Global 21-cm Data Analysis Pipeline for Hydrogen Cosmology using Lunar-based Observations

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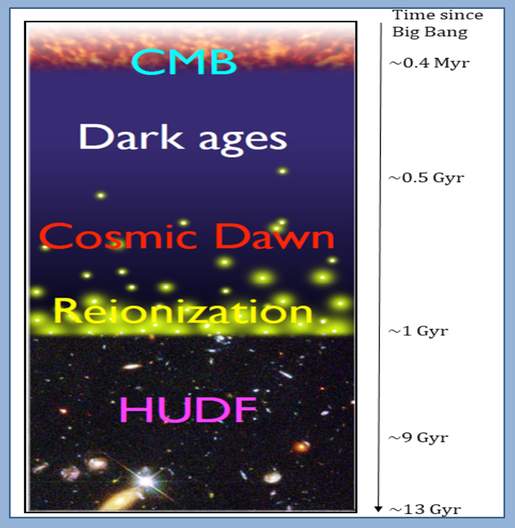
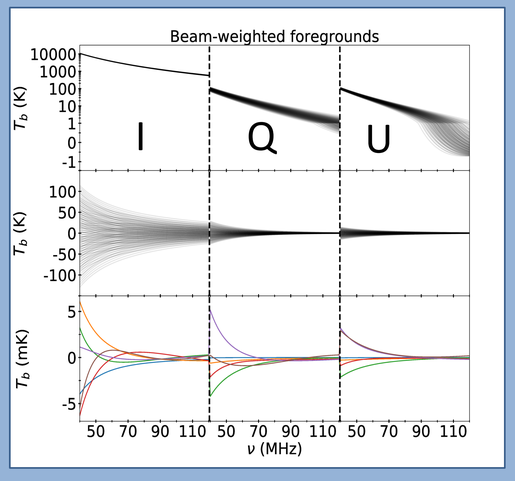
Introduction/Outline

As part of the SSERVI Network for Exploration and Space Science (NESS) team, we are developing a data analysis pipeline for concepts of missions to observe neutral hydrogen's cosmological 21-cm signal from radio-quiet environs in lunar orbit at low frequencies (~10-200 MHz; ~10 Myr-1 Gyr).

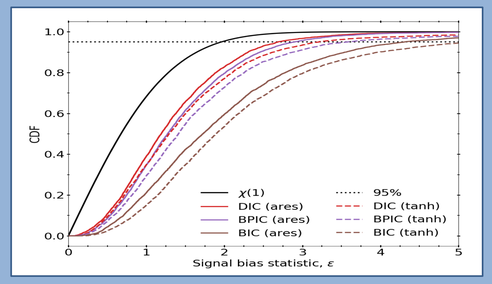


We parametrize signal and systematics with two separate sets of modes derived from training sets through Singular Value Decomposition (SVD).



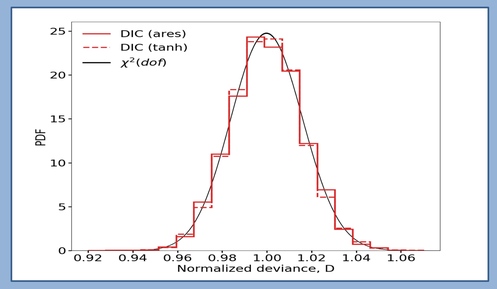
Our pipeline incorporates all Stokes parameters consistently in the likelihood. The polarization induced by rotation about the anisotropic foreground helps significantly in separating this from the isotropic, unpolarized signal.

Signal Bias Statistic



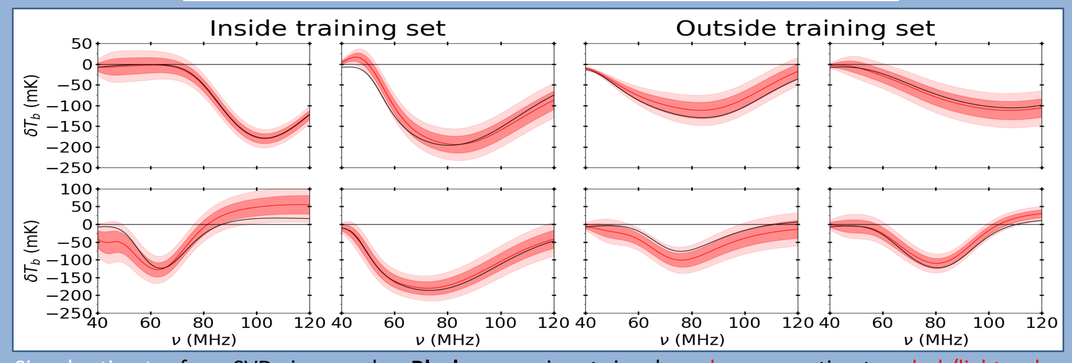
Estimate of the Cumulative Distribution Function (CDF) of a measure of the root mean square error weighted bias of the signal fits from 5000 input simulated datasets.

Normalized deviance



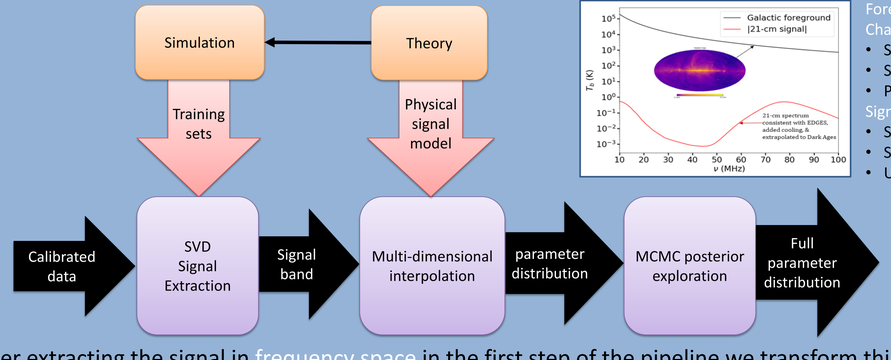
The deviance normalized by the degrees of freedom contains information about how well the training sets fit the data. Histogram of the Probability Distribution Function (PDF) for 5000 values.

Extracted Global 21-cm Signals using Pylinex



Signal estimates from SVD eigenmodes. **Black** curves**:** input signals; red curves: estimates; dark/light red bands: 68/95% confidence intervals. The 4 left input signals are from the *ares* code, and the 4 right from the tanh model. See Tauscher et al. (2018) and the pylinex code: https://bitbucket.org/ktausch/pylinex

SVD/MCMC data analysis pipeline (preliminary)



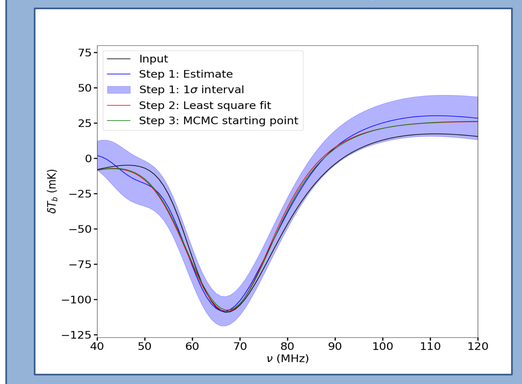
Foreground Characteristics
- Spectrally smooth
- Spatial structure
- Polarized

Signal Characteristics
- Spectral structure
- Spatially isotropic
- Unpolarized

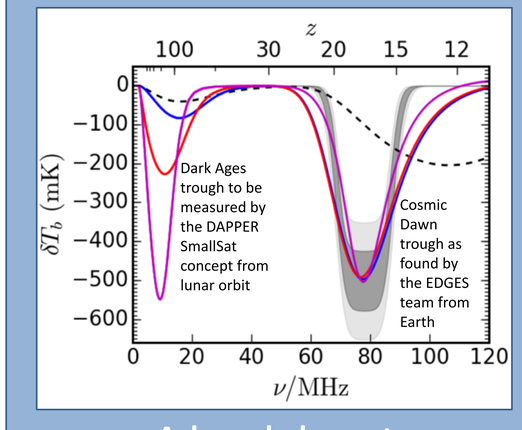
After extracting the signal in frequency space in the first step of the pipeline we transform this result into a constraint in physical parameter space. For this, we use a multi-dimensional interpolation using a Delaunay mesh and then a Markov Chain Monte Carlo (MCMC) search to constrain the full probability distribution.

Interpolation

Generalized linear interpolation to arbitrary input and output dimensions. We use this interpolation to perform a least square fit (red line) using the training set. Having a good MCMC starting point (green line) within the estimated error (blue band) provided by pylinex is crucial for convergence in a vast parameter space where we do not have otherwise any prior information on the solution and its uncertainty.



We use the *ares* code (Mirocha et al. 2014; https://bitbucket.org/mirochaj/ares) to model the imprints of the first stars, galaxies, and black holes on the 21-cm spectrum, as well as additional cooling due to potential exotic physics, as suggested by the recent EDGES results (gray bands).



Acknowledgments

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