Dark Cosmology: Investigations of Dark Matter in the Dark Ages with the Space-Based Dark Ages Polarimeter Pathfinder (DAPPER)

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After the Cosmic Microwave Background photons decoupled from baryons, the Dark Ages epoch began: density fluctuations imprinted from earlier times grew under the influence of gravity, eventually collapsing into the first stars and galaxies during the subsequent Cosmic Dawn. In the early universe, most of the baryonic matter was in the form of neutral hydrogen, detectable via its ground state's "spin-flip" transition. A measurement of the 21-cm global spectrum maps the history of the hydrogen gas. The ground-based EDGES experiment recently reported a ≈78 MHz (redshift z~17) absorption trough roughly consistent with that expected from Cosmic Dawn, but ~3 times deeper than was thought possible from standard cosmology and adiabatic cooling of neutral hydrogen. Interactions between baryons and mini-charged Dark Matter particles with a proton-like mass provide a potential explanation of this difference but many other cooling mechanisms are also being investigated.

The Cosmic Dawn trough is affected by cosmology and the complex astrophysical history of the first luminous objects. On the other hand, a Dark Ages trough, predicted to occur at lower frequencies (i.e., higher z), is determined entirely by cosmological phenomena (including Dark Matter effects) already active before star formation began. A new space-based experiment, the Dark Ages Polarimeter PathfindER (DAPPER), will be described that is designed to observe this pristine epoch (15-30 MHz; z~93-46) which is inaccessible from Earth. DAPPER will search for deviations from the trough predicted by the standard cosmological model (with a minimum at ~18 MHz and an amplitude of ~40 mK). In addition to Dark Matter properties such as annihilation, decay, temperature and interactions, the low-frequency background radiation level can significantly modify this trough. Hence, this observation constitutes a powerful, clean probe of exotic physics at the end of the Dark Ages. DAPPER will observe the 21-cm spectrum in the presence of bright foregrounds using: (1) a polarimeter to measure both intrinsically polarized emission and polarization induced by the anisotropic foregrounds and large antenna beam, which greatly aids in the separation of the foregrounds from the isotropic, unpolarized global signal, and (2) a novel pattern recognition analysis pipeline based on well-characterized training sets of foregrounds from sky observations, instrument systematics from simulations and laboratory measurements, and signals from theoretical predictions. DAPPER was recently selected by NASA for an Astrophysics Science SmallSat Study.