In this work we present our research into the separation of astrophysical components using numerical Bayesian techniques.

The work is motivated by the Planck satellite project ESA's Planck satellite, which is to be launched in 2007, will provide 9 all-sky maps ranging in frequency from 30 GHz to 900 GHz, and in angular resolution from 30 to 4.5 arcminutes. Celestial microwave radiation is generated by various astronomical sources, and the measured signals are superimpositions of the source signals, corrupted by measurement noise. Source signals include the cosmic microwave background (CMB), the thermal Galactic dust radiation, the synchrotron radiation (caused by the interaction of the electrons with magnetic field of the galaxy) and the free-free radiation (due to the thermal bremstrahlung from hot electrons when accelarated by ions in the interstellar gas); among which CMB is of paramount importance since it is a relic radiation remaining from the first instant light was able to travel in the universe and therefore contains the picture of the very early universe. In addition, the measurement of the anisotropies in the CMB will place fundamental constraints on models for the evolution of large scale structure in the universe. Each of the other source signals is also of interest in cosmology and astrophysics. Our goal is to reconstruct these signals.

We implement first a Markov Chain Monte Carlo (MCMC) algorithm to perform Bayesian source separation, with application to the separation of signals of different origin in sky radiation maps. The problem is formulated as the separation of an instantaneous linear mixing

$$\mathbf{x} = \mathbf{A}\ \mathbf{s} + \mathbf{n}$$

where $\mathbf{s}$ contains the astrophysical sources, $\mathbf{x}$ houses the observations over various frequency channels and $\mathbf{A}$ is the mixing matrix where each row contains the frequency response of each source at a certain frequency channel.

The problem has been dealt with using other methods by several researchers in the literature including [1] and [2] who implemented a neural network based approach and [2] who implemented the FastICA algorithm which had limited success in the presence of significant noise. A source model was introduced in [3] implementing the Independent Factor Analysis (IFA) technique which also included the noise in the mixing model. Despite this added flexibility, IFA uses a fixed source model which lacks freedom in modelling source model parameters and moreover could not deal with non-stationary noise which is the case in our problem. In this work, we aim at overcoming these limitations by providing a full Bayesian analysis equipped with statistical priors for the source parameters and utilising the prior information about the mixing as well.

Since the MCMC methods provide samples from the full posterior distribution, one can easily infer other functions of the parameters and their uncertainities. The great flexibility of the sampling approach allows us to make appropriate modelling choices for our problem. In particular, we have used a Gibbs sampling scheme and have adopted a Gaussian mixture model for the sources.

We also note that antenna noise is Gaussian but non-stationary, with a different but known variance at each pixel. To accommodate the nonstationarity in the noise and the signals, we then extend the work to sequential Monte Carlo techniques. Particle filtering gives significantly better results which will be presented at the conference.

[1] Baccigalupi, C. and Bedini, L. and Burigana, C. and De Zotti, G. and Farusi, A. and Maino, D. and Maris, M. and Perrotta, F. and Salerno, E. and Tonazzini, A. and Toffolatti, L. ",
Neural networks and the separation of cosmic microwave background and astrophysical signals in sky maps",Monthly Notices of the Royal Astronomical Society, vol. 318, 2000, pp. 769-780.

[2] Maino, D. and Farusi, A. and Baccigalupi, C. and Perrotta, F. and Banday, A.J. and Bedini, L. and Burigana, C. and De Zotti, G. and Gorski, K.M. and Salerno, E."All-sky astrophysical component separation with Fast Independent Component Analysis (FastICA)", "Monthly Notices of the Royal Astronomical Society", vol. 334, 2002, pp. 53-68.

[3] Kuruoglu, E.E. and Bedini, L. and Salerno, E. and Tonazzini, A."Source Separation in Astrophysical Maps using Independent Factor Analysis", Neural Networks, vol. 16,no.3-4, 2003, pp. 479-491.