A MISSION TO DETECT DECIHERTZ GRAVITATIONAL WAVES FROM A PERMANENTLY SHADOWED LUNAR CRATER

Future gravitational-wave detectors like the Laser Interferometer Space Antenna (LISA), Cosmic Explorer and Einstein Telescope (ET) will herald a new era of science and astronomy. Together with pulsar timing arrays and inflationary probes, several frequency bands spanning over 20 decades will be under observation [1]. However, there are important gaps between these detectors, most notably in the decihertz band, which holds exciting possibilities for cosmology, multi-messenger astronomy, and fundamental physics. The decihertz band is seen as technologically challenging to cover as space-borne detectors should have short arms and stable optical cavities and terrestrial detectors have no chance to go below 1 Hz as they battle the microseismic peak. One could think of our near-future gravitational-wave detection ability as an incomplete orchestra. We have the terrestrial piccolo flutes, the space-borne cellos, the pulsar timing array of basses and the inflationary contrabass tubas. I would like to present the violins: the Lunar Gravitational-wave Antenna (LGWA) [2].

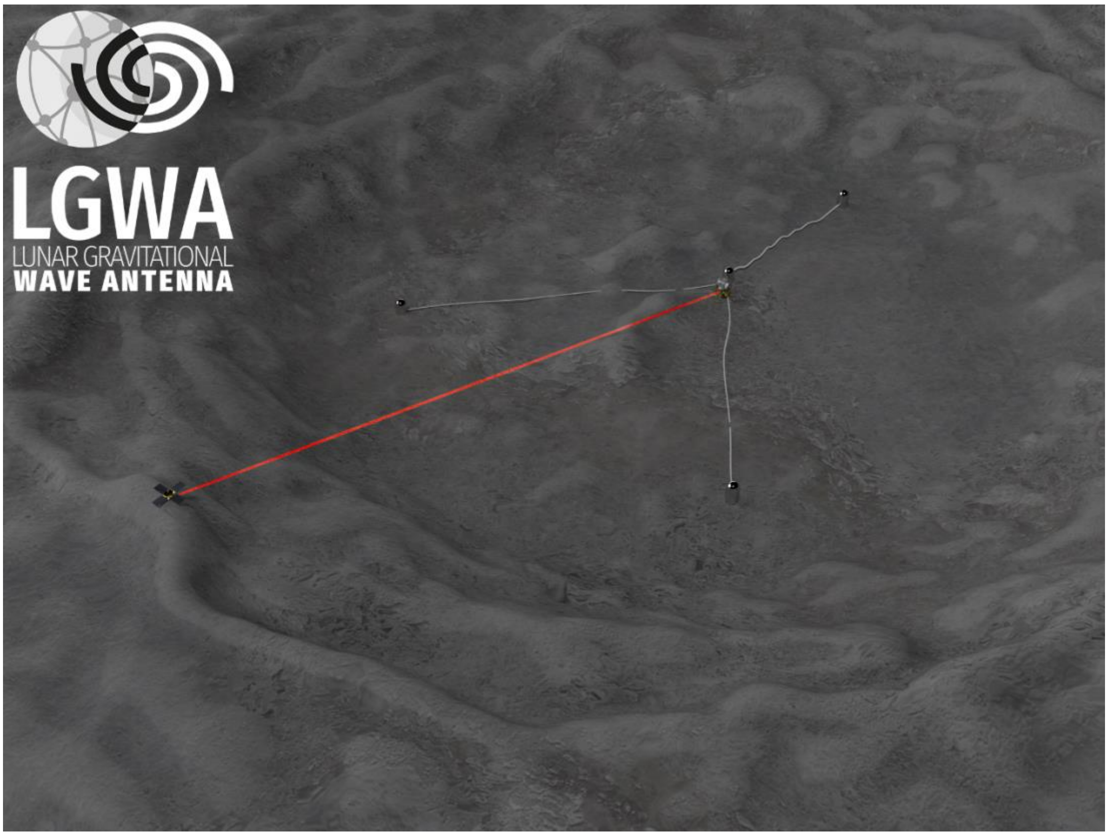

Figure: The detector in a crater at the south pole of the Moon, a permanently shadowed 35 K natural cryostat. That benefits the thermal noise in our inertial sensors housed in a central station and 3 other seismic stations. A challenge is electrical power as there is no sunlight reaching the detector. A possible solution is solar panels on the crater edge and then 'beam' to the central station with a microwave laser. Credit: Jan Harms (GSSI)

At the heart of LGWA is a cryogenic inertial sensor with sufficient sensitivity in the decihertz band [3,4]. An array of four of these sensors is to be deployed in a permanently shadowed region as shown in the above figure. The Moon is known to be several orders of magnitude quieter than Earth in terms of seismic perturbations, and the array allows for subtraction techniques to further reduce the extremely weak seismic background predicted from meteoroid impacts and moonquakes. In this way, LGWA becomes a technologically feasible concept fully exploiting the unique lunar environment and with the capability to achieve the first gravitational-wave observations in the decihertz band. LGWA can deliver rich science : black hole mergers across a broad & asymmetric mass range, early warning for BNS mergers, testing of general relativity, cosmology with stochastic signals and more [4]. In this seminar, I will present the current gravitational-wave landscape and how LGWA will be complementary for current sources and make possible the study of new sources. I will focus the on the technologies under development and their current status for LGWA. As the inertial sensor can also be deployed in ET to monitor residual motion near the cryogenic mirrors, I will end with some aspects ET and its research facilities ETpathfinder [6,7] and E-TEST [7].

[1] Miller, M.C., Yunes, N. (2019) Nature 568, 469–476

[2] Harms, J. et al. (2021) ApJ 910 1

[3] van Heijningen, J.V. (2020) JINST 15 P06034

[4] van Heijningen, J.V. et al. (2022) NIM A 167231

[5] Harms, J. et al. (2021) Research campaign paper in the Decadal Survey of BPS

[6] Utina, A. et al. (2022) arXiv:2206.04905

[7] Di Pace, S. et al. (2022) Galaxies, 10(3), 6