Introduction to Ando Lab

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6th Floor Joint Seminar

Ando Lab

- 2 Staff
- 3 Master Students
- 8 Ph.D Students

Our Physics

GW

KAGRA

DECIGO

TOBA

SQL Measurement

Polarization of GW

Optomechanics

Axion Search

Lorentz Invariance

CSL

Inverse Square Law

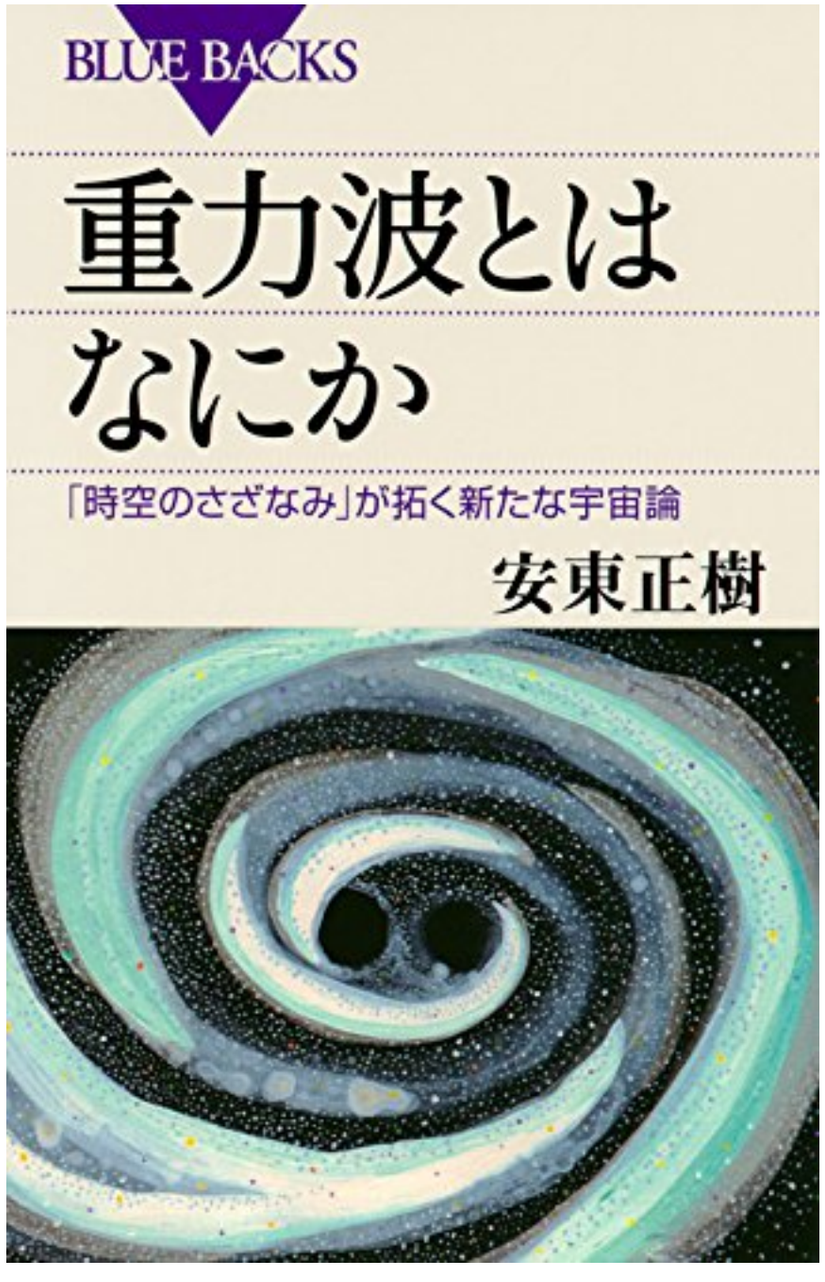
Quantum

Beyond GR

References

重力波とはなにか

「時空のさざなみ」が拓く新たな宇宙論

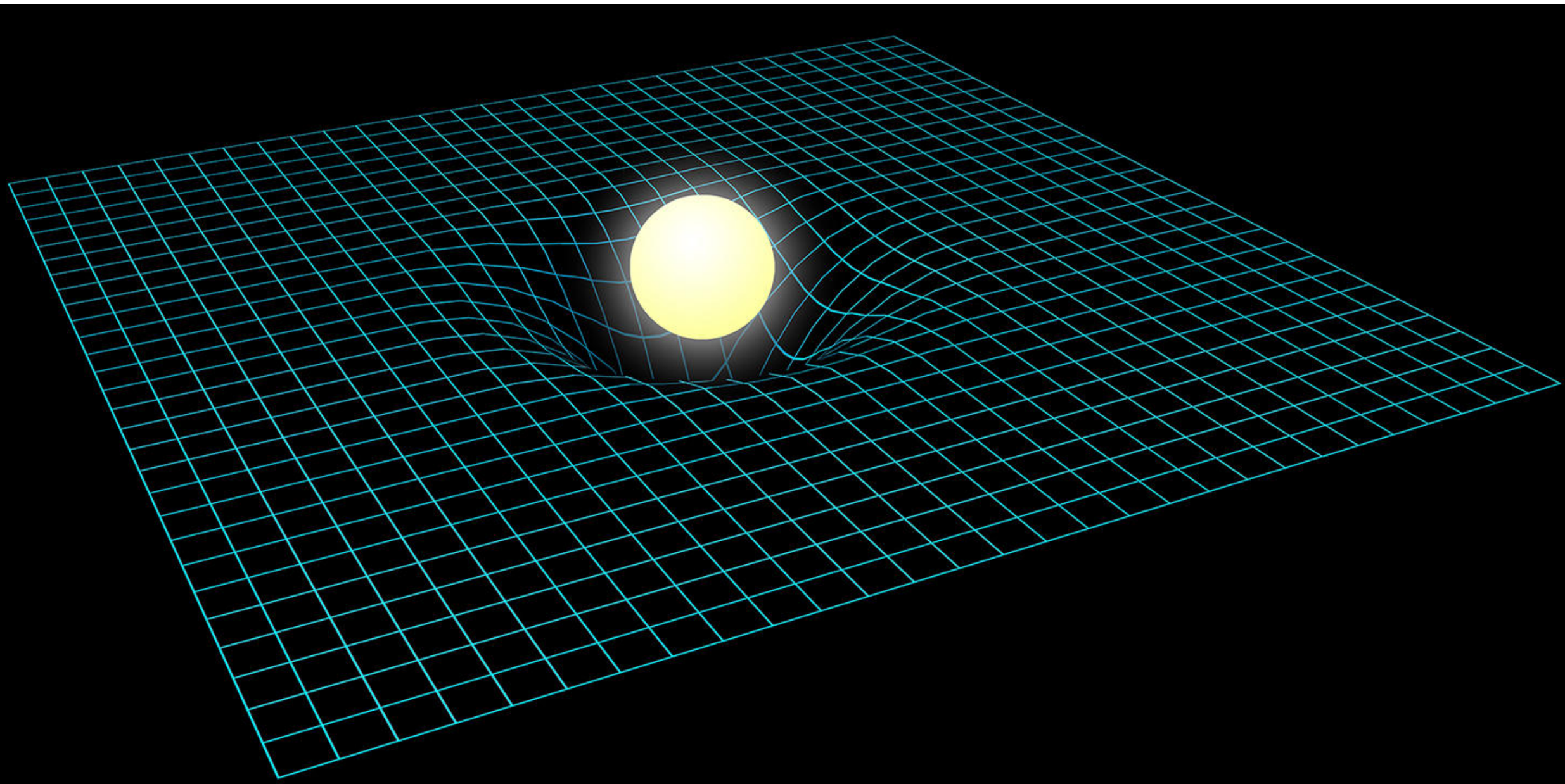


重力波で見える宇宙のはじまり

「時空のゆがみ」から宇宙進化を探る

Gravity in GR

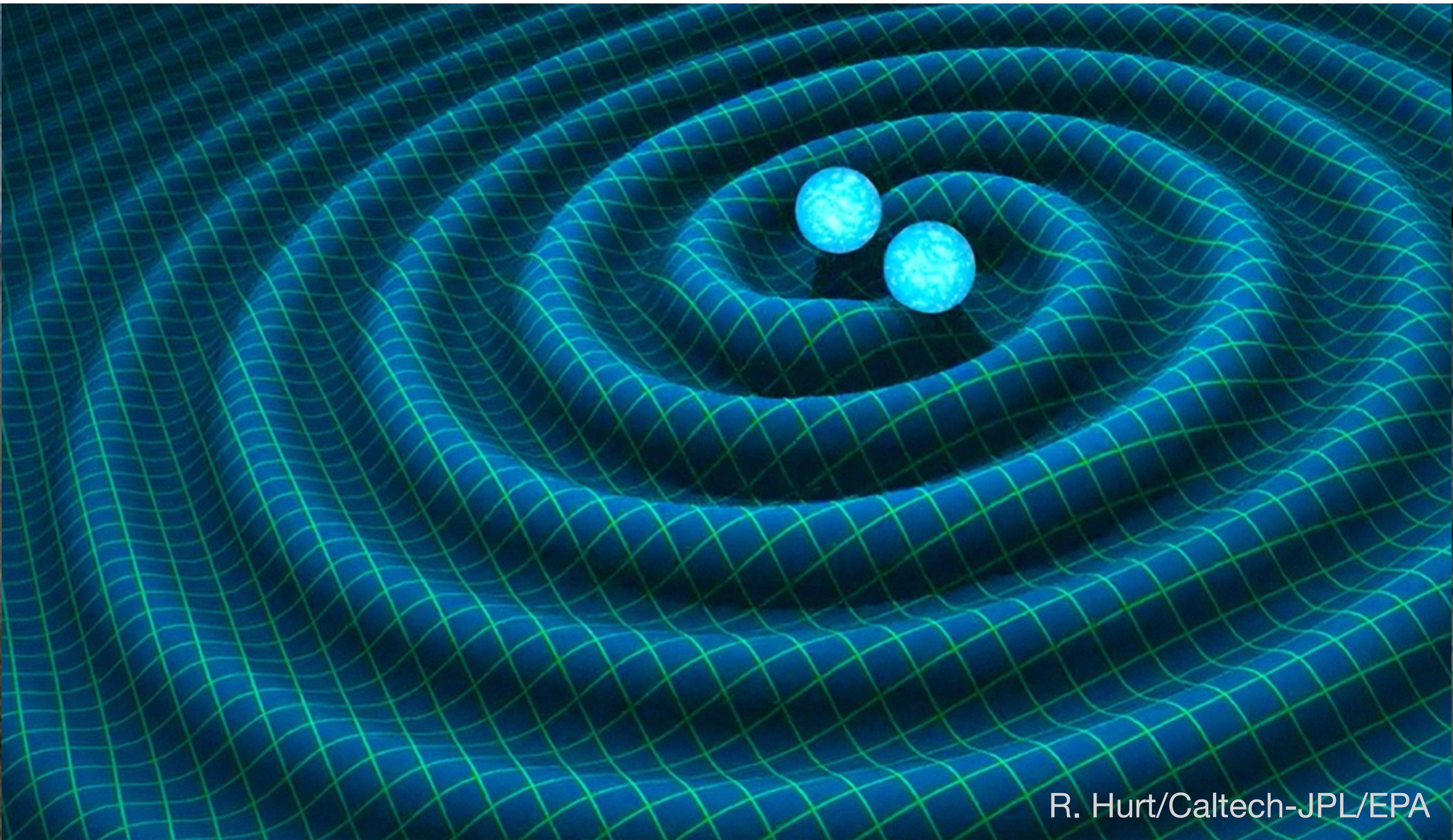
- Gravity: Strain of space-time
- The heavier an object, the larger the induced strain



NAOJ Gravitational Wave Project Office

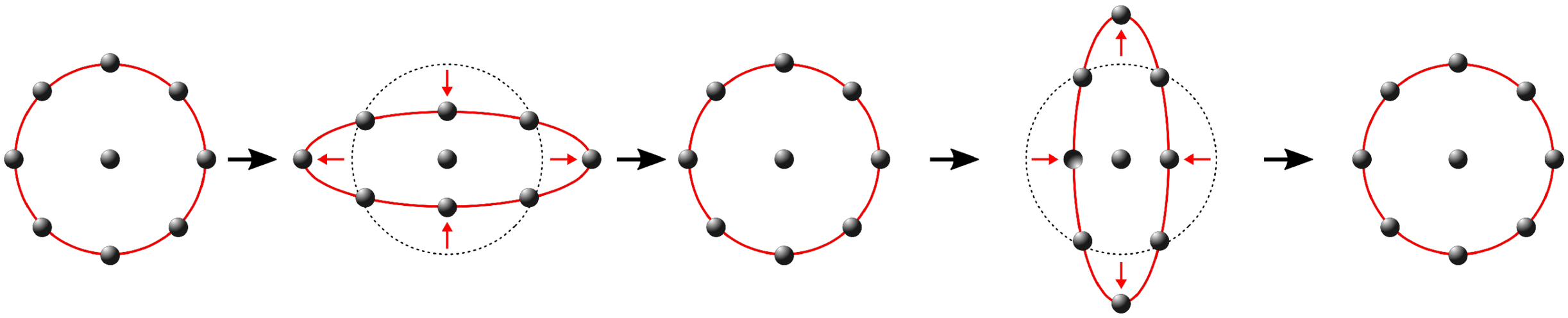
Gravitational Wave

- Gravitational wave = propagation of strain



Characteristic of GW

- Tidal force

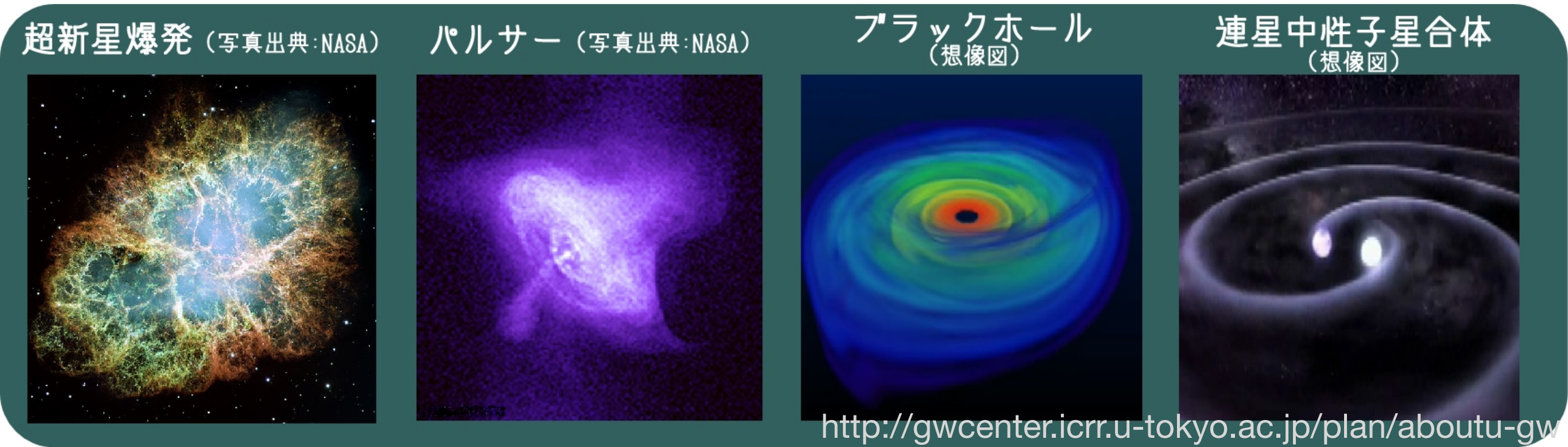


- High transparency

Source of GW

- Sources of GW: mainly astronomical objects
  - Compact binary merger (black hole, neutron star)
  - Supernova
  - Pulsar
  - Early universe
- GW tells us what we can’t see by EM wave

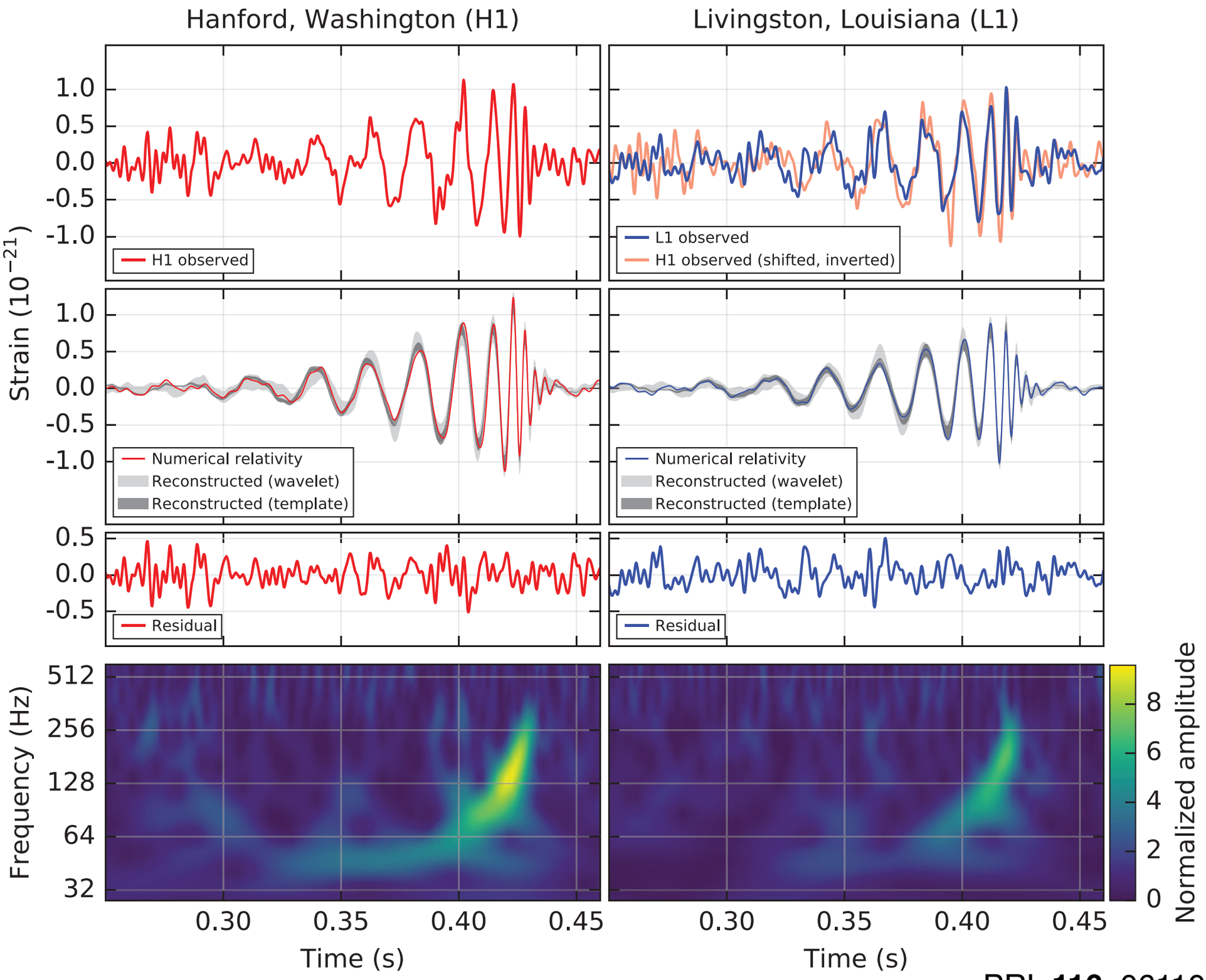
→ GW detector is our new “eye”



Physics of GW

- What we have learned from GW:
  - Propagation speed (almost the same as light)
  - GR is consistent
  - There are BHs with O(10) solar mass
  - Constraints on equation of state of NS
  - NS merger generates heavy nuclei
  - etc…
- What we will learn from GW:
  - Test of GR
  - Generation process of Supermassive black hole
  - Fluctuation of early universe
  - etc…

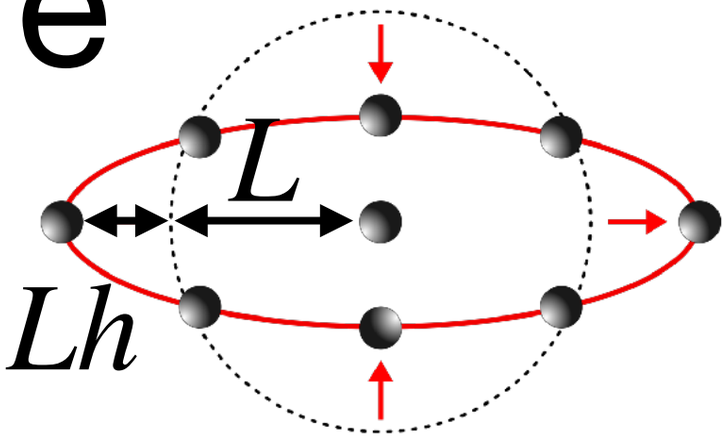
First Detection



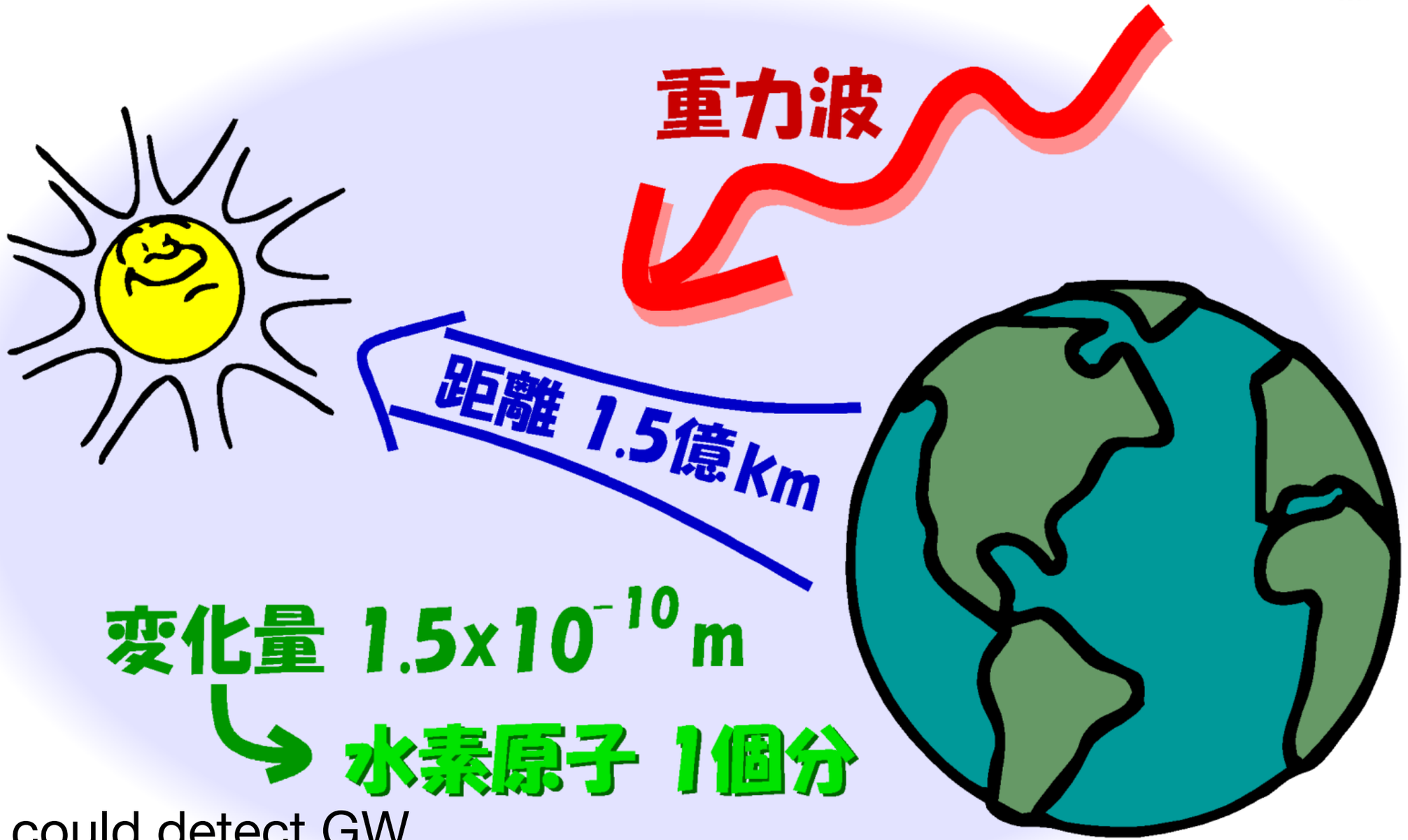
PRL **116**, 061102

How to Measure

- Typical scale: h ~ 10^{-21}
  - Very precise measurement



$$\delta L = Lh$$



“ If you could detect GW,
you could do anything else as well”

GW Detector

- Resonant-Mass
  - 1st GW detector

- Laser interferometer
  - Current standard

- Torsion pendulum
  - Our original

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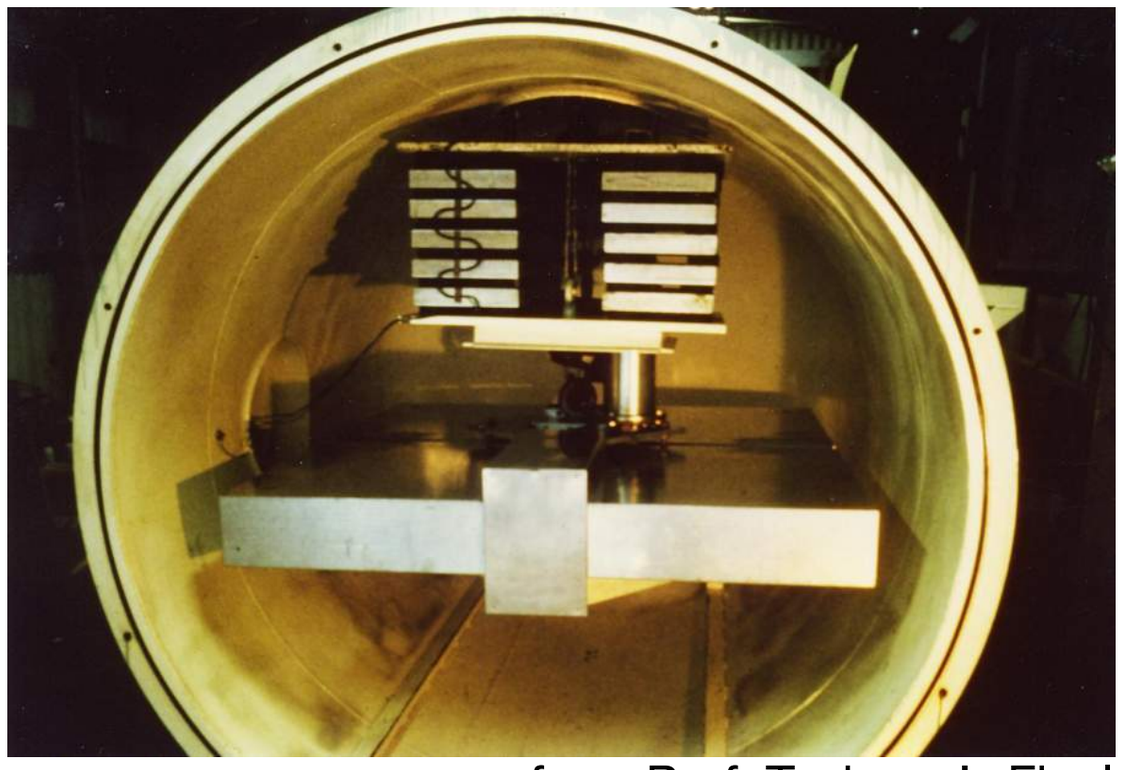
← Weber Bar

Resonant-Mass Detector
↓ (Hirakawa lab era)



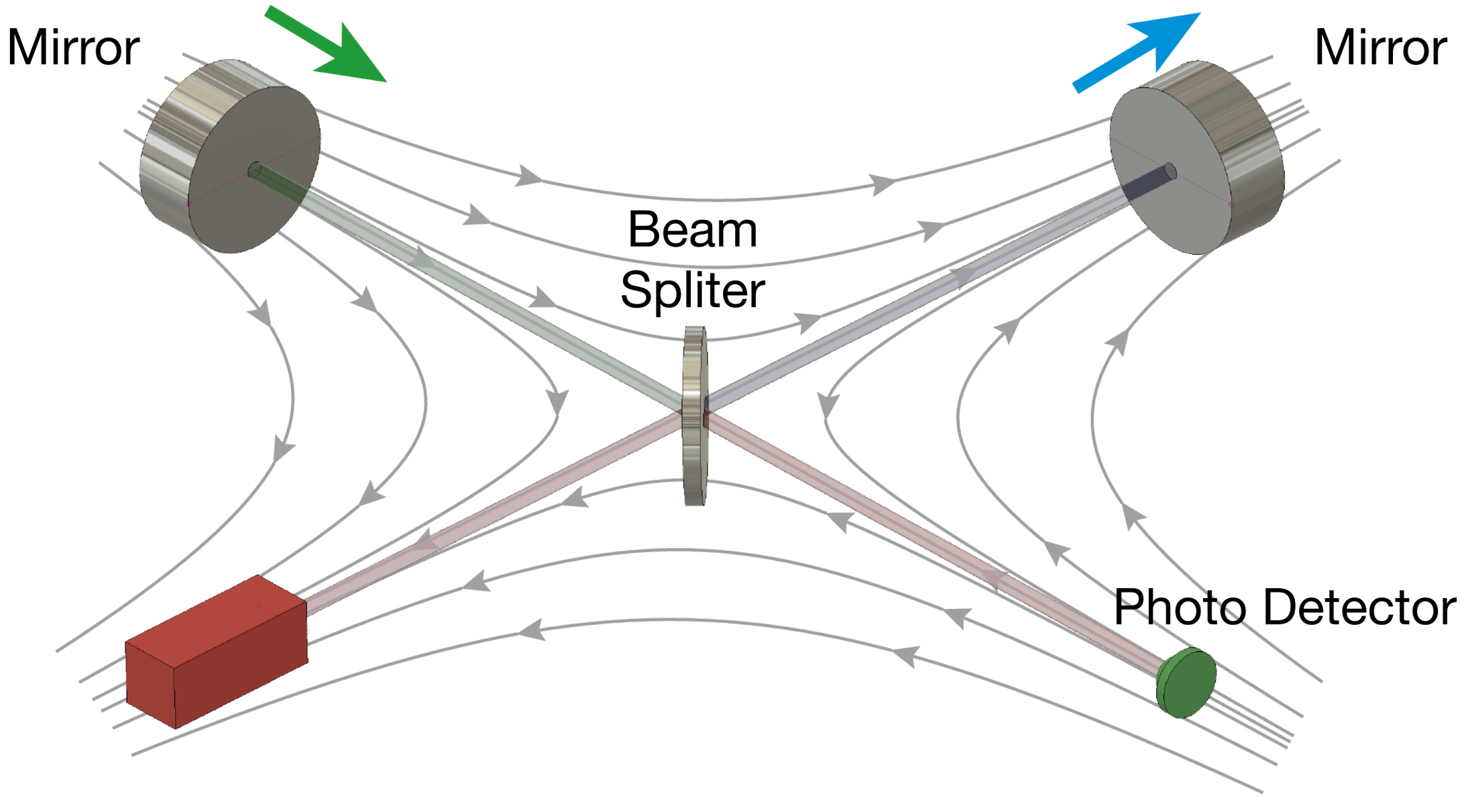
from Prof. Tsubono's Final Lecture

GW Detector

- Resonant-Mass
  - 1st GW detector
- Laser interferometer
  - Current standard
  - KAGRA (on earth): L ~ 3km
  - DECIGO (in space): L ~ 1000km
- Torsion pendulum
  - Our original

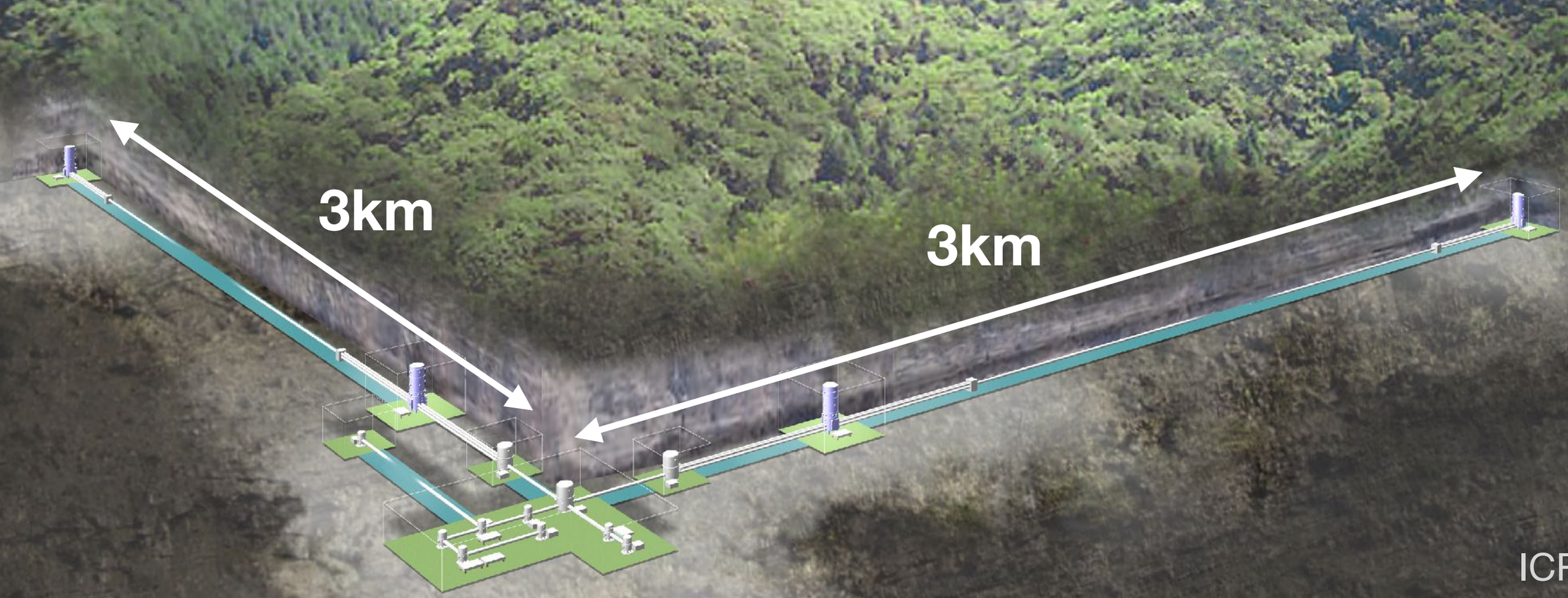
Laser Interferometer

- Make use of interference of laser
  - ▸GW comes → Arm length changes
    → Laser power at photodetector changes



KAGRA

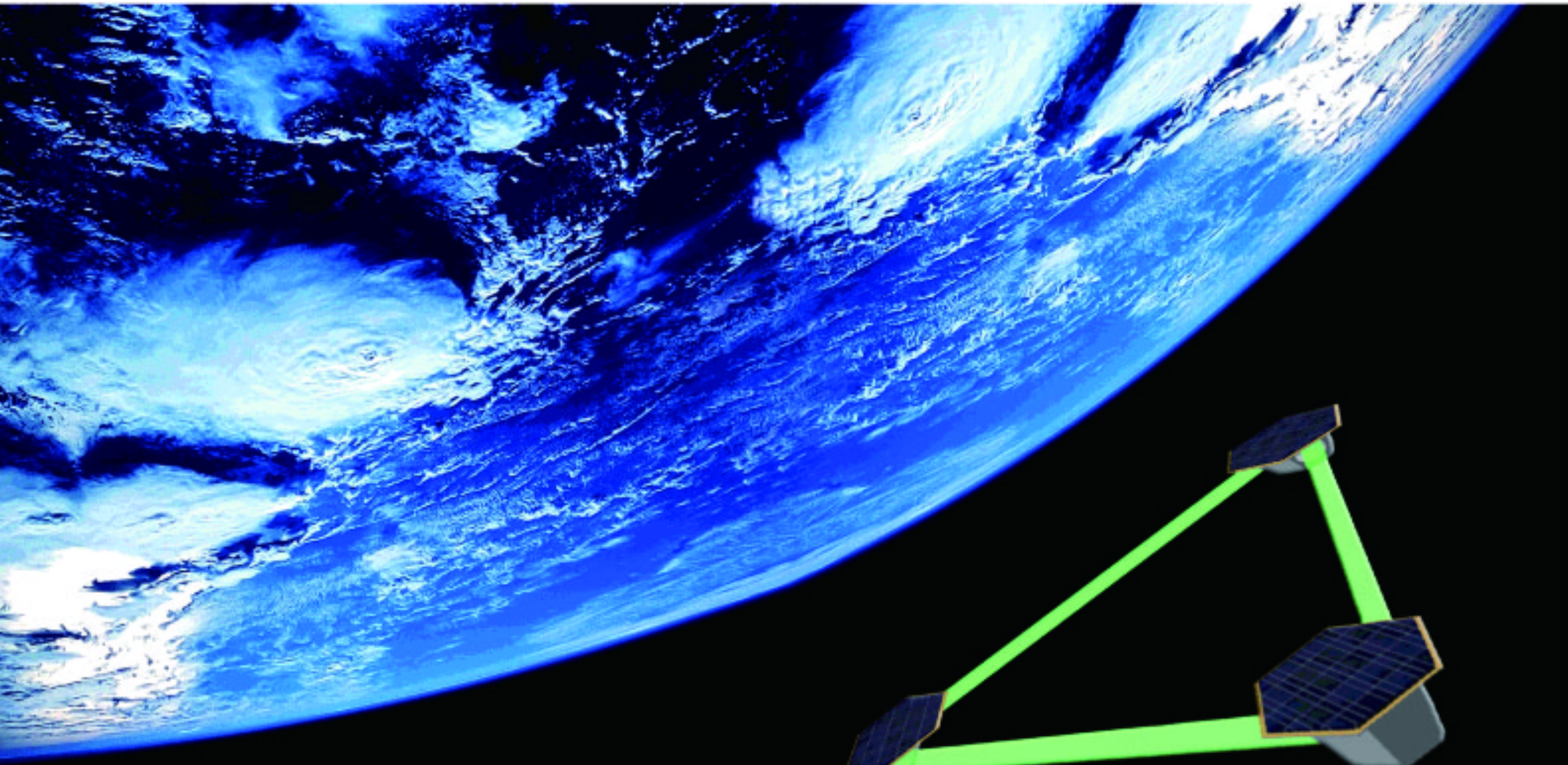
- Underground of Kamioka, Gifu
- Now under construction
- Operation will start in FY2019



画像はイメージです

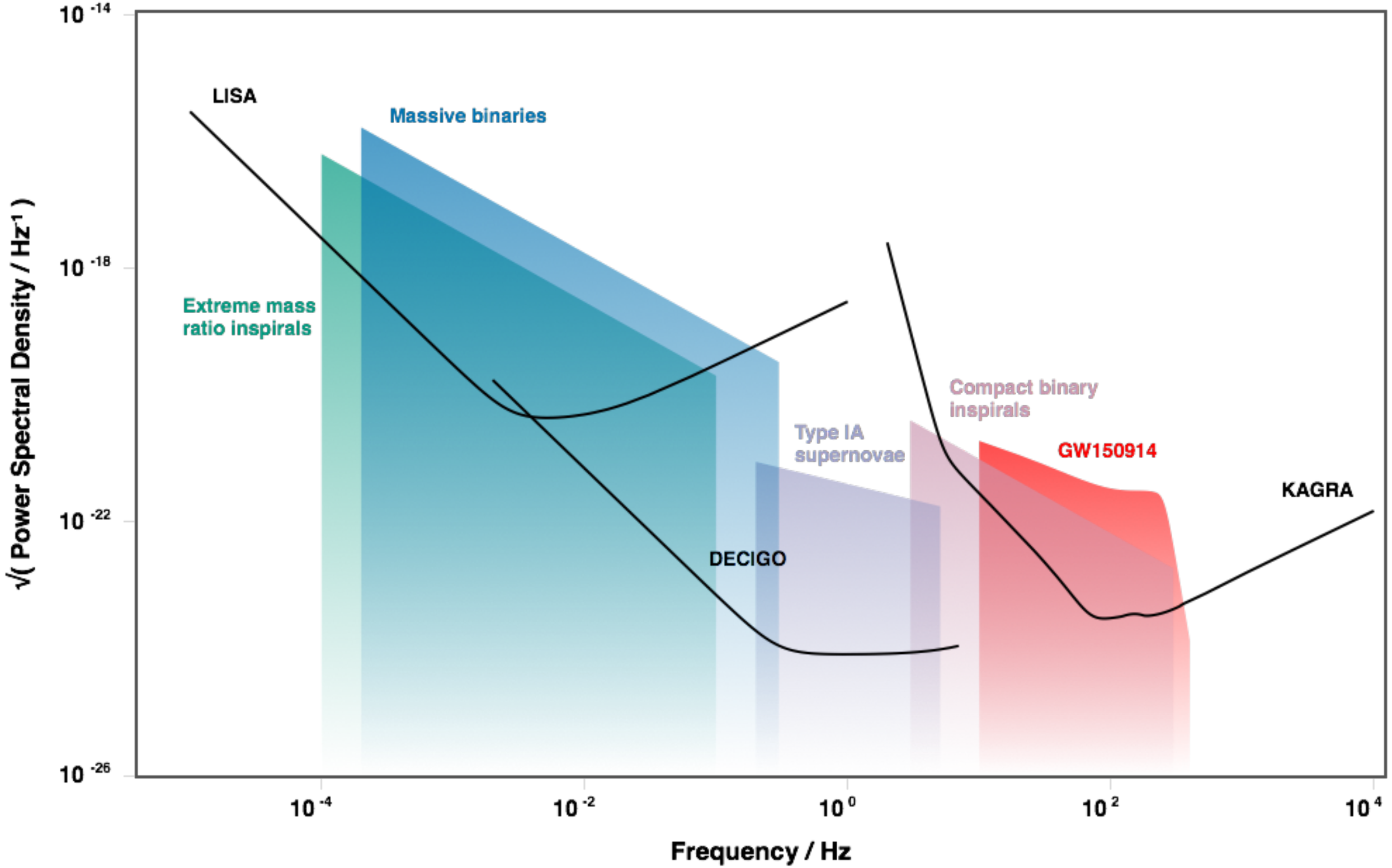
DECIGO

- Laser Interferometer in space
- Arm length: L ~ 1000km



PTEP 2016 (2016) no.9, 093E01

Sensitivity

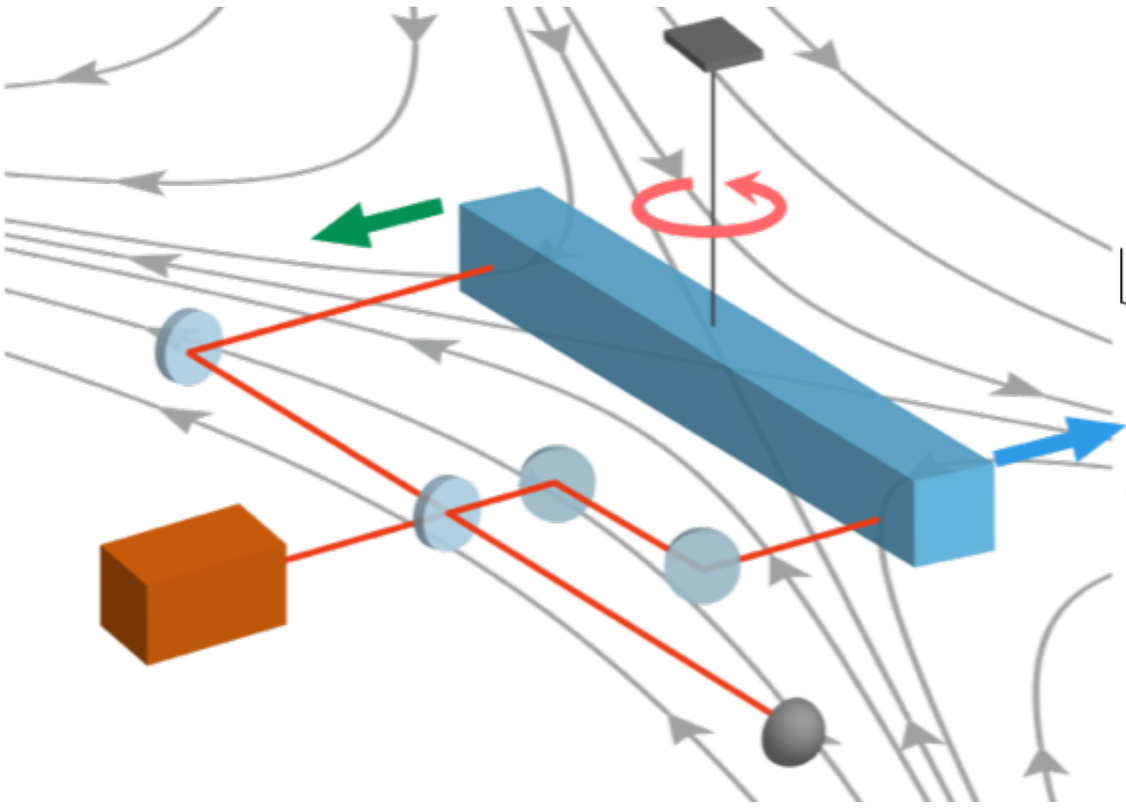


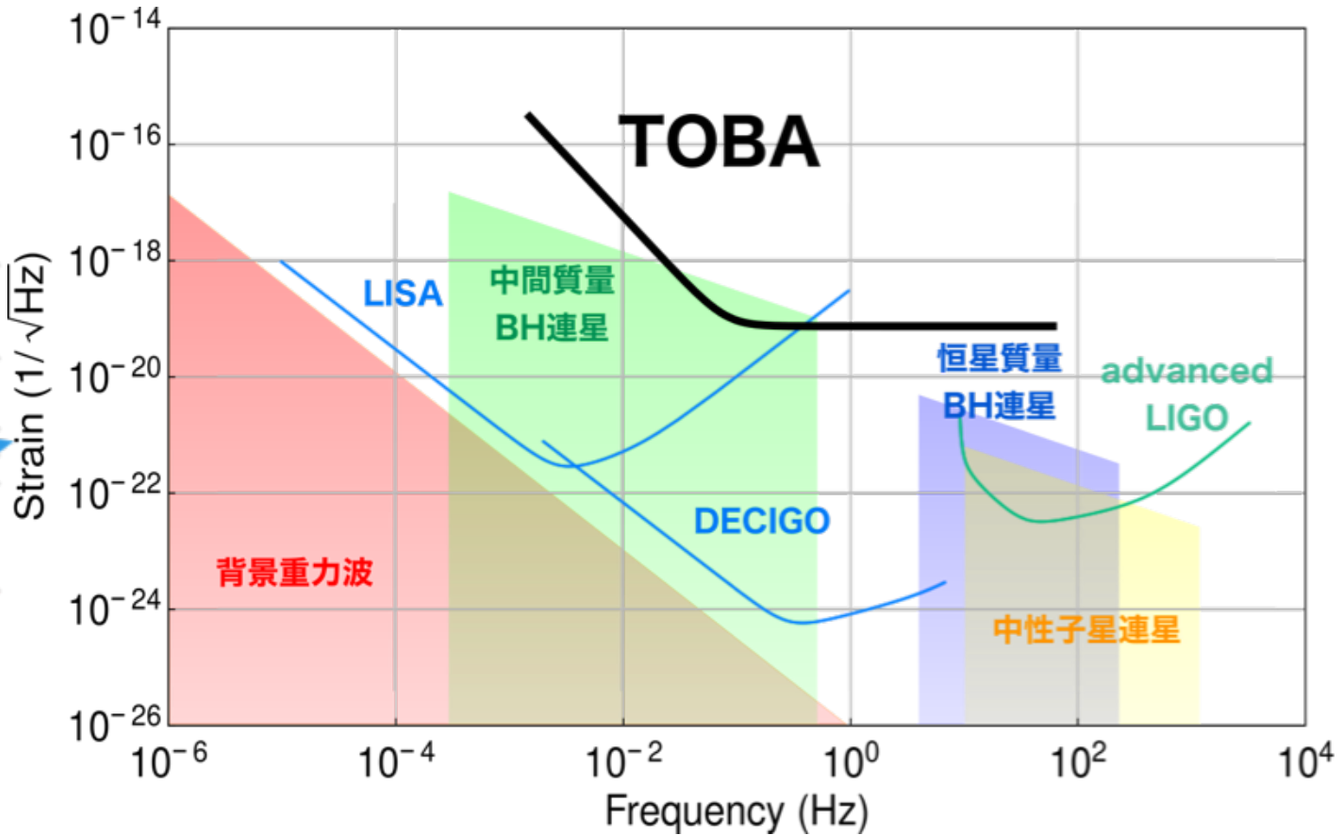
GW Detector

- Resonant-Mass
  - 1st GW detector
- Laser interferometer
  - Current standard
- Torsion pendulum
  - Our original
  - TOBA

TOBA

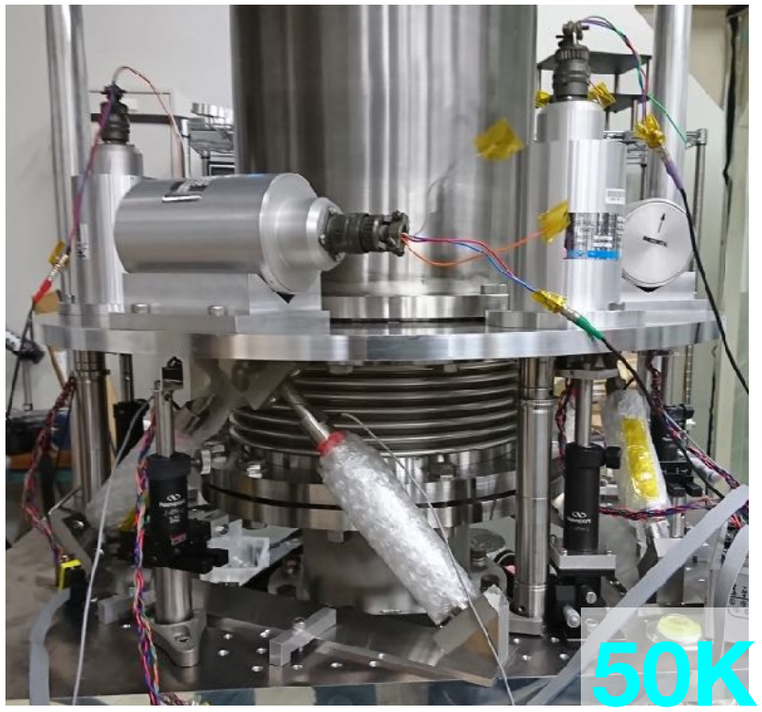
- TOBA = TOrsion-Bar Antenna
- Measure the rotational motion of a bar
- Resonant frequency:
  - Normal pendulum: ~ 1Hz
  - Torsion pendulum: ~ a few mHz
- More sensitive at low frequency (< 1Hz)

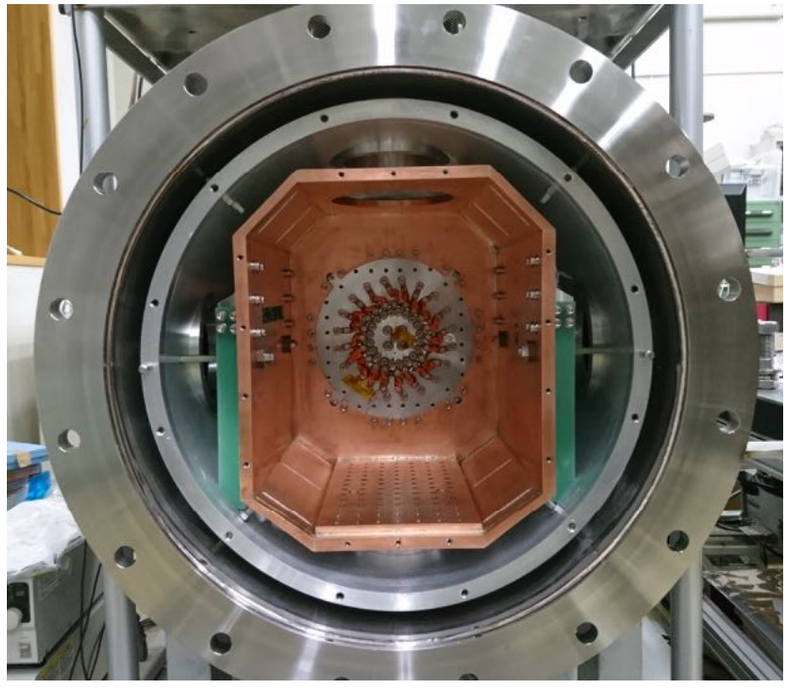


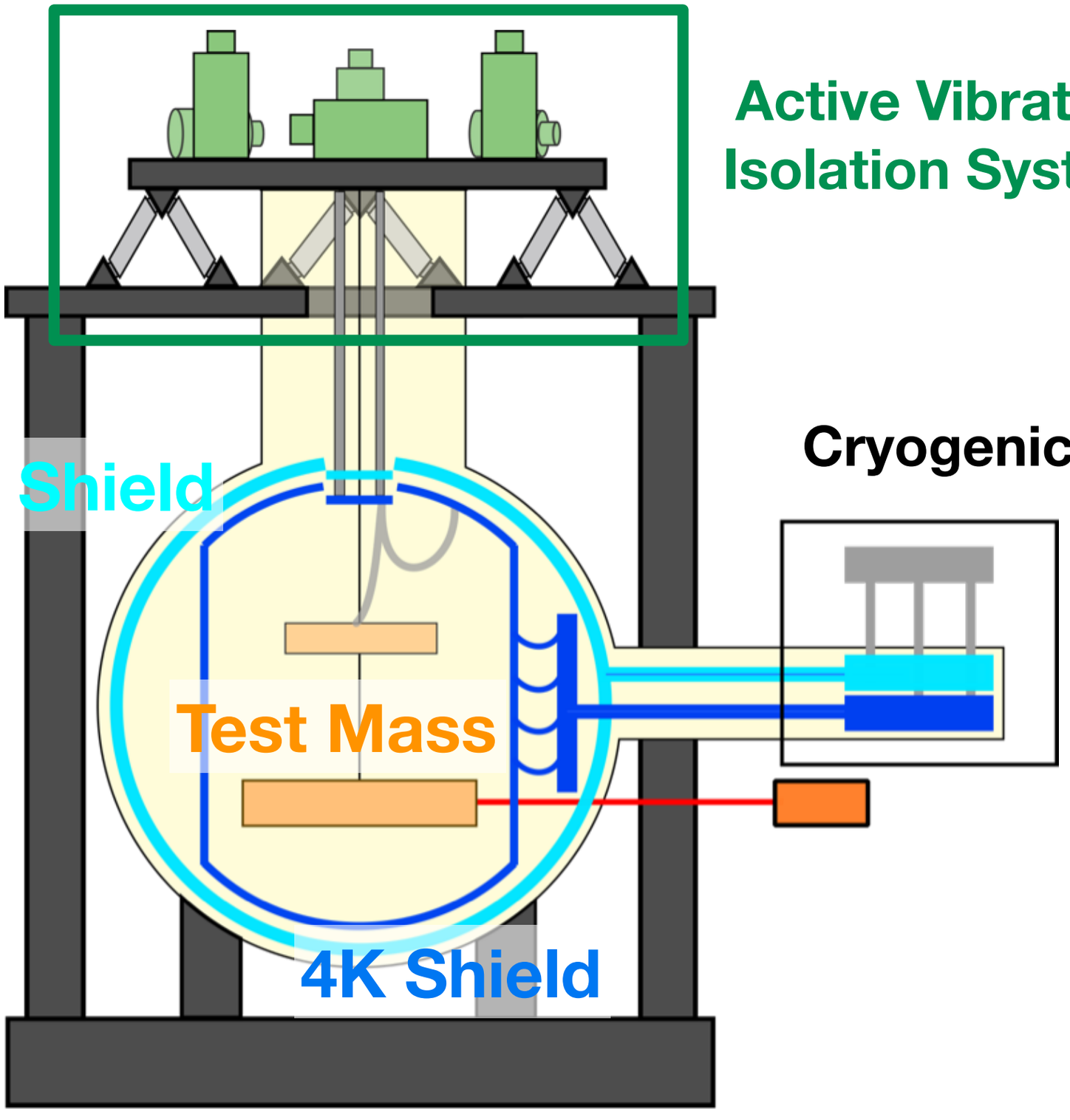


Phase-III TOBA

- Now constructing of a prototype (Phase-III TOBA)

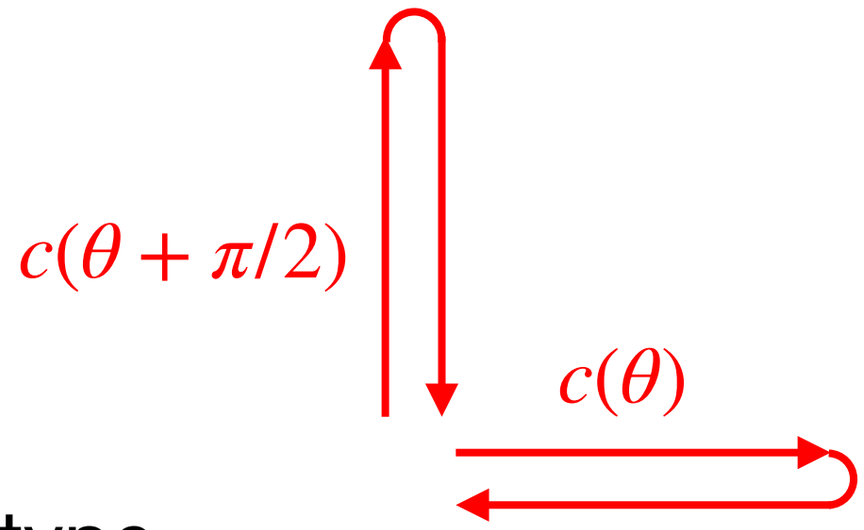






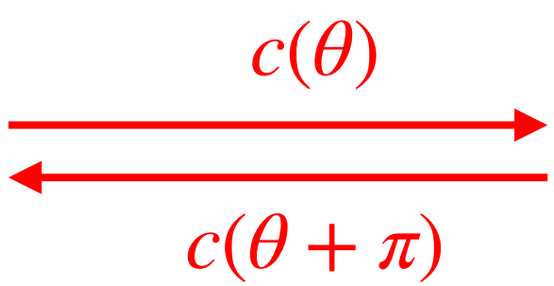
Lorentz Invariance Test

- Isotropy of light speed: principle of (general) relativity
- But could only be an approximate
- Test of anisotropy
  - Two-way: Michelson-Morley type



$$\left|\frac{\delta c}{c}\right| \lesssim 10^{-18}$$

  - One-way: our type



$$\left|\frac{\delta c}{c}\right| \lesssim 10^{-15}$$

World Best!

Setup

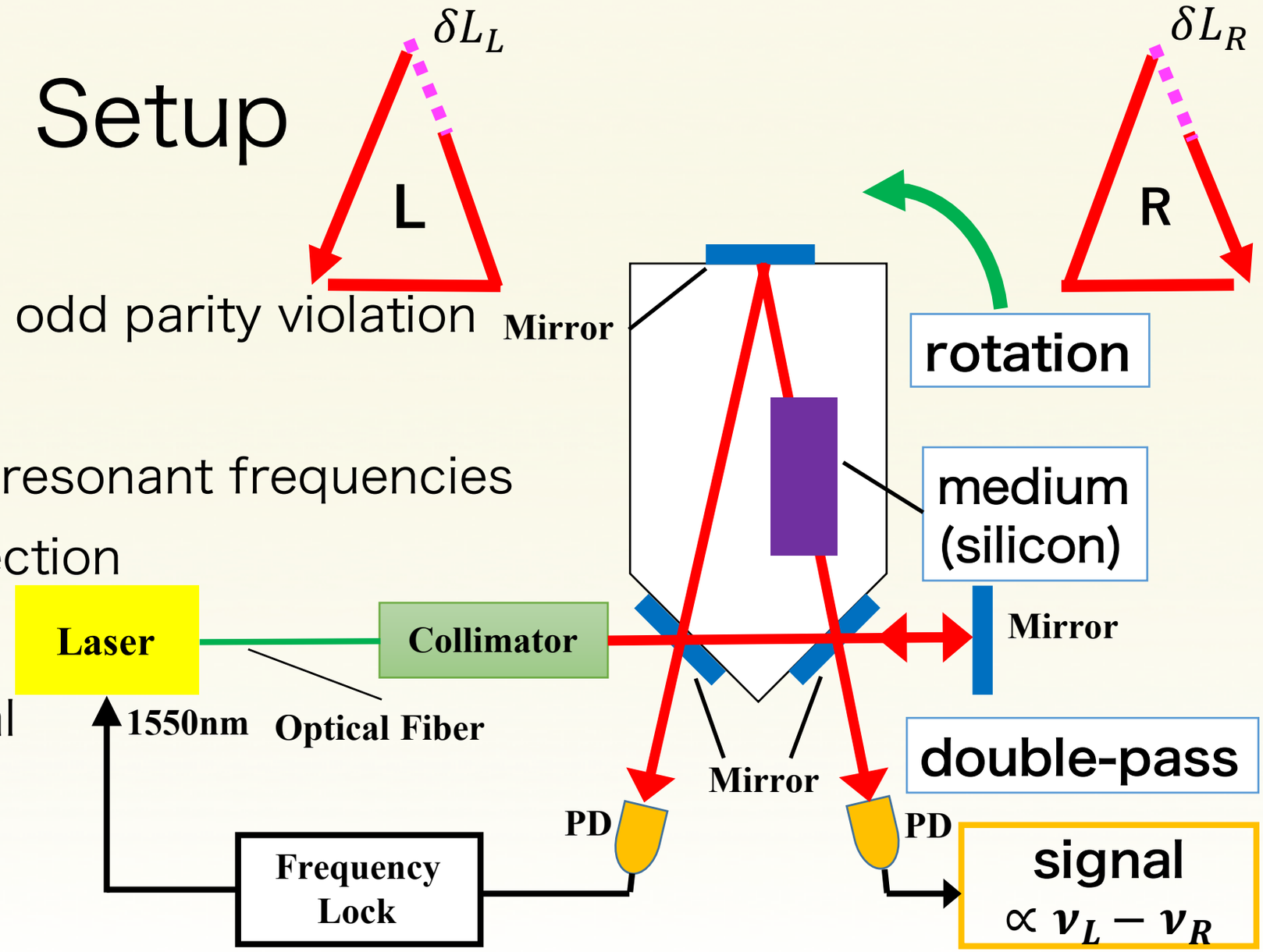
Experimental Setup

- medium→ sensitivity for odd parity violation
- double-pass

  → comparison between resonant frequencies

  high common mode rejection
- Rotation

→ modulation of the signal



Made by Hiroki Takeda