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THE ASTRONOMICAL LUNAR OBSERVATORY (ALO) - PROBING THE COSMOLOGICAL DARK AGES AND COSMIC DAWN WITH A DISTRIBUTED LOW-FREQUENCY RADIO ARRAY ON THE LUNAR FAR SIDE

Abstract

The Moon provides an attractive location both from a exploration- and a scientific perspective and over the recent years the interest in the Moon has been revived, both from agency driven programmes (e.g. NASA's Artemis CLPS, CNSA Chang'E) as well as commercial entities (e.g. Astrobotics, Intuitive Machines, Chandrayaan) which seek to land on the moon within the decade. Here we present the European Space Agency (ESA) Topical Team for an Astronomical Lunar Observatory (ALO), as part of the ESA's European Large Logistics Lander (EL3) programme.

Following the detection of gravitational waves, and taking into account the wealth of astronomical instrumentation across the electromagnetic spectrum, the radio frequency range below 30 MHz remains the last virtually unexplored frequency domain. The Earth's atmosphere reflects back all radiation from space below its ionospheric plasma frequency (around 20 MHz), and the turbulent ionosphere gives rise to "radio seeing", making ground-based radio observations of the sky more difficult at frequencies below 100 MHz but certainly prohibiting observations at the lowest frequencies. An additional complication at lower radio frequencies is that strong man-made Radio Frequency Interference (RFI) levels close to Earth require either locations which provide partial or complete obscuration of the Earth, or locations that are sufficiently remote so that the RFI levels are significantly attenuated. In addition, stable temperature and gain conditions are essential to allow for careful calibration of the radio antennas. These requirements are met only for a number of locations of which the lunar far side, is by far the most promising one.

There is a wealth of science to be addressed in the low-frequency radio regime, ranging from the study of Solar and Jupiter emission to the detection of exo-planets, but the real treasure-trove is the detection and imaging of the redshifted 21-cm line emission from the neutral Hydrogen in the pristine periods of the universe known as the Dark Ages (DA) and the Cosmic Dawn (CD; see e.g. Jester Falcke, 2009; Bowman et al. 2010; Pritchard Loeb 2010; Loeb Zaldarriaga, 2004). The only conceivable signal from the CD and DA comes from the hyperfine 21-cm line from neutron Hydrogen caused by the spin flip of the electron. The high redshift involved causes this emission to redshift in the frequency range between $1.4 - 140$ MHz, with the global DA and CD signals peaking around 30 MHz and 70 MHz, respectively, and being rather broad, hence requiring space-based or lunar-based low-frequency radio instrumentation.

Hence, the ESA EL3 plans to allow for scientific infrastructure to be placed on the Moon and in particular the lunar far side, will open up the last, virtually unexplored, window on the universe. Here we report on the status of the ALO topical team efforts, in particular on the findings of a dedicated ESA CDF engineering study.