O3 Estimated Sensitivity for FPMI, PRFPMI and RSE

Yutaro Enomoto, Yuta Michimura

Department of Physics, University of Tokyo

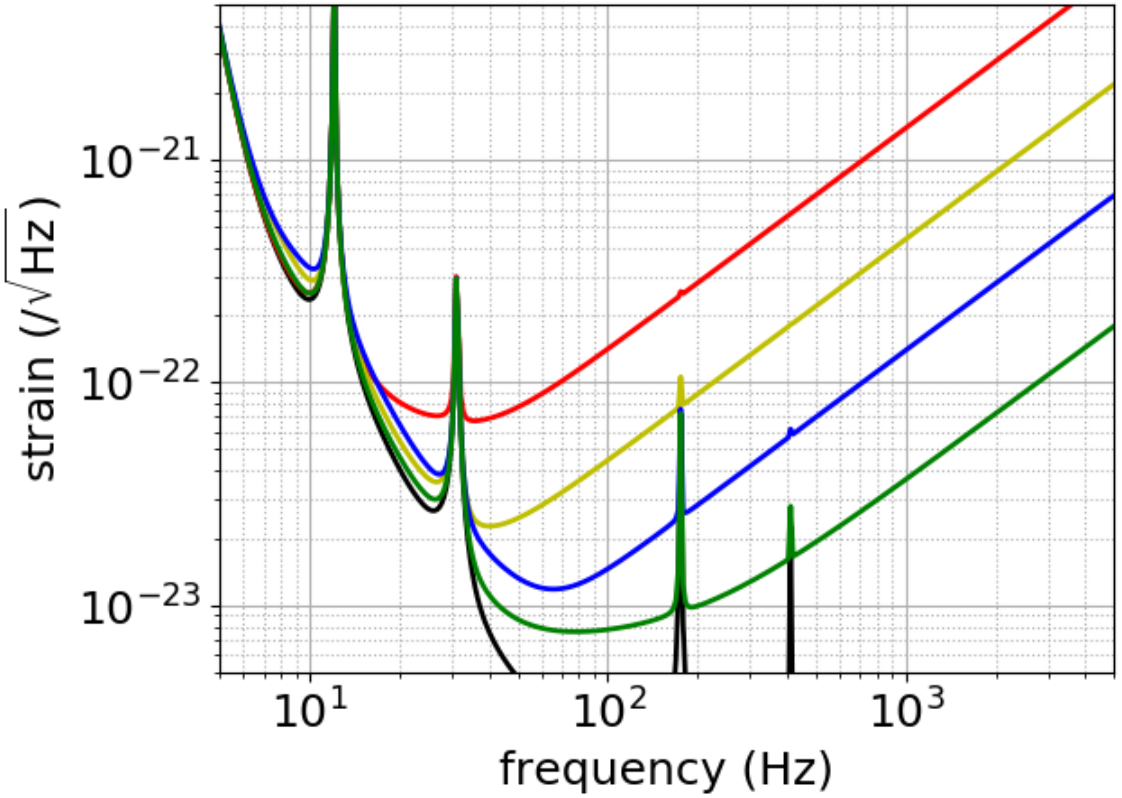
Kentaro Somiya

Department of Physics, Tokyo Institute of Technology

Conditions

- 10W input
- Shot noise coupling with feedforward gain 100 included
- Four IFO configurations
  - FPMI with tilted PRM (equivalent to 1W input power)
  - FPMI with blank PRM
  - PRFPMI (R_SRM=0 %)
  - RSE with R_SRM=70 %
- Four excess noise models
  - No excess
  - aLIGO O1 level
  - 4x aLIGO O1 level (AdV O2 level)
  - 8x aLIGO O1 level
- Suspension and mirror thermal noise at 22 K

Sensitivity with No Excess Noise



thermal

excess 0 x O1

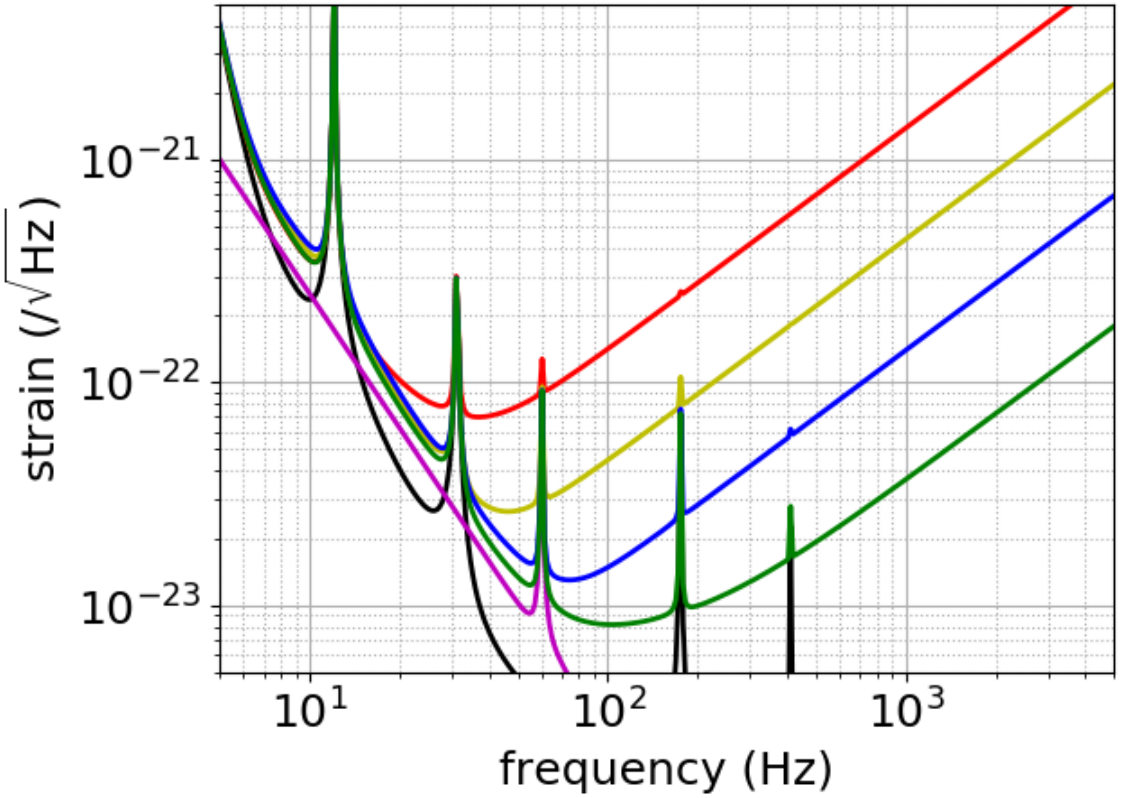
FPMI 1W (10W with PRM)
1.4-1.4 BNS: 18.0 Mpc
30-30 BBH:0.2349 Gpc

FPMI 10W
1.4-1.4 BNS: 36.7 Mpc
30-30 BBH:0.4970 Gpc

PRFPMI 10W
1.4-1.4 BNS: 57.9 Mpc
30-30 BBH:0.8215 Gpc

RSE 10W, R_SRM=70%
1.4-1.4 BNS: 93.4 Mpc
30-30 BBH:1.4323 Gpc

Sensitivity with O1 Excess Noise



thermal

excess 1 x O1

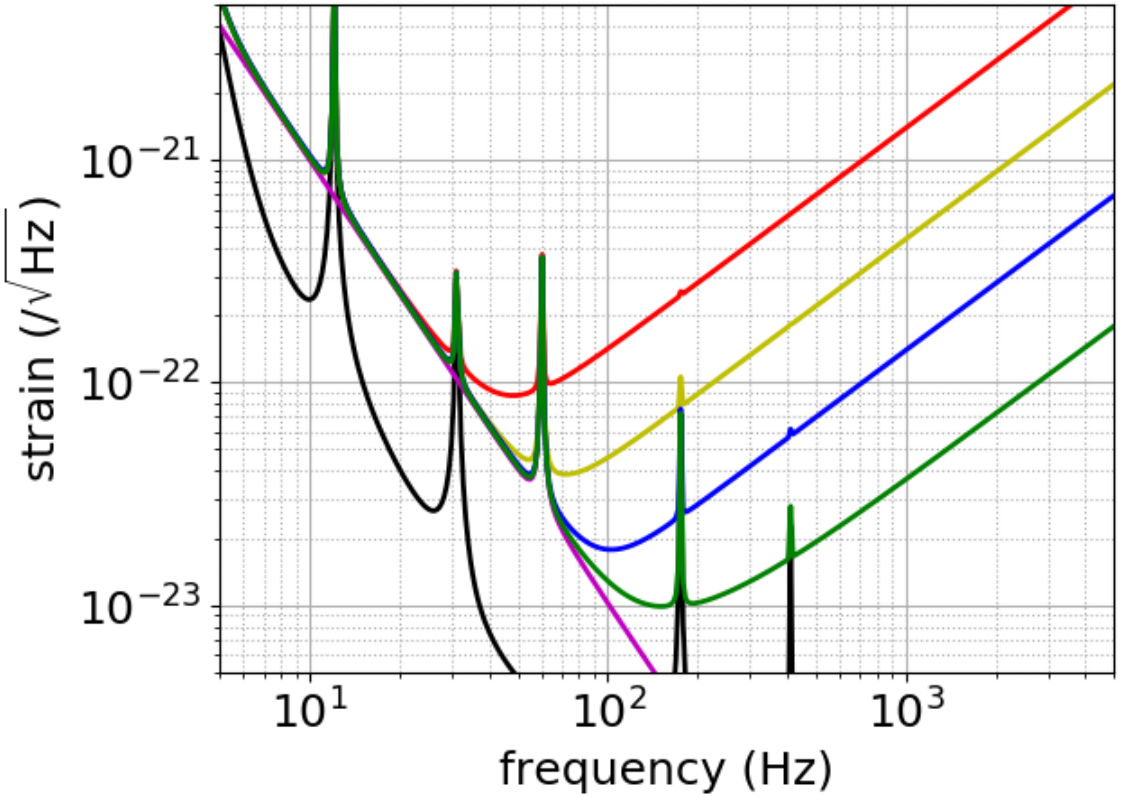
FPMI 1W (10W with PRM)
1.4-1.4 BNS: 15.6 Mpc
30-30 BBH:0.2025 Gpc

FPMI 10W
1.4-1.4 BNS: 30.0 Mpc
30-30 BBH:0.4016 Gpc

PRFPMI 10W
1.4-1.4 BNS: 47.6 Mpc
30-30 BBH:0.6649 Gpc

RSE 10W, R_SRM=70%
1.4-1.4 BNS: 71.0 Mpc
30-30 BBH:1.0673 Gpc

Sensitivity with x4 O1 Excess Noise



thermal

excess 4 x O1

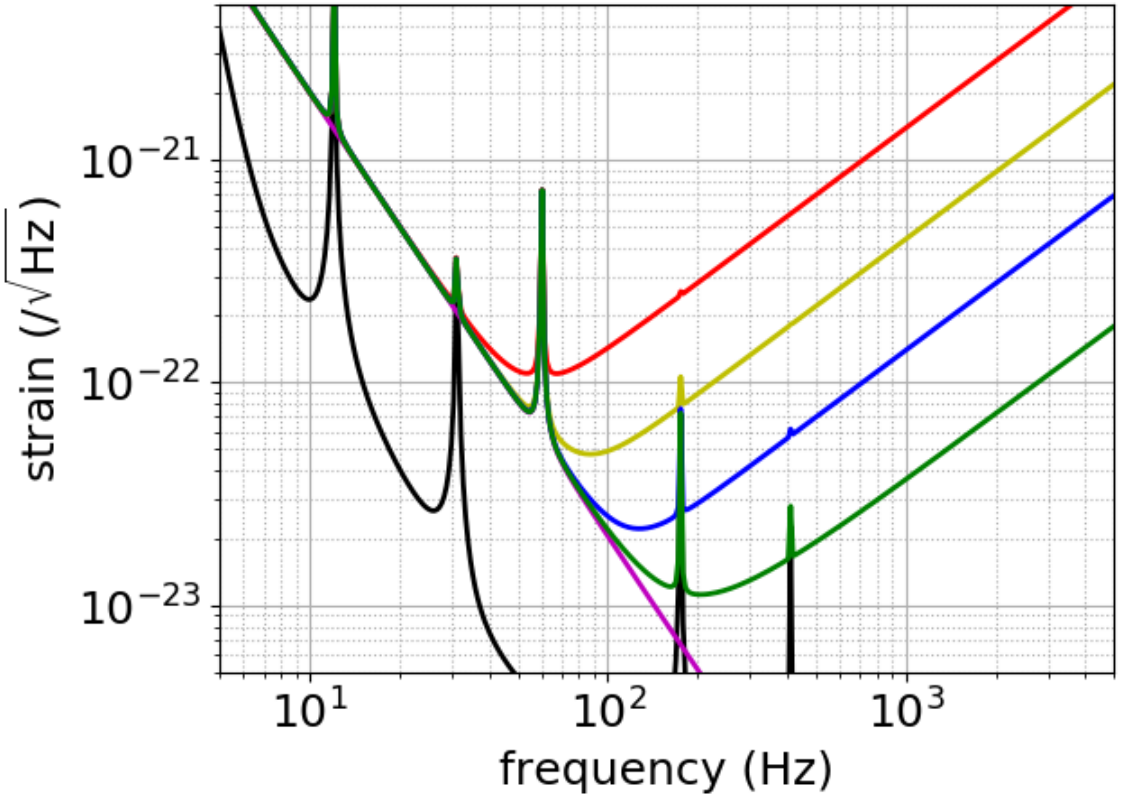
FPMI 1W (10W with PRM)
1.4-1.4 BNS: 9.5 Mpc
30-30 BBH:0.1228 Gpc

FPMI 10W
1.4-1.4 BNS: 16.3 Mpc
30-30 BBH:0.2137 Gpc

PRFPMI 10W
1.4-1.4 BNS: 27.1 Mpc
30-30 BBH:0.3737 Gpc

RSE 10W, R_SRM=70%
1.4-1.4 BNS: 41.6 Mpc
30-30 BBH:0.6219 Gpc

Sensitivity with x8 O1 Excess Noise



thermal

excess 8 x O1

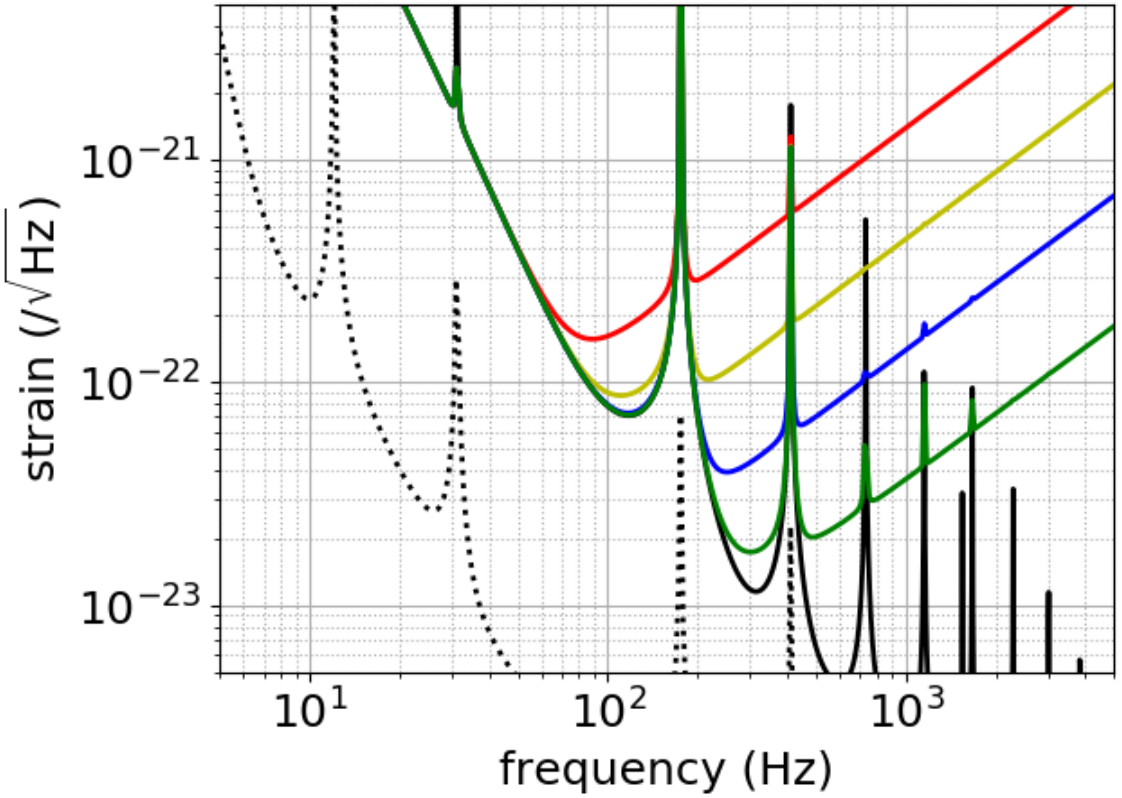
FPMI 1W (10W with PRM)
1.4-1.4 BNS: 6.7 Mpc
30-30 BBH:0.0859 Gpc

FPMI 10W
1.4-1.4 BNS: 11.2 Mpc
30-30 BBH:0.1477 Gpc

PRFPMI 10W
1.4-1.4 BNS: 19.0 Mpc
30-30 BBH:0.2637 Gpc

RSE 10W, R_SRM=70%
1.4-1.4 BNS: 30.2 Mpc
30-30 BBH:0.4572 Gpc

Sensitivity at 300K

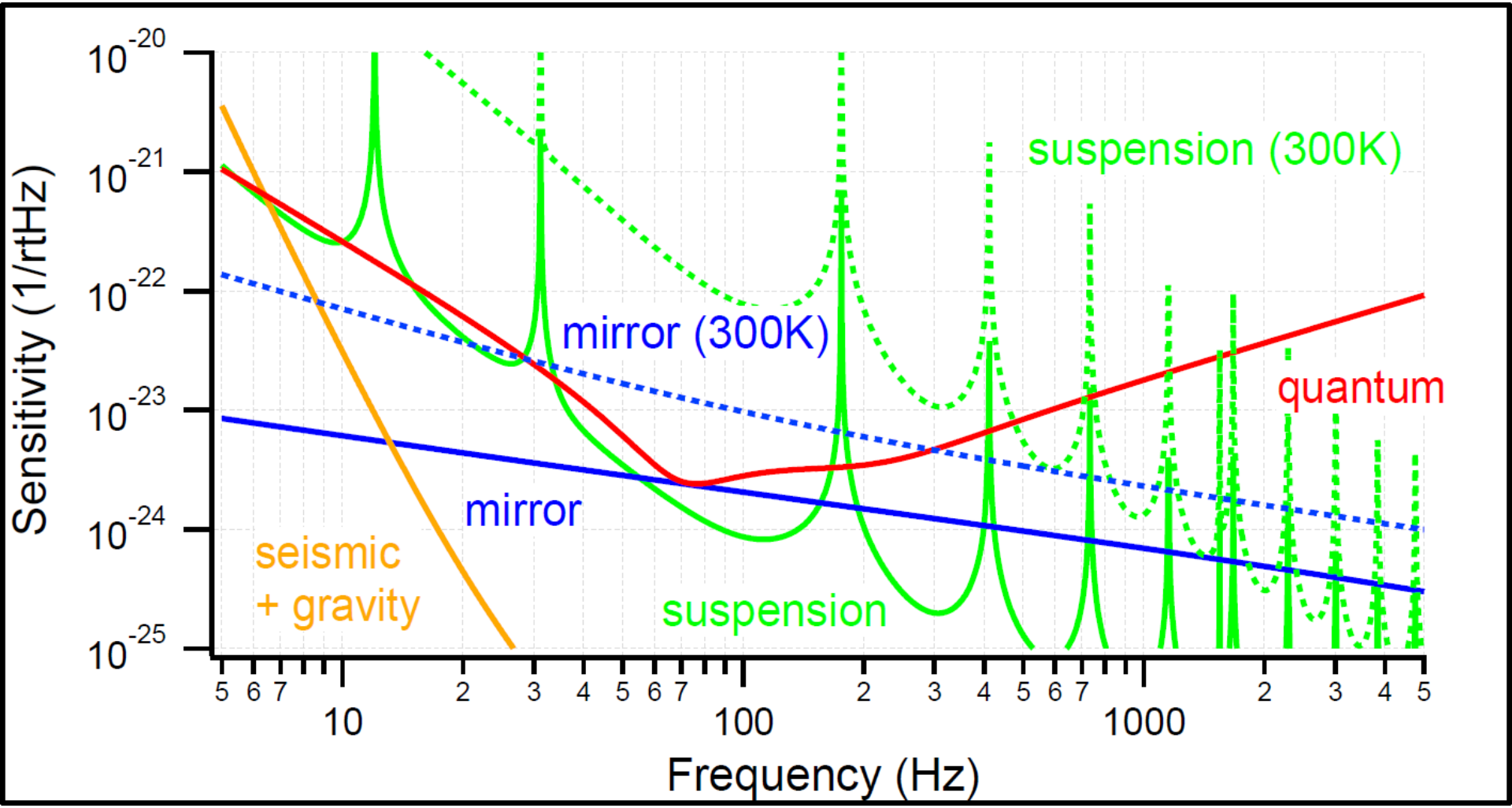


thermal 22K
thermal 300K
FPMI 1W (10W with PRM)
1.4-1.4 BNS: 3.1 Mpc
FPMI 10W
1.4-1.4 BNS: 4.9 Mpc
PRFPMI 10W
1.4-1.4 BNS: 6.9 Mpc
RSE 10W, R_SRM=70%
1.4-1.4 BNS: 11.6 Mpc

- 300 K might be OK for RSE case?
- ~100 K without heatlinks could be an option?

Cryogenics: Necessary

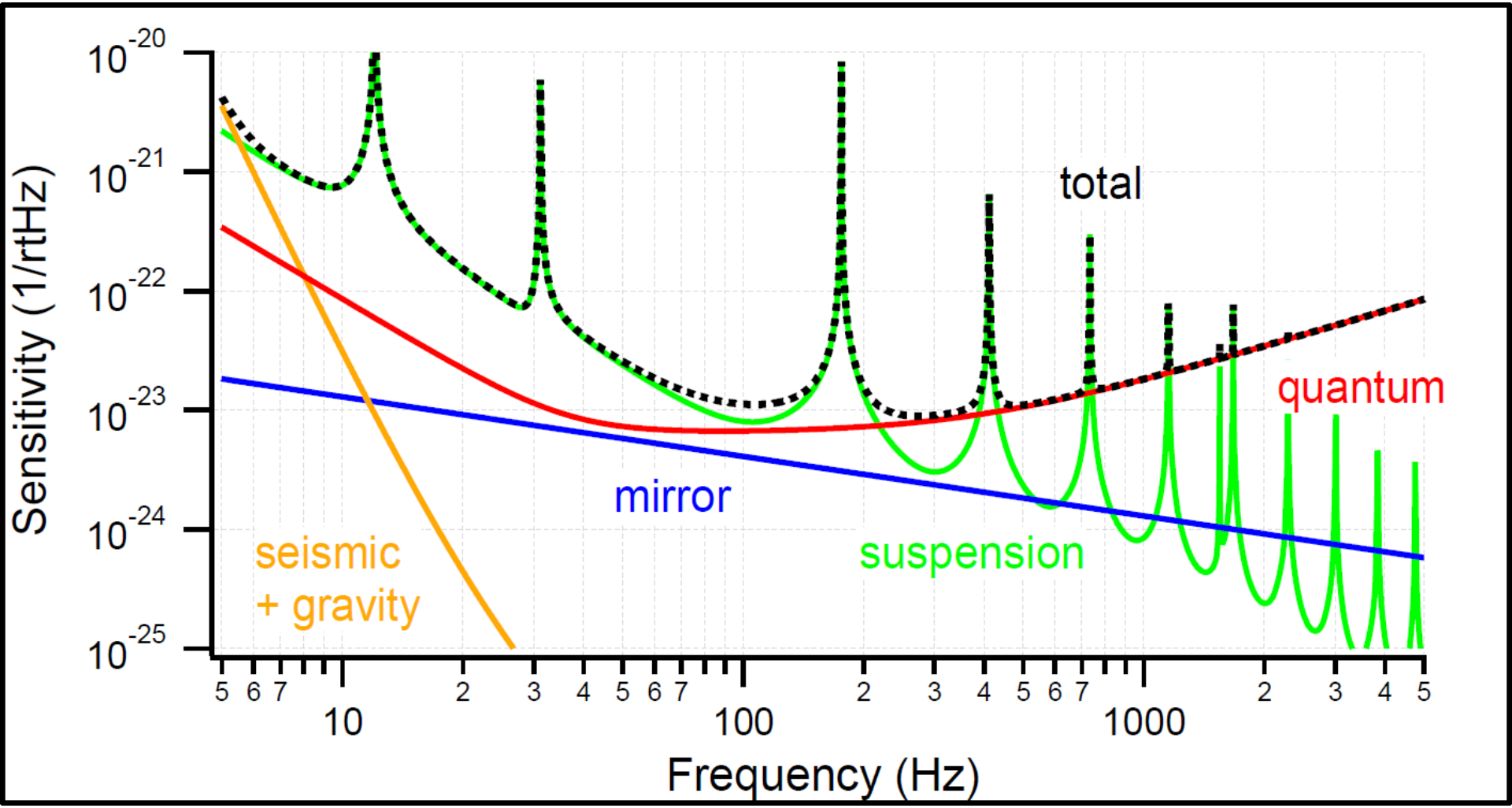
- 300K suspension thermal noise is x100 worse



By K. Somiya (see [kagra-isc 01736] 300K sensitivity, 2017/11/06)

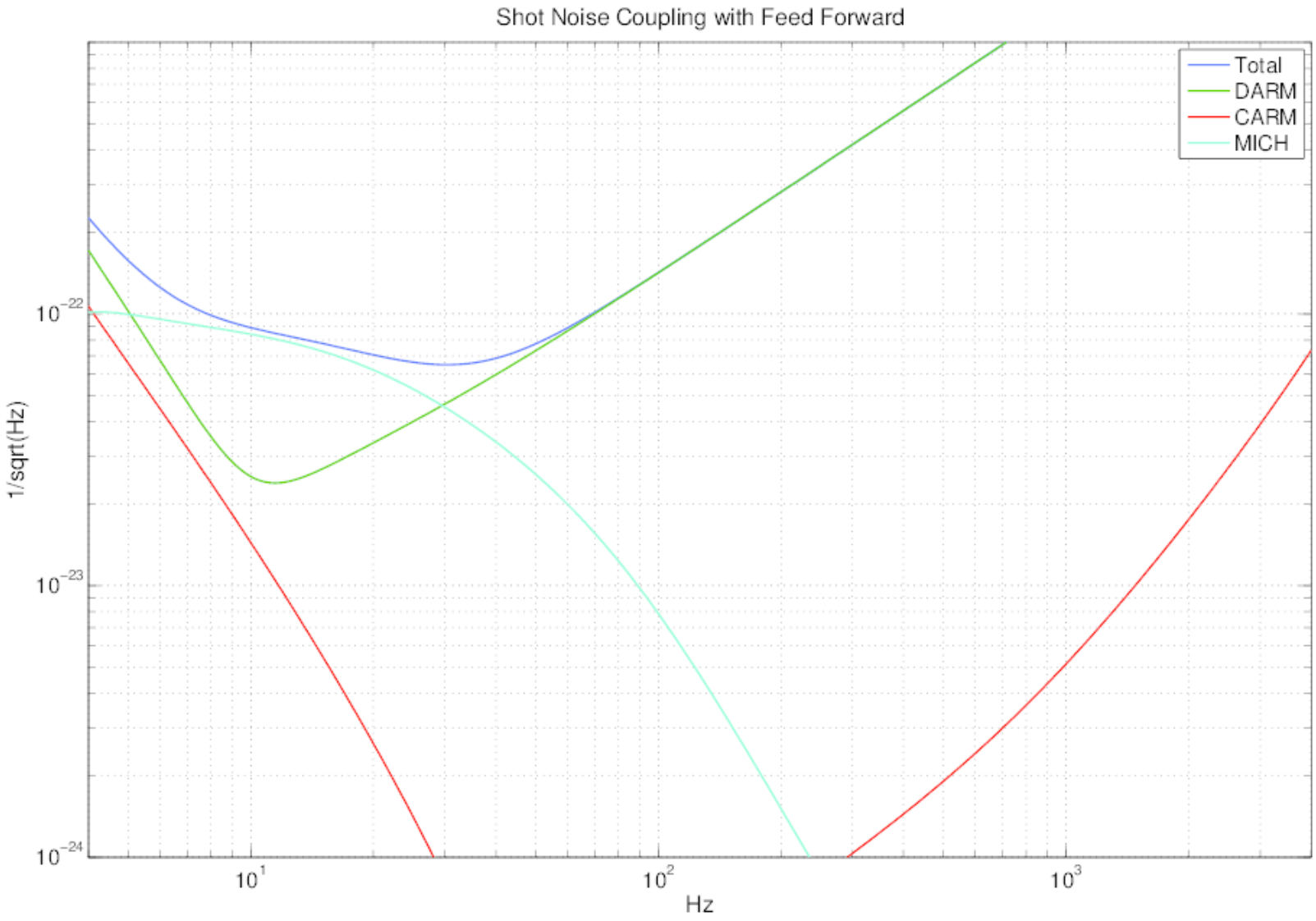
Cryogenics: Necessary

- 100K could be an option?

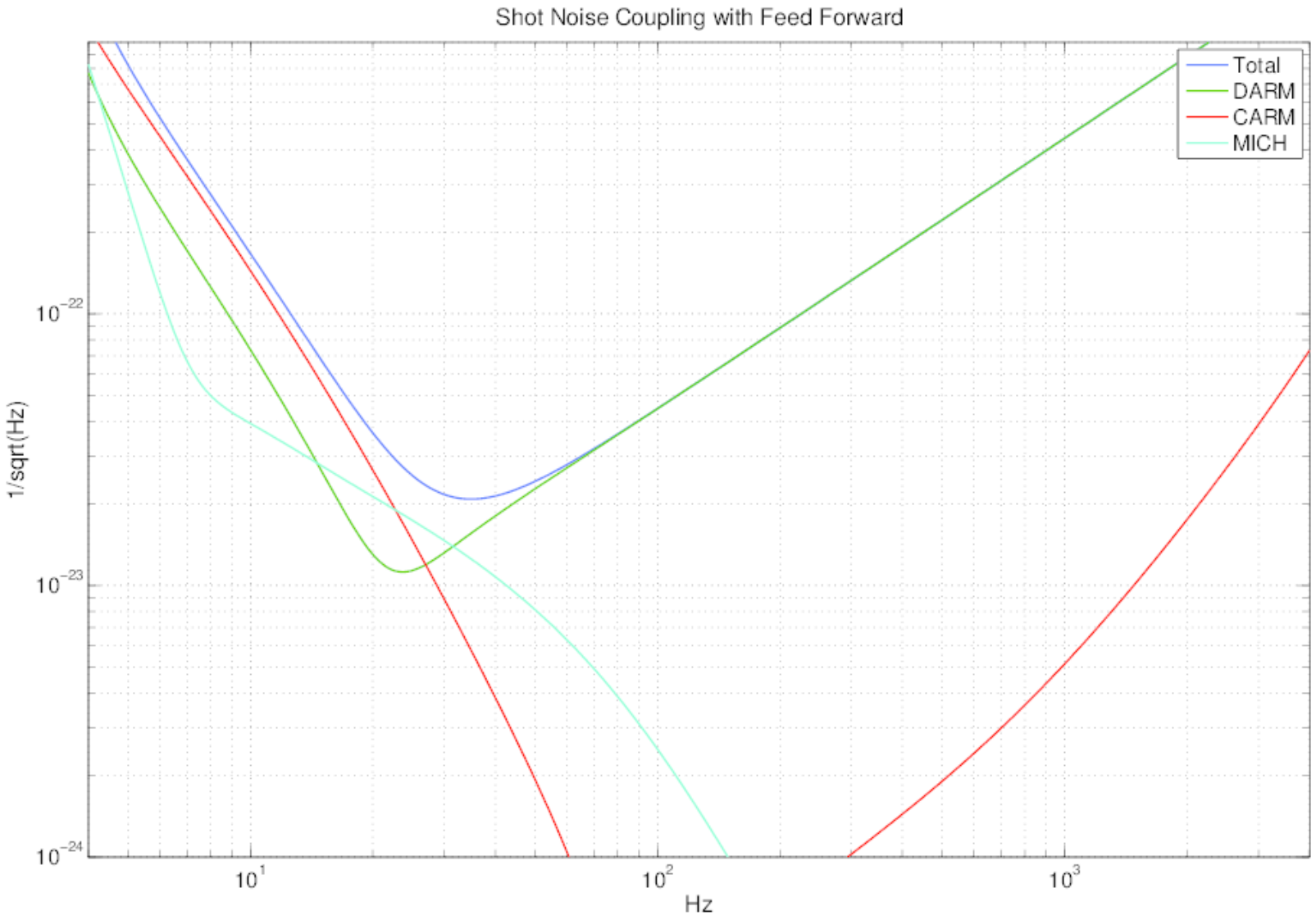


By K. Somiya on 2018/4/25 (100K at 20W, RSE)

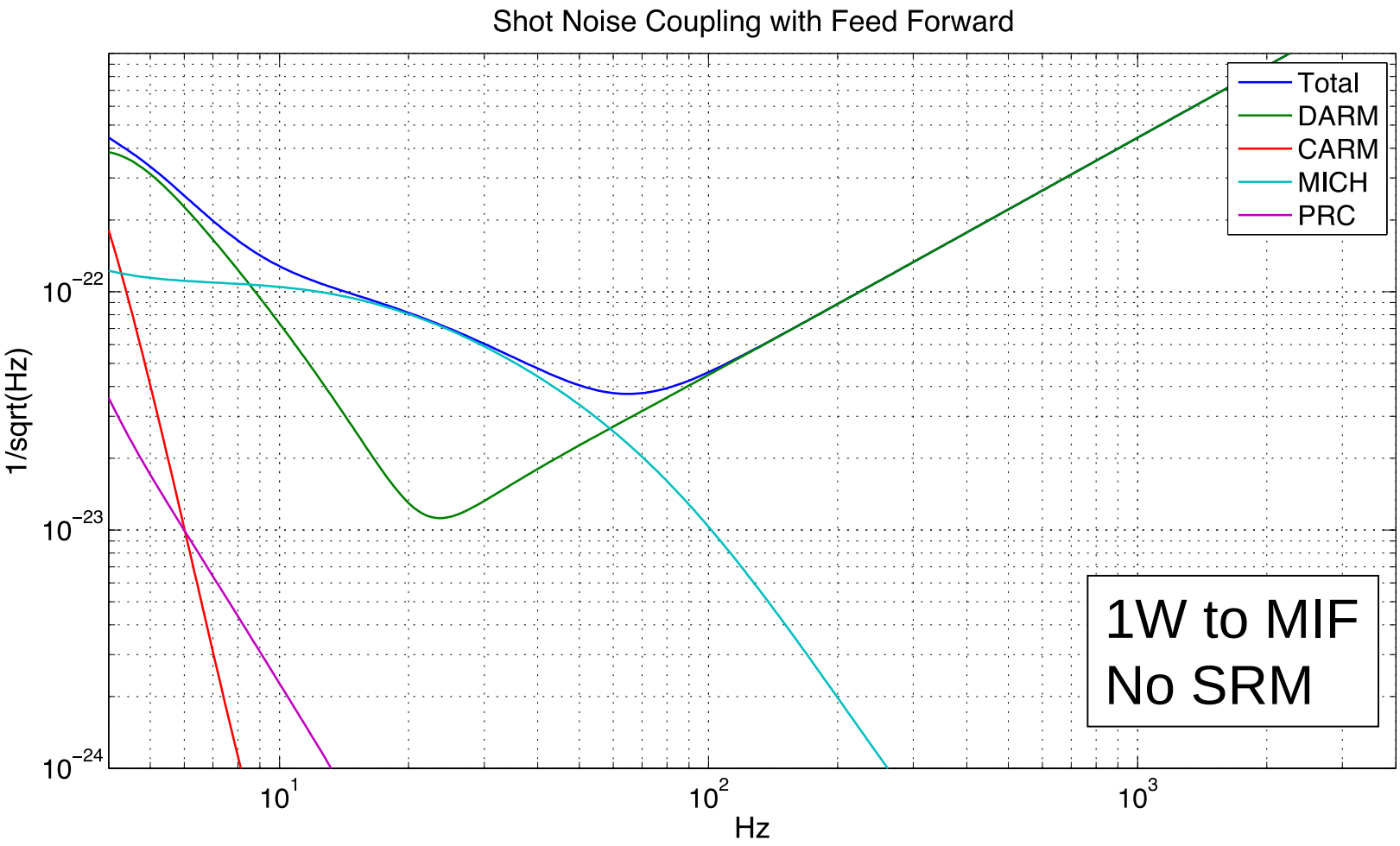
Shot Noise Coupling FPMI 1W



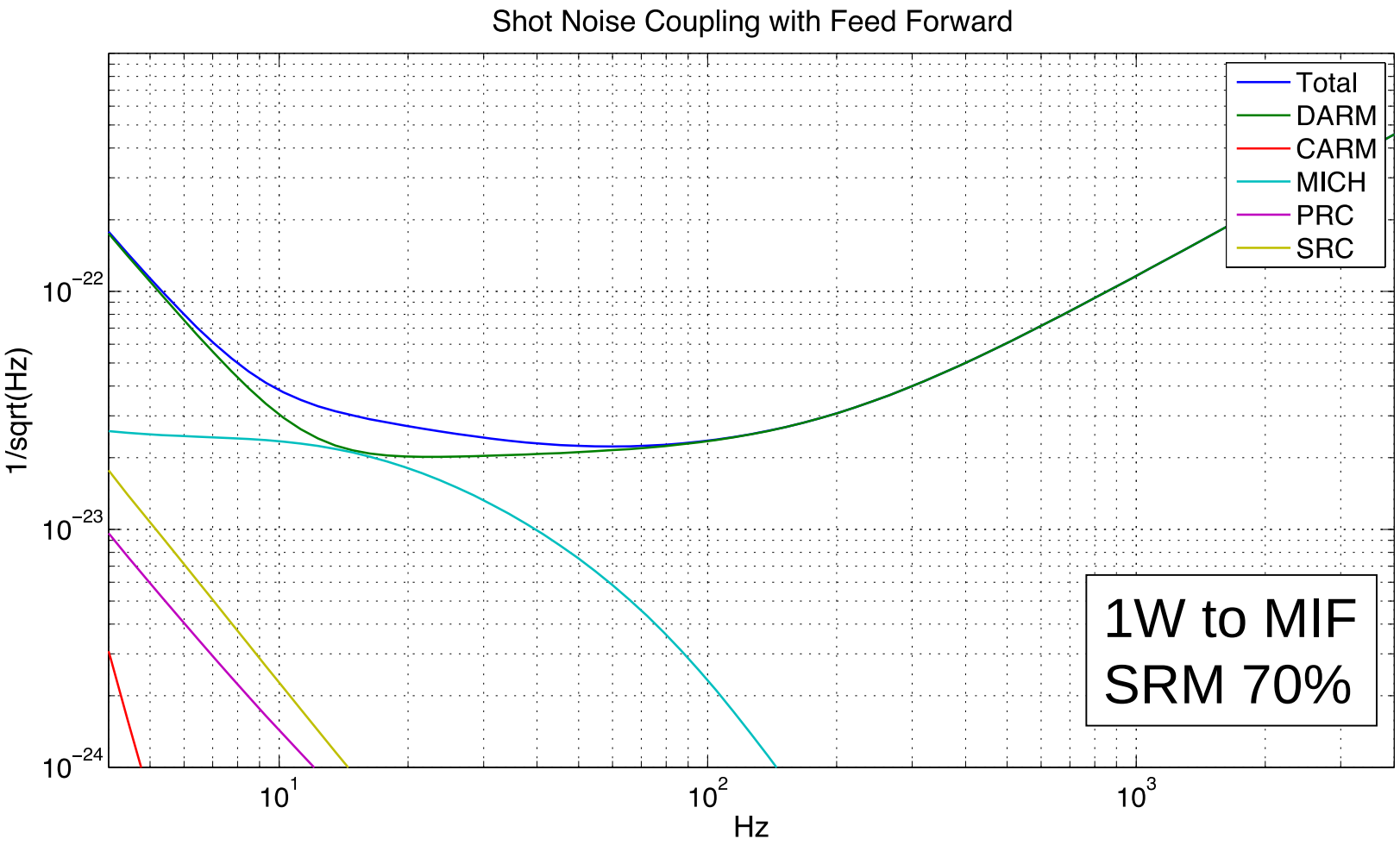
Shot Noise Coupling FPMI 10W



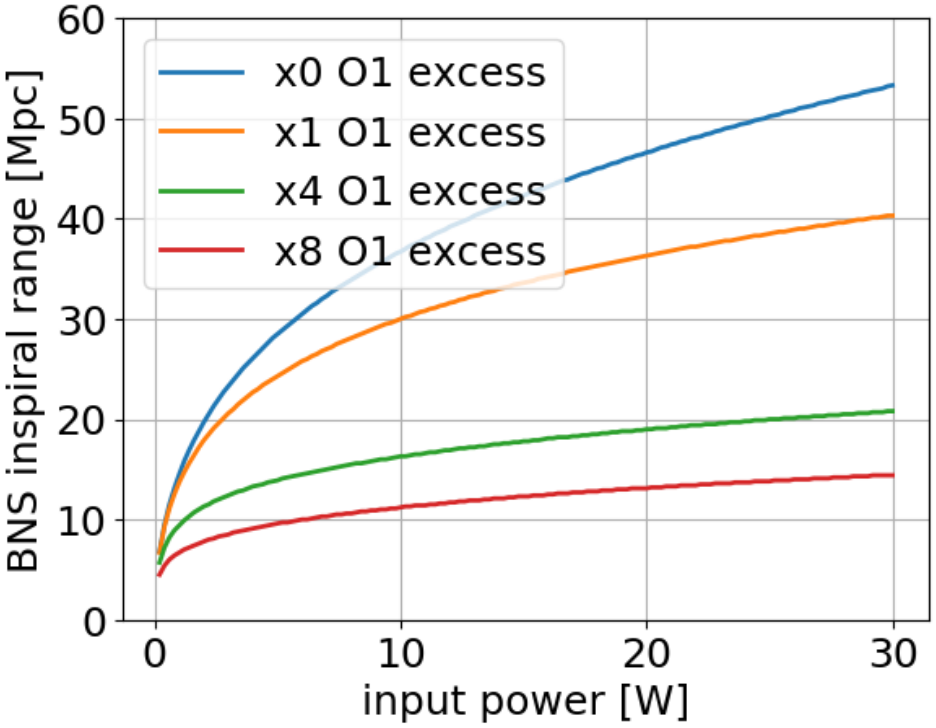
Shot Noise Coupling PRFPMI

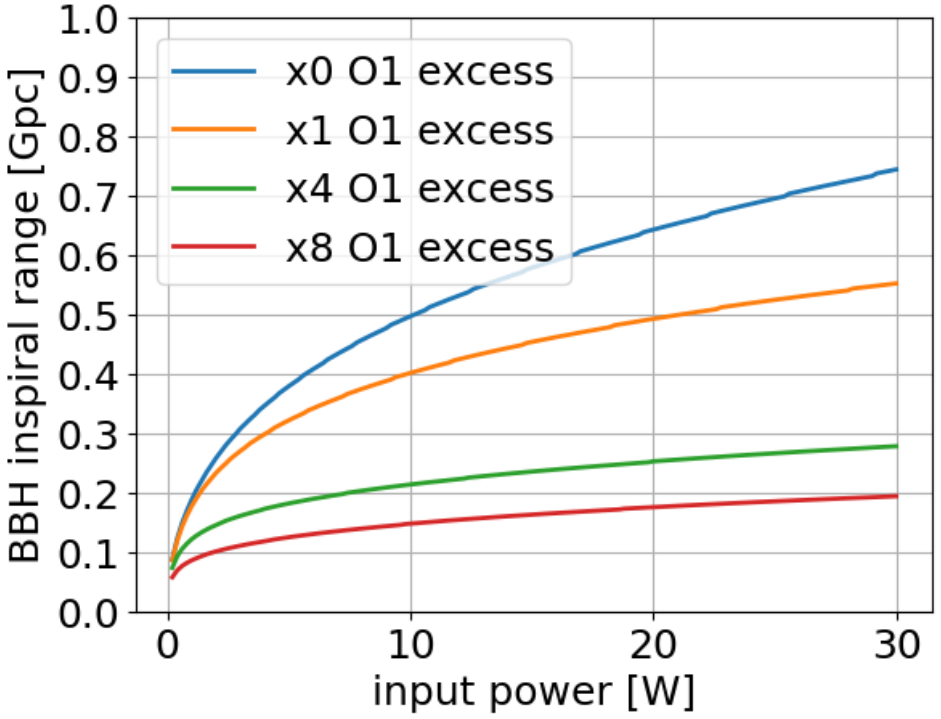


Shot Noise Coupling RSE



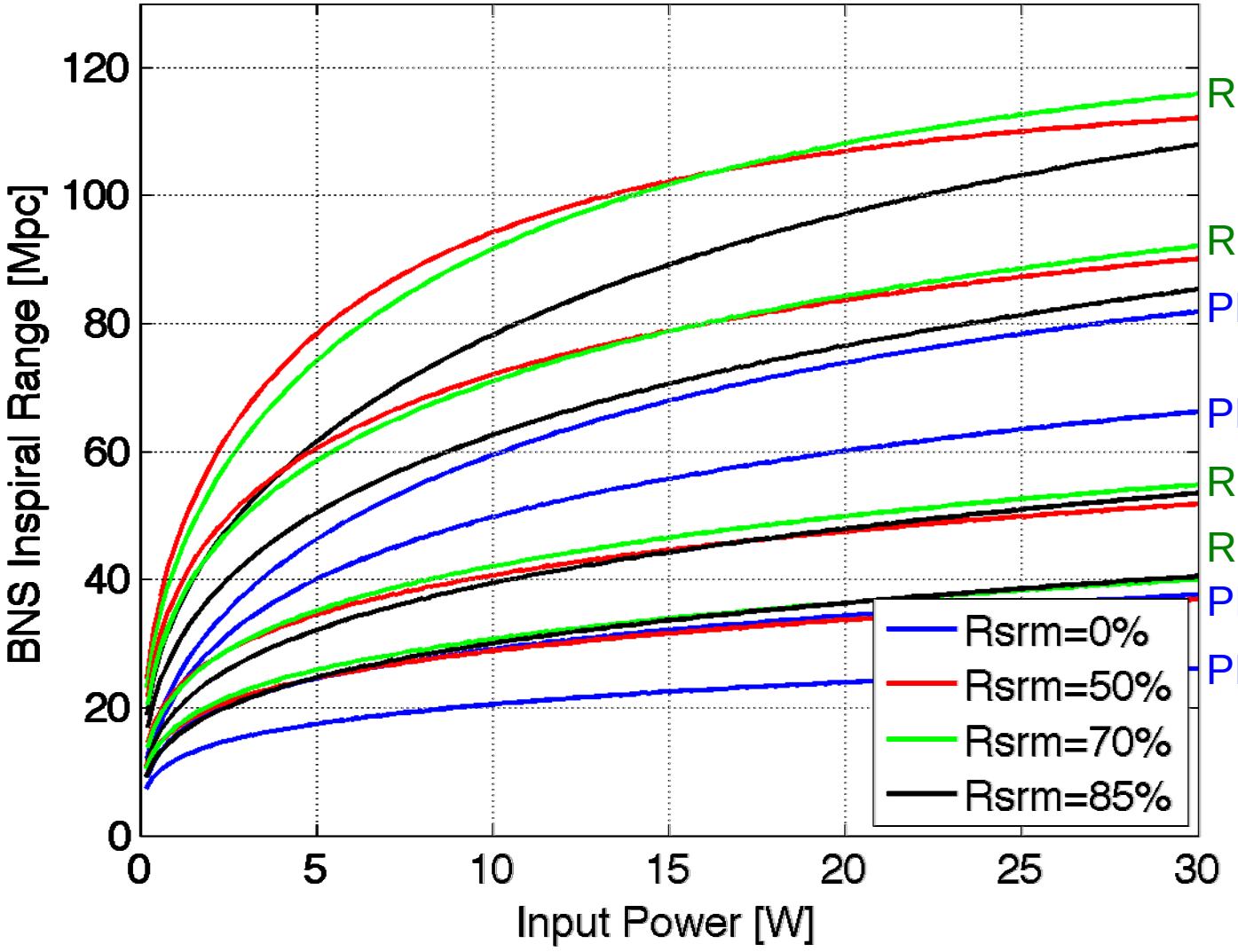
IR vs Power FPMI





Note: Shot noise coupling calculation is done only at 10 W and scaled with $1/\sqrt{P}$

IR vs Power PRPFMI/RSE



RSE x0 O1 excess

RSE x1 O1 excess

PRFPMI x0 O1 excess

PRFPMI x1 O1 excess

RSE x4 O1 excess

RSE x8 O1 excess

PRFPMI x4 O1 excess

PRFPMI x8 O1 excess

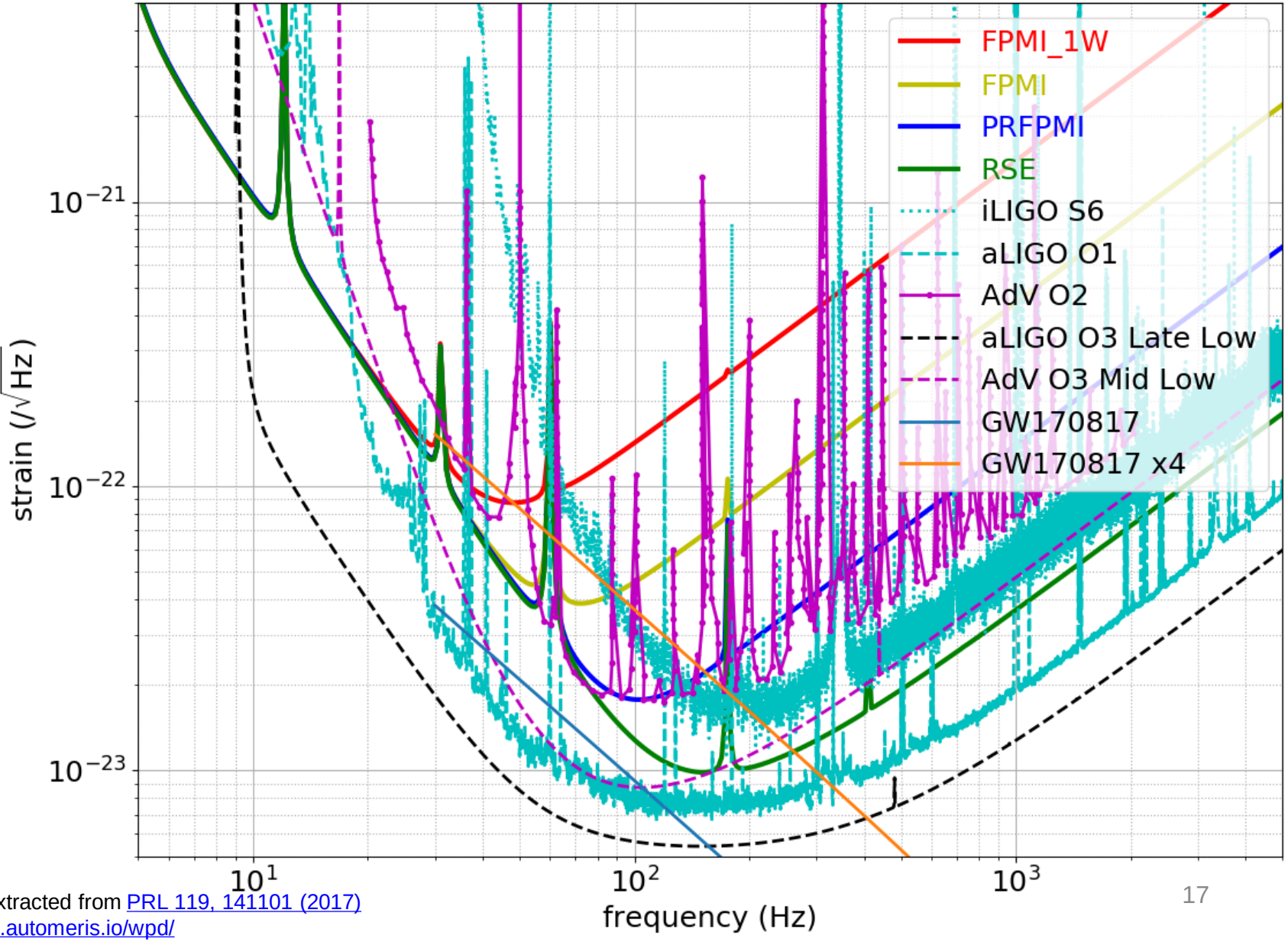
Necessity

◎: Necessary for locking
○: Can be omitted with extra work
△: Can be omitted with sensitivity degradation
×: Not necessary

Sensitivity (10W, x4 O1 excess)	RSE (42 Mpc)	PRFPMI (27 Mpc)	FPMI (9.5 / 16 Mpc)
ALS (green lock)	◎	○	× (better to have)
f3 AM (MZI *)	◎	○	×
Extra locking simulation	×	◎	×
SRC ASC	◎	×	×
SRM	◎	○ (Blank or move OMMT)	○ (Blank or move OMMT)
OMC	△	△	△
Comment	SRC ASC might be tough	f1 will be 1/10, no SRC mode cleaning	PRM: tilt or blank or move IMMT No PRC jitter attenuation

* AM generation with 45 deg tilted EOM is not possible with wedged EOM

Sensitivity Comparison

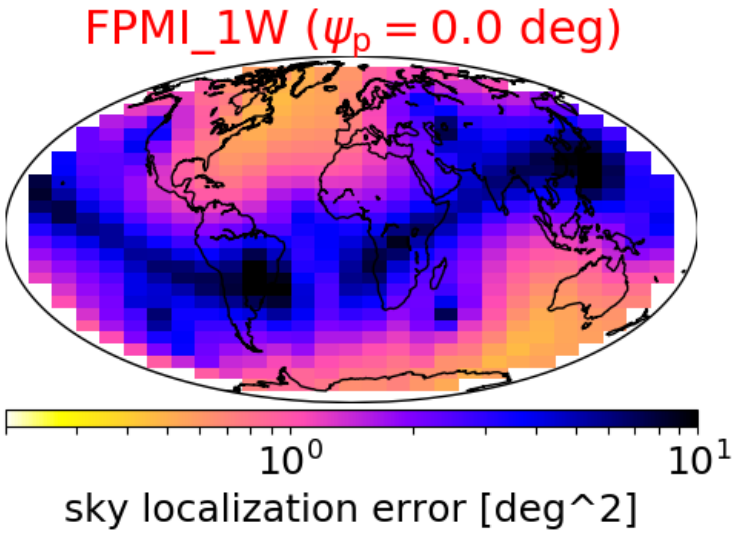


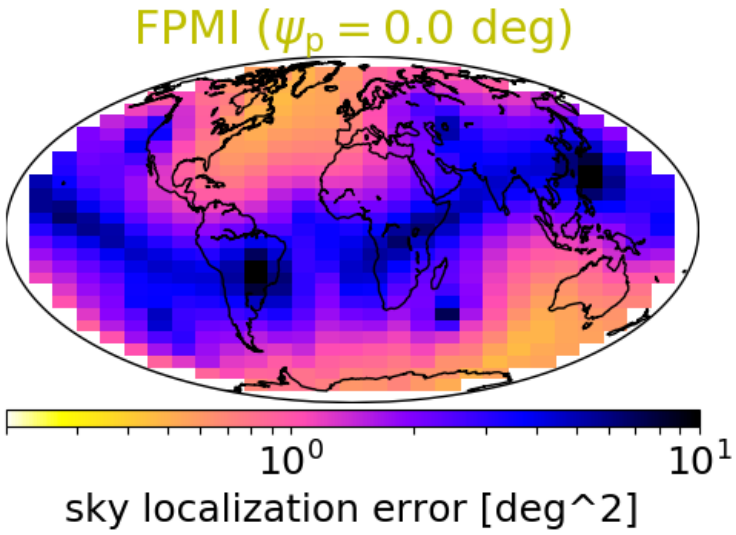
AdV O2 curve extracted from PRL 119, 141101 (2017)
with https://apps.automeris.io/wpd/

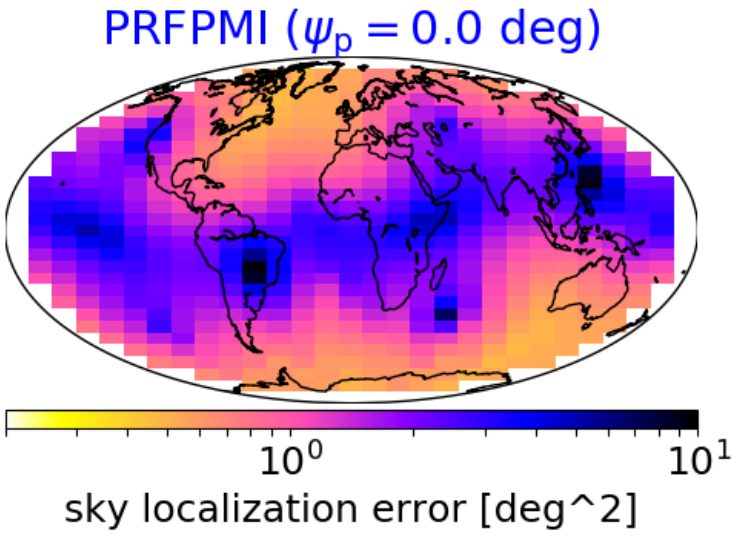
Sky Localization Calculation

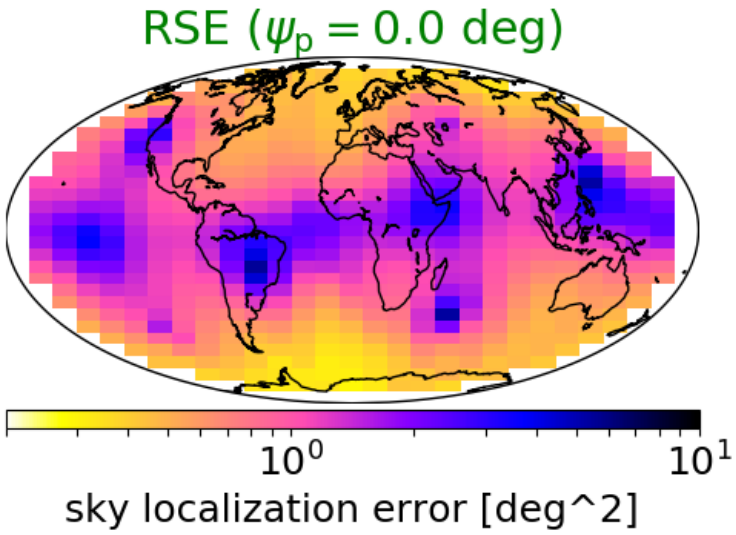
- 10W input, x4 O1 excess noise
- Source parameters (GW170817-like, no spins)
  - redshift: 0.009 (~ 40 Mpc)
  - total/chirp mass: 2.74 / 1.188 Msun
  - inclination angle: 28 deg
  - source locations: equally distributed 648 locations
  - polarization angle: 3 angles
  -> 1944 realizations
- Waveform
  PhenomD upto inspiral (PRD 93, 044007 (2016))
  fmin=10Hz, fmax=fISCO~1.6 kHz
- Network sensitivity
  - aLIGO: Late Low (116 Mpc) LIGO-P1200087
  - AdV: Mid Low (63 Mpc) LIGO-P1200087
- Fisher analysis (see, also JGW-T1808090)

Sky Localization Map



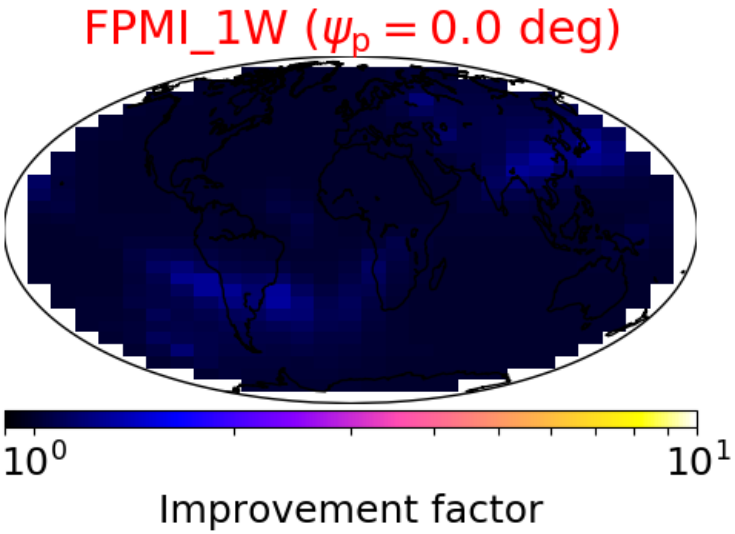


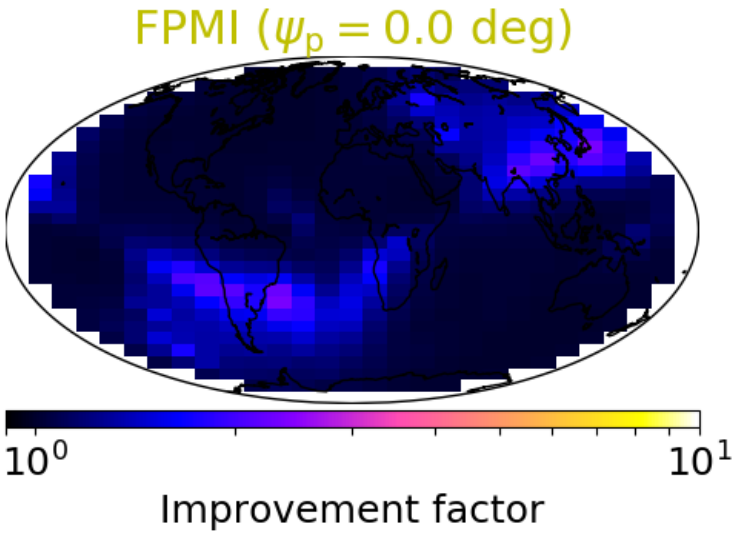


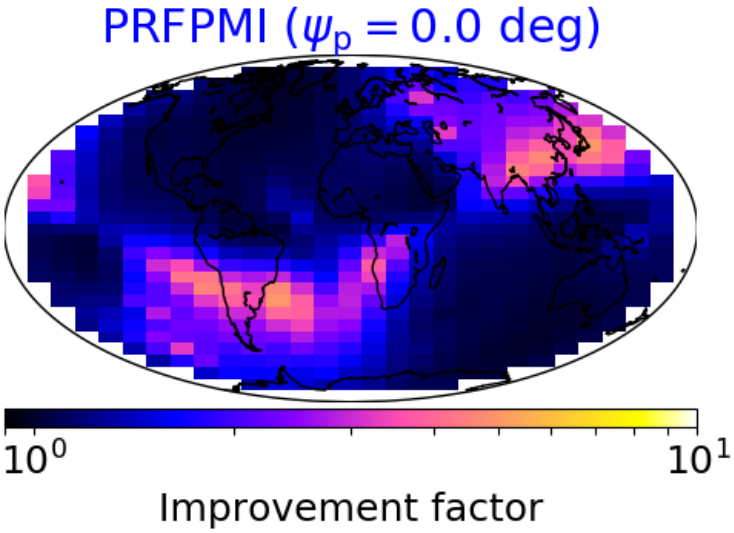


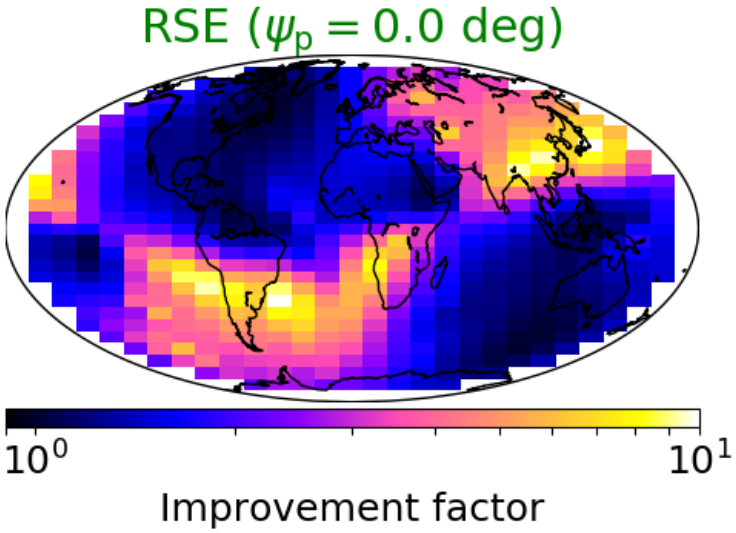
Sky Localization Improvement Map

Improvement factor = HLVK / HLV









Sky Localization Distribution

Improvement factor = HLVK / HLV

- FPMI 1W at 9.5 Mpc gives only slight improvement for sky localization (few % in most cases)