Search for Compact Binary Signals Using Coherent WaveBurst

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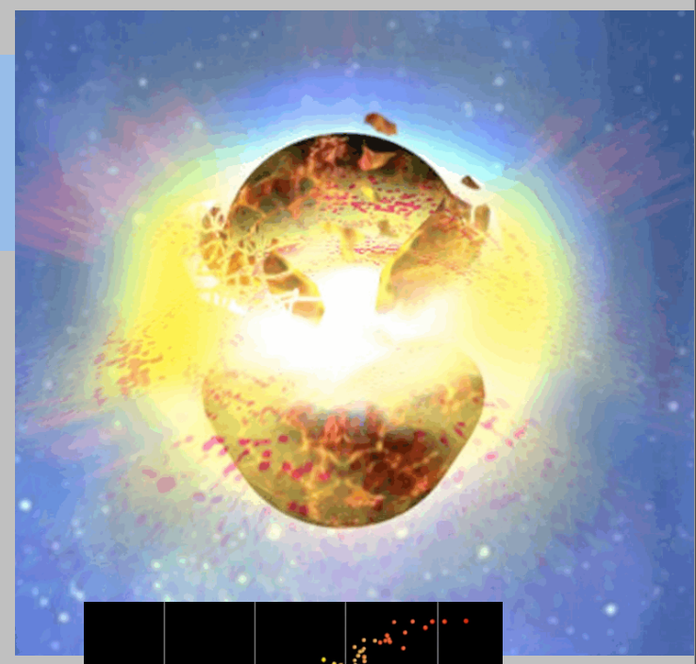
Motivation

Mergers are laboratories for strong field interactions in GR and one of the most sought after sources in gravitational wave astronomy

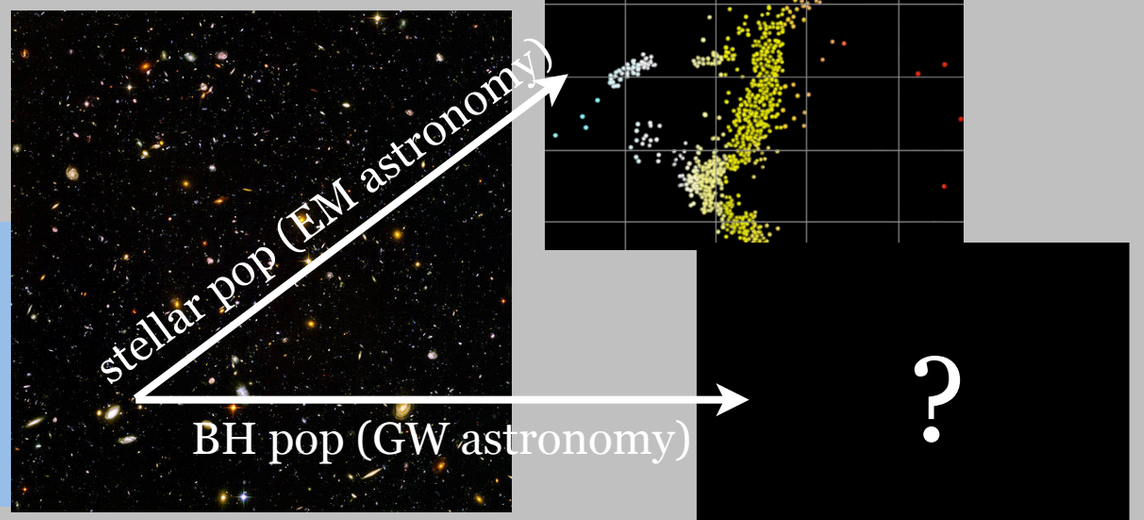
Exploration of neutron star equation of state, and interaction of spinning black holes



Large Magellanic Cloud

Discovery of new astronomical phenomena[1][2] (intermediate mass black holes)

Provides insight into compact object population models and the rate of their coalescences

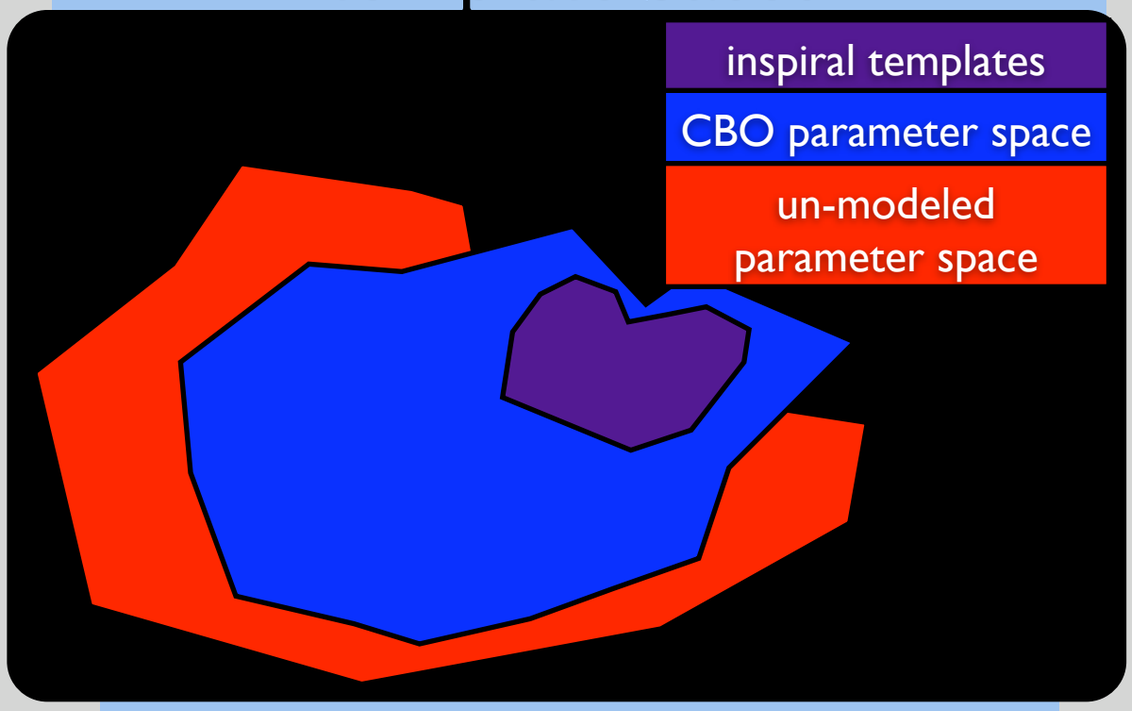


Hubble UDF

Methods

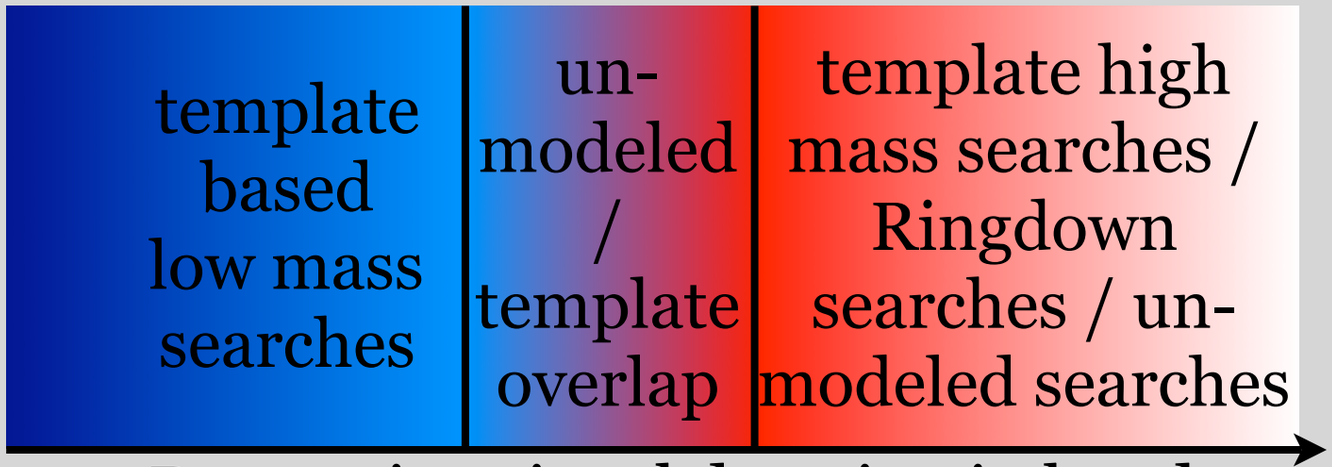
Current template based searches do very well, but there are other methods that can fill in the gaps

Un-modeled searches span a wider parameter space than template based



Can make detections of sources not currently modeled

Not optimal, but requirements for detection are not reliant on accurate templates

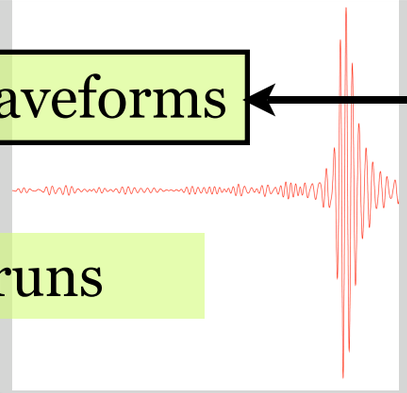


Doesn't require, but *can use* simulated waveforms from numerical GR

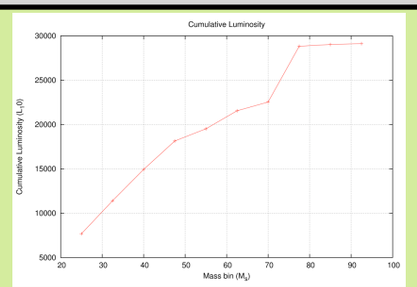
Search Method

Outline of search method -- perform the search over all of the most recent LIGO data set with new waveforms

+ simulated waveforms



CBO galaxy catalog



rate upper limit

injection runs

interferometer data

cWB

detection studies

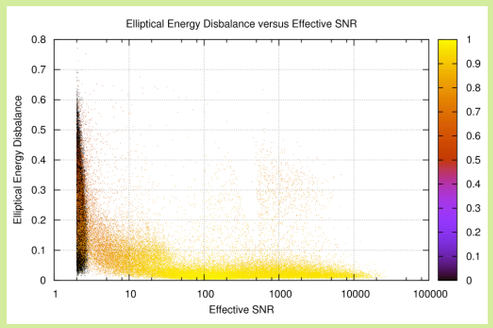
detection?

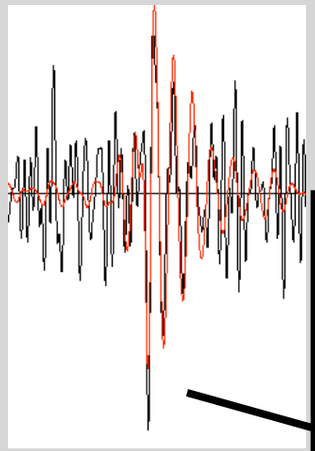
no...

yes!

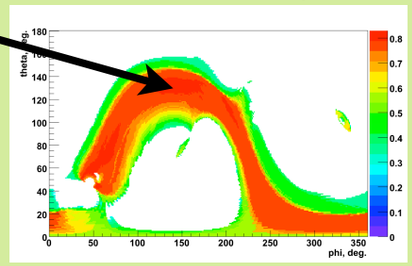
time slides

trigger analysis and thresholding procedures





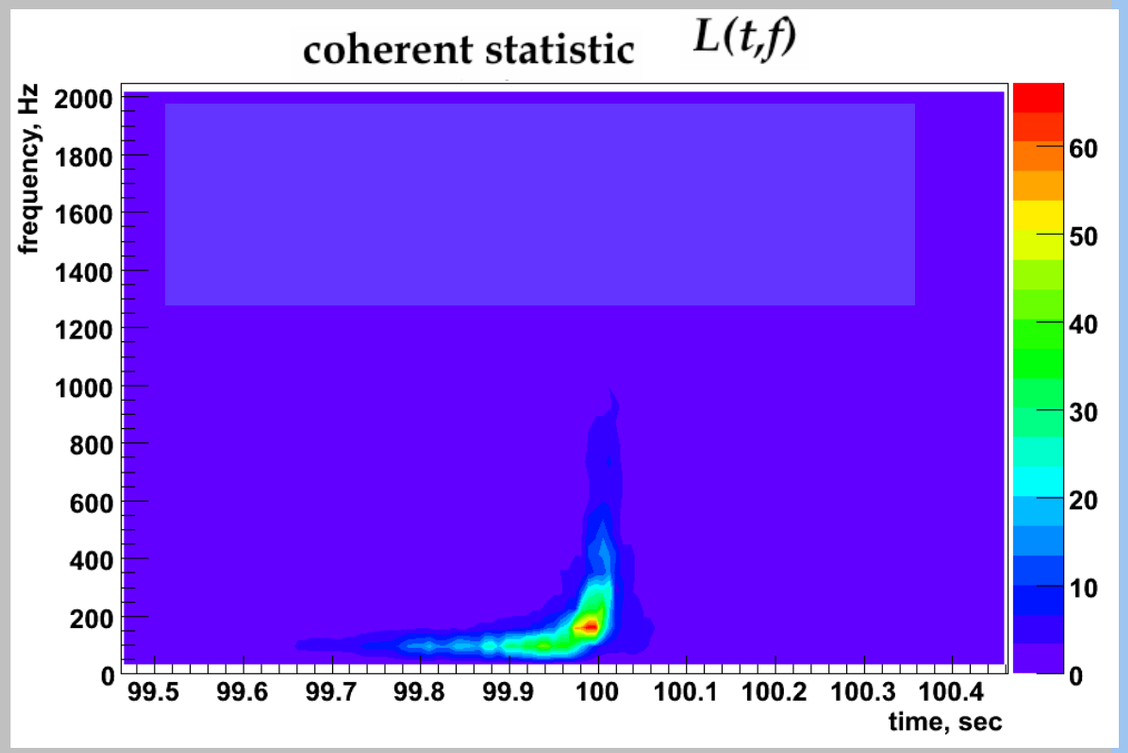
follow up (parameters, sky location)



accept Nobel prize

Coherent WaveBurst

Coherent WaveBurst is an analysis tool for short duration, un-modeled gravitational wave bursts



time-frequency map of 18 Ms binary at 2 Mpc using un-modeled search in the LIGO network

Uses a likelihood ratio to supply estimators of the waveforms

$$\log L = \sum_{i}^{samp} \sum_{k}^{det} \frac{x_{i,k}^2}{\sigma_{i,k}^2} - \frac{(x_{i,k} - \xi_{i,k})^2}{\sigma_{i,k}^2}$$

Represents the ratio of the probability of a GW signal ($x_{i,k}$ -- detector strain data) and no GW signal ($x_{i,k}$-$\xi_{i,k}$ -- estimated noise)

Developed and used during previous science runs for LIGO

Elliptical Constraint

One can constrain the likelihood ratio to specialize to a certain type of signal morphology

Previous searches used an un-modeled version (generic waveform)

$$\left.\begin{array}{r}\xi(h_+(t), h_\times(t)) = F_+ h_+(t) + F_\times h_\times(t) \\ \xi(\psi, a, h(t)) = F_+(\psi) h(t) + a F(\psi)_\times \tilde{h}(t)\end{array}\right\}$$

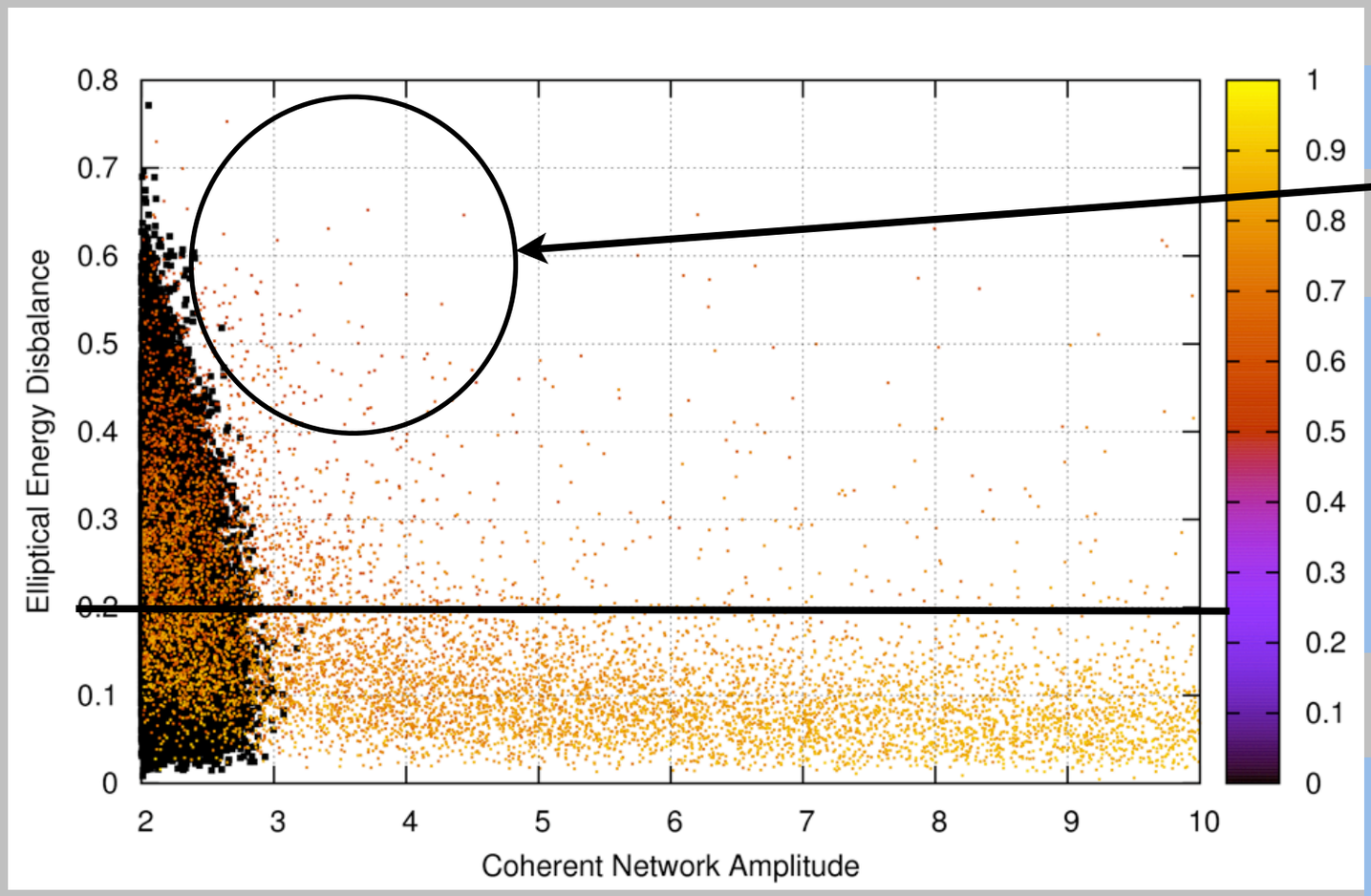
Un-modeled case, 2N parameters
Elliptical case, N+2 parameters

This search will use a constrained version (elliptically polarized waveform)

Constraining the free parameters should allow for more accurate reconstruction of a polarized GW signal

Test Run

Examine the parameters available to use from the algorithm, as well as test our ability to detect our signal



Threshold indicated allows for a FAR of about 10^{-6} Hz with a final detection statistic threshold of ~3 and a false dismissal of ~10% of the recovered injection set

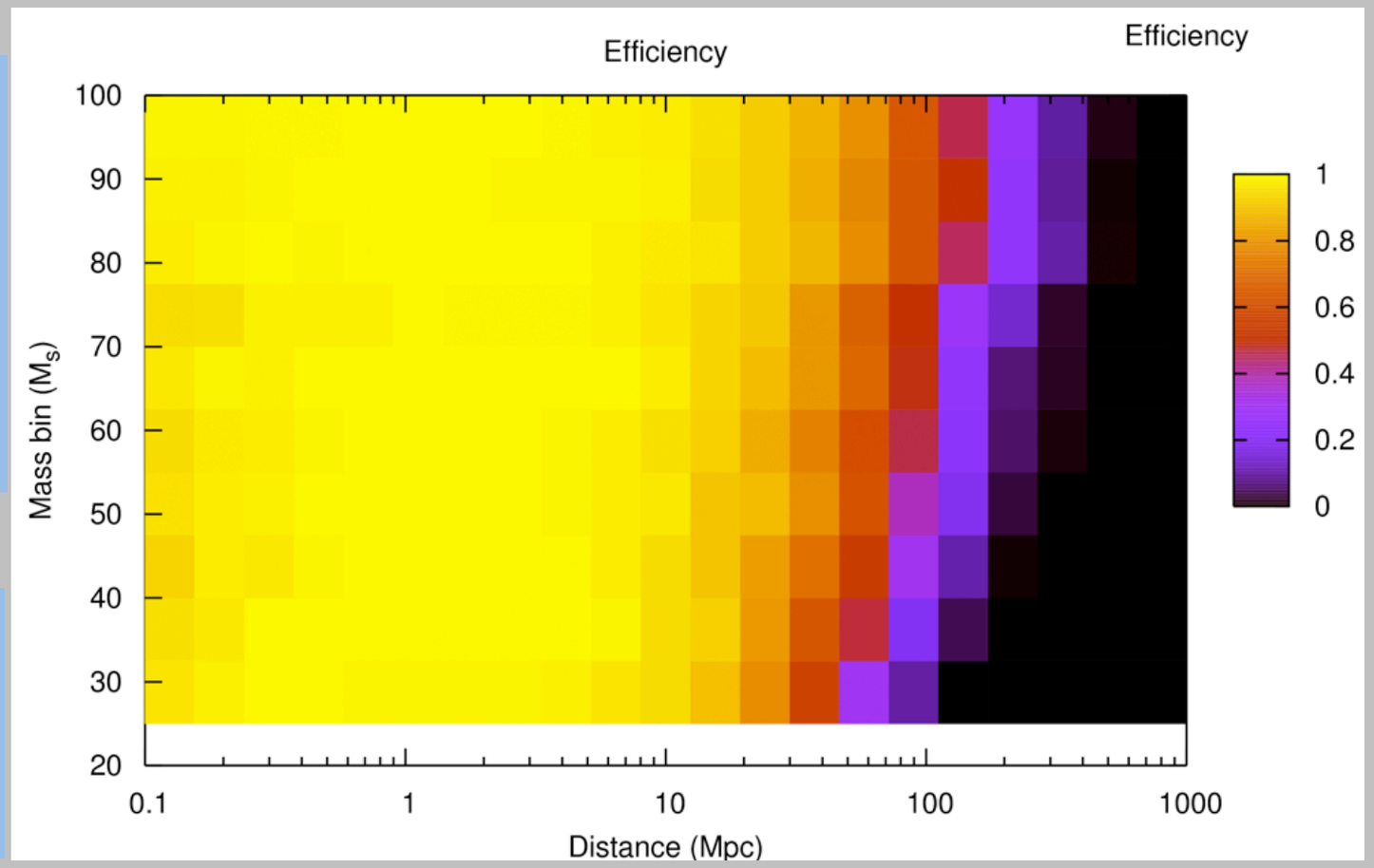
Glitch region in actual data

Threshold determines false alarm rate from background as well as false dismissal probability for injected signals

Color of dots also a controllable threshold on consistency between detectors

Test Results

Detection efficiencies for a set of simulated LIGO network data with "Effective One Body" numerical relativity waveforms[3]



Low mass set detection efficiency versus total mass and distance

90% detection efficiency beyond the Virgo cluster (at 18 Mpc) for initial LIGO sensitivity

~50% of luminosity contained in catalog[4] is "visible" for 25-100 M_s

Summary

- Updated and enhanced an un-modeled algorithm to be weakly model dependent and specialize to a more specific source model
  - Implementation by a constraint against elliptical polarization
- Complementary search method to current template based searches
- A search is currently underway using real detector data collected recently
- Use new phenomenologically motivated gravitational waveforms
- Early test results are promising, should be able to “see” beyond the Virgo cluster

References

[1] **Thomas J. Maccarone, Arunav Kundu, Stephen E. Zepf, and Katherine L. Rhone *A black hole in a globular cluster*, Nature (2007)**

[2] **John M. Fregeau, Shane L. Larson, M. Coleman Miller, Richard Shaughnessy, and Frederic A. Rasio *Observing the IMBH-IMBH Coalescence via Gravitational Radiation*, Ap. J. (2006)**

[3] **T. Damour, A. Nagar, M. Hannam, S. Husa, B. Brugmann *Accurate Effective-One-Body waveforms of inspiralling and coalescing black-hole binaries*, (Phys. Rev. D 2008)**

[4] **R. Kopparapu, C. Hanna, V. Kalogera, R. O’Shaughnessy, G. Gonzalez, P. Brady, S. Fairhurst *Host Galaxies Catalog Used in LIGO Searches for Compact Binary Coalescence Events*, (Ap. J. 2008)**