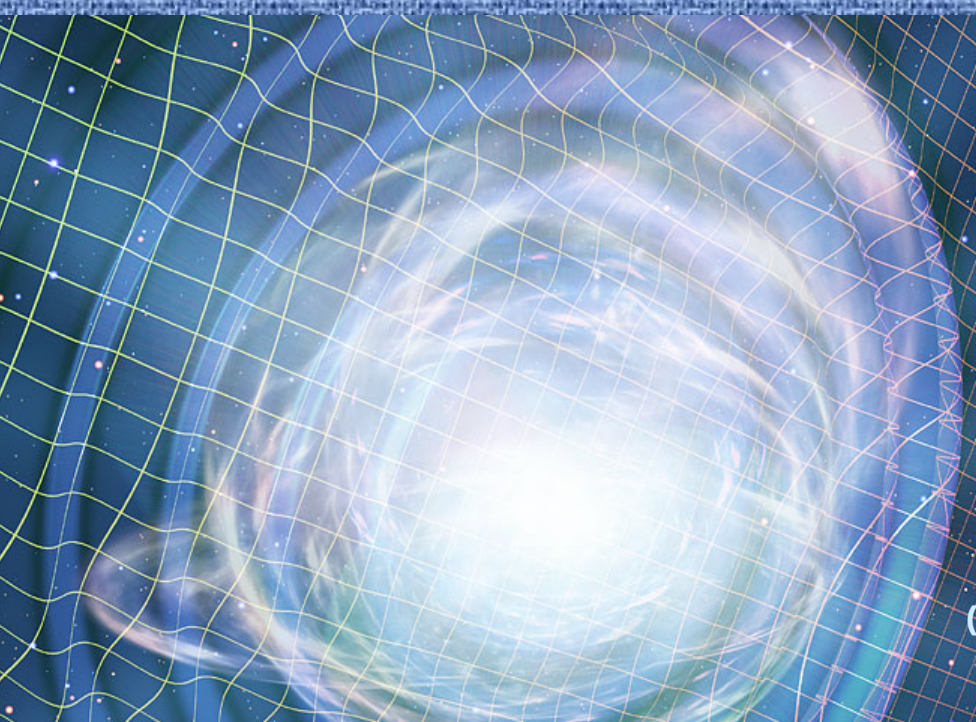
DECIGO :
the Japanese Space Gravitational Wave Antenna



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11th Marcel Grossmann Meeting on General Relativity (July 23 - 29, 2006, Freie Universität Berlin)

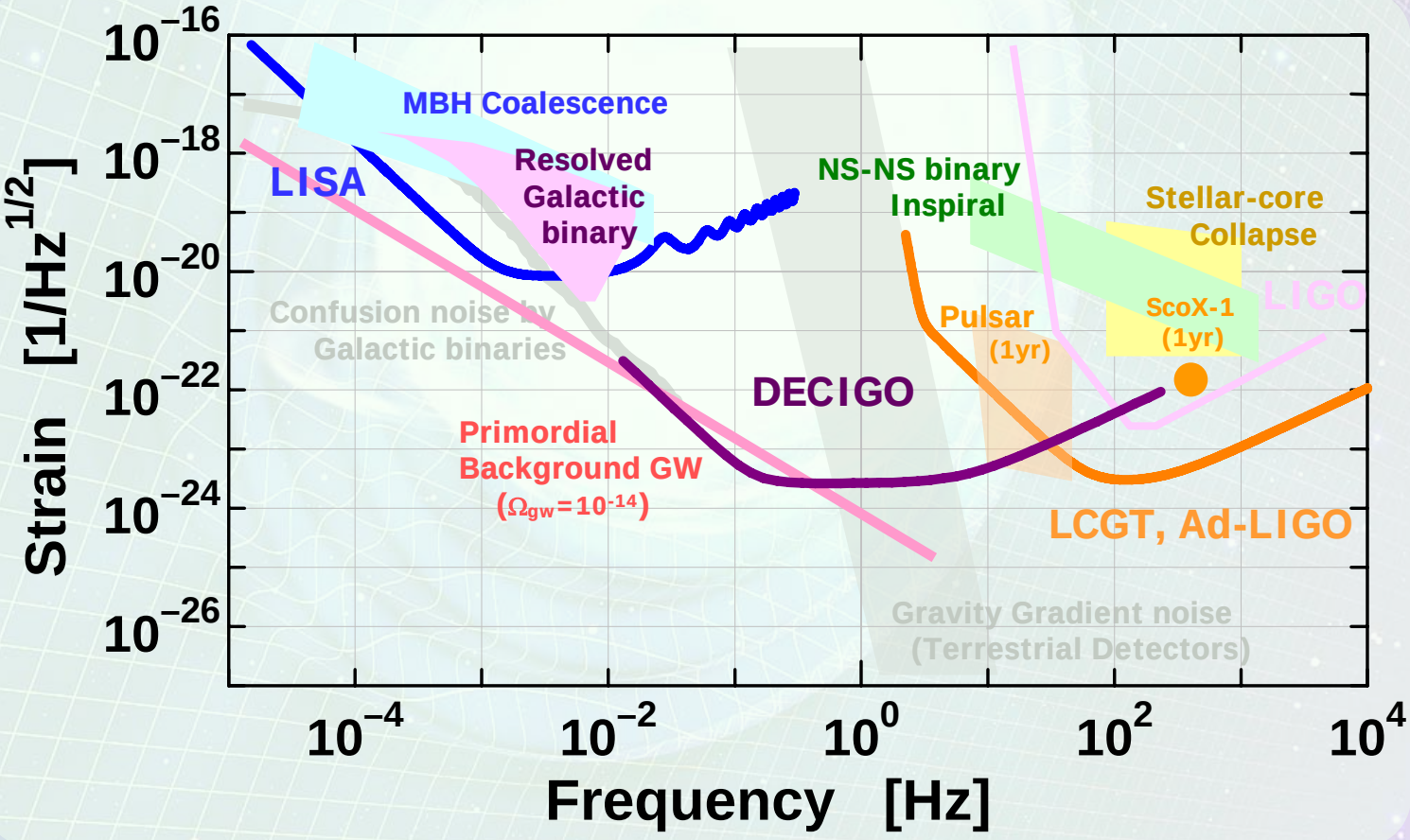
Contents

Introduction

- **DECIGO**

Deci-hertz Interferometer Gravitational Wave Observatory

⇨ **bridges the gap between LISA and terrestrial detectors**



Pre-conceptual Design (1)

- **Pre-conceptual Design**

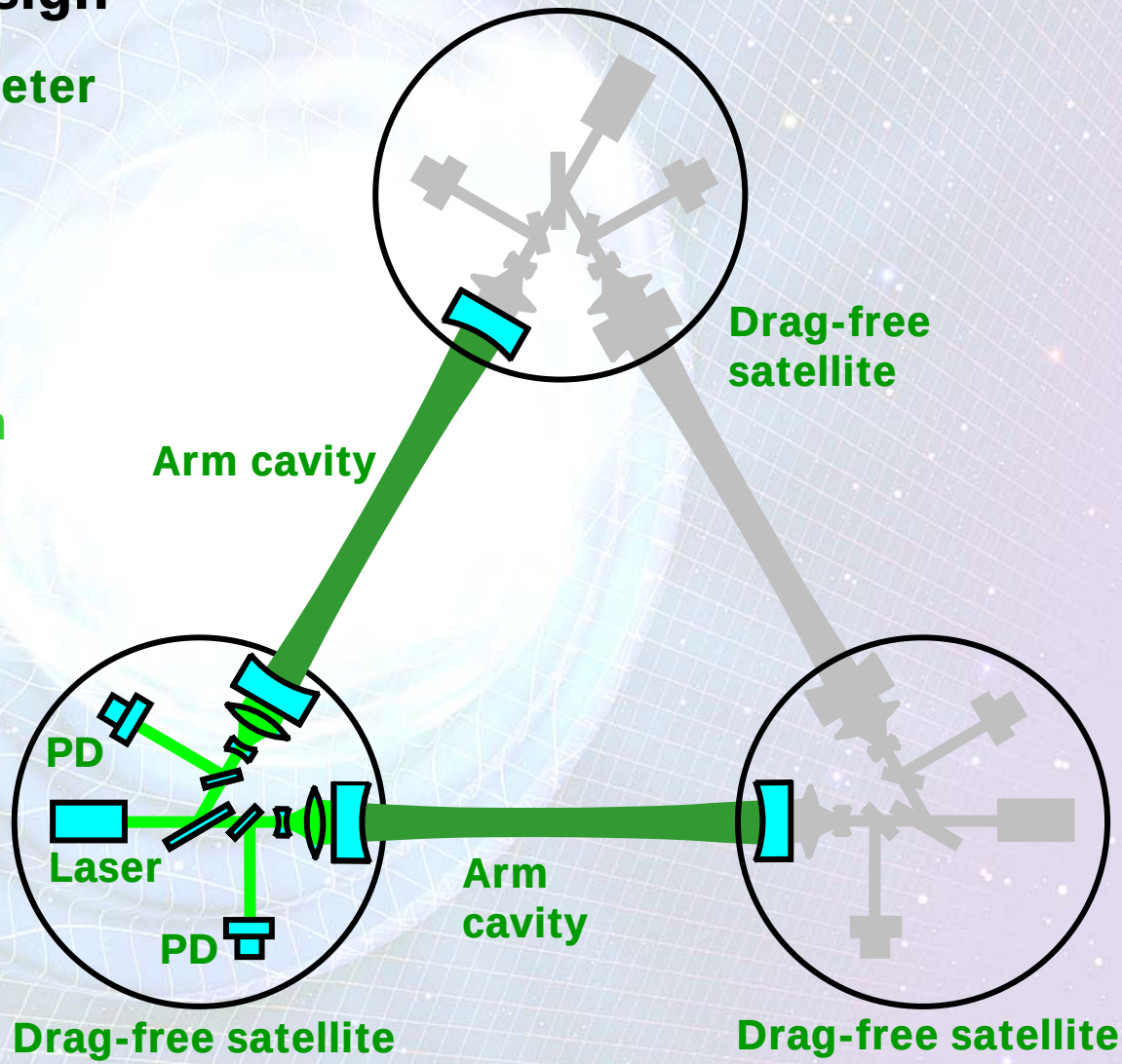
FP-Michelson interferometer

Arm length: 1000 km
Finesse: 10

Laser
Power: 10 W
Wavelength: 532 nm

Mirror (Test mass)
Diameter: 1 m
Mass: 100 kg
Shielded by S/C

Orbit and
constellation: TBD



S. Kawamura, et al.,
CQG 23 (2006) S125-S131

Pre-conceptual Design (2)

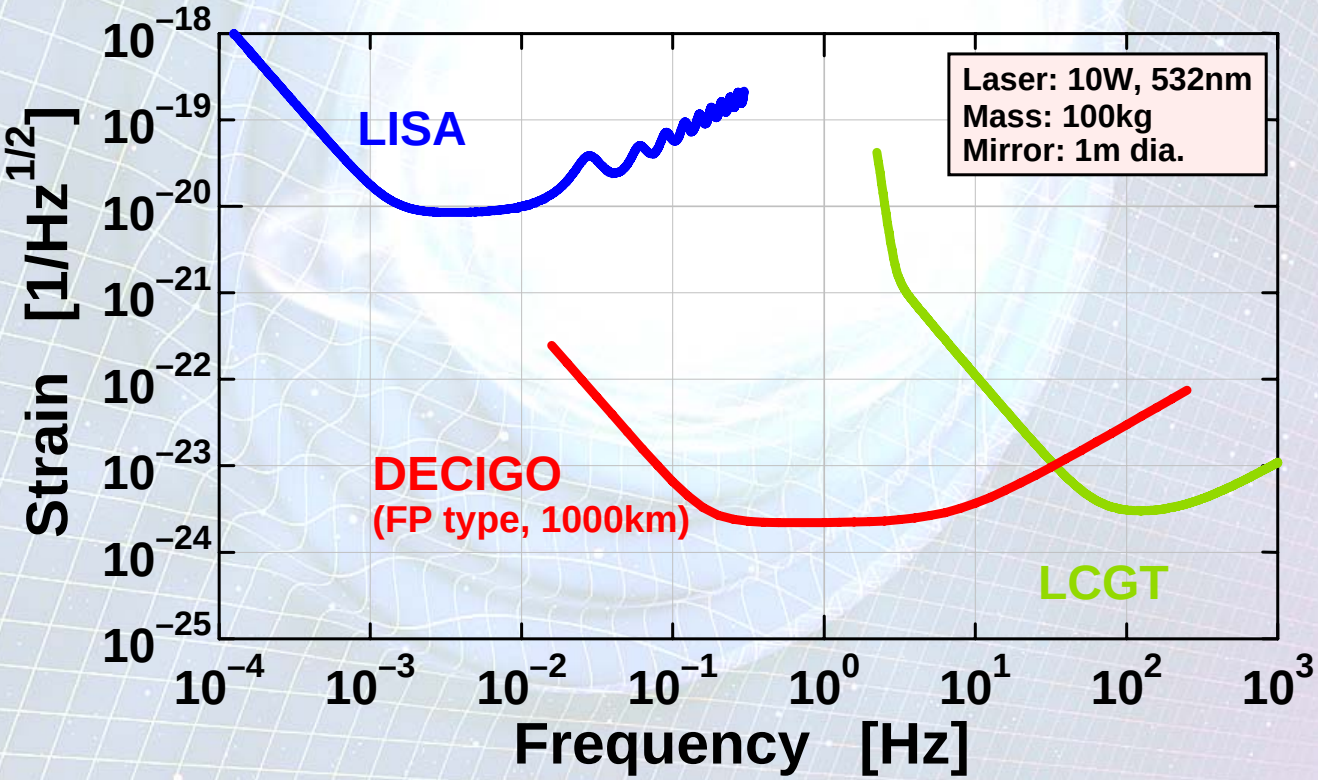
- **Sensitivity**

  Floor level : 2×10^{-24} /$Hz^{1/2}$ (0.1 - 10Hz)

  Noise sources

  Low freq.: Acceleration noise, Radiation pressure noise

  High freq.: Shot noise (7.5Hz cut-off freq.)



Pre-conceptual Design (3)

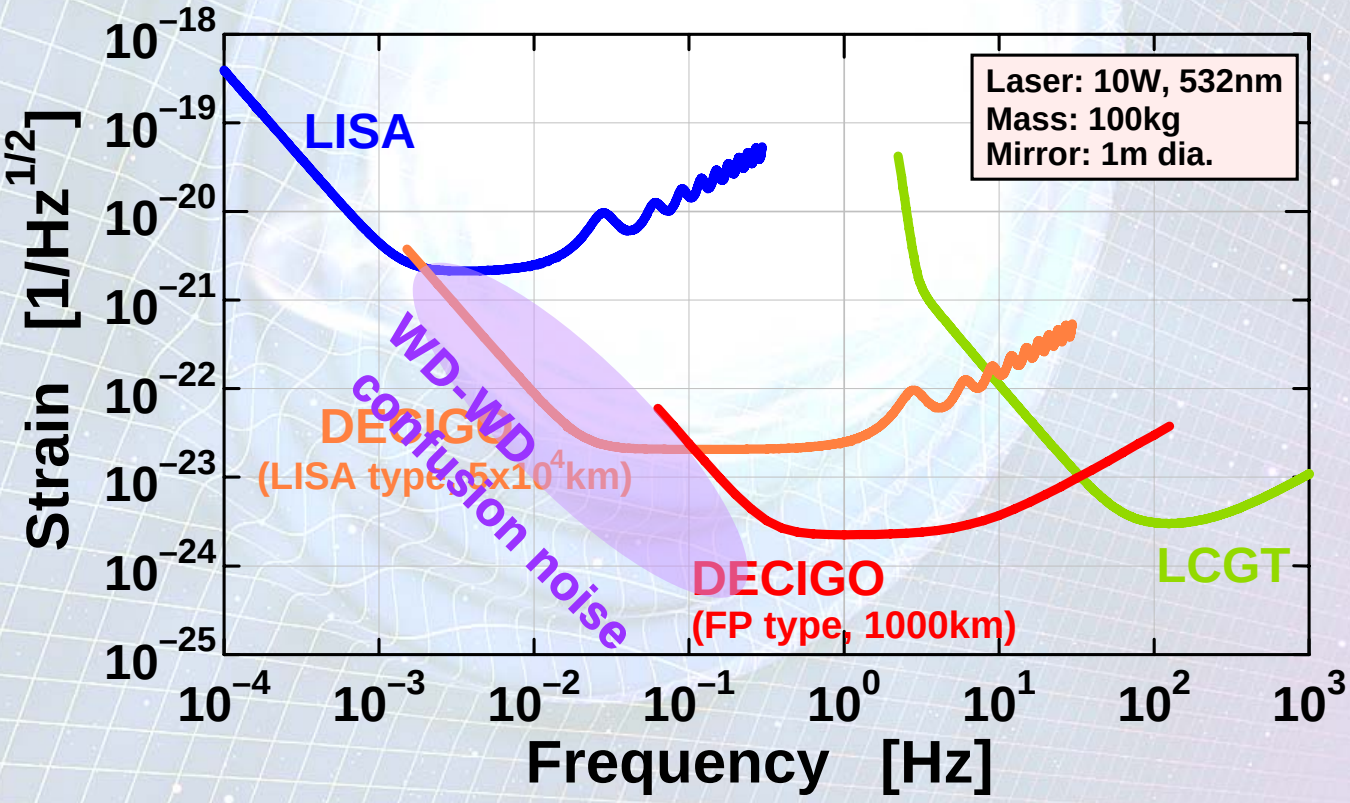
- **Interferometer Design**

Transponder type vs Direct-reflection type

Compare: Sensitivity curve and Expected Science

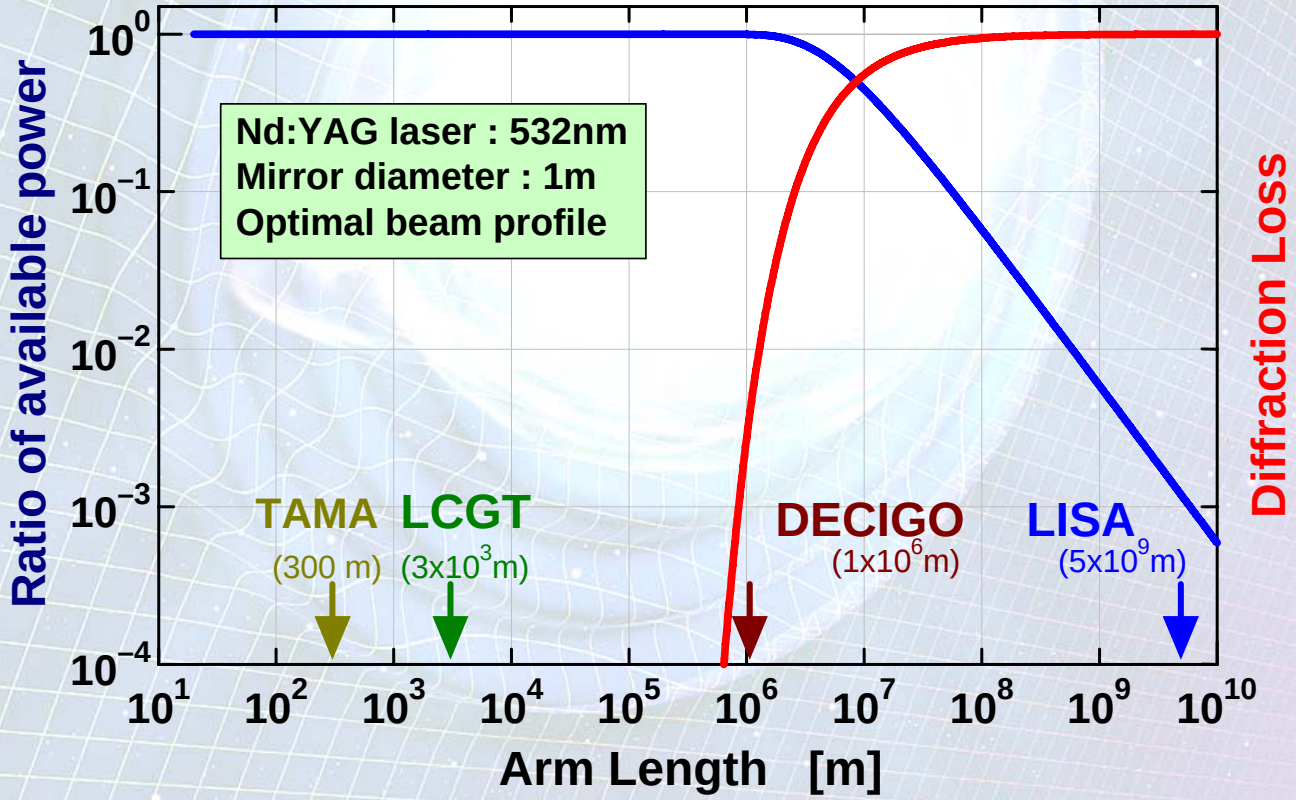
Same detector parameters (Mirror, Laser, etc.)

Decisive factor: Binary confusion noise



Pre-conceptual Design (4)

- **Arm length**
  - **Cavity arm length : Limited by diffraction loss**
    - **Calculate Effective reflectivity ($TEM_{00} \rightarrow TEM_{00}$)**
      - **Laser wavelength : 532nm, Mirror diameter: 1m**
      - **Optimal beam size**



Pre-conceptual Design (5)

- **Requirements**

Practical force noise:

4×10^{-17} N/Hz$^{1/2}$ per mirror

(Mirror mass: 100kg)

Frequency Noise (at 1 Hz)

First-stage stabilization: 1 Hz/Hz$^{1/2}$

Stabilization gain

by common-mode arm length: 10^5

Common-mode rejection ratio : 10^5

Pre-conceptual Design (6)

- **Cavity and S/C control**

  Cavity length change

  PDH error signal → Mirror position (and Laser frequency)

  Relative motion between mirror and S/C

  Local sensor → S/C thruster

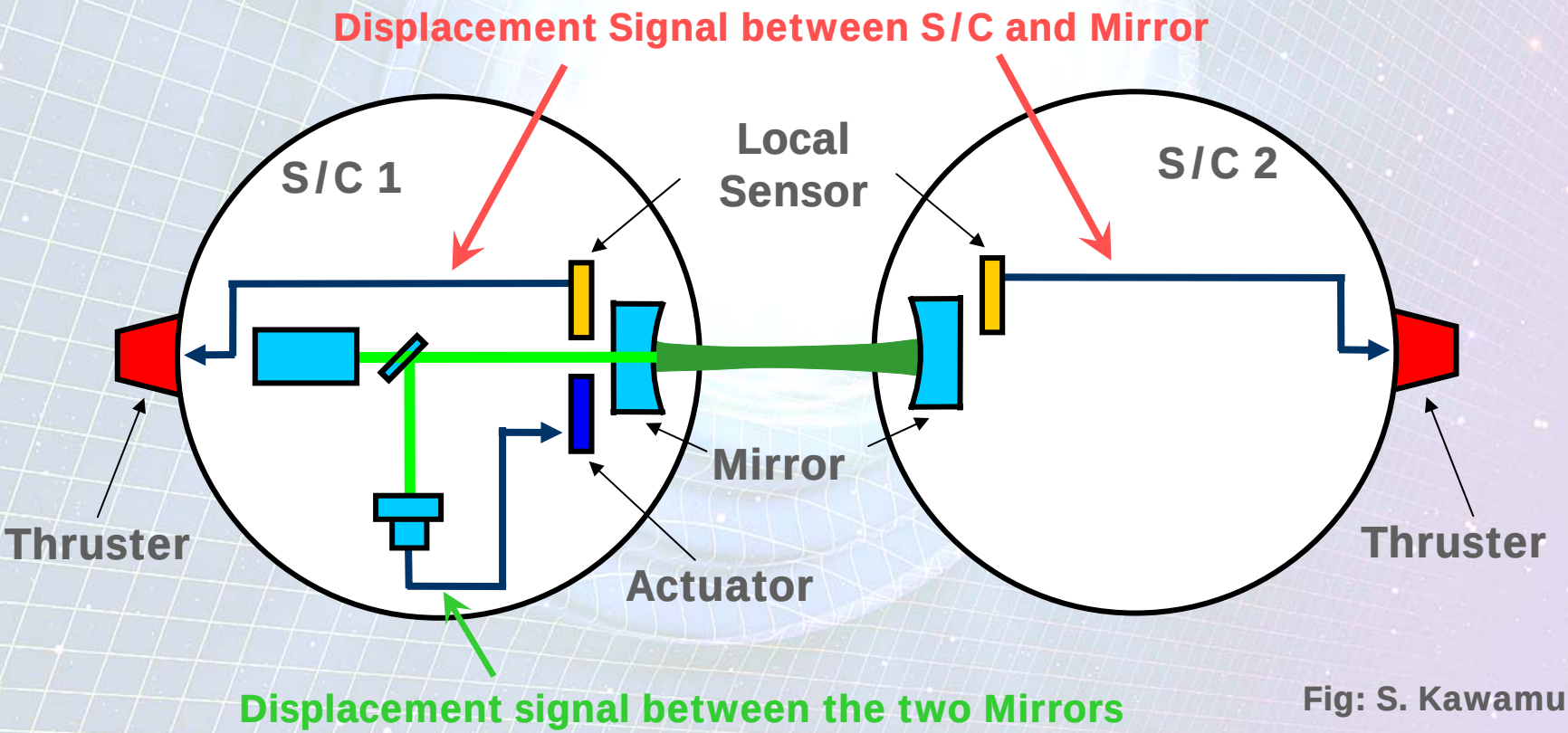


Fig: S. Kawamura

Pre-conceptual Design (7)

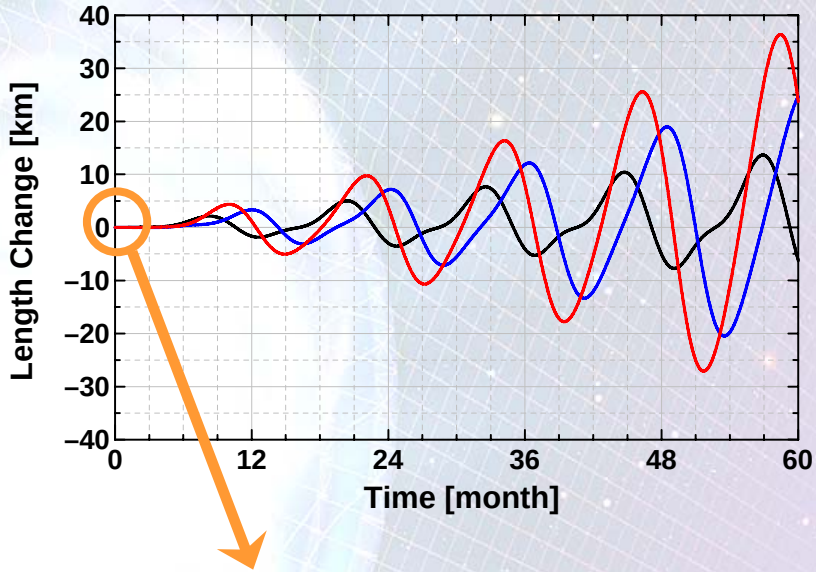
- **S/C thruster force**

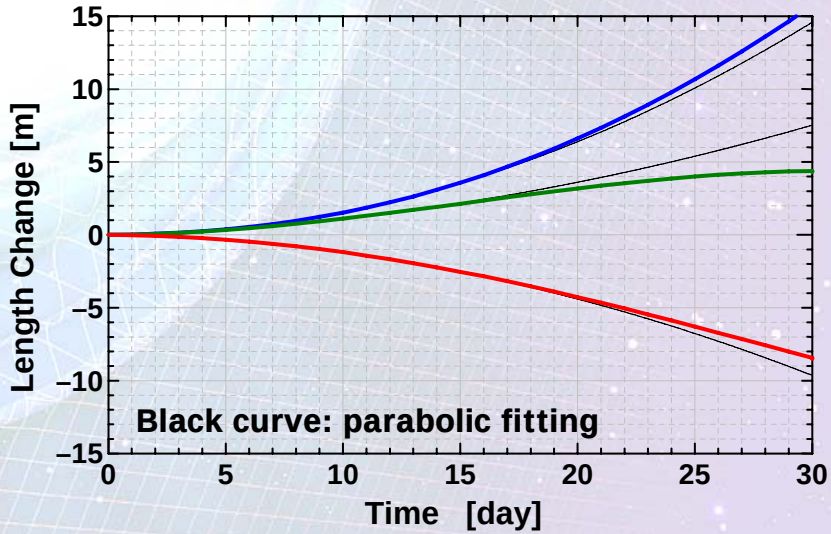
S/C orbit : TBD

(ex) Similar orbit as that of LISA

Numerical simulation of multi-bode system

Include gravity of planets
Arm length: 1000km
Earth-like orbit,
20deg. Behind the earth

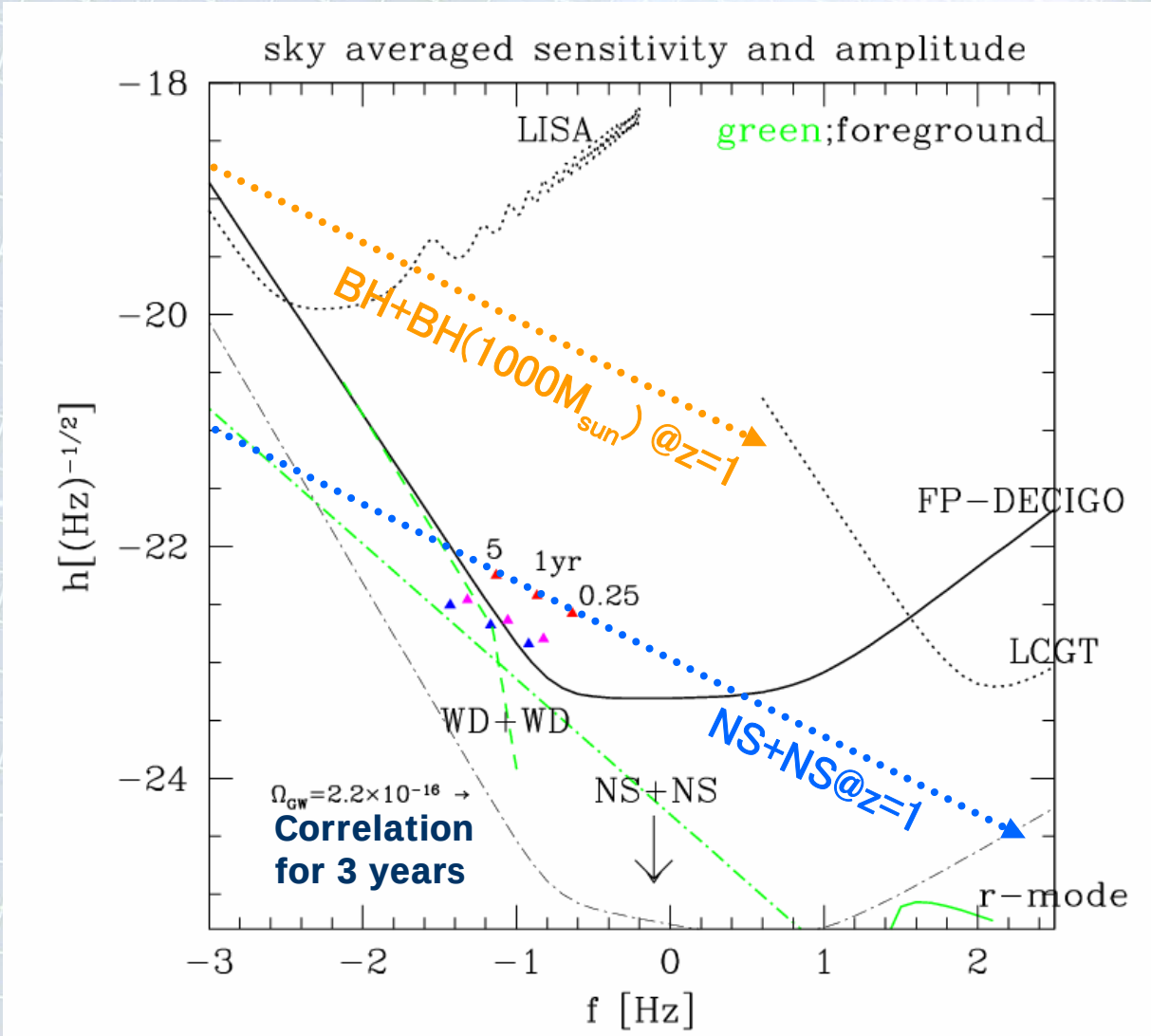




Length control is indispensable
Acceleration to be controlled:
~4x10^{-12} m/s^2

Science by DECIGO (1)

- **Binary Inspiral**



Extremely high rate for NS-NS inspirals

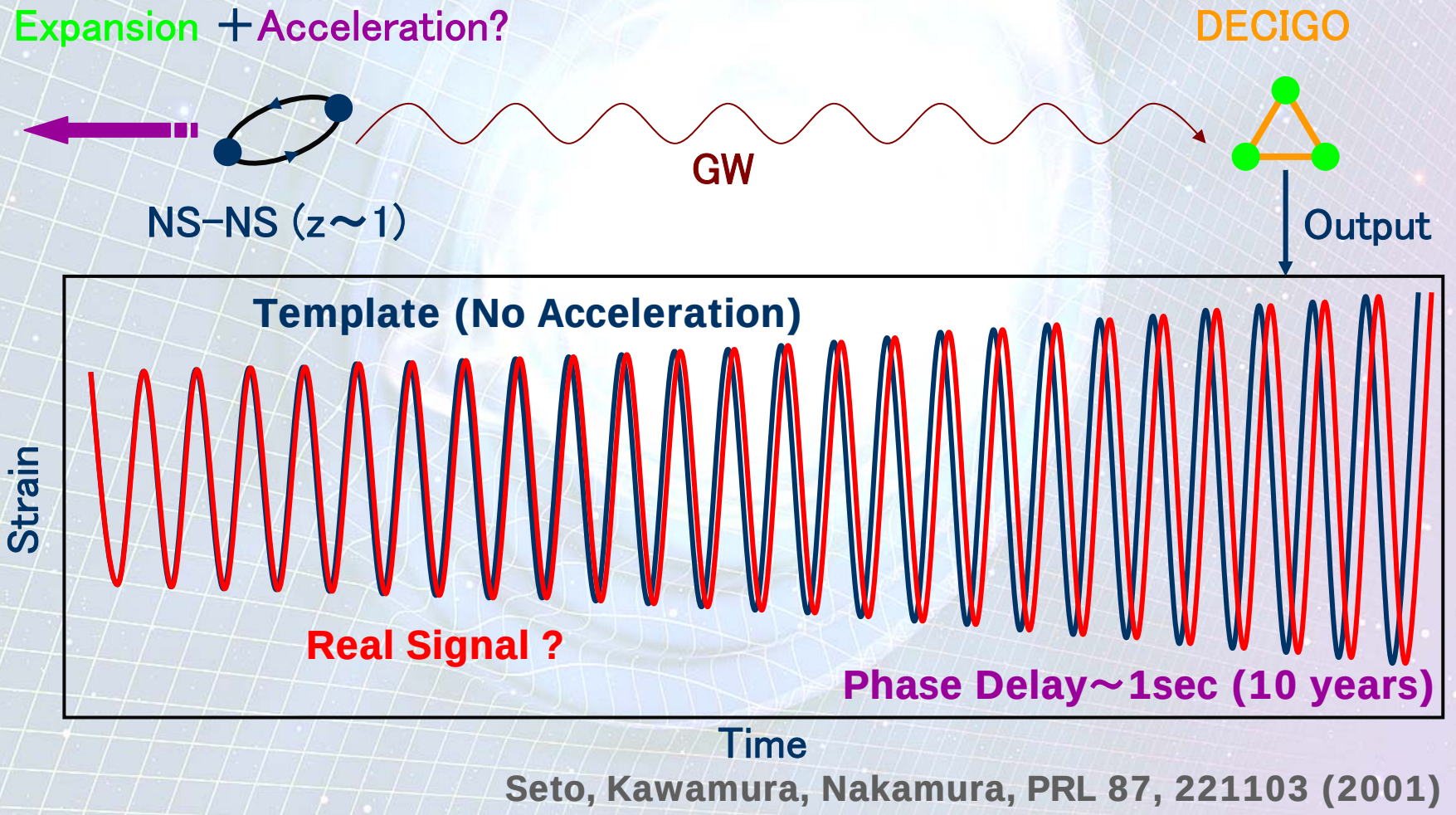
NS-NS ($1.4+1.4M_{sun}$)
z<1 (SN>26: 7200/yr)
z<3 (SN>12: 32000/yr)
z<5 (SN>9: 47000/yr)
IMBH ($1000+1000M_{sun}$)
z<1 (SN>6000)

Fig: N. Seto

Science by DECIGO (2)

- **Acceleration of Expansion of the Universe**

  Distant binary is a precise clock → Monitor Doppler shift



Seto, Kawamura, Nakamura, PRL 87, 221103 (2001)

Science by DECIGO (3)

- **Constraint to Dark Energy**

Distance – Red shift relationship for NS-NS binaries

→ **Constraint to dark energy**

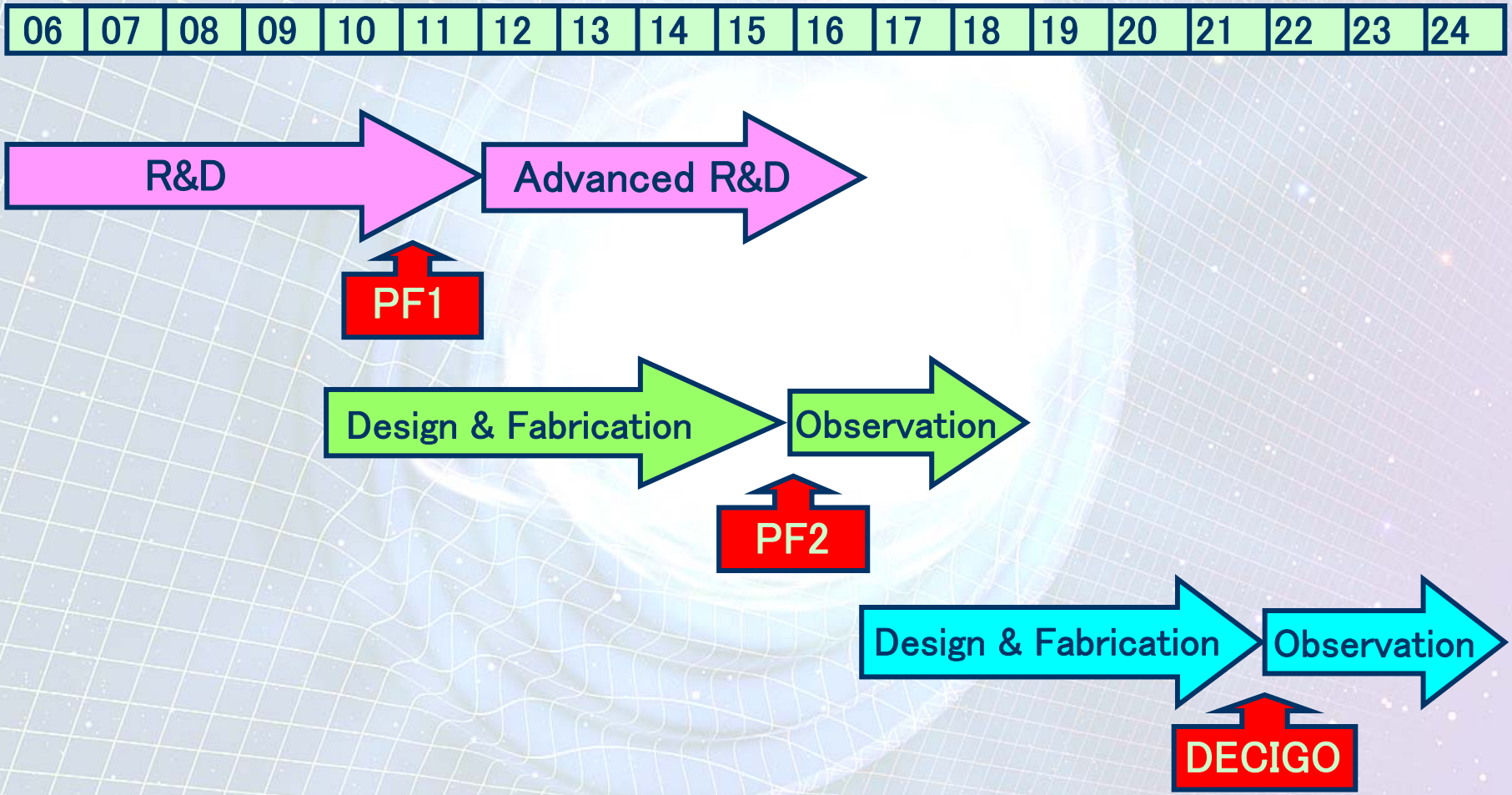
Distance: determined directly by GW observation

Red shift: determined by identifying the host galaxies

(10 arcsec at z=1 for two far-separate DECIGOs)

Roadmap and R&D (1)

- **Roadmap to DECIGO**



Roadmap and R&D (2)

- **DECIGO Pathfinder1**

Single S/C with
- **Test mass**
- **Laser interferometer**
- **Drag-free system**

Objectives
- **Drag-free system**
- **Cavity locking in space**
- **Modest sensitivity at 0.1 – 1 Hz**
  - **→ GW observation**

Details: TBD

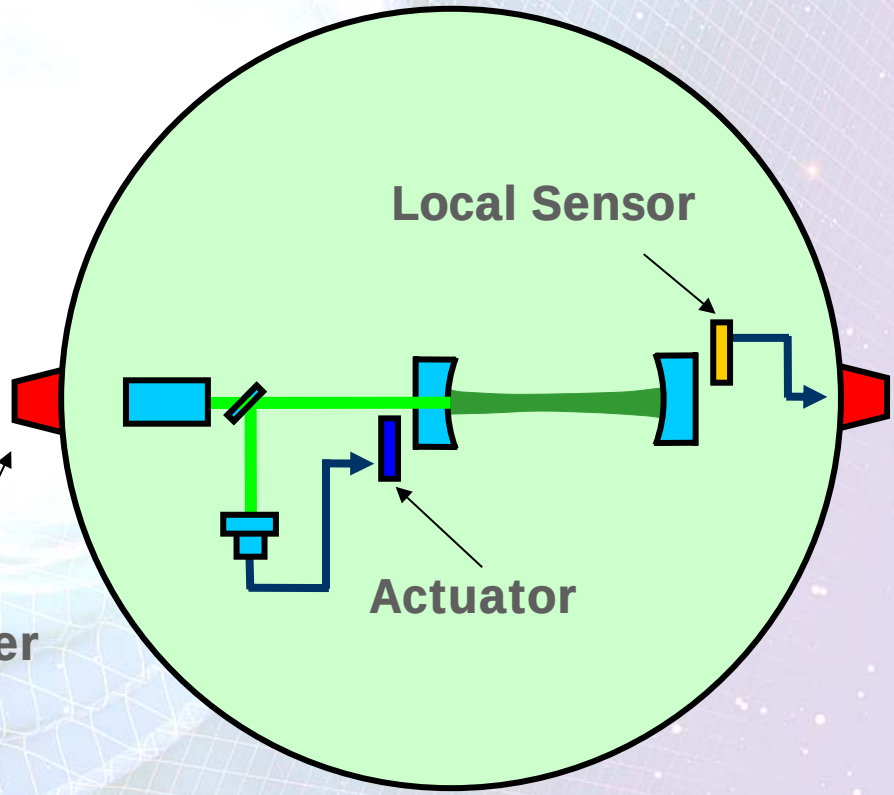


Fig: S. Kawamura

Roadmap and R&D (3)

- **DECIGO Pathfinder2**

Fig: S. Kawamura

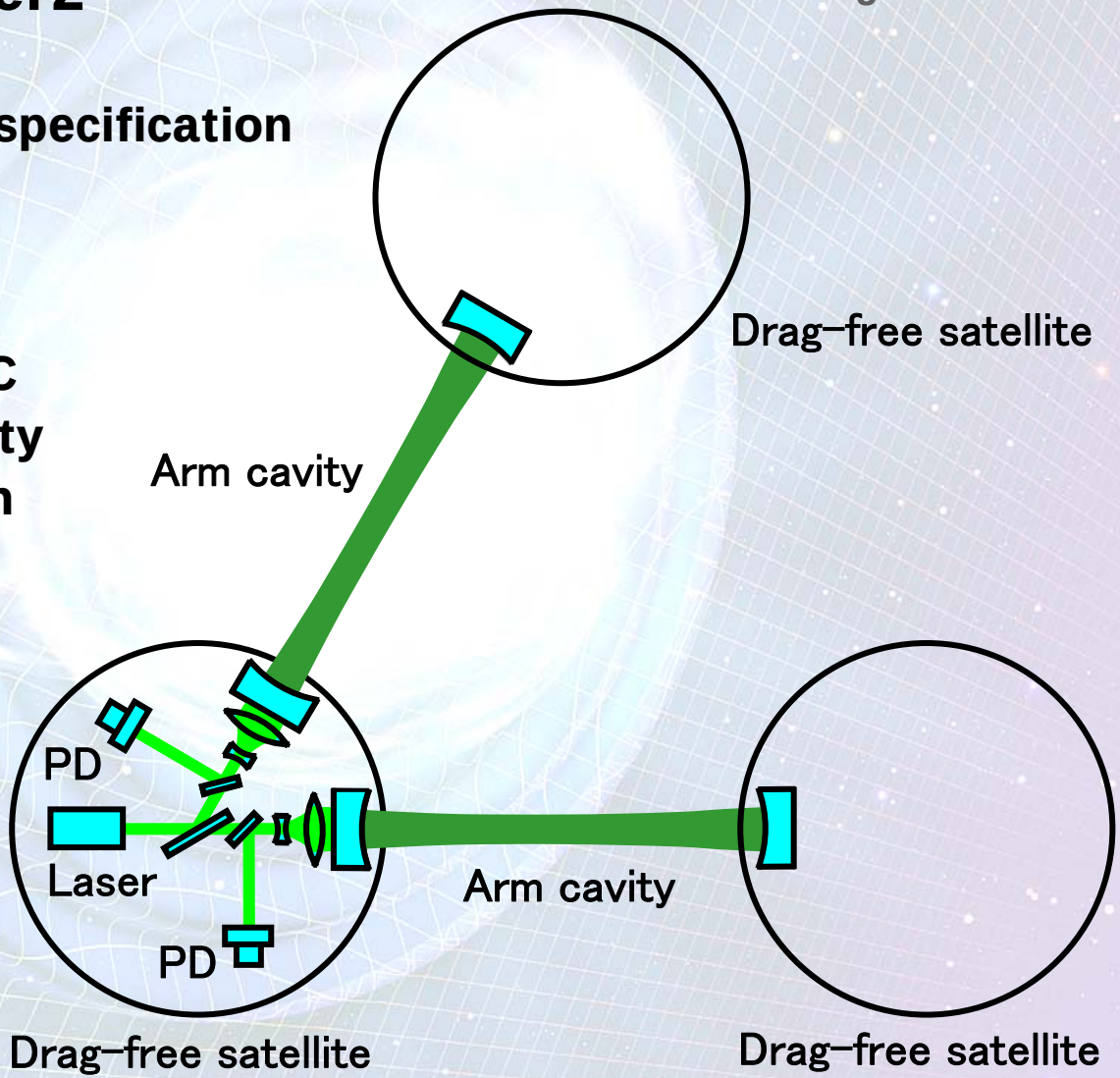
DECIGO with modest specification

Objectives

Cavity locking between two S/C

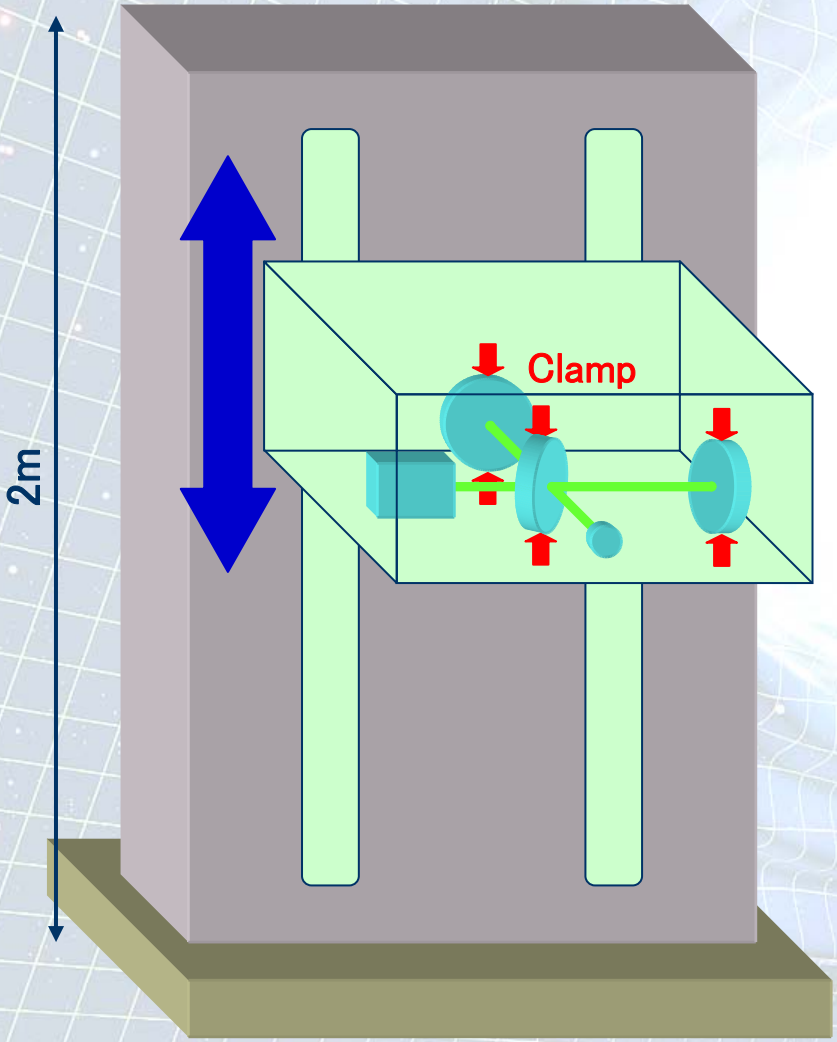
Meaningful sensitivity → GW observation

Details: TBD



Roadmap and R&D (4)

- **DECIGO Simulator**



Objectives

Continual free-fall environment

Clamp release

Modest sensitivity down to 0.1Hz

Possibility of long arm

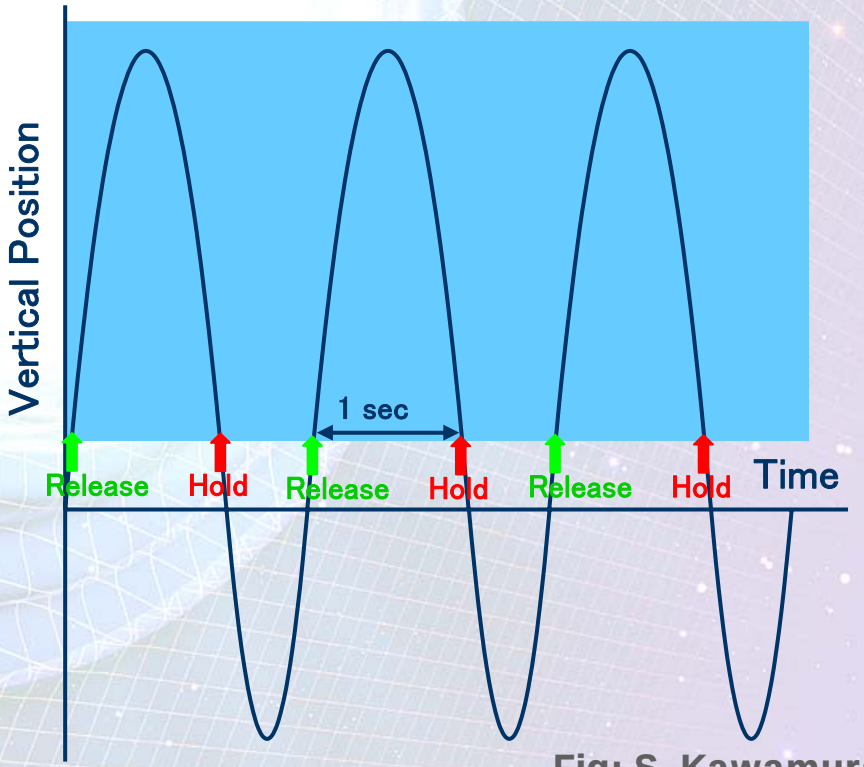


Fig: S. Kawamura

Roadmap and R&D (5)

- **DECIGO Demonstrator**
  - **Objectives**
    - **Lock acquisition**
    - **Drag-free control demonstration**

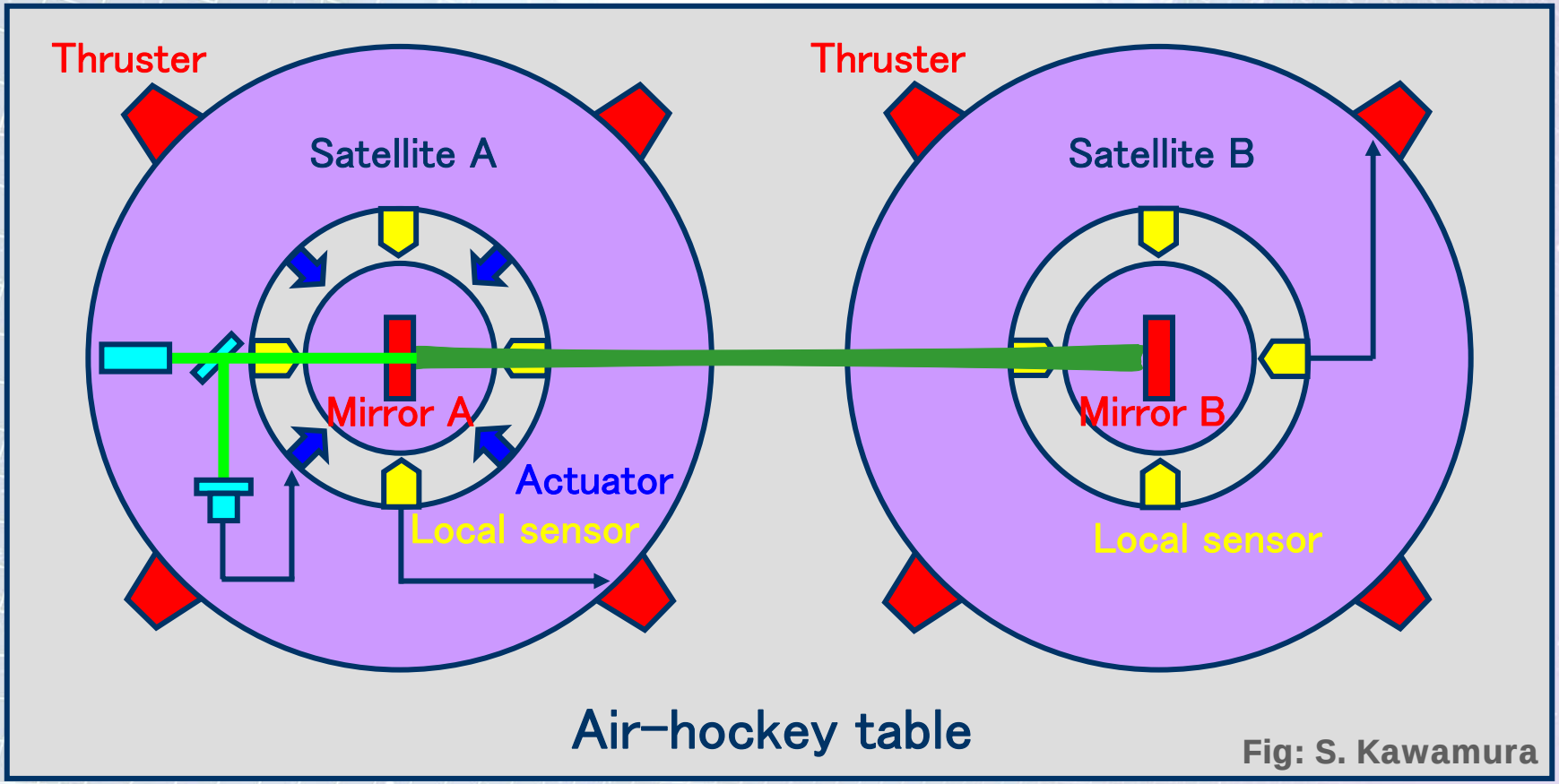


Fig: S. Kawamura

Roadmap and R&D (6)

- **Budget**

Budget request for

"Frontier of All Wavelength Gravitational Wave Astronomy"

submitted in 2005

- TAMA and CLIO

- R&D for DECIGO

- Pulsar Timing

- Super-high frequency G.W. detection

Not approved to our surprise

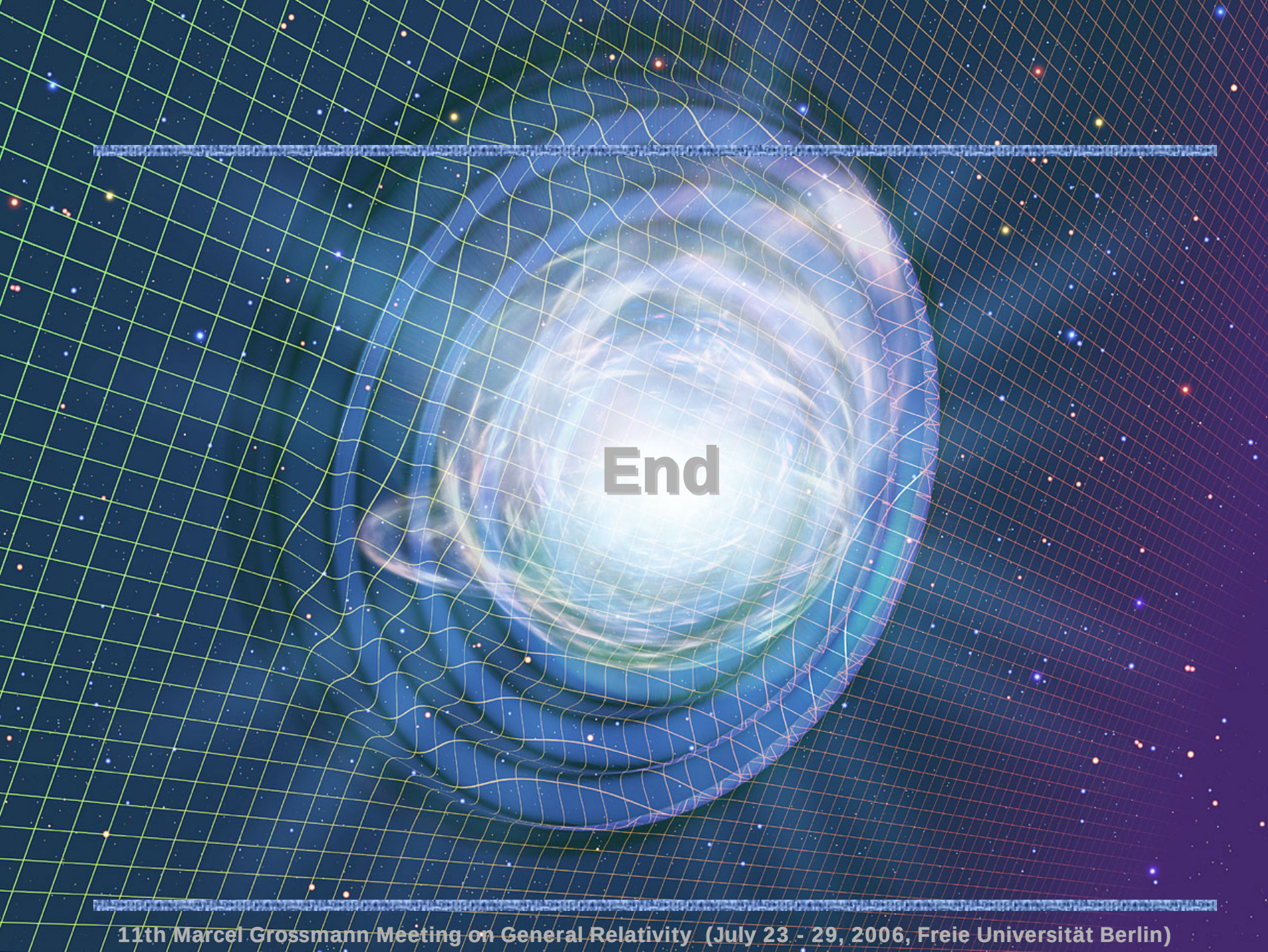
Try again?

Summary

DECIGO will have an extremely good sensitivity
and open the GW window widely.

DECIGO requires
extremely challenging technology development.

We hope that we will be able to
start the R&D for DECIGO very soon.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