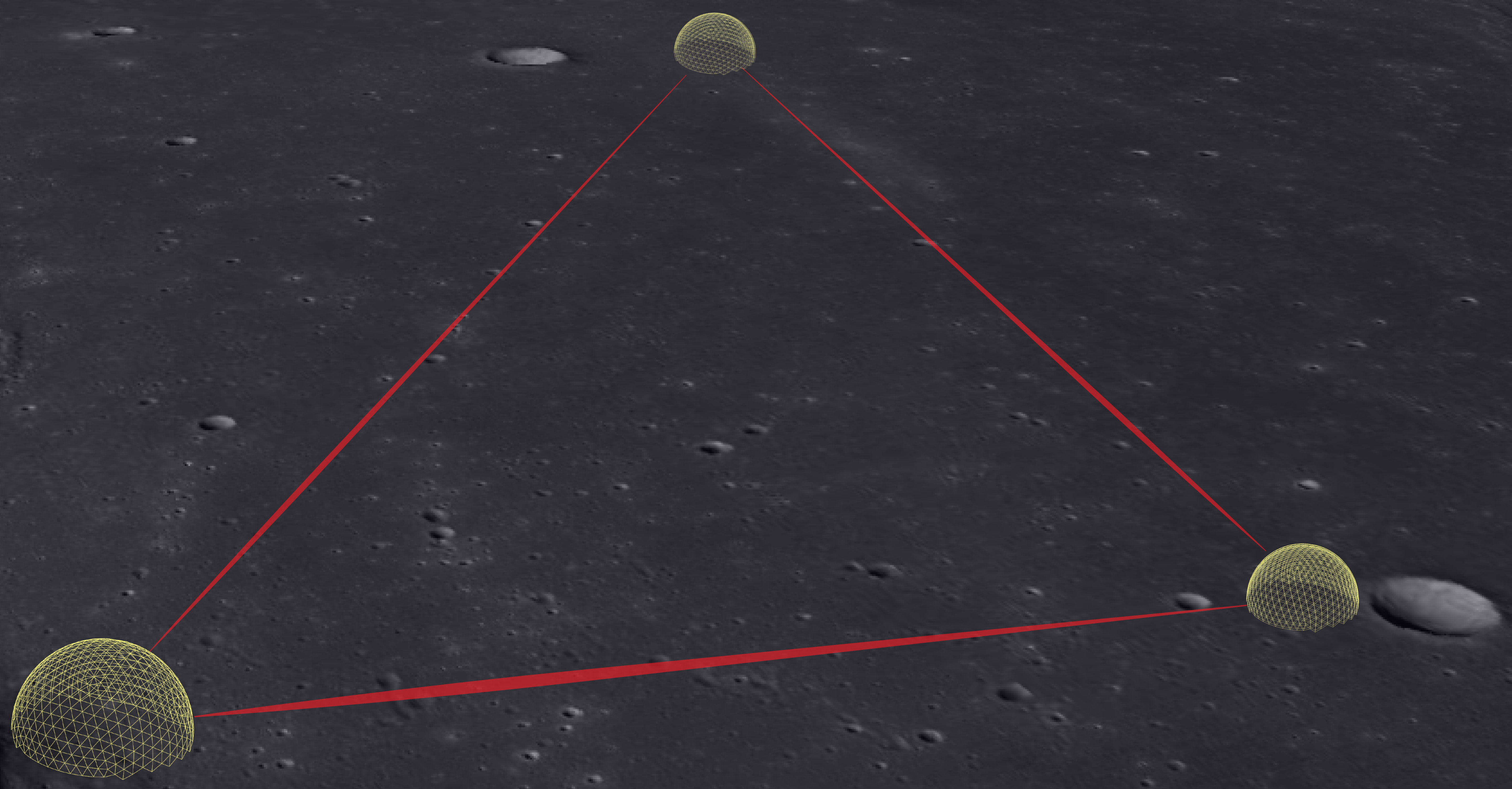
Gravitational-Wave Lunar Observatory for Cosmology (GLOC)

Karan Jani

Vanderbilt University

@astrokpj



Why go to the Moon?

- Moon offers a natural environment for constructing large-scale GW interferometer
- The atmospheric pressure on the surface is comparable to LIGO’s ultra high vacuum
- At low-frequencies, Moon is seismically quieter than the Earth
- Only weakly affected by environmental factors. Not corrupted (yet) by any human activities.
- Long term investment which can be improved for decades (unlike space missions)
- NASA Artemis, NASA Commercial Lunar Payload Services, Private Industries, ESA European Large Logistics Lander, Chinese Lunar Exploration Program …

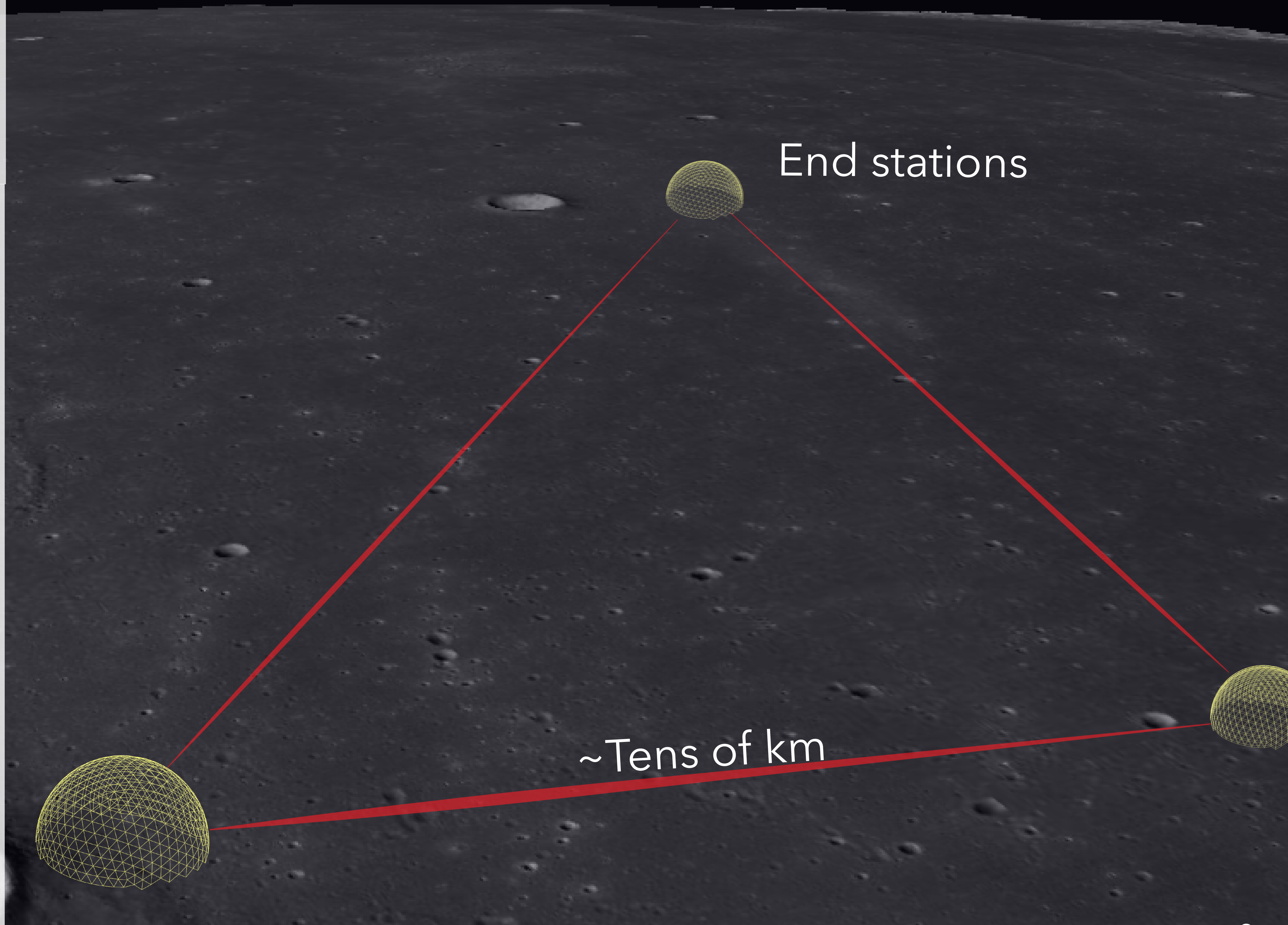
Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

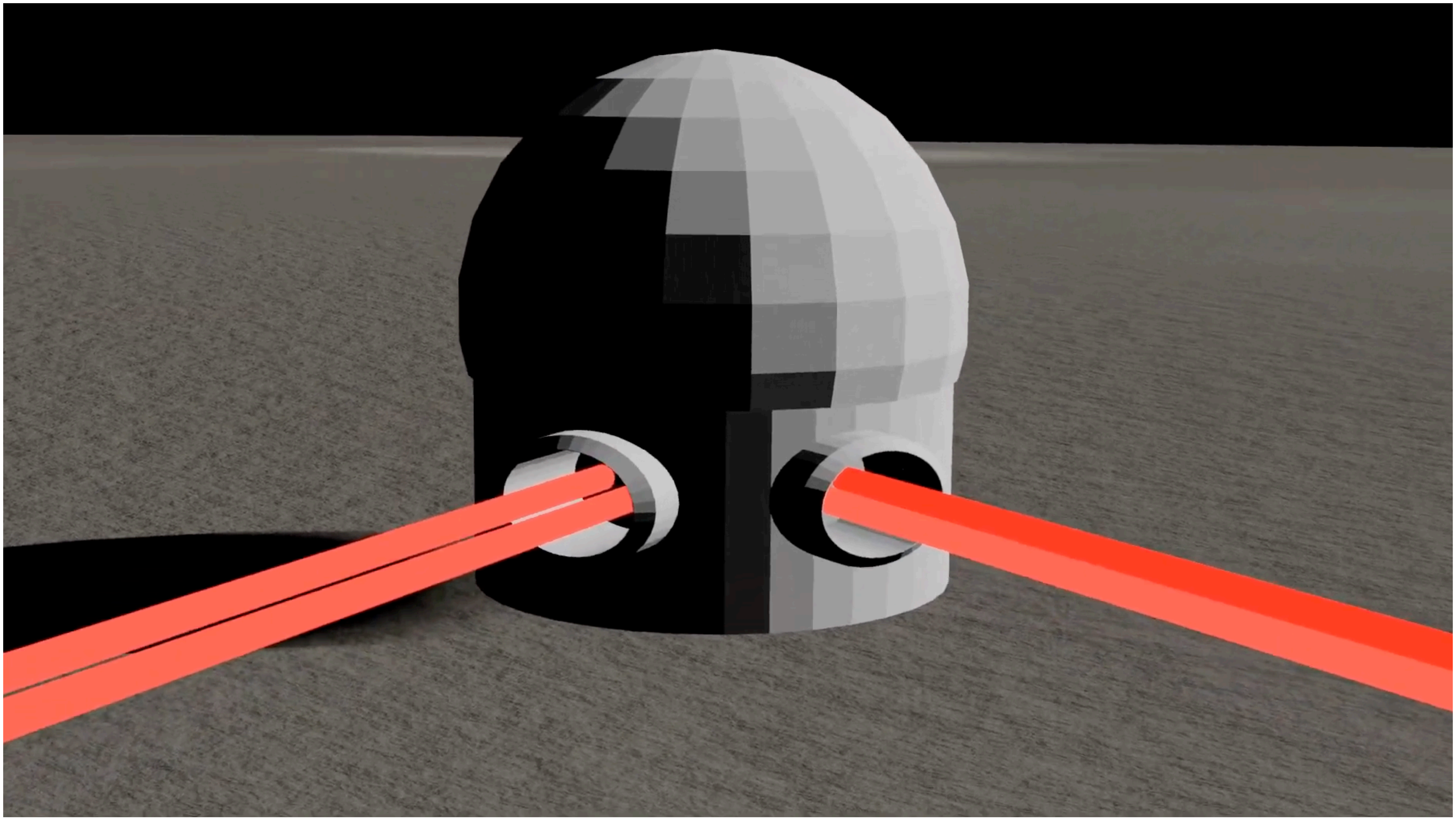
Gravitational-wave Lunar Observatory for Cosmology

K. Jani[a,*] and A. Loeb[b]

[a]Department Physics & Astronomy, Vanderbilt University,
2301 Vanderbilt Place, Nashville, TN, 37235, U.S.A.
[b]Department of Astronomy, Harvard University,
60 Garden Street, Cambridge, MA 02138, U.S.A.

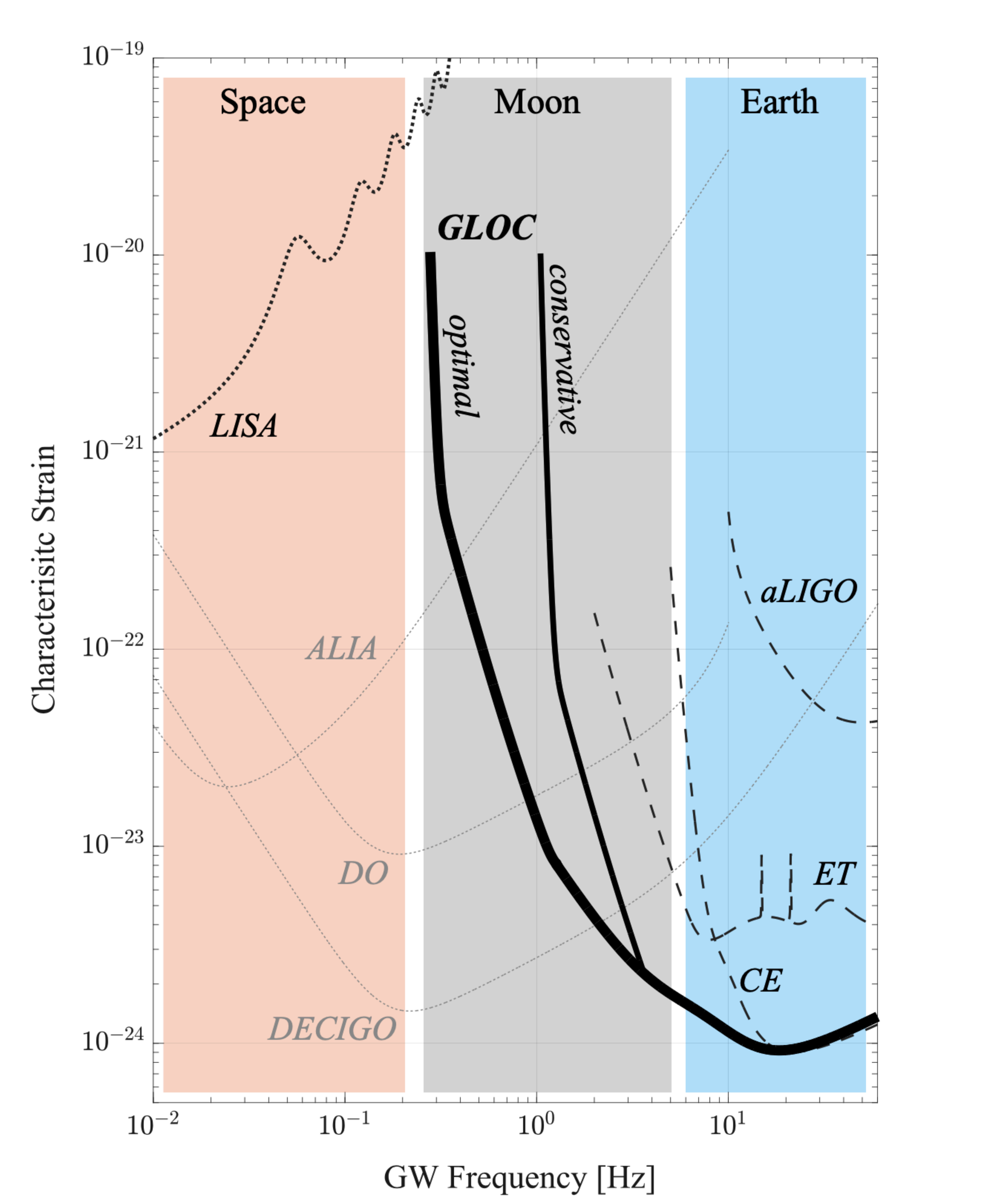
- First concept design in the NASA Artemis and detection era for a GW observatory on the Moon
- Relies on feasible interferometer technologies - similar to LIGO, ET - we know this setup works!
- Deployment through lunar landers
- Triangular geometry, temperature controlled domes to host optics and protect from cosmic rays





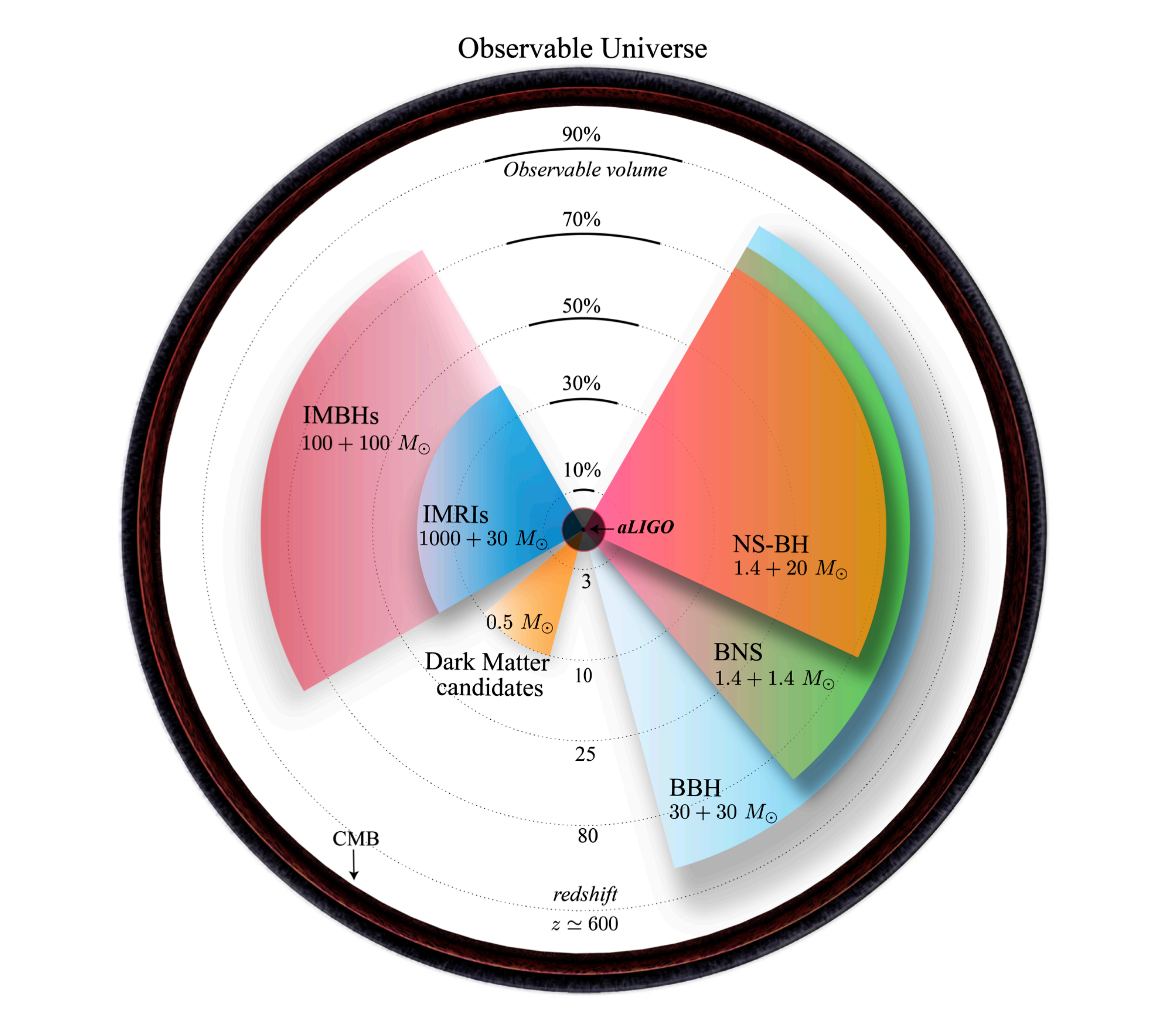
Video: Ravikiran S Hegde, Debarati Chatterjee (LIGO-India)

GLOC: A "new window" in the GW spectrum



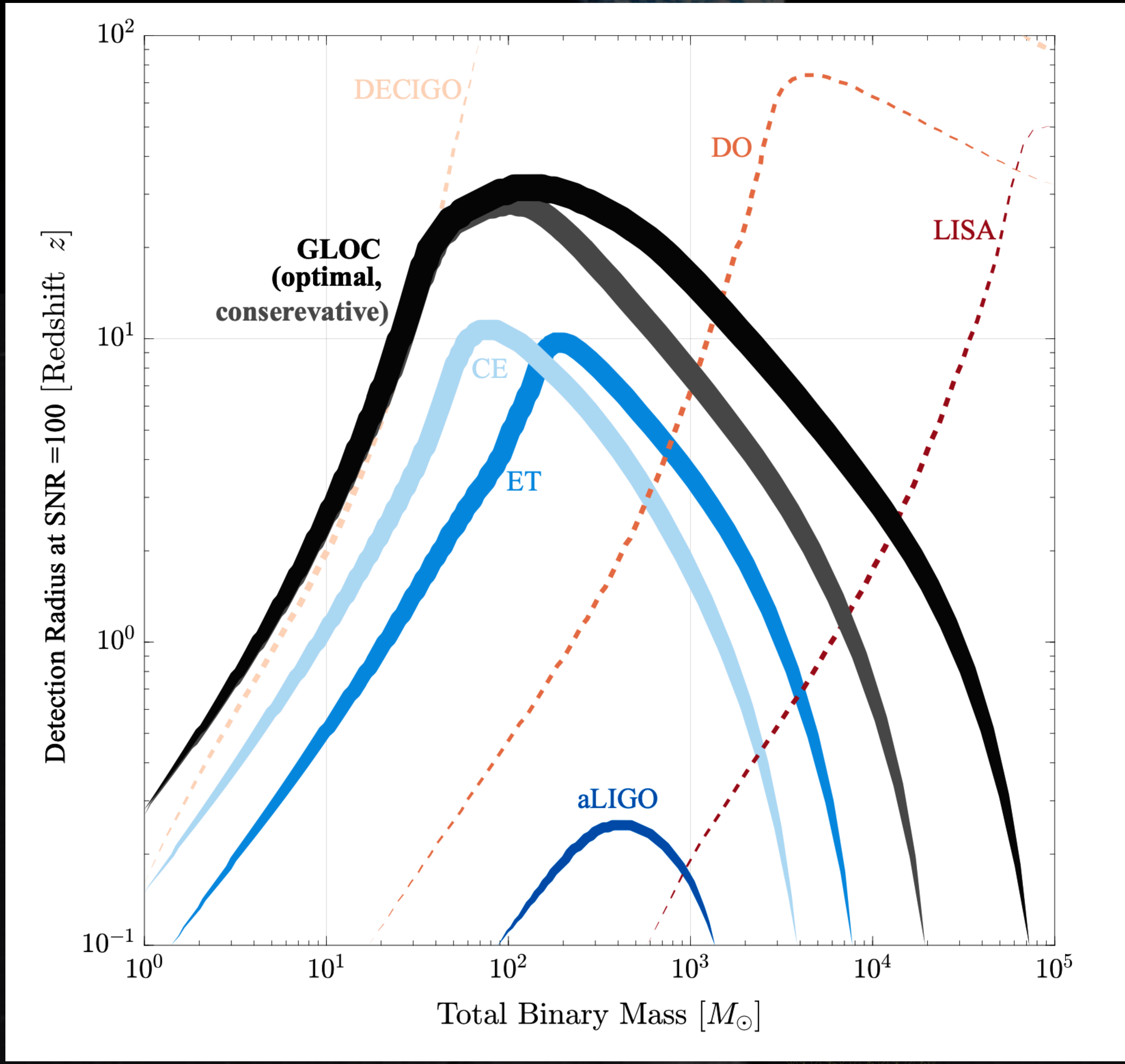
- Two projections for sensitivity:
  - GLOC conservative: f_{low} = 1 Hz
  - GLOC optimal: f_{low} = 0.25 Hz
- Improvement below ~1 Hz will be governed by the seismic noise and the suspension thermal noise
- The seismic noise in GLOC could be at least 3-4 orders of magnitude lower than an ET-like configuration on Earth.

GLOC: An Unprecedented Cosmological Observatory



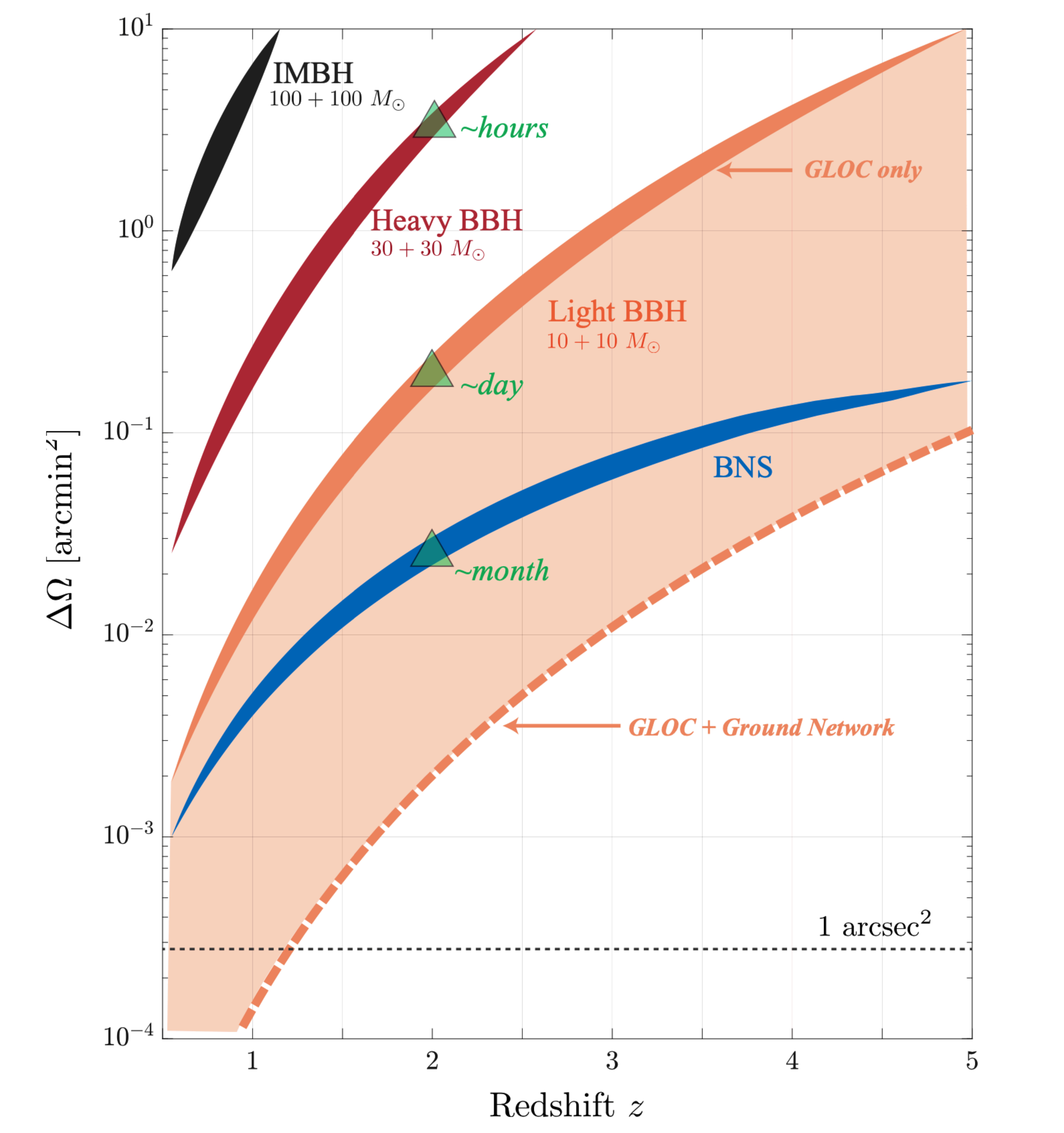
- Rare advantage of accessing GWs across many orders of magnitude in mass - from sub-solar dark matter candidates to massive black holes.
- Large fraction of the entire cosmological population of these systems could be observed into the dark ages of the universe.

Advances the science goals with Earth and Space facilities



- High SNR sources at cosmological scales: a new probe in the SMBH seed formation
- Multi-wavelength measurement for all stellar compact binaries
- Triple band measurements for pair-instability SNe black holes: earth, moon, space

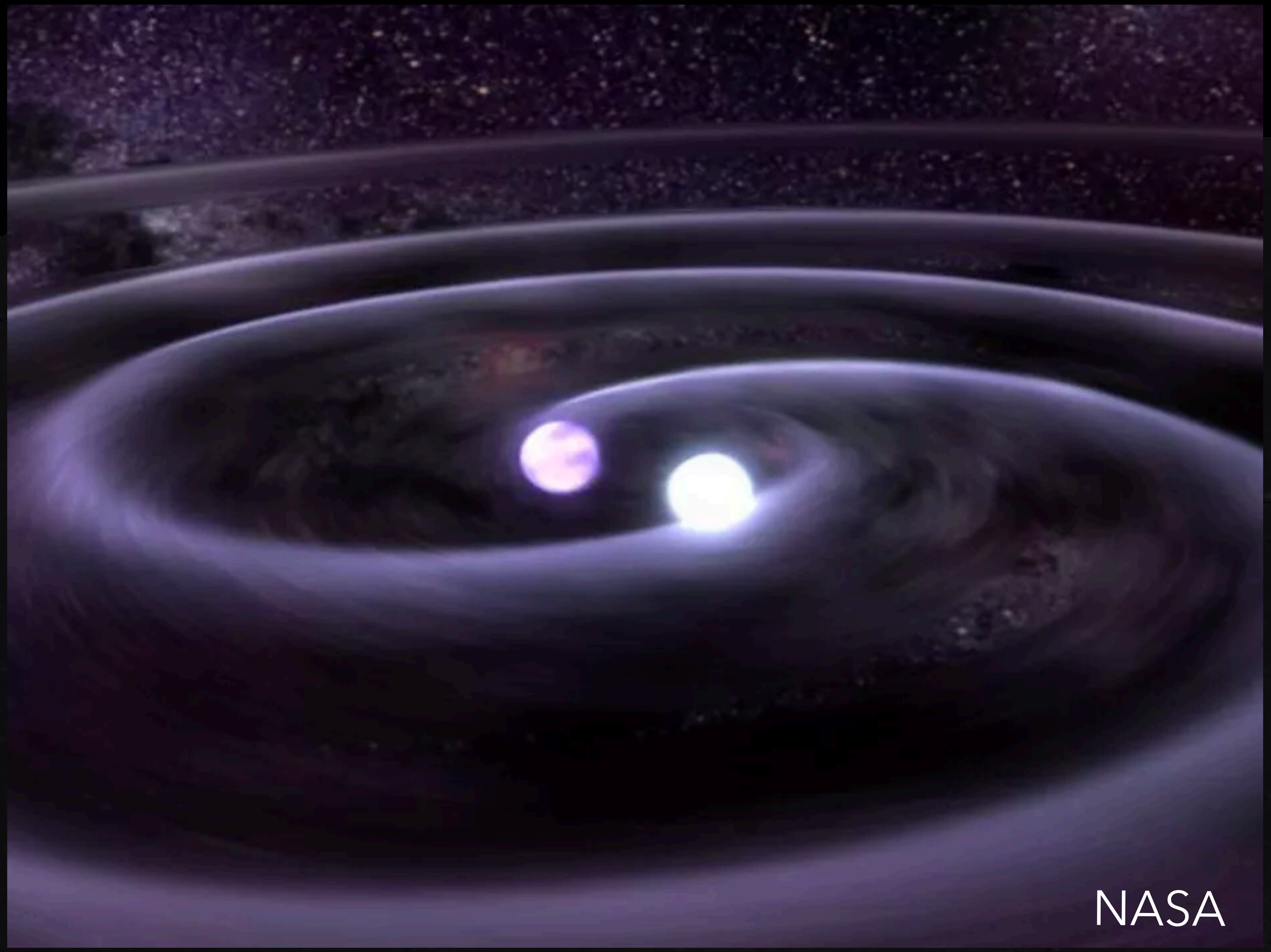
GLOC: a Novel Multi-messenger Probe for Dark Energy



- BNS up to redshift ~2 will be "in band" for an entire orbital period of the Moon, allowing sharp sky-location early on for EM follow up
- Lighter BBHs (like GW151226) would be seen days in advance. Combined measurement with 3G detectors can put sky-location at the angular scale of galaxy!
- New sources for high redshift dark sirens to independently measure the cosmic evolution

KPJ and A. Loeb *(arXiv: 2007.08550, 2020; Journal of Cosmology & Astroparticle Physics, 2021)*

GLOC: unique telescope for calibrating Type Ia supernovae



- Long-term detection sensitivity at ~1 Hz is unique to GLOC
- Enables a direct discrimination between the single and double degenerate scenarios of Type Ia SN
- If the progenitors of are mergers of two white dwarfs, GLOC can detect up to ~2 Gpc
- Reduces the error budget in calibrating the standard candles

Towards an international lunar GW community

Snowmass2021 - Letter of Interest

A deci-Hz Gravitational-Wave Lunar Observatory for Cosmology

Thematic Areas: (check all that apply ☐/■)

☐ (CF1) Dark Matter: Particle Like
☐ (CF2) Dark Matter: Wavelike
■ (CF3) Dark Matter: Cosmic Probes
☐ (CF4) Dark Energy and Cosmic Acceleration: The Modern Universe
■ (CF5) Dark Energy and Cosmic Acceleration: Cosmic Dawn and Before
■ (CF6) Dark Energy and Cosmic Acceleration: Complementarity of Probes and New Facilities
■ (CF7) Cosmic Probes of Fundamental Physics
☐ (Other) *[Please specify frontier/topical group]*

Contact Information:
Karan Jani (Vanderbilt University) [karan.jani@vanderbilt.edu]

Authors (full list with affiliations after the text):
Karan Jani, Abraham Loeb, Kelly Holley-Bockelmann, Manuel Arca Sedda, Nicola Bartolo, Nicola Bellomo, Daniele Bertacca, Stéphane Blondin, Florian Beutle, Ofek Birnholtz , Béatrice Bonga , Marica Branchesi, Laurentiu Caramete, Pedro R. Capelo, David Chernoff, Carmelita Carbone, Jose A. R. Cembranos, Katy Clough, Geoffrey Compère, Giuseppe Congedo, Andrea Derdzinski, Daniela Doneva, Xiao Fang, Daniel Felea, Pedro G. Ferreira, Robert Fisher, Noemi Frusciante, Mandeep S.S. Gill, Chris Gordon, Jan Harms, Lavinia Heisenberg, Daniel Holz, Philippe Jetzer, Albert Kong, Savvas M. Koushiappas, Ryan N. Lang, Jacob Lange, Michele Liguori, Lucas Lombriser, Sabino Matarrese, Charalampos Markakis, Sean McGee, Eugenio Megías, Cole Miller, David F. Mota, David Neilsen, Savvas Nesseris, Giorgio Orlando, Antonella Palmese, George Pappas, Vasileios Paschalidis, John Quenb, Ashley J Ruiter, Sébastien Renaux-Petel, Milton Ruiz, Martin Sahlén, Mairi Sakellariadou, B.S. Sathyaprakash, Olga Sergijenko, Sarah Shandera, Lijing Shao, Deirdre Shoemaker, Nikolaos Stergioulas, Arthur Suvorov, Obinna Umeh, Elias C. Vagenas, Yu-Dai Tsai, Alasdair Taylor, James Annis, Stoytcho Yazadjiev, Petruta Stefanescu, Saurya Das, Ovidiu Tintareanu-Mircea, Miguel Zumalacarregui, Leon Vida, N. Paul M. Kuin

@ Particle Physics

GRAVITATIONAL-WAVE LUNAR OBSERVATORY FOR FUNDAMENTAL PHYSICS

K. Jani*, Vanderbilt U.; A. Loeb, Harvard U.; K. Holley-Bockelmann, Vanderbilt U.; A. J. Ruiter, U. of New South Wales; A. Palmese, Fermi National Accelerator Laboratory; B. L. McKernan, American Museum of Nat. History; G. Congedo, Institute for Astronomy, U. of Edinburgh; J. Harms, GSSI, Italy; K. E. S. Ford, American Museum of Nat. History; M. Arca Sedda, Heidelberg U., Germany; M. Branchesi, Gran Sasso Science Institute, Italy; M. Gill, Stanford; M. Ruiz, U. of Illinois-Urbana-Champaign; N. Schmerr, U. of Maryland; O. Birnholtz, Bar-Ilan U., Israel; P. Jetzer, U. of Zurich; P. Lognonné, IPGP, France; R. Fisher, U. Mass.-Dartmouth; S. Katsanevas, European Gravitational Obs.; S. Marka, Columbia U.; S. Shandera, Pennsylvania State U. | ***contact person:* karan.jani@vanderbilt.edu

Call for Artemis Science White Papers

@ NASA Artemis

GLOC in news!

SPACE.com

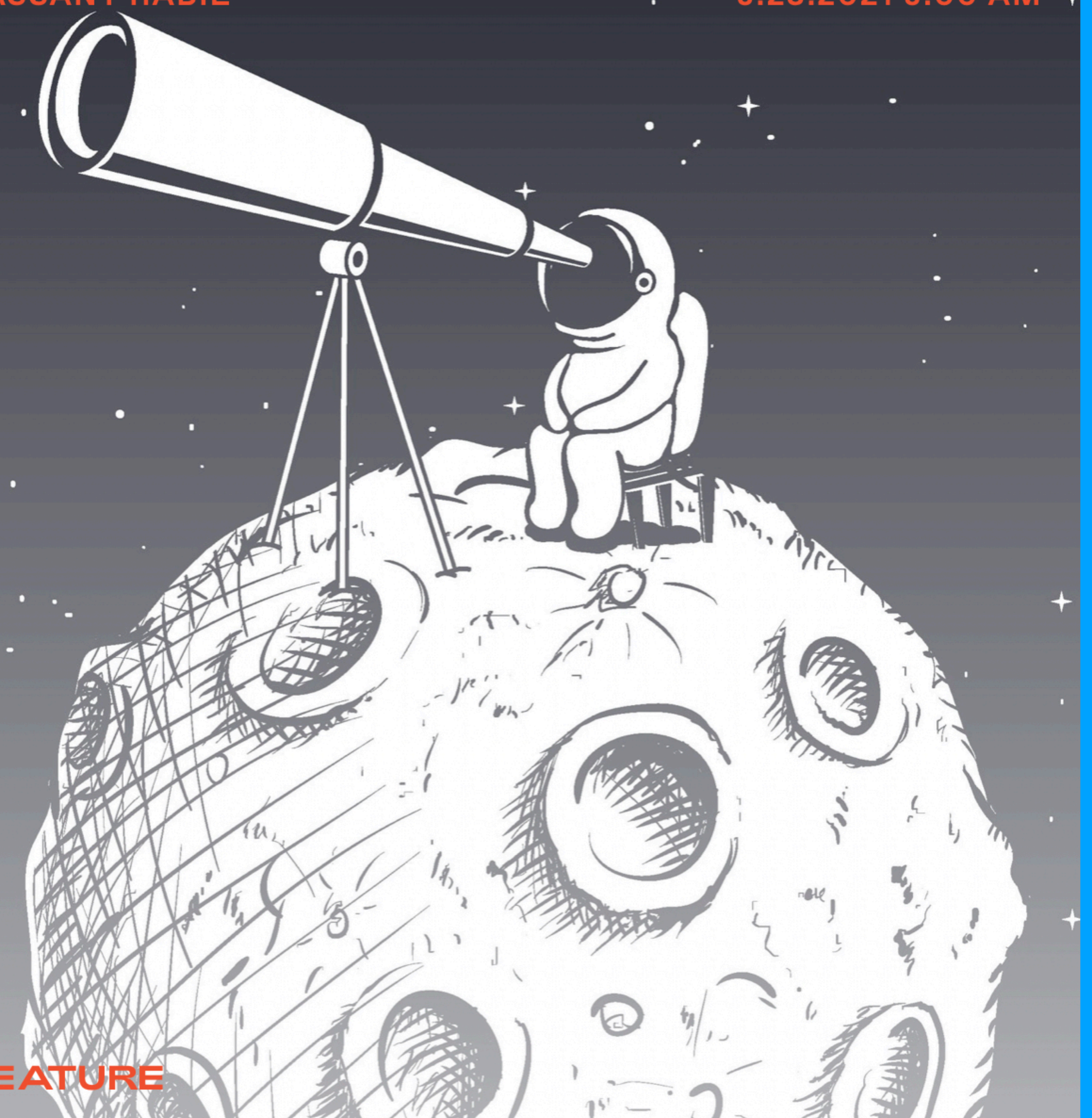
Subscribe ▼

We could hunt gravitational waves on the moon if this wild idea takes off

INVERSE

PASSANT RABIE

8.23.2021 8:00 AM



FEATURE

THE FUTURE OF COSMOLOGY IS 239,000 MILES AWAY — BUT CLOSER THAN EVER

A formidable pitch sounds like sci-fi, but NASA may just approve it.

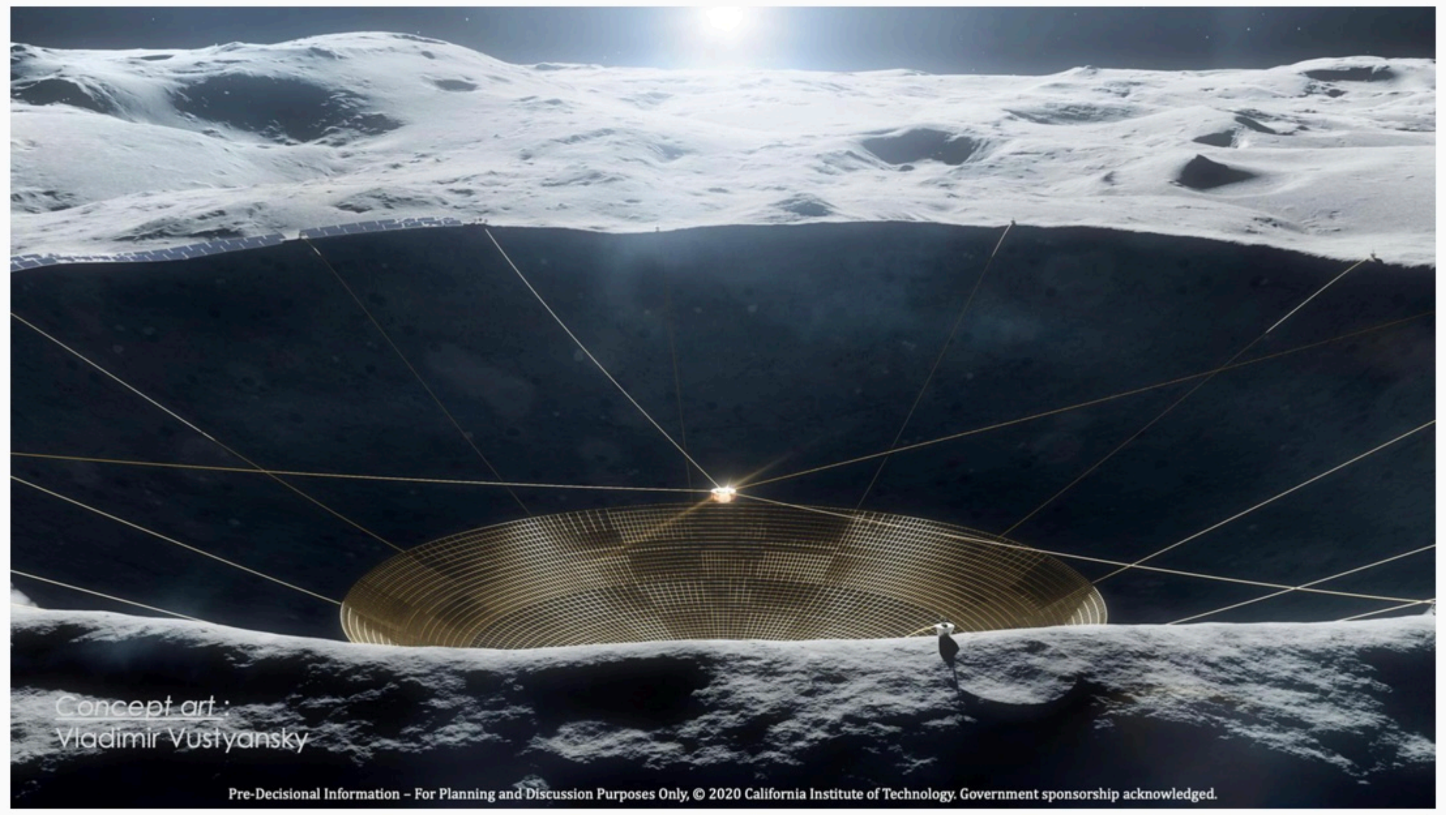
Forbes

AA

It's Time NASA Built A 'Cosmic Dawn' Telescope On The Moon—And It Has Four Astonishing Plans To Choose From

Jamie Carter Contributor

Jul 29, 2021



SYFY WIRE

AA

Credit: NASA

Space

IF WE PUT AN OBSERVATORY ON THE MOON, THESE ARE THE AWESOME THINGS IT COULD SEE

Once we overcome the barrier of landing on the moon, a whole new horizon opens for our civilization to probe the fundamental laws of Nature.

Thank you!