Analysing Transit Telescopes with the m-mode Formalism

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Among the next generation of radio interferometers are a class of transit telescopes such as the Canadian Hydrogen Intensity Mapping Experiment (CHIME) which are designed for surveying cosmological 21 cm emission. Analysing the data from these instruments is challenging: they are instantaneously very wide-field, map most of the observable sky every day, and require the removal of foregrounds many orders of magnitude brighter than the 21 cm signal.

We have developed a new method for treating the data from transit telescopes called the m-mode formalism. This formalism allows us to transform the data into a large number of independent, finite dimensional m-modes, with the measurement equation becoming a simple matrix relation linking each mode to the spherical harmonics on the sky. With the formalism we can easily apply all the standard tools of statistical signal processing to the analysis. Unlike traditional interferometric analysis, this requires no approximation, and remains an exact treatment even in the wide-field limit.

These m-modes are statistically independent, allowing us to analyse each independently. This provides a huge computational saving, allowing us to efficiently and optimally tackle 21 cm survey interferometer analysis:

- Imaging is performed by applying a pseudo-inverse of the measurement equation, giving the maximum likelihood map of the sky.
- Foreground cleaning can be performed in an optimal manner by transforming into a Karhunen-Loeve basis which separates the 21cm signal from the astrophysical foregrounds. This is effective even in the presence of Faraday rotated polarised foregrounds.
- Powerspectra are estimated by straightforward application of the minimum variance quadratic estimator in the foreground cleaned basis. This keeps track of all the transformations done to the data giving an optimal, unbiased powerspectrum estimate.

I this talk I will give an overview of this method, describing its advantages and limitations, and demonstrate its effectiveness on simulated timestreams from a pathfinder CHIME instrument that is being built now with 10% of the full CHIME collecting area.