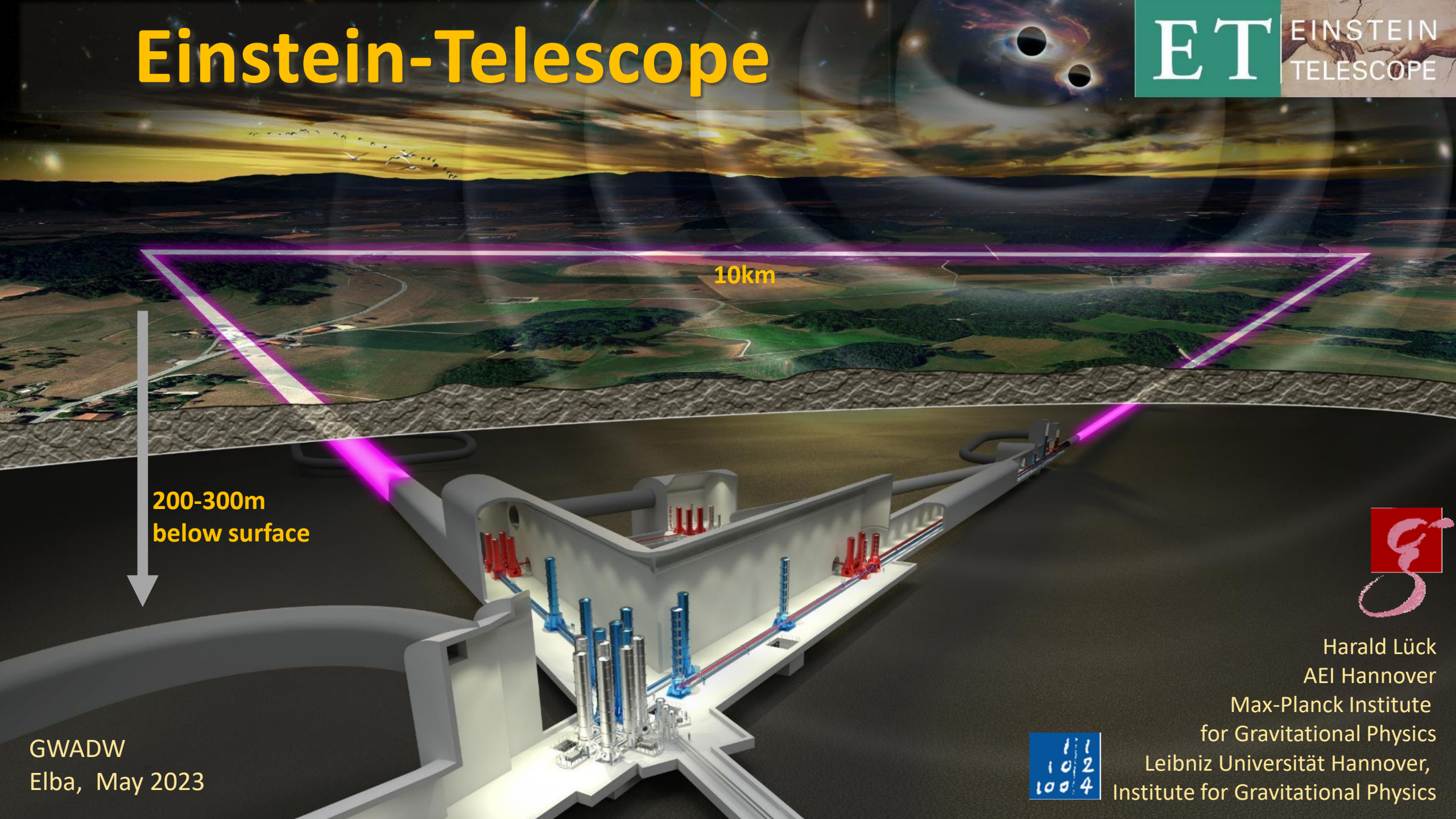
Einstein-Telescope

ET EINSTEIN TELESCOPE



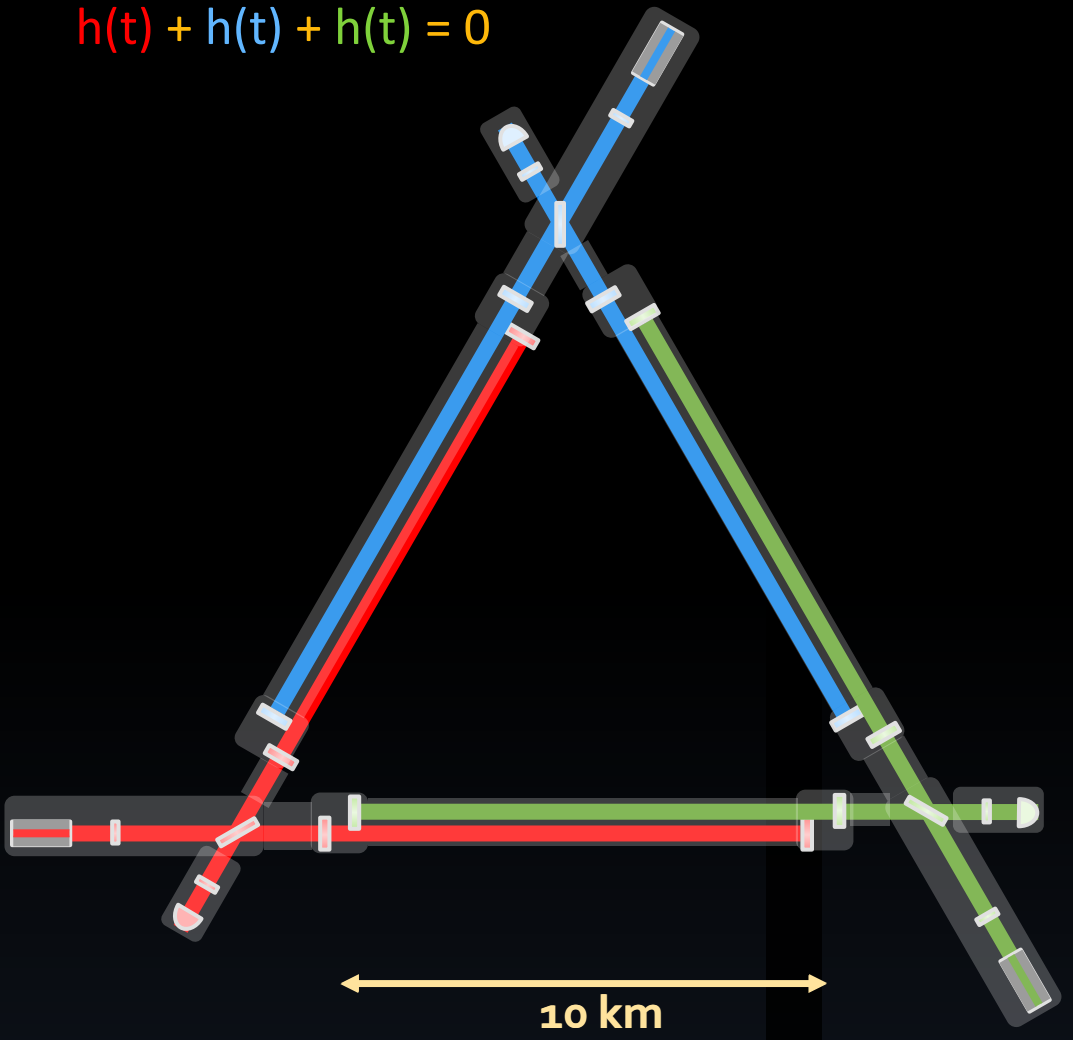
GWADW
Elba, May 2023

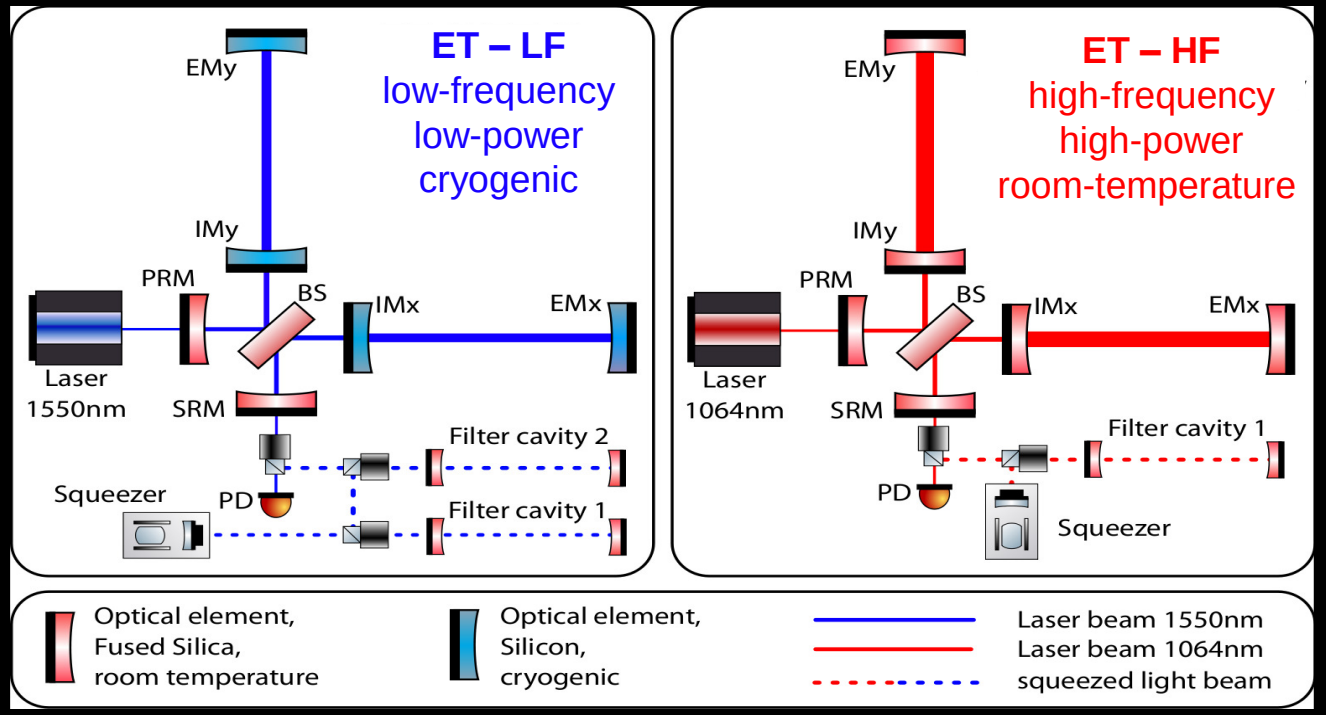
Harald Lück
AEI Hannover
Max-Planck Institute
for Gravitational Physics
Leibniz Universität Hannover,
Institute for Gravitational Physics

Einstein Telescope

3 detectors in triangular configuration:

- Sensitive for both polarisations
  Null Stream:
  h(t) + h(t) + h(t) = 0





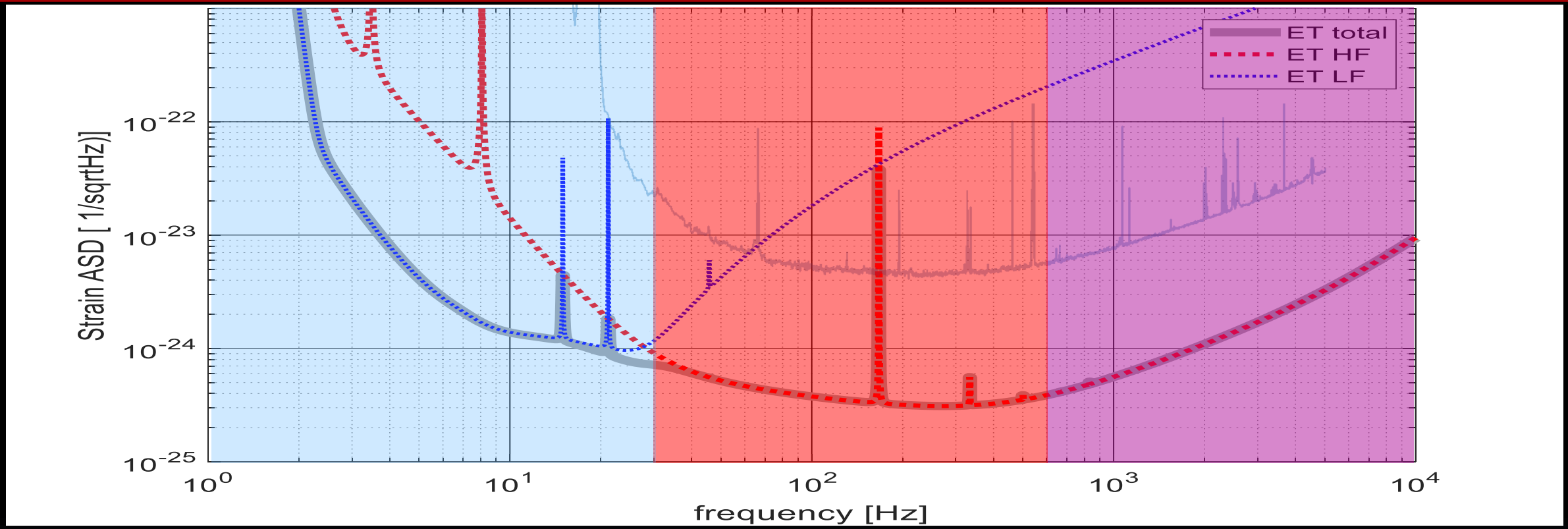
ET-LF: 10 – 20 K

- Cryogenics
- Long Seismic suspensions (17m towers)
- Silicon (Sapphire) test masses
- Large test masses (200kg, 45cm diam.)
- New coatings
- New laser wavelength (1550nm)
- + low power
- Frequency-dependent squeezing

ET-HF: 300 K

- 1064 nm Laser (500W)
- High circulating light power, 3MW
- Thermal compensation
- Large test masses (SiO2, 200kg)
- New coatings
- Frequency dependent squeezing

The sensitivity we're aiming for



Many contributing noise sources:
Quantum Noise (over most of the LF band),
→ **Squeezing** 10dB FDS: similar requirements as for ET-HF but for **1550 nm** and narrower bandwidth
Control Noise , **Newtonian** Noise, suspension Thermal, **scattered** light, **environmental** noise, many unknowns!
Need: large Cryo-Optics (silicon), low loss cryo-cooling!, coatings

- Coating thermal noise ¼ loss (aLIGO/AdVirgo)
- Suspension thermal noise

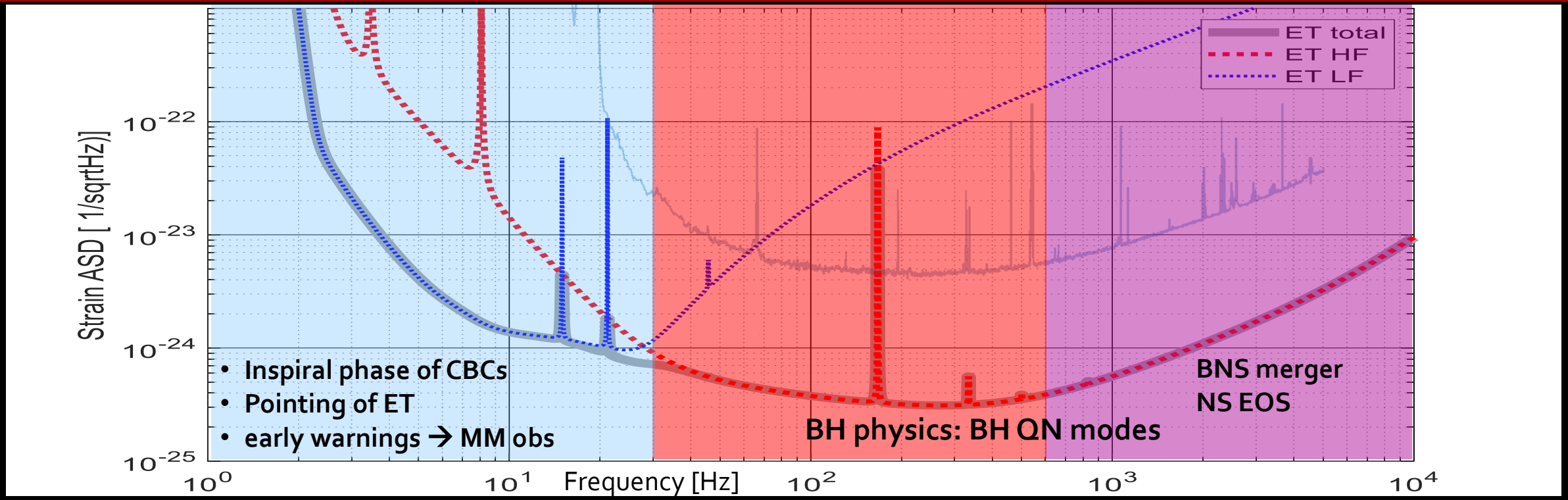
High squeezing level: 10 dB 1550nm / 1064 nm

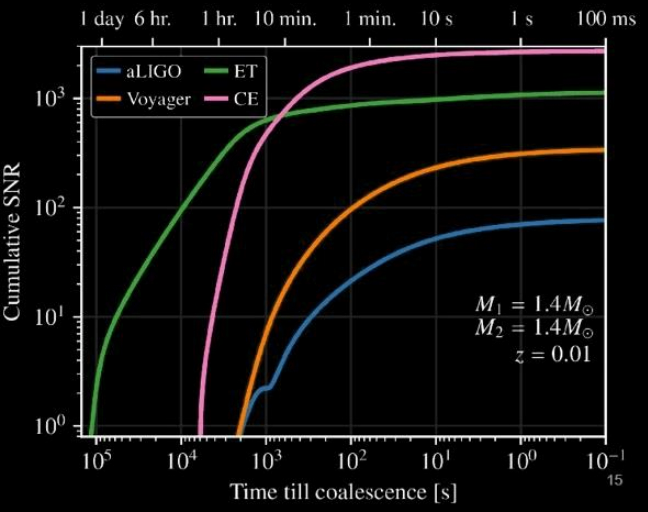
- High efficiency Squeezer (>15dB)
- Low loss optics
- Faraday isolators
- Mode matching (adaptive?)
- High QE PDs
- Low loss OMC

High laser power: 3 MW

- High power lasers
- Low abs. coatings
- Low optical losses
- No point absorbers
- Good TCS, esp. BS
- Param.Inst. mitigation

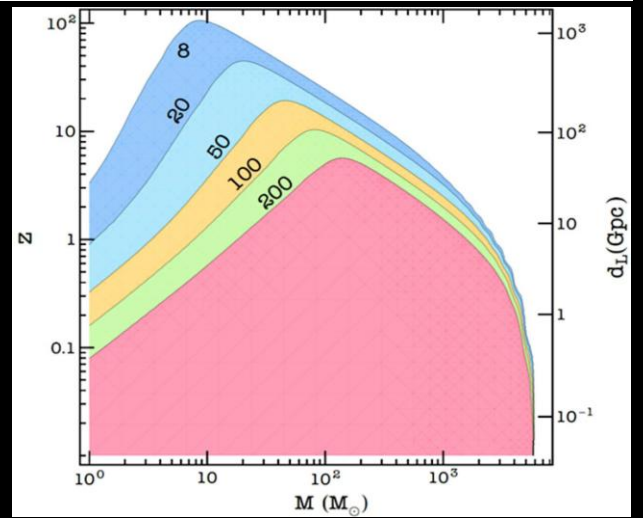
Which frequencies yield what?





Range (most of SNR):

- **Population studies. Detect**
  - **Heavy CBCs closeby**
  - **Light CBCs distant (dark ages)**
- **High SNR studies closeby**
- **CW sources**
- **SN II**



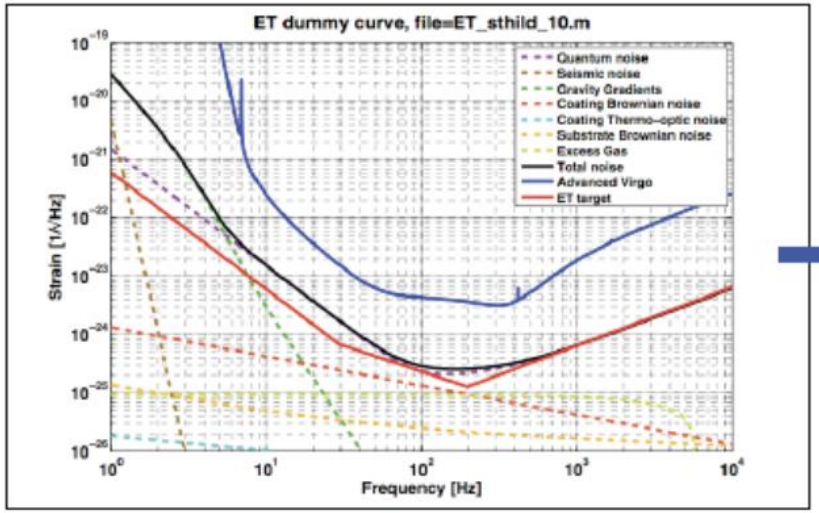
An important ingredient 😉

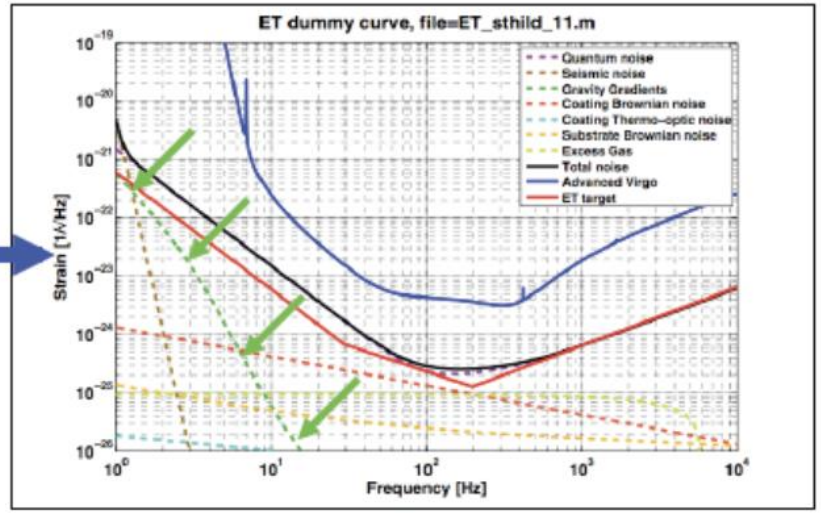
ET EINSTEIN TELESCOPE

UNIVERSITY OF BIRMINGHAM

EGO

Step 9: Gravity gradient supression





DRIVER: Gravity gradient noise

ACTION: MAGIC

EFFECT: Decrease gravity gradient noise by a factor 50.

ET Enabling Technologies

- The multi-interferometer approach asks for two parallel technology developments:

Parameter	ET-HF	ET-LF
Arm length	10 km	10 km
Input power (after IMC)	500 W	3 W
Arm power	3 MW	18 kW
Temperature	290 K	10-20 K
Mirror material	fused silica	silicon
Mirror diameter / thickness	62 cm / 30 cm	45 cm/ 57 cm
Mirror masses	200 kg	211 kg
Laser wavelength	1064 nm	1550 nm
SR-phase (rad)	tuned (0.0)	detuned (0.6)
SR transmittance	10 %	20 %
Quantum noise suppression	freq. dep. squeez.	freq. dep. squeez.
Filter cavities	1×300 m	2×1.0 km
Squeezing level	10 dB (effective)	10 dB (effective)
Beam shape	TEM_{00}	TEM_{00}
Beam radius	12.0 cm	9 cm
Scatter loss per surface	37 ppm	37 ppm
Seismic isolation	SA, 8 m tall	mod SA, 17 m tall
Seismic (for $f > 1$ Hz)	$5 \cdot 10^{-10}$ m/f^2	$5 \cdot 10^{-10}$ m/f^2
Gravity gradient subtraction	none	factor of a few

- **ET-LF:**
  - Underground
  - Cryogenics
  - Silicon (Sapphire) test masses
  - Large test masses
  - New coatings
  - New laser wavelength
  - Seismic suspensions
  - Frequency dependent squeezing

- **ET-HF:**
  - High power laser
  - Large test masses
  - New coatings
  - Thermal compensation
  - Frequency dependent squeezing

Challenging engineering

New technology in cryo-cooling

New technology in optics

New laser technology

High precision mechanics and low noise controls

High quality opto-electronics and new controls

Evolved laser technology

Evolved technology in optics

Highly innovative adaptive optics

High quality opto-electronics and new controls