Heterogeneous Detector Networks

Sky Localization with 3G Detectors

May 26, 2016

Daniel Sigg
LIGO Hanford Observatory
Issue

- **Sky localization is vital**
  - EM counter parts (maybe)
  - Full waveform reconstruction
  - Distance determination (z goes into source frame mass)

- **Full Sky Coverage**

- **Advanced detectors:**
  - Network with 4-5 detectors of similar sensitivity
  - Sky localization by triangulation

- **3G detectors:**
  - Network probably much smaller
  - Sky localization by polarization?
  - Heterogeneous network with Advanced detectors?
Basics

- Inverse problem solved: Gürsel, Tinto 1989
  - Requires 3 detectors: not collinear, not coplanar (can be collocated)
  - For example: 3 L’s randomly on Earth, or 1 Δ & 1 L, or 2 Δ’s
  - With similar detectors combined SNR matters (detector null fine)
  - Sky location by polarization and antenna pattern

- Triangulation:
  - Need 3 facilities minimum
  - Base length matters & high frequency signals give better timing
  - Tends to be superior (on Earth approx. factor of 10 in angle)
  - SNR of worst detector determines resolution (detector null bad)

- Monte Carlo code combines both methods
Advanced Detector Network

Low SNR events dominate in plot!
Triangulation Error

Time Resolution

Effective Bandwidth

\[ \sigma_t = \frac{g(\rho_1, \rho_2)}{\pi \sigma_f \rho} \]

with \[ g(\rho_1, \rho_2) = \frac{\rho_1^2 + \rho_2^2}{2\rho_1\rho_2} \]
Heterogeneous Networks

- 1-2 3G detector facilities + advanced detectors
- Cut on high SNR events in 3G detector
- Solid angle reduction (SNR 3G/AD ~ 10)
  - Add one 3G facility: ~2
  - Add two 3G facilities: ~10
  - Three 3G facilities: ~70 (due to reduced bandwidth)

- Will allow for distance measurements
- Two 3G facilities on their own?
Double Trigon Configuration

- Measure both polarization at both observatories
- Try to locate 90° apart on Earth
- Detector normals:

\[
\begin{pmatrix}
+1 \\ 0 \\ +1 \\ -1
\end{pmatrix}
\]
Solid angle for SNR 100 events (BW 50Hz)

Polarization alone

Polarization & Timing
Open Questions

- How important is accurate sky localization?
- Is the sky localization of the advanced detector network good enough for 3G physics?
  - If not, need more than one 3G facility
- How important is full sky coverage?
  - If you can see all binary inspiral events, you can subtract/veto them from the stochastic background!
- How many facilities can we afford?
  - Trade off: 3 L’s vs 2 Δ’s?
- Need MC code simulations