# Discussion on Interferometer Configuration for O4

Yuta Michimura

# Executive Summary

- We are not sure yet if DRFPMI is feasible or not, and if polarizers in PRC/SRC will improve the situation (both sensitivity wise and stability wise)
- We are also not sure yet if inhomogeneous ITM transmission map is limiting our frequency noise and intensity noise coupling
- Therefore, we cannot conclude at this point
- Measurements (especially DRFPMI characterization and frequency/intensity noise coupling) before the vent for O4 is necessary to investigate the necessity of polarizers and ITM re-polishing
- Measurements will require at least ~2 weeks

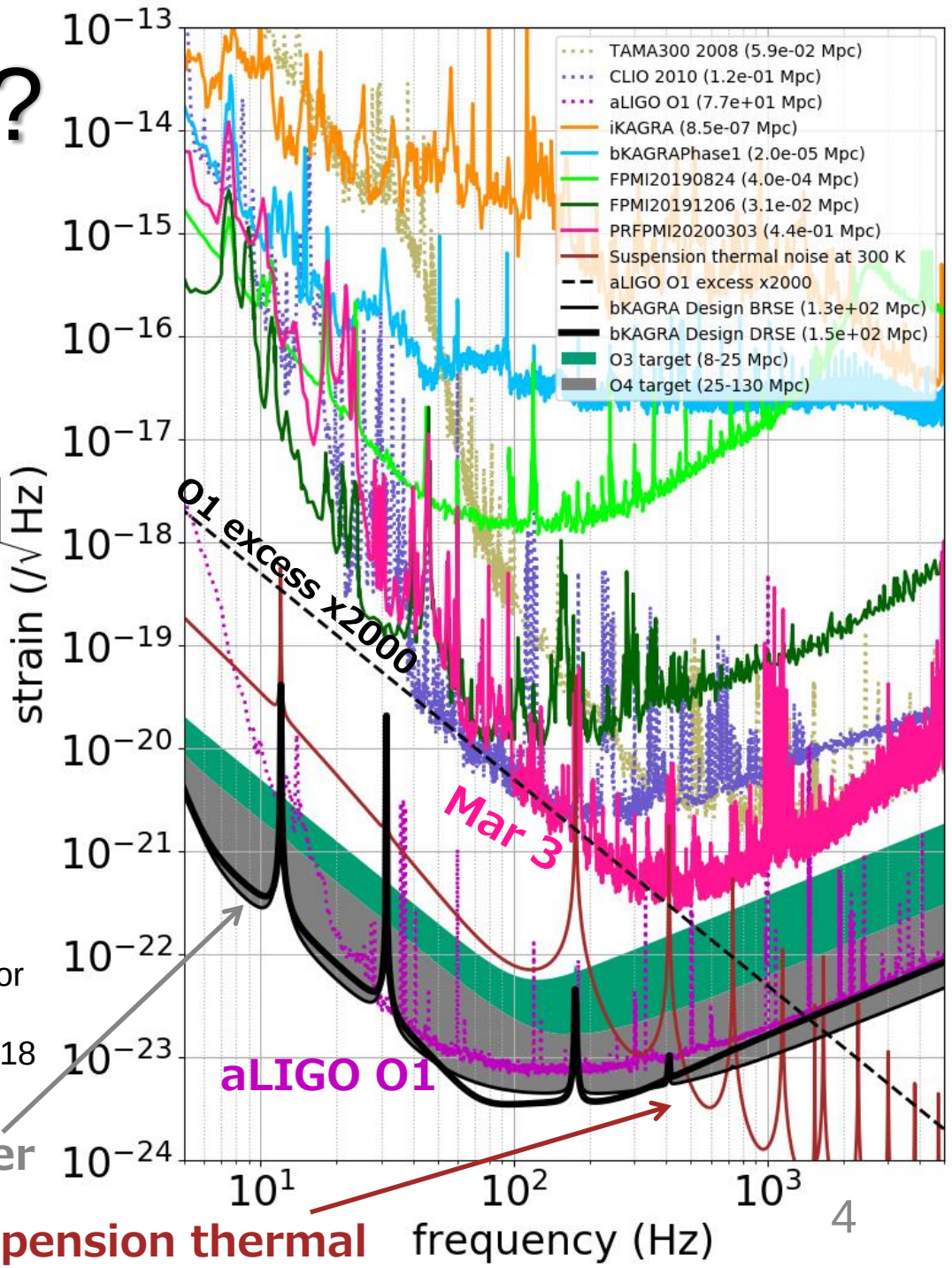
# List of Considerations for O4

- Cryogenic temperature necessary?
  - Depends on sensitivity necessary
- Which SRM reflectivity?
  - 0 % or 70 % or 85 % (compound or monolithic)
  - Depends on feasibility of DR locking
- Polarizers in PRC and SRC necessary?
  - Depends on birefringence effect to sidebands
  - See JGW-T1910396 for proposal
- ITM re-polishing and re-coating necessary?
  - Depends on the effect of transmission asymmetry and TWE to CMRR of frequency/intensity noise

# Where Are We?

- 400-500 kpc
- PRFPMI with 70% SRM tilted, 3-5 W to PRM, ~240 K, DC readout
- O1 excess x2000 !
- Pretty close to shot noise (klog #13144)?

(klog #12772 gives 6e-18 m/rtHz @ 1 kHz for 1.4 W input, 3.4 mW at OMC PDA. 4.5 W input, 8 mW at OMC PDA should give ~2e-18 m/rtHz for current setup.)




**O4 target on Obs. Scenario Paper 25-130 Mpc by ~2021**

**300 K suspension thermal**

# Current Status and O4 Target

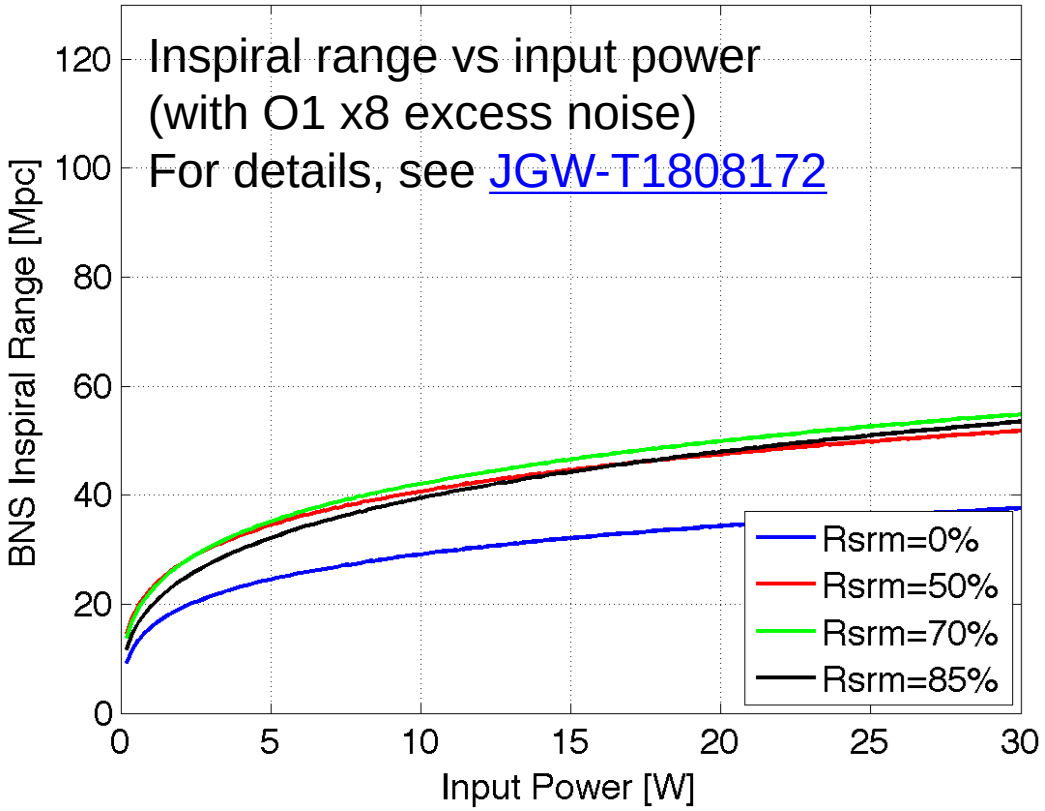
- Cryogenic necessary for sure

| | Mirror temp. | Power at BS | SRM reflectivity | Detuning angle | Homodyne angle | Excess noise |
|---|---|---|---|---|---|---|
| **NOW** | **~240 K** | **30-50 W** | **70% tilted** | **~90 deg (PRFPMI)** | **~90 deg (conventional)** | **O1 x 2000** |
| O3 low | 22 K | 10 W | 0 % | 90 deg (PRFPMI) | 90 deg (conventional) | O1 x 20 |
| O3-15Mpc | 22 K | 10 W | 70 % | 90 deg | 90 deg | O1 x12 |
| O3 high / O4 low | 22 K | 33 W | 70 % | 90 deg (BRSE) | 90 deg (conventional) | O1 x 8 |
| O4 80Mpc | 22 K | 404 W | 85 % | 90 deg | 90 deg | O1 x 2 |
| O4 high | 22 K | 673 W | 85 % | 90 deg (BRSE) | 90 deg (conventional) | no excess |
| Design | 22 K | 673 W | 85 % | 86.5 deg | 135.1 deg | no excess |

For details, see JGW-T1809078

# DR Necessary?

- DR is better and almost necessary (especially better when low frequency excess noise is too much)
- Still, 70% SRM seems good for O4 (we don't have much confidence on higher power)



# Feasibility of Locking DR

- According to Nakano-kun
  - DRMI on 1f is fine. Lasts 30 min or so
  - DRMI on 3f lasts 5 min or so klog #12535
- Needs more time (~ a week?) to assess if DRFPMI is feasible or not with current ITMs
- If not feasible, our choice for O4 will be
  - Go with PRFPMI, install 0% SRM
  - Evaluate if polarizers in PRC and SRC will help locking DRFPMI

# Compound or Monolithic SRM

- Only monolithic SRM we have is 85%
- If compound SRM is not OK for O4, and 70% or 0% SRM is necessary, we have to make a monolithic SRM

  cf. aLIGO O1 was done with compound SRM
  KAGRA might have more HOMs at AS which give more scattered light due to compound SRM
- If compound SRM is giving a nasty effect, may be we should use 85 % monolithic SRM
- Need to estimate the effect of compound SRM if we could lock DRFPMI

# Effect of T_ITM asymmetry

- See JGW-T1910352
- Considering frequency noise and intensity noise coupling, achieving the designed sensitivity is not feasible, but achieving O4 target (25-130 Mpc) should be possible with current ITM transmission asymmetry (if inhomogeneity effect is not considered)
- Just re-coating is not necessary for O4 (the problem is TWE map and birefringence)

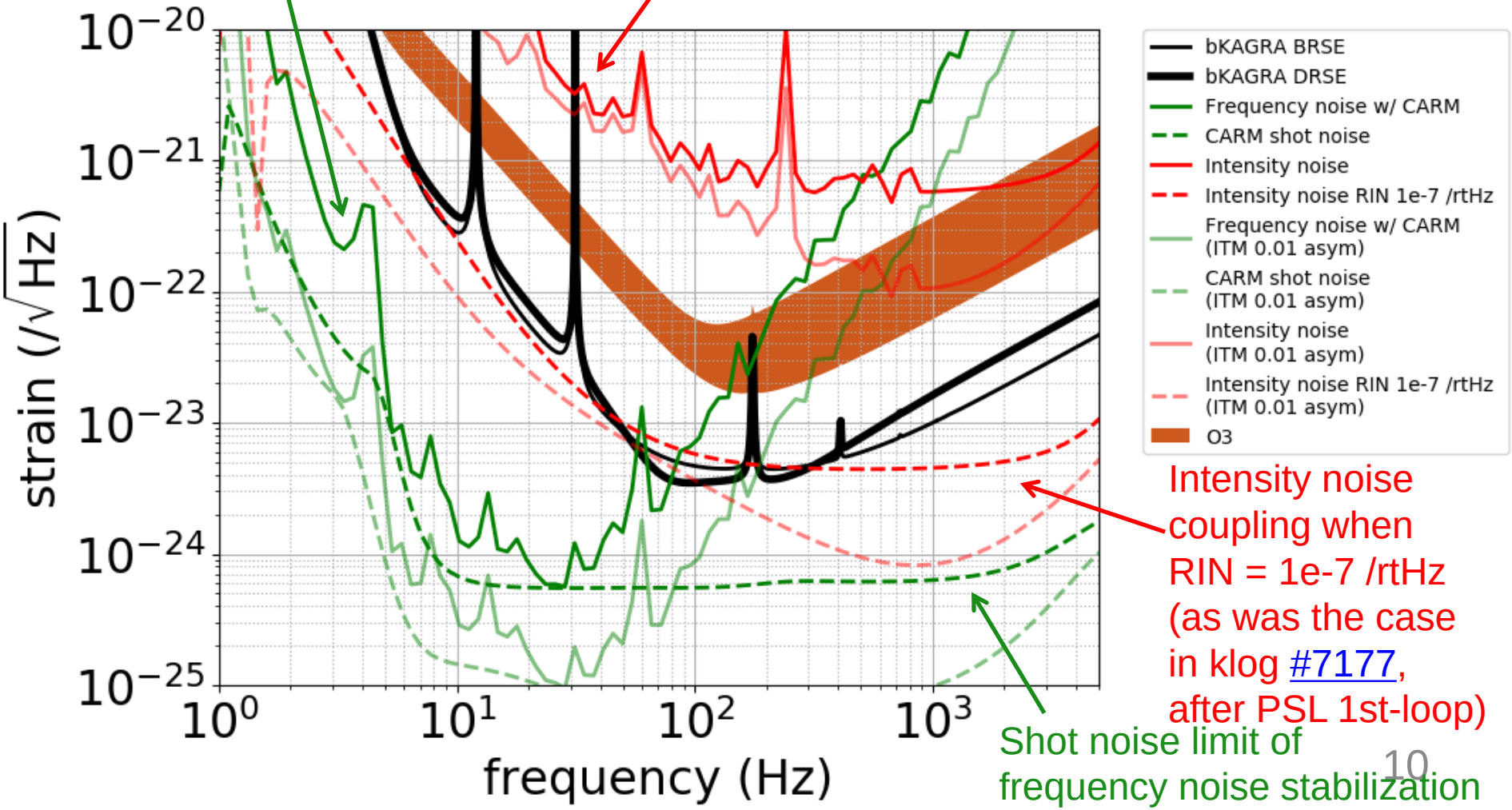
# Resul

Copied from JGW-T1910352

Frequency noise coupling estimated with current measured frequency noise; CARM loop turned on (could be limited by measurement noise at high frequencies)

Intensity noise coupling estimated with current measured intensity noise (stabilization servo not on yet)

Dim lines represent same curves when ITM transmission asymmetry was 0.01

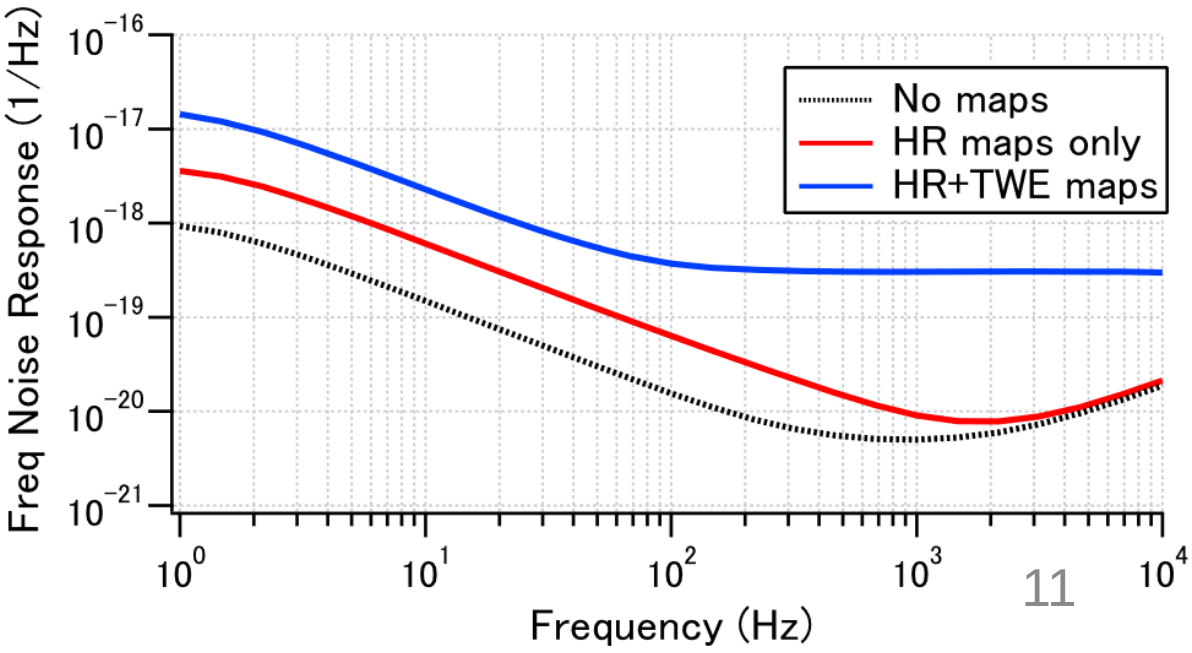



Intensity noise coupling when RIN = 1e-7 /rtHz (as was the case in klog #7177, after PSL 1st-loop)

Shot noise limit of frequency noise stabilization

# Effect of ITM TWE

- See Phys. Rev. D **100**, 082005 (2019)
- According to Somiya-san's simulation, ITM TWE gives x8 frequency noise coupling @ 100 Hz
- Intensity noise coupling not yet simulated
- Needs to assess the effect both with simulation and measurement
- If the effect of birefringence is bigger, TWE correction is not important



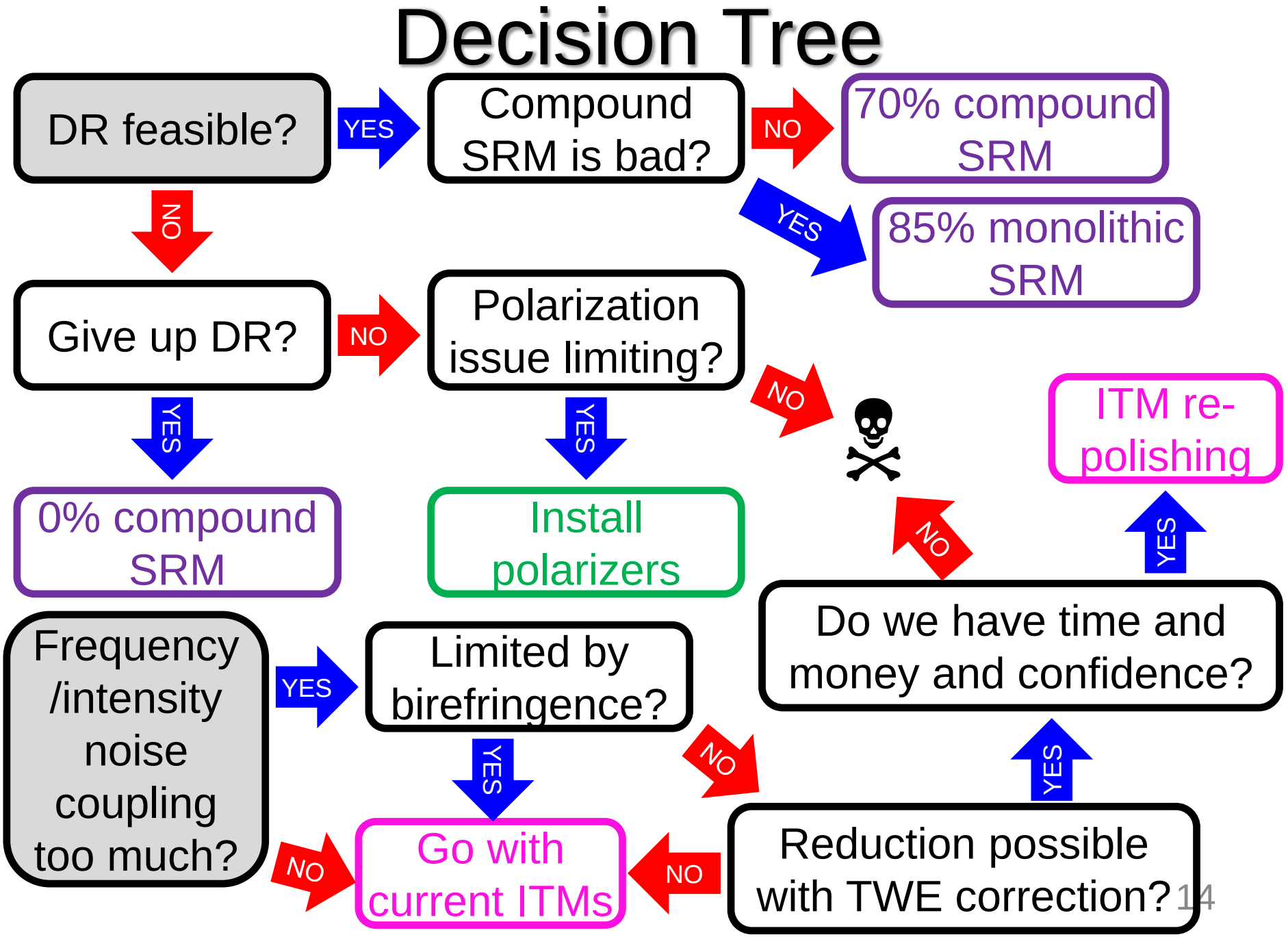
# Conclusions So Far

- Cryogenic temperature necessary?
  - Necessary to achieve O4 target (25-130 Mpc)
- Which SRM reflectivity?
  - DR is better but we have to assess if DR locking is feasible or not
  - If DR is feasible, 70% SRM is good
  - If compound SRM is not good, use 85% monolithic SRM
- Polarizers in PRC and SRC necessary?
  - We need to assess if DR locking is feasible without polarizers
- ITM re-polishing and re-coating necessary?
  - Recoating is not necessary but we should estimate the effect of inhomogeneity to see if re-polishing is necessary to compensate TWE

# List of Measurements to be Done

- Feasibility of locking DRFPMI (~ 1 week)
- Shot noise calculation (~ 0.5 day)
- Power recycling gain for sidebands (~ 0.5 day)
- LSC and ASC sensing matrix (~ 2 days)
- MICH/PRCL/SRCL to DARM coupling (~ 1 day)
- Frequency and intensity noise coupling (~ 1 day)
- MICH contrast defect with MICH locked and FPMI locked (~ 1 day)
- Mode content of AS (OMC cavity scan) (~ 0.5 day)
- The effect of compound SRM for sensitivity (~ 0.5 day)
- Scattered light investigations (~ 1 week)
- Compare measurements with Optickle/FINESSE simulations

# Decision Tree



# Yuta's Personal Opinion

- Cryogenic temperature necessary?
  - Necessary to achieve O4 target (25-130 Mpc)
- Which SRM reflectivity?
  - Use 70% compound SRM.
- Polarizers in PRC and SRC necessary?
  - No. It is likely that we can lock DR without them.
- ITM re-polishing and re-coating necessary?
  - No. We should concentrate on making ITMs without birefringence.