Desenvolvimento e Utilização de Metodologias em Análise de Dados no Estudo de Detectores e Fontes de Ondas Gravitacionais



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GWINPE

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

for the LIGO Scientific Collaboration
and the Virgo Collaboration

Ligo Scientific Collaboration

Abilene Christian University
Albert-Einstein Institut
Andrews University
American University
California Institute of Technology
California State Univ., Fullerton
Canadian Inst. Th. Astrophysics
Carleton College
College of William and Mary
Columbia U. in the City of New York
Embry-Riddle Aeronautical Univ.
Eötvös Loránd University
Georgia Institute of Technology
Goddard Space Flight Center
Hobart & William Smith Colleges
ICTP-SAIFR
IndIGO
IAP-Russian Acad. of Sciences
Inst. Nacional Pesquisas Espaciais
Kenyon College
Korean Gravitational-Wave Group
Louisiana State University
Montana State University
Montclair State University
Moscow State University
National Tsinghua University
Northwestern University

Penn State University
Rochester Institute of Technology
Sonoma State University
Southern Univ. and A&M College
Stanford University
Syracuse University
Szeged University
Texas Tech University
Trinity University
Tsinghua University
Universitat de les Illes Balears
University of Alabama in Huntsville
University of Brussels
University of Chicago
University of Florida
University of Maryland
University of Michigan
University of Minnesota
University of Mississippi
University of Oregon
University of Sannio
Univ. of Texas-Rio Grande Valley
University of Washington
University of Wisconsin-Milwaukee
Washington State University
West Virginia University
Whitman College

LIGO Laboratory: California Institute of Technology, Massachusetts Institute of Technology, LIGO Hanford Observatory, LIGO Livingston Observatory

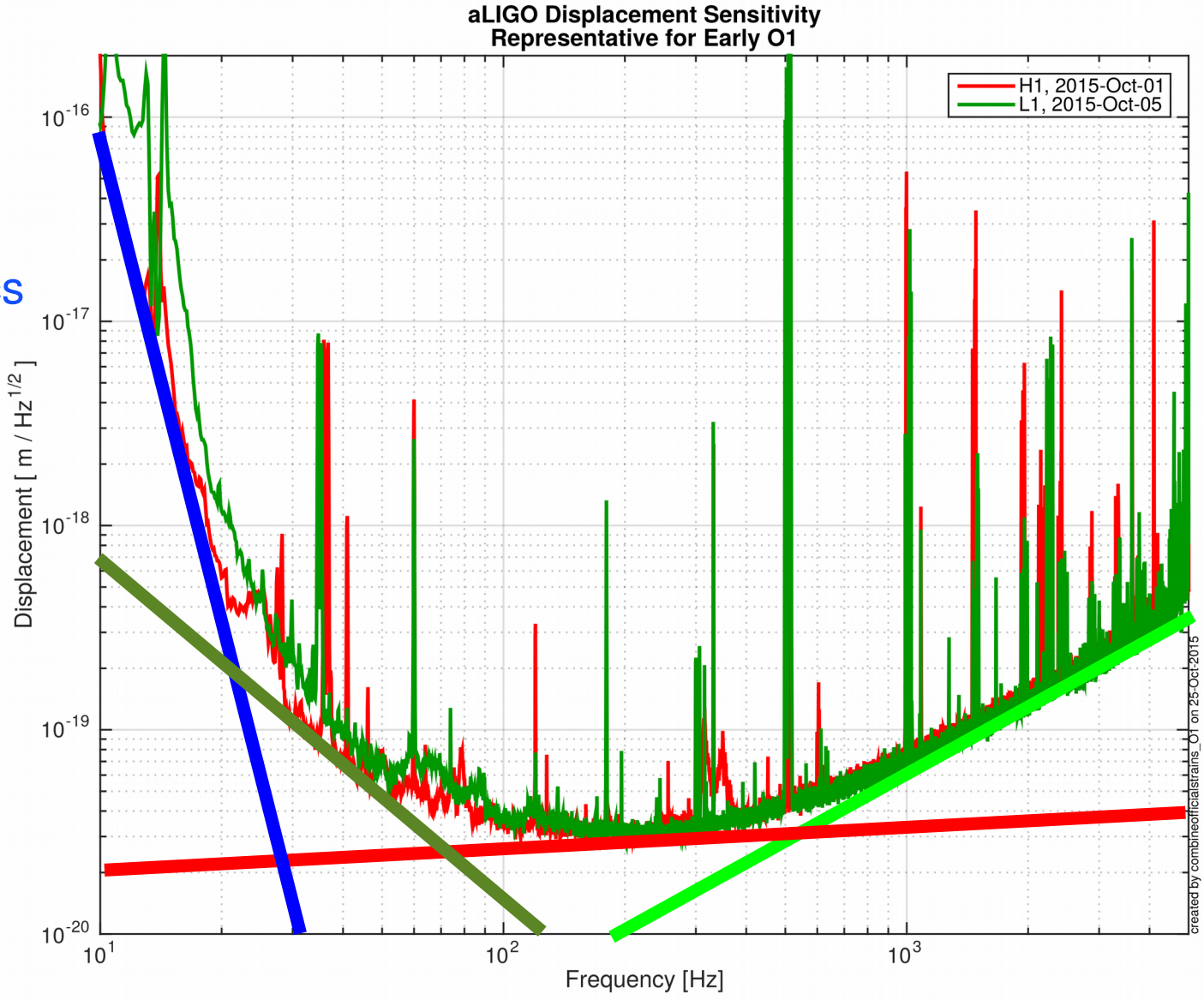
Australian Consortium for Interferometric Gravitational Astronomy (ACIGA):
Australian National University, Charles Sturt University, Monash University, University of Adelaide, University of Melbourne, University of Western Australia

German/British Collaboration for the Detection of Gravitational Waves (GEO600):
Cardiff University, Leibniz Universität Hannover, Albert-Einstein Institut, Hannover, King's College London, Rutherford Appleton Laboratory,
University of Birmingham, University of Cambridge, University of Glasgow, University of Hamburg, University of Sheffield,
University of Southampton, University of Strathclyde, University of the West of Scotland

Two black holes colliding 1.3 billion years ago

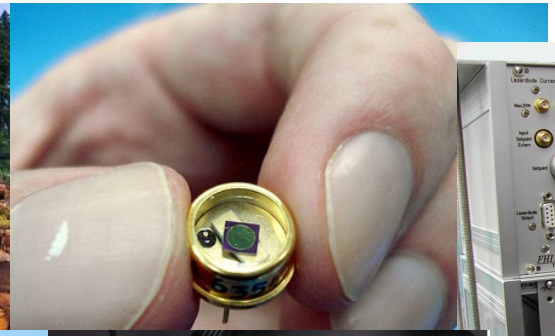
O1 sensitivity

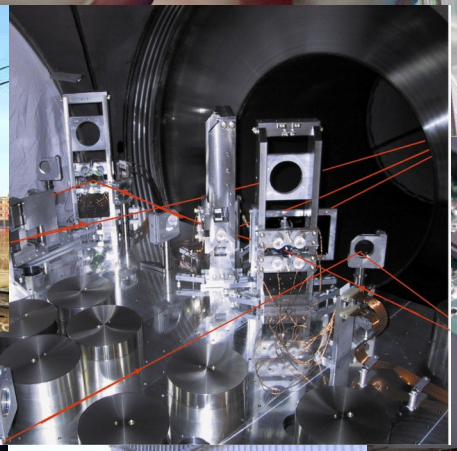
- **Sensitivity Curve**
  - Stationary spectra
  - Limited by known physics
    - **seismic**, **radiation pressure**, **thermal noise**, **shot noise**, residual gas, etc

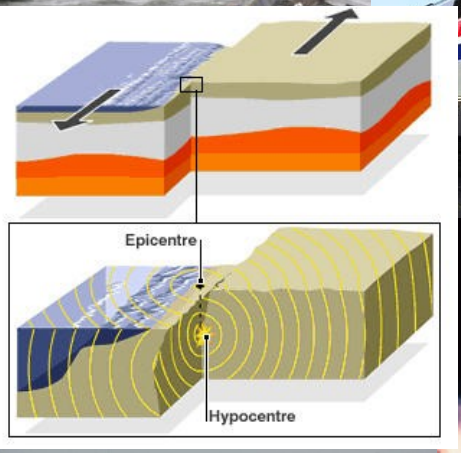


Environmental and Instrumental Noise Sources

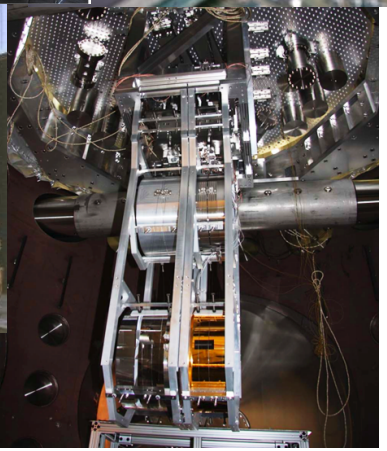




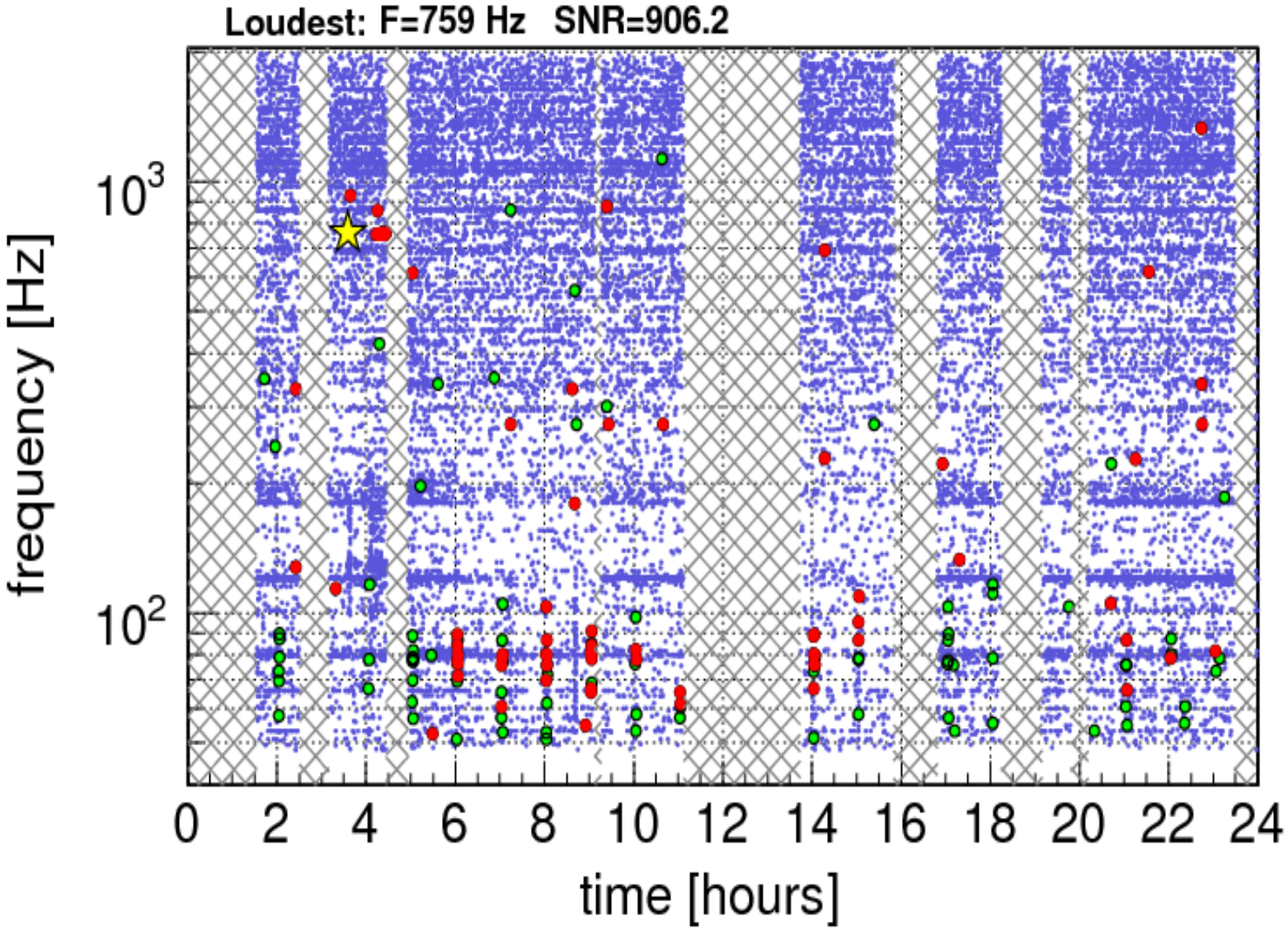






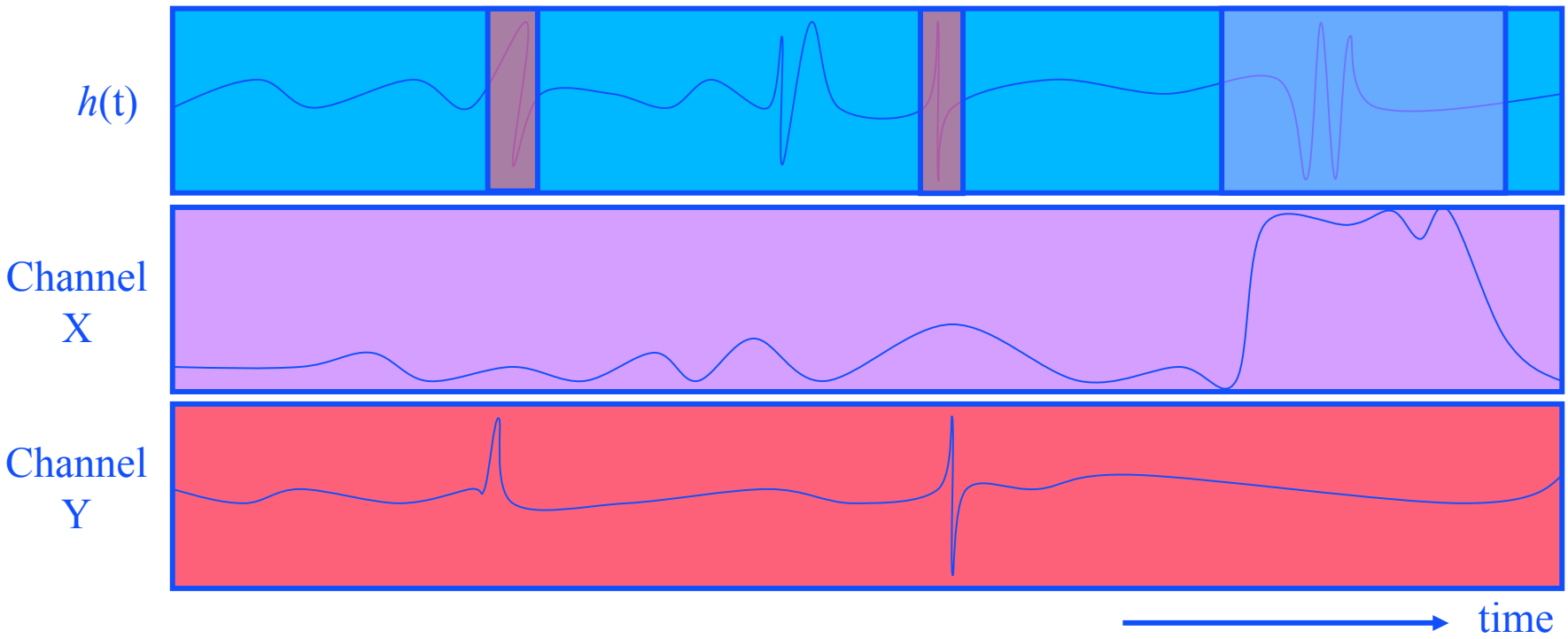


Transients


Loudest: F=759 Hz SNR=906.2
frequency [Hz]
10^3
10^2
0 2 4 6 8 10 12 14 16 18 20 22 24
time [hours]

Data Quality

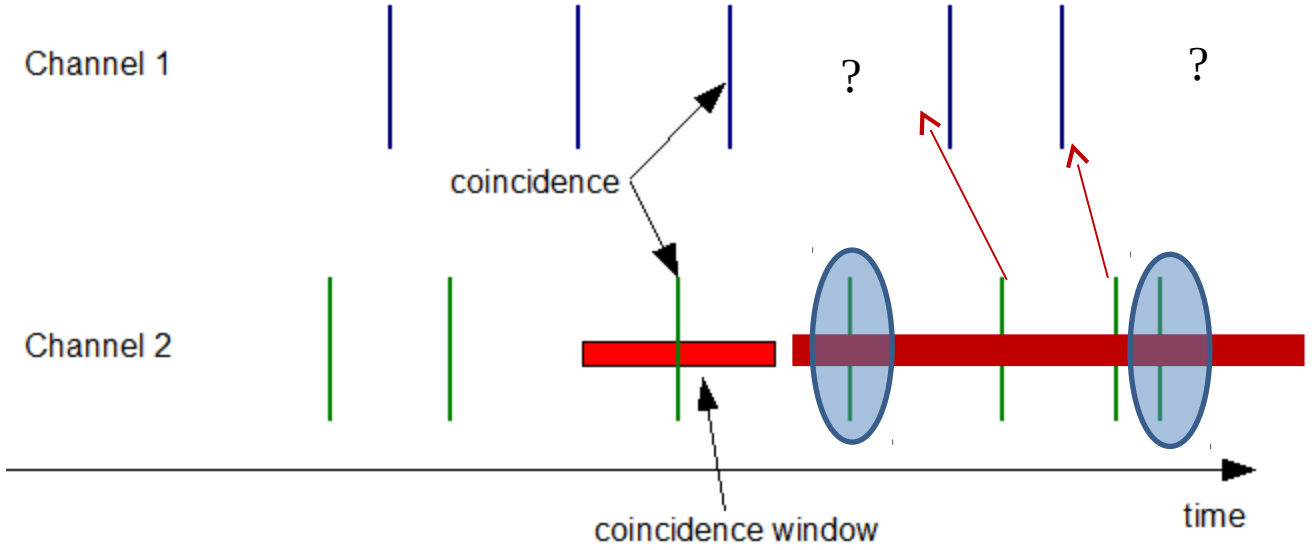
- Compare h(t) (or it's raw equivalent, DARM_ERR) with auxiliary channels.
  - Time coincidences points to probable responsible.
- Data quality flags cut out some number of seconds long times of bad behavior.



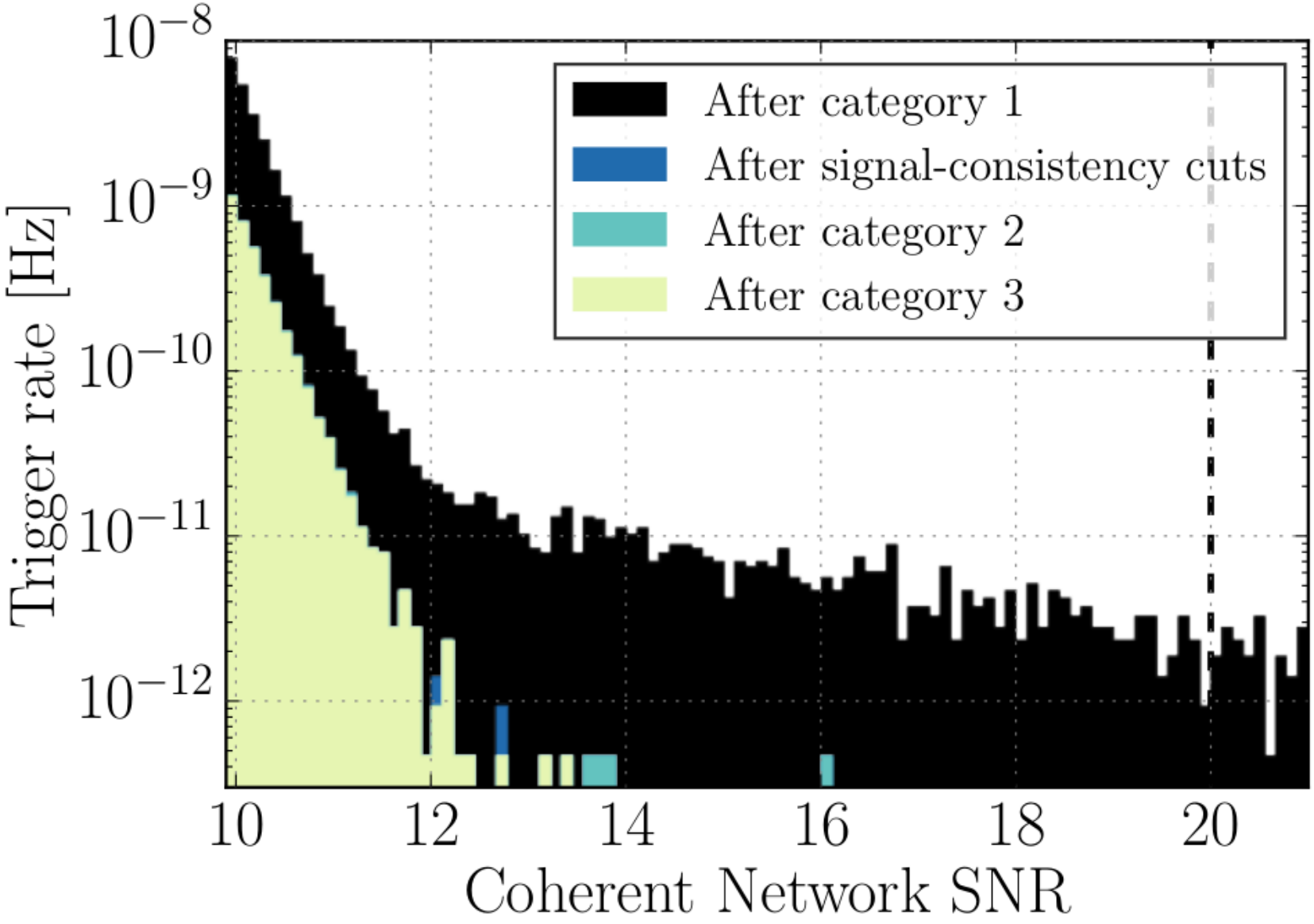
Data Quality Flags

- Collections of transient properties (generated by ETGs) are compared (gpstime, amplitude, snr, frequency band, duration, etc)
- Statistical methods must be applied and developed

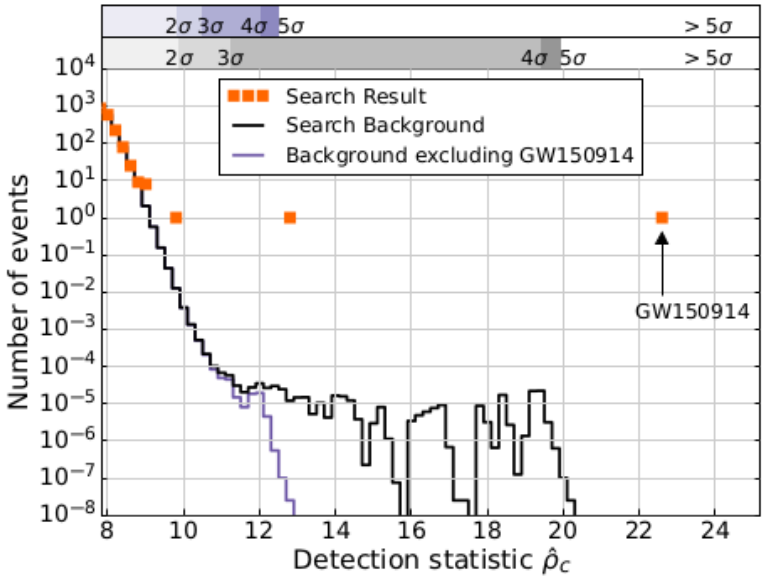
$$Y = y_1, y_2, \ldots, y_n \qquad X = x_1, x_2, \ldots, x_n$$

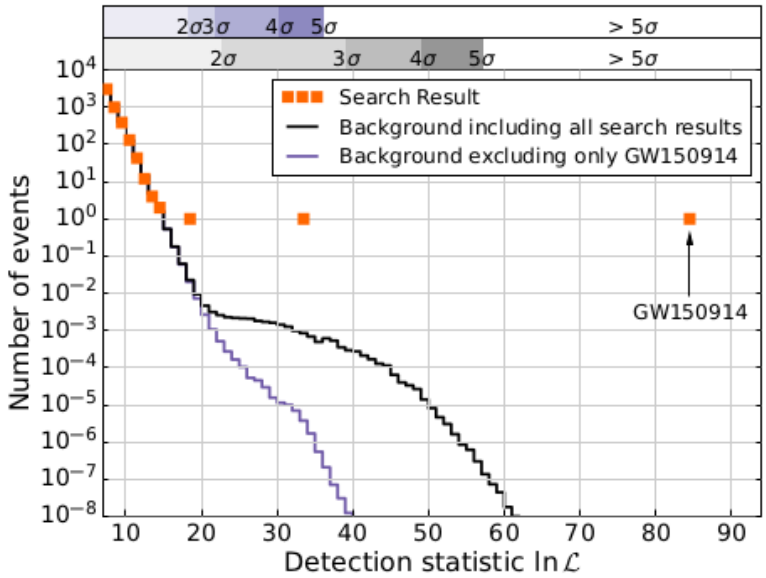


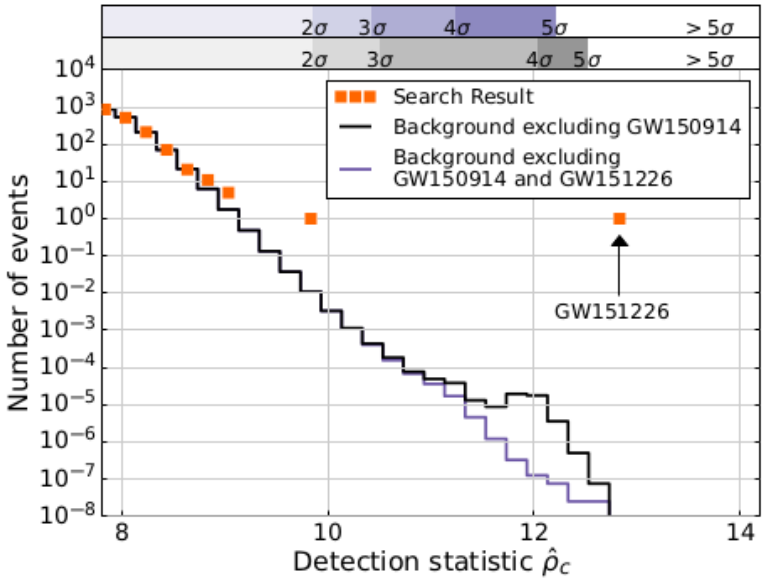
Coherent Data Quality

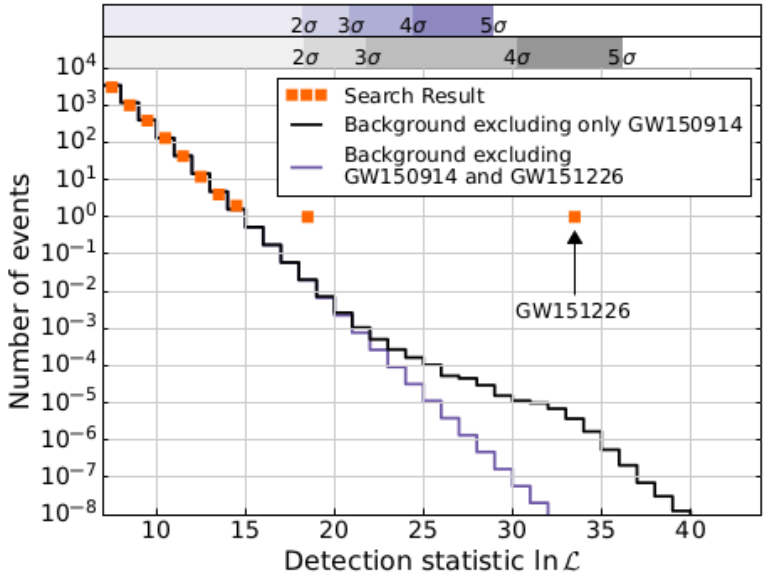


Statistical Significance

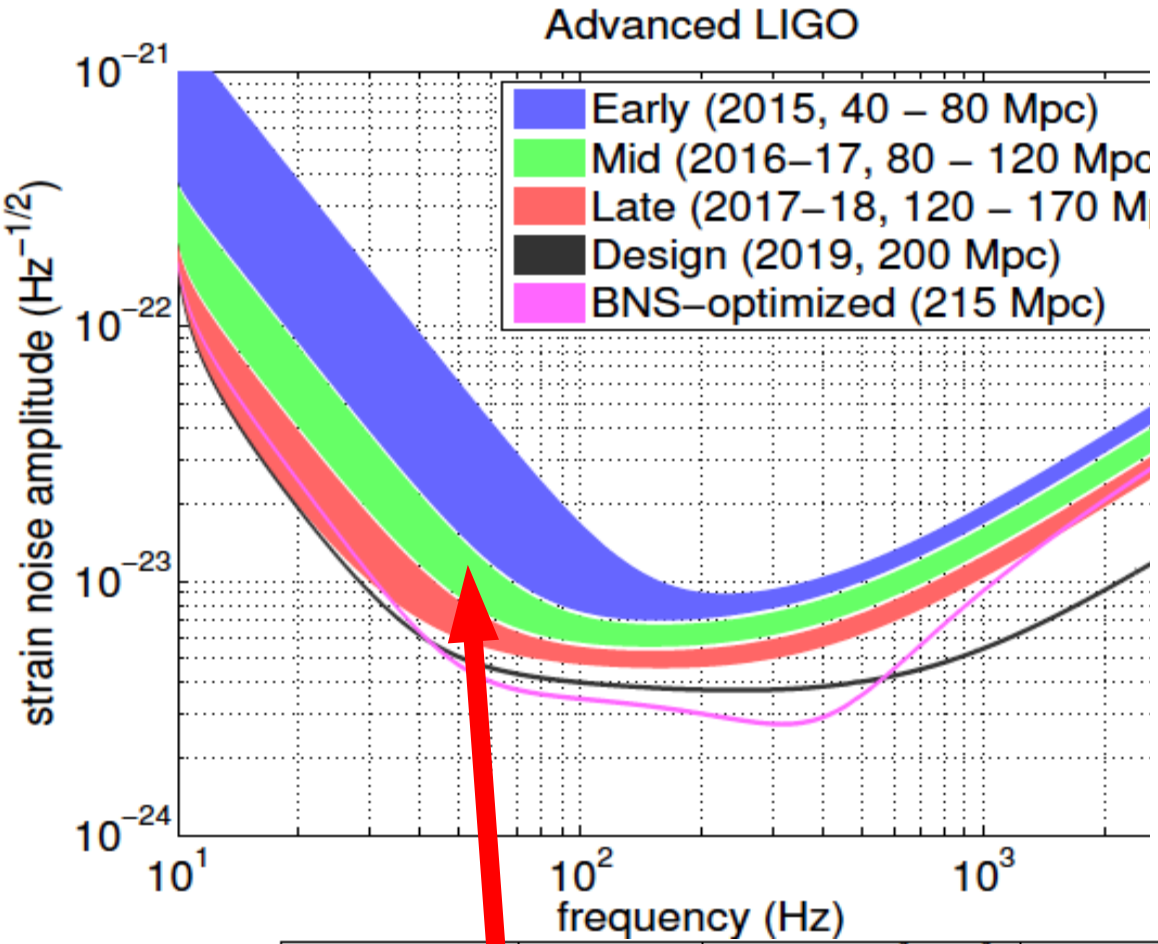


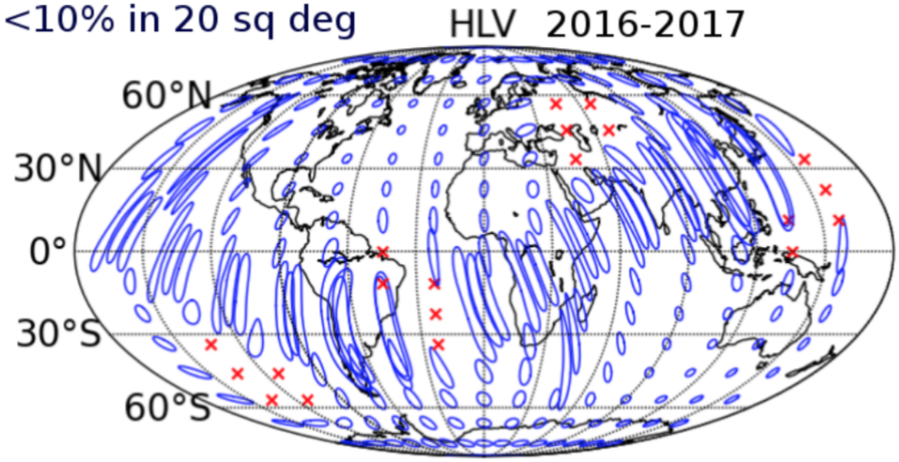






aLIGO-aVIRGO rough timeline: Focused on BNS





Epoch	Estimated Run Duration	$E_{GW} = 10^{-2} M_\odot c^2$ Burst Range (Mpc)		BNS Range (Mpc)		Number of BNS Detections	% BNS Localized within	
		LIGO	Virgo	LIGO	Virgo		5 deg^2	20 deg^2
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48

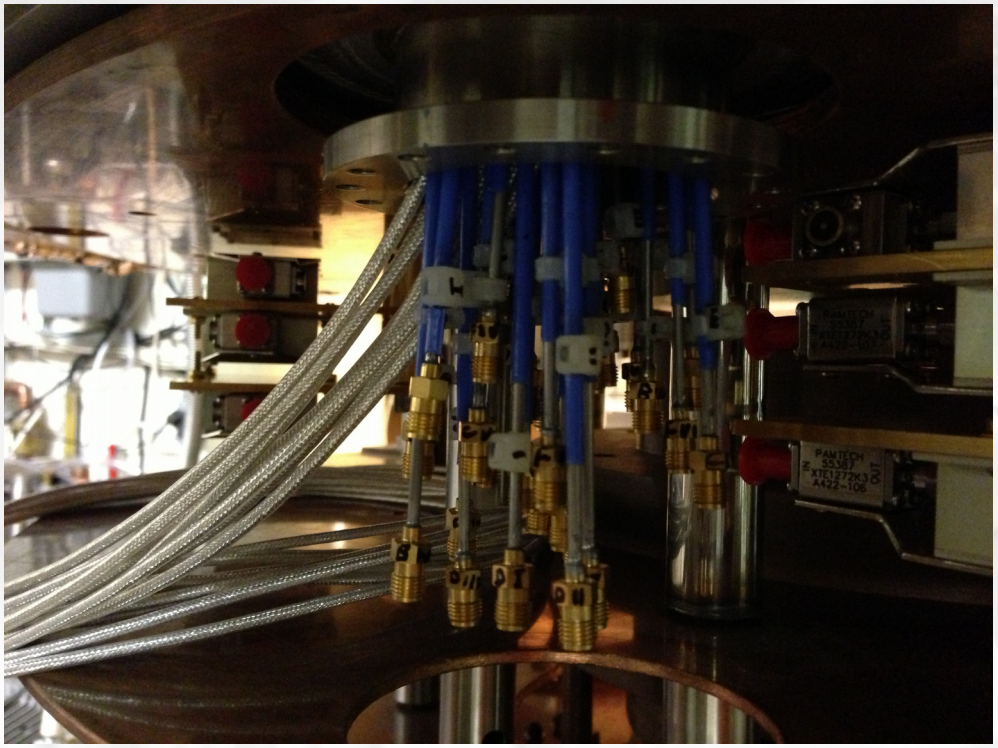
PGDAS

- PósDoc Sênior (PNPD)
  - Caracterização instrumental e ambiental do aLIGO
  - Desenvolvimento pipeline para análise de canais auxiliares
  - Estudo de fontes astrofísicas de ondas gravitacionais

- Membro do corpo docente permanente da DAS/INPE (conselho)
  - Sinais e Sistemas (Estudo orientado)
  - Astroestatística
- Alunas:
  - Tábata
    - Análise Multidimensional dos Transientes do LIGO
  - Pietra
    - Estudo da relação entre Buracos Negros Primordiais e as ondas gravitacionais detectadas pelo aLIGO

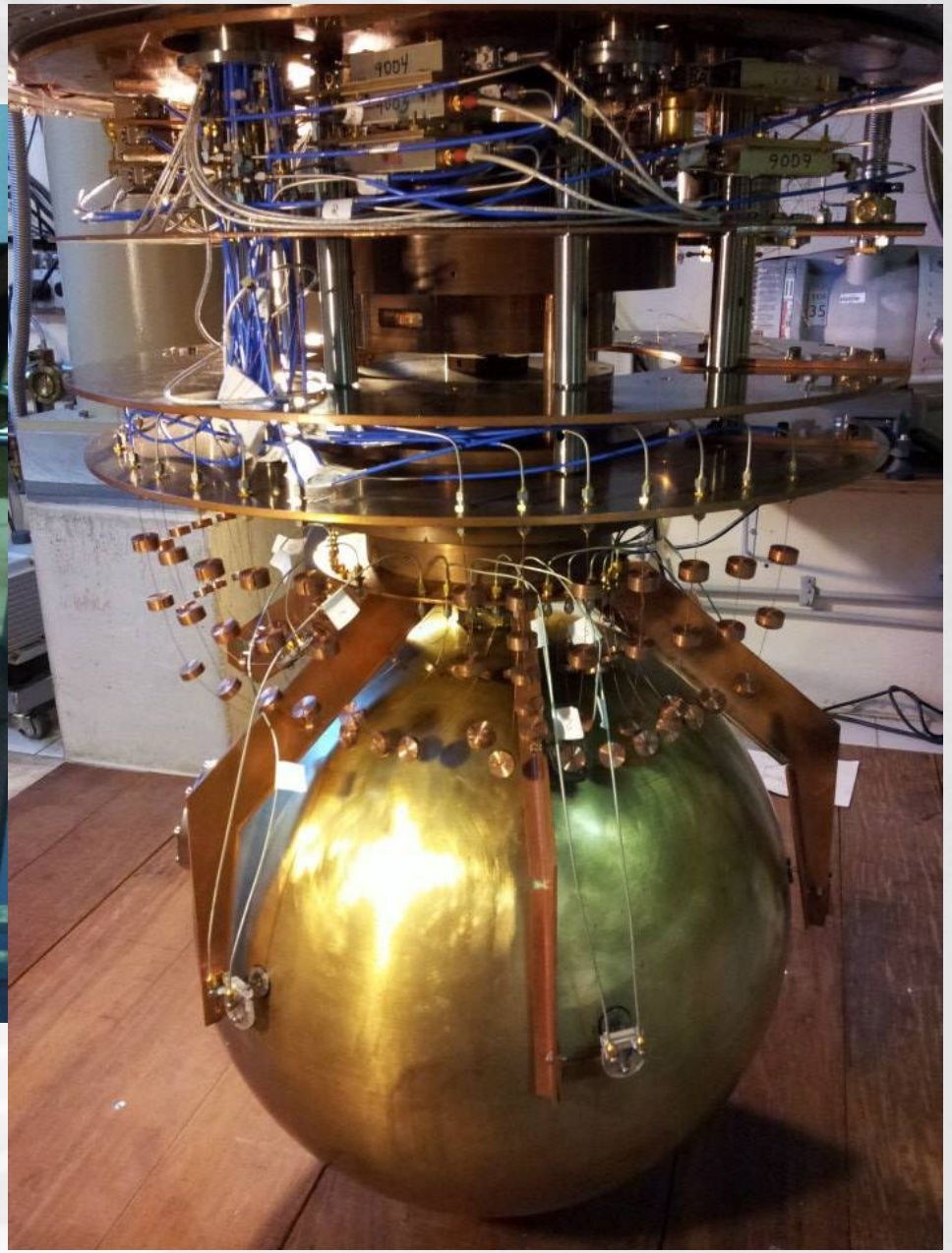
- **Parcerias:**
  - **Instituto Nacional de Pesquisas Espaciais**
  - **Unicamp**
  - **Unesp (ICT-SJC)**
  - **IFSP (São Paulo)**
  - **JPL/NASA**
  - **Louisiana State University**
  - **UTB (University of Texas – Brownsville)**
  - **UWM (University of Wisconsin - Milwaukee)**
  - **LIGO Livingston Observatory**
  - **LIGO Hanford Observatory**

Mario Schenberg



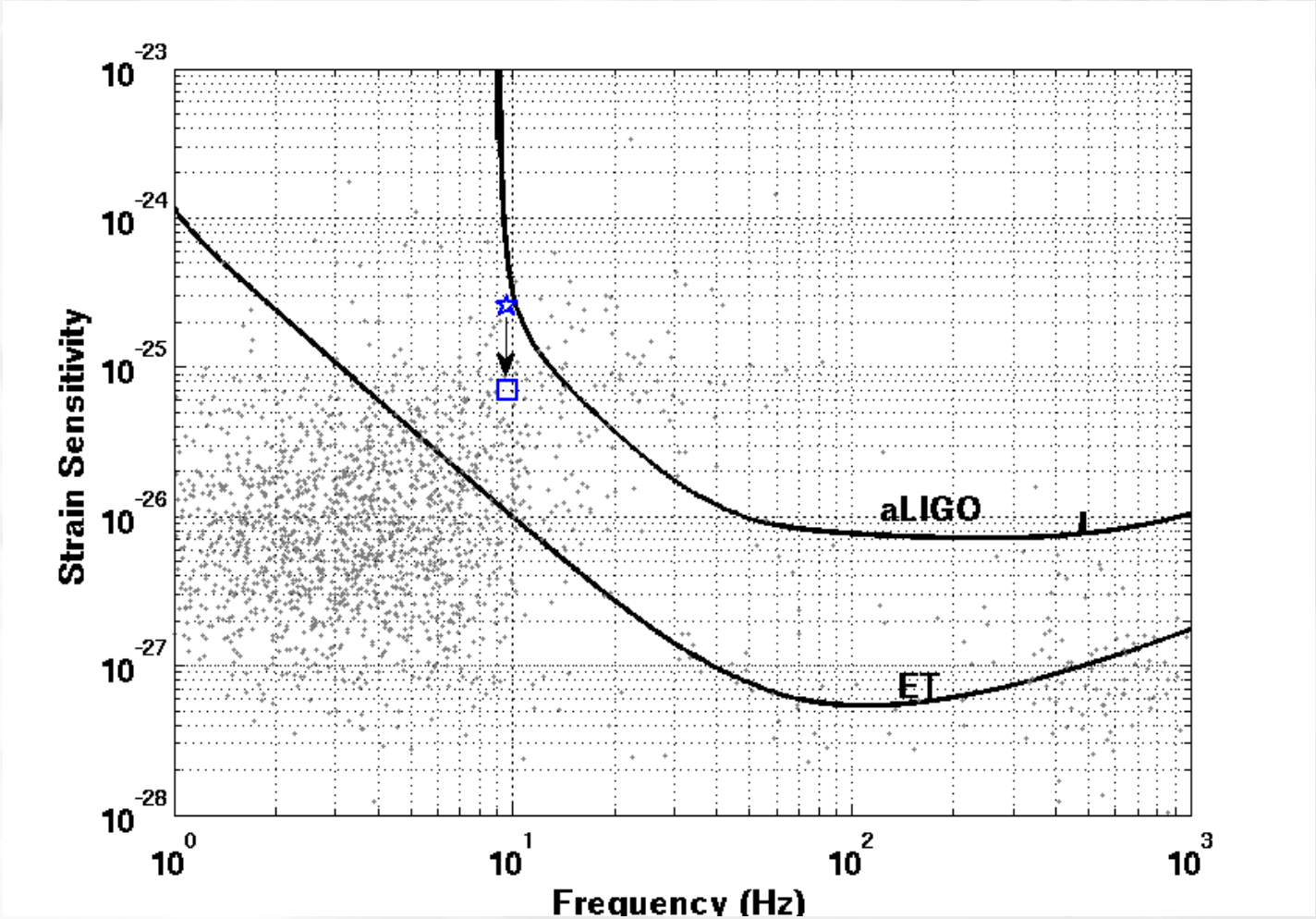
- Instalação dos amplificadores criogênicos de micro-ondas
- Osciladores de micro-ondas e demoduladores
- Amplificadores de áudio
- Sistema de Aquisição de Dados

Corrida Científica 2015



Estudo de pulsares como fontes de OGs

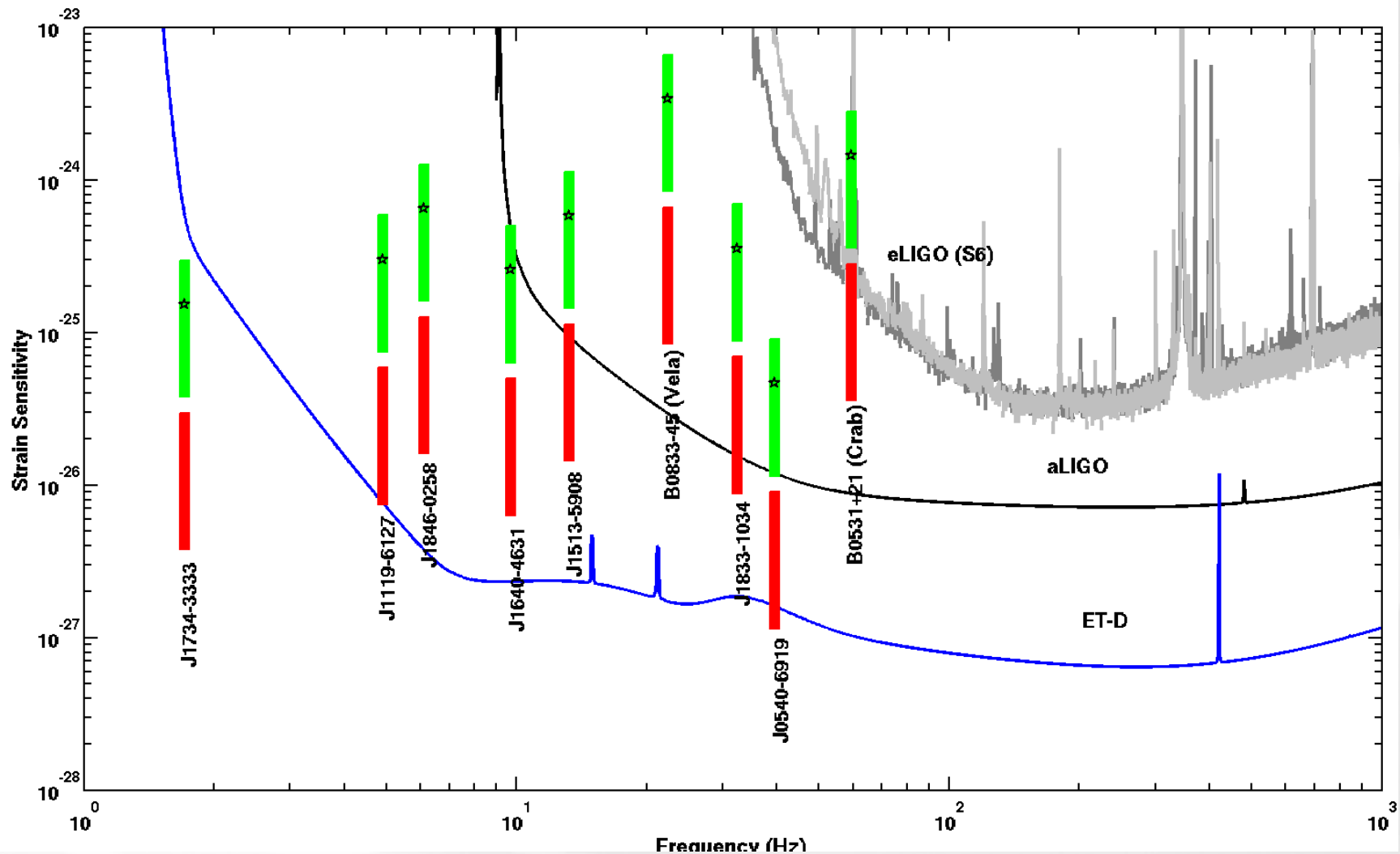
- **José Carlos e Jaziel**
  - **Estudo do Pulsar PSR J1640-4631 com braking index medido (n=3.15)**



JCAPhysics, v. 2016, p. 023, 2016

Estudo de pulsares como fontes de OGs

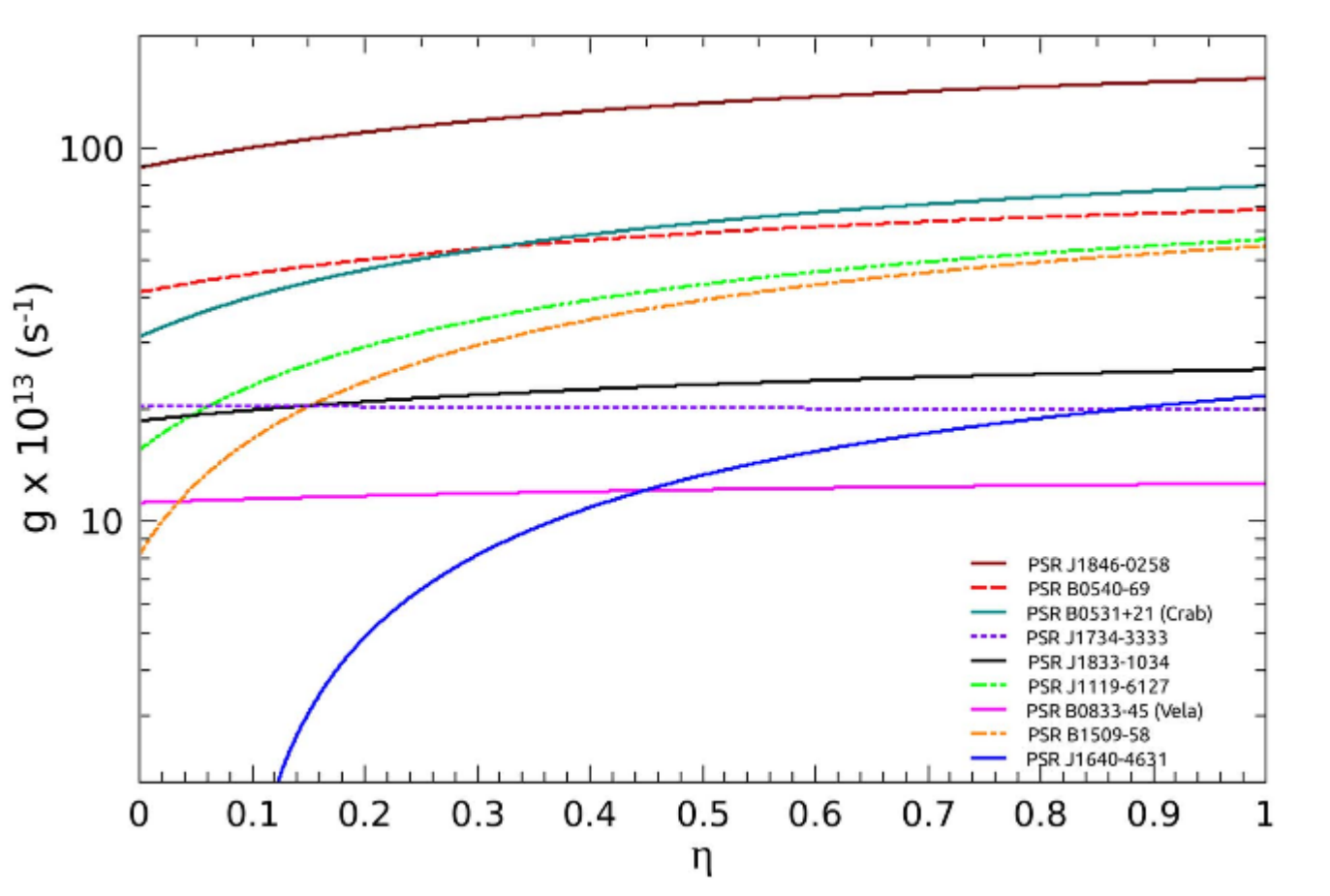
- **José Carlos e Jaziel**
  - **Pulsares com braking index conhecidos (9)**



EPJ C, v. 76, p. 481, 2016

Estudo de pulsares como fontes de OGs

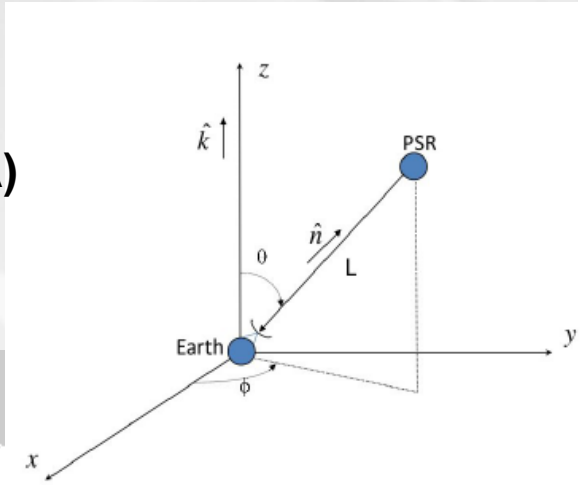
- **José Carlos e Jaziel**
  - **Estudo do papel do campo magnético variante no tempo no braking index de pulsares**

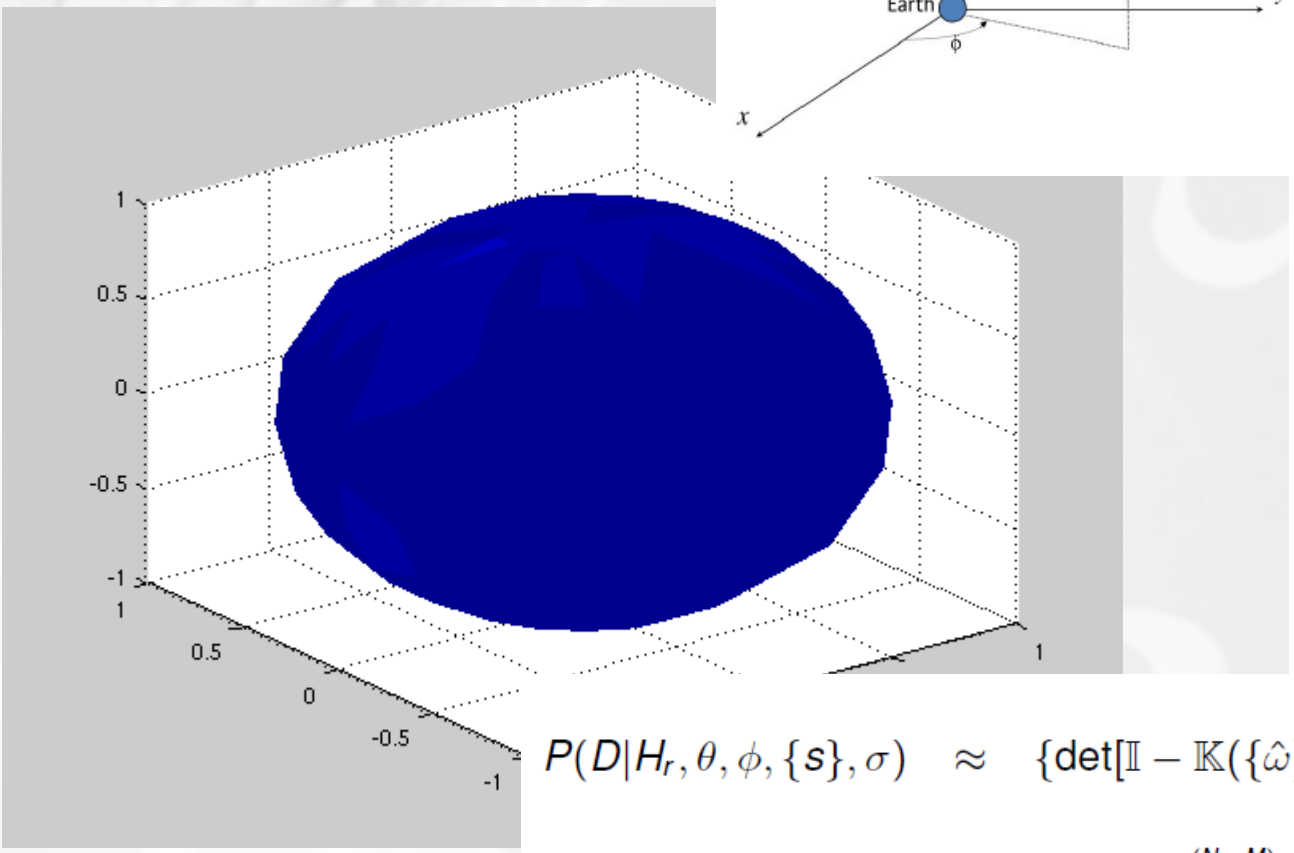


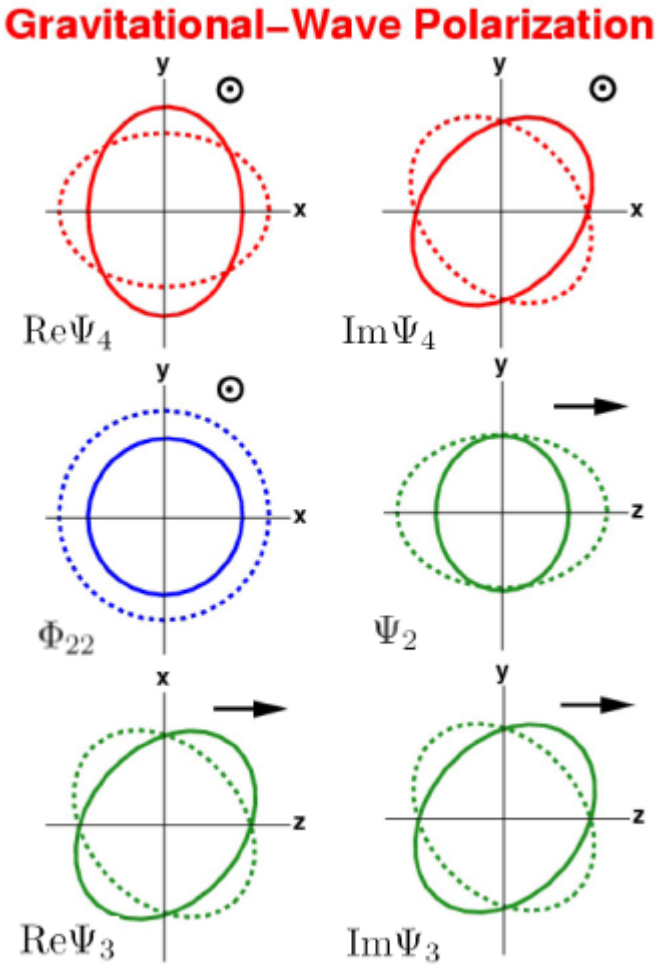
Astrophysical Journal, v. 831, p. 35, 2016.

Bayesian Detection of Alternative GW Polarizations by using Pulsar Timing Array

- Márcio Alves (Unesp/SJC)
- Massimo Tinto (JPL/NASA)







$$P(D|H_r,\theta,\phi,\{s\},\sigma) \approx \{\det[\mathbb{I}-\mathbb{K}(\{\hat{\omega}\})]\}^{\frac{1}{2}} \frac{\Gamma(\frac{M}{2})}{2\ln(R_\gamma)} \left(\pi M\overline{\omega^2}\right)^{-\frac{M}{2}}$$

$$\times \quad (2\pi\sigma^2)^{-\frac{(N-M)}{2}} [\det(\mathbb{B})]^{-\frac{1}{2}} \exp\left[-\frac{N\overline{d^2}-2n\overline{q^2}(\{\hat{\omega}\})}{2\sigma^2}\right]$$

Thanks!

National Science Foundation
WHERE DISCOVERIES BEGIN

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