Les Rencontres de Physique de la Vallée d'Aoste

Recent results in CMB Experiments

Francesco Piacentini

&

the BOOMERANG collaboration

Goal: Cosmology

Main goal of this experiments is:

Use the

Cosmic Microwave Background radiation

as

a probe in the early Universe,

to measure the cosmological parameters

and test Inflationary theories

Cosmological parameters

Space-Time metric

$$ds^2 = c^2dt^2 - a^2(t)\left(\frac{dr^2}{1-kr^2} + r^2d\theta^2 + r^2\sin^2(\theta)d\psi^2\right)$$

temporal term

spatial term

Temporal evolution of the spatial term

Einstein field equations

Cosmological parameters

$$\left(\frac{\dot{a}}{a}\right)^2 = \Omega_K + \Omega_b + \Omega_{DM} + \Omega_\Lambda$$

curvature

densities

Different equations of state

Different functions of a

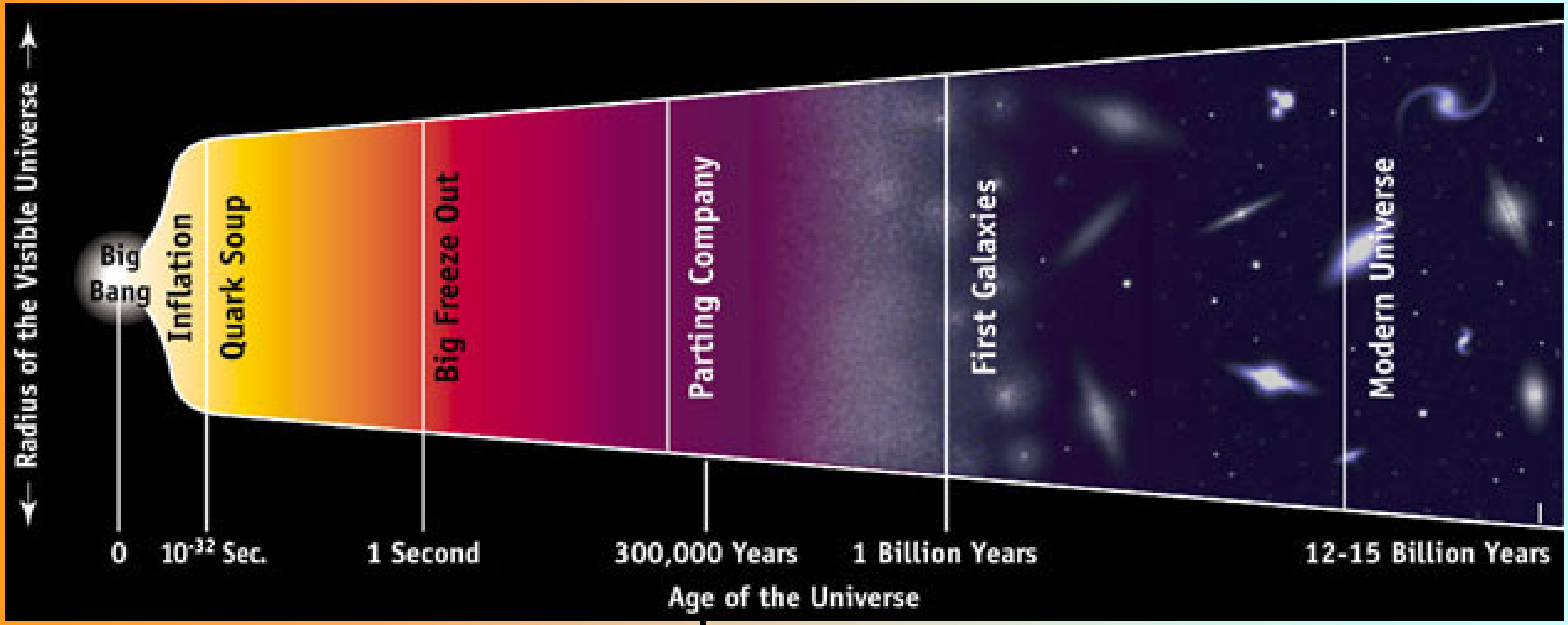
And:

H_0: Hubble constant now

n_s: initial conditions

What is the CMB ?

Thermal history of the Universe



Dense & Hot Universe

Plasma

Opaque (photons mean free path is small)

Radiation Pressure: structures oscillate

Cold Universe

Neutral gas

Transparent (photons mean free path in ~infinite)

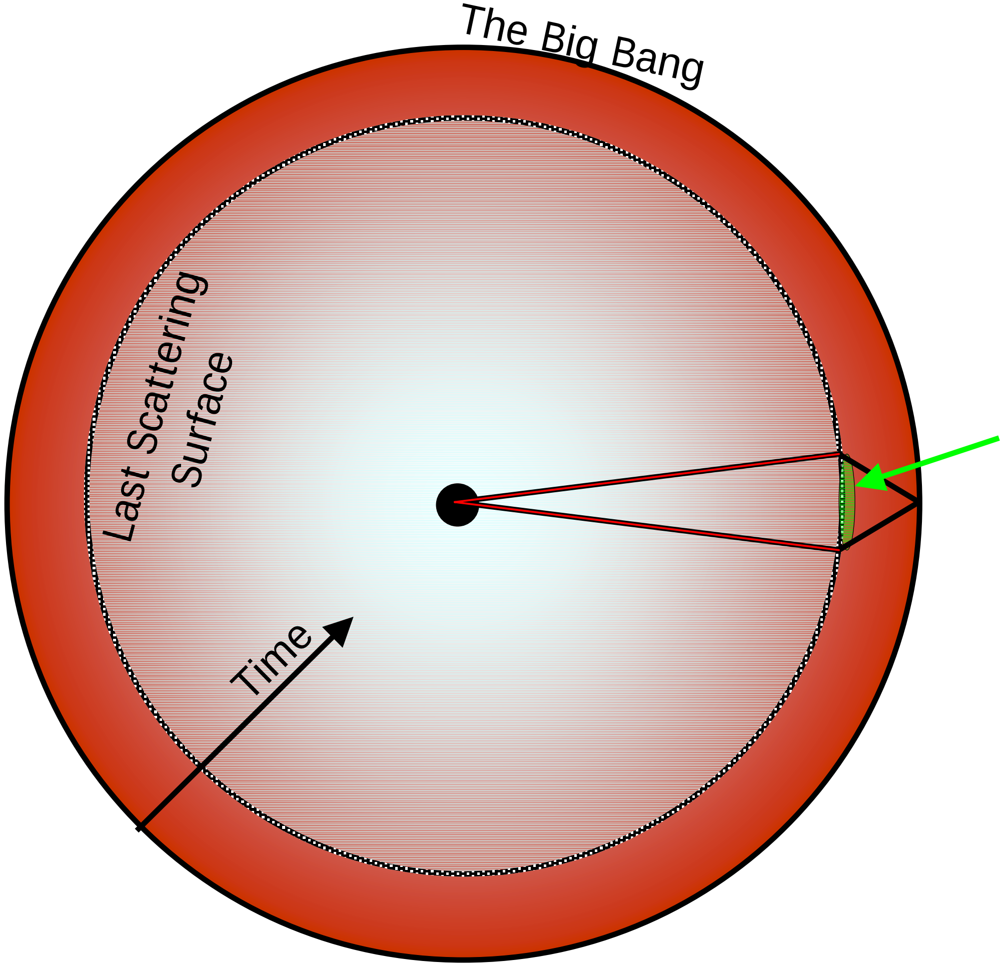
Gravity: structures collapse

What is the CMB ?

From our point of view

Looking far enough we can see photons from the Last Scattering Surface (LSS).

The linear dimension of the structures we see in the LSS is linked to the causal horizon at that epoch.



Largest structure in the LSS:

as large as the sound horizon at that epoch

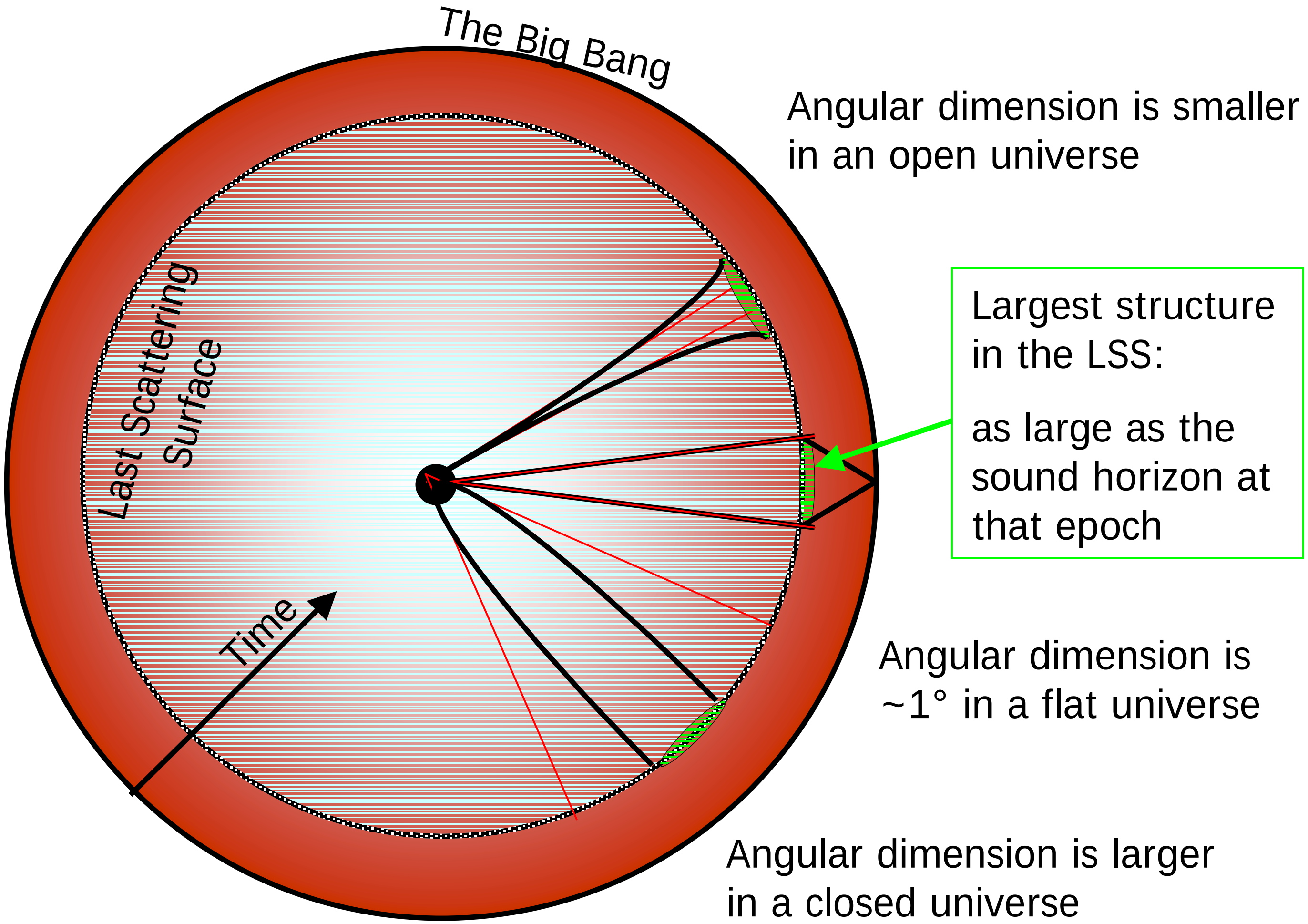
What is the CMB ?

How is related to the curvature of the Universe

Looking far enough we can see the LSS photons.

The linear dimension of the structures we see in the LSS is linked to the causal horizon at that epoch.

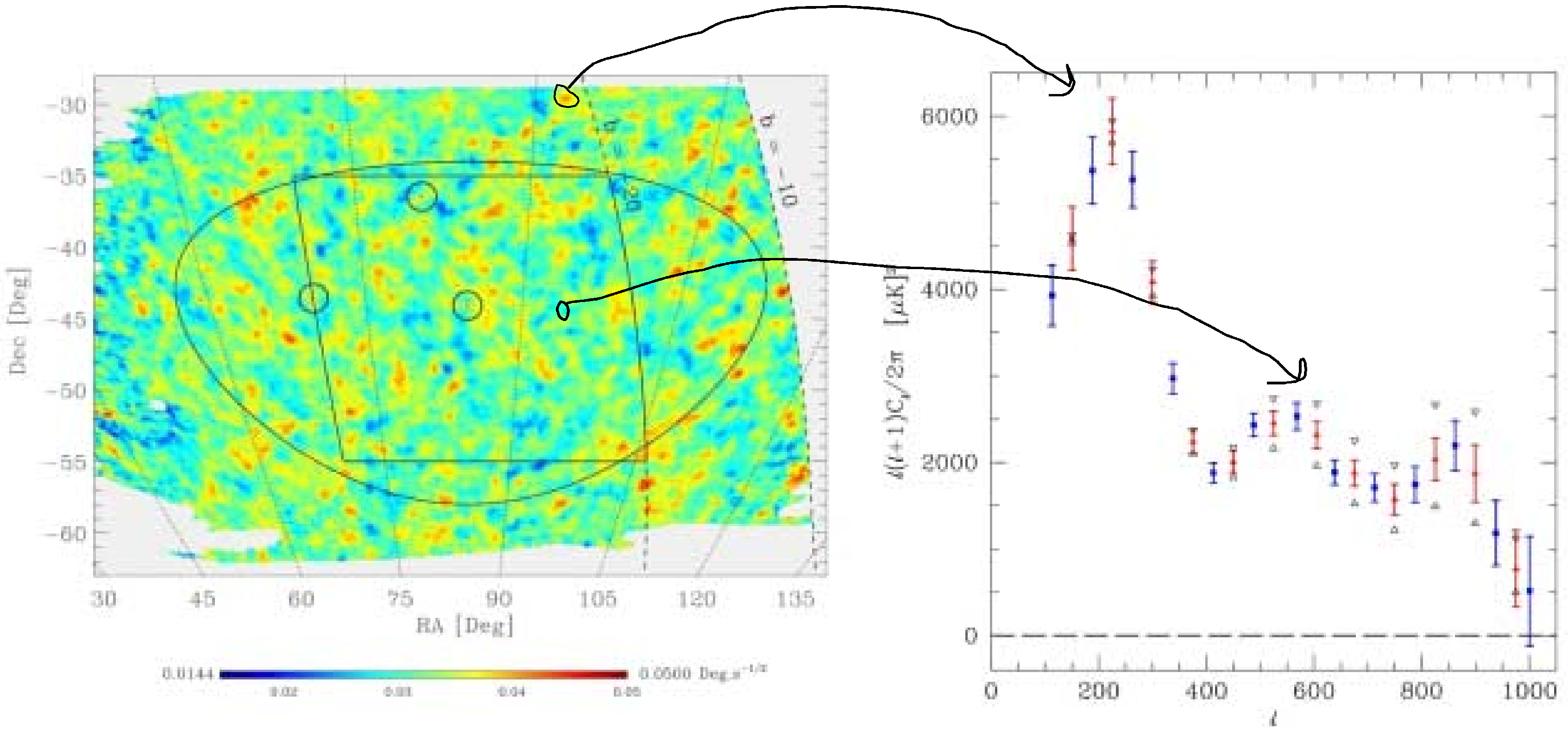
The angular dimension we see depends on the geometry of the universe.



What is the CMB ?

Cosmological information is mostly in the

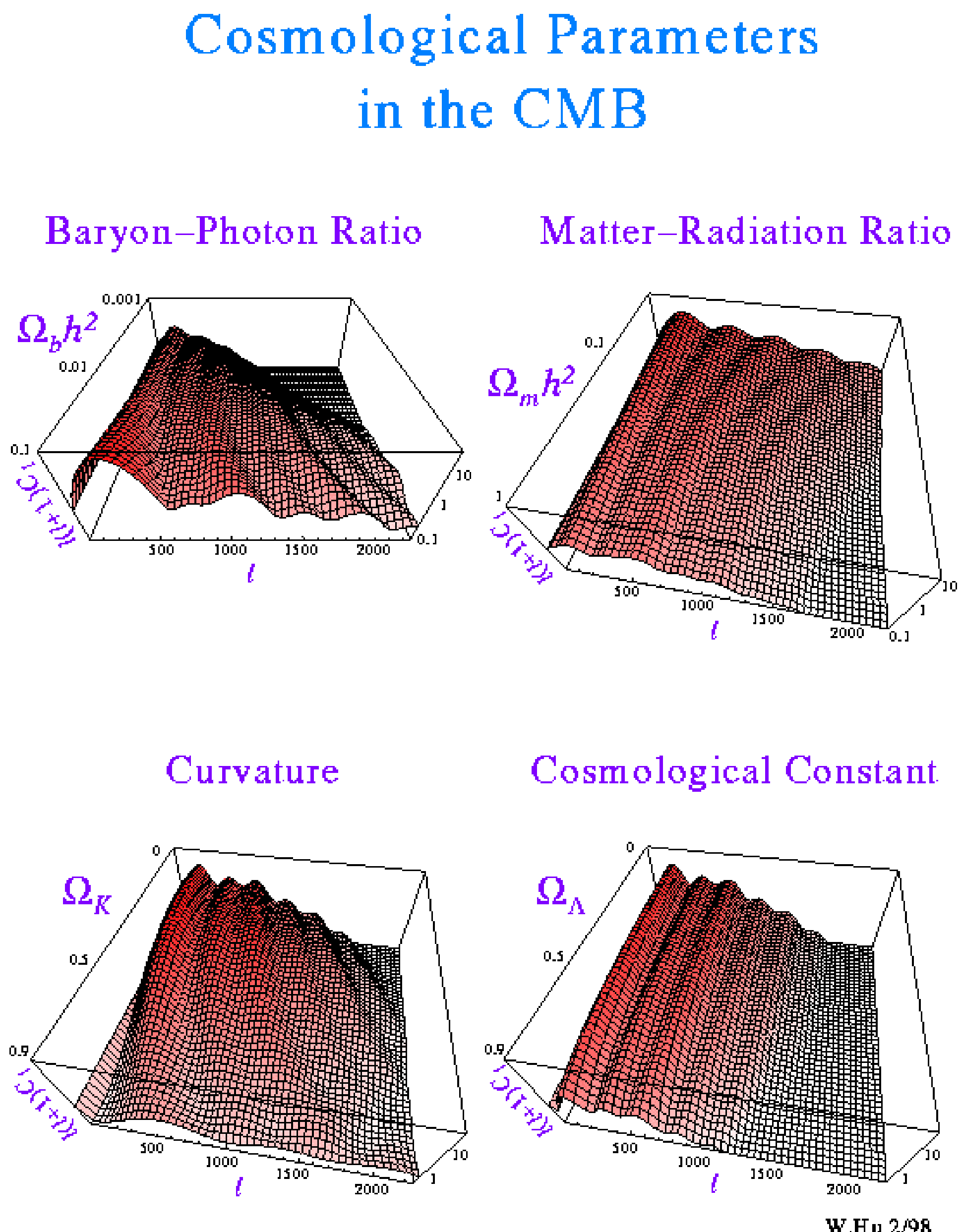
ANGULAR POWER SPECTRUM



What is the CMB ?

Ratio between first and second peak

Position of the first peak



Amplitude of the first peak

Almost insensitive

Short History of CMB Anisotropies

1965 — Penzias & Wilson discover CMB

1970

1975 — *"The age of upper limits…"*

1980

1985

COBE-DMR measures first anisotropies…

1990

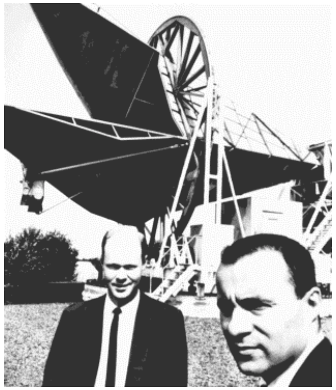
1995

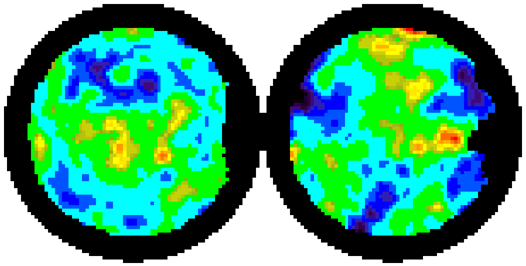
Toco sees first acoustic peak

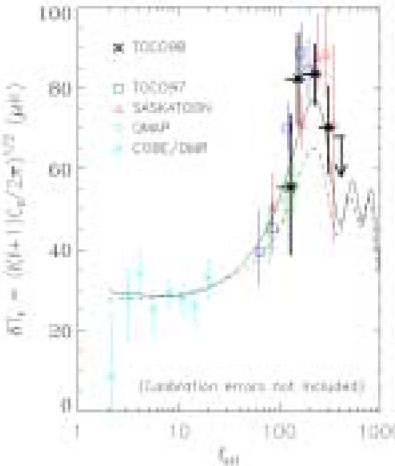
2000

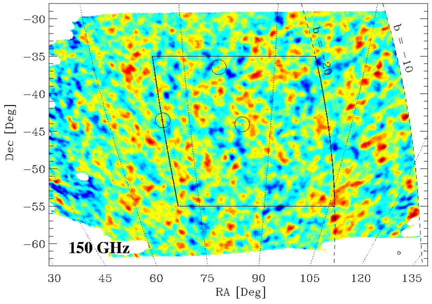
First detailed images…

(More to come!…)









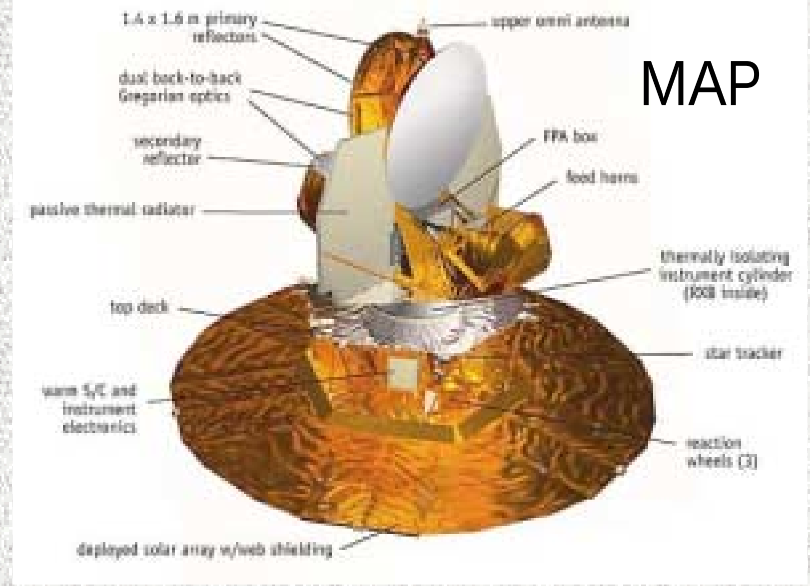
The challenge

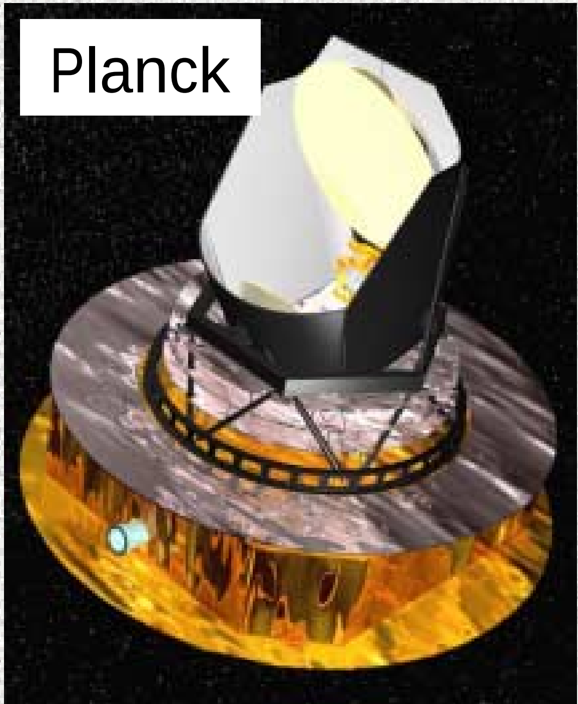
Measuring fluctuations: $\dfrac{\Delta T}{T} \cong 10^{-5}$

NEED:

high **sensitivity**	=>	technology
high **resolution** @ mm Wavelength	=>	microwave optics
control of **systematic effects**	=>	redundancy
control of **foreground signals**	=>	spectral analysis

The challenge





BOOMERANG

U. Roma I
- P. deBernardis
- S. Masi
- F. Piacentini
- G. Polenta
- G. De Troia
- F. Scaramuzzi

UCSB
- P. Farese
- T. Kisner
- T. Montroy
- J. Ruhl
- E. Torbet

IROE-CNR
- A. Boscaleri
- E. Pascale

UCB
- J. Borrill
- A. Jaffe

U. Roma II
- N. Vittorio
- G. DeGasperis
- P. Natoli

Oxford
- P. Ferreira
- A. Melchiorri

IPAC
- K. Ganga
- E. Hivon

Caltech
- B. Crill
- V. Hristov
- A. Lange
- P. Mason
- K. Shelton

U. Cardiff
- P. Ade
- P. Mauskopf

JPL
- J. Bock

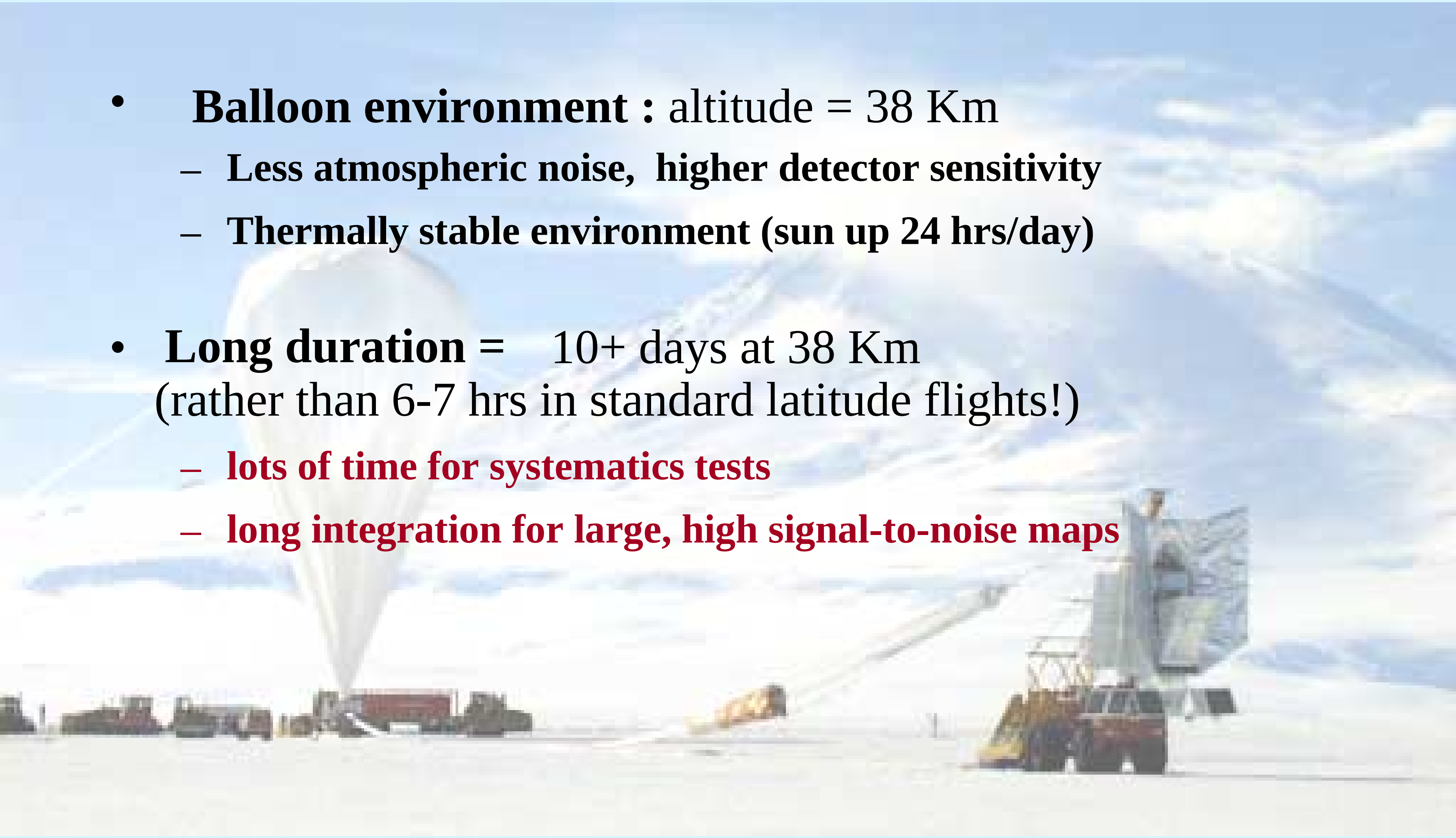
U. Toronto
- D. Bond
- B. Netterfield
- D. Pogosyan
- S. Prunet
- C Contaldi

BOOMERANG

Antarctic Long Duration Ballooning

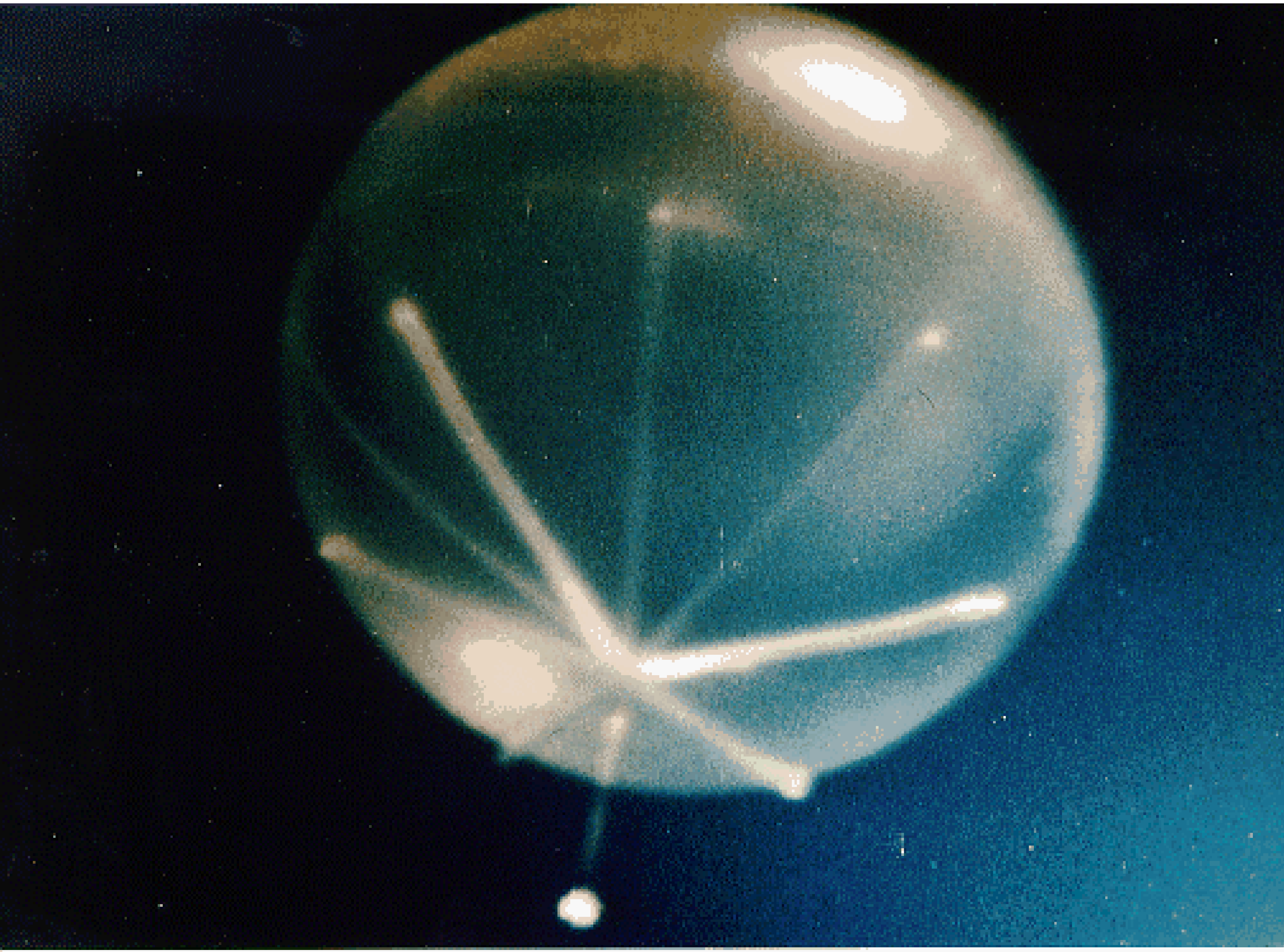
- **Balloon environment :** altitude = 38 Km
  - **Less atmospheric noise, higher detector sensitivity**
  - **Thermally stable environment (sun up 24 hrs/day)**

- **Long duration =** 10+ days at 38 Km
  (rather than 6-7 hrs in standard latitude flights!)
  - **lots of time for systematics tests**
  - **long integration for large, high signal-to-noise maps**



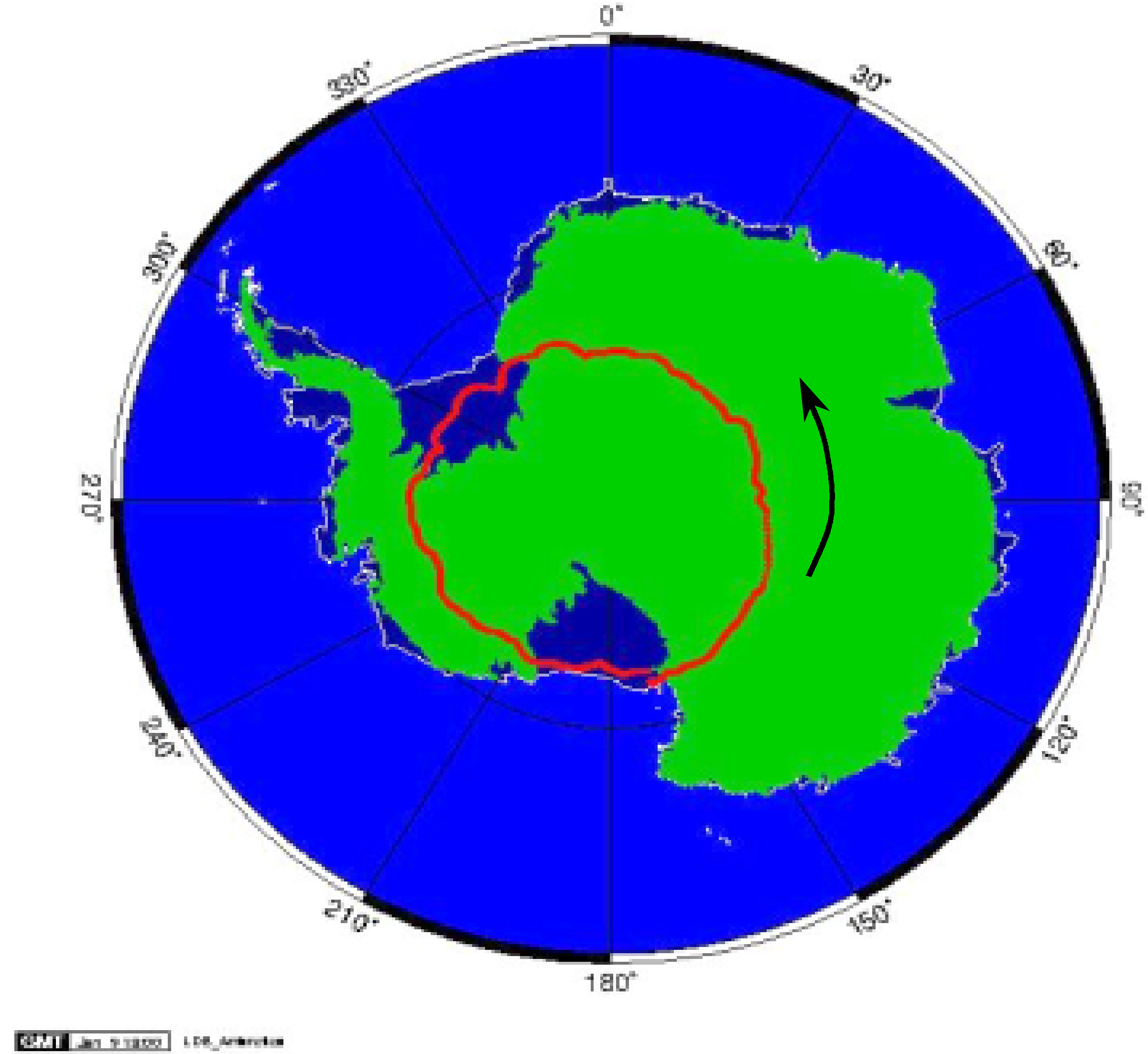
The launch: Dec. 29, 1998

P.de Bernardis Oct. 2000



Boomerang's Track

(1 lap in 10.6 days...)



Stratospheric vortex takes the payload around the continent

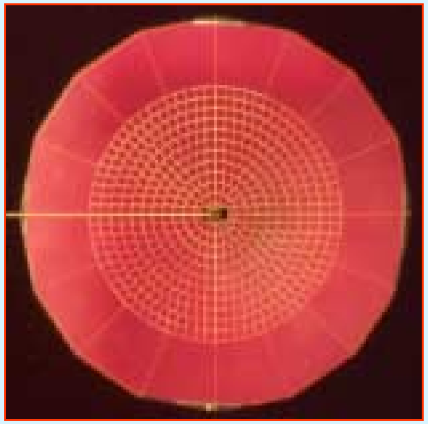
≈ 38 Km altitude

TDRSS Satellite link ⇒ real-time data downlink and commanding for analysis and control

“soft landing”

BOOMERANG Detectors

Receivers: 16 spider web bolometers @ 280 mK



Arranged in 4 single frequency channels (90 GHz, 150 GHz)
+ 4 triple frequency photometers (150/240/410 GHz)

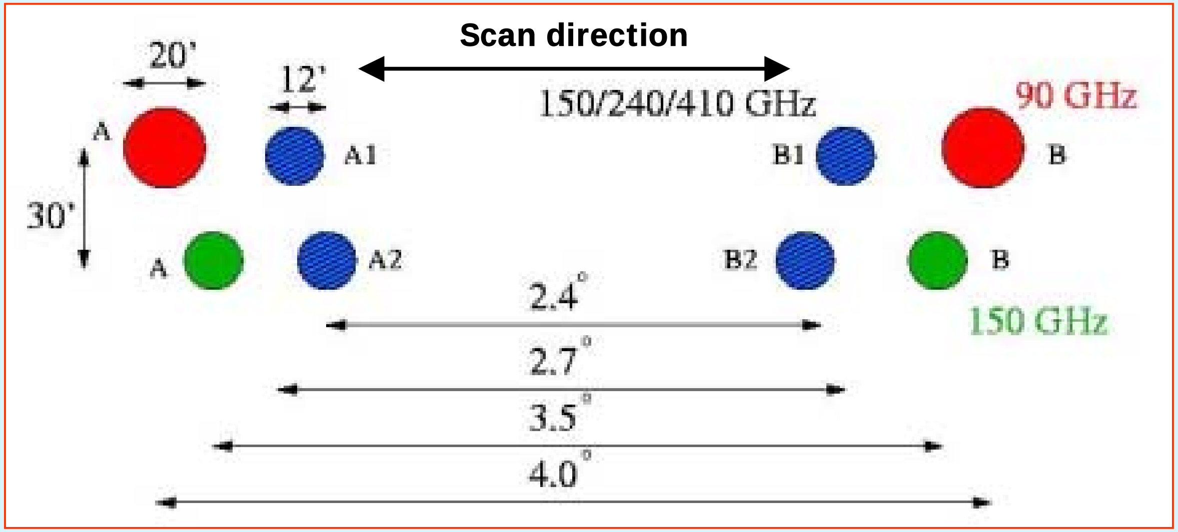
Disposition in the focal plane

This disposition allow cross checking in:

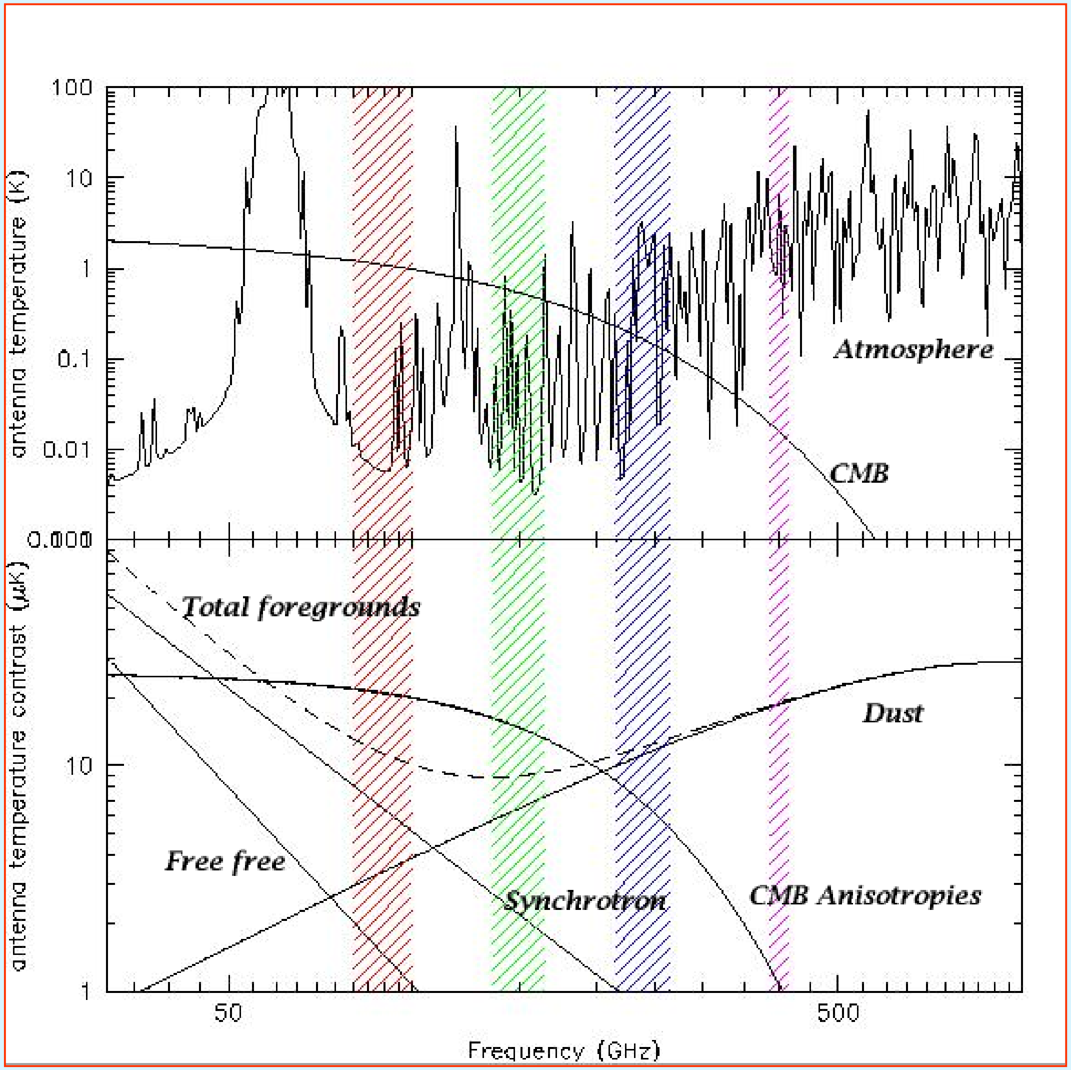
time ordered data,

maps,

power spectrum.



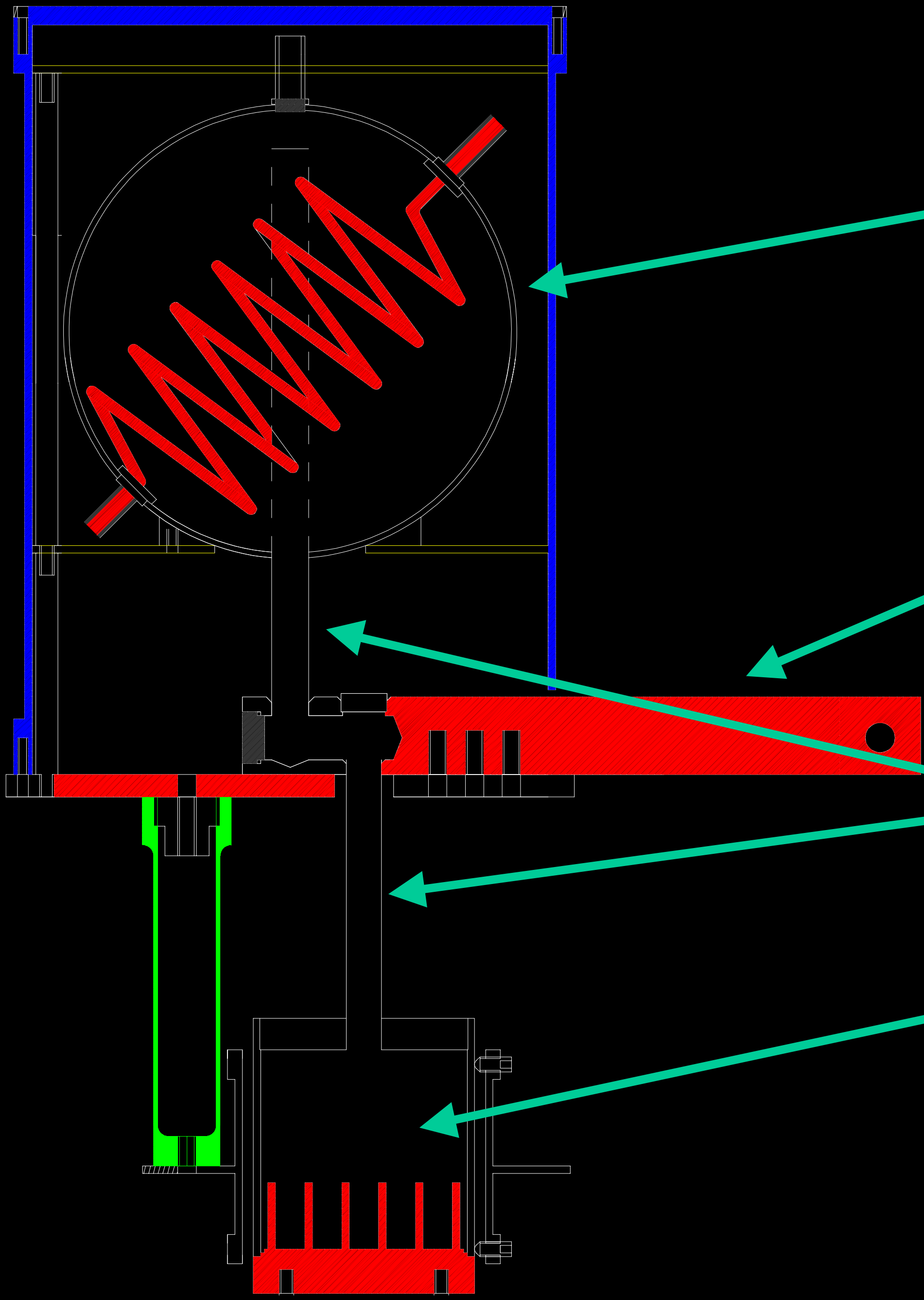
BOOMERANG Detectors



The atmosphere emission is comparable with CMB emission at high frequencies

CMB anisotropies (25μK) are larger than galactic foregrounds at 90 and 150 GHz, marginal at 240 GHz, negligible at 400 GHz

S. Masi et al. **Cryogenics**, 38, 319-324, 1998



The Fridge: 280 mK 14D

Cryopump

It works with charcoal carbon grains

It adsorbs when T < 5 K
(mechanical thermal switch)

It desorbs when T > 12 K (heater)

Condensation point

Thermally connected to the ^{4}He bath with 2 gold coated copper rods

Pumping tubes

Thin wall stainless steel tubes

Liquid ^{3}He evaporator

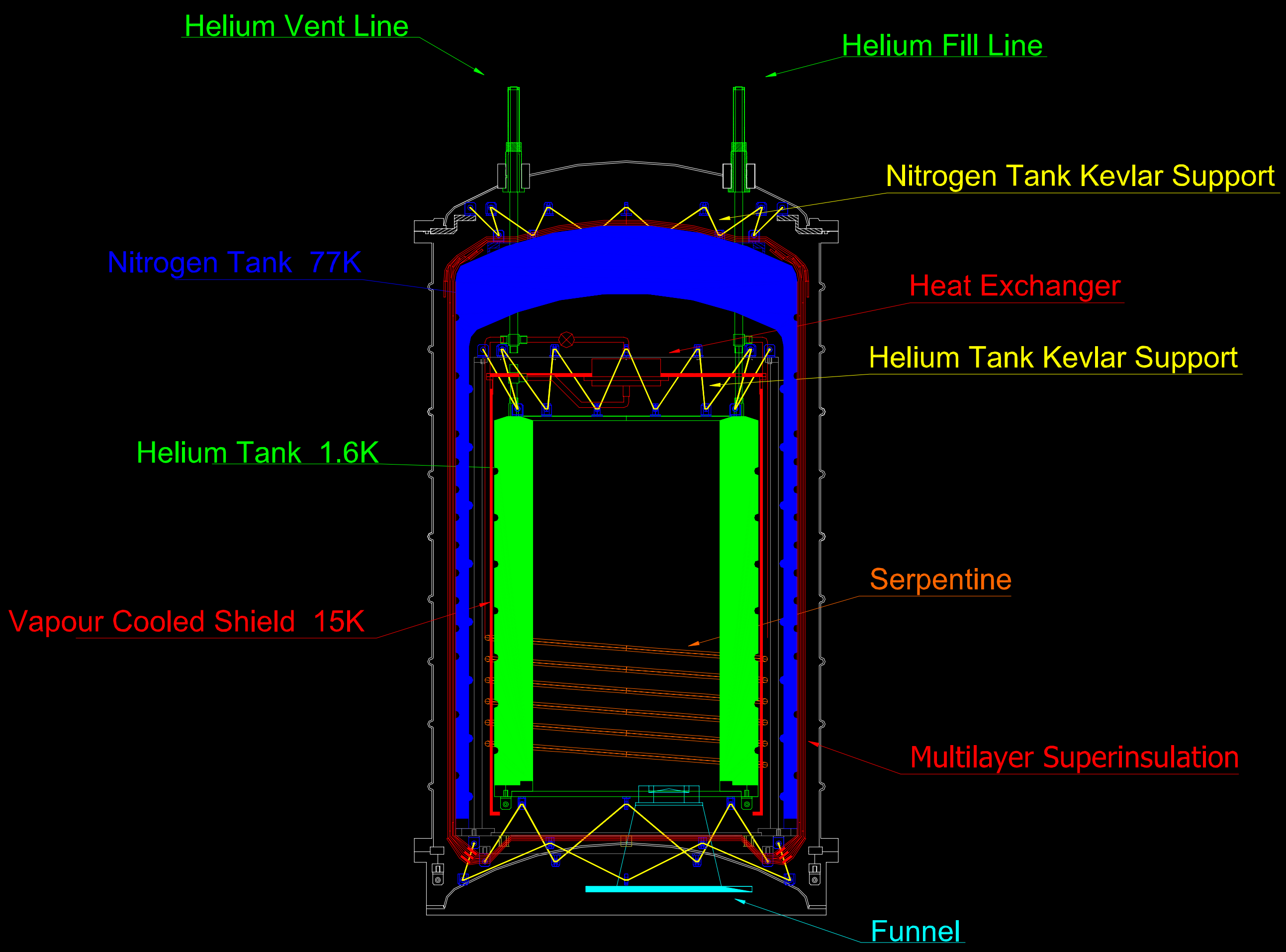
T = 0.280 K

Volume = 130 cm^3

34 STP liters of ^{3}He gas

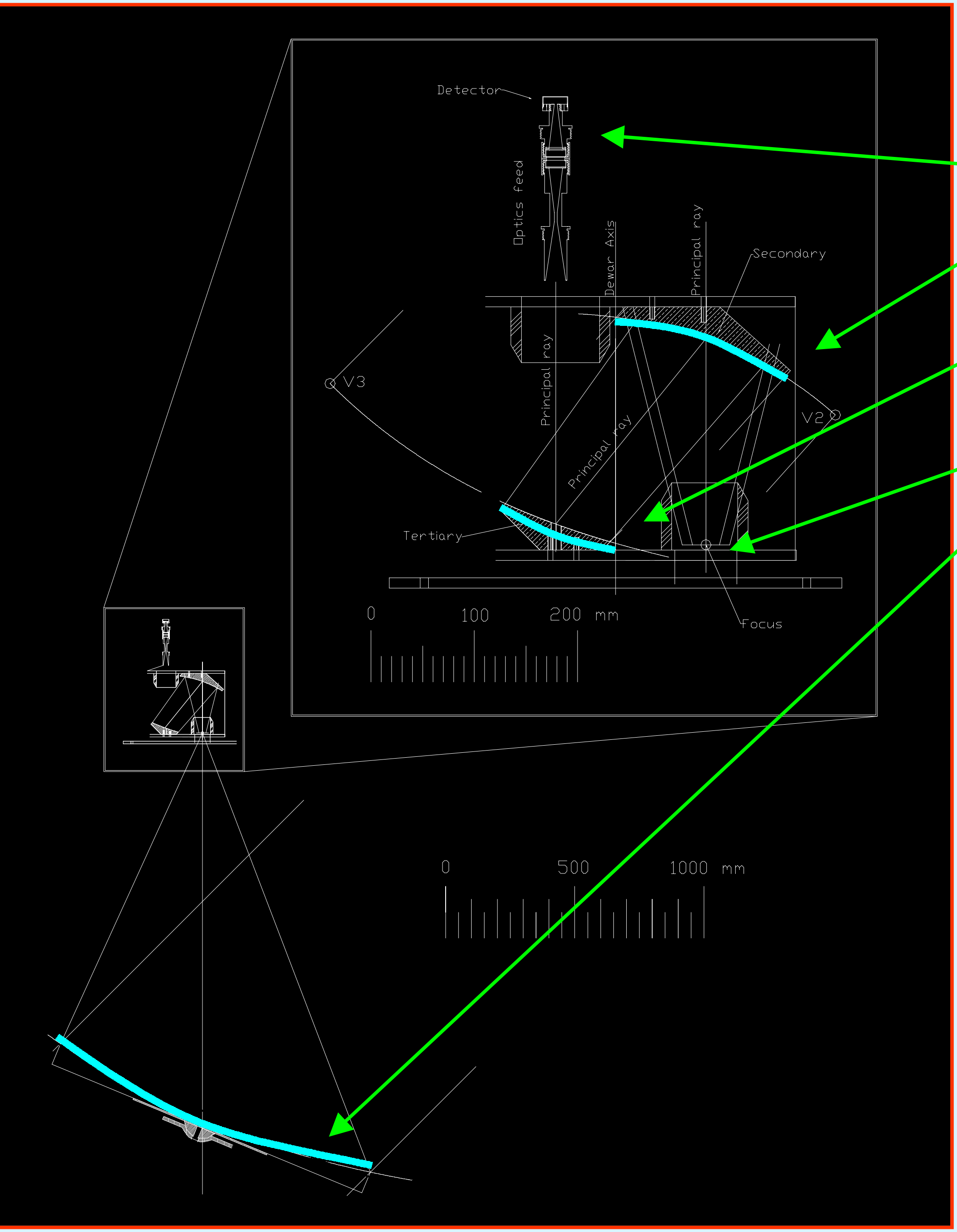
Holding time: 14 days

BOOMERANG Cryostat



S. Masi et al. **Cryogenics**, 39, 217-224, 1999

Optics



Photometers (280 mK)

Secondary mirror (1.6K) ellipsoidal

Tertiary mirror - Lyot stop (1.6K) ellips.

Polyethylene window (50µm thick)

Primary mirror: 1.3 m off-axis
50% underfilled

Resolution: 10 arcmin

AND

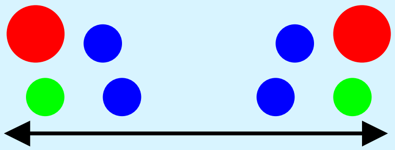
Filters rejecting high frequencies radiation on the 77K and 1.6K (metal mesh + Yoshinaga)
Calibrator in the center of the tertiary mirror
Throughput 0.1-0.05 cm^2/sr
Correct Focal Plane Field ~5 deg x ~3 deg

S. Masi et al. **Cryogenics**, 38, 319-324, 1998

BOOMERANG systematics control

Pixel disposition in the Focal Plane + sky rotation

Allows cross checking, in time ordered data, maps, angular power spectrum



16 detectors total

Long Duration — Allows jack-knife tests (1st half 2nd half 1dps 2dps)

Multiband Observations — Control foregrounds: galactic dust, free-free, synchrotron, atmosphere

2 Modes Observations — Control 1/f noise and Scan Synchronous Noise

Contaminants Modulation: Rotation around the Sun (10 days => 10 degrees)
Rotation around the Earth (full rotation)

Data analysis:

1) **Raw** data **->** **T**ime **O**rdered **D**ata

RAW

Despiking - cleaning

Time constants deconvolution

Calibration

Pointing reconstruction

TOD

new!

Data analysis:

2) **T**ime **O**rdered **D**ata -> **Maps**

Separation of signal and noise needs the inversion of the pixel-pixel correlation matrix: ~100 000 x 100 000 elements matrix for Boomerang

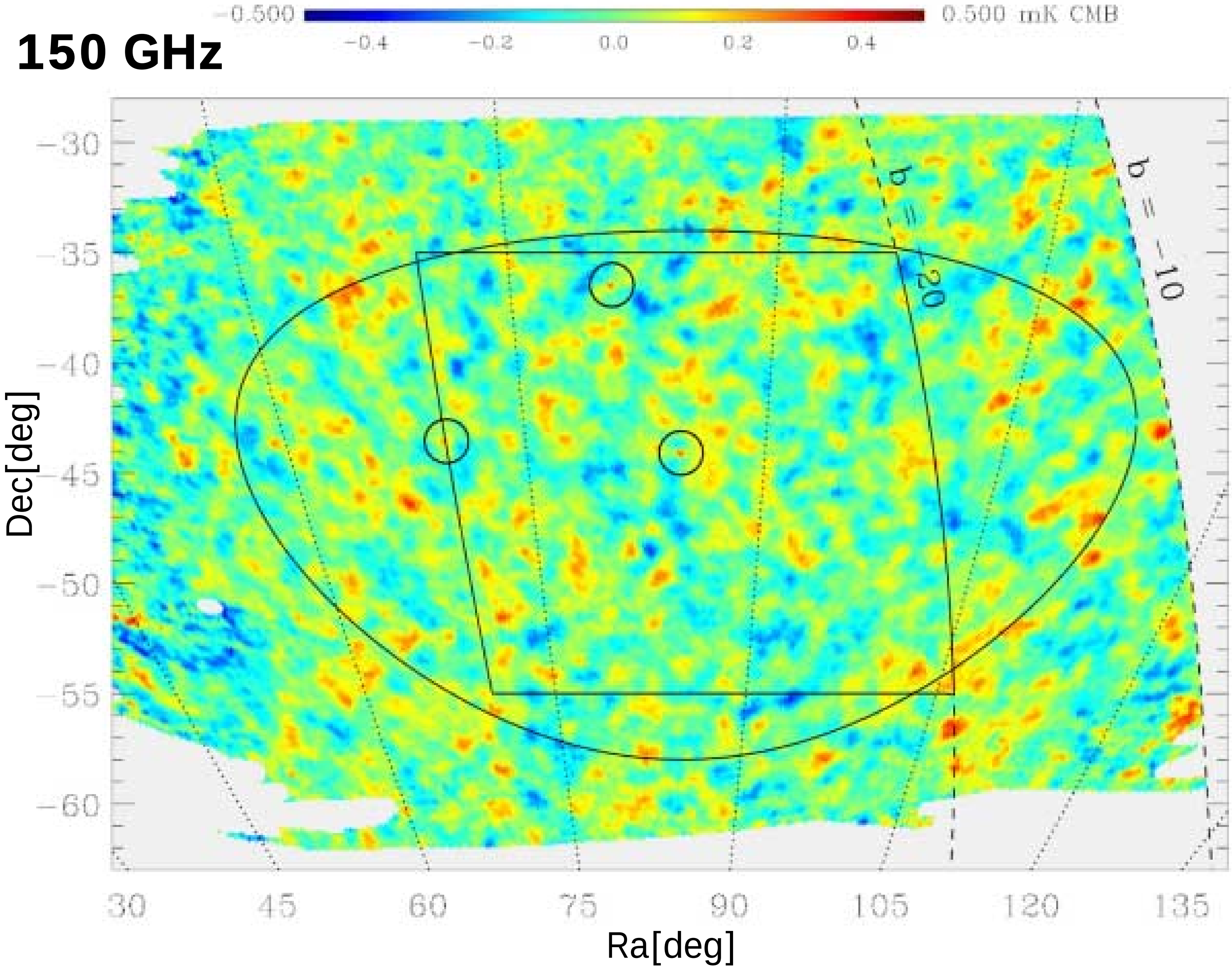
Rigorous approach:
with supercomputers,
slow, allow consistency

Iterative approach:
with standard computers,
fast, allows checks.

Allows combination and destriping controlled by Montecarlo simulations:
simulated sky-signal with measured noise

Last map from BOOMERANG

150 GHz



Data analysis

3) **Maps** **->** **P**ower **S**pectrum

Realized in parallel with map-making, using similar methods

Spherical harmonic transform, controlled by Montecarlo simulations:
-Simulated sky signal with real noise
-Definition of a transfer function
-Transfer function deconvolution
-Beam deconvolution

Systematic Tests using Montecarlo simulations:

•Compared sections of timestream: First Half - Second Half

•Compared scan modes: 1dps - 2dps

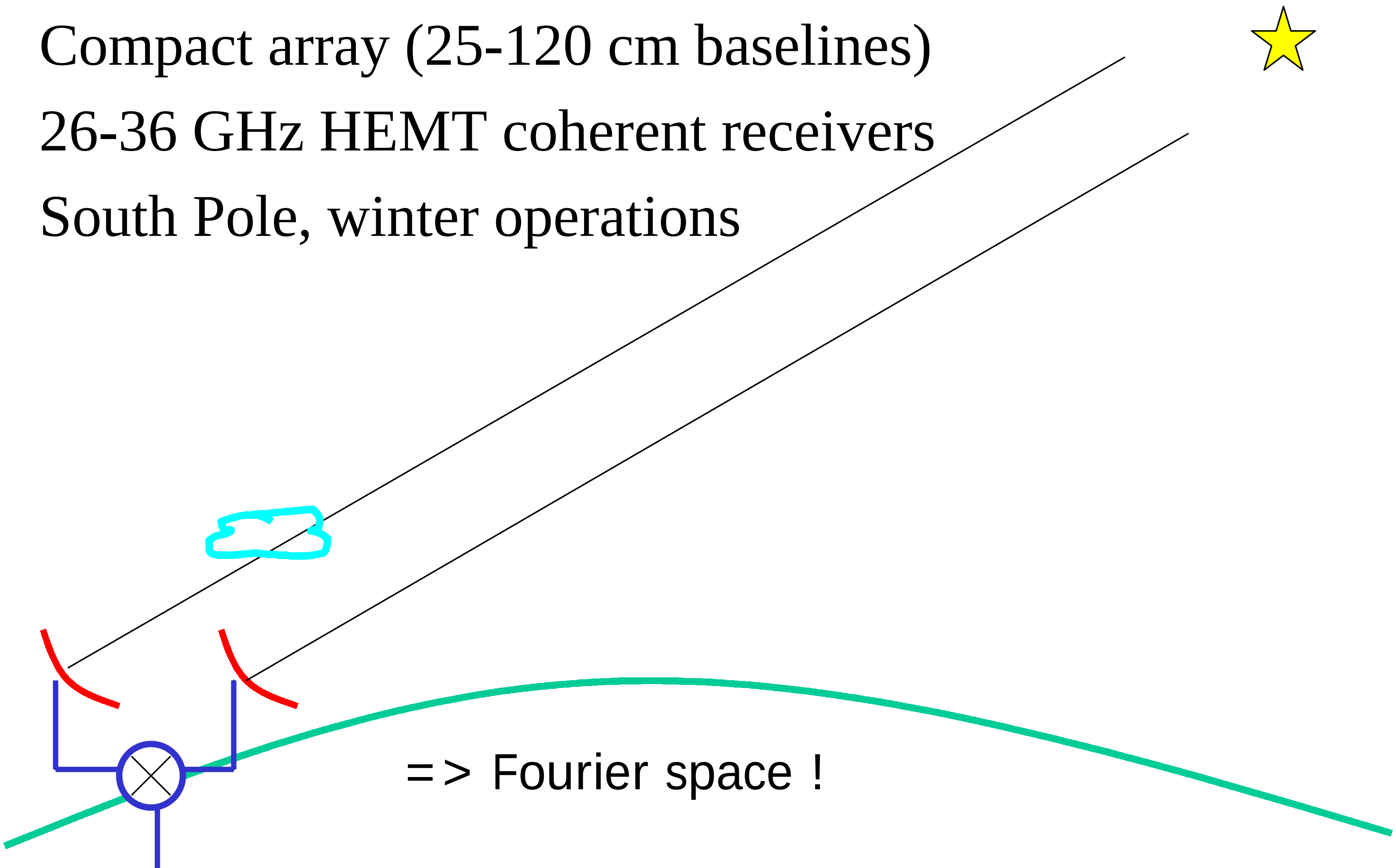
•Compared scan directions: Left_going - Right_going

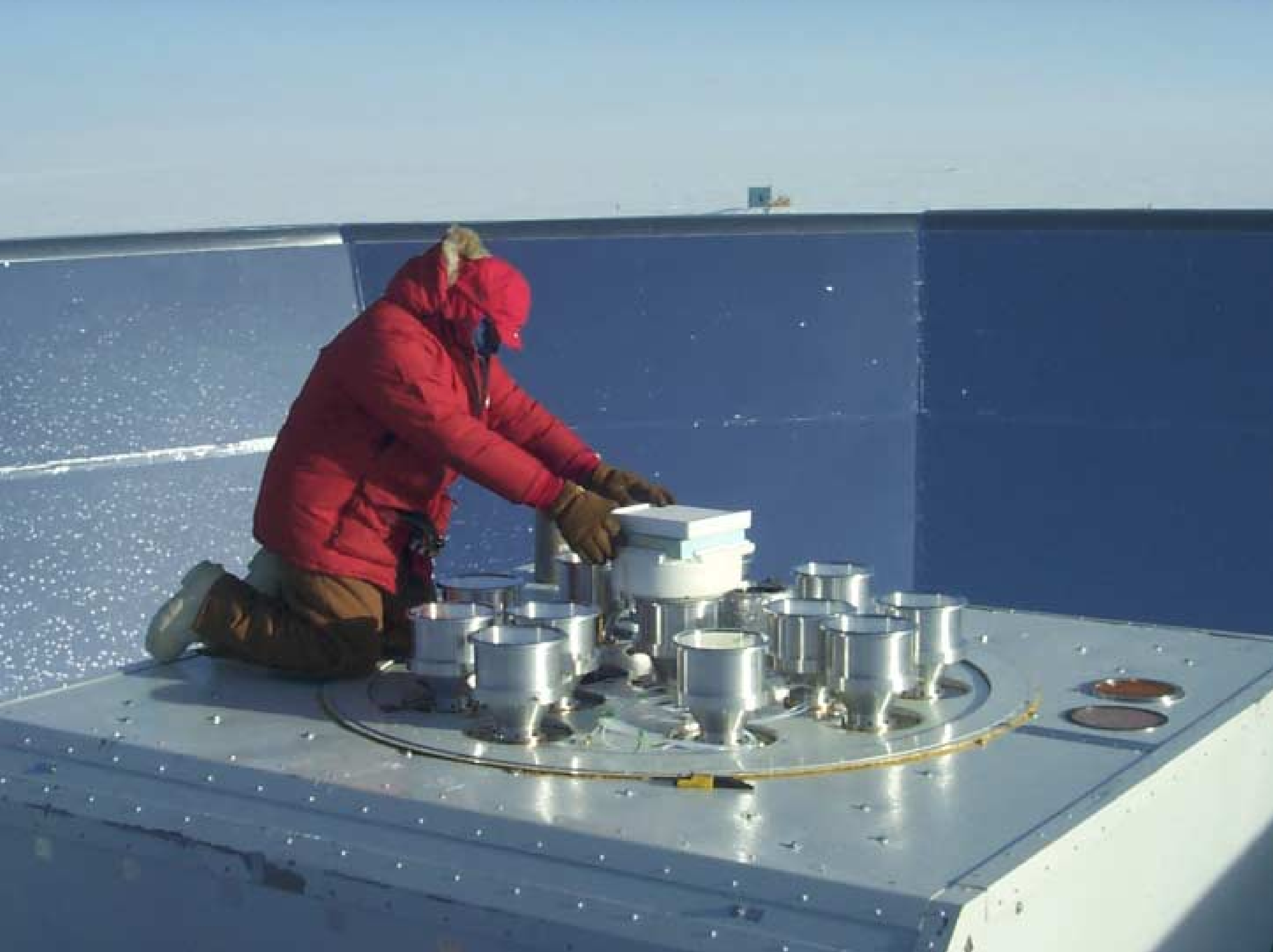
•Compared channels: (A+A1) - (A1+B2)

Result: **PASSED.**

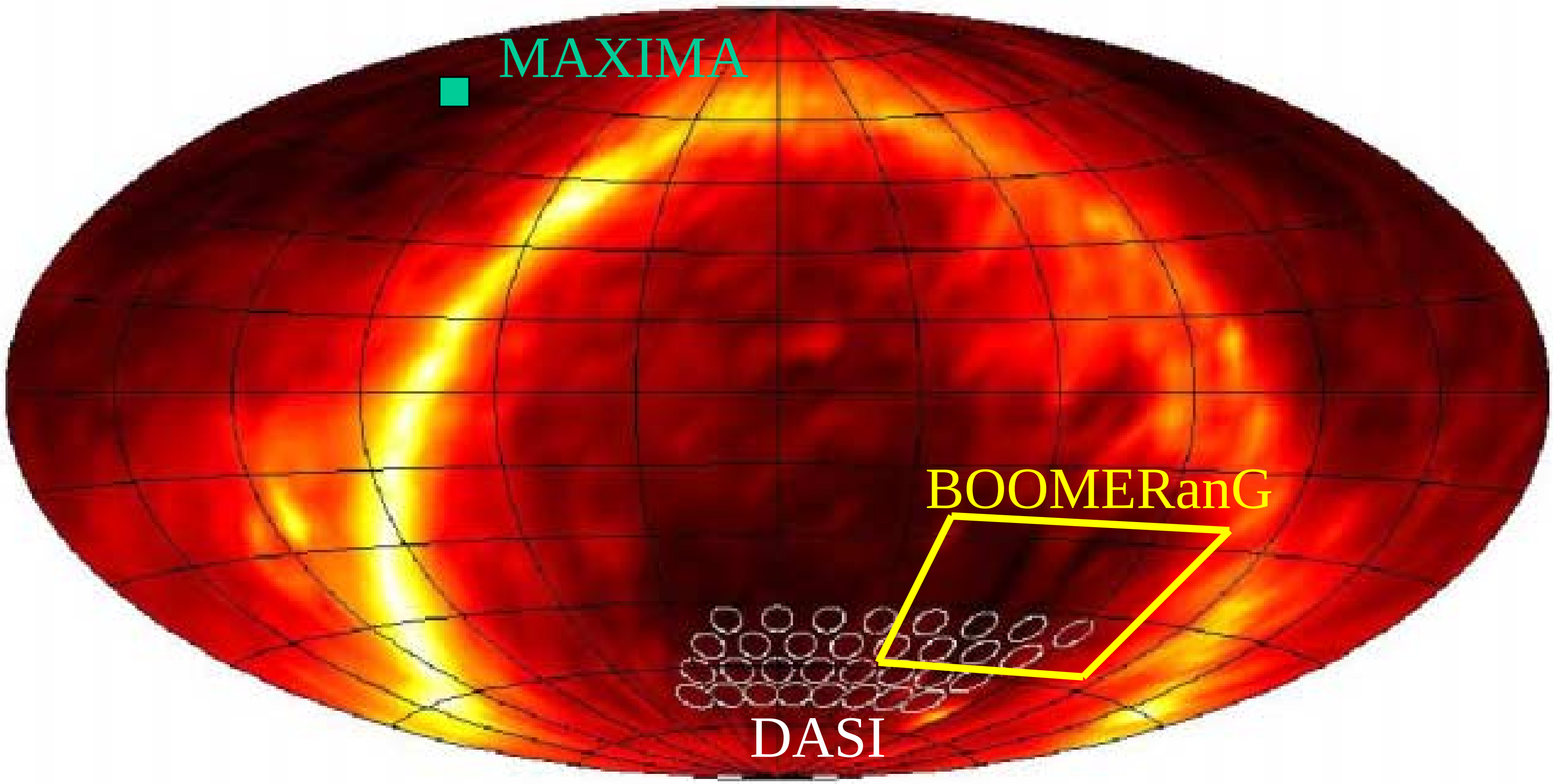
DASI

- **D**egree-**A**ngular-**S**cale-**I**nterferometer.
- Array of 17 small telescopes (3.4^o FWHM fields)
- Compact array (25-120 cm baselines)
- 26-36 GHz HEMT coherent receivers
- South Pole, winter operations

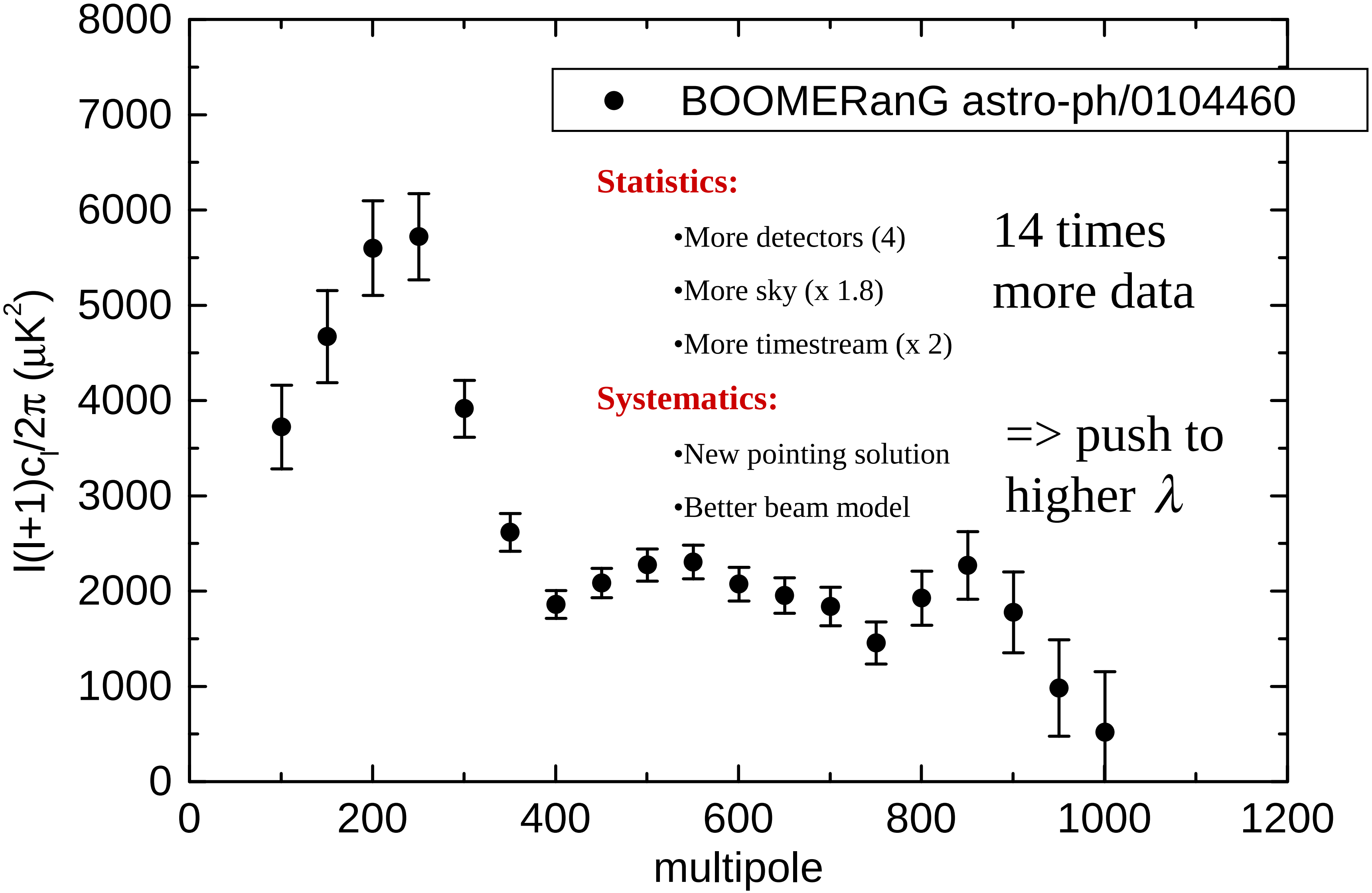




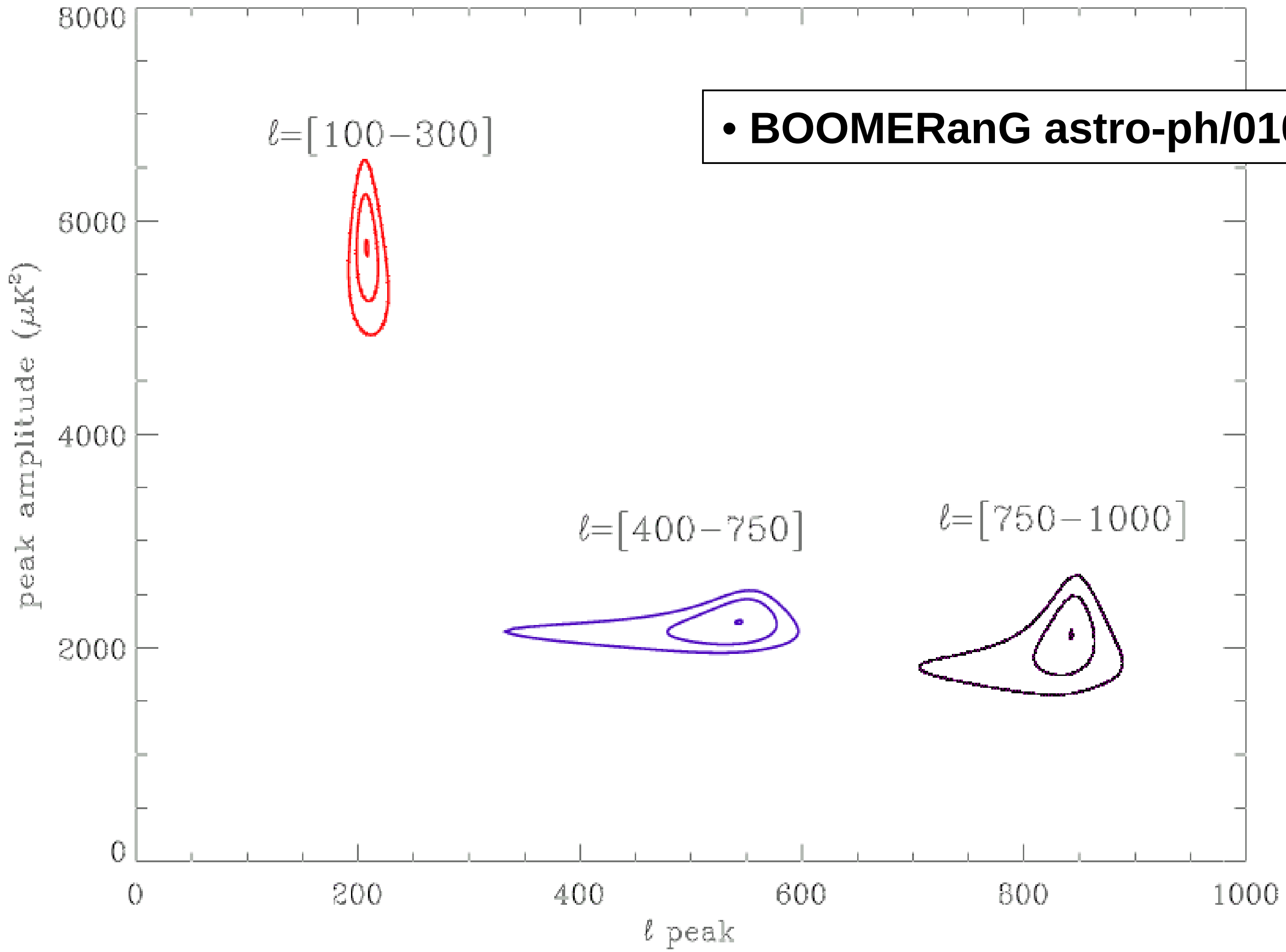
Partial Overlap in sky coverage with BOOMERanG



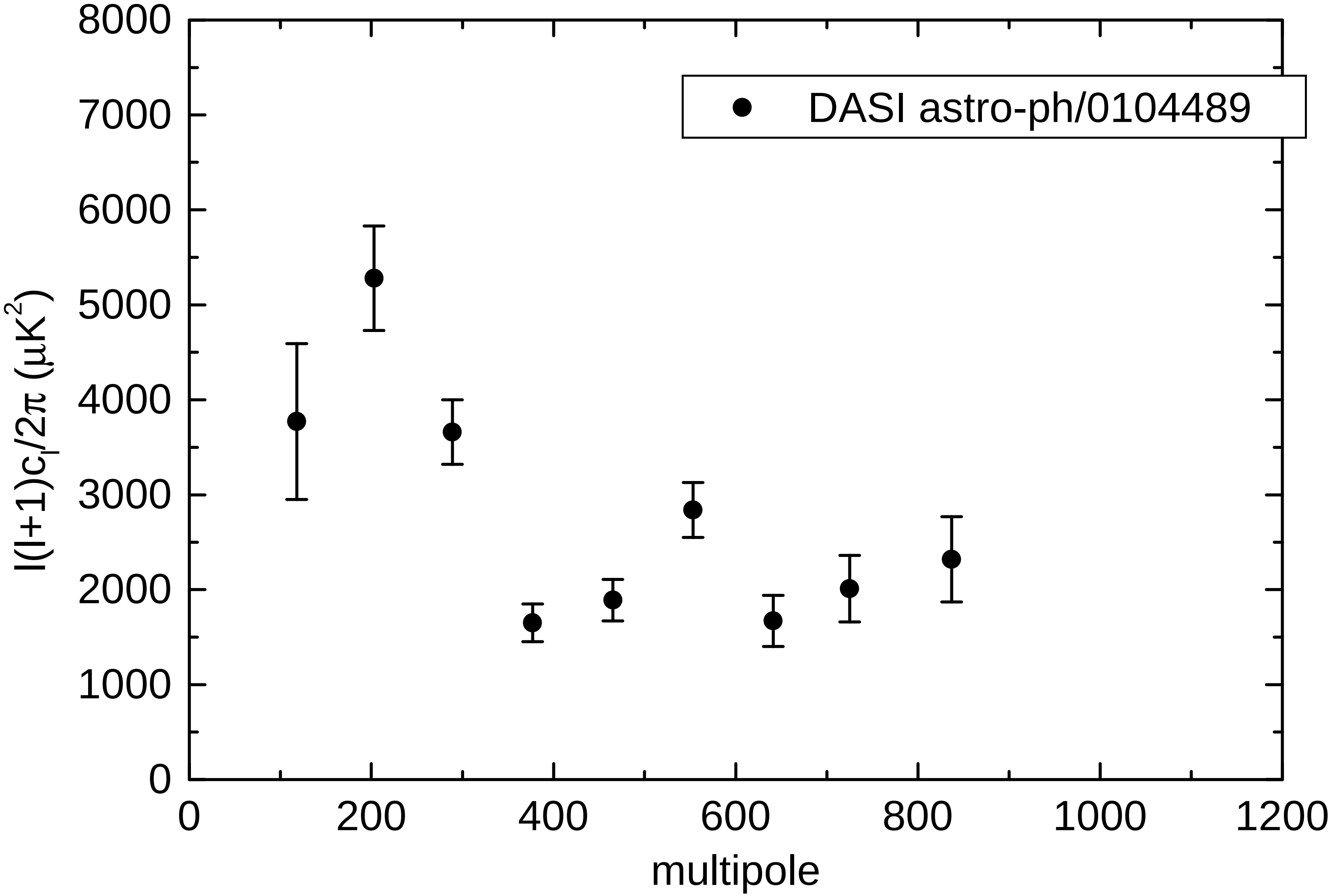
Comparison of overlapping fields: very good (work in progress)



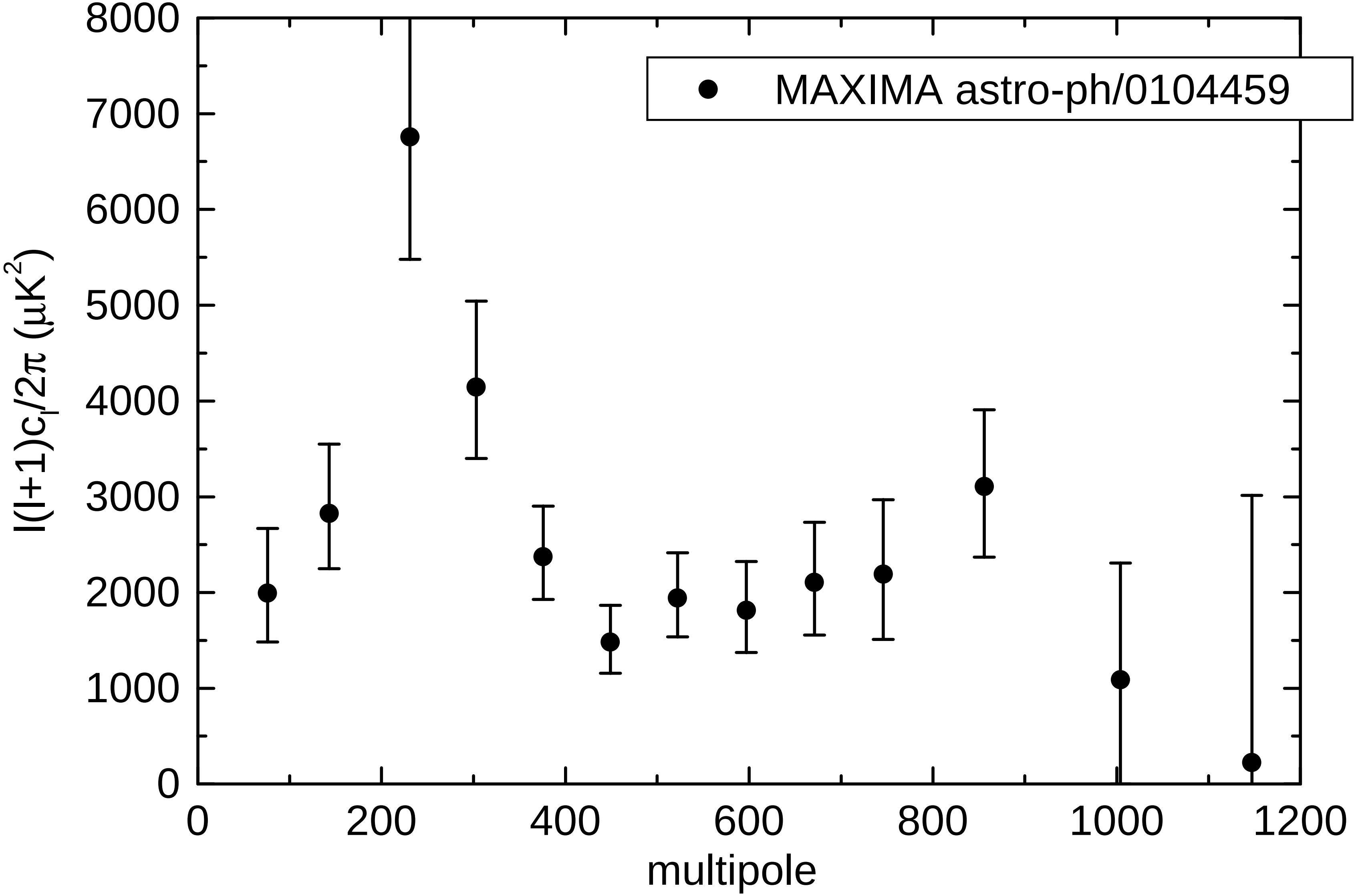
8000
7000
6000
5000
4000
3000
2000
1000
0
0
200
400
600
800
1000
1200
multipole
l(l+1)c_l/2π (μK^2)
BOOMERanG astro-ph/0104460
Statistics:
•More detectors (4)
•More sky (x 1.8)
•More timestream (x 2)
14 times
more data
Systematics:
•New pointing solution
•Better beam model
=> push to
higher λ



• **BOOMERanG astro-ph/0105296**



DASI astro-ph/0104489
l(l+1)c_l/2π (μK²)
multipole
0
1000
2000
3000
4000
5000
6000
7000
8000
0
200
400
600
800
1000
1200



MAXIMA astro-ph/0104459
l(l+1)c_l/2π (μK^2)
multipole
0
1000
2000
3000
4000
5000
6000
7000
8000
0
200
400
600
800
1000
1200

Cosmological interpretation

Model Space:

$\boldsymbol{x} \equiv \Omega_b h^2$
$\boldsymbol{y} \equiv (\Omega_k, \Omega_\Lambda, \Omega_{cdm} h^2, n_s, \tau_c)$
+ calibration and beam uncertainties…

(some "degeneracies"…)

To find the "best" parameter value and error on, eg. $\Omega_b h^2$, calculate:

L(x,y) = "likelihood" of data given model x,y; goes as $\exp(-\chi^2)$
P(y) = "prior probability", eg set = 0 for age < 10 Gyr, etc
for *all* the parameter combinations...

and integrate over all values of other parameters…

$$L(\Omega_b h^2 = \boldsymbol{x}) = \int P(\boldsymbol{y})\, L(\boldsymbol{y},\boldsymbol{x})\, d\boldsymbol{x}\, d\boldsymbol{y}$$

Cosmology

TABLE 4

RESULTS OF PARAMETER EXTRACTION

Priors	Ω_{tot}	n_s	$\Omega_b h^2$	$\Omega_{cdm} h^2$	Ω_Λ	Ω_m	Ω_b	τ_c	h	Age
Weak only	$1.03^{0.06}_{0.06}$	$0.93^{0.10}_{0.08}$	$0.021^{0.004}_{0.003}$	$0.12^{0.05}_{0.05}$	$(0.52^{0.24}_{0.19})$	$(0.50^{0.20}_{0.20})$	$0.07^{0.03}_{0.03}$	$0.10^{0.16}_{0.08}$	$(0.56^{0.11}_{0.11})$	$15.4^{2.1}_{2.1}$
LSS	$1.03^{0.05}_{0.05}$	$0.95^{0.09}_{0.07}$	$0.022^{0.004}_{0.003}$	$0.13^{0.03}_{0.02}$	$0.54^{0.09}_{0.09}$	$0.50^{0.11}_{0.11}$	$0.07^{0.02}_{0.02}$	$0.09^{0.13}_{0.07}$	$0.55^{0.09}_{0.09}$	$15.1^{1.3}_{1.3}$
SN1a	$1.02^{0.07}_{0.05}$	$0.96^{0.10}_{0.09}$	$0.023^{0.004}_{0.004}$	$0.09^{0.04}_{0.03}$	$0.74^{0.07}_{0.11}$	$0.31^{0.06}_{0.06}$	$0.06^{0.03}_{0.02}$	$0.12^{0.19}_{0.09}$	$0.60^{0.09}_{0.09}$	$16.2^{2.5}_{2.5}$
LSS & SN1a	$0.99^{0.03}_{0.04}$	$1.00^{0.09}_{0.08}$	$0.023^{0.003}_{0.003}$	$0.14^{0.03}_{0.02}$	$0.65^{0.05}_{0.06}$	$0.35^{0.07}_{0.07}$	$0.05^{0.02}_{0.02}$	$0.11^{0.15}_{0.08}$	$0.67^{0.09}_{0.09}$	$13.7^{1.3}_{1.3}$
$h = 0.71 \pm 0.08$	$0.98^{0.04}_{0.05}$	$0.94^{0.09}_{0.08}$	$0.021^{0.004}_{0.003}$	$0.14^{0.06}_{0.04}$	$0.62^{0.11}_{0.17}$	$0.39^{0.13}_{0.13}$	$0.05^{0.02}_{0.02}$	$0.09^{0.13}_{0.07}$	$(0.65^{0.08}_{0.08})$	$13.8^{1.7}_{1.7}$
Flat	(1.00)	$0.92^{0.08}_{0.08}$	$0.021^{0.003}_{0.003}$	$0.13^{0.04}_{0.04}$	$(0.57^{0.12}_{0.37})$	$(0.47^{0.25}_{0.25})$	$0.06^{0.02}_{0.02}$	$0.08^{0.11}_{0.06}$	$(0.62^{0.13}_{0.13})$	$14.3^{0.6}_{0.6}$
Flat & LSS	(1.00)	$0.96^{0.09}_{0.07}$	$0.021^{0.003}_{0.003}$	$0.13^{0.02}_{0.01}$	$0.62^{0.06}_{0.07}$	$0.38^{0.07}_{0.07}$	$0.05^{0.01}_{0.01}$	$0.10^{0.13}_{0.07}$	$0.62^{0.06}_{0.06}$	$14.4^{0.7}_{0.7}$
Flat & SN1a	(1.00)	$0.94^{0.10}_{0.08}$	$0.022^{0.003}_{0.003}$	$0.12^{0.01}_{0.02}$	$0.68^{0.04}_{0.06}$	$0.33^{0.05}_{0.05}$	$0.05^{0.01}_{0.01}$	$0.08^{0.12}_{0.06}$	$0.66^{0.05}_{0.05}$	$14.0^{0.5}_{0.5}$
Flat, LSS & SN1a	(1.00)	$1.00^{0.09}_{0.08}$	$0.022^{0.003}_{0.003}$	$0.13^{0.01}_{0.01}$	$0.66^{0.04}_{0.06}$	$0.33^{0.05}_{0.05}$	$0.05^{0.01}_{0.01}$	$0.12^{0.15}_{0.08}$	$0.66^{0.05}_{0.05}$	$14.0^{0.6}_{0.6}$

NOTE.—Results of parameter extraction using successively more restrictive priors, following Lange et al. (2001). The confidence intervals re 1σ. The quoted values are reported after marginalizing over all other parameters. For the primary database parameters, 16% and 84% ntegrals are reported as $\pm 1\sigma$ errors. For Ω_m, Ω_b, h, and Age, which are functions of the other parameters, the mean and standard deviation ver the distribution are reported. All entries are subject to a weak prior in which only models with $0.45 < h < 0.90$ and age > 10 Gyr are onsidered. The LSS (Bond & Jaffe 1999) and SN1a supernovae (Riess et al. 1998; Perlmutter et al. 1999) priors are as described in Lange t al. (2001). The strong h prior is a Gaussian with the stated 1σ error. Parentheses are used to indicate parameters that did not shift more han 1-σ or have their errors reduced by a factor of two upon the inclusion of the CMB data, compared with an analysis using the priors only. Thus, in these cases the parameter range reflects the choice of prior, rather than a constraint by the CMB. The age column is in units of Gyr.

Cosmology

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LSS	$1.03^{0.03}_{0.05}$	$0.95^{0.09}_{0.07}$	$0.022^{0.004}_{0.003}$	$0.13^{0.03}_{0.02}$	$0.54^{0.09}_{0.08}$	$0.50^{0.11}_{0.11}$	$0.07^{0.02}_{0.02}$	$0.09^{0.13}_{0.07}$	$0.55^{0.09}_{0.08}$	$15.1^{1.3}_{1.3}$
SN1a	$1.02^{0.07}_{0.05}$	$0.96^{0.10}_{0.08}$	$0.023^{0.004}_{0.004}$	$0.09^{0.04}_{0.03}$	$0.74^{0.07}_{0.11}$	$0.31^{0.06}_{0.06}$	$0.06^{0.03}_{0.03}$	$0.12^{0.19}_{0.09}$	$0.60^{0.09}_{0.08}$	$16.2^{2.5}_{2.5}$
LSS & SN1a	$0.99^{0.03}_{0.04}$	$1.00^{0.09}_{0.08}$	$0.023^{0.003}_{0.003}$	$0.14^{0.03}_{0.02}$	$0.65^{0.05}_{0.06}$	$0.35^{0.07}_{0.07}$	$0.05^{0.02}_{0.02}$	$0.11^{0.15}_{0.08}$	$0.67^{0.09}_{0.09}$	$13.7^{1.3}_{1.3}$
$h = 0.71 \pm 0.08$	$0.98^{0.04}_{0.05}$	$0.94^{0.09}_{0.08}$	$0.021^{0.004}_{0.003}$	$0.14^{0.06}_{0.04}$	$0.62^{0.11}_{0.17}$	$0.39^{0.13}_{0.13}$	$0.05^{0.02}_{0.02}$	$0.09^{0.13}_{0.07}$	$(0.65^{0.08}_{0.08})$	$13.8^{1.7}_{1.7}$
Flat	(1.00)	$0.92^{0.08}_{0.08}$	$0.021^{0.003}_{0.003}$	$0.13^{0.04}_{0.04}$	$(0.57^{0.12}_{0.37})$	$(0.47^{0.25}_{0.25})$	$0.06^{0.02}_{0.02}$	$0.08^{0.11}_{0.06}$	$(0.62^{0.13}_{0.13})$	$14.3^{0.6}_{0.6}$
Flat & LSS	(1.00)	$0.96^{0.09}_{0.07}$	$0.021^{0.003}_{0.003}$	$0.13^{0.02}_{0.01}$	$0.62^{0.06}_{0.07}$	$0.38^{0.07}_{0.07}$	$0.05^{0.01}_{0.01}$	$0.10^{0.13}_{0.07}$	$0.62^{0.06}_{0.06}$	$14.4^{0.7}_{0.7}$
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Cosmology

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Parameters: CMB Alone (BOOMERanG + COBE)

- Adiabatic initial perturbations:
  Multiple peaks in the spectrum

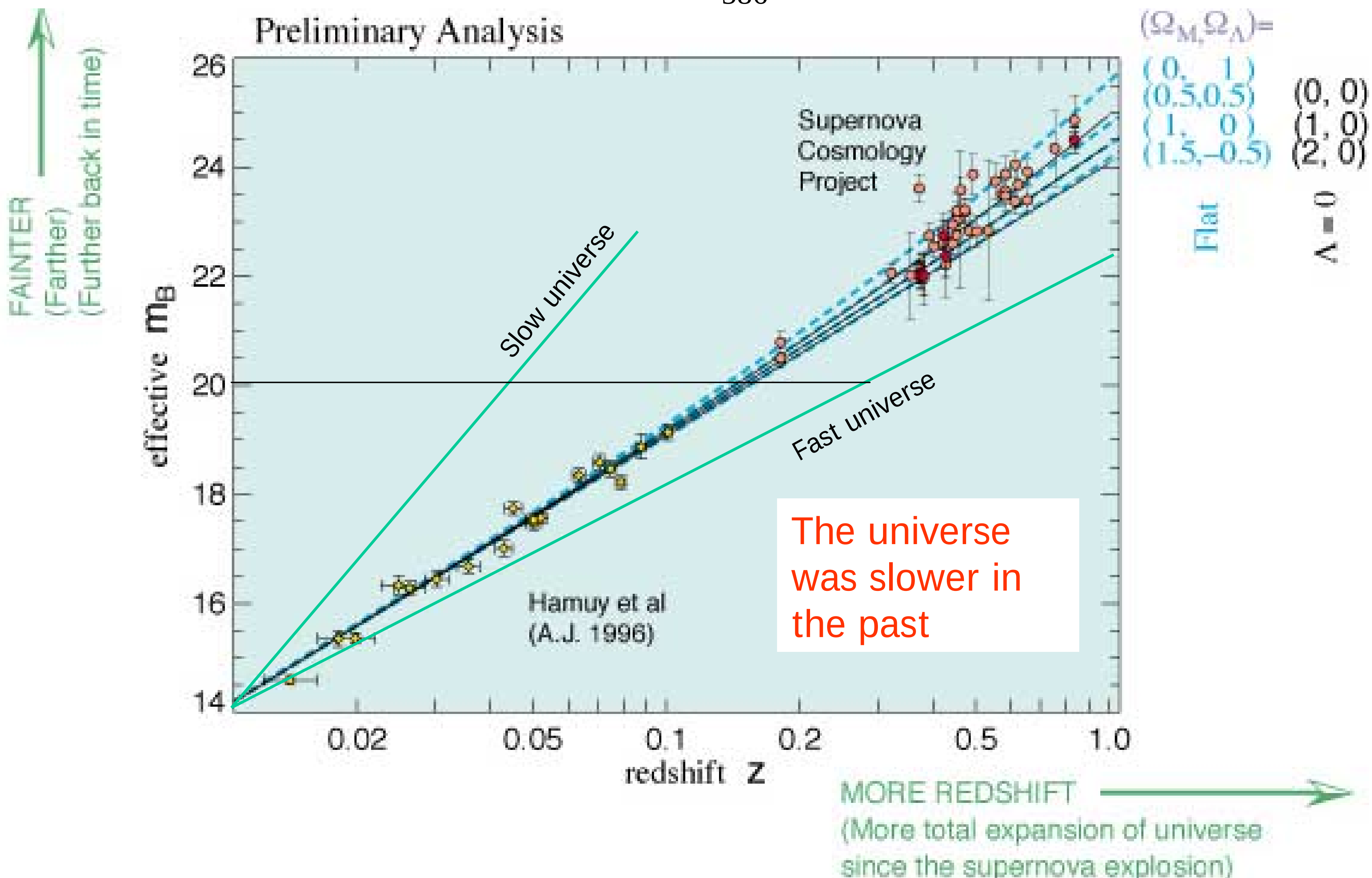
- The Universe is globally Flat:
  Ω_{tot} = 1.03 +- 0.06

- The initial power spectrum of the Universe was scale invariant:
  n_s = 0.93 +-0.09

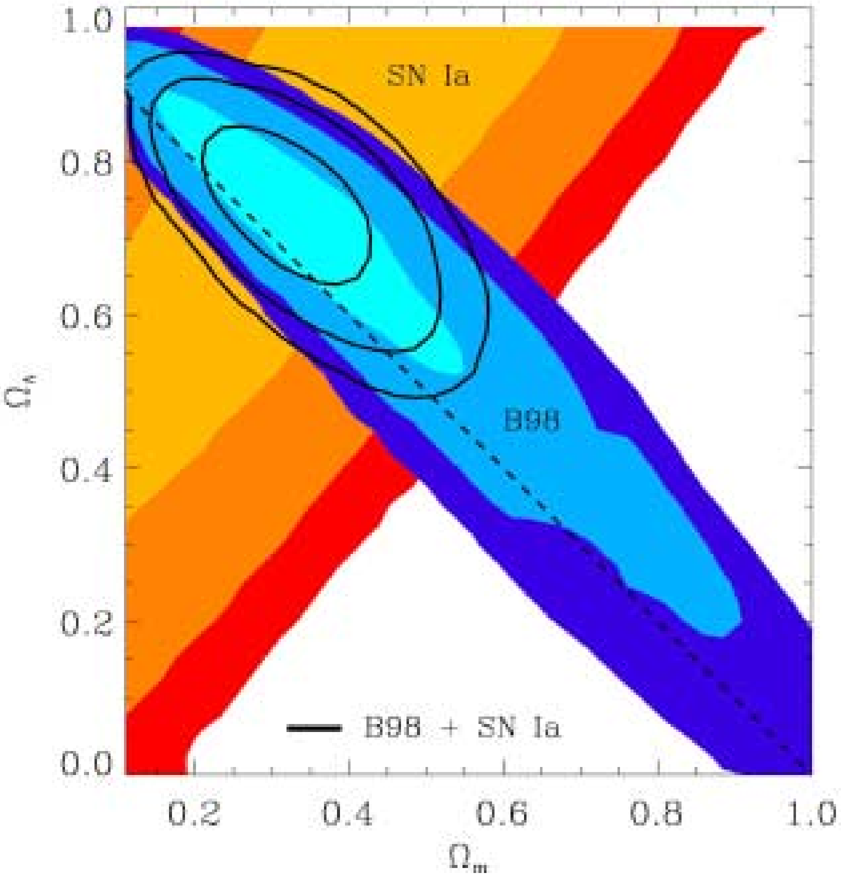
- We know the Baryon Density of the Universe:
  $\Omega_b h^2$ = 0.021+-0.003
  (discrepacy vs Light Element BBN solved)

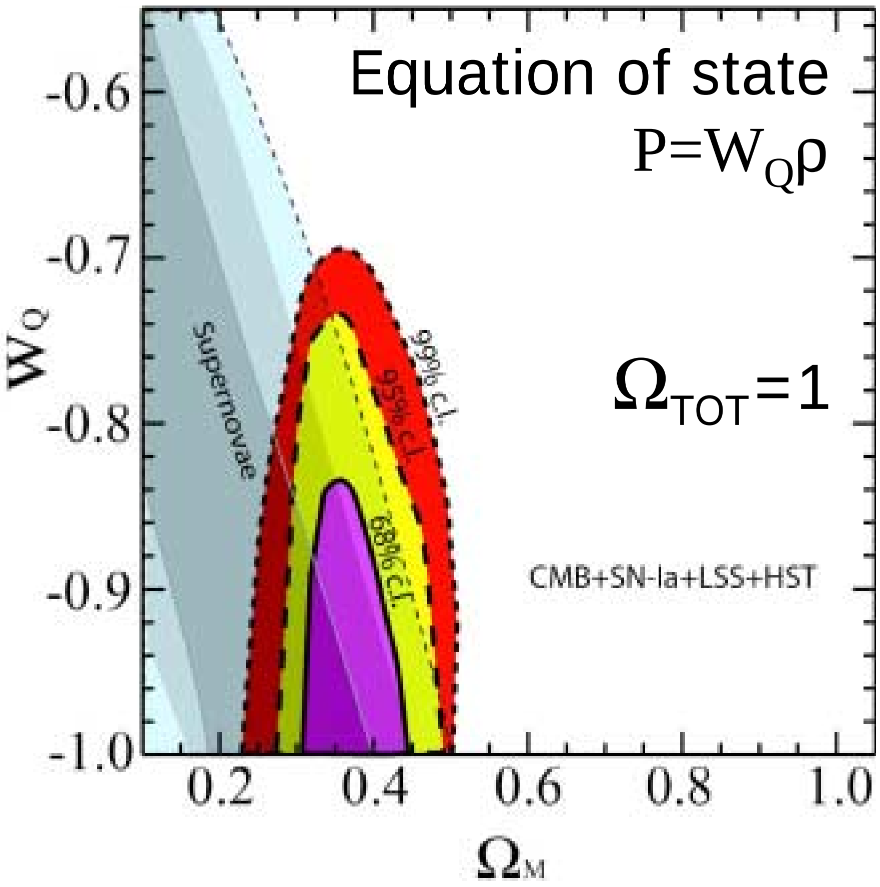
Type Ia Supernovae

S. Perlmutter *et al*. Astrophys.J. 517 (1999) 565-586



Contour plots





R. Bean, A. Melchiorri, 2002

Cosmological constant

Λ **=>** **W**= **-1**

Quintessence **=>** $\mathbf{W_Q}$>**-1**, evolves

Cosmology

With supernovae

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Flat & LSS	(1.00)	$0.96^{0.09}_{0.07}$	$0.021^{0.003}_{0.003}$	$0.13^{0.02}_{0.01}$	$0.62^{0.08}_{0.07}$	$0.38^{0.07}_{0.07}$	$0.05^{0.01}_{0.01}$	$0.10^{0.13}_{0.07}$	$0.62^{0.06}_{0.06}$	$14.4^{0.7}_{0.7}$
Flat & SN1a	(1.00)	$0.94^{0.10}_{0.08}$	$0.022^{0.003}_{0.003}$	$0.12^{0.01}_{0.02}$	$0.68^{0.04}_{0.06}$	$0.33^{0.05}_{0.05}$	$0.05^{0.01}_{0.01}$	$0.08^{0.12}_{0.06}$	$0.66^{0.05}_{0.05}$	$14.0^{0.5}_{0.5}$
Flat, LSS & SN1a	(1.00)	$1.00^{0.09}_{0.08}$	$0.022^{0.003}_{0.003}$	$0.13^{0.01}_{0.01}$	$0.66^{0.04}_{0.06}$	$0.33^{0.05}_{0.05}$	$0.05^{0.01}_{0.01}$	$0.12^{0.15}_{0.08}$	$0.66^{0.05}_{0.05}$	$14.0^{0.6}_{0.6}$

NOTE.—Results of parameter extraction using successively more restrictive priors, following Lange et al. (2001). The confidence intervals are 1σ. The quoted values are reported after marginalizing over all other parameters. For the primary database parameters, 16% and 84% integrals are reported as $\pm 1\sigma$ errors. For Ω_m, Ω_b, h, and Age, which are functions of the other parameters, the mean and standard deviation over the distribution are reported. All entries are subject to a weak prior in which only models with $0.45 < h < 0.90$ and age > 10 Gyr are considered. The LSS (Bond & Jaffe 1999) and SN1a supernovae (Riess et al. 1998; Perlmutter et al. 1999) priors are as described in Lange et al. (2001). The strong h prior is a Gaussian with the stated 1σ error. Parentheses are used to indicate parameters that did not shift more than $1\text{-}\sigma$ or have their errors reduced by a factor of two upon the inclusion of the CMB data, compared with an analysis using the priors only. Thus, in these cases the parameter range reflects the choice of prior, rather than a constraint by the CMB. The age column is in units of Gyr.

Cosmology

Other constraints:

h = 0.71 +- 0.08

σ_8 & Γ

TABLE 4

RESULTS OF PARAMETER EXTRACTION

Priors	Ω_{tot}	n_s	$\Omega_b h^2$	$\Omega_{cdm} h^2$	Ω_Λ	Ω_m	Ω_b	τ_c	h	Age
Weak only	$1.03^{0.06}_{0.06}$	$0.93^{0.10}_{0.08}$	$0.021^{0.004}_{0.003}$	$0.12^{0.05}_{0.05}$	$(0.52^{0.24}_{0.10})$	$(0.50^{0.20}_{0.20})$	$0.07^{0.03}_{0.03}$	$0.10^{0.16}_{0.08}$	$(0.56^{0.11}_{0.11})$	$15.4^{2.1}_{2.1}$
LSS	$1.03^{0.03}_{0.05}$	$0.95^{0.09}_{0.07}$	$0.022^{0.004}_{0.003}$	$0.13^{0.03}_{0.02}$	$0.54^{0.09}_{0.08}$	$0.50^{0.11}_{0.11}$	$0.07^{0.02}_{0.02}$	$0.09^{0.13}_{0.07}$	$0.55^{0.09}_{0.08}$	$15.1^{1.3}_{1.3}$
SN1a	$1.02^{0.07}_{0.05}$	$0.96^{0.10}_{0.09}$	$0.023^{0.004}_{0.004}$	$0.09^{0.04}_{0.03}$	$0.74^{0.07}_{0.11}$	$0.31^{0.06}_{0.06}$	$0.06^{0.03}_{0.03}$	$0.12^{0.19}_{0.09}$	$0.60^{0.09}_{0.08}$	$16.2^{2.5}_{2.5}$
LSS & SN1a	$0.99^{0.03}_{0.04}$	$1.00^{0.09}_{0.08}$	$0.023^{0.003}_{0.003}$	$0.14^{0.03}_{0.02}$	$0.65^{0.05}_{0.06}$	$0.35^{0.07}_{0.07}$	$0.05^{0.02}_{0.02}$	$0.11^{0.15}_{0.08}$	$0.67^{0.09}_{0.09}$	$13.7^{1.3}_{1.3}$
$h = 0.71 \pm 0.08$	$0.98^{0.04}_{0.05}$	$0.94^{0.09}_{0.08}$	$0.021^{0.004}_{0.003}$	$0.14^{0.06}_{0.04}$	$0.62^{0.11}_{0.17}$	$0.39^{0.13}_{0.13}$	$0.05^{0.02}_{0.02}$	$0.09^{0.13}_{0.07}$	$(0.65^{0.08}_{0.08})$	$13.8^{1.7}_{1.7}$
Flat	(1.00)	$0.92^{0.08}_{0.08}$	$0.021^{0.003}_{0.003}$	$0.13^{0.04}_{0.04}$	$(0.57^{0.12}_{0.37})$	$(0.47^{0.25}_{0.25})$	$0.06^{0.02}_{0.02}$	$0.08^{0.11}_{0.06}$	$(0.62^{0.13}_{0.13})$	$14.3^{0.6}_{0.6}$
Flat & LSS	(1.00)	$0.96^{0.09}_{0.07}$	$0.021^{0.003}_{0.003}$	$0.13^{0.02}_{0.01}$	$0.62^{0.08}_{0.07}$	$0.38^{0.07}_{0.07}$	$0.05^{0.01}_{0.01}$	$0.10^{0.13}_{0.07}$	$0.62^{0.06}_{0.06}$	$14.4^{0.7}_{0.7}$
Flat & SN1a	(1.00)	$0.94^{0.10}_{0.08}$	$0.022^{0.003}_{0.003}$	$0.12^{0.01}_{0.02}$	$0.68^{0.04}_{0.06}$	$0.33^{0.05}_{0.05}$	$0.05^{0.01}_{0.01}$	$0.08^{0.12}_{0.06}$	$0.66^{0.05}_{0.05}$	$14.0^{0.5}_{0.5}$
Flat, LSS & SN1a	(1.00)	$1.00^{0.09}_{0.08}$	$0.022^{0.003}_{0.003}$	$0.13^{0.01}_{0.01}$	$0.66^{0.04}_{0.06}$	$0.33^{0.05}_{0.05}$	$0.05^{0.01}_{0.01}$	$0.12^{0.15}_{0.08}$	$0.66^{0.05}_{0.05}$	$14.0^{0.6}_{0.6}$

NOTE.—Results of parameter extraction using successively more restrictive priors, following Lange et al. (2001). The confidence intervals are 1σ. The quoted values are reported after marginalizing over all other parameters. For the primary database parameters, 16% and 84% integrals are reported as $\pm 1\sigma$ errors. For Ω_m, Ω_b, h, and Age, which are functions of the other parameters, the mean and standard deviation over the distribution are reported. All entries are subject to a weak prior in which only models with $0.45 < h < 0.90$ and age > 10 Gyr are considered. The LSS (Bond & Jaffe 1999) and SN1a supernovae (Riess et al. 1998; Perlmutter et al. 1999) priors are as described in Lange et al. (2001). The strong h prior is a Gaussian with the stated 1σ error. Parentheses are used to indicate parameters that did not shift more than 1-σ or have their errors reduced by a factor of two upon the inclusion of the CMB data, compared with an analysis using the priors only. Thus, in these cases the parameter range reflects the choice of prior, rather than a constraint by the CMB. The age column is in units of Gyr.

Concordance cosmology

(CMB + LSS + Type 1a Supernovae)

$\Omega_{tot} = 0.99 \pm 0.03$

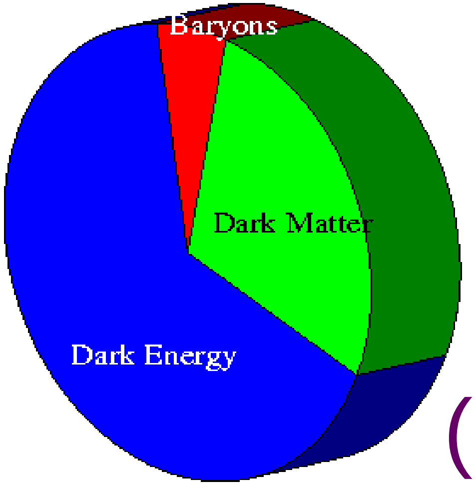
$n_s = 1.00 \pm 0.08$

} Inflation (!) (?)

$\Omega_b h^2 = 0.021 \pm 0.003$

$\Omega_{cdm} h^2 = 0.14 \pm 0.02$

$\Omega_\Lambda = 0.65 \pm 0.05$



(?)

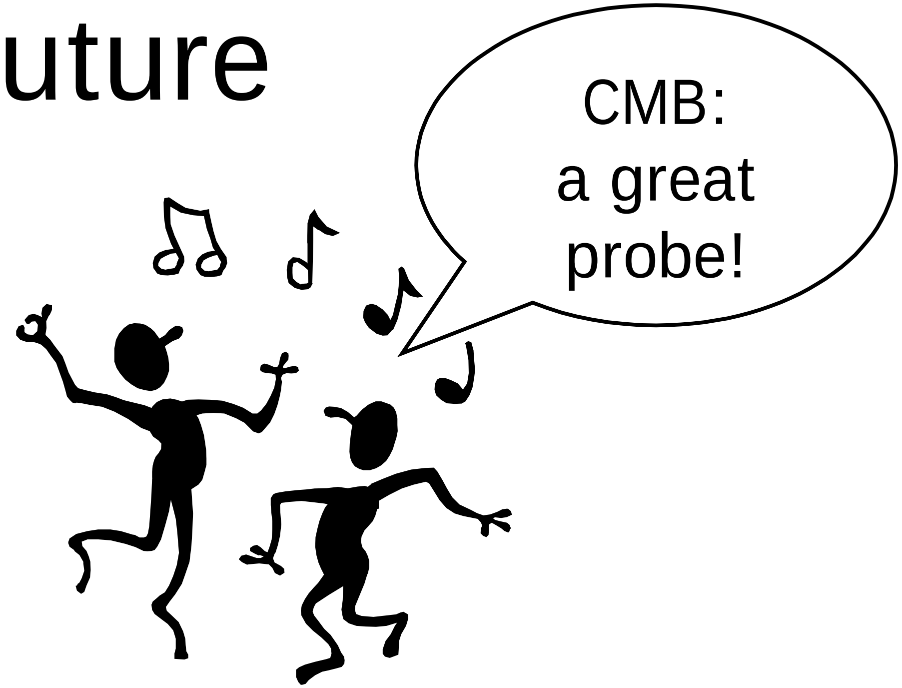
$h = 0.67 \pm 0.09$

Age: 13.7 ± 1.3 GYr

} OK !

The future

Soon: CBI results
Next: MAP results
And: Polarization of the CMB



But still....