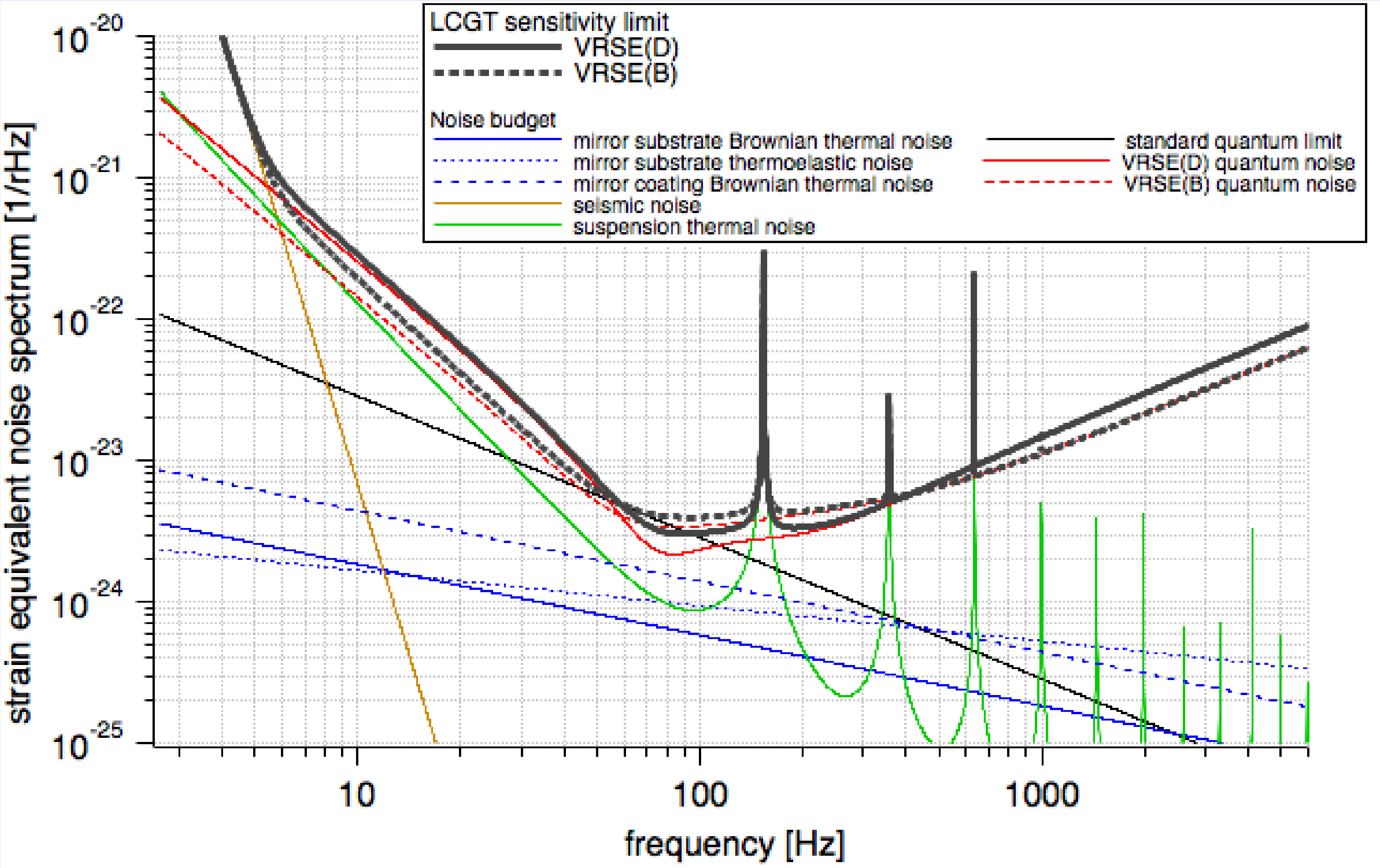
Thermal Noise in Non-equilibrium states

K. Shibata
(U. Tokyo)

Suspension Thermal Noise

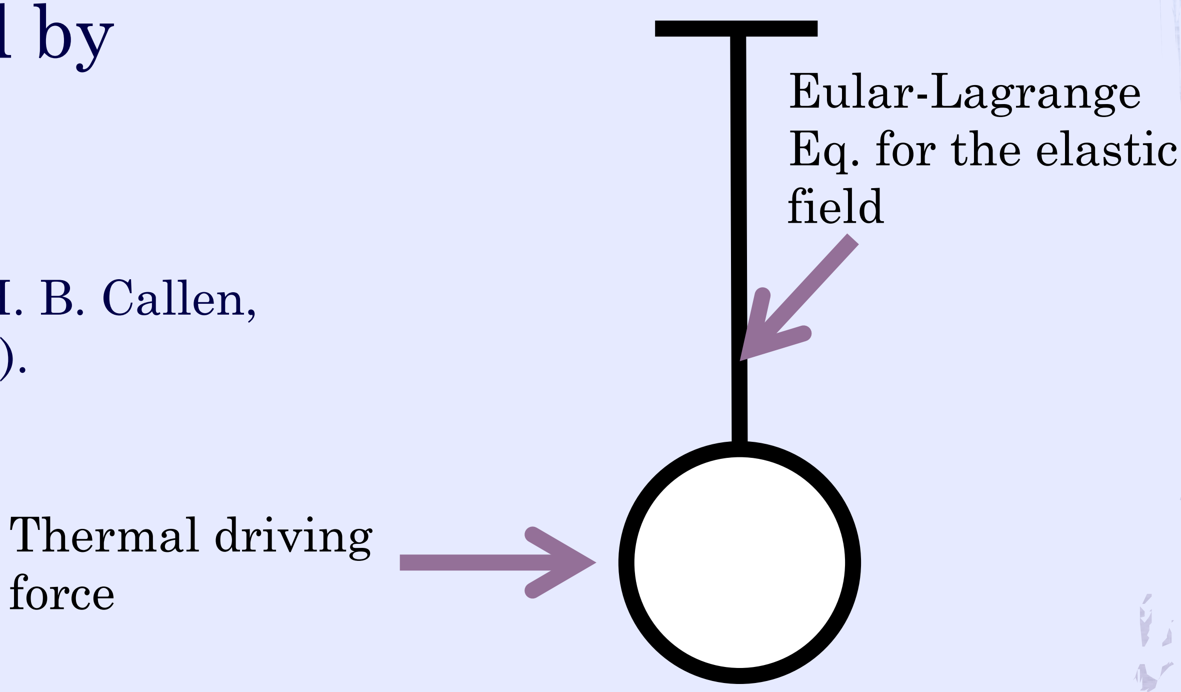


Cited from KAGRA Web page

Suspension Thermal Noise

- The spectrum of the thermal driving force is calculated by FDT[1].

[1] R. F. Greene and H. B. Callen, Phys. Rev. 83, 6 (1951).



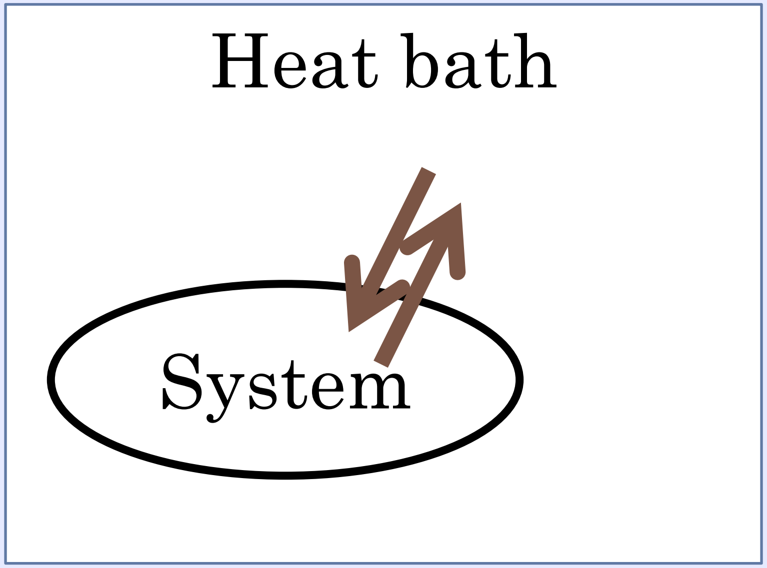
Fluctuation-Dissipation Theorem

- Assumption: “Equilibrium,” and “Isolated” system[1].

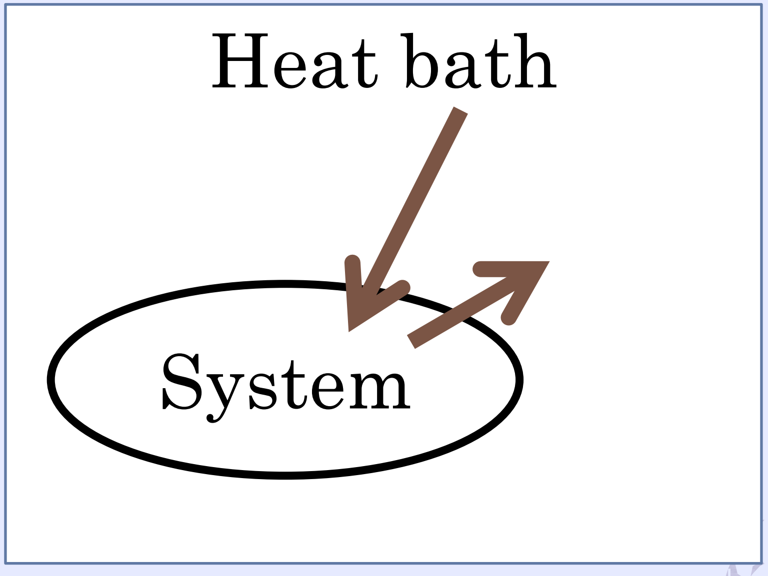
[1] R. F. Greene and H. B. Callen, Phys. Rev. 83, 6 (1951).

Equilibrium / Non-Equilibrium

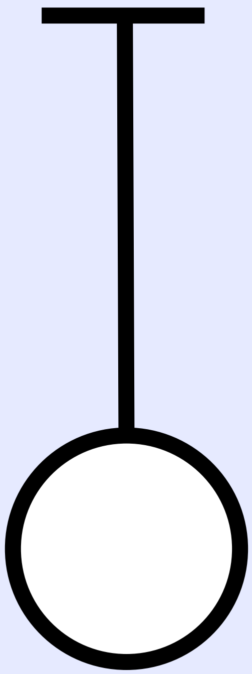
Equilibrium



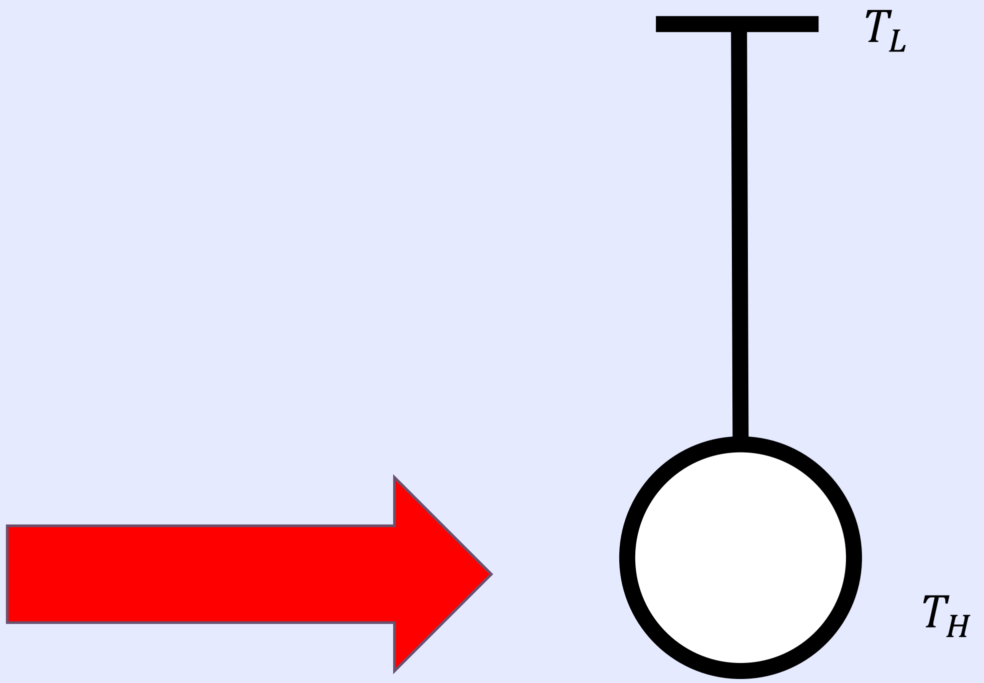
Non-equilibrium



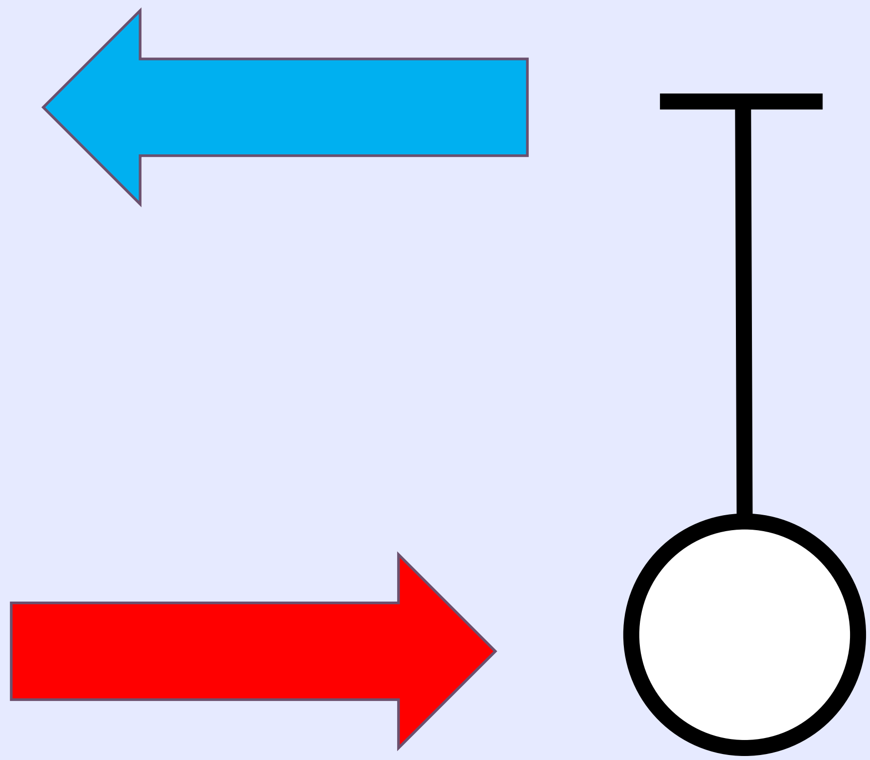
Cryo-Suspension in KAGRA



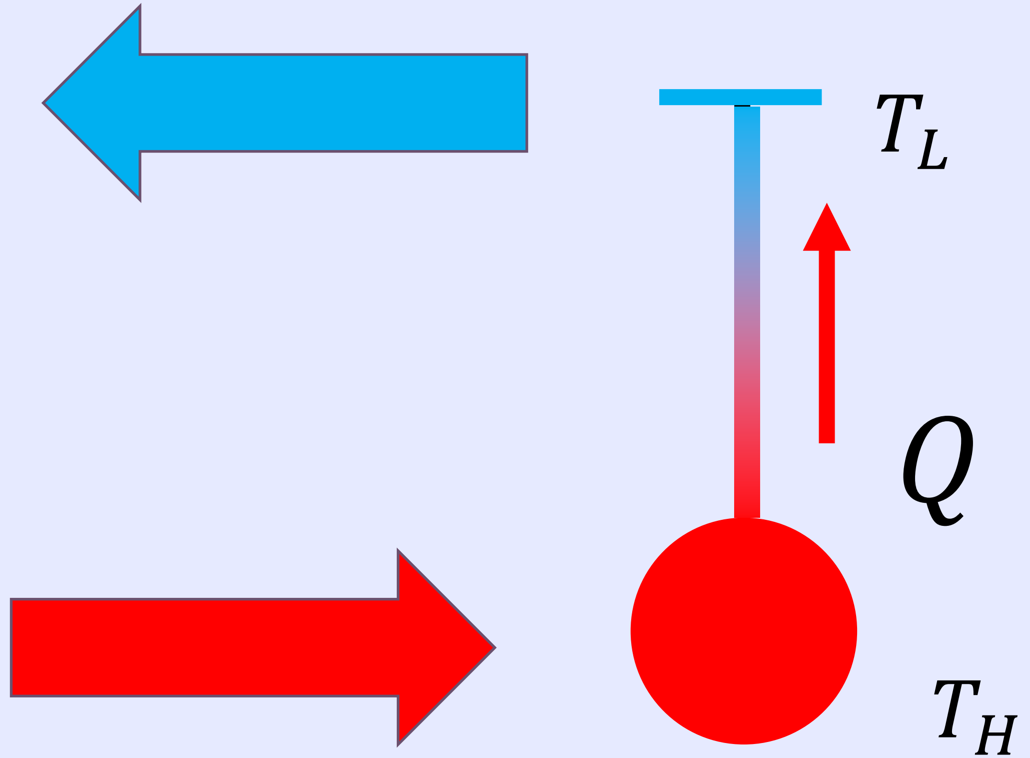
Cryo-Suspension in KAGRA



Cryo-Suspension in KAGRA

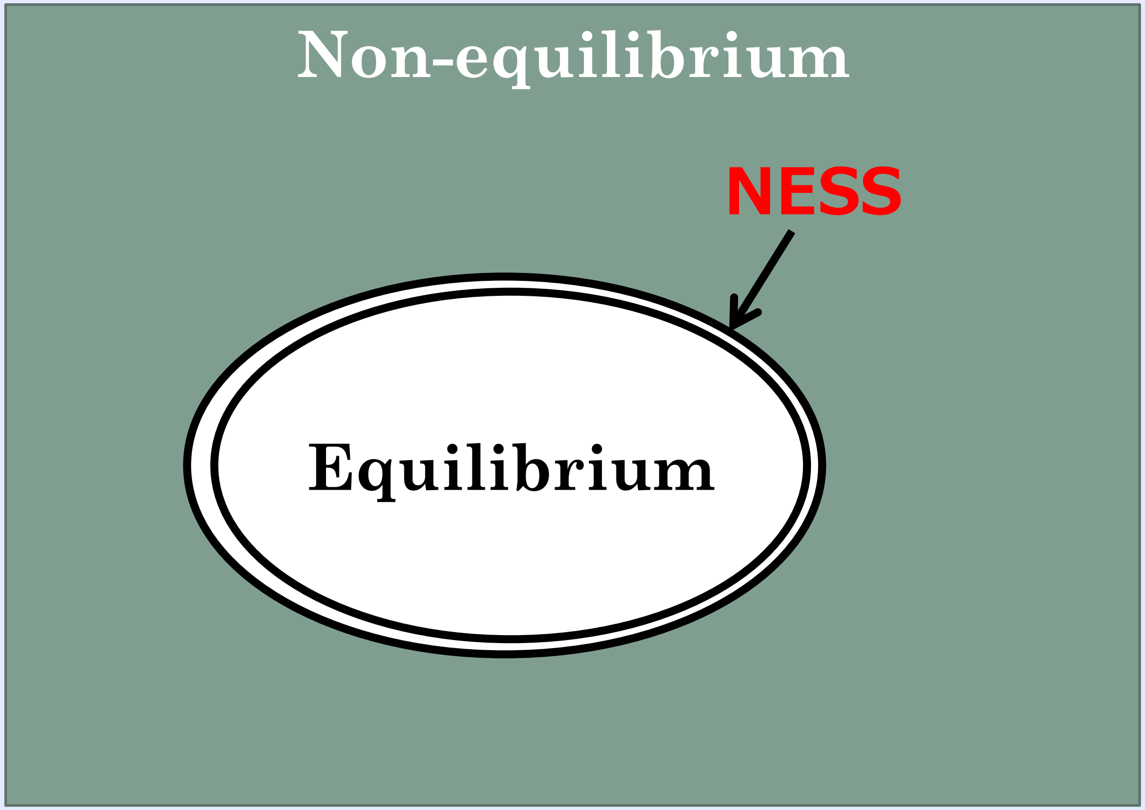


Cryo-Suspension in KAGRA



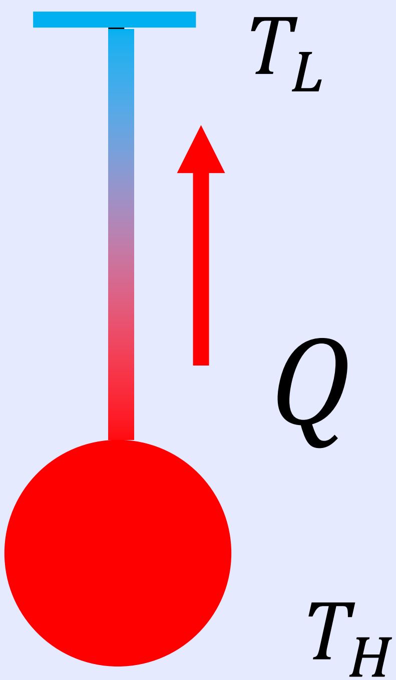
Modeled by K. Otomura (U. Tokyo)

Non-Equilibrium Steady States (NESS)



Model for Suspension thermal noise in NEES

- Consider numbers of slices along the wire.
- To each slice, we define its temperature and can apply the FDT. (idea of **Local EQ System**)

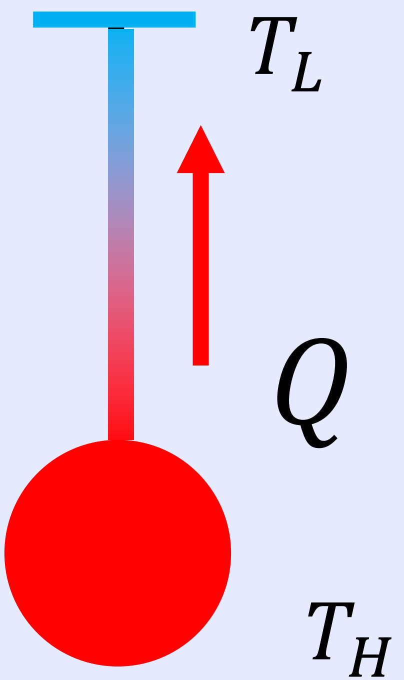


Modeled by K. Otomura (U. Tokyo)

Model for Suspension thermal noise in NEES

REMARK:

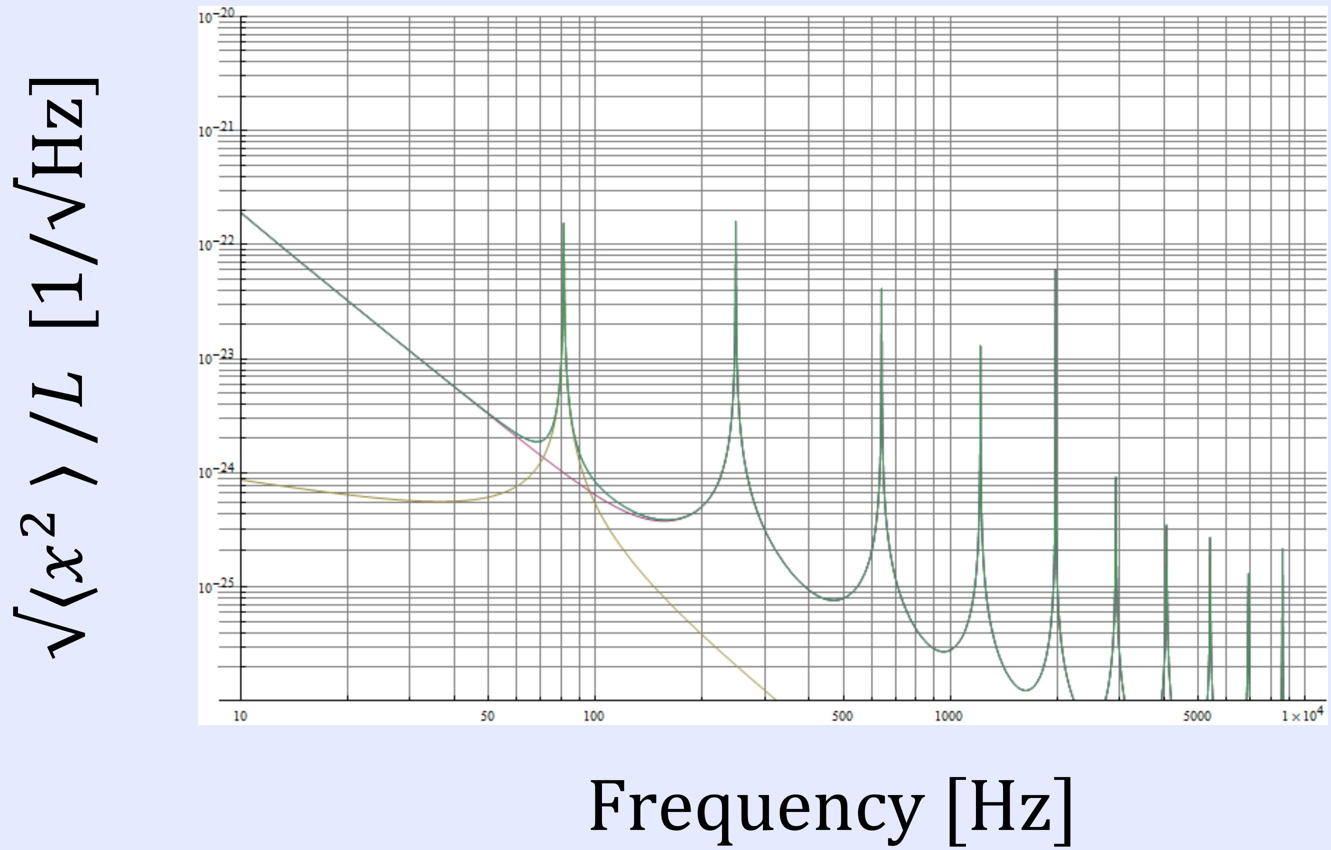
- When we calculate temperature distribution, we already assume the local EQ.
- Therefore, we DO NOT introduce any new assumptions in this model.



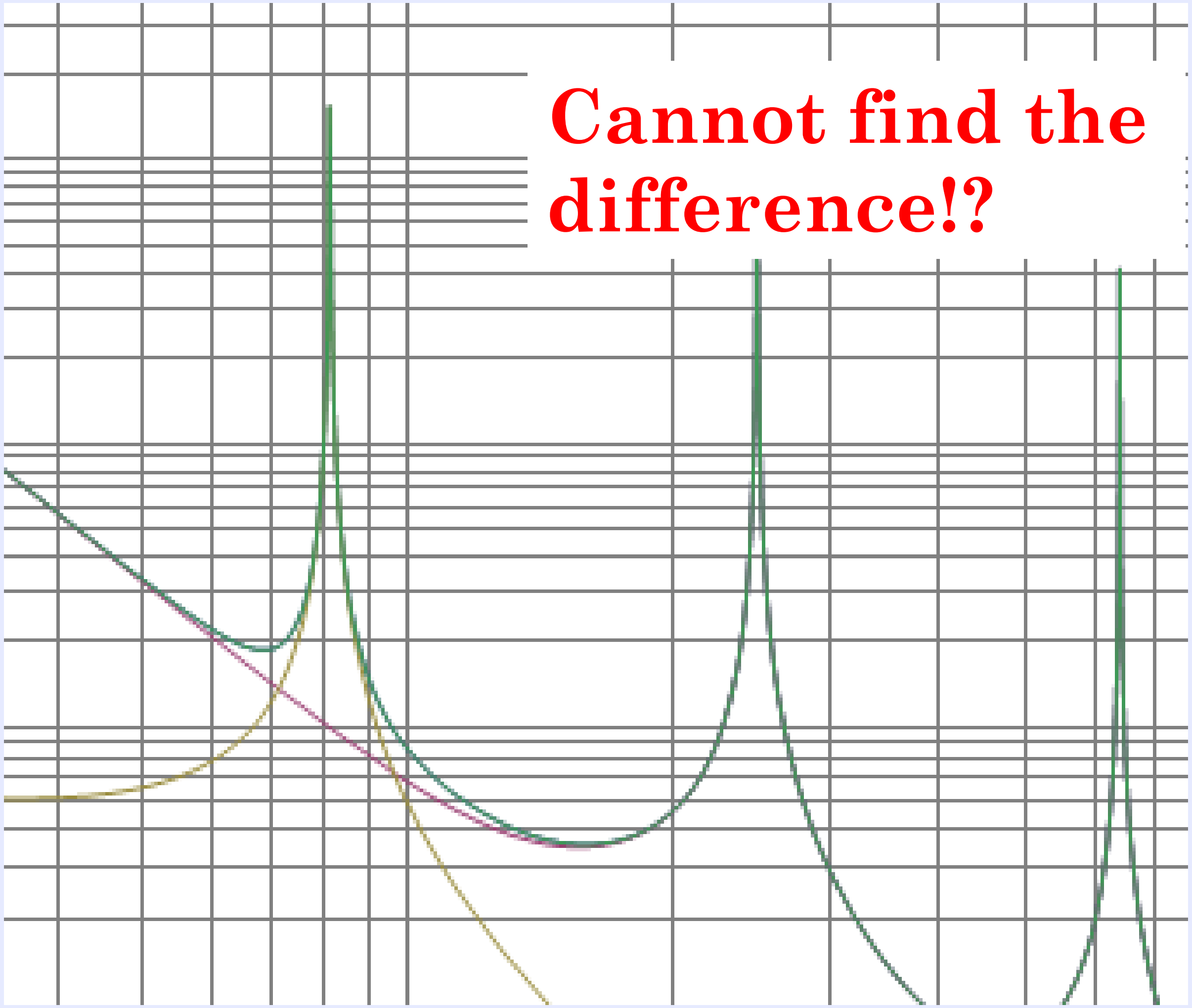
Modeled by K. Otomura (U. Tokyo)

Calculated result

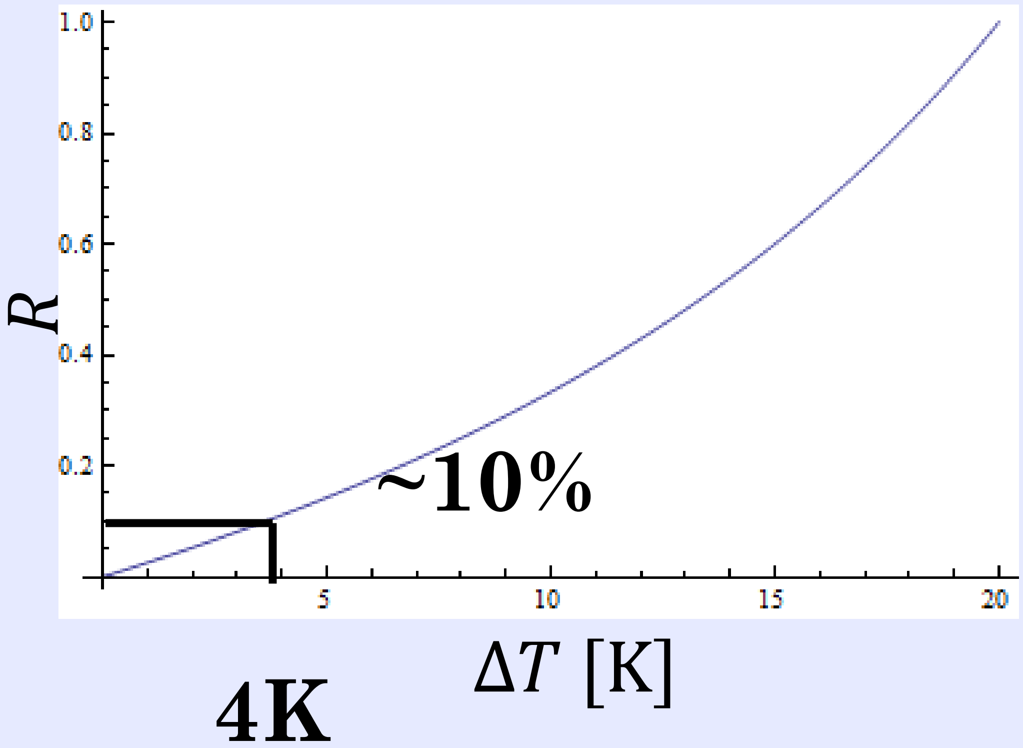
Blue: previous work
Green: this work(ΔT = 4K)



Calculated result



Calculated result



$$R = \frac{\langle x^2 \rangle^{\mathrm{NESS}}}{\langle x^2 \rangle^{\mathrm{EQ}}} - 1$$

$$= C_1 \Delta T + C_2 (\Delta \mathrm{T})^2$$

In KAGRA, R is around 10%

Conclusion

- Modeled using the idea of LES for NESS.
- The result is not so far from the idea of the effective temperature (but this time it's justified theoretically).
- In KAGRA, the difference btw. EQ and NESS is little compared to its noise level.
- Should be confirmed by experiments (now we're preparing).

Fin