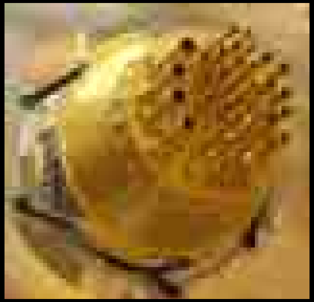
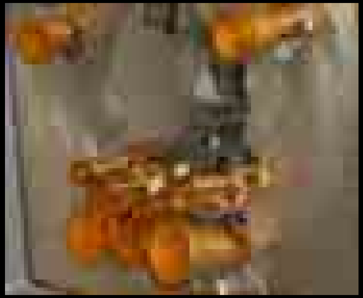
B-Pol & low frequencies

M.Bersanelli et al.





B-Pol & low frequencies

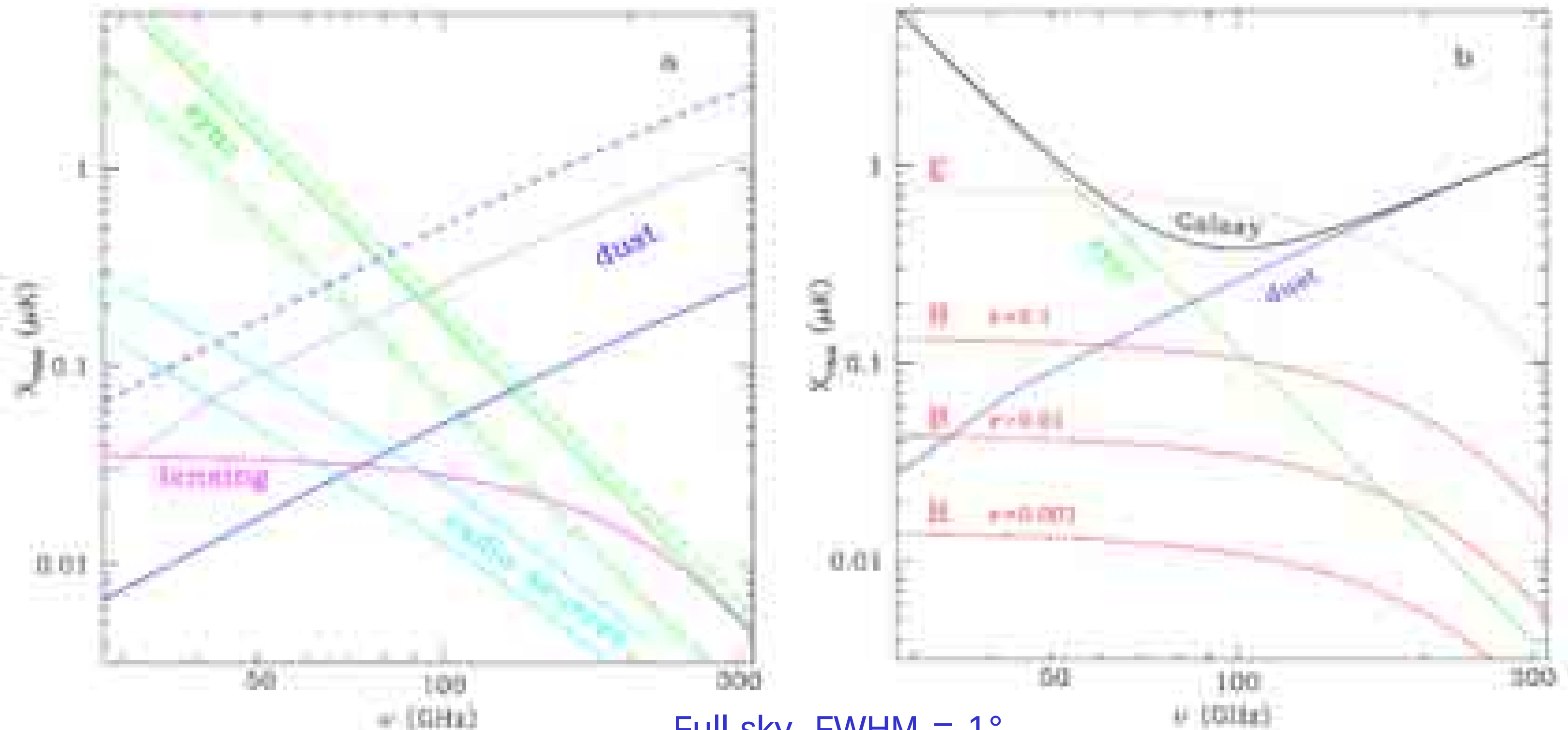
- CMB B-mode polarisation provides unique opportunity for probing the very early universe

- Measurement is extremely challenging:
  - Even in most optimistic scenario, signal is at sub-μK level
  - The actual intensity is largely unknown (discovery mission)
  - Foregrounds dominate the polarized sky

- Requirements
  - High Sensitivity: Large arrays, state of the art detector technology
    - These must be extremely clean from the Xpol viewpoint
  - Systematic errors must be suppressed at sub-μK level
    - We do not know which effects will turn out to be limiting factors for B-pol (*Planck*)
    - We do know some “built-in”, “new” problems
      - *Elliptical beams? (optics and large focal plane)*
      - *Far sidelobes? (need 2 order of magnitude beyond Planck!)*
      - *In-flight Calibration? (polarization amplitide and angle)*
  - Very robust separation of foreground contamination is
    - A wide frequency range is mandatory

Foregrounds

M. Tucci, E. Martınez-Gonzalez, P. Vielva, J. Delabrouille 2005



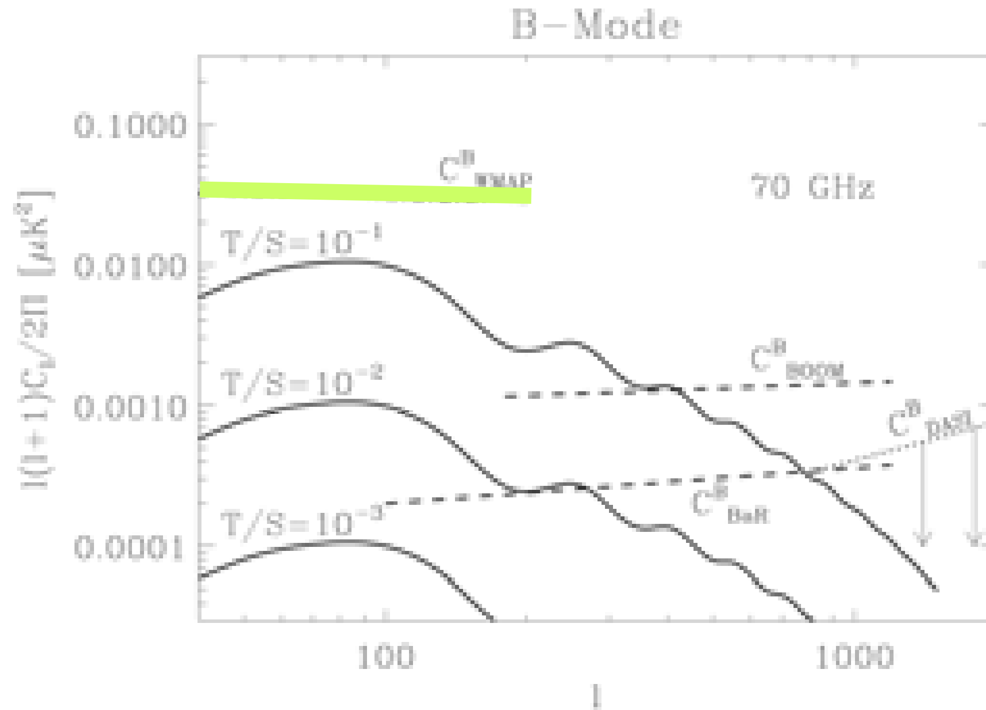
Full sky, FWHM = 1°

Figure 2. The rms value of foreground and CMB X = E, B modes versus the frequency, as predicted by an experiment with FWHM = 1°. Panel (a): Estimates of foregrounds from different data. Synchrotron (labelled 'sync', green online): 10–30 per cent of the *WMAP* ΔT_{rms} (dotted lines); estimates from Brouw & Spoelstra data (dashed line), from high-resolution low-latitude polarization surveys (solid line) and from observations of high-latitude polarization (Abidin et al. 2003; long-dashed line). The spectral index is $\beta_s = -3.1$. Dust ('dust', dark blue): 5 per cent of the *WMAP* ΔT_{rms} (dashed line) and the result from the Prunet et al. (1998) model (solid line). For the frequency spectrum we consider a one-component dust model with $T = 18$ K and emissivity $\alpha = 1.7$. The dotted line is obtained by the '100 μm map' (Schlegel et al. 1998) extrapolated to microwave frequencies using model 8 of Finkbeiner et al. (1999). Radio sources ('radio sources', light blue): estimates from Tucci et al. (2004), taking the flux limits 1 and 0.2 Jy. Lensing-induced polarization ('lensing', magenta). Panel (b): The black solid line is the total X_{rms} contribution of foregrounds, taking for the synchrotron emission 20 per cent of the *WMAP* estimate and $\beta_s = -3.1$; for the dust model 8 of Finkbeiner et al. (1999). CMB ('E' and 'B', red lines): E_{rms} (dotted line) and B_{rms} (with $r = 0.1$, 0.01, 0.001; solid lines) for the 'concordance' model with $\tau = 0.1$.

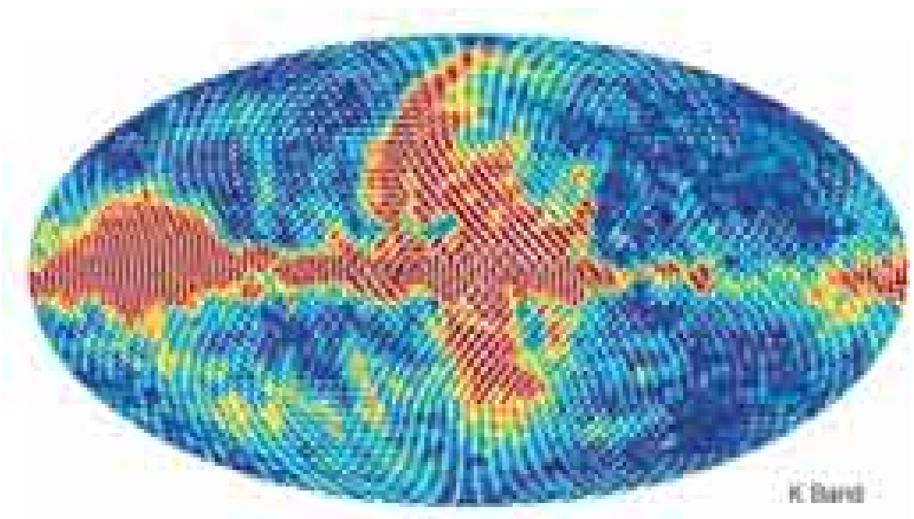
Minimum near 70 GHz

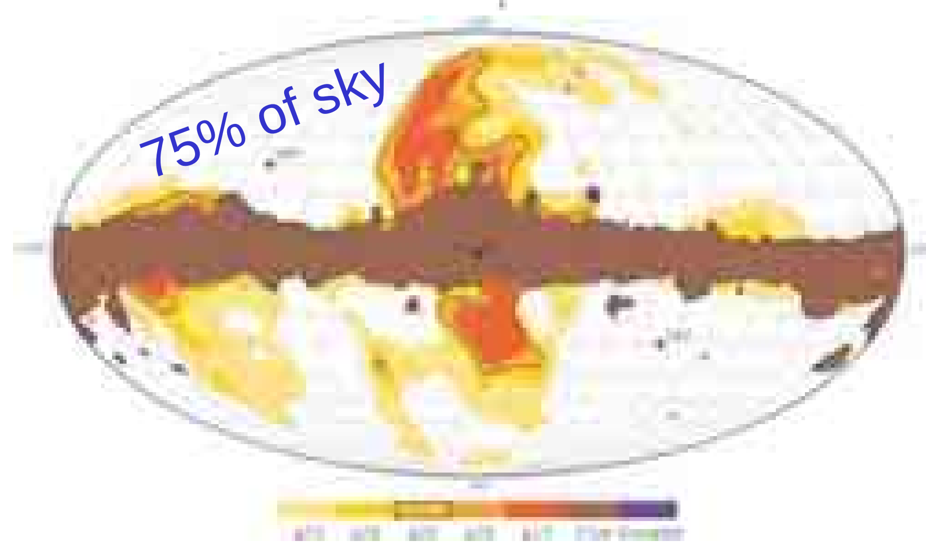
22.8 GHz WMAP survey

- High Galactic Latitudes (75% sky fraction): strongly contaminated
- Synchrotron even larger than the E-mode
- Corresponding to T/S ~ 0.3



Page, et al., 2006, astro-ph/0603450





Page et al. 2006 astro-ph/0603450

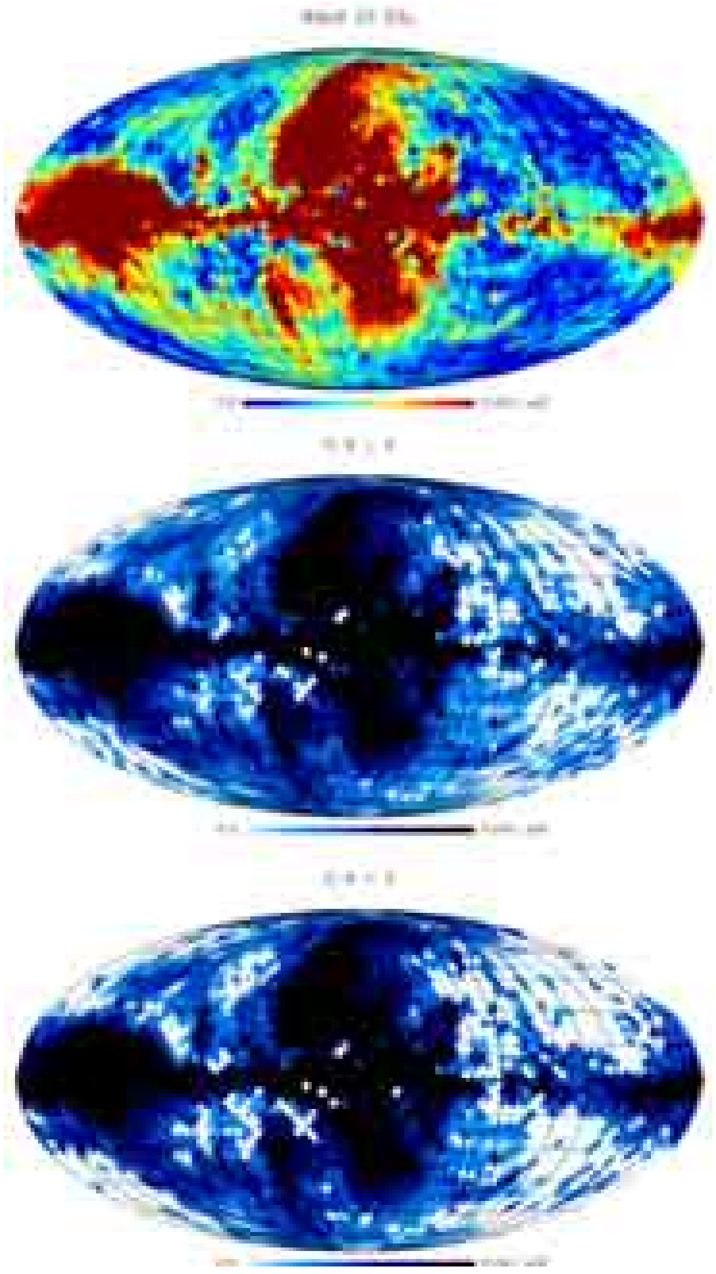
Low emission Regions in WMAP data

Carretti, Bernardi, & Cortiglioni 2006,
MNRAS Lett., 373, L93

- Two low emission regions can be selected from WMAP 23 GHz map:
  - S/N < 2 16% sky fraction
  - S/N < 3 26%

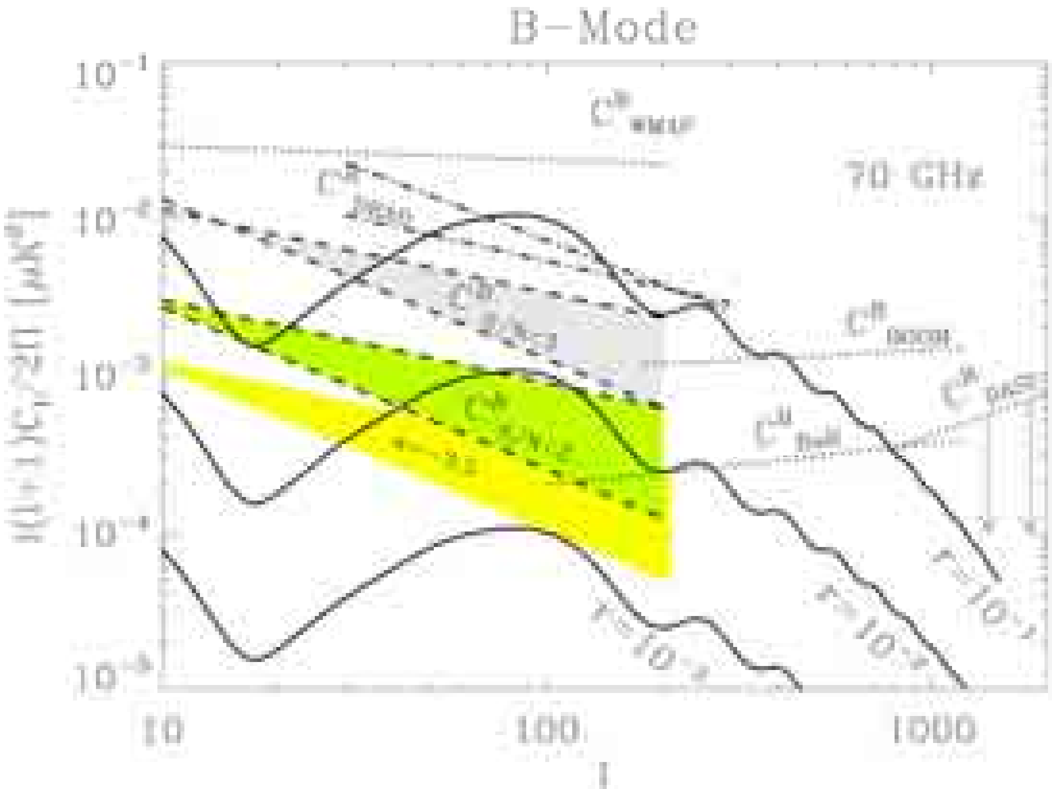
- S/N < 2: $T/S = 10^{-2}$ to 10^{-3} @70 GHz
- S/N < 3: 5x higher

- 16% of sky: $T/S = 10^{-2}$-10^{-3} without cleaning



Low emission Regions in WMAP data

Carretti, Bernardi, & Cortiglioni 2006, MNRAS Lett., 373, L93



Extrapolations:

Multipole	Frequency
$C_\ell \propto \ell^{-\beta}$	$T \propto \nu^{-\alpha}$
$2.5 < \beta < 3.0$	$\alpha = 2.5, 3.5$

If r = 10^{-2}, B-mode CMB spectrum at the level of the cleanest 15% sky regions

If r = 10^{-3}, the B-mode CMB spectrum is everywhere dominated by synchrotron

Summary

- High Galactic Latitudes are highly contaminated:

  T/S = 0.3 - 0.5 @70-GHz

  Need for accurate knowledge of the synchrotron emission to clean

- Lowest emission regions present interesting perspectives:

  T/S = 10^{-2} – 10^{-3} in a 16% sky fraction

  Extrapolation uncertainties

- Synch + dust minimum @60-80 GHz?

→ Need for a 30-40 GHz (or so) channel

→ Resolution ~2° to monitor B-mode foregrounds

35 nm InP Technology

NGST 35 nm MMIC
Up to **350 GHz**

- Breakthoughs in the device production
- Mass production techniques are the key to building large (few 10^3) arrays.
- Cell-phone industries have triggered high precision automated assembly techniques for assembly of semiconductor circuits.

- LNA technology exists up to 350 GHz
- Major sensitivity improvements up to 100 GHz
- Models based on measured room T LNA data predict at least factor 2 noise improvement wrt Planck radiometers
- Expected to 2.5 x (quantum limit) in W band and below

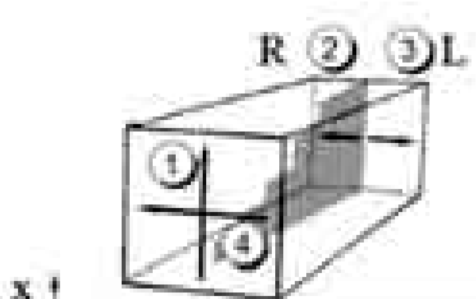
Polarization performance: OMTs

Polarization performance needed by B-pol (e.g. –35dB isolation) has been fully demonstrated by existing coherent receivers (Planck, BarSport, Quiet, … etc)

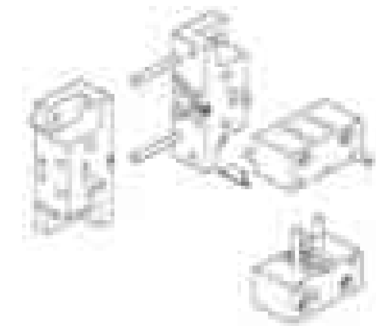
Techniques are needed (and being developed!) for

- **Low cost (mass production)**

- **High performance (20% bandwidth, low loss, amplitude balance, flat phase, high isolation), low systematics**



Definition of ports

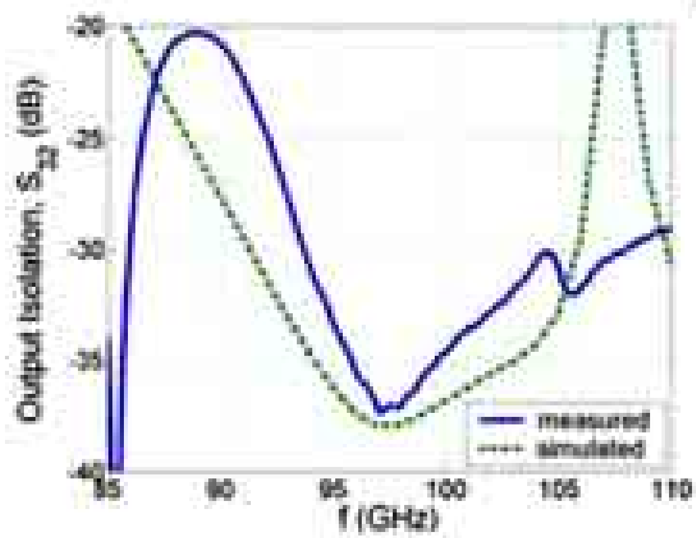


Assembly of split blocks

QUIET OMT Polarizers

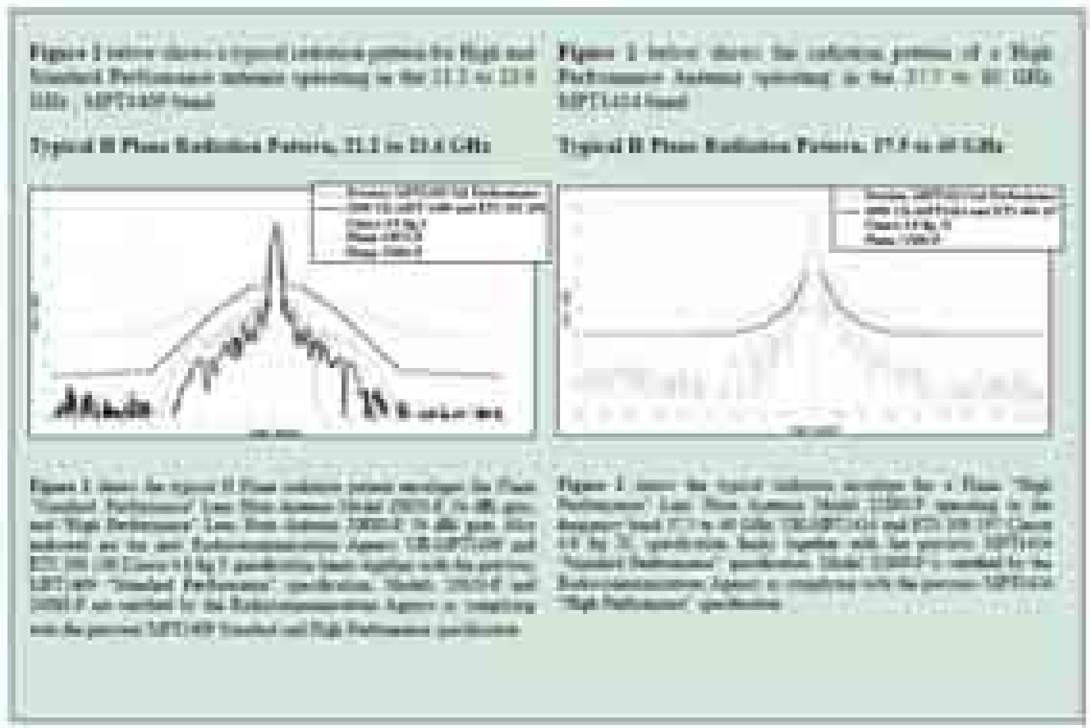
- **The circularly polarizing OMTs split the incoming radiation into L and R**

- **Developed $K_a$band (28-36 GHz) and Wband (84-104 GHz) OMTs with ridge waveguide septum polarizer**



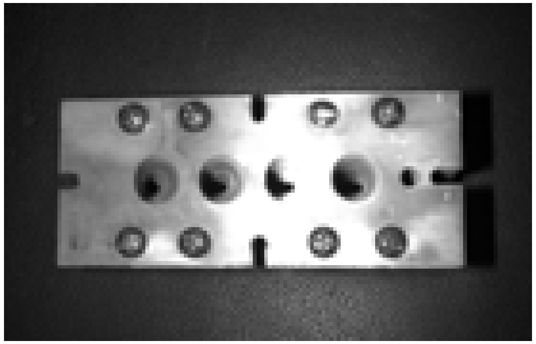
W-band prototype

Lens horn antennas array (10-100 GHz)



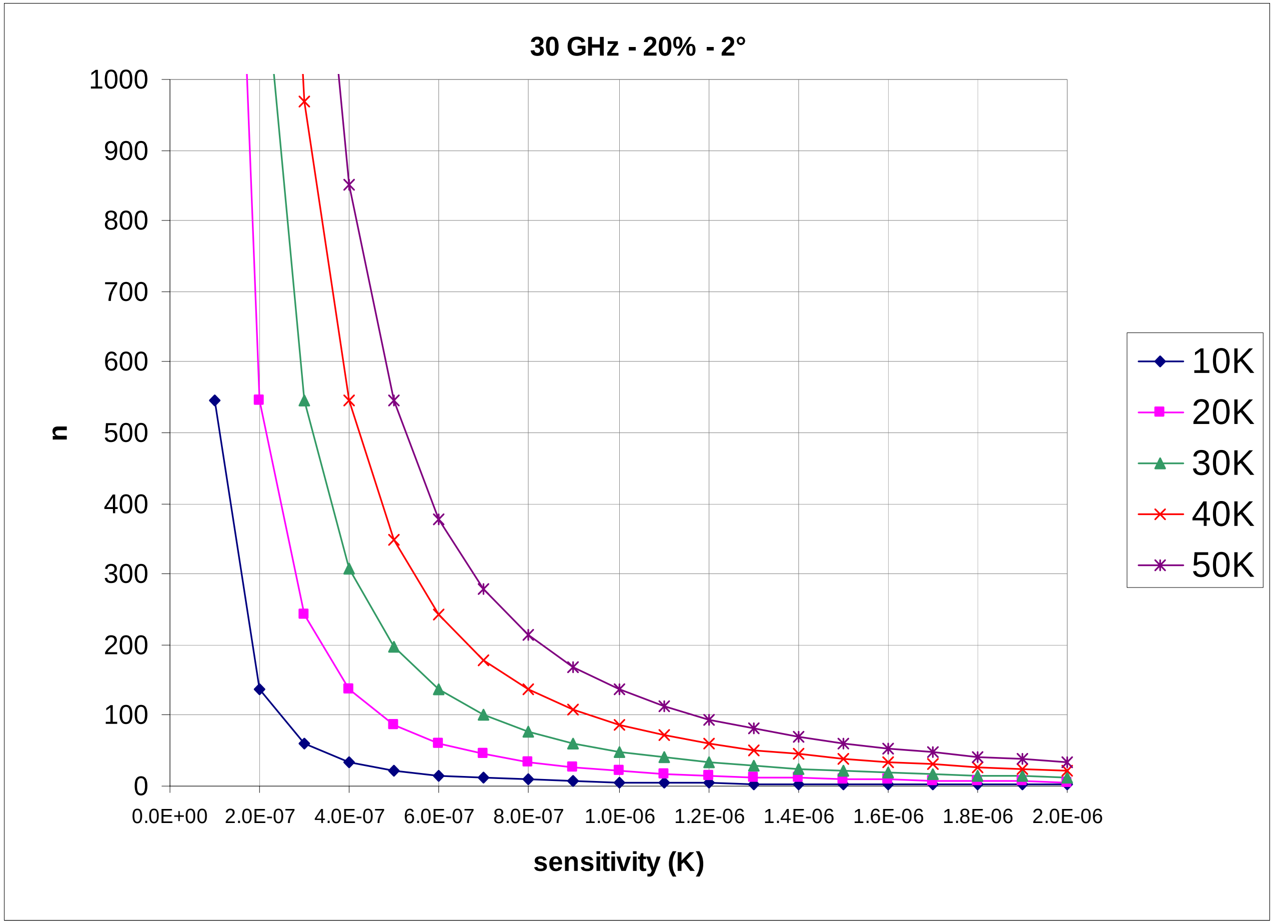
FWHM < 2°
Low sidelobes (<40dB)
Highly simmetric beam

Massive corrugated feeds arrays at low cost, high performance:
- Platelet technique
- Direct machining of aluminum
- Automated testing for k-element arrays

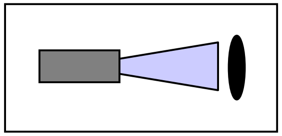


University of Milano
UCSB (Miikka M. Kangas et al, IEEE, 2006)

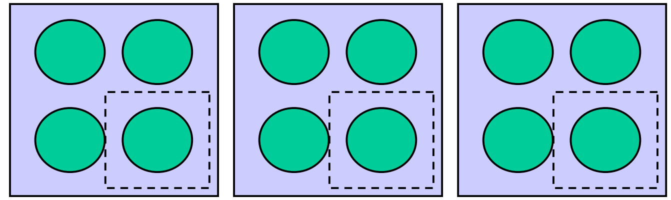
Number of array antennas
assuming demonstarted (Planck) performances



Roma Mar 2007
Low frequency B-pol concept

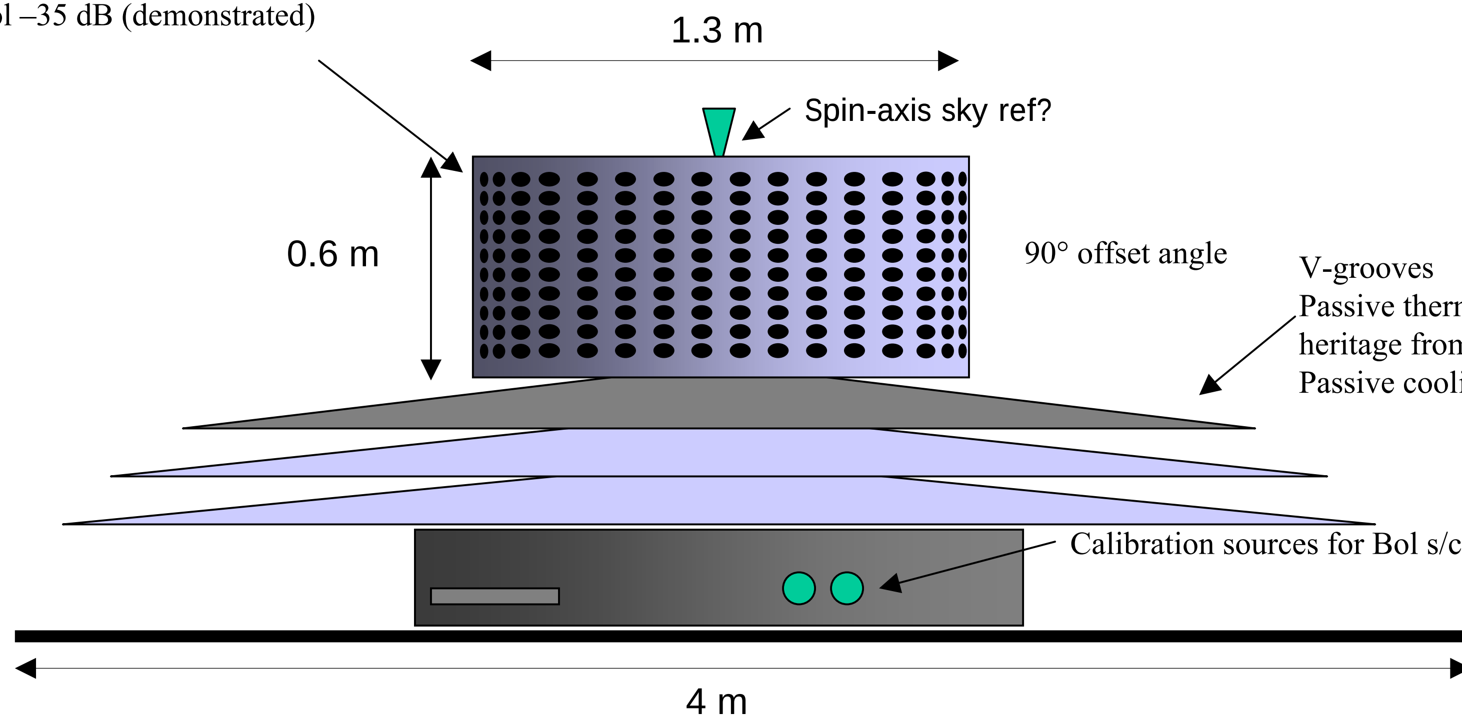


Rad-pol module
Light-weight, compact elements



2 x 2 “cells” of radiometer modules

Beam symmetry (by design)
Cross-pol –35 dB (demonstrated)



90° offset angle

V-grooves
Passive thermal design:
heritage from Planck
Passive cooling to ~35K

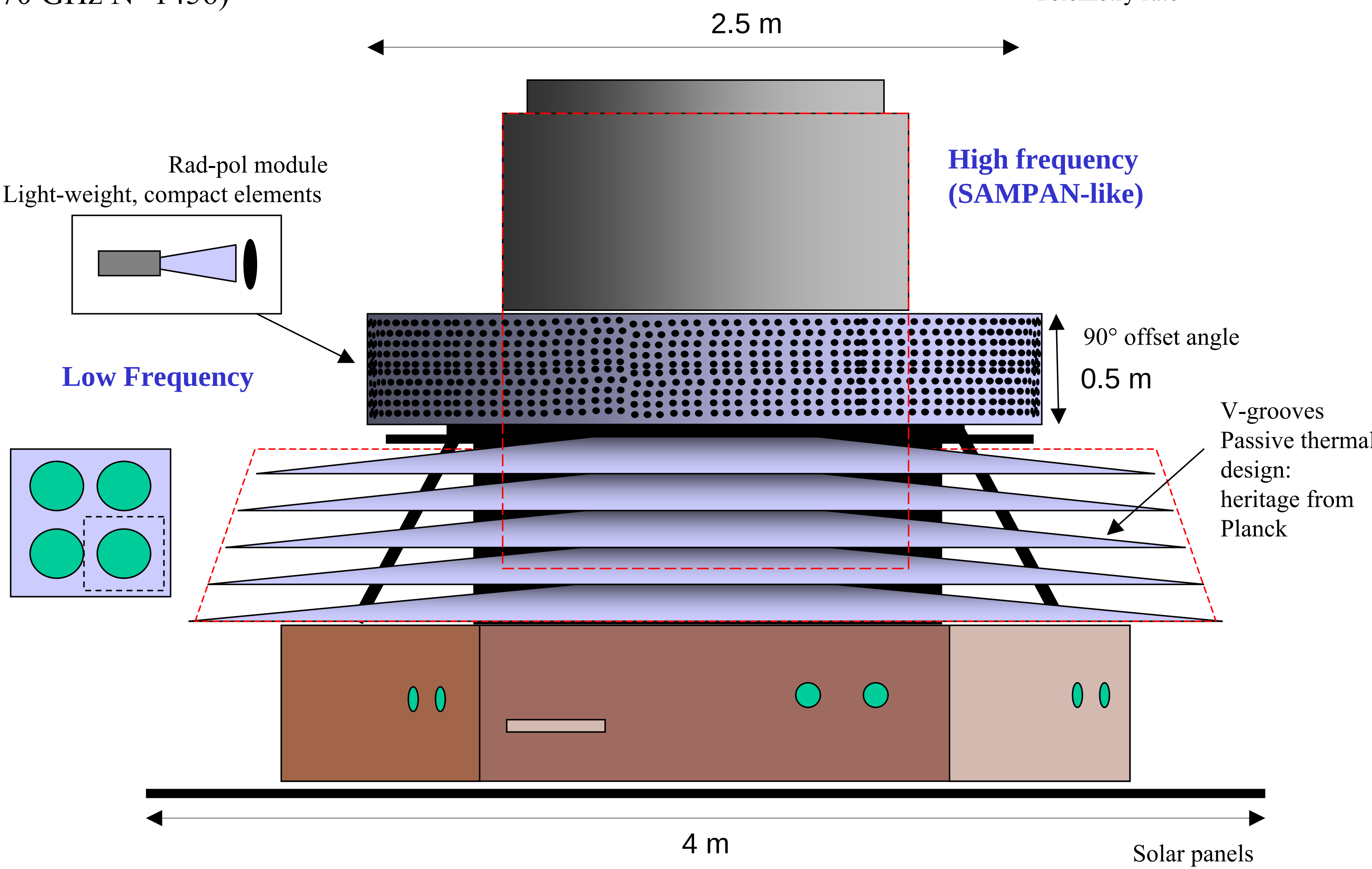
Calibration sources for Bol s/c

Scanning strategy to provide angle and pixel redundancy
(Depending on offset angle)

Low Freq B-Pol
Roma 28 Mar 2007

Angular resolution = 2°
Feed HPBW = 8°
30 GHz N=535
(70 GHz N=1456)

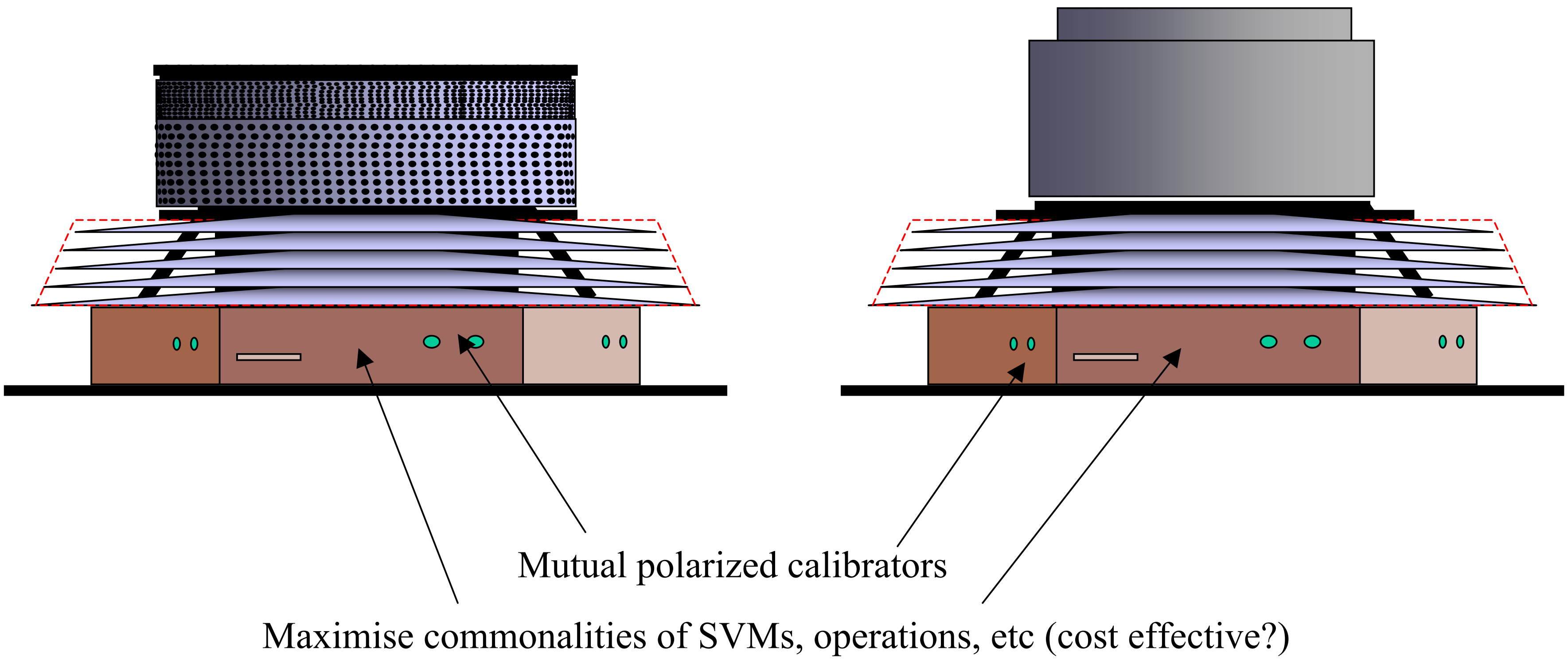
Receiver concept and performance
Passive elements technology
Polarisation
Thermal requirements
Power consumption
Telemetry rate



Double satellite concept
30-600 GHz, self-calibrating, formation-flight system

Angular resolution = 2°
Feed HPBW = 8°
30 GHz N=535
44 GHz N = 850
70 GHz N=1456

Angular resolution = 0.5°
70-600 GHz



High precision attitude control in Formation-flight is technically mature (Symbol X Study)