OPTIMIZING LUNAR RADIO TELESCOPES: RELIABLE EXTRAPOLATIONS OF THE FIRST GENERATIONS OF GALAXIES

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Introduction: Modern cosmology has observed galaxies well into the first billion years of the Universe's history. However, pushing into the first 100 million years, when the first stars were being born, remains beyond the reach of direct observation with current and even next-generation telescopes. Fortunately, these stars' effects on their surroundings, the neutral gas that fills the Universe, can be observed via the 21-cm line of hydrogen, redshifted into low frequencies (>200 MHz) by the expansion of the Universe. Low-frequency observations of the cosmic 21-cm signal are at the forefront of astronomy, but observing this line has its challenges, including a foreground many times larger than the signal itself, as well as man-made and ionospheric interference. Fortunately, our solar system hosts a nearby pristine laboratory free from the terrestrial sources of noise: the far side of the moon.

Project Summary: A key goal in the eras of cosmic dawn and re-ionization is to determine the dominant source of the 21-cm signal. With high redshift data ($z<12$) from upcoming infrared telescopes such as JWST and WFIRST, it is possible to calibrate a baseline model of "normal" galaxies' contribution to the 21-cm signal and to extrapolate their effects to even higher redshifts ($z>20$). Such a baseline is essential for interpreting 21-cm observations from lunar telescopes, because those observations offer only indirect constraints on galaxy populations. With the baseline well-established, any mismatch between expectations and observations would suggest additional sources at these early times. Unfortunately, observing galaxies at $z\sim12$ will be complicated by (among other things) cosmic variance; understanding the effects of cosmic variance on galaxy surveys is crucial for a meaningful extrapolation to high-z. Here we develop a physically-motivated and self-consistent model of the cosmic variance intrinsic to measurements of the galaxy luminosity function at early times. We find that cosmic variance will be a significant source of error for high-z galaxy surveys but also discuss simple strategies that can be used to mitigate its effects. We also explore how this cosmic variance induces fluctuations in the 21-cm signal that can be observed by future telescopes like FARSIDE.