LUNAR, CISLUNAR, NEAR/FARSIDE LASER RETROREFLECTORS FOR THE ACCURATE: POSITIONING OF LANDERS/ROVERS/HOPPERS/ORBITERS, COMMERCIAL GEOREFERENCING, TEST OF RELATIVISTIC GRAVITY AND METRICS OF THE LUNAR INTERIOR

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Abstract: Since 1969 Lunar Laser Ranging (LLR) to Apollo/Lunokhod laser retroreflector (CCR) arrays supplied accurate tests of General Relativity and new gravitational physics: possibile changes of the gravitational constant Gdot/G, weak and strong equivalence principle, gravitational self-energy (PPN parameter beta), geodetic precession, inverse-square force-law [1][2][3]; it cal also constraints gravitomagnetism. Some of these measurements also allowed for testing extensions of General Relativity, including spacetime torsion, non-minimally coupled gravity (that may explain the gravitational universe without dark matter and dark energy)[4]; in principle, although technically and programmatically very challenging, also effective quantum gravity exploting the L1 lagrangian point. LLR has also provided, and will continue to provide, significant information on the composition of the deep interior of the Moon, complementary to the GRAIL mission of NASA. LLR first provided evidence of the existence of a fluid component of the deep lunar interior, confirmed also by lunar seismometry data [1].

In 1969 CCR arrays contributed a negligible fraction of LLR error. Since laser stations improved by >100, now, because of lunar librations, current arrays dominate the error. We developed a next-generation single large CCR, MoonLIGHT-NGR[1] unaffected by librations that supports an improvement of the space segment of the LLR accuracy up to x100. INFN also developed INRRI (INstrument for landing-Roving laser Retroreflector Investigations), a microreflector to be laser-ranged by orbiters. MoonLIGHT/INRRI, characterized at SCF-Lab [5] of INFN-LNF, Italy, for their deployment on the lunar surface or the cislunar space, will accurately position landers-rovers-hoppers-orbiters of GLXP/agency missions, thanks to LLR observations from select ground station of the International Laser Ranging Service (like APOLLO in the USA, GRASSE in France and MLRO in Italy).

INRRI was launched with the ESA ExoMars EDM 2016 mission, deployed on the Schiaparelli lander [6]. INRRI is also proposed for the ESA ExoMars 2020 Rover. Based on a NASA-ASI Implementing Arrangement signed in July 2017, a similar INFN payload (LaRRI, Laser RetroReflector for InSight) has been delivered to JPL and integrated on the NASA InSight 2018 Mars Landers in August 2017. Following a separate NASA-ASI Implementing Arrangement (already signed by NASA) a microreflector (LaRA, Laser Retroreflector Array) will be delivered by INFN to JPL in 2019 for deployment on the NASA Mars 2020 Rover.

The first opportunities for the deployment of MoonLIGHT-NGR will be from early to late 2018 with commercial missions, followed by opportunities with space agency misions, including the proposed deployment of MoonLIGHT/INRRI on NASA's Resource Prospectors and its evolutions.

LLR data analysis is carried out since the Apollo days with PEP, the Planetary Ephemeris Program developed and maintained by CfA. New LLR data, will provide useful input to improve the lunar models that PEP needs [7], as already shown by the implementation of data collected by GRAIL into LLR analysis.

References:

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