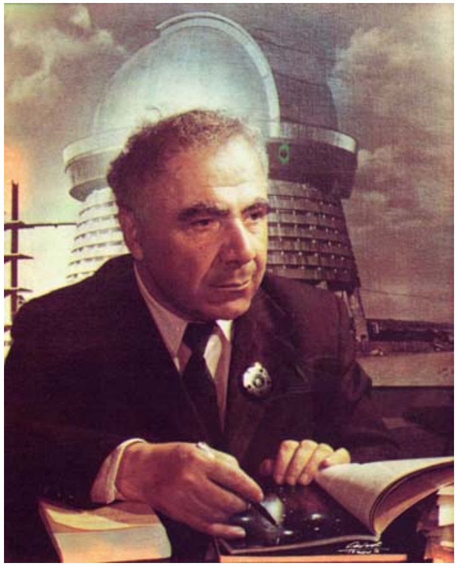
Gravitational wave sources in medium frequency band



- Avetis Abel Sadoyan
- D.Sedrakian
- M.Hairapetyan

Yerevan State University

Funded by ANSEF PS-astroth-1389

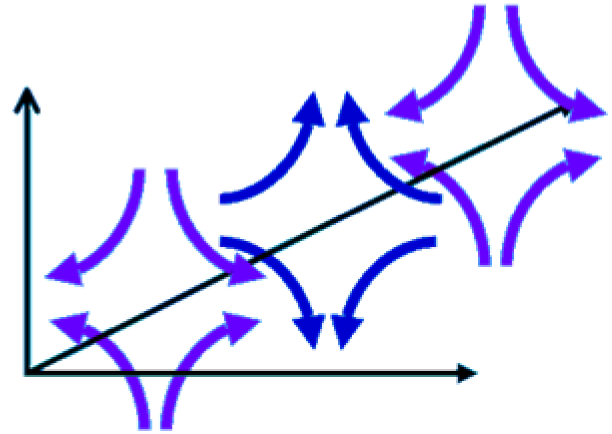
FAR
FUND FOR ARMENIAN RELIEF

Gravitational Waves

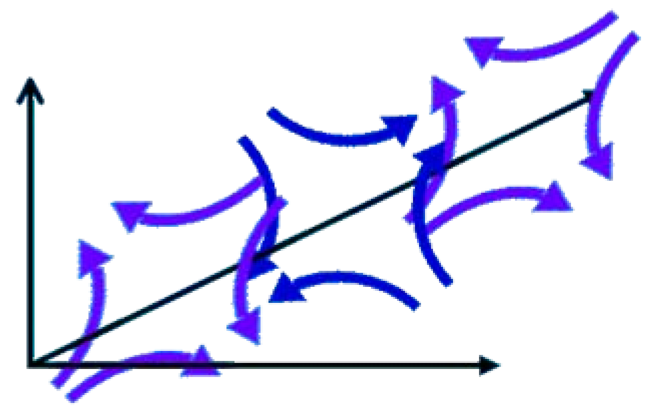
- Ripples in Spacetime
- Predicted Theoretically in 1916(Einstein),
- Initially were misinterpreted as coordinate waves: waves that have no physical meaning, that can disappear due to the change of coordinate frame (Eddington 1922)
- Piranii (1956) showed what will happen to experimental particles under GW

Perturbations of Space-Time

- that are described by wave equation

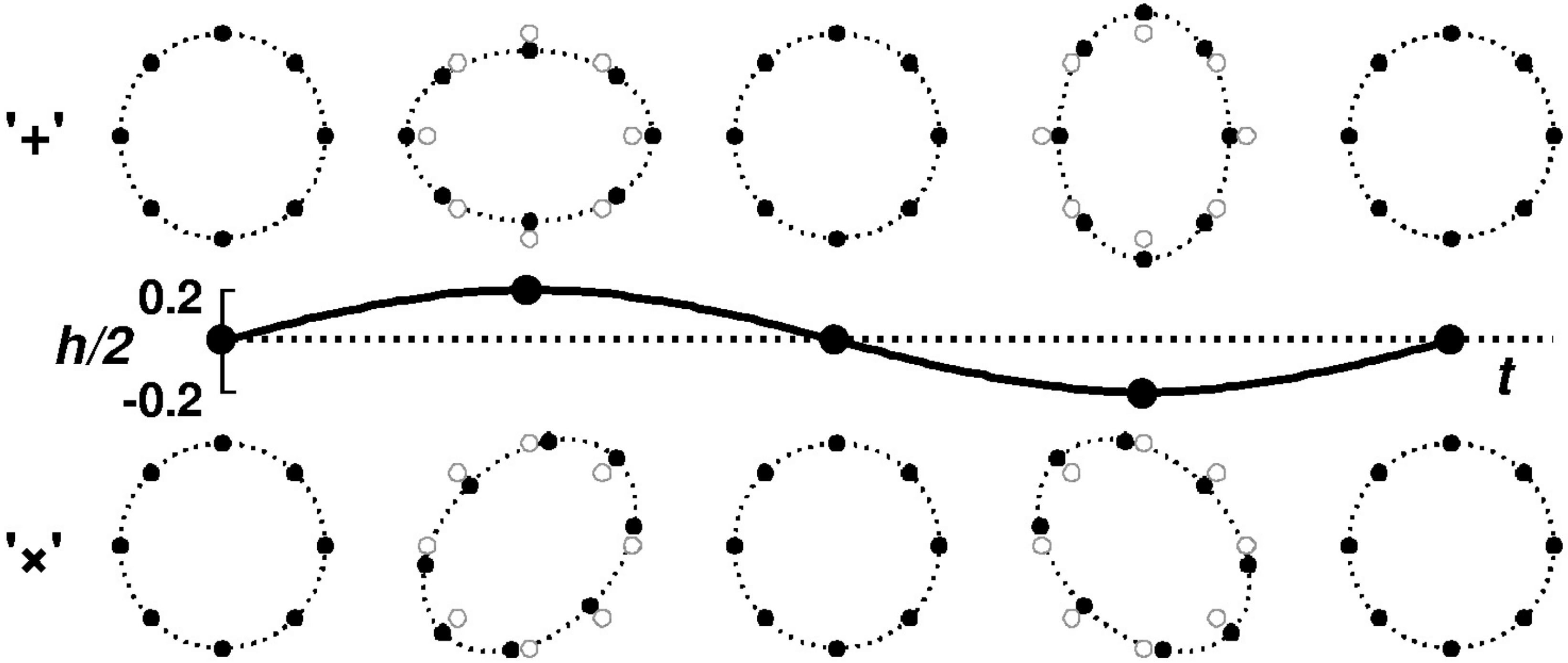


h_+



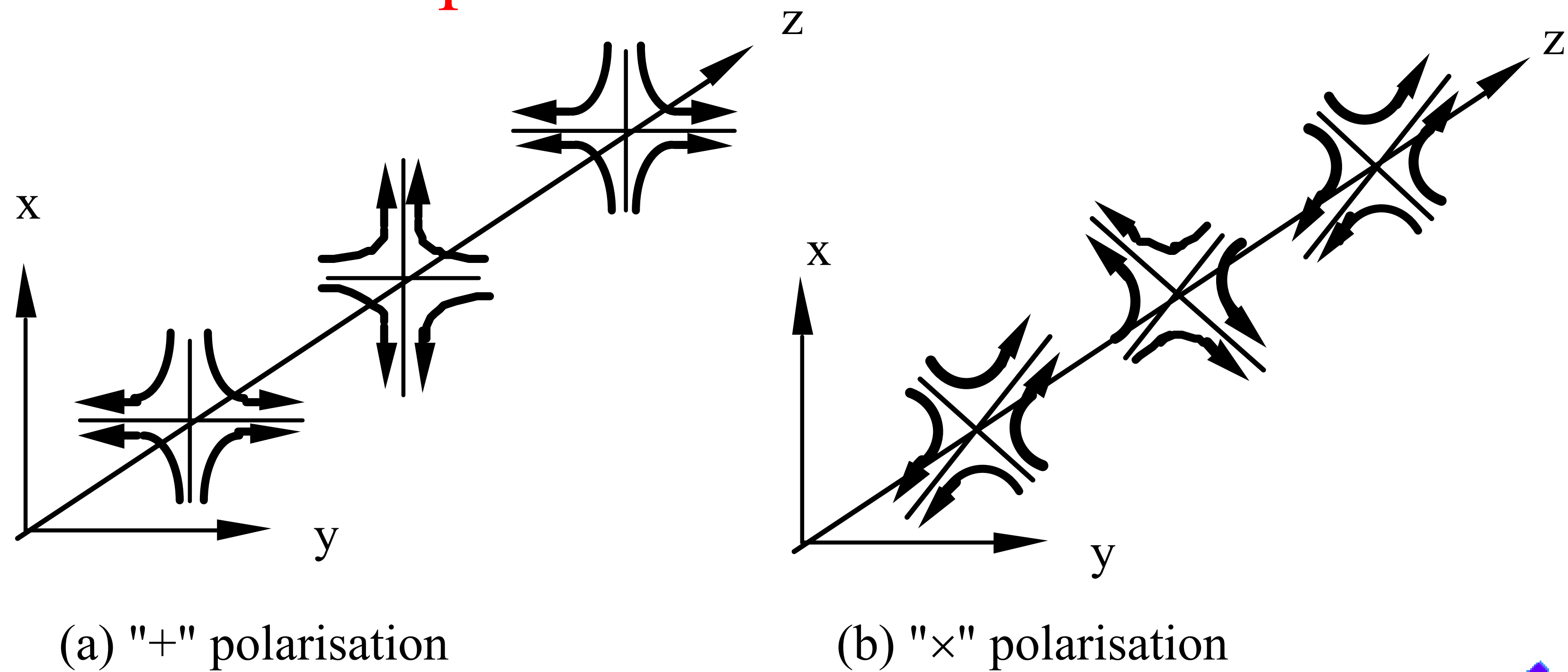
$h_\times$

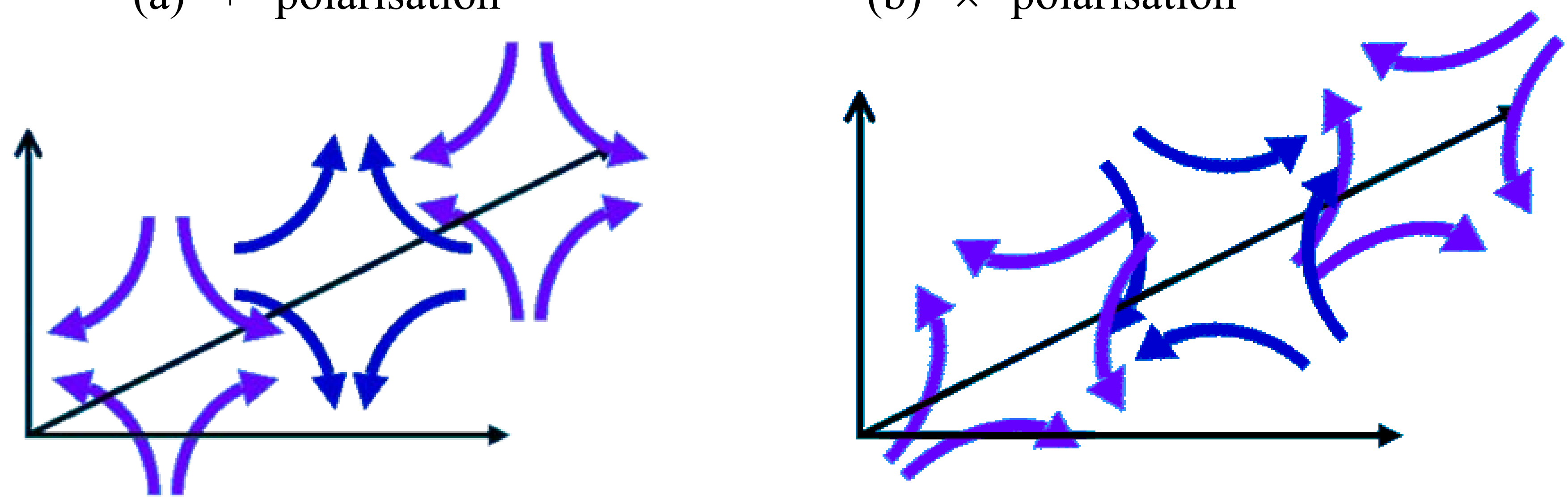
Two polarizations of Gravitational Wave interacting with experimental Particles



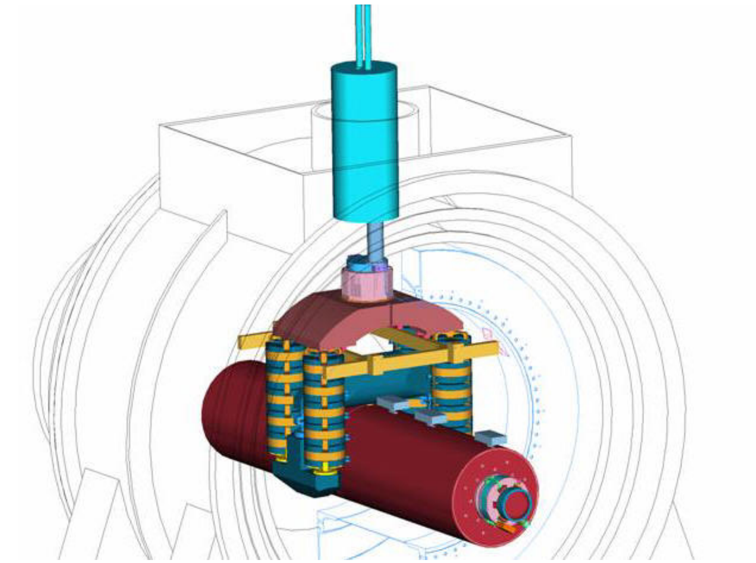
$$h = \frac{2\Delta L}{L}$$

Plane wave polarizations

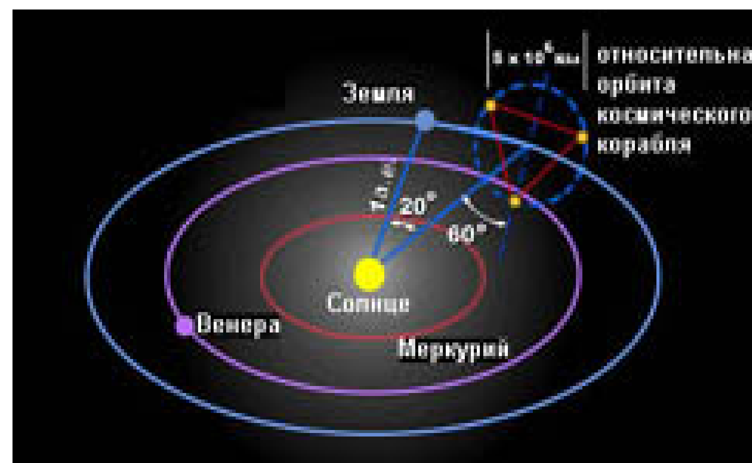




Types of GW Detectors

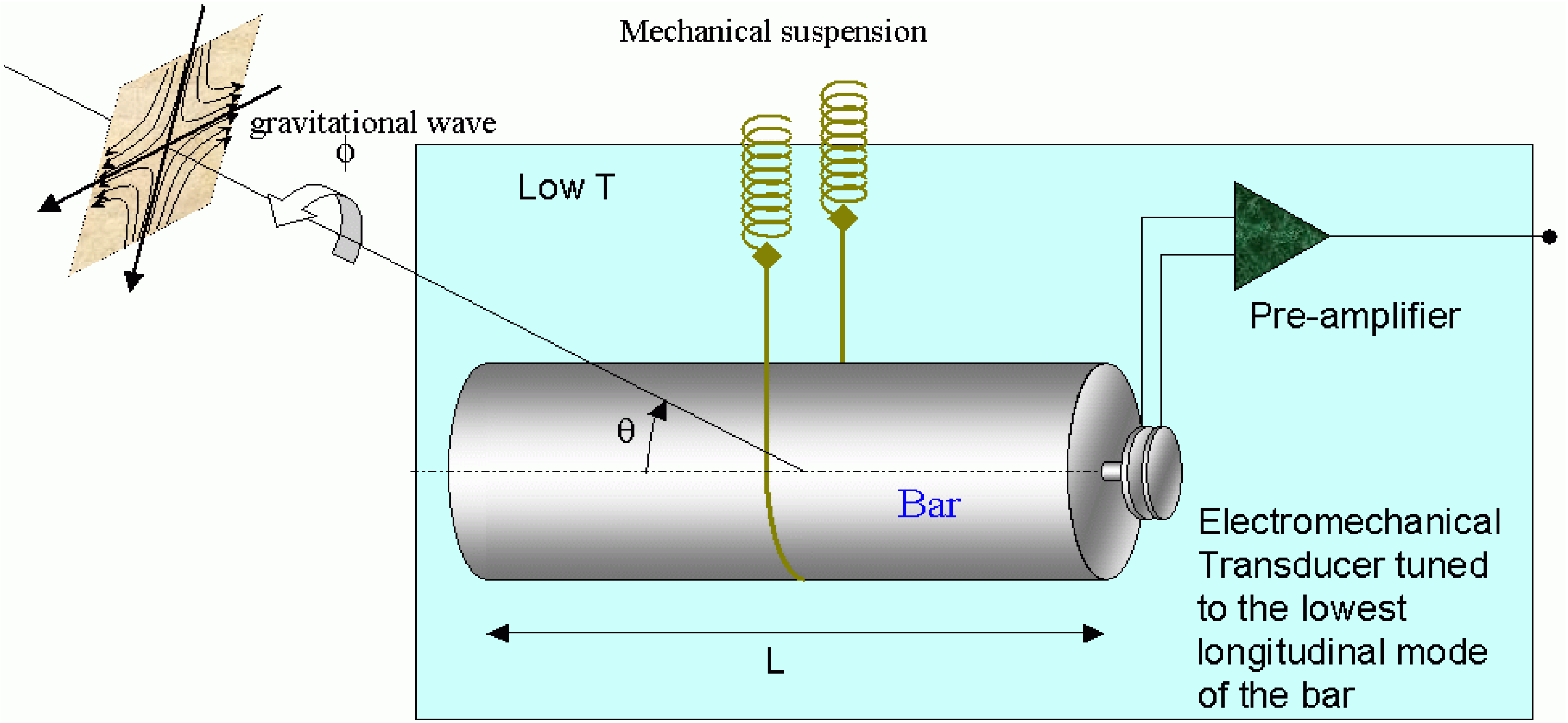


- Resonant Bar Detectors
- Laser Interferometers
- Einstein Telescope 2008
- Space based Interferometers



- PPT Pulasar Timing Array

Bar Detectors

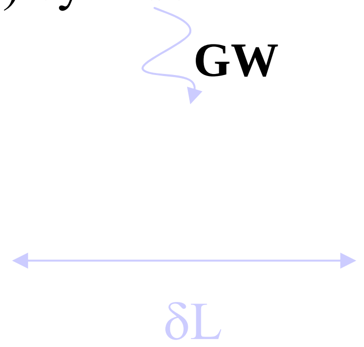


G. W. DETECTORS: Components and Noises

The GW excites the longitudinal mode of vibration of a massive (~2 ton) cylinder

$$h = \frac{\Delta L}{L}$$

$$K(f) = \frac{S(f)e^{-i2\pi f t_0}}{N(f)}$$



Mechanical vibration — Electrical signal

→ TRANSDUCER → AMPLIFIER → DATA → Matched Filtering

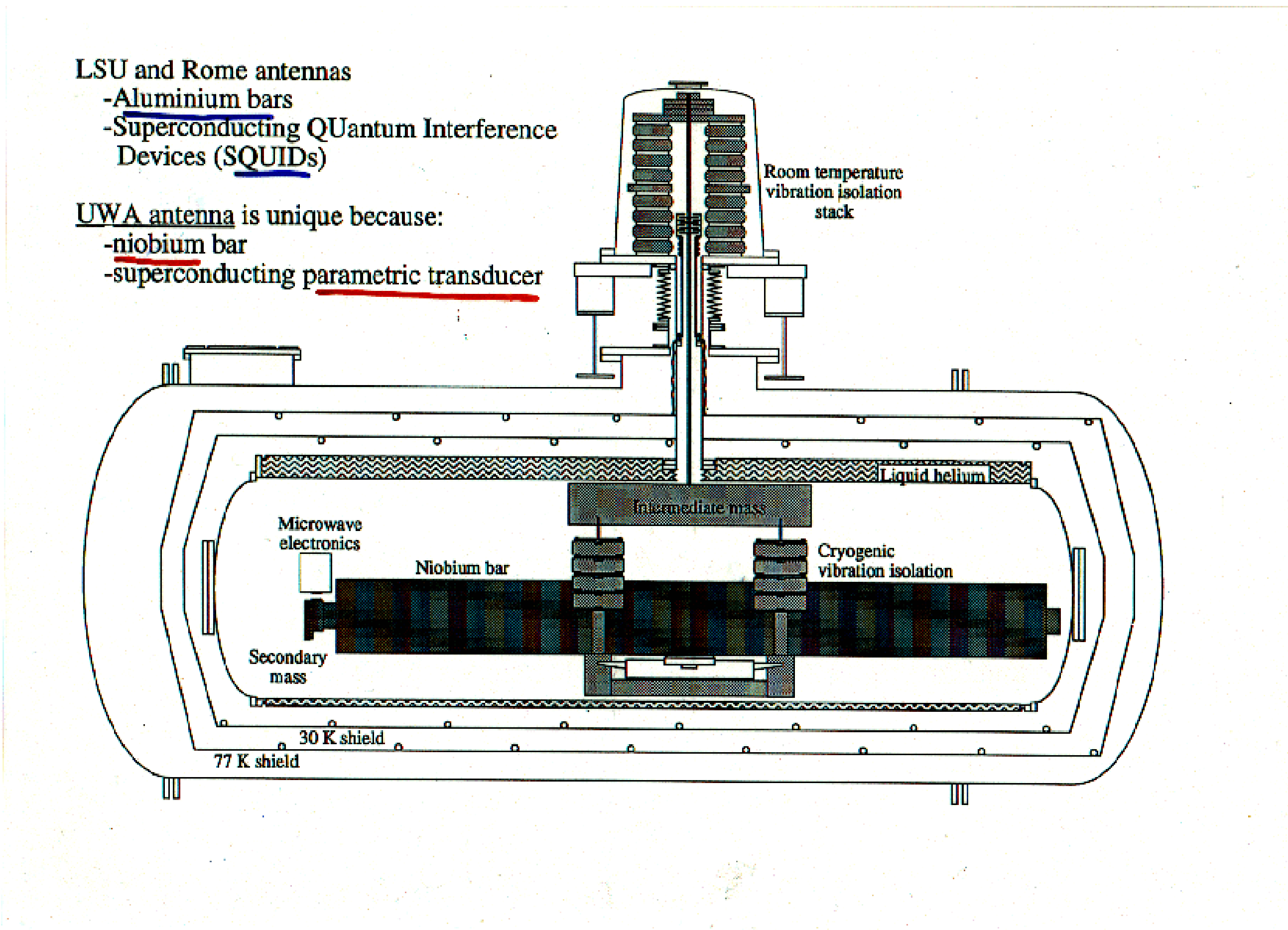
Seismic noise → Mechanical filters

Thermal noise → Low and ultralow temperature

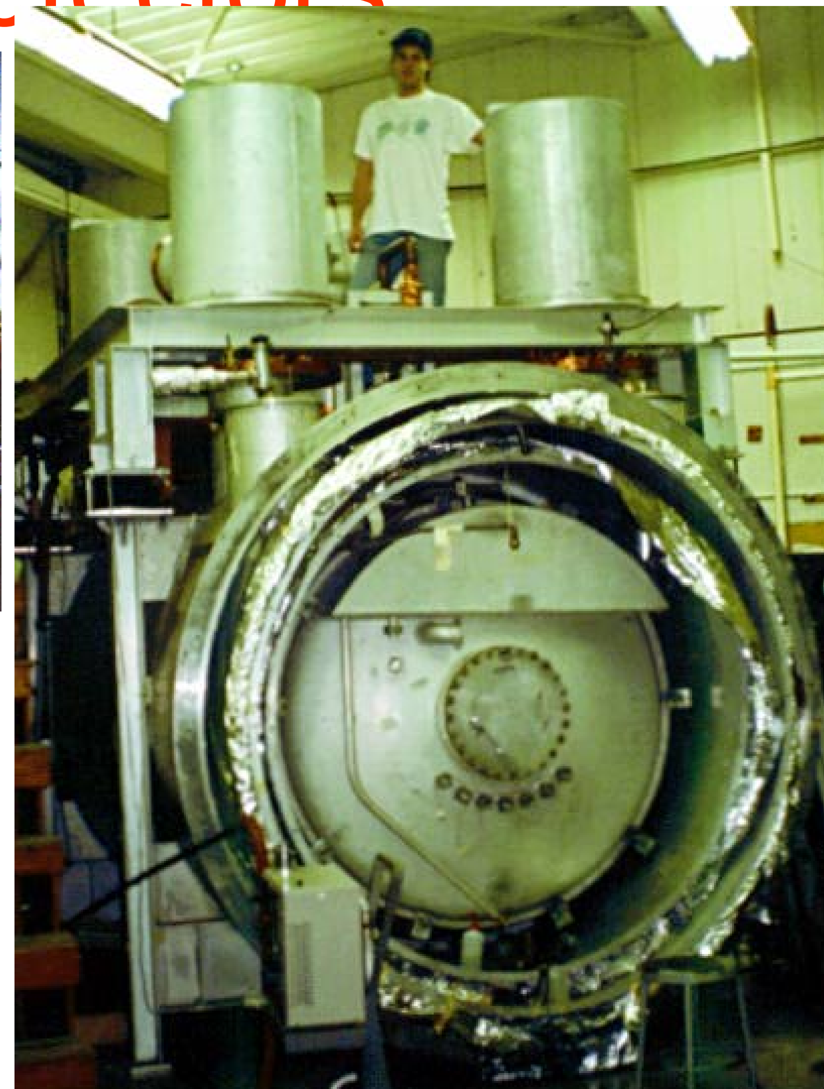
Electronics noise → Low noise amplifier (SQUID)

Cosmic ray noise → Veto

Bar Detectors

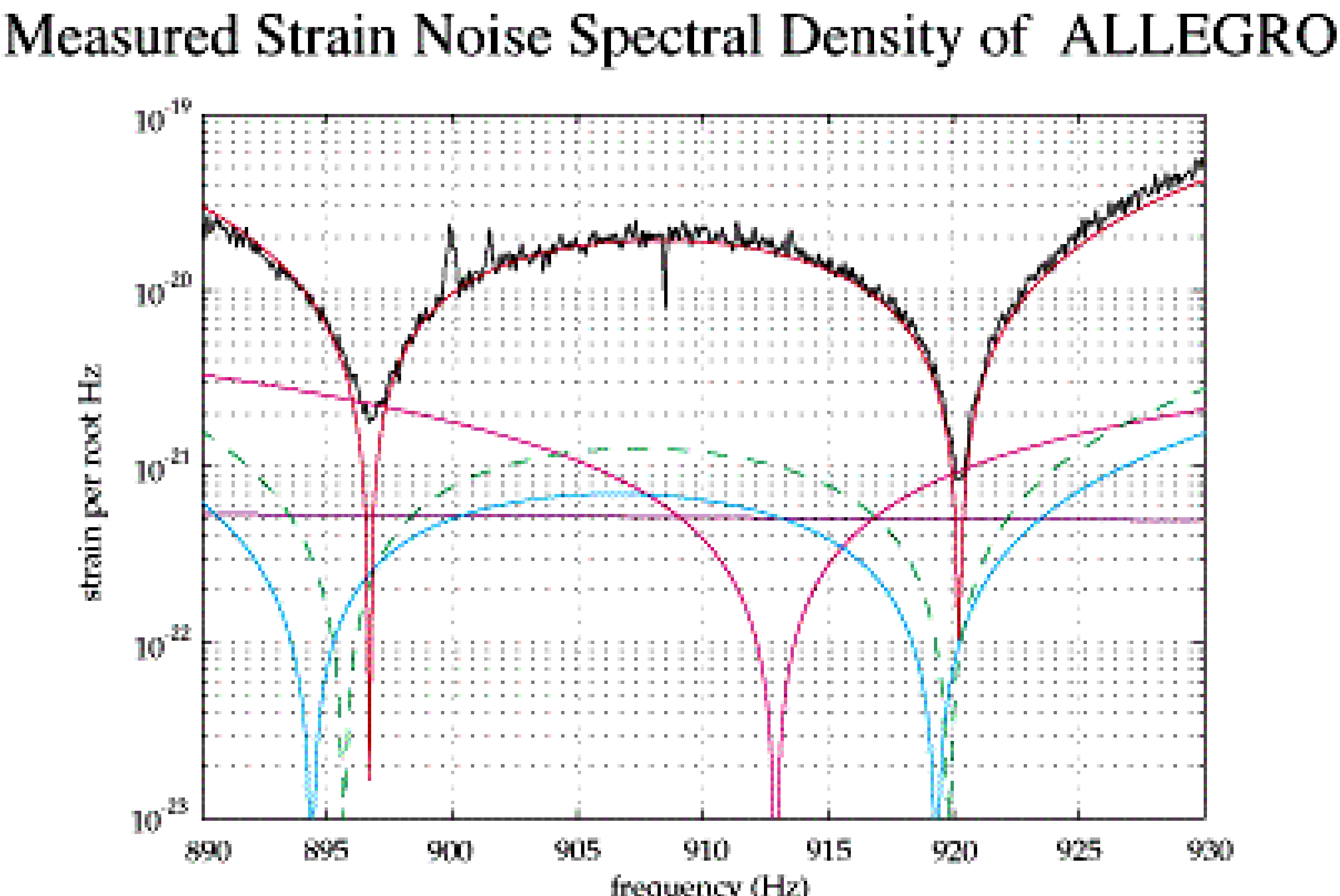


Bar Detectors



Bar Detectors

Bar Detectors



WIDENING THE BAND IN EXPLORER

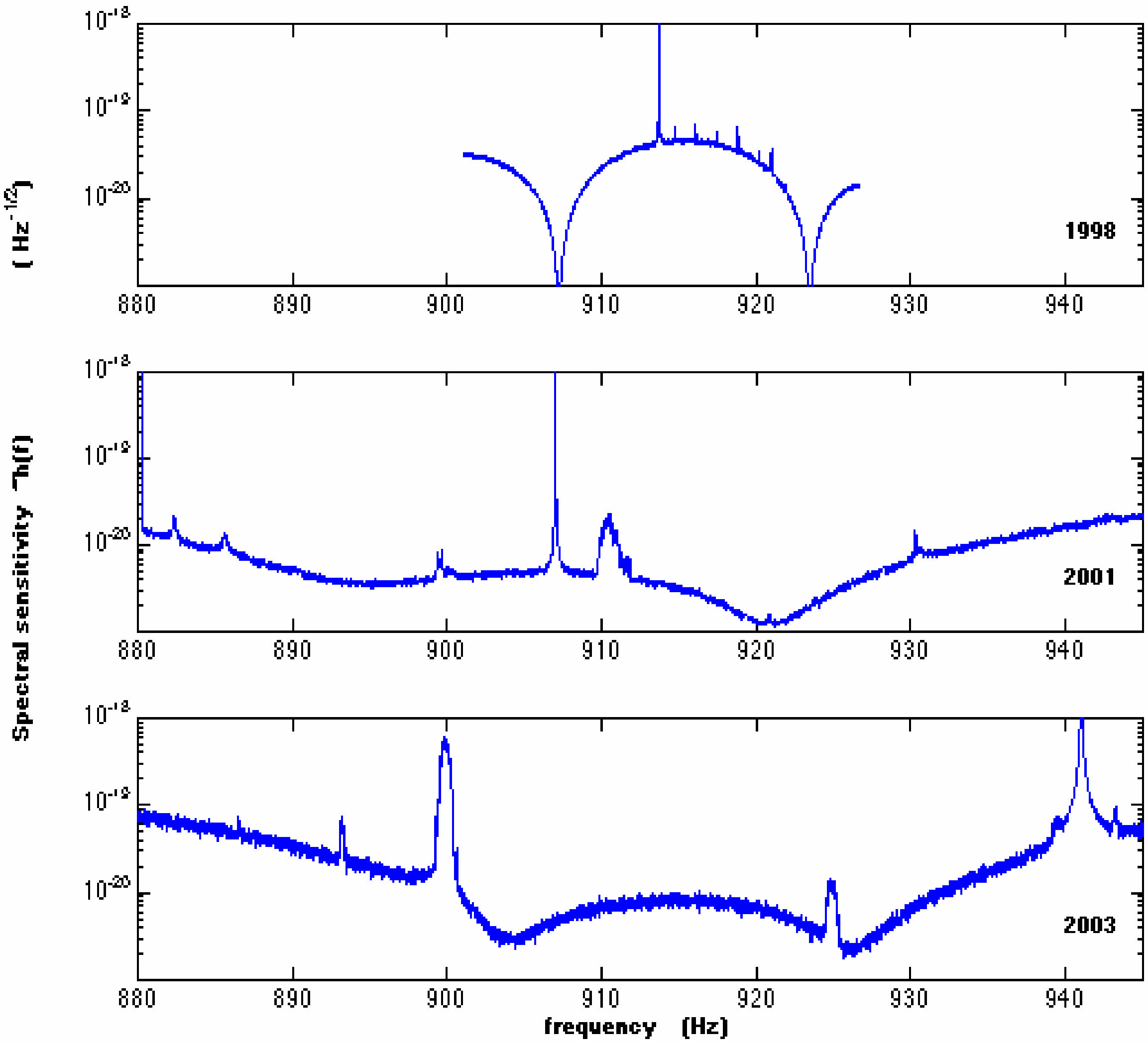
EXPLORER has been on the air since May 2000 with:

-new, 10 μm gap transducer

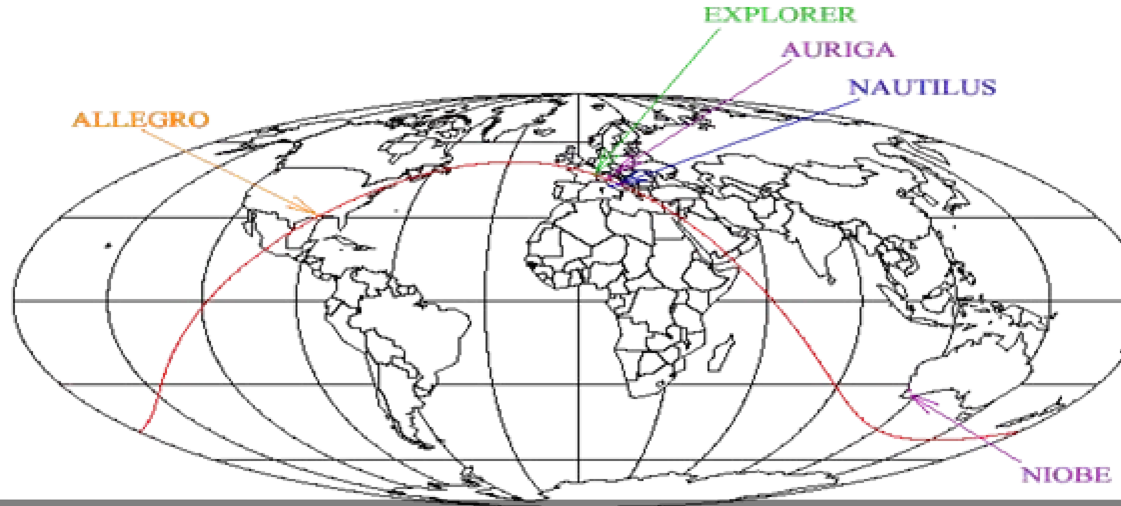
-New, high coupling SQUID

The noise temperature is < 3 mK for 84% of the time.

Bandwidth: the detector has a sensitivity better than 10^{-20} $Hz^{-1/2}$ on a band larger than 40 Hz



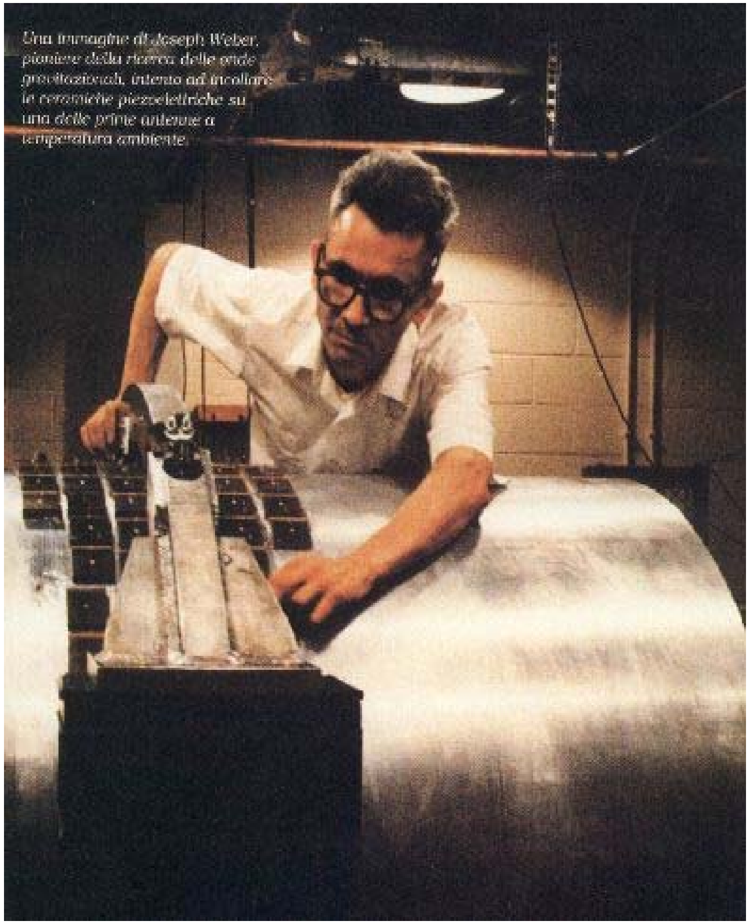
I.Resonant Bar Detectors



Name	Place	Position	Bar	L	2R	Hz	Date	T
ALLEGRO	Baton Rouge Louisiana	30°27'45"N 91°10'44"W	2300kg	3m	0.6m	~900hz	1991	4.2 K
AURIGA	Lengaro Italy	45°21'12"N 11°56'54"E	2300kg	3m	0.6m	~1Khz	1997	0.2 K
EXPLORER	Geneva Switzerland	46°27'N 6°12'E	2270kg	3m	0.6m	904.7hz 921.3hz	1989	2.6 K
NAUTILUS	Rome Italy	41°49'26"N 12°40'21"E	2300kg	3m	0.6m	908hz 924hz	1994	0.1 K
NIOBE	Perth Western Australia	31°56'S 115°49'E	1500kg			~700hz	1993	5.0 K

RESONANT DETECTORS:

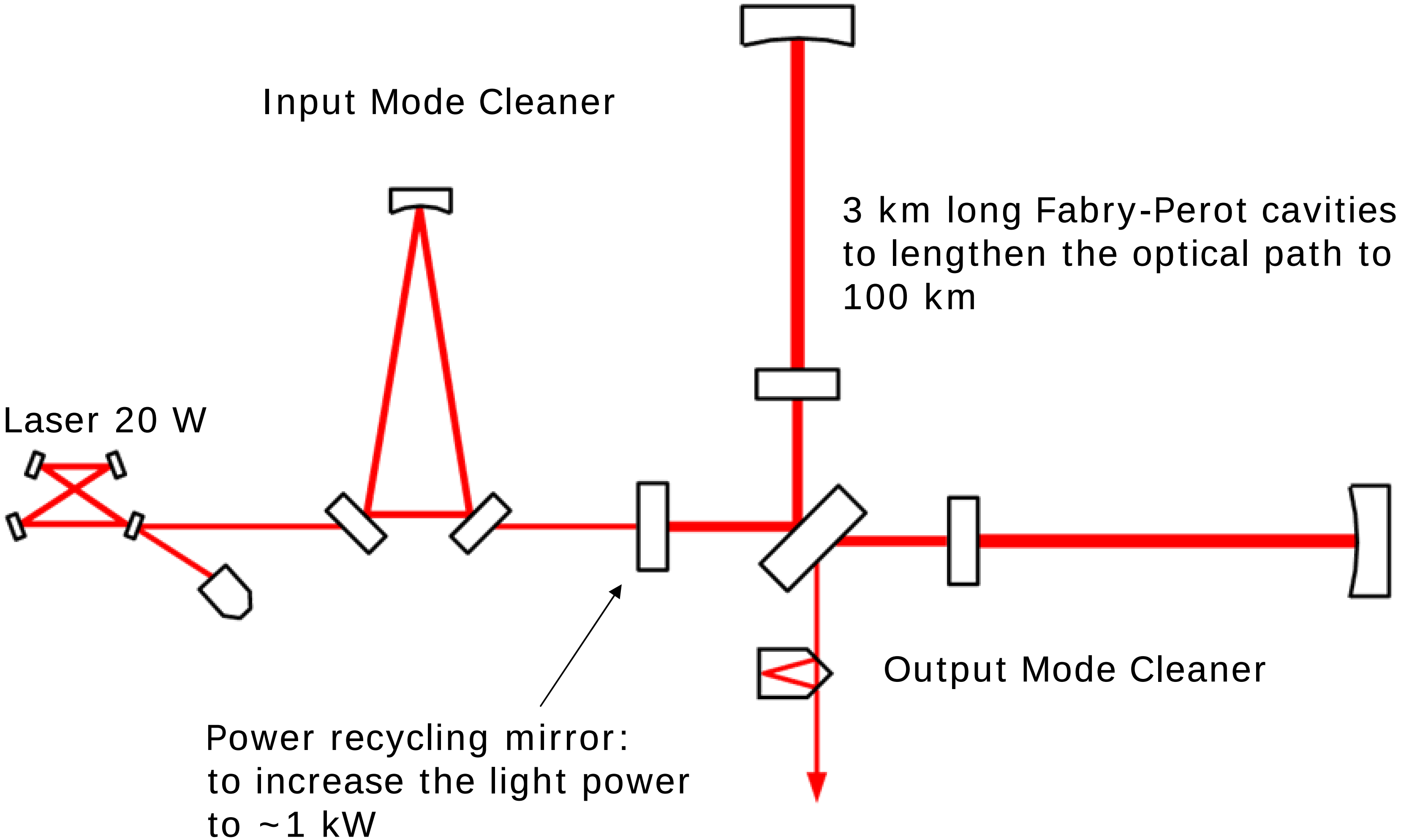
Past



J.Weber

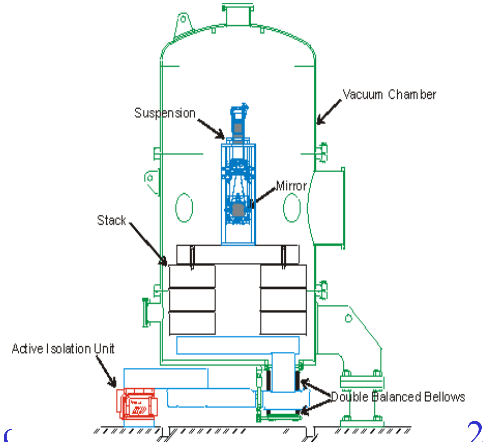
Future

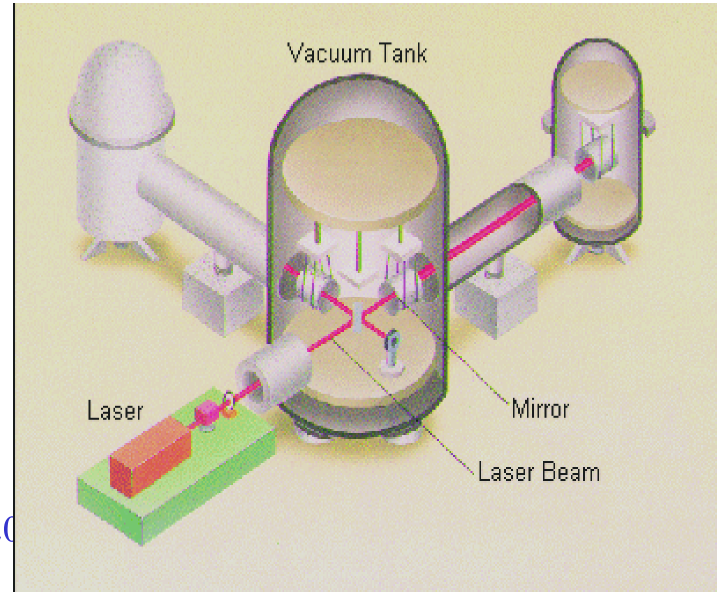
II Generation Detectors: Interferometers



Interferometers

- LIGO 2x 4000m
- VIRGO 1x 3000m
- GEO 1x 600m
- TAMA 1x 300m
- AIGO 0x 500m

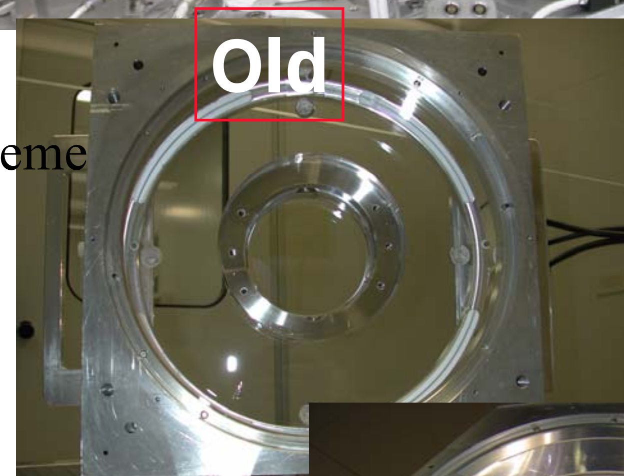




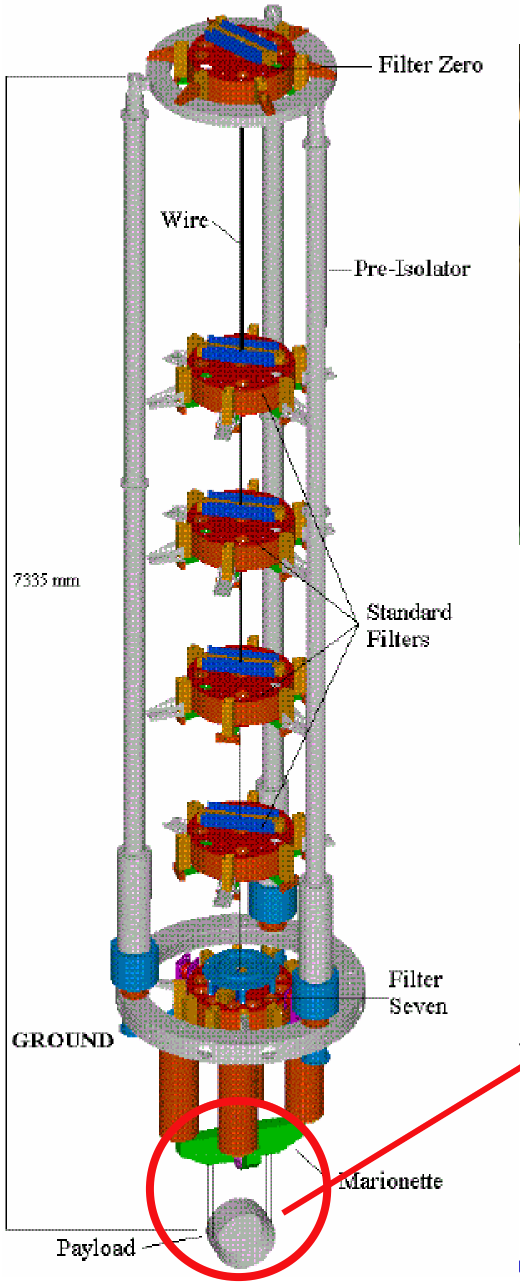
Activity after C6/C7

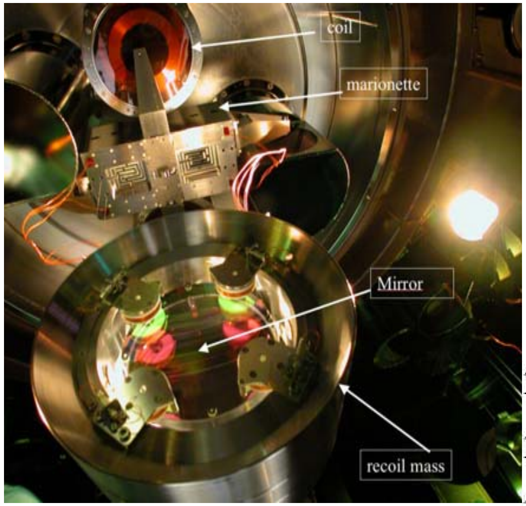
- **Shut down: end of September 05**
- **New injection bench:**
    - Toward the nominal power
  - Full redesign
  - Faraday isolator
  - New Input Mode cleaner alignment scheme

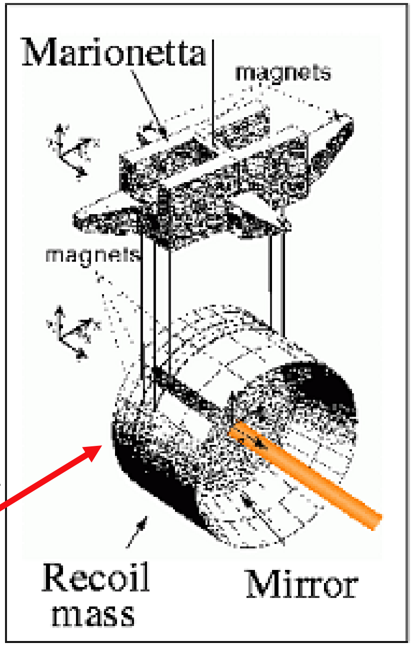
- **New Recycling mirror**
- Go to a monolithic mirror (flat geometry)
- Change the input telescope
- Use parabolic mirror on the "injection bench"
- Adjusting the reflectivity (92%-95%)
- increase of the recycling factor
- 750W expected on the beam splitter
  - x30 compared to C7
- **Back to vacuum: end of November 05**

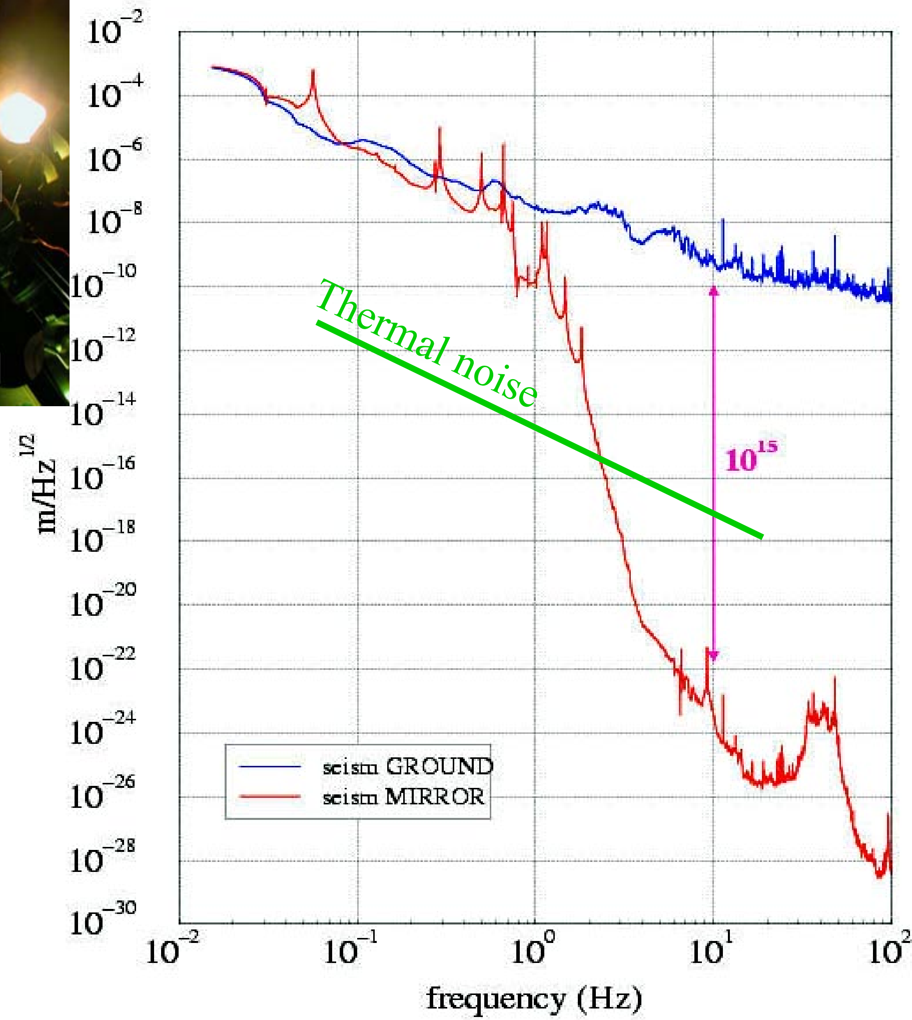


Free falling test masses

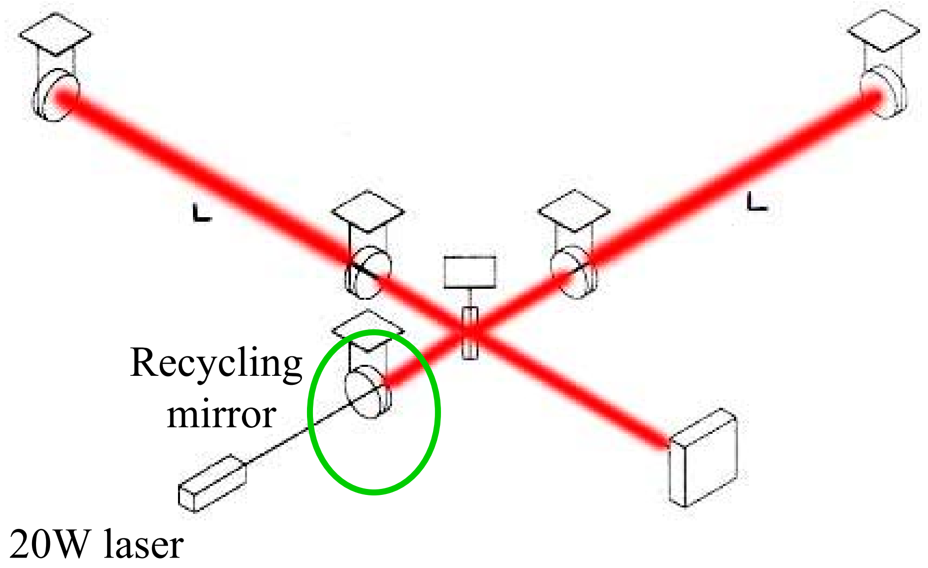








1 kW Power ?



- P_{eff}= *Recycling factor* $\cdot P_{in}$ 20 W → 1 KW
- Shot noise reduced by a factor ~7
- One more cavity to be controlled

Optics requirements

- Recycling finesse*Arms finesse = 2500

  → mirror loss<< 1/2500

Mirror losses :

poor reflectivity

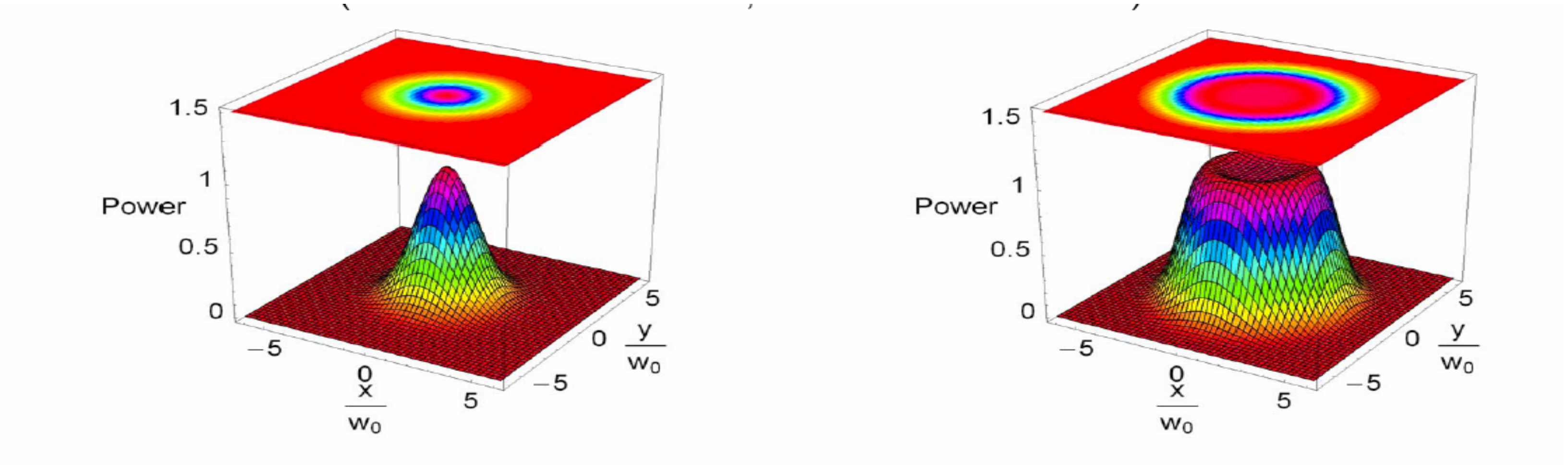
coating and substrate absorption

scattered light

polishing

local defects, dust

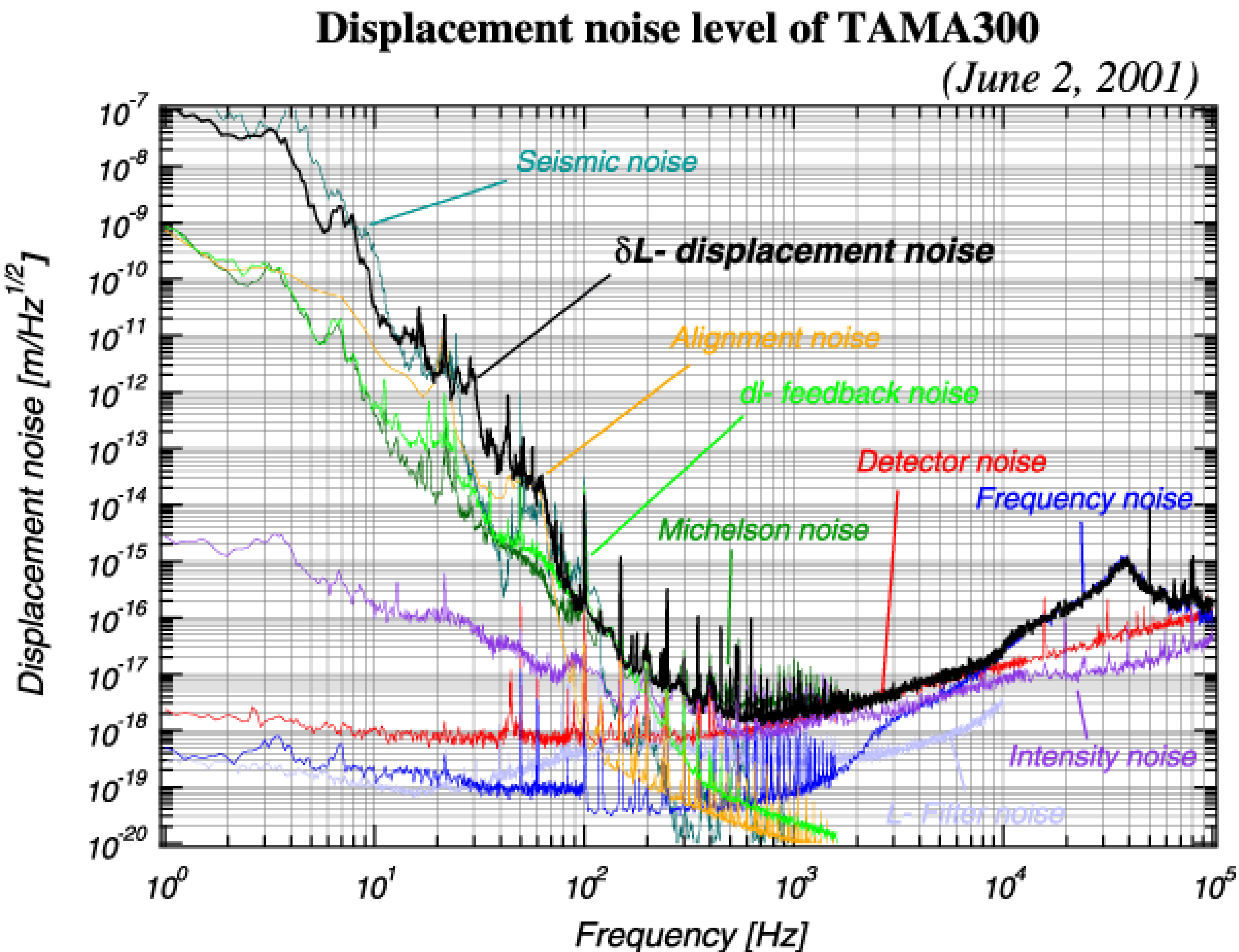
Flat beams



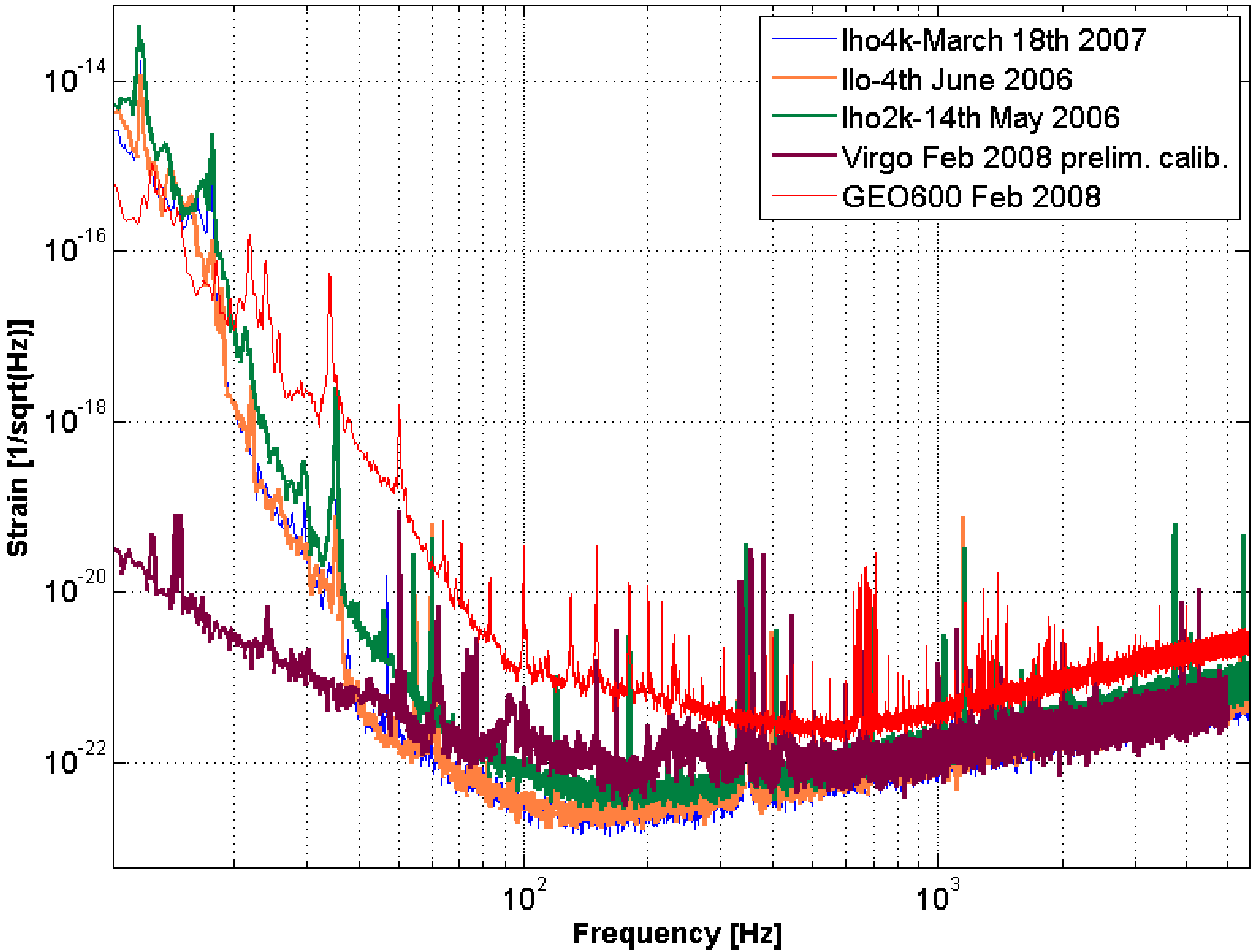
Advantages of the flat beams:

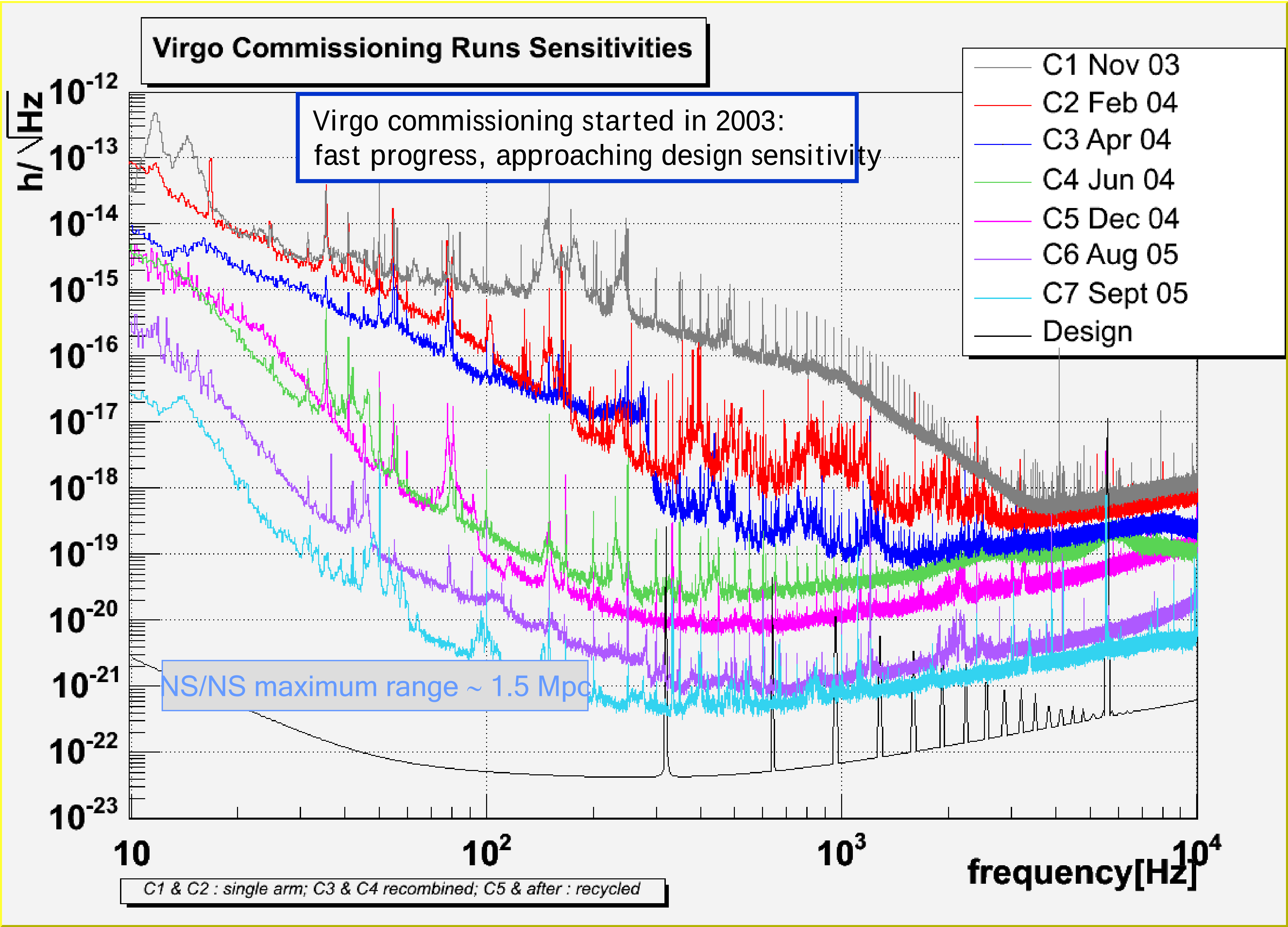
– Better averaging of the mirror thermal fluctuations → lower noise (2-3 times)

Interferometers

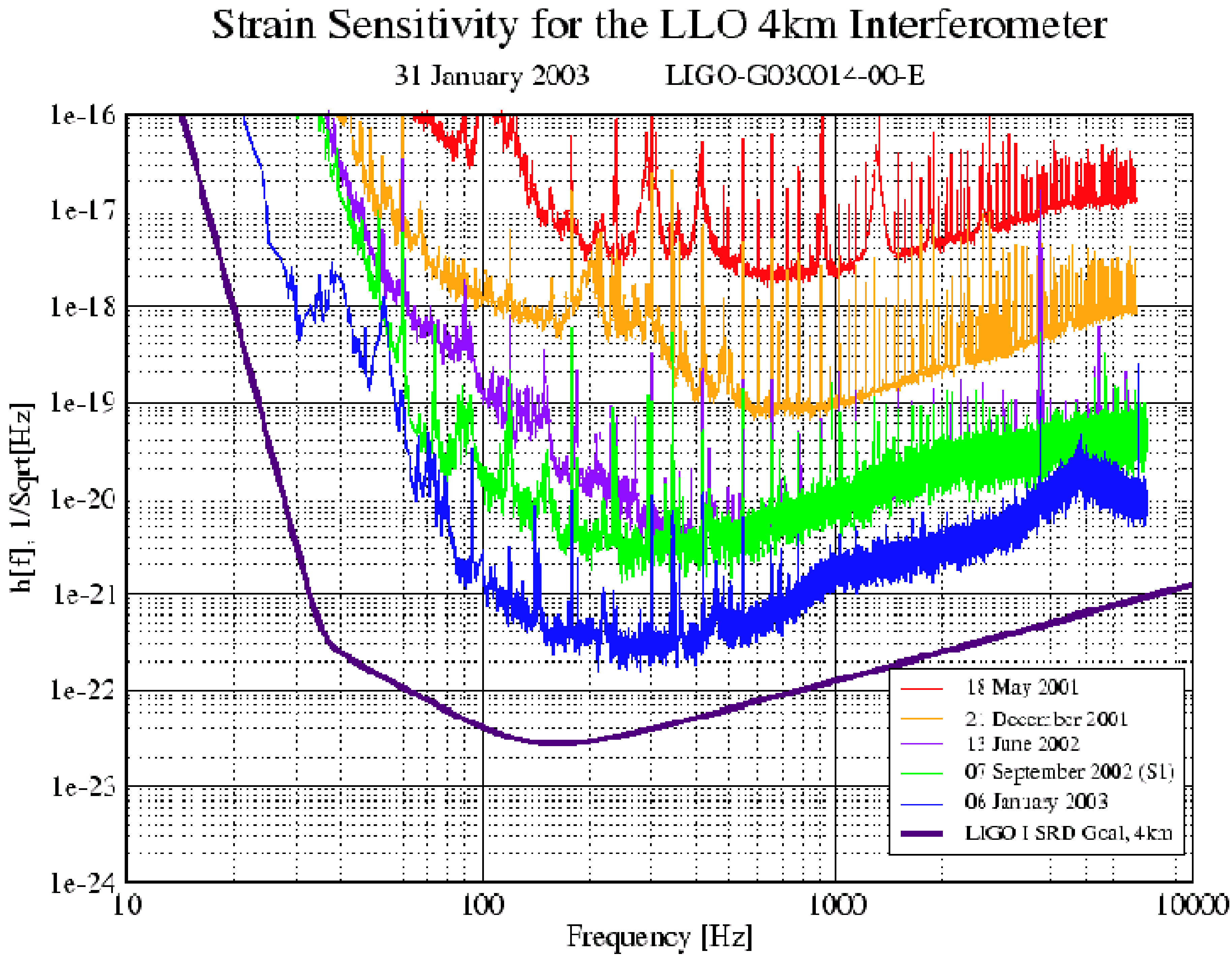


Current / S5 Sensitivities



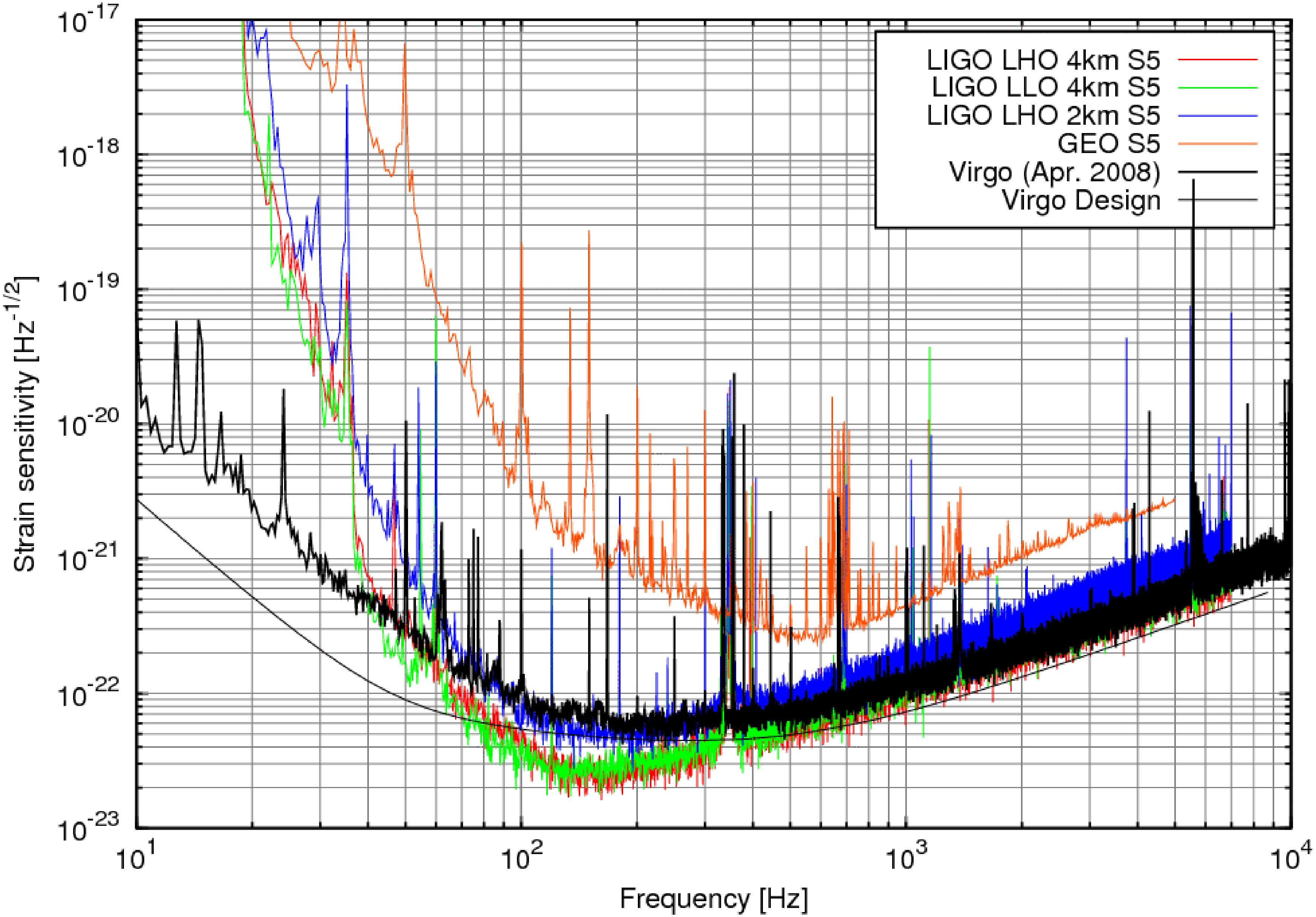


Virgo Commissioning Runs Sensitivities
Virgo commissioning started in 2003:
fast progress, approaching design sensitivity
C1 Nov 03
C2 Feb 04
C3 Apr 04
C4 Jun 04
C5 Dec 04
C6 Aug 05
C7 Sept 05
Design
h/√Hz
10-12
10-13
10-14
10-15
10-16
10-17
10-18
10-19
10-20
10-21
10-22
10-23
NS/NS maximum range ~ 1.5 Mpc
10
102
103
104
frequency[Hz]
C1 & C2 : single arm; C3 & C4 recombined; C5 & after : recycled

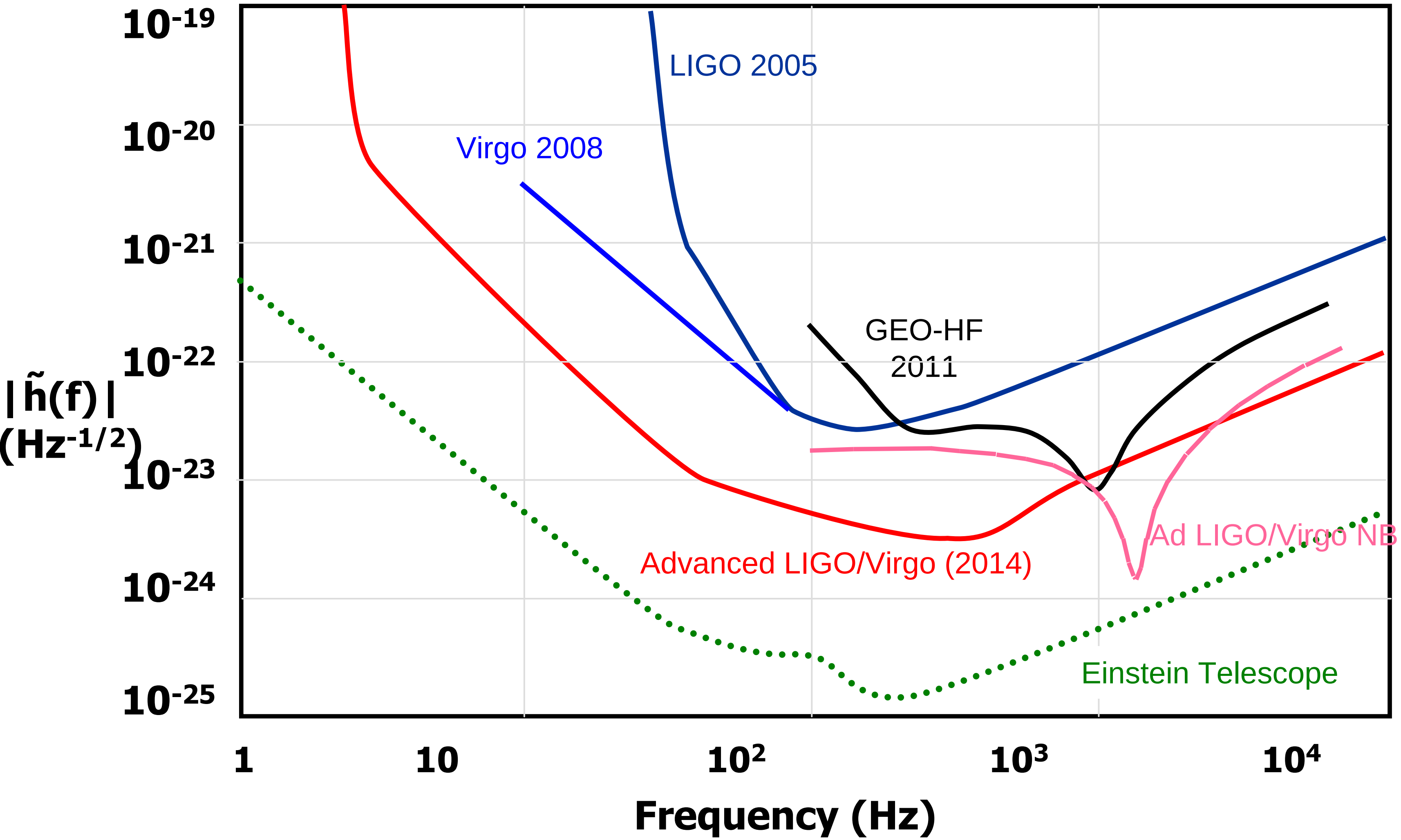


Strain Sensitivity for the LLO 4km Interferometer
31 January 2003
LIGO-G03C014-00-E
h[f], 1/Sqrt[Hz]
Frequency [Hz]
1e-16
1e-17
1e-18
1e-19
1e-20
1e-21
1e-22
1e-23
1e-24
10
100
1000
10000
18 May 2001
21 December 2001
13 June 2002
07 September 2002 (S1)
06 January 2003
LIGO I SRD Goal, 4km

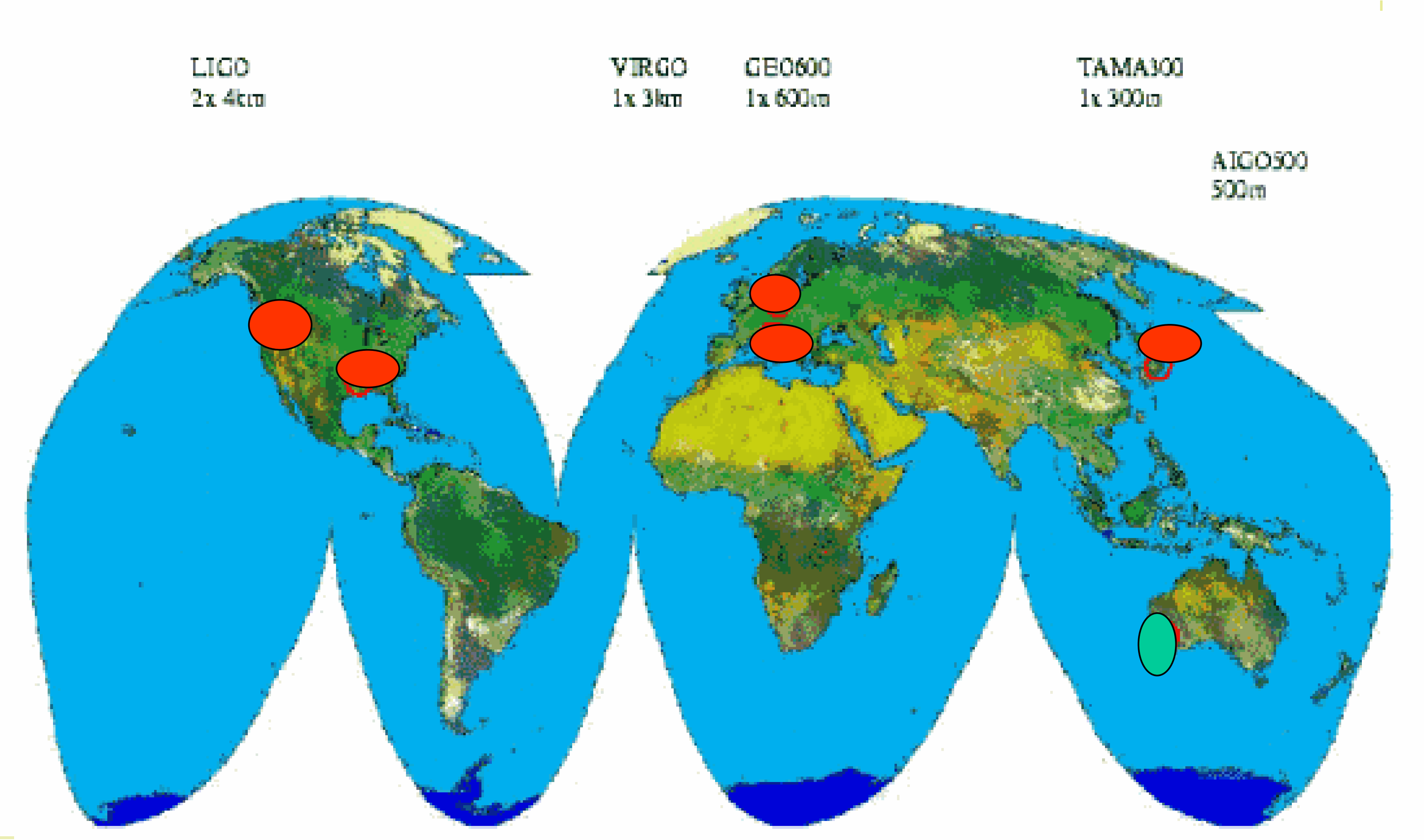
Virgo sensitivity: April 2008



Sensitivities

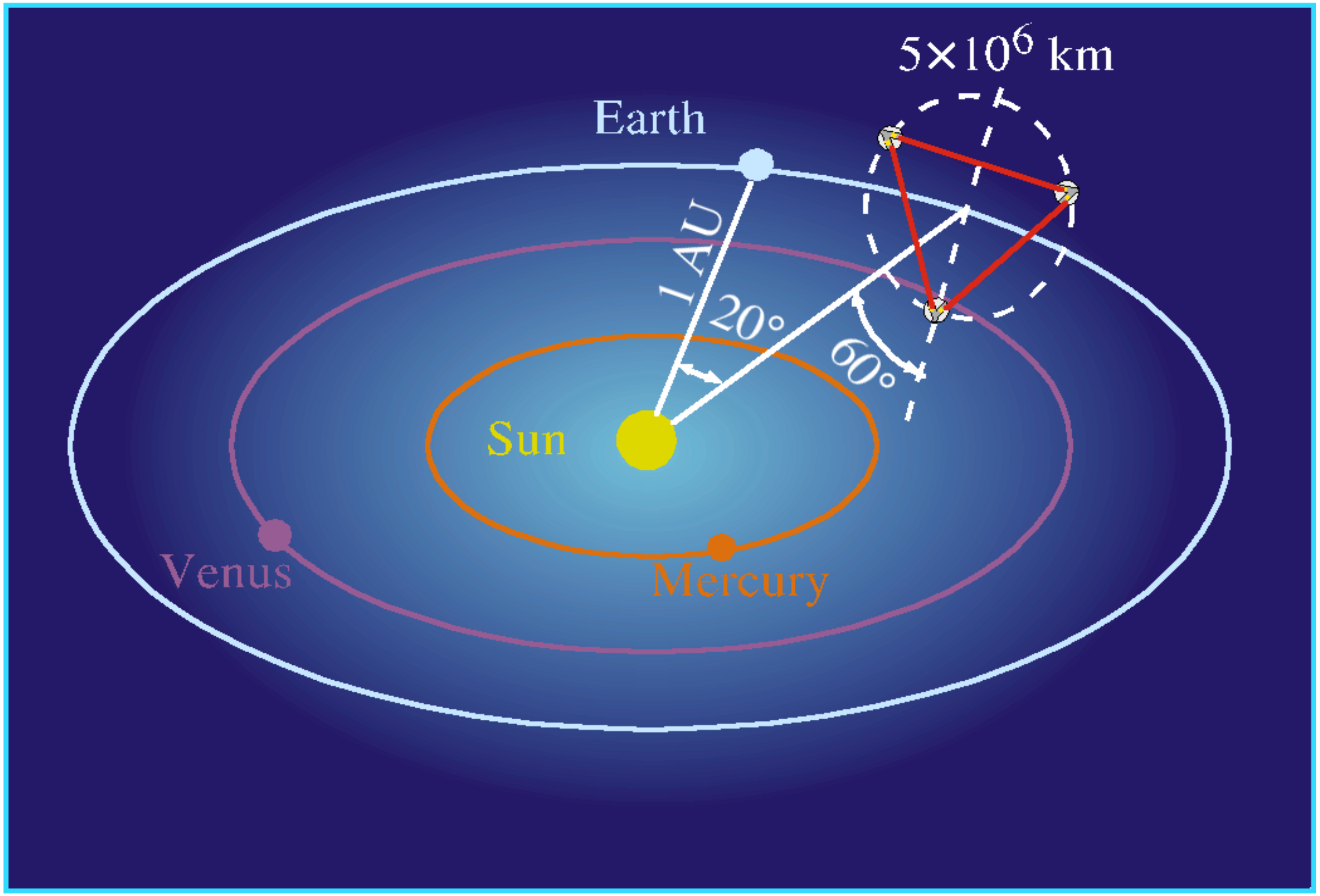


Laser Interferometers in World

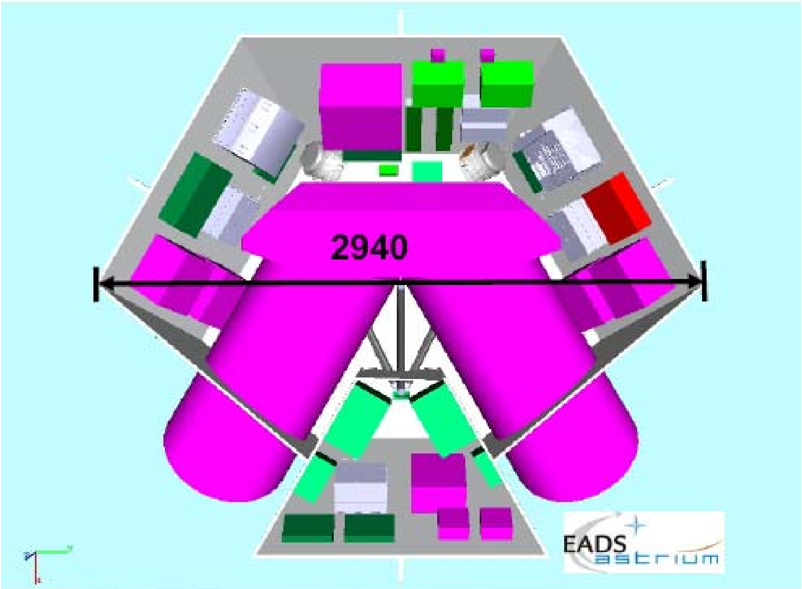


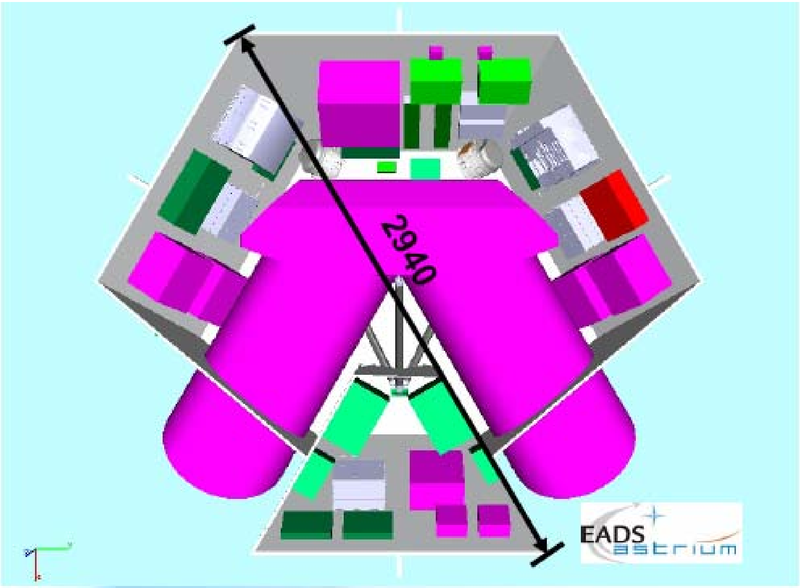
III Generation Detectors

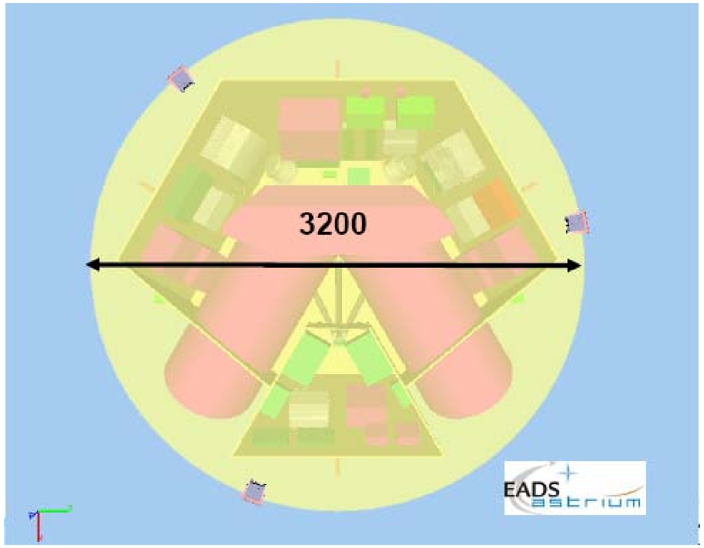
LISA the Laser Interferometer Space Antenna
2008-2012

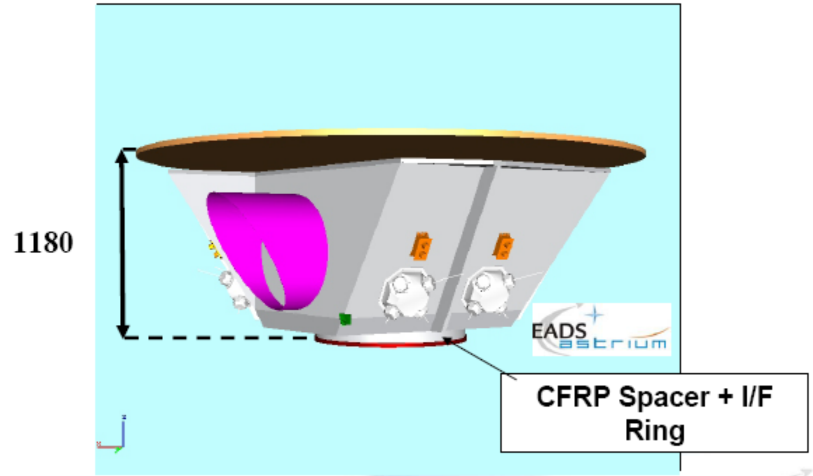


Spacecraft


2940
EADS astrium


2940
EADS astrium

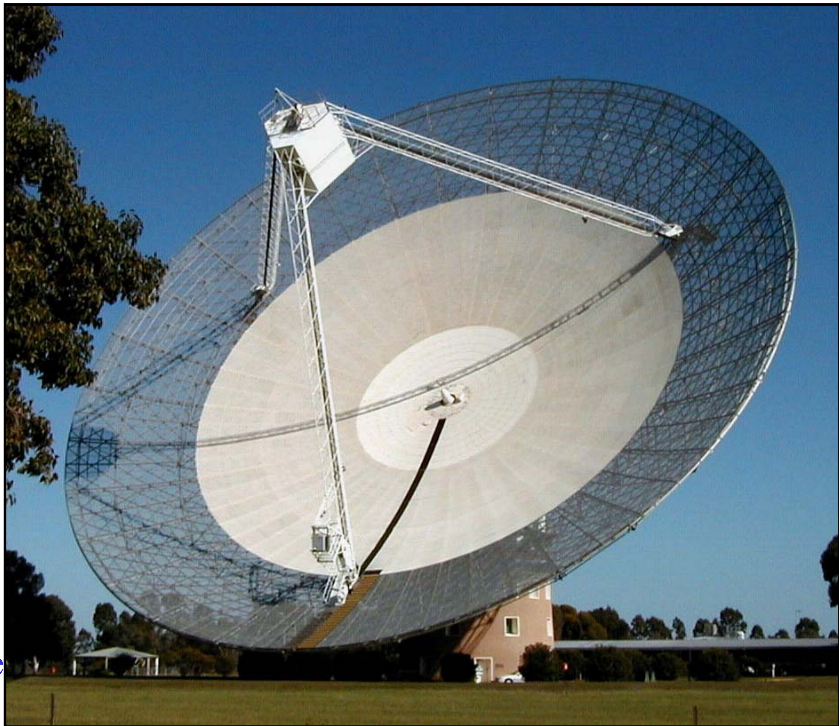

3200
EADS astrium


1180
EADS astrium
CFRP Spacer + I/F Ring

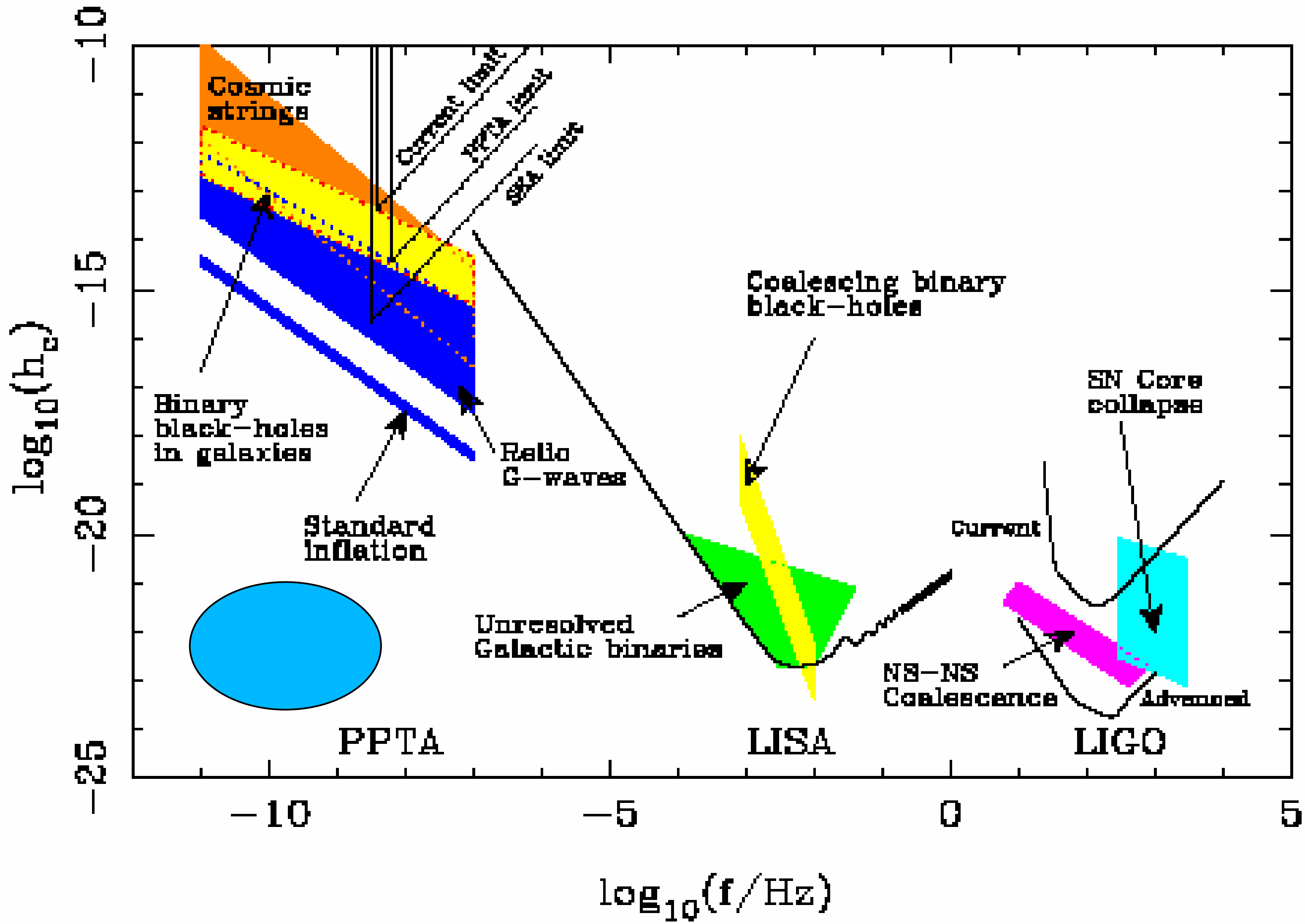
The Parkes Pulsar Timing Array Project

Collaborators:

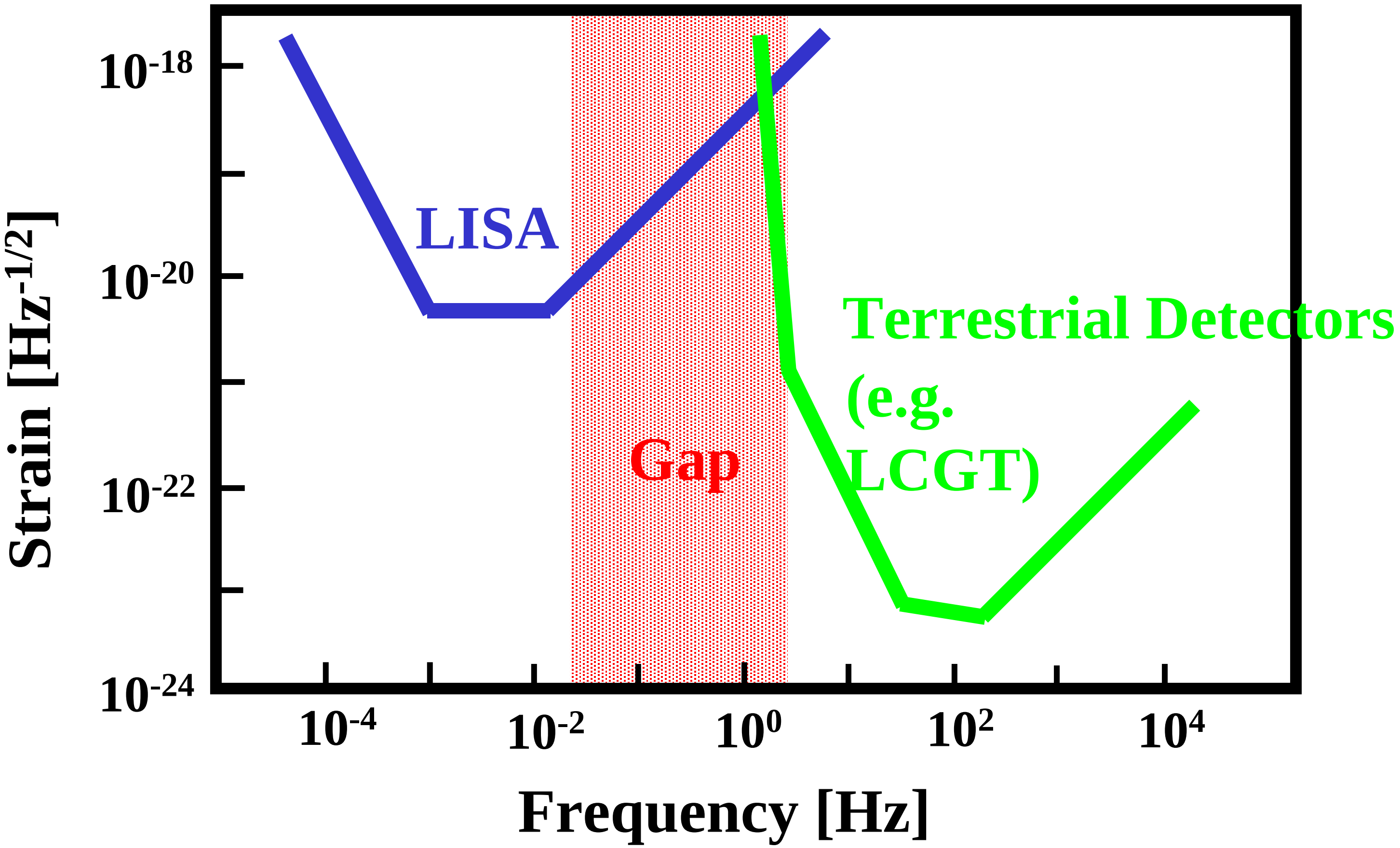
- Australia Telescope National Facility, CSIRO, Sydney
  Dick Manchester, George Hobbs, David Champion, John Sarkissian, John Reynolds, Mike Kesteven, Grant Hampson, Andrew Brown, David Smith, Jonathan Khoo, (Russell Edwards)
- Swinburne University of Technology, Melbourne
  Matthew Bailes, Ramesh Bhat, Willem van Straten, Joris Verbiest, Sarah Burke, Andrew Jameson
- University of Texas, Brownsville
  Rick Jenet
- Franklin & Marshall College, Lancaster
  Andrea Lommen
- University of Sydney, Sydney
  Daniel Yardley
- National Observatories of China, Beijing
  Johnny Wen
- Peking University, Beijing
  Kejia Lee
- Southwest University, Chongqing
  Xiaopeng You
- Curtin University, Perth
  Aidan Hotan



Strain sensitivity



Gap between Terrestrial Detectors and LISA

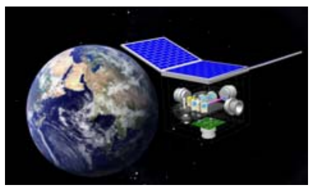


DECIGO Roadmap

	2007	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

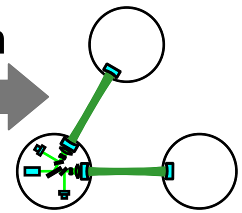
Mission

R&D Fabrication



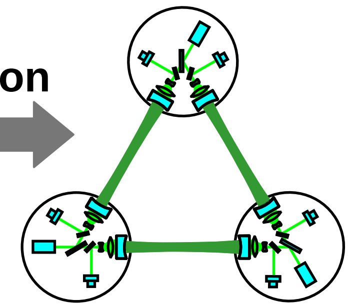
DICIGO Pathfinder (DPF)

R&D Fabrication



Pre-DECIGO

R&D Fabrication



DECIGO

	DPF	Pre-DECIGO	DECIGO
Objectives	Test of key technologies	Detection of GW w/ minimum spec. Test FP cavity between S/C	Full GW astronomy
Scope	1 S/C 1 arm	3 S/C 1 interferometer	3 S/C, 3 interferometer 3 or 4 units

Back to Sources
GW Sources at Laboratory?

- Beryllium rode
- $M \sim 6\ 10^{10}$g,
- $2L \sim 34$m,
- $\omega \sim 10^{3}$ 1/sec

- $J_0 \sim 10^{-7}$ erg/sec
- $h \sim 10^{-33}$

GW Astrophysical Sources

- Expected sources of gravitational radiation include numerous astrophysical sources such as compact binaries, suppermassive black holes, and binary coalescence
- In addition, there is an expected cosmological background of gravitational radiation arising from the very earliest times of the universe

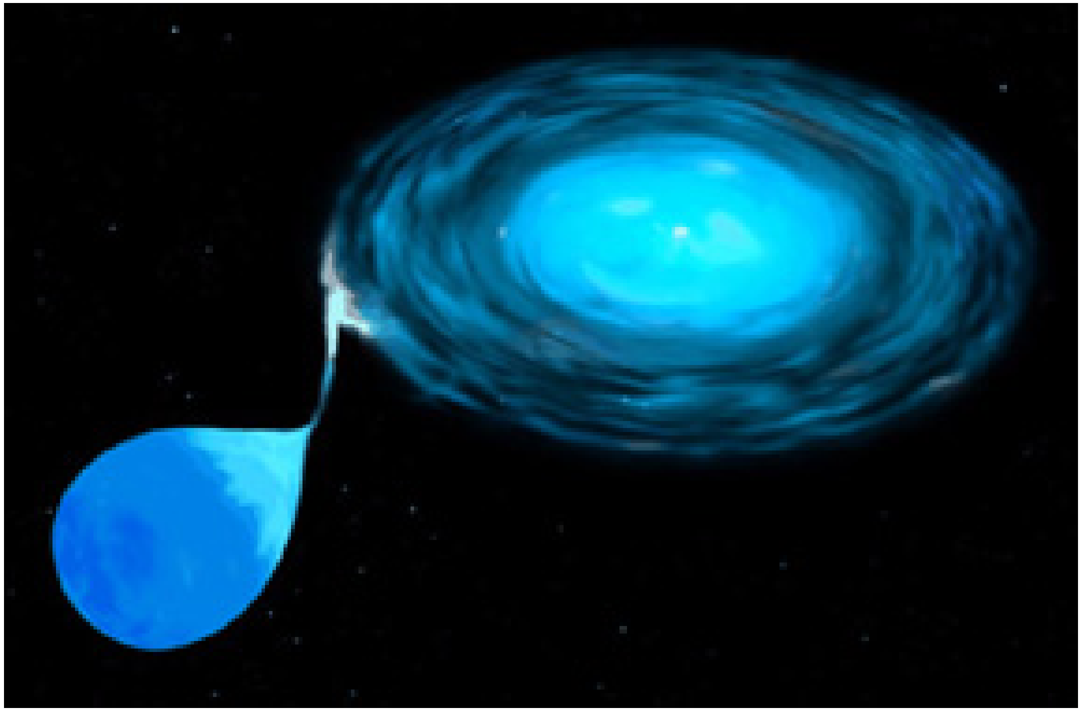
Events Generating Gravitational Waves: GW Sources

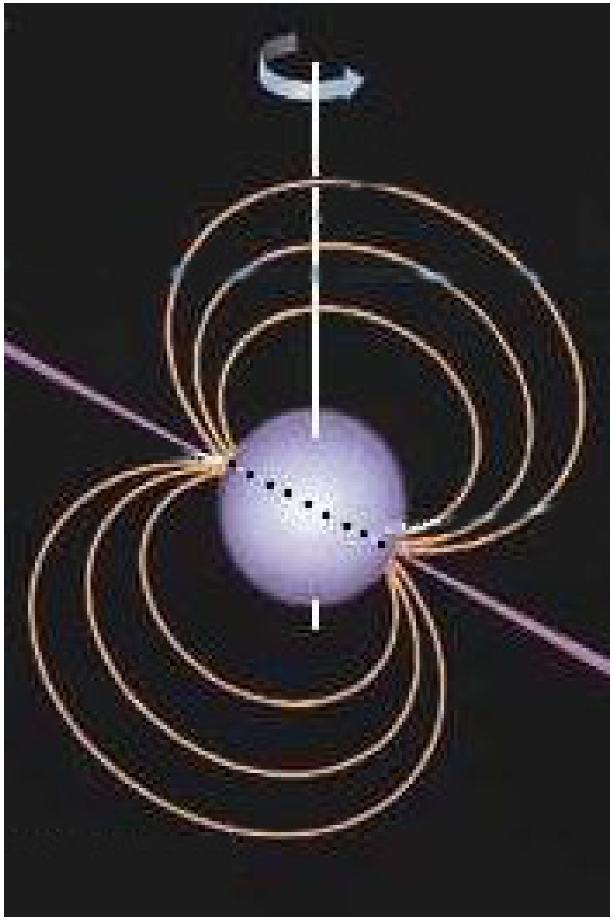
- BH-BH Collisions
- Star Collisions 10^{44}erg/s
- Mergers NS-NS 1/1000y/Galaxy
- Asymmetric Explosion
- GRB activity

GW Astrophysical Sources

- Expected sources of gravitational radiation include numerous astrophysical sources such as compact binaries, suppermassive black holes, and binary coalescence
- In addition, there is an expected cosmological background of gravitational radiation arising from the very earliest times of the universe

Gravitational radiation generated by binary systems or rotating aspherical objects.





Permanent Sources of Gravitational Waves

- Binary Systems $2x10^{32}$ erg/s
- Asymmetric Rotation of a star
- Oscillations

- These sources are permanent

(SS) Self-Similar Oscillations:

- Coordinates $$x_\alpha = x_\alpha^0 (1 + \eta \sin \omega t)$$
- η is amplitude of oscilation, should be less then 1. ω is frequency of oscillation.

$$Q_{\alpha\beta} = \int \rho \left(x_\alpha x_\beta - \frac{1}{3} \delta_{\alpha\beta} x_\gamma^2 \right) dV$$

$$Q_{\alpha\beta} = Q_{\alpha\beta}^0 (1 + 2\eta \sin \omega t)$$

- Quadruple Moment became time dependant

$$Q_{xx}^0 = Q_{yy}^0; \; Q_{zz}^0 = -2Q_{xx}$$

Gravitational Radiation Intensity

- Gravitation radiation intensity :

$$J = \frac{G}{5c^5} \left| \dddot{Q}_{\alpha\beta} \right|^2$$

- Using the eq. for Quadruple moment one can easily obtain

$$J_0 = \frac{6G}{5c^5} \eta^2 \omega^6 \left| Q_{zz}^0 \right|^2$$

$$J = \frac{6G}{5c^5} \eta^2 \omega^6 \left| Q_{zz}^0 \right|^2 \cos^2 \omega t' = J_0 \cos^2 \omega t'$$

Calculation of GW amplitudes

$$\dot{h}_+ = \frac{1}{2}\left(\dot{h}_{yy} - \dot{h}_{zz}\right) = -\frac{G}{c^4} r \left(\dddot{Q}_{yy} - \dddot{Q}_{zz}\right)$$

$$\dot{h}_\times = \dot{h}_{yz} = -\frac{2G}{c^4 r}\dddot{Q}_{yz} \qquad \dot{h}_\times = 0$$

$$\dot{h}_+ = \frac{3G\eta\omega^3}{c^4 r}\left|Q^0_{zz}\right|\cos\omega t' = \frac{1}{r}\sqrt{\frac{7{,}5 J_0 G}{c^3}}\cos\omega t'$$

$$h_+(t') = \frac{1}{r}\sqrt{\frac{7{,}5 J_0 G}{c^3\omega^2}}\sin\omega t' = \frac{3G\eta\omega^2}{c^4 r}\left|Q^0_{zz}\right|\sin\omega t' = h_0 \sin\omega t'$$

GW Amplitudes and SS Oscillation Amplitudes are:

$$h_0 = \frac{1}{r}\sqrt{\frac{7{,}5 J_0 G}{\omega^2 c^3}} = \frac{3G\eta\omega^2}{c^4 r}\left|Q^0_{zz}\right|$$

$$\eta = \frac{1}{\omega^3 \left|Q^0{}_{zz}\right|}\sqrt{\frac{5}{6}\frac{J_0 c^5}{G}}$$

Gravitational Wave Sources

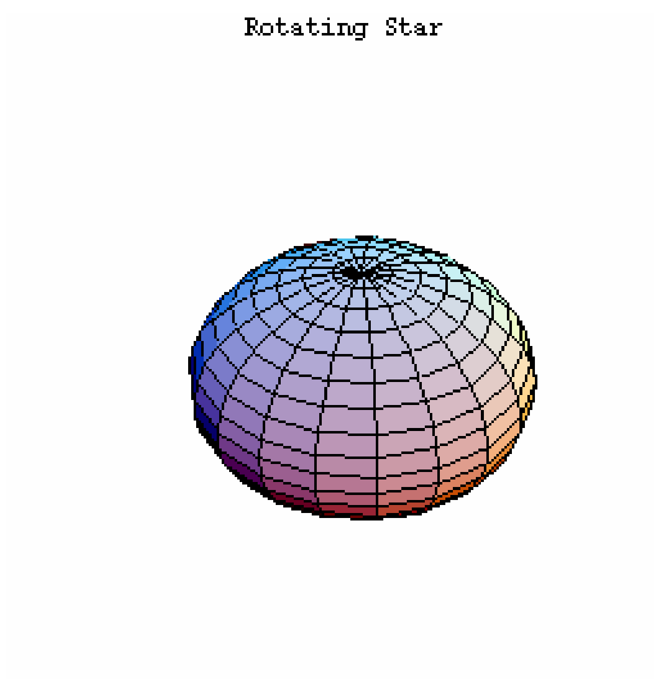
- Magnetized White Dwarfs
- Differentially rotating White Dwarfs

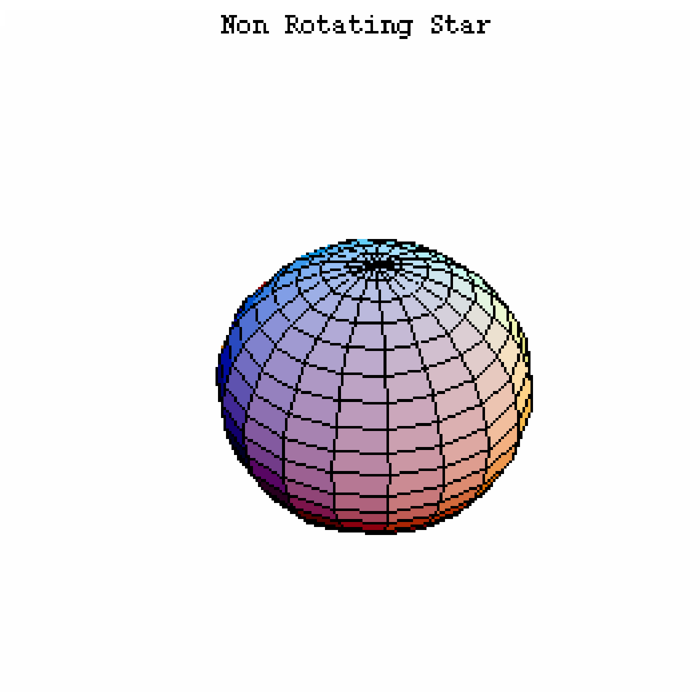
Energy Sources for Oscillation

- Deformation Energy of Star
- Energy of Differential Rotation

Continuous Energy sources for gravitational radiation

- Deformation energy release during the star spin-down can be a good continuous energy source





$$W_{def}(\Omega) = (M - M_0)c^2 - W_r(\Omega)$$

- M and M_o are mass of rotating and non-rotating configurations with same complete number of baryons N

$$W_r = I\Omega^2 / 2$$

$$\Delta M = (\alpha_0 - \alpha)mN$$

Parameters of neutron Stars & WDs with maximal angular velocity

$\rho_c \times 10^{-15}$ (g/cm^3)	$\frac{M}{M_\Theta}$	$\Omega_m \times 10^{-3}$ (sec^{-1})	$I \times 10^{-44}$ (g.cm^2)	$\omega \times 10^{-3}$	$N \times 10^{-57}$	$D_{zz}^{0m} \times 10^{-43}$ (g cm^2)	$\alpha_0 - \alpha$	$W_{def} \times 10^{-53}$ (erg)
0.546	0.7815	5.97	4.92	3	1.51	7.68	0.082	1.85
1.14	1.3737	8.37	9.85	5	1.76	9.73	0.068	1.79
2.44	1.7127	12.3	11.1	7	2.02	30.7	0.07	2.10

$\rho_{c(6)}$	M/M_Θ	Ω_{max}	$I_{(48)}$	ω	$N_{(57)}$	$Q^0{}_{(48)}$	$W_{r(49)}$	$W_{def\,(49)}$
2.403	0.5946	0.196	128	0.758	0.4997	20.48	0.246	4.55
19.38	0.9993	0.476	88.6	0.794	0.8398	14.27	1.00	7.06
157.7	1.2731	1.063	39.5	1.51	1.0695	4.766	2.23	8.05
866.1	1.3502	2.042	15.9	1.99	1.1340	1.554	3.32	7.58
2586	1.3412	3.105	8.17	0.967	1.1261	0.673	3.94	6.89

Gravitational Radiation Intensity

$$J = \frac{6G}{5c^5}\eta^2\omega^6\left|Q^0_{zz}\right|^2\cos^2\omega t' = J_0\cos^2\omega t'$$

$$J_0 << \omega^6\left|Q^0{}_{zz}\right|^2\frac{6}{5}\frac{G}{c^5}$$

Thermal Losses

Results

$$\frac{\xi}{2}\left(\sigma_{ij}-\frac{2}{3}\delta_{ij}\,div\vec{V}\right)^2+\zeta\left(div\vec{V}\right)^2+\frac{c^2}{16\pi^2\sigma_e}\left(rot\vec{b}\right)^2+\kappa\Delta T$$

$$J_T=\int_0^R\int_0^{\sqrt{R^2-r_\perp^2}}2\pi r_\perp\frac{\xi}{2}\left(r_\perp\frac{\partial\Omega(r_\perp)}{\partial r_\perp}\right)^2dr_\perp dz$$

neglected because in our star material is made up of one kind of atom

Joule losses they are also small, especially in comparison with viscosity losses

neglected due to high thermal conductivity of degenerate electron gas

Why White Dwarfs?

- White Dwarfs(WD) are stellar configurations with central densities $\sim 10^6$-10^9 g/ cm^3
  -they are on the border between normal stars and relativistic configurations
- Quadrupole moment of WDs is $Q \sim 10^{48}$g cm^2
  - several orders higher then Neutron Star's Quadrupole moment

Why White Dwarfs ?

- White Dwarfs(WD) are the most close potential sources of GWs
  - there are White Dwarfs at 8 pc distance.

- WD Population is estimated about $\sim 10^8$ in the Galaxy
  -WDs are the largest population among potential astrophysical sources of GWs

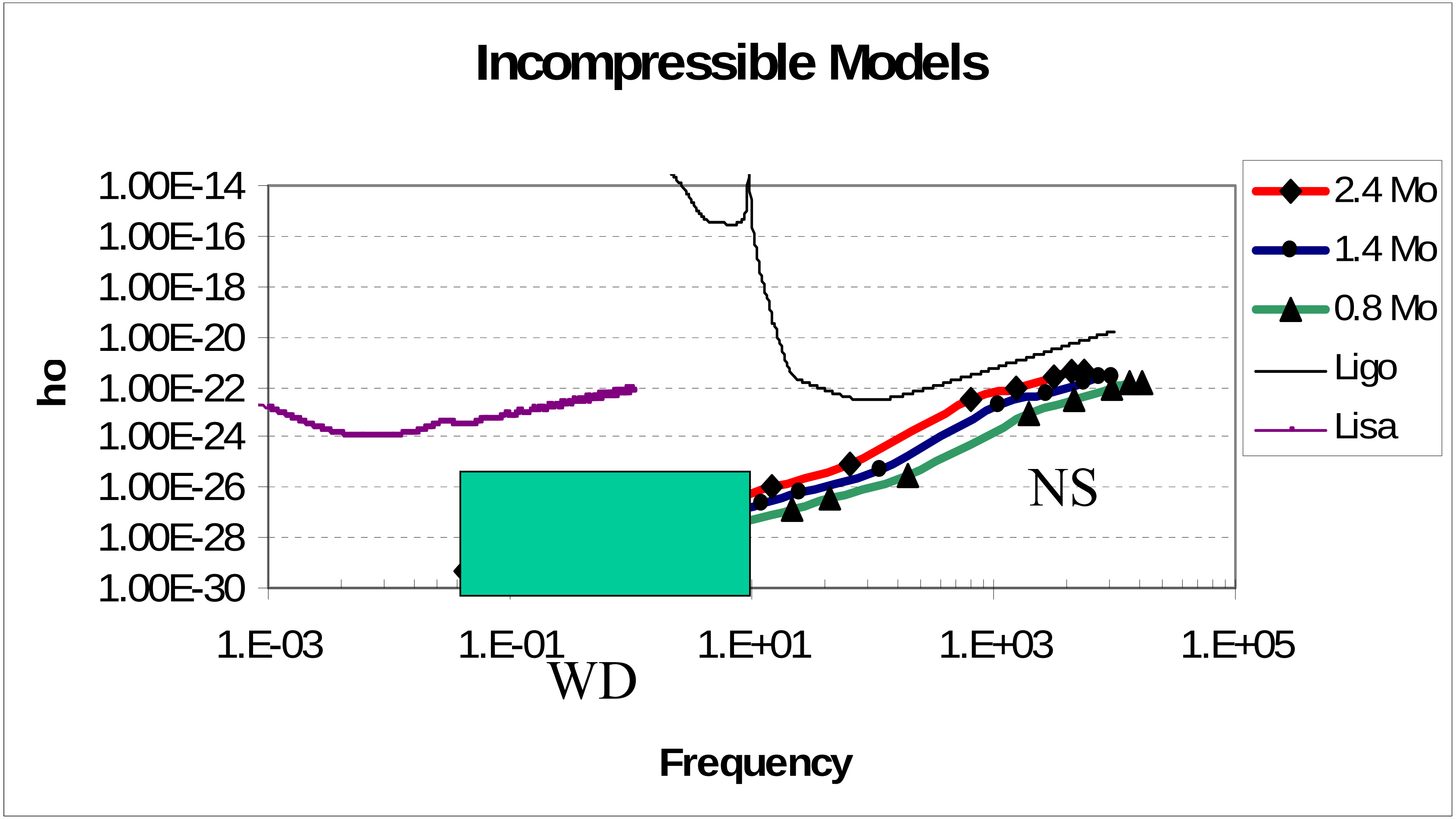
Parameters of neutron stars & WDs with maximal angular velocity

ω

$\rho_c \times 10^{-15}$ (g/cm^3)	$\frac{M}{M_\Theta}$	$\Omega_m \times 10^{-3}$ (sec^{-1}) Ω	$I \times 10^{-44}$ (g.cm^2)	$\omega \times 10^{-3}$	$N \times 10^{-57}$	$D_{zz}^{0m} \times 10^{-43}$ (g cm^2)	$\alpha_0 - \alpha$	$W_{def} \times 10^{-53}$ (erg)
0.546	0.7815	5.97	4.92	3	1.51	7.68	0.082	1.85
1.14	1.3737	8.37	9.85	5	1.76	9.73	0.068	1.79
2.44	1.7127	12.3	11.1	7	2.02	30.7	0.07	2.10

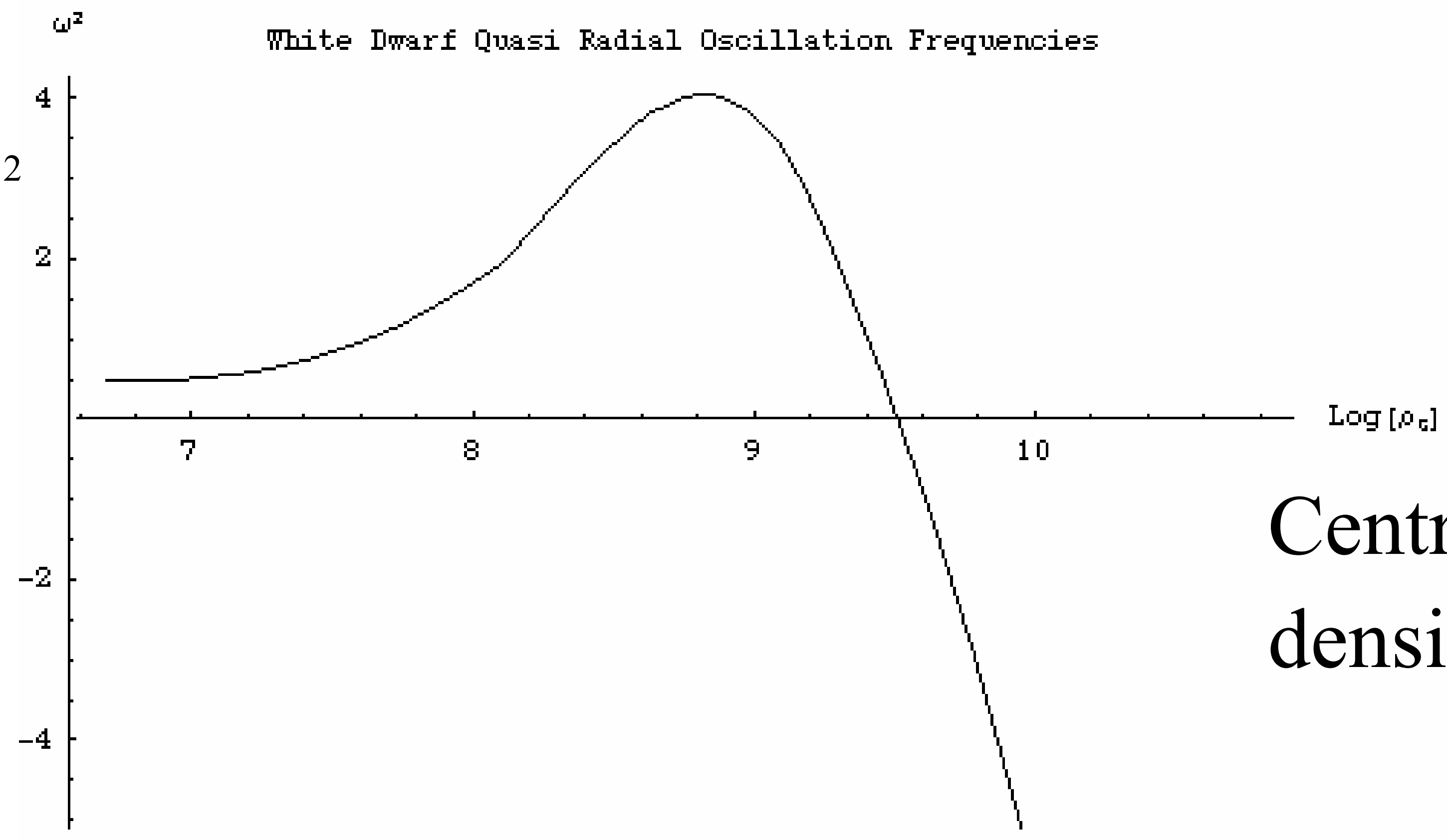
$\rho_{c(6)}$	M/M_Θ	Ω_{max}	$I_{(48)}$	ω	$N_{(57)}$	$Q^0_{(48)}$	$W_{r(49)}$	$W_{def\,(49)}$
2.403	0.5946	0.196	128	0.758	0.4997	20.48	0.246	4.55
19.38	0.9993	0.476	88.6	0.794	0.8398	14.27	1.00	7.06
157.7	1.2731	1.063	39.5	1.51	1.0695	4.766	2.23	8.05
866.1	1.3502	2.042	15.9	1.99	1.1340	1.554	3.32	7.58
2586	1.3412	3.105	8.17	0.967	1.1261	0.673	3.94	6.89

Why White Dwarfs?



Frequency Range of WD Oscillations

$$\omega^2 = (2\pi\nu)^2$$



Central density

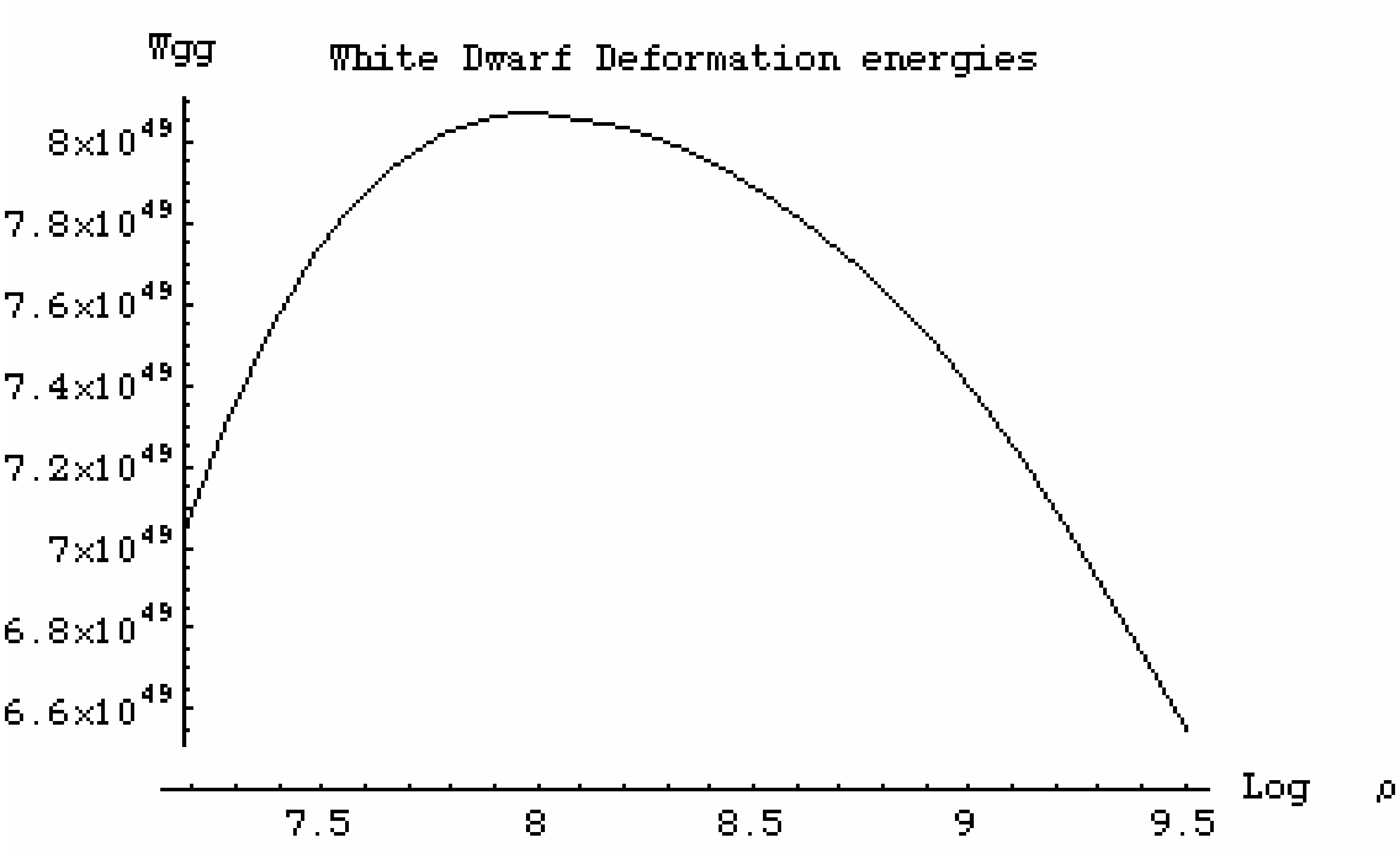
Deformation Energy

$$W_{def}(\Omega) = (M - M_0)c^2 - W_r(\Omega)$$

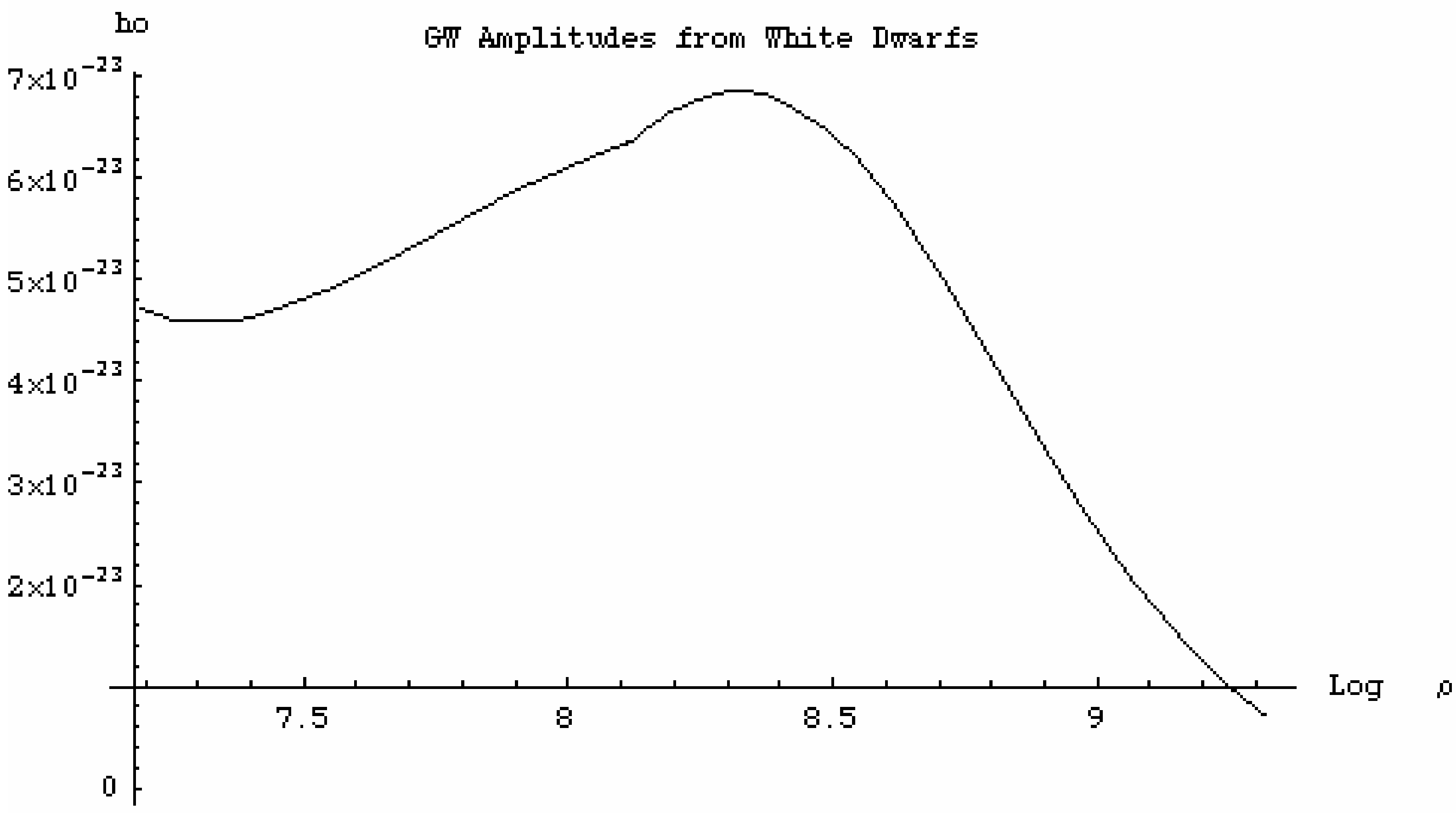
- M and M_o are mass of rotating and non-rotating configurations with same complete number of baryons N

$$W_r = I\Omega^2/2 \qquad \Delta M = (\alpha_0 - \alpha)mN$$

White Dwarfs Maximal deformation Energy versus Central density



GW Amplitudes from WDs rotating with Keplerian angular velocities



Mechanisms of GW Radiation

1. GWs from Magnetized WDs: -
   deformation energy is feeding oscillations
   -magnetodipol radiation torque is breaking rotation

2. GWs from differentially rotating WDs

3. GWs coming from WDs with triaxial shape

Types of Models of WDs

- Model 1.a is calculated by requiring that the largest Doppler broadening of spectral lines due to pulsations be less than thermal Doppler broadening
- Model 1.m is based on assumption that all non-dissipated part of deformation energy is going to oscillations, it is maximal possible model to that sense.

GWs from Magnetized WDs 1.a

WD Name	r (pc)	B (MG)	h_o	F	t (Gy)	η
PG 1031+234	142	500	$6.0\ 10^{-29}$	$6.1\ 10^{-17}$	11.0	$1.02\ 10^{-02}$
EUVE J0317-855	35	450	$1.0\ 10^{-27}$	$6.7\ 10^{-15}$	1.7	$4.03\ 10^{-03}$
PG 1015+015	66	90	$9.3\ 10^{-30}$	$1.1\ 10^{-18}$	571.9	$7.09\ 10^{-04}$
Feige 7	49	35	$1.6\ 10^{-28}$	$4.9\ 10^{-17}$	125.1	$5.18\ 10^{-04}$
G99-47	8	25	$3.5\ 10^{-27}$	$5.9\ 10^{-16}$	50.6	$3.70\ 10^{-04}$
KPD 0253+5052	81	17	$2.9\ 10^{-30}$	$4.6\ 10^{-20}$	11852	$3.46\ 10^{-04}$
PG 1312+098	----	10	$1.5\ 10^{-30}$	$3.8\ 10^{-21}$	70313.	$2.04\ 10^{-04}$
G217-037	11	0.2	$9.0\ 10^{-31}$	$8.2\ 10^{-23}$	$2\ 10^{8}$	$4.08\ 10^{-06}$

GWs from Magnetized WDs 1.m

WD Name	r (pc)	B (MG)	h_o	F	t (Gy)	η
PG 1031+234	142	500	$2.58\cdot10^{-28}$	$1.13\cdot10^{-15}$	11.0	$4.7\cdot10^{-2}$
EUVE J0317-855	35	450	$9.69\cdot10^{-26}$	$6.04\cdot10^{-11}$	1.7	$3.8\cdot10^{-1}$
PG 1015+015	66	90	$3.81\cdot10^{-28}$	$1.93\cdot10^{-15}$	571.9	$2.9\cdot10^{-2}$
Feige 7	49	35	$1.47\cdot10^{-26}$	$3.96\cdot10^{-13}$	125.1	$4.7\cdot10^{-2}$
G99-47	8	25	$3.45\cdot10^{-25}$	$5.84\cdot10^{-12}$	50.6	$3.7\cdot10^{-2}$
KPD 0253+5052	81	17	$2.06\cdot10^{-28}$	$2.33\cdot10^{-16}$	11852.8	$2.5\cdot10^{-2}$
PG 1312+098	----	10	$9.38\cdot10^{-29}$	$1.56\cdot10^{-17}$	70313.8	$1.3\cdot10^{-2}$
G217-037	11	0.2	$8.97\cdot10^{-29}$	$8.19\cdot10^{-19}$	$2.4\cdot10^{7}$	$4.1\cdot10^{-4}$

Energy of Differential Rotation

- for each infinitesimally thin cylinder

$$\Omega(r_\perp) = \frac{L}{M r_\perp{}^2} l(u(r_\perp))$$

- energy of differential rotation is equal to

$$E_{diff} = 2\pi \int_0^R \int_0^{\sqrt{R^2 - r_\perp{}^2}} r_\perp \rho\left(\sqrt{r_\perp{}^2 + z^2}\right) \left(\Omega^2(r_\perp) - \Omega_0{}^2\right) r_\perp{}^2 \, dr_\perp \, dz$$

Energy Losses to Friction

M/M_{Θ}	Ω_k	$I_{(48)}$	$Q^0_{(48)}$	$E_{dis(32)}$ I	$E_{dis(32)}$ II
0.5946	**0.196**	**128**	**20.48**	0.057	0.039
0.9993	**0.476**	**88.6**	**14.27**	1.1	0.73
1.2731	**1.063**	**39.5**	**4.766**	9.97	6.5
1.3502	**2.042**	**15.9**	**1.554**	47.3	30.7

Oscillating Magnetized White Dwarfs feed by Deformation Energy

WD	U_t	U_g	h_0	F	τ (Gyr)	ή	B MG
J0317-855	$1.61\cdot10^{28}$	$1.58\cdot10^{29}$	$9.69\cdot10^{-26}$	$6.04\cdot10^{-11}$	1.7	$3.84\cdot10^{-1}$	450
Feige 7	$1.68\cdot10^{28}$	$7.04\cdot10^{28}$	$1.47\cdot10^{-26}$	$3.96\cdot10^{-13}$	125.1	$4.66\cdot10^{-2}$	35
G99-47	$8.55\cdot10^{27}$	$1.65\cdot10^{30}$	$3.45\cdot10^{-25}$	$5.84\cdot10^{-12}$	50.6	$3.69\cdot10^{-2}$	25
KPD 0253+5052	$1.42\cdot10^{26}$	$1.47\cdot10^{26}$	$2.06\cdot10^{-28}$	$2.33\cdot10^{-16}$	11852	$2.47\cdot10^{-2}$	17

Gravitational Radiation from Differentially rotating White Dwarfs for Angular momentum Distrib. N1

	Edifrot I	Ediss I	LifeTime (Gyr)	Jo I	ho	η Etta	F Flux
PG 1031+234	8.7411E+42	1.2574E+26	2,2	1.26E+25	1.39E-27	6.54E-01	3.3E-14
EUVE J0317-855	4.0005E+44	8.5162E+28	0,1	8.52E+27	5.86E-26	2.19E-01	2.2E-11
PG 1015+015	1.4919E+43	9.8724E+26	0,5	9.87E+25	4.39E-27	6.78E-01	2.6E-13
Feige 7	3.4674E+43	9.3271E+25	11,8	9.33E+24	3.63E-27	1.72E-01	2.4E-14
G99-47	1.6782E+44	4.5143E+26	11,8	4.51E+25	4.89E-26	7.83E-02	1.2E-13
KPD 0253+5052	7.0347E+42	1.012E+26	2,2	1.01E+25	2.18E-27	7.29E-01	2.6E-14
PG 1312+098	3.4271E+42	4.93E+25	2,2	4.93E+24	2.68E-27	1.04E+00	1.3E-14
G217-037	2.5262E+43	3.634E+26	2,2	3.63E+25	3.05E-26	3.85E-01	9.4E-14
Averege	8.3E+43	1.1E+28	3.06	1.1E+27	1.9E-26	5.0E-01	2.8E-12

Gravitational Radiation from Differentially rotating White Dwarfs for Angular momentum Distrib. N2

	Edifrot II	Ediss II	LifeTime (Gyr)	Jo II	ho	η Etta	Flux
PG 1031+234	3.638E+42	8.4434E+25	1,4	8.44E+24	1.14E-27	5.36E-01	2.2E-14
EUVE J0317-855	9.4765E+43	5.5308E+28	0,1	5.53E+27	4.72E-26	1.77E-01	1.4E-11
PG 1015+015	4.3709E+42	6.4883E+26	0,2	6.49E+25	3.56E-27	5.50E-01	1.7E-13
Feige 7	1.8693E+43	6.3832E+25	9,3	6.38E+24	3.00E-27	1.42E-01	1.7E-14
G99-47	9.0472E+43	3.0895E+26	9,3	3.09E+25	4.04E-26	6.47E-02	8.0E-14
KPD 0253+5052	2.9278E+42	6.7951E+25	1,4	6.80E+24	1.79E-27	5.98E-01	1.8E-14
PG 1312+098	1.4263E+42	3.3104E+25	1,4	3.31E+24	2.20E-27	8.56E-01	8.6E-15
G217-037	1.0514E+43	2.4402E+26	1,4	2.44E+25	2.50E-26	3.15E-01	6.3E-14
Averege	2.8E+43	7.1E+27	3,06	7.1E+26	1.6E-26	4.0E-01	1.8E-12

Differentially Rotating WDs model 2.1

	Edifrot I	Ediss I	LifeTime (Gyr)	Jo I	ho	η Etta	F Flux
PG 1031+234	8.7411E+42	1.2574E+26	2,2	1.26E+25	1.39E-27	6.54E-01	3.3E-14
EUVE J0317-855	4.0005E+44	8.5162E+28	0,1	8.52E+27	5.86E-26	2.19E-01	2.2E-11
PG 1015+015	1.4919E+43	9.8724E+26	0,5	9.87E+25	4.39E-27	6.78E-01	2.6E-13
Feige 7	3.4674E+43	9.3271E+25	11,8	9.33E+24	3.63E-27	1.72E-01	2.4E-14
τ G99-47	1.6782E+44	4.5143E+26	11,8	4.51E+25	4.89E-26	7.83E-02	1.2E-13
KPD 0253+5052	7.0347E+42	1.012E+26	2,2	1.01E+25	2.18E-27	7.29E-01	2.6E-14
PG 1312+098	3.4271E+42	4.93E+25	2,2	4.93E+24	2.68E-27	1.04E+00	1.3E-14
G217-037	2.5262E+43	3.634E+26	2,2	3.63E+25	3.05E-26	3.85E-01	9.4E-14
Average					1.9E-26		

Differentially Rotating WDs model 2.2

	Edifrot II	Ediss II	LifeTime (Gyr)	Jo II	ho	η Etta	Flux
PG 1031+234	3.638E+42	8.4434E+25	1,4	8.44E+24	1.14E-27	5.36E-01	2.2E-14
EUVE J0317-855	9.4765E+43	5.5308E+28	0,1	5.53E+27	4.72E-26	1.77E-01	1.4E-11
PG 1015+015	4.3709E+42	6.4883E+26	0,2	6.49E+25	3.56E-27	5.50E-01	1.7E-13
Feige 7	1.8693E+43	6.3832E+25	9,3	6.38E+24	3.00E-27	1.42E-01	1.7E-14
G99-47	9.0472E+43	3.0895E+26	9,3	3.09E+25	4.04E-26	6.47E-02	8.0E-14
KPD 0253+5052	2.9278E+42	6.7951E+25	1,4	6.80E+24	1.79E-27	5.98E-01	1.8E-14
PG 1312+098	1.4263E+42	3.3104E+25	1,4	3.31E+24	2.20E-27	8.56E-01	8.6E-15
G217-037	1.0514E+43	2.4402E+26	1,4	2.44E+25	2.50E-26	3.15E-01	6.3E-14

Triaxsial WDs model 3.r

- Rotating triaxsial white dvarfs of ellipsoidal shape

$\rho_c \times 10^6$, g/cm^3	M/M_Θ	$R_e \times 10^8$	$I_3 \times 10^{48}$ g.cm^2	Ω_{max}	H, km	$\varepsilon \times 10^{-5}$	$J_0 \times 10^{29}$ erg/sec	h_0	$\tau_0 \times 10^2$ Gyear
2.403	0.5946	10.93	128	0.196	0.699	6.4	0.667	$0.69\ 10^{-24}$	12.25
19.38	0.9993	7,342	88.6	0.476	0.187	2.56	10.5	$1.13\ 10^{-24}$	3.19
157.7	1.2731	4.625	39.5	1.063	0.058	1.26	62.1	$1.23\ 10^{-24}$	1.19
866.1	1.3502	3.044	15.9	2.04	0.024	0.784	197	$1.14\ 10^{-24}$	0.56
2586	1.3412	2.287	8.17	3.11	0.014	0.059	373	$1.03\ 10^{-24}$	0.35

Triaxsial WDs model 3.n

- Non Rotating, oscillating triaxsial WDs of ellipsoidal shape

$\rho_c \times 10^6$ g/см^3	M_0/M_Θ	$R \times 10^8$ cm	$I_0 \times 10^{50}$ g.см^2	ω, s^{-1}	H, km	$\varepsilon \times 10^{-5}$	h_o	$\tau \times 10^3$ Gyear
2.403	0.5087	8.873	4.81	0.758	0.539	6.1	$2.1\ 10^{-26}$	0.35
19.38	0.8854	5.903	3.70	0.794	0.137	2.3	$3.4\ 10^{-26}$	2.59
157.7	1.1612	3.747	1.96	1.51	0.042	1.1	$3.7\ 10^{-26}$	1.60
866.1	1.2538	2.492	0.934	1.99	0.017	0.69	$3.4\ 10^{-26}$	2.92
2586	1.2582	1.888	0.538	0.967	0.010	0.52	$3.1\ 10^{-26}$	160

Stochastic background level

- Background is not isotropic: Assuming a galactic distribution of white dwarfs to follow the disk population, we assign a density distribution of WDs:

$$\rho = \rho_0 e^{-r/R_0} e^{-z/h}$$

in galacto-centric cylindrical coordinates, with R_0=2.5kpc and h=200pc

Conclusions

- Gravitational radiation spectrum near 1 hz is inhabited by Isolated White dwarfs
- Model 1.a $h_{av+} = 8.35\ 10^{-27}$
- Model 1.m $h_{av+} = 7.94\ 10^{-25}$
- Model 2.1 $h_{av+} = 2.01\ 10^{-25}$
- Model 2.2 $h_{av+} = 1.62\ 10^{-25}$

- Standard inflation gives $h \sim 10^{-27} – 10^{-29}$ in this frequency range.

Peculiarities of GW Radiation in medium Frequency band

- Permanent radiation on a given medium frequency band, no changes in chirp for long time,-a big advantage for Data Analyses
- h+=2.0116E-25
- h+=1.6217E-25
- On Frequency range 0.12 – 0.32Hz a b

WHY GWs?

- Detection of gravitational wave radiation from isolated sources: sources that are not a part of a double system, will be very important to start a new discipline in physics *Astroseismology*.
- It will allow to open a new type of investigation of celestial bodies, through their chirp of gravitational radiation.

END