GWADW2019 summary

with contests and prizes

Livia Conti

INFN Padova

GWADW2019 - Gravitational-Wave Advanced Detector Workshop - From Advanced Interferometers to Third Generation Observatories

19-25 May 2019
Hotel Hermitage, La Biodola, Isola d'Elba
Europe/Rome timezone

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S. Vitale (MIT)
R. Ward (ANU)
B. Willke (AEI)

28 males , 1 female

Disclaimer

- The following reflects only my personal views of the conference.
- Talks were all interesting
- For each talk(1) I selected the slide which I found most significant or representative.
- For parallel sessions I could only attend some of the talks

(1) only talks which slides where uploaded in the indico page in time

Mo AM 1:
Science for 3G Multi-messenger¶
Convener: Marica Branchesi (GSSI)

Take-home message

- multimessenger aspects play a key role in the present and future of GW astronomy ⟶ should be given full consideration in planning 3G detectors

3G era - multimessenger perspective

- **NSNS/NSBH** - from single event investigation to large statistical analysis ⟶ compact binary population, SGRBs, nucleosynthesis, ..

- great opportunities for yet undetected sources

  - increased potential to fully understand GW emission from **galactic SNe** (but not increased event rates)

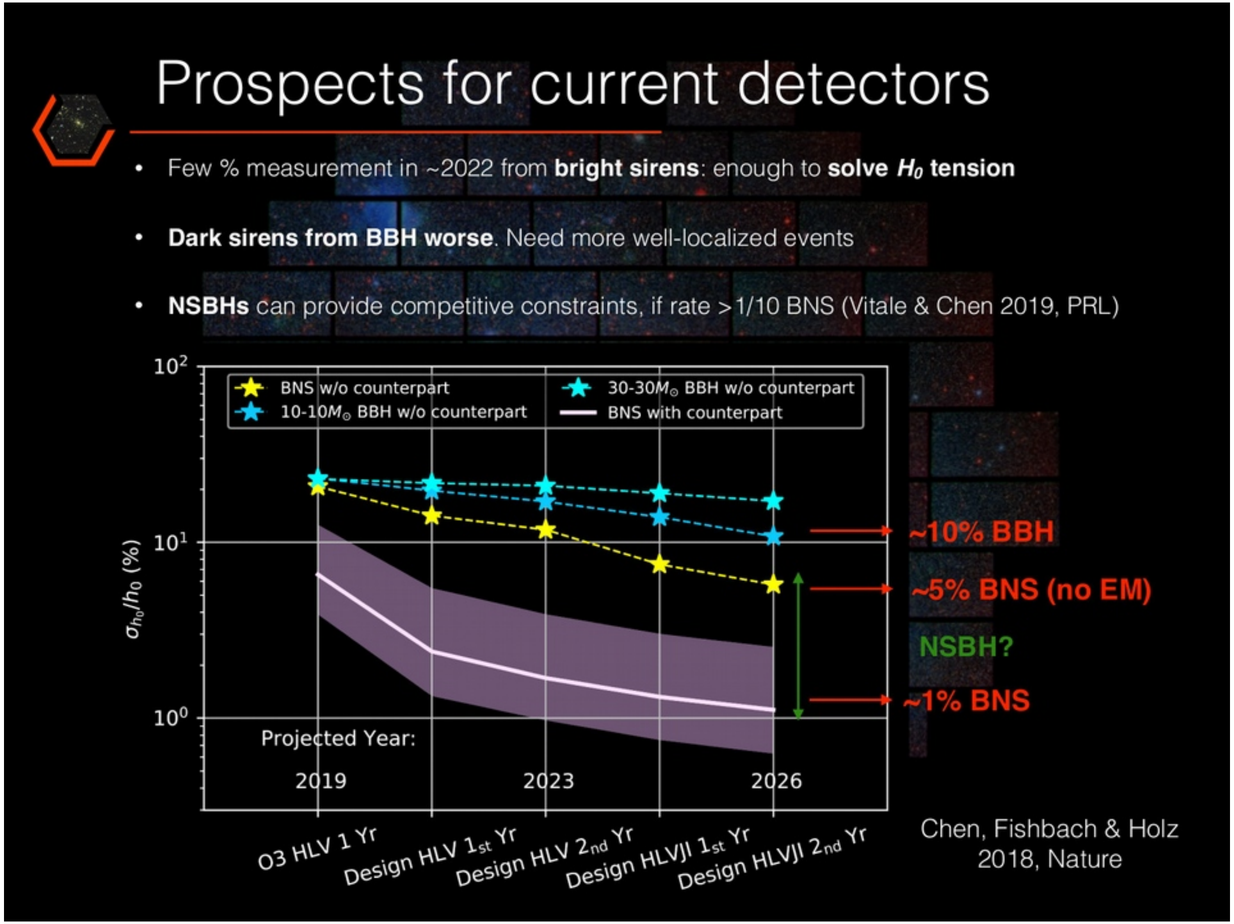
  - much better prosepects to detect continuous GW signals from **isolated and accreting NSs** and GW transients from **bursting/glitching NSs**

Mo.AM1
Multimessenger astrophysics with neutron stars: looking ahead towards the 3G era
Speaker: Dr Riccardo Ciolfi (Istituto Nazionale di Fisica Nucleare)

The contribution of EM searches

- We are very confident that we do not miss any SN event within 10-20 Mpc
- BUT: SN event timing becomes crucial
- A reverse approach: the EM transient triggers an a-posteriori, targeted search for the GW signal in the interferometric data.
- The ET era will greatly enhance this business.
- That is the are were we (meaning EW people) should work.
- Requires a higher coordination level: not yet there.
- LSST era: see talk by A. Palmese

Mo.AM1
Multi-messenger observatories¶
Speaker: Nando Patat (ESO)

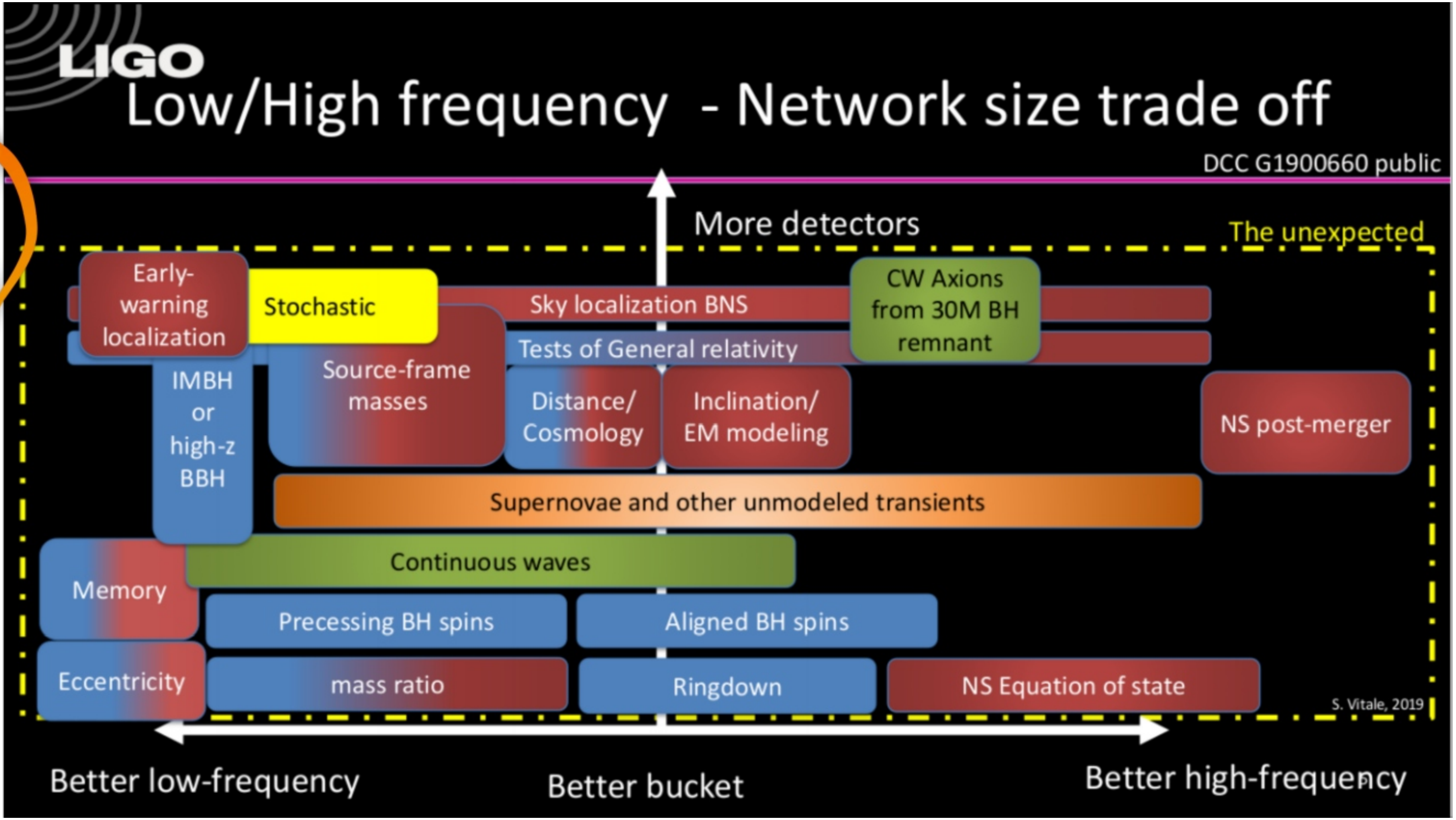


Mo. AM1

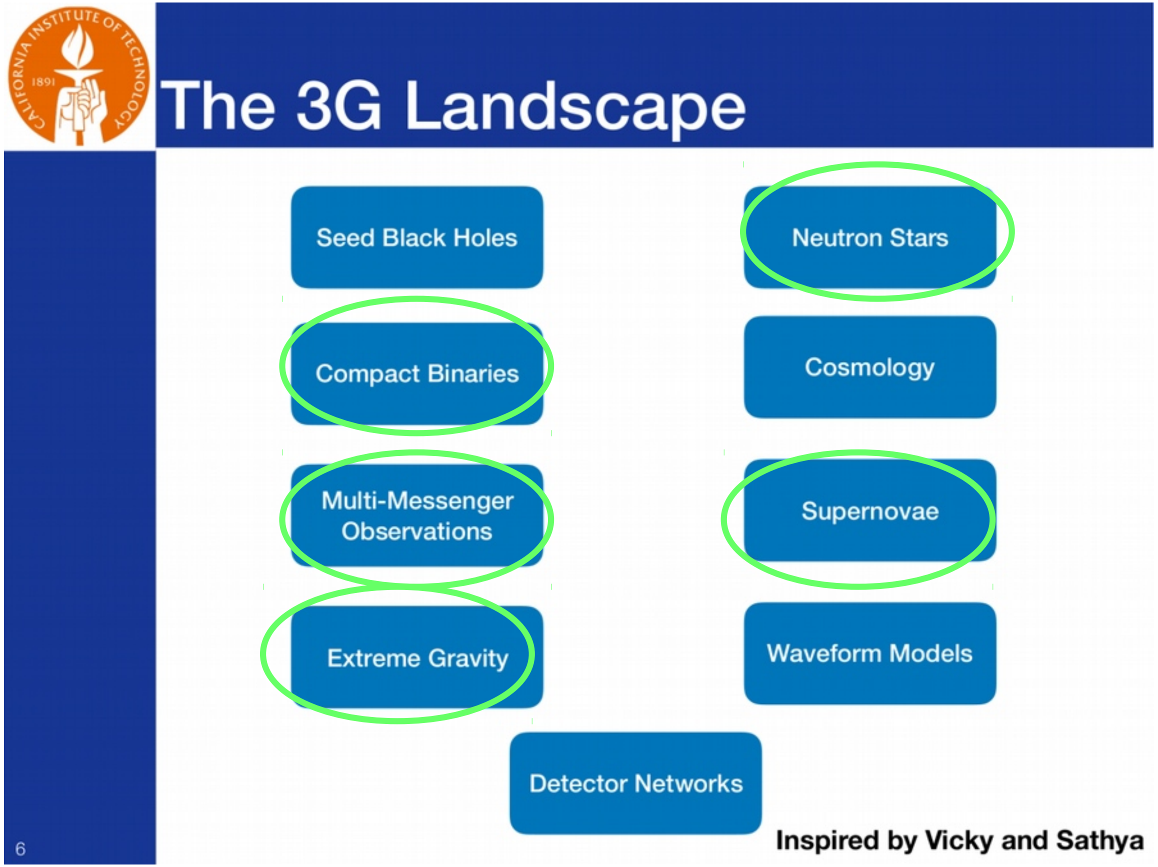
Gravitational wave cosmology with large galaxy surveys

Speaker: Antonella Palmese (Fermilab)

Mo AM 2:
Science for 3G
Conveners: Katerina Chatziioannou (Flatiron), Salvo Vitale (LIGO MIT), Yuri Levin (Flatiron)

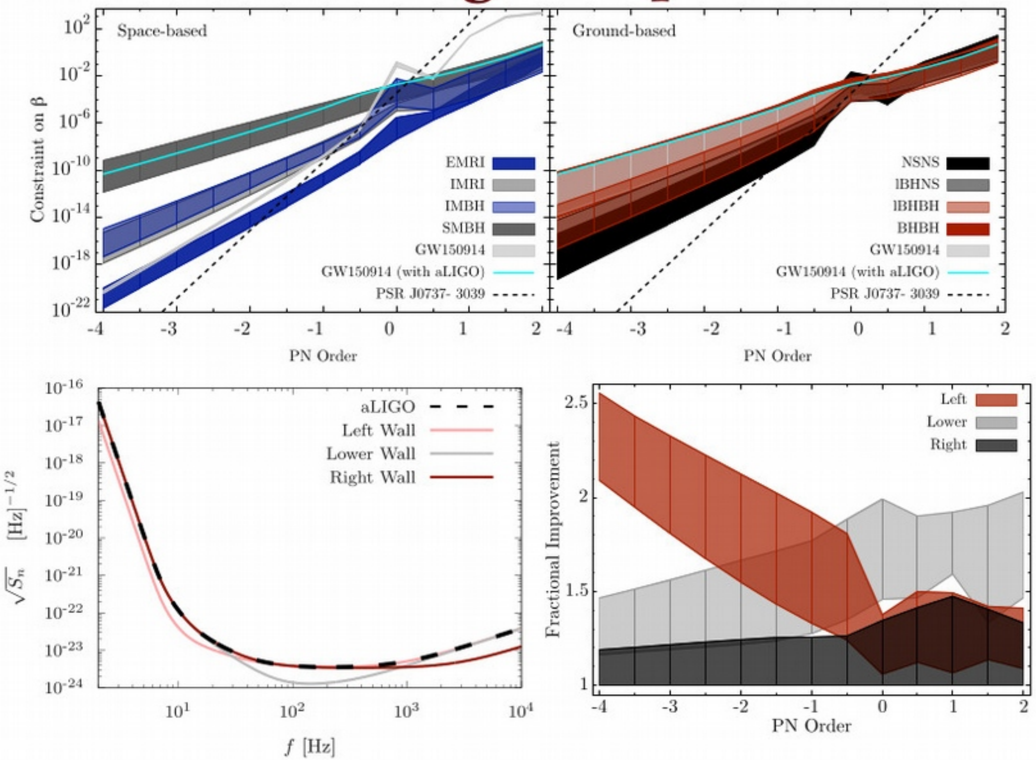


Mo.AM2
Low frequency and populations¶
Speaker: Salvo Vitale (LIGO MIT)



Mo.AM2
High Frequency
Speaker: Michael Coughlin (California Institute of Technology)

Low vs high frequencies



taken from Chamberlain & Yunes, Phys. Rev. D 96, 084039 (2017)

Thomas P. Sotiriou - GWAWD, Elba, May 20th 2019

Mo.AM2
Fundamental physics with 3G detectors
Speaker: Thomas Sotiriou (University of Nottingham)

Mo PM 3:
Upgrades to present facilities
Convener: Stefan Ballmer (Syracuse University)

AdV+ project is divided into 2 phases

- Phase I — *next 2 years* / *this presentation*
  - 40-50W input power
  - signal recycling mirror
  - Newtonian noise cancellation
  - frequency depend squeezing
  - preparatory work for phase II

- Phase II — *beyond 2022*
  - large mirrors implementation

Mo.PM3
AdV+
Speaker: Jerome Degallaix (Laboratoire des Matériaux Avancés - CNRS)

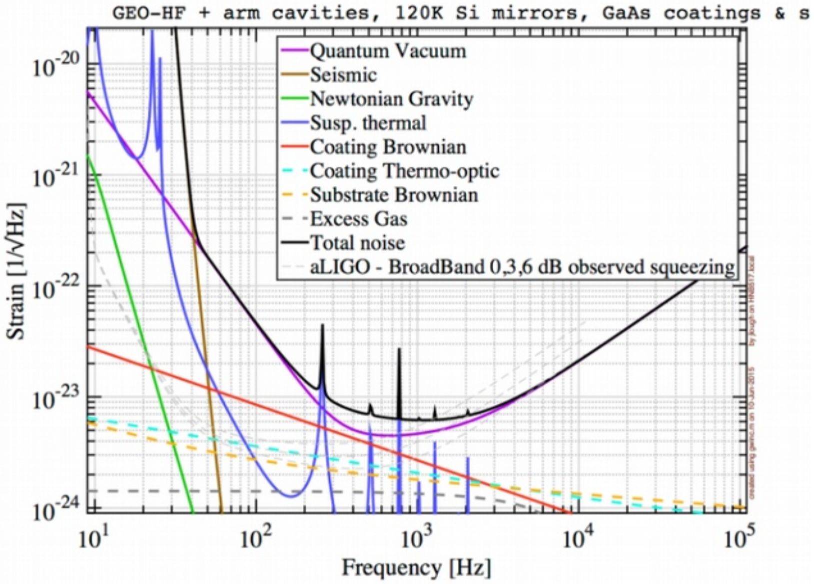
A+ Enhancements

- Improved Coatings
- Frequency Dependent Squeezing
- Boosted Optical Efficiency for Deeper Squeezing
  - High-efficiency Faraday isolators
  - Adaptive Wavefront Control (US/Australia)
- Balanced Homodyne Readout (UK)
  - Several improvements, SRC control, backscatter (see G1800459)
- Enlarged Beamsplitter and Suspension (UK)
- Improved Suspension Fibers (UK)
  - see G1900942

Mo.PM3
A+
Speaker: Lee McCuller (MIT)

Sensitivity

- No plans for competitive sensitivities
- In 2015, we decided to NOT pursue this route ->
  - or any other major sensitivity upgrades
- Pursuing technologies applicable to high frequency sensitivity



Mo.PM3
GEO600
Speaker: James Lough (AEI Hannover)

Four upgrades examples

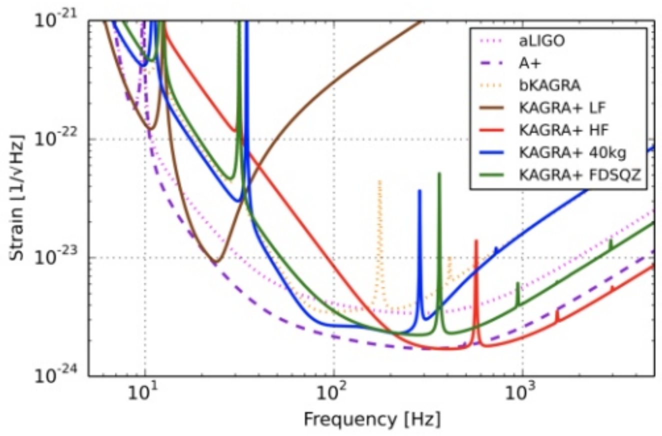


Figure 48: Sensitivity curves for bKAGRA and upgrade candidates. Sensitivity curves for Advanced LIGO (aLIGO), A+ and bKAGRA are shown for comparison [464].

1. Low frequency
2. High frequency
3. 40kg test masses
4. Freq. dependent squeezing

Mo.PM3
KAGRA+ upgrade plan
Speaker: Matteo Leonardi (NAOJ)

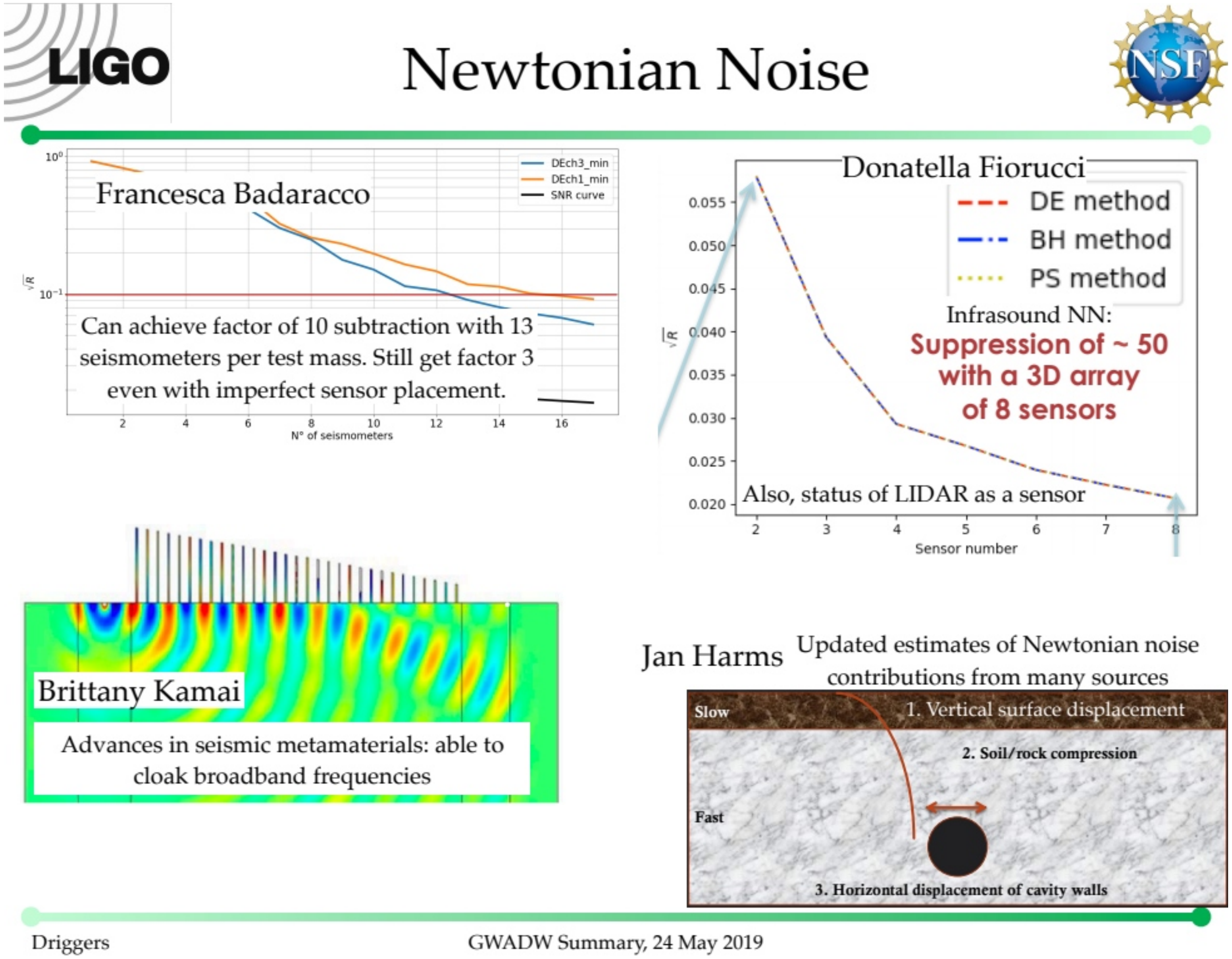
Mo PM 4: Newtonian Noise
Convener: Jenne Driggers (Caltech)

Mo.PM4
NN cancellation in underground GW detectors
Speaker: Francesca Badaracco (GSSI)

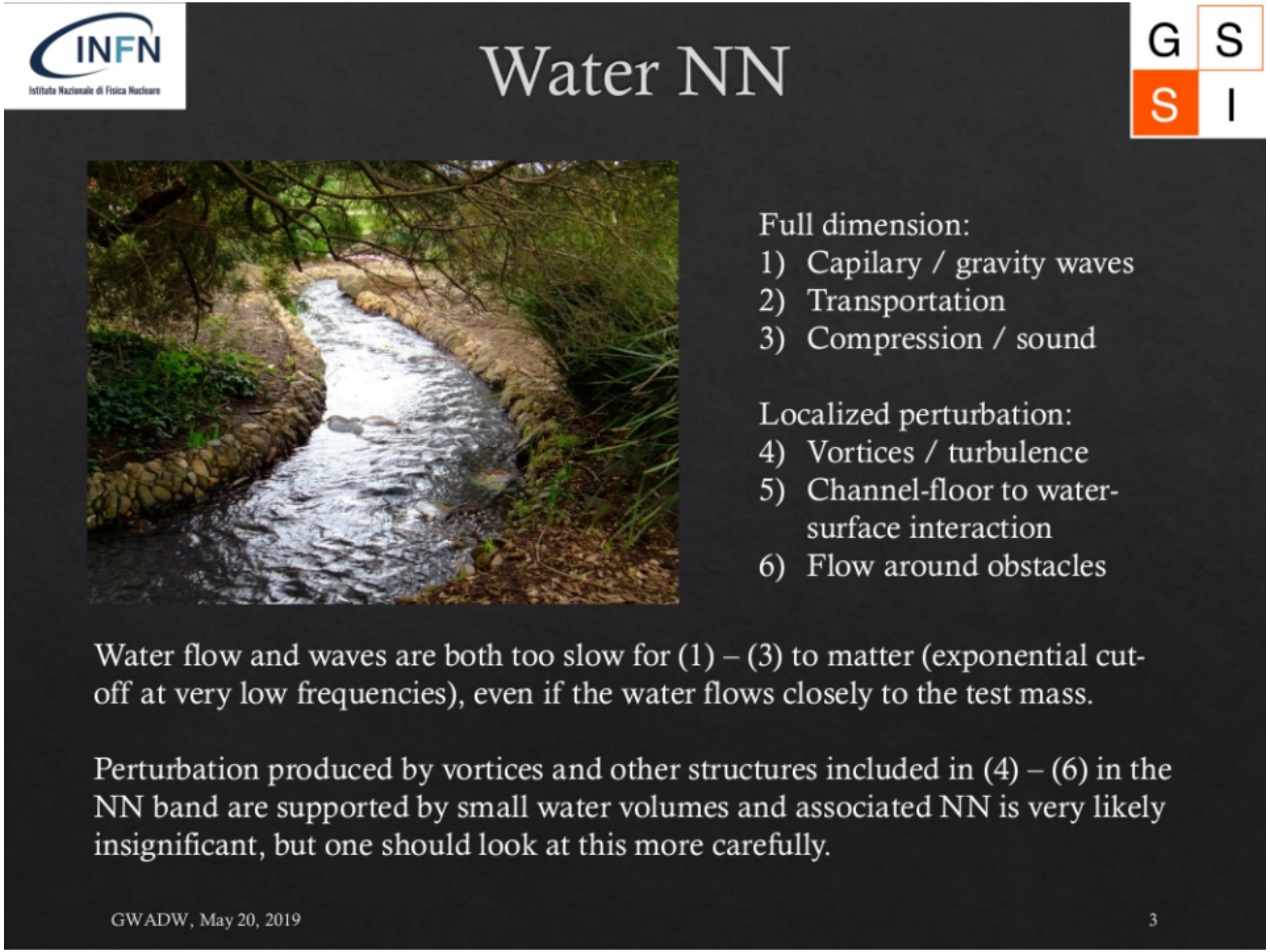
Infrasound NN cancellation
Speaker: Donatella Fiorucci (CNRS)

Seismic metamaterials and their applications to reducing Newtonian Noise
Speaker: Dr Brittany Kamai (Caltech)

ET seismic NN estimation
Speaker: Jan Harms (GSGC)



best friend of environment



Mo.PM4
ET seismic NN estimation
Speaker: Jan Harms (GSGC)

Tu AM 1:
Thermal Noise
Conveners: Bram Slagmolen (The Australian National University), Stuart Reid (University of the West of Scotland)

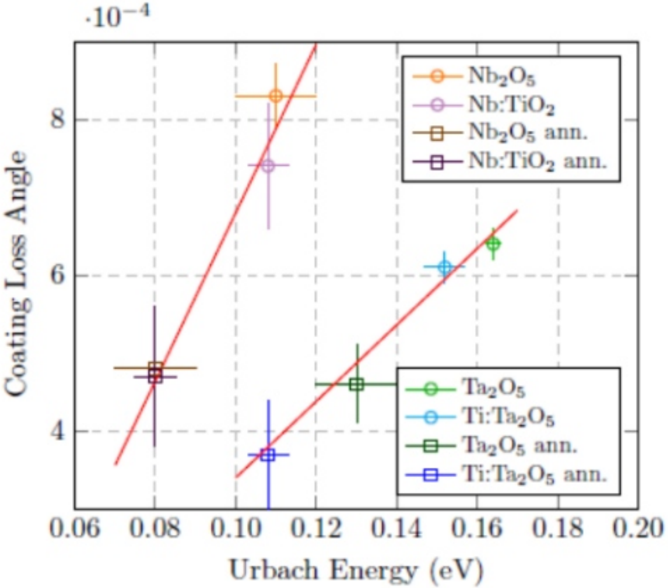
Summary

- Building blocks + staffing established over first 18 months
  - deposition tools
    - CSU, UCB, UH, Strathclyde, Sannio, Montreal, LL
  - characterization tools
    - high throughput RT mechanical loss: Caltech, Syracuse
    - additional cryo loss tools: SU, U Glasgow
  - computational tools: SU, UF
    - scattering data -> structures
    - structure-property relations
  - fabrication concepts
    - high-T deposition
    - doping suppression of crystallization
    - nano-layer suppression of crystallization
- Further connections emerging between theory and exp't
- Design concepts tested
  - multi-material coatings
- Using theory to direct experimental choices

Tu.AM1
A+ timeline, plans, and requirements (plus mention of LIGO India plans)
Speakers: Martin Fejer (Stanford University), Michael Zucker

Absorption

The **Urbach energy** is a parameter which quantifies the homogeneity of the structure by absorption investigation, probing a multi-range structural organization. **Annealing and doping** modify the structure leading to a more organized/ homogeneous atomic dispositions, reducing the mechanical loss angle.



Amato et al 2019
arXiv:1903.06094

Tu.AM1
Virgo, AdV+ and future plans/requirements
Speakers: Matteo Lorenzini (GSSI), Paola Puppo (ROMA1)

KAGRA

4.Summary

1. KAGRA+ thermal noise

   Thermal noise itself in white paper does not matter.

   Kazuhiro’s comment : Smaller absorption mirror or higher thermal conductivity sapphire fibers are necessary to simplify assembly.

2. Thermo-optic noise

   Thermal noise interferometers can give constrain on α and β of coating, which are important parameters to evaluate thermo-optic noise.

   At room (cryogenic) temperature, thermo-optic noise could be an issue in near future (is not problem at all).

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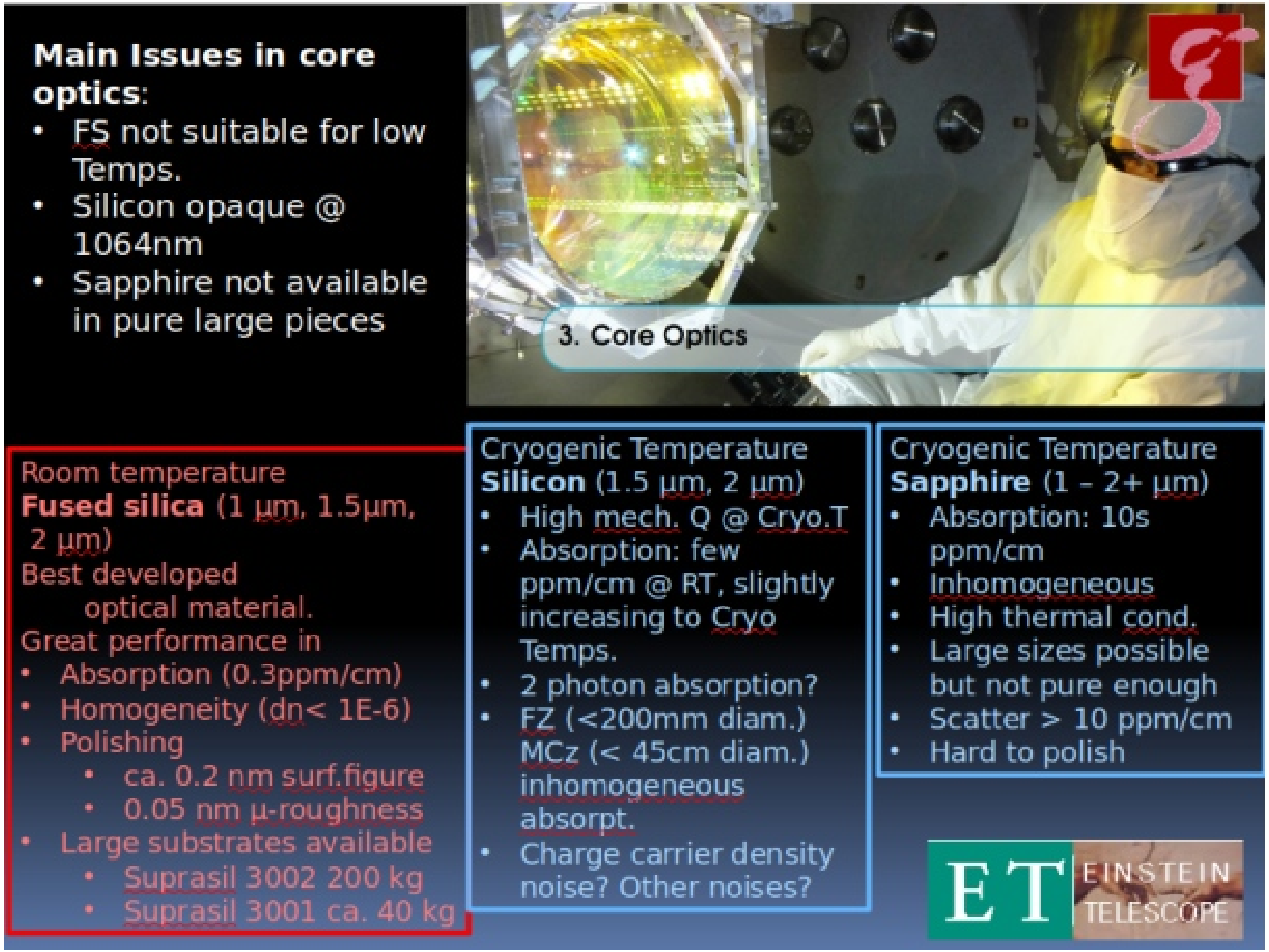
Tu.AM1
KAGRA and future plans for suspensions and optics in KAGRA¶
Speaker: KAZUHIRO YAMAMOTO (University of Toyama)



Tu.AM1

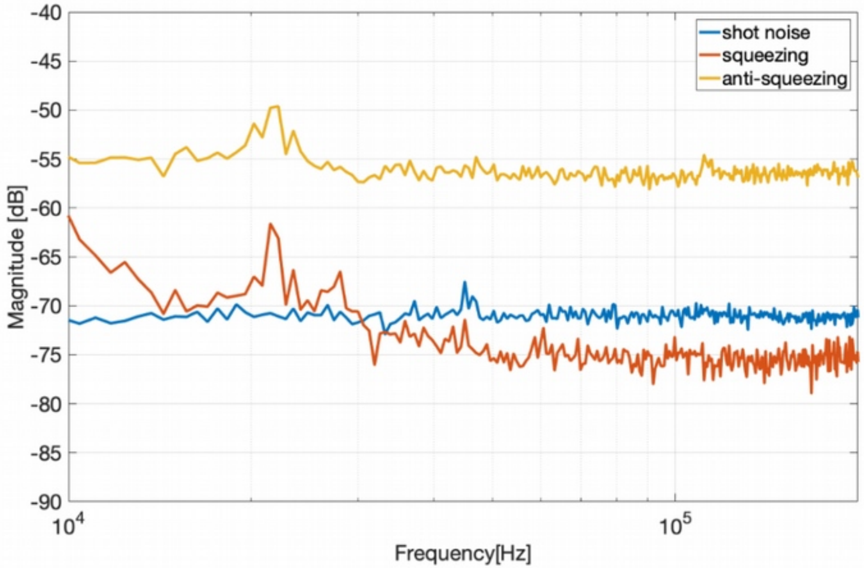
Thermal noise in 3G instruments¶

Speaker: Harald Lueck (AEI Hannover (MPI f. gravitational Physics / Inst. f. Grav.physics Leibniz Un

Tu AM 2:
Upgrades to Current Facilities
Convener: Stefan Ballmer
(Syracuse University)

Current squeezing performance

- About 4.5 dB of squeezing (and 15 dB of anti-squeezing) down to ~30 kHz



Tu.AM2
Status of the filter cavity experiment at TAMA
Speaker: Eleonora Capocasa (NAOJ)

Work packages

Five research themes and one management theme have been identified this time.

PI of Project : Hammond (UK) / Raychaudhury (India)

- WP1: Project management (Hammond, Raychaudhury + representatives from all Institutes)
- WP2: Data analysis and Modelling (Heng, Andersson, Sutton, Raychaudhury)
- WP3: Low thermal noise coatings and suspensions (Reid, Hammond, Rajalakshmi, Prabhakar, Raman)
- WP4: Interferometer modelling & simulation (Daw, Rapol)
- WP5: Entrepreneurial Activities (Gibson, Raychaudhury, Indian Trade Embassy representatives)
- WP6: Outreach Activities (Vecchio, Souradeep)

Objectives delivered through research exchanges, industrial engagement, educational initiatives and outreach activities.

Tu.AM2
The UK-India collaborative efforts - the Newton Bhabha project
Speaker: Mariela Masso Reid

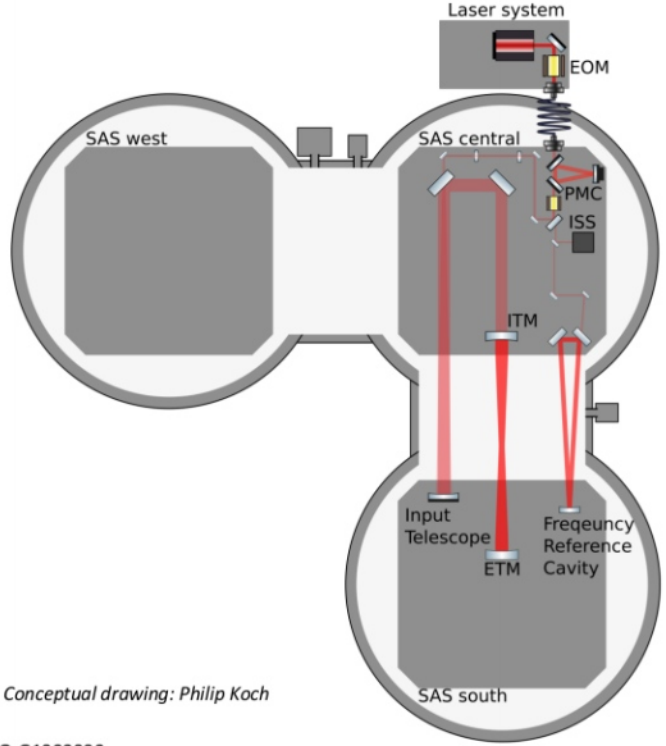
Science goals

- Low phase noise interferometry with cryogenic silicon mirrors of up to ~100kg
- Providing a flexible testbed to explore various combinations of cryogenic temperatures and laser wavelength
- Investigating the interplay of thermal noise, quantum noise and control noises in the sub 10Hz region
- Various tests of cryogenic issues (liquids vs cryo-coolers; stable control of mirror temperature; contamination handling of mirror surfaces; low power actuators ...)
- Testbed for new control techniques and sensors

Tu.AM2
Plans for ETpathfinder prototype
Speaker: Bas Swinkels (NIKHEF)

Current Status

- Seismic Attenuation System (AEI-SAS)
  - Suspension platform interferometer (SPI)
  - Optical levers
- Pre-Stabilised Laser
  - Power stabilisation (aLIGO style PD array)
  - Frequency stabilisation (10 m suspended reference cavity)
- Single Arm Test
  - 100 g pilot optics (wire suspension)
- Control and Data System (CDS)



Conceptual drawing: Philip Koch

Tu.AM2
Plans for AEI 10m prototype
Speaker: David Wu

Tu PM 3:
Space technology for the future
Convener: Seiji Kawamura (Nagoya University)

From LPF to LISA

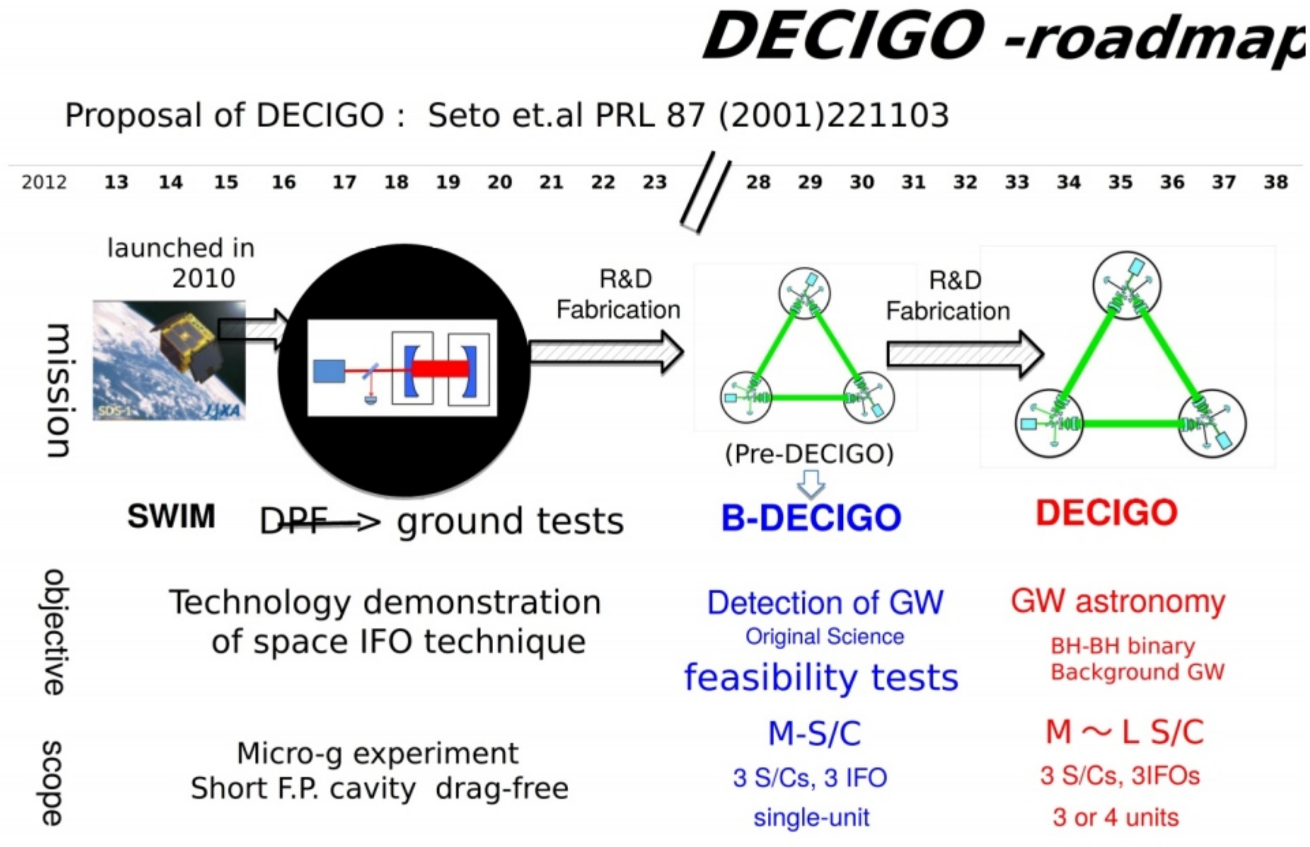
- In LISA all the **TMs will be** drag-free along their x-axis.
- **Force gradients and Tilt-To-Length (TTL)** need to be calibrated.
- **Inertial forces in LISA** could enter the signal through actuation crosstalk
- **Force glitches** need to be understood both as instrumental origin that for discrimination techniques
- **TDI mixes many signals and introduces correlations** that makes even instrument noise characterization non trivial

Tu.PM3
From LISA Pathfinder to LISA, a gravitational waves space-based observatory
Speaker: Daniele Vetrugno (Istituto Nazionale di Fisica Nucleare)

Study Office Near-term Goals

- Develop “menu” of possible NASA contributions
  - Payload systems and subelements (req. tech development)
  - Spacecraft components
  - Ground segment contributions
  - Operations contributions
  - Science support
  - …
- Assess each contribution
  - Compatibility with partners/ease of interface
  - US interest
  - NASA capabilities
  - Cost
- Work with NASA HQ, ESA, Consortium to consolidate final roles and responsibilities

Tu.PM3
LISA technology development in the U.S.
Speaker: John Conklin (University of Florida)



Tu.PM3

The Japanese space gravitational wave detector DECIGO/B-DECIGO

Speaker: Mitsuru Musha (Instutute for Laser Science, University of Electro-communications)

Conclusions

A robust method of charge management using photoelectrons with the following advantages:

- Infrequent or no charge measurement
- Precise timing of UV illumination not required
- Power stability of UV source not critical
- No need for the accurate determination of the UV illuminated surface properties
  - Quantum efficiency
  - Angle dependence of photoemission
  - Reflectivity
- No precise processing or maintenance of the UV illuminated surfaces required
- Simple in-flight fine-tuning of system for unforeseen changes

The PCM method relies upon the:

- Stability of the surface properties of materials (after aging)
- Straightforward biasing by either dc bias sleeves/plates or AC modulation of the UV-LEDs

Tu.PM3
Passive Charge Management of Floating Test Masses in Inertial Sensors
Speaker: Dr Sasha Buchman (Stanford University)

We AM 1,2 A:
Thermal Noise and Coatings
Convener1: Riccardo Bassiri (Stanford University)
Convener2: Gianpietro Cagnoli (University of Lyon)

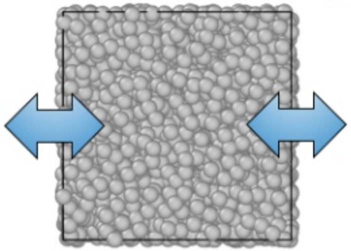
Conclusions and Open Questions

- Are low TLS in ultrastable *a*-Si (and IMC) the "exception that proves the rule" of universal low T glass properties? Or, is there a new rule – "universal glass properties" at low T are perhaps due to the universal nature of liquid quenching and domain growth/correlation length growth/boundaries?
- Is low TLS related to growth near T_K? (If (and only if) surface mobility during growth is high). Fragile glasses have T_K near T_g, where mobility is high, so low TLS would be correlated with fragility
- Or is low TLS related to nature of bonding: overconstrained (tetrahedral Si) versus underconstrained e.g. Si-O-Si bonds in *a*-SiO_2 and TLS in *a*-Si due to nanovoids
- Silica, alumina show increased density and reduced loss at low T with increased T_{growth}; not as much as a-Si, but not yet at $T_{growth}= 0.8T_g$.
- Tantala shows reduced losses at low T with increased growth T; not as much as a-Si, and likely at $T_{growth} = 0.8T_g$; annealing big effects, T_{growth} not stabilizing structure.
- Low losses at room temperature in all are not well correlated with low losses at low T
- Route to low room T losses is to find a material like *a*-SiO_2 with strong well formed bonds in liquid state (i.e. strong glass) and moderately high T_g
- Route to low low T losses is fragile glass with moderate T_g and suppress crystallization

We.AM1a
Two Level Systems and Ultrastable Glasses
Speaker: Frances Hellman (UC Berkeley)

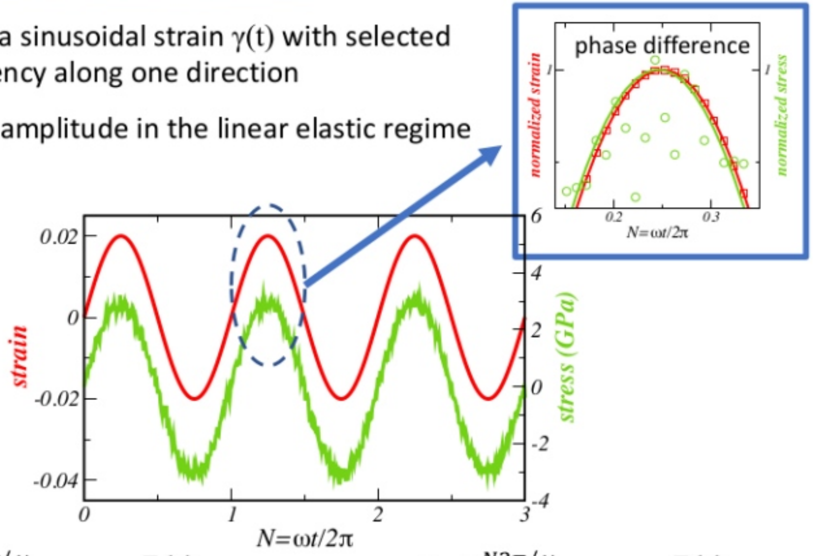
Molecular Dynamics – Mechanical Spectroscopy (MD-MS)

Unilateral tensile oscillatory deformation



Apply a sinusoidal strain $\gamma(t)$ with selected frequency along one direction

Strain amplitude in the linear elastic regime



Storage and loss moduli

$$E' = \frac{\omega}{N\pi}\int_0^{N2\pi/\omega} \sin(\omega t)\frac{\Sigma(t)}{\gamma_0}dt \qquad E'' = \frac{\omega}{N\pi}\int_0^{N2\pi/\omega} \cos(\omega t)\frac{\Sigma(t)}{\gamma_0}dt$$

Dissipation $\quad Q^{-1} = \tan\delta = \frac{E''}{E'}$

We.AM1a
Mechanical Loss Calculations
Speaker: Francesco Puosi (University of Pisa and INFN Pisa)

MBE

AlGaAs

- Developed technology ✓
- Optical performance ✓

- Grown on GaAs wafers ✗
- Requires transfer ✗

AlGaP

- Mechanical loss ✓
- Lattice matched to silicon ✓

- Not well-developed ✗
- Optical properties ✗
- Growing on 200kg scale optics ✗

Others?!?!

- AlGaN

Growth on Al_2O_3, GaN or AlN.

Issues of quality of films on Al_2O_3 cited by Novikov et al. Journal of Vacuum Science & Technology B 34, 02L102 (2016)

Common challenges:

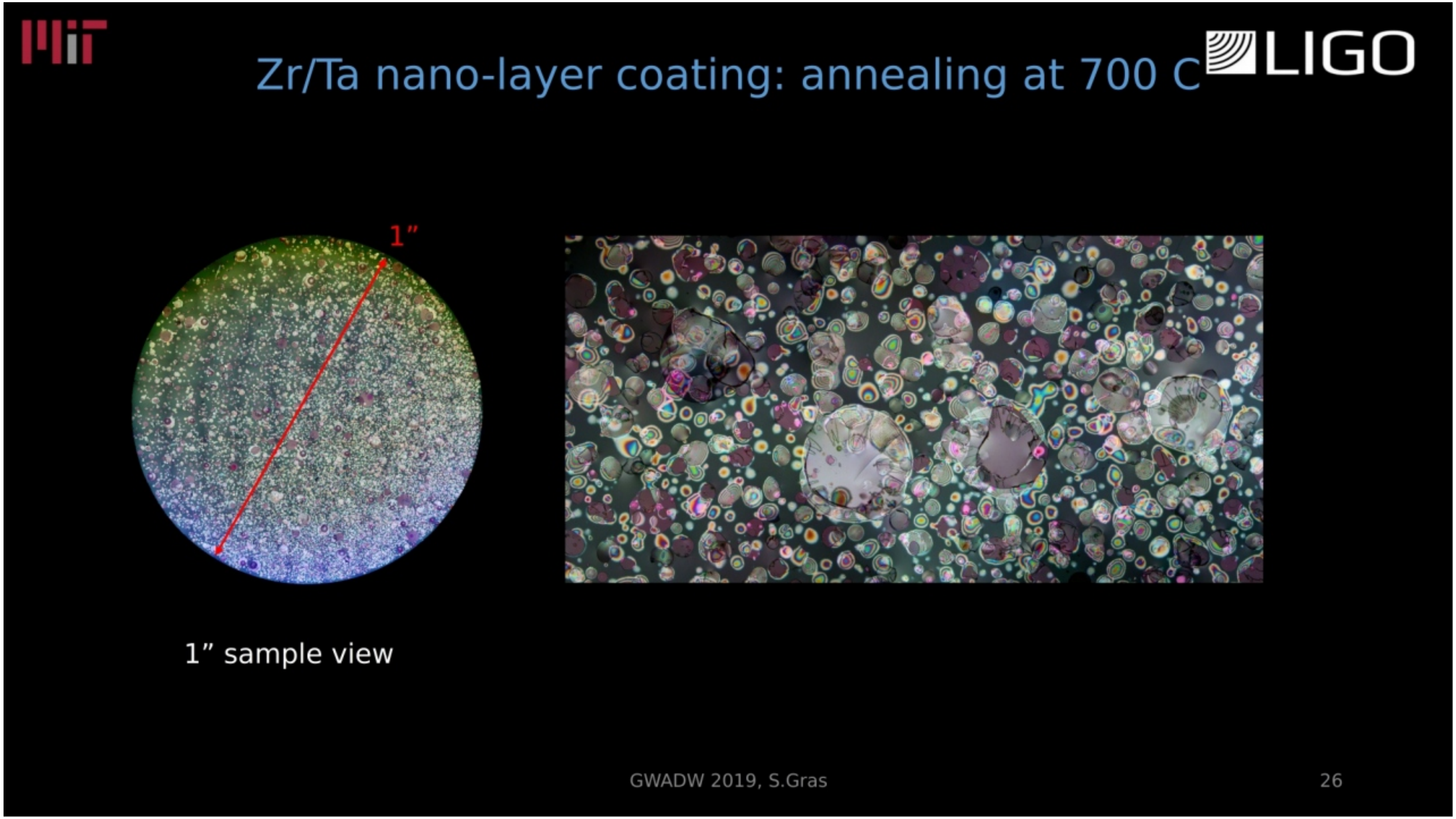
- electro-optic and piezoelectric effects (initial discussion Abernathy T1400726)
- scaling (Cole estimated ~$40M for GaAs substrate + MBE + bonding tool)
- Mechanical loss at RT on crystalline substrates
- Scatter and absorption evaluation, effect of defect, large area
- Who is doing the work? (how much will industry drive, how much do we need to do)?

discussion...

We.AM2a

Crystalline Coatings

Speaker: Stuart Reid (SUPA, University of Strathclyde)



We.AM2a
Alloys, nanolayers and multi-material coatings
Speaker: Slawek Gras (MIT)

We PM 3 B:
kHz detection
Convener: Denis Martynov
(University of Birmingham)

Finding the state-space rep for transfer func.

Identify desired transfer function **(freq. domain)**

↓

Find a *state-space* representation **(time domain)**

↓

Find the physically realizable one

Example: tuned cavity

$$G(i\omega) = \frac{i\omega - \gamma}{i\omega + \gamma}$$

$$\dot{\vec{x}} = A\vec{x} + B\vec{u}$$

$$\vec{y} = C\vec{x} + D\vec{u}$$

No unique mapping from G to (A, B, C, D)!

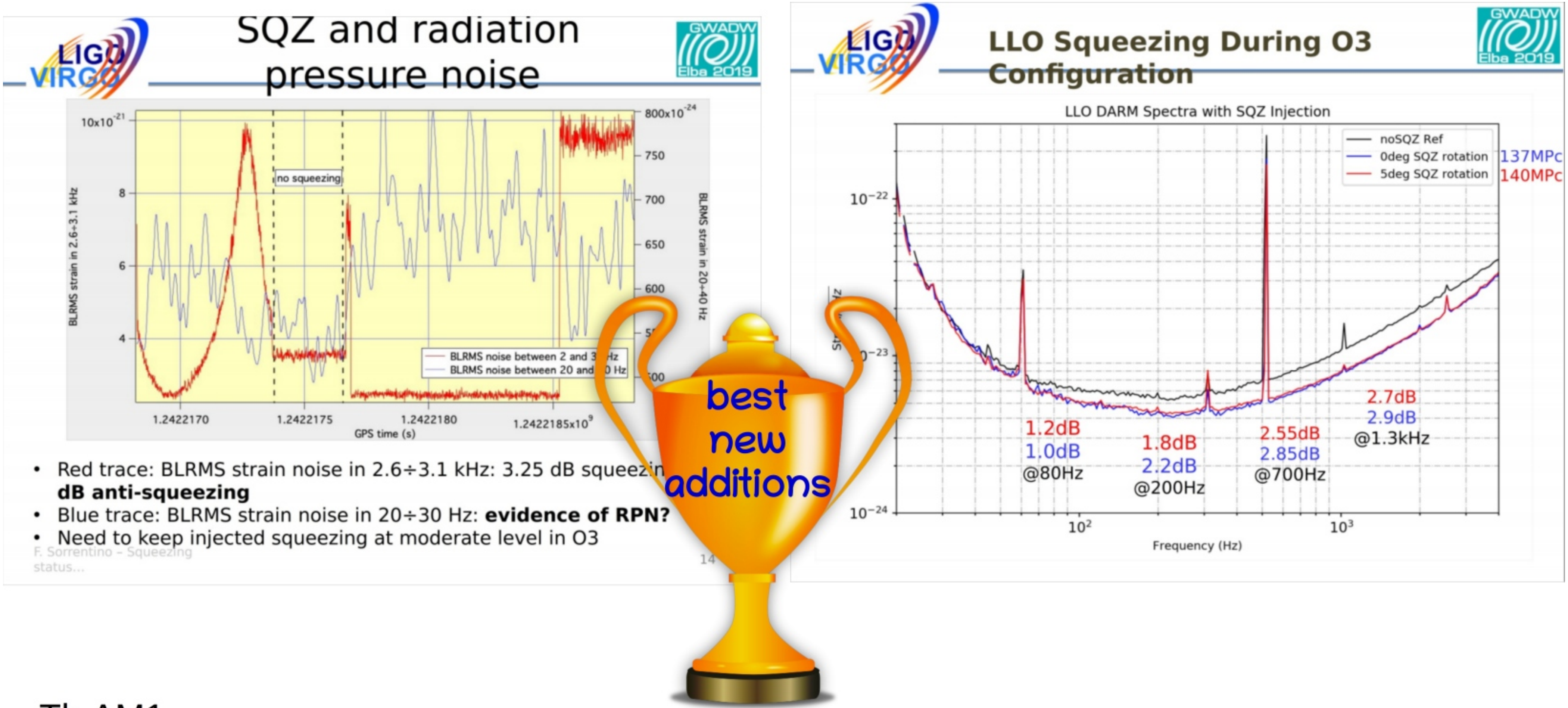
Need to ensure that

$$d[x_i, x_j] = 0$$

Constrains (A, B, C, D)

We.PM3B
On the physical realisation of an (unstable) optical filter
Speaker: Joe Bentley

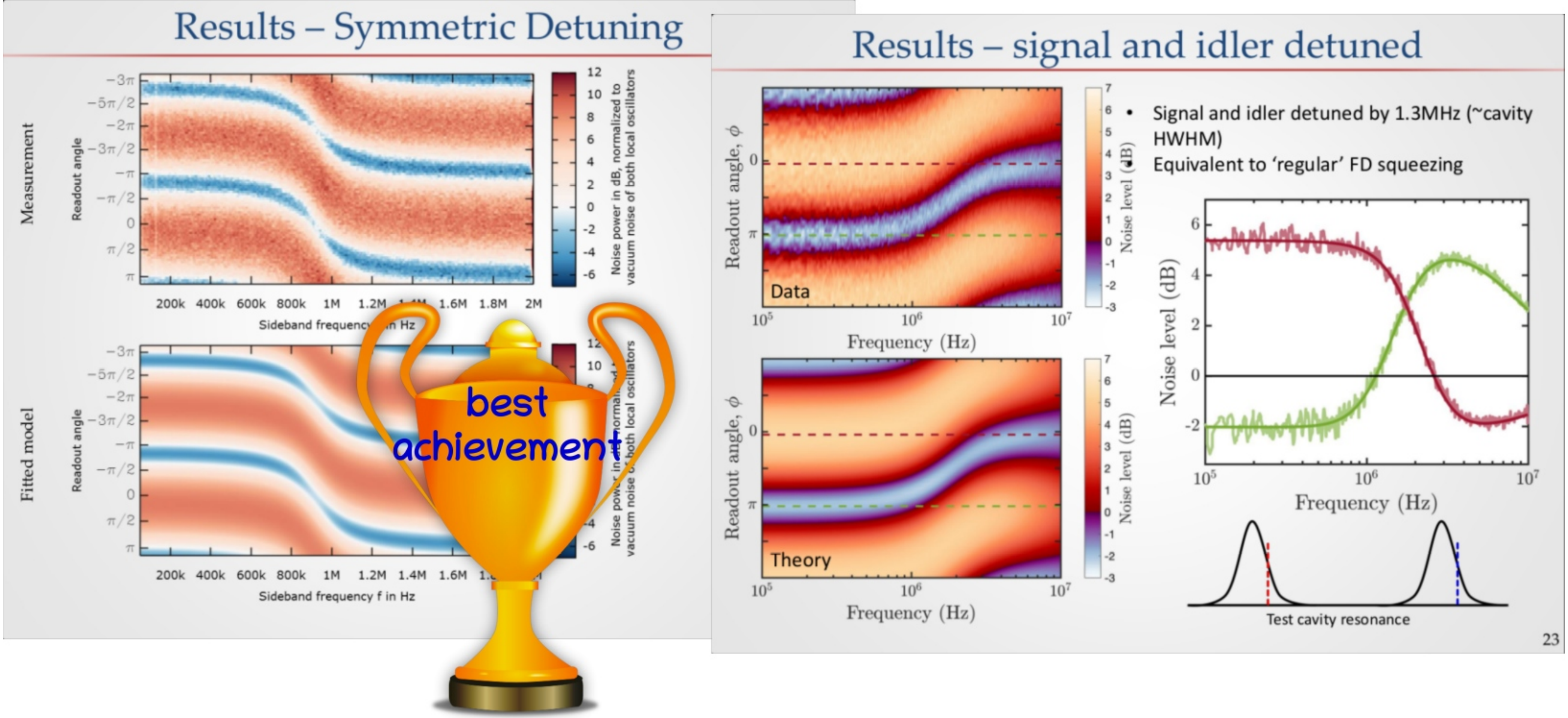
Th AM 1: Squeezing, Topology, Quantum Information Convener: Haixing Miao (University of Birmingham)



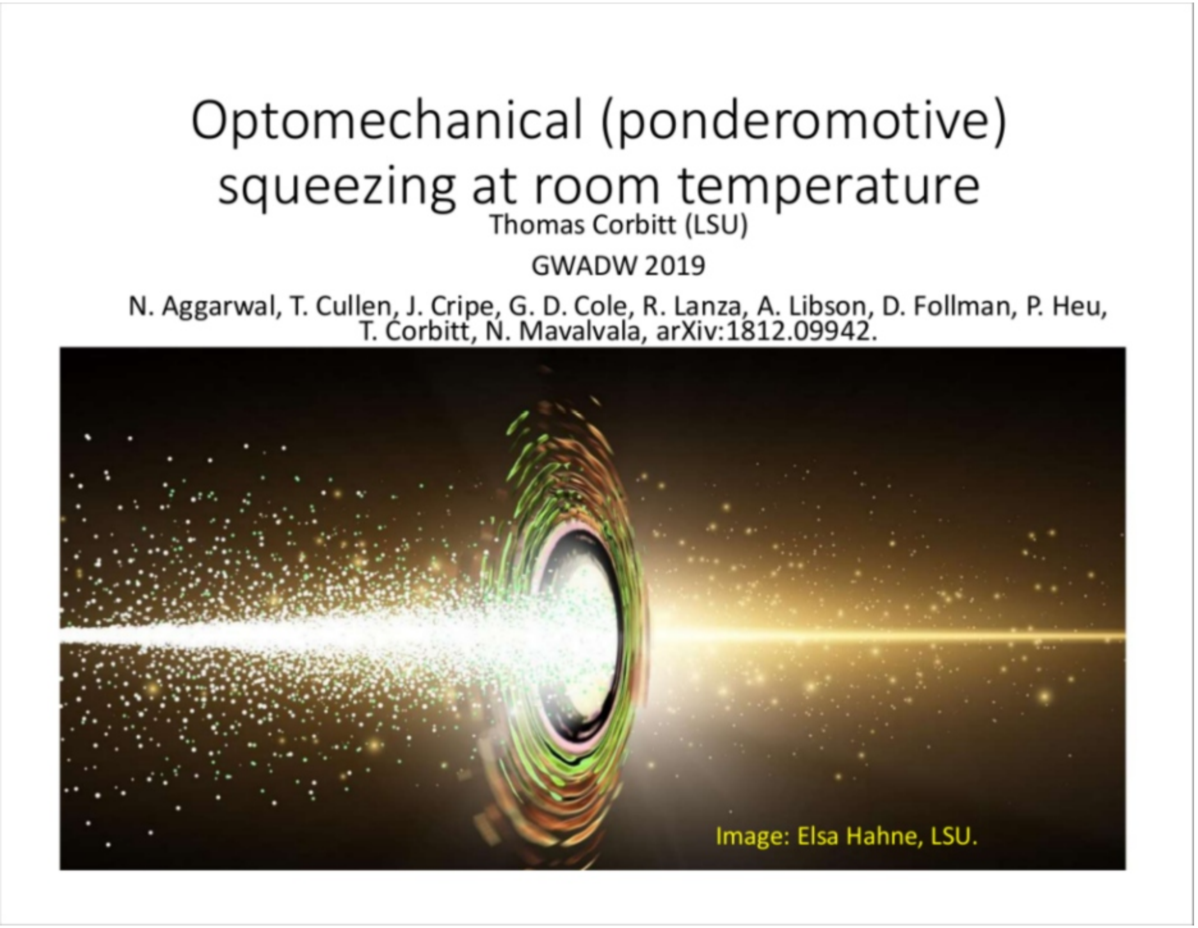
Th.AM1

Squeezing status from LIGO & VIRGO

Speakers: Fiodor Sorrentino (GE), Haocun Yu



Th.AM1
Einstein-Podolsky-Rosen (EPR) squeezing experiments from ANU & Hamburg
Speakers: Jan Gniesmer (University of Hamburg), Min Jet Yap (Australian National University)



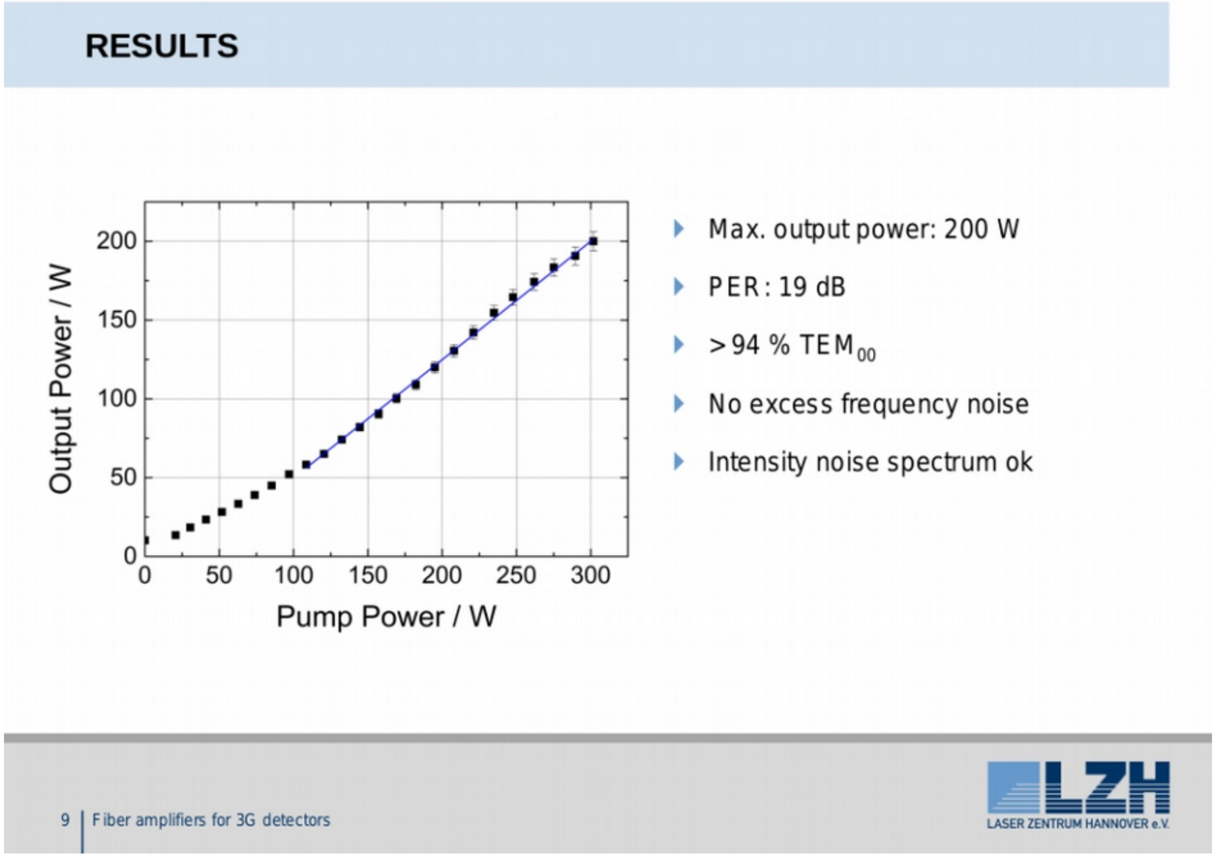
Th.AM1
Optomechanical squeezing experiment at LSU
Speaker: Thomas Corbitt (LSU)

Current status

- Chip design being finalised
- Ongoing study on coupled cavity control (modelling+experiment)
- First aLIGO CDS standalone rack built in Birmingham
- Practising optomechanics with the existing chip
- Design of the experimental layout ongoing

Th.AM1
Enhancing the optomechanical interaction with a coupled cavity
Speaker: Artemii Dmitriev (University of Birmingham)

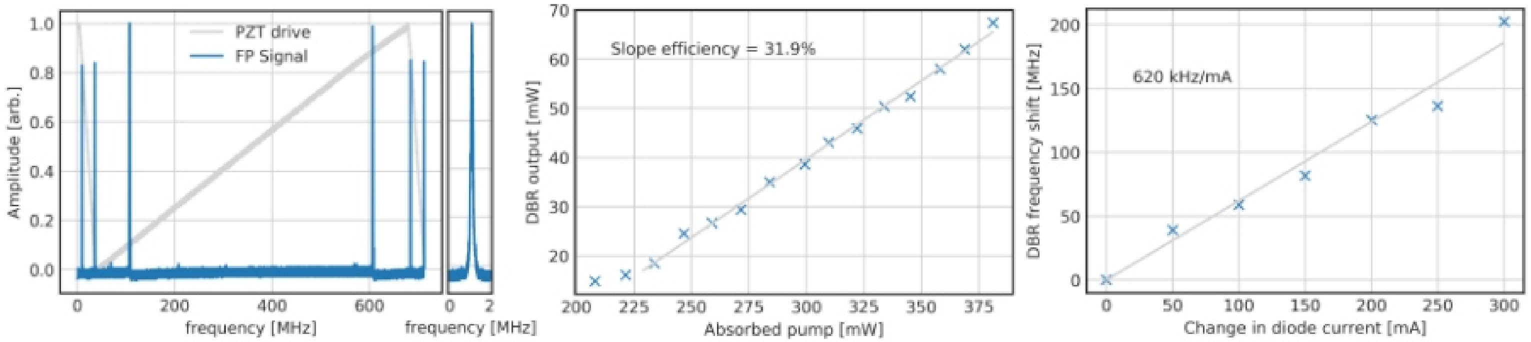
Th AM 2: 3G Light Sources and Optics
Convener: Benno Willke (Albert Einstein Institute Hannover)



Th.AM2
Fiber amplifiers for 3G GWDs
Speaker: Michael Steinke

Diode-pumped MO: 50mW, compact

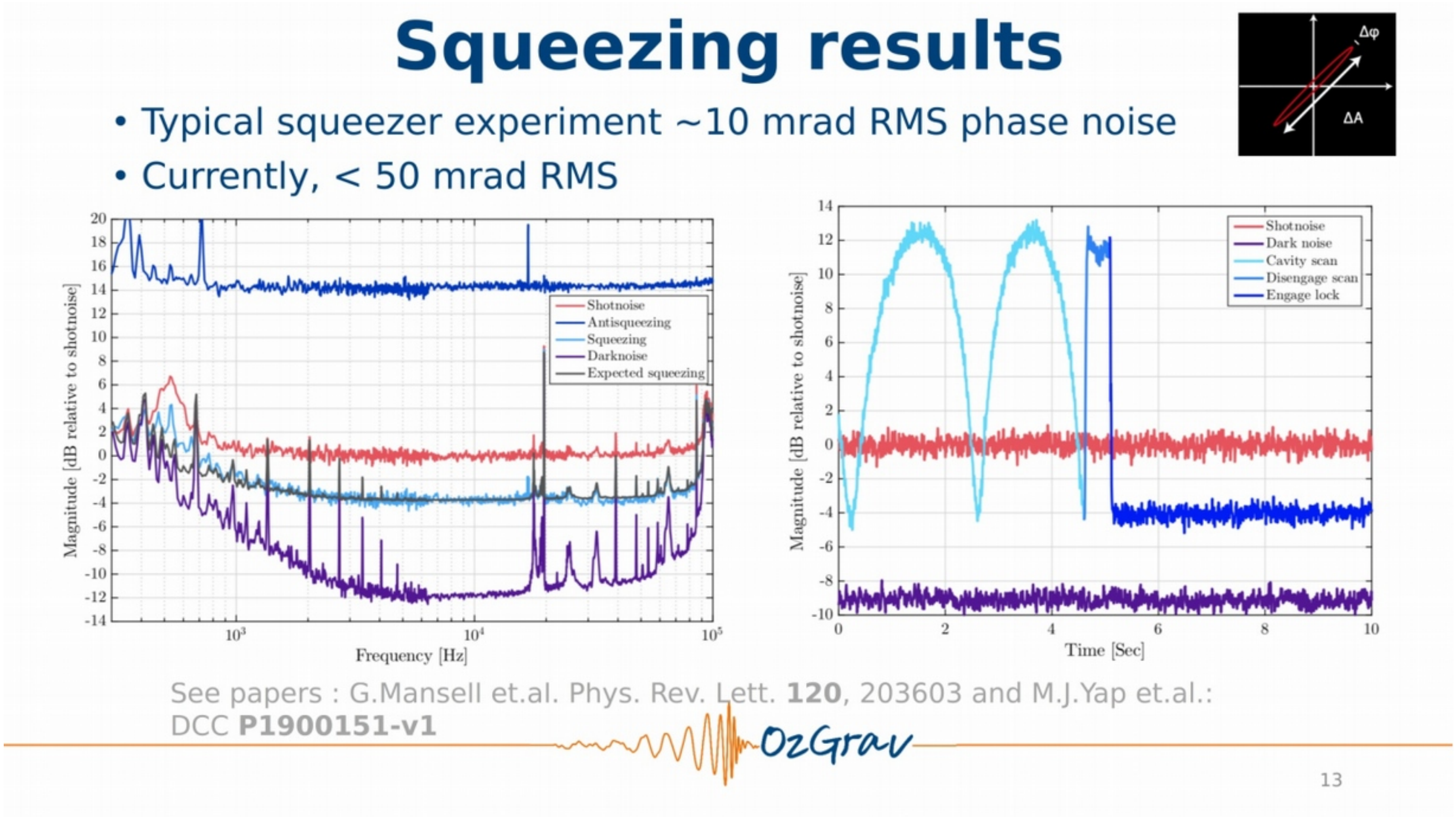
- Pump using 450mW 1.55μm single-mode fiber-coupled diode laser
- Single longitudinal mode, linewidth < 100 kHz
- Output power 70mW max, limited by pump power
- Pump-power dependent frequency tuning of 620 kHz/mA (bandwidth?)



Scanning FP

Frequency v's diode current

Th.AM2
Tm:fiber lasers and optical absorption at 2um
Speaker: Peter Veitch (University of Adelaide)



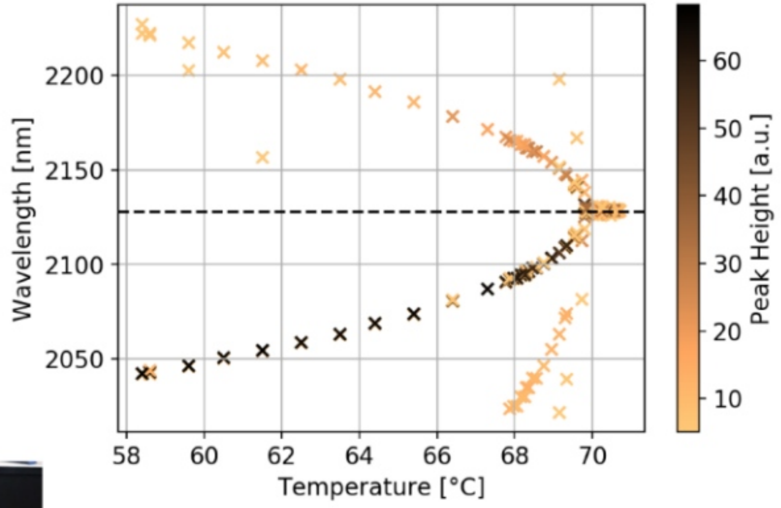
Th.AM2

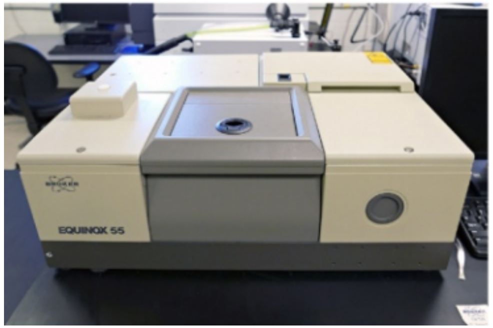
Squeezed light at 2 um

Speaker: Vaishali Adya (Australian National University)

First Results: OPO Wavelength Tuning

- measured OPO output spectra for different temperatures of the nonlinear crystal
- degeneracy reached at around 70°C (higher than expected, needed some redesign of our OPO to reach those temperatures)

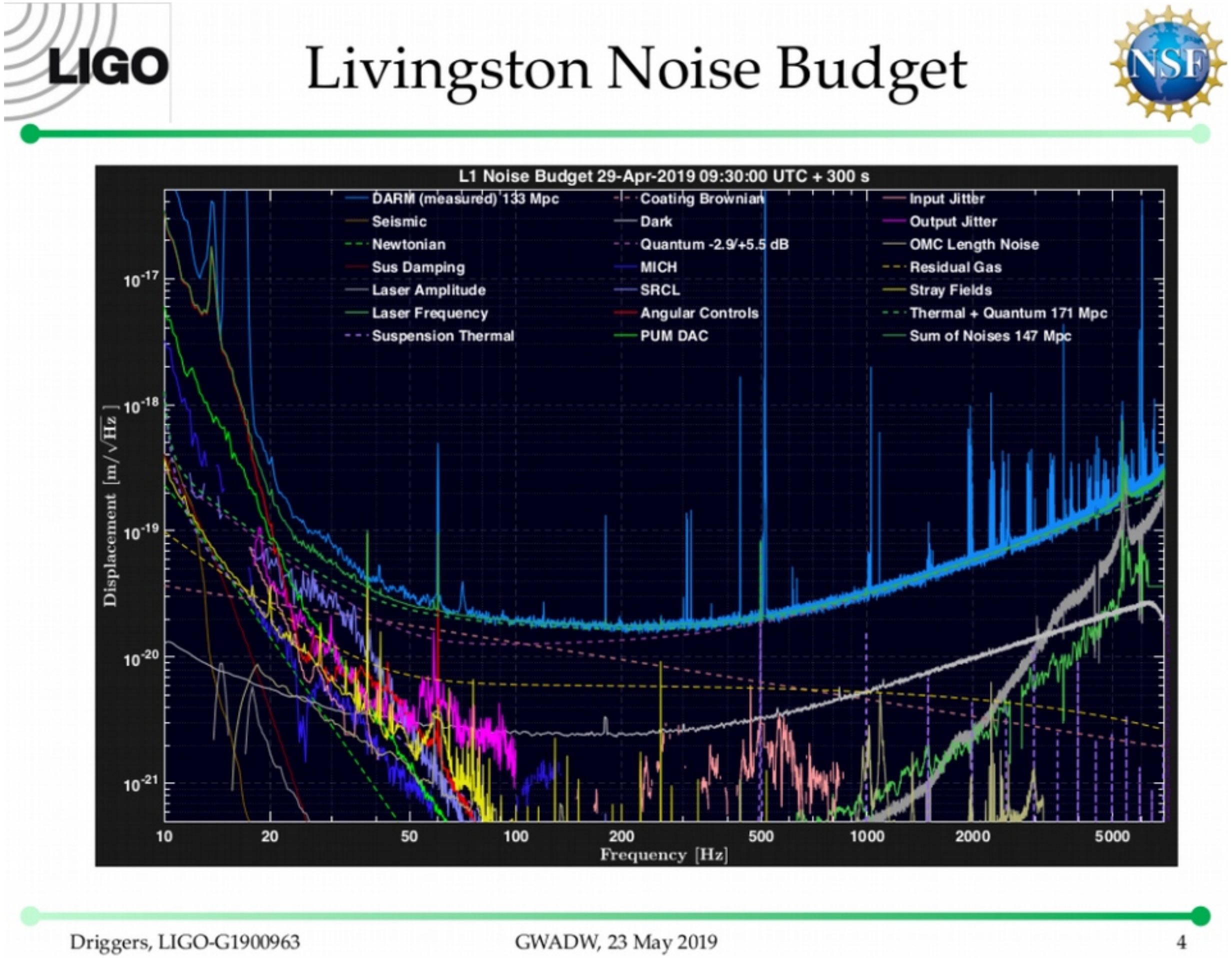




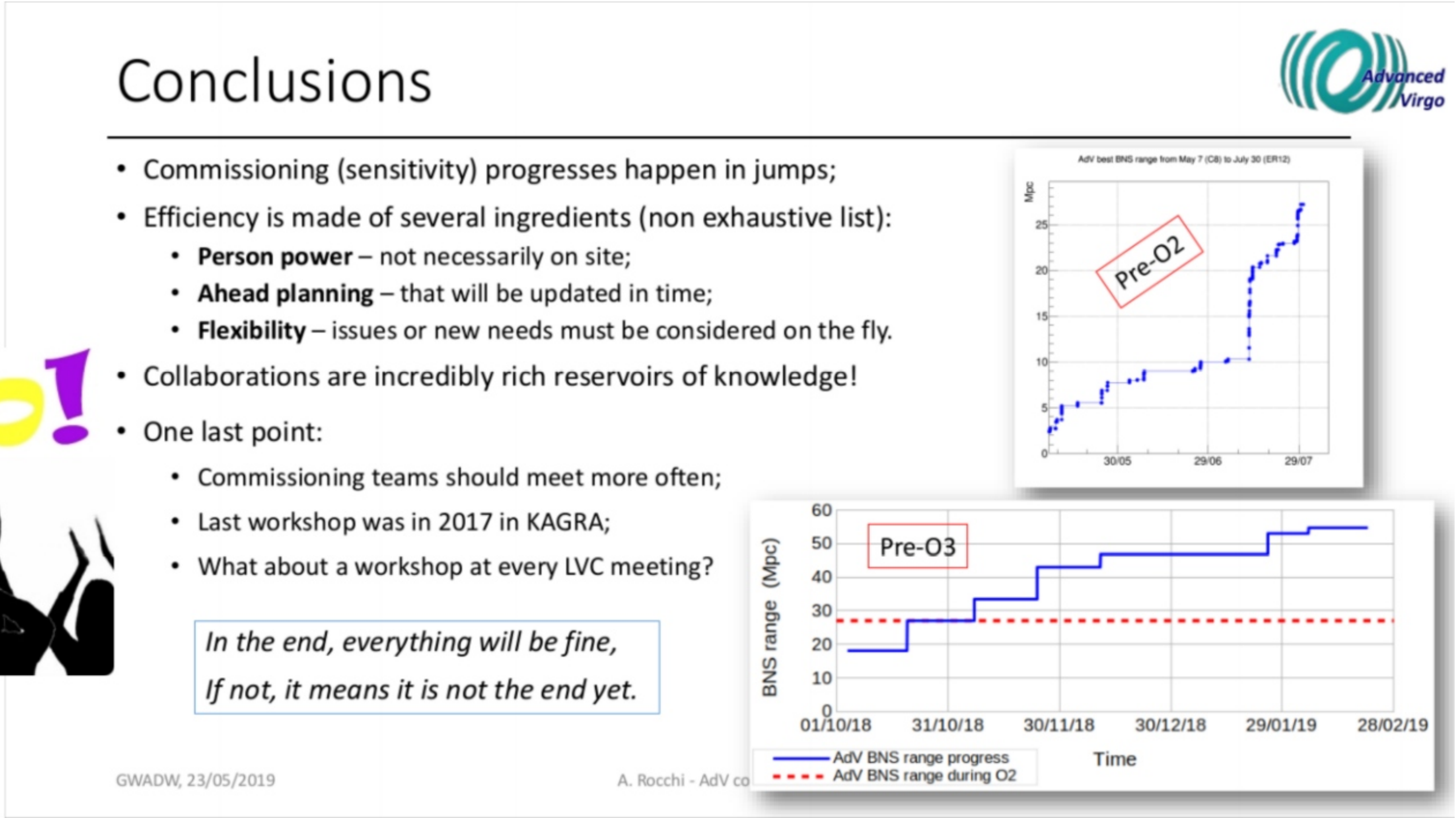
Bruker Equinox 55 FT-IR Spectrometer
(picture from UWLAX, ours looks similar)

Th.AM2
3G light sources at 2um
Speaker: Dr Sebastian Steinlechner (University of Hamburg)

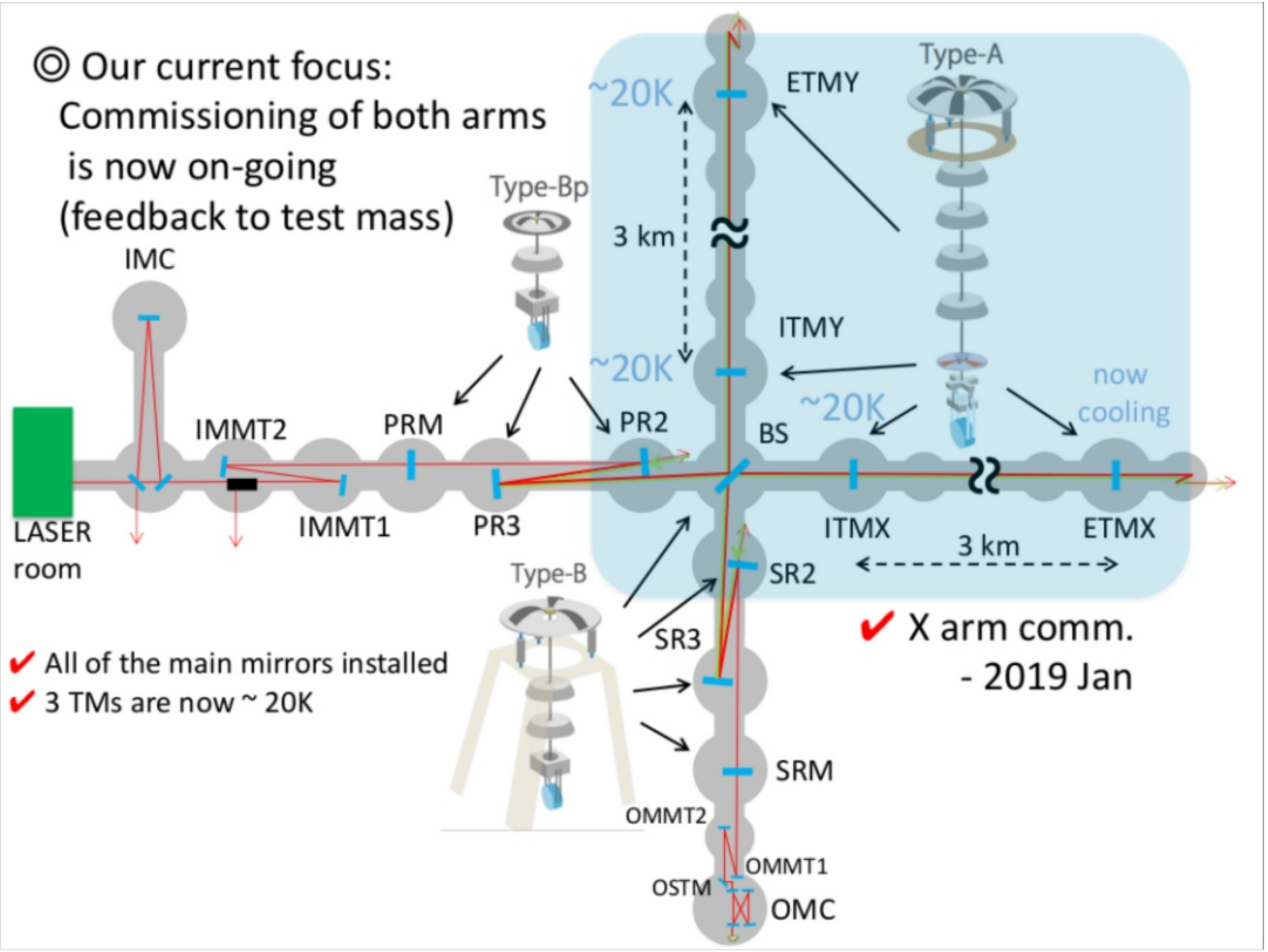
Th PM 3:
Commissioning 2G
Convener: Viviana Fafone (ROMA2)



Th.PM3
LIGO
Speaker: Jenne Driggers (Caltech)



Th.PM3
VIRGO
Speaker: Alessio Rocchi (ROMA2)



Th.PM3
KAGRA
Speaker: Yutaro Enomoto (ICRR, University of Tokyo)

Th PM 4:
Backscatter Modeling/Interferometer Simulation
Convener: Andreas Freise (University of Birmingham)

Comparing to LISO

- **LISO files in Zero can be compared to LISO automatically**
  - `zero liso my-circuit.fil --compare`
  - Runs LISO directly and overlays results to Zero
- **Automatic tests against hundreds of LISO files identical within 10^-5 relative/absolute tolerance**

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Th.PM4
Zero: a modern circuit simulation tool¶ 10m
Speaker: Sean Leavey (AEI Hannover)

Conclusion

EGO - VIRGO

- Stray-light is an old enemy of GW interferometric antennas
  - It comes from a diversity of possible defects
  - It can probe seismically excited mechanical structures and recombine with the ITF main beam burying GW signals
  - It is difficult to simulate
  - It is ineherently non-linear

- Despite huge efforts, it threatens the achievement of design sensitivity, in particular at low frequency
- Further advances in prediction, mitigation and monitoring are needed
- New materials with lower BRDF are to be explored for 3rd gen, and possibly chose a site that is...

Th.PM4
Scattered light in Virgo
Speaker: Francesco Fidecaro (PI)

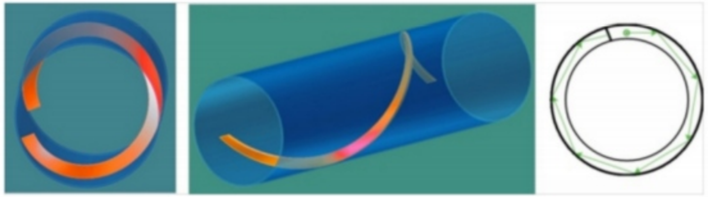
Conclusions

- Still useful to use analytic calculation to search parameter spaces, find solutions
- Useful to check all cases of chosen realization through simulation
  - Need tools to help here
- Diffuse scatter more a geometric problem, but plugs into optical sensitivities (determinable through incoherent simulation)
  - Is diffuse modeling fully separable?
  - Backscatter not separable, but also less geometric.
  - Specular scatter geometric, is it separably modellable
- (squeezed) shotnoise-limited field sensitivity sufficient for output backscatter calculations
  - Radiation Pressure effect “ignorable” (must use worst case)
  - (but does not relax reqs. W.R.T. SN.)
- Unmodelled sensing noise isn’t necessarily a scatter problem, but (more total) controls modeling may prevent design flaws.
  - Want to drive this point for future ASC design

Th.PM4
Scattering in filter cavities
Speaker: Lee McCuller

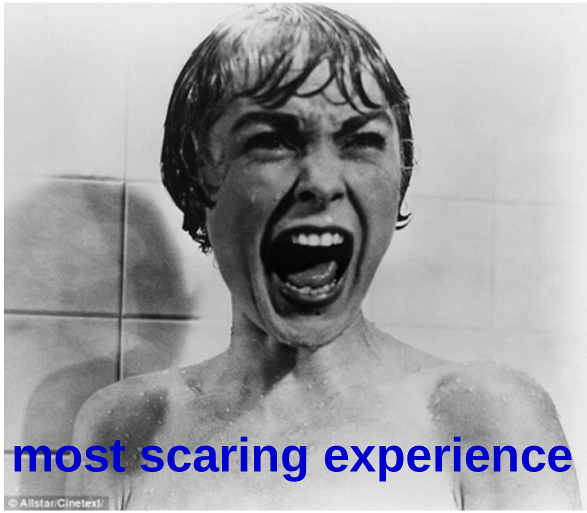
Better Baffles : Helical

- Reflections on a helical baffle send light in an infinite helical path along the beam pipe, which is always hidden from the mirrors.
- Light is effectively totally absorbed without a chance of scattering towards the mirrors.
- This removes the requirement that the pipe surfaces are dark.
- Spiral baffles also do not need to be dark.
- Shiny hydrophobic surfaces can be implemented
    - To reduce surface scattering on the baffles themselves
    - To reduce the vacuum water load in the pipe, the bake-out requirements and its costs.

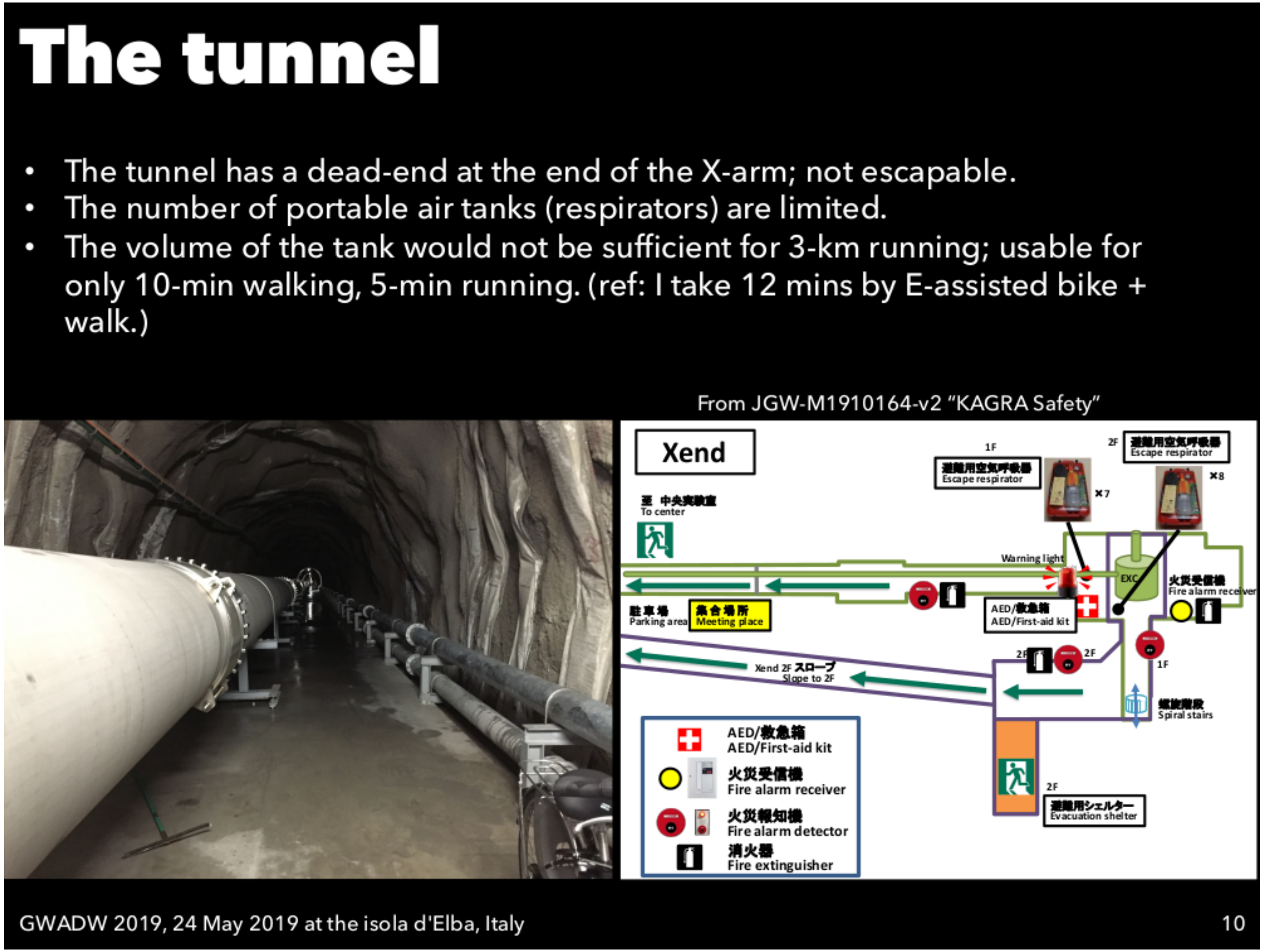


Th.PM4
Light Baffles and Beam Pipe Design for Gravitational Wave Detectors
Speaker: Stefano Selleri (University of Florence)

Fr AM 1:
Errors Not To Be Made Again
Convener: Harald Lueck (AEI Hannover (MPI f. gravitational Physics / Inst. f. Grav.physics Leibniz Uni Hannover))



most scaring experience



Fr.AM1

The beauty of hindsight: a discussion of Mis-steps in KAGRA

Speaker: Tomotada Akutsu (National Astronomical Observatory of Japan)

Happy Ending

- Completed
  - » within budget
  - » on schedule
- Detections were made
- We are eager to do it again
  - » …and make new mistakes

G1900929

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Fr.AM1

The beauty of hindsight: a discussion of Mis-steps in LIGO

Speaker: David Shoemaker (MIT LIGO)

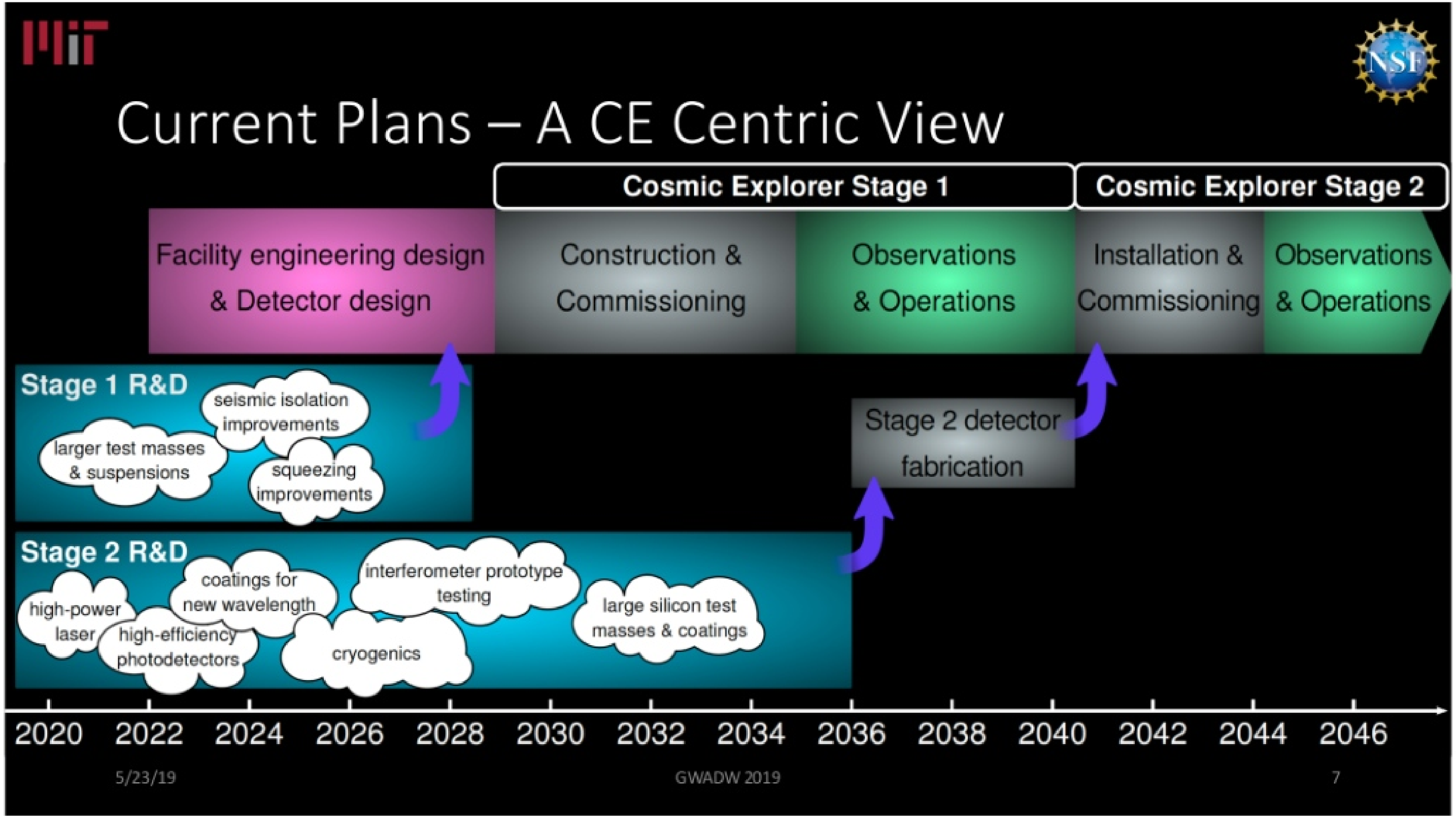
Fr AM 2:
Future Detectors and New Infrastructures
Convener: Stefan Hild (University of Glasgow)

ET: **challenging** project roadmap

ET EINSTEIN TELESCOPE

- 2018-2019 Form the ET collaboration
- 2019-2020 ESFRI roadmap
  - Light TDR to be realised, refine CDR cost evaluation, key options to be selected, ESFRI proposal
- 2022 Site Selection
  - Technical/political activity
  - Requirements need to be compared with the site characteristics through an intense experimental activity in the next 3 years
- 2023 Full Technical Design Report
  - Cost definition
- 2025 Infrastructure realization start (excavation, ….)
- 2030 -2031 end of infrastructure construction, beginning of installation
- 2032+: installation / commissioning / operation

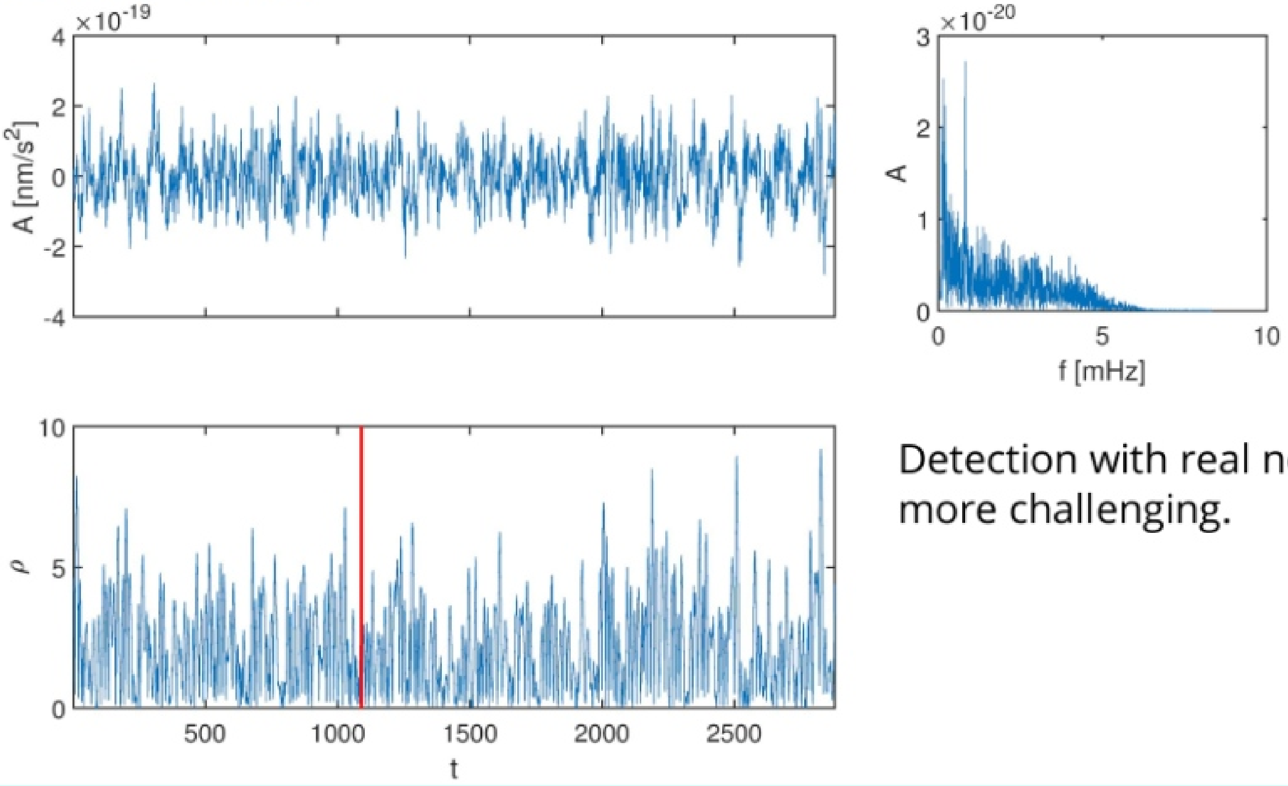
Fr.AM2
Einstein Telescope
Speaker: Michele Punturo (PG), Harald Lueck (AEI)



Fr.AM2
Cosmic Explorer
Speaker: Matthew Evans (MIT)

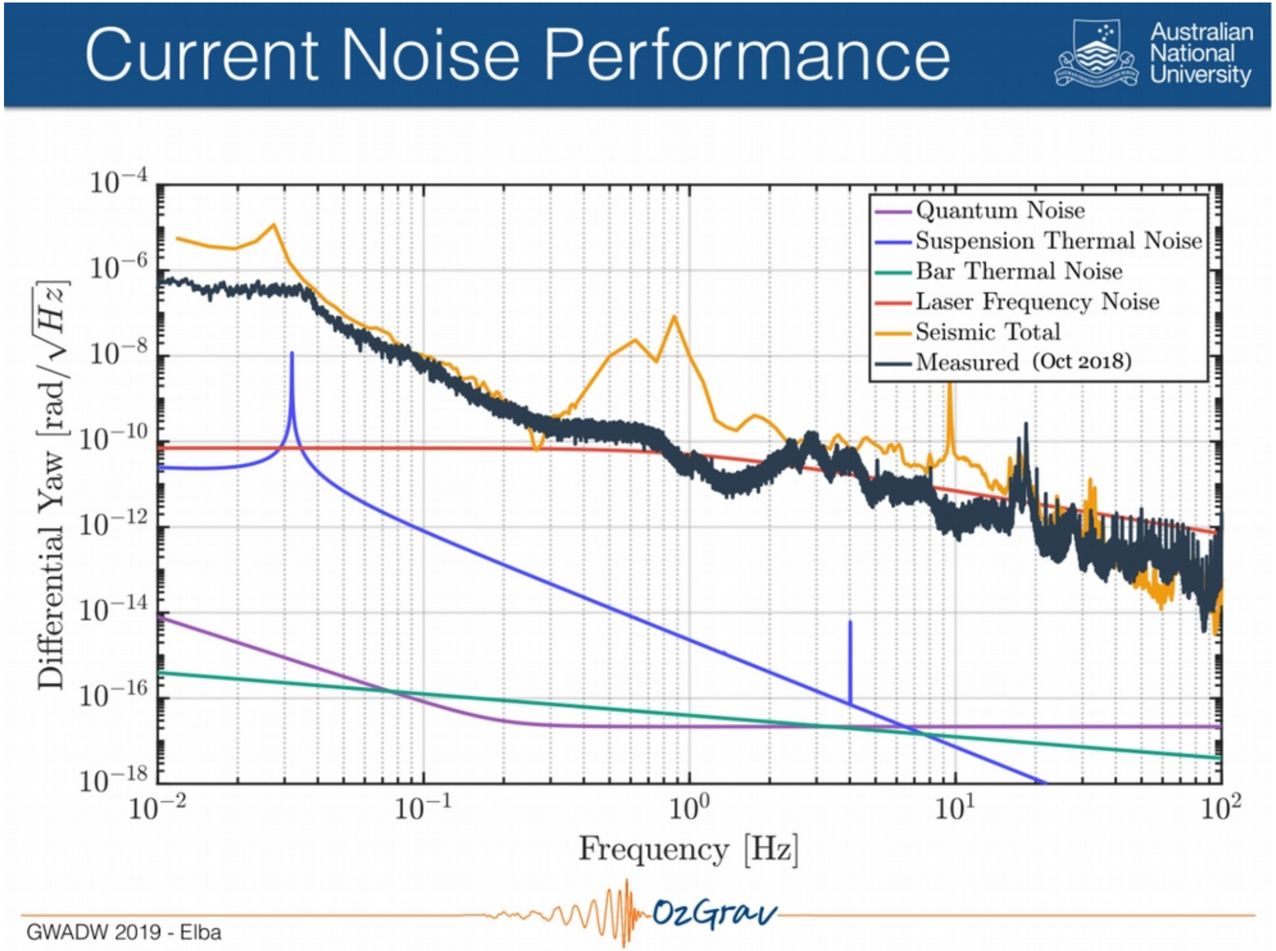
Fr PM 3:
Beyond GW IFO
Conveners: Fiodor Sorrentino (GE), Matteo Barsuglia (APC-CNRS)

Real noise MF output



Detection with real noise more challenging.

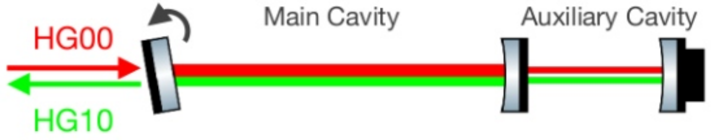
Fr.PM3
The search for gravitational-waves from white dwarf binaries in gravimetric and seismic data using Earth’s normal modes resonance response in the mHz frequency band
Speaker: Josipa Majstorovic



Fr.PM3
Status of TORPEDO torsion bar
Speaker: Bram Slagmolen (The Australian National University)

Readout Scheme

Coupled-cavity wave front sensor (new idea)

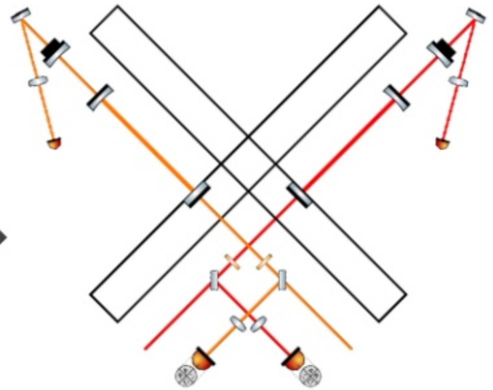


Compensate Gouy phase by auxiliary cavity

- HG10 mode resonates as well as HG00
- Induced HG10 is enhanced
- Higher sensitivity than normal WFS

5×10^{-16} rad/$\sqrt{\text{Hz}}$ @ 0.1 Hz

Optical configuration →



Fr.PM3
Status of TOBA torsion bar¶ 22m
Speaker: Satoru Takano (The University of Tokyo)


AND THE
WINNER IS...

L. Conti - GWADW2019