Directional searches for transient gravitational waves

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Introduction

- All-sky coherent un-triggered Searches
  - Analyze full data set for all possible sky positions/polarizations, making the minimal assumptions on the GW signals
- Externally triggered Searches
  - Analyze ~hundreds of seconds around an astrophysical trigger (e.g. a GRB) using the information on the direction of incoming
  - Roughly a factor 2 more sensitive than All-sky search on single GRB search

- An intermediate case: Directional searches
  - Simplest example: targeting a sky position continuously (e.g. the SgrA*).
  - Anisotropy Search
  - Directional Searches for distributed gw sources
- You may gain in:

False Alarm Rate reduction and better sensitivity

Better source parameter reconstruction

All-sky Anisotropy Search

Idea: Use directional reconstruction abilities of a worldwide 3-site network to perform an all-sky search for a gravitational wave point source. Similar to point source analyses conducted in MACRO, IceCube, etc.

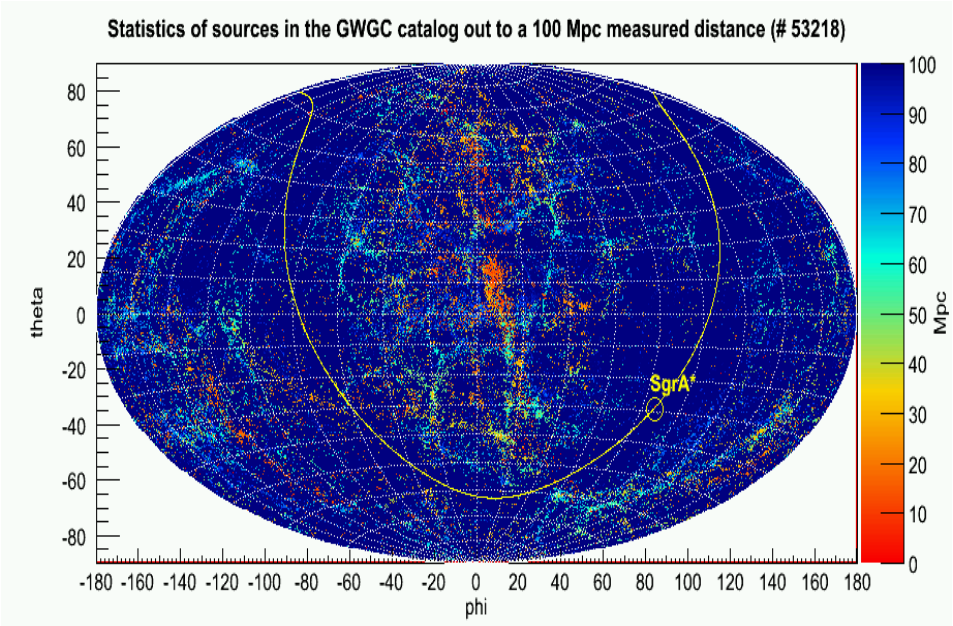
By looking for directional correlations, it is possible to probe substantially below our current sensitivity.
The main limiting factor is pointing resolution, which forces us to group together events from large sky regions instead of using tighter bins.

To increase the pointing accuracy we are testing:
• Signal constraints (e.g. elliptical polarization)
• Sky mask: consider only positions (theta, phi) on which we have good coordinate reconstruction

Directional Searches for distributed gw sources

• **IDEA:** Use the information on the position of nearby galaxies to constrain the direction of incoming of GW signals
The population of galaxies (e.g. up to 20Mpc) can be analyzed searching within smaller area

Target:
• Increase positioning performances for 3 sites network configurations
• Lower False alarm rate



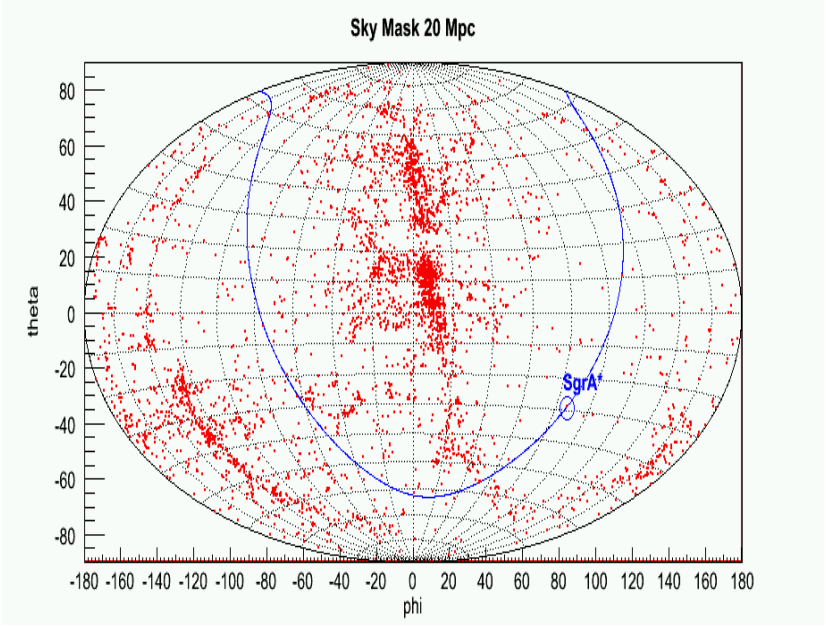
Sky map Example

• Example: considering the distribution of nearby galaxies up to **20 Mpc** on a grid of sky pixels 0.5x0.5 degrees, we obtain a sky mask (red dots) which covers **2%** of the total sky area

This constrain can be folded in the search:

• **Post-production cut**: within the EM followup with wide-field optical telescopes for the S6-VSR2 online burst pipeline, the LUMIN project weights the sky positions according to the mass distribution of Galaxies up to 50 MPc.

• **Production constraint:** we force the algorithm to try to reconstruct the signal in that 2% of the sky only. In such way, we don't lose much in terms of detection efficiency.



Tests on Simulated data

Comparison between 2 Reconstruction Algorithms: Coherent WaveBurst (cWB) with an **All-sky** and a **sky masked** constrained likelihood method to localize the source in the sky and reconstruct the waveform

Network: 3 detectors network, L1-H1-V1

Data Set: 4 days of simulated gaussian noise assuming S5 H1 sensitivity for all 3 detectors

Simulated Signal Waveform: several types of waveforms with different frequencies, amplitudes and polarization states

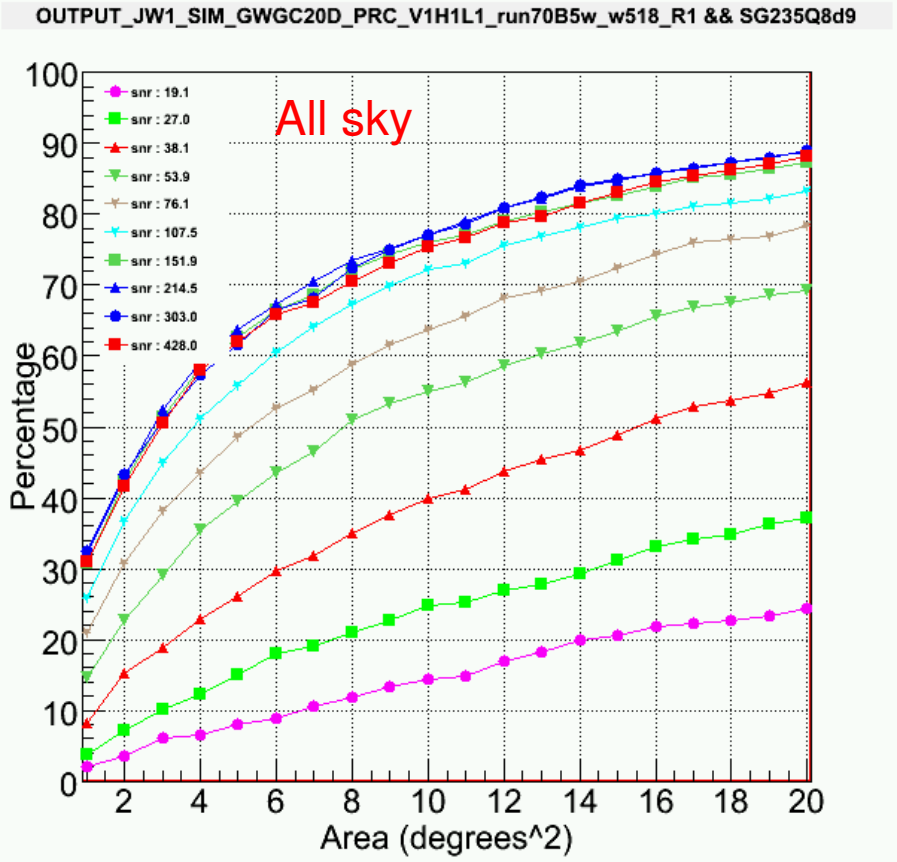
- *Sine Gaussian SGQ3, SGQ9 linear polarized (235,1053 Hz)*
- *Sine Gaussian SGCQ9 circulary polarized (235,1053 Hz)*
- *White Noise Burst WNB random polarized (250-350 Hz, 1-2 kHz) 0.1s*

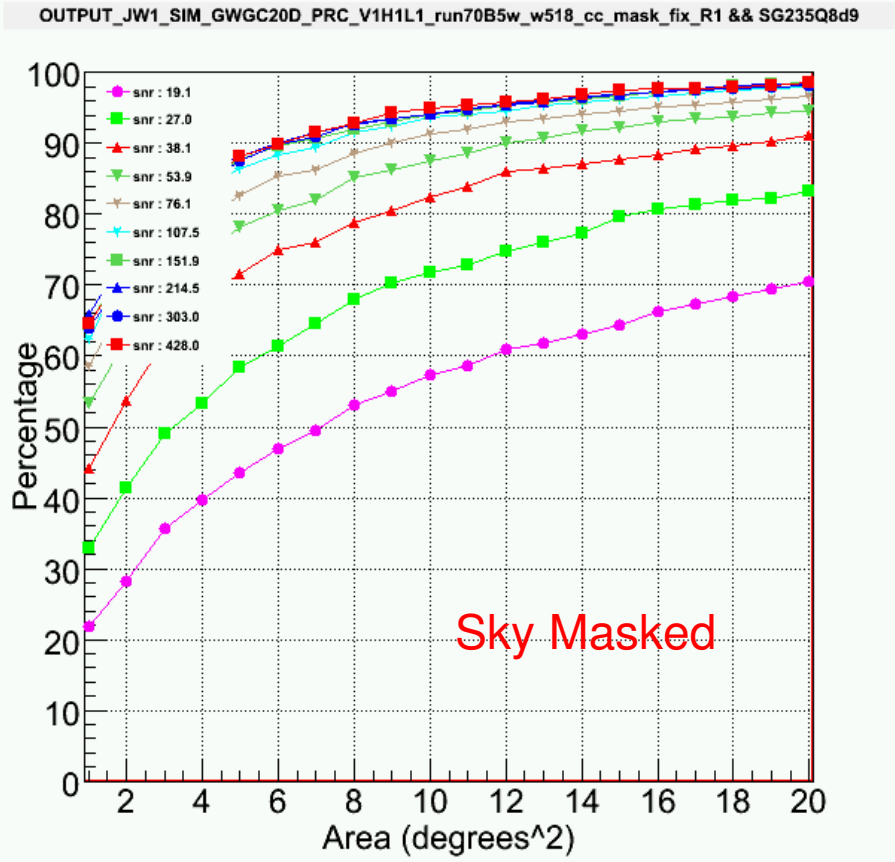
Simulated Signal source population:

The signals are generated with directions taken from Galaxies Distribution GWGC Catalog up to 20 Mpc and their amplitudes are rescaled to be proportional to the inverse of the distance (e.g. hrss=2.5e-21 @ 10 Mpc)

Improved coordinate reconstruction

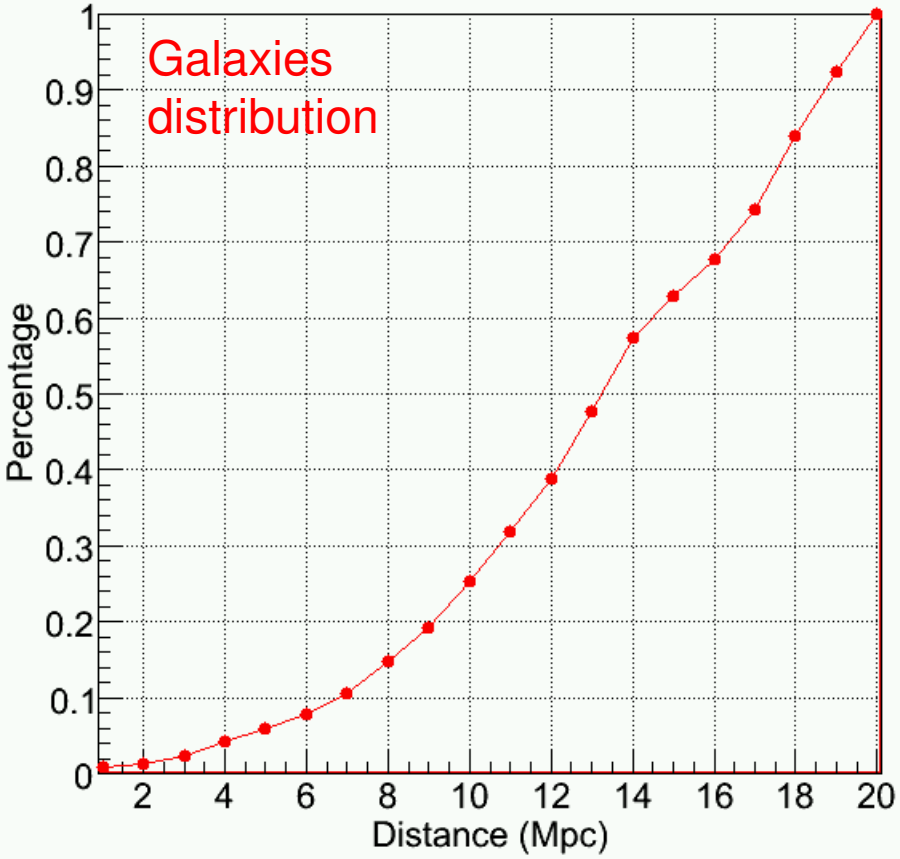
• Percentage of signals reconstructed within an Error Region < given Area. The signals are binned with respect to their snr. On the left, an All-sky search; on the right, the corresponding values having applied a sky mask (20 Mpc – 2%) in production. **Caveat**: error regions areas may be split in few disjoint patches.



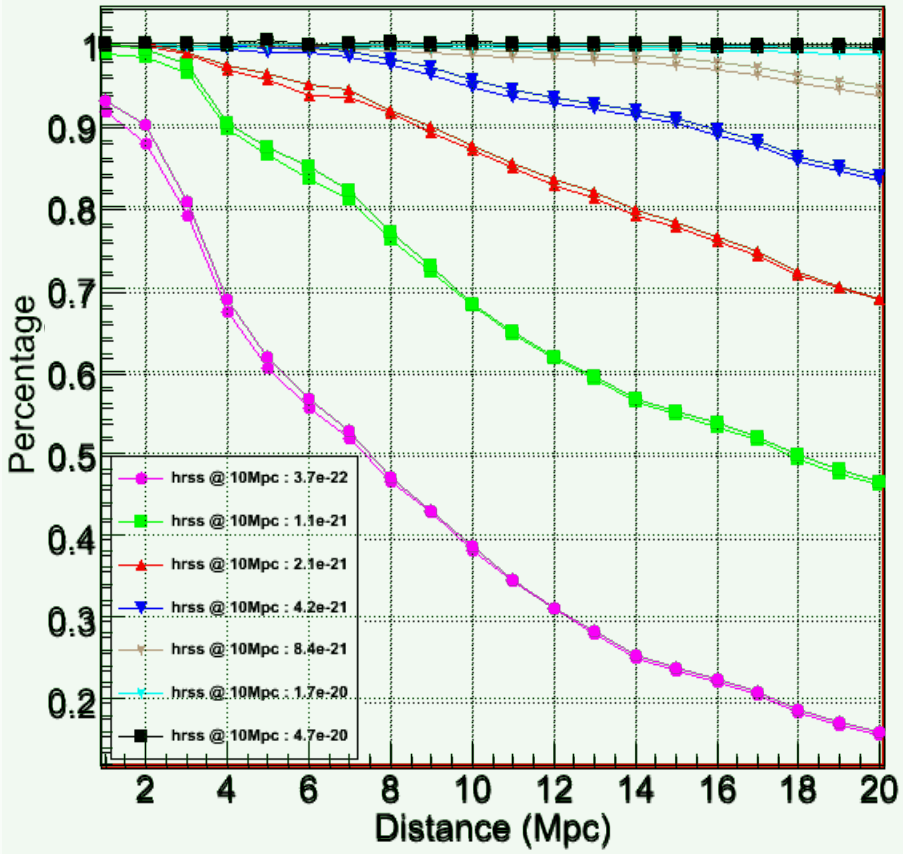


Detection efficiency

On the left, the MonteCarlo source distribution: percentage of signals within a given distance. On the right, the Sky Masked/All Sky cumulative detection efficiency as a function of the distance for different signal strength: detection efficiency is preserved.



Cumulative Detection efficiency
Sky masked (20 Mpc – 2%)/All-Sky



Summary

• Recent results on coordinate reconstruction push towards investigating some interesting possibilities connected with Directional Searches. Such searches may complement/improve the standard All-sky and ExtTrig Searches.
• Preliminary studies with different flavours of directionality are on-going:
  – Anisotropy Search
  – Directional Search for distributed gw sources

• Concerning the latter, some preliminary results on the application of a sky mask in production stage were presented, showing that, under the assumption that signals come from nearby galaxies (within 20 MPc):
  – the coordinate reconstruction improves (as expected)
  – The detection efficiency is preserved