All-sky burst searches to test alternative theories of gravity

Xavier Siemens

Center for Gravitation and Cosmology

UNIVERSITY of WISCONSIN
UWMILWAUKEE

Optimistic outlook

“Now, a few words on looking for things. When you go looking for something specific, your chances of finding it are very bad. Because of all the things in the world, you're only looking for one of them. When you go looking for anything at all, your chances of finding it are very good. Because of all the things in the world, you're sure to find one of them.”

D. Zero (The Zero Effect)

Basic pipe-line idea: internally triggered search (Intrig?)

- Start with a basic excess power single instrument search. Use triangulation to determine sky location (assumes speed of gravity=c). Find antenna pattern functions

$$\mathbf{F}_i = \{F_i^+, F_i^x, F_i^b, F_i^l, ...\}$$

- i labels detectors. Our data is

$$d_i = \mathbf{F}_i \cdot \mathbf{h} + n_i$$

Waveform estimation (least-squares) $\hat{\mathbf{h}} = \left(\mathbf{F}^T\mathbf{F}\right)^{-1}\mathbf{F}^T\mathbf{d}$

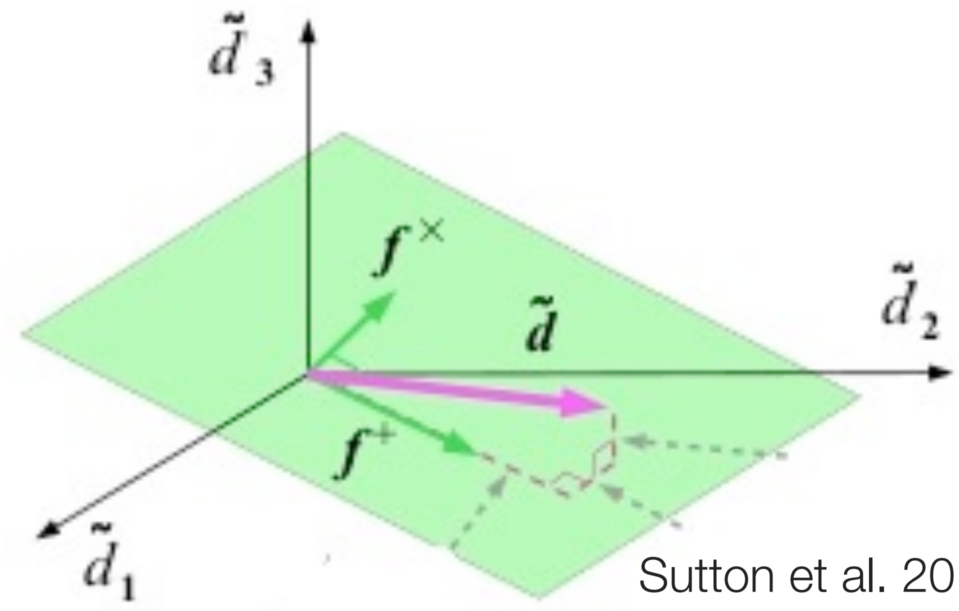
- But cannot faithfully re-construct more than i polarizations. Expect system is underdetermined (i.e. we'll have i=3 maybe 4 detectors, could have as many as 6 polarizations)

Intrig pipeline cntd.

- Maximum likelihood is

$$E_{SL} = \mathbf{d}^T \mathbf{P}_{GW} \mathbf{d}$$

$$\mathbf{P}_{GW} = \mathbf{F} \left(\mathbf{F}^T \mathbf{F} \right)^{-1} \mathbf{F}^T$$



Sutton et al. 2010

- So we can construct likelihoods and say whether it is more likely that we have 2 (Einstein's GR) or more (some other theory of gravity) polarizations though we will not be able to say which. So this is only a yes-or-no test of GR.

Can we do more?

- We can borrow stochastic background methods (see Stefanos's talk tomorrow morning) to burst searches to unravel the different polarization content of gravity
- Suppose we cross-correlate data at the time of events we identified in the previous pipeline and combine all cross-correlated data (we know how to do this optimally).
- Provided the bursts are isotropically distributed in the sky (!) and un-polarized (!) we can see which overlap reduction function combination gives us more signal to noise:

$$\mathrm{SNR} = \frac{3H_0^2}{10\pi^2}\sqrt{T}\left[\int_{-\infty}^{\infty} df\, \frac{\gamma^2(|f|)\Omega_{\mathrm{gw}}^2(|f|)}{f^6 P_I(|f|)P_J(|f|)}\right]^{1/2},$$

where $\Omega_{\mathrm{gw}}\gamma = \Omega_{\mathrm{gw}}^T\gamma^T + \Omega_{\mathrm{gw}}^V\gamma^V + \xi\Omega_{\mathrm{gw}}^S\gamma^S$.

$$\gamma_{IJ}^T(f) \equiv \frac{5}{2}\int_{S^2}\frac{d\hat{\Omega}}{4\pi}e^{2\pi i f\hat{\Omega}\cdot\Delta\vec{X}/c}(F_I^+F_J^+ + F_I^\times F_J^\times), \quad (22)$$

$$\gamma_{IJ}^V(f) \equiv \frac{5}{2}\int_{S^2}\frac{d\hat{\Omega}}{4\pi}e^{2\pi i f\hat{\Omega}\cdot\Delta\vec{X}/c}(F_I^xF_J^x + F_I^yF_J^y), \quad (23)$$

$$\gamma_{IJ}^S(f) \equiv \frac{15}{1+2\kappa}\int_{S^2}\frac{d\hat{\Omega}}{4\pi}e^{2\pi i f\hat{\Omega}\cdot\Delta\vec{X}/c}(F_I^bF_J^b + \kappa F_I^\ell F_J^\ell). \quad (24)$$

Questions

- The devil's in the details (we can discuss some of these now)
- Not addressed GWs traveling at a different speed than c. Searching over different speeds will make things more complicated.
- Question for Cliff: What is a reasonable range of values for the speed of gravitational waves?
- Should we focus our efforts more on particular polarization contents (3/6, 5/6)?
- Other ideas for all-sky searches?
- Infrastructure development (hardware and software injections)
- How much power is there in the other polarizations? vs. phasing