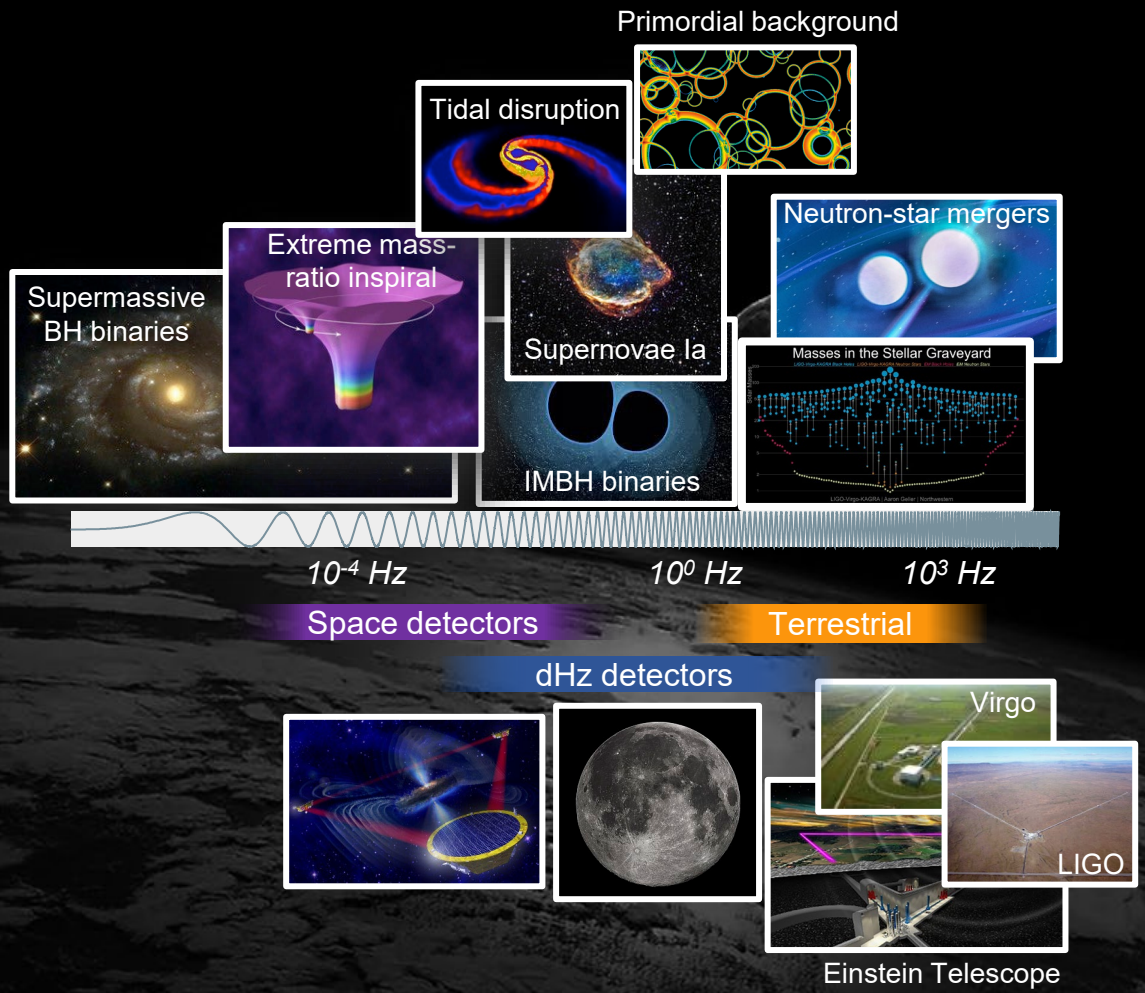
LGWA
LUNAR GRAVITATIONAL
WAVE ANTENNA

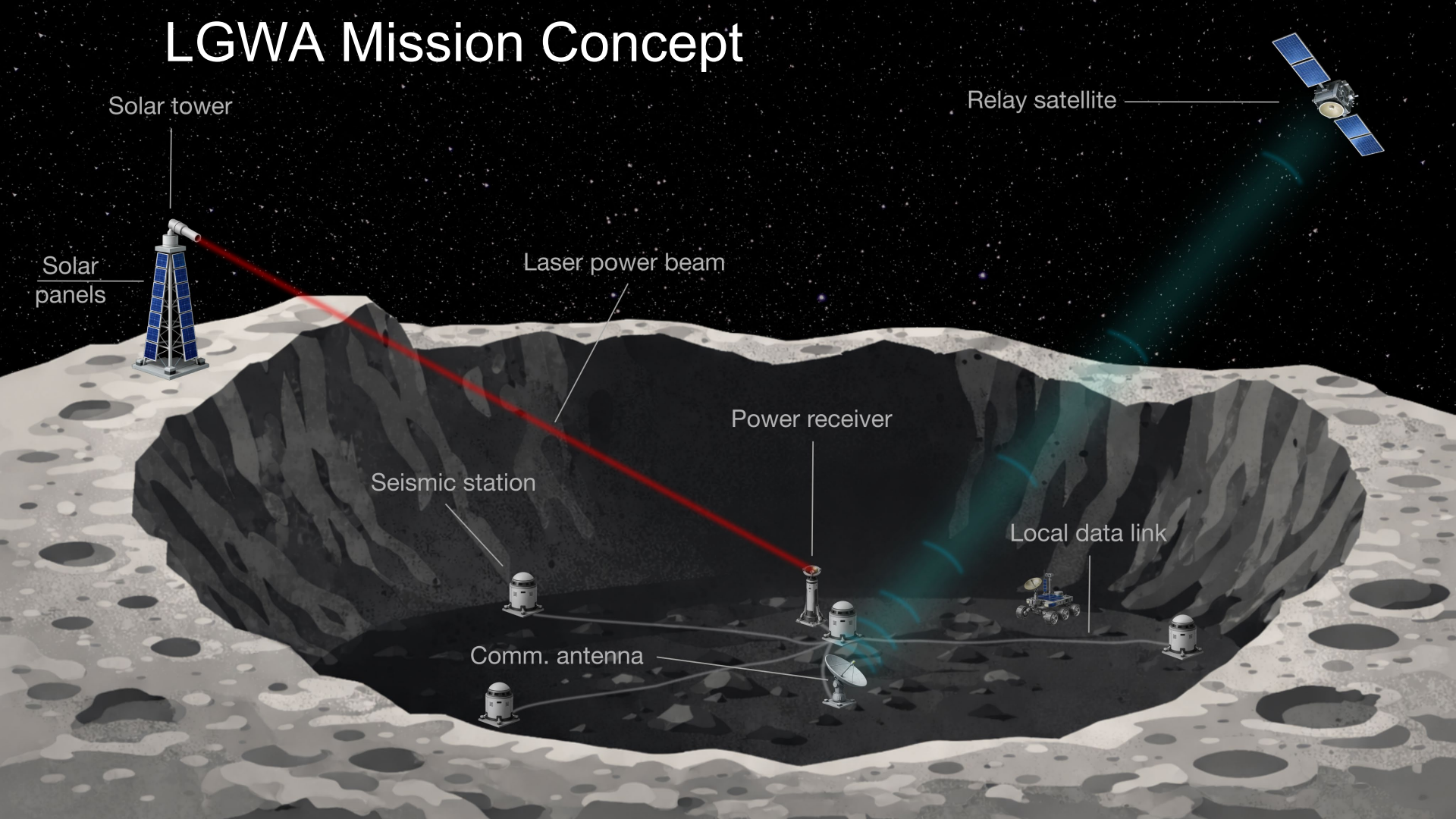


Jan Harms

Gran Sasso Science Institute
INFN - LNGS


Primordial background
Tidal disruption
Extreme mass-ratio inspiral
Supermassive BH binaries
Supernovae Ia
Neutron-star mergers
Masses in the Stellar Graveyard
IMBH binaries
10^{-4} Hz
10^{0} Hz
10^{3} Hz
Space detectors
Terrestrial
dHz detectors
Virgo
LIGO
Einstein Telescope

LGWA Mission Concept



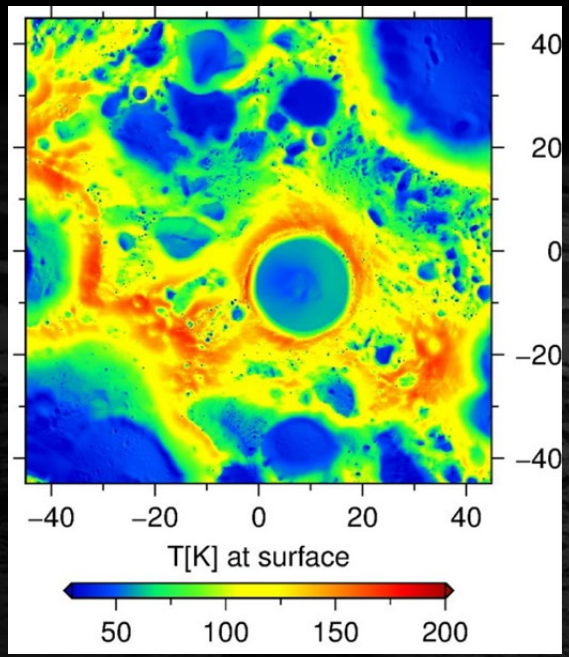
Key Mission Features

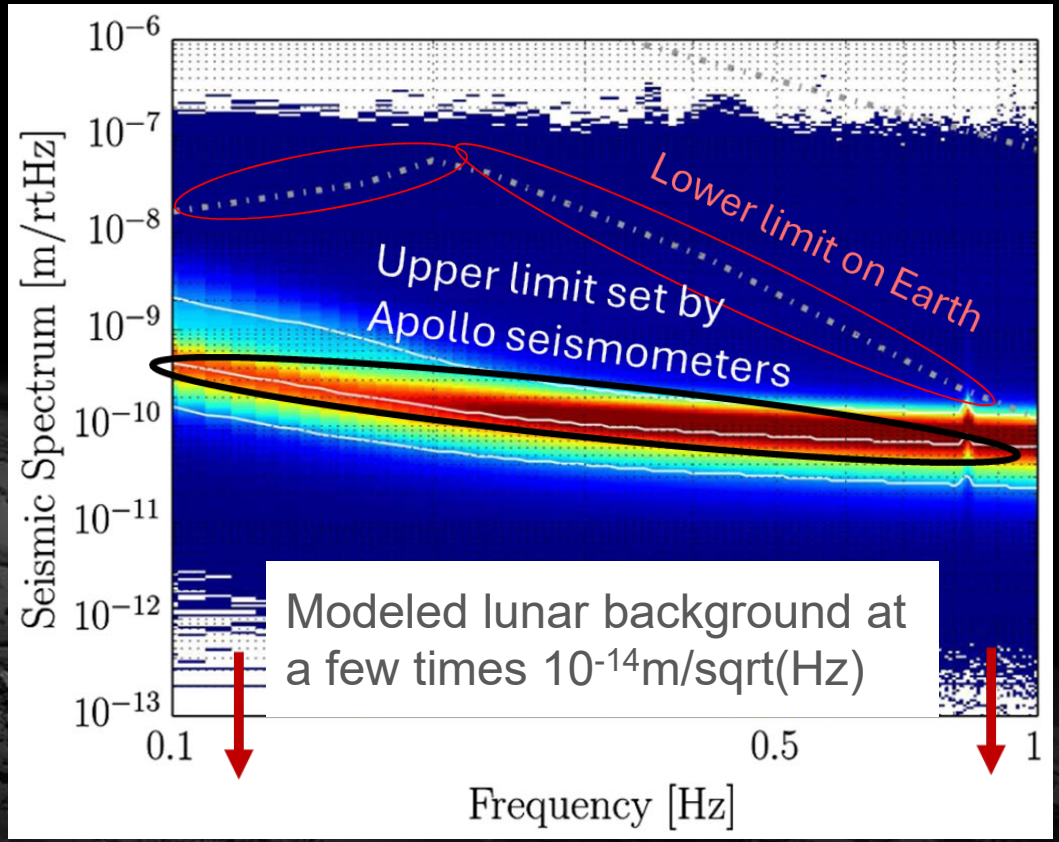
- Sub-femtometer precise ground-vibration measurement to observe the lunar response to gravitational waves (GWs)
- Exploiting the extremely low seismic background on the Moon
- Exploiting the extremely low temperature and high temperature stability inside permanently shadowed regions at the lunar poles
- Station array to mitigate the noise from the seismic background in post-processing

Why the Moon?

The Moon's PSRs might be the seismically quietest sites in the solar system in the dHz band

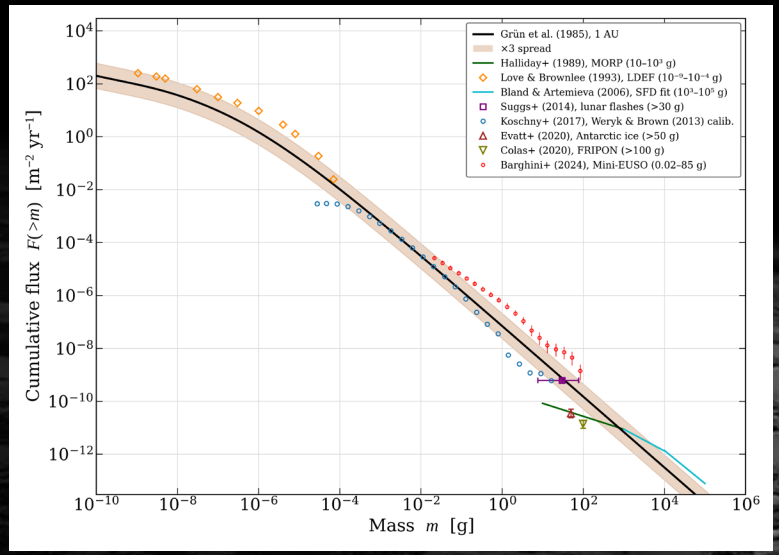
Cold and relatively stable temperatures inside a PSR





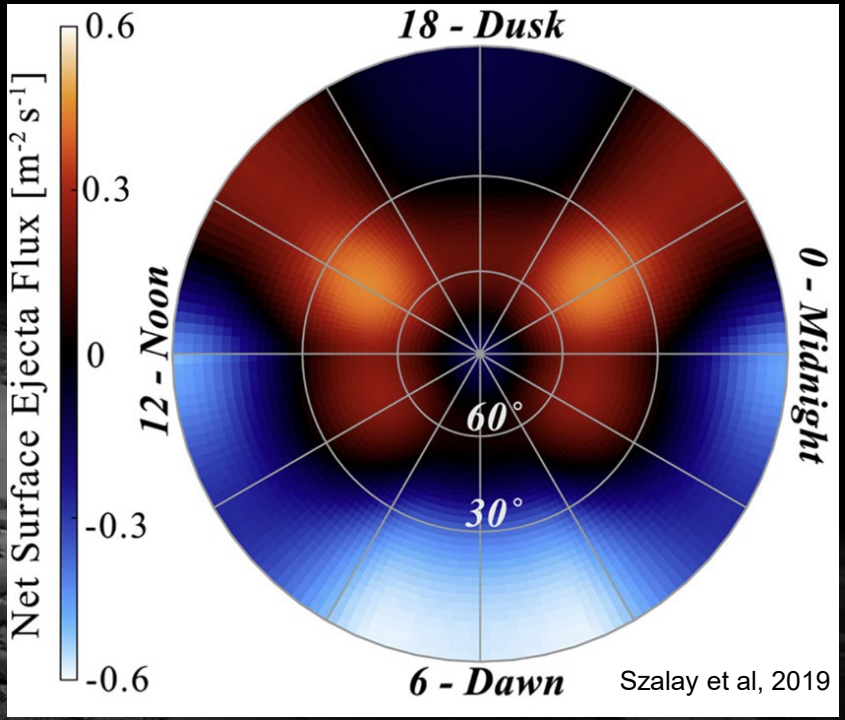
Studying the Spatial Distribution of Meteoroid Impacts

Meteoroid impacts produce a seismic background



From Yan et al (under preparation)

Weak impact ejecta flux at the poles (simulation)



Szalay et al, 2019

Seismic background mitigation with the Lunar Gravitational-wave Antenna

Accepted for PRD

Han Yan[1,2,3*] and Jan Harms[3,4]
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[2]Kavli Institute for Astronomy and Astrophysics, Peking University, 100871 Beijing, China
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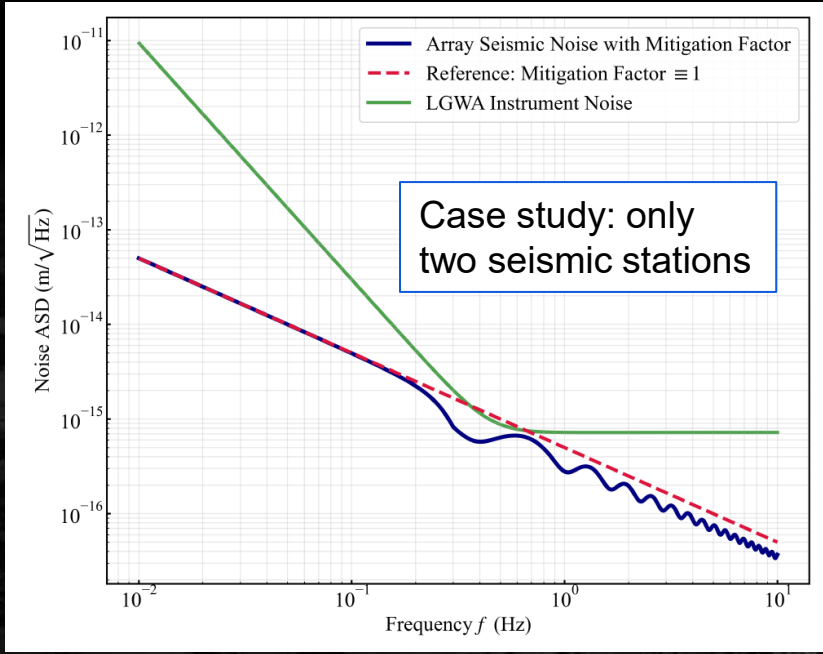
[4]INFN, Laboratori Nazionali del Gran Sasso, 67100 Assergi, Italy

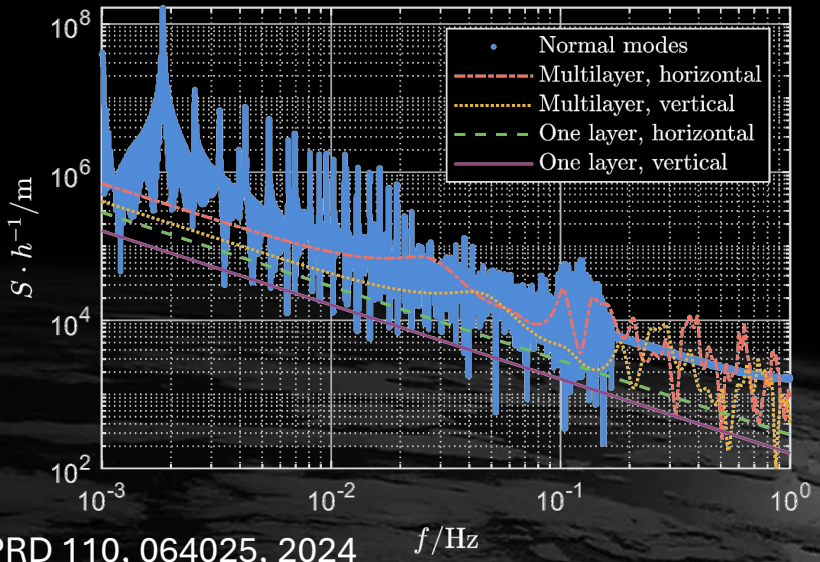
(Dated: April 29, 2026)



- A first study of the seismic background reduction through optimal array processing is under review
- Considering two stations, the average mitigation of an isotropic seismic background was calculated.
- Up to a factor 2.3 reduction can be achieved on average depending on frequency and distance between the two stations.

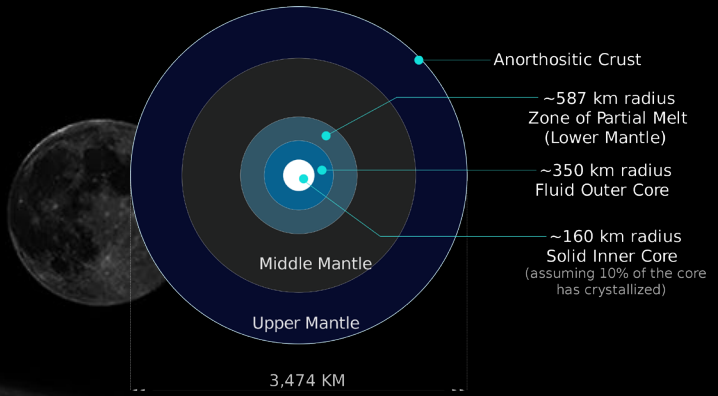
Lunar GW Response

Preliminary models of lunar GW response



PRD 110, 064025, 2024

Moon's internal structure



- Calculating LGWA instrument requirements
- Calibrating LGWA data

PHYSICAL REVIEW LETTERS **137,** 021409 (2026)

Featured in Physics

Gravitational-Wave Tomography of the Moon: Constraining Lunar Structure with Calibrated Gravitational Waves

Han Yan[1,2,3,*] and Jan Harms[3,4]

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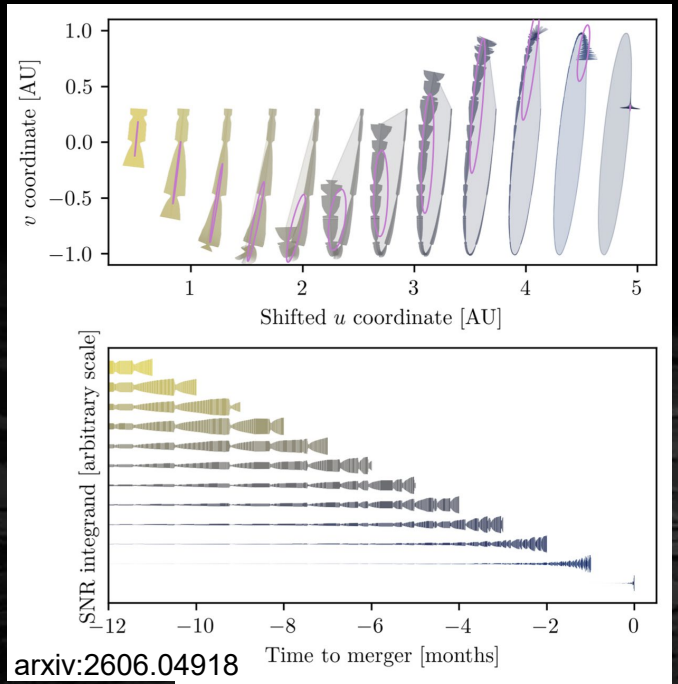
(Received 9 January 2026; accepted 13 May 2026; published 9 July 2026)

Soundcheck selected in 2023 by ESA into the Reserve Pool of Science Activities for the Moon

	Soundcheck (PSR geophysical explorer)	**LGWA** (GW observatory)
Number of seismic stations	1 seismic station (two horizontal channels) deployed on ground	4 seismic stations (each with two horizontal channels) deployed on ground and forming a kilometer-scale array
Displacement sensitivity	<1pm/Hz$^{1/2}$ between 0.1-1Hz	<1pm/Hz$^{1/2}$ at 0.1Hz, <fm/Hz$^{1/2}$ at 1Hz
Deployment site	Inside any PSR (<100K)	Inside PSR with T<40K
Proof-mass material	Niobium	Niobium or silicon
Proof-mass temperature	Ambient PSR temperature (<100K)	Cooled to 4K with low-vibration cryocooler
Readout	Laser interferometric	Laser interferometric or through superconducting coils and SQUIDs
Targeted mission lifetime	2 months	10 years

Multi-band GW Observations

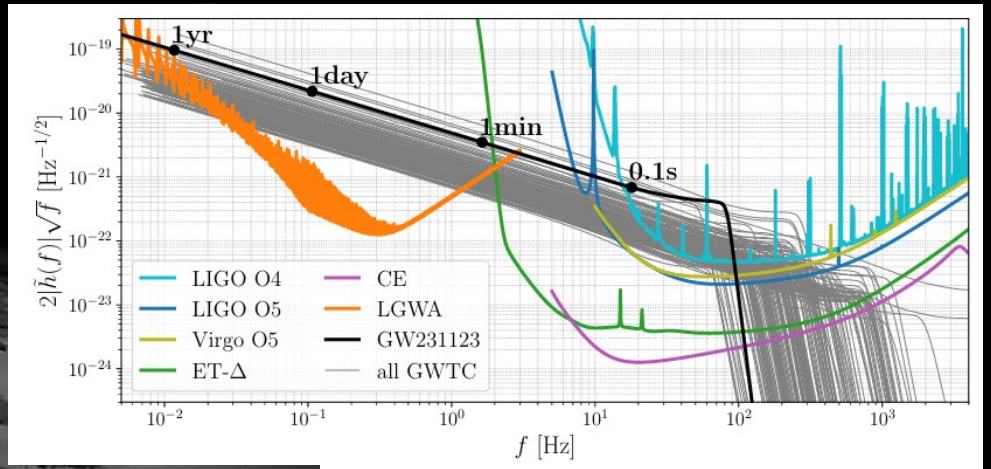
Located between future space-based and terrestrial detectors, dHz detectors are the ideal multiband partners.



arxiv:2606.04918

The geometry of lunar gravitational wave detection

Jacopo Tissino, Filippo Santoliquido, Francesco Iacovelli, Ulyana Dupletsa, Tito Dal Canton, Matteo Ballelli, Ansh Chopra, Luis Enrique Espinosa Castro, Laura Pezzella, Matteo Schulz, Izumi Takimoto Schmiegelow, Jan Harms



PHYSICAL REVIEW D **113,** 123062 (2026)

Gravitational-wave parameter estimation to the Moon and back: Massive binaries and the case of GW231123

Francesco Iacovelli, Jacopo Tissino, Jan Harms and Emanuele Berti
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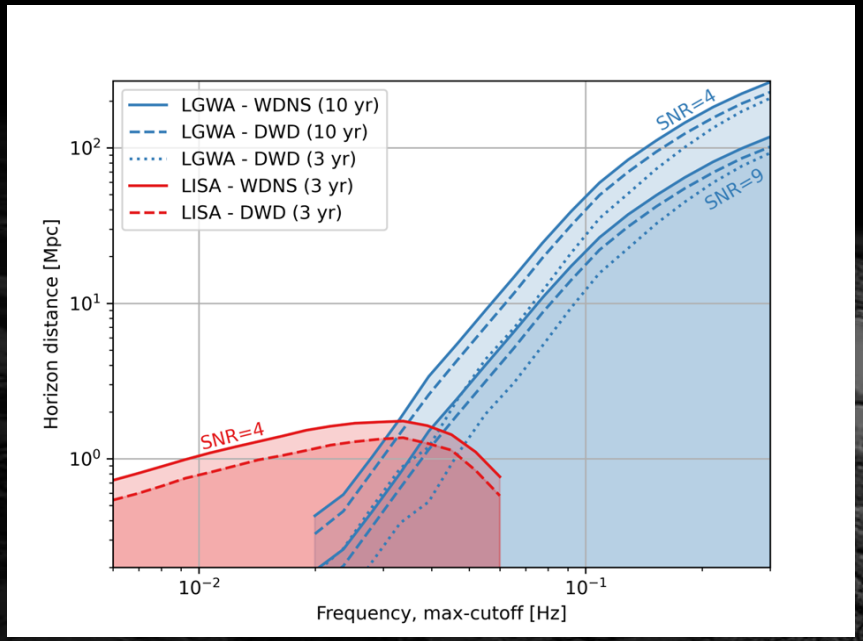
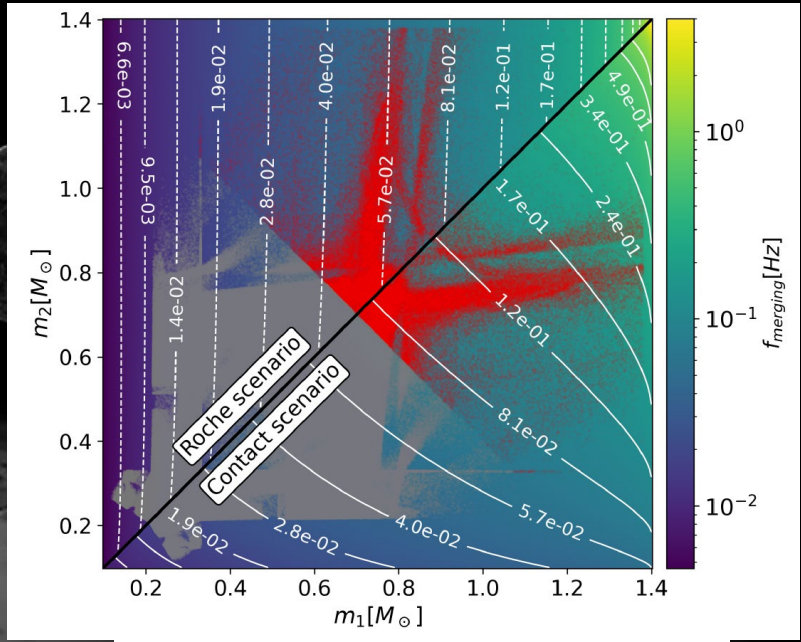
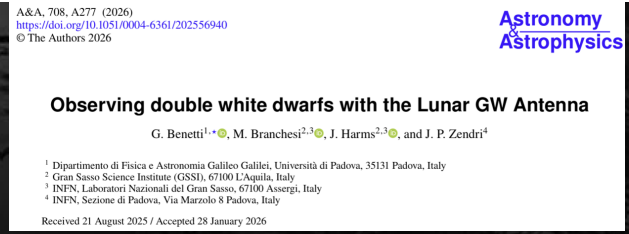
White-dwarf Mergers

The maximum signal frequency has an important impact on the DWD detection horizon



Simulated Milky-way population




A&A, 708, A277 (2026)
https://doi.org/10.1051/0004-6361/202556940
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Astronomy & Astrophysics

Observing double white dwarfs with the Lunar GW Antenna

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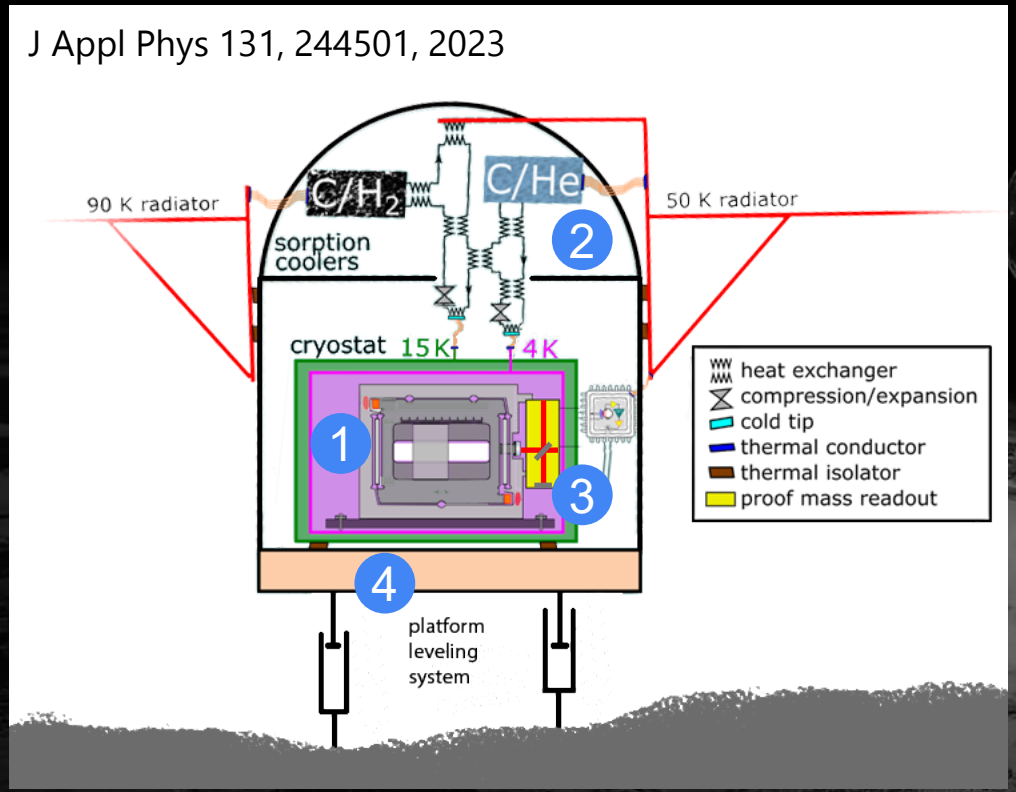
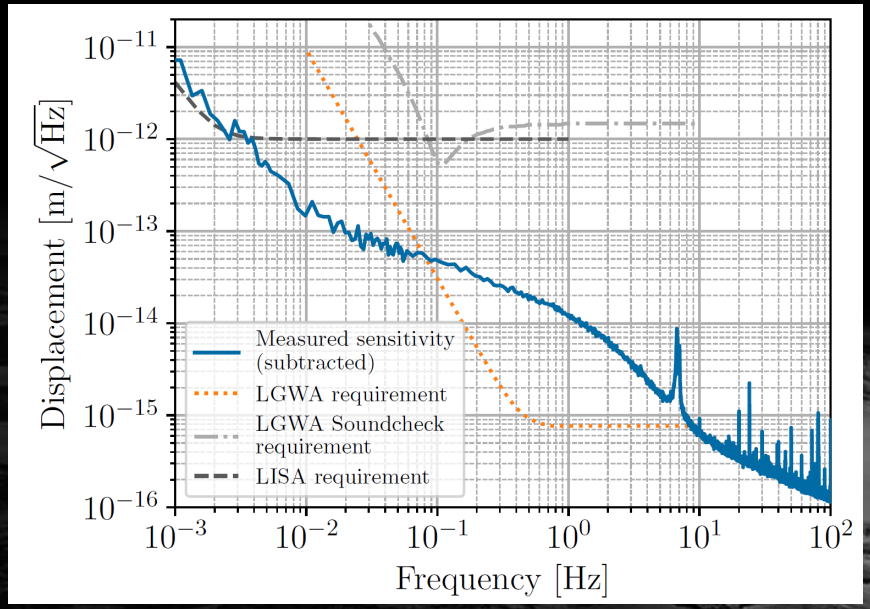
The LGWA Payload Concept



1. Ultra-high quality mechanical structure with superconducting actuators
2. Vibration free sorption cooling (not in Soundcheck)
3. Quantum limited readout
4. Microradian precision leveling at cryo-temperatures

Quantum-limited Sensing

Compact laser interferometer (heterodyne cavity tracking): University of Hamburg



Demonstration of a compact optical resonator-based displacement sensing technique with sub-femtometer precision

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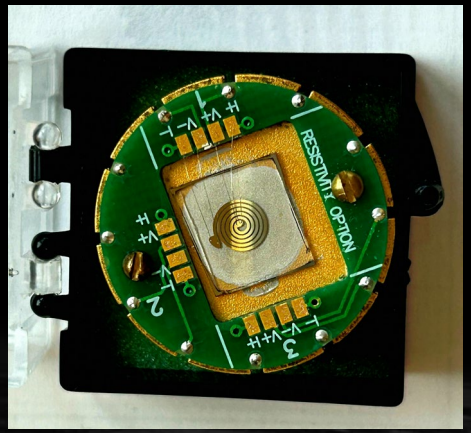
Lunar silicon cavity

Jun Ye[a,1], Zoey Z. Hu[a], Ben Lewis[a], Wei Zhang[b], Fritz Riehle[c], Uwe Sterr[c], Yiqi Ni[d], and Julian Struck[d]

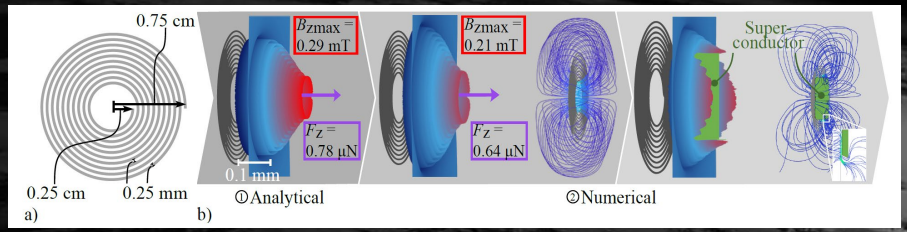


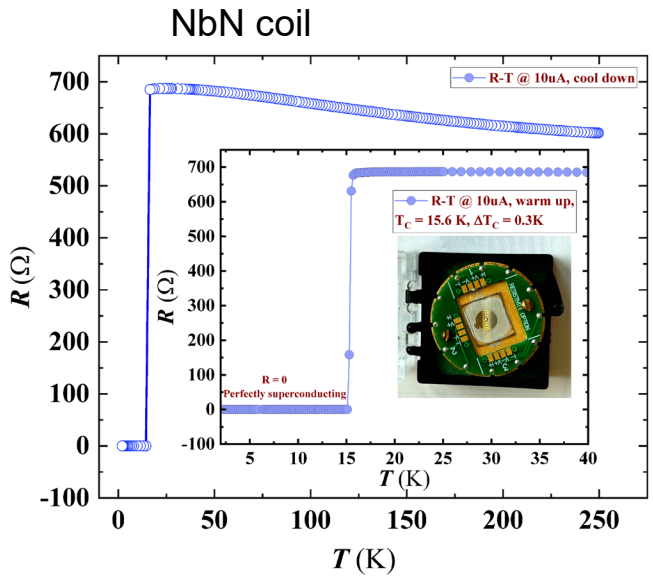
Proof-mass Actuation



Superconducting coils:
Uni Camerino, MPG CPFS, NPL New Delhi, VU Amsterdam

Goal: >60K superconducting actuator coils





Sharma et al (2026)

GR24-AMALDI16 IOP Publishing
Journal of Physics: Conference Series **3177** (2026) 012102 doi:10.1088/1742-6596/3177/1/012102

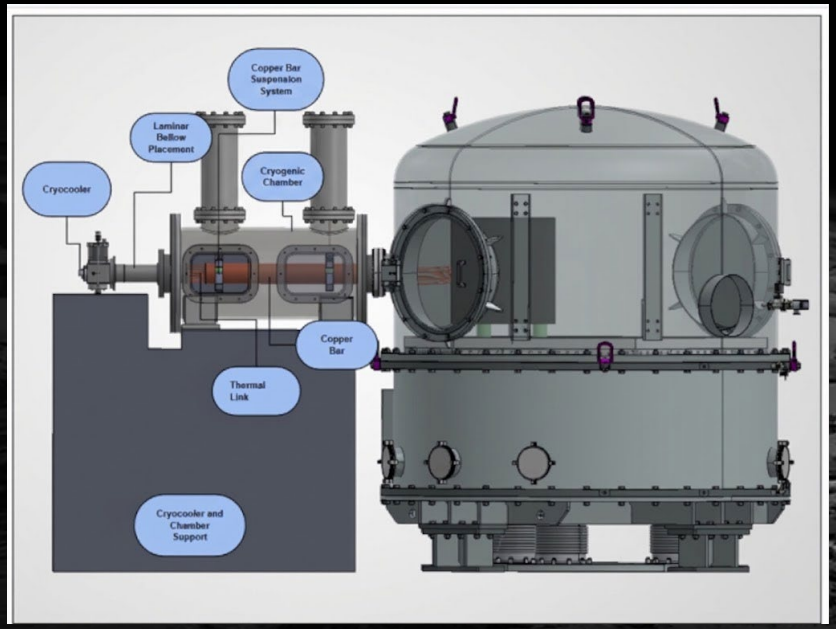
Design and manufacturing of superconducting coils for cryogenic (inertial) sensing and actuation

VJ Ellenbroek[1,2], M Sharma[3], SP Singh[4], M Zeoli[5,6], A Gatti[7], C Collette[5,8], J. Harms[9,10], A Perali[11,12], N Pinto[13], F Tavernier[7], U Vool[3] and JV van Heijningen[1,2]

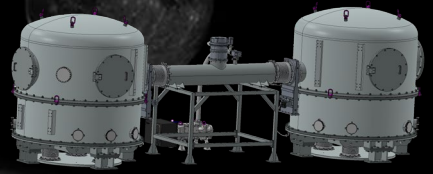
GEMINI: Moon Emulator

GEMINI site is 1.4km underground

The Moon Emulator is integrated into the GEMINI facility providing a 40K and seismically stabilized environment for LGWA payload tests.

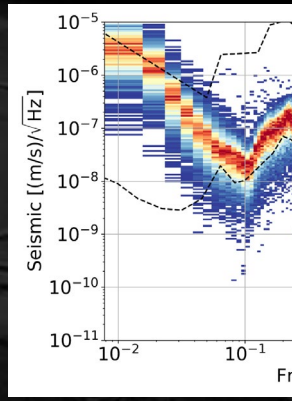


GEMINI is an ET R&D facility for active seismic isolation





Seismic spectrum at LNGS



Progress in the last year

- Signing of an agreement between ASI and GSSI, and formation of Italian Consortium with Uni Camerino, INAF, INFN, INGV (LGWA preparatory studies 2025 – 2027)
- Definition of key deliverables on the development of analysis pipelines, calibration, simulation,…
- Inclusion of the science ground segment in the project planning
- Several key publications on LGWA (payload, science case, lunar GW response, seismic background mitigation, GW data analysis)
- 2nd Sino-European meeting on lunar GW detection in Dunhuang
- ESA has listed the qualification of the Moon for GW detection as one of its exploration-enabled lunar science targets
- Submission of the Soundcheck proposal to ESA Lunar Science Building Blocks
- 4th LGWA collaboration meeting in Liège

Deliverables 2030

We set ourselves a deadline for Soundcheck analysis pipeline and calibration procedures together with a list of deliverables.

WG1 (GW + MM)

- Autonomous and multiband GW signal calibration pipelines
- Mock Soundcheck data
- Search pipelines for low-high mass CBCs (WD/WD + IMBBH)
- Data analysis and GW Multiband analysis pipelines with Soundcheck and terrestrial detectors (including pre-alerting pipelines)
- Synthetic catalogs from simulations, population analyses, event occurrence rates, and emission modeling.
- Multimessenger analysis pipelines
- Ground Segment

WG2 (lunar + site)

- Numerical model (mesh generation, seismic forward modelling, geological model, regolith model, scattering regime modelling)
- Geodynamic model
- Evaluation of seismic noise
- Evaluation of best array layout
- Simulation of thermal deformations and thermal seismic events
- Tidally induced ground tilt
- Assessment of impact of human activity
- Landing site regolith modelling, seismometer ground coupling, analog experiment, array testing

Conceivable Timeline

