LIGO-G1100990-v2

EM Followup of GW Transients:

Background, first attempt, and prospects

Nickolas Fotopoulos (Caltech)

for the LIGO Scientific Collaboration

and the Virgo Collaboration

Image courtesy of Leo Singer (Caltech)

Outline

- Audience: EM astronomers

- GW transient signals—what can we learn?
- GW detector networks as telescopes
- First attempt at EM followup of GW transient candidates
- Working toward the advanced detector era

Gravitational waves

- Arise from accelerating masses
- Require asymmetry
- Propagate undisturbed through matter
- Hard to detect
- Provides window into central engine

Electromagnetic waves

- Arise from accelerating charges, high temperatures, shocks
- Require matter
- Can be scattered, refracted, attenuated
- Easy to detect
- Provides view of last scattering surface

Compact binary coalescence

- Hubble constant
- NS equation of state
- Tests of GR
- Constrain star formation
- Short GRB progenitor?

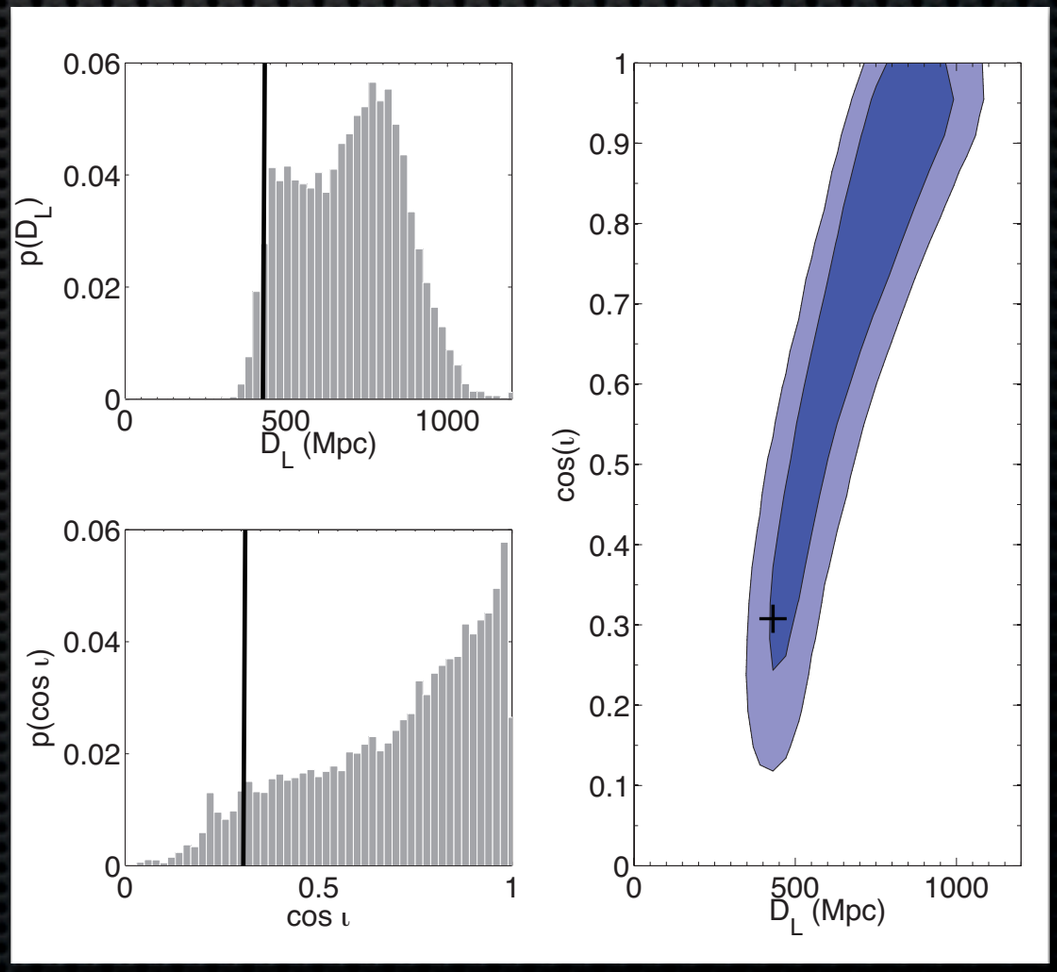

Image: Nissanke et al, ApJ 2010

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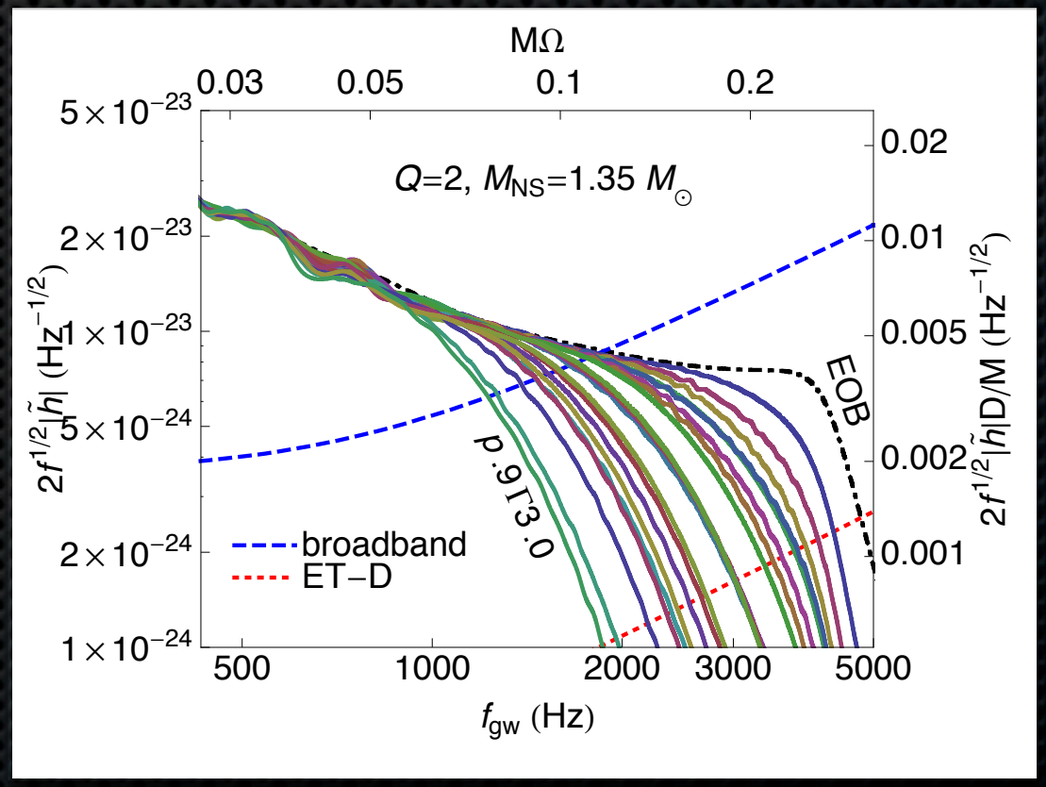

Image: Lackey et al, arXiv:1109.3402

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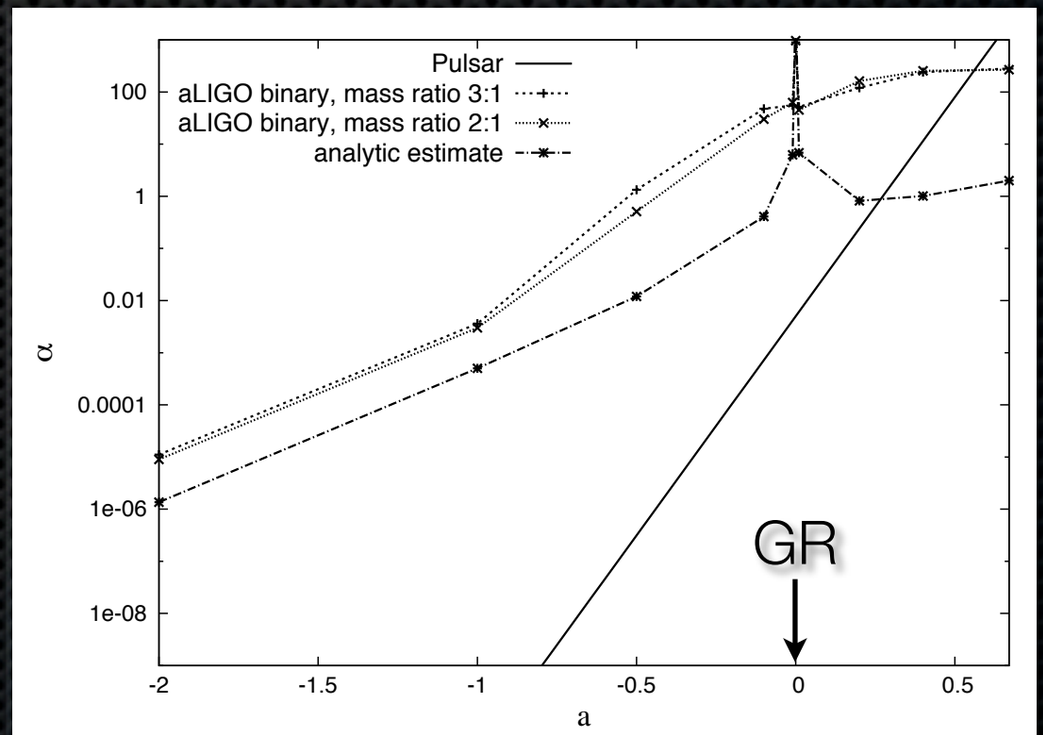

Image: Cornish et al, arXiv:1105.2088

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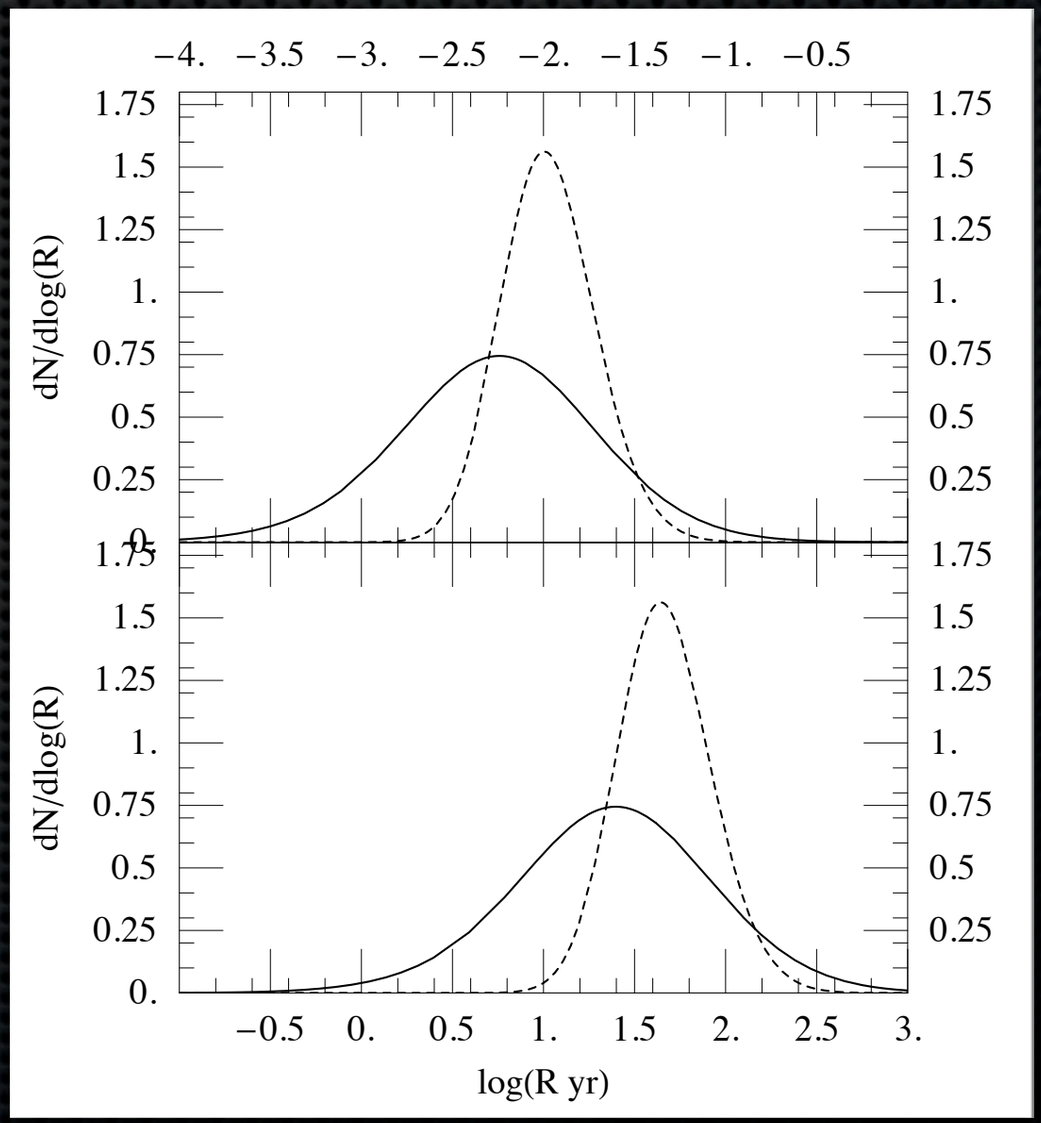

Image: O'Shaughnessy et al, ApJ 2008

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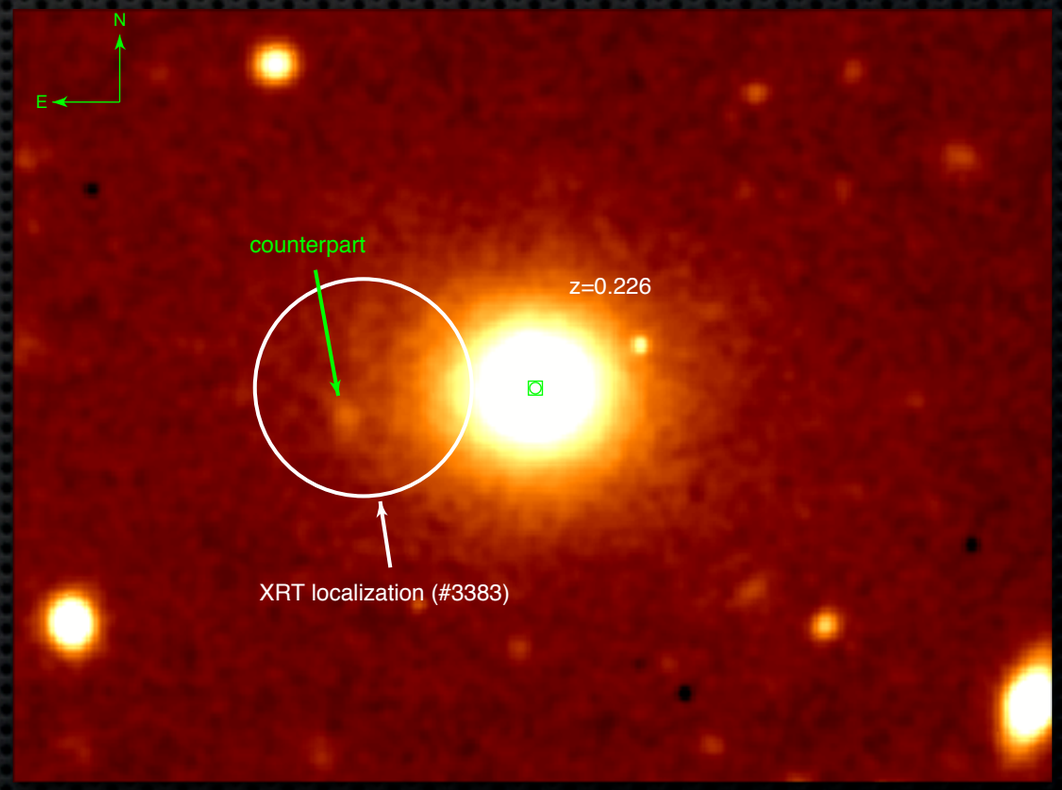
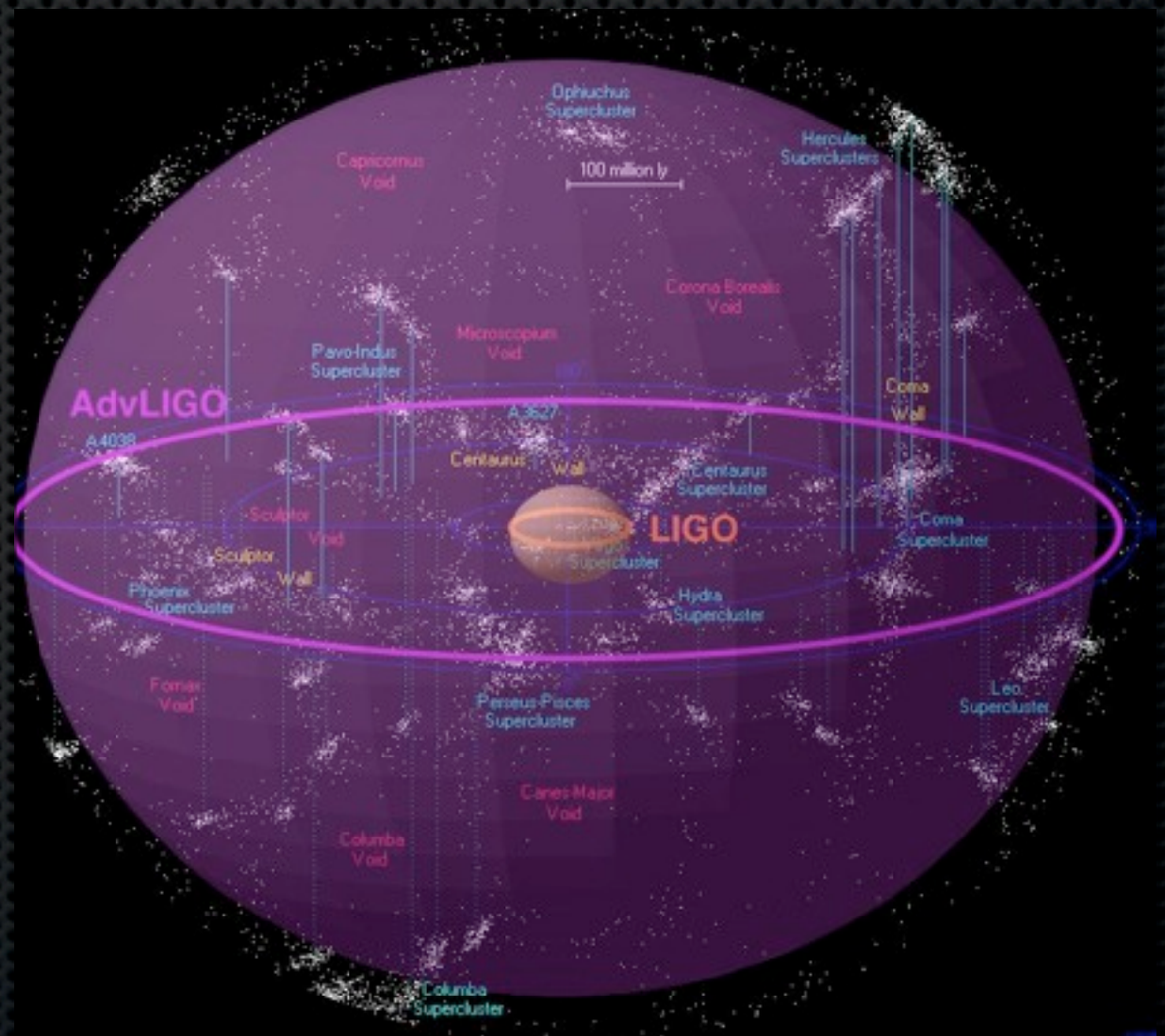


GRB 050509B

Image: Bloom et al, GCN 3392

Sensitivity to CBCs

- Binary neutron star systems exist that will merge in < t_H
- Optimally oriented, we can observe out to (BNS / NSBH):
  - Initial LIGO: 33 / 70 Mpc
  - Adv. LIGO: 445 / 927 Mpc
- Expected rates:
  - Initial LIGO: 0.02 / 0.004 yr^{-1}
  - Adv. LIGO: 40 / 10 yr^{-1}



Rates: Abadie et al, CQG 2010 | Image: R. Powell, atlasoftheuniverse.com

Unmodeled burst search

- Expected (messy) source: Galactic SNae
- Important to keep ears open for the unknown
- Several pipelines tuned different ways

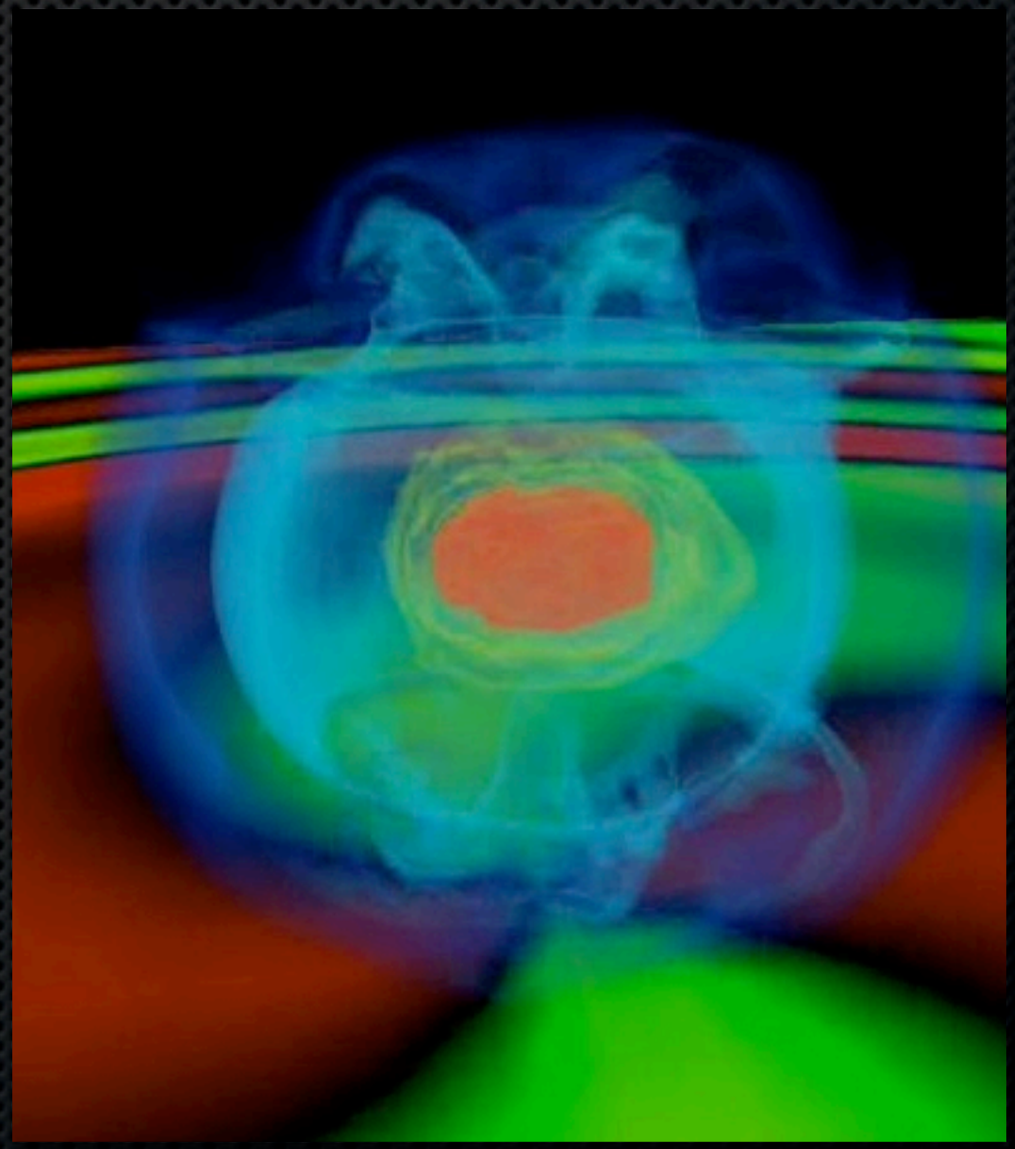
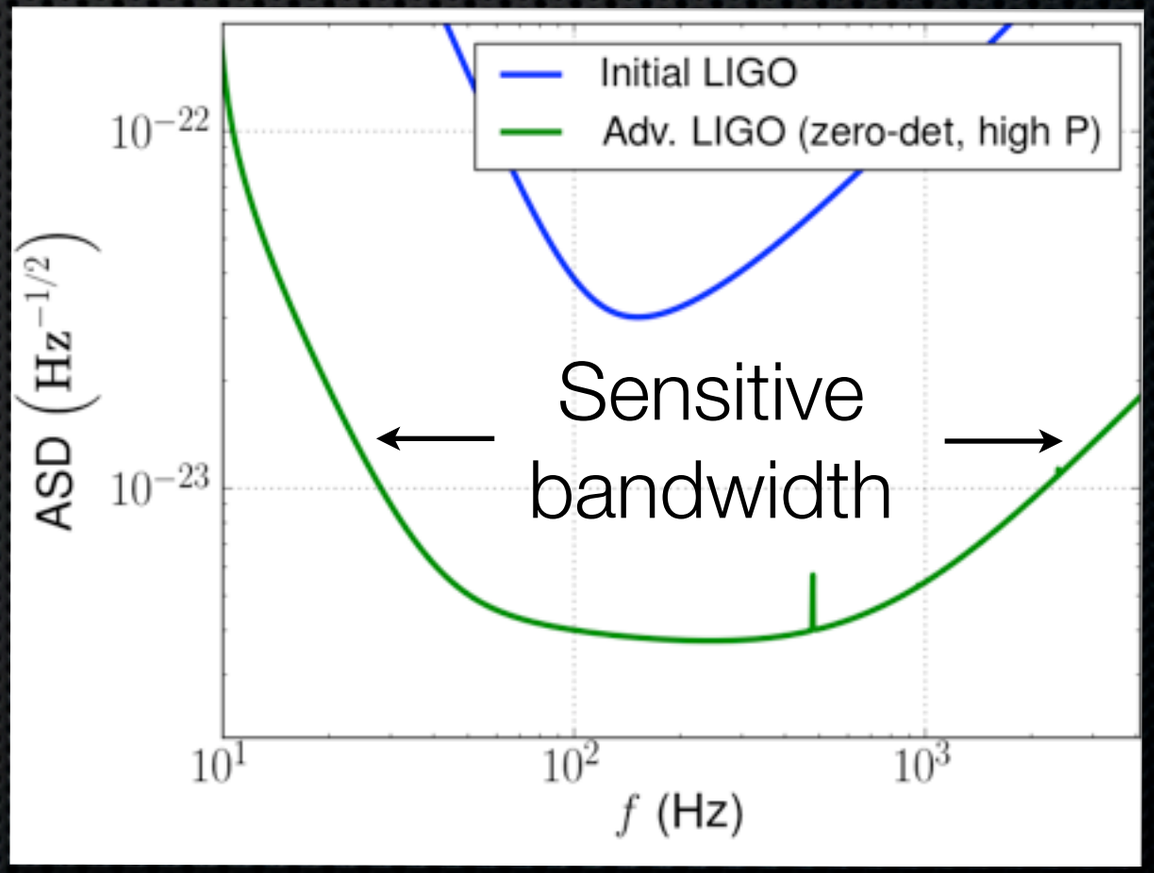


Image: Ott, Dimmelmeier, Hawke, Schnetter, Kahler

GW detectors as telescopes

Ground-based interferometers as telescopes

- Operating frequencies in human audible band
- Response maximum at zenith and nadir
- Wide beam pattern → poor localization
- Sensitivity modulated by cycles of human activity and weather



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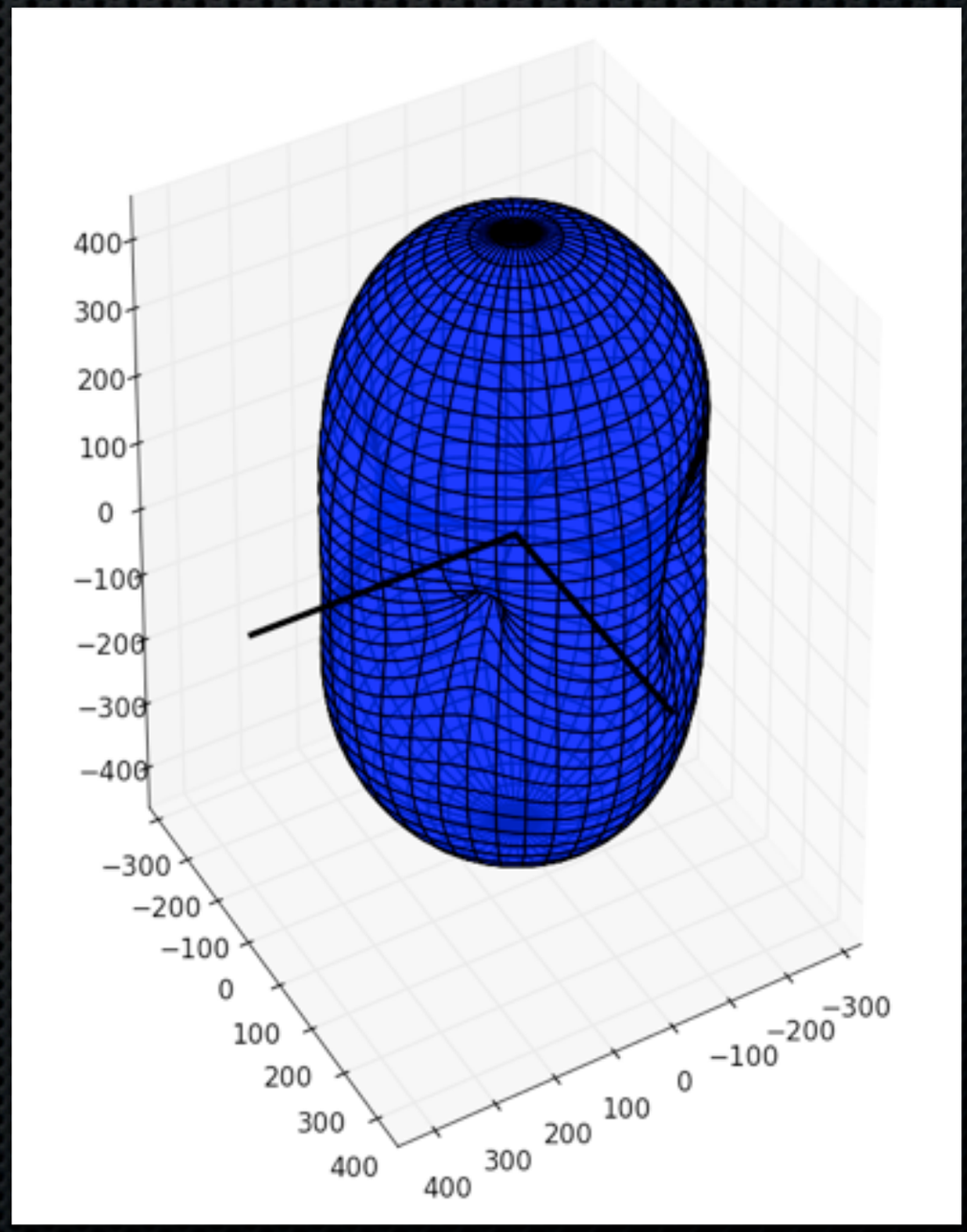

NS-NS sensitive volume (Mpc^3)

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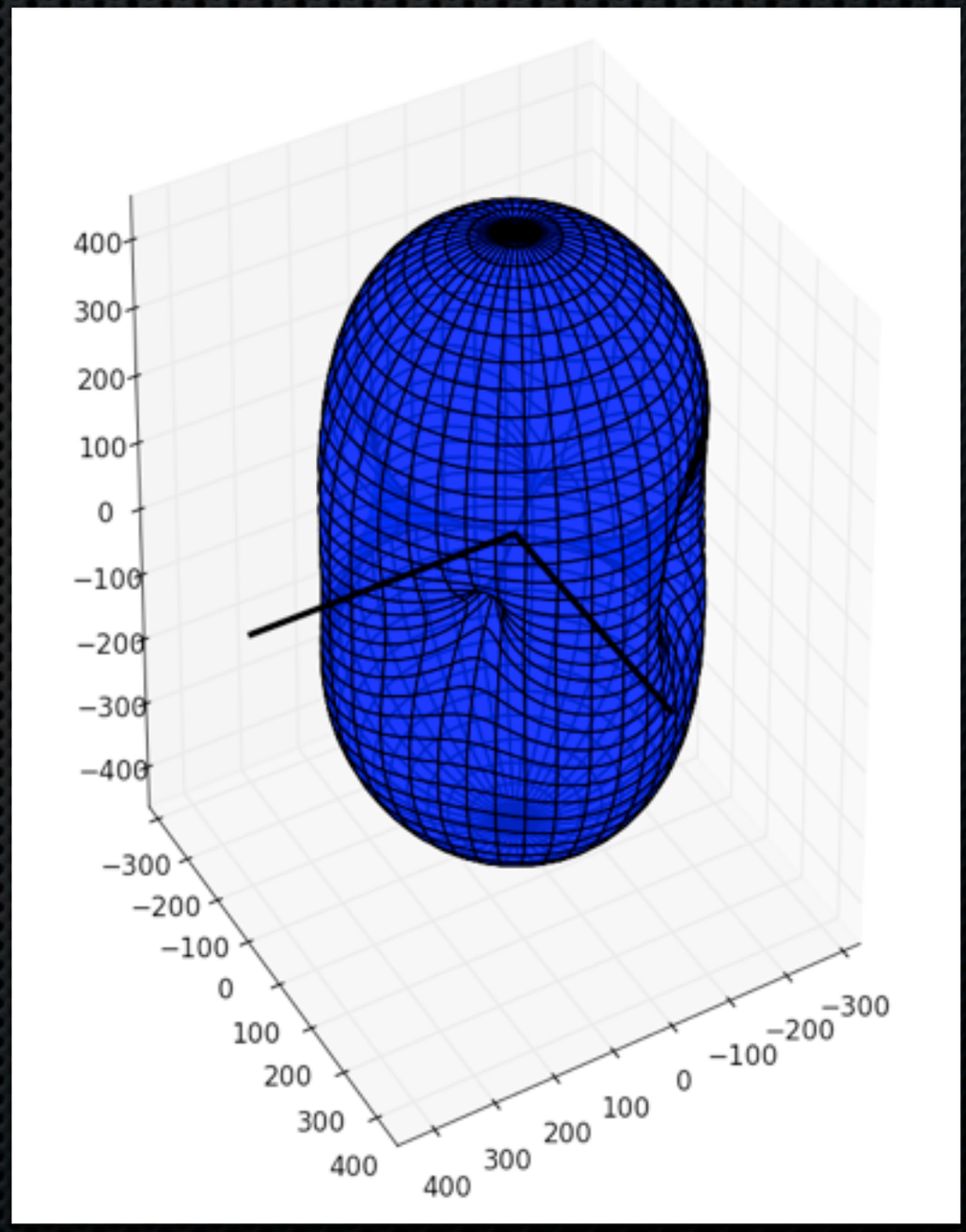

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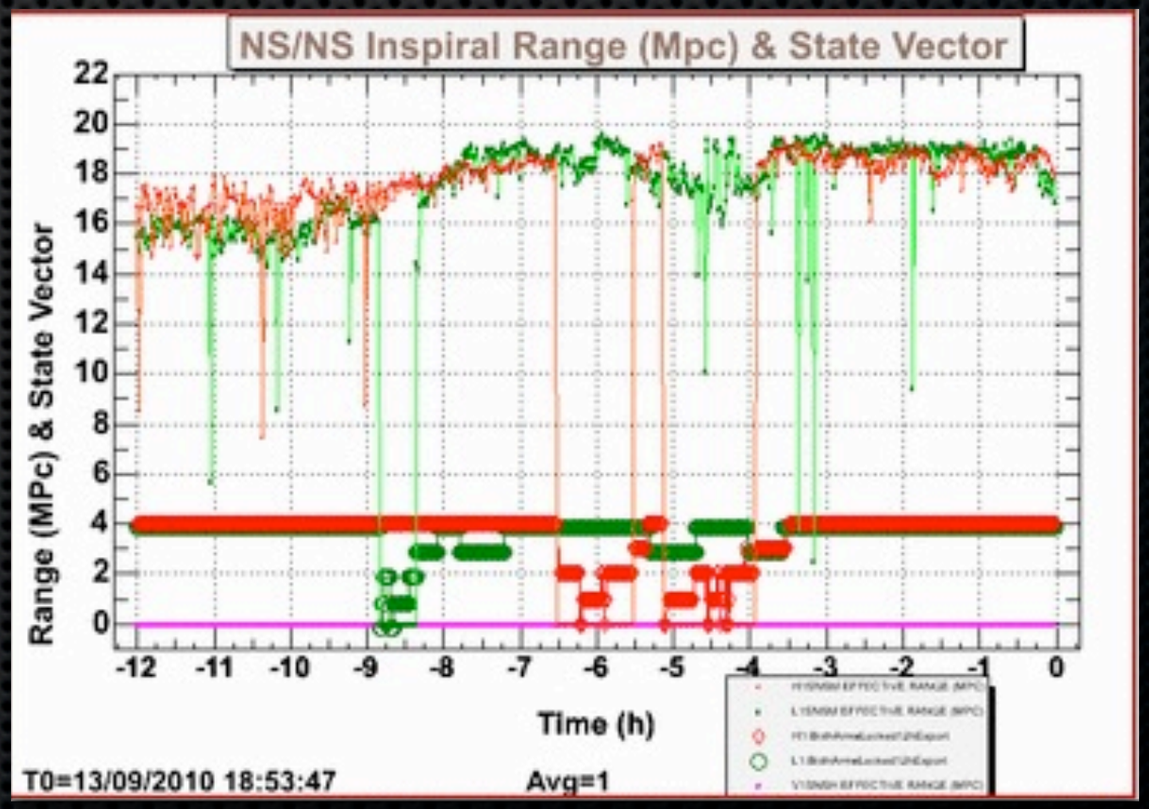
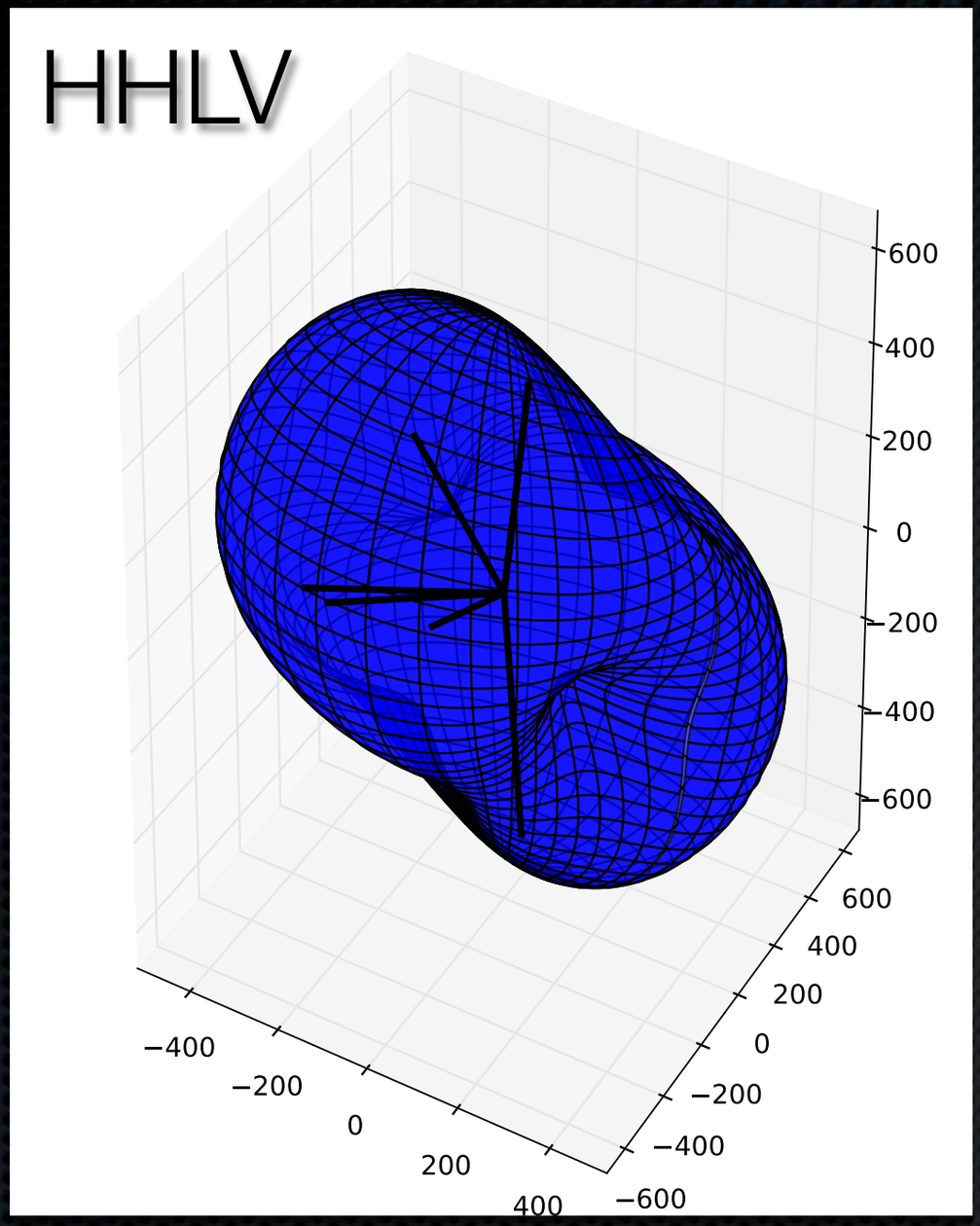
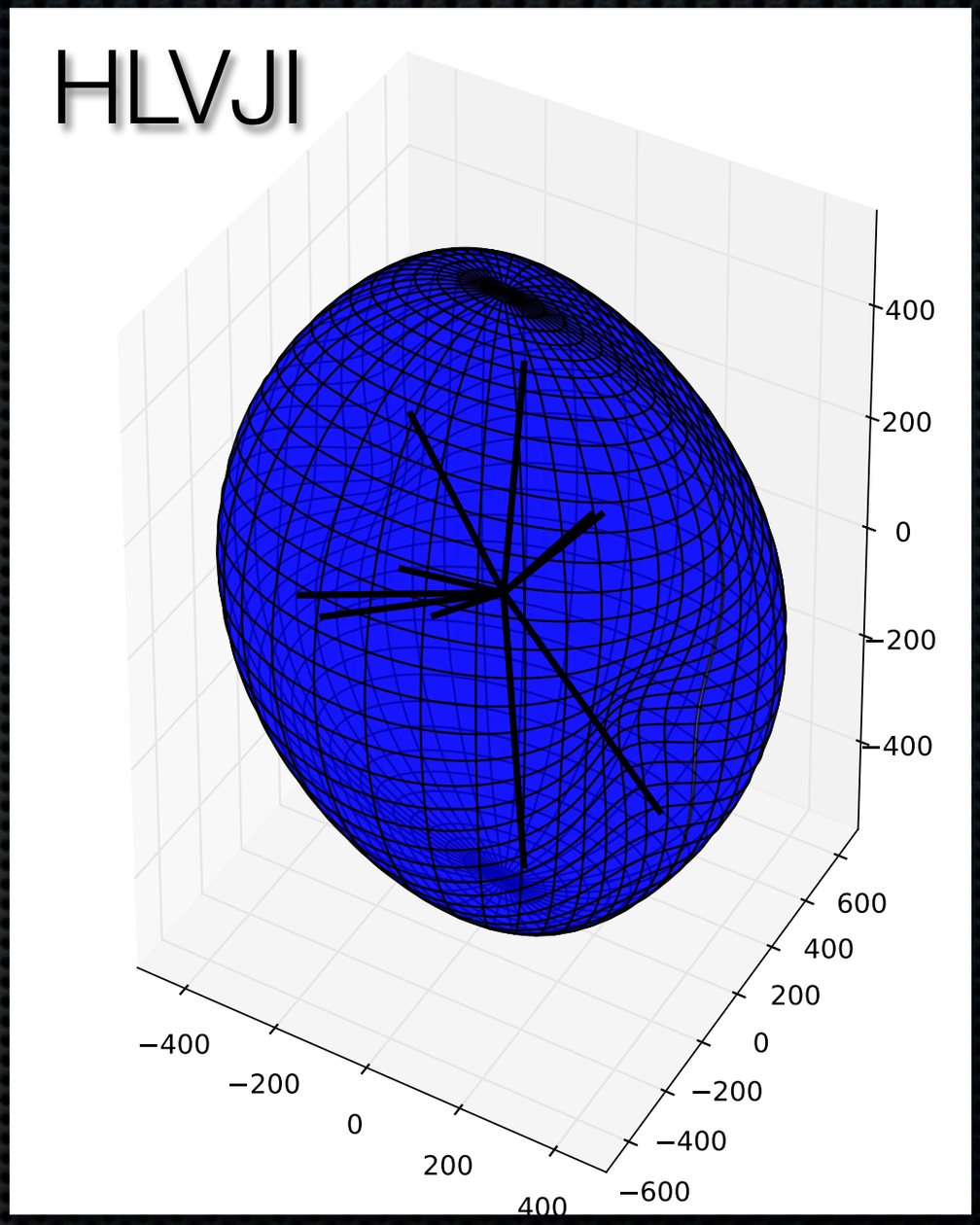


Sensitivity increases after rush hour

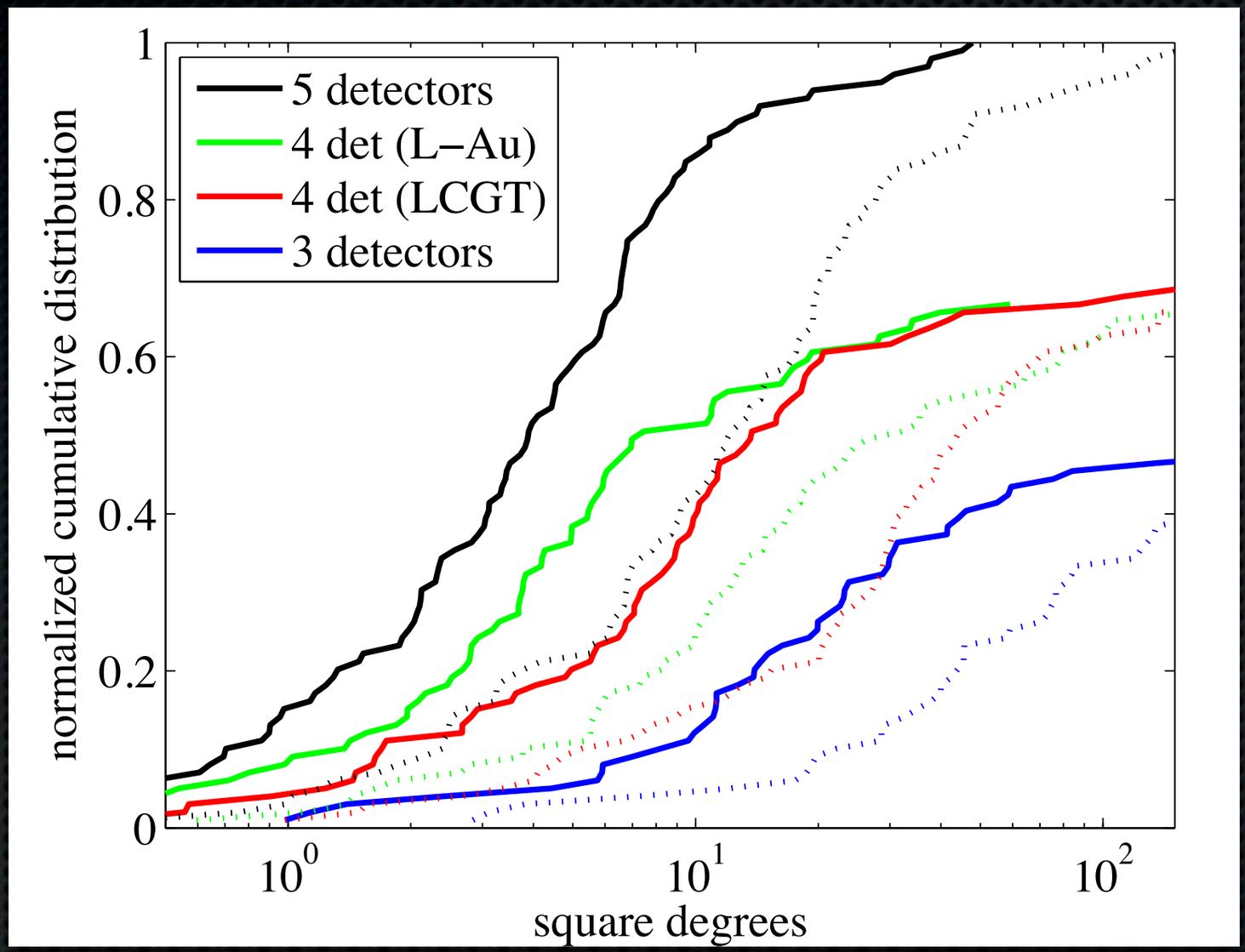




Advanced detector networks

Face-on NS-NS sensitivity volume (Mpc^3) in a geocentric frame (SNR=8)

Plot inspired by Schutz, CQG 2011



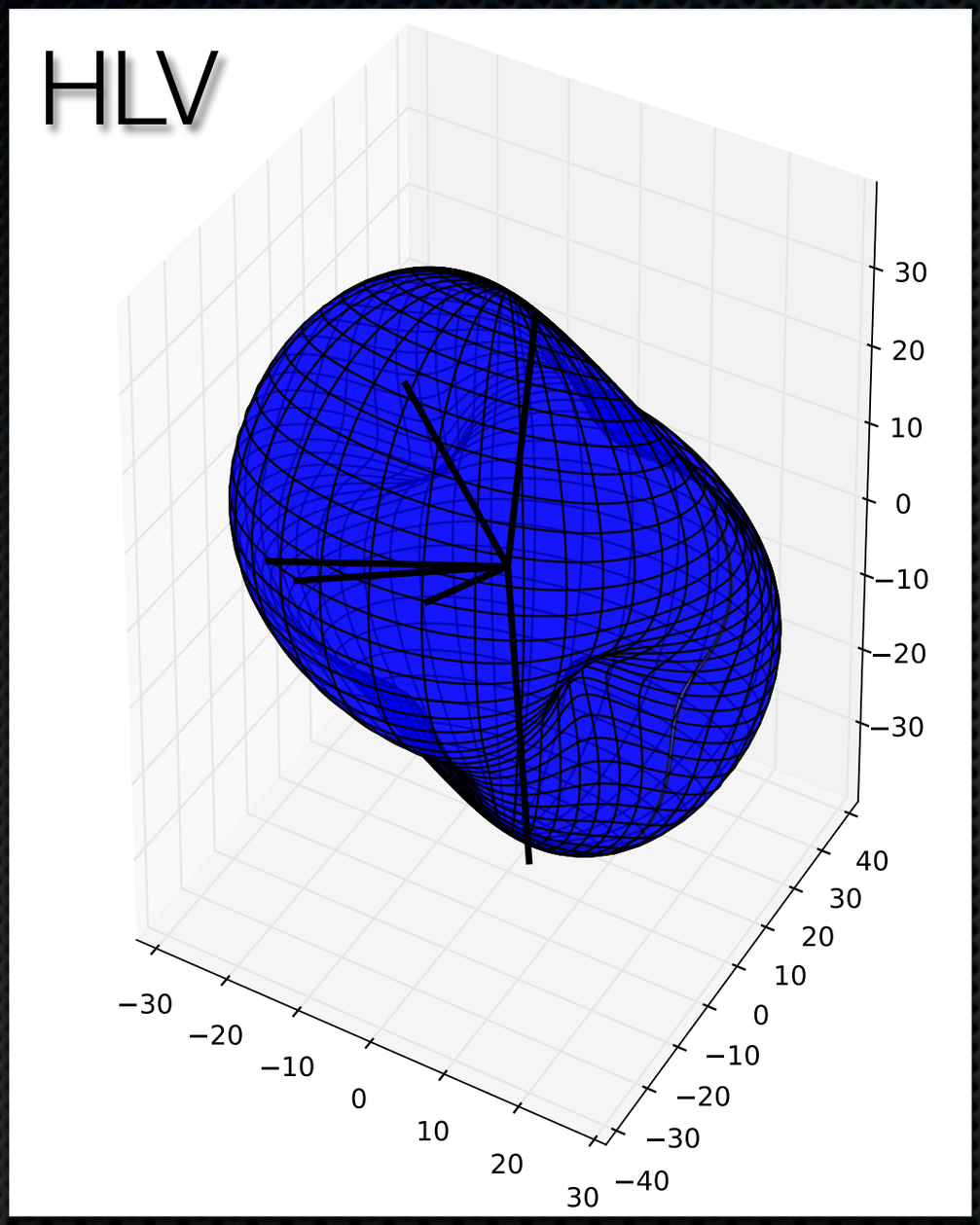
Advanced detector networks

Sky localization primarily from triangulation

Image: Nissanke et al, ApJ 2011

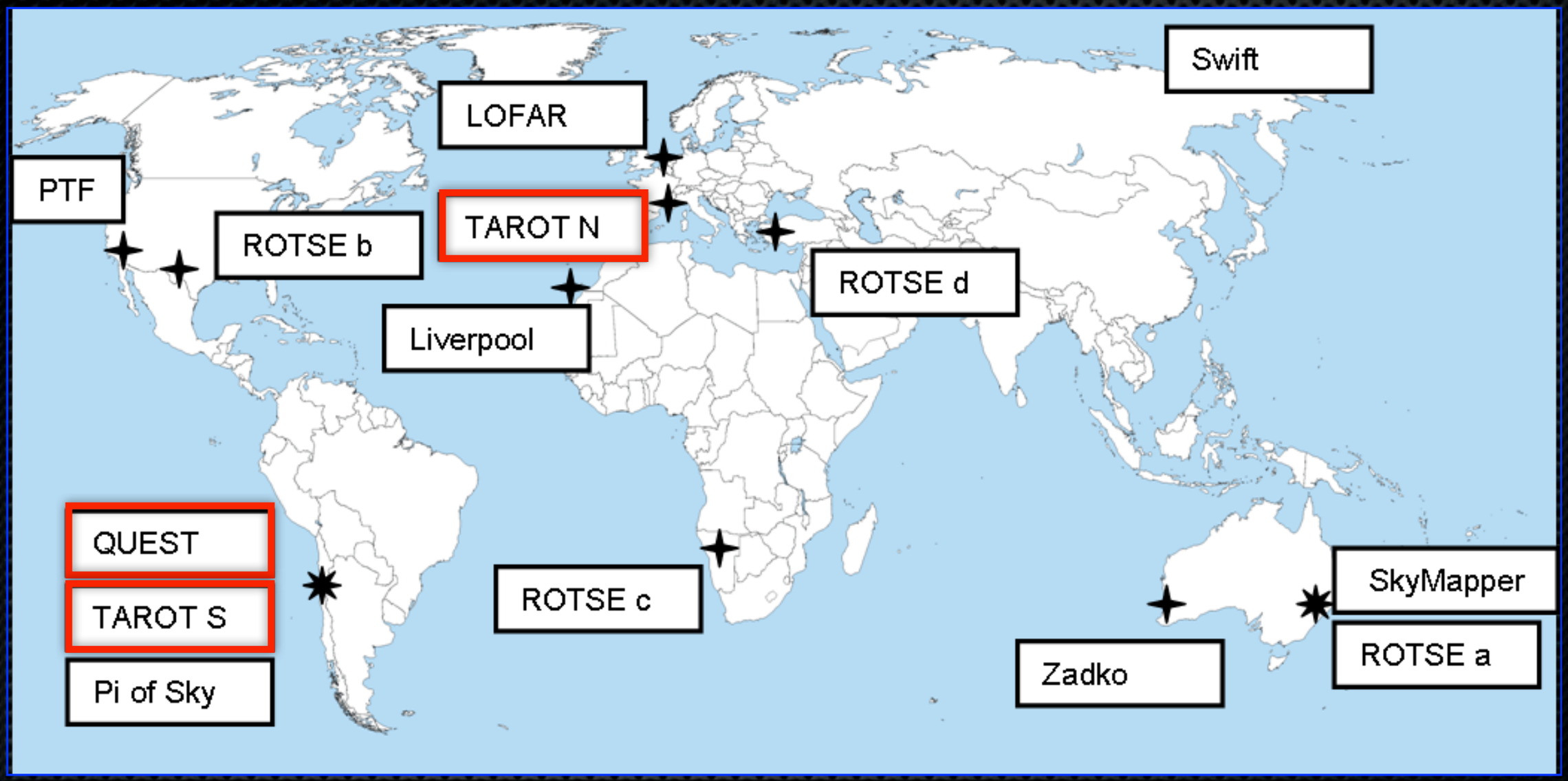
The First Attempt at EM followups of GW transients

2009–2010



Initial detector network

Face-on NS-NS sensitivity volume (Mpc^3) in a geocentric frame (SNR=8)

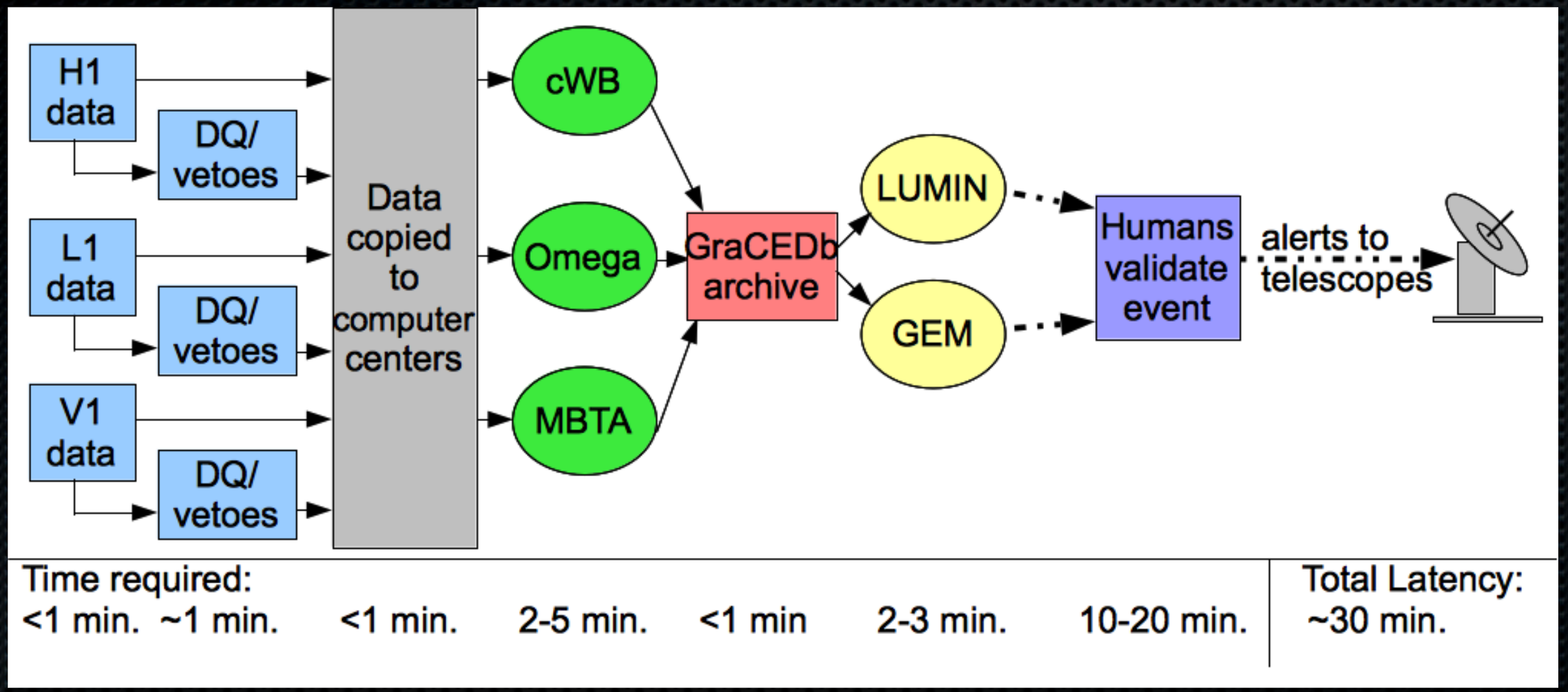


EM telescope network

Intentionally diverse team

Used in Winter and Autumn runs

Used in Autumn run only



Alert generation and latency

Observations made

- Winter run Dec 2009 – Jan 2010 (S6/VSR2)
  - Earlier version of procedures with only 3 telescopes
  - 8 triggers sent, 4 followed up
- Autumn run Sep–Oct 2010 (S6/VSR3)
  - More mature version of analysis
  - 6 triggers sent, 4 followed up

Current status

- Analysis of images underway by a number of LVC members
- Addressing issues of EM background rate, etc.
- Methods paper describing EM follow-up program is now available at arXiv:1109.3498
- Results paper happening on longer timescale

Working toward the advanced detector era

Advanced detector challenges

- CBC search will have new computational challenges:
  - Lower seismic cutoff frequency → CBC waveforms will be in band for up to 30 minutes (40x as long)
  - Wider bandwidth → finer discrimination of signal models → 10x more templates
  - Want lower latency
- New algorithms have been developed: LLOID, SPIIR

LLOID: arXiv:1107.2665 | SPIIR: arXiv:1108.3186

Image analysis

- Why GW people are analyzing telescope images:
  - Some telescope teams were unwilling
    - Require uniformity in quality of calibration and reference-image subtraction
    - Require quantification of false-alarm probability
- Going forward, we hope that telescope data reduction pipelines will be automated and characterized by the telescope teams.

Data-sharing model

- In S6/VSR2&3, the LIGO and Virgo collaborations used memoranda of understanding (MoUs) binding telescope partners to publication agreements.
- The LIGO Astronomy and Astrophysics Advisory Panel (LAAAP) strongly recommended that most or all triggers be made public immediately in order to maximize the telescope availability.
- Please share your thoughts with us.

Where you can join the conversation

- LIGO Open Data Workshop
  October 29–30, 2011 @ LIGO Livingston Observatory, Louisiana, USA
- Gravitational-wave Physics and Astronomy Workshop
  June 4–7 2012 @ Albert Einstein Institute, Hannover, Germany