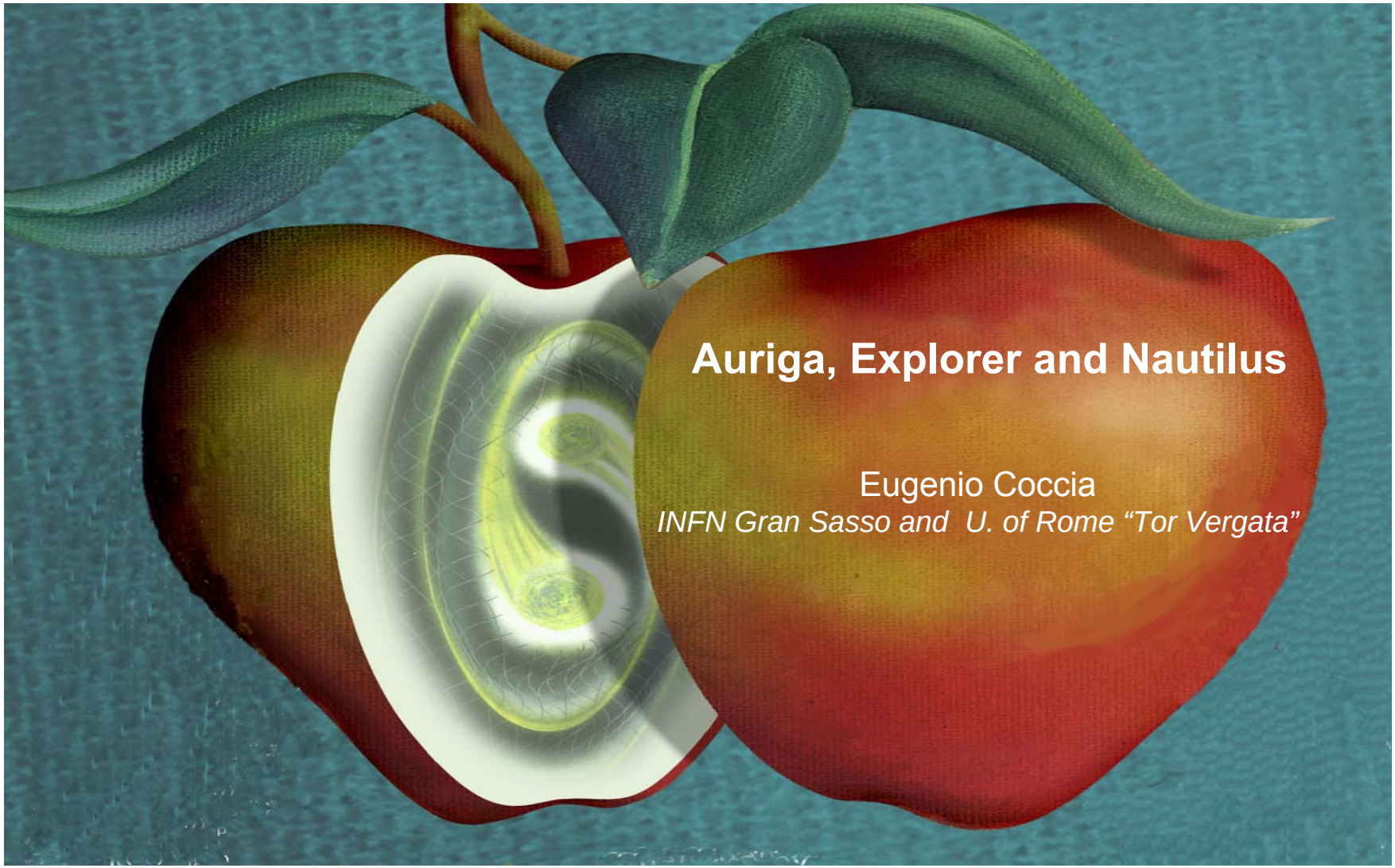
LIGO-G060317-00-Z

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

GWADW

Elba 2006



Gravitational Wave Detectors

MiniGRAIL, Leiden (Olanda)

Allegro, LSU Lousiana

Auriga, Legnaro

MINIGRAIL
GEO
AURIGA
EXPLORER
NAUTILUS
LIGO
LIGO
ALLEGRO

Explorer, CERN

Nautilus, Frascati

Schenberg, San Paolo (Bra)

MARIO SCHENBERG

AIGO
NIOBE

Antenne risonanti nel mondo

gravitational wave research

Frequency emitted by a dynamic system of density ρ :

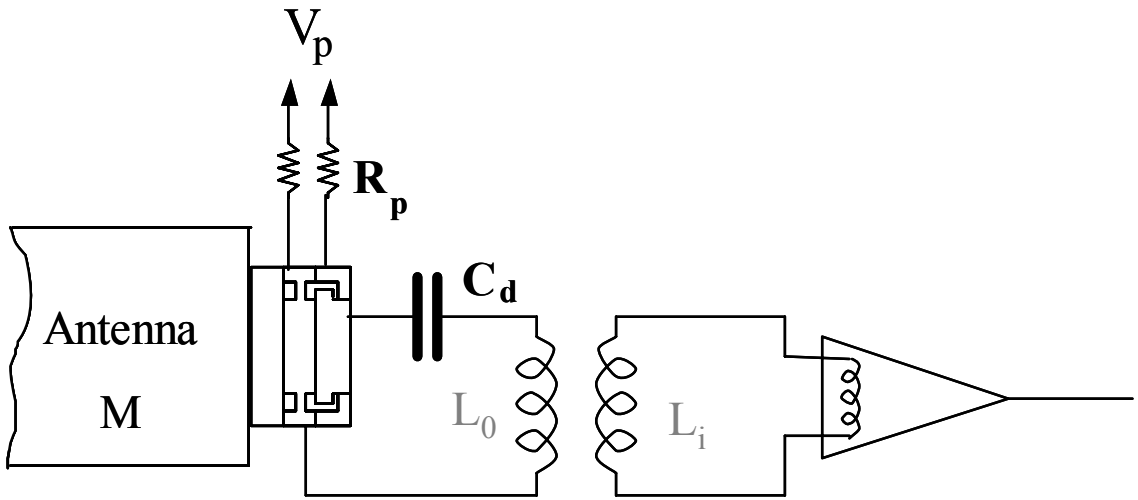
$$f \sim \sqrt{G\rho}$$

kHz frequencies correspond to nuclear densities (10^{-15} g/cm^3)

Sources: compact objects

- gravitational collapse to form neutron star or black hole,
- last orbits of an inspiraling neutron star or black hole binary system, its merging, and its final ringdown,
- starquakes, phase transitions neutron to quark star

EXPERIMENTAL CONFIGURATION



Capacitive transducer

Al 5056
m_t = 0.75 kg
ν_t= 916 Hz
C_t = 11 nF
E = 2.6 MV/m

Superconducting Low-dissipation Transformer

Lo=2.86 H
Li=0.8μH
K=0.8

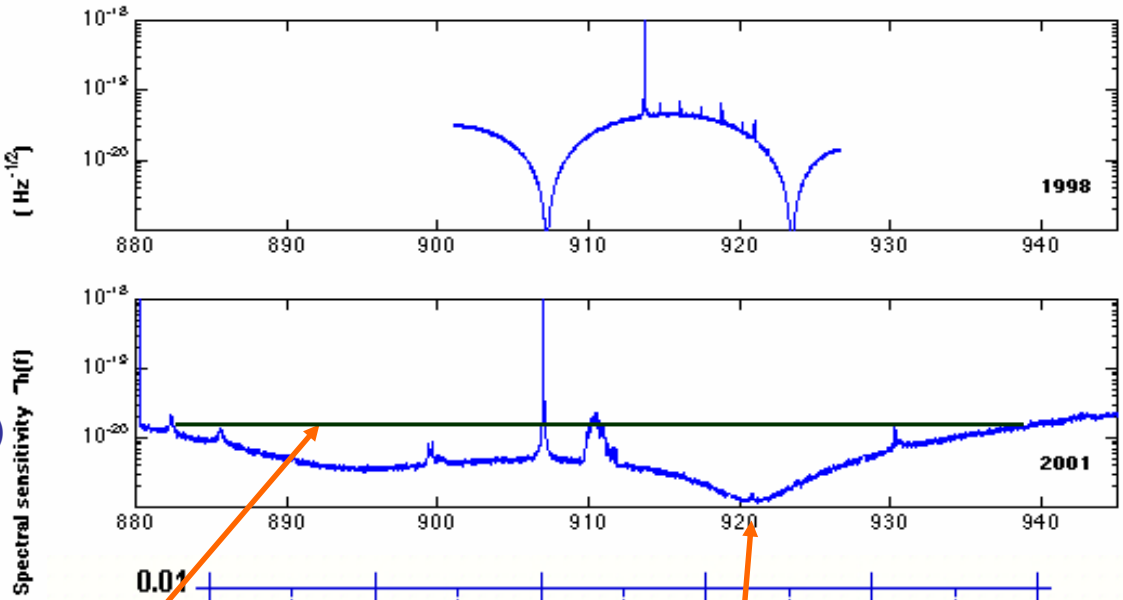
dc-SQUID

M_s = 10 nH
$\Phi_n = 3 \cdot 10^{-6}\ \Phi o/\sqrt{Hz}$

EXPLORER

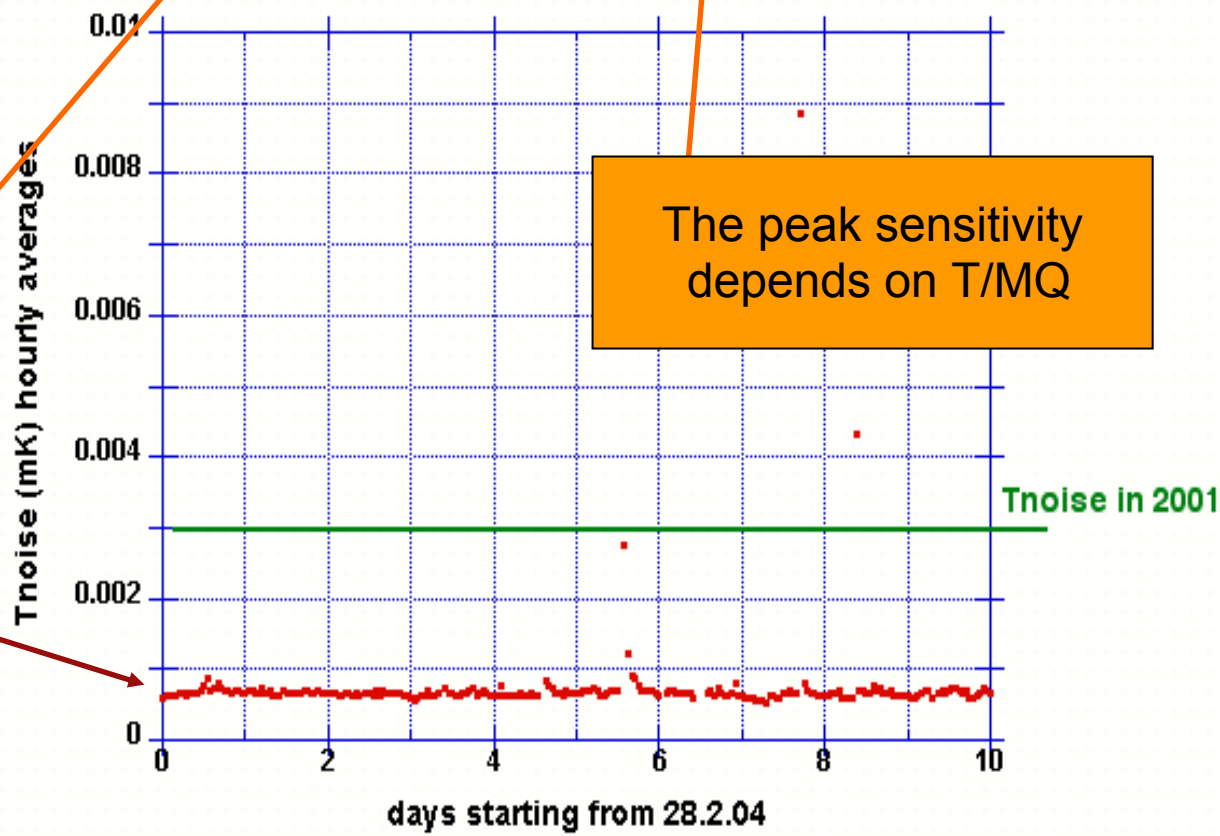
Duty cycle > 90%

Astone et al.(ROG Collaboration)
Phys. Rev. Lett. 2003



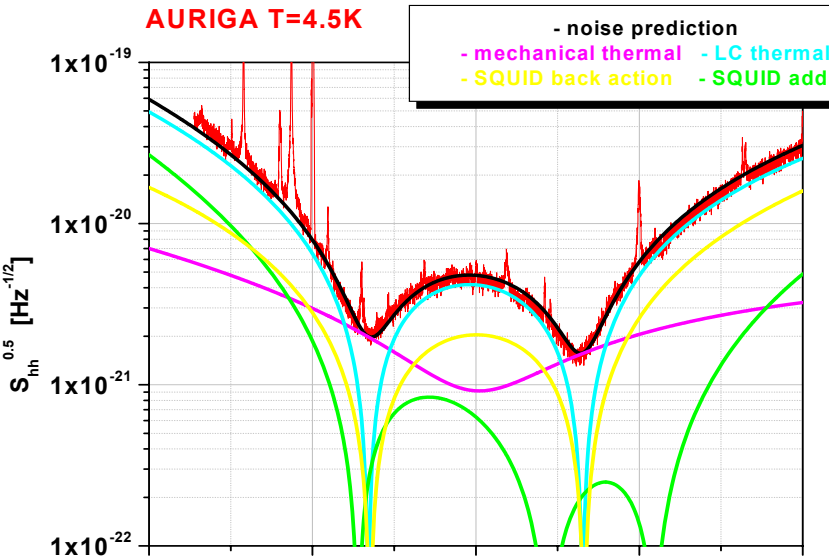
The bandwidth depends mainly on the transducer and amplifier

The peak sensitivity depends on T/MQ

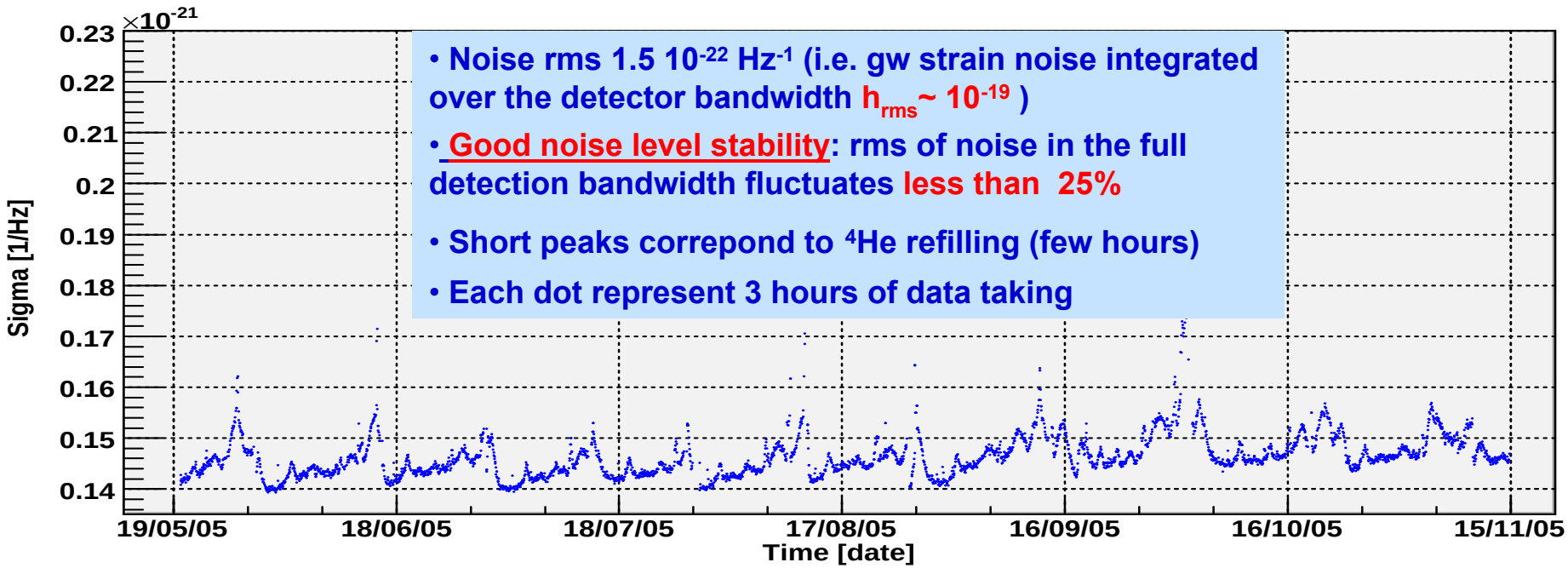


T noise = 690 μK

AURIGA Status: duty cycle, sensitivity and physics @ T=4.5 K

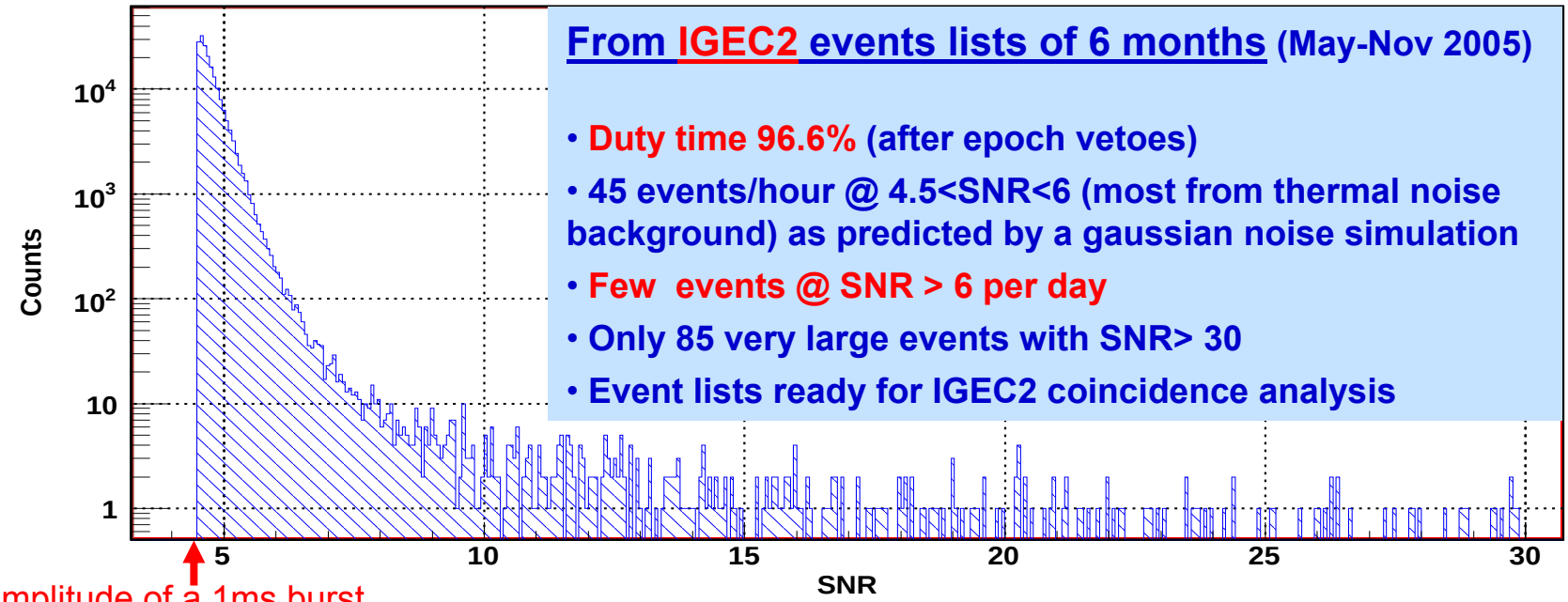


- 1 year of continuous data taking with sensitivity $1.5\times10^{-21} < S_h < 5\times10^{-21}$ $Hz^{-1/2}$ within a 100 Hz band
- Thorough study of intrinsic noise via fluctuation/ dissipation theorem: small fluctuations agree with Re{1/Z(ω)} (thermal noise)
- Detector sensitivity is dominated by thermal noise of bar and 2 modes transducer (purple + blu lines)
- Events due large fluctuations in the 800 1000 Hz band mostly due to up-conversion of noise in the very low frequency band (5-70 Hz) but limited to few events per day



- Noise rms 1.5 10^{-22} Hz^{-1} (i.e. gw strain noise integrated over the detector bandwidth $h_{rms} \sim 10^{-19}$)
- Good noise level stability: rms of noise in the full detection bandwidth fluctuates less than 25%
- Short peaks correpond to ^{4}He refilling (few hours)
- Each dot represent 3 hours of data taking

Joint search of gw burst events



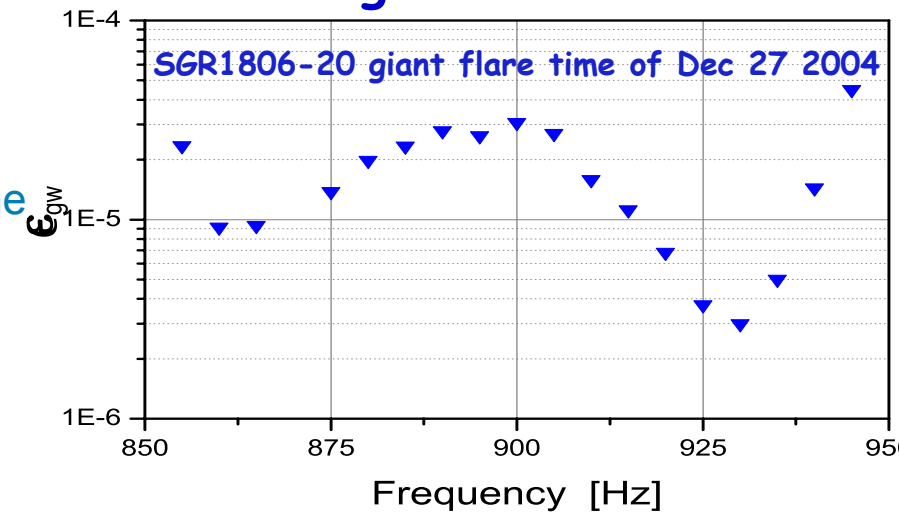
From IGEC2 events lists of 6 months (May-Nov 2005)

- **Duty time 96.6%** (after epoch vetoes)
- 45 events/hour @ 4.5<SNR<6 (most from thermal noise background) as predicted by a gaussian noise simulation
- **Few events @ SNR > 6 per day**
- Only 85 very large events with SNR> 30
- Event lists ready for IGEC2 coincidence analysis

Amplitude of a 1ms burst
SNR=4.5 → h ~1.4 10^{-18}

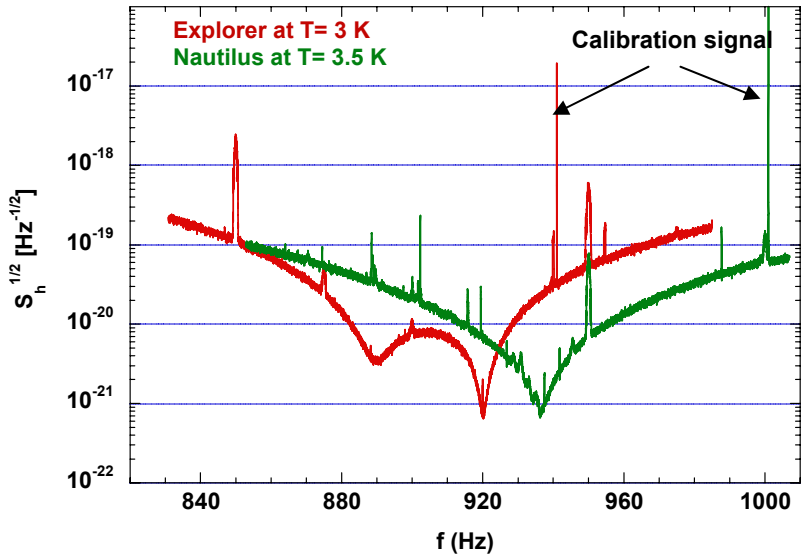
AURIGA targeted searches of gw

- Search for periodic signal from binary pulsars with em phase measured by Radio Telescopes
- Search for gw flux from stationary sources using the Antenna Pattern properties (sidereal time analysis)
- Search for gw in coincidence with X or Gamma flares emitted by Soft Gamma Repeaters (SGR) e Gamma Ray Bursts (GRB) e.g. the giant flare of SGR1806-20 due to crustal failure of a magnetar (see L. Baggio et al. Phys Rev Lett **95** 081103 (2005))



95%confidence upper limits on gw energy emitted @ the flare time: $\varepsilon_{gw} < 5\ 10^{-6}\ M_O c^2$

Explorer and Nautilus status

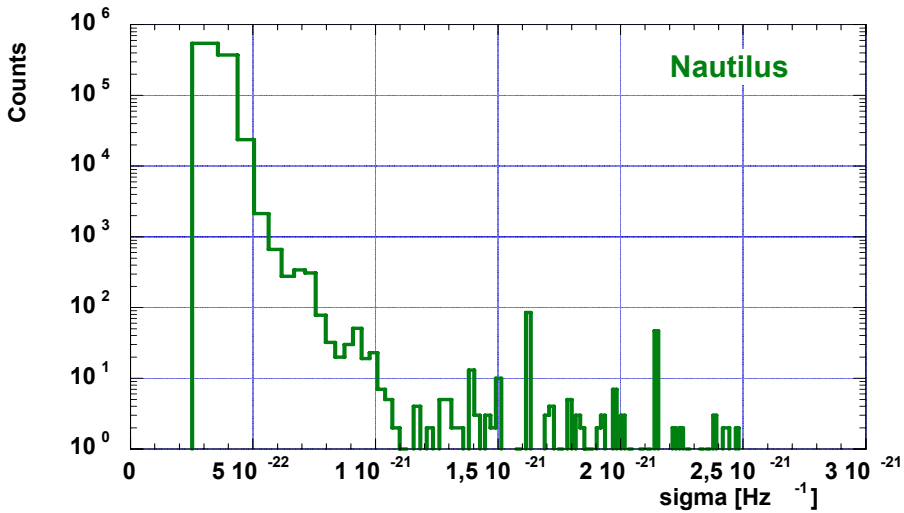


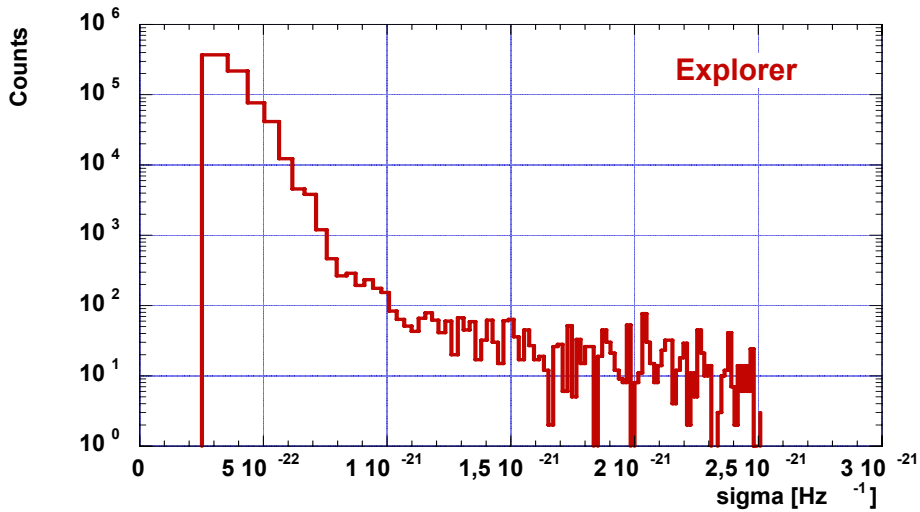
Since 2003 in continuous data taking with a sensitivity $8 \cdot 10^{-22} < S_h^{1/2} < 10^{-20}$ within 40 Hz bandwidth.

Analysis of the Explorer-Nautilus coincidences in the years 2001 and 2003 already published, in progress for 2004.

IGEC2 joint search for GW burst events in the period May-December 2005 in progress.

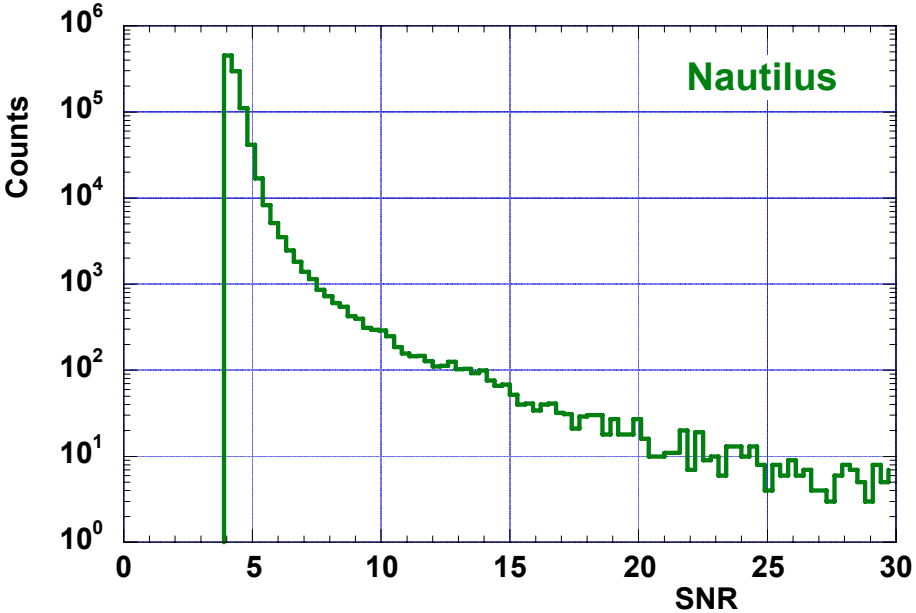
Variance of the noise computed over 10 minutes before each event in the period May-December 2005

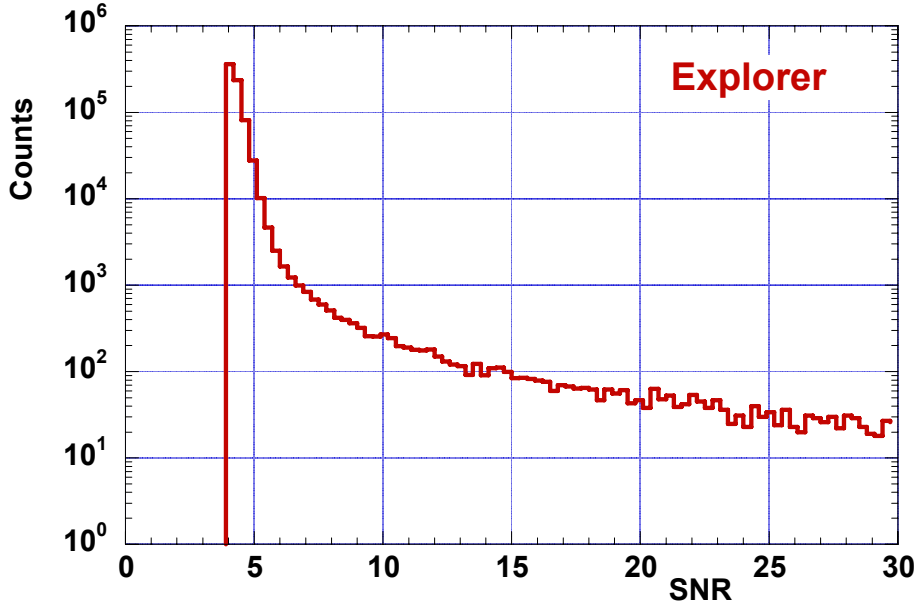




www.lnf.infn.it/esperimenti/rog

Distribution of the SNR of the events in the period May-December 2005, for IGEC2 coincidence analysis





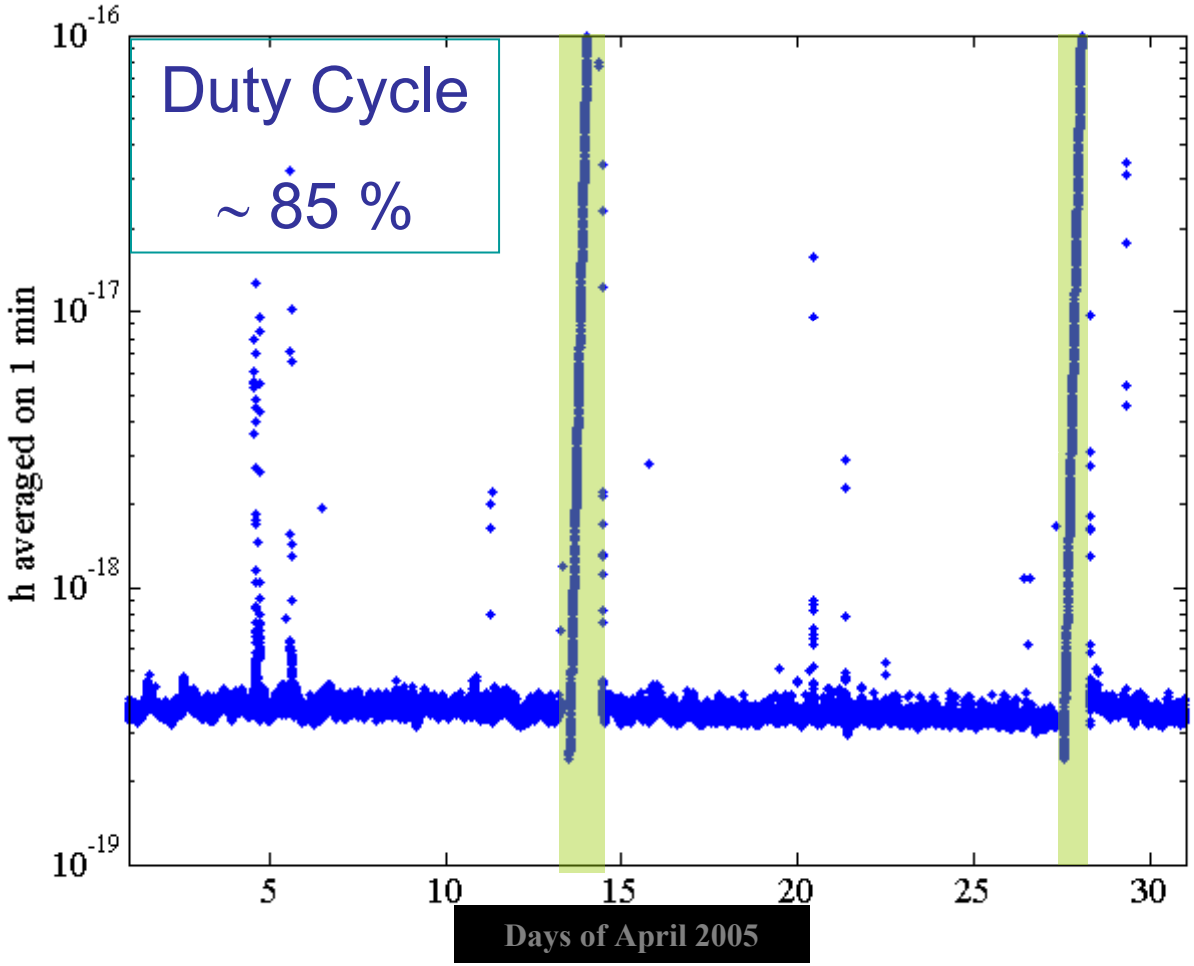
- **Operation with high duty cycle.**

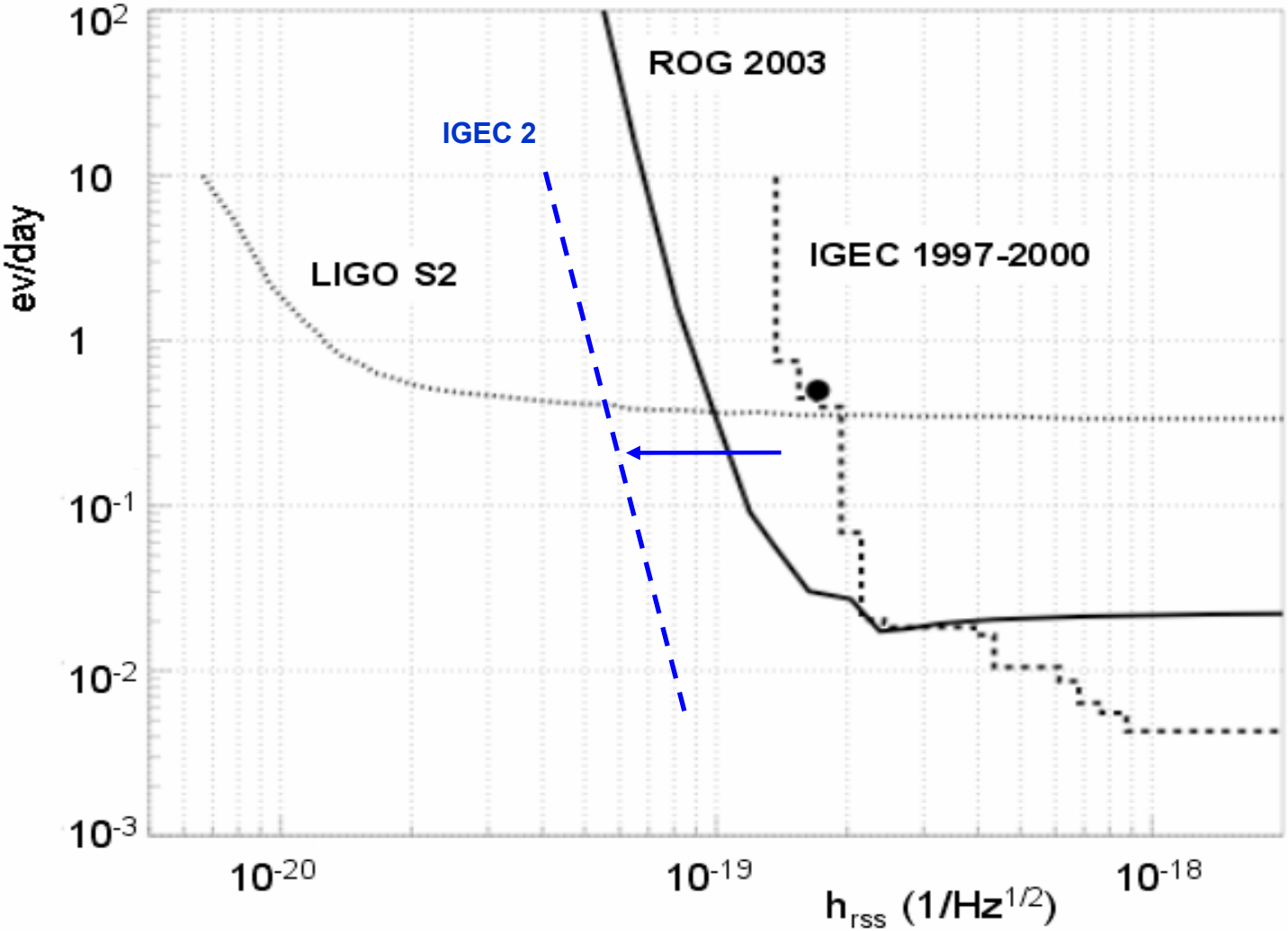
  In the period May-December 2005: Explorer 89%, Nautilus 90% (preliminary - validation in progress).

- **99% of events associated to a noise with sigma < 6.9 10^{-22} Hz^{-1}(Explorer) and < 4.7 10^{-22} Hz^{-1} (Nautilus)**

Cumulative analysis of the association between the data of the gravitational wave detectors NAUTILUS and EXPLORER and the gamma ray bursts detected by BATSE and BeppoSAX
Phys. Rev. D 71, 042001 (2005)

NAUTILUS OPERATIONS DURING April 2005





The IGEC Network of 4 Resonant Detectors set upper limits for burst signals

The EXPLORER/NAUTILUS SEARCH FOR SHORT GW BURSTS

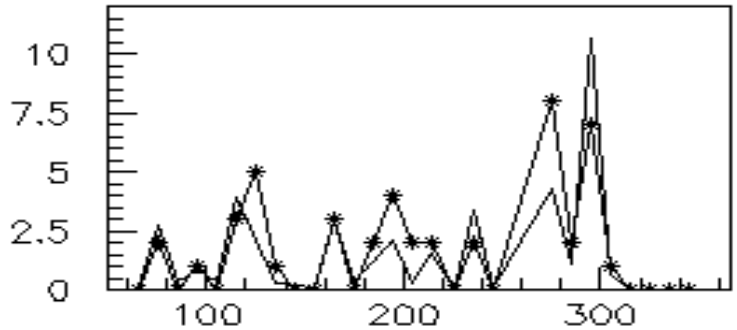
1997- 2000 IGEC search *PRL 85, 5046 (2000)*

1998	931 hours; *CQG 18, 43 (2001)*
2001	2156 hours; *CQG 19, 5449 (2002)*
2003	3677 hours; CQG Amaldi 6, (2006)
2004	5196 hours; Analysis being completed

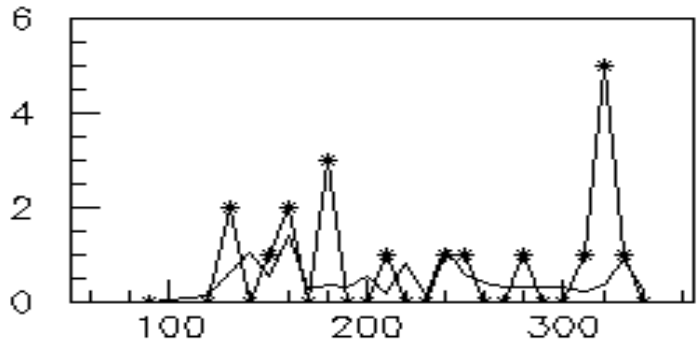
2005 Analysis in progress in the IGEC2 framework

year	detector	T	frequencies	bandwidth	window
1998	EXPLORER	94.5 days	904.7, 921.3 Hz	$\sim 0.4\ Hz$	$\pm 1\ s$
	NAUTILUS		907.0, 922.5 Hz	$\sim 0.4\ Hz$	
2001	EXPLORER	90 days	904.7, 921.3 Hz	$\sim 9\ Hz$	$3\sigma \sim 0.5\ s$
	NAUTILUS		907.0, 922.5 Hz	$\sim 0.4\ Hz$	
2003	EXPLORER	148.7 days	904.7, 921.3 Hz	$8.7\ Hz$	$\pm 30\ ms$
	NAUTILUS		926.3, 941.5 Hz	$9.6\ Hz$	
2004	EXPLORER	216.5 days	904.7, 921.3 Hz	$8.7\ Hz$	$\pm 30\ ms$
	NAUTILUS		926.3, 941.5 Hz	$9.6\ Hz$	

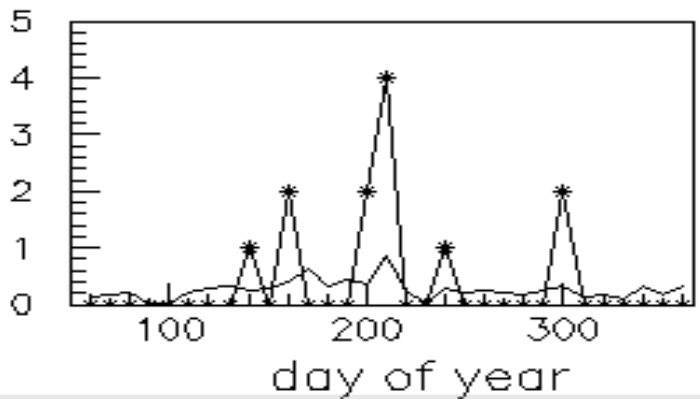
year	n_c	$\bar{n}$
1998	64	52.1
2001	31	27.2
2003	24	18.8
2004		



2001

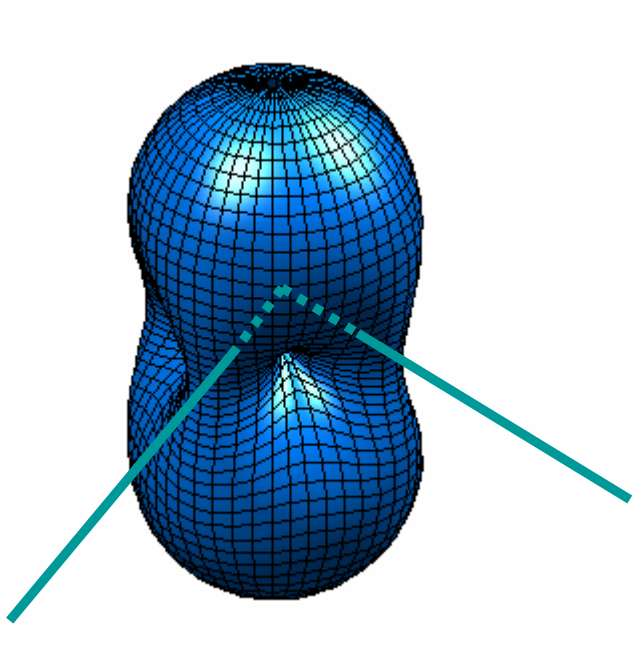


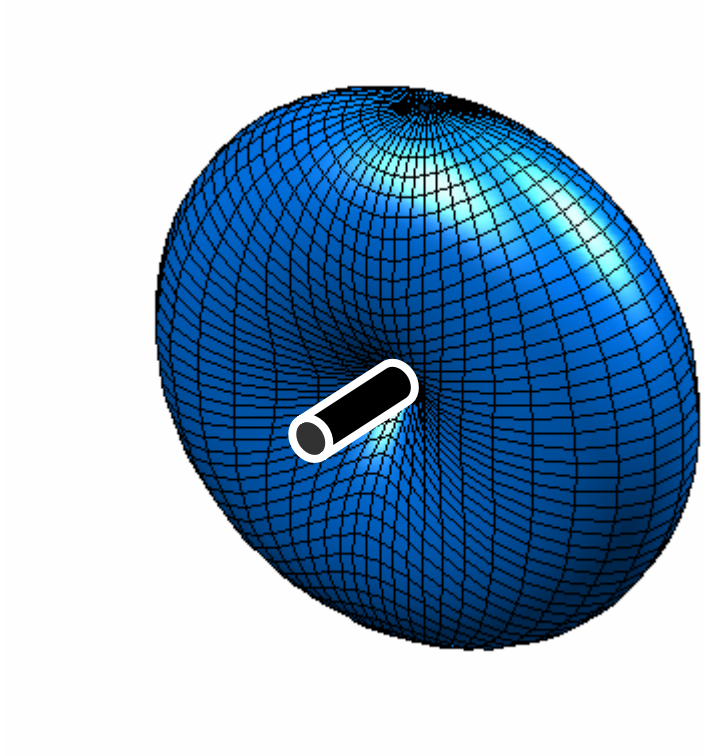
2003



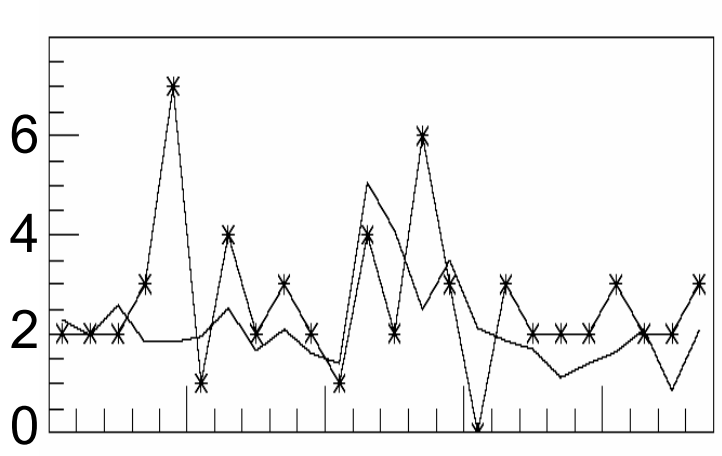
2004

DIRECTIONALITY

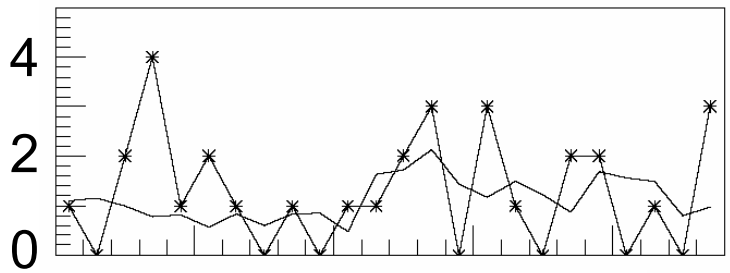




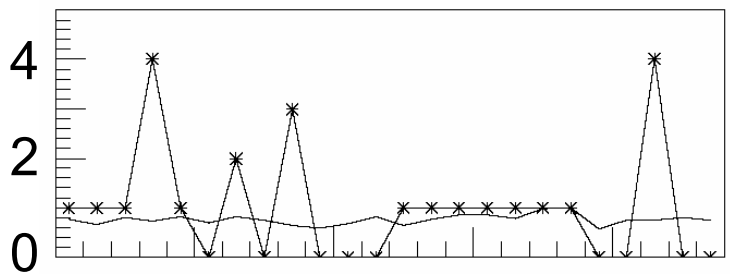
1998



2001

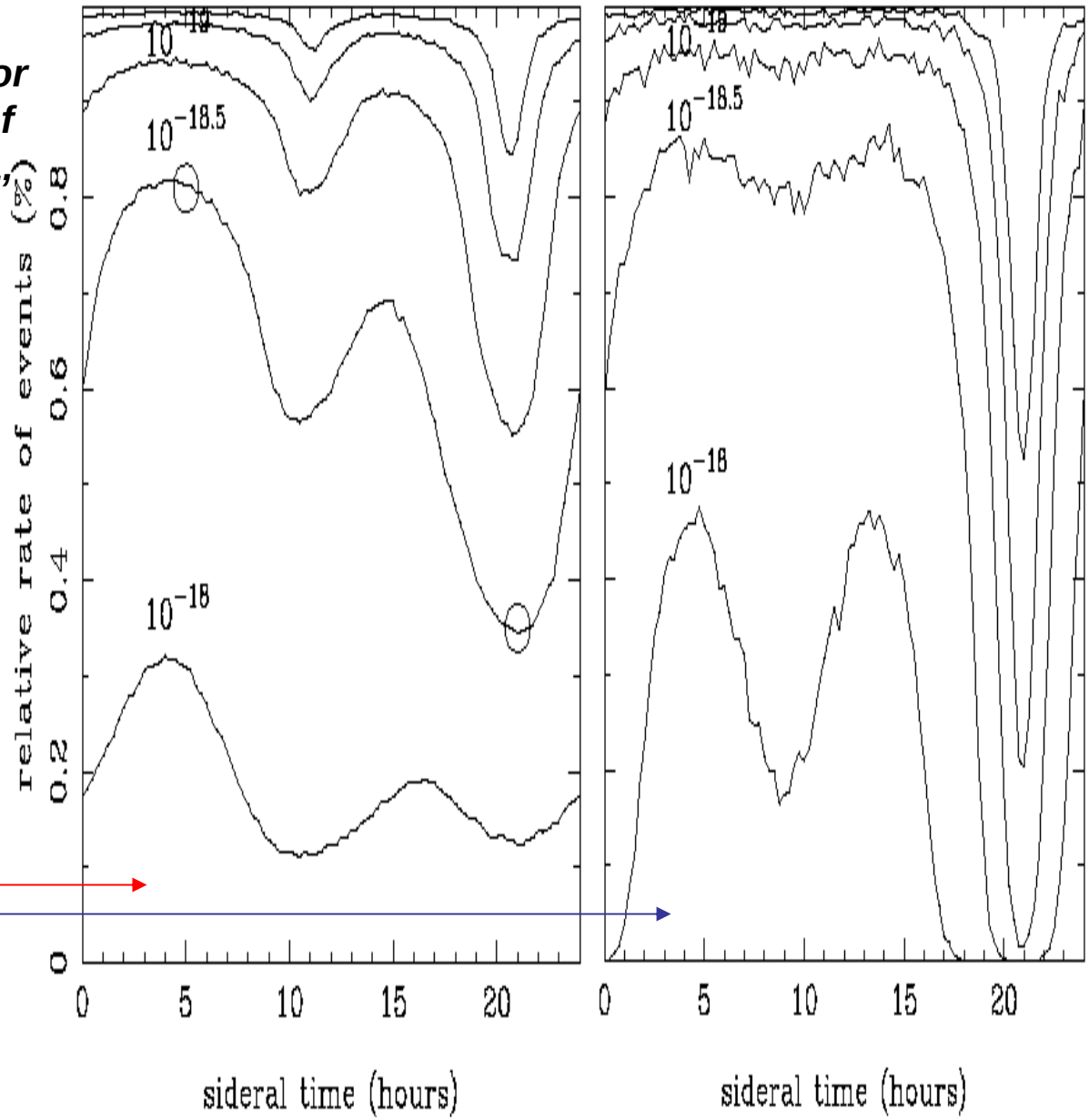


2003



G. Paturel, Yu.V. Barishev
Sidereal time analysis as a tool for study of the space distribution of gw sources. Astro-ph/0211604v1, A&A 398, 377 (2003)

The expected rate of events on EXPLORER for sources on the galactic disc and on the GC



A&A 421, 811-813 (2004)
DOI: 10.1051/0004-6361:20040239

Considerations on coincidence experiments between two gravitational wave detectors for sources in the Galactic Centre

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(Received 17 February 2004 / Accepted 8 May 2004)

Abstract
In a coincidence experiment between gravitational wave detectors, the sidereal time analysis can provide very useful and powerful indications. We studied, with the help of a MonteCarlo simulation, the sidereal time pattern to be expected in such an experiment in the particular case of the resonant bars NAUTILUS and EXPLORER and for sources located in the Galactic Centre. It is shown that for linearly polarized gravitational waves the sidereal time pattern exhibits just a large peak at hour 3.5 and only a small peak at about hour 12.

gr-qc 0405047, PRD 2004

On the possible sources of gravitational wave bursts detectable today

Eugenio Coccia,[1] Florian Dubath,[2] and Michele Maggiore[2]
[1] *University of Rome "Tor Vergata" and INFN Gran Sasso*
[2] *Département de Physique Théorique, Université de Genève, 24 quai Ansermet, CH-1211 Genève 4*
(Dated: May 11, 2004)

We discuss the possibility that galactic gravitational wave sources might give burst signals at a rate of several events per year, detectable by state-of-the-art detectors. We are stimulated by the results of the data collected by the EXPLORER and NAUTILUS bar detectors in the 2001 run, which suggest an excess of coincidences between the two detectors, when the resonant bars are orthogonal to the galactic plane. Signals due to the coalescence of galactic compact binaries fulfill the energy requirements but are problematic for lack of known candidates with the necessary merging rate. We examine the limits imposed by galactic dynamics on the mass loss of the Galaxy due to GW emission, and we use them to put constraints also on the GW radiation from exotic objects, like binaries made of primordial black holes. We discuss the possibility that the events are due to GW bursts coming repeatedly from a single or a few compact sources. We examine different possible realizations of this idea, such as accreting neutron stars, strange quark stars, and the highly magnetized neutron stars ("magnetars") introduced to explain Soft Gamma Repeaters. Various possibilities are excluded or appear very unlikely, while others at present cannot be excluded.

gr-qc 0405145

Short gravitational wave bursts induced by r-mode spin-down of hybrid stars

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Dipartimento di Fisica, Università di Ferrara and INFN, Sezione di Ferrara, 44100 Ferrara, Italy

Z. Berezhiani
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We show that sudden variations in the composition and structure of an hybrid star can be triggered by its rapid spin-down, induced by r-mode instabilities. The discontinuity of this process is due to the surface tension between hadronic and quark matter and in particular to the overpressure needed to nucleate new structures of quark matter in the mixed phase. The consequent mini-collapses in the star can produce highly energetic gravitational wave bursts. The possible connection between the predictions of this model and the burst signal found by EXPLORER and NAUTILUS detectors during the year 2001 is also investigated.

PACS numbers: 04.30.Db, 25.75.Nq, 26.60.+c, 97.60.Jd

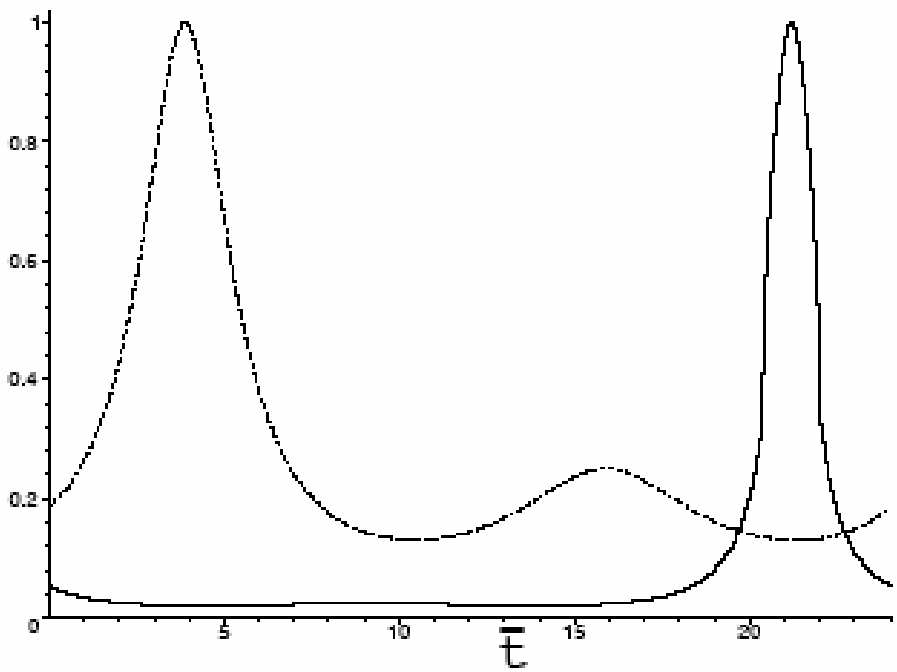
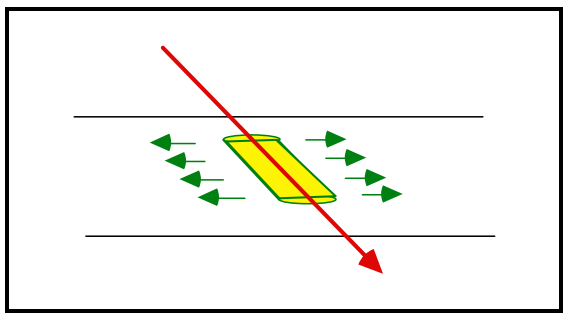


FIG. 16: The response function of the bar for the acustic detection of massive particle, for a source located at the center of the Virgo cluster (dashed line), and for a source in the galactic center (solid line), as a function of sidereal time $\bar{t}$.

Cosmic ray interaction in the bar

Thermo-Acoustic Model:

the ***energy deposited*** by the particle is converted in a ***local heating*** of the medium:



$$\delta T = \frac{\delta E}{\rho C V_0}$$

$$\delta p = \gamma \frac{\delta E}{V_0} \qquad \gamma = \frac{\alpha Y}{\rho C}$$

Excitation of the longitudinal modes of a cylindrical bar

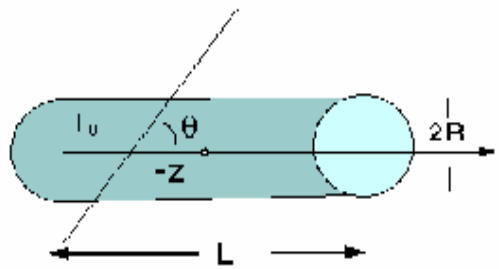
$$E_n = \frac{1}{2}\frac{l^2}{V}\frac{G_n^2}{\rho v^2}\gamma^2\left(\frac{dE}{dX}\right)^2$$

Allega A.M. & Cabibbo N. Lett Nuovo Cim 38 (1983) 263-

A. De Rujula & B. Lautrup, Nucl Phys. B242 (1984) 93-144

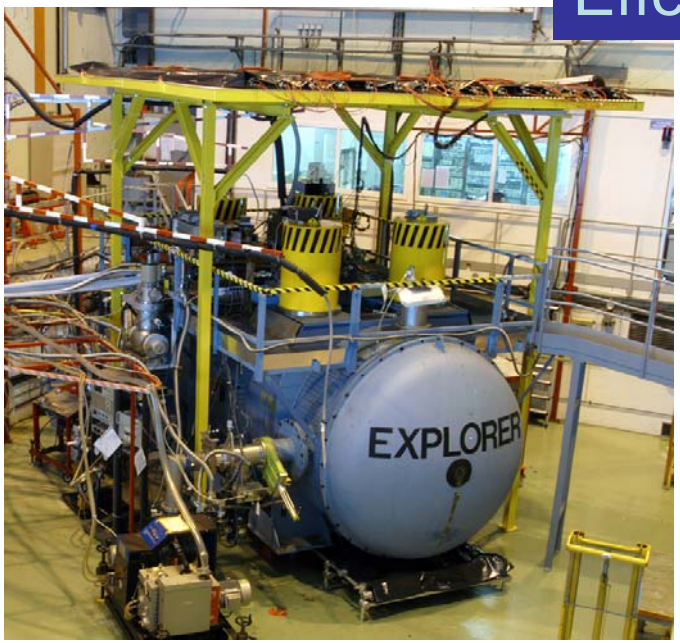
G_n form factor

A resonant gw detector used as a particle detector is different from any other particle detector



γ = Gruneisen "constant"

Effect of cosmic rays

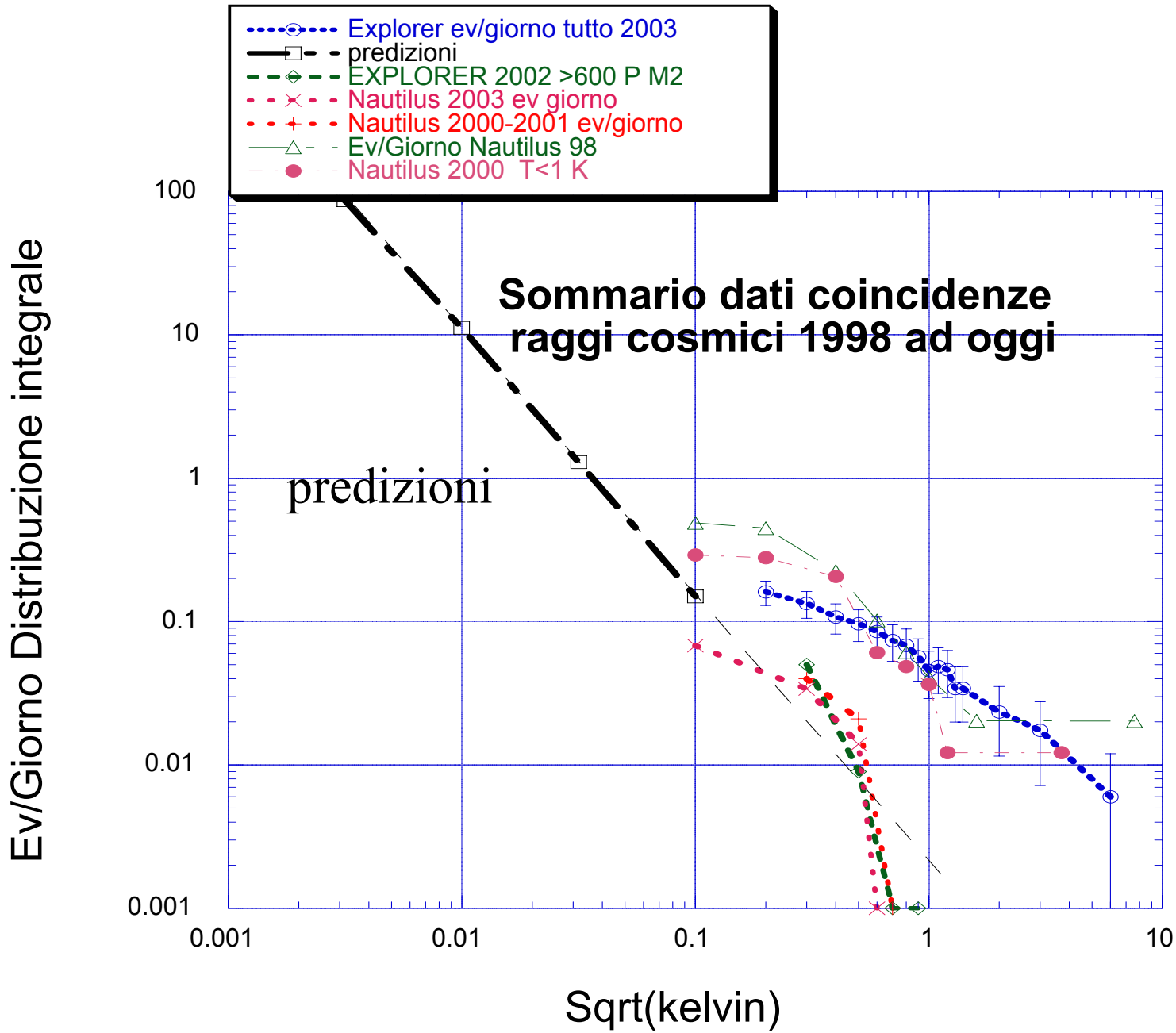


EXPLORER is equipped with 3 layers (2 above the cryostat - area 13m^2 - and 1 below -area 6 m^2) **of Plastic Scintillators.**

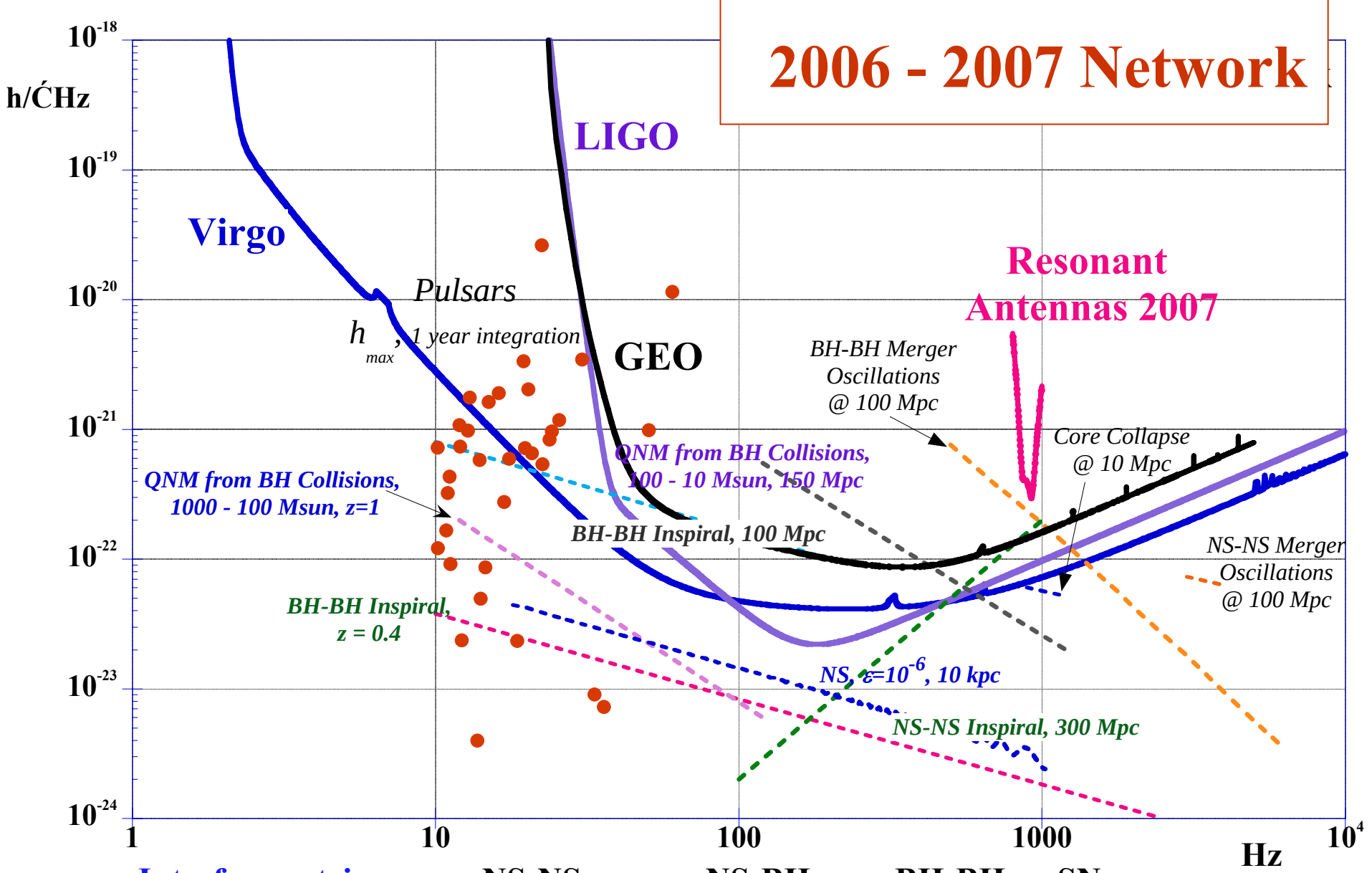
NAUTILUS is equipped with 7 layers (3 above the cryostat - area 36m^2/each - and 4 below -area 16.5 m^2/each) **of Streamer tubes.**

The cosmic ray effect on the bar is measured by an offline correlation, driven by the arrival time of the cosmic rays, between the observed multiplicity in the CR detector (saturation for M≥10^3 particles/m^2) and the data of the antenna, sampled each 4.54 ms and processed by a filter matched to δ signals

ΔE = 1 mK = 0.15 μeV

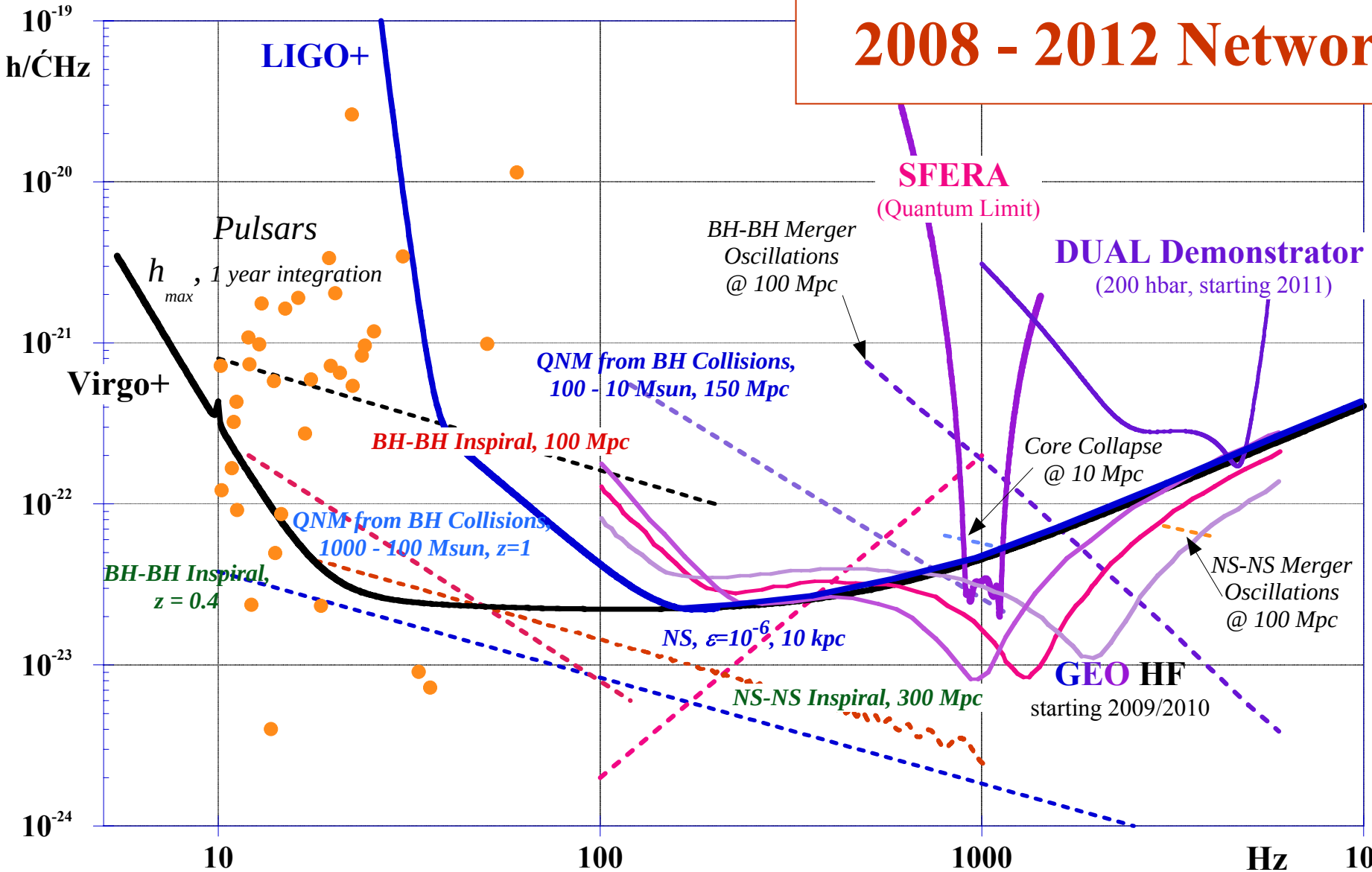

Explorer ev/giorno tutto 2003
predizioni
EXPLORER 2002 >600 P M2
Nautilus 2003 ev giorno
Nautilus 2000-2001 ev/giorno
Ev/Giorno Nautilus 98
Nautilus 2000 T<1 K
Sommario dati coincidenze
raggi cosmici 1998 ad oggi
predizioni
Ev/Giorno Distribuzione integrale
Sqrt(kelvin)
100
10
1
0.1
0.01
0.001
0.001
0.01
0.1
1
10

2006 - 2007 Network

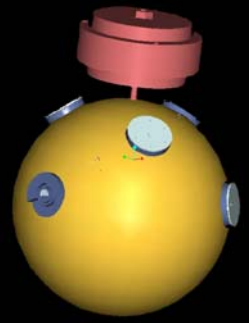


Interferometric Network	NS-NS	NS-BH	BH-BH	SNe
Event Rate (per year)	$3\ 10^{-4}$ - 0.3	$4\ 10^{-4}$ - 0.5	10^{-3} - 3	0.05
Range (Mpc)	30	60	145	0.1

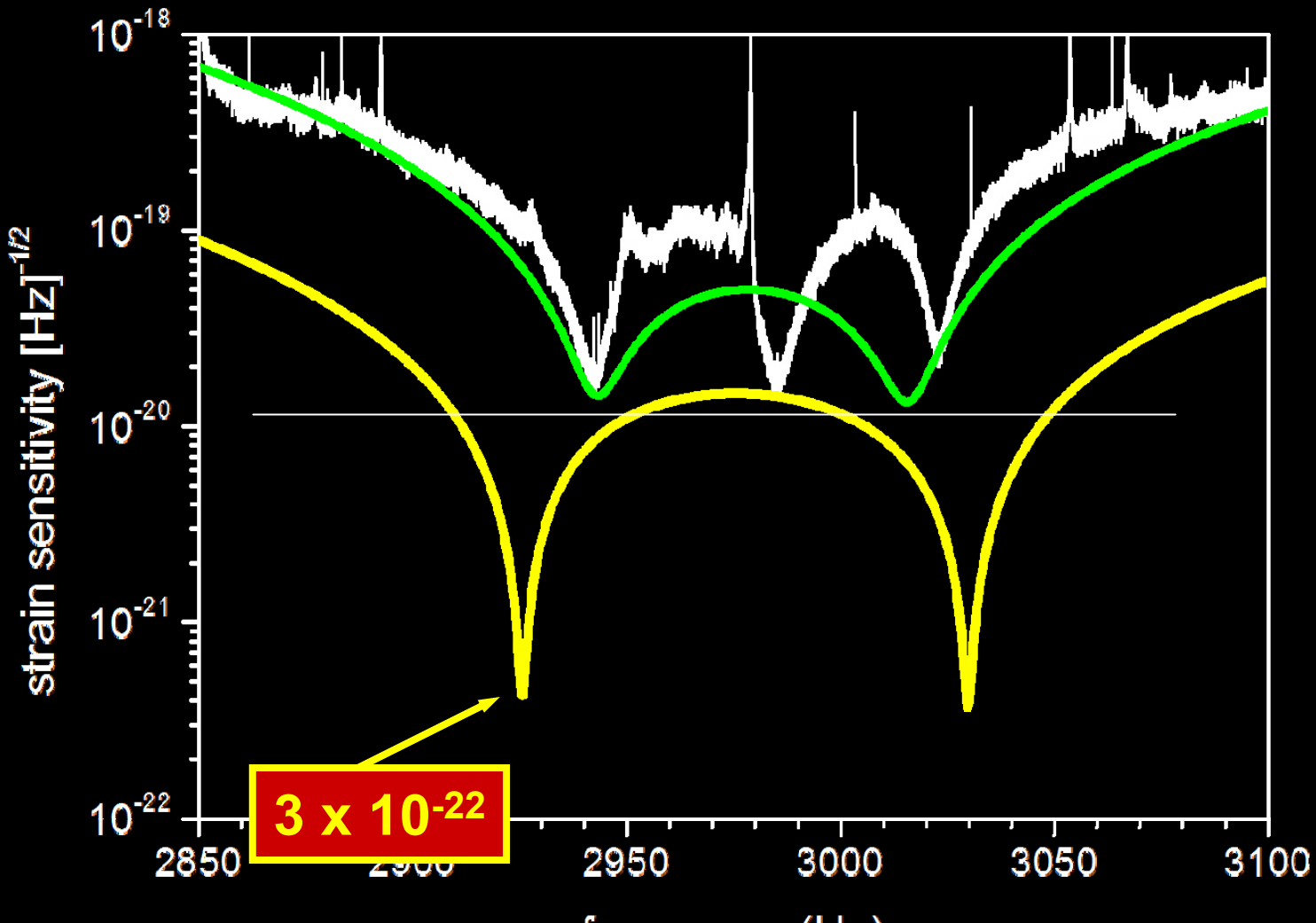
2008 - 2012 Network



Interferometric Network	NS-NS	NS-BH	BH-BH	SNe
Event Rate (per year)	0.025-10	10^{-3}-15	3 10^{-2}-90	1
Range (Mpc)	114	230	584	10



Sensitivity predicted for next run



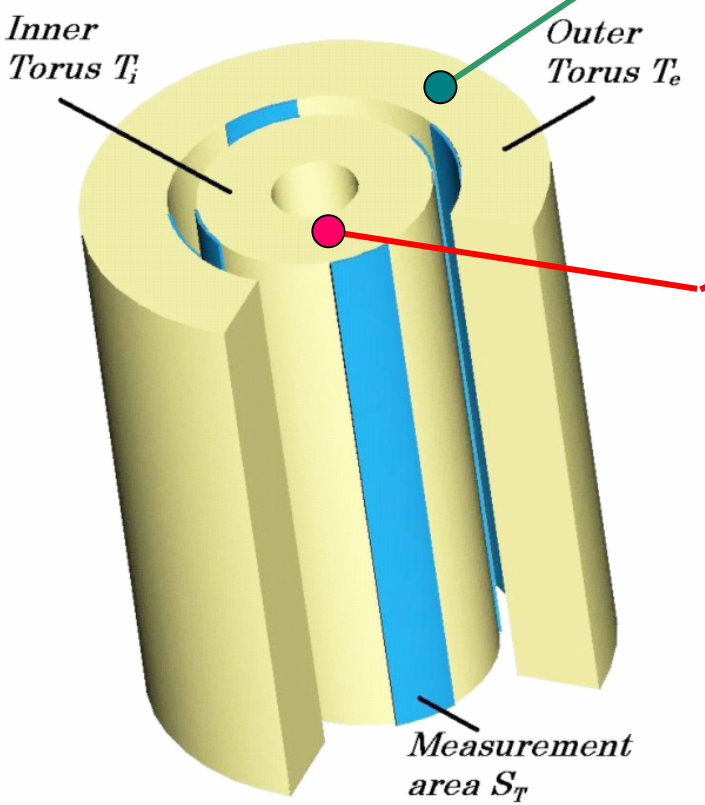
Dual Main Concept

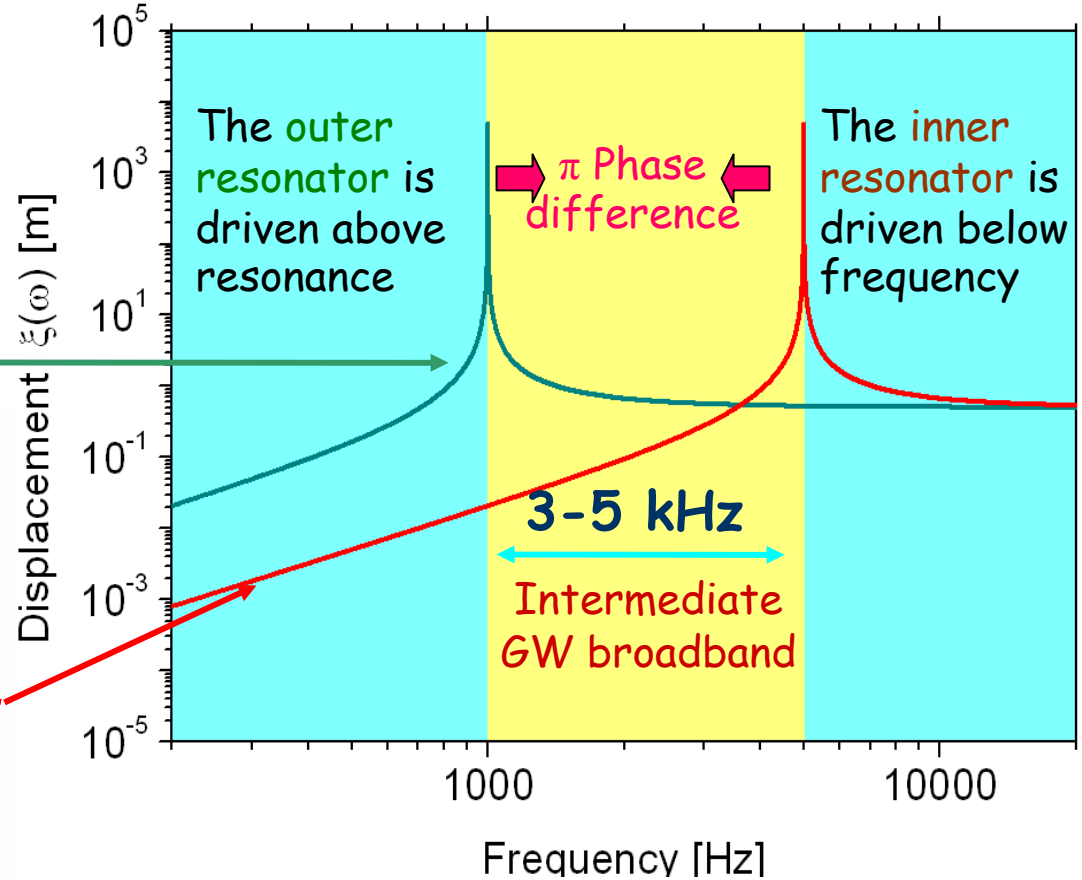
- gw signals add -
- back action noises subtract -

MC et al. PRL 87 (2001) 031101

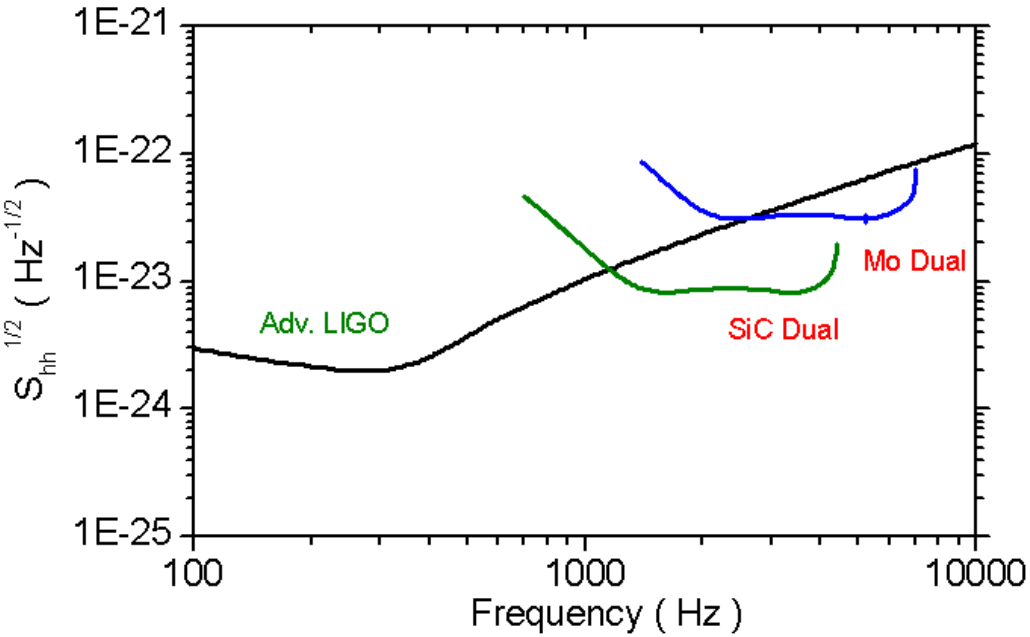
MB et al. PRD 68 (2003) 102004

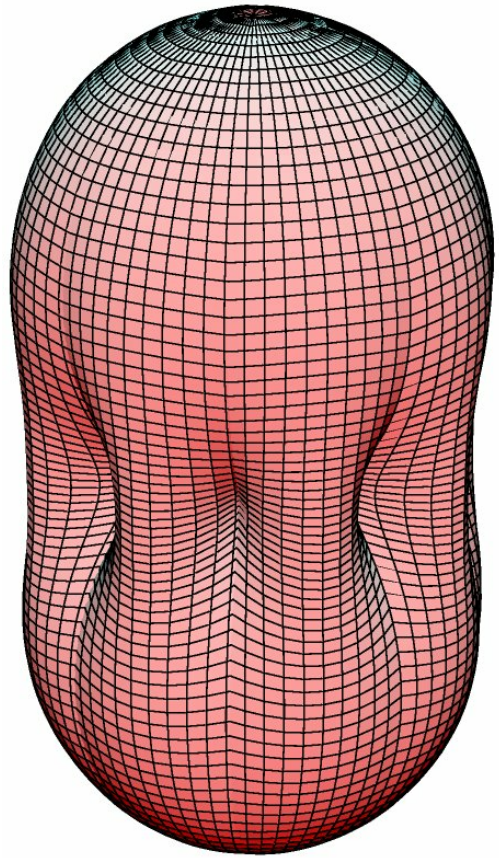
Read the differential deformations of two nested resonators





Spectral sensitivity @ SQL





Mo Dual 16.4 ton height 2.3m ⌀ 0.94m

SiC Dual 62.2 ton height 3.0m ⌀ 2.9m

$Q/T=2\times10^{8}\ K^{-1}$

M. Bonaldi et al.
Phys. Rev. D **68** 102004 (2003)

Antenna pattern: like 2 IFOs co-located and rotated by 45°

M. Bonaldi et al. gr-qc/0605004

Conclusions

- Auriga, Explorer and Nautilus are taking data continuously with high duty cycle

- Events lists of 6 months May-Nov 2005 ready for analysis

- Explorer-Nautilus coincidence search 1998-2004 published soon: excitements and limits of a two-detectors coincidence search.

- INFN Roadmap:
  - Bars ON up to 2009.
  - No large Spherical detector project.
  - Continuation of the R&D for Dual.