A Riemann Manifold Hamiltonian Monte Carlo (RMHMC) for binary neutron star parameter estimation

Yann Bouffanais and Edward K. Porter

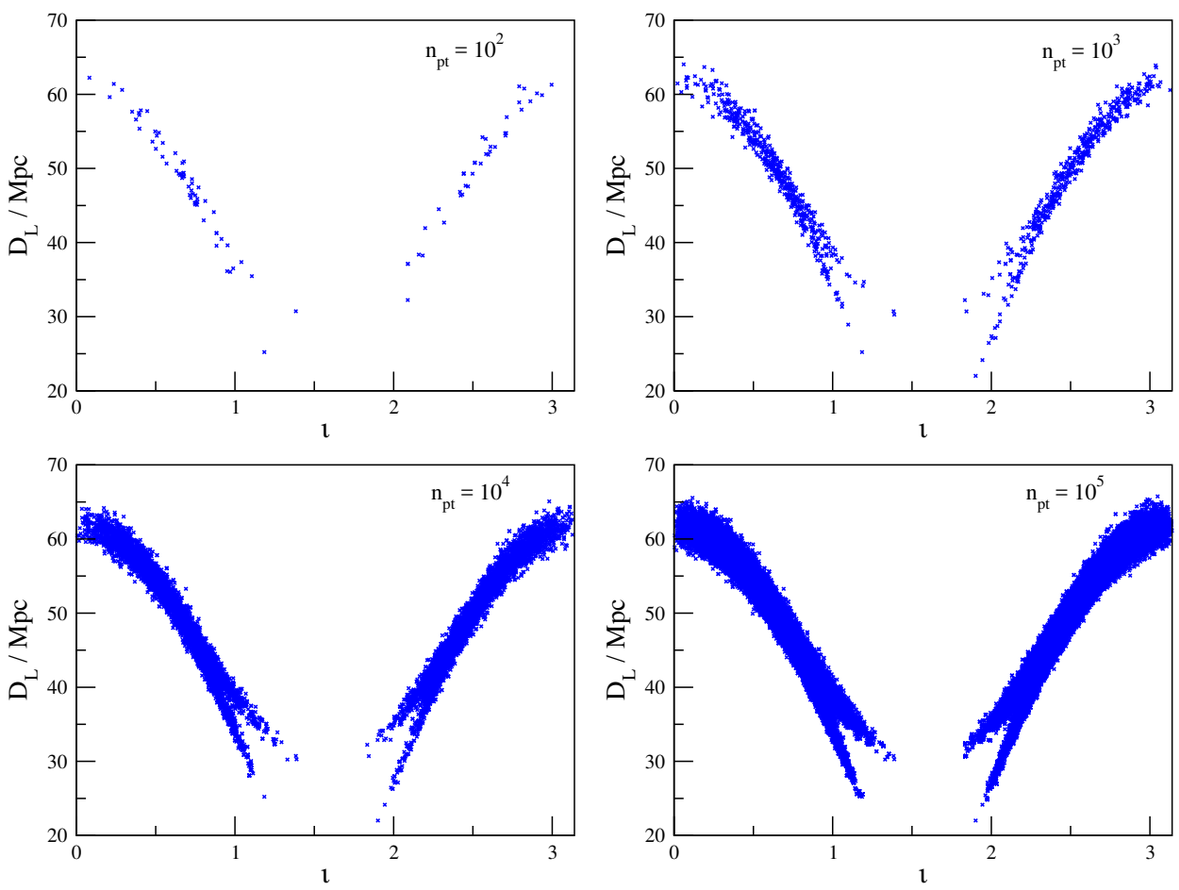
Concept : Consider the inverse log-likelihood as a gravitational potential and evolve trajectories in phase space using Hamilton's equations

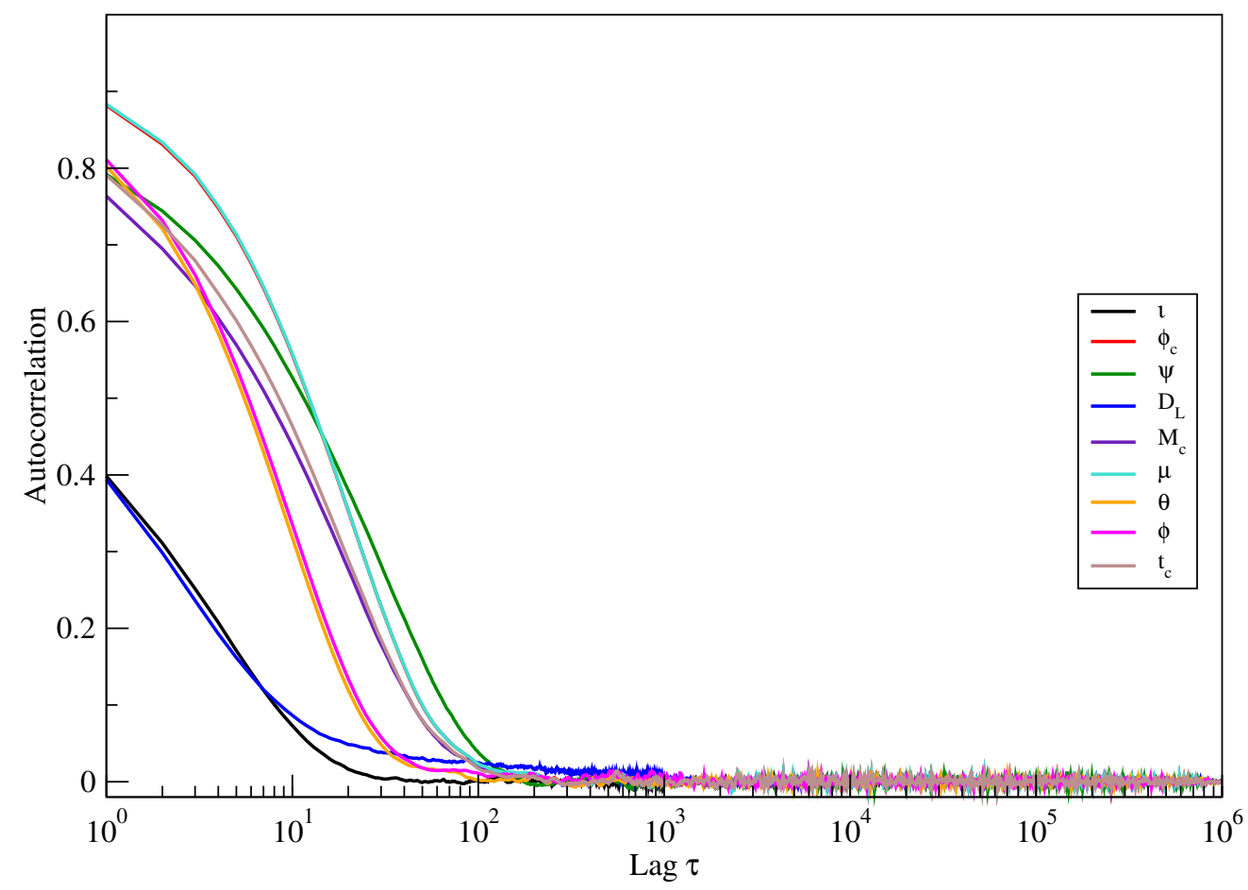
Features : Avoids random walk sampling: efficient exploration of parameter space

Can tackle multi-modal distributions

Low correlation : higher number of samples

Computationally affordable when using fitting methods for the gradients of the log-likelihood

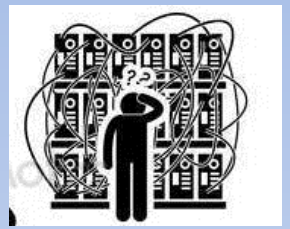




An improved semi-coherent follow-up method for FrequencyHough all-sky Continuous Waves (CW) candidates

Sabrina D'Antonio (sabrina.dantonio@roma2.infn.it) for Roma1 and Roma2 CW group

We present an improved, and computationally cheap, semi-coherent method to perform the follow-up of candidates selected by the FrequencyHough pipeline.
Thanks to:

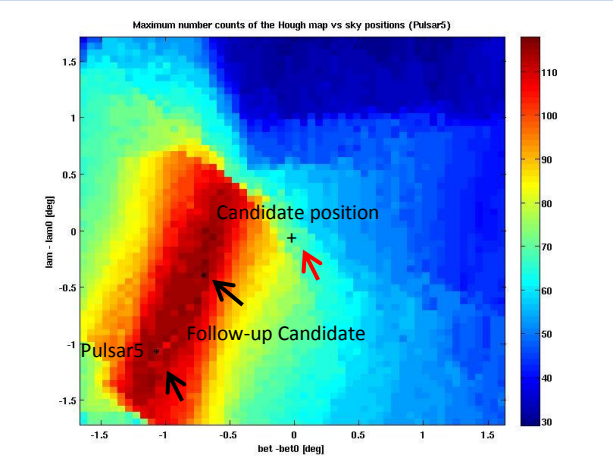


- ✓ *a fast and easy data access*
- ✓ *an efficient coherent data correction based on the heterodyne*
- ✓ *an efficient organization of the input peak-map for the Frequency Hough transform*

allows, with a computing energy of 1000 cores per one week, to perform O(10^5) follow-ups over six months of data

possibility to perform a number of follow-ups much larger than before and to significantly increase the coherence time of the follow-up for the most interesting candidates.

We have tested, using Hardware Injections, the capability of the method to improve parameter estimation and the significance of signal candidates.



(Details -> @ N.48)

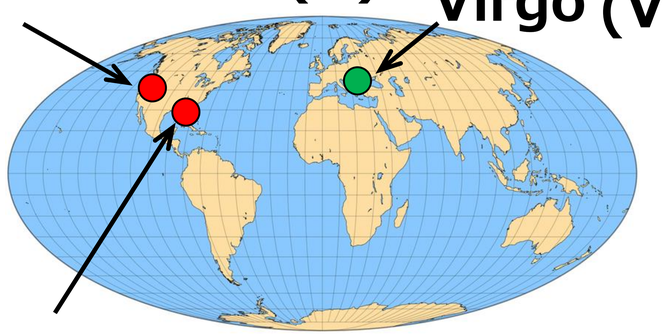
Fast localization with a hierarchical network of gravitational wave detectors

Y. Fujii, T. Adams, F. Marion, R. Flaminio

Hierarchical network

Higher sensitivity
LIGO Hanford**(H)**

Lower sensitivity
Virgo (V)

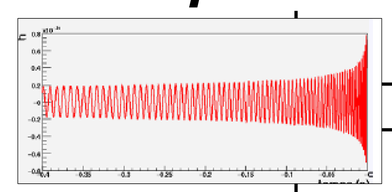


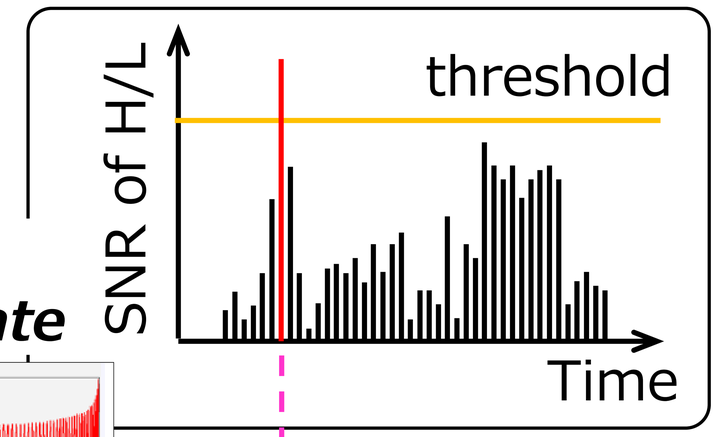
Higher sensitivity
LIGO Livingston **(L)**

(At the beginning)

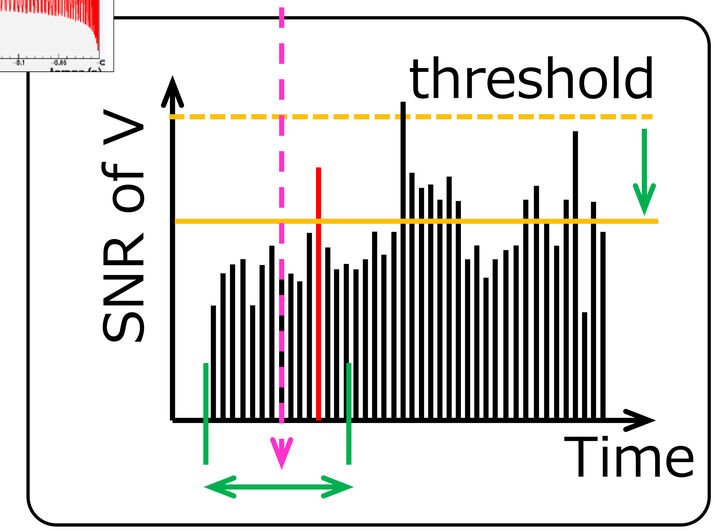
Higher sensitivity detectors
sub network detects candidate event.

One template





Less sensitive detectors
are added into network
1. with lower SNR threshold
2. using same parameters &
3. a small window around time of double coincidences.



→ How does this approach improve the localization?

The hierarchical search
→ useful when adding new detectors to the network.

Hierarchical data-driven approach to fitting waveform models for non-precessing binary black holes to numerical data

G. Pratten, S. Husa, M. Colleoni, X. Jiménez Forteza, C. García, A. Ramos, R. Jaume

D. Keitel

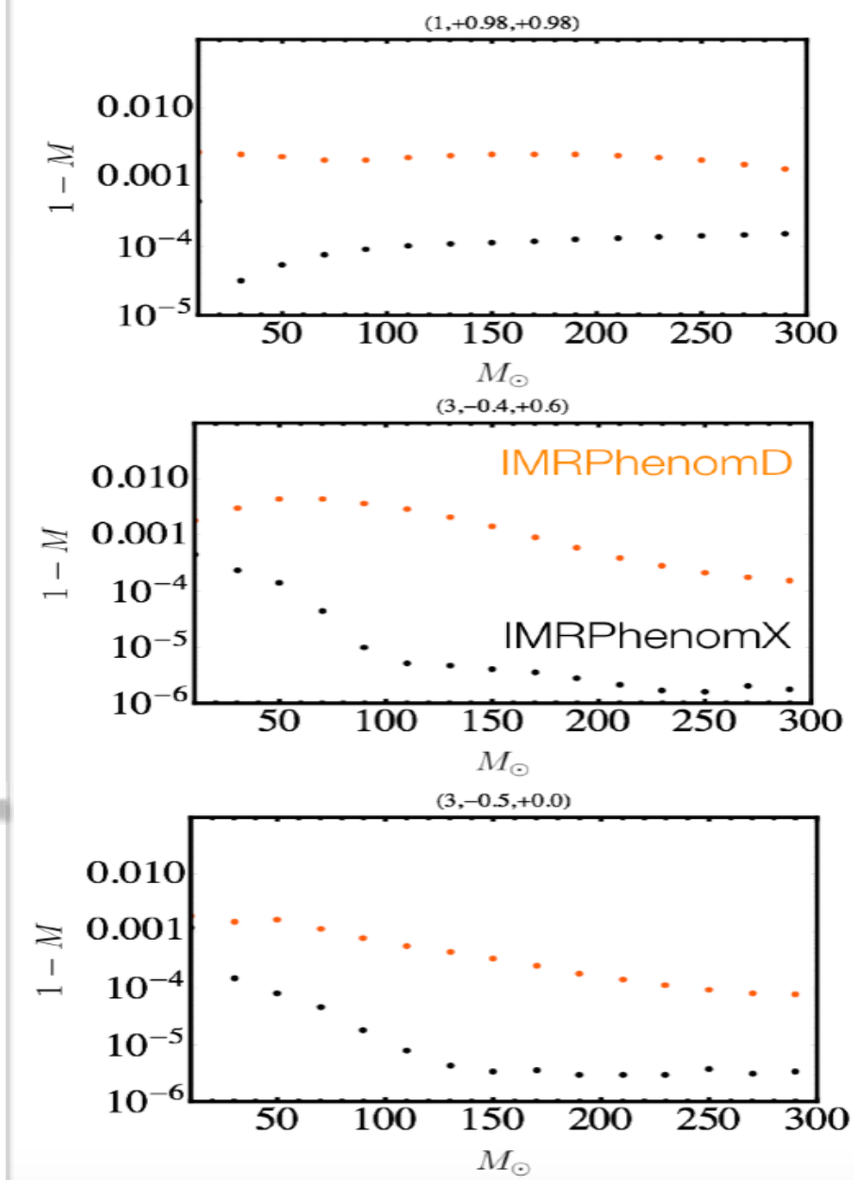
Universitat de les Illes Balears

University of Glasgow

PhenomD/PhenomP: fast IMR waveform models for BBH.

Key PhenomD improvements in this work:

- Calibrate full double-spin effects -> resolve 3D non-precessing parameter space.
- Calibrate to extreme mass ratio limit.
- Systematic procedure of fitting model across the parameter space avoids both underfitting & overfitting.



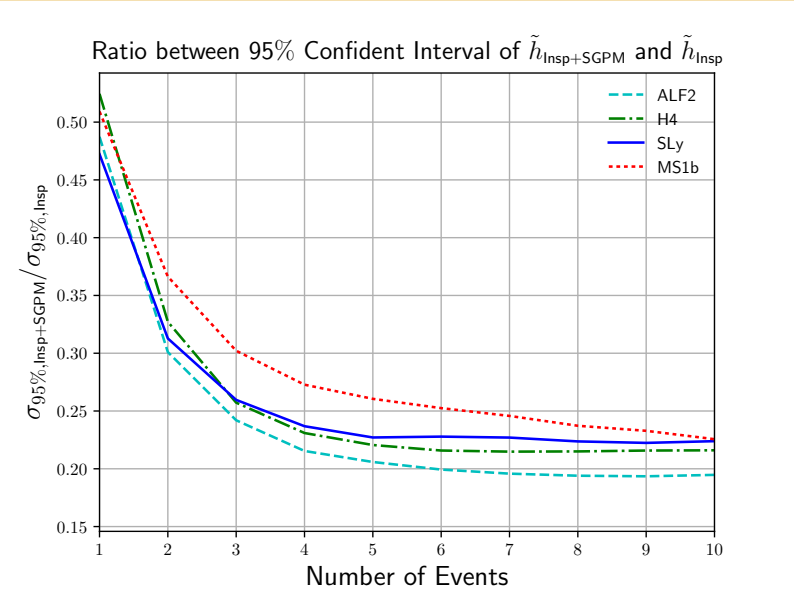
Conclusions

- improved matches between numerical WFs and model.
- upcoming in LAL; can also be used to further improves phenomenological models for precession & higher harmonics.

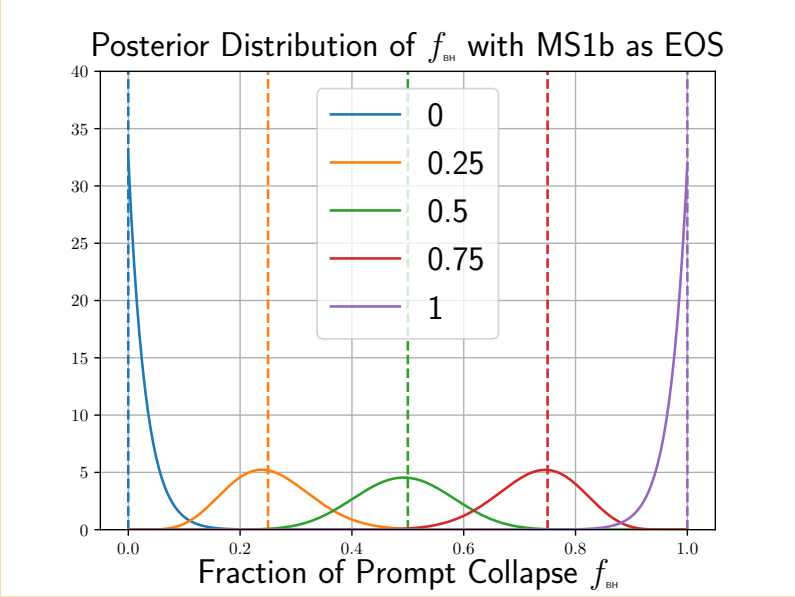
Enhancing Binary Neutron Stars Studies by Combining Inspiral and Postmerger Information

P.T.H. Pang, T.G.F. Li, S. Bernuzzi

What can we learn by including postmerger information?



Improve inference on tidal deformability



Distinguish between prompt collapse vs. HMNS/SMNS

X-PIPELINE: Gravitational-Wave Burst search applied to LIGO data

E. Massera*, R. Kennedy, T. Edo, E. Daw
University of Sheffield, UK

The goal of the X-PIPELINE [1] all-sky search is to perform an all-times, all-sky search for generic gravitational-wave bursts using an approach based on spherical radiometry.

The spherical radiometry [2] engine transforms the problem of computing correlations between time-series data streams into the spherical harmonic domain.

$$\xi_{12}(\hat{s}) = \frac{1}{N}\sum_{\ell=0}^{\ell_{\max}}\sum_{m=-\ell}^{\ell}\sum_{q}\left[\tilde{g}_1[q]\left(\frac{1}{N}\tilde{T}_q(\vec{r}_1\cdot\hat{s})\tilde{T}_q^*(\vec{r}_2\cdot\hat{s})\right)^{(\ell m)}\tilde{g}_2^*[q]\right]Y_{\ell m}(\hat{s})$$

s = sky position versor
ri = detector position
g̃1 and g̃2 = data streams
T = time delay operator for s
Ylm(s) = spherical harmonics

Current work

- Improvements to reduce computational cost
- Development of a graphical support (Fig.1)

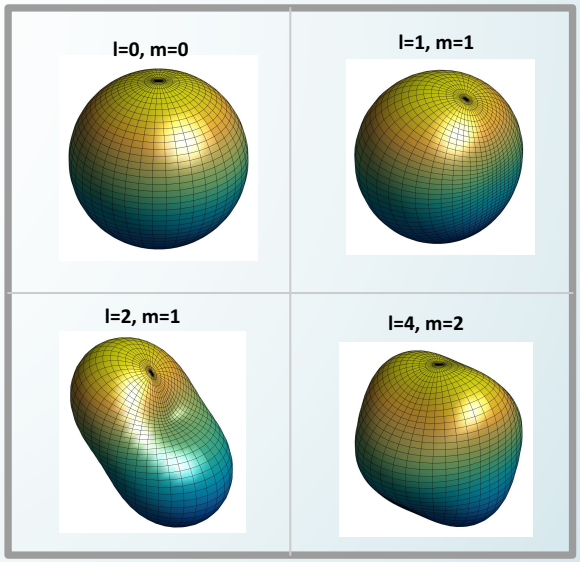


Fig 1. Four examples of spherical harmonics.

REFERENCES
[1] P.J. Sutton et al. (New Journal of Physics 12 (2010)
[2] K. Cannon Physical Review D 75, 123003 (2007)

*Contact: elena.massera@sheffield.ac.uk

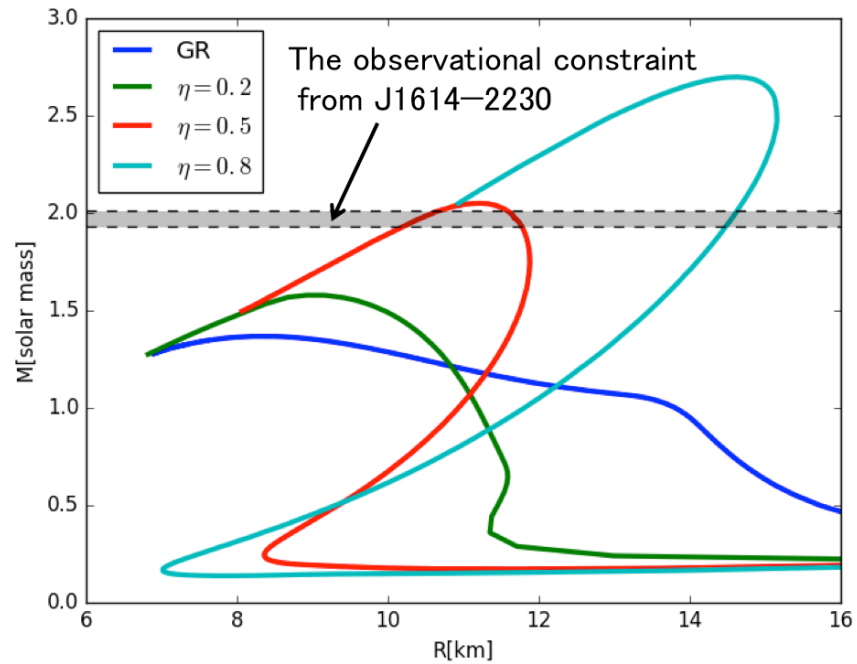
Mass-Radius Relation of Neutron Stars in a Scalar-Tensor Theory

Soichiro Morisaki, Teruaki Suyama

Motivation

- Tests of GR by NS-NS coalescence
- The existence of the $2M_\odot$ NS

We investigated
→ the structure of NSs in modified gravity.



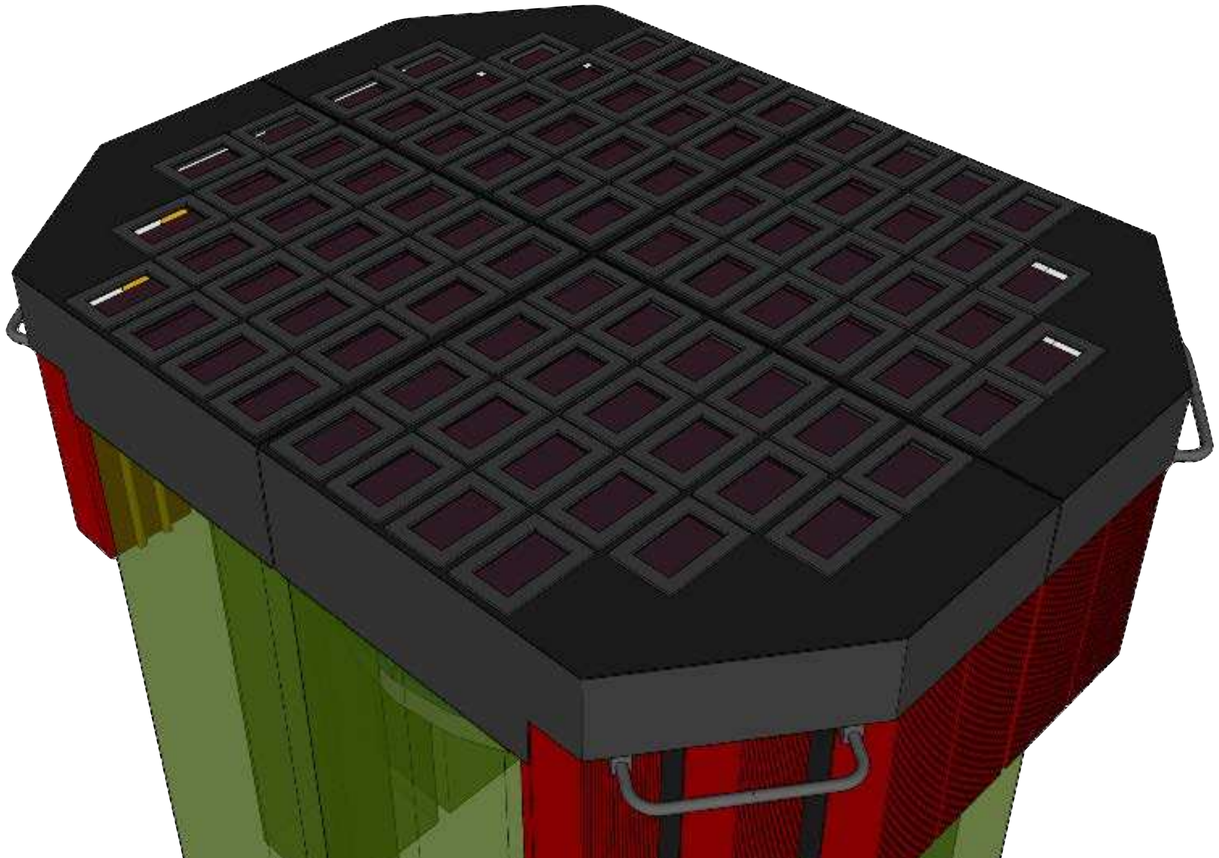
$2M_\odot$ is allowed!!

Development of a Wide-Field CMOS Camera: Tomo-e Gozen and Contributions to EM Follow-up Observations of GW Events

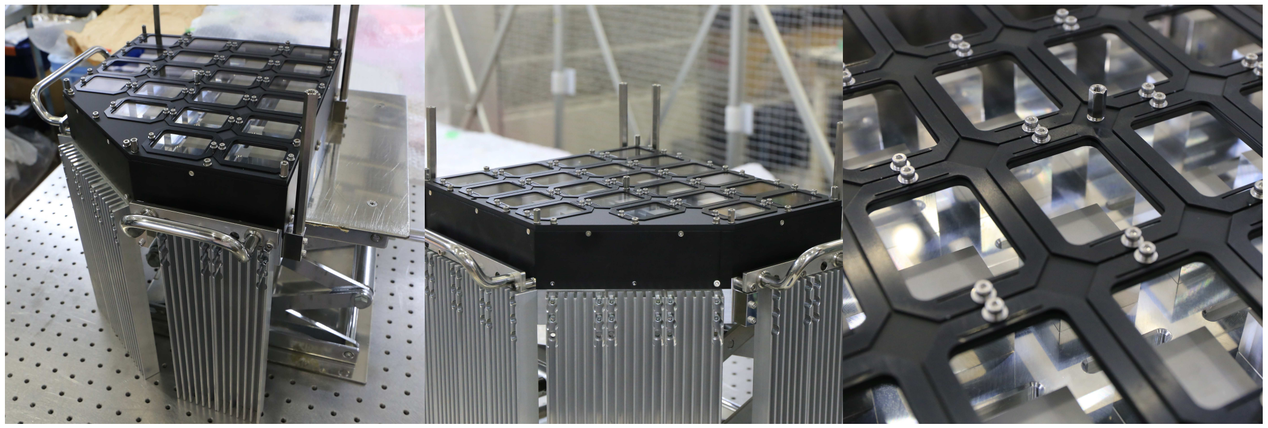
Ryou Ohsawa, Shigeyuki Sako, Toshikazu Shigeyama, Mamoru Doi, Kentaro Motohara, Tomoki Morokuma, Naoto Kobayashi (Univ. Tokyo), Nozomu Tominaga (Konan Univ.), Masaomi Tanaka (NAOJ), and Tomo-e Gozen Project Team

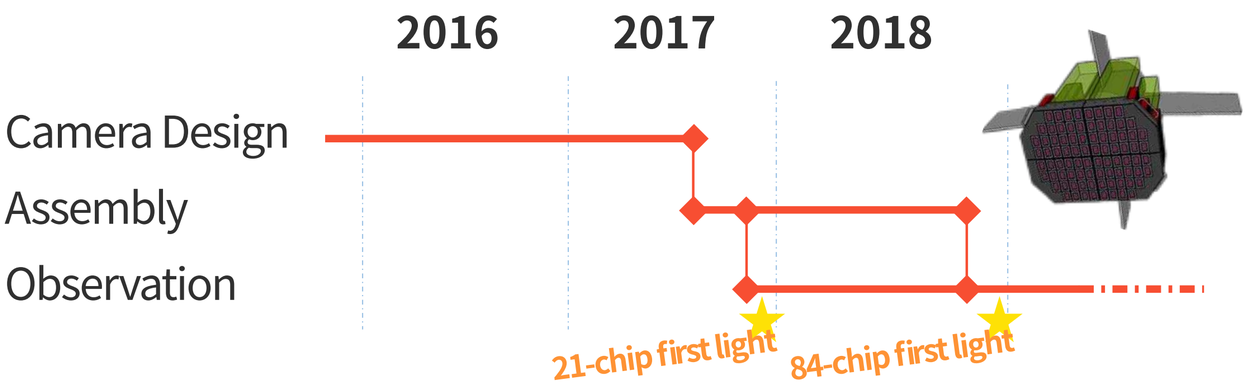
1. We are developing a mosaic CMOS camera for a 1-m telescope at Kiso Obs.
2. The camera, equipped with 84 CMOS sensors, has a FOV of ~20 sq-degree.
3. A 1,000 sq-degree area will be covered in ~3 hours($m_{lim,V}$ ~ 20 mag.).
4. The Tomo-e Gozen will start its operation with 21 sensors in Dec. 2017. The operation with 84 sensors is schduled in 2018.

Focal plane of the Tomo-e Gozen



One of camera modules with 21 CMOS sensors



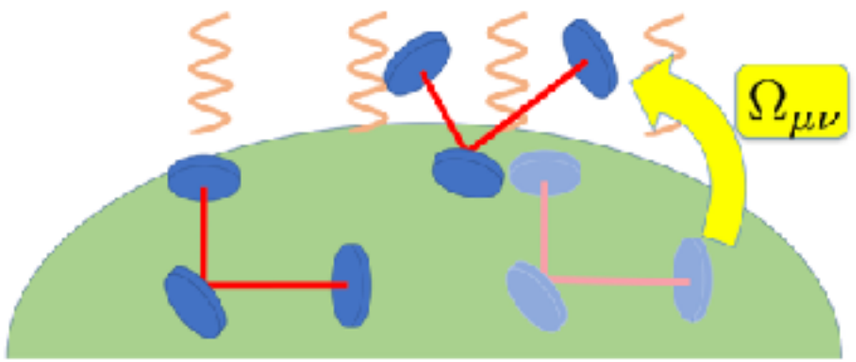


[46]

New parameter estimation method being free from the bias depending on sky region for targeted GW

Kenji Ono, Kazuhiro Hayama, Masatake Ohashi

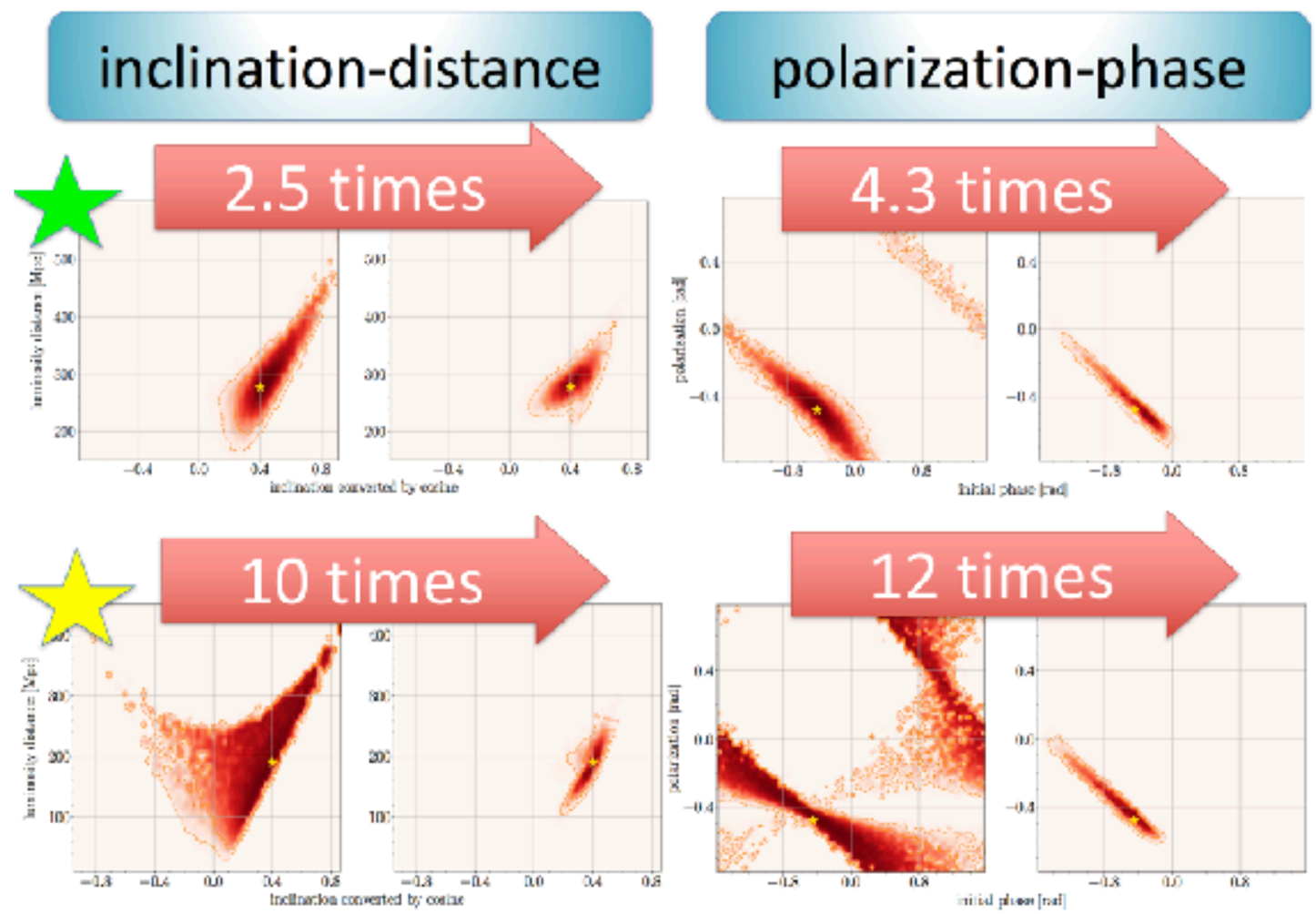
We develop the method to break the degeneracy of GW modes by the use of the full optimized regulator.



The VIRTUAL shift of interferometers breaks the degeneracy!

$$(M_{\mu\nu} + \Omega_{\mu\nu})\hat{A}^{\nu}_{g} = (s|h_{\mu})$$

Our new method provides to determine the regulator minimizing the residual error.



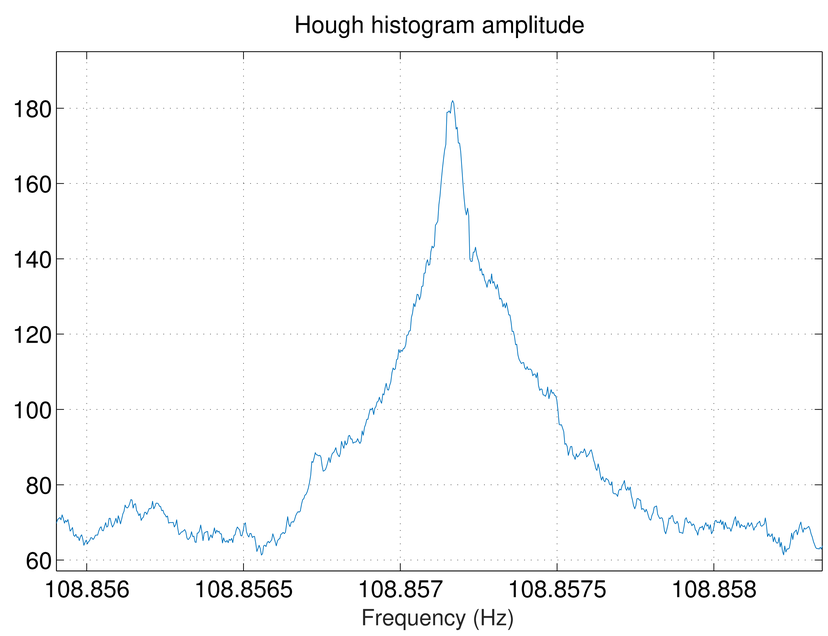
Setting up a direct search for continuous gravitational wave signals using the Band Sample Data collection - POSTER 44

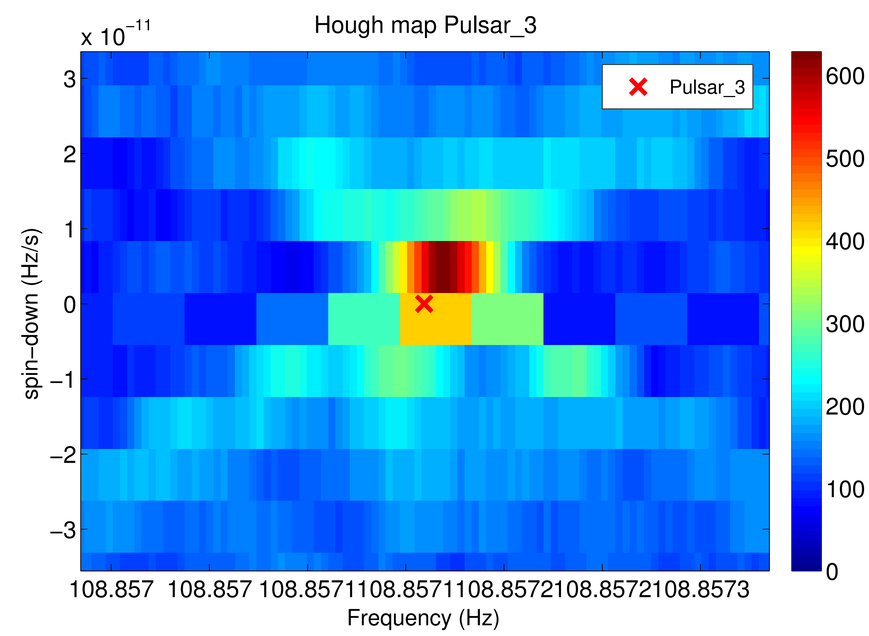
Ornella Juliana Piccinni[a,b] for the Rome CW group – ornella.juliana.piccinni@roma1.infn.it
[a]University of Rome "Sapienza", I-00185 Roma, Italy, [b]INFN, Sezione di Roma, I-00185 Roma, Italy

In a direct search e.g. for the Galactic Center or Fermi-LAT "unassociated" sources:

- sky position $(\lambda, \beta) \Rightarrow$ known or with slight uncertainty
- rotational parameters f, $\dot{f} \Rightarrow$ completely unknown

We have developed a new method based on a modified version of the classical Doppler correction





- How to deal with the unknown rotational parameters?
- How accurate should the sky position be?

Check it out in poster 44

Estimation of starting times of quasi-normal modes in ringdown gravitational waves with the Hilbert-Huang transform

Kazuki Sakai, Ken-ichi Oohara, Hiroyuki Nakano, Masato Kaneyama and Hirotaka Takahashi

■ Overview

$$h_{\mathrm{QNM}}(t) = A_0 \mathrm{e}^{-(t-t_0)/\tau} \cos\{2\pi f_{\mathrm{c}}(t-t_0) + \varphi_0\}$$

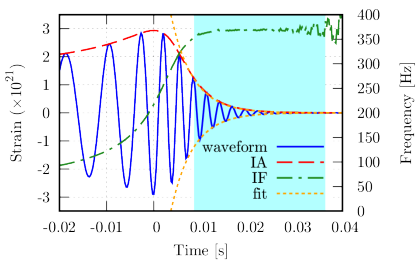
Hilbert-Huang transform →

$$\log a(t) = -(t-t_0)/\tau + \log A_0, \quad \phi(t) = 2\pi f_{\mathrm{c}}(t-t_0) + \varphi_0$$

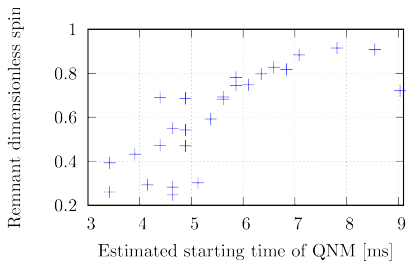
Instantaneous amplitude — Instantaneous phase

The starting time of QNM is an initial time of a section where the data optimally be fit by these forms

■ Application to simulated wavefomrs free from detector noise

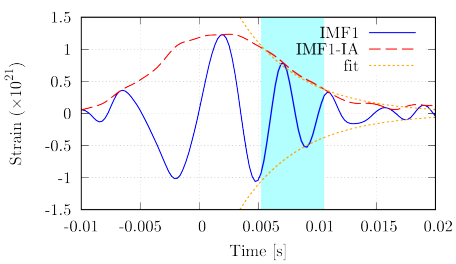


Estimation error is **less than 1 %** on average for 26 waveforms



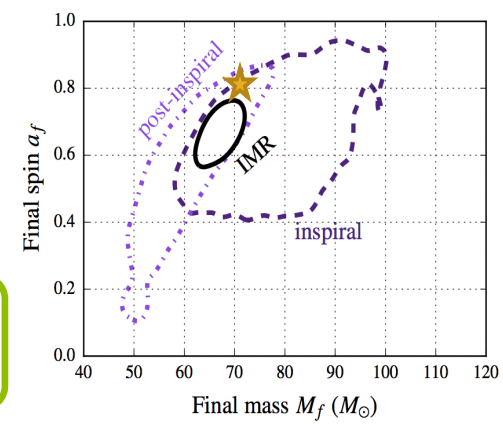
There is a **correlation** between the starting time of QNM and remnant spin (r = 0.75)

■ Application to GW150914



t_0/ms	remnant spin	remnant mass/M_{sun}
5.223	$0.8151^{+0.092}_{-0.096}$	$71.65^{+0.77}_{-0.75}$

cf.) result by LIGO and Virgo

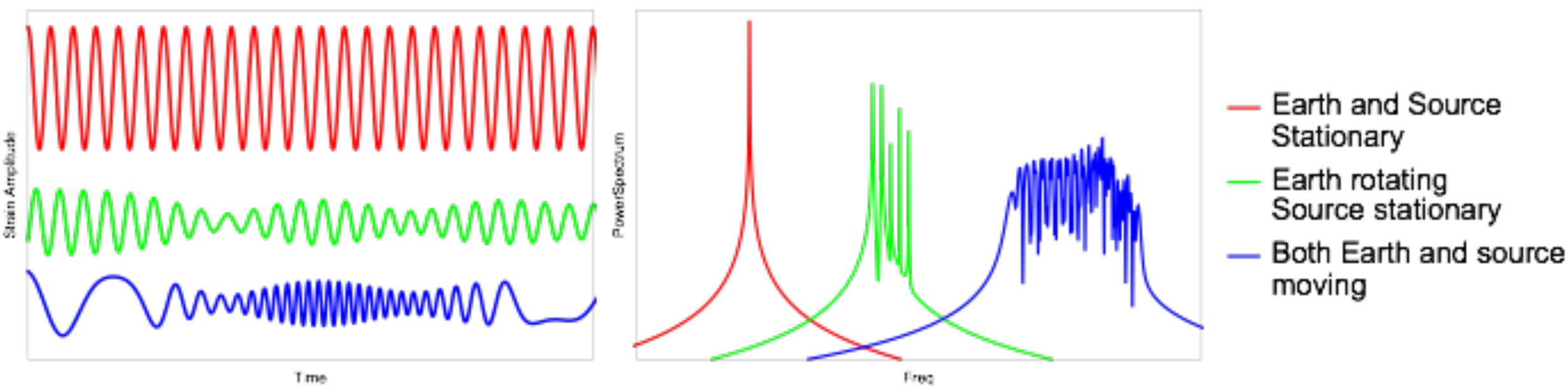


Although there are some systematic errors, the results are **consistent** with those given by LIGO and Virgo and a **reasonable starting time** is estimated.

77: Generalized resampling methodology for binary pulsars

Akshat Singhal, INFN-ROMA

- >50% pulsars in binary system (in LIGO-Virgo band)
- **Goal:** Extension to binary pulsars of existing 5-vector method for the targeted search of Continuous waves.
- **Problem:** Orbital Doppler effect spreads signal in several frequency bins



- **Preliminary results** on the tolerance to uncertainties in binary parameters in order to recover the signal.

Physical metric, gravitational waves and dark energy

Yukio Tomozawa, University of Michigan

1) Schwarzschild metric does not fit the time delay experiment of the solar system. The physical metric, in which g_00 = g_θθ = g_φφ = ω, does fit the data. This metric is an exact solution of Einstein Equation, as is shown by Schwarzschild 101 years ago.
   (J. Mod Phys 6, 335 (2015))
2) In physical metric, the size of BH and neutron stars is 2.60 times of Schwarzschild Radius (SR) (called extended horizon, E-H) and gravity inside E-H is repulsive).
3) As a result, the masses of BH merger in GW150914 are14 and 11 Solar Mass (SM), instead of reported 36 and 29 SM. This is consistent with the observed mass of stellar BH, which is less than 16 SM.
4) By a coordinate transformation of physical metric to Friedmann (FRW) metric, one can prove that the acceleration of the universe expansion, a''(t)>0. The acceleration of the universe expansion is a result of repulsive gravity inside the E-H of the physical metric. In other words, the acceleration is a natural result of the correct metric for the gravity, the physical metric. Dark energy or cosmological constant may not be needed.

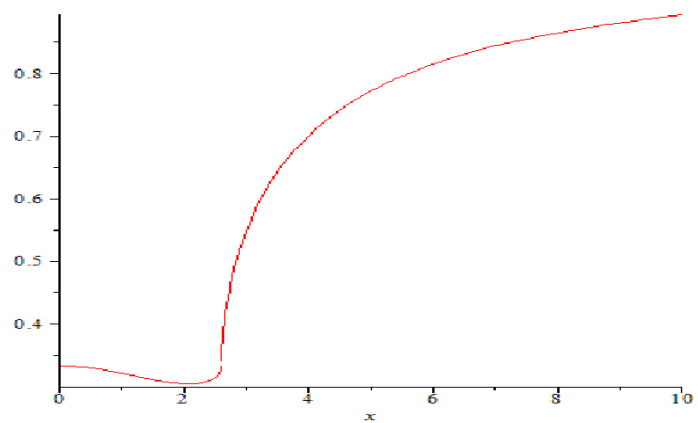


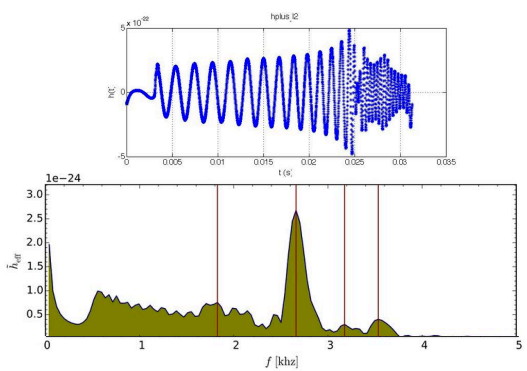
Fig. Figure for physical metric with constant density inside E-H.

EXTRACTING THE POST-MERGER GRAVITATIONAL WAVE SIGNAL FROM BINARY NEUTRON STARS

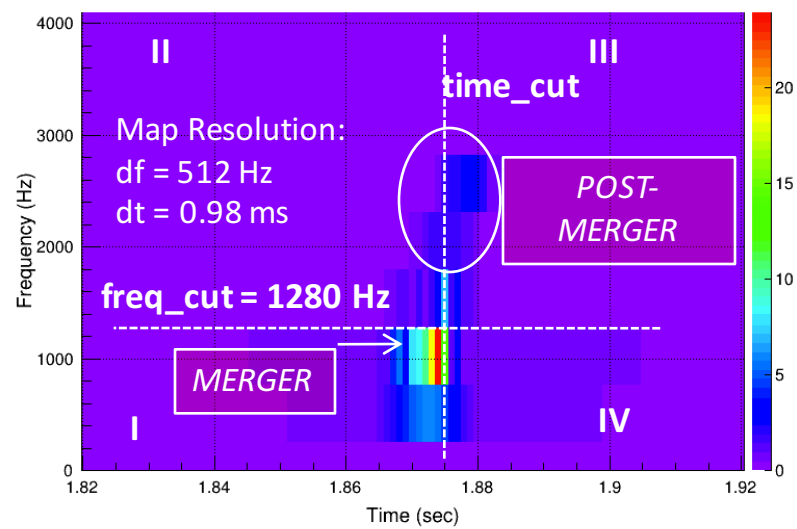
PhD student M. C. Tringali for Trento – Padova group

in collaboration with Florida and Hannover and Numerical Relativity group at Trento

- GW signal from merger of NS-binary contain (in in-spiral and PM) signatures of EoS of matter at nuclear densities.
- Among the excited modes, the fundamental (quadrupolar) mode of the NS is expected to produce a strong peak in the emitted GW spectrum, typically in the kHz range (fpeak).



Time - Freq map of SHT-M2.0-S



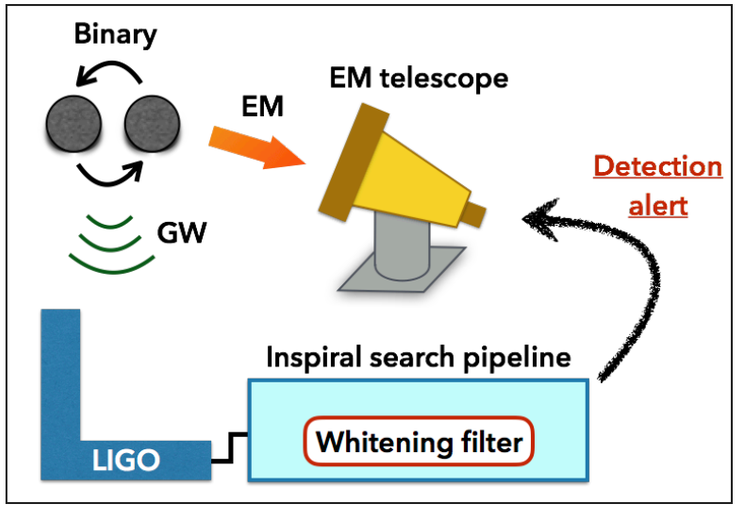
- We are developing a tool to characterize the PMNS, studying the TF map. The tool has been tested on different NR waveforms.

Application of a Zero-latency Whitening Filter to CBC GW Searches

Leo Tsukada

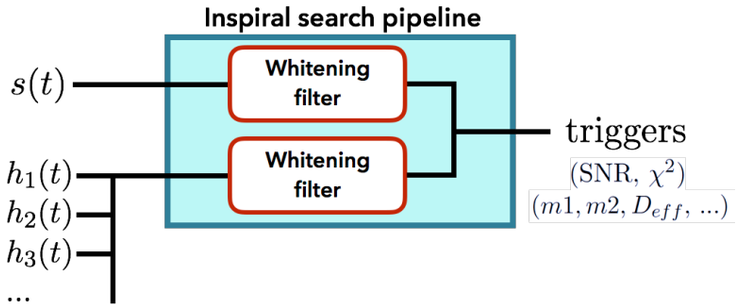
① LATENCY PROBLEM

Latency must be reduced!!



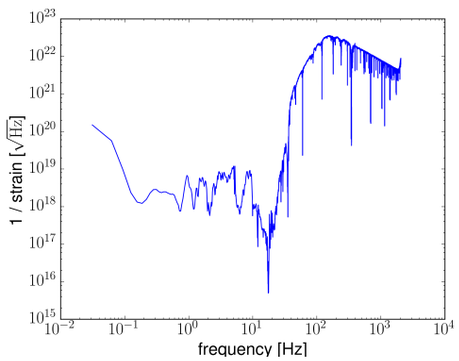
② WHITENING FILTER

$$(s(t), h(t)) \propto \int_0^\infty \frac{\tilde{h}^*(f)\tilde{s}(f)}{S_n(f)} df = \int_0^\infty \underbrace{\frac{\tilde{h}^*(f)}{\sqrt{S_n(f)}} \cdot \frac{\tilde{s}(f)}{\sqrt{S_n(f)}}}_{\text{Whitening transformation}} df$$

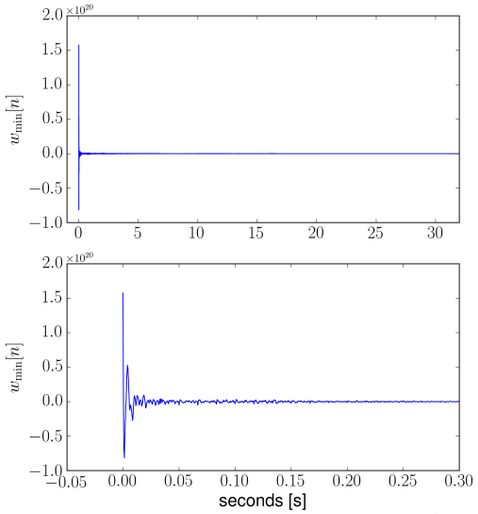


③ IMPROVEMENTS

IDFT + approx.

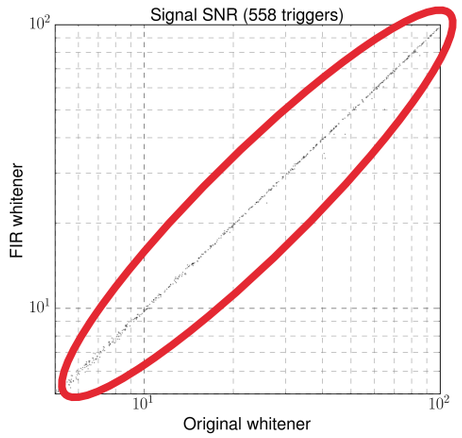


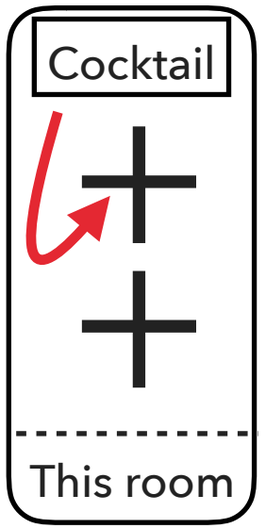
Amplitude response



causal (zero-latency) filter

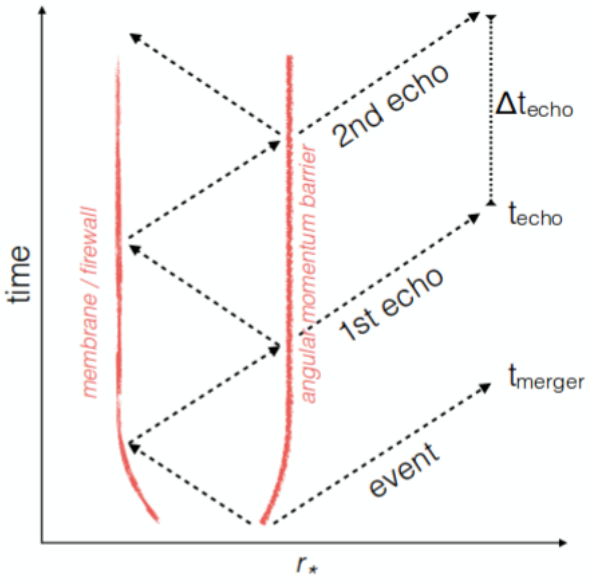
④ TESTS & CONCLUSION





Overall latency : ~30 s → 18 s !

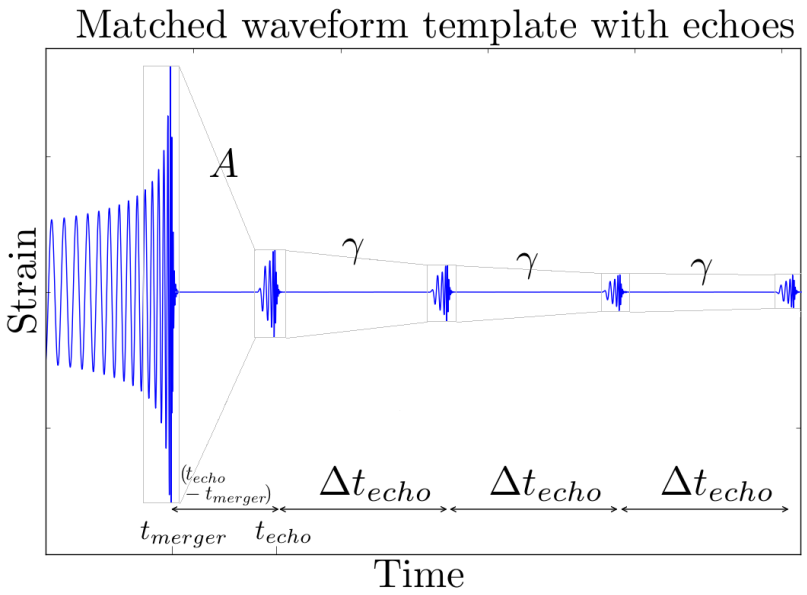
Templated search for black hole GW echoes

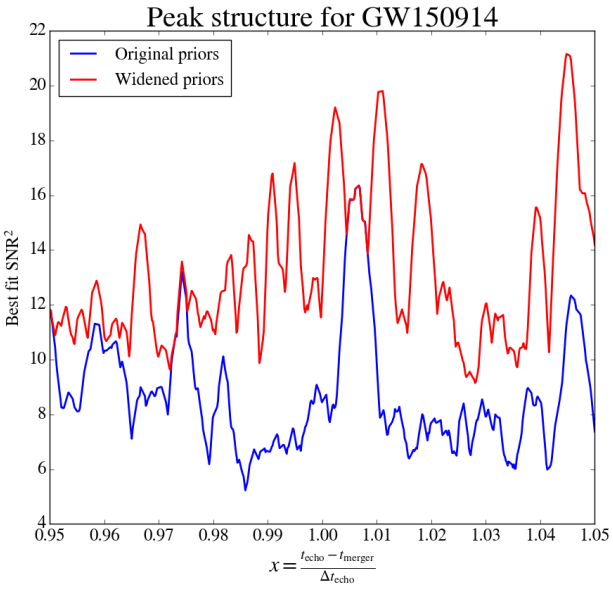


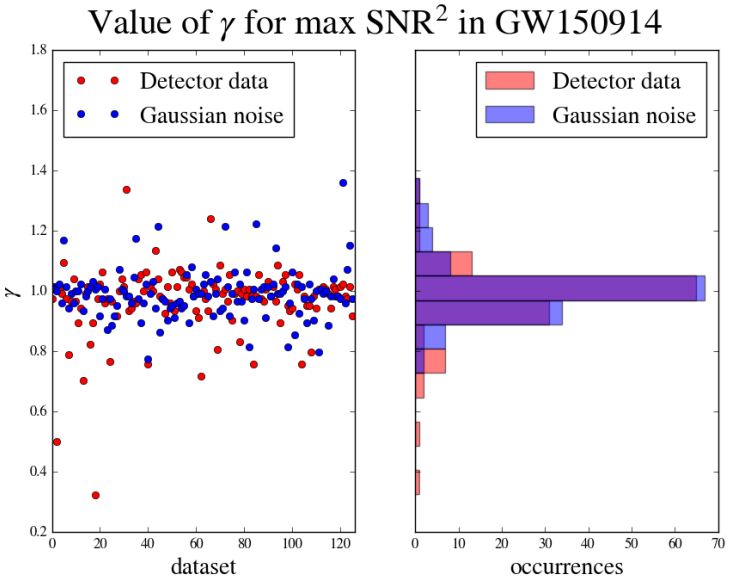
Claimed with p-value 0.01

↓

New significance estimate







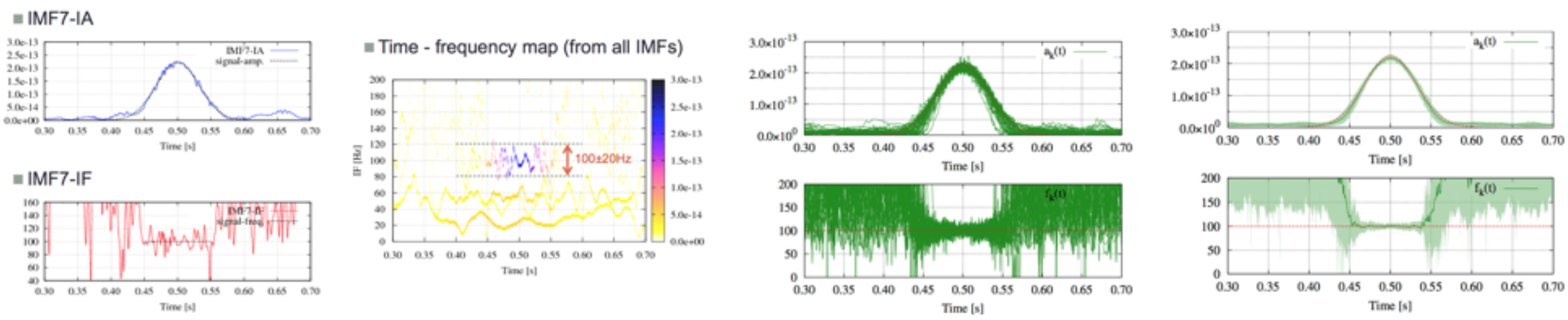
Study of Hilbert-Huang transform using iKAGRA injection data

Takaaki Yokozawa on behalf of KAGRA collaboration (postdoc Osaka City University)

- We studied the Hilbert-Huang transform using iKAGRA hardware/software injection data
  - iKAGRA Mar. 25 - Apr .25, 2016
  - iKAGRA hardware injection : displace mirror by actuator (through feedback signal)

- Hilbert-Huang Transform (HHT)
  - One of the time-frequency analysis proposed by Huang et at(1996)
  - Empirical Mode Decomposition + Hilbert Spectral Analysis

- Results:
  - Introduced automation process to obtain best HHT convergence condition ε
  - Evaluated the significance to 100Hz Sine-Gaussian data (SNR~120)
  - We confirmed the effectiveness to HHT analysis to observed data

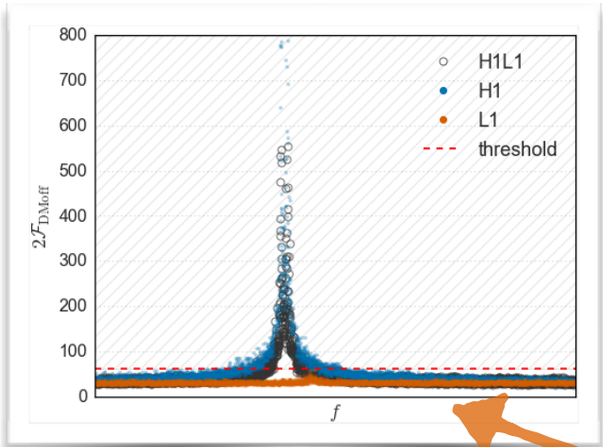


Referenced from S.Ueki master thesis(Nagaoka Univ. of Tech.)

- We showed preliminary result to apply supernova numerical simulation waveform

The **new DMoff veto** for Einstein@Home searches for **continuous gravitational waves**

Sylvia J. Zhu, Maria Alessandra Papa, Sinéad Walsh



We run a simplified version of our search but with the Doppler modulation turned off (DMoff), making instrumental artifacts more prominent while suppressing astrophysical signals. This veto [1] was successfully used in the most recent Einstein@Home all-sky search [2] where it yielded a very high noise rejection.