

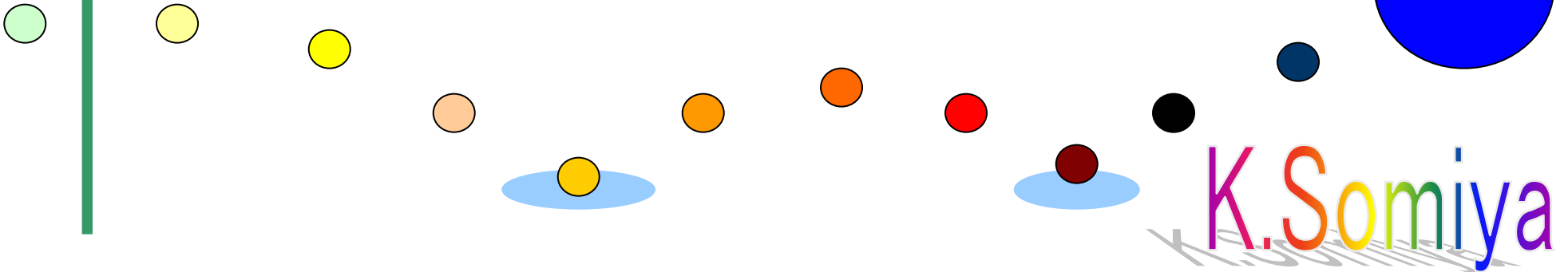
# LCGT Bandwidth Study

~ Consideration of low-frequency configurations ~

LCGT F2F meeting @ ICRR  
Aug. 2011

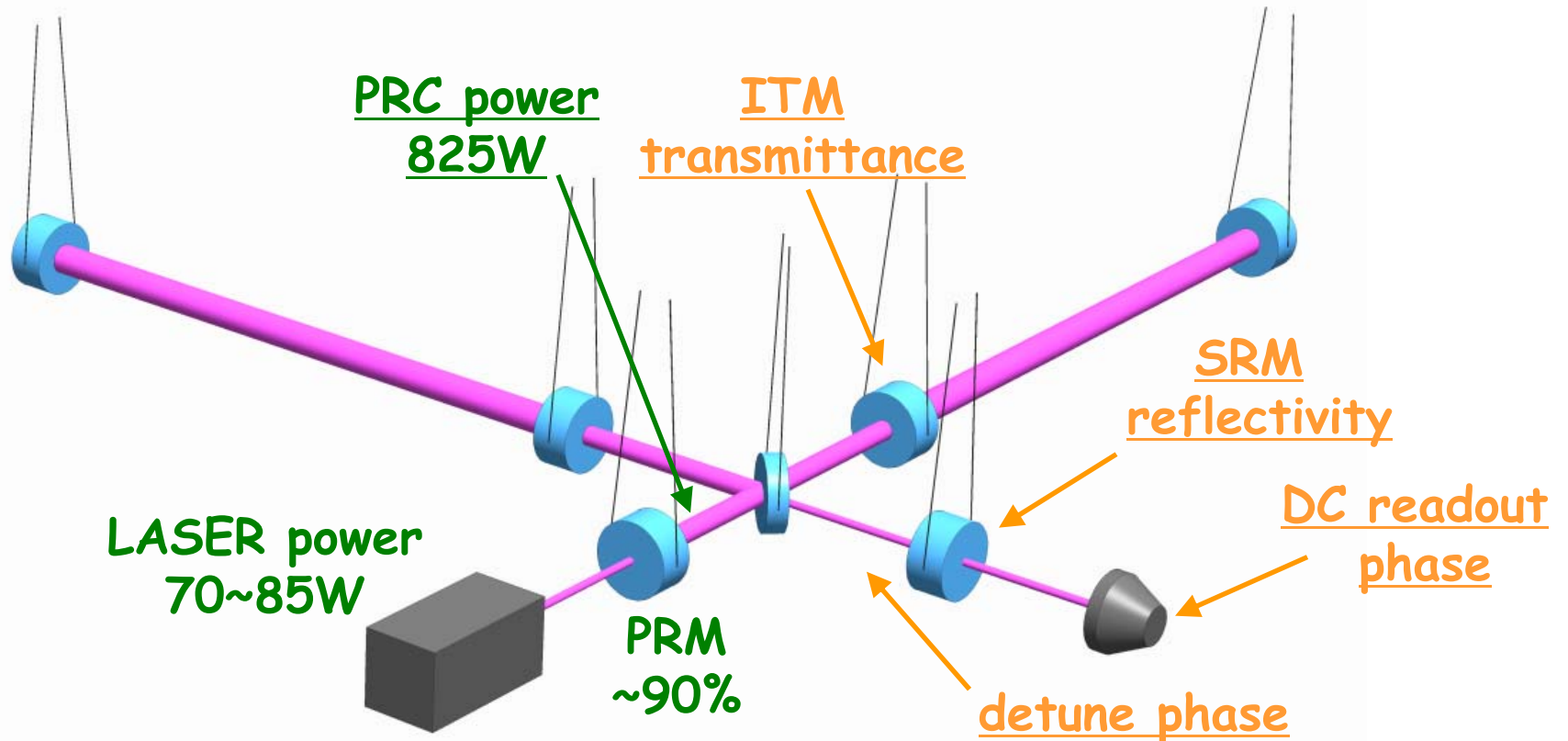
*Tokyo Inst of Technology*  
**Kentaro Somiya**

on behalf of  
LCGT-LF Special WG



# LCGT configuration

[Figure: courtesy by Aso]

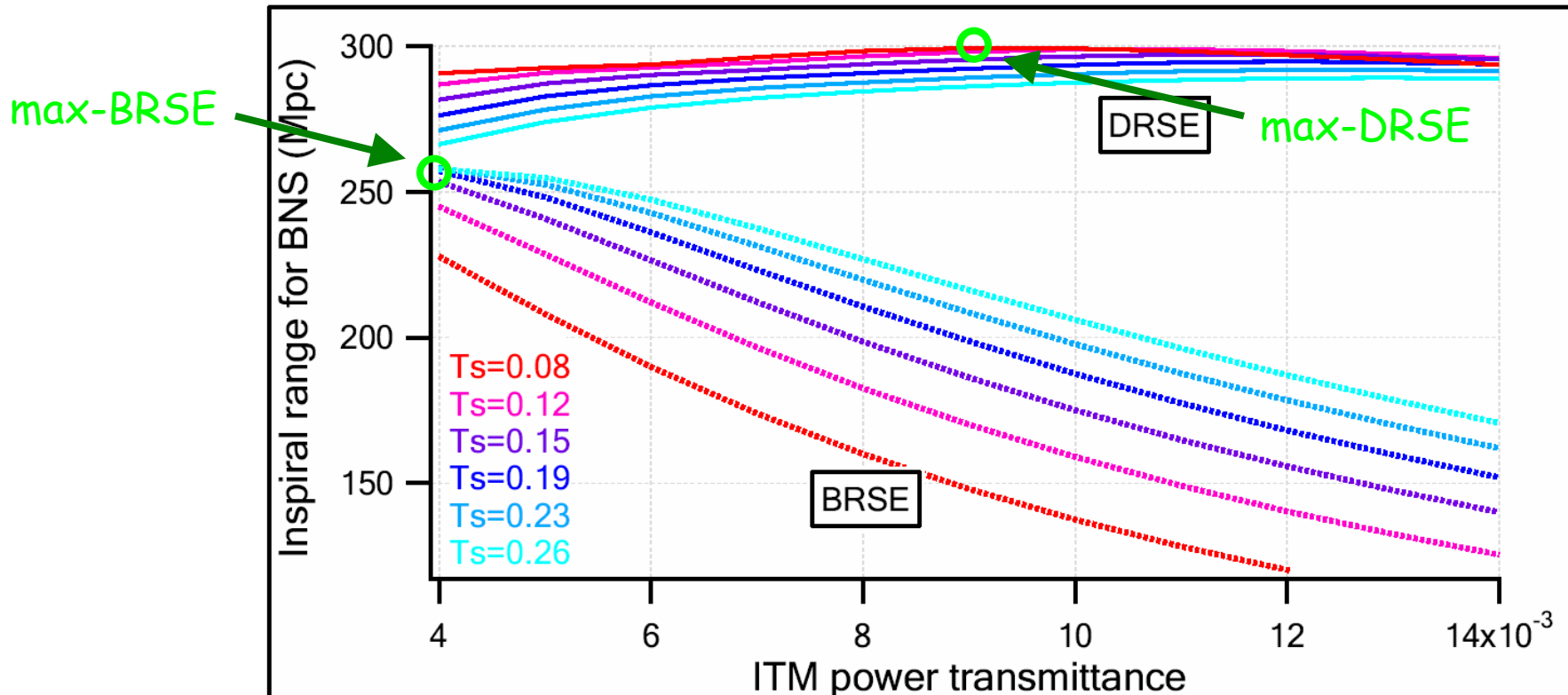


- Input power is limited by the cooling capability
- There are 4 parameters to be tuned

# Setups for the highest IR

[BW study 2009]

Detune phase and DC readout phase are chosen to maximize IR at each point

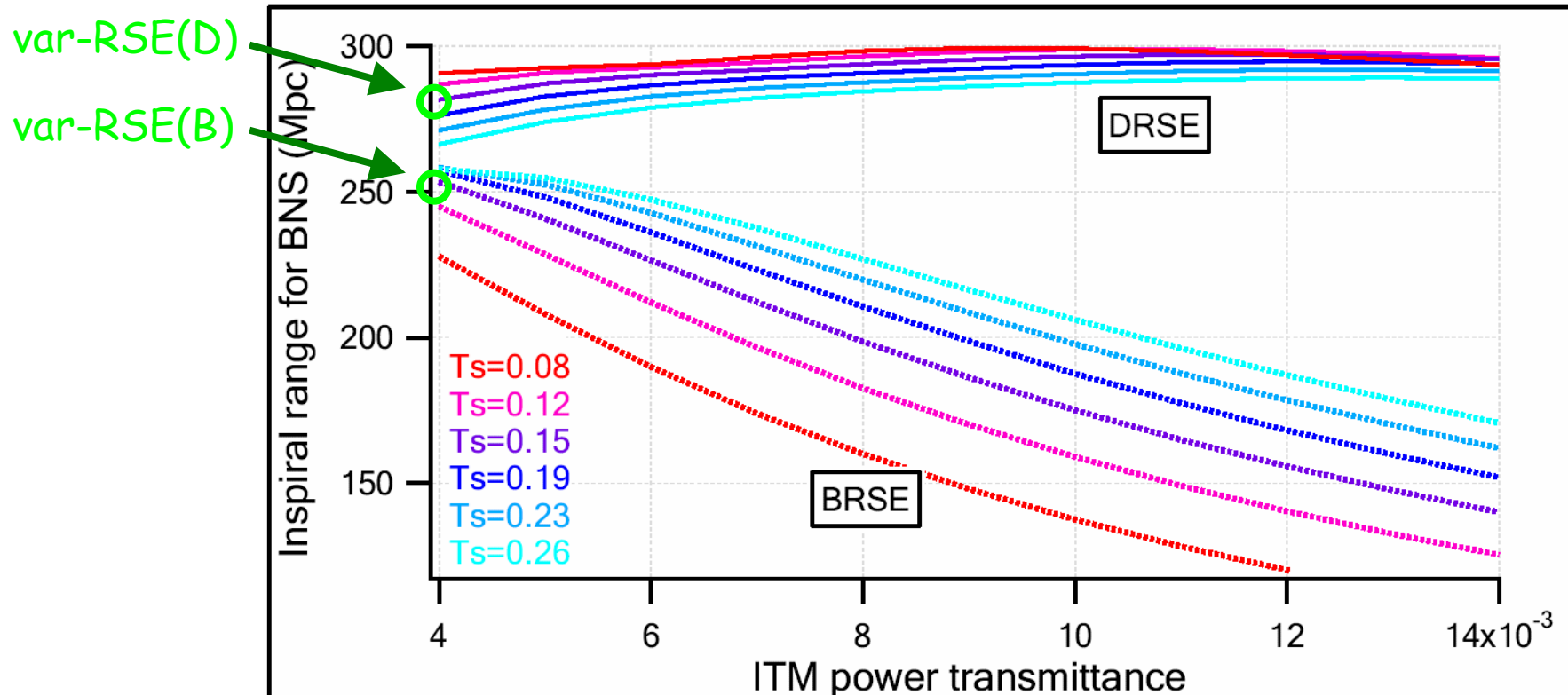


- Max-BRSE and Max-DRSE are not compatible
- Max-DRSE spectrum is quite narrow-band
- High-IR DRSE with decent-IR BRSE is desirable

# Compatibility

[BW study 2009]

Detune phase and DC readout phase are chosen to maximize IR at each point



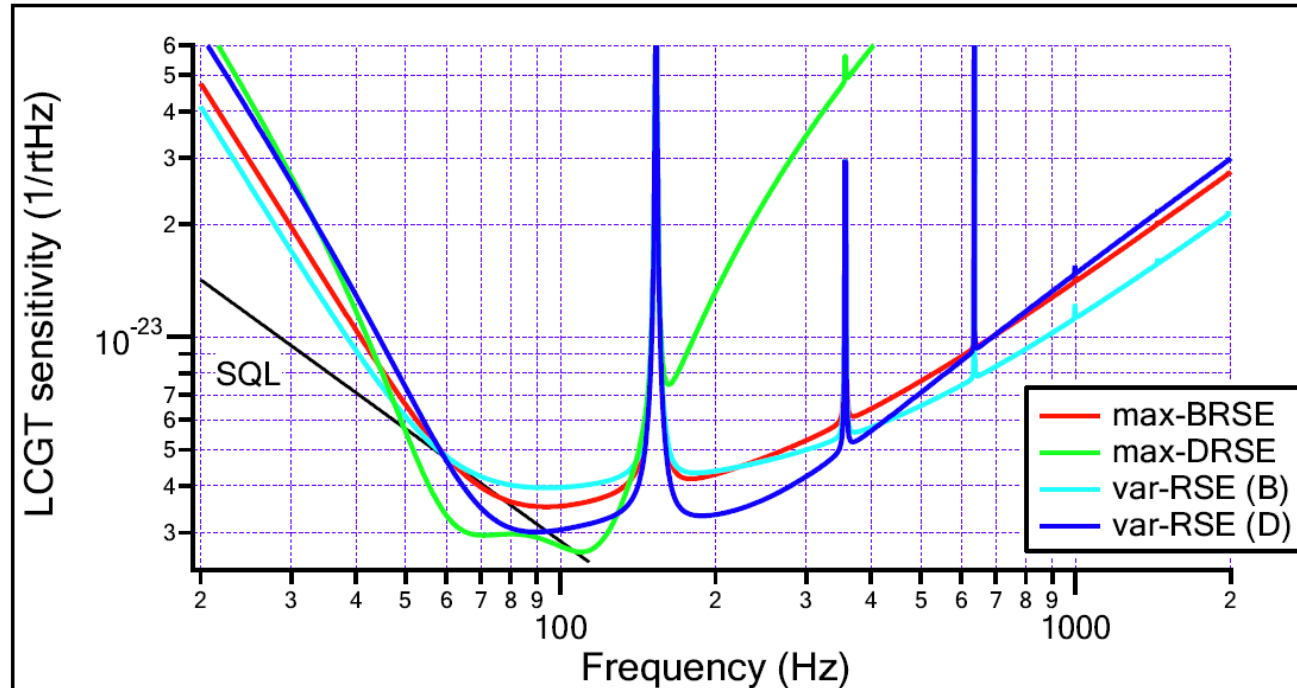
Variable-RSE with an intermediate optical setup



bLCGT configuration

# Sensitivity spectra

[BW study 2009]

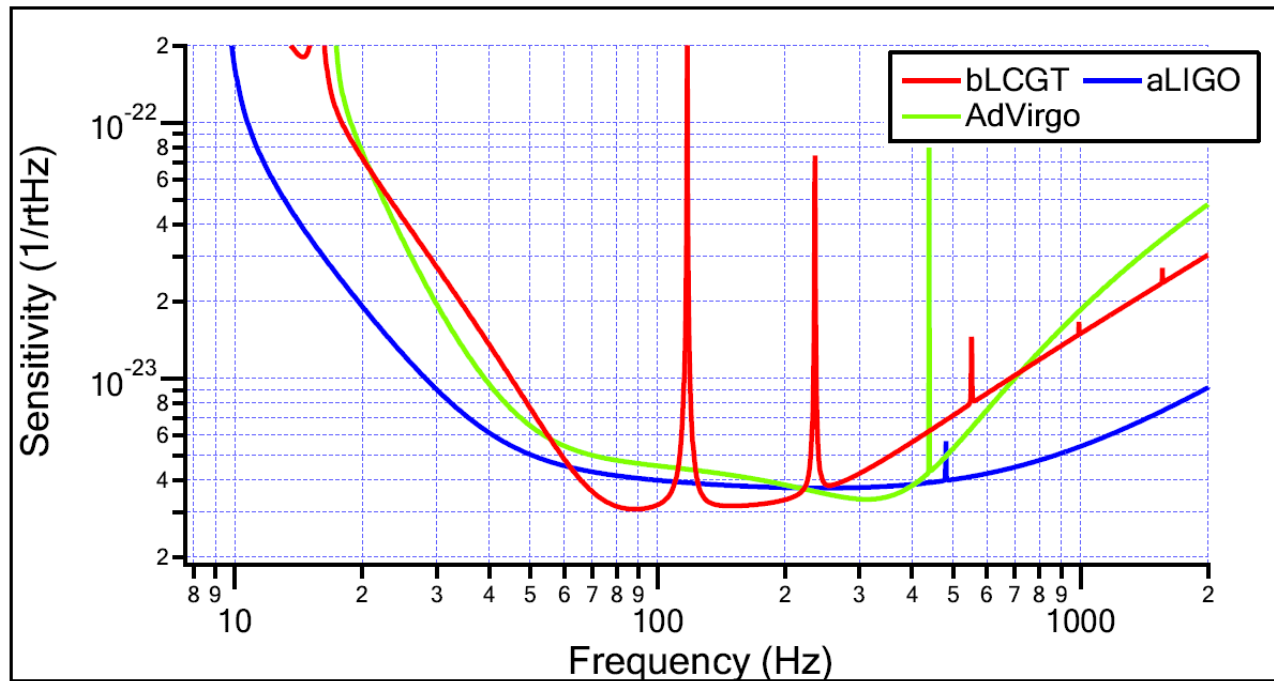


	$T_{ITM}$	$T_S$	$\phi$	$\zeta$	$IR_{(SN8)}$
mB	0.4%	23%	90 <sub>deg</sub>	128 <sub>deg</sub>	259Mpc
mD	0.9%	8%	75 <sub>deg</sub>	104 <sub>deg</sub>	299Mpc
vB	0.4%	15%	90 <sub>deg</sub>	122 <sub>deg</sub>	255Mpc
<b>vD</b>			87 <sub>deg</sub>	135 <sub>deg</sub>	<b>281Mpc</b>

We decided to start with the var-DRSE configuration.

Changeable to the var-BRSE in the future.

# Comparison with other detectors



\*LCGT noise curves have been updated

IR=309Mpc (aLIGO), 242Mpc (AdVirgo), 273Mpc (LCGT)

[309Mpc  $\times$   $\frac{3}{4}$  =231Mpc]

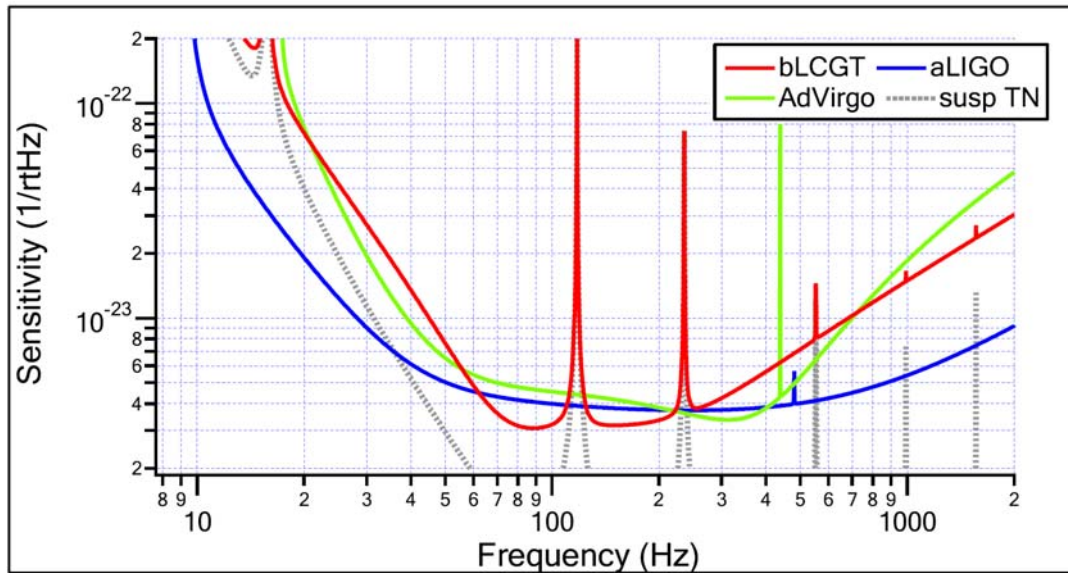
LCGT strategy

cryogenics  $\rightarrow$  low Mirror TN  $\rightarrow$  deep spectrum

aLIGO strategy

4km  $\rightarrow$  already high IR  $\rightarrow$  broad spectrum

# Significance in GW network



IR=309Mpc (aLIGO), 242Mpc (AdVirgo), 273Mpc (LCGT)

\*Without suspension TN, IR of LCGT would be 301Mpc.

- Optimization so far was for LCGT as a single detector



LCGT could put more significance to GWIC by going low frequencies

- Optimization so far was with the highest power (400kW in arm)



Suspension TN could be reduced by low-power operation



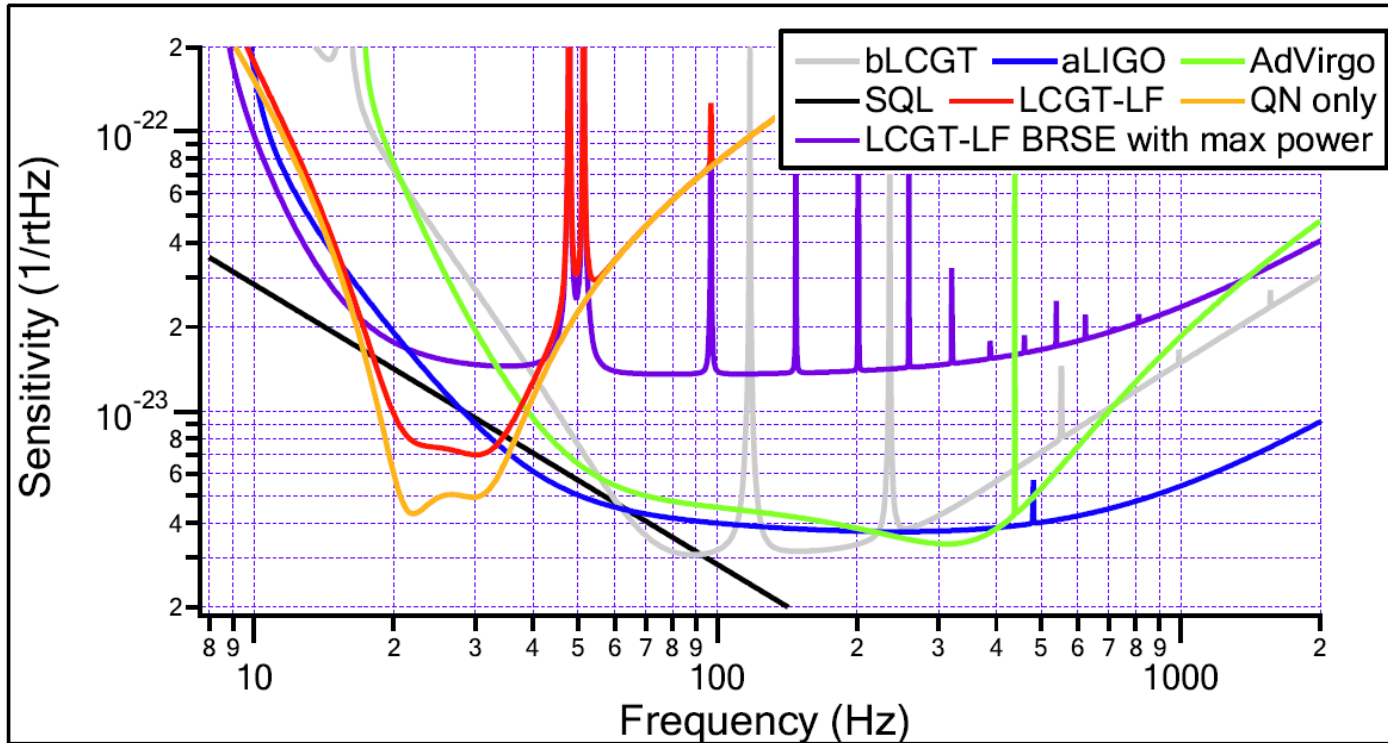
## LCGT-LF study

(WG member: Agatsuma, Aso, Hayama, Kanda, Kuroda, Takahashi, K.Yamamoto, me + collaboraton)

- Possible LF configuration
- LF/HF GW sources
- Technical feasibility ... etc.

[Ref: JGW-T1000446-v2]

# LCGT-LF



- Input power 1.5~12W
- $T_s$  15%  $\rightarrow$  12%
- $T_{ITM}$  0.4  $\rightarrow$  0.6%
- Fiber length  
30cm  $\rightarrow$  120cm
- Fiber thickness  
1.6mm  $\rightarrow$  1.4mm
- Max 170mW cooling

(for BNS)

IR=309Mpc (aLIGO)

IR=242Mpc (AdVirgo)

IR=273 (bLIGO)

IR for BNS = 196Mpc

IR for 100Ms BBH = 4.17Gpc

[IR w/o TN: 282Mpc/6.88Gpc]

(for 100Ms BBH)

IR=3.45Gpc (aLIGO)

IR=3.98Gpc (aLIGO BBH)

Inspiral End Freq = 44Hz

- (1) How much do we gain at low freq?
- (2) Is there any technical benefit?



# Discussion (1) GW at low freq

- **BH-BH inspirals**

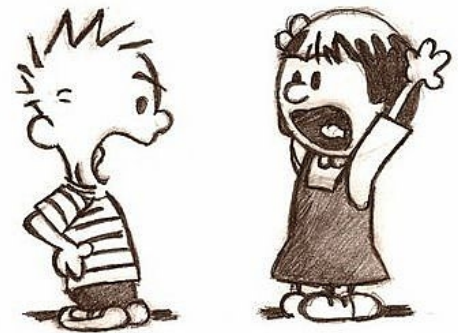
- ~ High-end of 50-50Ms BBH inspiral is 44Hz  
Mass ratio etc. are not given by ring-downs but by inspirals

- **Vela pulsar**

- ~ 22Hz

- **NS-NS inspirals**

- ~ LCGT-LF's IR is as high as 196Mpc  
Observation at unique frequencies  
Lower accuracy in parameter estimates



# Discussion (2) GW at high freq

- **NS-NS merger**

  - ~ Merger signals would appear at 2~8 kHz

- **LMXB**

  - ~ Most of them are outside the range but ScoX-1 is possible

- **Supernova**

  - ~ Event rate is not high but we cannot miss an event in our galaxy

  - ~ Possibility of multi-channel observation

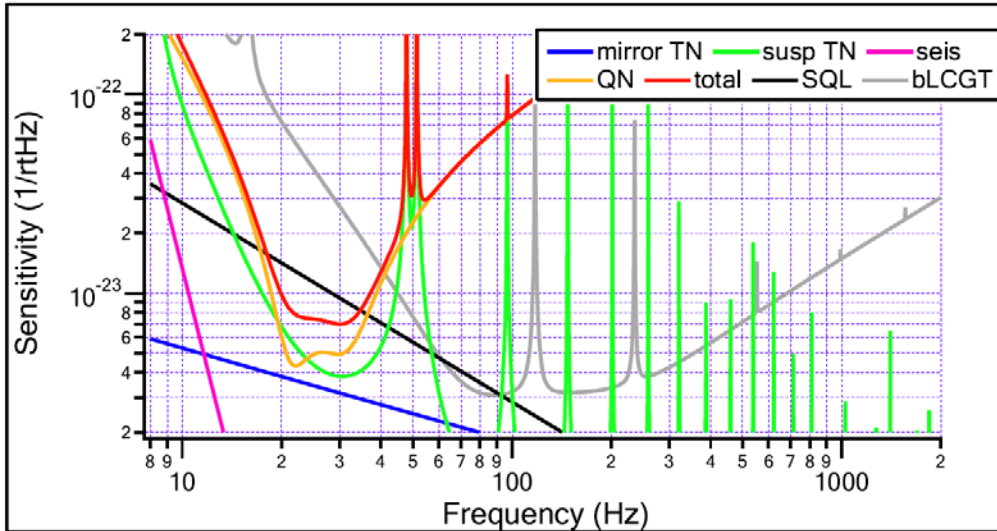


## Discussion (3) narrow-banding

- As was studied in 2009, even if the IR is same, the accuracy of parameter estimates for binary inspirals decreases by narrow-banding
- For cosmic GW background, cross-correlation with multiple detectors is necessary and having a unique spectrum will become a disadvantage
- Xylophone would work if 2 detectors are on a same site like ET, but it is different with LCGT and AdVirgo that have different antenna patterns



# Discussion (4) technical points



- Low RMS motion would result in the reduction of various technical noise sources
- We can avoid the absorption issues of Sapphire that we rely on companies



# However...

[Miyoki, yesterday]

## Toss the Table (TDT)

- ① Original targeted sapphire mirror diameter is 25 cm for bLCGT.
- ② Recently, not 25cm but 22cm mirror substrate preparation was decided.
- ③ 22cm substrate cannot be used for the present bLCGT design, because the beam diameter on ETM is larger ETM diameter and we will get a lot of optical loss.



buy mirrors now



- low mass
- high absorption
- high loss

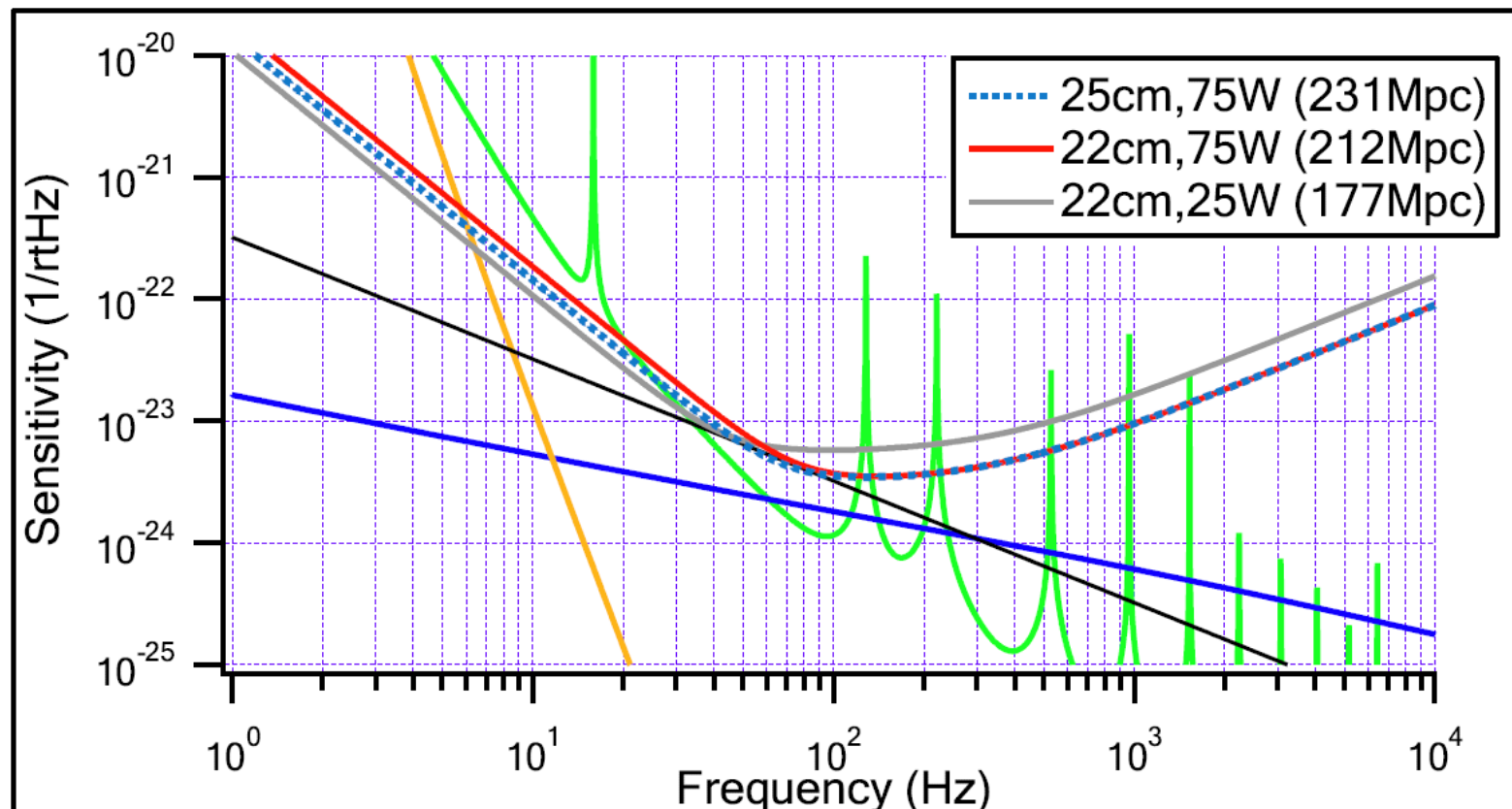


- RP noise ↗
- shot noise ↗
- susp TN ↗

Yesterday, I said the inspiral range will decrease by a large factor, but it seems we can recover the range by detuning.

# BRSE with 22cm mass

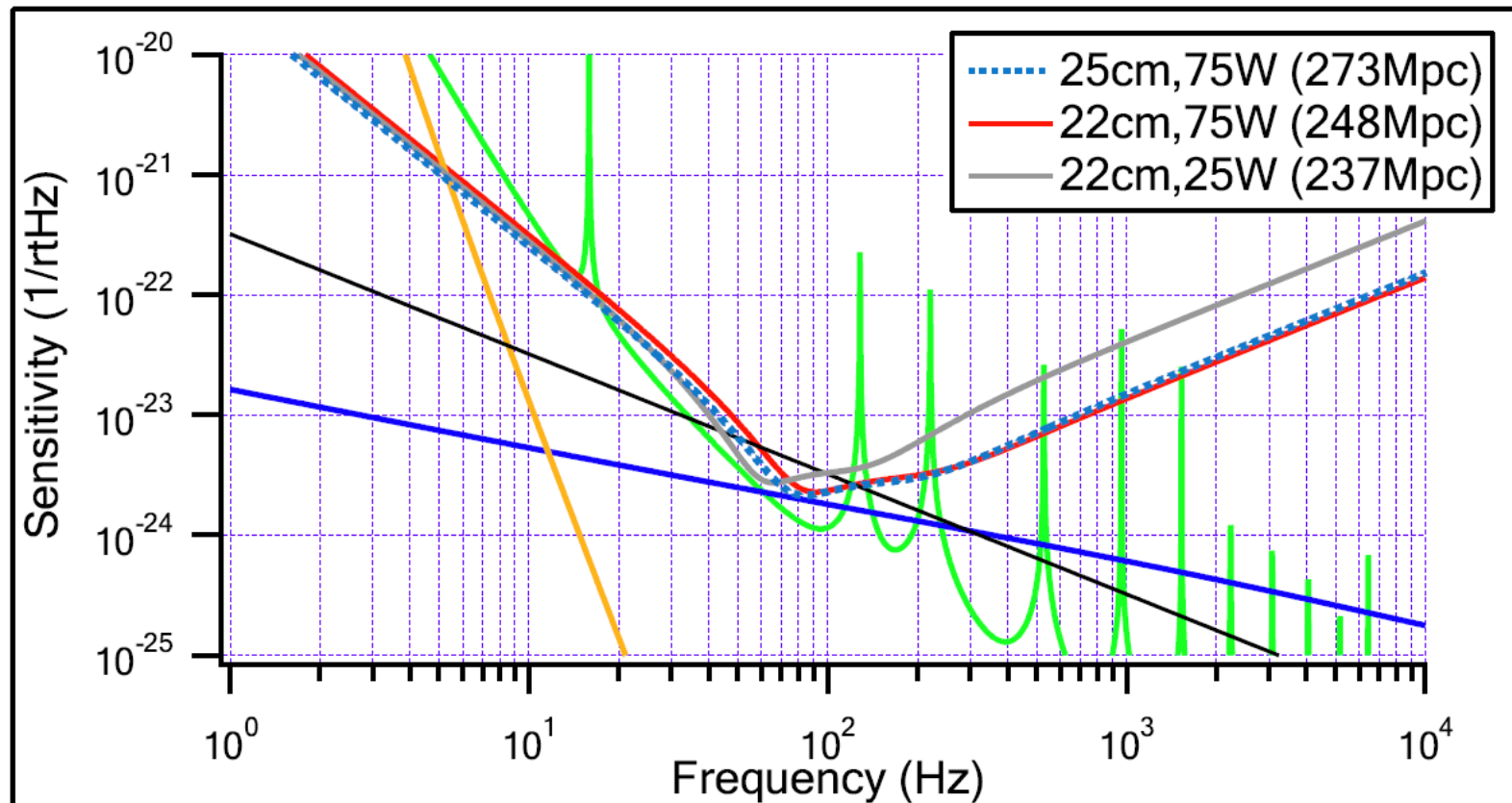
w=4cm/4cm



- Absorption being  $\times 3$ , we should reduce the power by  $1/3$
- IR may decrease by 23% compared with BRSE (25cm, 75W)
- IR should be 200+Mpc for 1 event/year w/90% probability

# DRSE with 22cm mass

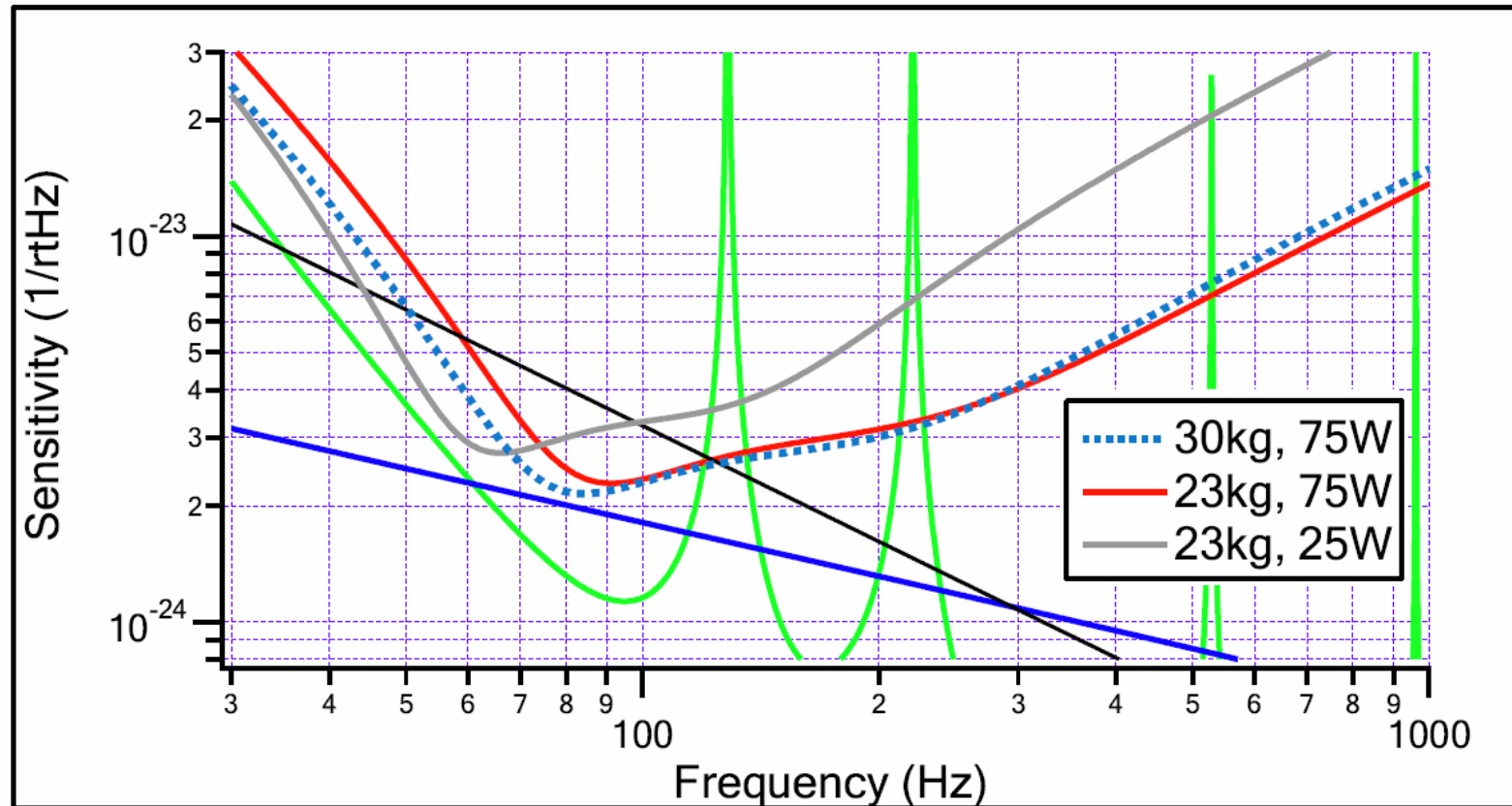
w=4cm/4cm



- IR reduction can be recovered by bandwidth reduction
- HF sensitivity is worse by  $\sim 4$
- Detuning is as large as 6.0 degrees ( $\sim 3.5$  deg for 25cm)

# DRSE with 22cm mass

w=4cm/4cm



- We can recover the bandwidth as we improve the mirror quality (absorption)
- Similar to AdVirgo strategy



# Summary

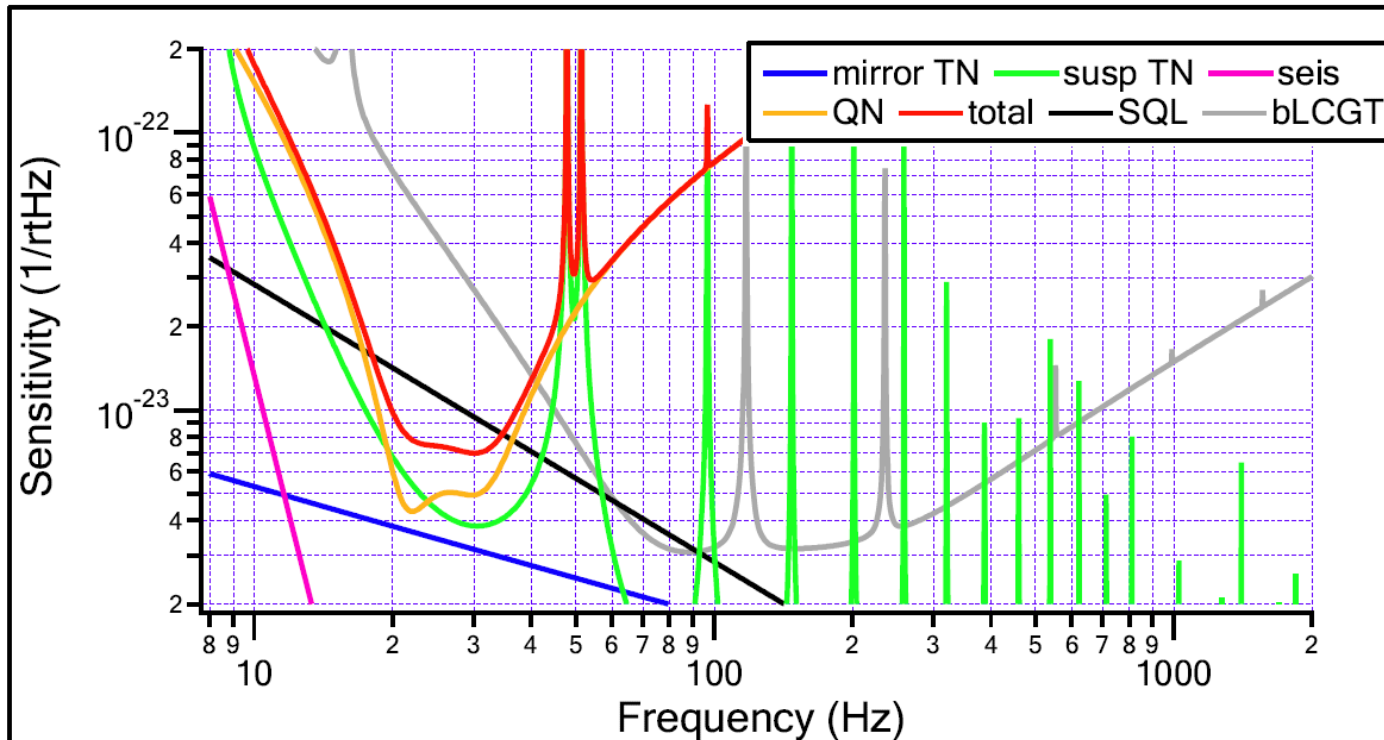
- Cryogenic detector can go deeper in the spectrum
- Trade-off of bandwidth and good sensitivity
- Narrow-band operation is not good
- Low-power low-frequency operation is not good
  
- Table was tossed
- Maybe we should sacrifice the bandwidth now
- Maybe we should re-optimize the setup parameters
- Maybe we should go for silicon

[ In my opinion, it is certainly necessary to purchase the 22cm Sapphire mirrors, but it's just to improve the mirror quality; we don't use the mirrors but wait for better and bigger mirrors. ]



Supplementary slides

# Noise Budget of LCGT-LF



- Input power 1.5~12W
- PRG=11, Rsr=88%
- Finesse 1050
- Fiber length 120cm
- Fiber thickness 1.4mm
- Max 170mW cooling

- Vertical resonance and 1<sup>st</sup> violin overlapped at 50Hz
- Broadband operation at these frequencies is challenging
- T(=20K) could be 12.4K (IM Temperature is set 10K)