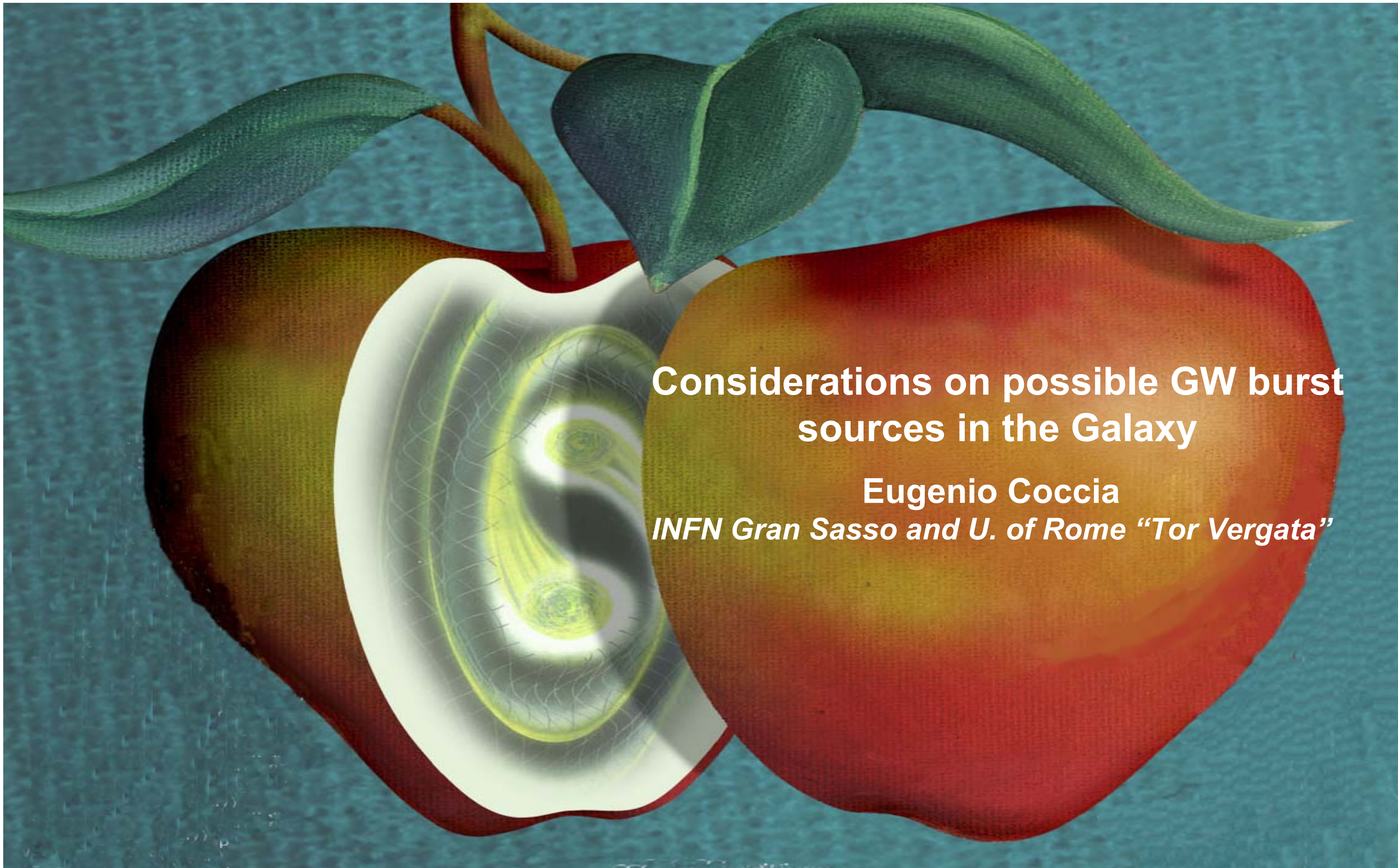
Les Rencontres de Physique de la Vallee d’Aoste

La Thuile - March 1, 2004



Considerations on possible GW burst sources in the Galaxy

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Gravitational Wave Detectors
Interferometric
Resonant-Mass
LISA
GEO
AURIGA
EXPLORER
VIRGO
NAUTILUS
TAMA
LIGO
LIGO
ALLEGRO
NIOBE
gravitational wave research

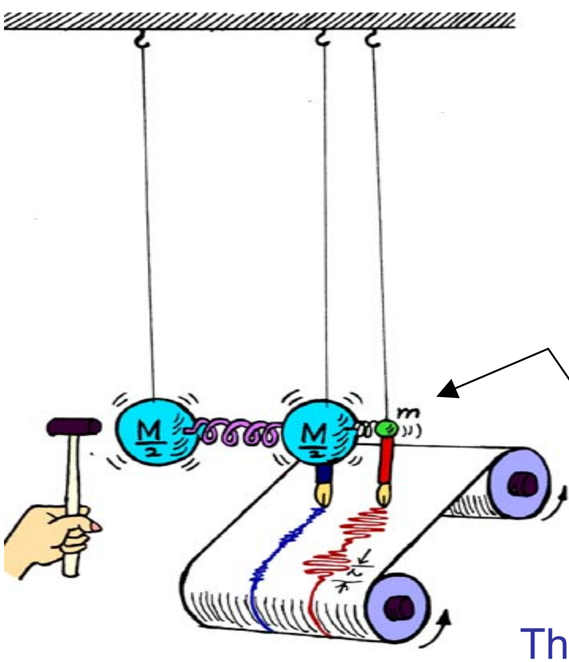
Gravitational Wave Detectors

ROG Collaboration

LNF, Roma1, Roma2

GWs excite those vibrational modes of a resonant body that have a mass quadrupole moment, such as the fundamental longitudinal mode of a cylindrical antenna.

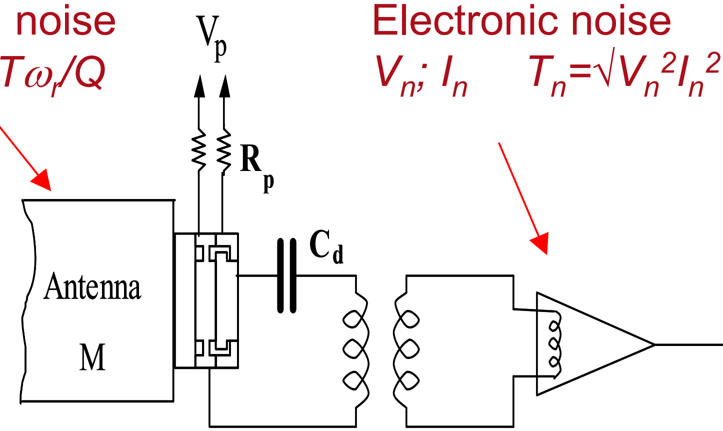
$$\ddot{x}(t)+\tau^{-1}\dot{x}(t)+\omega_0^2 x(t)=\frac{\ell}{2}\ddot{h}(t)$$



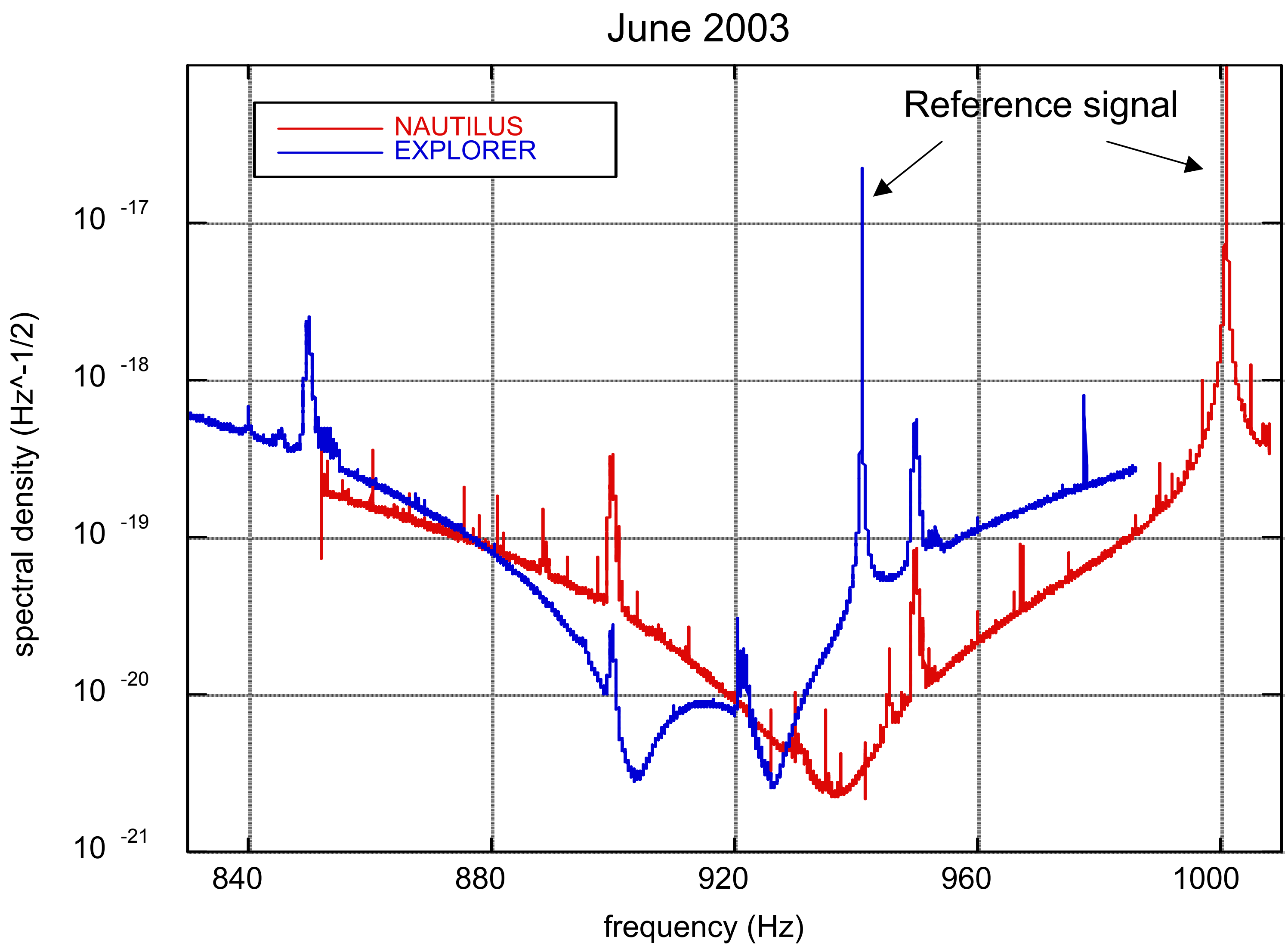
The displacement
of the secondary oscillator
modulates a dc electric field

Thermal noise
$S_F = MkT\omega_r/Q$

Electronic noise
V_n; I_n $T_n=\sqrt{V_n^2 I_n^2}/k$




NAUTILUS
INFN - LNF



June 2003
NAUTILUS
EXPLORER
Reference signal
spectral density (Hz^-1/2)
10^{-17}
10^{-18}
10^{-19}
10^{-20}
10^{-21}
840
880
920
960
1000
frequency (Hz)

•Because of the inherent weakness of GW signals, and the difficulty in distinguishing them from a myriad of noise sources, the direct detection of a gw burst require coincident detection by multiple detectors with uncorrelated noise.

$$n_c << N_1, N_2$$

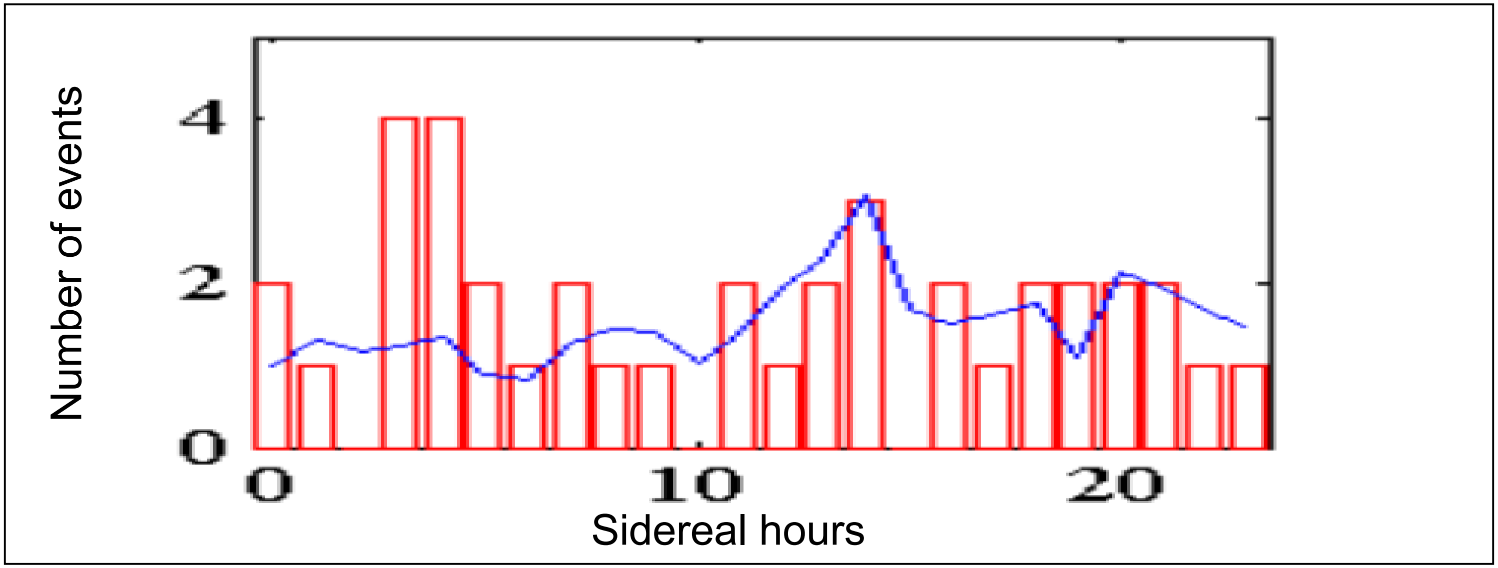
•Background: expected number of coincidences <n>, during the observation time T

$$\langle n \rangle = \frac{N_1 N_2 \Delta t}{T}$$

This background can be *measured*: one shifts the time of occurrence of the events of one of the two detectors for a number of times, and takes the average

EXPLORER-NAUTILUS 2001 data analysis

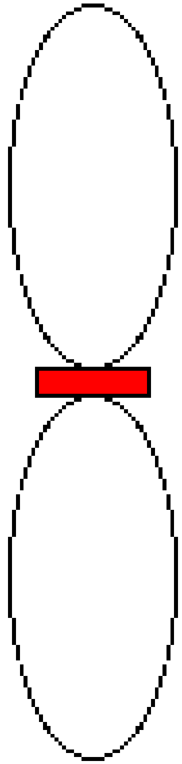
During 2001 EXPLORER and NAUTILUS were the only two operating resonant detectors, with the best ever reached sensitivity.

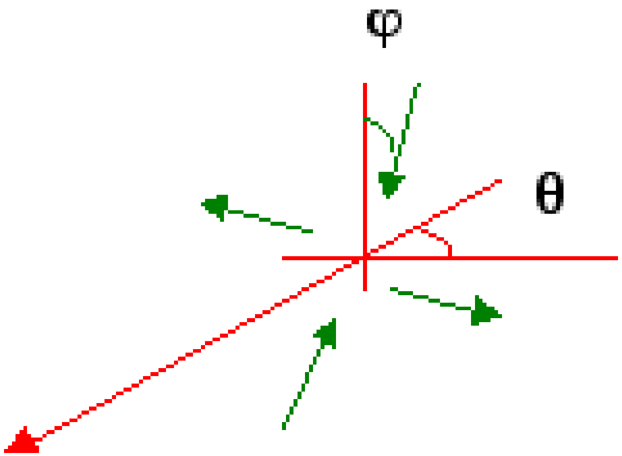


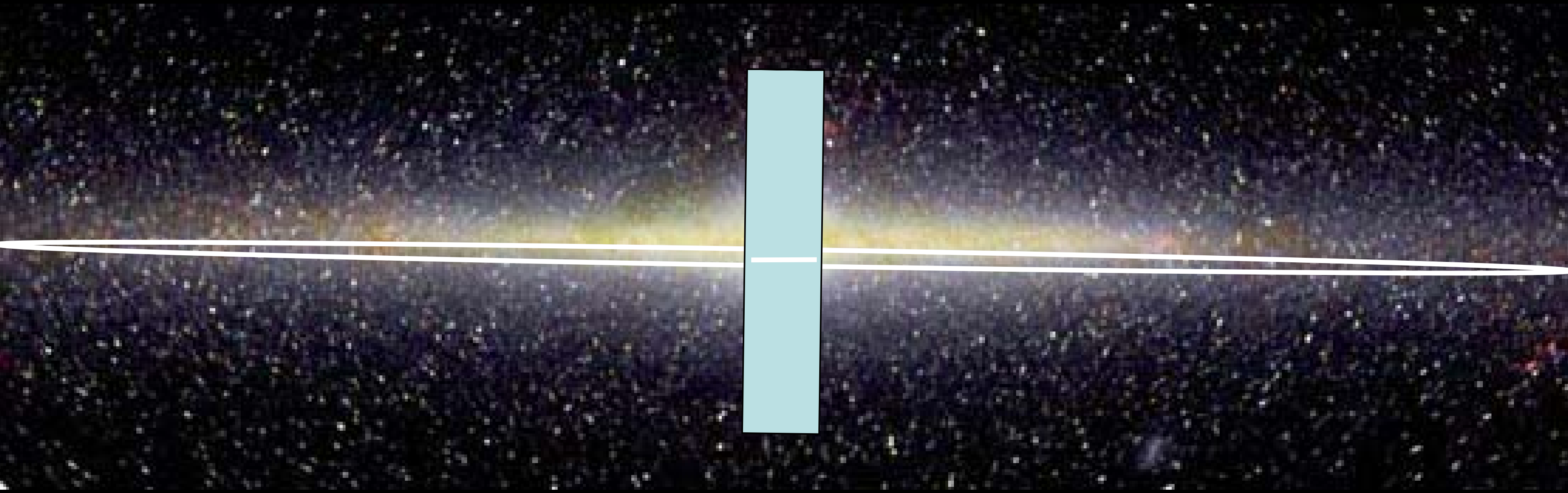
*ROG Coll.: CQG **19**, 5449 (2002)*
*L.S.Finn: CQG **20**, L37 (2003)*
P.Astone, G.D'Agostini, S.D'Antonio: CQG 20, 365 (2003) Proc. of GWDAW 2002, gr-qc/0304096
E. Coccia ROG Coll.:CQG 20, 395 (2003) Proc. of GWDAW 2002, gr-qc/0304004

The cross section of a bar detector depends on the wave propagation direction and polarization

$$\sigma_c = \frac{8}{\pi}\frac{G}{c^3} M v_s^2 \left[\sin^4(\theta)\cos^2(2\varphi)\right]$$







Sidereal hour 4.3

Indication:

- Hundreds events/year
- Signals at kHz frequencies ↔ NS or BH
- $E_s \sim 100$ mK; $h_{1ms} \sim 2\times10^{-18}$; $M_{gw} \sim 0.01\ M_o$

  $-M_{Galaxy} \sim 1\ M_o/y$
- From galactic disc

*Let us discuss further on the really unexpected **possibility** of GWs signals detectable today*

Is there an enormous number of compact object in our Galaxy?
The abundance of compact objects in our Galaxy is largely unknown because they emit little radiation unless they happen to be accreting material from a companion star, or, for NS, if they happen to emit pulsar radiation in our direction.

However, if we assume the mass loss of $1M_o$/y is due to a number of different sources distributed in the galactic disk,
It is difficult to imagine that its rate changed dramatically with time over the age of the Galaxy. The total mass loss over the history of the Galaxy turns out to be at least **$2\ 10^{10}\ M_o$**. For comparison, $M_{disk} \sim 6\ 10^{10}$

There are stringent limits on the mass loss coming from galactic dynamics
- effect on the radial velocity of stars
- outward motion of the LSR
- globular clusters

It turns out that it is difficult to reconcile the indicated mass loss of $1\ M_o$/y with these limits.

Different possibility *:

All bursts originates from a single, relatively close source, which periodically emits GW bursts.

For instance, if $r \sim 800$ pc,

$M_{gw} \sim 10^{-4}\ M_o$; $-M_{Galaxy} \sim 10^{-2}\ M_o/y$

No more "energetic" difficulties

Periodic behavior from compact objects ?
Example: X-ray bursters

* *E.C., F. Dubath, M.Maggiore: paper in preparation*

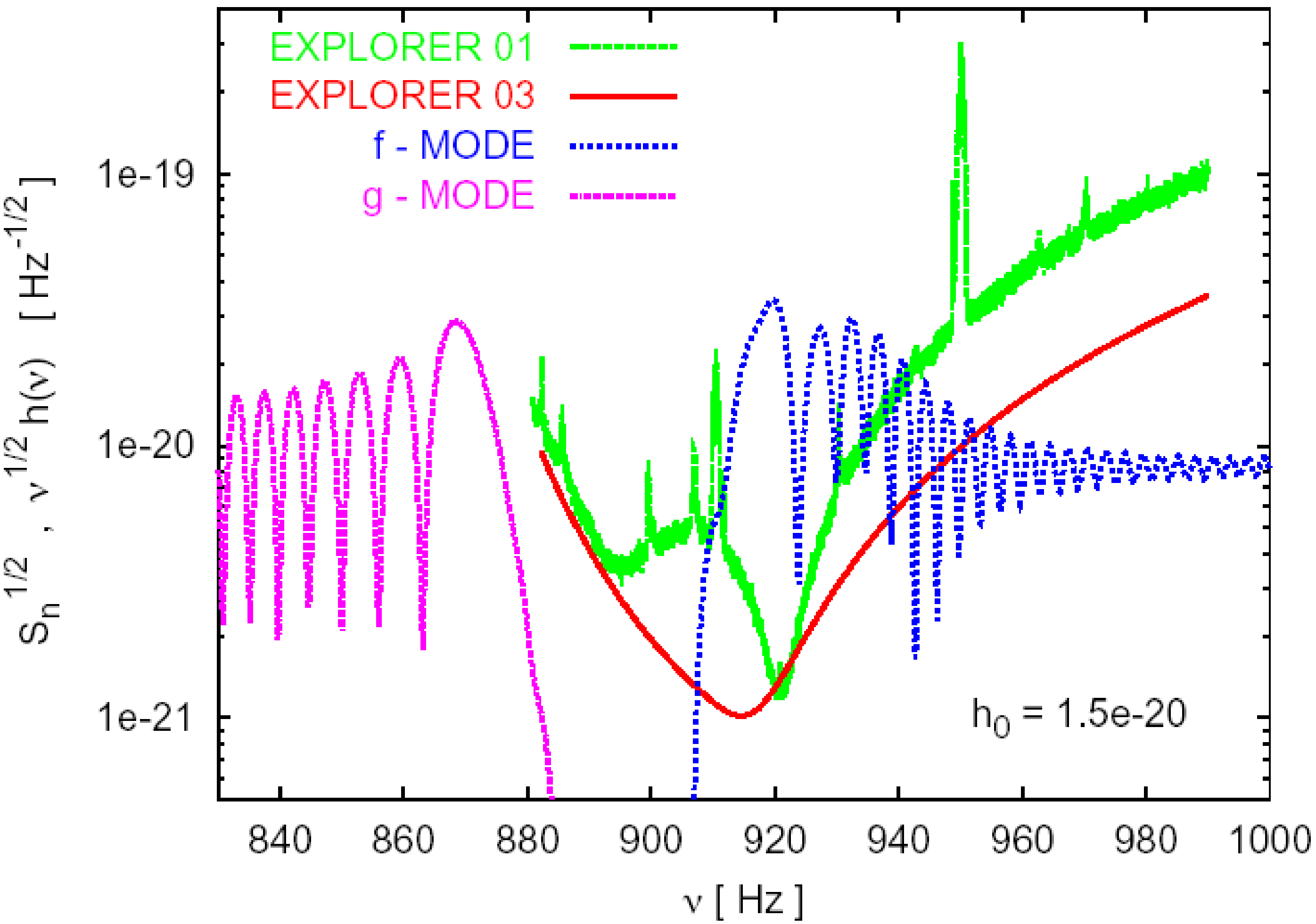
Candidate source:

Accreting neutron star, periodically undergoing structural changes (microcollapses) which are accompanied by excitation of NS quasi normal modes and emission of GWs

Structural change:

Phase transition from a hadronic to a quark-gluon phase. Energy gained in the transition ~ 0.15 $M_{\odot}c^2$,

It may be released in a periodic series of bursts?



V. Ferrari et al. (2002)

Table 1. The frequencies of the fundamental mode, of the first p mode and of the discontinuity g mode are shown for a set of stellar models with $M = 1.4\,\mathrm{M_\odot}$ and $\Gamma = 2$. For each star, the equilibrium parameters are also tabulated. The polytropic coefficient K is $K\,(1 + \Delta\rho/\rho_d)^2 = 180\,\mathrm{km}^2$, so that all stars have the same low-density equation of state. The first entry corresponds to a model with no density discontinuity.

R (km)	ρ_c (g cm^{-3})	$\sqrt{\bar{\rho}}$ (km^{-1})	ρ_d (g cm^{-3})	$\Delta\rho/\rho_d$	ν_f (kHz)	ν_p (kHz)	ν_g (kHz)
13.44	0.92×10^{15}	0.0292	–	0.0	1.666	4.045	–
12.04	1.39×10^{15}	0.0344	3×10^{14}	0.1	1.998	4.637	0.504
12.22	1.36×10^{15}	0.0337	4×10^{14}	0.1	1.962	4.548	0.567
12.42	1.32×10^{15}	0.0329	5×10^{14}	0.1	1.915	4.459	0.613
12.65	1.27×10^{15}	0.0319	6×10^{14}	0.1	1.857	4.365	0.644
12.92	1.19×10^{15}	0.0310	7×10^{14}	0.1	1.792	4.260	0.659
13.21	1.11×10^{15}	0.0300	8×10^{14}	0.1	1.723	4.146	0.658
13.43	1.02×10^{15}	0.0292	9×10^{14}	0.1	1.670	4.052	0.641
10.71	2.17×10^{15}	0.0410	4×10^{14}	0.2	2.408	5.325	0.840
10.99	2.07×10^{15}	0.0395	5×10^{14}	0.2	2.330	5.155	0.912
11.35	1.95×10^{15}	0.0376	6×10^{14}	0.2	2.226	4.970	0.961
11.83	1.77×10^{15}	0.0354	7×10^{14}	0.2	2.088	4.750	0.987
12.50	1.51×10^{15}	0.0325	8×10^{14}	0.2	1.901	4.452	0.979
13.38	1.15×10^{15}	0.0294	9×10^{14}	0.2	1.680	4.072	0.906
8.68	4.44×10^{15}	0.0562	5×10^{14}	0.3	3.216	6.683	1.211
9.13	3.95×10^{15}	0.0521	6×10^{14}	0.3	3.039	6.325	1.281
9.66	3.46×10^{15}	0.0479	7×10^{14}	0.3	2.831	5.953	1.326
10.41	2.88×10^{15}	0.0428	8×10^{14}	0.3	2.553	5.506	1.339
12.15	1.87×10^{15}	0.0340	9×10^{14}	0.3	2.002	4.632	1.251

Miniutti et al. MNRAS 338, 389 (2003)

A nearby periodic burst source:

Overcomes the energetic difficulties

Can explain the narrow peak in the sidereal time analysis

It is a definite hypothesis that is possible to test on further data