

Non-gravitational wave sciences with gravitational wave detectors

Koji Nagano (長野 晃士)

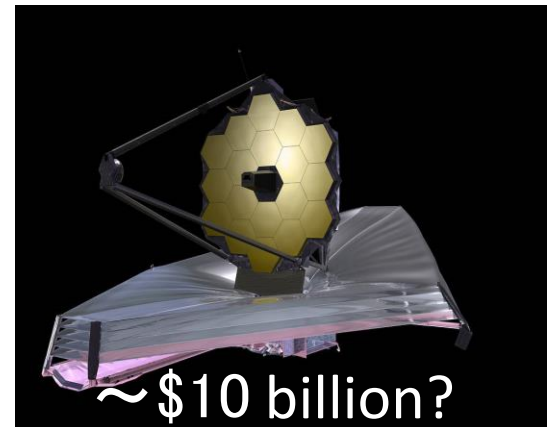
ISAS/JAXA

Background: Science is getting bigger.

- The term of “Big Science” is attributed to an article by A. M. Weinberg in 1961 (according to Wikipedia)[1].
- From 1961, science is getting bigger.



Spitzer Space Telescope (2003)
(Credit, NASA)



James Webb Space Telescope (2021)
(Credit, NASA)

[1] A. M. Weinberg, “Impact of Large-Scale Science on the United States,” Science. (1961)

[2] https://www.jpl.nasa.gov/news/press_kits/spitzer/quick-facts/

Limited resources

- Resources on the Earth are limited.
 - Human resource: 8 billion people (as of Nov. 15th)
 - Money (household wealth): \$274 trillion (JWST = 0.004%)
 - Time: 5 billion years (The Sun swallows the Earth!)



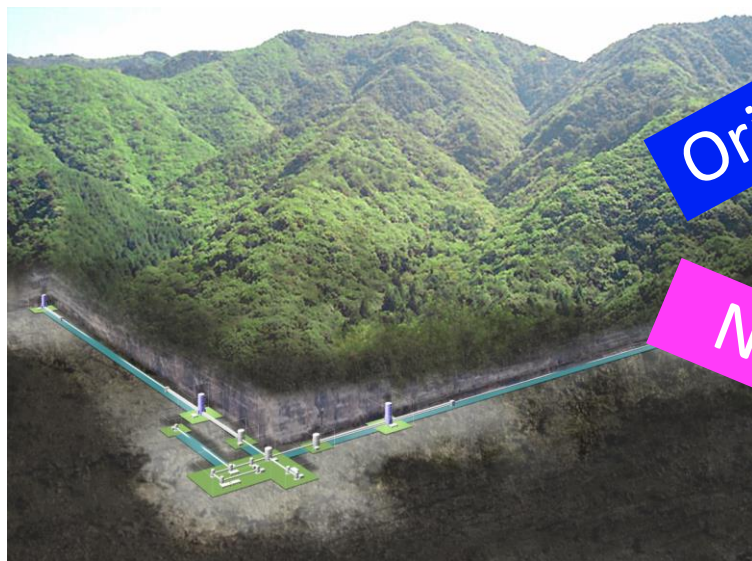
Nov. 15th was
“Day of 8 Billion”

Science should become more efficient

- To increase the scientific achievement within the limited resources, **science should become more efficient.**

One idea

- Use the existing facility for other applications, such as KAGRA.



Original

New

Gravitational waves

Dark matter

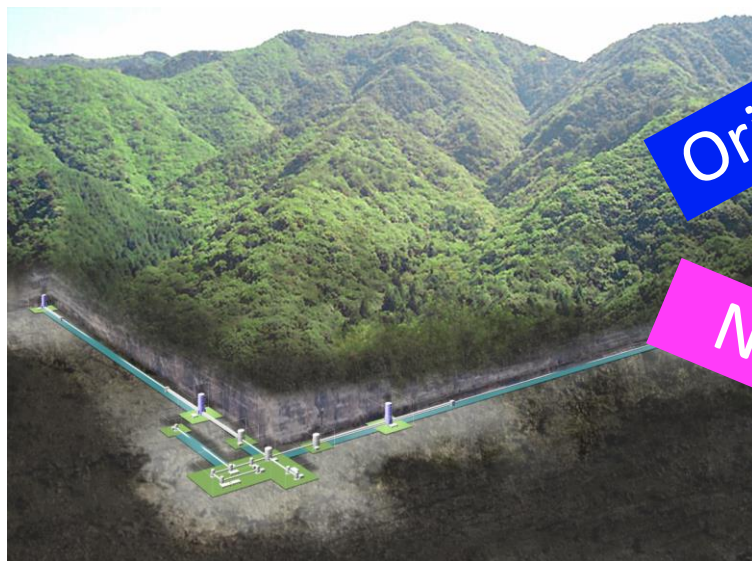
Quantum mechanics

Theory of gravity

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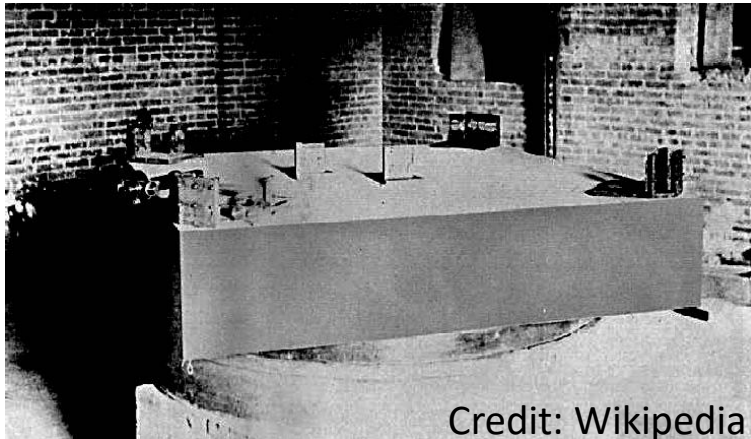
Theory of gravity

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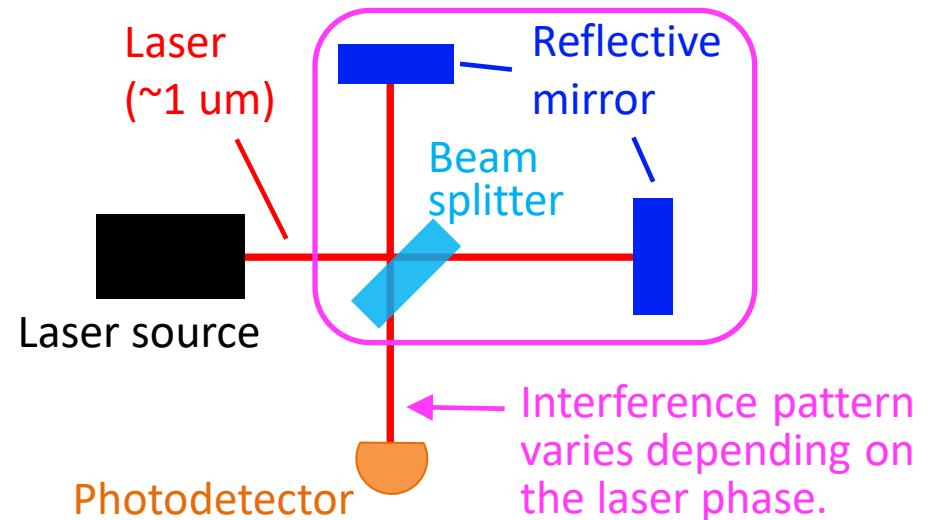
What can be done with
interferometers?

Essence of the interferometer

- Laser interferometer =
“Instrument measures laser phase difference.”



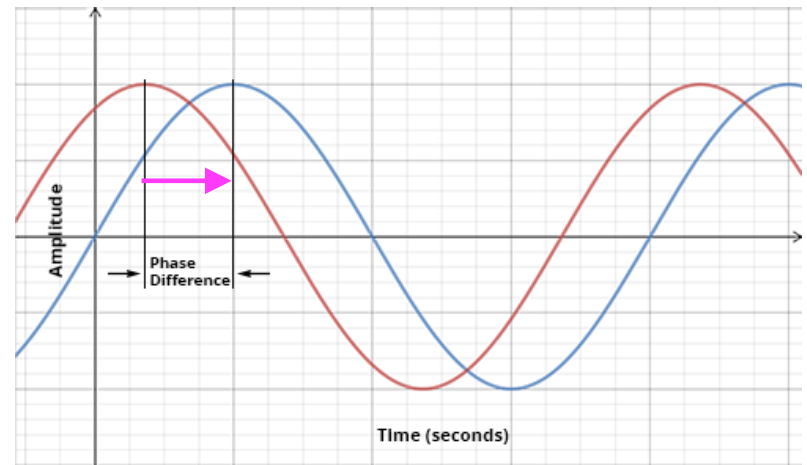
Michelson-Morley's interferometer
used for measuring the speed of light.



Schematic of the laser interferometer.

What science can we do?

- We can observe physical phenomena that cause the “laser phase difference.”
- Source of the laser phase difference
 - Gravitational waves
 - Ultra light dark matters
 - Fifth force
 - Quantum mechanics (measurement backaction)
 - and so on



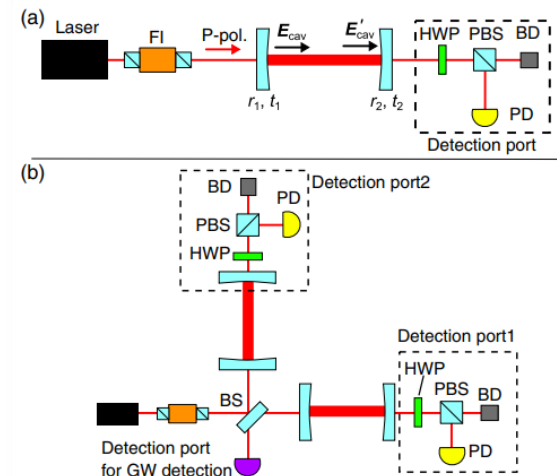
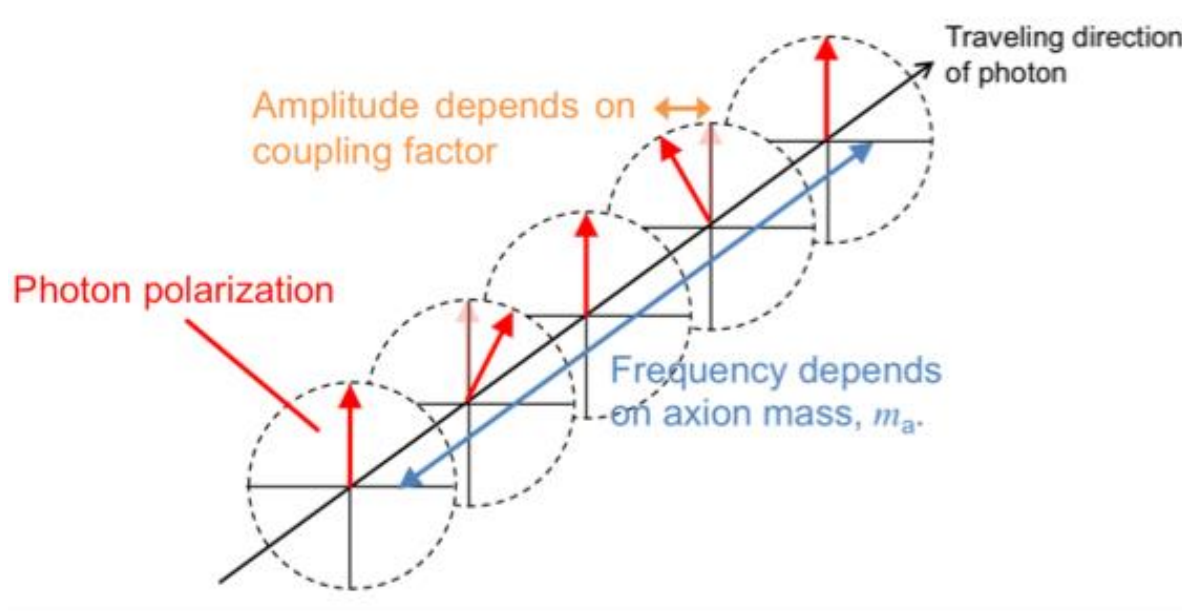
Examples

- Take-home message:
Consider any physical phenomena leading to the laser phase difference.
 - They might be able to be observed with GW detectors.
- Hereafter, as a hint in your consideration, some examples of the non-GW physics with the GW detectors are shown.



Axion dark matter

- Cause: Axion dark matter
- Effect: Variation of speed of light

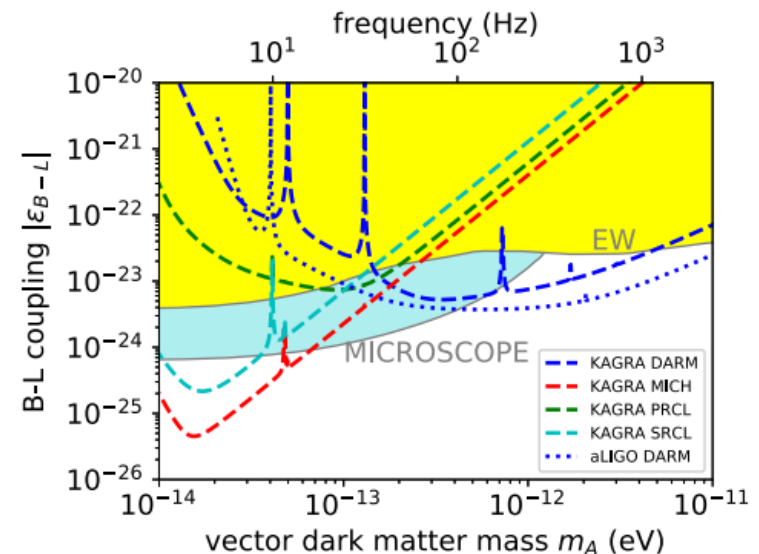
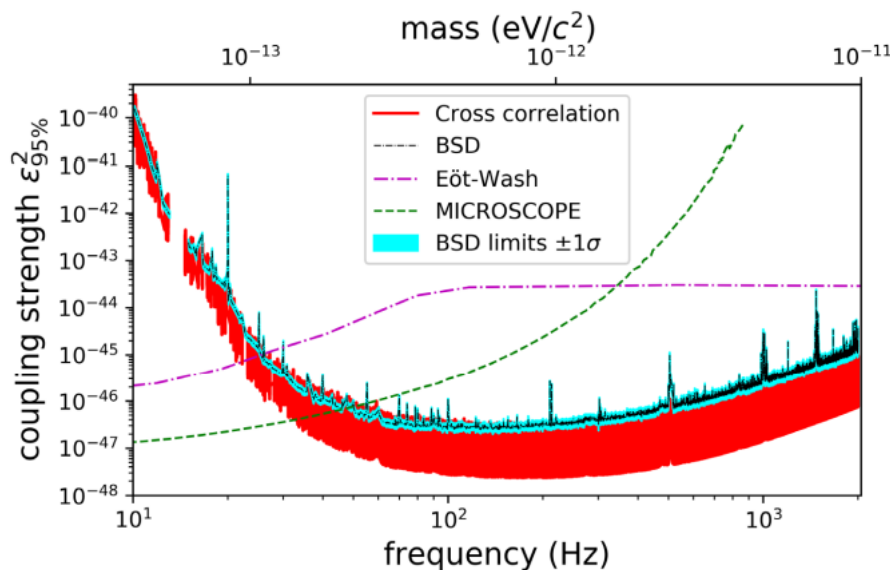


[1] Koji Nagano, Tomohiro Fujita, Yuta Michimura, and Ippei Obata
Phys. Rev. Lett. 123, 111301

[2] Koji Nagano, Hiromasa Nakatsuka, Soichiro Morisaki, Tomohiro Fujita, Yuta Michimura, and Ippei Obata
Phys. Rev. D 104, 062008

Vector dark matter

- Cause: Vector dark matter
- Effect: Force applied to the suspended mirrors.

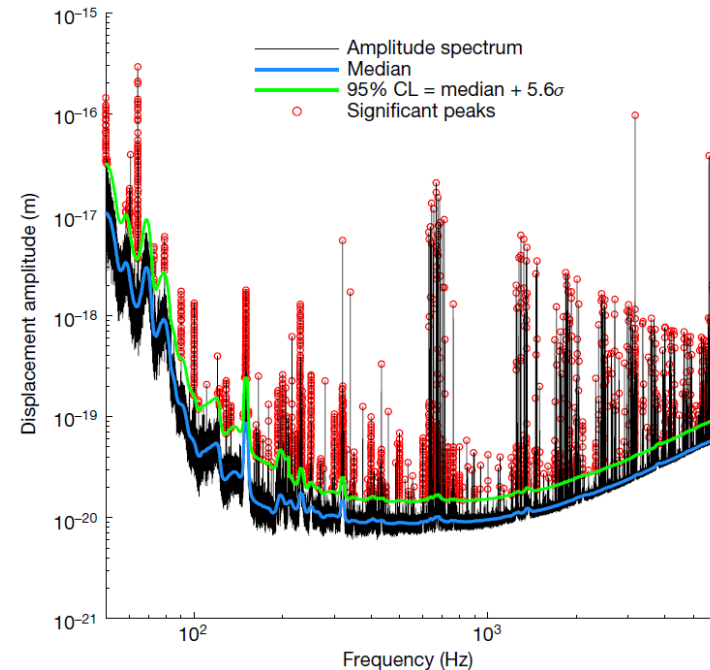
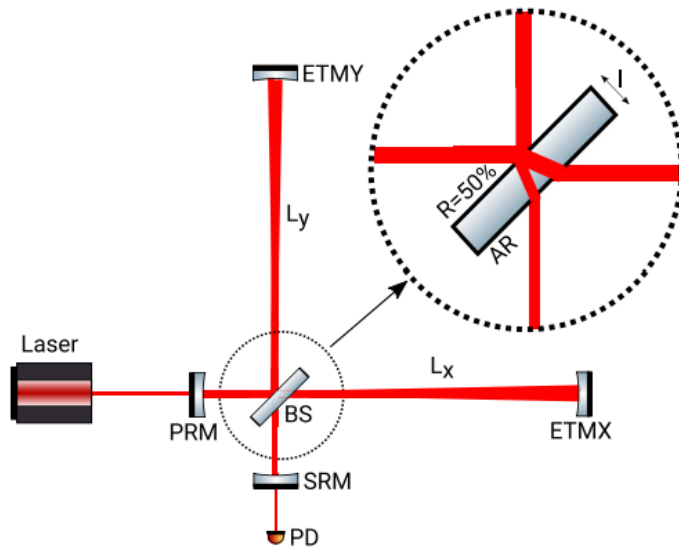


[1] R. Abbott et al. (LIGO Scientific Collaboration, Virgo Collaboration, and KAGRA Collaboration)
Phys. Rev. D 105, 063030

[2] Yuta Michimura, Tomohiro Fujita, Soichiro Morisaki, Hiromasa Nakatsuka, and Ippei Obata
Phys. Rev. D 102, 102001

Scalar dark matter

- Cause: Scalar dark matter
- Effect: Variation of the volume of the mirrors, spacers, and so on.

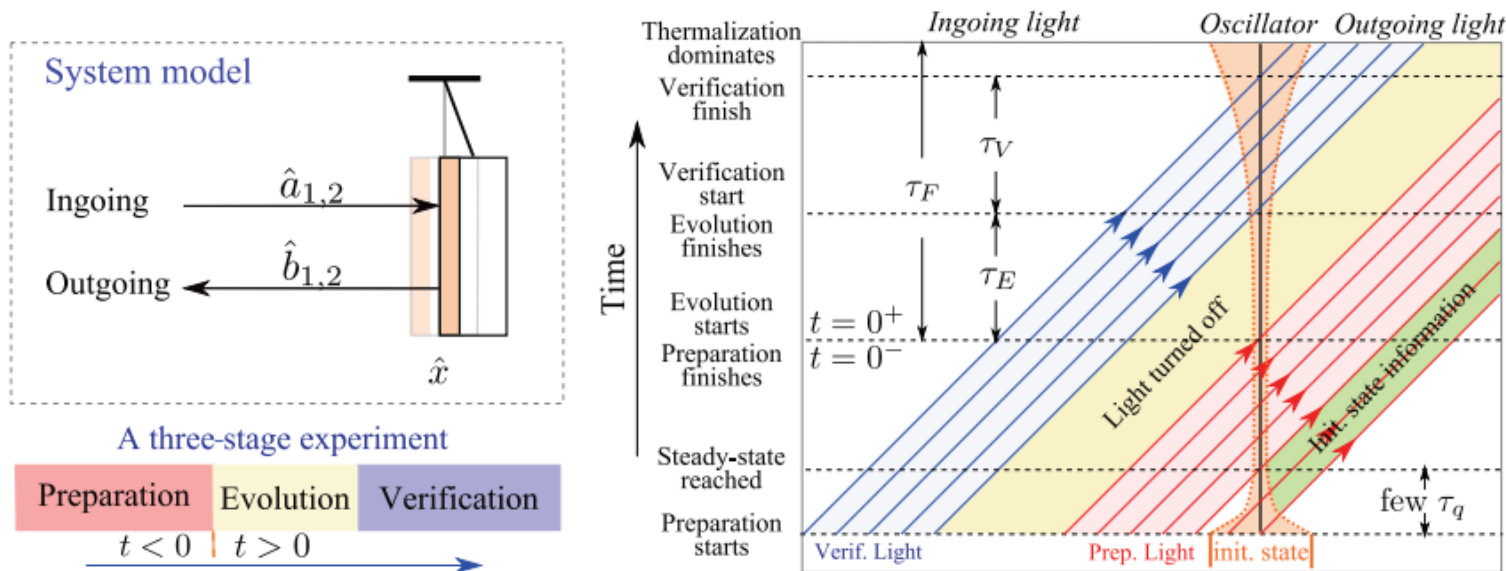


[1] Grote and Y. V. Stadnik, Phys. Rev. Research 1, 033187

[2] Vermeulen, S.M., Relton, P., Grote, H. et al. Direct limits for scalar field dark matter from a gravitational-wave detector. Nature 600, 424–428 (2021)

Quantum entanglement

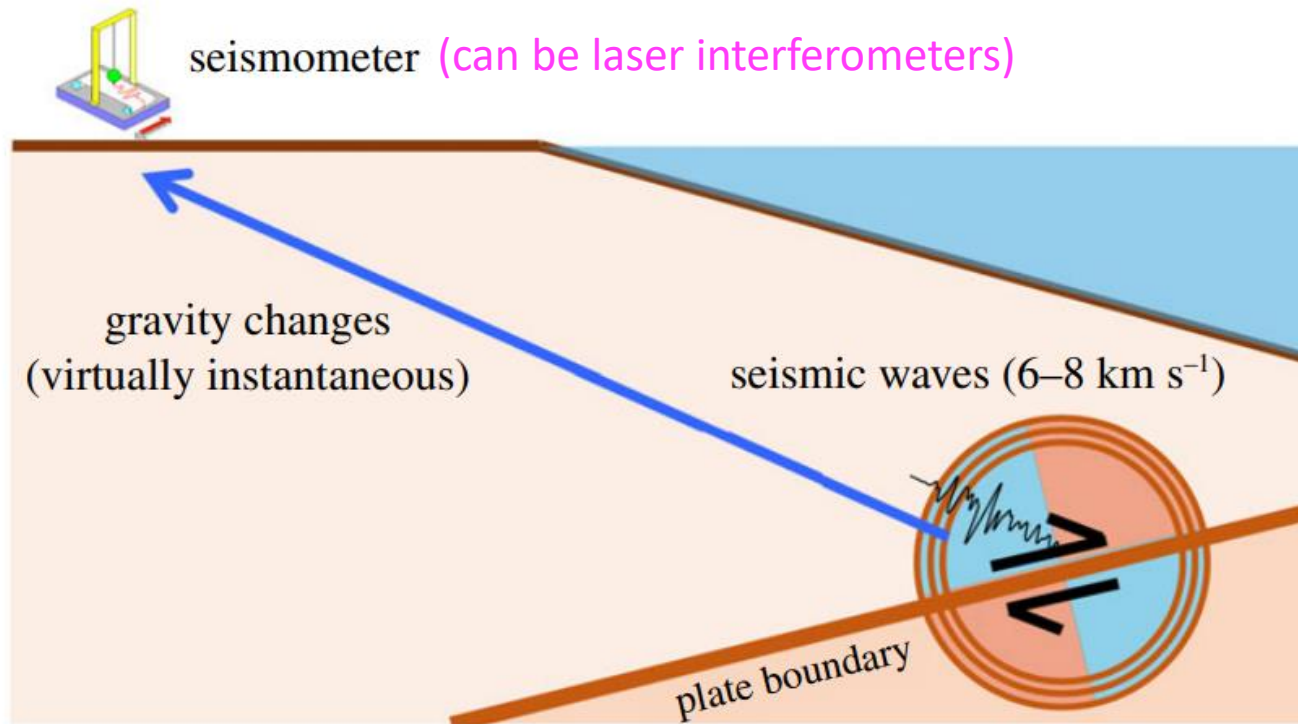
- Cause: Measurement backaction.
- Effect: Momentum variation of the suspended mirrors.



Haixing Miao, Stefan Danilishin, Helge Müller-Ebhardt, Henning Rehbein, Kentaro Somiya, and Yanbei Chen, Phys. Rev. A 81, 012114

Geophysical event (earthquake)

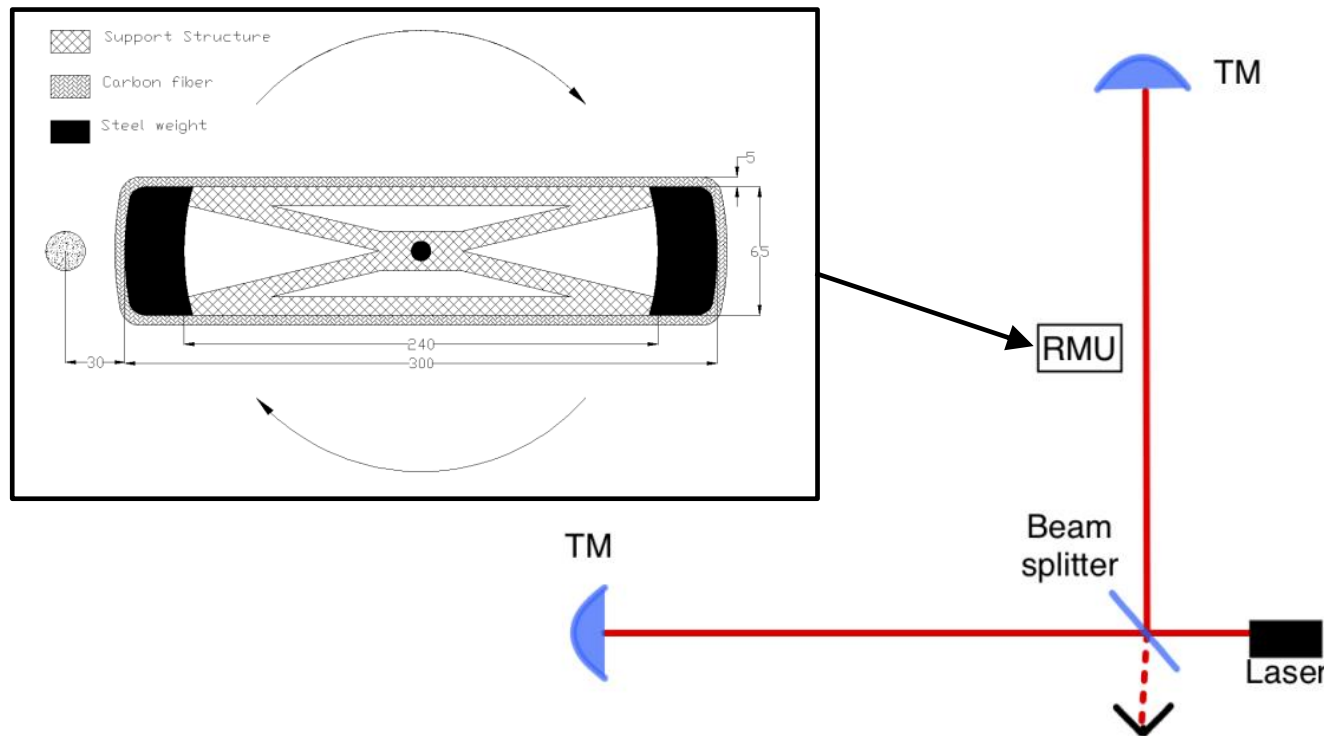
- Cause: Terrestrial movement
- Effect: Force on the suspended mirrors.



Kame Nobuki 2021 “Pre-P gravity signals from dynamic earthquake rupture: modelling and observations” Phil. Trans. R. Soc. A.3792020013620200136

Theory of gravity

- Cause: Shapiro delay
- Effect: Space-time variation.



Andrew G Sullivan *et al* 2020 *Class. Quantum Grav.* **37** 205005

Summary

- Laser interferometer can be used for the various non-gravitational wave sciences.
 - Dark matter, Quantum mechanics, and more
- **Do you get any ideas on the non-GW sciences?**
Please share/discuss them!!

