THE 5-BARS G.W. OBSERVATORY:
RESULTS AND PROSPECTIVES

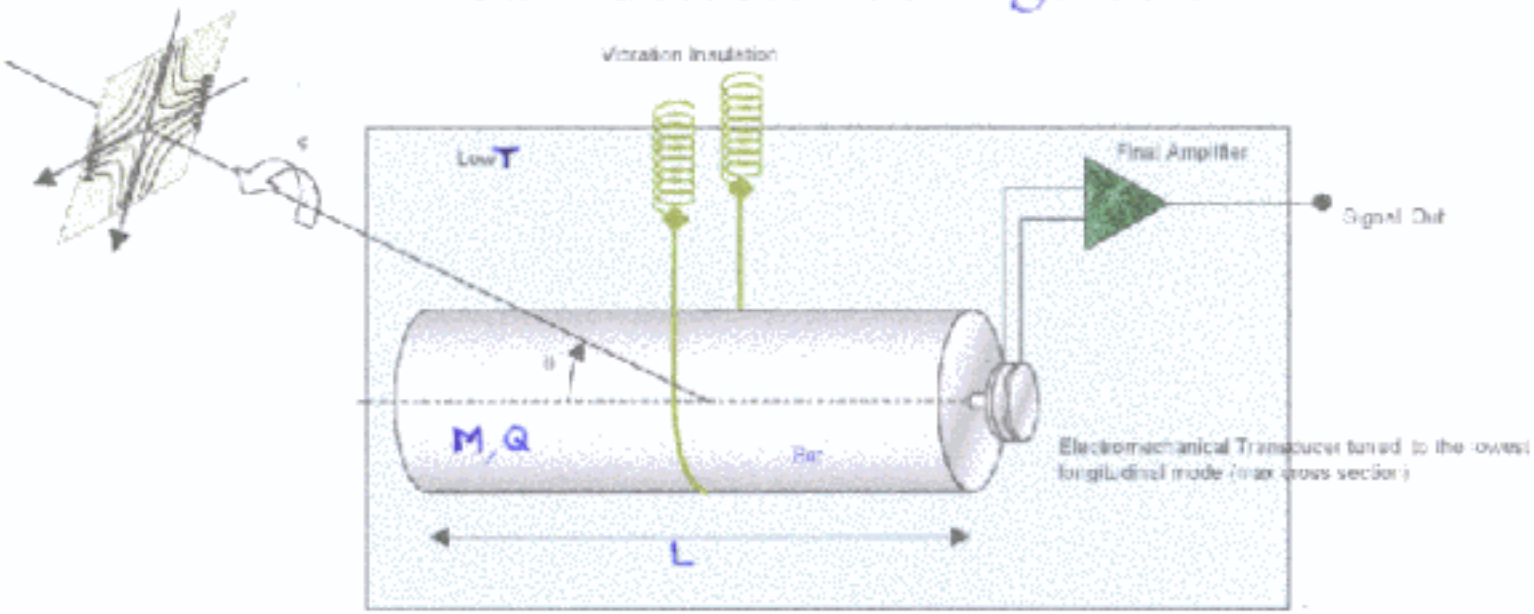
- Cryogenic "bar" g.w. detectors: *operation, upgrades*

- IGEC (International Gravitational Events Collaboration)
- The IGEC g.w. observatory:
  reach out
  limits on amplitudes and rates
  correlation with astronomical triggers (ν,γ,...)

- ULTIMATE "BARS"
  hollow spheres with resonant transducers
  "dual spheres" (hollow+full) *with non-resonant optical readout*

- LISA+"advanced" interferometers+"ultimate" bars
  Probing* directly *black-holes
  ***from* 10^8 $M_\odot$ to 1 $M_\odot$**

"bar" detector configuration



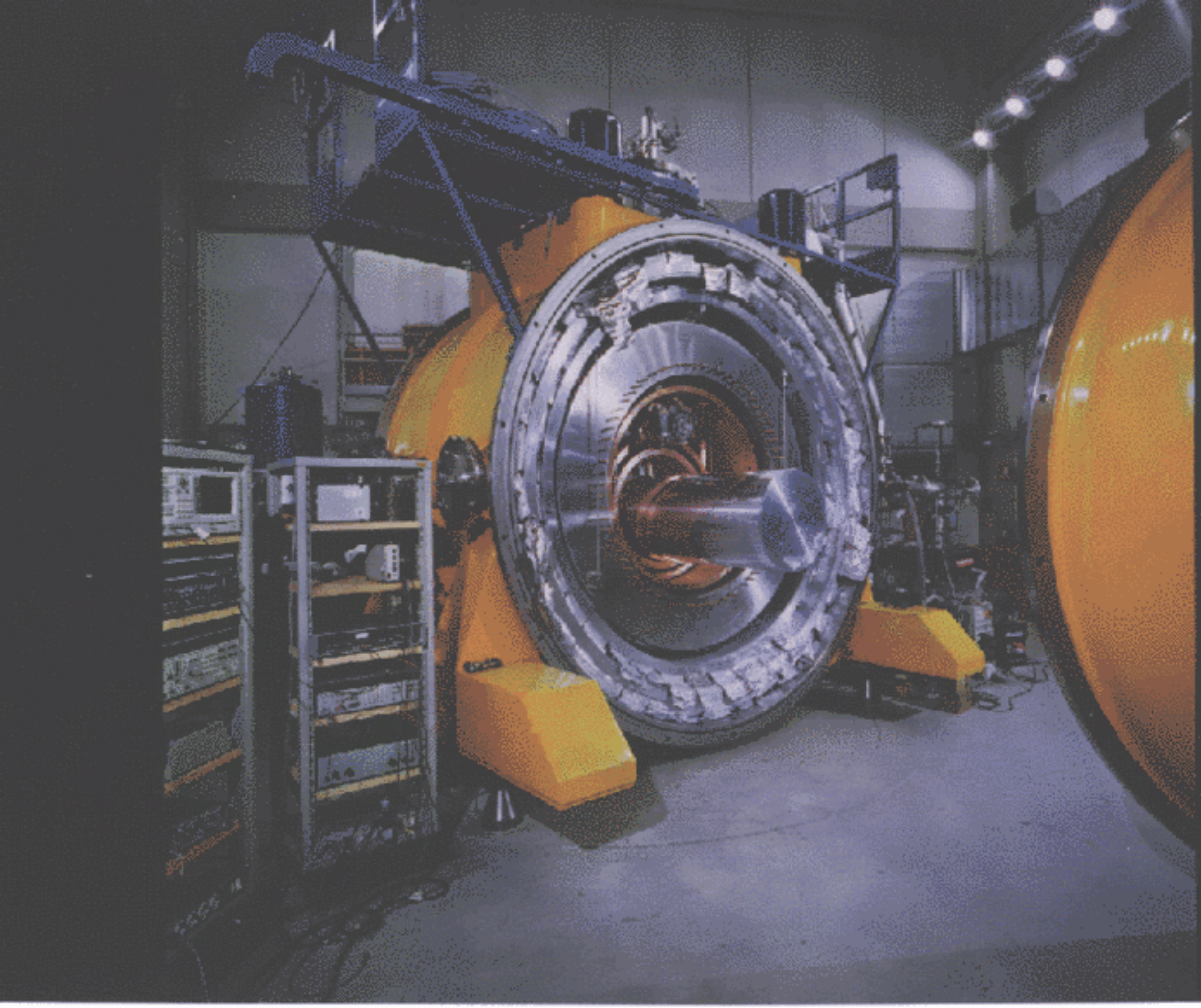
signal: the g.w. "tidal" force drives the lowest longitudinal bar mode (notice antenna pattern factor)

noise: 1) thermal + amplifier "back" heating
2) final amplifier

$$\text{signal/noise} \propto \frac{MQL^2}{T}$$

M	tons
Q	10^7
L	meters
T	0.1 K

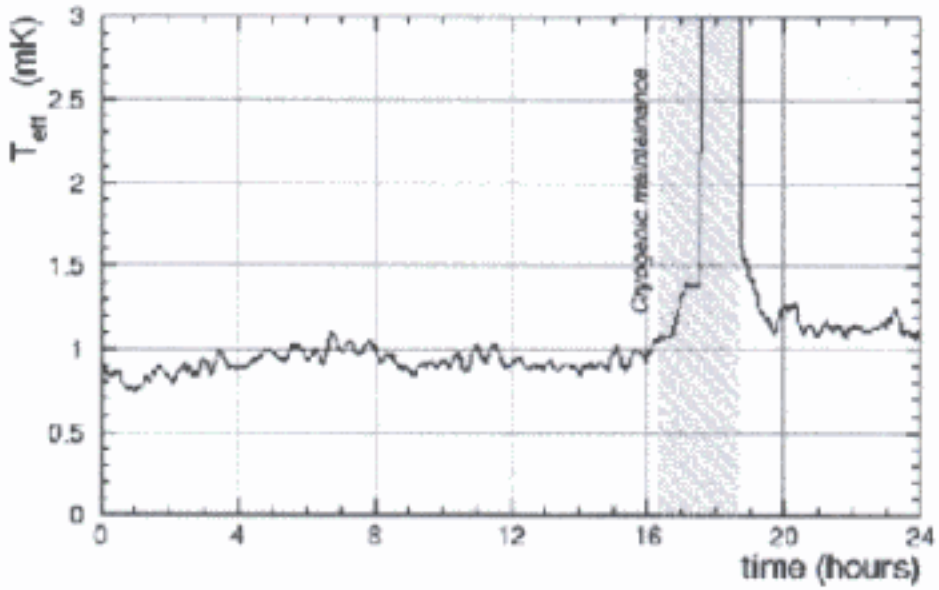
"thermal" noise common to itfs: merge the techs? ←

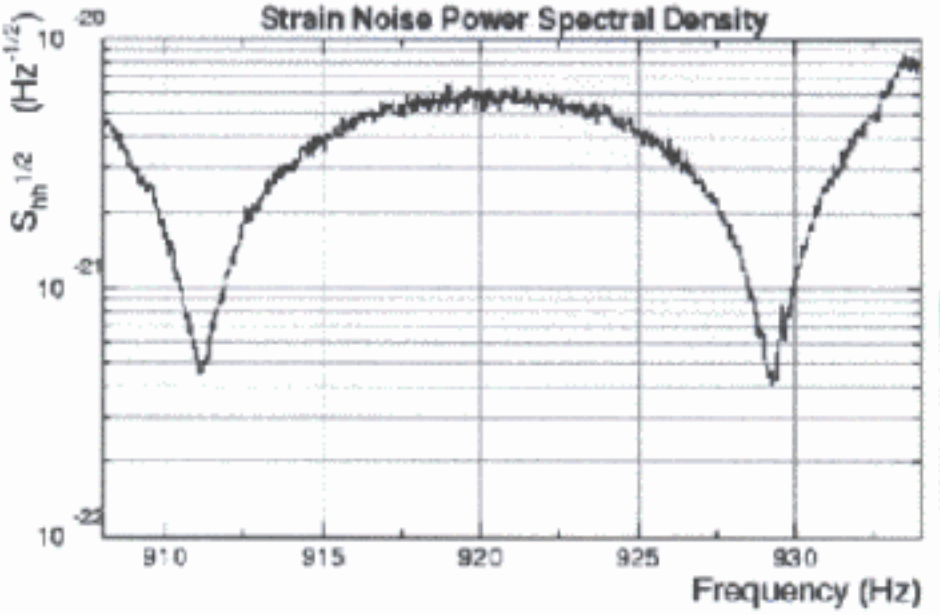


AURIGA

Bar at 0.2 K

DAY 185, SUNDAY Jul 4, 1999





$\Delta E_{abs}^{min} = k_B T_{eff}$

$T_{eff} \simeq 1\ mK$

$\Downarrow$

$\Delta E_{abs} \simeq 10^{4}\ \hbar\omega_{BAR}$

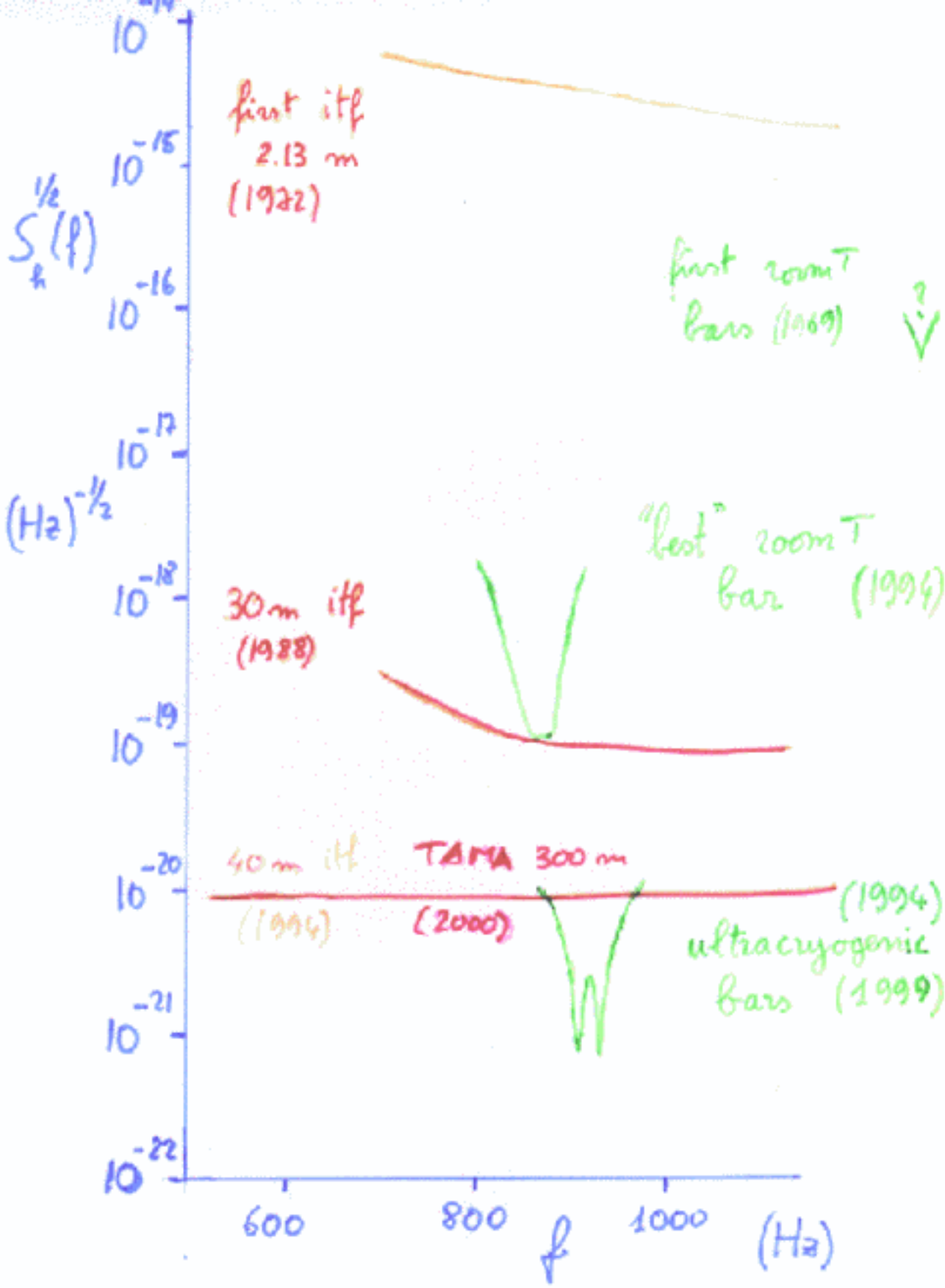
$\Downarrow$

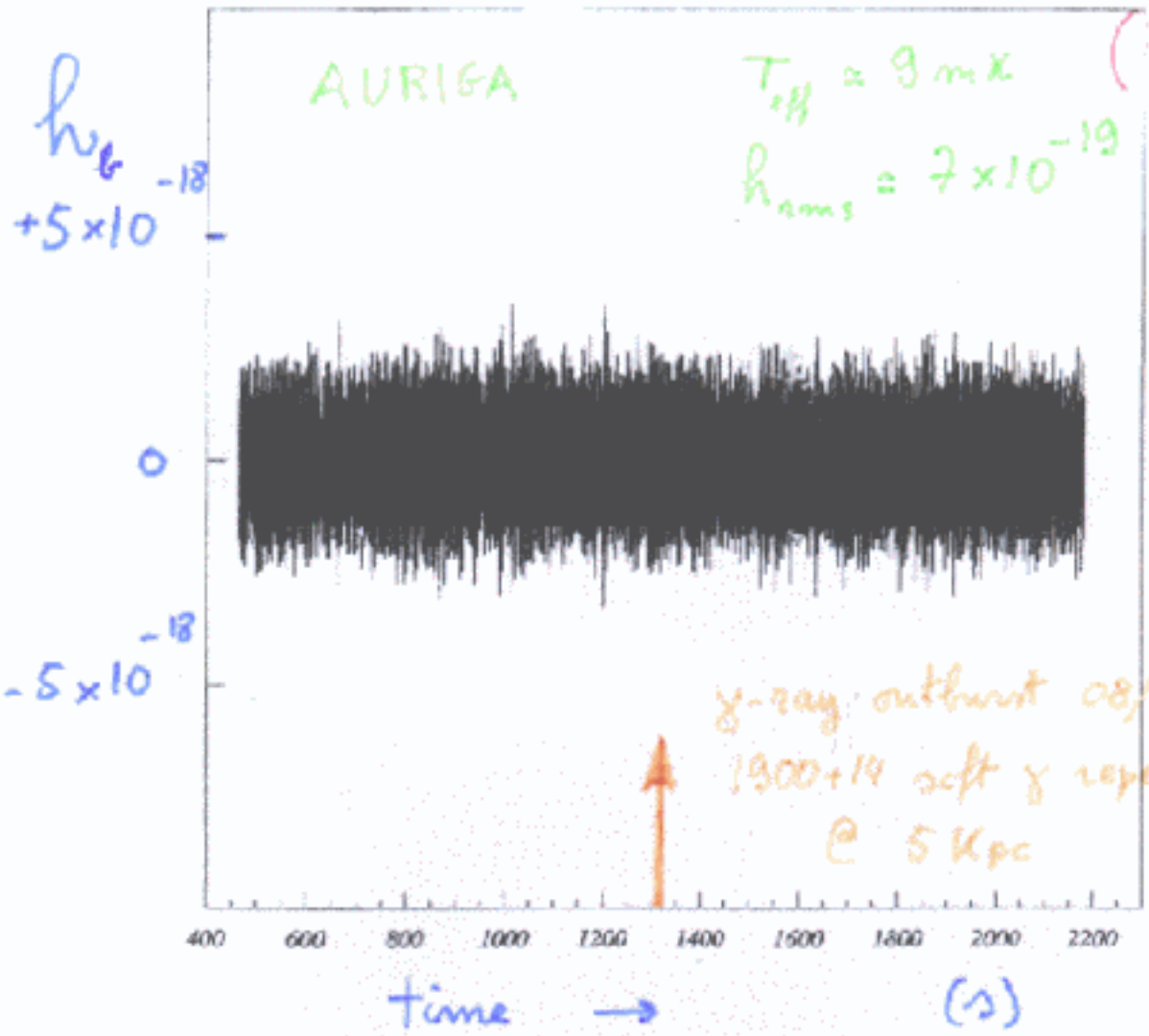
$h \simeq 3 \times 10^{-19}$

$\Downarrow$

$\simeq 10^{-4} M_\odot$ converted in gw @ Galactic Center 1 ms pulse

"best..."


10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-19}
10^{-20}
10^{-21}
10^{-22}
$S_h^{1/2}(f)$
$(Hz)^{-1/2}$
first itf
2.13 m
(1972)
first room T
bars (1969)
?
"best" room T
bar (1994)
30 m itf
(1988)
40 m itf
(1994)
TAMA 300 m
(2000)
(1994)
ultracryogenic
bars (1999)
600
800
1000
f
(Hz)



{antenna pattern factor ≃ 0.9}

$$h_b \simeq 3 \times 10^{-18} \Leftrightarrow \epsilon_{gw} \simeq 2 \times 10^{-3} M_\odot$$

∴ SIMILARLY FOR ANY ASTRONOMICAL TRIGGER OVER THE WHOLE 1.5 years PERIOD (June 97 to Dec 98)

IGEC International Gravitational Event Collaboration
http://igec.lnl.infn.it

ALLEGRO group: ***ALLEGRO (LSU)***
Louisiana State University, Baton Rouge - Louisiana
http://phwave.phys.lsu.edu

AURIGA group: ***AURIGA (INFN-LNL)***
INFN of Padova, Trento, Ferrara, Firenze, LNL
Universities of Padova, Trento, Ferrara, Firenze
CeFSA, ITC-CNR, Trento – Italia
http://www.auriga.lnl.infn.it

NIOBE group: ***NIOBE (UWA)***
University of Western Australia, Perth, Australia
http://www.gravity.pd.uwa.edu.au

ROG group: ***EXPLORER (CERN),***
NAUTILUS (INFN-LNF)
INFN of Roma and LNF
Universities of Roma, L'Aquila
CNR IFSI and IESS, Roma - Italia
http://www.roma1.infn.it/rog/rogmain.html

bars ≈ on a great circle
axis ≈ orthogonal to ↑
axis ≈ parallel each other

=> MAXIMIZE COINCIDENCE PROBABILITY

IGEC AGREEMENT (July 4th, 1997)

- ***GOAL***:
  search for **short** gravitational wave **bursts** (constant Fourier transform)

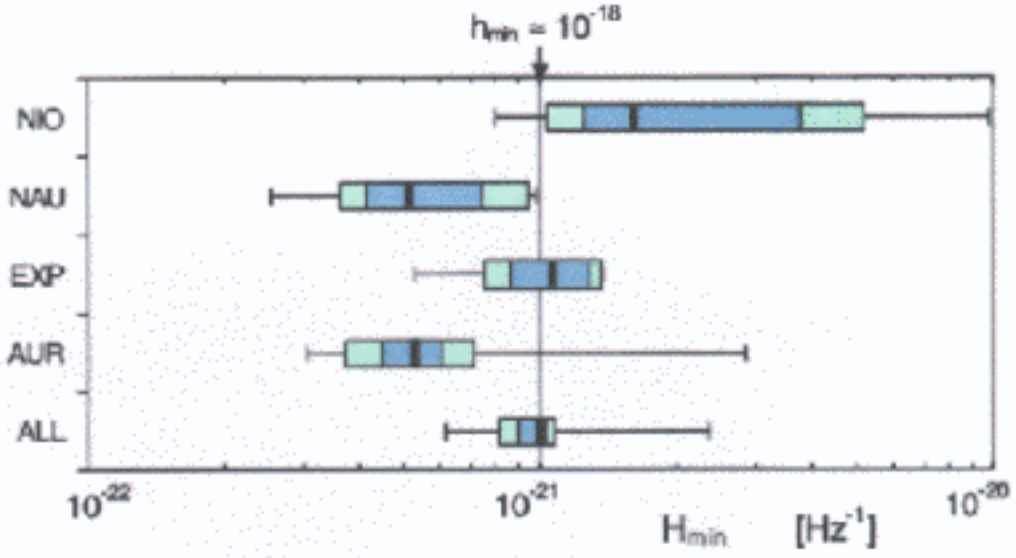
- ***POLICY***:
  - **each group** has responsibility to make available **lists of candidate g.w. events** and related information
  - **unanimous agreement** of members required to make public the results based on IGEC data exchange
  - **open** to new data taking partners

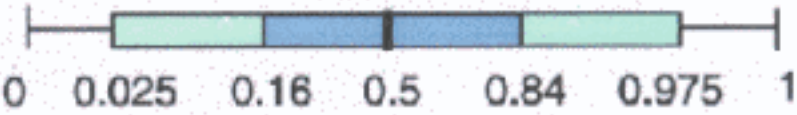
- ***COMMON DATA EXCHANGE PROTOCOL***:
  - search for **coincident excitations** at different detectors
  - max **rate of candidate events** currently ~100/day to limit false alarm probability
  - events described by **arrival time, Fourier component, detector noise** at that time
  - **effective observation time** of detectors

  … optional information …

SENSITIVITY of DETECTORS
1997-1998

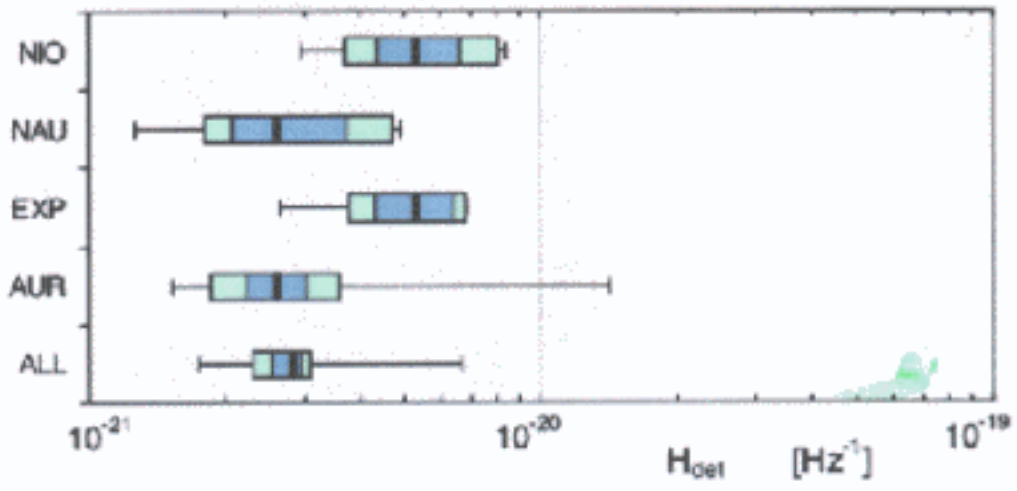
H_{min}: minimum detectable H at *SNR = 1*





fractions of observation time with detector noise < H_{min}

H_{det}: thresholds used for this g.w. search



COMMON OBSERVATION TIME

tables on 1997 – 1998 exchanged data

FOUR DETECTORS	COMMON OBSERVATION TIME [days]
ALL-AUR-EXP-NIO	7.6
ALL-AUR-EXP-NAU	7.9
TOTAL	**15.5**

THREE DETECTORS	COMMON OBSERVATION TIME [days]
ALL-AUR-EXP	34.6
ALL-AUR-NAU	17.1
ALL-AUR-NIO	17.7
ALL-EXP-NAU	35.0
ALL-EXP-NIO	11.7
AUR-EXP-NAU	8.6
AUR-EXP-NIO	11.5
TOTAL net	**89.7**

TWO DETECTORS	COMMON OBSERVATION TIME [days]
ALL-AUR	104
ALL-EXP	101
ALL-NAU	99
ALL-NIO	27
AUR-EXP	44
AUR-NAU	18
AUR-NIO	37
EXP-NAU	37
EXP-NIO	19
TOTAL net	**260**

at least ONE DETECTOR	625

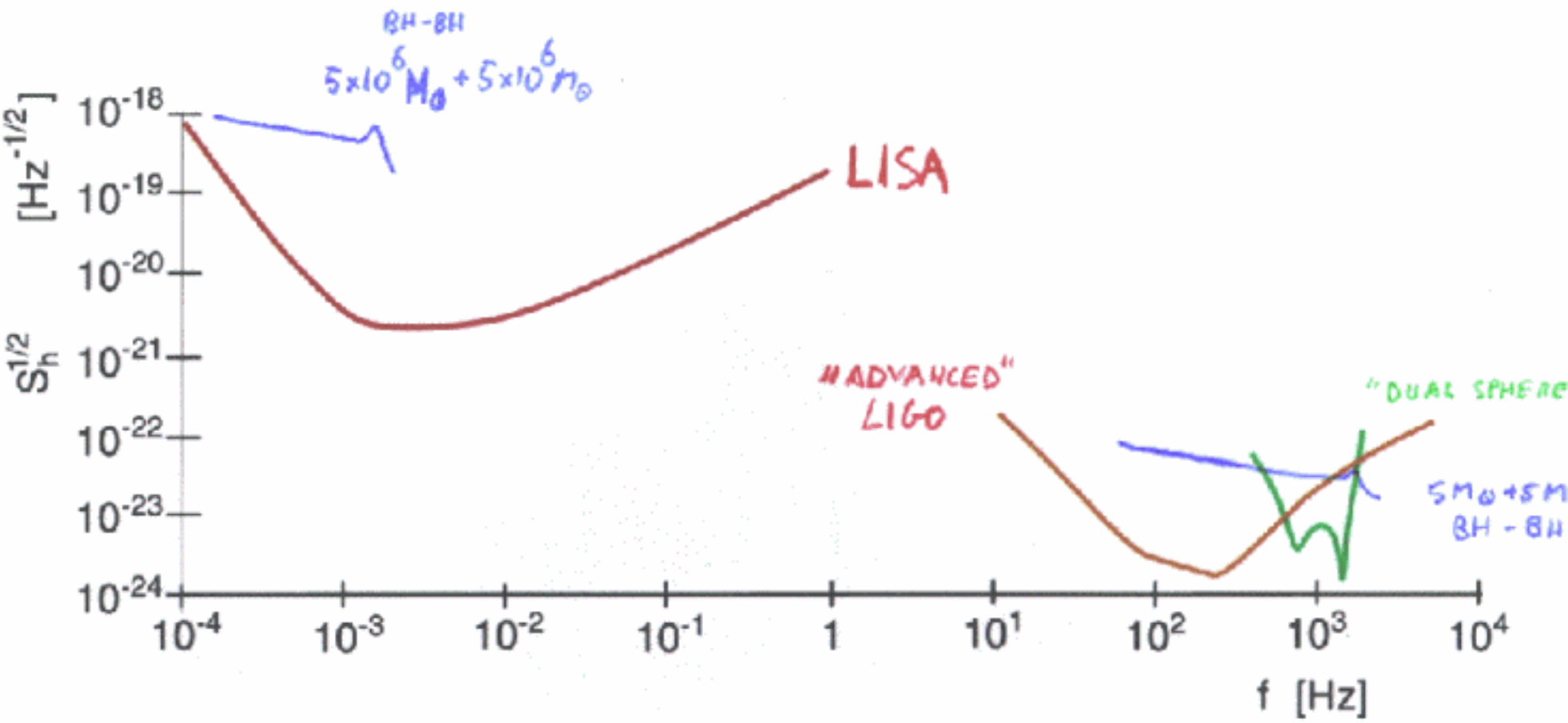
Allen et al (IGEC coll.) Phys. Rev. Letters [illegible] 85, 5046 (00)

IGEC results on a search for g.w. bursts on (part) of 1997 + 1998 data

- common observation time:
  - 4-fold coincidences 16 days
  - 3-fold " 90 days
  - (2-fold " 260 days)
- no coincidence on 3-fold and 4-fold (no significant excess on 2-fold)
- estimate of rates of accidentals at $h_{thr} \approx 4\times10^{-18}$ improves from 10^{-3} /day for 2-fold to 10^{-6} /day for 3-fold 10^{-11}/day for 4-fold *(<< 1/century)*
- upper limit $h \approx 4\times10^{-18}$ on incoming single burst during "on" times (+antenna pattern): correlate with astronomical triggers (neutrinos, γ-bursts)

{ 0.04 $M_\odot$ @ GC } → "WATCHING THE GALAXY"

- no correlation between pairs of detectors
- upgrade: reach out to LOCAL GROUP (x20 M_{GAL})
- "ultimate" bars (hollow spheres): COSMOLOGICAL DIST.


BH-BH
$5\times10^6 M_\odot + 5\times10^6 M_\odot$
LISA
"ADVANCED" LIGO
"DUAL SPHERE"
$5M_\odot + 5M_\odot$
BH - BH
$S_h^{1/2}$ [$Hz^{-1/2}$]
10^{-18}
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10^{1} 10^{2} 10^{3} 10^{4}
f [Hz]

CONCLUSIONS

THE BAR DETECTORS "OBSERVATORY"

in operation:

- reach out to 100 Kpc: watching the Galaxy (as neutrino detectors) for g.w. bursts
- 3-fold coincidences sufficient for false alarm rates << 1/century
- operation with astronomical triggers: limits on g.w. association with γ-bursts
- continuous sources and stochastic background

upgrades under way:

- reach out to the Local Group (×20 luminous mass under observation) and allow source location within degs (*initial interferometers may complement in a global network)*

future ???:

- "ultimate" bars (hollow spheres) would reach out to cosmological distances and complement LISA for black-hole physics exp research