Externally triggered searches of gravitational-wave bursts with Tikhonov regularization technique

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Coincidence with electro-magnetic observations

- The detection of GW can be enhanced by coincidences with electro-magnetic observations:
  - GRB, SGR, X-ray sources…
    [see talk by Isabel Leonor "Searching for GW bursts associated with GRBs… (talk U11-4 in this session)]
- The observational data are provided by
  - SWIFT, RXTE, HETE, Konus-Wind, Chandra, XMM-Newton
- The detection probability becomes increased by use of
  - coincidence in time (within the time window),
  - coincidence in sky location (within the resolution)

L.S. Finn, S.D. Mohanty, and J.D. Romano, Detecting an association between gamma ray and gravitational wave bursts, Phys.Rev. D 1999

K. Hayama et al., Regularized coherent network analysis pipeline for triggered searches of GW bursts, GWDAW 11, Potsdam, Dec. 2006

Maximum likelihood and regularization

Gravitational-wave signal: $\xi_i(t) = F_{i+}\, h_+(t) + F_{i\times}\, h_\times(t)$

Sky dependence: $F_{i+}, F_{i\times}, \tau_i$ depend on ϕ, θ

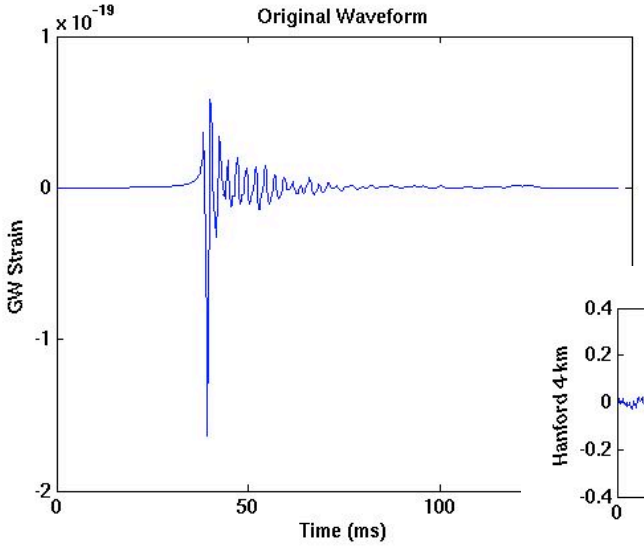
Likelihood functional: $L = \sum_{i=1}^{m} \frac{1}{\sigma_i^2} \| x_i(t) - \xi_i(t - \tau_i) \|^2$

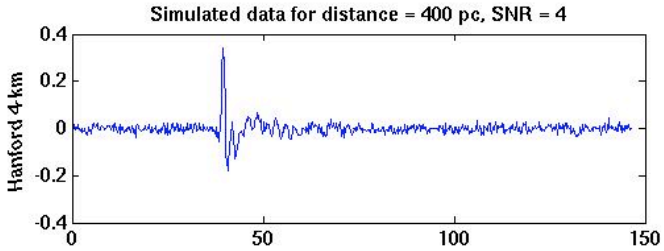
Tikhonov regularization: $L_g = L + g\,\Omega$

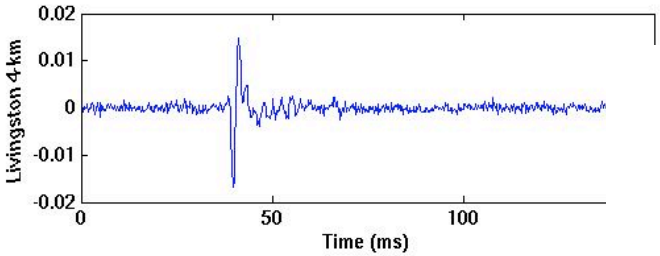
Maximum entropy principle: $\Omega = -S$, where S is entropy

Quadratic approximation: $\Omega = \sum_{i=+,\times} h_i \Omega_{ij} h_j$

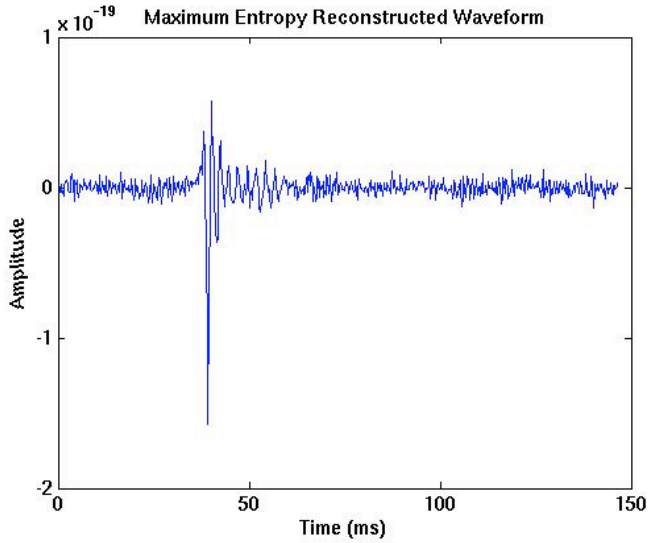
Waveform estimation (1 polarization)





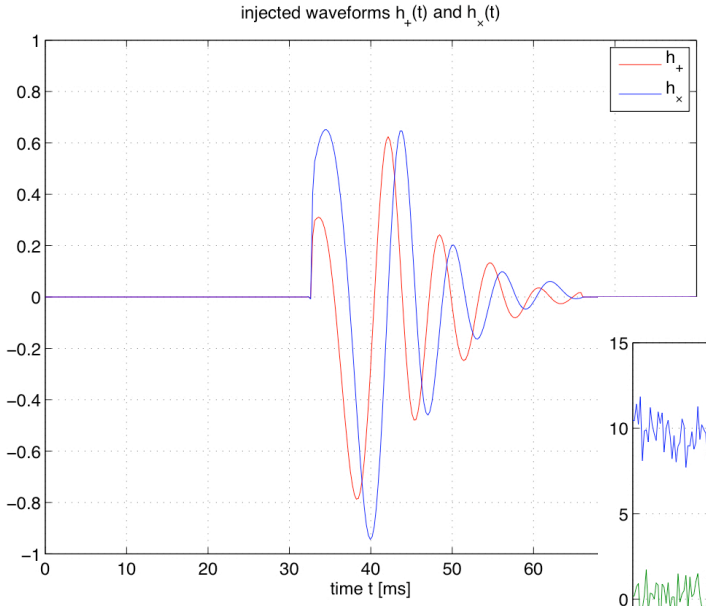


Reconstruction of 1-pol. waveform
(sim. of supernova core collapse)

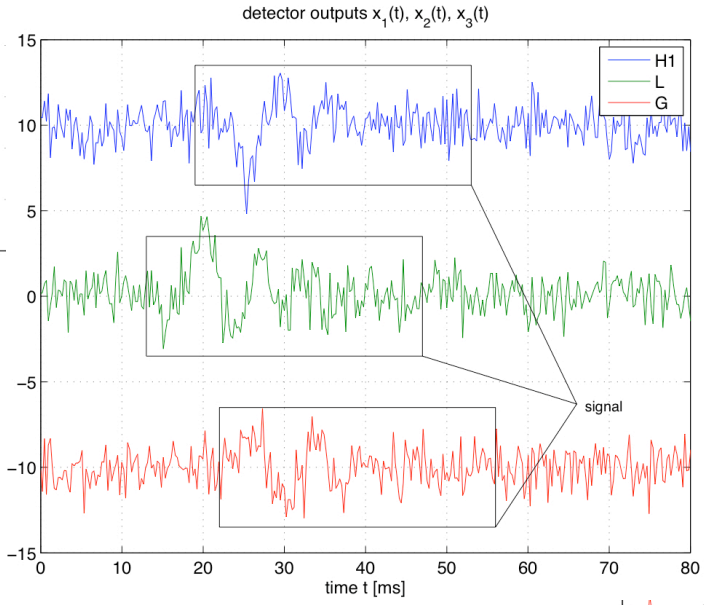


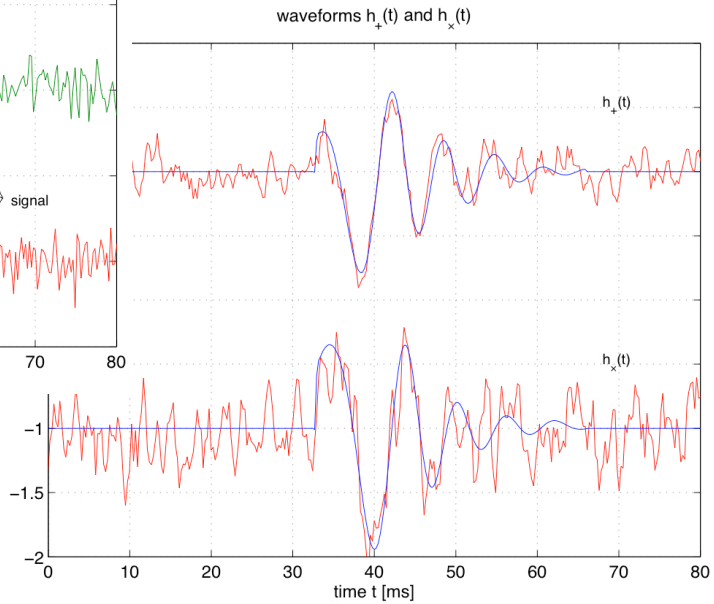
T.Z. Summerscales et al., Maximum entropy for gravitational wave data analysis… , ApJ, 2007

Waveform estimation (2 polarizations)



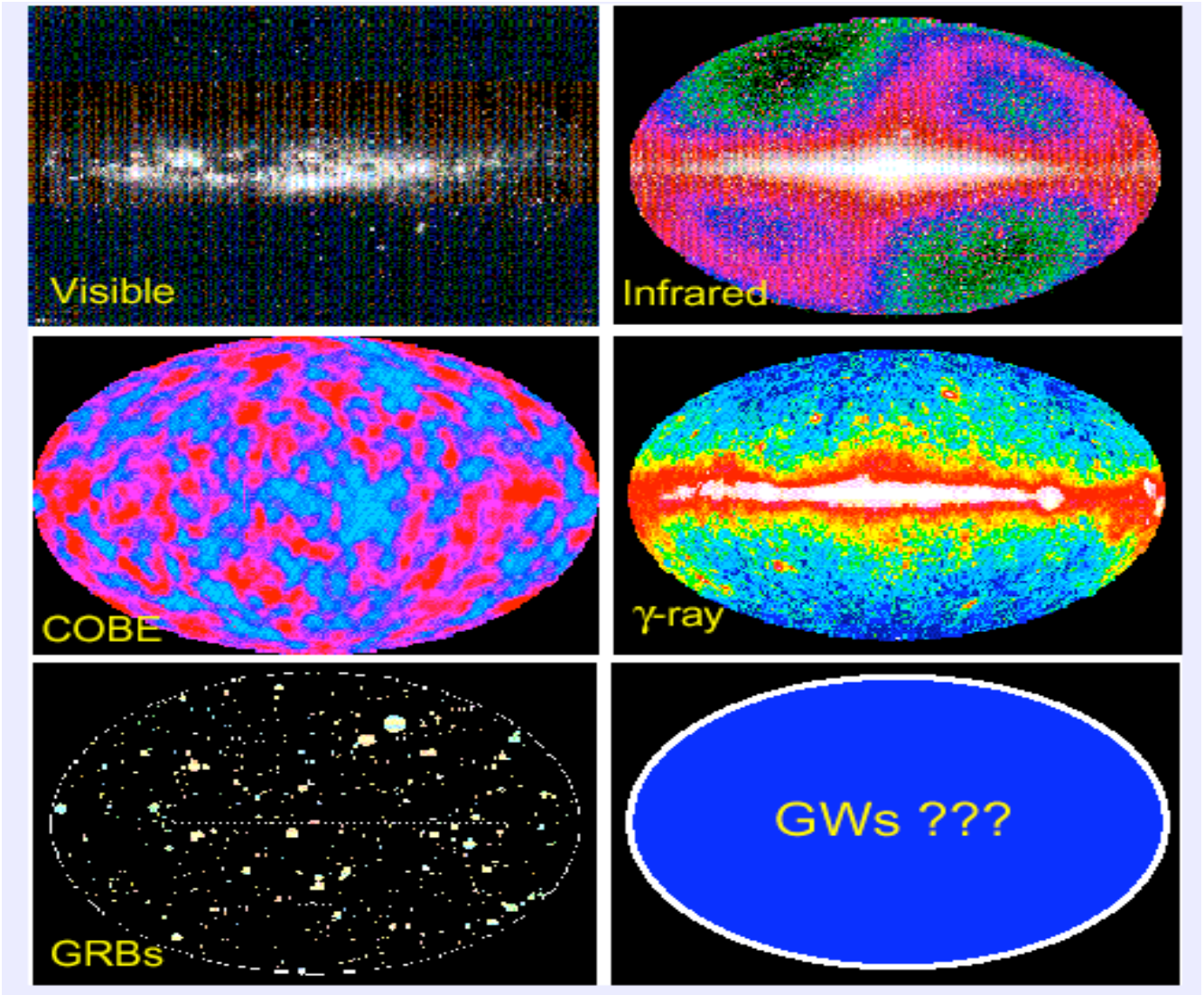
Reconstruction of 2-pol. waveform,
3 detectors: LIGO H1, L, and GEO



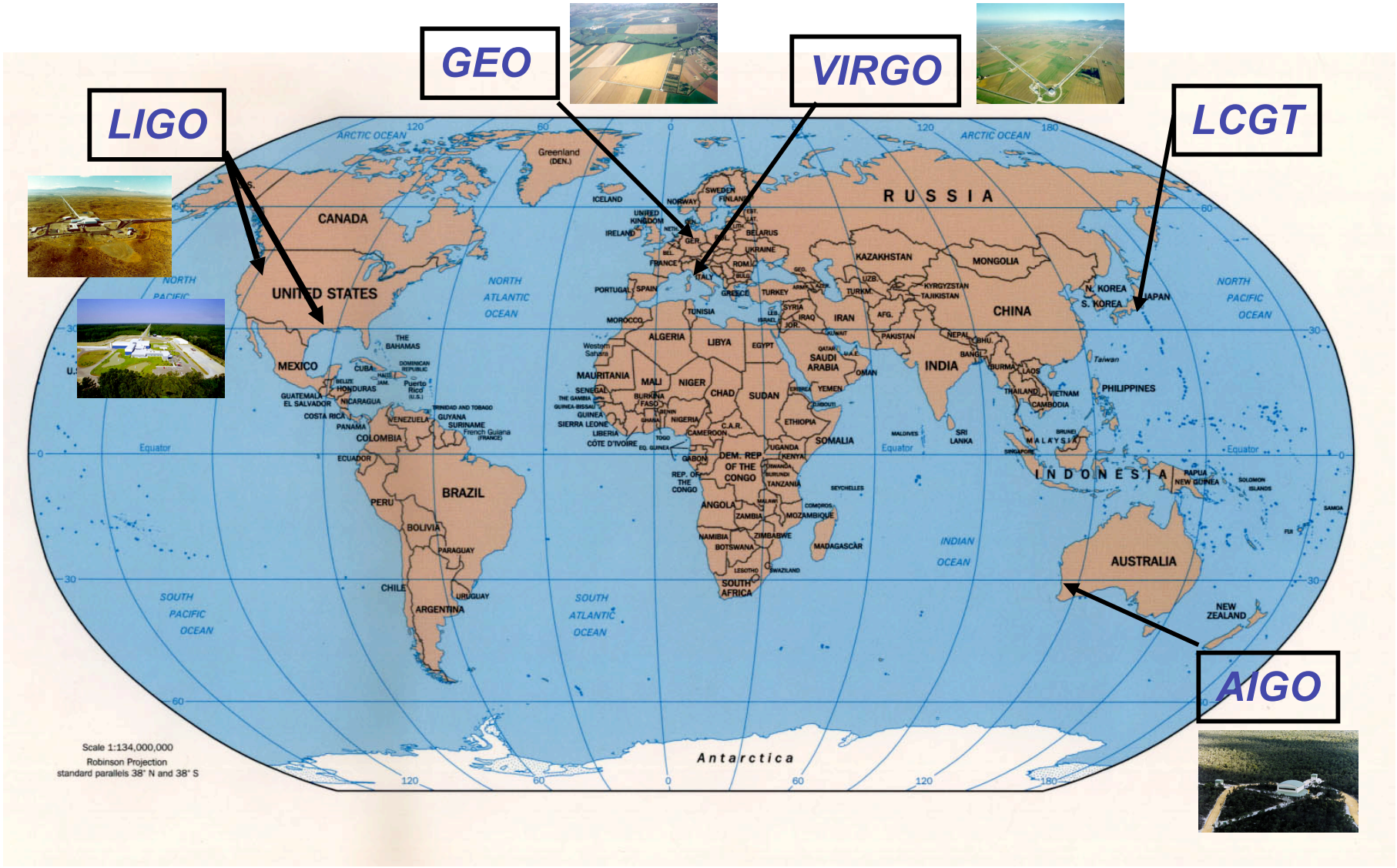


M. Rakhmanov, Rank deficiency and Tikhonov regularization for gravitational-wave bursts, Class.Quant.Grav., 2006

Viewing a source in GW spectrum



Network of laser GW detectors



Single source imaging (LIGO, VIRGO)

Numerical simulation:

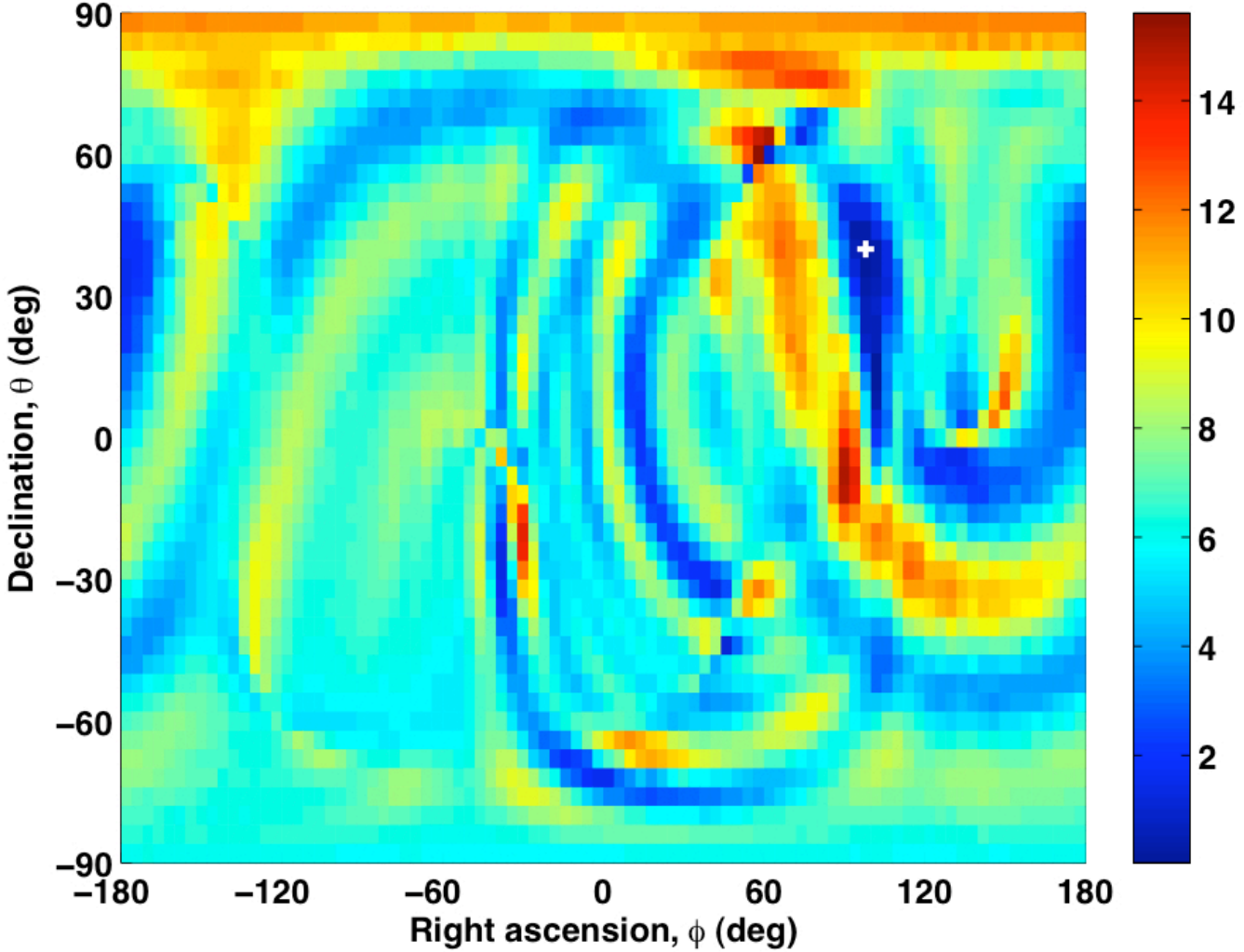
Maximum Likelihood Inference,

2-pol. source,

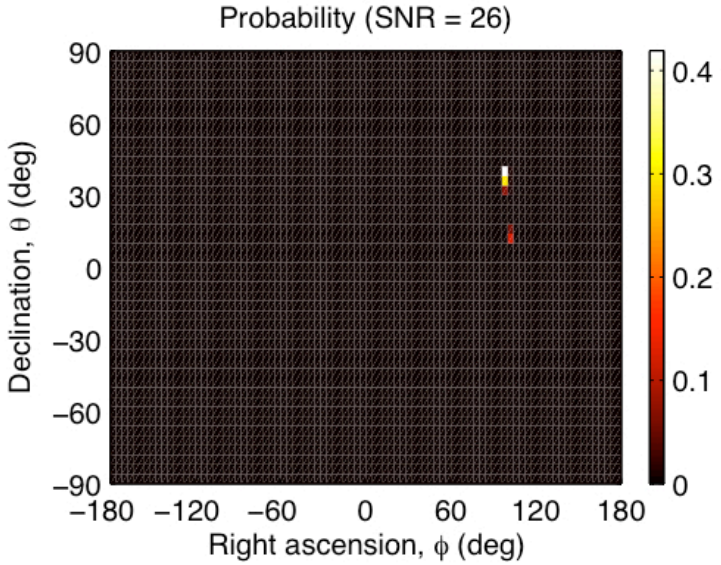
RA 40 deg,
DEC 98 deg,

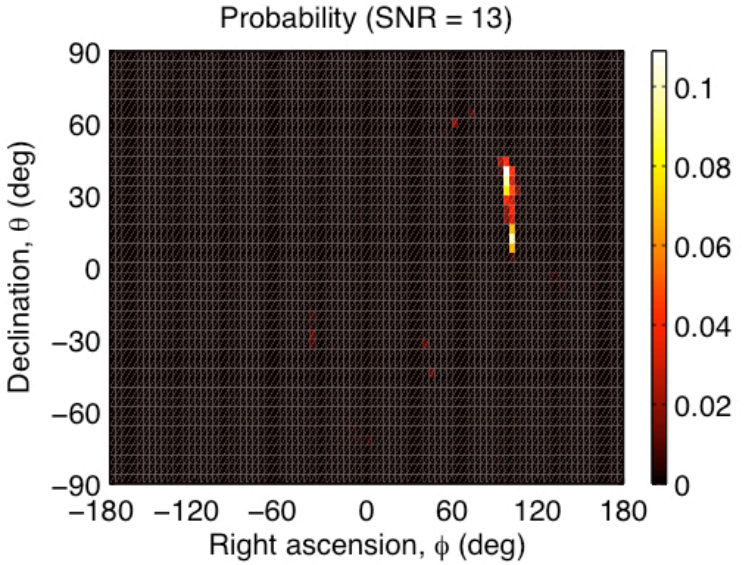
Detectors:
LIGO(3)+VIRGO

The value of the likelihood functional

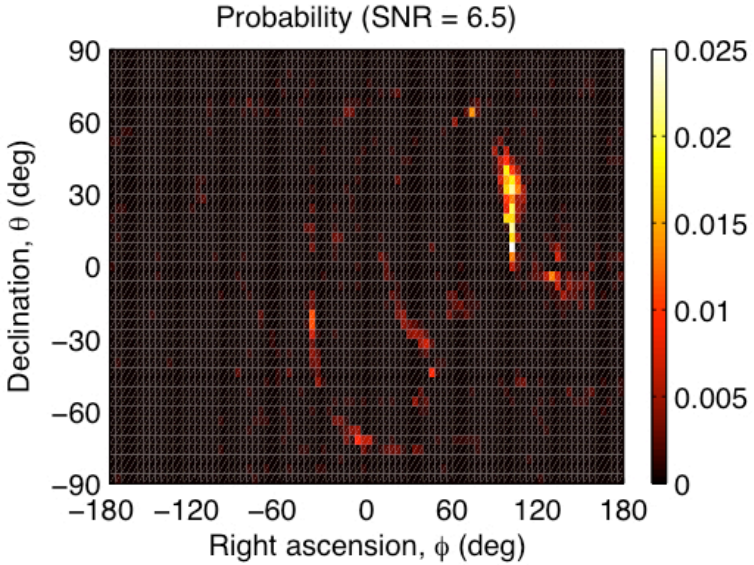


Angular resolution (maximum likelihood)

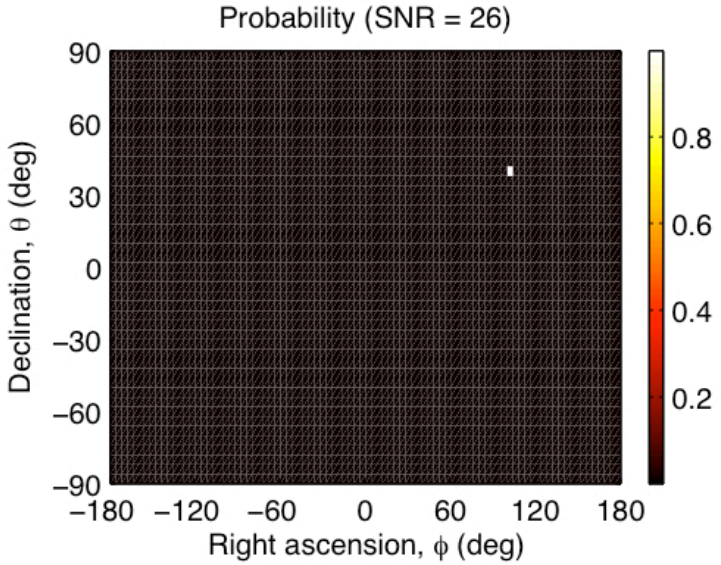


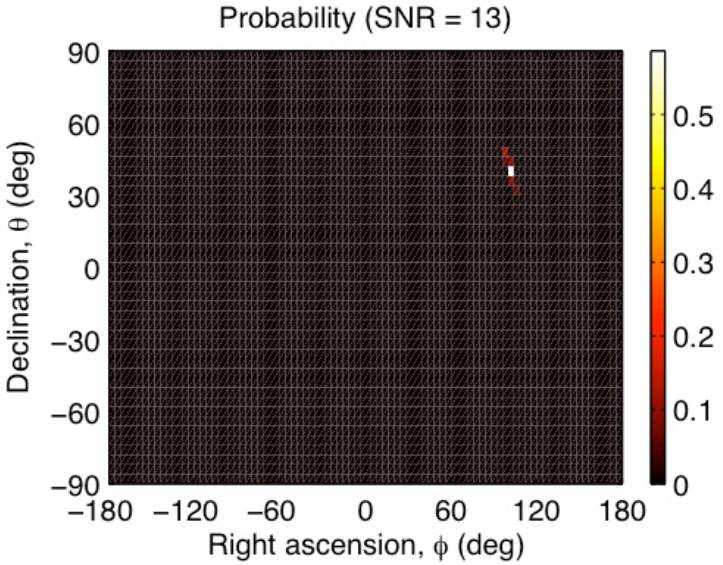


Numerical simulation:
1000 trials, 2-pol. waveform,
sky cell: 4-deg x 4-deg,
random Gaussian noise,
matched filter SNR,
detectors: LIGO(3)+VIRGO



Angular resolution (after regularization)





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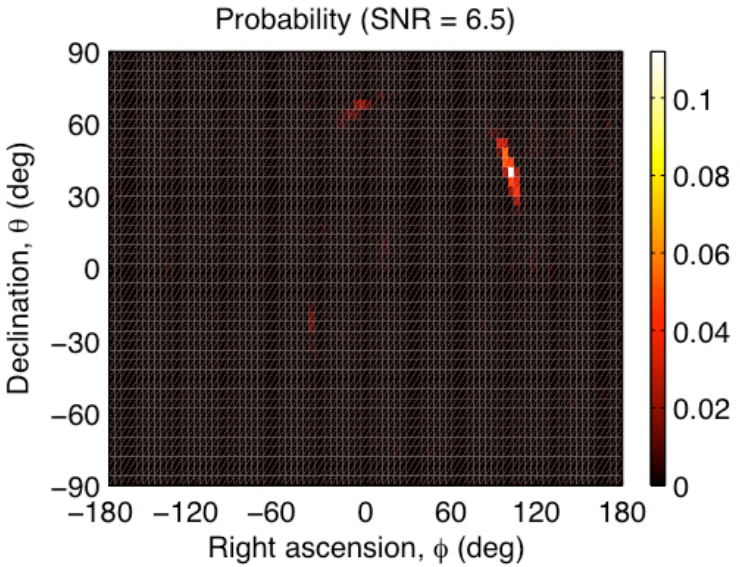

Conclusion

- **Summary:**
  - the search algorithm is now fully developed,
  - the codes are complete and tuning is in progress,
  - trial runs on simulated data have started

- **Plans:**
  - estimate the detection efficiency,
  - estimate accuracy of the waveform reconstruction and source localization,
  - apply the algorithm to data from LIGO, VIRGO and GEO