

Component separation for a CMB B-mode observation mission

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The component separation problem

- **Recognised as a key issue for a B-mode polarisation space mission**
- **If one targets to measure reliably (at good S/N) $r=T/S$ levels undetectable with Planck and from the ground, one has to reject galactic foregrounds by a factor of 50-100 on large scales.**
- **Point sources cannot be neglected. The brightest ones have to be blanked. Contamination from the others should be corrected for.**
- **The key issue (for galactic foregrounds in particular) is whether we can predict (in a way or another), in a set of CMB channels, polarised FG emission with confidence at the 1-2 % level.**

Galactic foregrounds

- **Highly complex, with many uncertainties.**
- **Main foregrounds : Synchrotron and dust**
 - **Uncertainties concerning some components (anomalous dust)**
 - **All components can be polarised (at least locally in special regions) at the few percent level**
 - **Remain open minded : surprises are not excluded**
- **Two main approaches for subtracting the galactic emission**
 - **Either we can model it physically to within 1% error and subtract it (we are far from that)**
 - **Or we can use statistical methods, which use the independence of CMB from foregrounds to extract the CMB**
- **Our understanding will improve drastically with the analysis of the Planck data**

CMB extraction with blind methods

- **Blind separation tools permit to extract the CMB with practically no assumption about the foregrounds**
- **The key issue is not the level of galactic emissions, but their coherence (from channel to channel) and emission law(s). It is much easier to remove a strong foreground which scales rigidly with frequency, than a faint foreground mostly uncorrelated from channel to channel.**
- **An example is faraday rotation, which breaks the coherence between 1 GHz polarisation and 100 GHz polarisation.**

CMB extraction with blind methods

- **In order to achieve residuals of order 1%, templates representing galactic emission must be 99% correlated from channel to channel.**
 - **This is unlikely to be the case over a large frequency range with one single template for each emission.**
 - **The alternative is to assume that multifrequency galactic emission can be represented with a set of templates (possibly correlated in space) so that the residual of this representation is $< 1\%$. The number of templates needed sets the number of frequency channels required.**
 - **This is what is discussed in Betoule et al. 2009 as the 'dimension of the galactic component'**
- **Blind methods rely on statistics. They work well when we have a large number of independent data point**
 - **An issue for the largest scales**
 - **May impact the optimal mission resolution**

Blind methods vs. physical models

- **Blind methods require statistics. They hence work best on small scales**
- **Modelling the emission is difficult on small scales (turbulent and complex behaviour of the galactic magnetic field, LOS integration effects) but plausibly easier on large scales (which requires 'only' the physical modelling of the galactic emission from the solar neighbourhood).**
- **1% error on foreground subtraction with blind methods requires computation of statistics with $\approx 1\%$ error, which requires 10.000 independent data points. It will work best on scales lower than 2° . Larger scales can be obtained if the statistical properties computed on small scales can be used to clean up larger scales, which is uncertain.**
- **Investigate hybrid methods which are based on a physical model of foreground emission on large scales, and use blind separation methods on smaller scales.**

Point sources

- **Are important mostly on small scales, but also on large scales for low r .**
- **Important for accurate measurement of B-modes from lensing.**
- **Residuals will appear as an additional noise, correlated from channel to channel.**
- **Cutting all sources above a certain level will leave many holes in the sky, in particular if the resolution is low.**
- **Subtraction of the emission of (moderately) bright point sources requires reliable flux estimates. It will probably have to be done using the data of the mission (or can we use ancillary data, e.g. Planck detections + ground based catalogues) ?**

Impact of Comp. Sep. on mission design

- **Impact on resolution**
 - **For point source identification and extraction**
 - **For statistics for using blind component separation methods**
- **Impact on frequency bands**
 - **Number**
 - **Location in frequency**
 - **Sensitivity**
 - **Resolution**
 - **Sky coverage at each freq. and resolution: e.g. can we use ground based, high resolution observations of the polarisation in small patches to measure contamination of the B-mode spectrum by unresolved point sources**
- **The mission design should be robust with respect to our uncertainties about the properties of the polarised foregrounds : number of relevant emissions, level, coherence and complexity, etc.**

Investigation plan

- **On short timescales (for response to A0)**
 - **Review existing measurements which constrain polarised foreground emission.**
 - **Review and summarize existing literature for polarised component separation, show limitations and major sources of uncertainty.**
 - **Review existing uncertainties about the models of polarised emission.**
 - **Contribute to the writing of the relevant section in the Bpol answer to the A0.**
- **On 2 year timescale**
 - **Strong connection with analysis of Planck data.**
 - **On the basis of Planck observations, improve the Planck Sky Model (PSM) both for foreground prediction and for simulation of plausible foreground complexity, which will permit to check robustness of component separation w.r.t. sky modelisation. Work involving Guillaume Castex, a PhD student dedicated to the development of the PSM (until oct. 2012).**
 - **Develop or generalise component separation methods specifically for polarisation measurement. Work involving Soumen Basak, a postdoc dedicated to polarised component separation (until dec. 2011).**