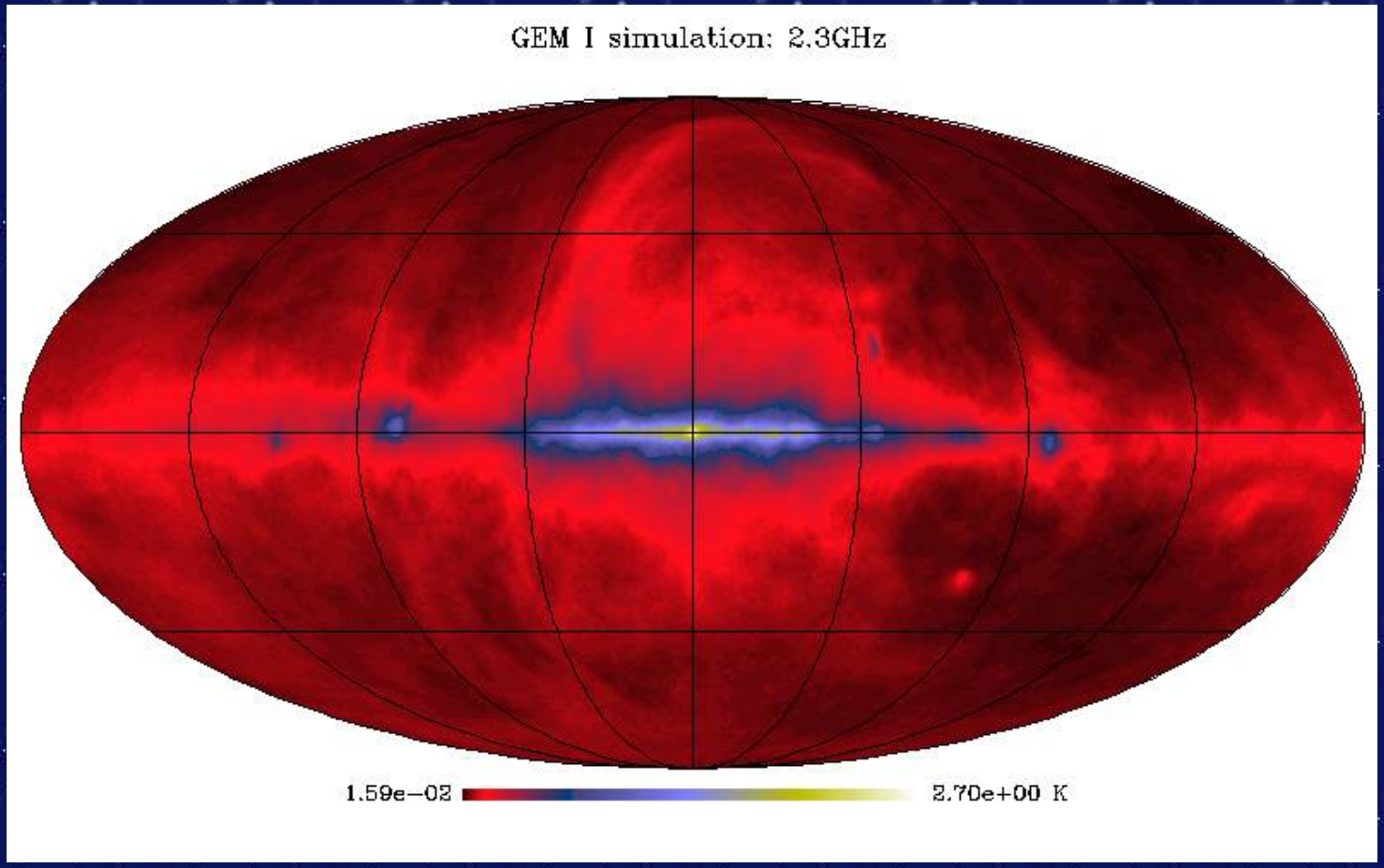
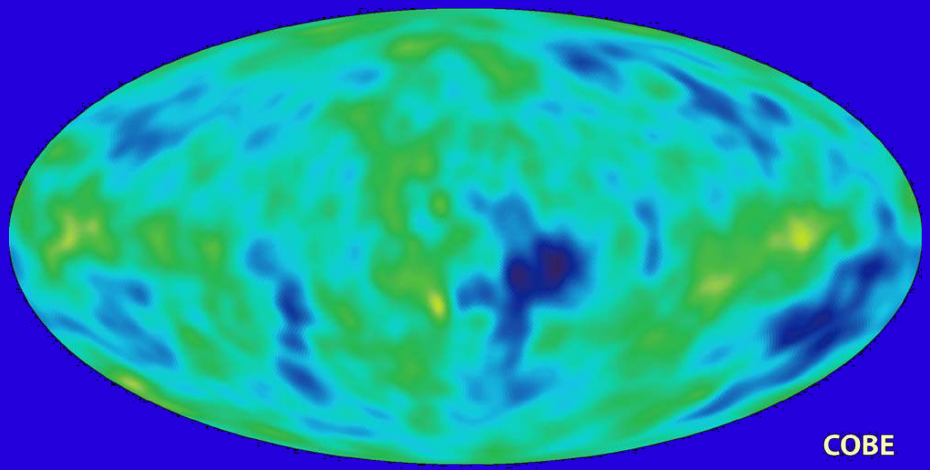
Probing CMB Polarized Foregrounds: The GEM experiment

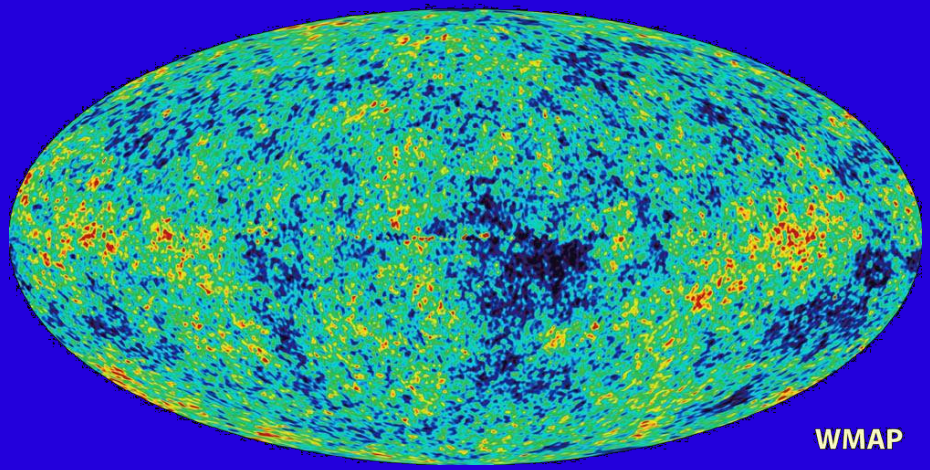


Domingos Barbosa (CdF/UP and CENTRA/IST, Portugal)

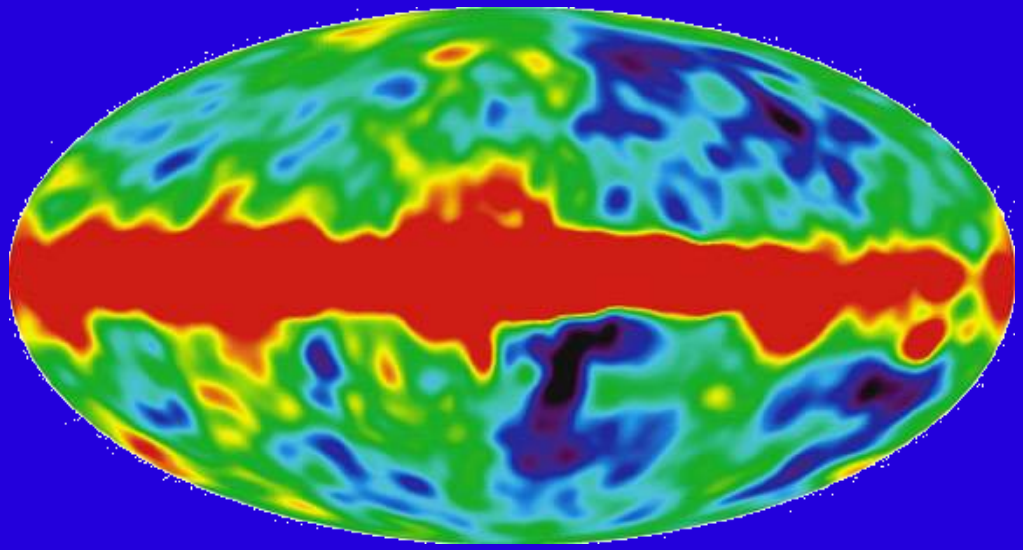
From COBE to WMAP

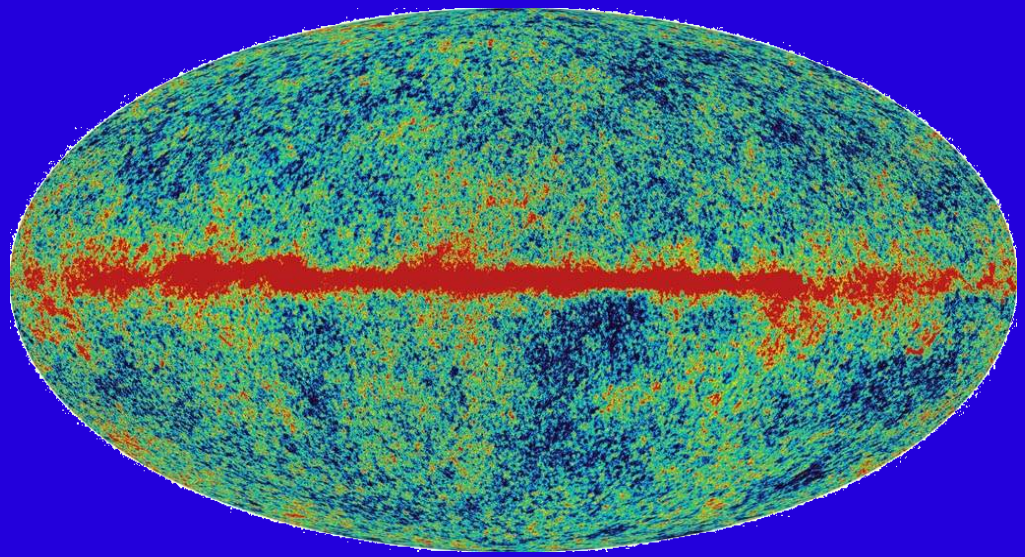


COBE



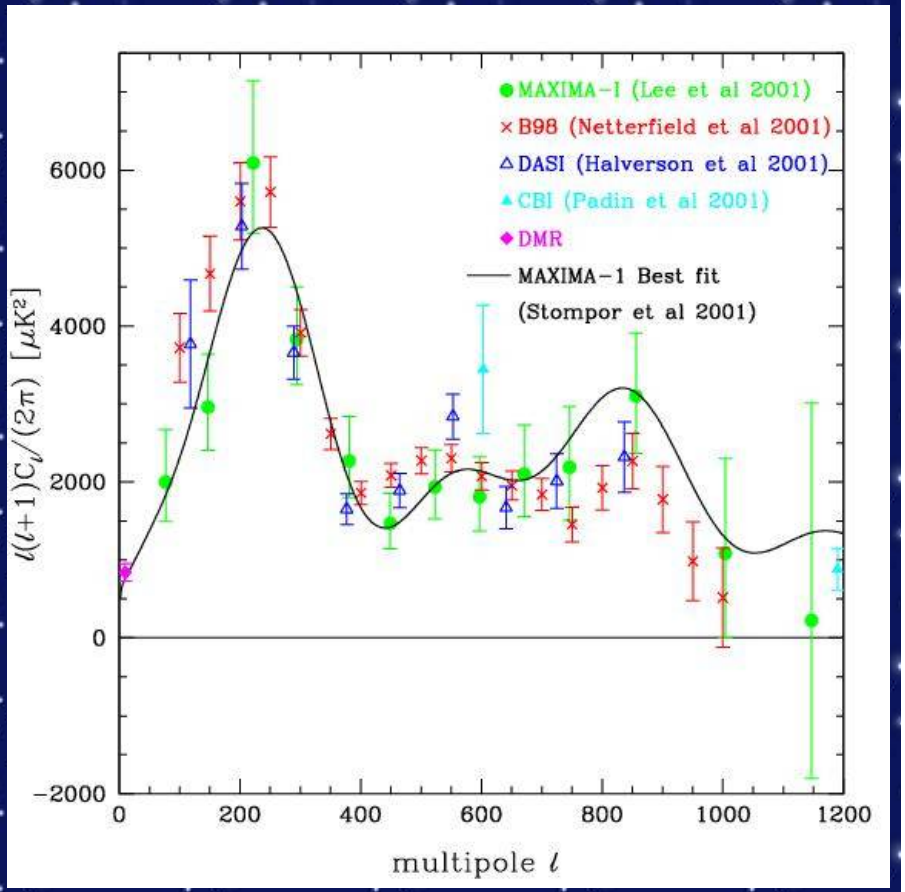
WMAP

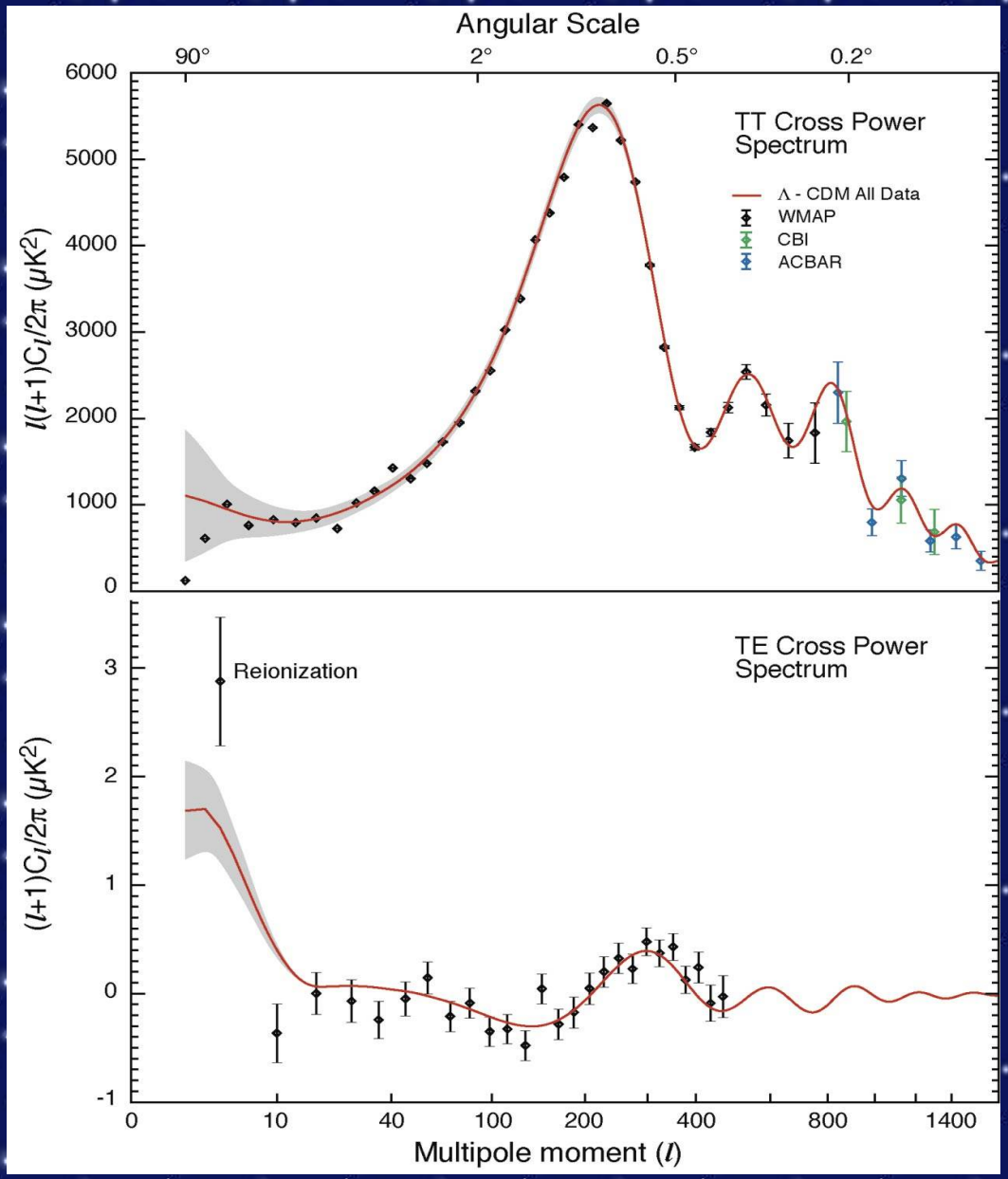




Courtesy of the NASA/WMAP Science Team

And the power spectra changed...



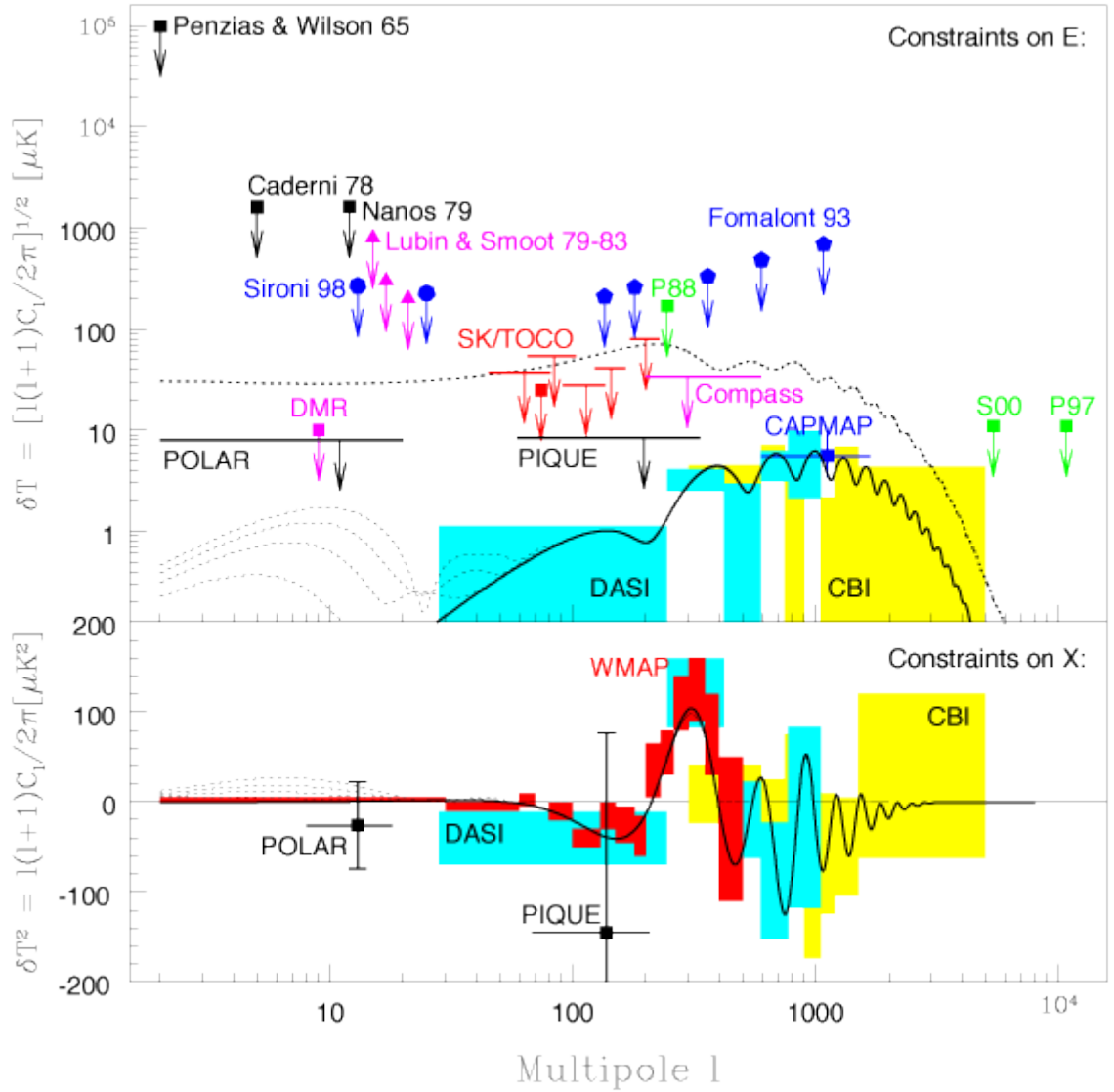


Constraining Inflation

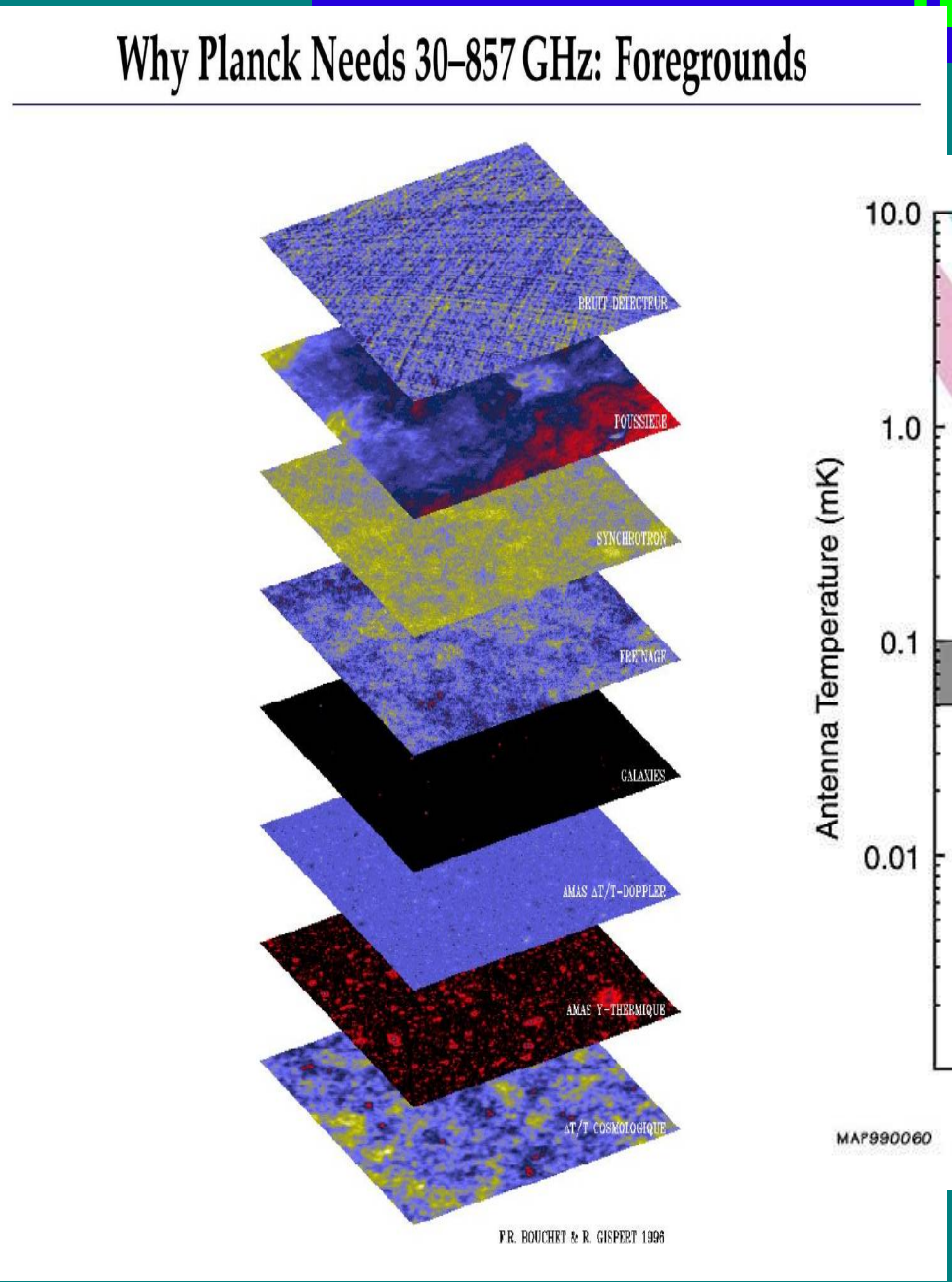
- Accurate measurement of the CMB can constrain the nature of the inflationary potential

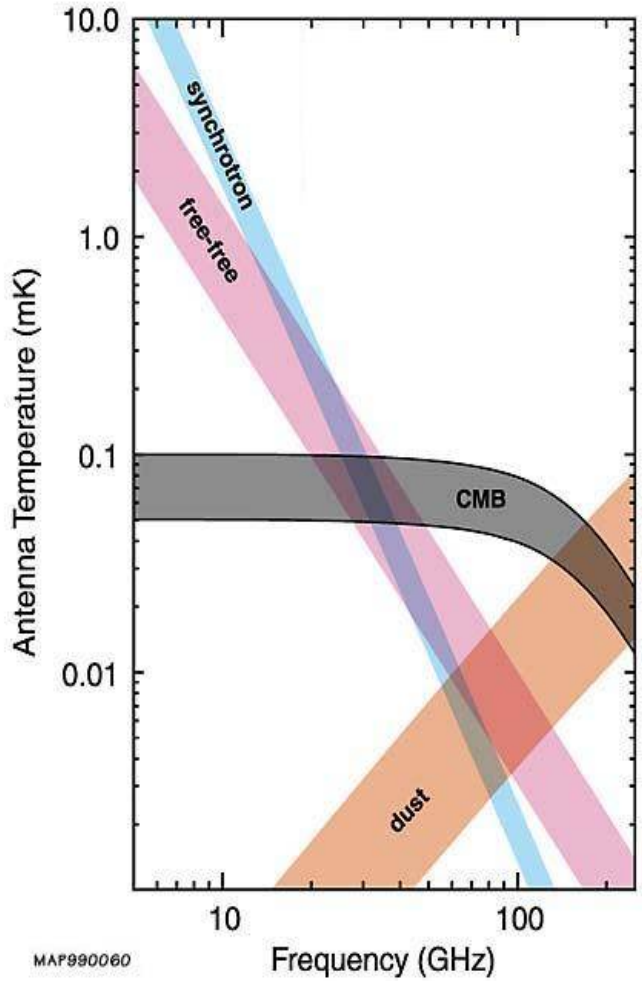
- in particular the ratio of scalar to tensor fluctuation amplitude r=T/S $\sim V^{1/4}/m_{pl}$

- and the *slope* n of the assumed power-law spectrum P(k): $$n-1=\frac{d\,ln(P_k)}{d\,ln(k)}$$


Penzias & Wilson 65
Constraints on E:
Caderni 78
Nanos 79
Lubin & Smoot 79-83
Fomalont 93
Sironi 98
P88
SK/TOCO
Compass
DMR
POLAR
PIQUE
CAPMAP
S00
P97
DASI
CBI
Constraints on X:
WMAP
CBI
POLAR
DASI
PIQUE
$\delta T = [l(l+1)C_l/2\pi]^{1/2}$ [μK]
$\delta T^2 = l(l+1)C_l/2\pi$[$\mu K^2$]
Multipole l

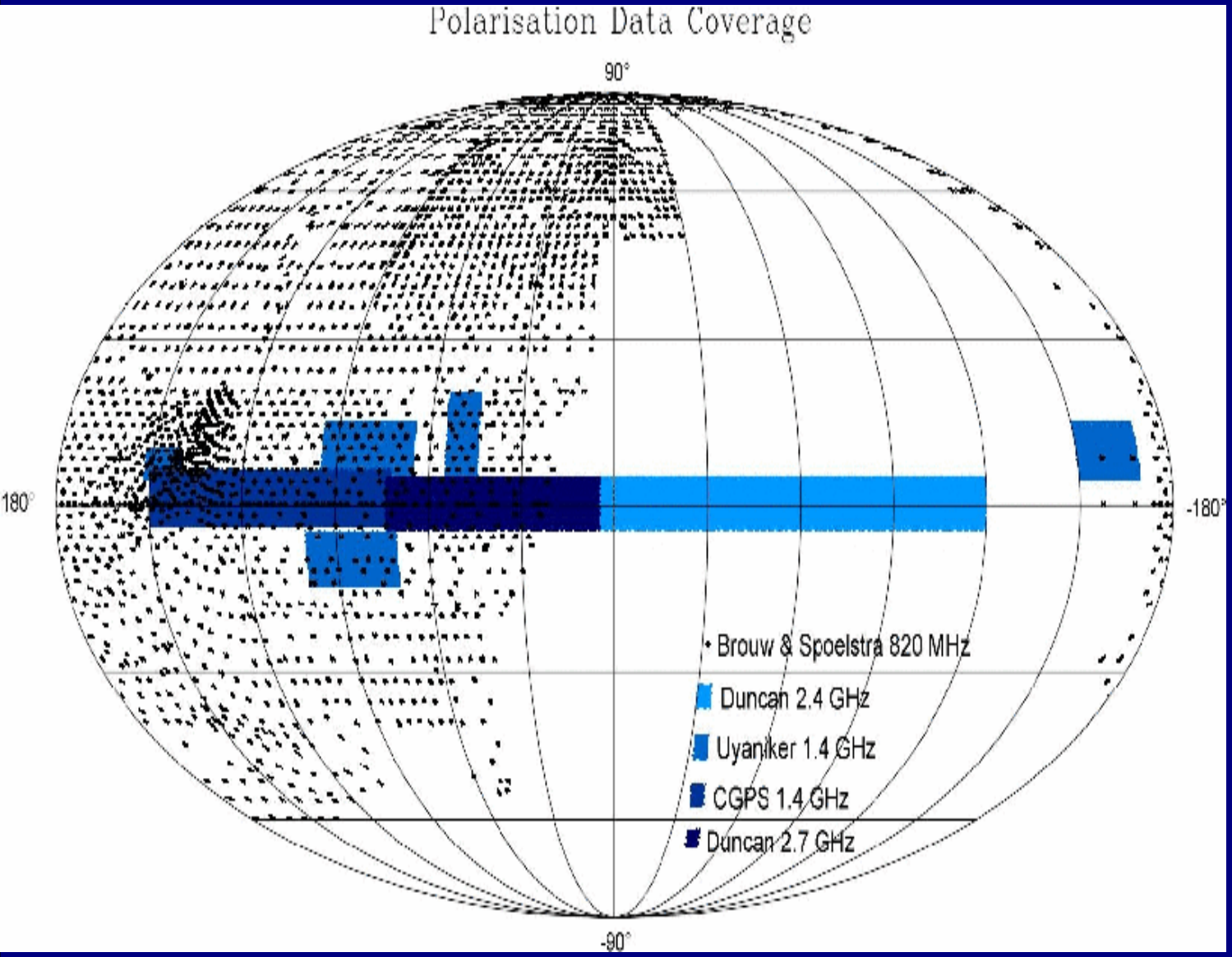
Good knowledge of foregounds needed





- Choose frequencies to avoid galactic synchrotron and free-free (>40 Ghz) and dust emission (< 200 Ghz).
- Cost: difficult from ground, better be a balloon or a satellite...

Worse for Polarization



- E-modes have some difficulties from synchrotron.

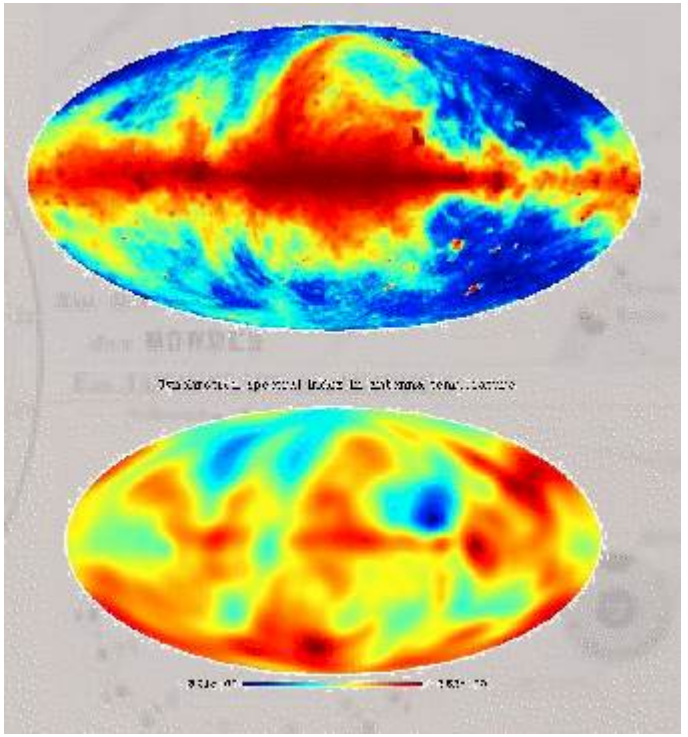
B-modes need reliable templates.

Real templates don't exist.

Simulate templates!

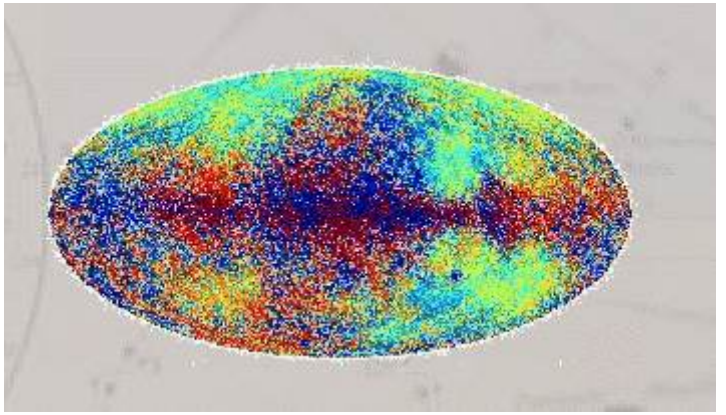
Synchrotron T

- T template from Haslam et al. (1982), assumed Gaussian on sub-degree scales
- Spectral index inferred from radio observations (Giardino et al. 2002)



Synchrotron Q,U

- **Assuming synchrotron theoretical polarization in Haslam et al. (1982)**
- **Random polarisation angle with fluctuations spectrum C_l / l^{-2} , as inferred from radio band up to b' 20° (Baccigalupi et al. 2001, Giardino et al. 2002)**



prepared by Roberta Paladini, Jean-Philippe Bernard, …

Next Steps: Critical Updates

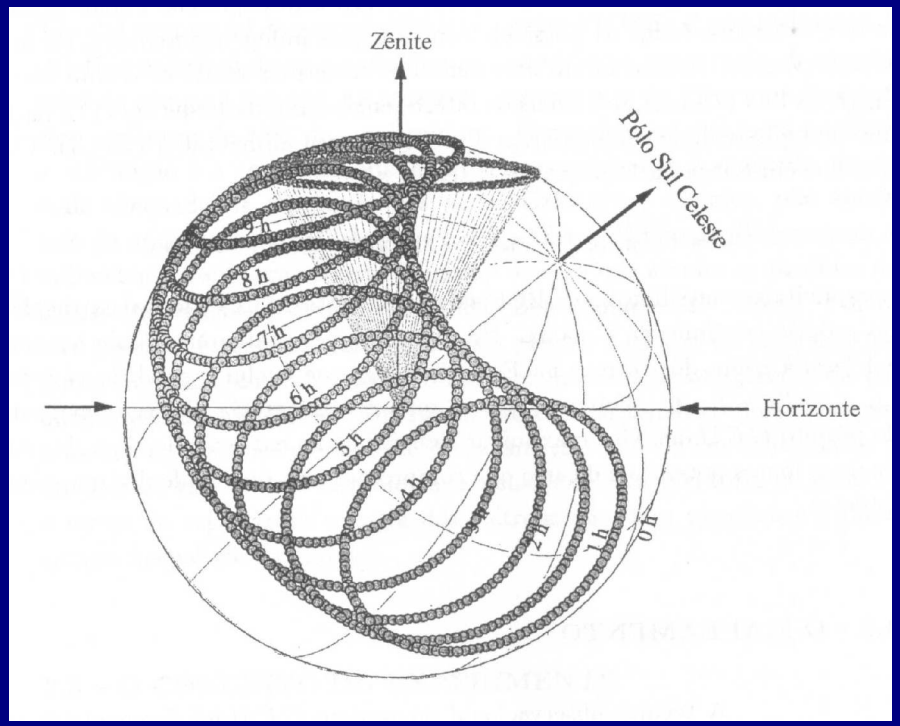
- **Synchrotron: we desperately need polarization observations at high Galactic latitudes. Extrapolation with the Giardino et al. estimated spectral index yields a too high signal, option with constant spectral index possibly reasonable**

Galaxy Emission Mapper

INPE, Brasil
U.Berkeley USA
LBNL, USA
Universita di Milano & TESRE/CNR, Italy
C.Tello,G. Smoot, S.Torres, T.Villella, M.Bersanelli

and now (2005):
CENTRA/IST & I.Telecomunicações/ U.Aveiro, Portugal

We can transport it!



- Now at Cachoeira Paulista (São Paulo, Brasil).
- Observations at 408, 1465 and 2300 Mhz.
- Upgrade to 5 GHz polarimeter

Survey strategy: cover 50% of the sky

- rotation in azimuth,
- **constant elevation – good for destriping**
- resolution : 45'-1°
- ***Large scale, absolute calibration***

Polarized Galactic Emission Mapping @ 5-10 GHz

Team Portugal (CdF, CENTRA, IT):

D.Barbosa, A.Mourão, R.Fonseca

D.Magalhães, L.Cupido

Team Brazil (INPE):

C. Tello , T.Villela, I.Ferreira,

Team USA (LBNL):

G.Smoot, D. Becker

International Collaborators:

S.Torres, M.Bersanelli, N. Mandolesi, J. Bartlett, G.Rocha

- Cover South Sky with 5.5-m dish
- Cover North Sky with 9-m dish .
- Resolution 45'-1.5º.
- Low noise cryogenic front-ends.

Pseudo-Correlation polarimeter :

Receptor de 5 GHz

OMT

Ex

Ey

G_1

G_2

Δv

ϕ

0-180º

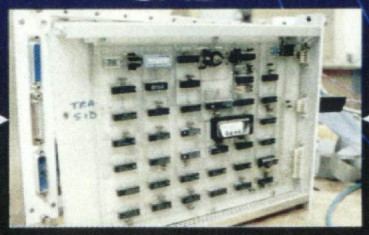
Square Wave modulation

Magic-T 180º

D

Lock-in

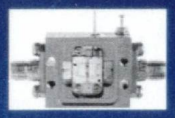
SAD



OMT

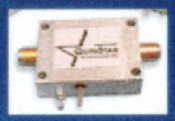
$$\begin{bmatrix} G_{OMT} & 0 \\ 0 & G_{OMT} \end{bmatrix}$$

HEMT



Amp1

$$\begin{bmatrix} G_{Amp1} & 0 \\ 0 & G_{Amp1} \end{bmatrix}$$



Amp2

$$\begin{bmatrix} G_{Amp2} & 0 \\ 0 & G_{Amp2} \end{bmatrix}$$

Filtro

$$\begin{bmatrix} G_{Filt} & 0 \\ 0 & G_{Filt} \end{bmatrix}$$

Comutador Fase

$$\begin{bmatrix} 1 & 0 \\ 0 & e^{i\Delta\phi} \end{bmatrix}$$

Magic-T

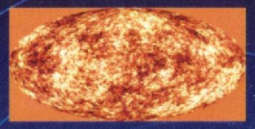
$$\frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

Detector

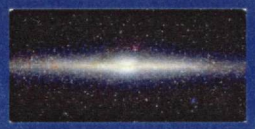
$$\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}, \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$$

Lock-in

Sensibilidade do receptor

T_{CMB}  CMB

\+ T_{cp}  Céu profundo

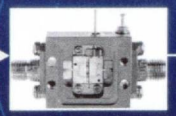
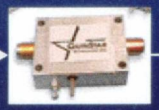
\+ T_{gal}  Galáxia

\+ T_{atm}  Atmosfera

\+ T_{IRF}  Interf. rádiofreq.

$$T_A = \sum T_i$$

\+ $T_{A,\,ant}$ 

T_{OMT}  T_{Amp1}  T_{Amp2}  $T_{\Delta\nu}$  T_{Φ}  $T_{M\text{-}T}$ 

Sensibilidade do receptor

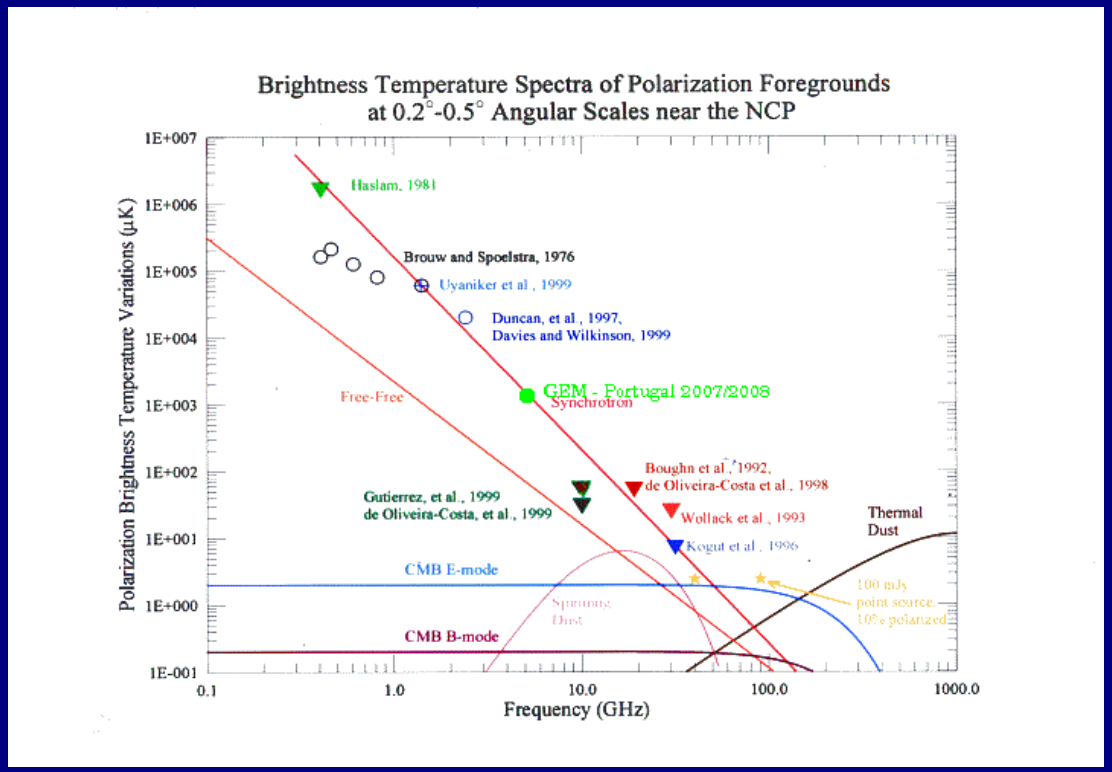
$$\Delta T_{\min} = T_{sys}\sqrt{\frac{1}{\Delta\nu\, t} + \left(\frac{\Delta G}{G}\right)^2}$$

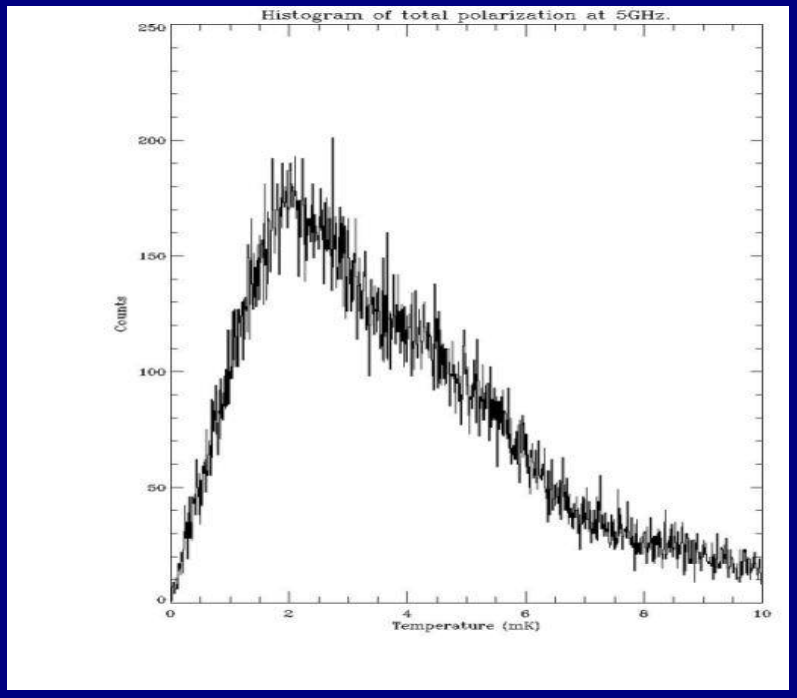
Temperatura do sistema

$$T_{sys} = T_A + T_R$$

- T_{sys}=21,23K
- ΔT_{min}=2,14mK
- G=5,85 ? 10^6
- *t* ~6 meses

$$T_R = T_{OMT} + \frac{T_{Amp1}}{G_{OMT}} + \frac{T_{Amp2}}{G_{OMT}\times G_{Amp1}} + \frac{T_{Filtro}}{G_{OMT}\times G_{Amp1}\times G_{Amp2}} + \frac{T_{PhaseShift}}{G_{OMT}\times G_{Amp1}\times G_{Amp2}\times G_{Filtro}} + \ldots$$





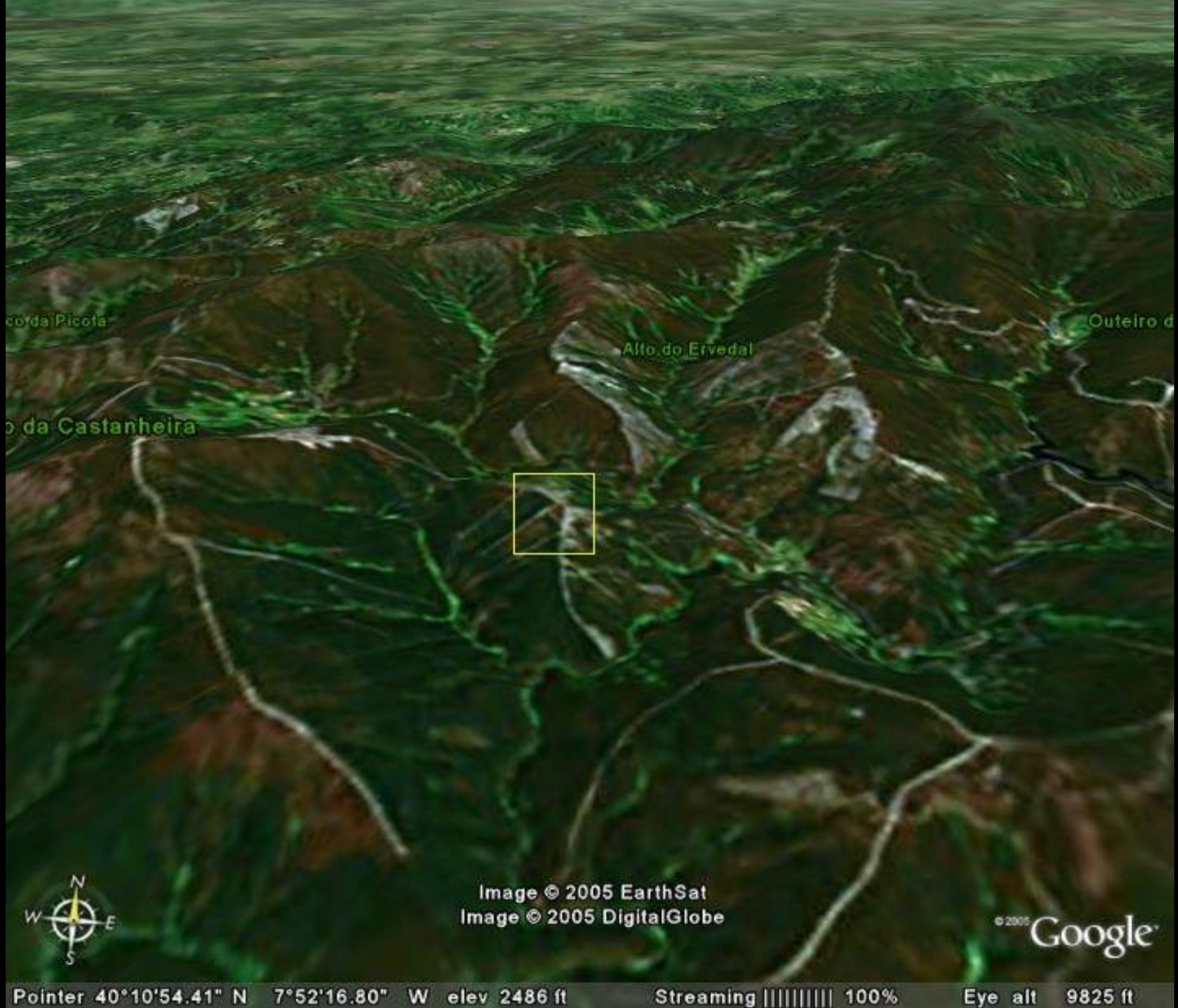
So, where is GEM ?

2.3 GHZ data coming

Tello et al., 2005, in preparation

95% of pixels > 2mK total P

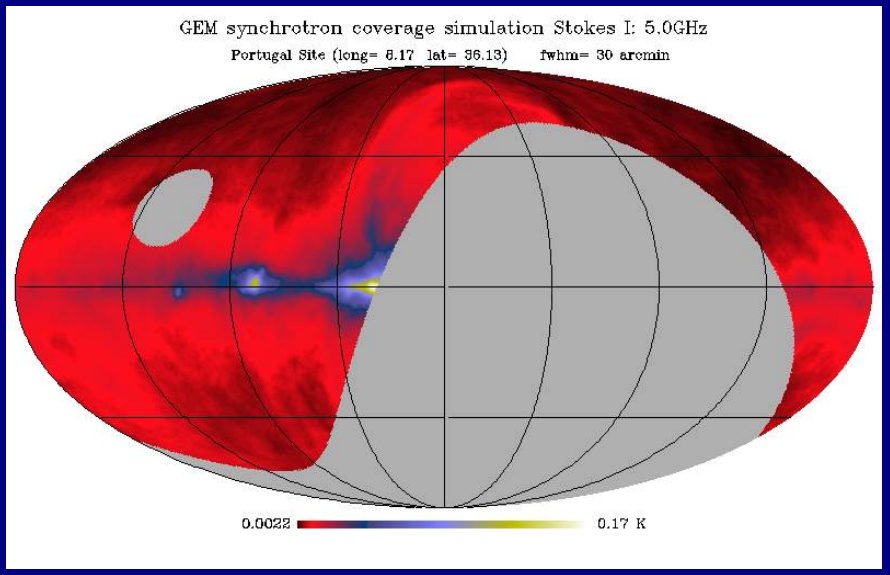
sensitivity, U,Q ~ 1mK


co da Picota
Alto do Ervedal
Outeiro d
o da Castanheira
N
W
E
S
Image © 2005 EarthSat
Image © 2005 DigitalGlobe
©2005 Google
Pointer 40°10'54.41" N 7°52'16.80" W elev 2486 ft
Streaming 100%
Eye alt 9825 ft

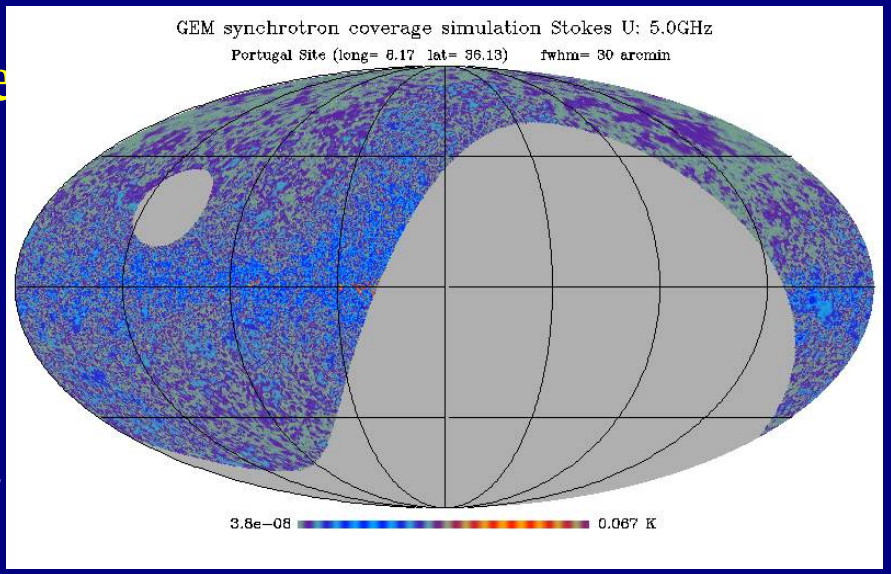
Conclusions

* GEM will map the polarized synchrotron foreground of the galaxy with absolute calibration.

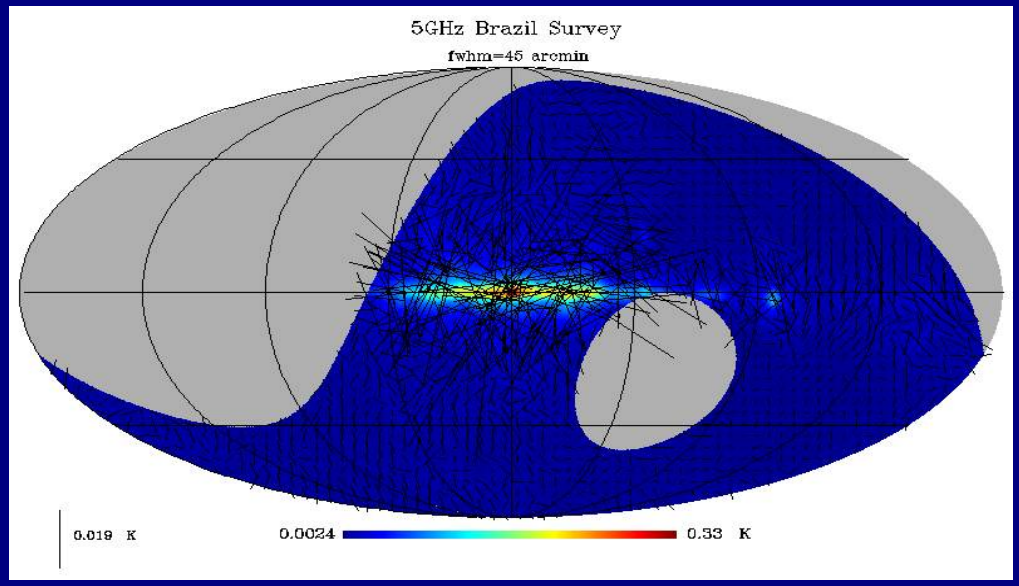
* Legacy data directly feeding Planck Surveyor data needs.



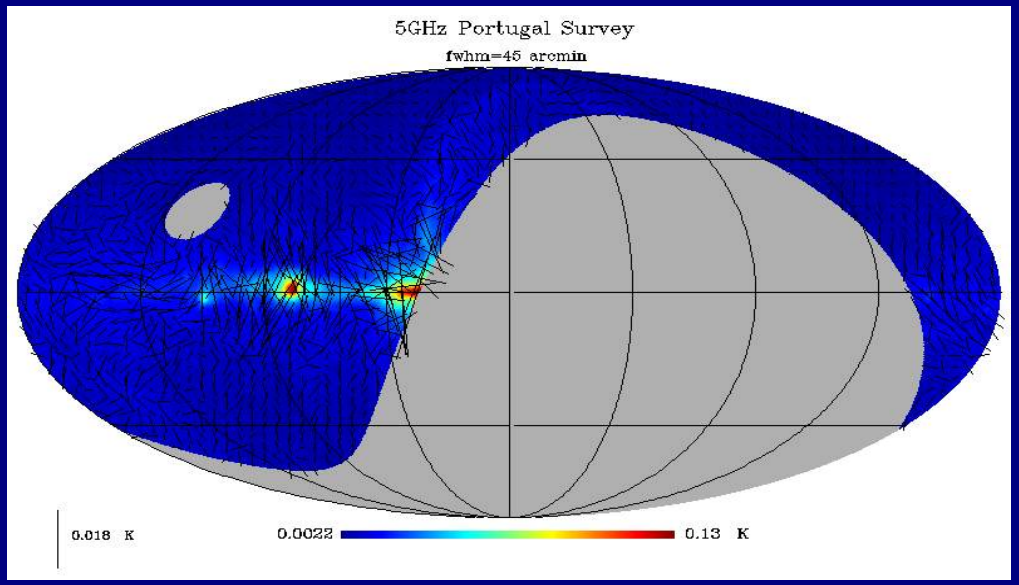
* Biggest polarization foreground template. Merge with Brazil data (2007-2008) for an almost complete sky covered (85%) polarize synchrotron map.



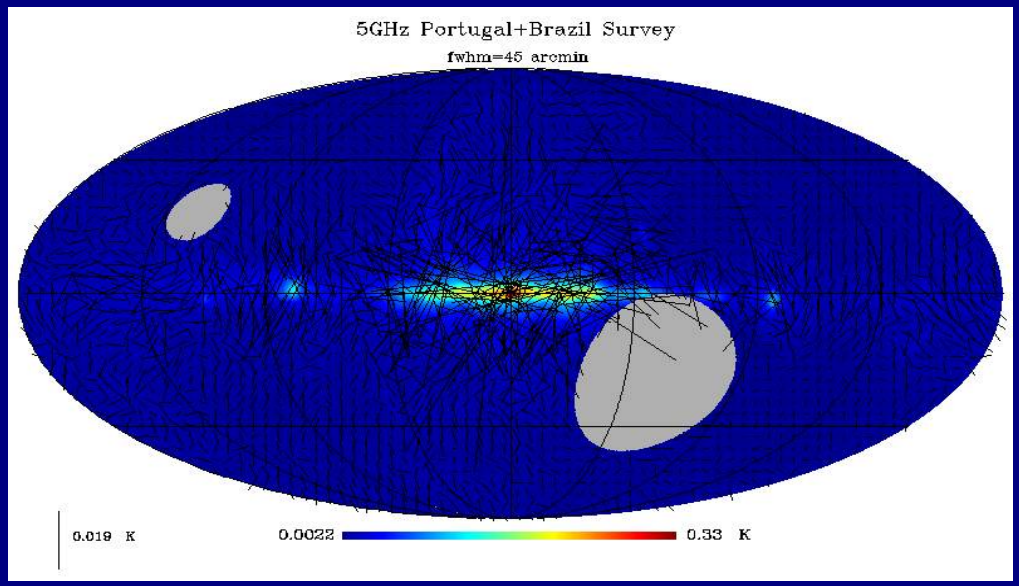
** Start upgrade for 10 GHz to probe spectral change of the seXiest foreground...



2006



2007



2007