Light Dark Matter Scattering in Gravitational Wave Detectors

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1. Motivation

- How to find **dark matter (DM)**?
- Can we use **gravitational wave (GW)** detectors to look for a DM signal?

2. When DM particles hit the GW detector...

- The mirrors of the GW interferometer would be swinging!
- The system behaves like coupled harmonic oscillators.
- Solve the equation of motion for KAGRA as example:

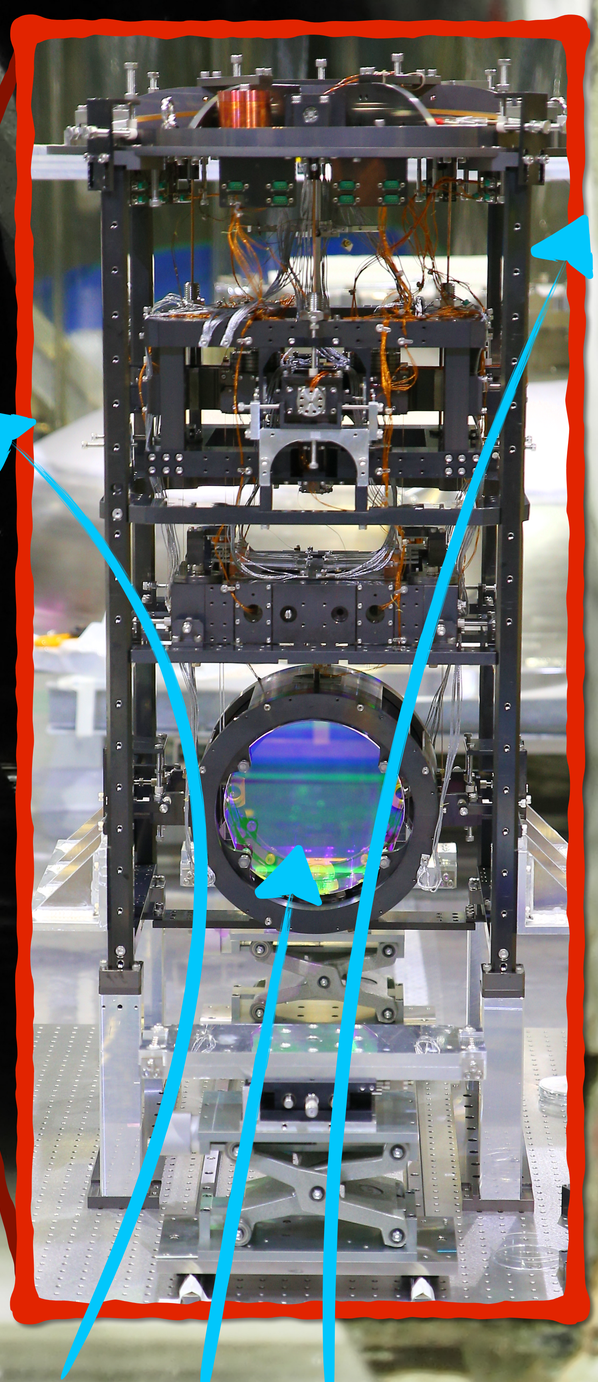
$$M_T \ddot{\vec{x}} + K\vec{x} = \frac{\vec{F}_{\rm DM}}{L}$$

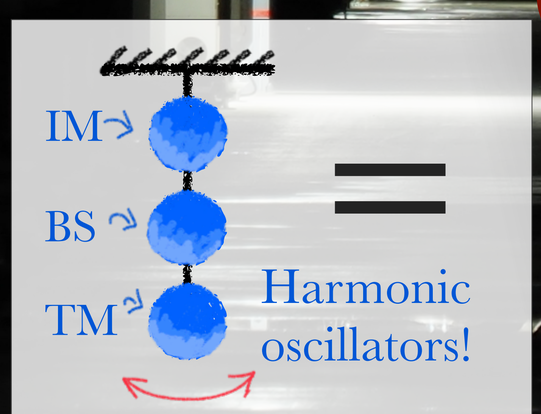
Masses of the components, a 3x3 matrix

Complex spring constants of the components, a 3x3 matrix

External DM force

Interferometer arm length





DM particles

3. What we have found

- Simplified signal-to-noise ratio (SNR):

$$\rho^2 \sim \frac{q_{\rm R}^2}{M_{\rm TM} k_{\rm B} T} = \frac{E_{\rm R}}{E_{\rm th}}$$

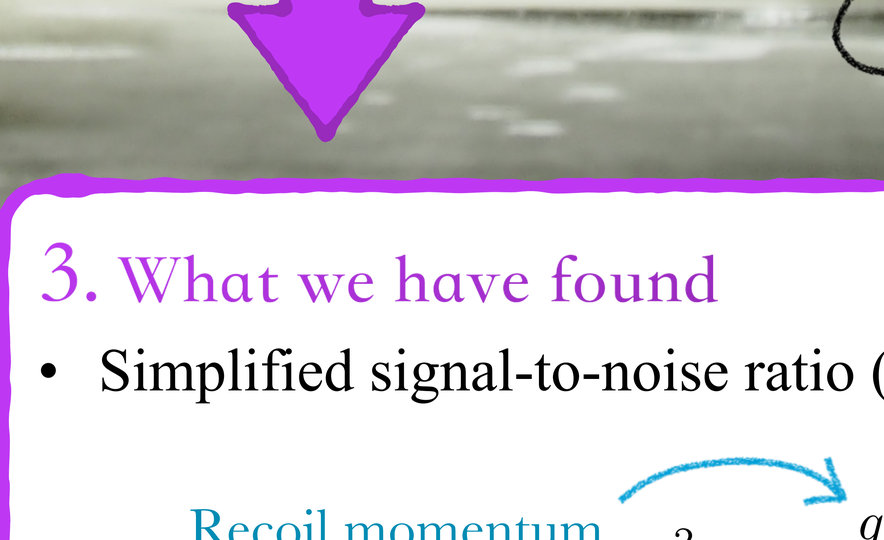
Recoil momentum

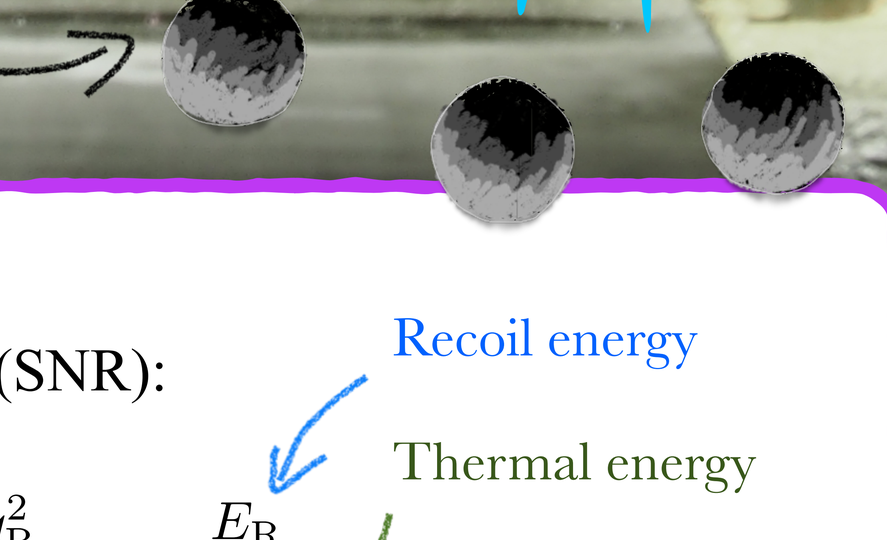
Boltzmann constant

Recoil energy

Thermal energy

Temperature of the suspension system





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4. Take Home Messages

- Require lighter test masses and colder systems!
- Optically levitated masses?
- Other technologies?
- We need more studies!

神樂 KAGRA

[Photos courtesy: KAGRA Observatory, ICRR, The University of Tokyo]