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Lunar LIGO and Gravitational Wave Astronomy on the Moon;

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Gravitational wave astronomy continues to be one of the exploration concepts under consideration in NASA's strategy for conducting physics and astrophysics from the lunar surface. As with other proposals for new concepts in science and astronomy from the Moon, this one has a number of very interesting features which need to be developed further in order to assess them adequately. The possibility of robotic deployment of a gravitational wave antenna on the Moon in a triangular configuration and the question of closure on the third interferometer leg are discussed here.

The preliminary proposal [1,2] that the Earth-based multi-LIGO system [3-6] can be augmented with a Lunar LIGO appears promising. This consists of emplacing a modest LIGO (Laser Interferometer Gravitational Wave Observatory) optical system [7] on the Moon, proving to be a simple and advantageous application in the vacuum environment of the lunar surface. Emplacement could be accomplished using unmanned robotic landers [8] such as the recent Artemis project [9,10], or by a manned landing program.

The distance between the Earth and Moon provides a long parallax baseline with terrestrial antennas for locating the sources of a gravitational event. Given that the lunar vacuum eliminates the need for long evacuated tunnels, a minimal Fabry-Perot antenna could be placed on the Moon using three robotic landers, one containing the laser source, the beam splitter, the detector, recycle mirrors, cavity mirrors, and other optics. The other two landers would contain the end mirrors of the interferometer arms (Figure 1 and 2), and provide closure phase along the third leg [11,12].

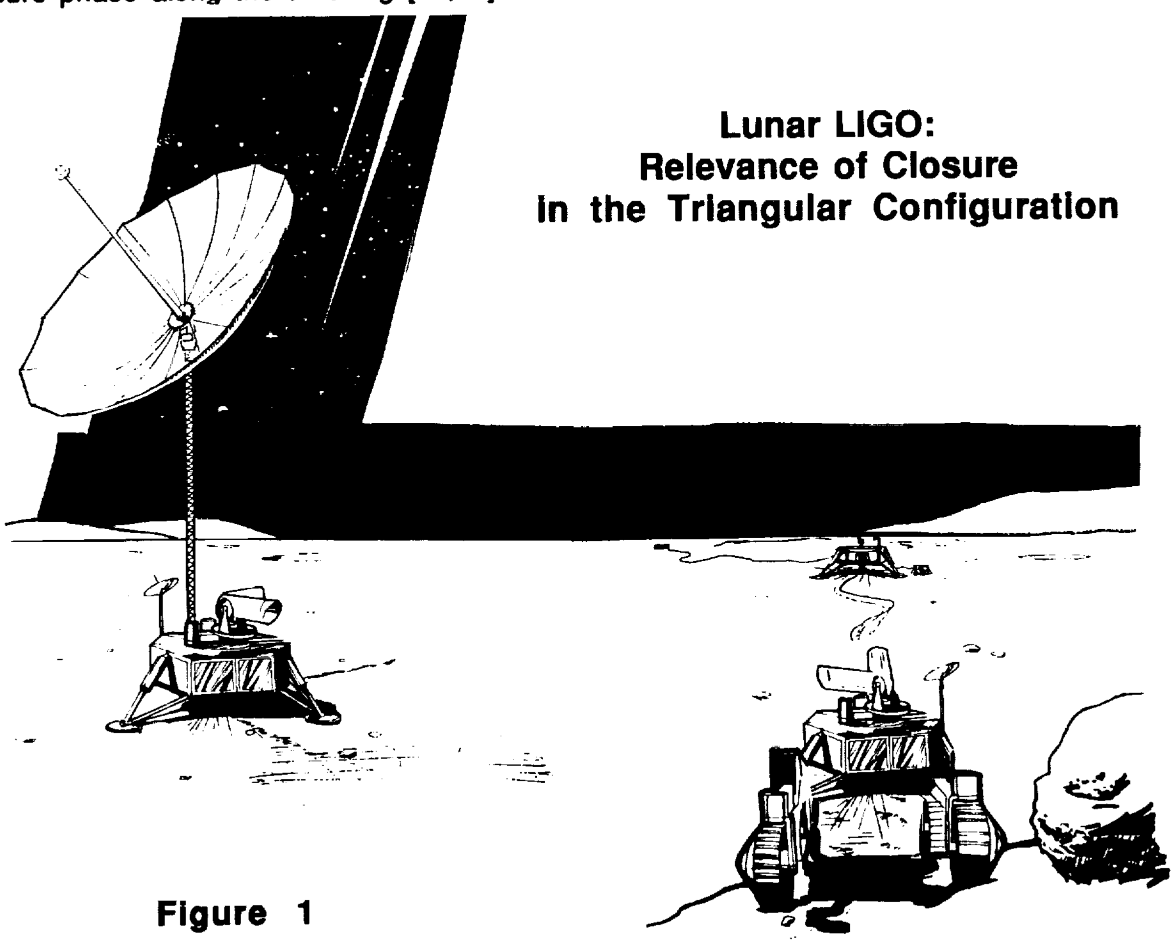

Figure 1

Lunar LIGO, Wilson, T.L., and LaFave, N.

The lack of arm enclosures allows the arms to be extremely long, limited only by a lunar radius of 1738 km. A judicious choice of landing sites could allow for longer arms by taking advantage of local topography. The arms could be easily altered by moving the landers containing the end mirrors.

It is possible that the same three landers could be used to assemble a set of three redundant arrays employing the equilateral concept [13] in Figure 2b. There would be a 13%

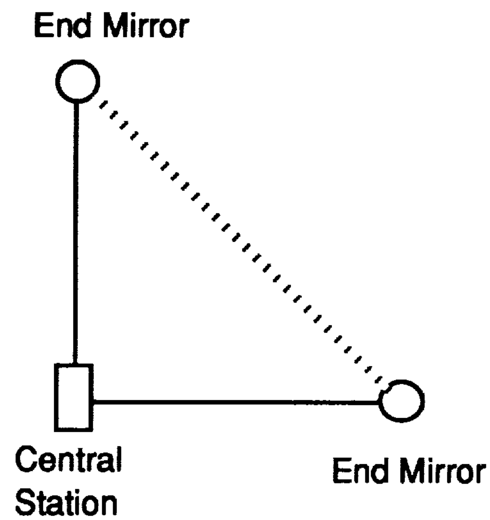

Figure 2a

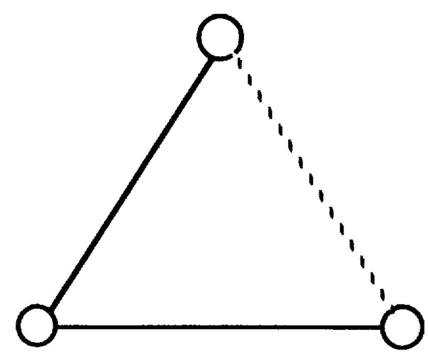

Figure 2b

reduction in the signal strength due to the 60° angle between the arms, but this is not prohibitive. Each lander would have a laser/detector/beam-splitter/ assembly and two end mirrors. This allows the observatory to be redundant and detect both wave polarizations. On the Earth, the third "leg" would require the costly construction and evacuation of a third arm. This is achieved for free on the Moon.

An advanced, man-tended version of the Lunar LIGO would allow for even more flexibility. Detectors and mirrors could be repaired and/or upgraded by the lunar base personnel. The antenna could be actively monitored and seismic data could be screened using gravimeters to aid in the data's noise analysis. For instance, a large array of antennas could be built to allow for better spurious signal elimination by coincidence. A large number of antennas would be easier to build and maintain on the Moon than on the Earth due to the lack of evacuated tunnels.

In conclusion, this investigation shows that a lunar-based Fabry-Perot gravitational wave antenna would provide a valuable complement to the Earth-based systems, both for conclusive, first detection and for continued gravitational wave astronomy. Furthermore, due to unique features of the lunar environment, the life-cycle costs could be competitive with Earth-based antennas.

References

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