Ensuring the robustness of the analysis of 21-cm cosmological observations from the farside of the Moon

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Abstract. The farside of the Moon provides a unique radio quiet environment free of both terrestrial Radio Frequency Interference (RFI) and the contaminating effects of Earth's ionosphere (Bassett et al. 2020). Thus, the farside offers the optimal location to perform sensitive low radio frequency astronomical observations. In particular, the farside affords an opportunity to observe the highly redshifted 21-cm transition of neutral hydrogen from the Dark Ages, before luminous objects formed, and Cosmic Dawn, when the first stars and galaxies "turned on." The Dark Ages Polarimeter PathfindER (DAPPER) is a NASA-funded concept to take advantage of this radio-quiet environment to probe physics beyond the standard model of cosmology with the 21-cm global signal.

Pylinex is a publicly available code designed for extracting the 21-cm global signal from observations in the presence of systematic effects (Tauscher et al. 2018). The signal extraction method relies on Singular Value Decomposition (SVD) of "training sets" built from measurements, theory, and simulations. SVD then produces basis vectors specifically suited for a given observation with which to fit the data. Pylinex has been heavily tested with simulated data in which the true 21-cm signal is known. These tests are essential for ensuring the extraction is both precise and accurate, but in the case of real observations, the true form of the signal will not be known. In this instance, an independent test that does not rely on the true signal must be able to detect if the signal extraction is unreliable.

Commonly used goodness-of-fit metrics such as chi-squared may indicate a good fit to the full data set even when the 21-cm signal has not been extracted properly. However, the number of SVD basis vectors chosen to fit each of the components of the data (e.g. foreground and 21-cm signal) can provide more information about the quality of the 21-cm signal reconstruction. A reference distribution created by fitting simulated data realizations taken from the training sets directly serves as the baseline against which the fit to the observed data is compared. If the fit falls within the reference distribution, we have confidence that the signal extraction is reliable. If the fit is outside of the reference distribution, it is likely that the training set is inadequate and needs to be altered to better represent that data.

References

Bassett, N., Rapetti, D., Burns, J. O., Tauscher, K., MacDowall, R., *Advances in Space Research*, 2020.
Tauscher, K., Rapetti, D., Burns, J. O., & Switzer, E., *Astrophysical Journal*, 2018.