B-POL for ESA's COSMIC VISION
The Meeting was at IAP on 31/06/2006, from 11:00 to 17:30

Present:

Martin Bucher, LPT, Orsay
Eduardo Battaner, Granada
Lucio Piccirillo, Manchester
Jose Alberto Rubino-Martin, IAC/Tenerife
Enrique Martiez-Gonzales, IFCA/Santander
Paolo Natoli, Univ. Tor Vergata, Roma
Paolo de Bernardis, Univ. La Sapienza, Roma
F. Xavier Desert, LAOG, Grenoble
Bruno Maffei, Cardiff/Manchester
Reno Mandolesi, INAF-IASF Bologna
George Efstathiou, Inst.Astron., Cambridge
Tony Banday, MPIfA, Garching
Joe Silk, Univ. of Oxford
Anthony Lasenby, Cavendish, Cambridge
Carlo Burigana, INAF-IASF Bologna
Francois Bouchet, IAP, Paris
Nicolas Ponthieu, IAS, Orsay
Walter Gear, Cardiff Univ., Cardiff
Silvia Masi, Univ. La Sapienza, Roma
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Summary (by P. de Bernardis and F. Bouchet)

F. Bouchet summarized the situation with ESA's Cosmic Vision call. The latest news is that the call will be issued around the end of December. The purpose of the meeting is to define the kind of B-modes mission the European CMB community wants to submit.

L. Piccirillo presented a mission concept based on a pseudo-interferometer with coherent detectors. These are optimal in the range where could be the minimum of polarized foregrounds (around 75 GHz in the WMAP 3-years survey). The interferometer would have a 10deg primary beam and a resolution of around 20' (depending on the size of the focal plane). The advantages of this concept are

1) simple satellite (wmap class) with many more detectors.
2) no telescope, angular resolution is obained with the separation of the horns. Need a separation of more than 1 m, i.e. a large cold focal plane.
3) The syntesized beam is extremely clean
4) The correlation receiver measures U,Q,I simultaneosly
5) the interferometer should be superior in controlling systematic effects

Manchester-Jodrell-Bank will test this concept with a 4x4 pseudo-interferometer

The presentation triggered a number of comments/questions. The main ones were:
- the system is not simple, and a large array of HEMTs is a serious cryogenic challange
- it does not cover the high frequency region, due to the coherent technique required.
- The system is not optimal for the largest scales, which are the ones to be studied principally from space. Mosaic-ing of many images will inevitably introduce 1/f noise. This could be overcome with partial overlap and rotating the instrument and re-observing the same field, but detailed study would be needed.

Francois Bouchet gave a number of general remarks and then presented the results of the SAMPAN study, carried out in France and funded by CNES.

General remarks:

This CMB proposal will be competing with all fields of astronomy and space science. For sure we aim at making a single CMB proposal. In the current ESA plan, there are slots for "medium" (300-400MEuro) proposals and "large" (>600MEuro) proposals. We need to make a choiche of where we are competing. We already know a few "large" proposals: LISA (grav.waves), Con-X/XEUS (X-rays), etc. The science goals for the CMB proposals are as follows:
- gravitational waves background at low multipoles
- signal from gwb @ ell up to 200
- neutrino mass - lensing of E modes - matter power spectrum -> high ell

We must show that what we propose cannot be done with balloons or from ground and that the proposal will survive the time (2015 at best, but 2020 more likely). The mission should have superb control of the foregrounds. The mission concept and measurement technology is not in hand yet. There are data analysis issues: 10x sensitivity compared to Planck. The data volume will be huge, even considering Moore's law.

The SAMPAN study was carried with all the above in mind. It was carried out by a small mission group, on behalf and in contact with the french community at large. The work was donewith CNES and industrial contractors, with the aim to make a complete exercise, all the way to costing, or identify possible show-stoppers. For SAMPAN the target sensitivity has been set at 5 uK arcmin, which corresponds to the level of lensing of the E-modes, with a sensitivity on r=T/S=0.001

(optimistic, from the Fisher matrix analysis, assuming that all the foreground and systematic issues are solved). The analysis of this sensitivity vs. angular resolution shows that the angular resolution requirement is at least 40' @ 100 GHz (and with diffraction limited scaling for higher frequencies). Moreover, it was also shown that most of the signal of interest is indeed at large angular scales: the T/S detection threshod improves by a factor 30 if the minimum ell is extended ell_min=30 to ell_min=3. These estimates assume that no cleaning for lensing is done. With a more aggressive concept, aiming at say 1 uK arcmin sensitivity and 1' resolution, it would be possible to reconstruct the matter power spectrum and clean for lensing internally. However, the cost of such a mission would really explode well above the ESA budget even maybe for large missions. The cost of the "simpler" SAMPAN concept is around 450 MEuro (without a posteriori optimisation).
SAMPAN is a bolometric imager with 4 bands at (100,143,217,353) GHz (optionally extended adding 70 and 545 GHz). The angular resolution in the 4 bands will be (40, 30, 20, 20) arcmin. Antenna coupled bolometer arrays are used. Each bolometer is sensitive to 1 linear polarization. The polarization signal is modulated by simply spinning the satellite, so that the sky in front of the focal plane rotates. This avoids the use of moving parts in the focal plane. Low background conditions are needed, so a cold optics is used. Bolometers are cooled at 0.1K. 20 000 pixels are needed to meet the goal in 2 years. This results in a 30 cm diameter focal plane. Refractive optics is used, with Strehel rations < 1% and low polarization (as provided by a double lens+curved focal plane). The scan strategy is optimized to obtain repeated observations of the same direction at different time scales and with different orientation of the polarization axis. It is a spinning satellite, nutating and precessing. The strategy has been opimized for observation of low multipoles: it covers tens of degrees in minutes. This raises a number of thermal issues. The study has shown that using "vertical V grooves" surrounding the instrument it is possible to operate even with the satellite axis (occasionally) orthogonal to the sun-satellite direction. Passive cooling can keep the external skin of the cryostat at 50K. The optical system will consist of a set of 50K baffles, a lens at 8K, another lens at 2K. We thus have a baseline for cosmic vision.

Following the presentation several issues were discussed.

The first one was "which detectors ?". There are several R&D activities on bolometers in Europe (France, Italy, SRON...). For SAMPAN the spin of period is around 20 s , so a 10 ms time constant is needed. This is one of the technology problems that make a launch in 2015 extremely optimistic.
Stability of the overall measurement chain is also demanding. But the real issue is our very limited knowledge of the foregrounds. This will be much better after Planck (and ongoing ground and balloon experements). From the experimental point of view there are two big issues :
- the level of foregrounds at low ell
- the level of systematics at low ell

A general discussion on the science case and on its robustness was then opened.

The core of the science case is primordial B-modes. The case is very strong since it is the only way to probe physics near the Planck scale, thus gathering the support of the particle physics community in addition to the cosmology community. If this was the only target of the mission, then the low-resolution mission would be OK. However, the risk is that this target is too narrow, and it may well end into setting a strong upper limit. In fact, some theorists say that only a small fraction of inflation models produce a detectable level of B-modes. It is clear that if there will be in the near future a claim of detection either from ground based or from balloon borne experiments, then there will be a very very strong case for this mission. The same if the n_s < 1 claim is confirmed. Instead, if there will be an upper limit at the r=0.01 level, then the case will be weaker. Complementary science for B-modes is
- parity non conservation (cross-spectra TB, BE)

- B modes from cosmic strings
- primeval magnetic fields

It is also agreed that a high resolution polarization mapper (1 arcmin) would warrant the measurement of neutrino mass , which is an obvious science case (and detect all clusters via SZ, allow secondary effect studies, etc...). The problem is the huge cost of such a mission.

Carlo Burigana gives a presentation on our current knowledge of polarized foregrounds. 70GHz is the lowest in foreground contamination. So there is a need for a system ranging from 30-40 GHz to 300-500 GHz. Moreover, we need to subtract foregrounds at better level than 1%. This adds weight to a space mission, because only from space is possible to cover simultaneously high frequencies and low frequencies.

One issue raised is the problem of Faraday rotation and depolarization: these could make problematic the use of the 30-40 GHz data.

At this point all the participants express their point of view on the key question large mission vs medium. The majority of the participants supports the small mission (intermediate resolution). There are comments on need for

- concentrate at low ell for this design study
- push cost down
- keep thinking on the ultimate mission. Anthony Lasenby suggests a two-stages approach in which the first "small" mission represent a single unit of a larger mission to be flown later for interferometry (formation flying).
- the contribution of a few US colleagues should be favoured (e.g. Bock or others with important expertise)

M. Bucher suggests the following issues for further discussion:

- be more precise on prediction of inflation
- be more specific about what you get for different resolution
- what you need for cleaning
- what can be done on ground (potential complementarity to be investigated)
- neutrino: which angular scale and coverage needed ?
- gravitational lensing: are we confident that the naive Fisher analysis is faithful ?
- foregrounds can be beated ? make convincing case !

It is reached an agreement on the formation of 3 working groups with 3 coordinators:

WG Science: M. Bucher
WG Measurement: P de Bernardis
WG Foregrounds: C. Burigana

These groups will draft a proposal in the coming months. A web-site will be setup for common work exchange.

Next meeting on 27th Sept 2006 (TBC).