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The road to global 21cm experiments in space.

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Measurements of 21cm emission and absorption originating from prior to reionization offer a potential window into the early universe. Radio receivers operating at wavelengths from 20 to 200 MHz could potentially probe the universe prior to star formation through to the formation of galaxies opening new ways to probe cosmological physics, formation of the first stars, primordial black holes and galaxies. Single antenna global temperature measurements and interferometers provide complementary measurements. Ground based instruments are limited by systematics arising from terrestrial influences and interference. Such instruments must observe through the ionosphere which at high frequencies adds distortion eventually transitioning to being unusably reflective at low frequencies. Redshifts above 30 are unusable from the ground and it is very possible that high redshift 21cm can only be properly observed from space. Proposed space-based instruments like the DAPPER lunar orbiter or the FARSIDE lunar surface installation take advantage of the moon as a radio shield. This location further raises the stakes of missions going to space and motivates early investment in technology and science practice.

Making the transition from ground to space requires changes to instrumental practice as well as improvements in many areas of instrument design and operation. The field of 21cm observation has developed recently with much of the technology and techniques quite unique to the field. This development has taken the form of iterative instrument deployment and development with deeper observations feeding back into better instrument design and observation practice. Here we outline a roadmap for elevating this process into space with a series of demonstrations which build technical capability for deploying space-based instruments to allow a similar iterative testing cycle in space. This roadmap defines a series of tests using balloons and low earth orbiting cubesats aimed at testing elements of the technology needed for space-based missions and for identifying new issues unique to space-based observations. As a first step we have developed a prototype space-capable instrument optimized to minimize Size Weight and Power (SWaP). All 21-cm measurements have been limited less by noise and more by instrument precision. The systematic level is primarily set by the performance of the radio front end which uses switches to attach calibration sources to the receiver. Ground based instruments use large, heavy, mechanical switches which provide the lowest possible insertion mismatch. We have investigated several miniaturization options including semiconductor and micro-electro-mechanical devices and report here on our findings. The completed instrument prototype includes a custom broadband calibration source, absolutely calibrated gain stages, software defined radio receivers, and custom compact antennas. Once complete this instrument will be thermal vacuum tested and flown on a high altitude balloon.