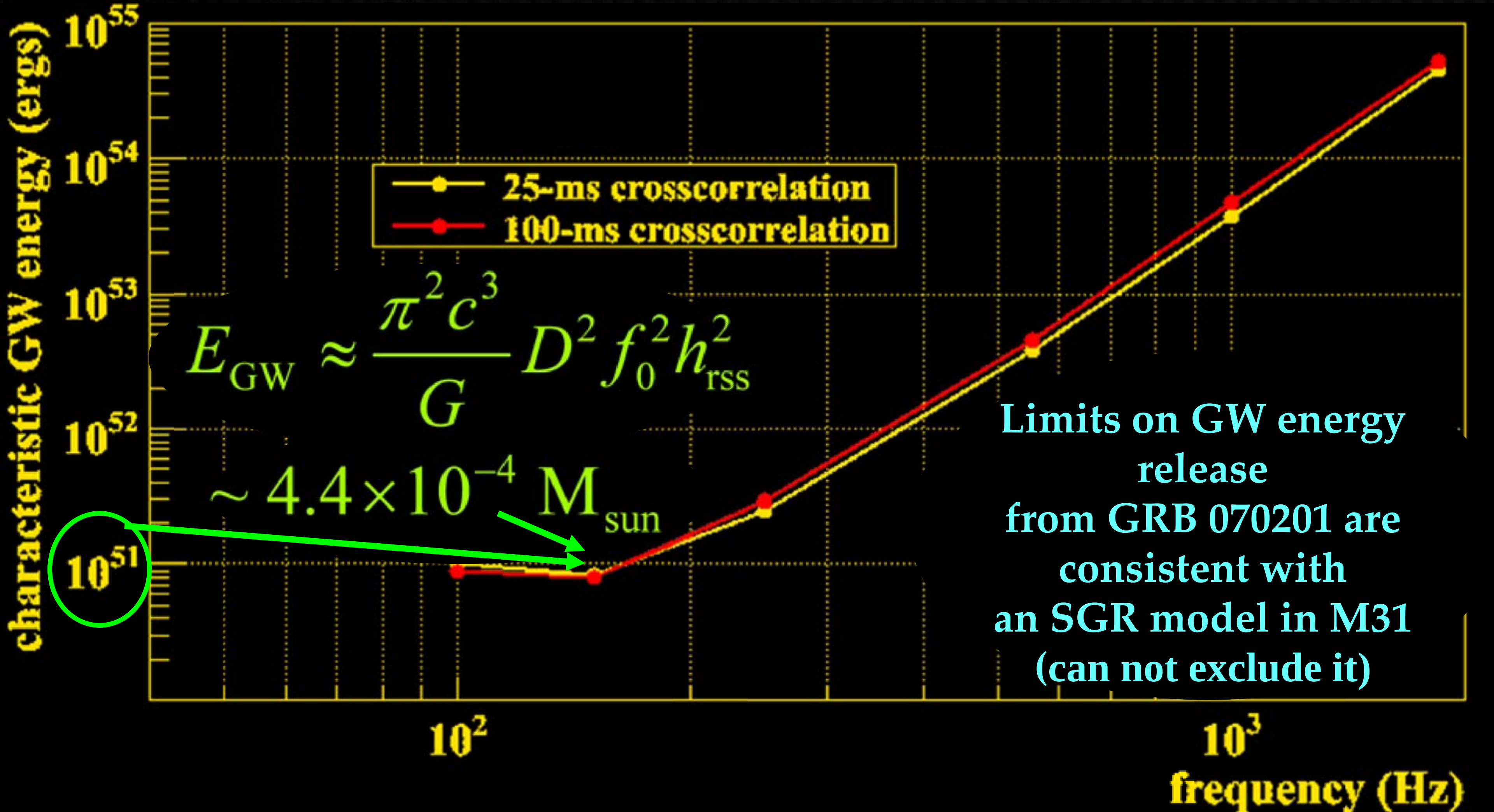
  no more than ~10^{46} ergs

Model independent burst search result

- Corresponding gamma-ray energy, assuming isotropic emission, with source at D = 770 kpc (M31):

$$E_{\gamma,\mathrm{iso}} = \phi \times 4\pi D^2 \approx 10^{45} \text{ ergs}$$

- SGR models predict energy release in GW to be no more than ~10^{46} ergs



Conclusions

"Implications for the Origin of GRB 070201 from LIGO Observations" (arXiv:0711.1163) paper accepted for publication in ApJ

- No plausible gravitational waves were identified
- Excluded compact binary progenitor in M31
- Corresponding limits on isotropic energy emission in GW do not exclude an SGR model in M31

Analysis is ongoing to search for gravitational waves associated with

- The sample of 213 GRB triggers contemporaneous with LIGO S5 run
- Other external triggers…

…and the future is bright…

LIGO Scientific Collaboration

- Australian Consortium for Interferometric Gravitational Astronomy
- The Univ. of Adelaide
- Andrews University
- The Australian National Univ.
- The University of Birmingham
- California Inst. of Technology
- Cardiff University
- Carleton College
- Charles Sturt Univ.
- Columbia University
- Embry Riddle Aeronautical Univ.
- Eötvös Loránd University
- University of Florida
- German/British Collaboration for the Detection of Gravitational Waves
- University of Glasgow
- Goddard Space Flight Center
- Leibniz Universität Hannover
- Hobart & William Smith Colleges
- Inst. of Applied Physics of the Russian Academy of Sciences
- Polish Academy of Sciences
- India Inter-University Centre for Astronomy and Astrophysics
- Louisiana State University
- Louisiana Tech University
- Loyola University New Orleans
- University of Maryland
- Max Planck Institute for Gravitational Physics
- University of Michigan
- University of Minnesota
- The University of Mississippi
- Massachusetts Inst. of Technology
- Monash University
- Montana State University
- Moscow State University
- National Astronomical Observatory of Japan
- Northwestern University
- University of Oregon
- Pennsylvania State University
- Rochester Inst. of Technology
- Rutherford Appleton Lab
- University of Rochester
- San Jose State University
- Univ. of Sannio at Benevento, and Univ. of Salerno
- University of Sheffield
- University of Southampton
- Southeastern Louisiana Univ.
- Southern Univ. and A&M College
- Stanford University
- University of Strathclyde
- Syracuse University
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- Univ. of Massachusetts Amherst
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- Univ. of Wisconsin-Milwaukee
- Washington State University
- University of Washington