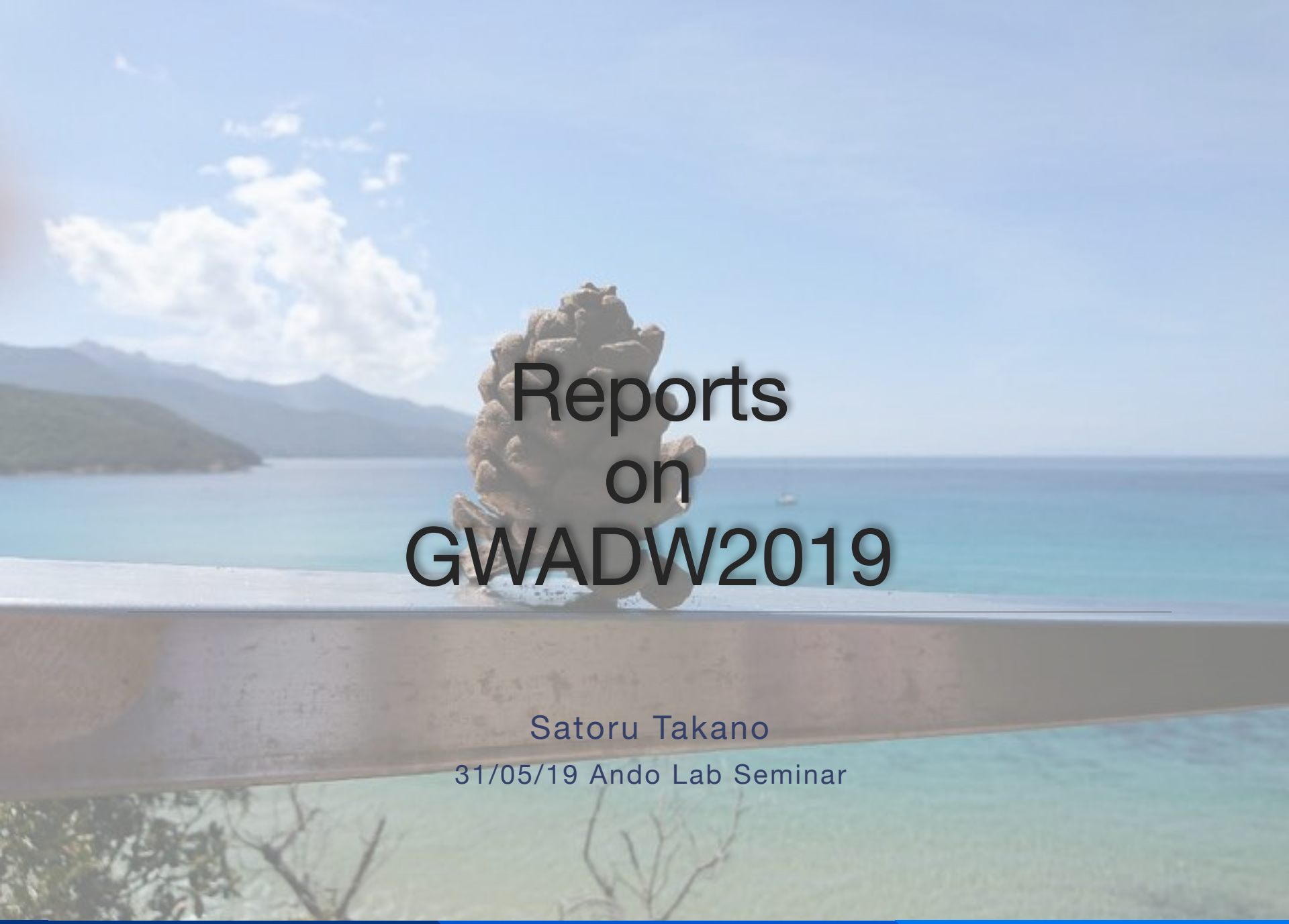


Reports on GWADW2019

Satoru Takano

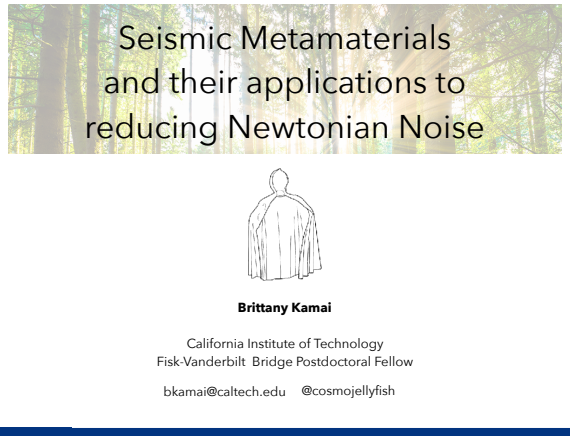
31/05/19 Ando Lab Seminar

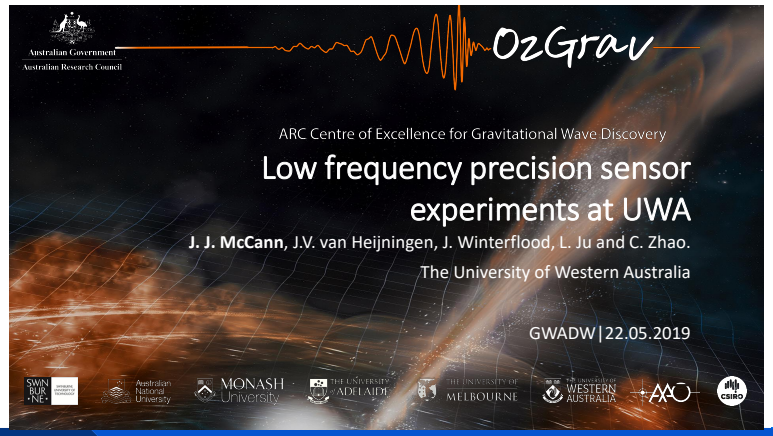
Overview (from my point of view)

- 20 May - 24 May
- A lot of talks about 3G
  - Coating thermal, Newtonian noise, 2 μm laser, facilities, …
  - Mirror coating is very hot (but not so huge progress?)
- Some small scale prototypes
  - 40 m (Caltech)
  - 10 m (AEI)
  - ET Pathfinder (NIKHEF)
- What I did: status talk of TOBA
- Some questions are received
  - The effect of cryostat on vibration
  - Drift during cooling
  - How about to make it underground?

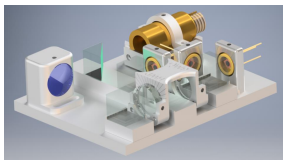
Selected Talks

- Seismic Metamaterials and their applications to reducing Newtonian Noise (B. Kamai, Caltech)
  - How to mitigate NN (also seismic noise) by surroundings
- Low frequency precision sensor experiments at UWA (J. McCann, UWA)
  - Tiltmeters and accelerometers
- Interferometric sensors for low frequency isolation and control (C. Mow-Lowry, Univ. of Birmingham)
  - New sensors for low frequency





Interferometric sensors for low frequency isolation and control



- **Sam Cooper**, Conor Mow-Lowry, Chris Collins, Leonid Prokhorov, Amit Ubhi, Denis Martynov, Chiara di Fronzo

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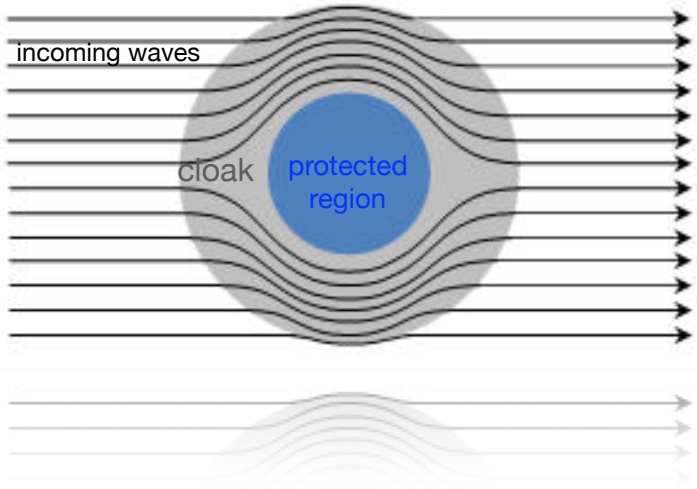
Seismic Metamaterials

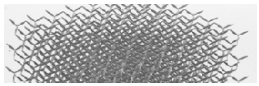
- Current mainstream of mitigation of NN:
  - Monitor by seismometers and cancel NN from strain data
- Another way:
  - Reduce seismic waves itself by metamaterials

Cloaking = Yes, invisibility cloaks

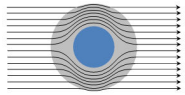


Incoming wave + **Metamaterials** = Cloaking

Electromagnetic
Acoustic
Seismic
Fluids



People-designed materials



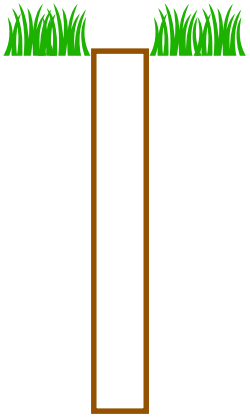
Cloaking has been experimentally demonstrated in a number of these applications (photonics, telecommunications, acoustic, underwater)

Fabulous overview : “Metamaterials Beyond Optics” Kadic 2013

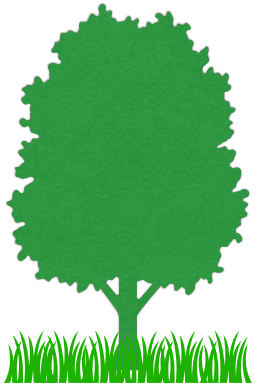
bkamai@caltech.edu Brittany Kamai, PhD 8

Metamaterials for Seismic Wave

Advances in the field of Seismic metamaterials



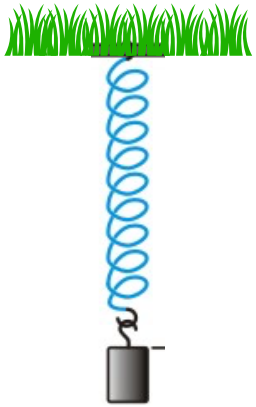
50 Hz notch-filter using holes in the ground



Bandgaps at 40 &110 Hz

Low pass filter 50 Hz

using trees



Buried resonators < 50Hz

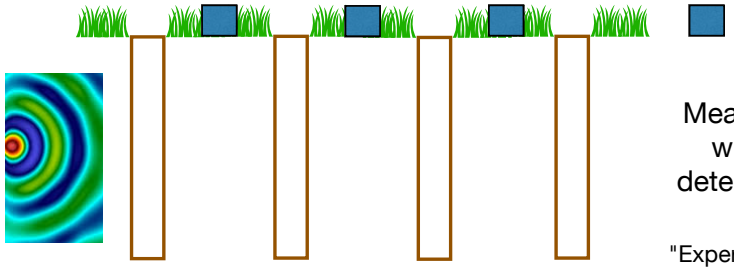
bkamai@caltech.edu

Brittany Kamai, PhD

An Example of Seismic Metamaterials

- Dig holes side by side to filter 50 Hz waves

"Experiments on Seismic Metamaterials: Molding Surface Waves" 2014
Brule, et al, PRL 2014

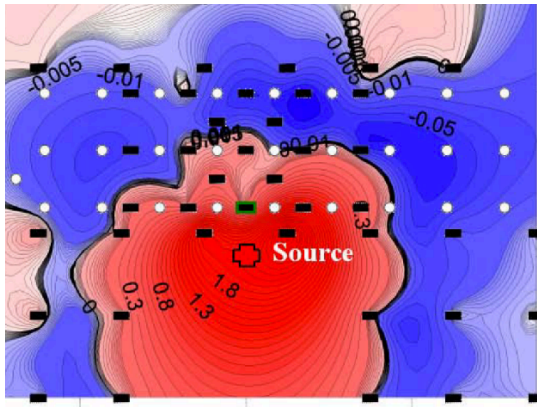


Measure with detectors

Generate 50 Hz waves

Set scale of metamaterials

"Experiments on Seismic Metamaterials: Molding Surface Waves" 2014
Brule, et al, PRL 2014



source (cross)
metamaterial (white circles)
detectors (black squares)

Main Results

- Reflected waves back towards the source
- Achieved a factor of 2 attenuation

Low Frequency Precision Sensor

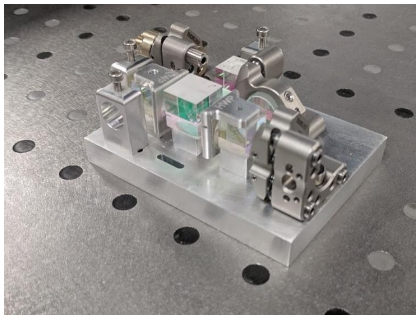
- HoQI: Homodyne Quadrature Interferometer

Breaking the seismic wall

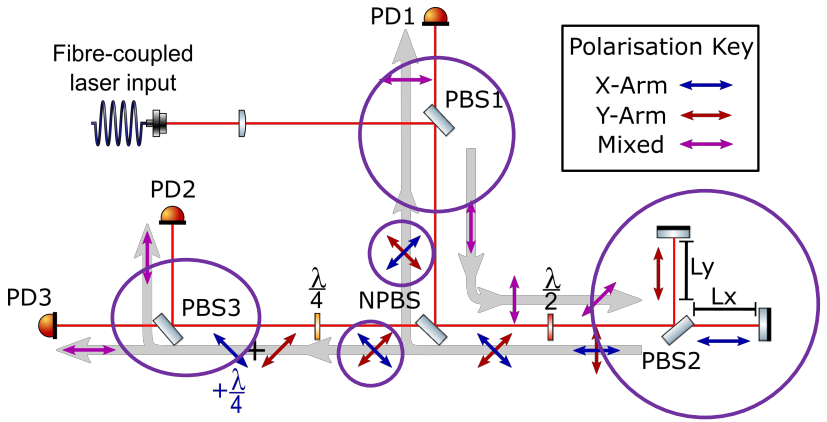
We have developed a tool that can fix this in two ways

1) Local damping of suspensions

2) Reducing ISI motion with new sensors



HoQI: HOmodyne Quadrature Interferometer



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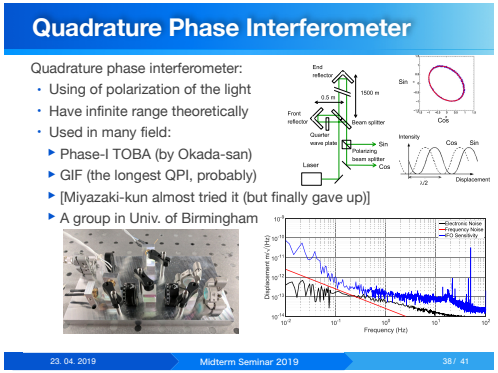
- That's what I just told in midterm seminar



Geophone with HoQI

- Read geophone's internal mass by HoQI (I don't know how they broke L-4C)

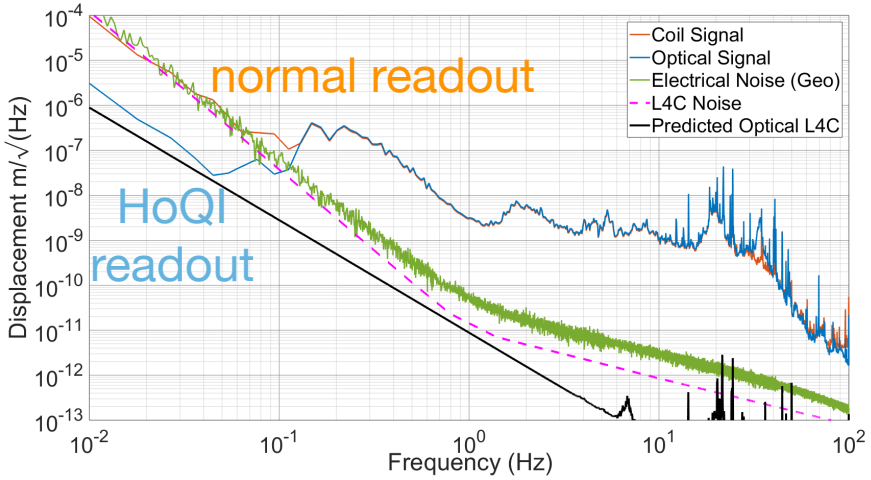
Breaking the seismic wall

We have developed a tool that can fix this in two ways

1) Local damping of suspensions

2) Reducing ISI motion with new sensors

Inertial Sensor Sensitivity (In air, no isolation)



~ 100x higher resolution @10mHz than coil L4C

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- Sensitivity at low frequency is much improved!

(~ 200 @ 0.1 Hz)

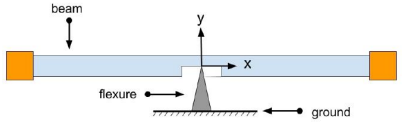
- I want this

Tiltmeter

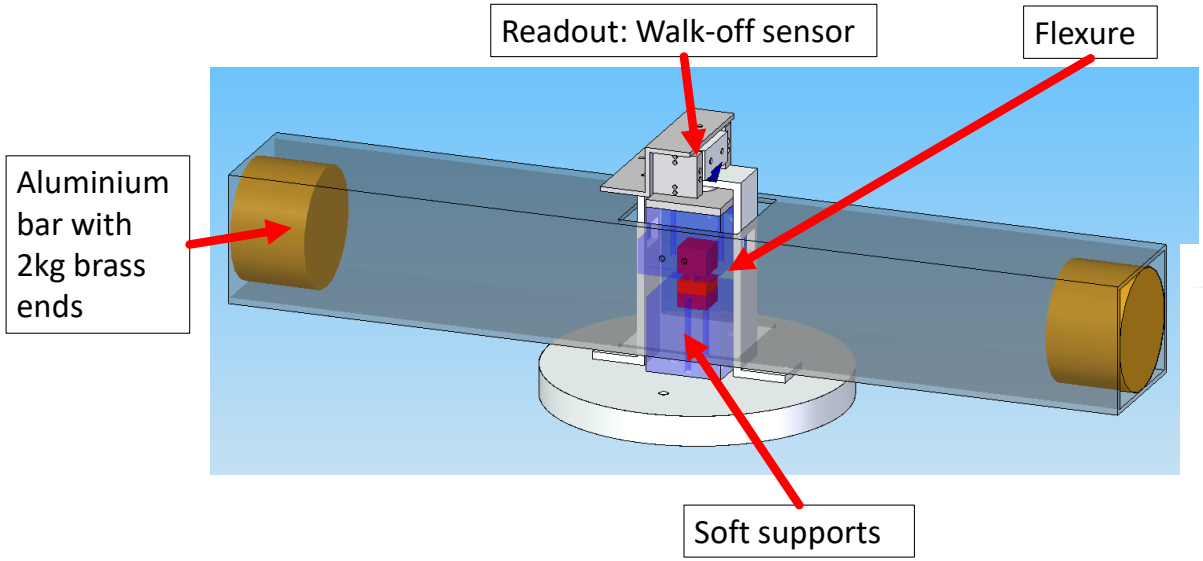
- Advanced Low Frequency Rotational Accelerometer ALFRA
- A balance beam type tiltmeter
  - Resonant frequency: ~ 10 mHz
  - Compact scale (~ O(10) cm)

ALFRA goals

- A balance beam style rotation sensor
- Capable of horizontal and vertical mounting
- Low resonant frequency – 10mHz
- Sensitivity of nano radians or below at 10mHz and above
- Compact

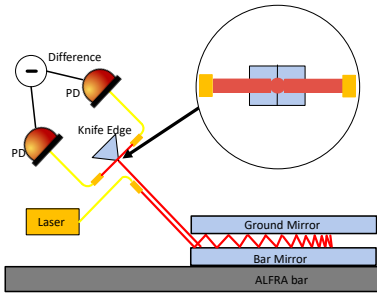


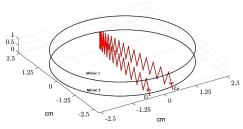
Overview: Conceptual design



Optical readout: Walk-off sensor

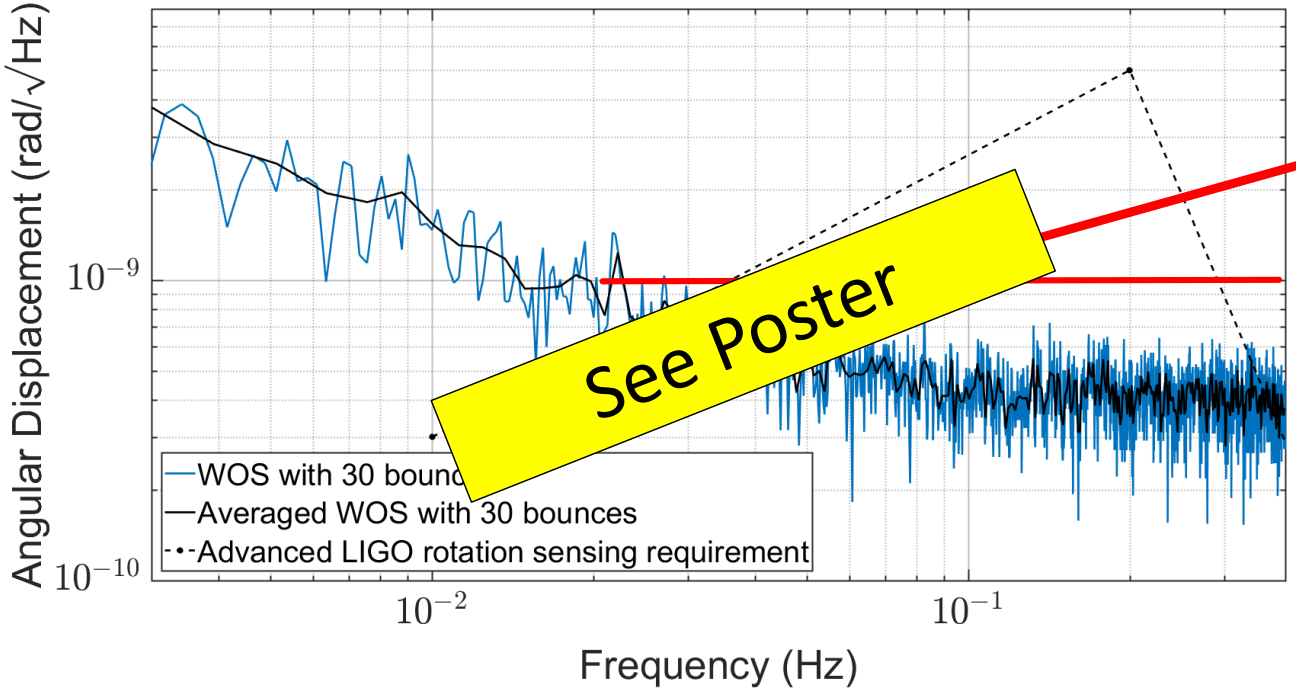
- Laser bounces between two mirrors in parabolic shape
- Angle change between mirrors can be detected by laser position change on a knife edge
- The bounces amplify the angular sensitivity





Readout of ALFRA

Sensitivity: Walk-off sensor not in air

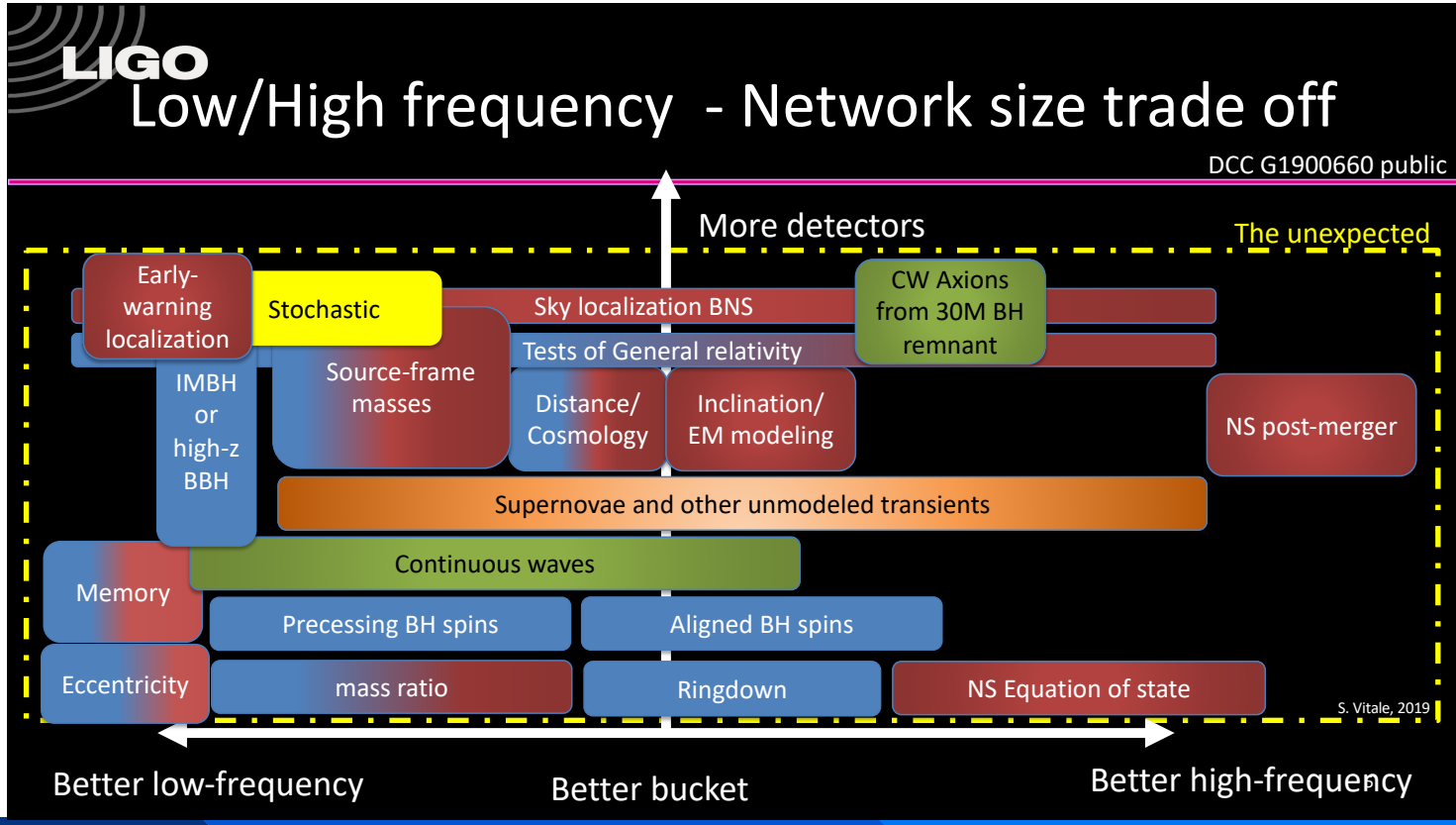


Currently at nano radians sensitivity above 20mHz

J. J. McCann et al., Rev. Sci. 90, 045005 (2019)

Summary

- R&D at Low frequency is a battle against seismic noise
- There is some room to contribute future detector about seismic noise reduction even by table top experiments




Fin.