BPOL Meeting,
Roma, 29 March 2007

BPOL Foreground WG Activity

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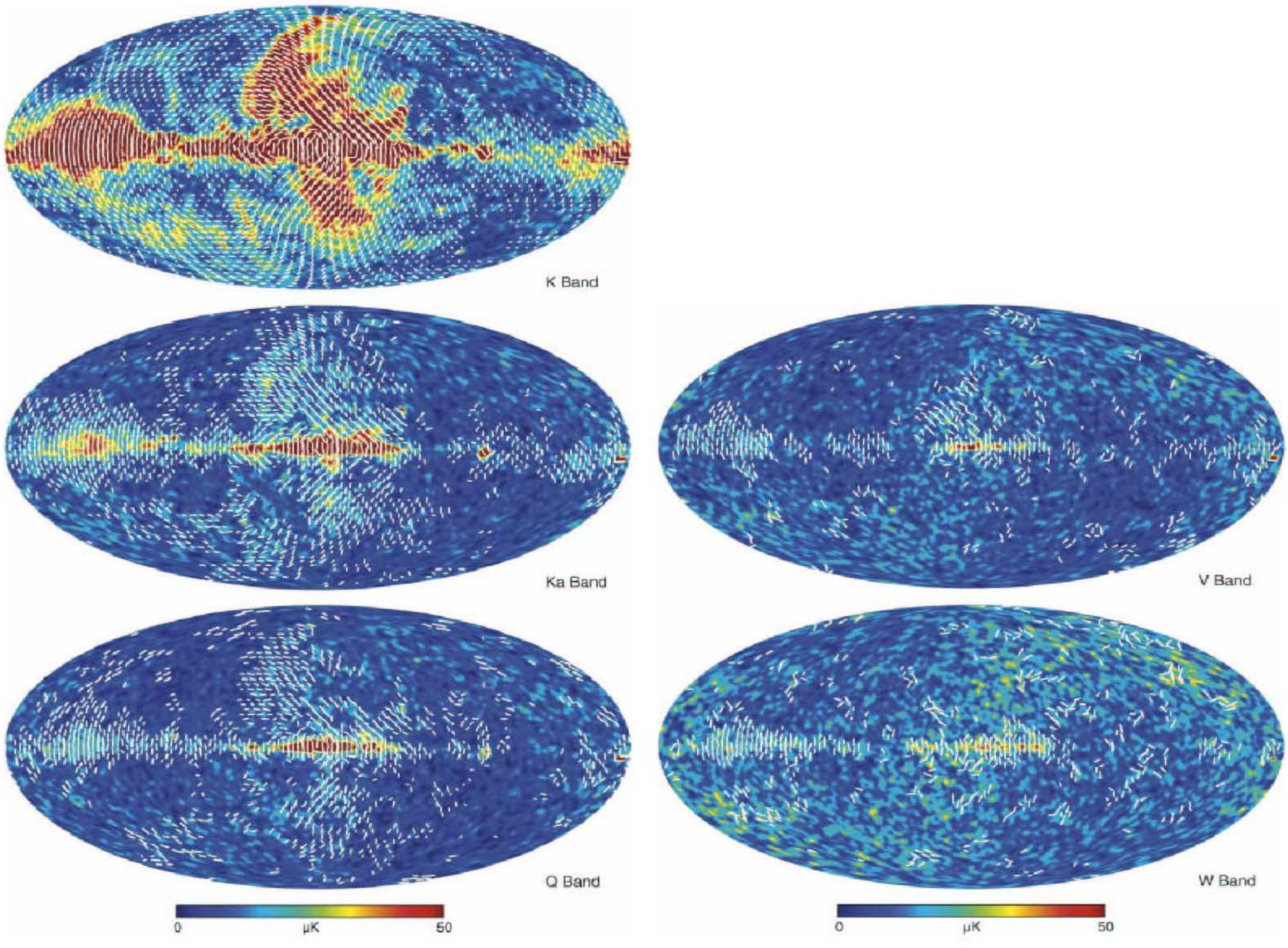
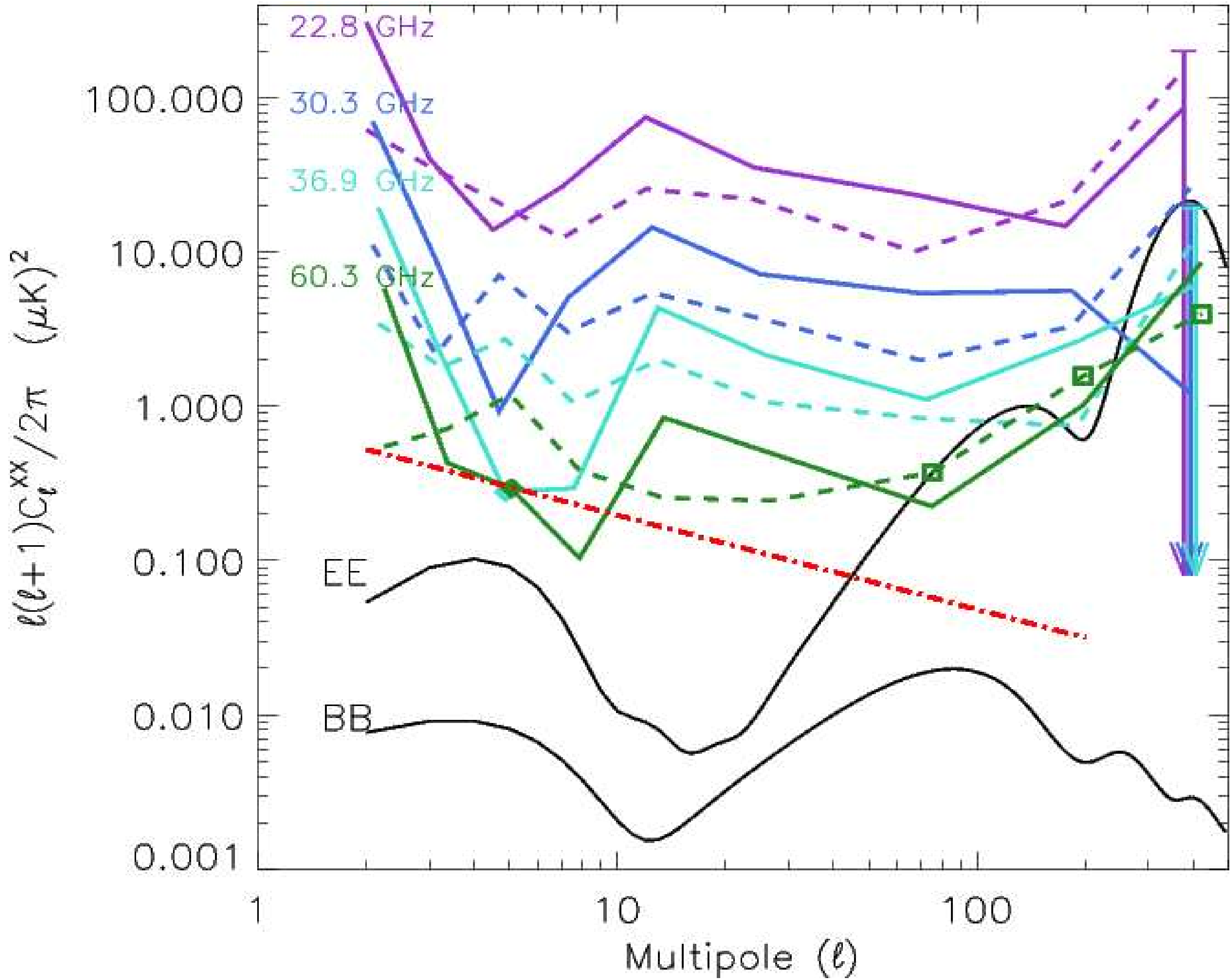
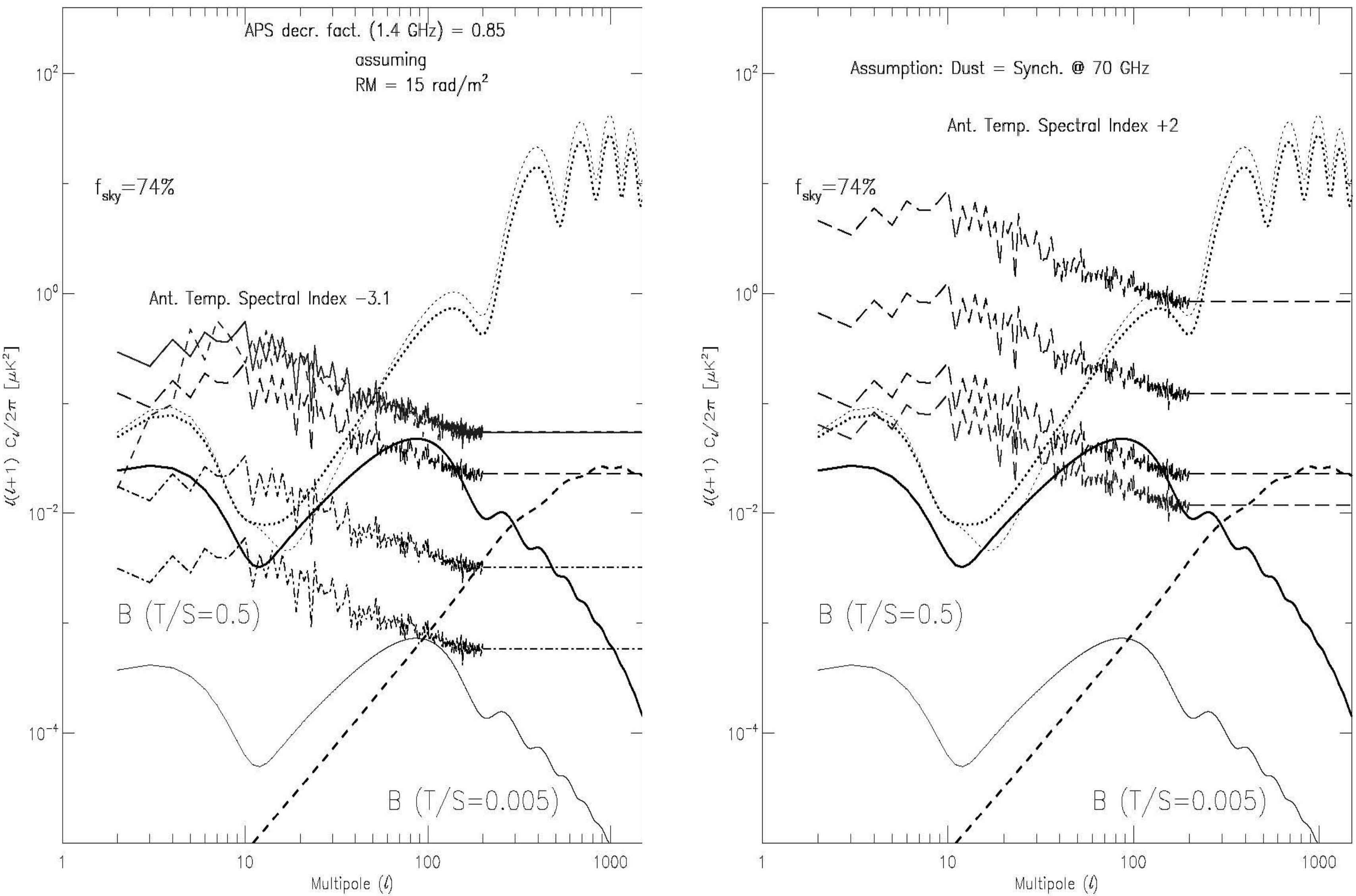
On behalf of BPOL Foreground WG


K Band
Ka Band
V Band
Q Band
W Band
0
μK
50
0
μK
50



22.8 GHz
30.3 GHz
36.9 GHz
60.3 GHz
EE
BB
100.000
10.000
1.000
0.100
0.010
0.001
1
10
100
Multipole (ℓ)
ℓ(ℓ+1)C_ℓ^XX/2π (μK)^2



APS decr. fact. (1.4 GHz) = 0.85
assuming
RM = 15 rad/m²
f_sky=74%
Ant. Temp. Spectral Index −3.1
B (T/S=0.5)
B (T/S=0.005)
ℓ(ℓ+1) C_ℓ/2π [μK²]
Multipole (ℓ)
Assumption: Dust = Synch. @ 70 GHz
Ant. Temp. Spectral Index +2
f_sky=74%
B (T/S=0.5)
B (T/S=0.005)
ℓ(ℓ+1) C_ℓ/2π [μK²]
Multipole (ℓ)

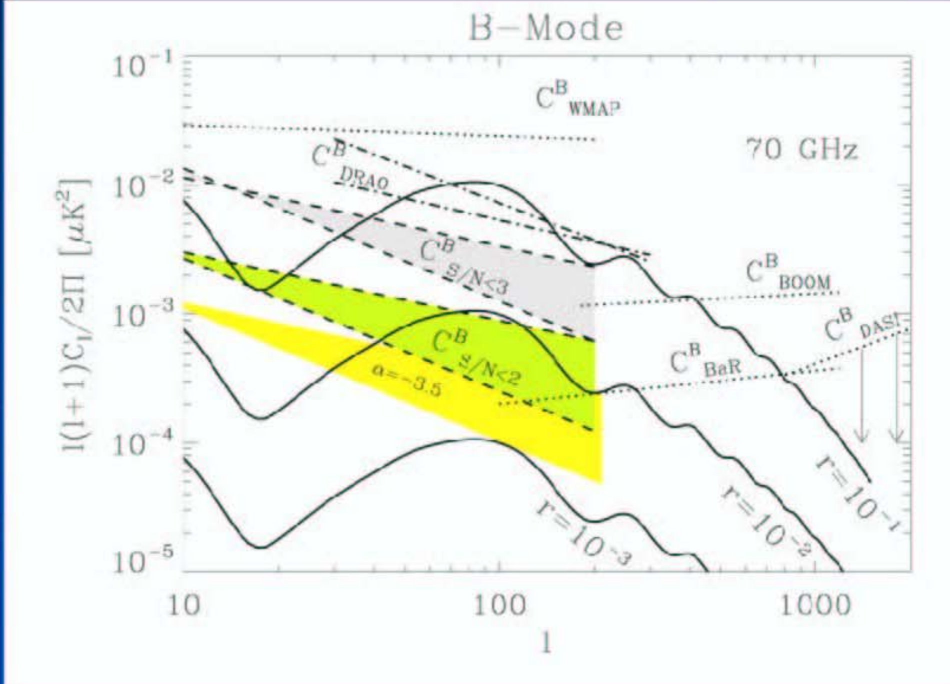
Spectra (low em. regions) (2)

Carretti et al., 2006, MNRAS Lett., astro-ph/0609288

- Angular extrapolation from signal dominated range (β = -2.5 / -3.0)
- S/N < 2: T/S = 10^{-2} - 10^{-3} @70 GHz
- S/N < 3: 5x higher
- 16% of sky: T/S = 10^{-2}-10^{-3} even without cleaning
-

Sky fract.	Δ(T/S) [3-σ]
15%	1×10^{-3}
70%	3.2×10^{-5}
100%	1.5×10^{-5}

α = -3.1



[Amarie et al., 2005, PRD, 72, 123006]

- **Foregrounds and Component Separation Chapter**
- **Extended Draft for Phase A Proposal → the presentation continues with the description of the corresponding .pdf file [currently restricted to the BPOL WG(s)]**
- **Only the previously agreed plan + some work activity suggestions / proposal are reported here**
- **Further discussions will follow**

1. Introduction

C. Burigana*, et al. burigana@iasfbo.inaf.it

2. Galactic foregrounds

Brief introduction to be agreed by reference persons of these subsections

2.1 Anchillary data

Brief introduction to be agreed by reference persons of these subsubsections

2.1.1 Polarized synchrotron emission: information from radio surveys

W. Reich*, C. Burigana, L. La Porta, E. Carretti, et al.
wreich@mpifr-bonn.mpg.de

2.1.2 Polarized dust emission: information from far-IR surveys

J.-P. Bernard*, P. Fosalba Vela, S. Masi, et al.
jean-philippe.bernard@cesr.fr

2.1.3 Extrapolations from anchillary data to microwaves

G. Bernardi*, C. Burigana, L. La Porta, et al. bernardi@astro.rug.nl

2.2 Galactic foregrounds from microwave surveys

A. Banday*, P. Leahy, S. Leach, et al. banday@mpa-garching.mpg.de

2.2.1 Anomalous components (UK***)

P. Leahy*, A. Banday, D. Maino, et al. j.p.leahy@manchester.ac.uk

2.3 Nearly all-sky and local analyses

L. La Porta*, E. Carretti, C. Burigana, J.-P. Bernard, et al.
laporta@mpifr-bonn.mpg.de

3. Extragalactic foregrounds

G. de Zotti*, L. Toffolatti, D. Clements, et al.
gianfranco.dezotti@oapd.inaf.it

3.1 Exploiting the existing catalogs from radio to far-IR

M. Massardi*, J. Gonzales-Nuevo, et al.
massardi@sissa.it

3.2 Contributions from radio sources

M. Tucci*, J. Gonzales-Nuevo, et al. tucci@iac.es

3.3 Contributions from far-IR sources (UK*)**

D. Clements*, A. Jaffe, et al. d.clements@ic.ac.uk

3.4 Relevance at various multipole ranges

L. Toffolatti*, F. Argueso, et al. ltoffolatti@uniovi.es

4. Future auxiliary observations

Brief introduction to be agreed by reference persons of these subsections

4.1 Future surveys of polarized diffuse components

E. Carretti*, P. Leahy, S. Poppi, et al. carretti@ira.inaf.it

4.2 Future polarization observations of extragalactic sources

K. Ganga*, E. Kreysa, D. Clements, P. Reich, et al.
ganga@apc.univ-paris7.fr

- **5. Non-Gaussianities in polarization**
  E. Martinez Gonzalez*, P. Naselsky, et al.
  martinez@ifca.unican.es
- **5.1 Non-Gaussianity from diffuse foregrounds**
  P. Naselsky*, P. Coles, et al.
  naselsky@nbi.dk
- **5.2 Non-Gaussianity from point sources**
  P. Vielva*, L. Moscardini, et al.
  vielva@ifca.unican.es

- **6. Methods to deal with diffuse components**
  Brief introduction to be agreed by reference persons of these subsections
- **6.1 Non-blind methods (UK***)**
  M. Hobson*, F. Stivoli, A. Lasenby, A. Banday, C. Carbone, D. Samtleben, et al. mph@mrao.cam.ac.uk
- **6.2 Blind methods**
  D. Maino*, C. Baccigalupi, F. Stivoli, et al. davide.maino@mi.infn.it
- **6.3 The phase method (UK***)**
  P. Coles*, P. Naselsky, et al. Peter.Coles@nottingham.ac.uk
- **6.4 "Hybrid" methods**
  S. Ricciardi*, A. Bonaldi, G. De Zotti, et al.
  Sara.Ricciardi@roma1.infn.it

- **7. Point source removal and background estimation**
  J. Gonzales-Nuevo*, E. Martinez Gonzalez, P. Vielva, M. Tucci, et al.
  gnuevo@sissa.it

- **8. Exploiting foreground physical modelling**
  R. Beck*, T. Arshakian, A. Banday, G. Bernardi, J.F. Macias-Perez, G. Chon, et al.
  rbeck@mpifr-bonn.mpg.de p181bck@mpifr-bonn.mpg.de

- 9. Residual contamination in CMB maps
  Brief introduction to be agreed by reference persons of these subsections

- 9.1 Residual errors from diffuse component separation
  J.F. Macias-Perez*, S. Stivoli, et al. macias@lpsc.in2p3.fr
- 9.2 Residual errors from point source removal
  P. Vielva*, J. Gonzales-Nuevo, et al.
  vielva@ifca.unican.es

- 9.3 Implications for the CMB
  C. Baccigalupi*, C. Burigana, A. Banday, R. Fabbri,
  F. Stivoli, et al. bacci@sissa.it

- 9.3.1 Residual errors at low multipoles (l < few tens)
  C. Burigana*, R. Fabbri, et al. burigana@iasfbo.inaf.it
- 9.3.2 Residual errors at intermediate multipoles
  (few tens < l < few hundreds)
  R. Fabbri*, E. Carretti, et al. roberto.fabbri@unifi.it
- 9.3.3 Residual errors at high multipoles (l > few hundreds)
  F. Stivoli*, C. Baccigalupi, et al. stivoli@sissa.it

- **10. Foreground implications for the BPOL cosmological aims**

- **10.1 Definition of the optimal frequency coverage**
- **10.2 Choice of the frequency channels**

- **10.3 Ultimate foreground limitation to CMB B-mode studies**
- **10.3.1 Implications for the reionization bump**
- **10.3.2 Implications for the primordial B-mode**
- **10.3.3 Implications for the lensing B-mode**

- **10.4 Implications for high accuracy E-mode analyses**

- **10.5 Implications for CMB non-Gaussianity analyses**

- **11. BPOL perspectives on foregrounds**
- **11.1 Implications for Galactic science**
- **11.2 Implications for extragalactic source science**

WORK GUIDELINES following Paris meeting etc., to be further discussed here!

1) frequency coverage & resolution

agreed:

freq. (GHz) =	70	100	143	217	353
FWHM (arcmin) =	30	20	15	10	10

to be studied:

I option

freq. (GHz) =	30	44
FWHM (arcmin) =	120	120

- the I option is of particular interest for experimental set-up able to measure Q & U but not T, in order to work at the same nu of Planck/LFI

II option

freq. (GHz) =	40	55
FWHM (arcmin) =	120	120

- the II option is of particular interest for the possibility to better test a low frequency departure from pure power law approximation by using these channels together with LFI, to work @ nu closer to the minimum of foreground, and to consider nu possibly lighter/smaller from the hardware point of view.

The resolution is that typically achievable with lens in front of feeds or with a (not high) performance telescope.

Consider also FWHM=5deg, as a possible very simple implementation of low frequency channels

- **2) typical sensitivity on Q & U**

- freq. (GHz) = 70 100 143 217 353
- rms (uK per pixel
- of 1 arcmin side) = 3 3 3 3 10

- (this corresponds to the agreed sensitivity of 5uk @ cosmological channels with a factor of margin)

- plus

- freq. (GHz) = 30 44 or 40 55
- rms (uK per pixel
- of 1 arcmin side) = 20 20 20 20

- (this corresponds to a sensitivity about 5-10 times better than LFI, achievable with a corresponding larger number of detectors &/or with reasonable factors of performance improvement per detector)

3) Concerning component separation of diffuse components

for methods that need to degrade maps at the lowest resolution it could be useful to consider two cases:

a) all channels degraded to 2 deg FWHM resolution
b) all channels degraded to 30 arcmin FWHM resolution

Include both polarized synchrotron emission and polarized dust emission according to reasonable templates (i.e. in agreement with current info at least within a factor of 2).

Case a) is of particular relevance for nearly all-sky analyses, for example by using a mask like that considered by WMAP team for the polarization analysis (about 74% of sky coverage).

Case b) is of particular interest for selected sky areas at low foreground contamination, large enough to avoid significant degradation by sampling variance (and boundary effects) at multipoles larger than about some tens (? TBC by work!), For example for areas equivalent to about 50 deg * 50 deg or 70 deg * 70 deg (about 6 % or 12% of the sky).

Such resolution assumes degradation of high nu channels to that of 70 GHz (minimum of foreground) and, at low nu, the combination of BPOL with dedicated observations by ground or balloon at 0.5 deg resolution (or better) "recalibrated“ on BPOL maps.

It will be extremely useful to understand what it happens by including or neglecting low nu channels in these two cases in the combined presence of dust & synchrotron, other than CMB.

As comparison case, one could refer to the LFI sensitivity on Q & U at 30 & 44 GHz of about 15 uK but on pixels of 10 arcmin side.

It will be extremely relevant to quantify the typical residuals after the separation of Galactic diffuse components in the above experimental conditions to understand if they are enough or not, the relevance of various channels (low nu, in particular) and, possibly, to distinguish between option I & II.

Are typical levels of residual foreground contamination close to 3, 1 e 0.3% of their original angular power spectrum (APS) reasonable guesses?

Or is this range of "foreground rejection" level too much ambitious even assuming future progress in component separation methods, or, maybe, already close to be achieved, so we could hope for further improvements?

Could we assume these numbers as "representative" for our "subsequent" studies on CMB?

High pixel resolution is not so important here at this stage; you can work for example @ nside=128 (or maybe better 256) of HEALPix (about 0.5 deg or 14') if this alleviates computational time difficulties.
(Or even @ lower resolution if you are studying implications@ relatively low l).

- **4) APS Galactic foreground "rescaling" in frequency & multipole**

- **Clearly, it will be useful to quantify foreground impact also independently of the component separation process, i.e. only on the basis of data and simple extrapolations.**
- **This approach could complement the component separation approach: a not too specialist reader may be more convinced by simple arguments than by sophisticated methods.**

- **It also helps us in the discussion of the implications of foregrounds (vs CMB), at their "original" level and/or at "residual" level according to the above point.**
- **I suggest to use the simple parametrization for the angular power spectrum (APS) given in the Page et al. WMAP paper in press on ApJ**
- **(http://lambda.gsfc.nasa.gov/product/map/current/map_bibliography.cfm) @ eq. (25).**

- **This refers to the case of the considered sky mask (about 74% of sky coverage) and to multipoles l < 100.**
- **It is simple enough (with synchrotron & dust terms uncoupled).**

The situation at higher l is not so clear.

In addition, eq. (25) could also include a minor contribution by sources (or noise) with the result of a certain flattening the APS; this effect should be negligible at lower l, but could be non fully negligible at l larger than 50.

Possible reasonable modifications could then exploit a steepening of the APS with l: for example, we could assume that formula up to l=50 and then C_l proportional to l^(-3) at l>=50 (this slope is more in agreement with radio surveys, after source subtraction).

This will represent a better case for our cosmological aim.

Contrarioulsy, as worse case, one could use that eq. (25) up to l=100 and then C_l proportional to l^(-2) at l>=100.

As estimates of the APS in regions and middle/low or very low foreground contamination we could exploit the same multipole & frequency dependences but with amplitudes scaled down in terms of APS by a proper factor.

I suggest to consider 12% or 6% sky coverage, both rescaled down with two representative factors of 5 or 50 in terms of APS, i.e. about 2.5 or 7 at rms maps level, as inferred from La Porta et al. 06 AA 455, L9 and Carretti et al. 06 MNRAS 373, L93 analyses,from radio surveys & WMAP, respectively

(the most optimistic case could derive for example by collecting few (2, 3) "connected" sky regions at very low foreground contamination).

These analyses allow to focus on the "different weight" of sampling variance and overall foreground impact.

If one likes to exploit different Galactic synchrotron frequency spectral indices, I suggest to consider values of -2.9, -3.1, -3.3, more in agreement with radio surveys indications.

Concerning other possible Galactic dust frequency spectral indices, I believe that this is not urgent at this stage in this context of comparison of foreground vs CMB & comp. sep.,

(while it is certainly relevant for the sections dedicated to the foreground description),

since the already agreed good BPOL sensitivity, resolution and frequency coverage at high nu very likely will make us in the condition to monitor very well the dust emission frequency scaling.

5) Concerning point source subtraction

it could be extremely relevant to understand the source contribution to the angular power spectrum (APS) (and in particular its rms uncertainty) after a source subtraction achievable with the above performance in polarization complemented by existing and future surveys (Planck for example), also in total intensity.

Maybe, it could be interesting to understand the different capabilities in terms of source subtraction and residual APS contribution if one uses temperature information with reasonable guesses on source polarization degrees or directly the polarization information.

(My first order feeling is that the first approach allows a deeper source subtraction and a lower residual APS contribution, since, given the typical low polarization degree of sources, particularly extragalactic, the BPOL improvement in terms of sensitivity - but not in terms of resolution in this scheme - probably does not allow to do better; maybe, more quantitative considerations could help.

On the other hand, probably BPOL could help to check the reliability of the first approach).

Maybe, for persons more devoted to sources than CMB it could help to express sensitivity also in terms of flux units (Jy). In this case, you could refer to eqs. (1), (2), (3) of the Cremonese et al. paper astro-ph/0209373 (New Astron. 7, 2002, pg. 483) for the conversion from the above sensitivity on the measure of thermodynamic temperature fluctuationsto the sensitivity on the measure of point source flux.

Obvioulsy not only noise but also Galatic foreground and CMB flucts. contribute to determine the "effective" noise for source detection, albeit multifrequency could help.

6) Comparison with CMB

If you have already done relevant work with a given choice of cosmological parameters, no problem.

In the opposite case, it could be useful to assume the same framework.

It seems to me that a good and reasonable simple case is given by the WMAP 3yr table (http://lambda.gsfc.nasa.gov/product/map/current/parameters.cfm)

for the model: lcdm+tens and the data set: wmap

For the two parameters probably more relevant here, tau and T/S, we could assume:

tau = 0.09 (& 0.06, 0.12) best fit and "limits"

T/S = 3.e-4, 1.e-3, 3.e-3, 1.e-2, 3.e-2, 0.1

(this range is between values small but not too much to be extremely pessimistic and a reasonable upper limit that could be detected but probably not accurately studied by Planck).

Obviously, the final goal is to understand if such "hardware set-up" is really appropriate for our scientific aims or, differently, improvements (or, at limit, simplifications) need to be investigated (or could be allowed) !!!

WORK SCHEDULE - DATES

- April: 1. draft of sections with defined coordinators
- Agreement on possible in practice experimental set-up
- Beginning of May: Definition of freq., res., … to define the two last sections of Foregrounds & Comp. Sep. Chapter
- May: refinement of sections of 1. draft & writing of the two last sections
- End of May: “consolidated version”of the whole chapter
- June: Iterations/End of Writing/Proposal Conclusion