A 5GHz Survey of the Galactic Polarized Emission in Portugal

by

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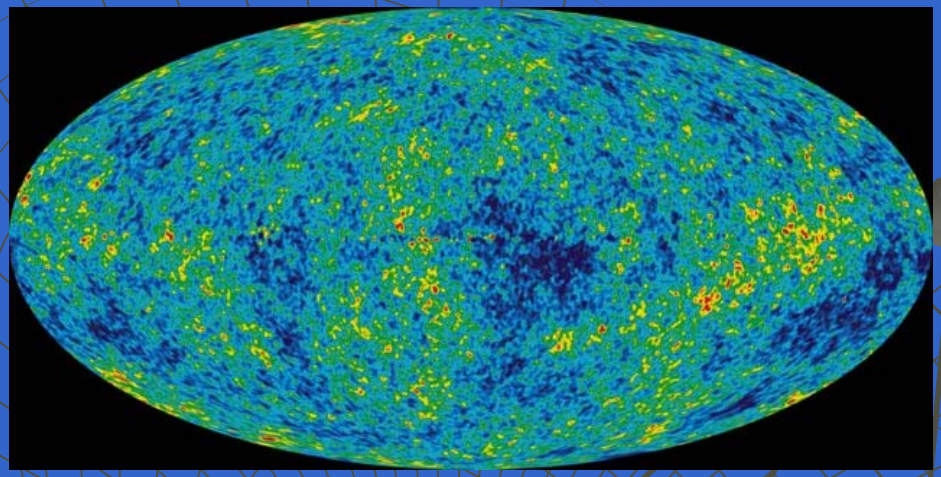
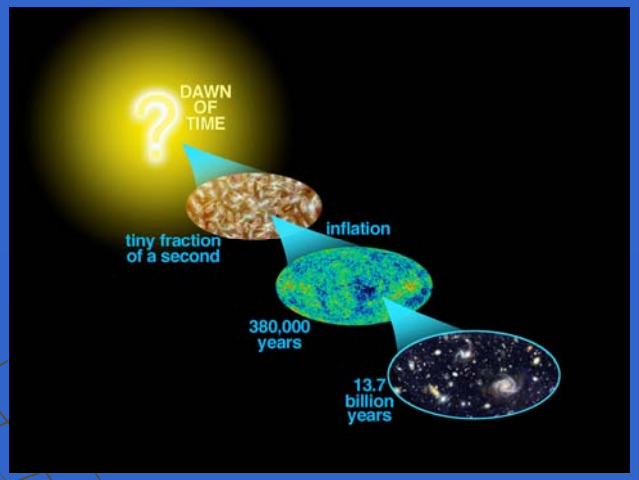
Index

- Universe and CMB
- CMB and Foregrounds
- Foregrounds and GEM
- GEM overview
- GEM-P current status
  - Site preparation
  - Mechanics
  - Control
  - Optics
  - Receiver
- GEM-B

CMBR – Cosmic Microwave Background Radiation

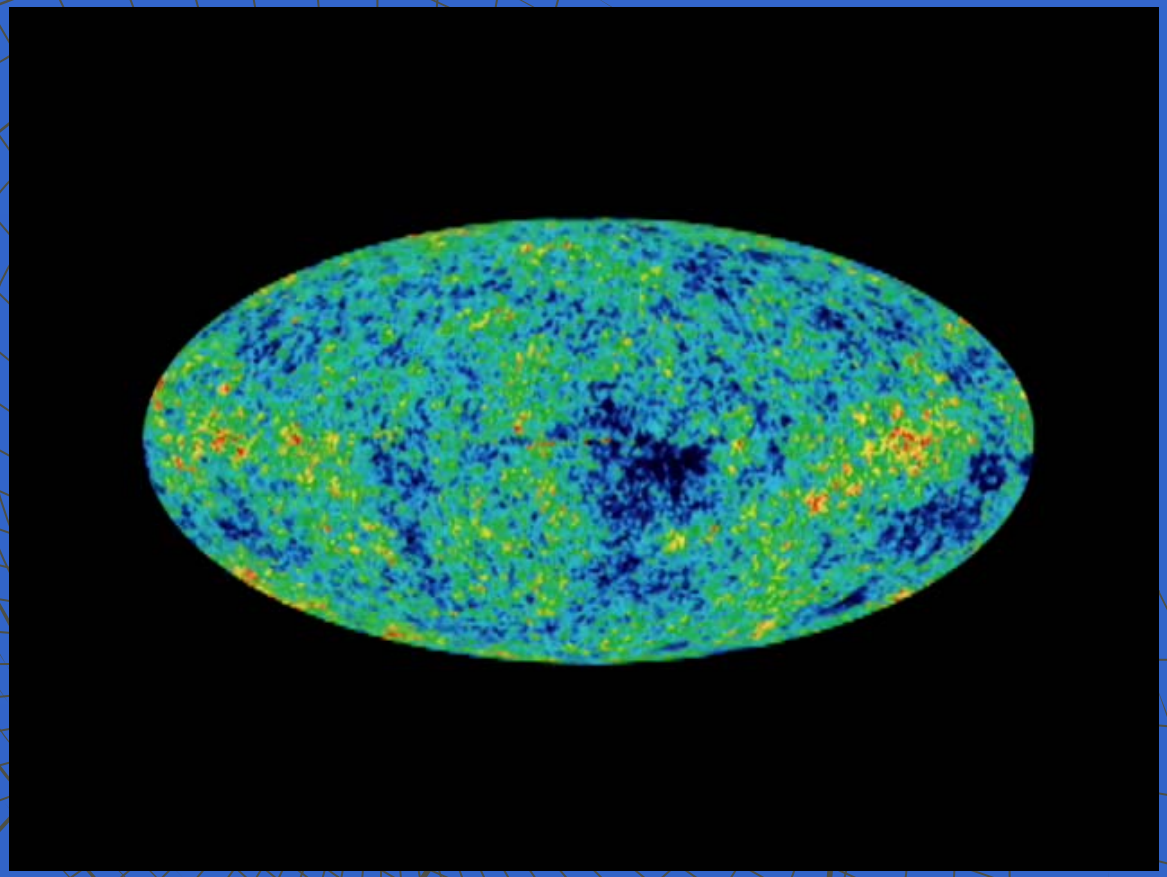


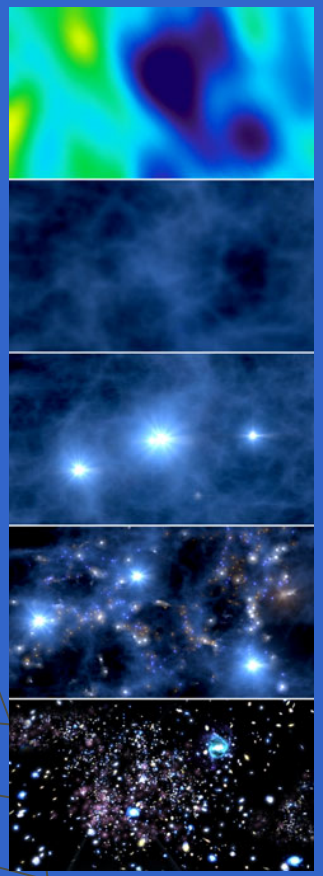


- “This 'fossil' radiation, the furthest that any telescope can see, was released soon after the 'Big Bang‘”
- “consider it as an echo or 'shockwave' of the Big Bang”
- “Will the Universe continue its expansion forever, or will it collapse into a 'Big Crunch'? “
- “What is the age of the Universe? “
- “What is the nature of the so-called 'dark matter? “
- “What is the nature of dark energy? “

Courtesy of the NASA-WMAP / ESA-Planck

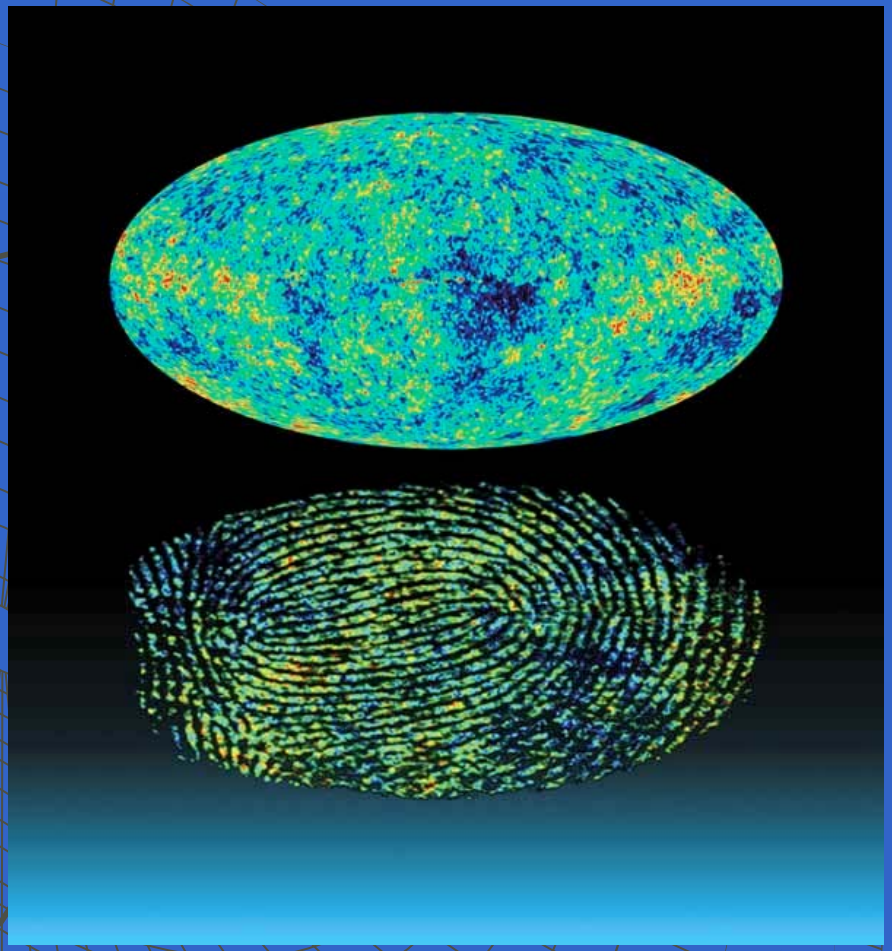
CMBR – Cosmic Microwave Background Radiation





Courtesy of the NASA-WMAP / ESA-Planck

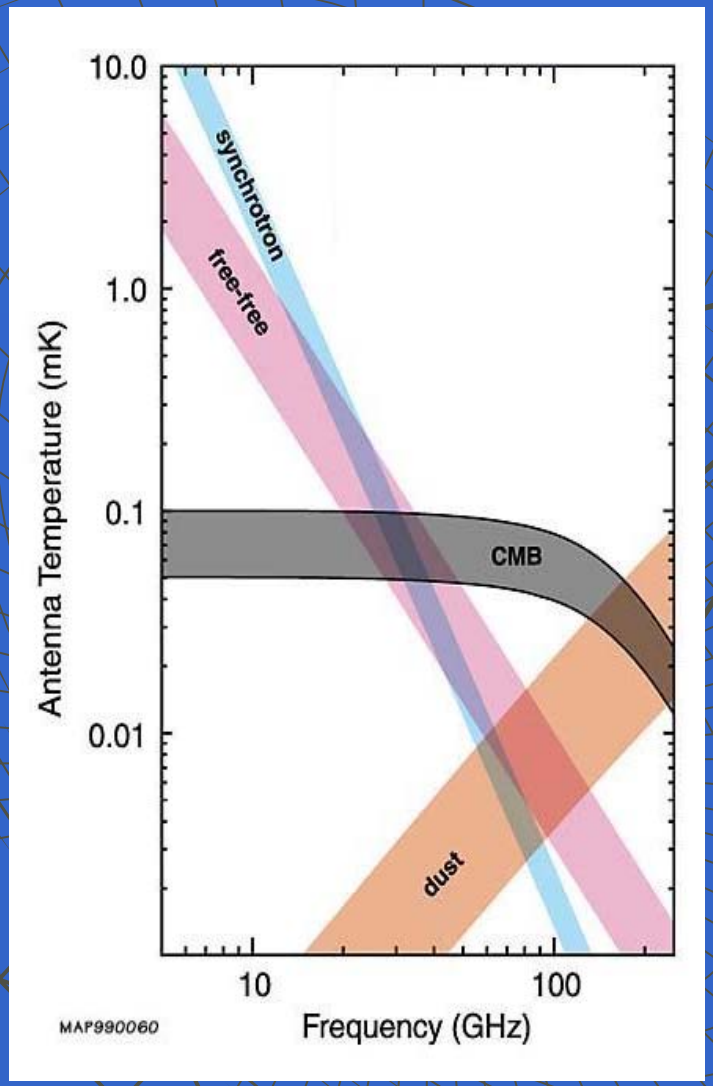
CMBR – Cosmic Microwave Background Radiation



CMB and Foregrounds

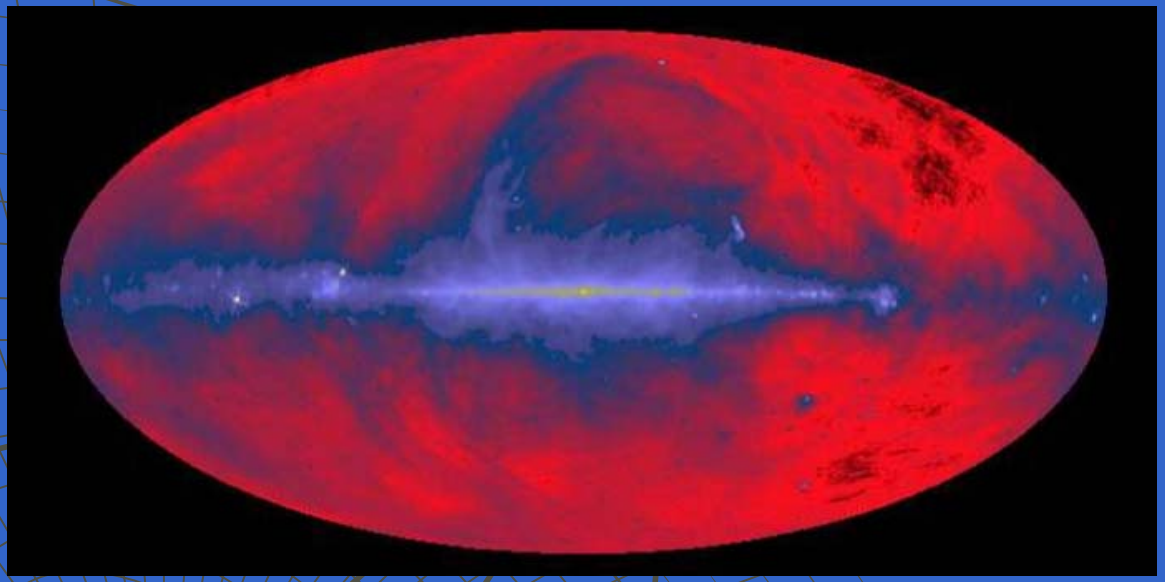
Courtesy of the NASA-WMAP / ESA-Planck

Foregrounds: Diffuse Galactic Emission



- Synchrotron: Relativistic electrons gyrating in interstellar magnetic fields
- Free-free: Thermal Bremsstrahlung from electrons produced in interstellar gas by the galactic UV radiation field
- Dust: Emission arises from thermal re-radiation of absorbed stellar light
- At low frequencies (1Ghz-15GHz) synchrotron prevails
- *Present and future = Polarization*

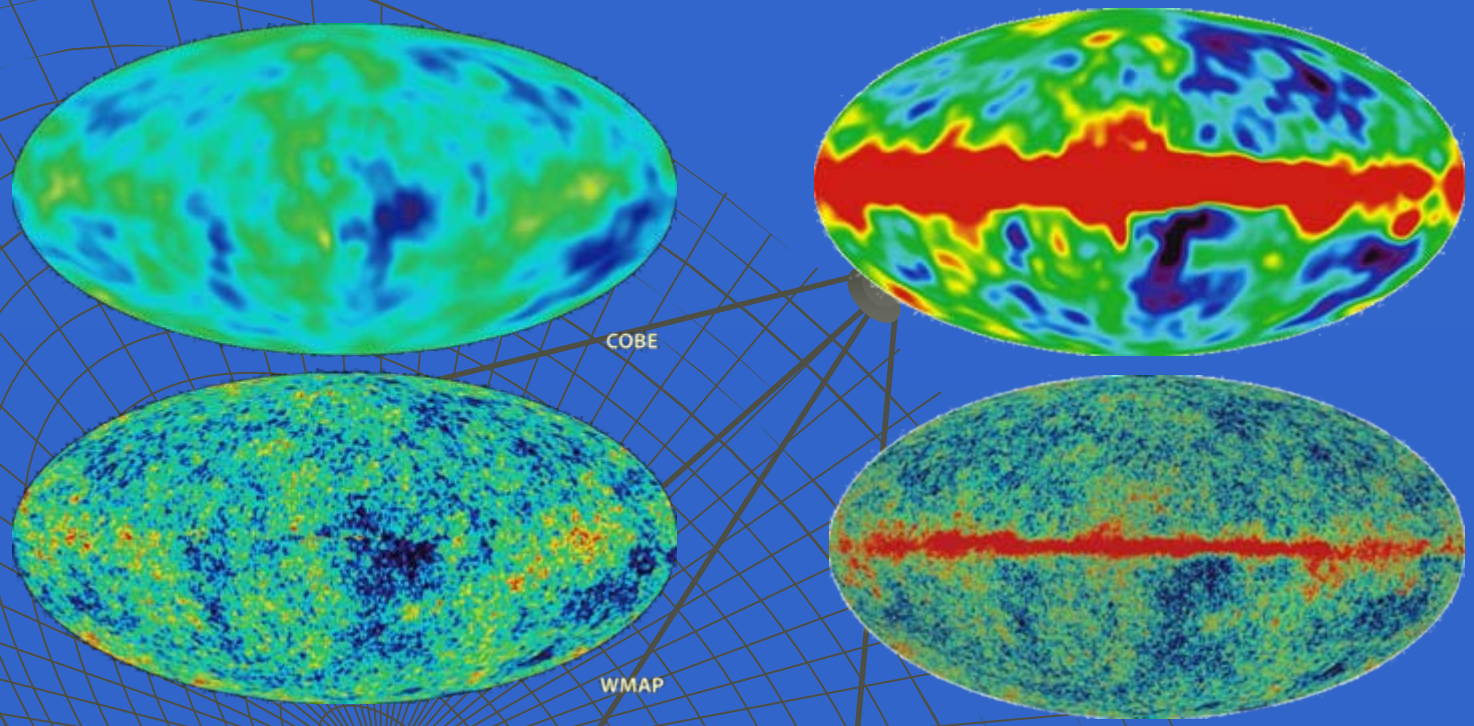
Foregrounds: Sky Surveys

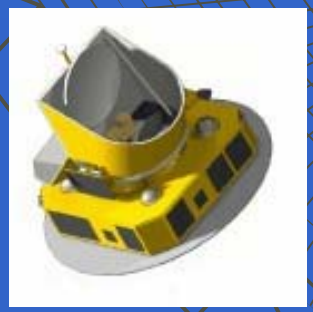


The Great Template : Full sky Haslam map (1982)

- Although it has a good angular resolution (0.85º), zero levels (±3K) and gain uncertainty (10%) make extrapolation to higher frequencies lack precision
- Comparable maps at a different frequencies are needed for extrapolation that accounts for spectral index variations

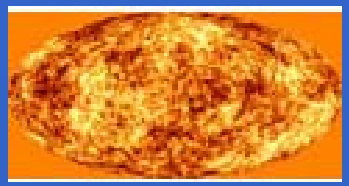
CMB and Foregrounds





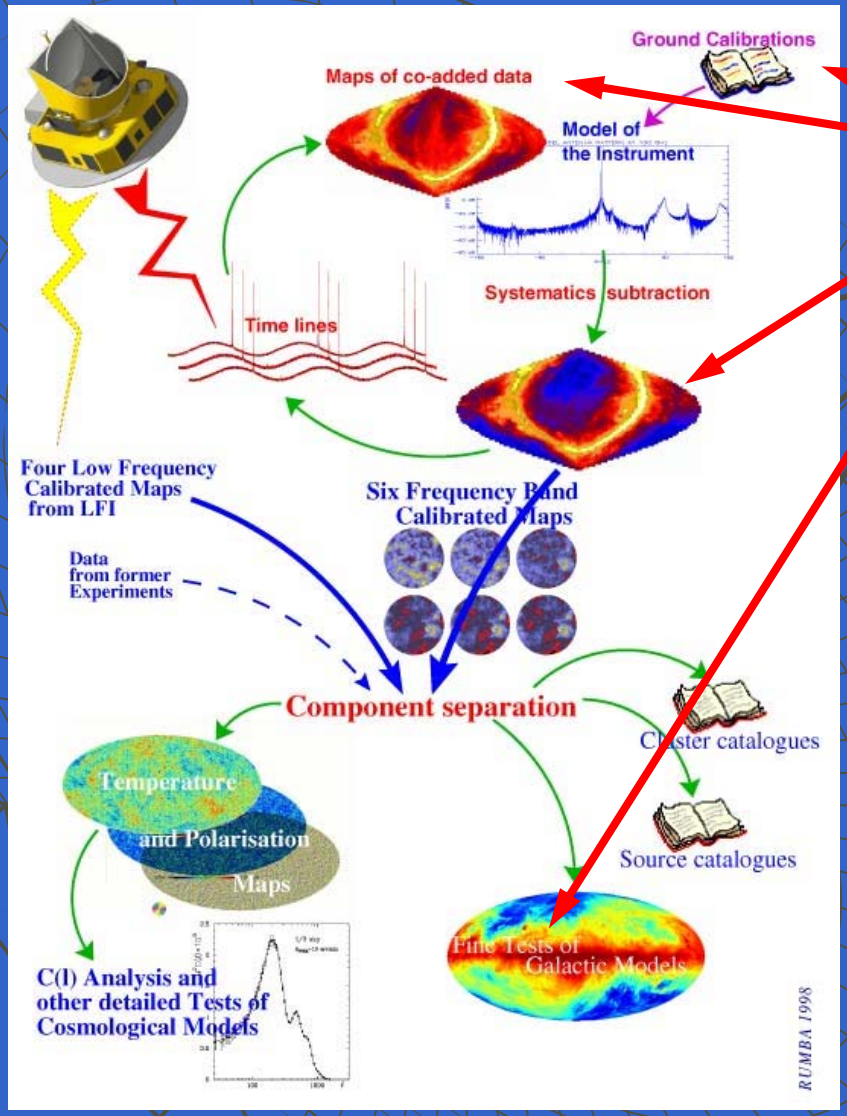
Planck Surveyour (ESA 2008)

Polarization, the future paradigm!



Courtesy of the NASA-WMAP / ESA-Planck

GEM Contribution to Planck

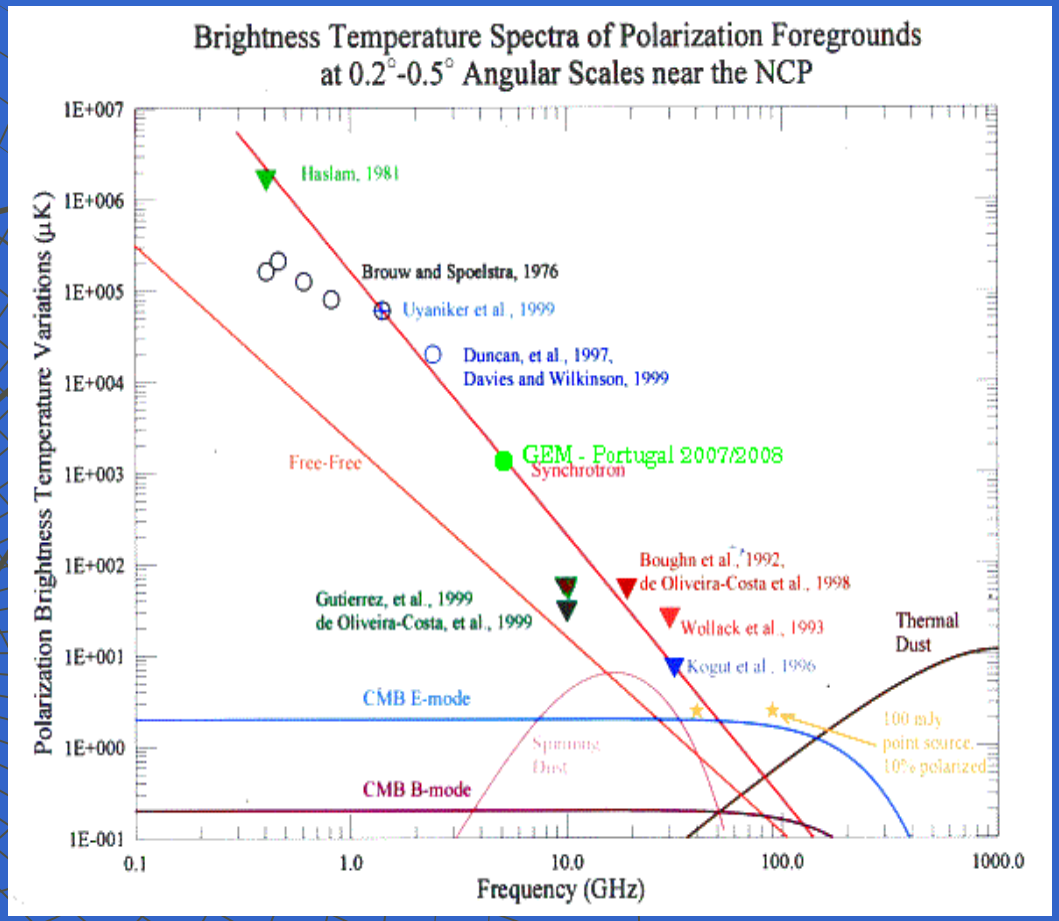


GEM

- Planck foreground removal is an important issue
- Need absolute ground calibrations at low frequencies
- GEM - aim to feed good low-freq. foreground data to Planck data pipeline (WG7)

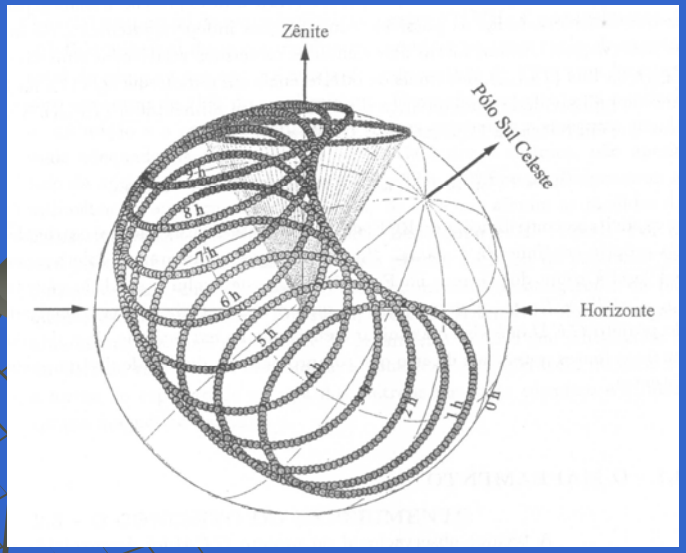
Synchrotron and Spining Dust rationale

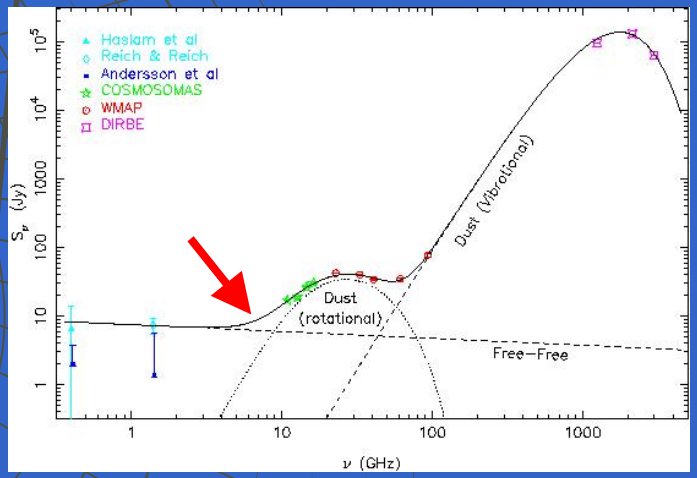
- Non existent reliable all sky synchrotron templates
- Polarized synchrotron templates needed for CMBP surveys
- Minimal Faraday depolarization @ 5GHz
- Maximum ~60% of polarization
- Microwave window for Earth based surveys
- Spinning dust (WMAP, Cosmosomas-IAC @ 13, 15 and 17 GHz)



GEM – Galactic Emission Mapping

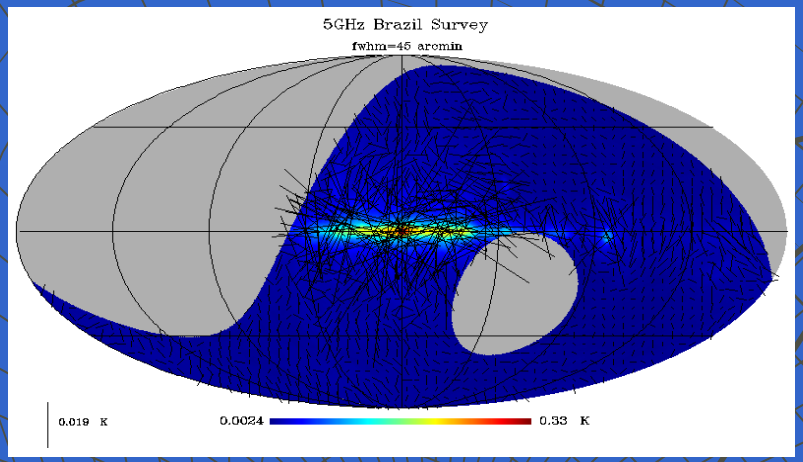
- Synchrotron polarization survey @ 5, 10 GHz
- North and South Hemispheres (Portugal and Brazil)
- 80% sky coverage
- Same scanning strategy of Planck Surveyor Mission
  - 1 rpm azimuthal rotation
  - Avoid HEMT 1/f noise and atmospheric noise drifts
- Complementary to COSMOSOMAS (IAC)
- Able to view spinning dust rise of the spectrum

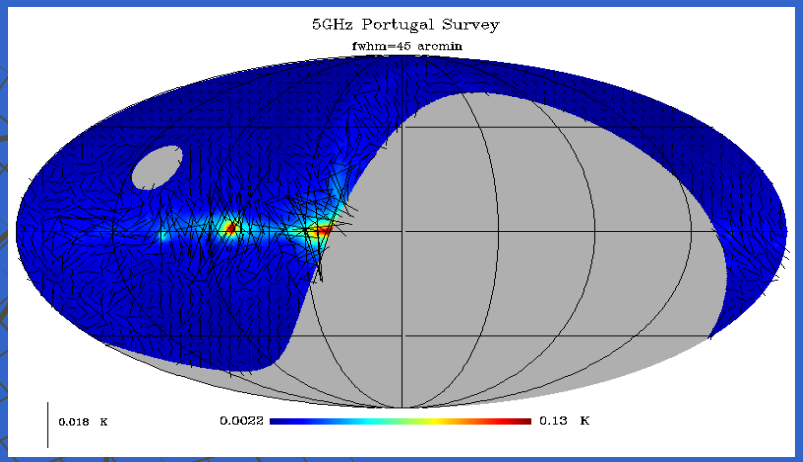


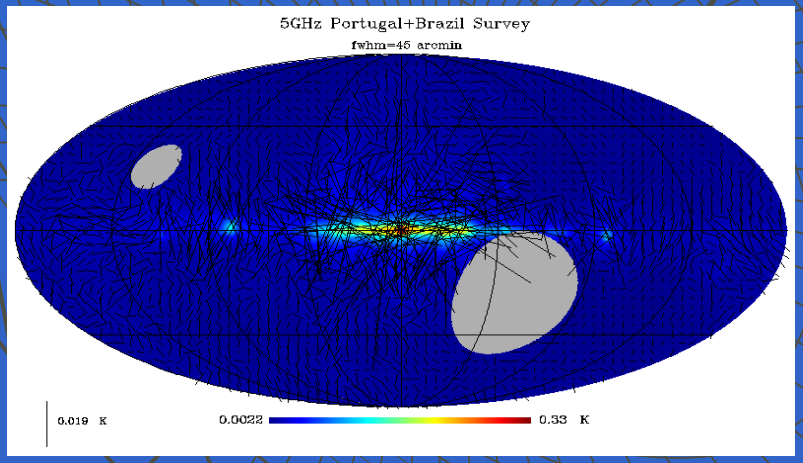


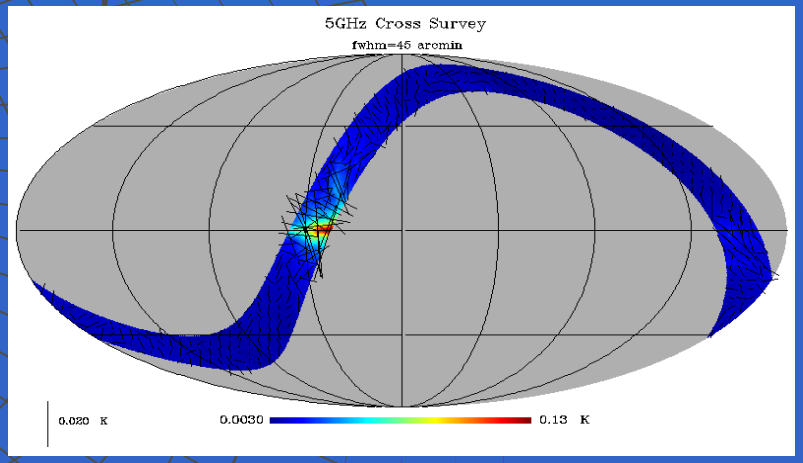
5 GHz Portugal and Brazil Surveys

Coverage simulations

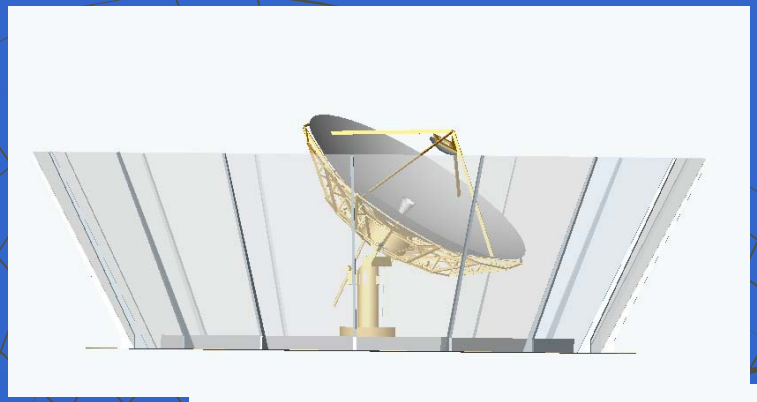




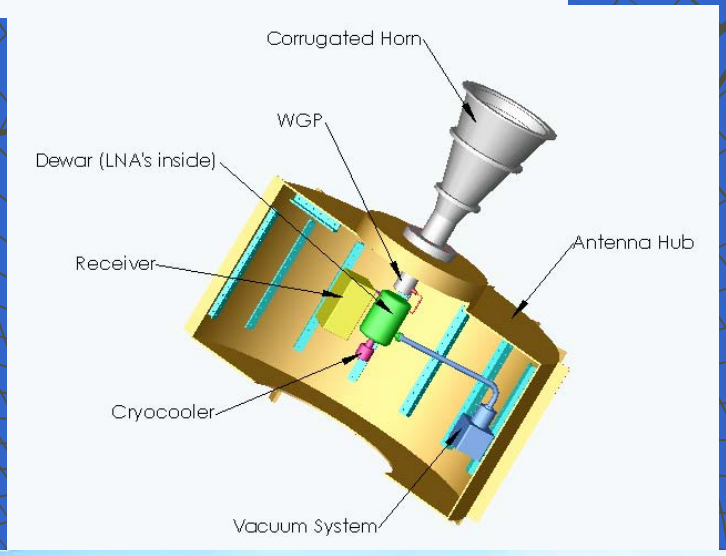




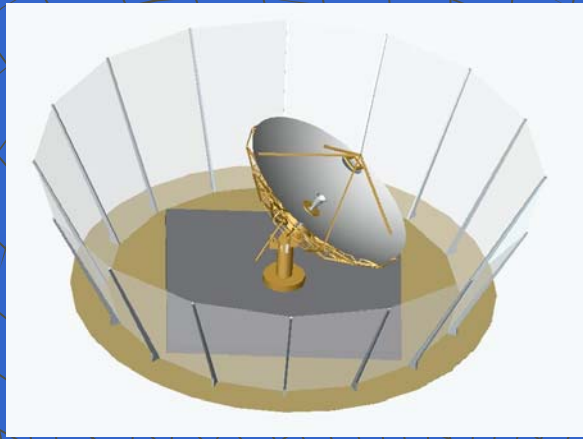
GEM-P

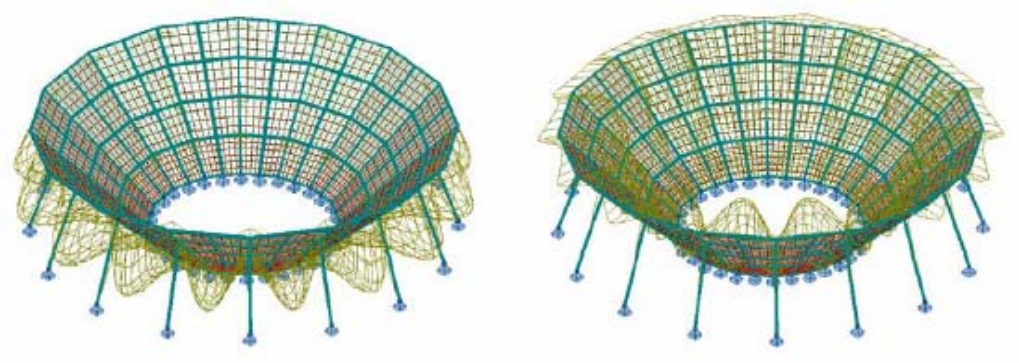


- Digital correlator receiver
- 9 m diameter dish (offered by PT)
- In installation
- First results by 2009/2010



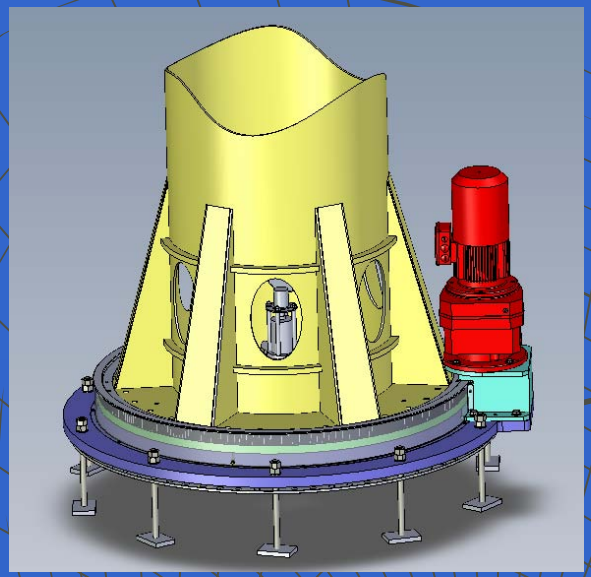
Antenna – Foundations and Ground Screen

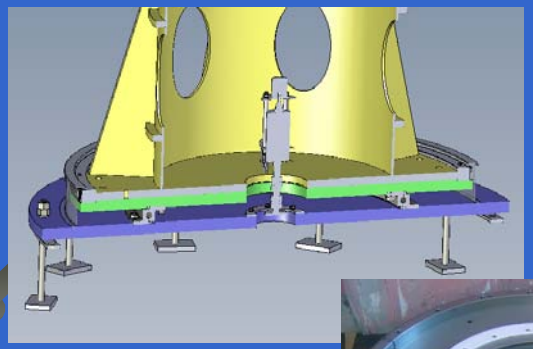


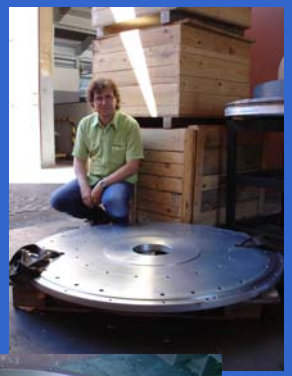


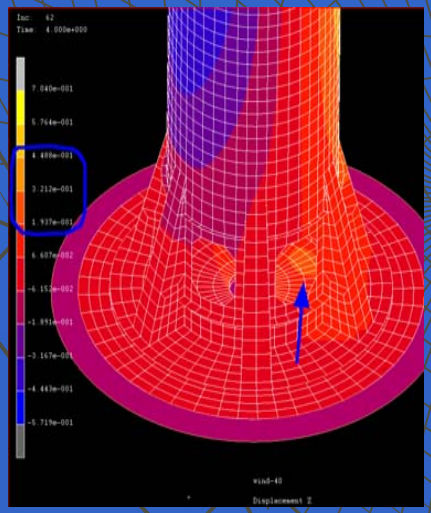
- Protect from ground pick-up
- Spillover & ground shielding (20 dB atten.)
- Mechanical simulations to check compliance with antenna and wind requirements
- Site in preparation for installation

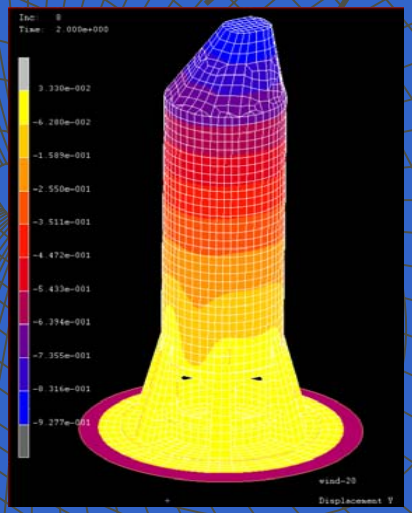
Antenna - Mechanics







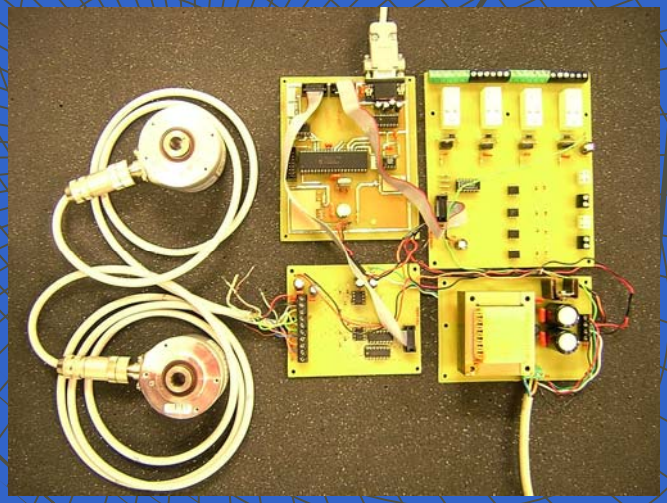


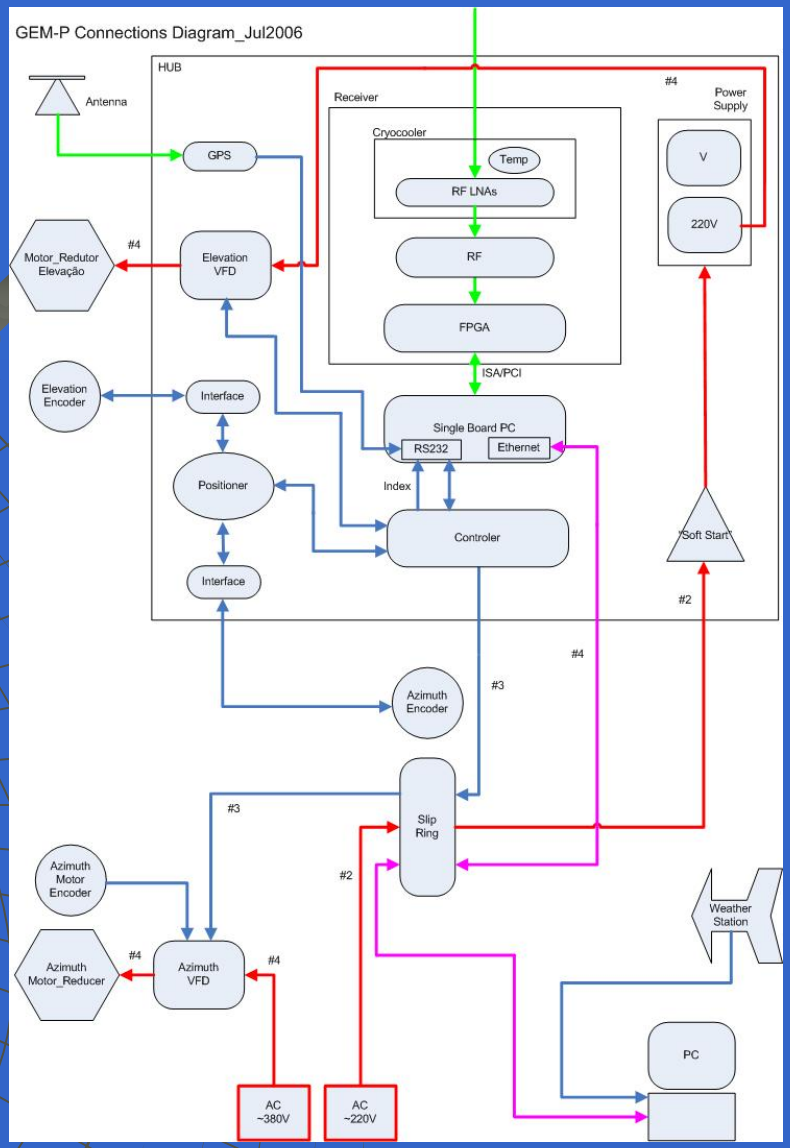


- Project pedestal changes for full rotation (3.5 t of metal)
- Mechanical simulations to comply with antenna requirements (operational winds ≥ 20Km/h)
- Motor and reducer
- Data and power connections

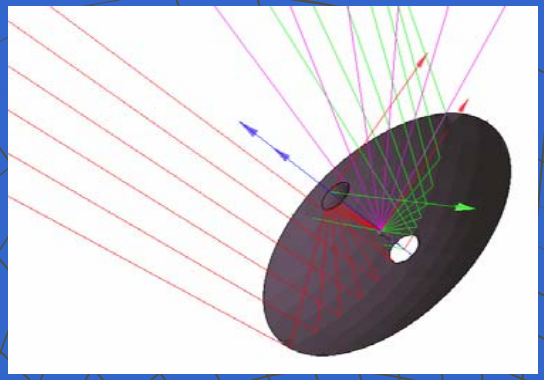
Antenna - Control

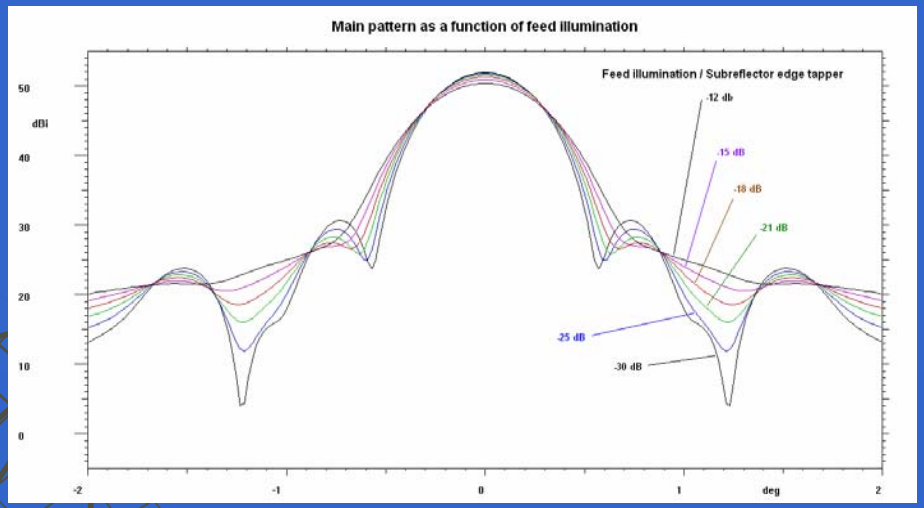
- Pointing accuracy, 1 arc min
- Absolute encoders, 17 bits
- Highly stable rotational speed, 1rpm
- Motors control by VFD (variable frequency drive)
- GPS for time reference
- Weather station

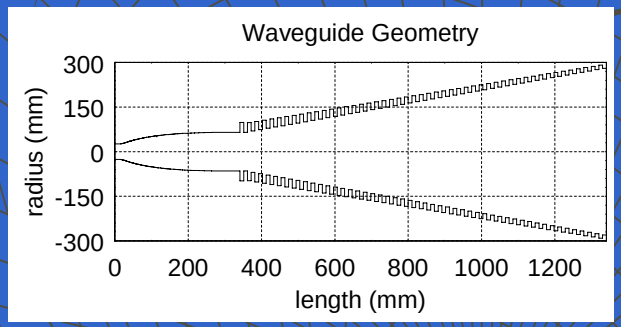


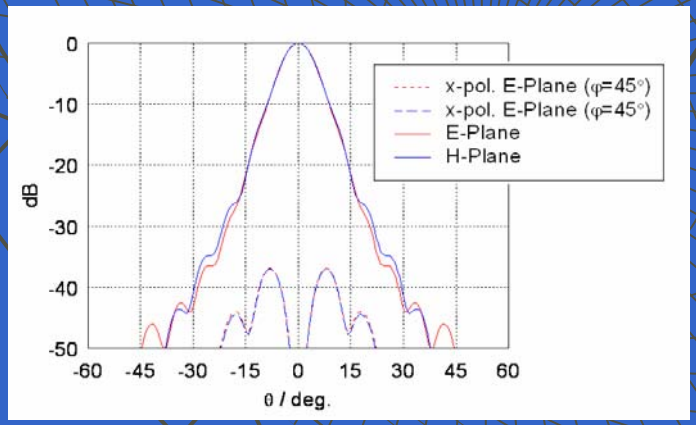


Antenna - Optics







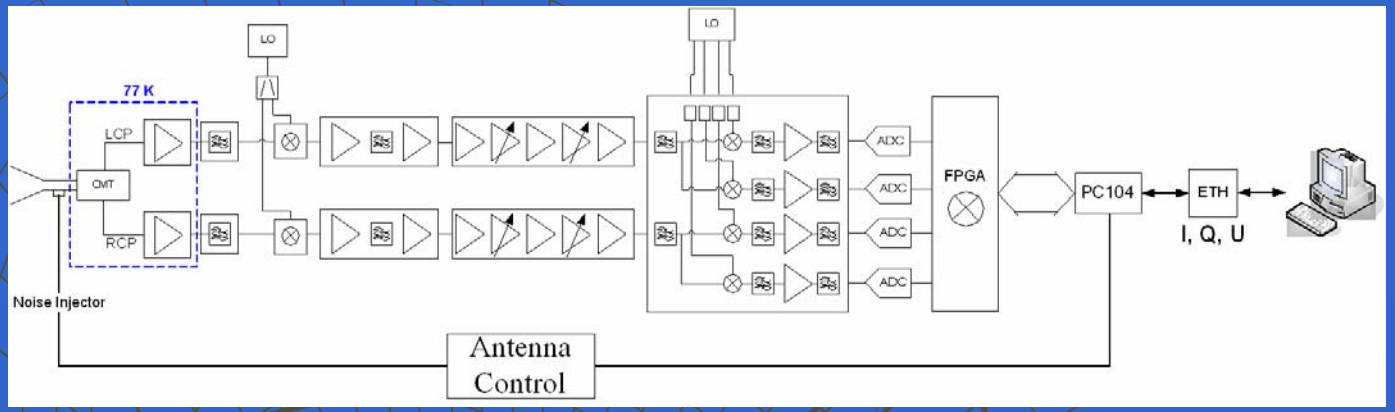


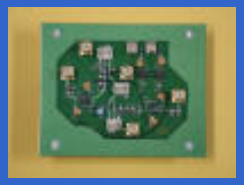
- Optimize antenna response, GRASP, HFSS, Planck IDIS Level S:

- Gain ~53 dB (9m antenna size)
- HPBW = ~30 arcmin
- main – 1st ~ 26 dB (RA goal)
- 40% < ηant < 60% (from a good design)
- x-pol < 30 dB (desirable for polarization survey)
- Gant/Tant ~ 40 dB/K (RA typical)
- Spillover & ground shielding (20 dB atten.)

Receiver

Digital Superheterodyne Correlator Receiver





- I, Q and U Stokes parameters
- Freq. = 4.9 GHz, B = 200 MHz
- Cryocooler cooled PHEMT preamplifiers;
- Tsys = 22 K
- Sensitivity = 0.5mK (~3.5months integration)
- Gain = 105 dB
- IF test OK
- Figures may improve
- Possibility of bandwidth increase (200→600MHz)
- 77K is superior limit; it is debated.

$$RL = \Re e\left(E_{rcp} E_{lcp}^{*}\right) \rightarrow Stokes\ U$$

$$LR = \Re e\left(E_{rcp,-\frac{\pi}{2}} E_{lcp}^{*}\right) \rightarrow Stokes\ Q$$

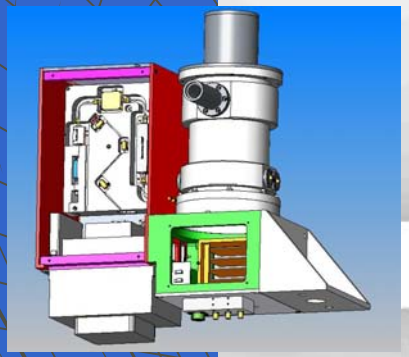
$$RR + LL = \left\langle E_{rcp} E_{rcp}^{*}\right\rangle + \left\langle E_{lcp} E_{lcp}^{*}\right\rangle \rightarrow Stokes\ I$$

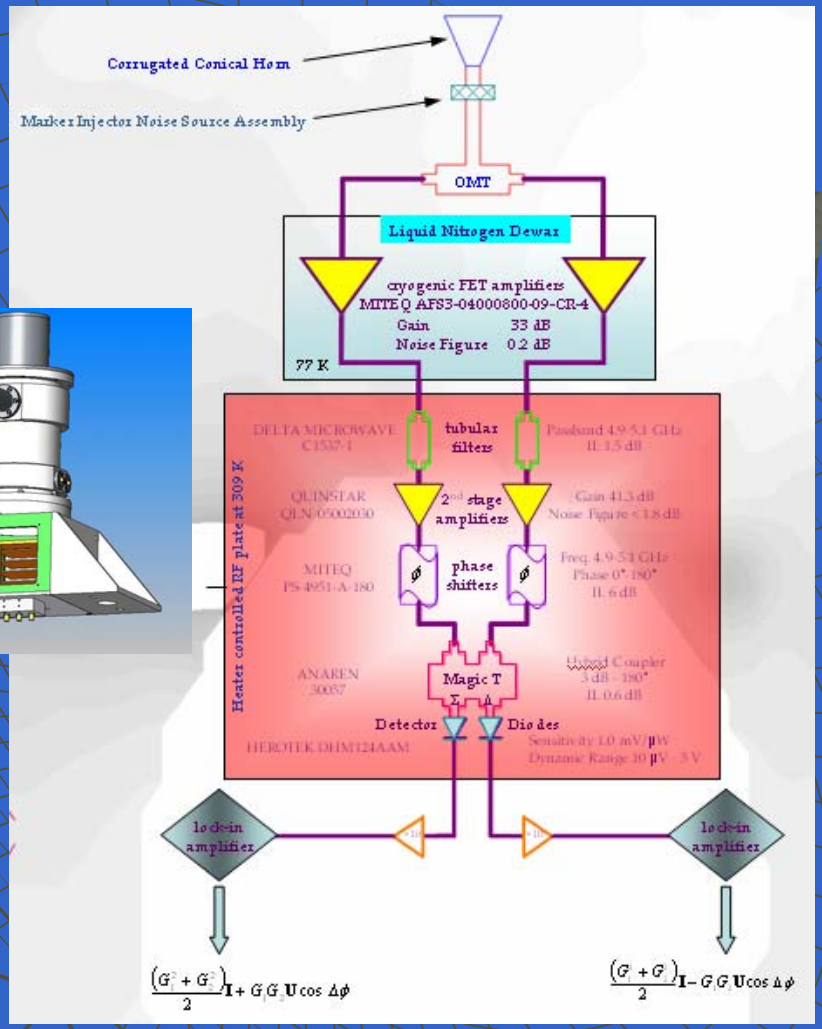
Receiver – FPGA and PC104

- ADC at 250 MSPS with 8 bits resolution
- FPGA Altera Cyclone II
- FPGA, working at 100MHz with interleaving
- FPGA configuration with VHDL code
- Currently being tested!

GEM Brasil

http://www.das.inpe.br/cosmo/index_gem.htm

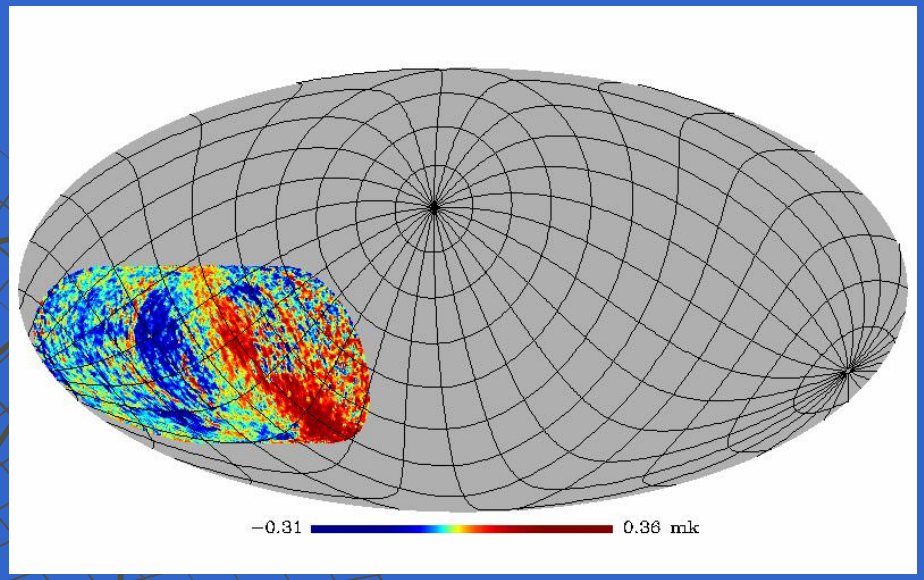




- Pseudo correlator receiver
- 5.5 m diam. dish (extended to 9 m)

First results expected in 2007

GEM Brasil



- Already had first light!
- Systematics (but galaxy looks visible!!)

GEM-P Team Colaboration

- **Team**
  - Domingos Barbosa
  - Dinis Santos
  - Rui Fonseca
  - Miguel Bergano
  - Francisco Fernandes
  - David Macário
  - Ana Mourão
  - George Smoot
  - Camilo Tello
  - Graça Rocha
  - Marco Bersanelli
  - Andrew Jaffe
  - Marco Tucci

- **Colaborators**
  - Luís Cupido
  - Aníbal Costa
  - Francisco Queirós de Melo
  - Rui Martins
  - Vasco Lagarto
  - Dietmar Wagner
  - James Bartlet
  - Nazareno Mandolesi
  - Luca Valenziano
  - Thyrso Villela
  - Ivan Ferreira

- **Institutions**

- **IT-Aveiro** – Instituto de Telecomunicações - Portugal
- **CENTRA** – Centro Multidisciplinar de Astrofísica, IST - Portugal
- **LBNL** – Lawrence Berkeley National Laboratory – EUA
- **INPE** – Instituto Nacional de Pesquisas Espaciais – Brasil
- **UNIMI -** Università di Milano, Dipartimento di Fisica - Italy
- **IASF - Bologna** – Instituto di Astrofisica Spaziale e Fisica Cosmica – Italy
- **CMdPS** - Câmara Municipal de Pampilhosa da Serra - Portugal

---

- CFN – Centro de Fusão Nuclear, IST - Portugal
- DEMUA – Departamento de Eng. Mecânica da UA - Portugal
- DECUA – Departamento de Eng. Civil da UA - Portugal
- Max Planck-Institut für Plasmaphysik - Germany
- Imperial College – London Planck Analysis Center - UK
- Université de Paris VII & College de France - France
- Caltech - USA