Space gravitational wave antenna DECIGO

Naoki Seto (Kyoto U, Japan)

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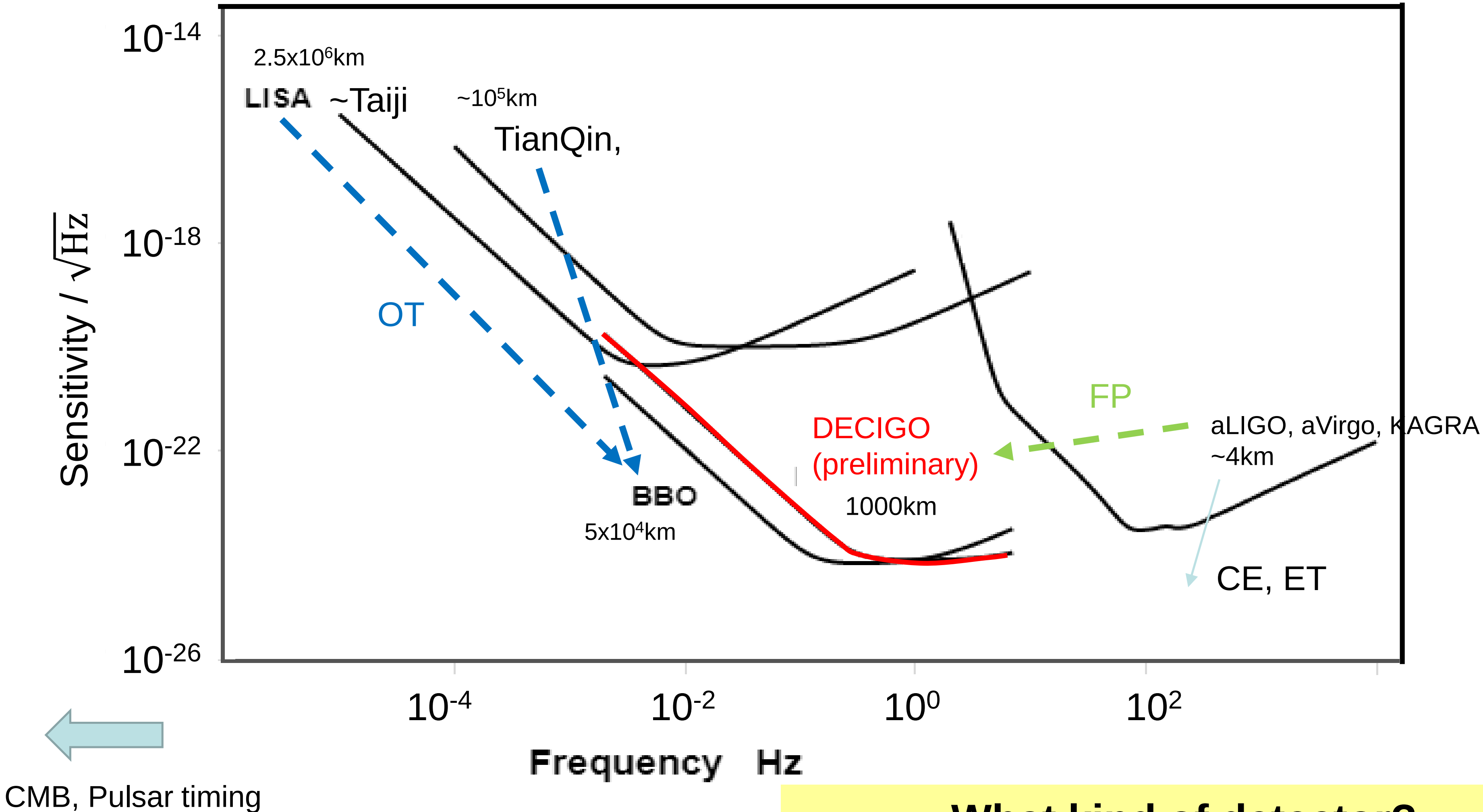
Gravitational Wave Probes of Physics Beyond Standard Model

Noise curves of GW detectors

rhcole.com/apps/GWplotter



What kind of detector?

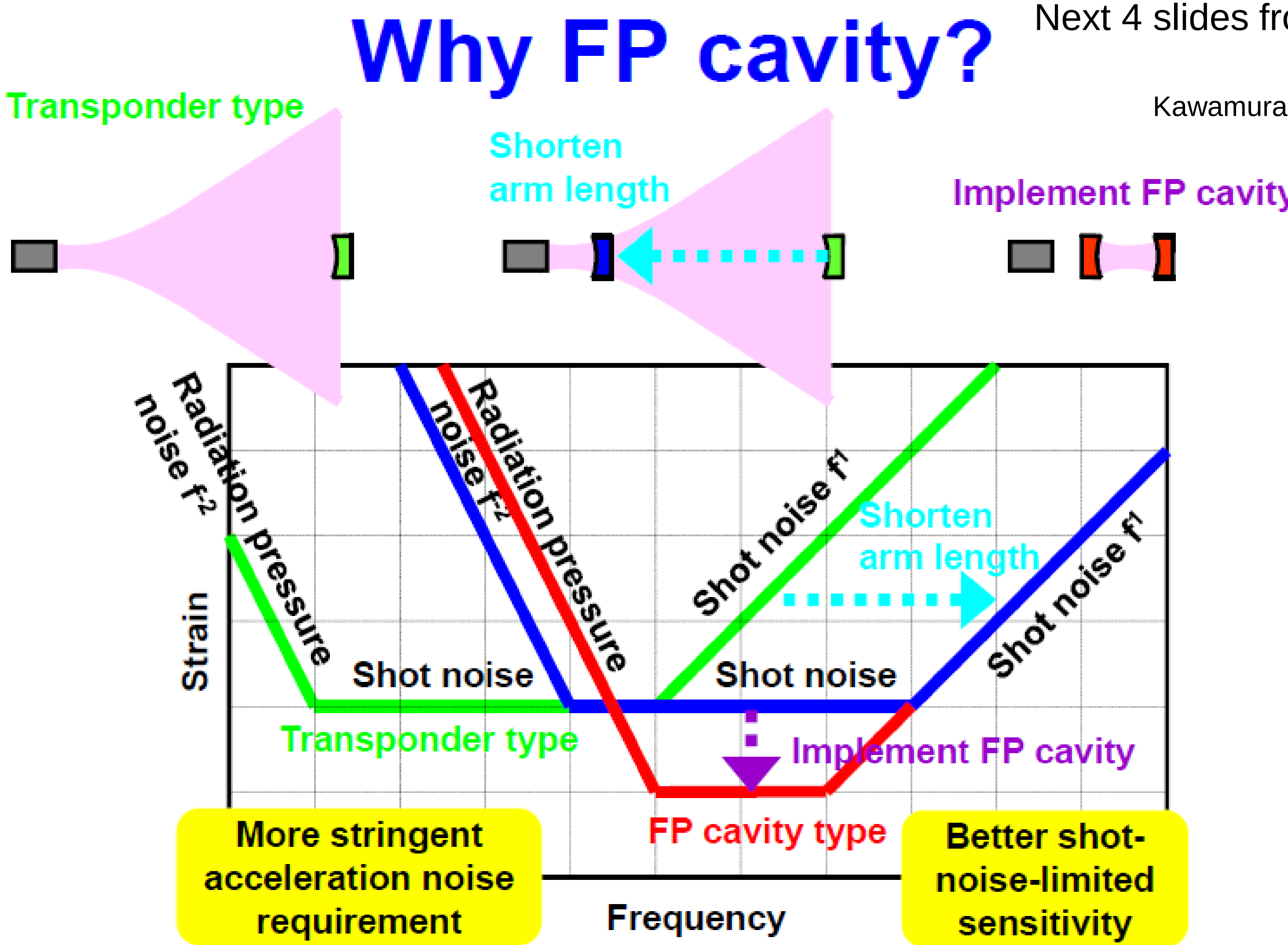
Scientific targets

Primordial GW backgrounds

Cosmological binaries

Basic design of DECIGO

Next 4 slides from Kawamura



Kawamura et al. CGQ 2011

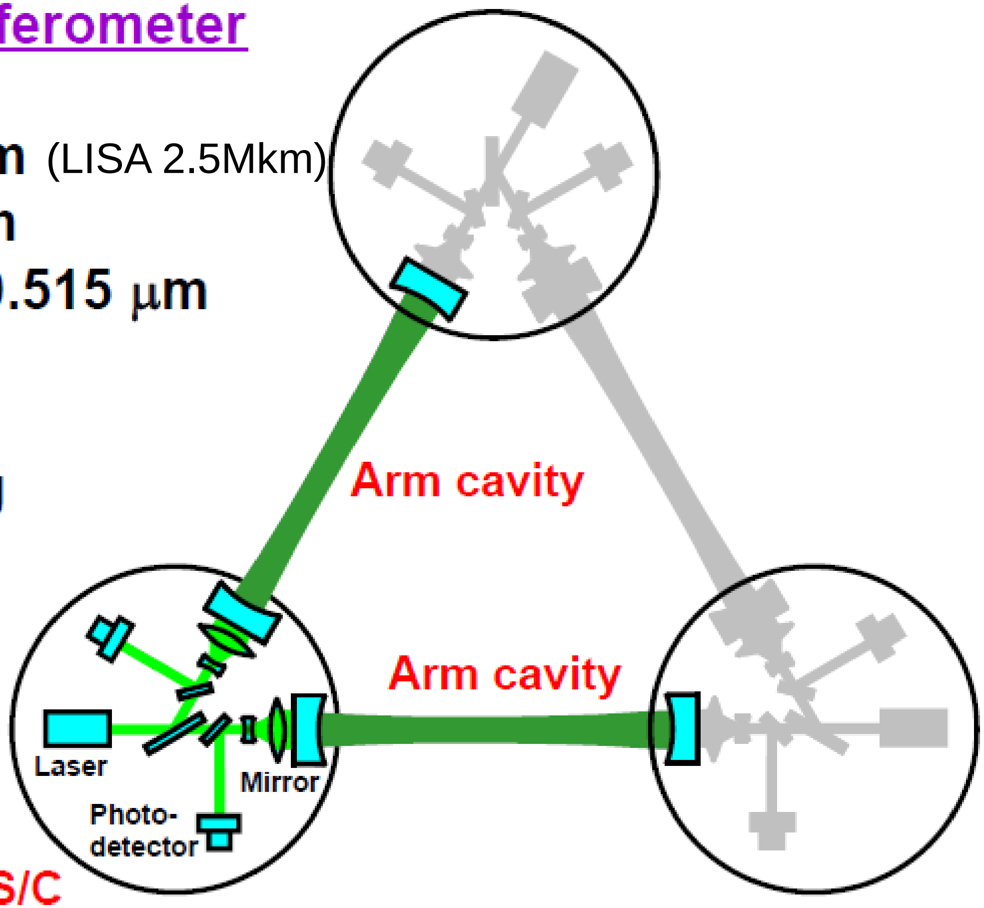
$$\delta h \sim \frac{\int dt \int dt\ \delta a}{L}$$ (low-f)

More photons available (high-f)

Pre-conceptual design

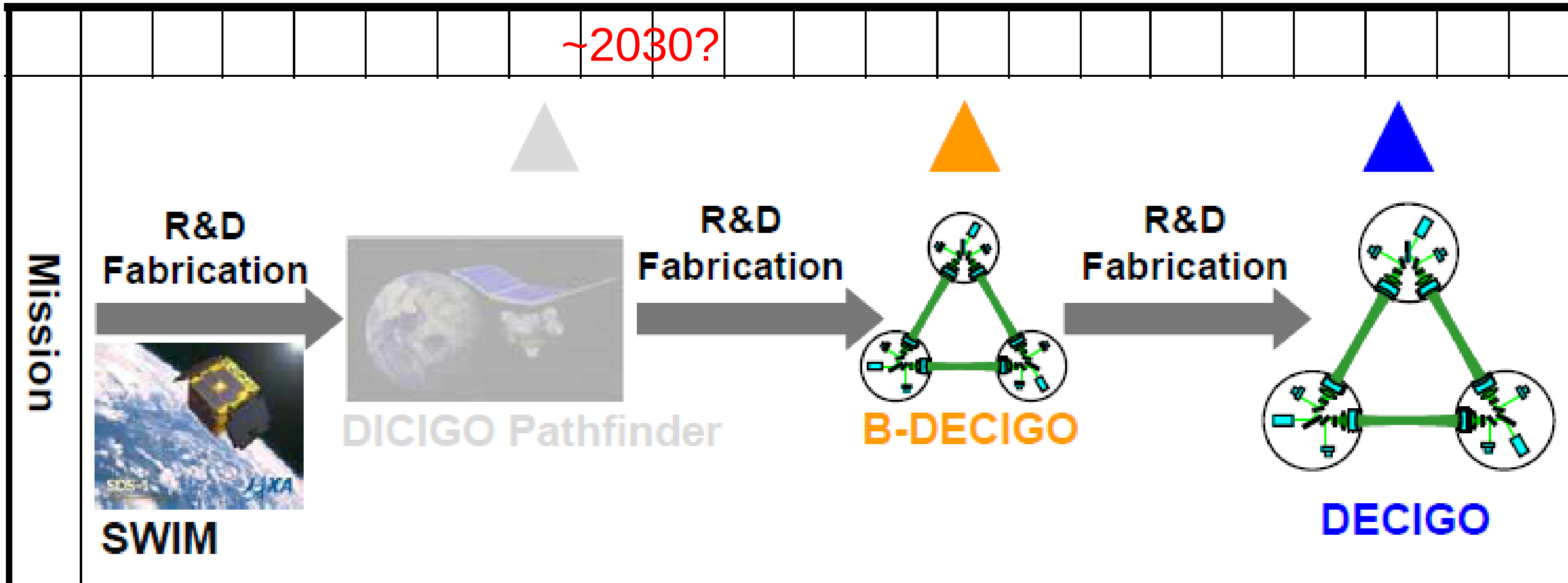
<u>Differential FP interferometer</u>

Arm length: 1000 km (LISA 2.5Mkm)
Mirror diameter: 1 m
Laser wavelength : 0.515 μm
Finesse: 10
Laser power: 10 W
Mirror mass: 100 kg
S/C: drag free
3 interferometers



from Kawamura

Roadmap updated



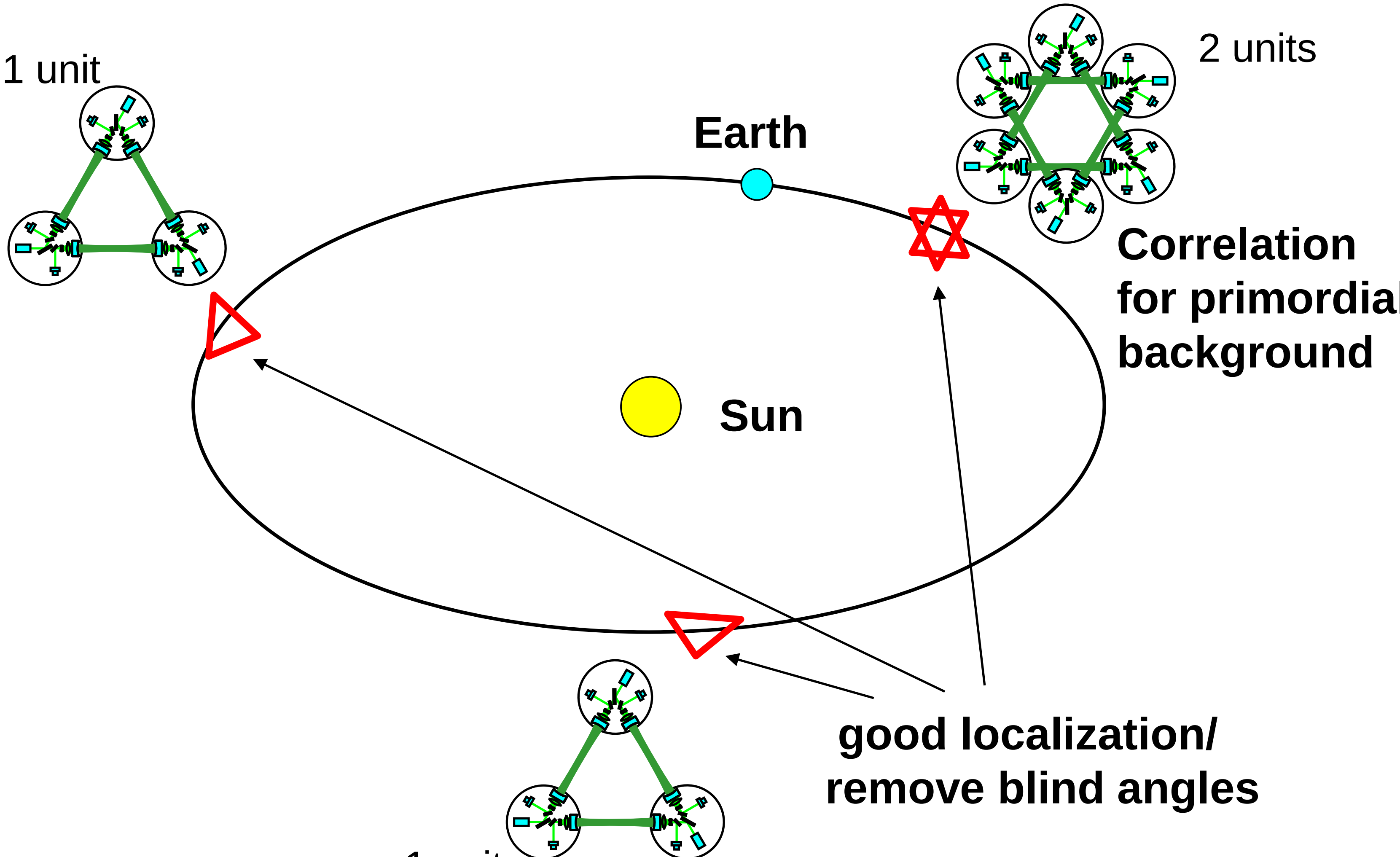
Objectives	Test of key technologies	Detection of GW w/ minimum spec. Test FP cavity between S/C	Full GW astronomy
Scope	1 S/C 1 arm	3 S/C 3 interferometer	3 S/C, 3 interferometers 4 clusters

>10 better sensitivity

from Kawamura

Orbit and constellation (preliminary)

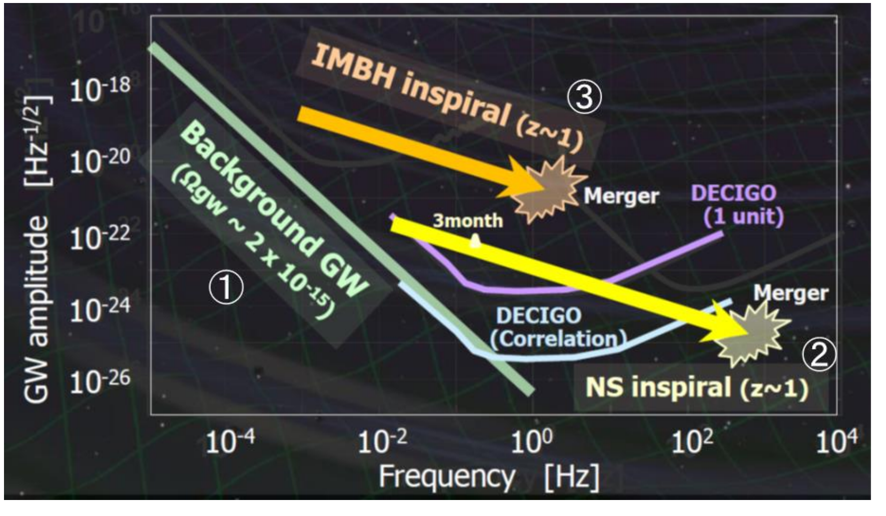
4 units would be used



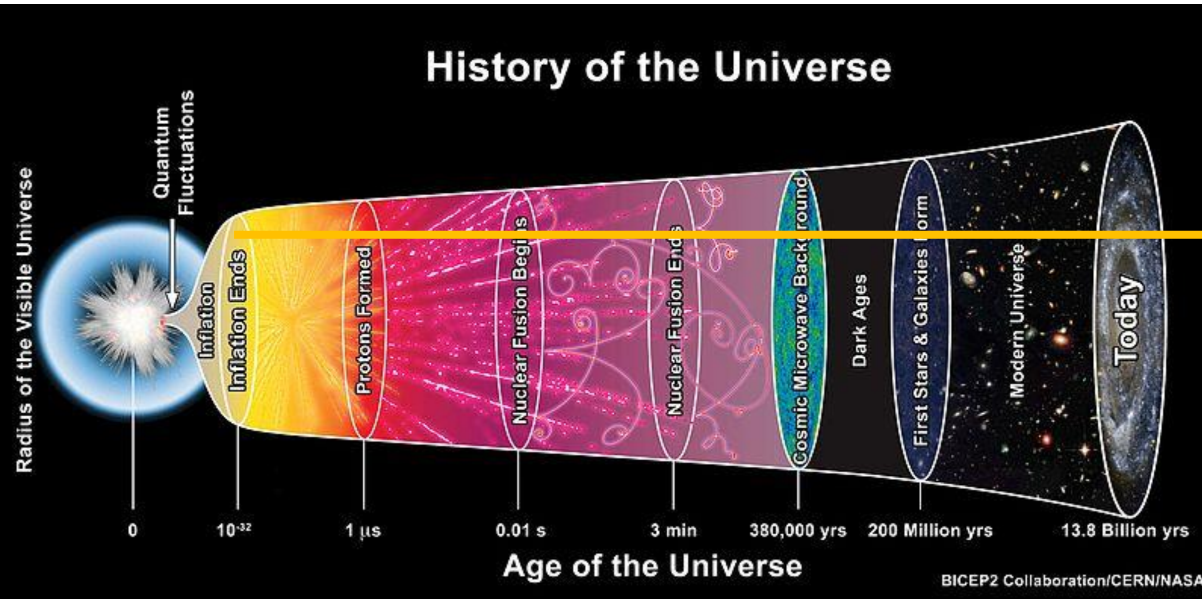
from Kawamura

Science targets of DECIGO -outline-

- Stochastic GW backgrounds
  - primordial backgrounds
  - Correlation analysis
- Cosmological binaries (s-BH, NS)
  - Foreground subtraction problem
  - Use them as powerful science tools
- GWs from Intermediate mass BHs (IMBHs)



Stochastic GWs from Early Universe



Important fossil

Gravitational interaction: weak

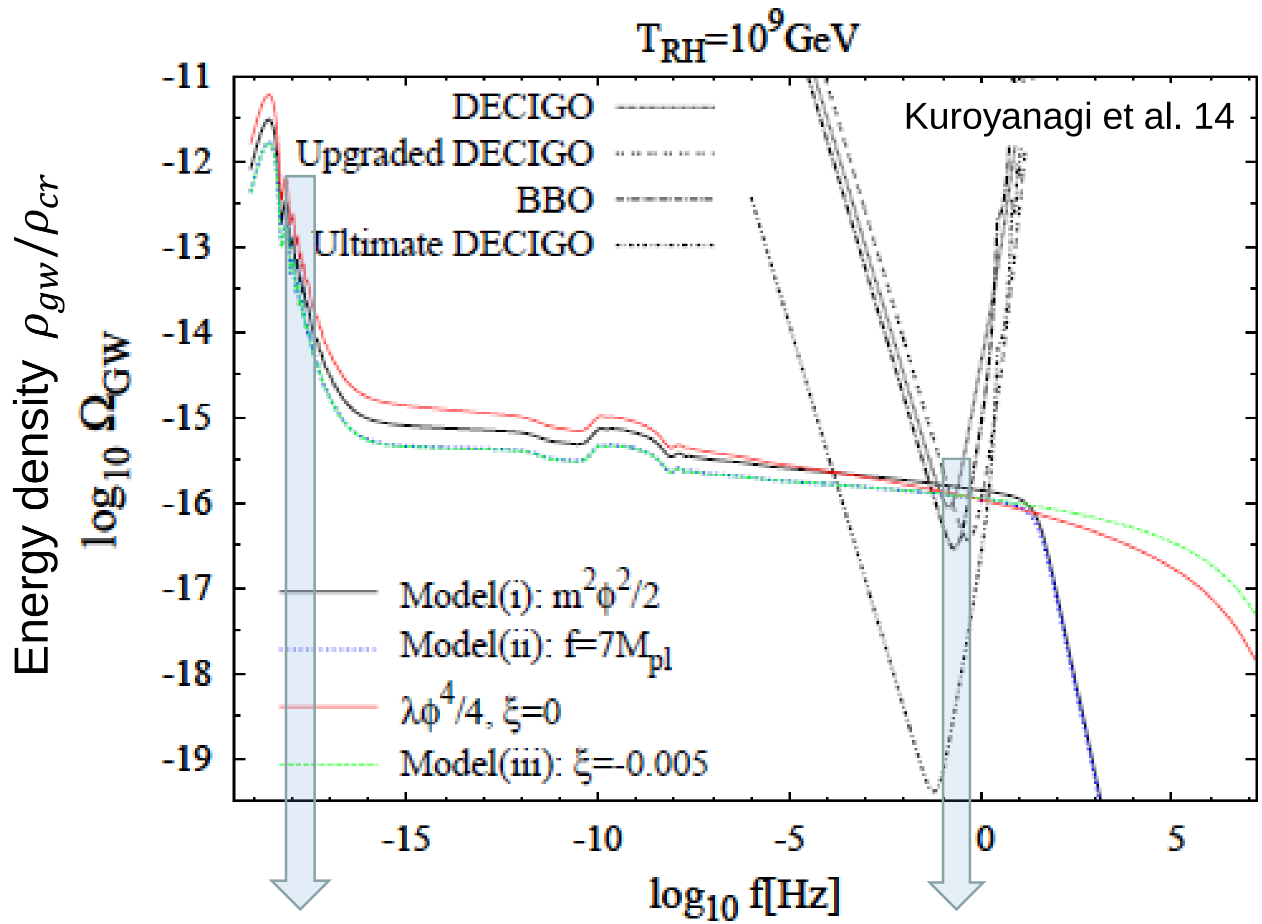
GWs：extremely high permeability

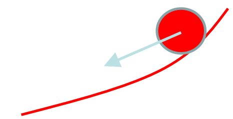
Directly catch
wave oscillation

Probe: generation + history

Strong candidate：GWs generated during Inflation (next slide)

Expected present-day spectrum





A. Generation：potential shape

×

Transfer function

B. Cosmic history

CMB~10^{-17}Hz

Probe A

0.1Hz

Probe A,B

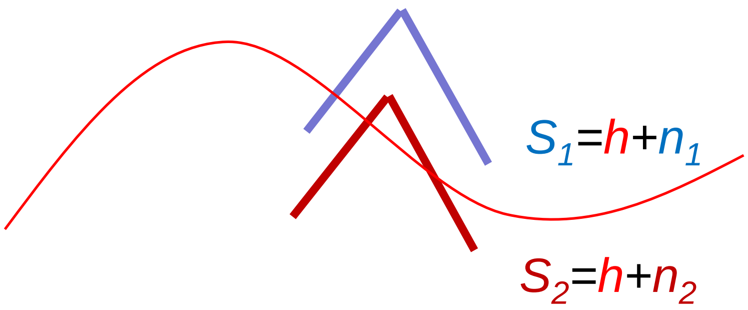
10^{16}

complimentary

Correlation analysis for GWB

Correlate two (noise) independent detectors

Christensen 92, Flanagan 93, Allen & Romano 99



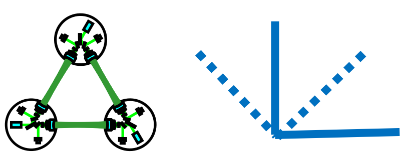
Separation<<wavelength

$$S_1S_2 = hh + \underbrace{n_1n_2 + h(n_1+n_2)}_{\propto T^{1/2}}$$

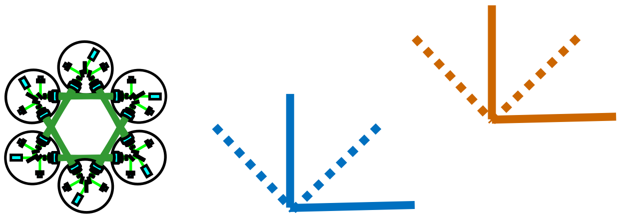
$$\int dt \qquad \propto T$$

Sensitivity to $\Omega_{GW} \propto T^{-1/2}$

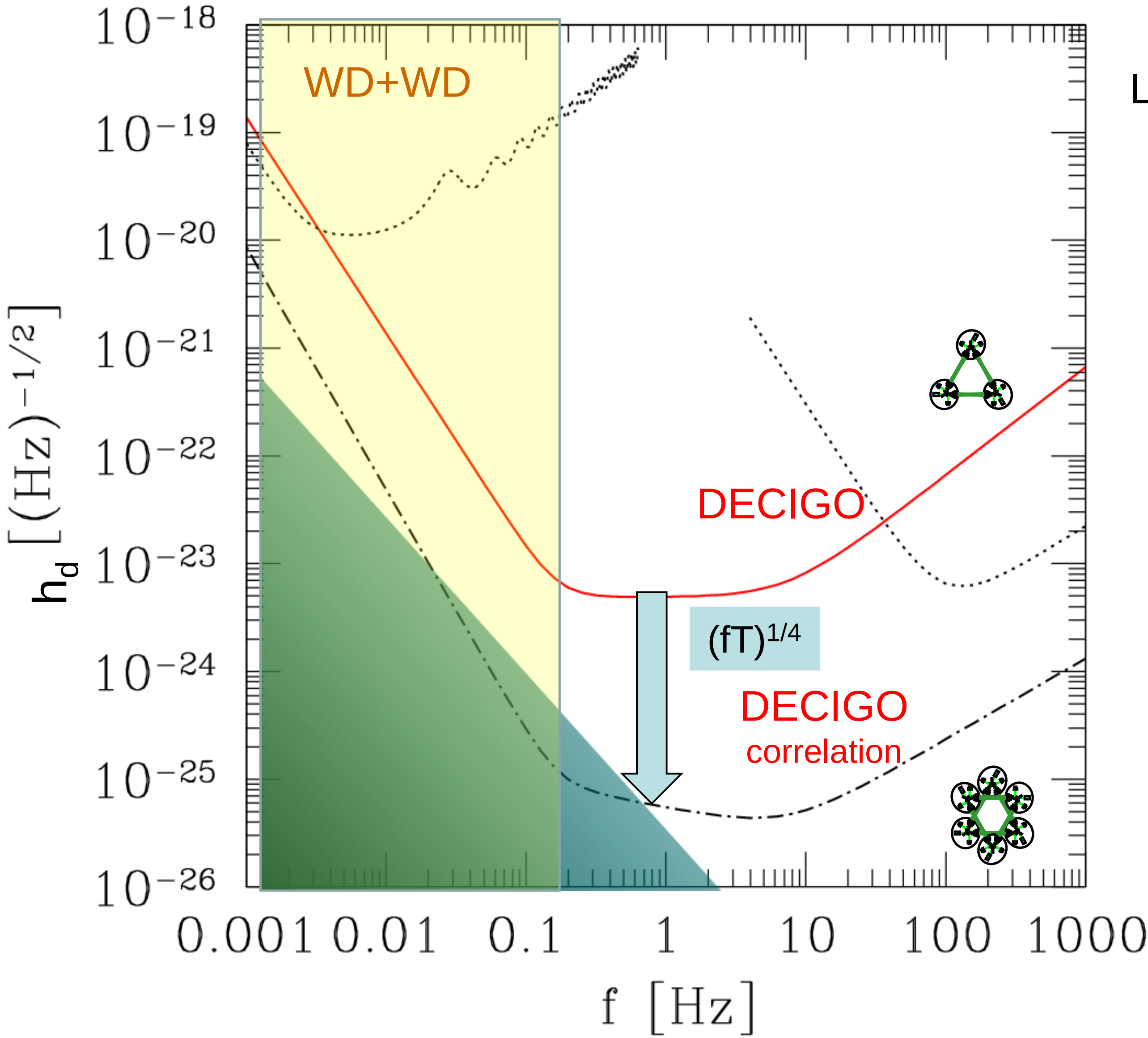
No correlation only with a single triangular unit



No overlap (cancel!)



Correlation analysis with DECIGO



Long-term signal integration

$$\Omega_{GW} \propto h^2 f^3 \propto T^{-1/2}$$

DECIGO

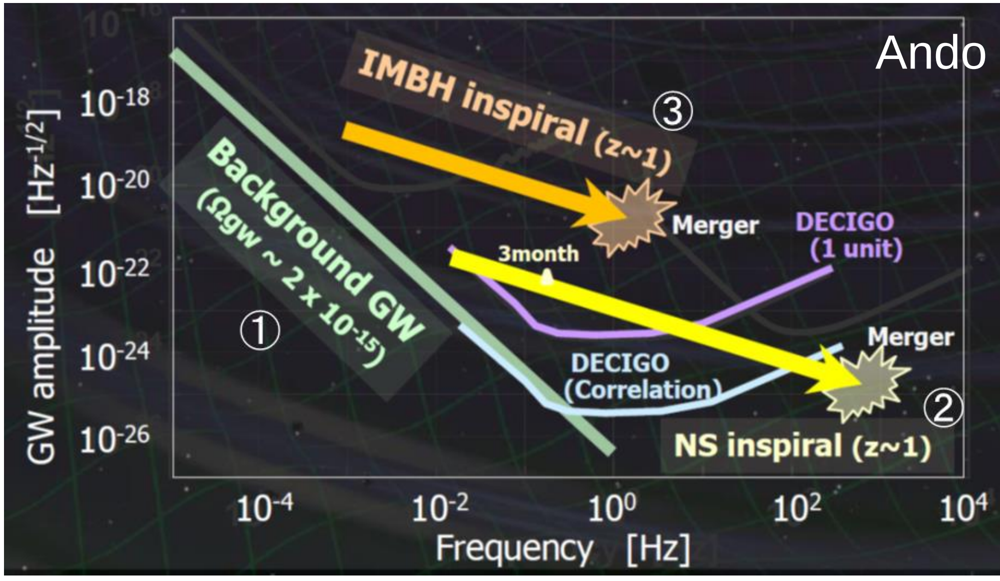
Designed to detect

$$\Omega_{GW} \sim 10^{-16}$$

Improve sensitivity goal?

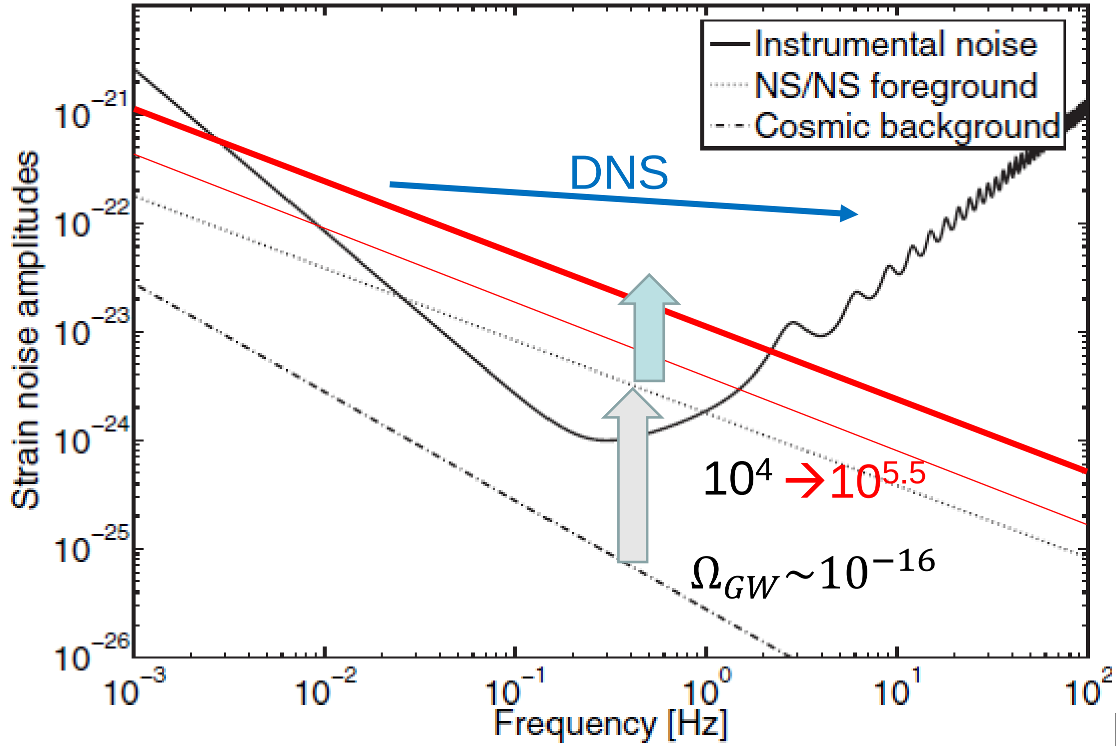
Outline

- Stochastic GW background from Early Universe
  - GW background generated during inflation
  - Correlation analysis
- GWs from cosmological compact binaries (s-BH, NS)
  - Foreground subtraction problem
  - Use them as powerful science tools
- GWs from IMBHs



Foreground cleaning around 0.1-1Hz

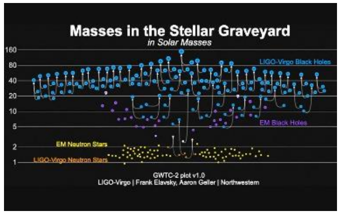
Pioneering work by Cutler & Harms 06 for NS-NSs (DNSs)



DNS+BBH (x30)

DNS (x3)

$$\Omega_{GW} \propto h^2 \propto rate \times mass^{5/3}$$



Many merger events after GW150914

1. Higher NS-NS (DNS) rate 100Gpc^{-3}yr^{-1} → ~300Gpc^{-3}yr^{-1}
2. Existence of BBH ~30+30M$_{sun}$ ~30Gpc^{-3}yr^{-1}

Foregrounds become much stronger

Binary Subtraction

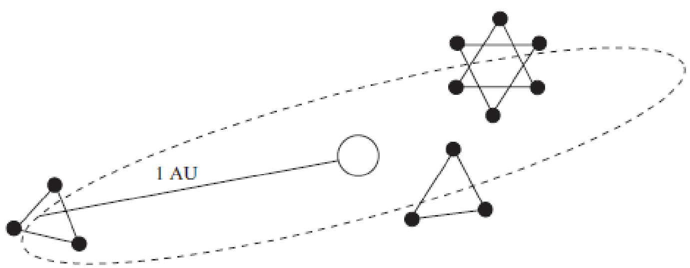
- Sufficient data amount
  - # of fitting parameters: 10×10^5/yr
  - # of data amount: $1\times(3\times10^7)$/yr
- redshift dependence
  - $SNR \propto (1+z)^{-1/6}$
  - Rotation cycles: smaller at high-z

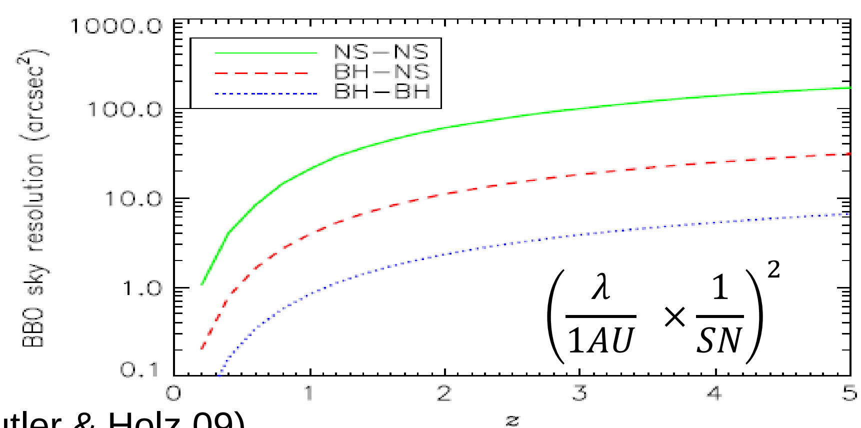
Most difficult at intermediate z

- Nearly sufficient sensitivity
- Complicated/weak signals?

Individual DNSs (BBHs)

- **New tools for physics, cosmology and astronomy**
  - large number, DNS: ~O(10^5/yr)
    - Must be identified for detecting primordial GWs
  - Large cycles with ~10 fitting parameters
    - Examine theory of gravity
  - Good sky localization + distance measurement
    - Dark energy
  - Merger time: predictable
    - GRB,…





Results for BBO (Cutler & Holz 09)

Summary

- DECIGO: FP-type
  - Shorter arm length
    - Larger photon number (suppress shot noise)
    - stringent requirement on acceleration noise
- scientific targets
  - primordial GWB ($\Omega_{GW} \sim 10^{-16}$)
    - Strong candidate: inflation background
    - Correlation analysis
  - Individual compact binaries
    - Foreground cleaning is essential ($\Omega_{GW} \sim 10^{-10}$)
    - powerful tools for cosmology/astronomy (Dark energy..)
      - sky localization for Host galaxy identification, reliable distance,..