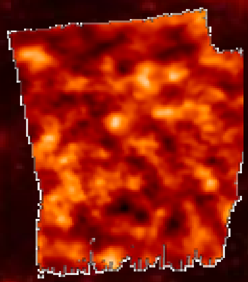
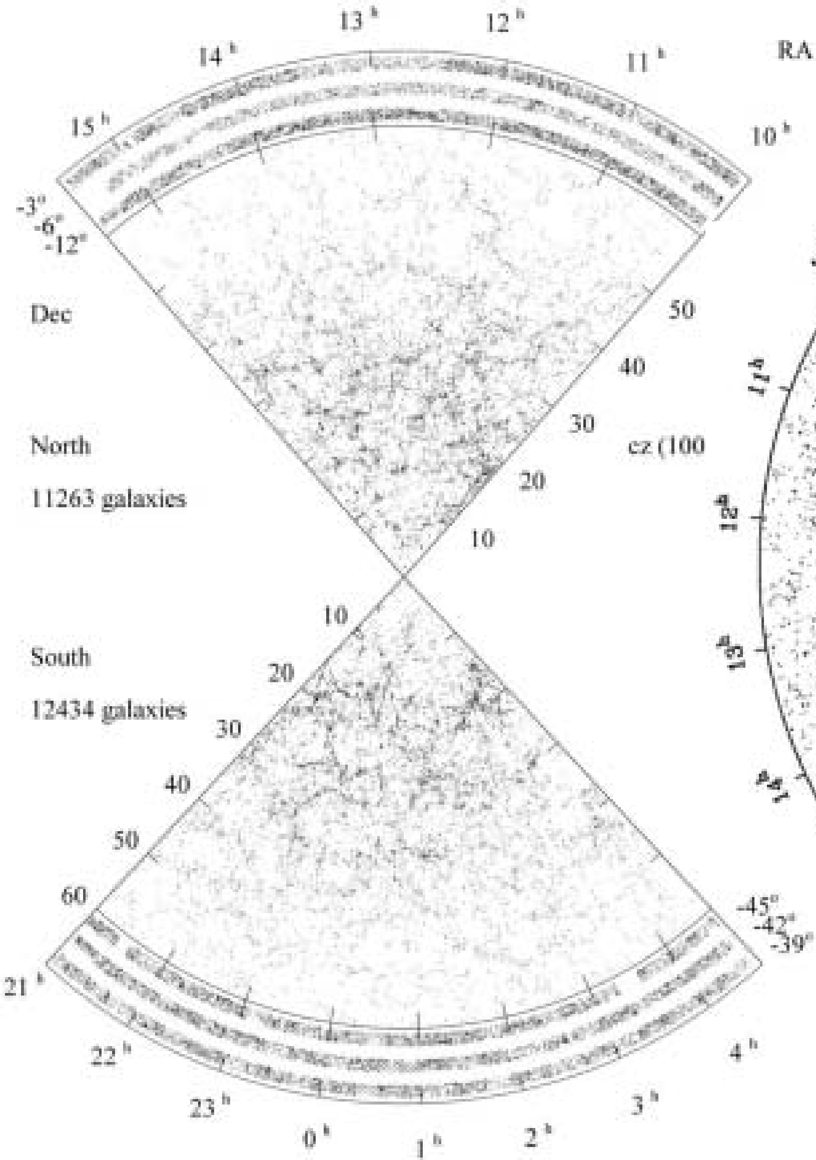
STRUCTURES COSMIQUES, CONDITIONS INITIALES, PARAMETRES & ANISOTROPIES DU RCF



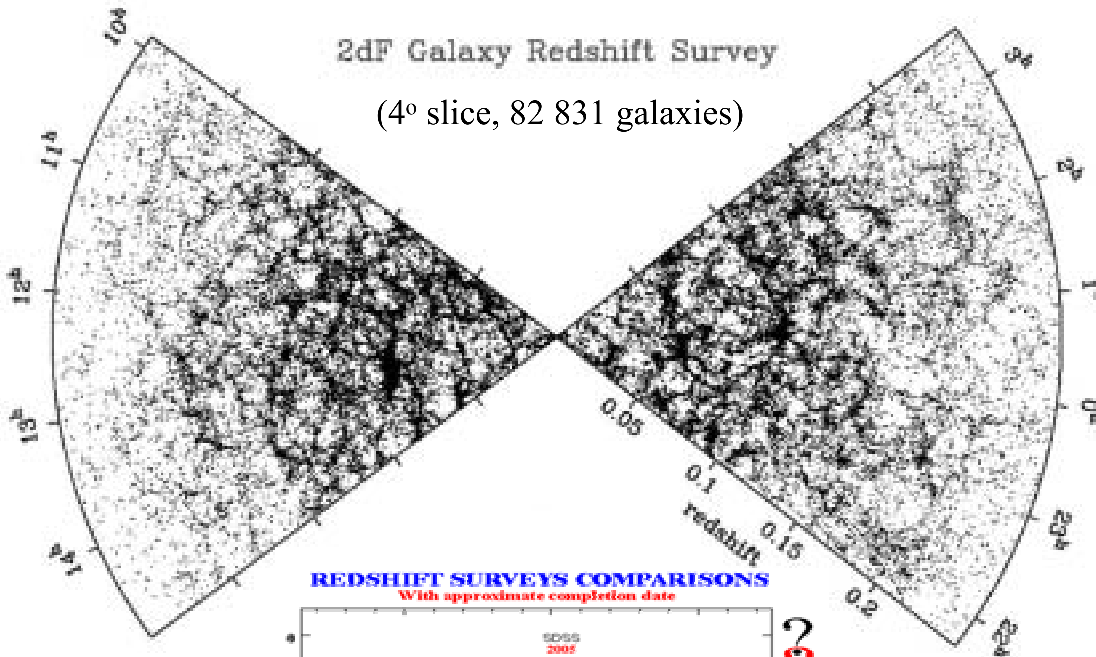
VI ECOLE DE COSMOLOGIE, MARSEILLE, SEPTEMBRE 2002

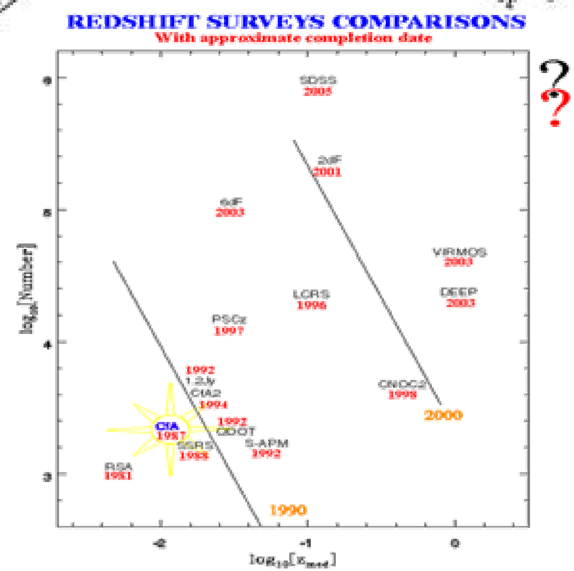
F.R. BOUCHET
INSTITUT D'ASTROPHYSIQUE DE PARIS, CNRS

MAPPING THE 3D STRUCTURES OF THE (LOCAL) UNIVERSE

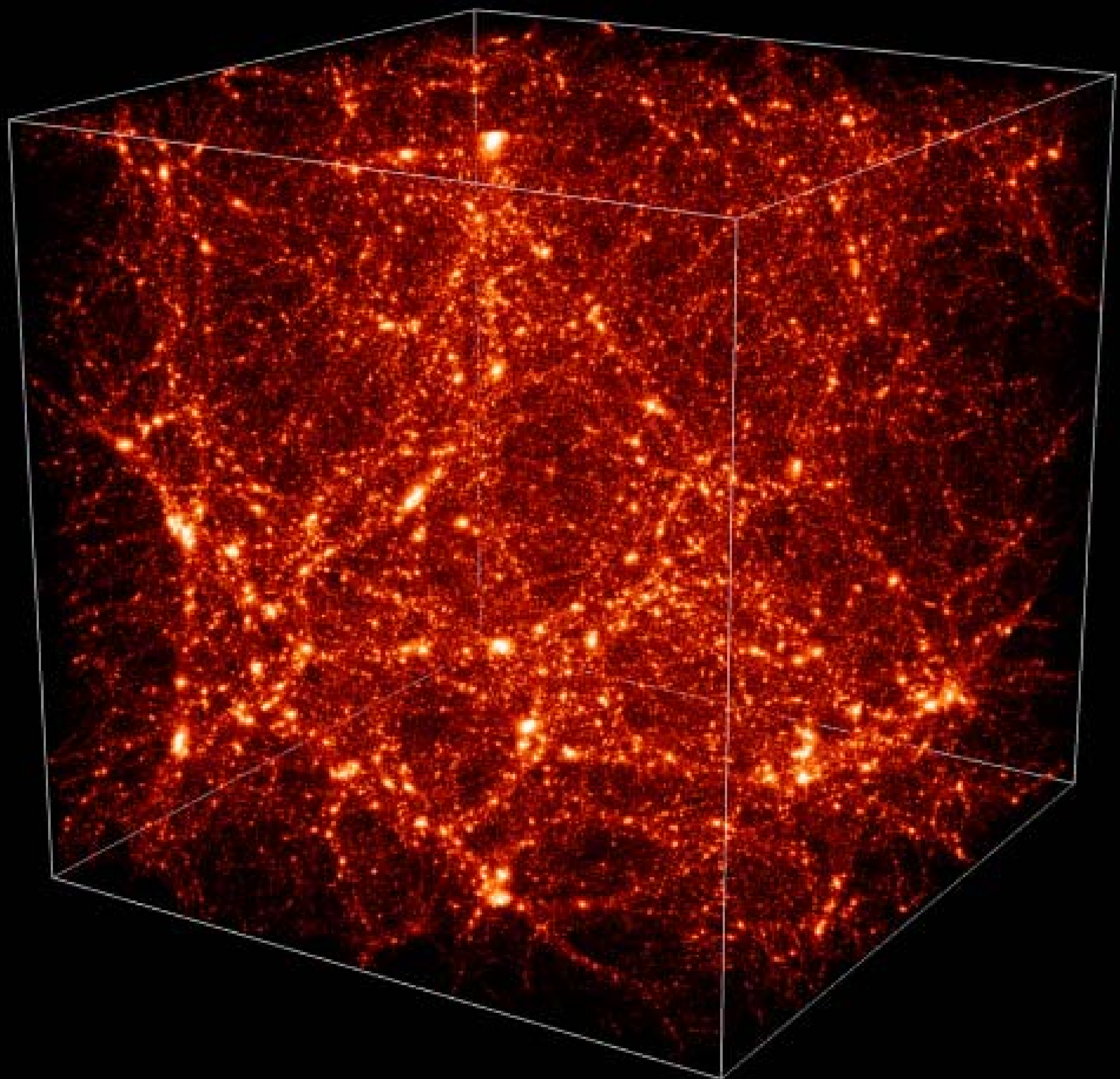


Las Campanas Redshift Survey (LCRS, 3 slices)



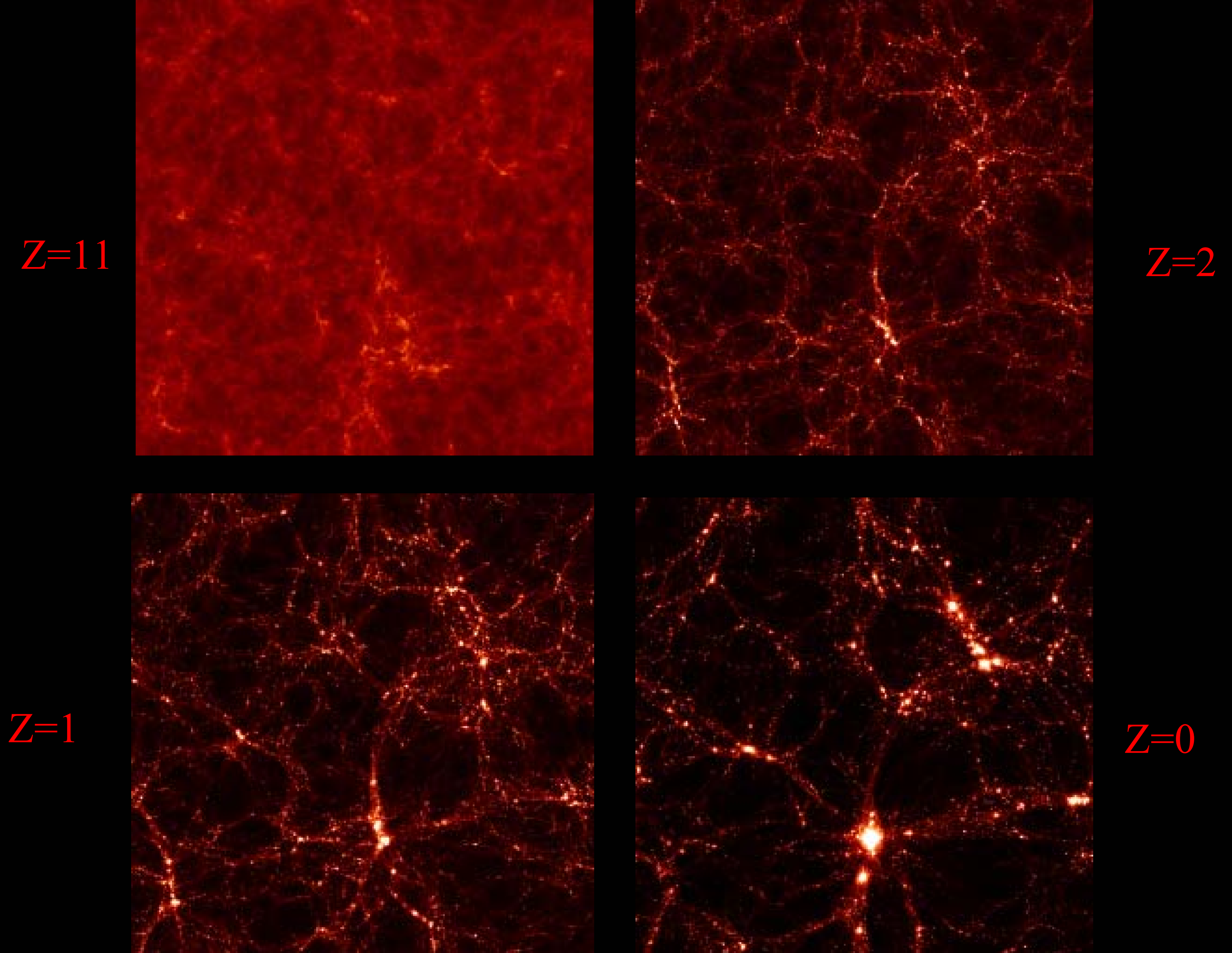


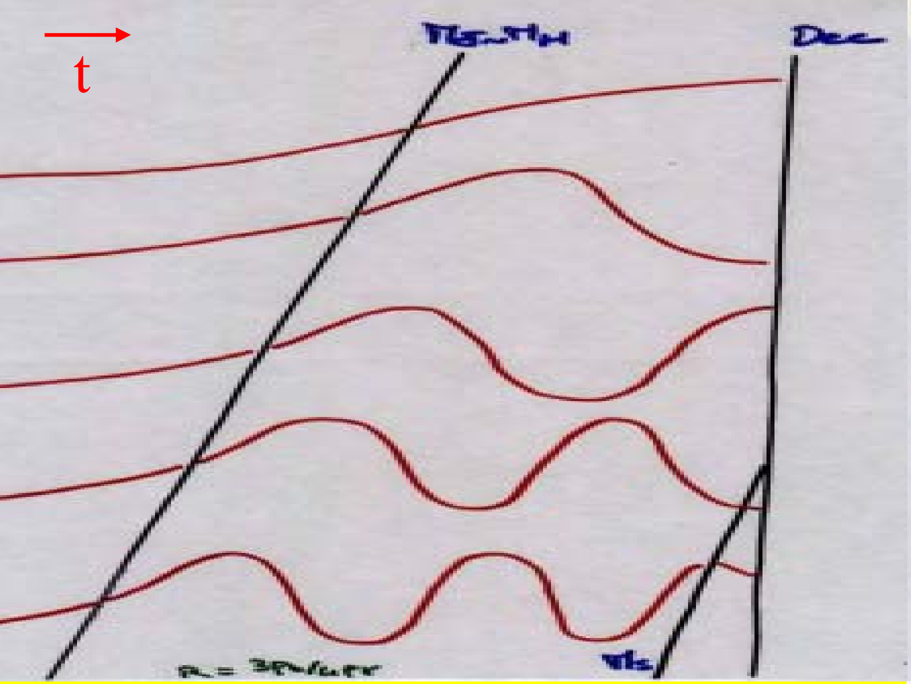
ΛCDM, 150 Mpc

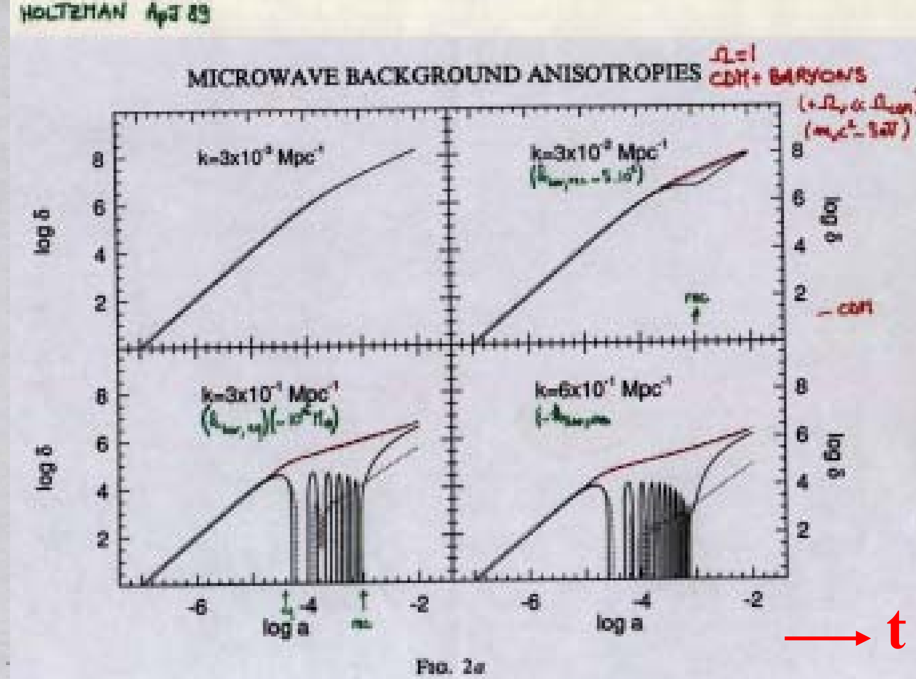


Bouchet et al. 2000

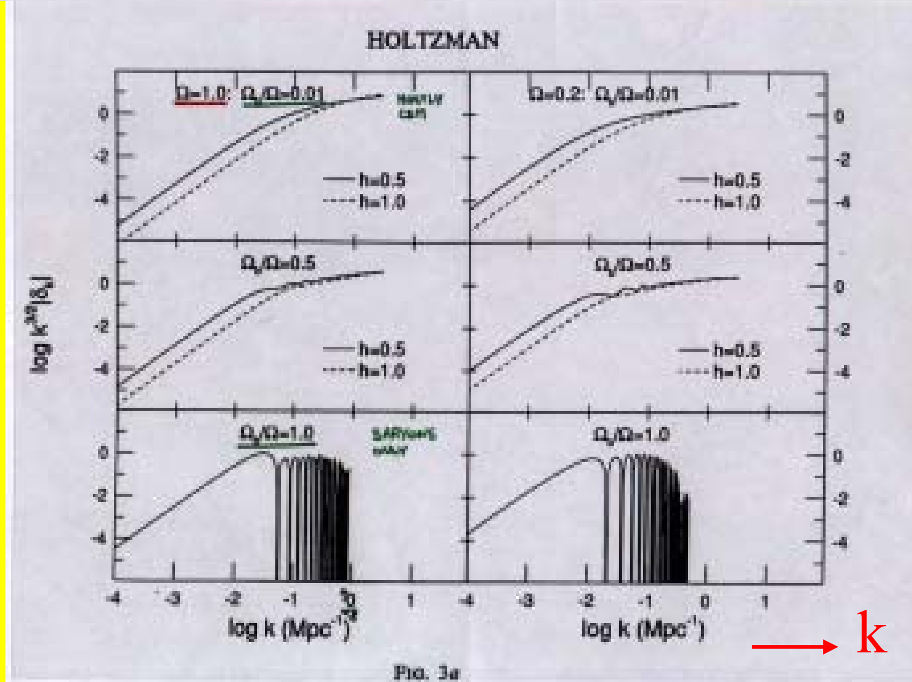
16 x 10^6 particles, // Treecode


Z=11
Z=2
Z=1
Z=0

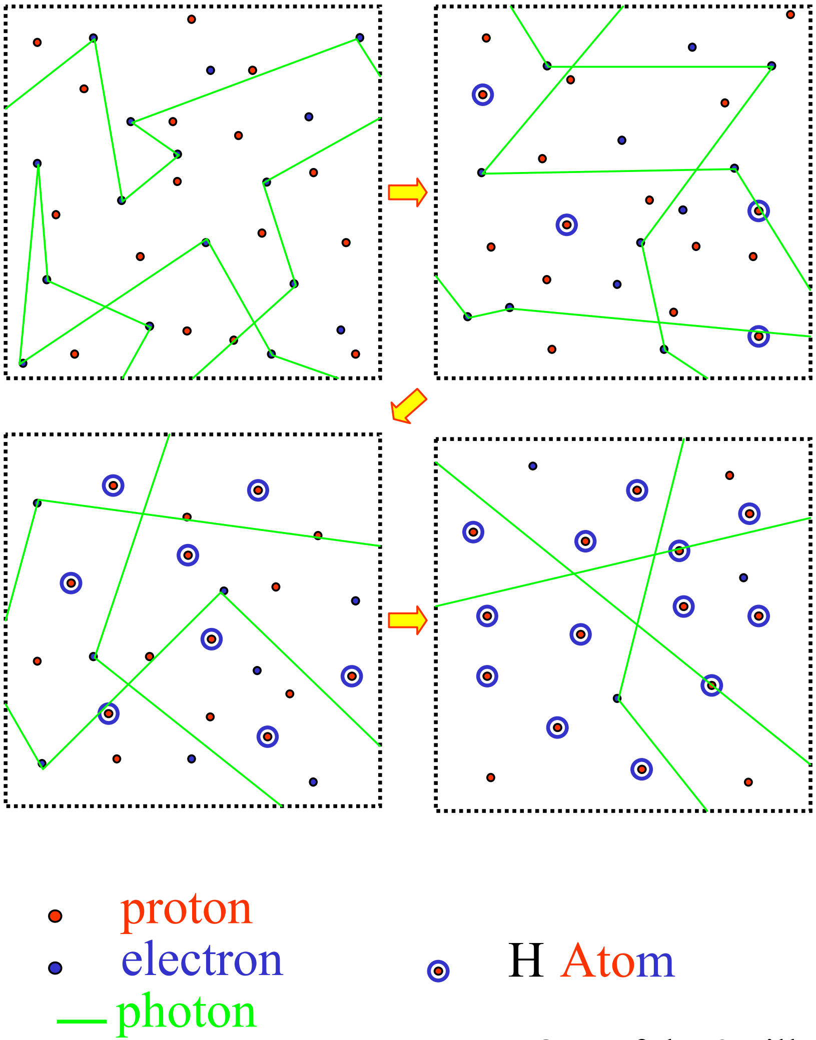


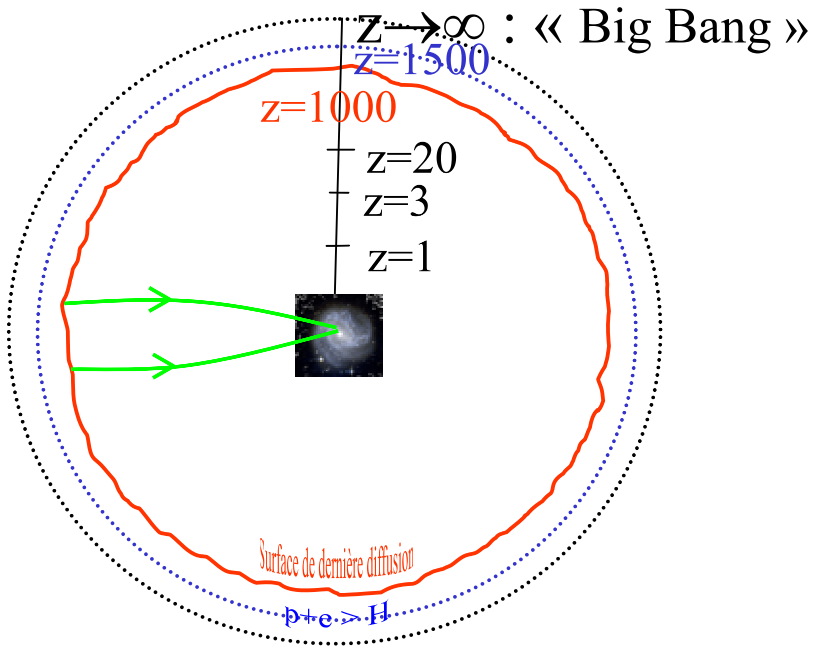


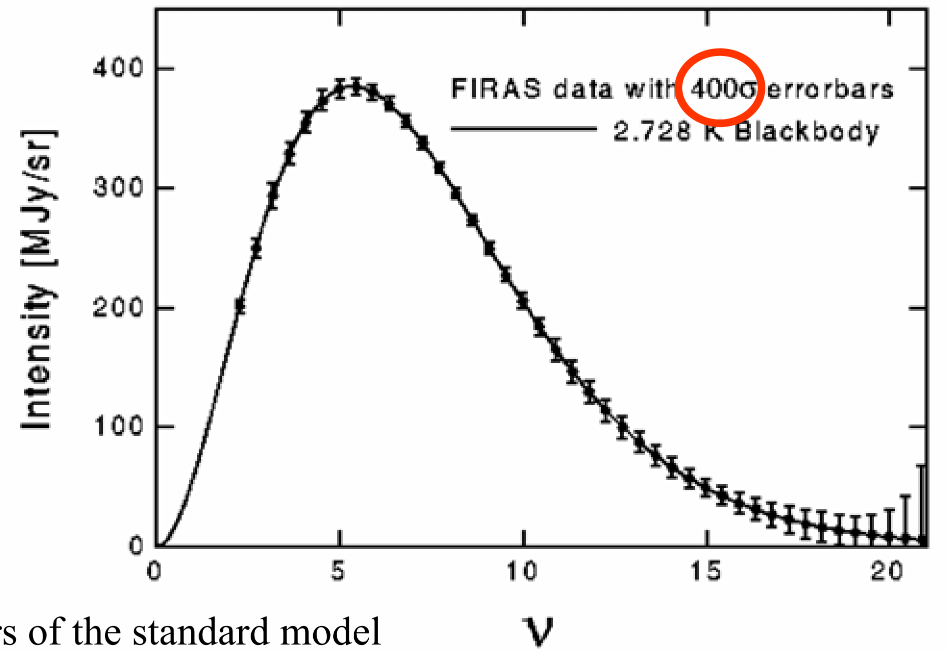
Given "initial" conditions (type & statistics, e.g. Adiabatic fluctuations only, Gaussian with $P(k) = A\,k^n$), and an energy census of the Universe (cosmological parameters, τ), one can compute the temporal evolution of each and every (linear) mode and obtain the "evolved" matter power spectrum, or it's transfer function at LSS (depending mostly on sound speed history at $M < M_J$). *Idem for the radiation Transfer Function.*



"CMB" & LAST SCATTERING "SURFACE"

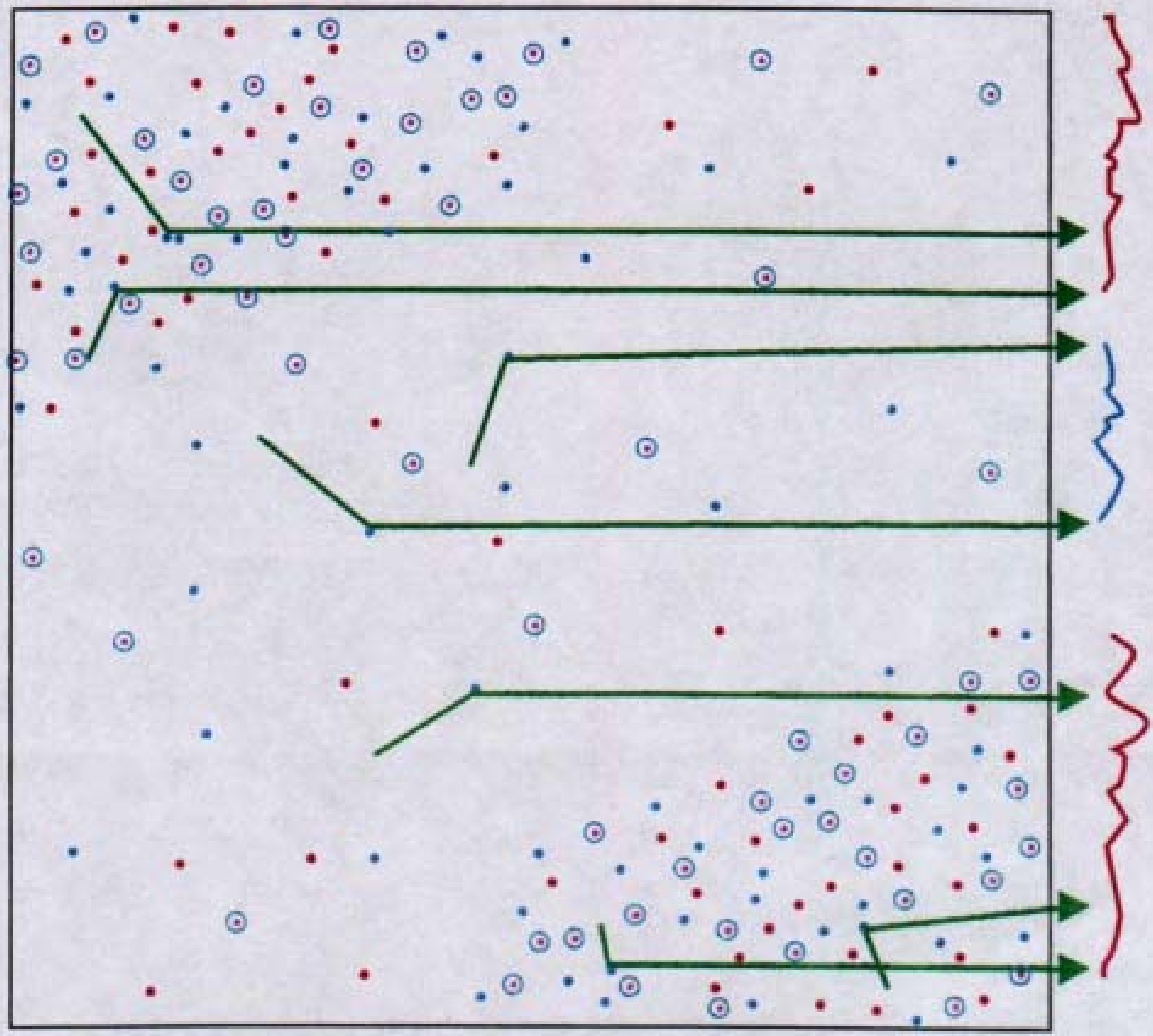






One of the 3 pillars of the standard model

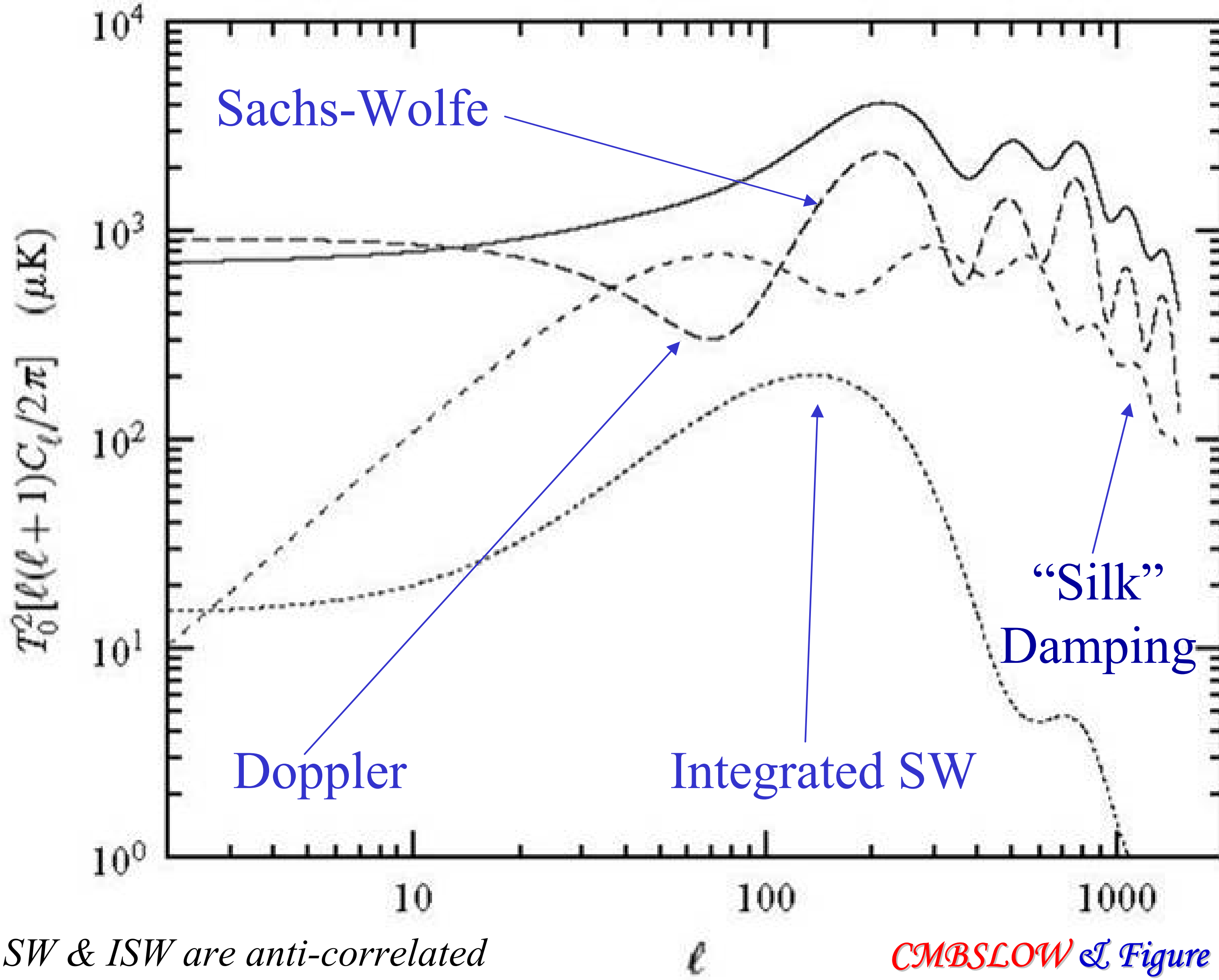
QUAND L'UNIVERS DEVIENT TRANSPARENT…



Dernières interactions des photons avec les électrons

+ ISW…

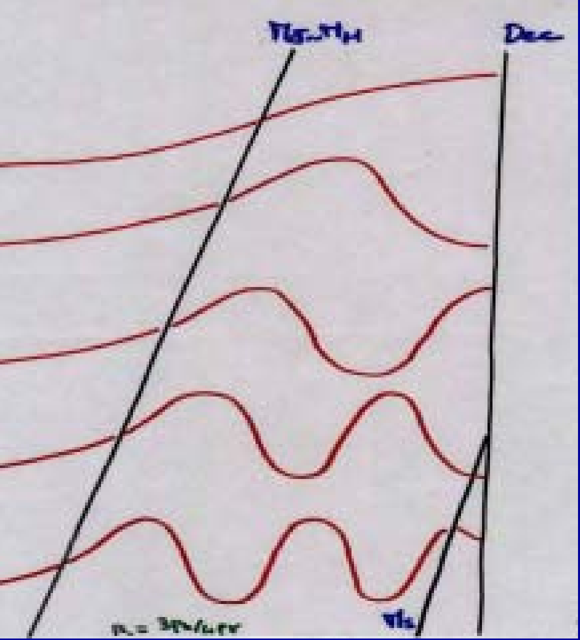
ANGULAR POWER SPECTUM OF ANISOTROPIES GENERATED BY SCALAR FLUCTUATIONS

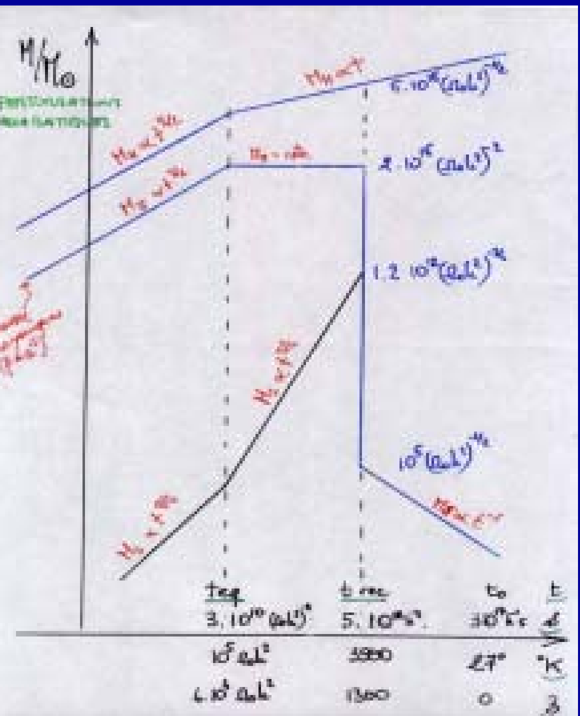


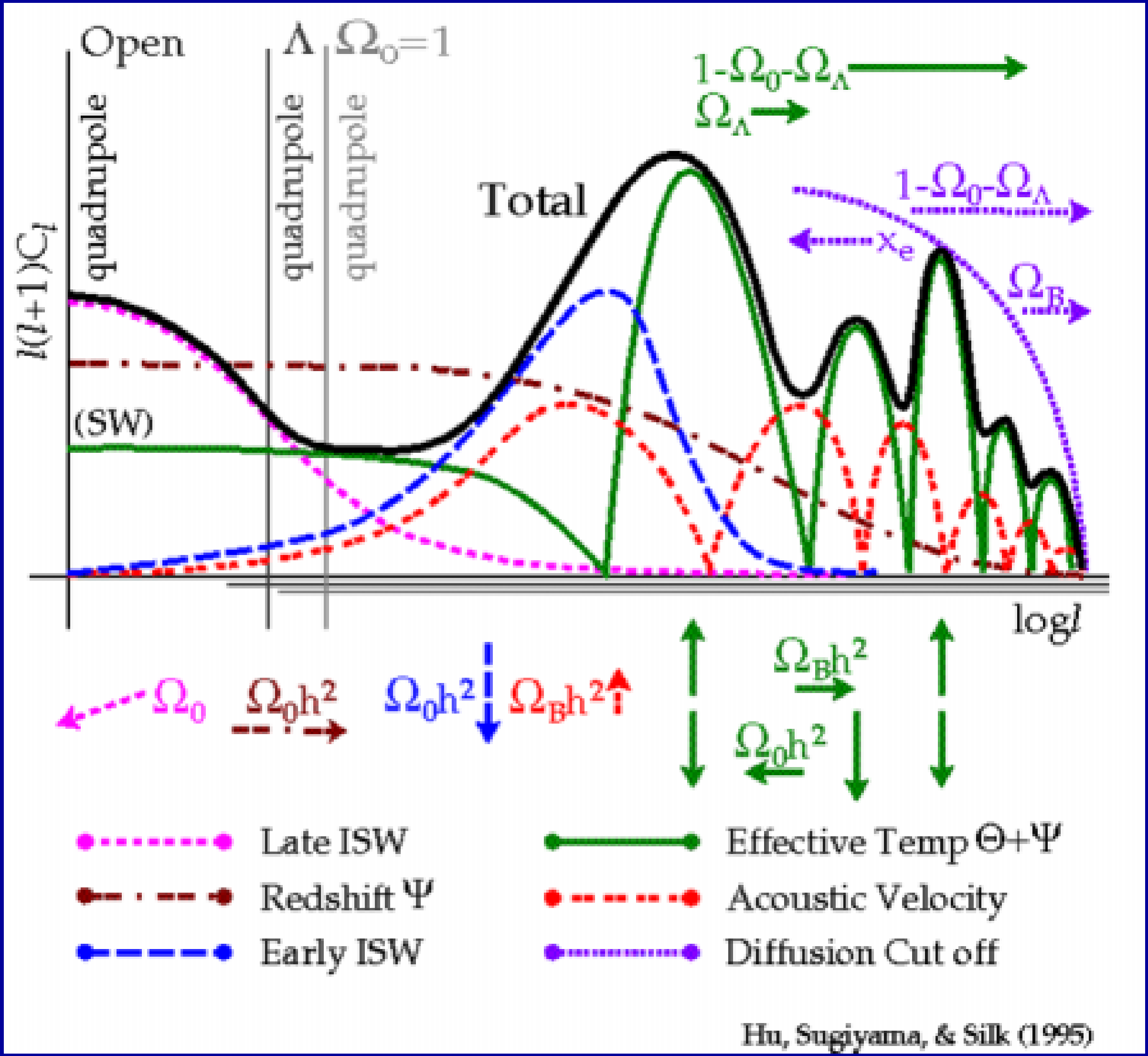
NB: SW & ISW are anti-correlated

CMBSLOW & Figure Thèse Riazuelo

POWER SPECTRUM SHAPE AND COSMOLOGICAL PARAMETERS

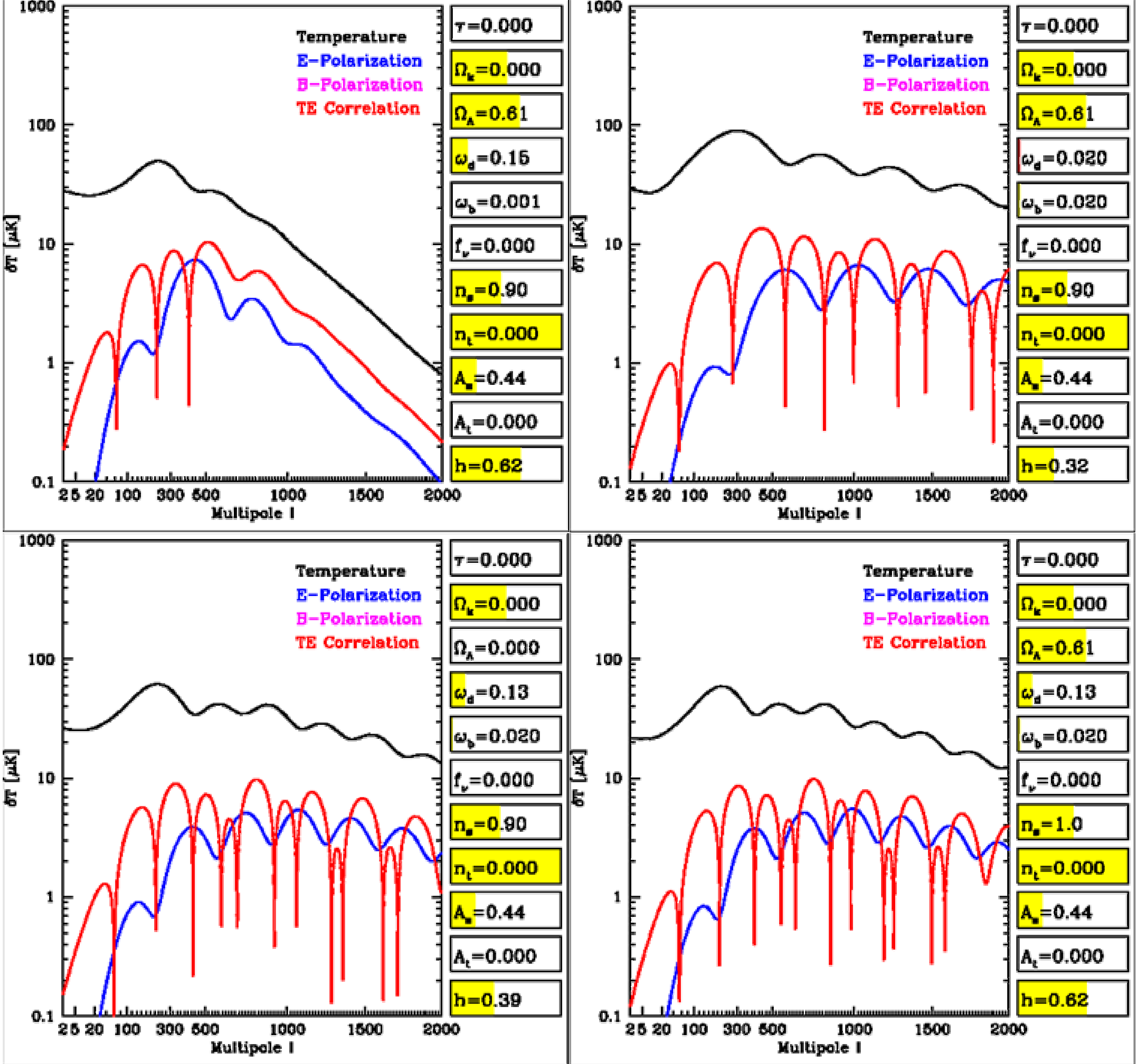






Ω_B

Ω_M

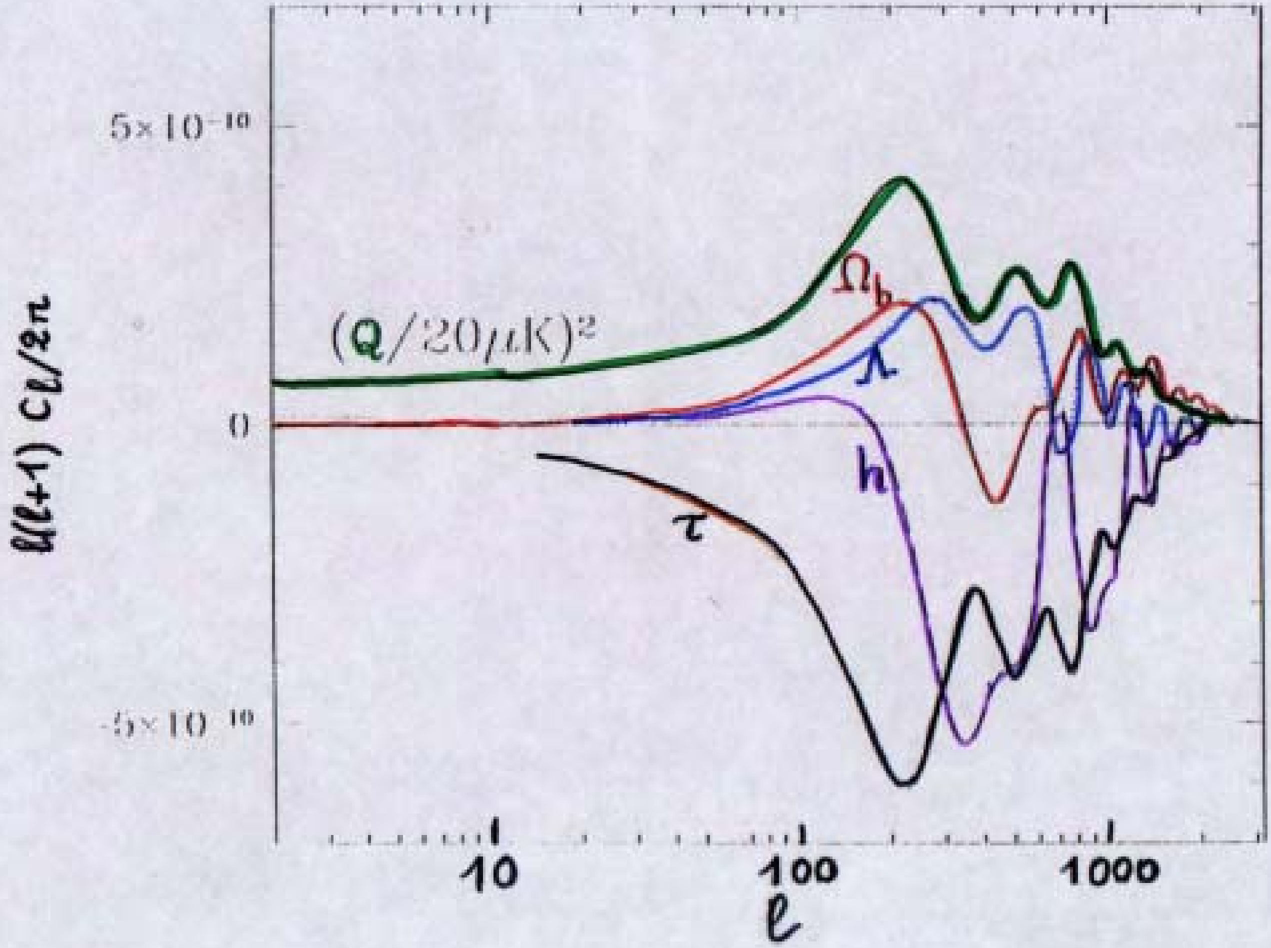


Ω_Λ

f_ν

From Tegmark's web site

RESOLUTION & SENSITIVITY CAN BREAK MOST DEGENERACIES



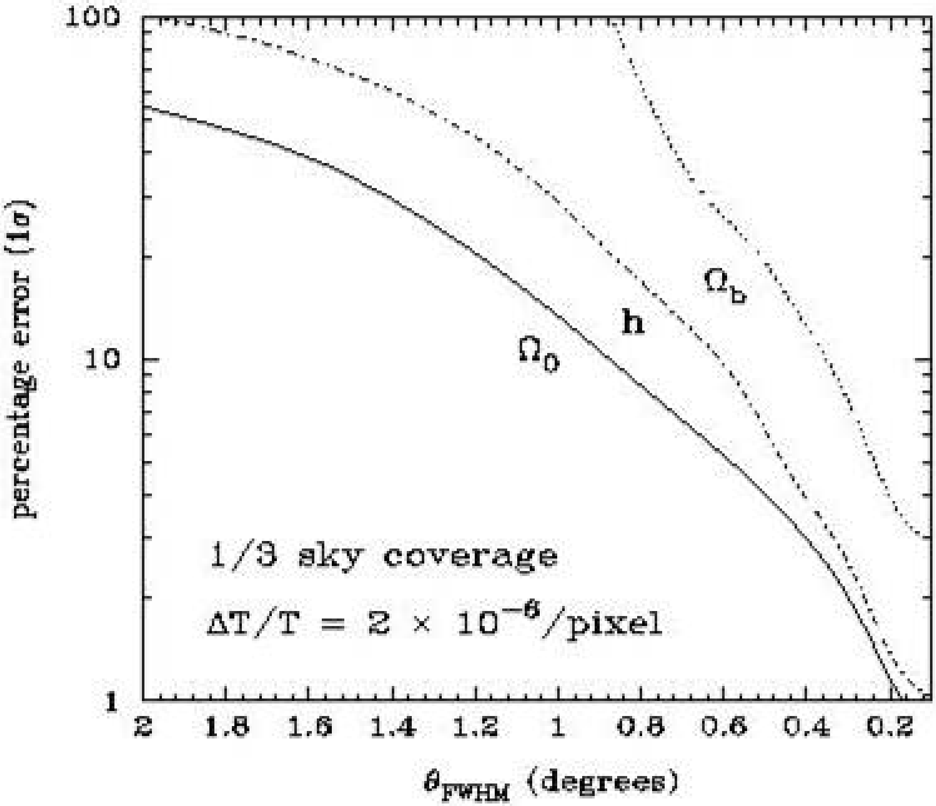
NB: Some parameter combinations are nearly perfectly degenerate, e.g. keeping D_A constant

Figure 11. The derivatives of the CDM power spectrum with respect to various parameters.

FISHER MATRIX GUIDELINES

- Microwave sky = primary + secondary + foregrounds
- Measured sky = Microwave sky + random errors + systematic errors.
- Theory $T_i = f(\theta_{p,}, IC_j)$
- Constraining theory with data : $P(T|D) \propto L(D|T)\, P(T)$
- Fisher matrix, $F_{ij} = \frac{\partial^2 \ln L}{\partial T_j \partial T_i}$, encodes the power of the data
- *Assume* we succeed in isolating *only* primary fluctuations and noise... $$F_{ij} = \sum_l \frac{(2l+1) f_{sky}}{2} [C_l + C_N \exp \theta_b^2 (l^2)]^{-2} \frac{\partial C_l}{\partial T_j} \frac{\partial C_l}{\partial T_j}$$
- Quantifies the (remaining) obstacles ($\sigma_i >= F_{ii}^{-1/2}$):
  - Degeneracies within the θ_p
  - Degeneracies within the IC, and IC vs. θ_p
  - Cosmic variance (one sky), noise (i.e. sensitivity), resolution

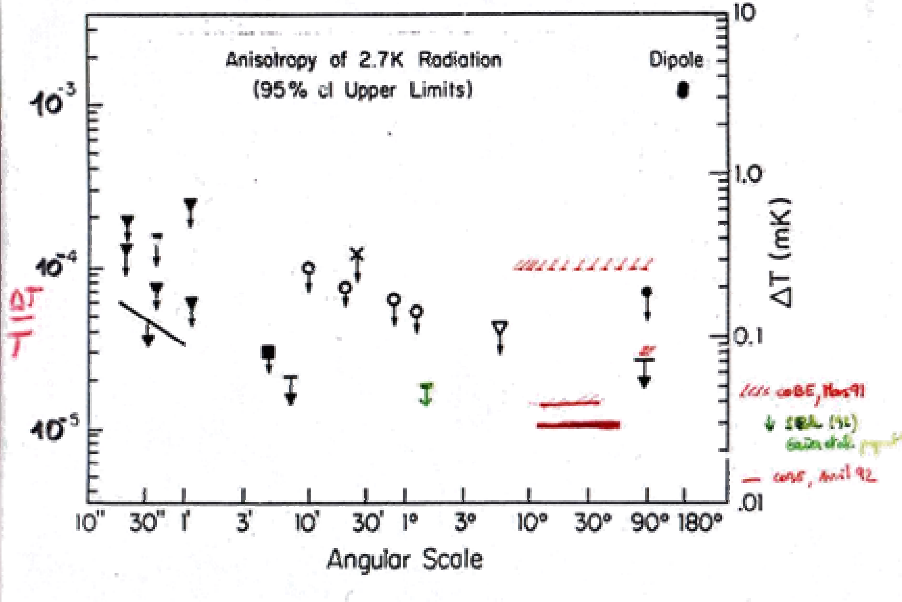
Accuracy of recovery of fundamental parameters



Maximum likelihood estimates in an eight dimensional parameter space

(Ω_0, h, Ω_b, $n_s{}^3$, Q_{rms}, n_s/n_t, Λ, τ_{relon})

HISTORY



1.6: RMS variation of the CMBR temperature as a function of the angular ... of the two antennes (from [13]).

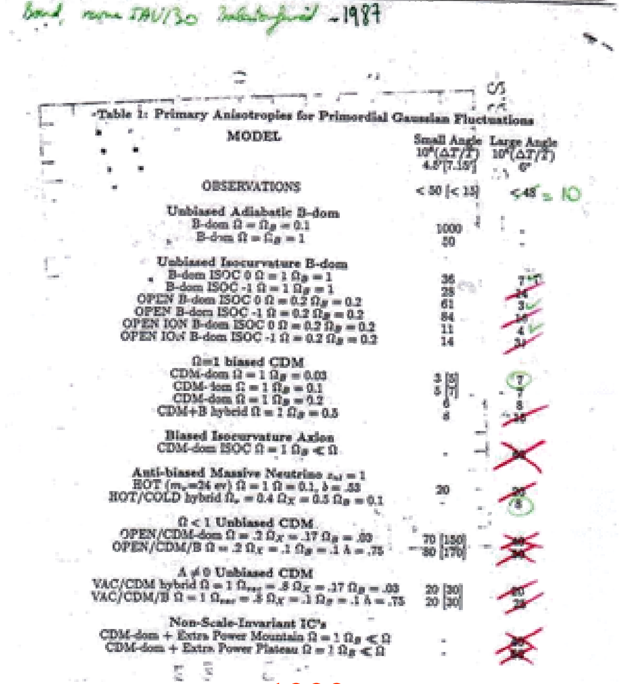
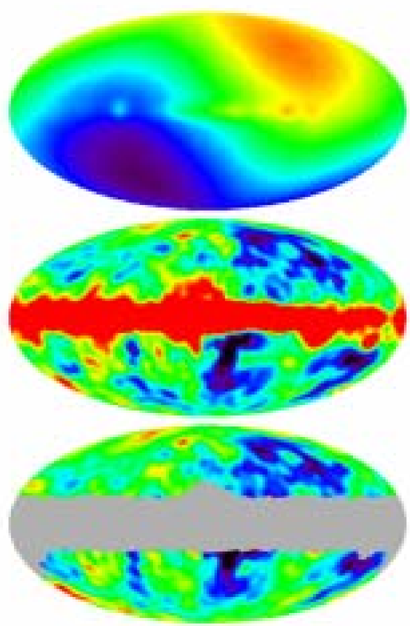
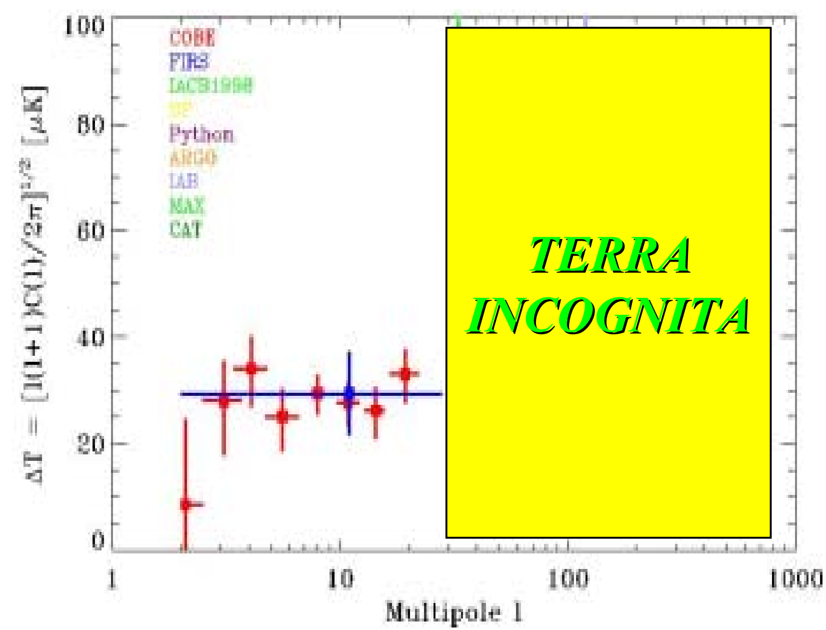


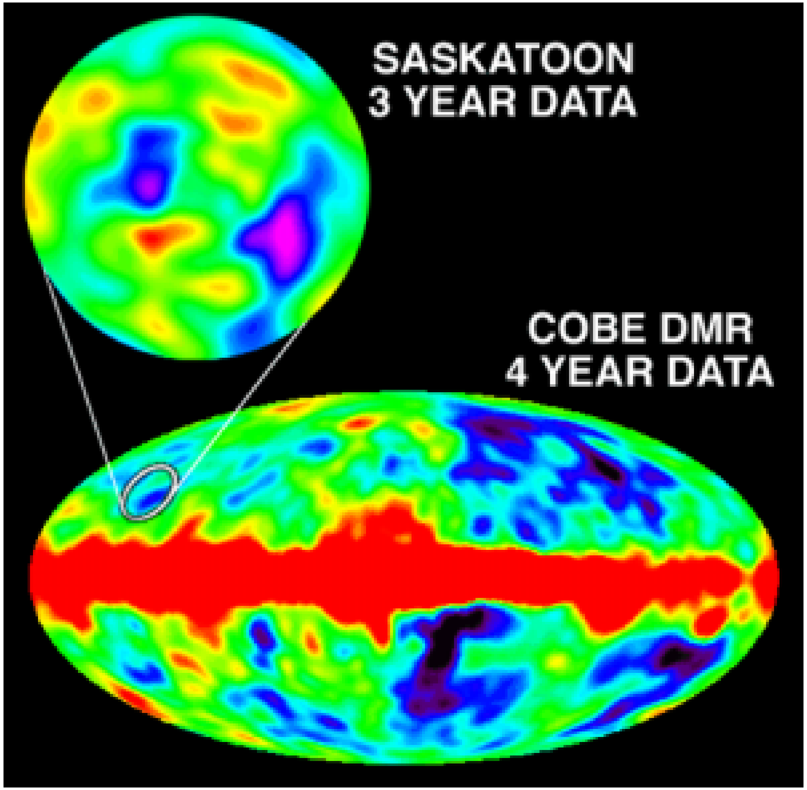
Table 1: Primary Anisotropies for Primordial Gaussian Fluctuations

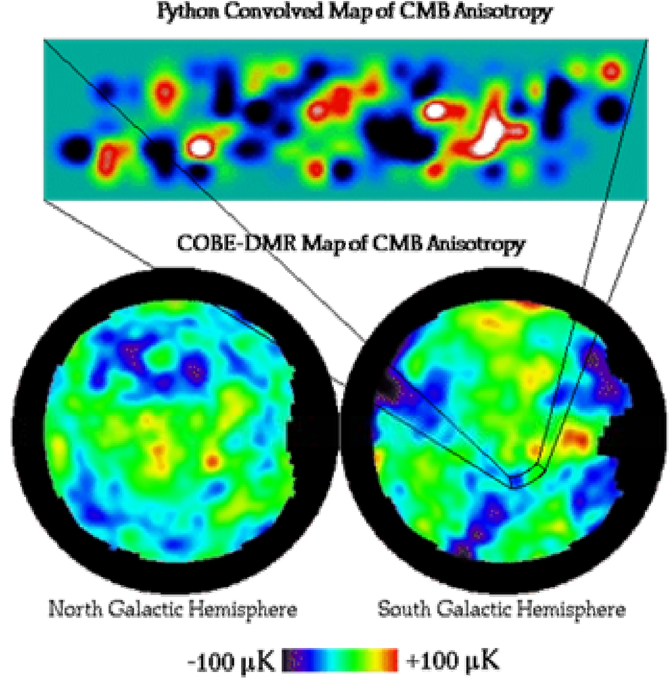
MODEL	Small Angle $10^6(\Delta T/T)$ 4.5' [7.15']	Large Angle $10^6(\Delta T/T)$ 6°
OBSERVATIONS	< 50 [< 13]	< 48
Unbiased Adiabatic B-dom		
B-dom $\Omega = \Omega_B = 0.1$	1000	-
B-dom $\Omega = \Omega_B = 1$	50	-
Unbiased Isocurvature B-dom		
B-dom ISOC 0 $\Omega = 1$ $\Omega_B = 1$	36	7
B-dom ISOC -1 $\Omega = 1$ $\Omega_B = 1$	28	14
OPEN B-dom ISOC 0 $\Omega = 0.2$ $\Omega_B = 0.2$	61	3
OPEN B-dom ISOC -1 $\Omega = 0.2$ $\Omega_B = 0.2$	84	[illegible]
OPEN ION B-dom ISOC 0 $\Omega = 0.2$ $\Omega_B = 0.2$	11	4
OPEN ION B-dom ISOC -1 $\Omega = 0.2$ $\Omega_B = 0.2$	14	[illegible]
Ω=1 biased CDM		
CDM-dom $\Omega = 1$ $\Omega_B = 0.03$	3 [5]	7
CDM-dom $\Omega = 1$ $\Omega_B = 0.1$	5 [7]	7
CDM-dom $\Omega = 1$ $\Omega_B = 0.2$	6	8
CDM+B hybrid $\Omega = 1$ $\Omega_B = 0.5$	8	[illegible]
Biased Isocurvature Axion		
CDM-dom ISOC $\Omega = 1$ $\Omega_B \ll \Omega$	-	[illegible]
Anti-biased Massive Neutrino $\sigma_{gal} = 1$		
HOT (m_ν=24 ev) $\Omega = 1$ $\Omega = 0.1$, $b = .53$	20	[illegible]
HOT/COLD hybrid $\Omega_\nu = 0.4$ $\Omega_X = 0.5$ $\Omega_B = 0.1$	-	8
$\Omega < 1$ Unbiased CDM		
OPEN/CDM-dom $\Omega = .2$ $\Omega_X = .17$ $\Omega_B = .03$	70 [150]	[illegible]
OPEN/CDM/B $\Omega = .2$ $\Omega_X = .1$ $\Omega_B = .1$ $\lambda = .75$	80 [170]	[illegible]
$\Lambda \neq 0$ Unbiased CDM		
VAC/CDM hybrid $\Omega = 1$ $\Omega_{vac} = .8$ $\Omega_X = .17$ $\Omega_B = .03$	20 [30]	[illegible]
VAC/CDM/B $\Omega = 1$ $\Omega_{vac} = .8$ $\Omega_X = .1$ $\Omega_B = .1$ $\lambda = .75$	20 [30]	[illegible]
Non-Scale-Invariant IC's		
CDM-dom + Extra Power Mountain $\Omega = 1$ $\Omega_B \ll \Omega$	-	[illegible]
CDM-dom + Extra Power Plateau $\Omega = 1$ $\Omega_B \ll \Omega$	-	[illegible]

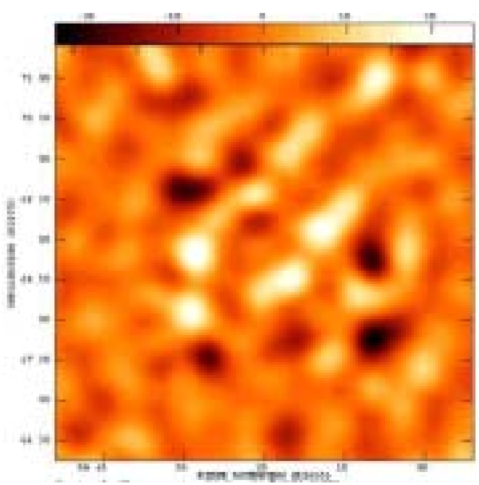


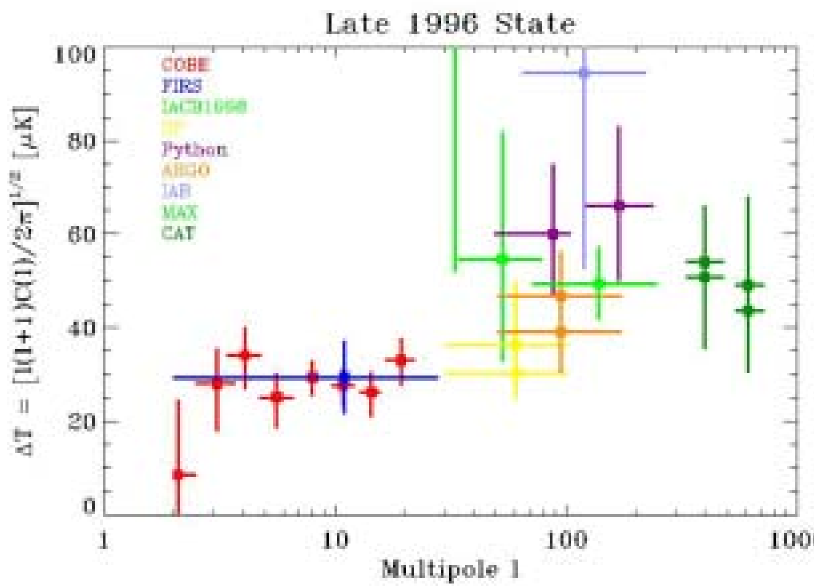
1992 state

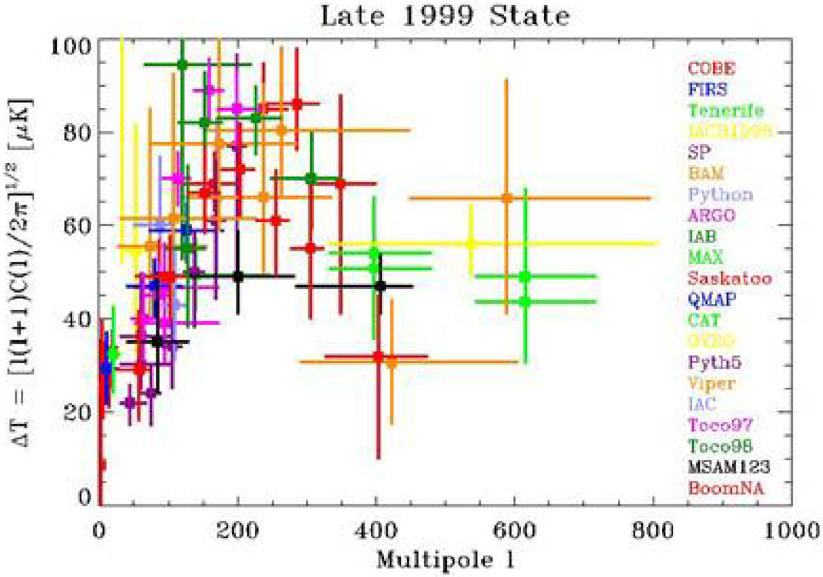


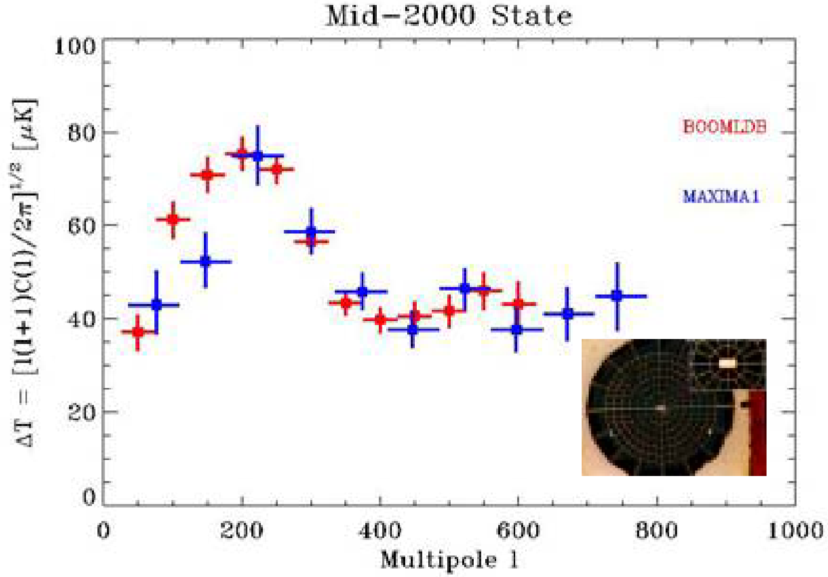

SASKATOON
3 YEAR DATA
COBE DMR
4 YEAR DATA


Python Convolved Map of CMB Anisotropy
COBE-DMR Map of CMB Anisotropy
North Galactic Hemisphere
South Galactic Hemisphere
-100 μK
+100 μK

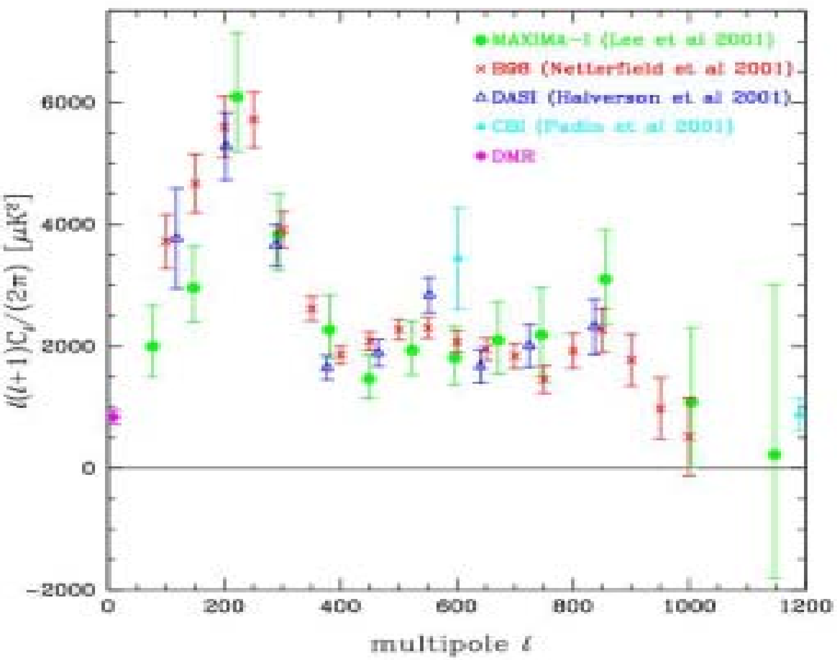


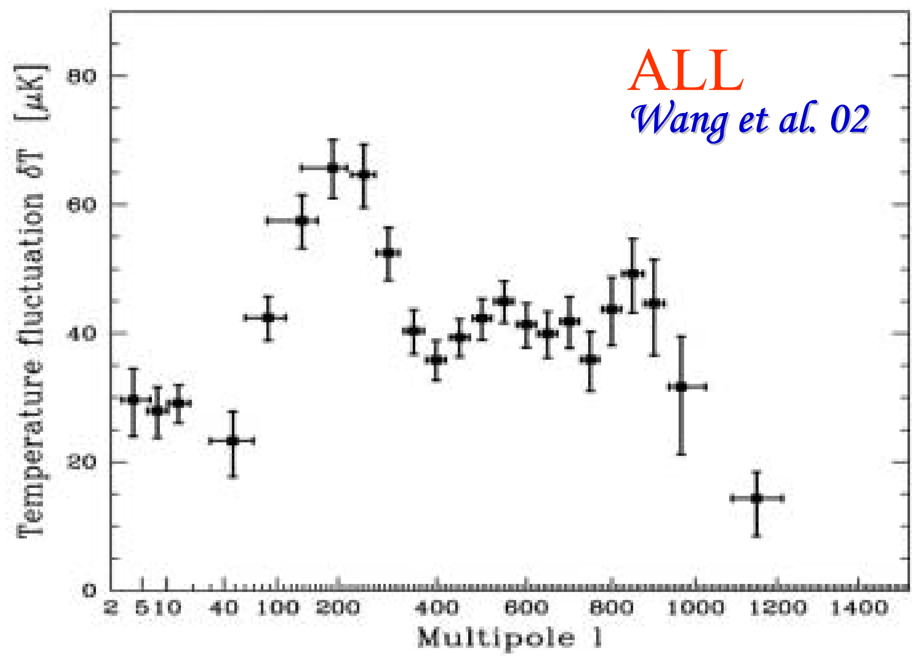

Late 1996 State
COBE
FIRS
Python
ARGO
IAB
MAX
CAT
ΔT = [l(l+1)C(l)/2π]^1/2 [μK]
Multipole l
0
20
40
60
80
100
1
10
100
1000


Late 1999 State
ΔT = [l(l+1)C(l)/2π]^1/2 [μK]
Multipole l
COBE
FIRS
Tenerife
IACB1998
SP
BAM
Python
ARGO
IAB
MAX
Saskatoo
QMAP
CAT
OVRO
Pyth5
Viper
IAC
Toco97
Toco98
MSAM123
BoomNA
0
200
400
600
800
1000
20
40
60
80
100

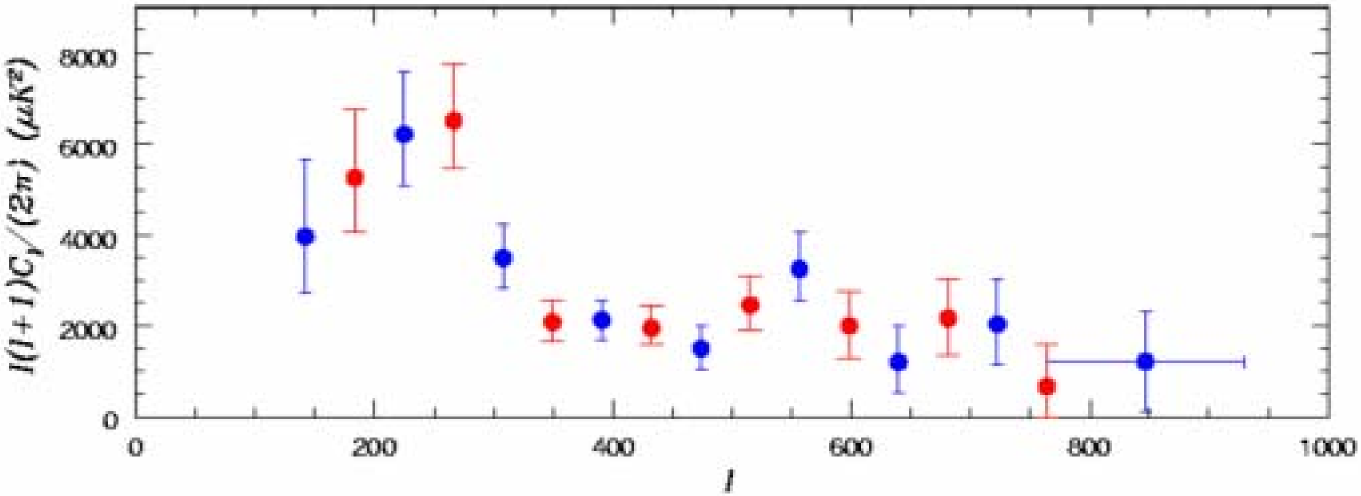

Mid-2000 State
ΔT = [l(l+1)C(l)/2π]^1/2 [μK]
Multipole l
BOOMLDB
MAXIMA1
0
200
400
600
800
1000
20
40
60
80
100

MARCH 2002

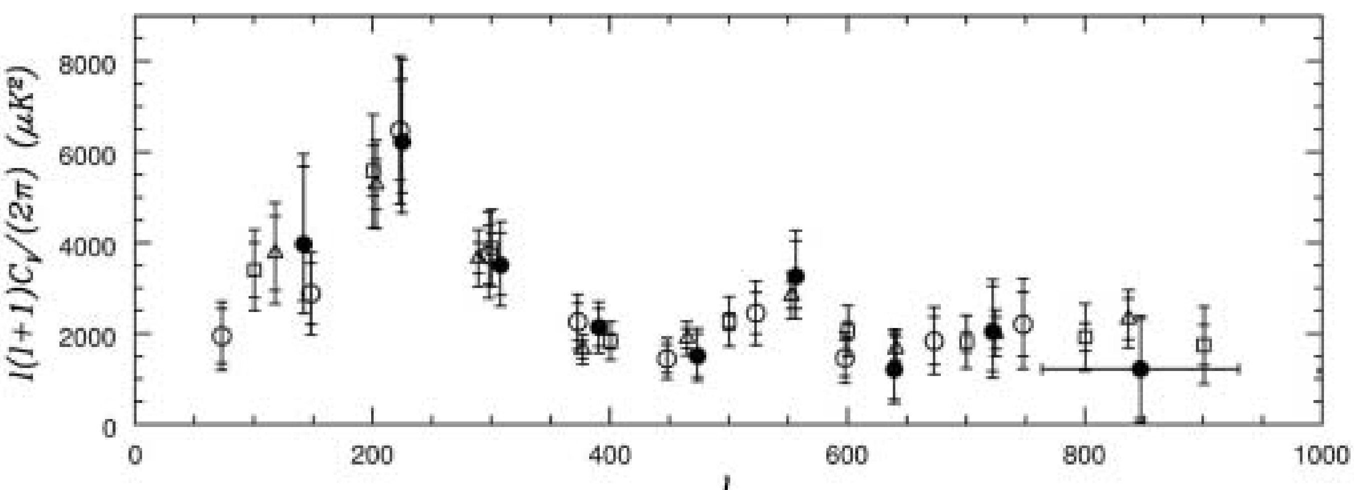

MAXIMA-1 (Lee et al 2001)
B98 (Netterfield et al 2001)
DASI (Halverson et al 2001)
CBI (Padin et al 2001)
DMR
l(l+1)C_l/(2π) [μK²]
multipole l
-2000
0
2000
4000
6000
0
200
400
600
800
1000
1200

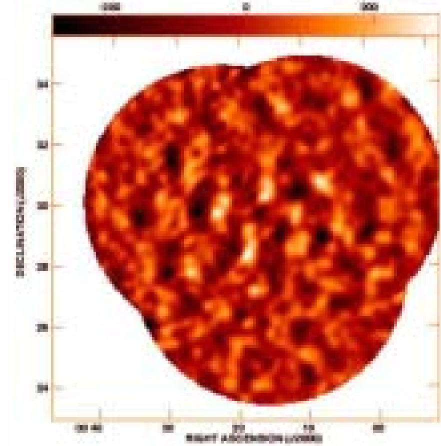

ALL
Wang et al. 02
Temperature fluctuation δT [μK]
Multipole l
0
20
40
60
80
2
5
10
40
100
200
400
600
800
1000
1200
1400

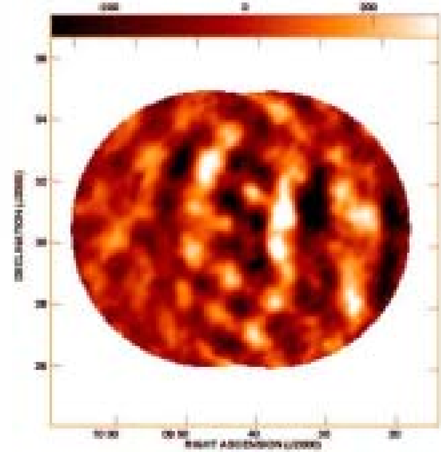
VSA, may 2002…

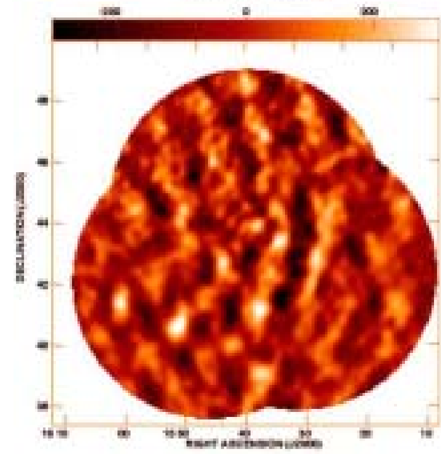


Compares well with BOOM, MAXIMA, DASI



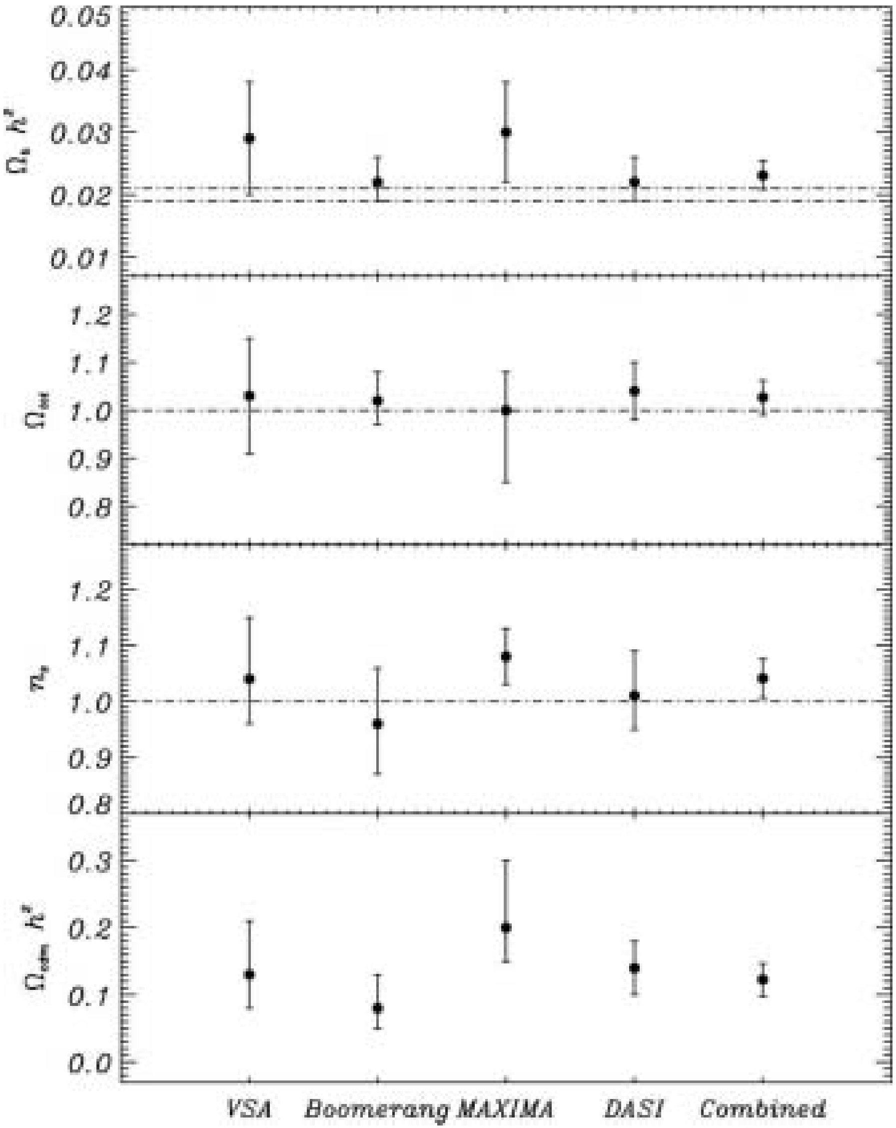


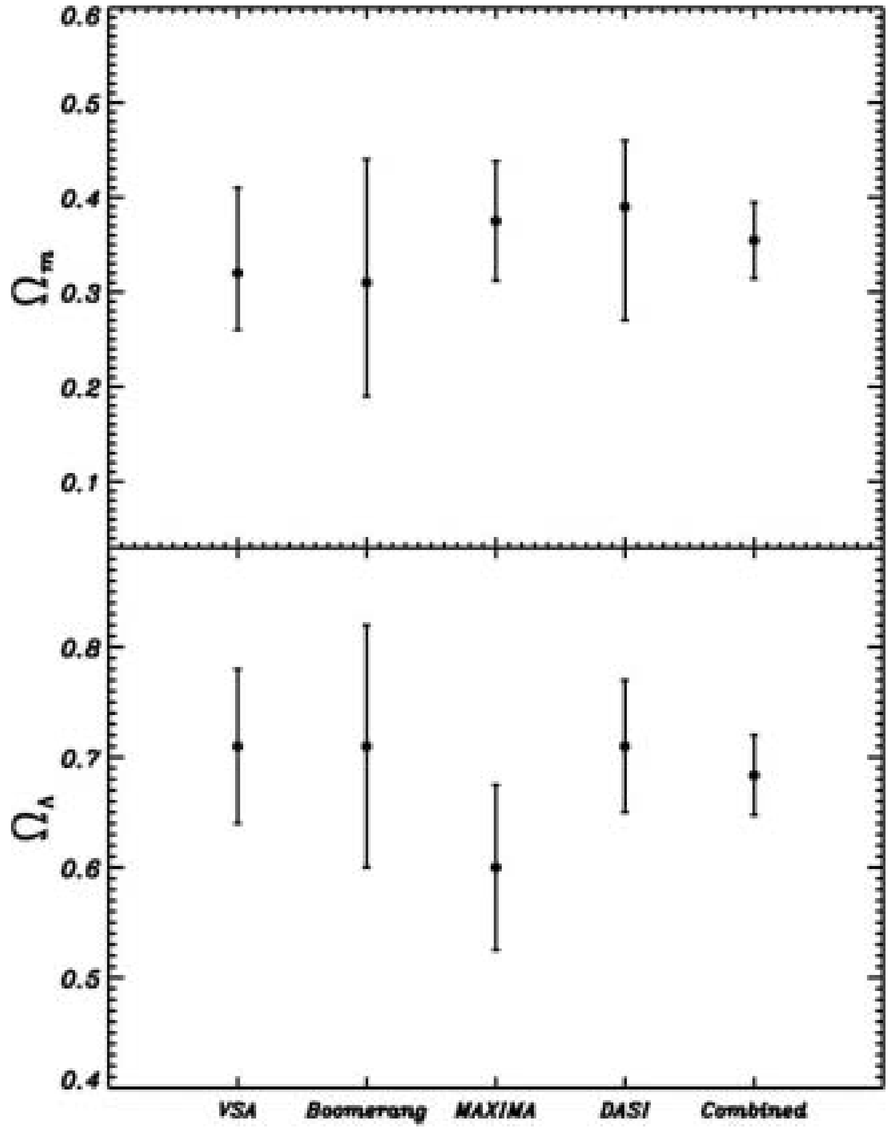




VSA III, Scott et al. astroph/0205380

And appears *quantitatively* consistent with BOOM, MAX & DASI…



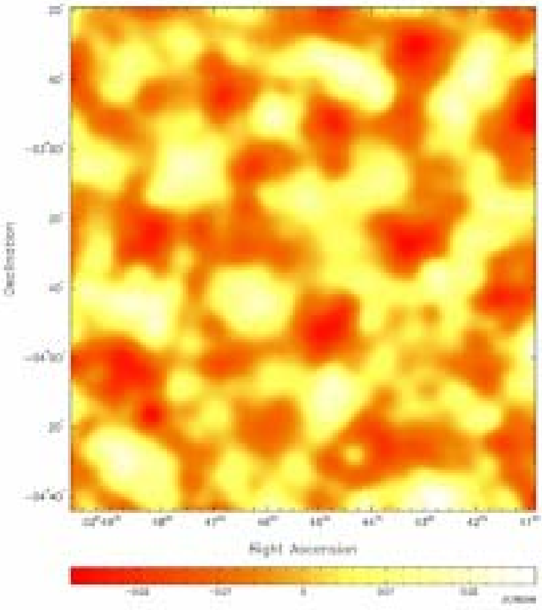


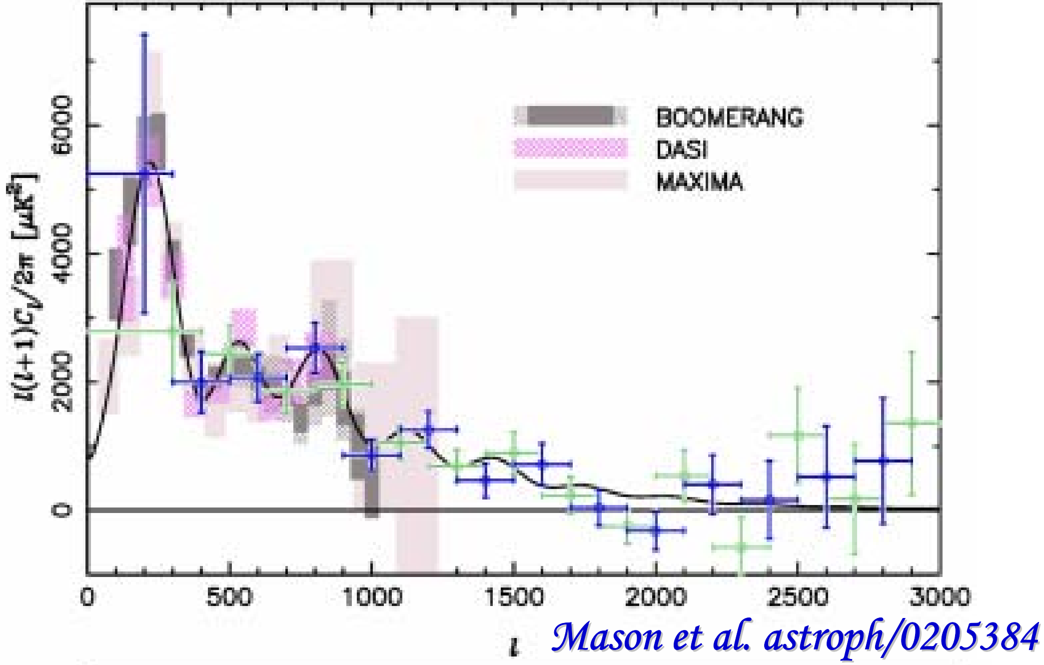
(All using DMR + similar prior)

VSA -IV, Rubino-Martin et al. astroph/0205367

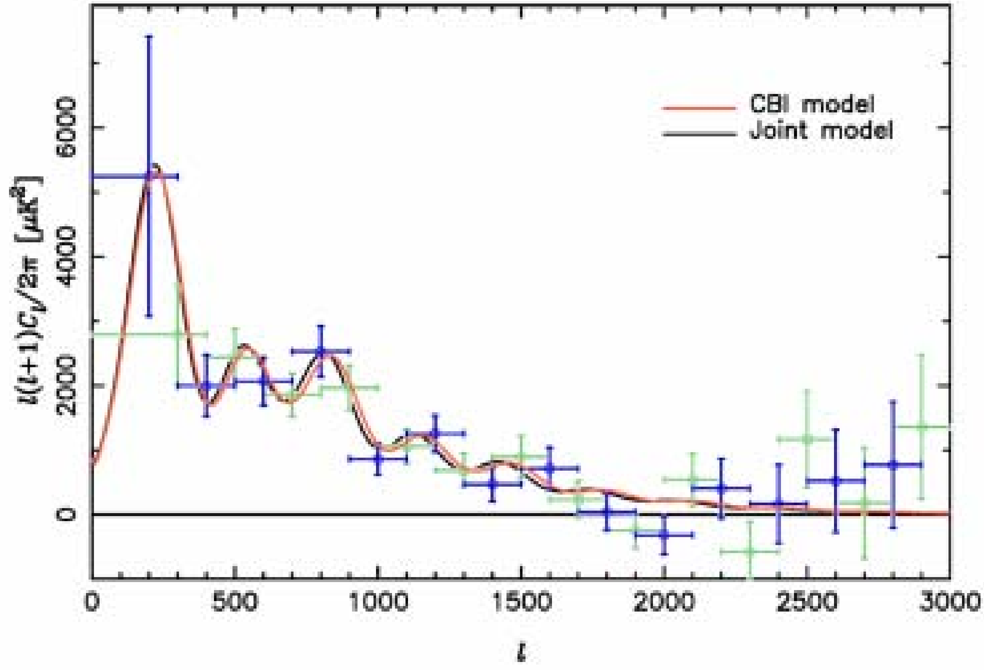
CBI…

(also May 2002)

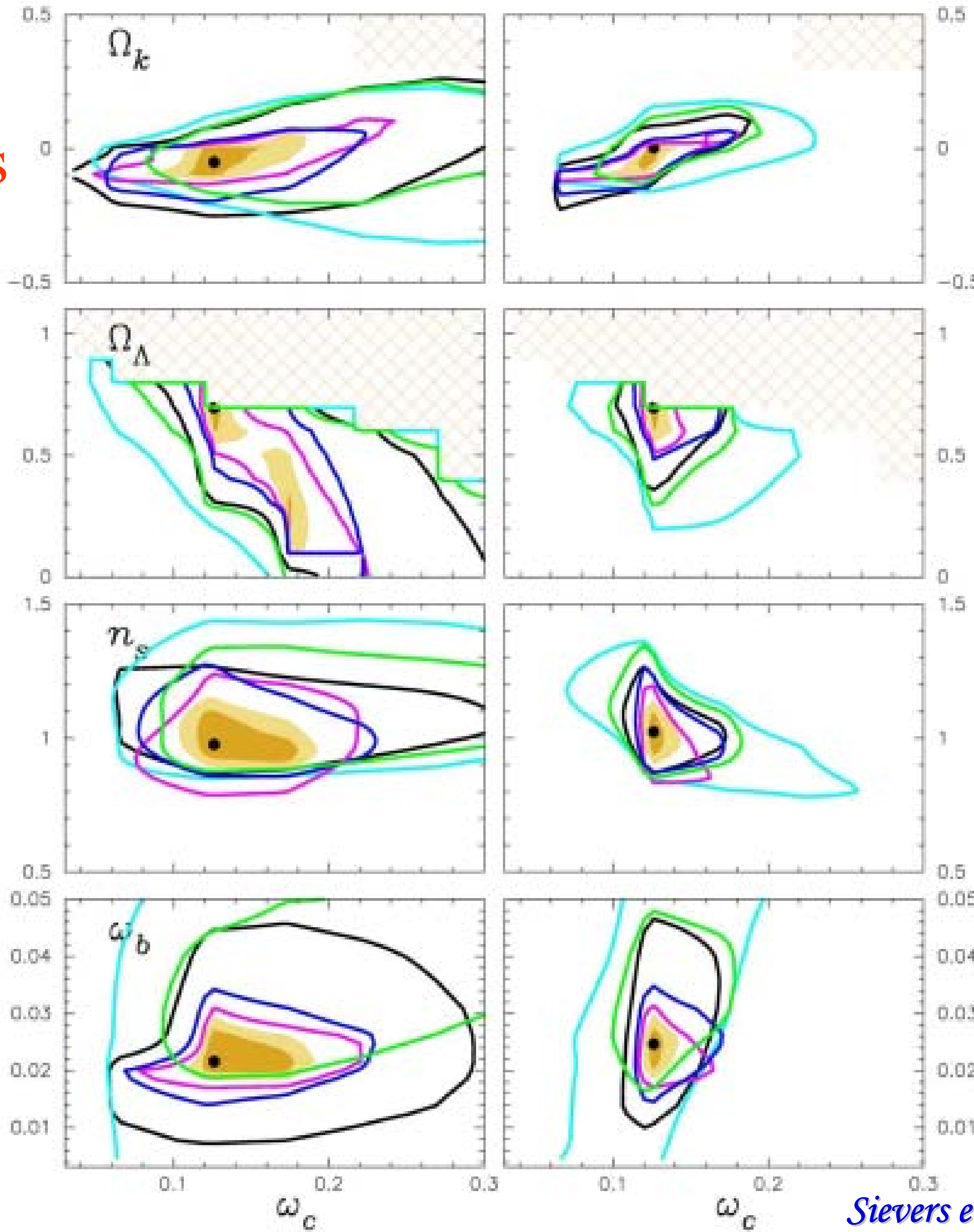




Mason et al. astroph/0205384



2σ contours
For DMR
+
CBI
BOOM
DASI
MAXIMA
PREVIOUS
(Boom NA
+ TOCO +
17 < Apr 99)
and
ALL (filled)
(& inner 1σ)



Left panels additionally include an « LSS » prior (constraint on σ_8 & Γ_{eff})

NB: all panels made for the « weak-h » prior (i.e. $0.45<h<0.9$ & $t_0 > 10$ Gyr & $\Omega_m > 0.1$)

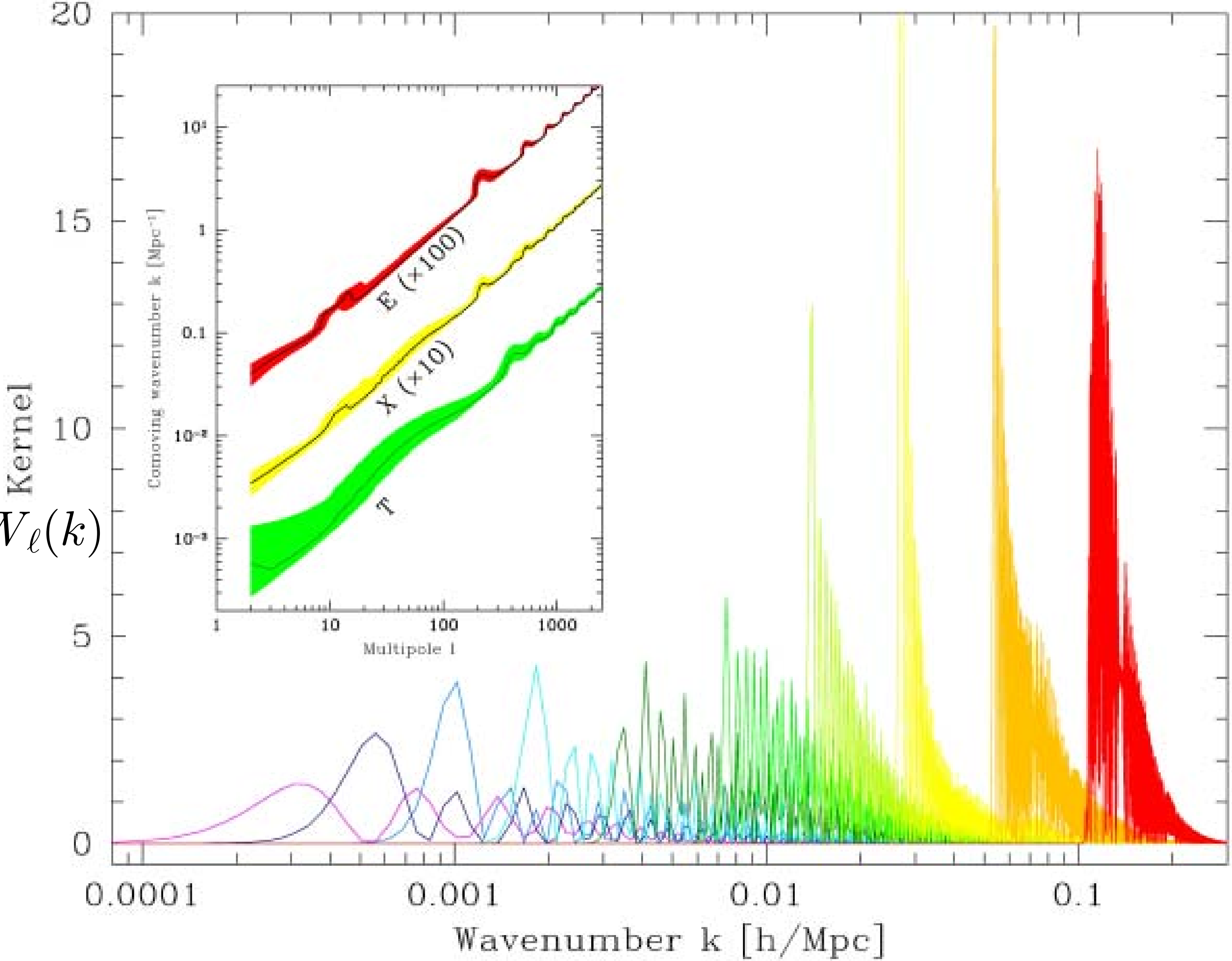
- *n_s & Ω_b panels add $\Omega_k=0$*
- *hatched regions not searched*

Sievers et al. astroph/0205387

CMB & P(k) vs PARAMS

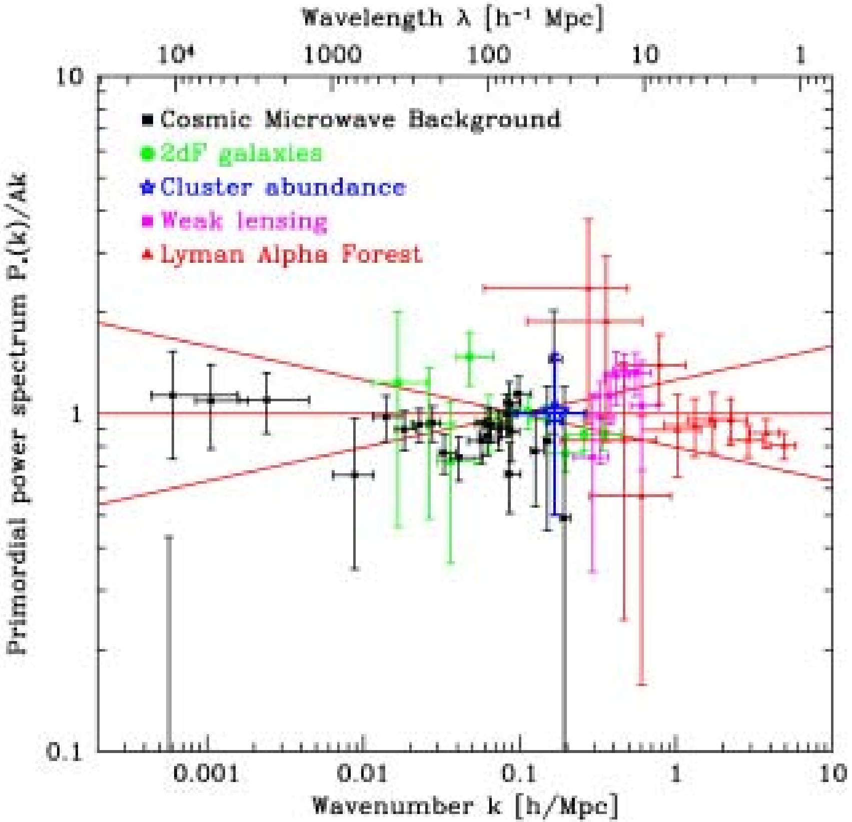
$$C(\ell) = \int_{-\infty}^{+\infty} W_\ell(k) P_\star(k) d\ln k$$

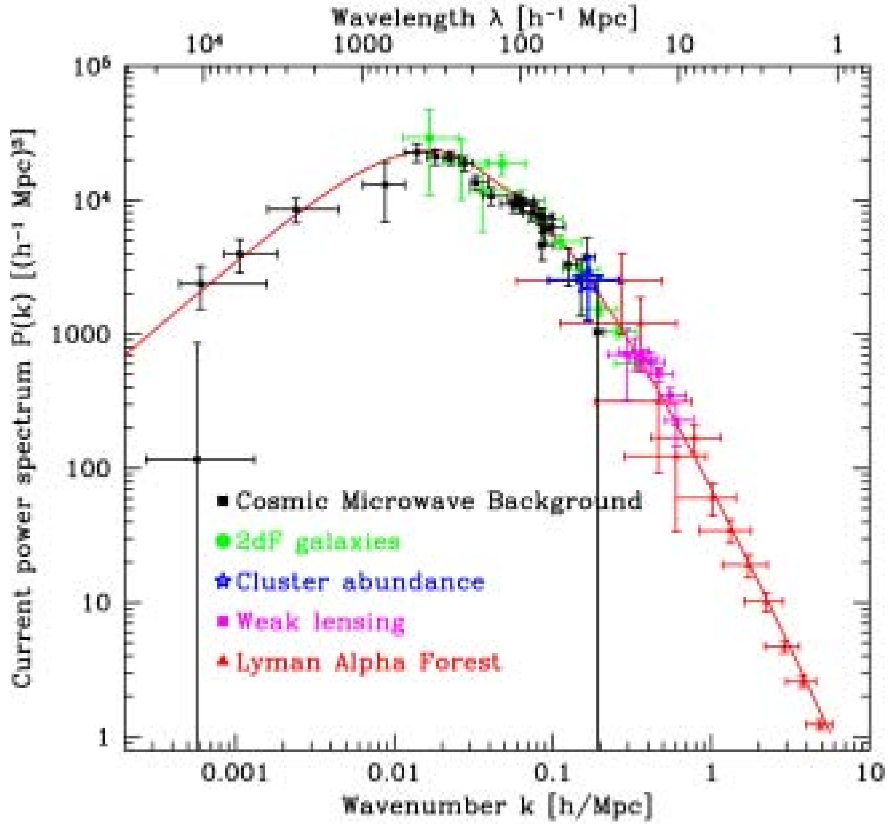
$$kW_\ell(k)$$



USING THE "CONCORDANCE MODEL" PARAMETERS…

$$h^2\Omega_m = 0.12, \quad h^2\Omega_b = 0.021, \quad \Omega_\Lambda = 0.71, \quad h = 0.7, \quad \tau = 0.05 \ \ (\leftrightarrow z_r = 8), \quad \sigma_8 = 0.815$$





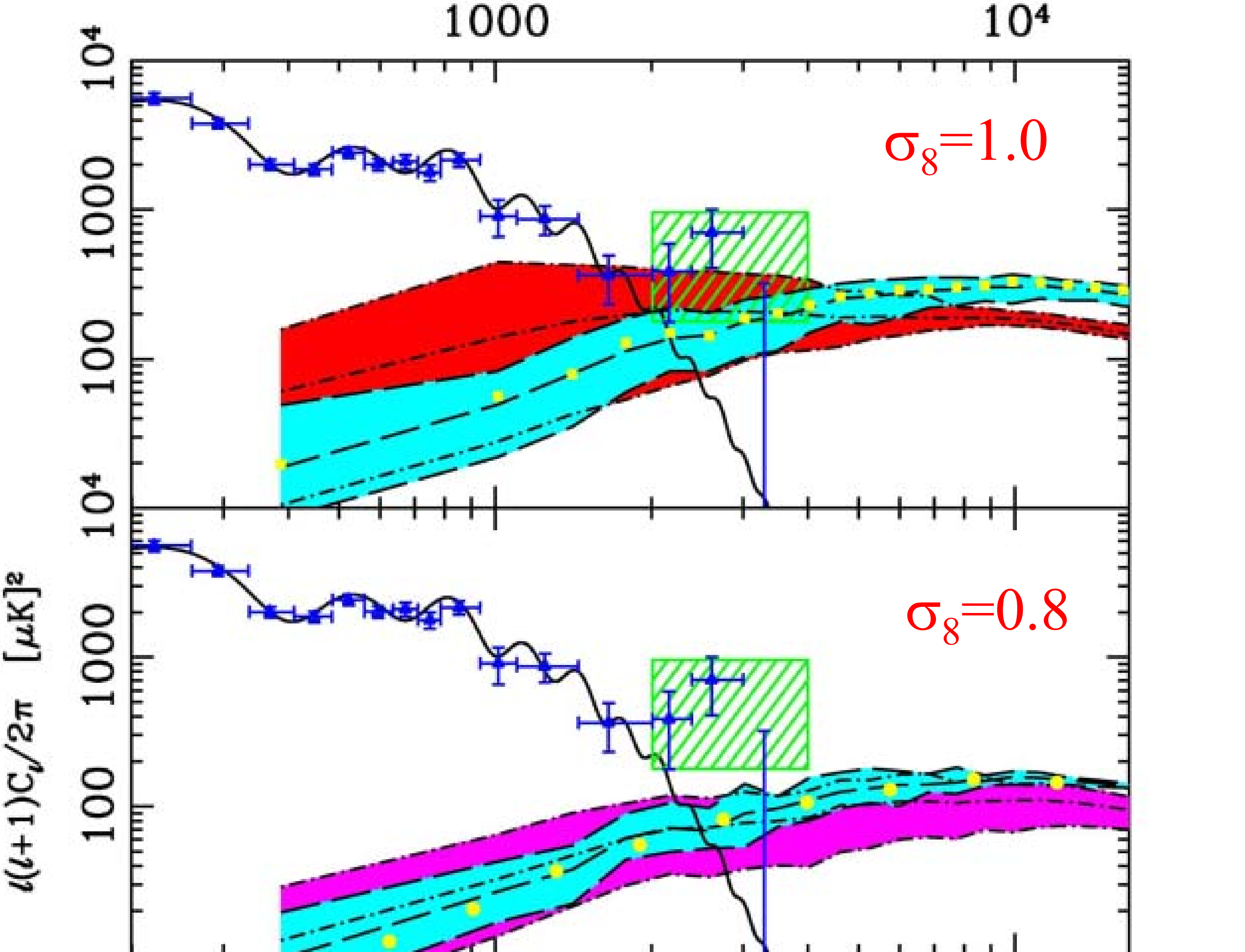
values plotted at $\widehat{P_{\star i}}$ /

$$k\,\widehat{P_{\star i}} = \frac{d_i}{\int_{-\infty}^{+\infty} W_i(k) \ \ d\ln k}$$

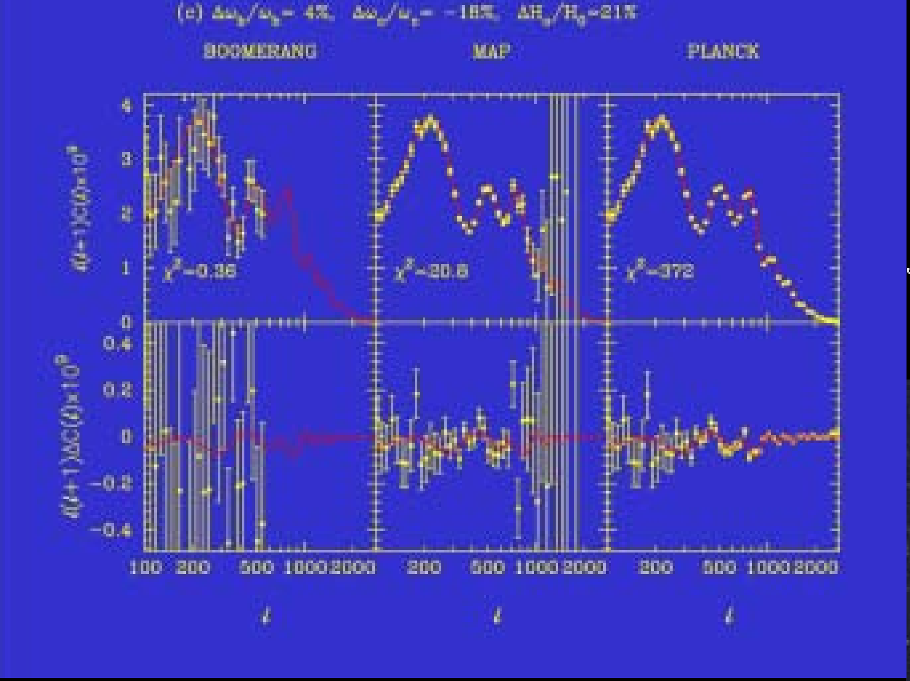
$$P(k,z) = P_\star(k) \times T^2(k,z)$$

Tegmark & Zaldarriaga, astroph/0207047

Un nuage noir dans un ciel bleu ?



MAP & PLANCK



Launch
in 2007

MAP

Launched by NASA
in June 2001

CMB experiments

	COBE/DMR	BOOMERanG	CBI	MAP	Planck
Freq. range	30-90	90-400 GHz	26-36 GHz	22-90 GHz	30-857 GHz
No. of freq. channels	3	4	10	5	9
Angular resolution	7°	10.5'-13'	4'.5-8'	12'.6-66'	5'-33'
Sky coverage	100%	3%	3%	100%	100%
10^{-6} ΔT Sensitivity (10'x10')	20 (in 10°x10°)	~40	~15	~50	~5
Polarisation	no	Future	yes	yes	yes
Raw data size	1 Gbyte	10 Gbyte		1 Tbyte	5 Tbyte
No of pixels	6144	10^5		10^6	$5x10^6$
Time to reduce data	2 yrs	2 yrs		1 yr	1 yr

1st generation — 2nd generation — 3rd generation

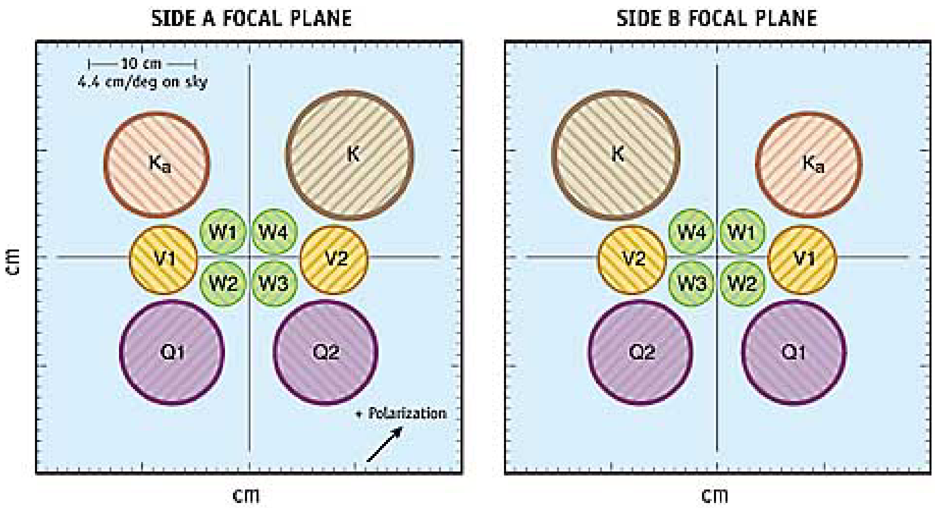
esa

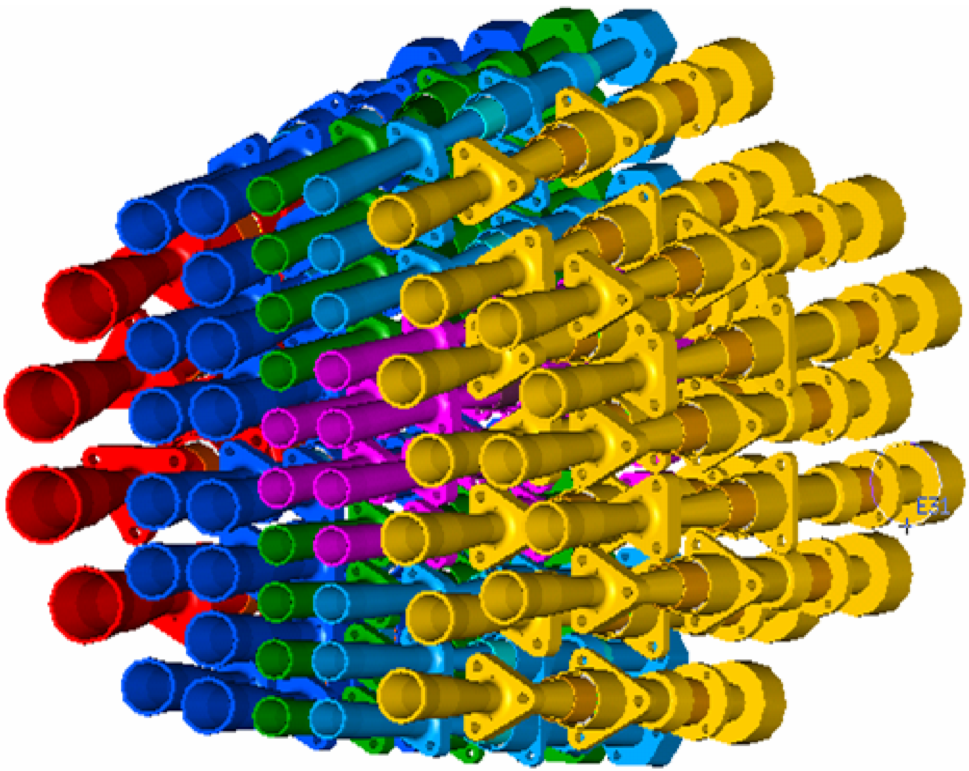
PLANCK

EXPERIMENTAL CHARACTERISTICS

- MAP & PLANCK both **full sky**, at **L2**, with **polarization** capability, making **highly redundant measurements**. **Differences:**
- Resolution: $\sigma_{Beam} \sim 10' \rightarrow 5'$, $\sigma_M/\sigma_P \geq 2$
- Sensitivity: $S = \sigma_{pix}\Omega_{pix}^{1/2} = 11.8\ \mu K.\ deg \rightarrow 0.8\ \mu K.deg$, $S_M/S_P > 10$ (mission duration sensitive, $\propto t^{-1/2}$)
- Frequency coverage: $[30, 44\ 70, 90]_{MAP} \rightarrow [30, 44\ 70, 100]_{LFI} + [100, 143, 217, 354, 550, 857]_{HFI}$, **a new window in space** (and foregrounds control)
- Ground & balloon experiment will continue doing a wonderful job at (very) good σ_B & S on a (relatively low) fraction of the sky (& relatively short duration / 1 year)
- NB:

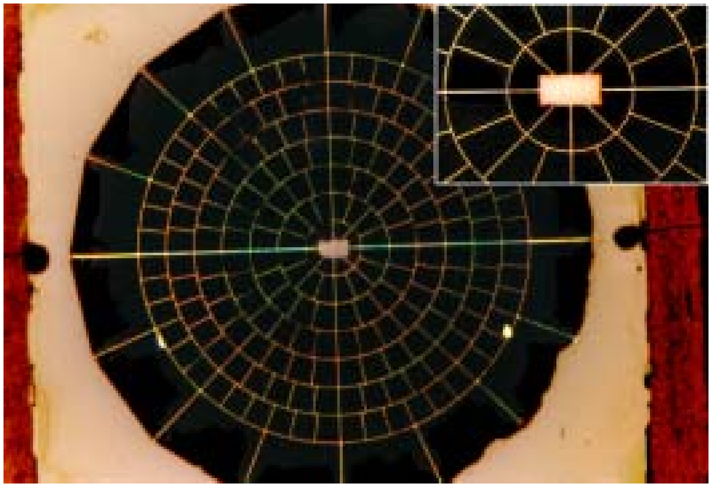
$$F_{ij} = \sum_l \frac{(2l+1) f_{sky}}{2} [C_l + C_N \exp \theta_b^2 (l^2)]^{-2} \ \frac{\partial C_l}{\partial T_j} \frac{\partial C_l}{\partial T_j}, \quad \sigma_i = F_{ii}^{-1/2}$$

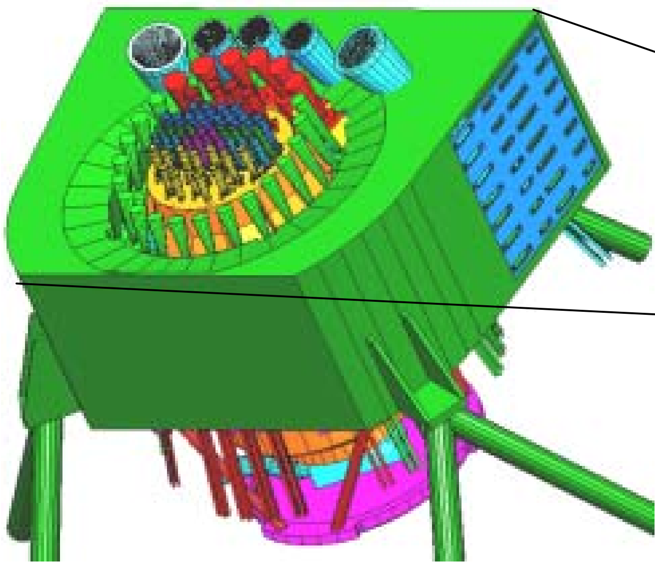




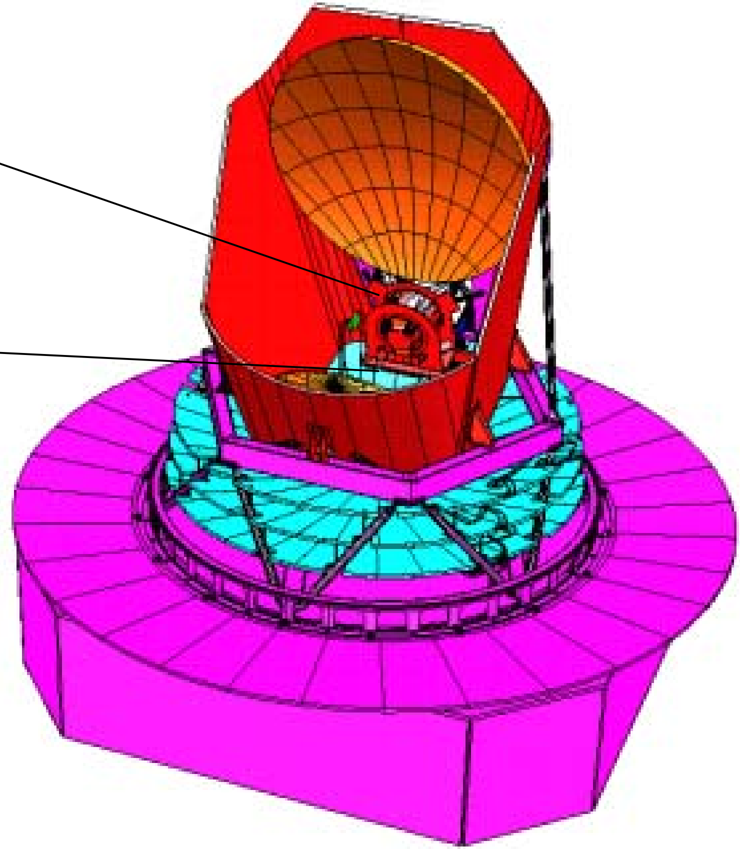
MAP uses passively cooled HEMTS

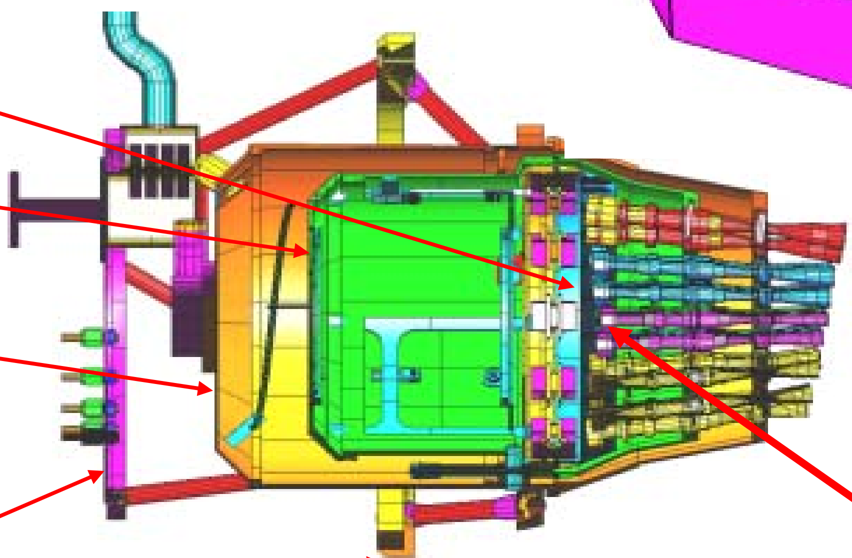
PLANCK HFI uses spider-web bolometers cooled to 0.1 K (LFI uses improved HEMTS)





PLANCK Focal plane





The HFI is built by a French-lead consortium

Planck References (voir aussi cours des Houches, FRB, Lamarre, Puget)

- The « red book » (end of phase A report)
  http://tonno.tesre.bo.cnr.it/Research/PLANCK/Redbook
- AAOs for the instruments
  http://tonno.tesre.bo.cnr.it/Research/PLANCK/ONLY_SOMEONE/AODOCS/intro.html

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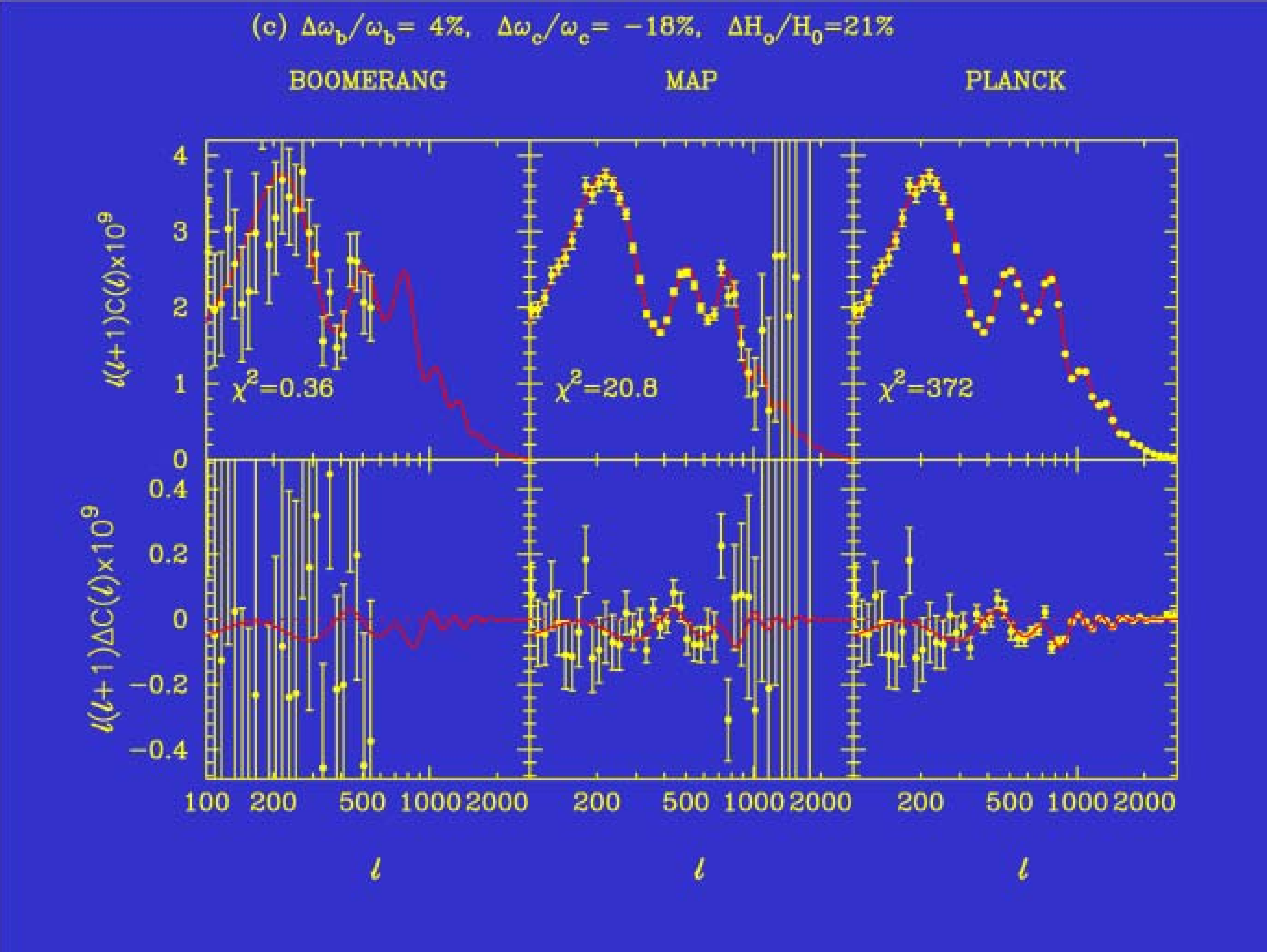
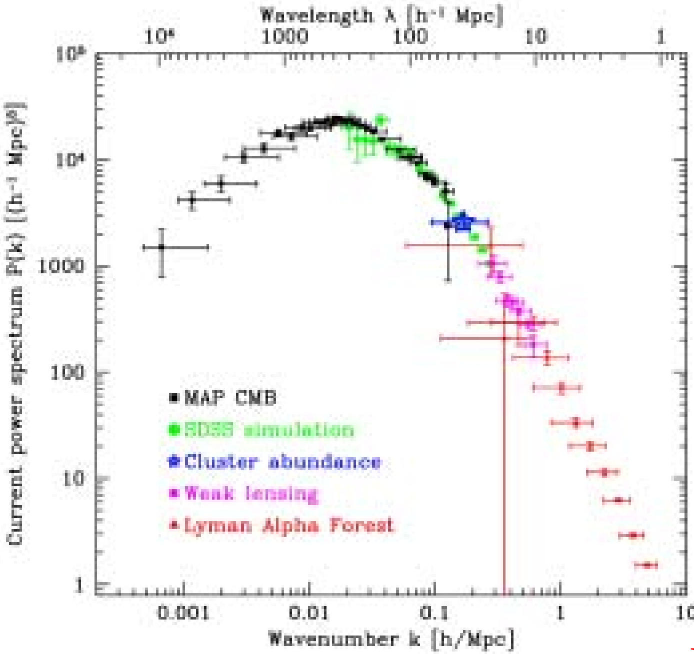
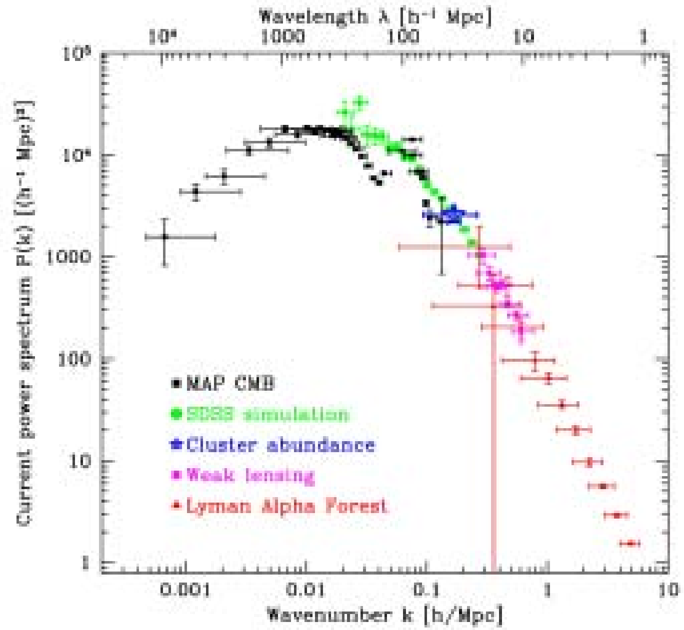
- Science team web pages @ ESTEC
  http://astro.estec.esa.nl/SA-general/Projects/Planck/
- The « blue book » (soon)
  « The scientific program of Planck », as of 2002

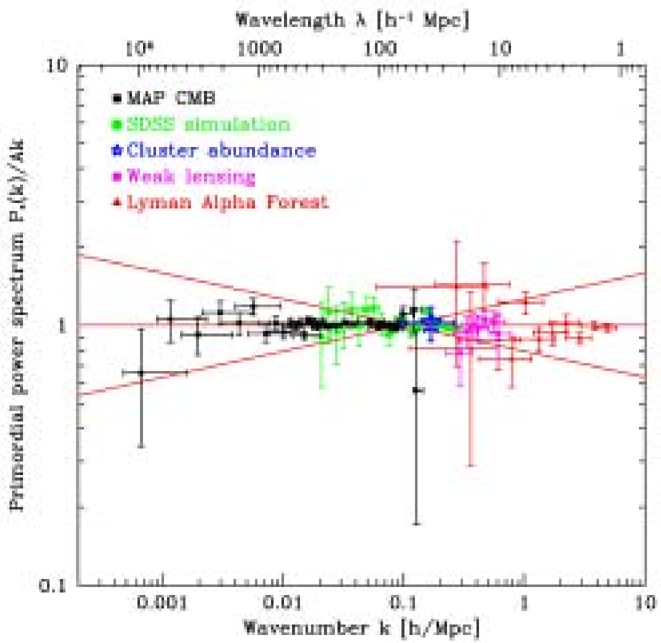


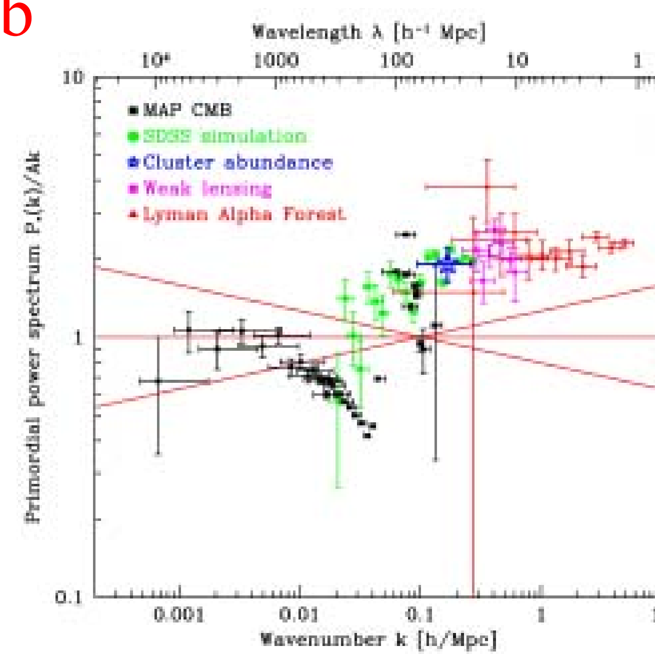
(c) $\Delta\omega_b/\omega_b$= 4%, $\Delta\omega_c/\omega_c$= −18%, $\Delta H_0/H_0$=21%
BOOMERANG
MAP
PLANCK
$\ell(\ell+1)C(\ell)\times10^9$
$\ell(\ell+1)\Delta C(\ell)\times10^9$
χ^2=0.36
χ^2=20.8
χ^2=372
100
200
500
1000
2000
ℓ



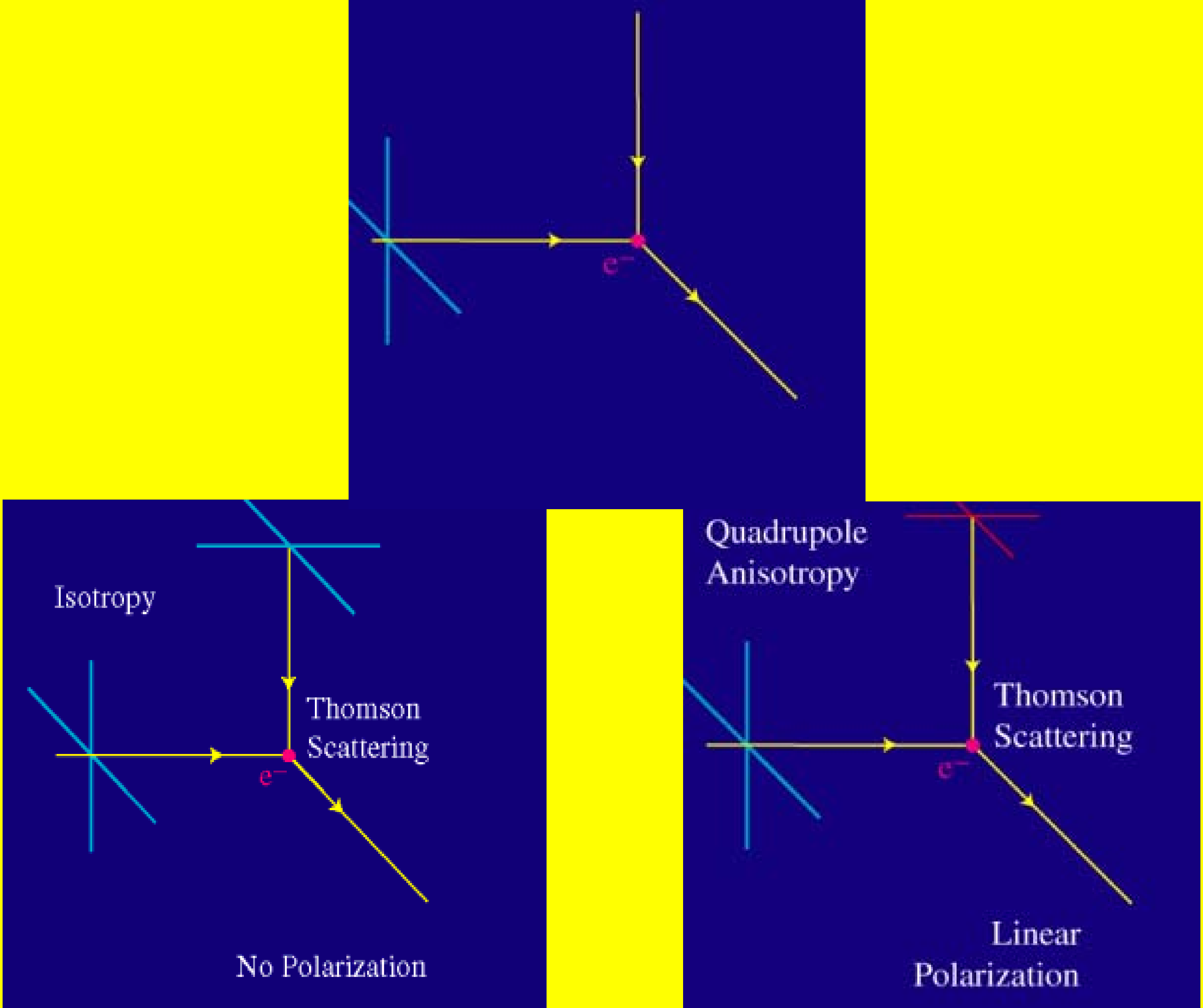


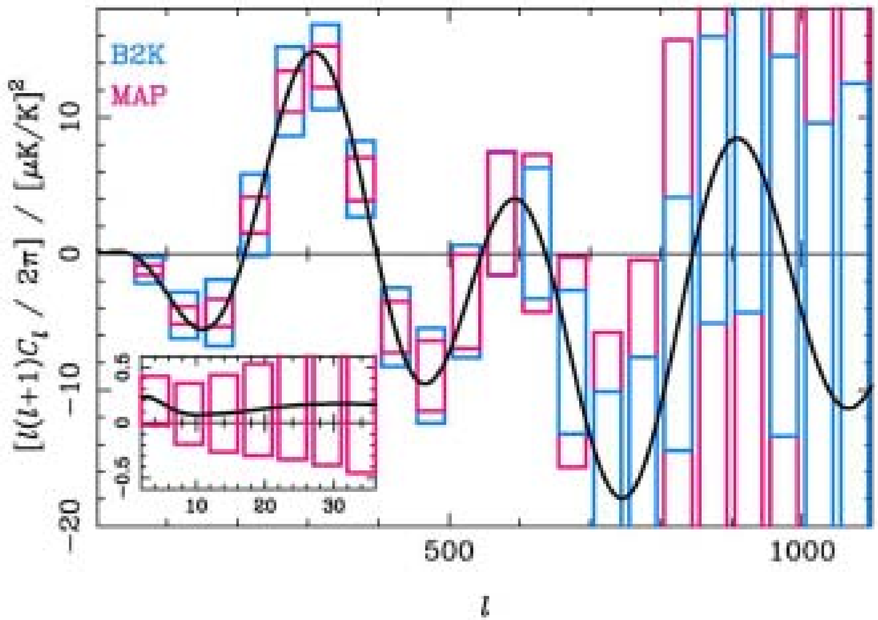
Wrong Ωb

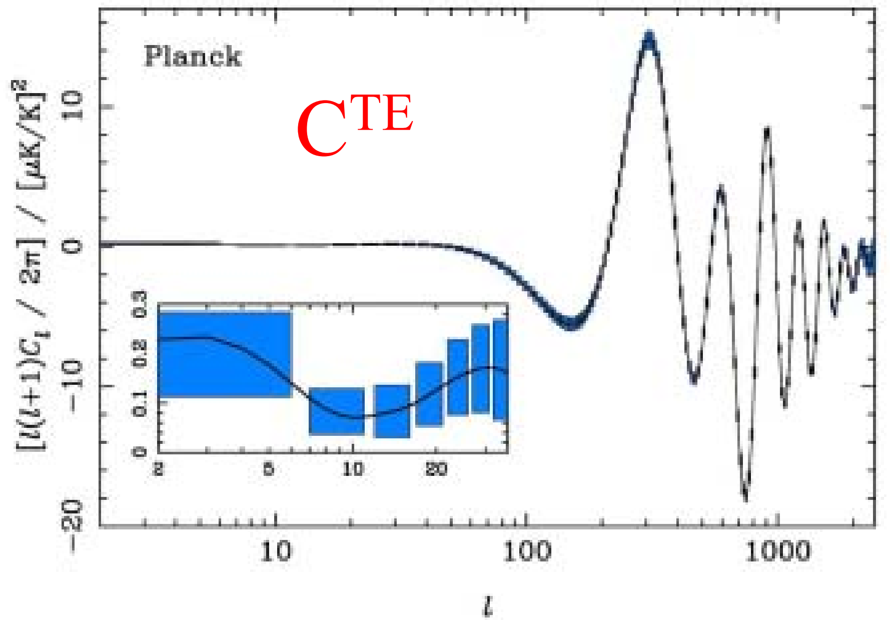




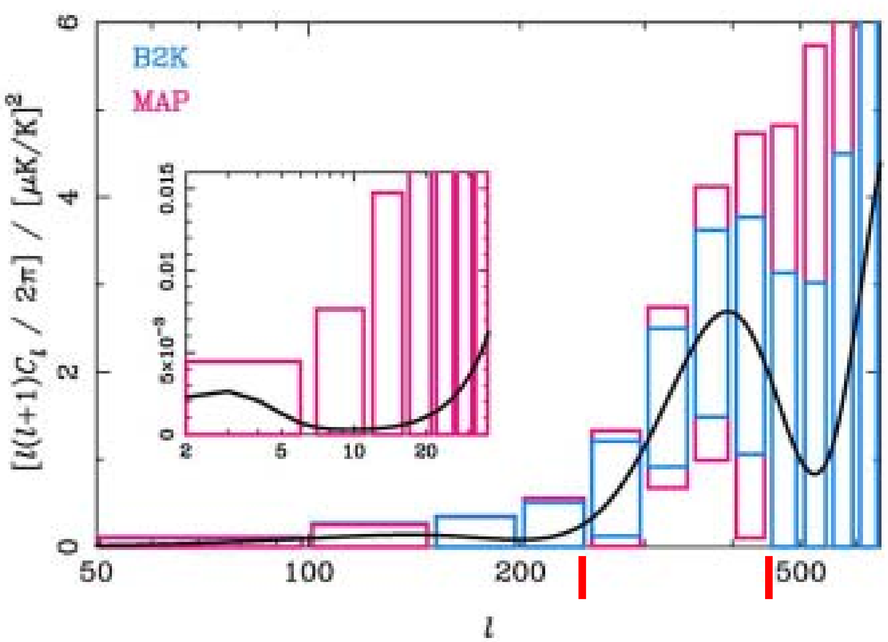
Tegmark & Zaldarriaga, astroph/0207047

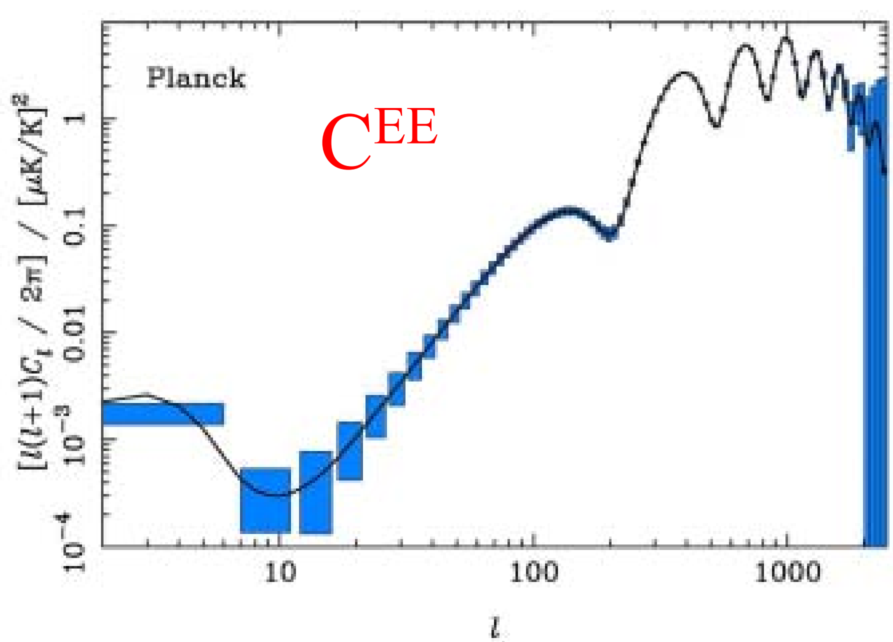

e⁻
Isotropy
Thomson
Scattering
e⁻
No Polarization
Quadrupole
Anisotropy
Thomson
Scattering
e⁻
Linear
Polarization

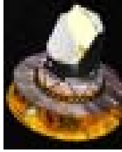




COMPARISONS OF *PROJECTED* C(l) SENSITIVITIES



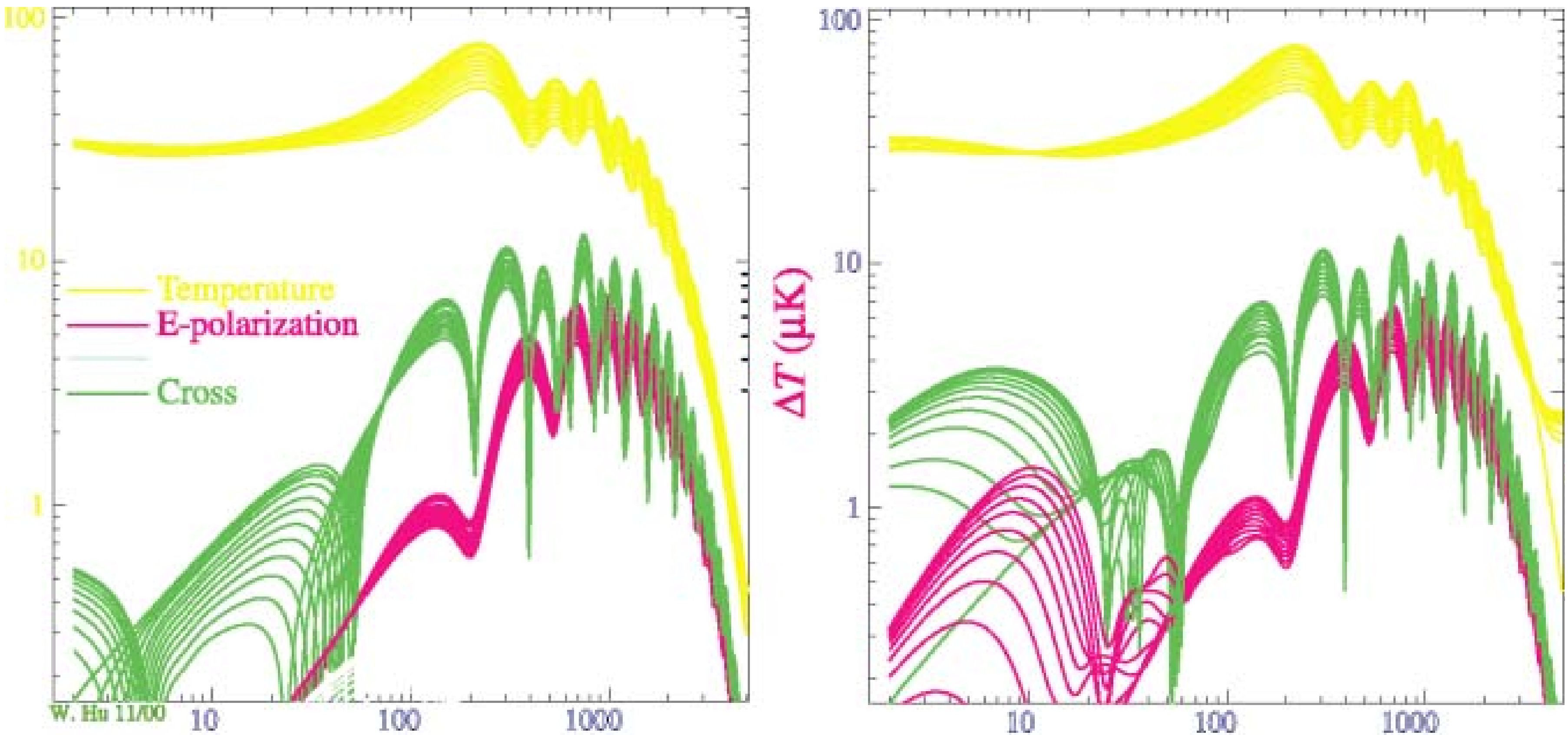




DEGENERACIES

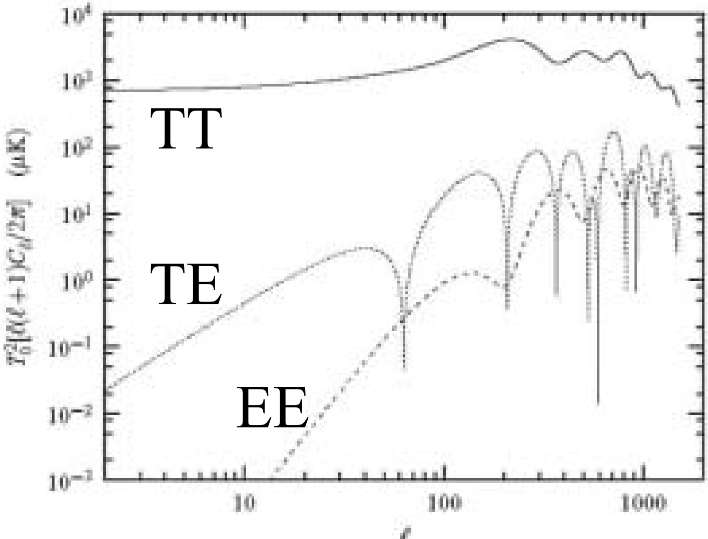
T/S ratio and reionisation optical depth have rather similar effects on the temperature C(*l*) since most of the difference is at low *l* where cosmic variance is largest …
This degeneracy may be lifted by looking at other signature of reionisation, i.e.

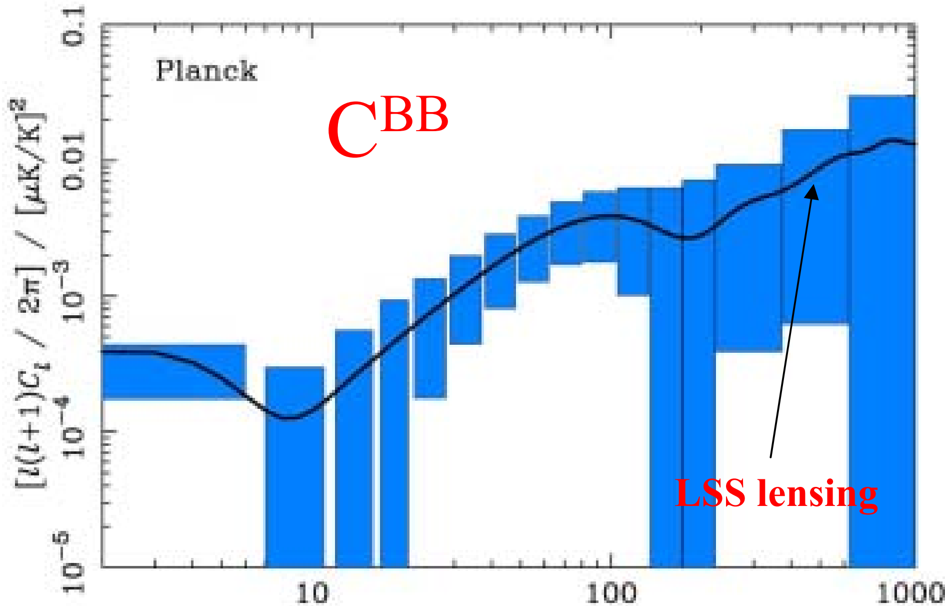
- Small scale temperature signatures (here OV)
- Large scale polarisation signature



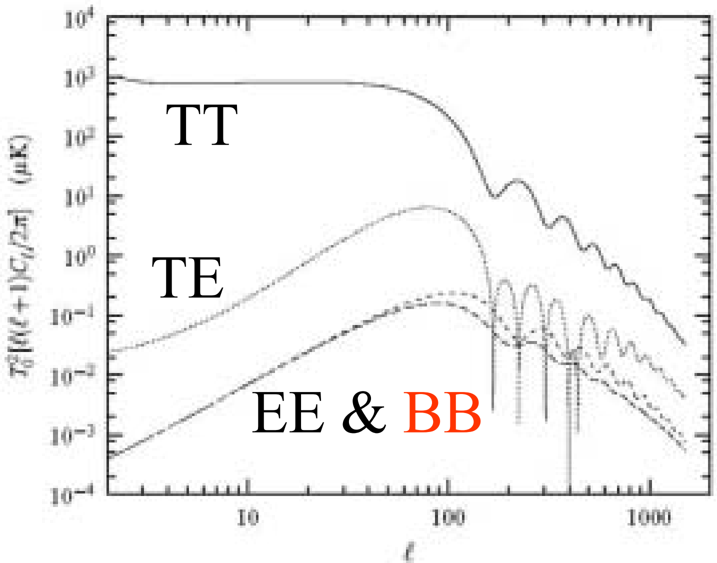
B-TYPE POLARISATION, Smoking gun of a Primordial gravity wave Background

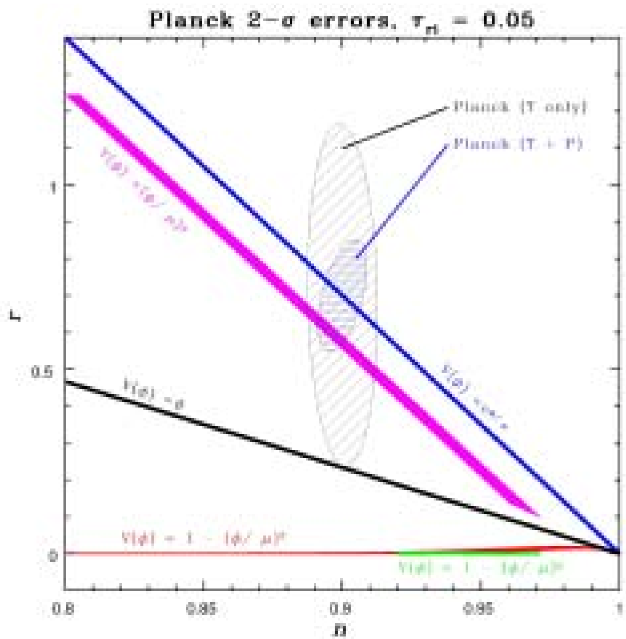
Scalar Modes





Tensor Modes



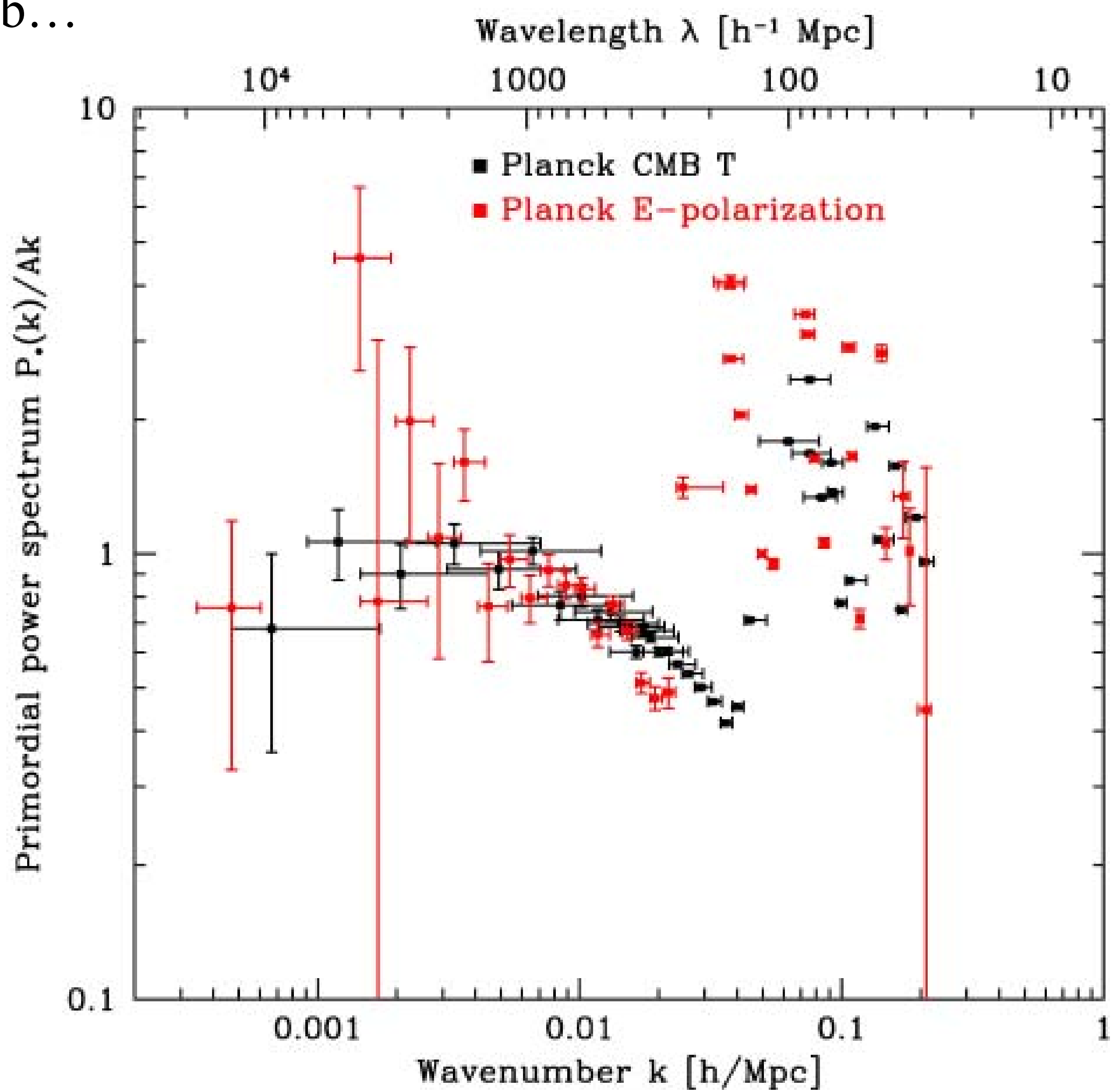


(Figs above from Thèse Riazuelo)

USING THE C(l)…

- Suppose the minimal model (standard inflation) holds; then :
  - Measure the parameters with phenomenal precision (if no inconsistency appears)
  - Verify consistency with other « clean »probes like gravitational lensing, anf if OK, refine even further the parameters determinations
  - Check consistency with more indirect probes, and extract from that "gastrophysical" lessons…
- Consider weak deviations around the minimal model by relaxing priors (prejudice?) on (the absence of) extra degrees of freedom (e.g. isocurvature modes, topological defects, extra scales in IC spectrum…)
- Consider more radical deviations as in brane cosmologies [e.g. $H^2=8\pi/3(\rho+\rho^2/\sigma)$ for Randall-Sundrum type models], although detailed predictions might turn out difficult to compute (e.g. C.S.)
- All tastes should be represented in a collaboration like Planck with ~ 350 physicists (today).
- NB: C(l) is only a first moment (transform of 2-pt correlation function)

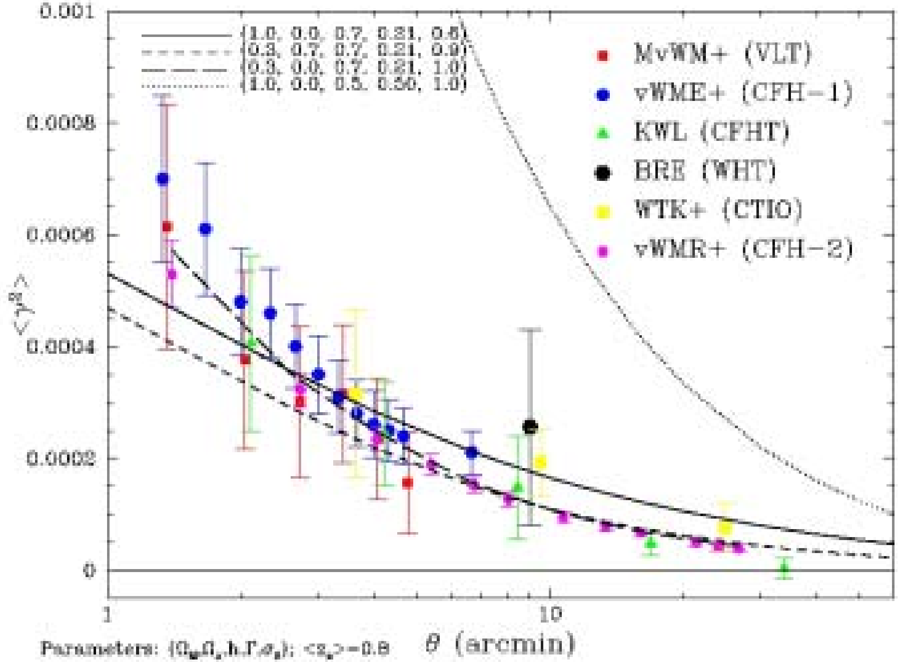
Wrong Ωb…



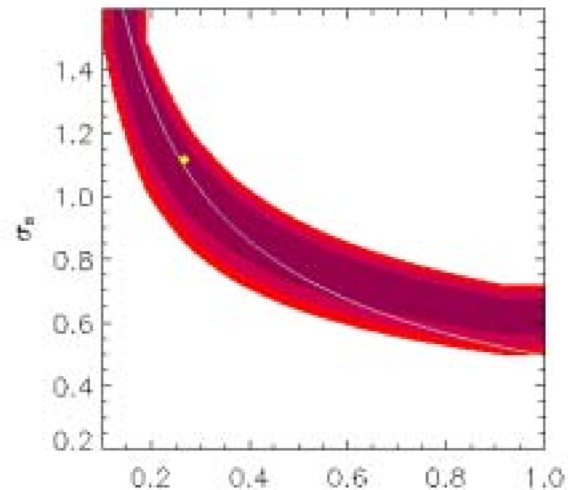
(h^2 Ωb=0.07 instead of 0.021)

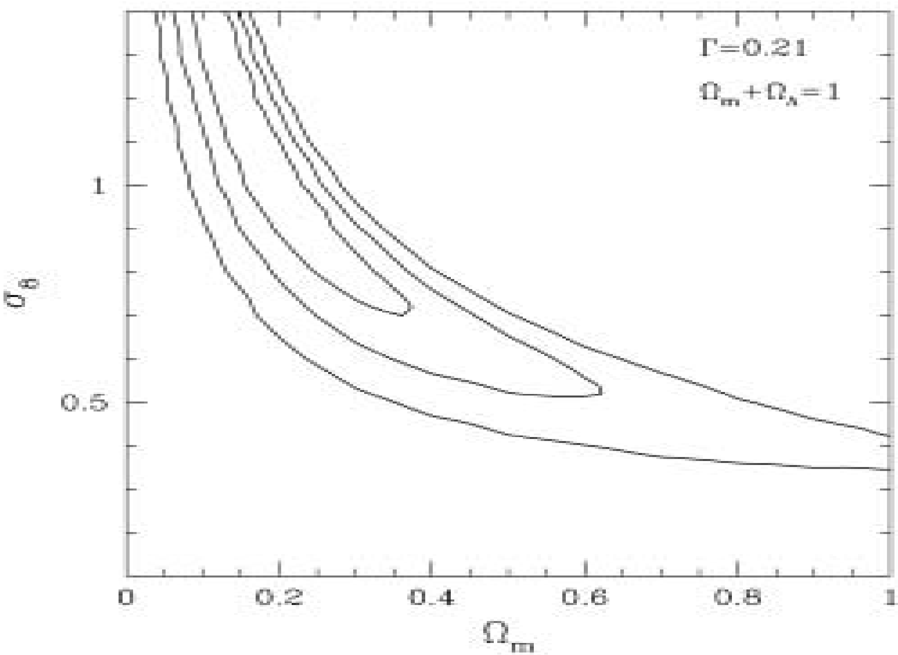
Tegmark & Zaldarriaga, astroph/0207047

LENSING



Maoli, van Waerbeke, Mellier et al 2000





Total area: 5.5 deg^2 **75 uncorrelated fields**

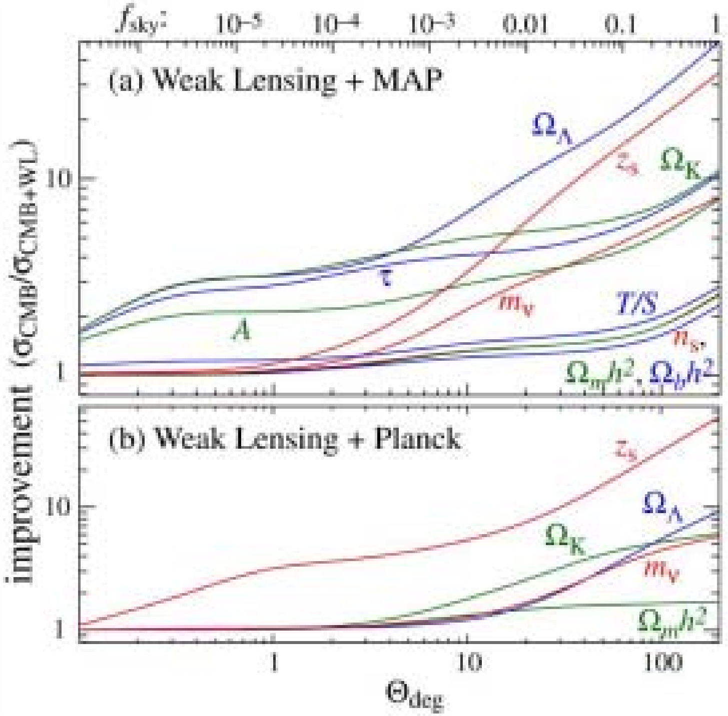
Red Sequence Cluster Survey, (RCS) using shear top hat measures

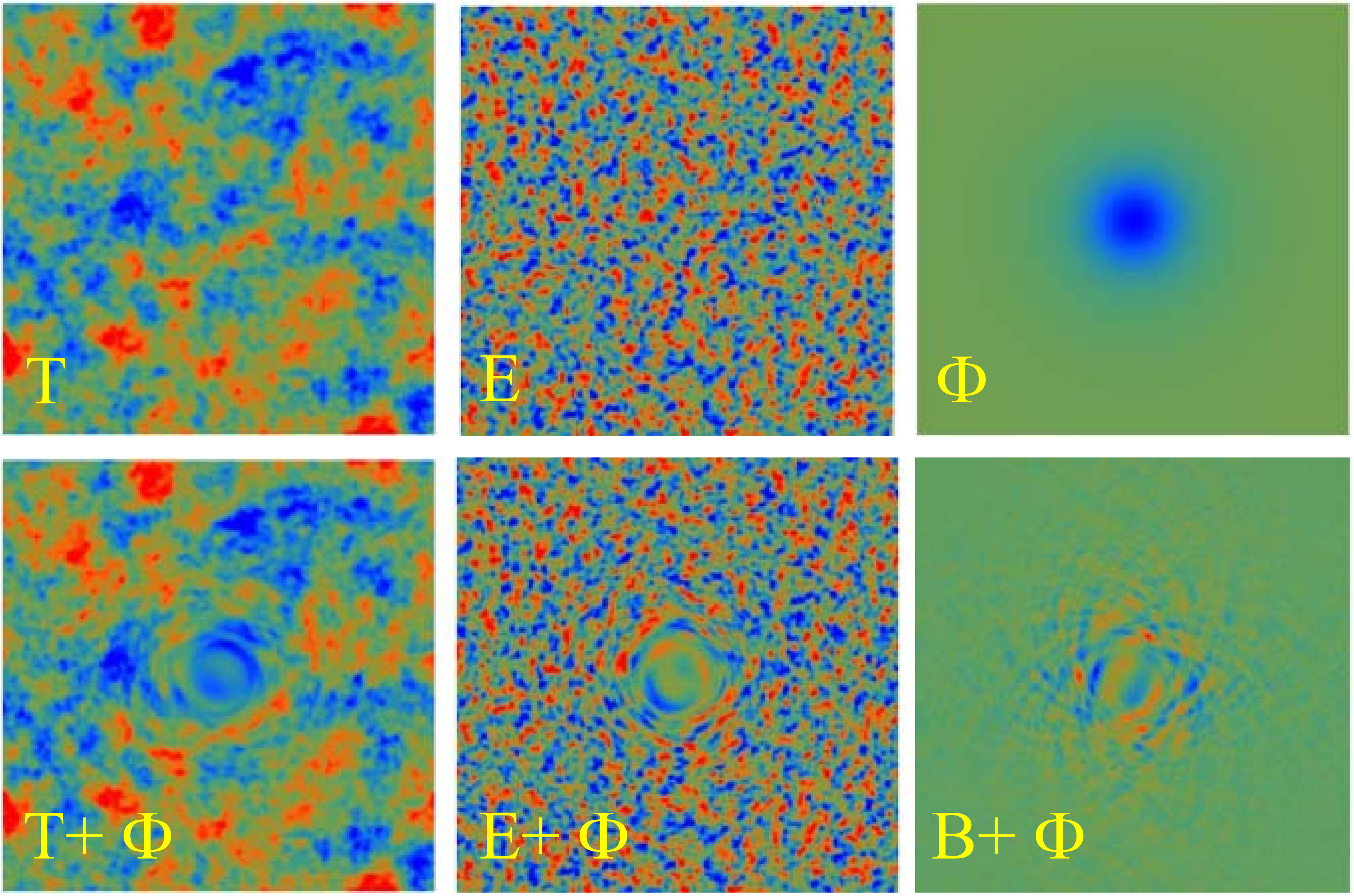
WEAK LENSING POWER SPECTRUM

- Although rather featureless, can give interesting clean constraints on cosmological parameters
- Errors $\Delta P_\kappa = [2/(2l+1)f_{sky}]^{1/2} \{P_\kappa + 0.4/<n_{Gal}>\}$ (Kaiser 92, 98)
- Fisher analysis of the lensing power spectrum (Hu&Tegmark 98)
- Shows that can WL surveys nicely complement CMB missions in helping break the degeneracies
- *CMB can thus focus more on constraining IC rather than $\{\theta\}$.*

Full-sky weak lensing survey compared with CMB satellites[1]

$\sigma(p_i)$	WL	MAP	Planck
$\sigma(\Omega_m h^2)$	0.024 (430)	0.029	0.0027
$\sigma(\Omega_b h^2)$	0.0092 (310)	0.0029	0.0002
$\sigma(m_\nu)$	0.29 (230)	0.77	0.25
$\sigma(\Omega_\Lambda)$	0.079 (180)	1.0	0.11
$\sigma(\Omega_K)$	0.096 (200)	0.29	0.030
$\sigma(n_S)$	0.066 (470)	0.1	0.009
$\sigma(\ln A)$	0.28 (310)	1.21	0.045
$\sigma(z_s)$	0.047 (56)	(1)	(1)
$\sigma(\tau)$	–	0.63	0.004
$\sigma(T/S)$	–	0.45	0.012
$\sigma(Y_p)$	(0.02)	(0.02)	0.01




T
E
Φ
T+ Φ
E+ Φ
B+ Φ

CMB POL X WL

Polarization vector Π =(Q, U) under WL $\rightarrow$ P(θ) = $\Pi(\theta+\xi)$

$$\Delta B = -\,2\epsilon_{ij}(\gamma^i\Pi^j + \gamma^i_{,k}\Pi^{j,j}) = -\,2(b_\Delta + b_\nabla)$$ γ=WL shear field

Estimate b's from γ probed by WL surveys. Thus one can measure cross-correlation between two lensing "planes", e.g.:

$$\chi_\Delta = \frac{<\kappa\ \kappa_G>}{<\kappa^2_G>} \quad \text{since} \quad \chi_\Delta == \frac{<\delta B\ \ b_\Delta>}{<\Delta E^2><\kappa^2_G>}$$

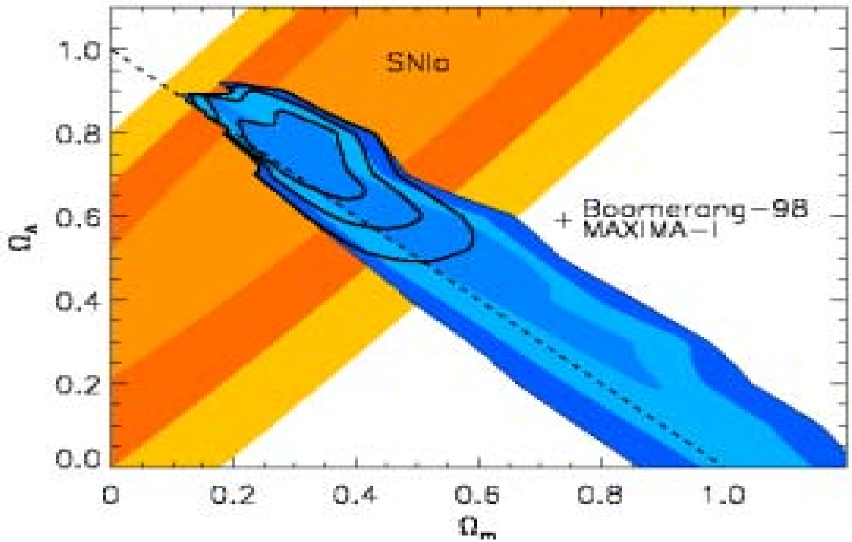
E, B, P are *observed* quantities. Similar expressions with the other b

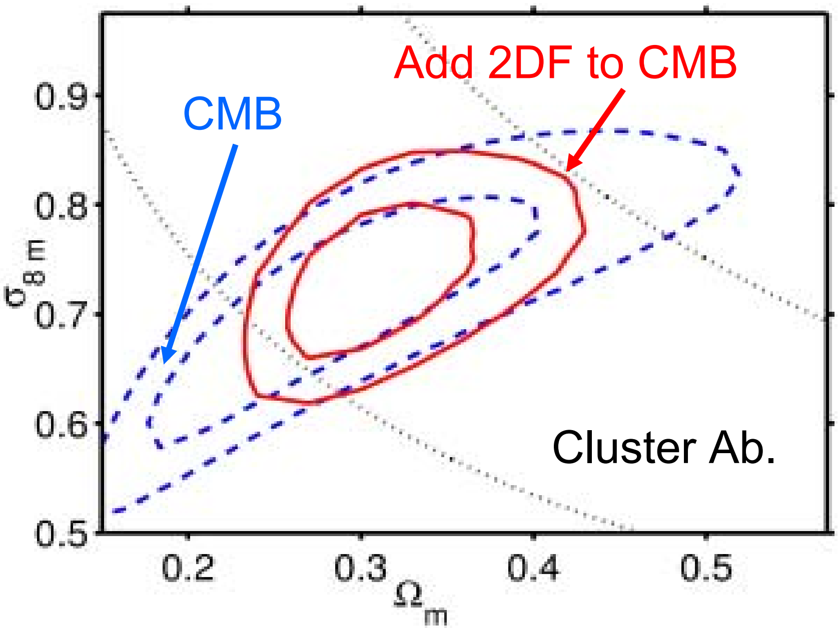
Good news: cosmic variance, for a realistic WL survey size of 100 deg^2 is around 5% for ~ 5 armin resolution

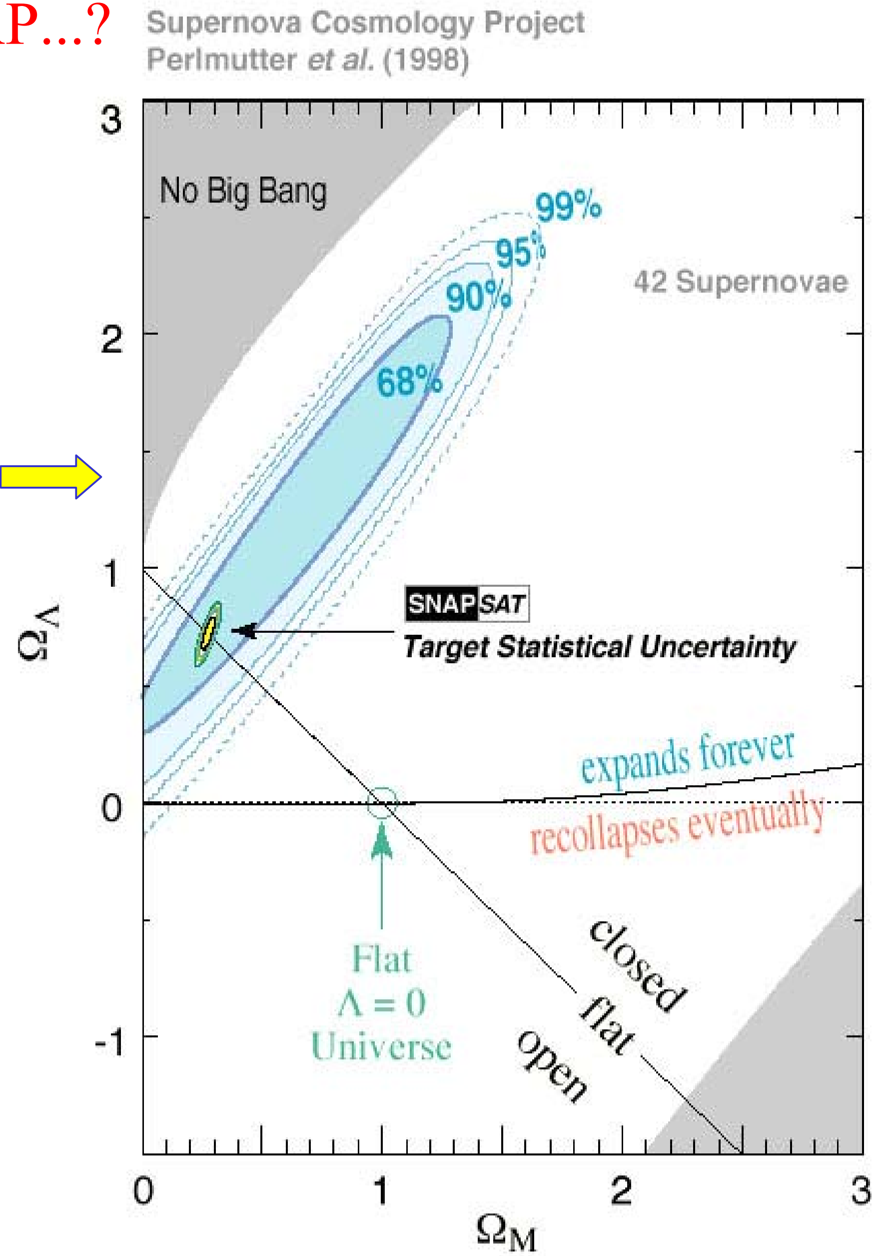
Benabed, Bernardeau, van Waerbeke [0003038]

Since testing lengths of arms of optical bench : rather sensitive to Ω_Λ

WILL CONSISTENCY KEEP HOLDING AT THE LEVEL OFFERED BY PLANCK, SDSS, CFHLS, SNAP...?

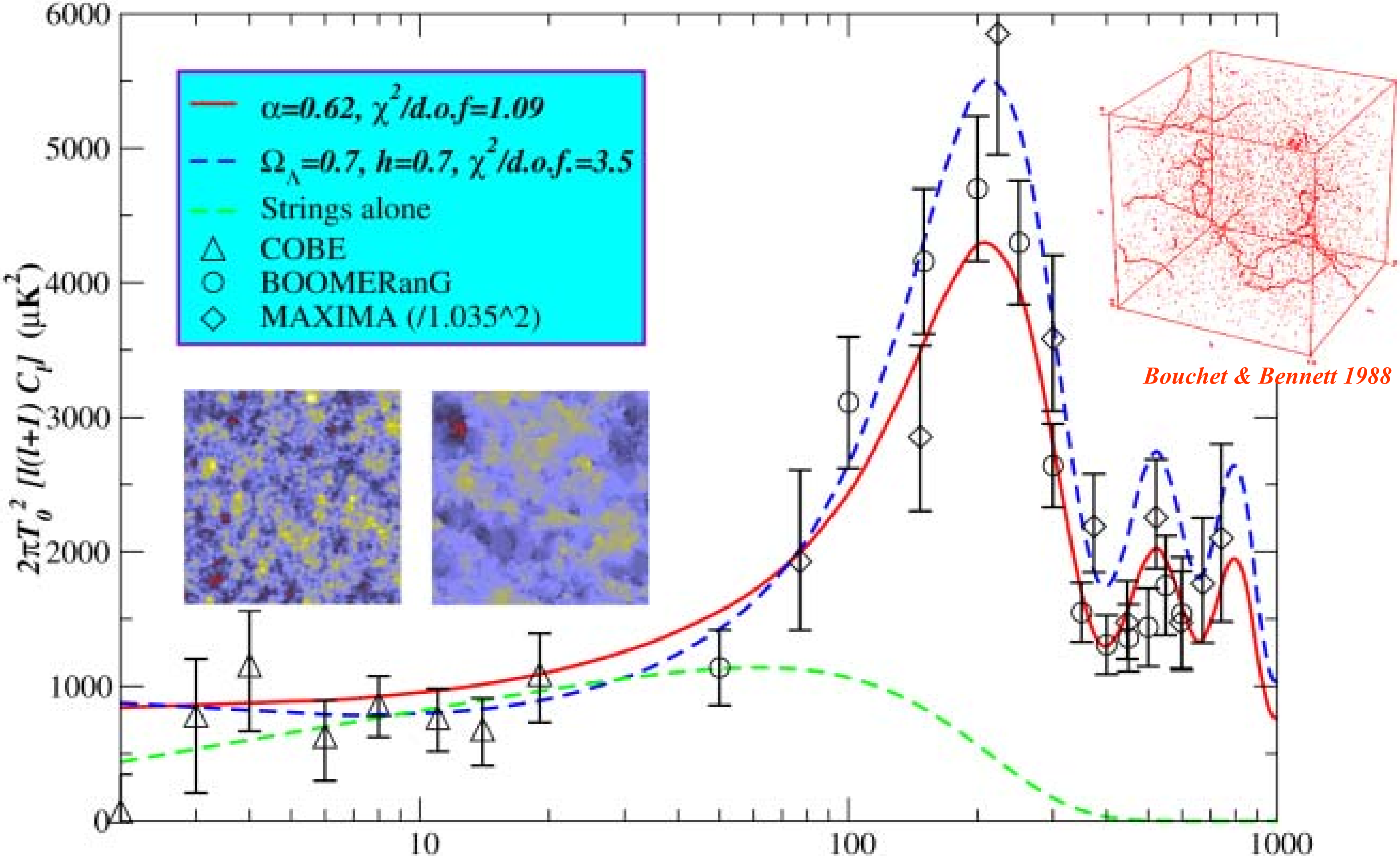






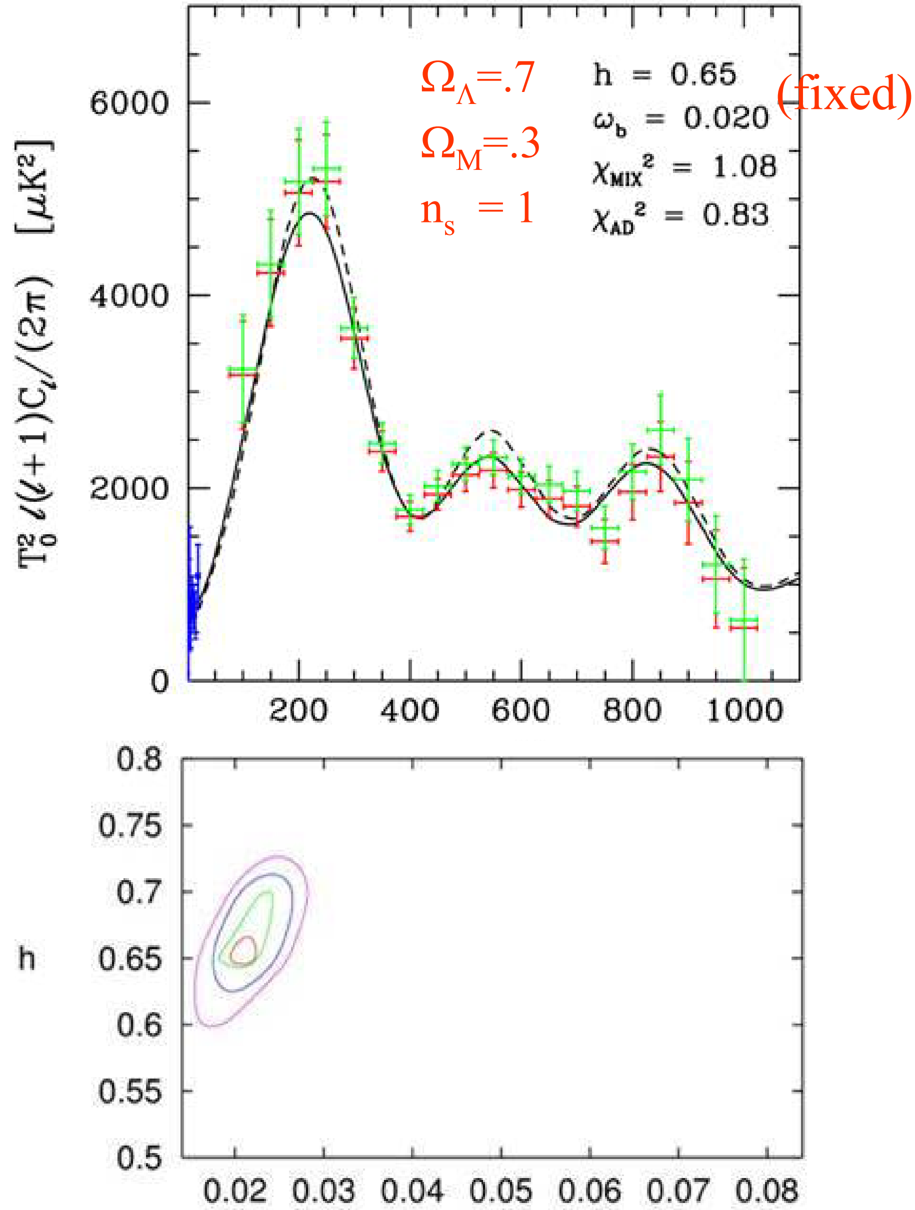
ISOCURVATURE DEGENERESCENCE VS MAP & PLANCK

Best fit with BOOMERanG and MAXIMA



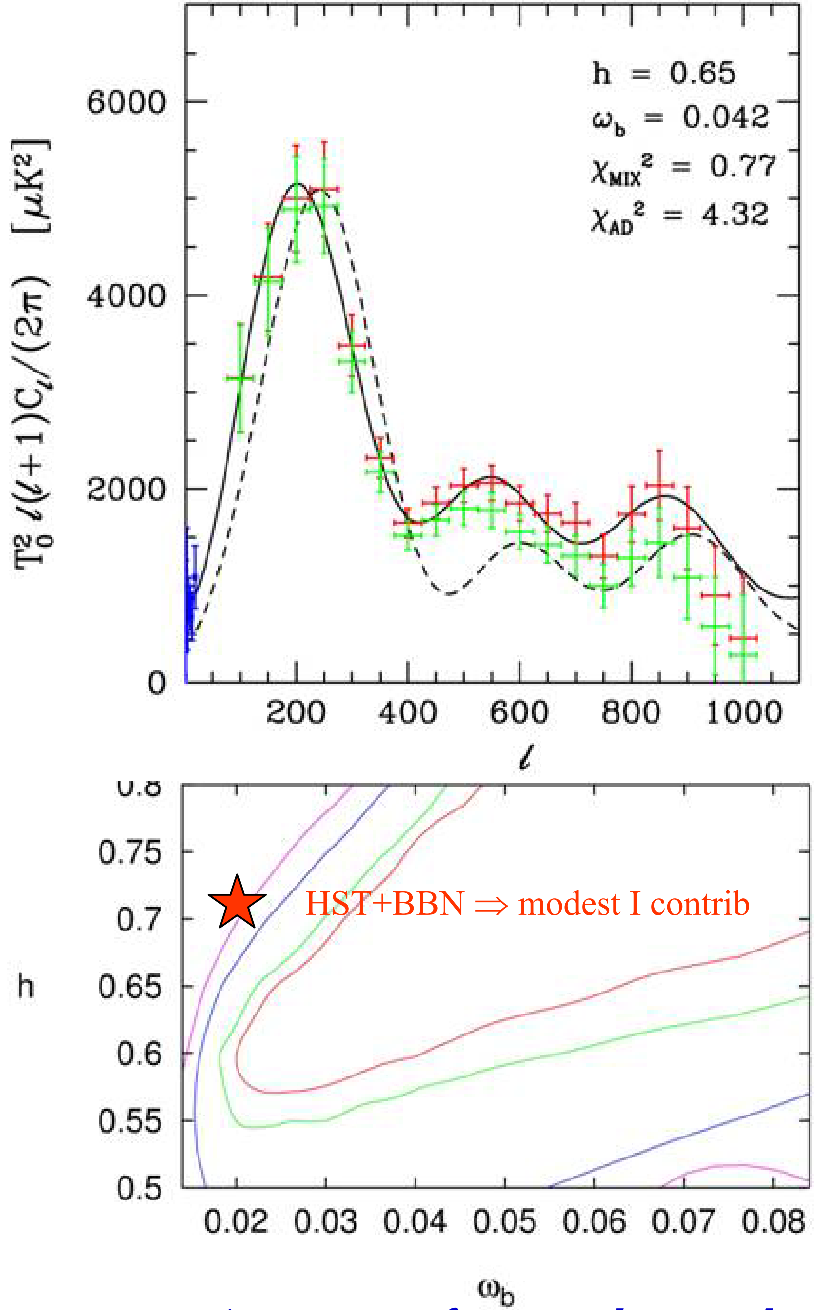
En attente de la thèse de C. Ringeval (05/07/02) pour faire (beaucoup?) mieux…

Bouchet, Peter, Riazuelo, Sakellariadou 2000



Mix à la Bucher et ω_b al. [0007360]

(Bucher et al. [0012141], δΩk 2%→577%!)



Trotta, Riazuelo, Durrer [0104017]

ISOCURVATURE MODES WITH SAME POWER-LAW I.C.

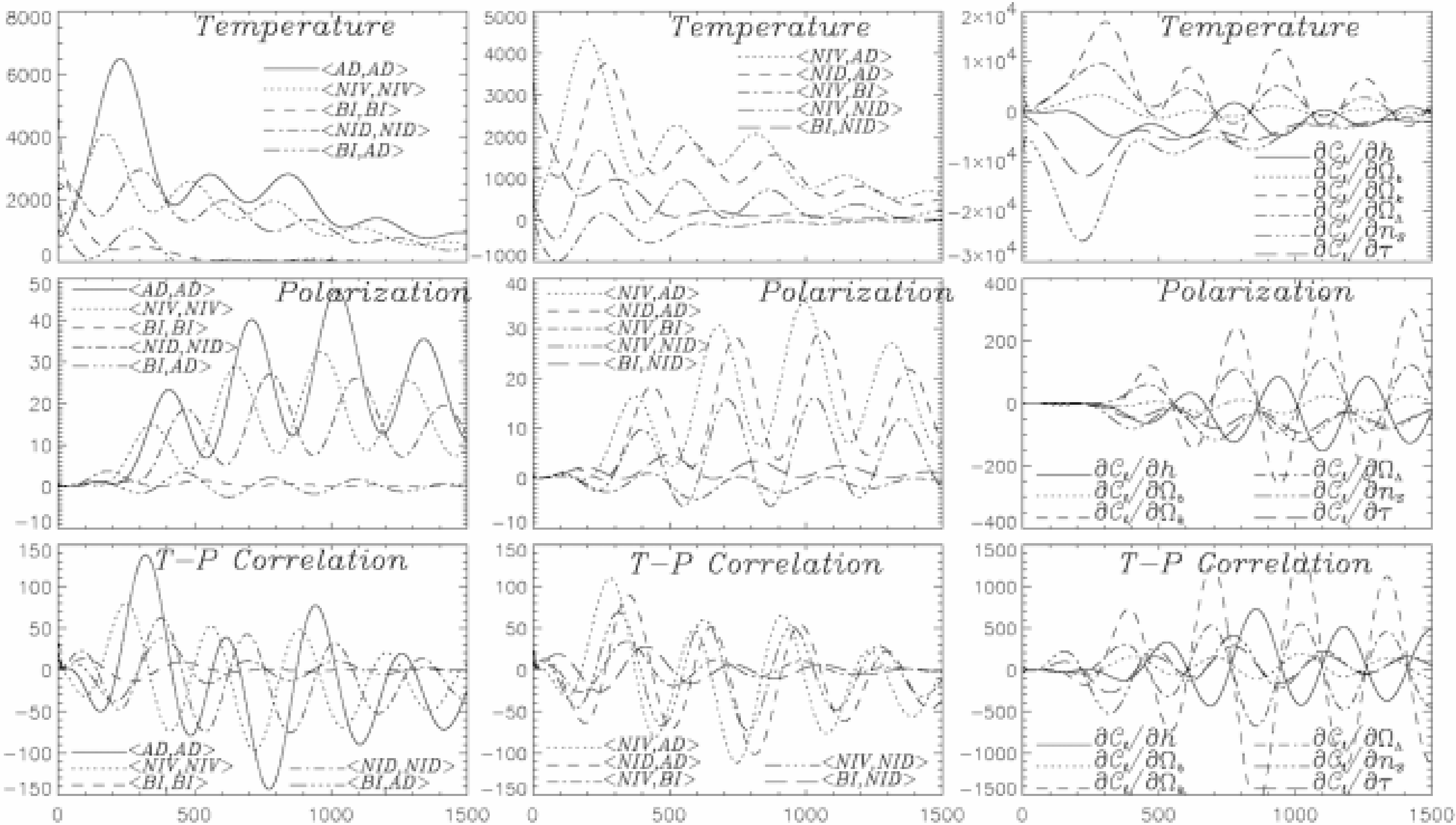


FIG. 1. CMB multipole spectra for the various modes, their cross-correlations, variations in the cosmological parameters. From top to bottom the rows show $l(l+1)C_l/2\pi$ for the temperature, polarization, and temperature-polarization cross correlation, respectively, in μK. The C_l spectra for the various modes and their cross correlations are shown in the first two columns. The rightmost column shows the derivatives of the spectra with respect to the different cosmological parameters. The modes are indicated as follows: adiabatic (AD), neutrino isocurvature velocity (NIV), baryon isocurvature (BI), and neutrino isocurvature density (NID). A fiducial model with the parameter choices $\Omega_b = 0.06$, $\Omega_\Lambda = 0.69$, $\Omega_{cdm} = 0.25$, $h = 0.65$, $\tau_{reion} = 0.1$ and $n_s = 1$ has been assumed. Because the CDM isocurvature mode produces a spectrum nearly identical to that of the BI mode, it is not considered separately.

Bucher, Moodley, Turok, astroph/0012141

	MAP T adia only	MAP TP adia only	MAP T all modes	MAP TP all modes	PLANCK T adia only	PLANCK TP adia only	PLANCK T all modes	PLANCK T+P all modes	PLANCK TP all modes
$\delta h/h$	12.37	7.42	175.84	20.40	9.93	3.69	40.13	7.31	4.36
$\delta\Omega_b/\Omega_b$	27.76	13.34	325.38	28.57	19.37	7.26	68.85	14.42	8.61
$\delta\Omega_k$	9.79	2.72	75.32	4.55	4.92	1.83	20.56	3.59	2.18
$\delta\Omega_\Lambda/\Omega_\Lambda$	12.92	5.02	123.63	18.53	2.74	1.21	5.93	2.45	1.49
$\delta n_s/n_s$	7.02	1.62	89.89	6.53	0.73	0.37	3.92	0.90	0.70
τ_{reion}	37.39	1.81	104.81	2.23	8.25	0.41	35.35	0.74	0.56
$\langle NIV, NIV\rangle$	..	..	114.34	11.47	..	..	43.45	1.36	1.14
$\langle BI, BI\rangle$	..	..	573.46	29.71	..	..	53.29	6.16	4.23
$\langle NID, NID\rangle$	..	..	351.79	29.87	..	..	19.18	4.77	2.37
$\langle NIV, AD\rangle$	..	..	434.70	44.06	..	..	121.59	8.21	4.69
$\langle BI, AD\rangle$	..	..	1035.02	59.25	..	..	58.75	15.03	8.97
$\langle NID, AD\rangle$	..	..	1287.60	67.49	..	..	114.39	13.87	5.77
$\langle NIV, BI\rangle$	..	..	601.70	32.29	..	..	46.91	7.72	3.67
$\langle NIV, NID\rangle$	..	..	744.00	46.46	..	..	80.01	7.55	2.97
$\langle BI, NID\rangle$	..	..	534.32	39.11	..	..	100.97	7.56	4.60

TABLE I. This table indicates the one sigma percentage errors on cosmological parameters and isocurvature mode amplitudes anticipated for the MAP and PLANCK satellite experiments. In the column headers, T denotes constraints inferred from temperature measurements alone, TP those from the complete temperature and polarisation measurements, and T+P those inferred if temperature and polarisation information is used separately without including the cross-correlation.

Phase space ““““volume””””:

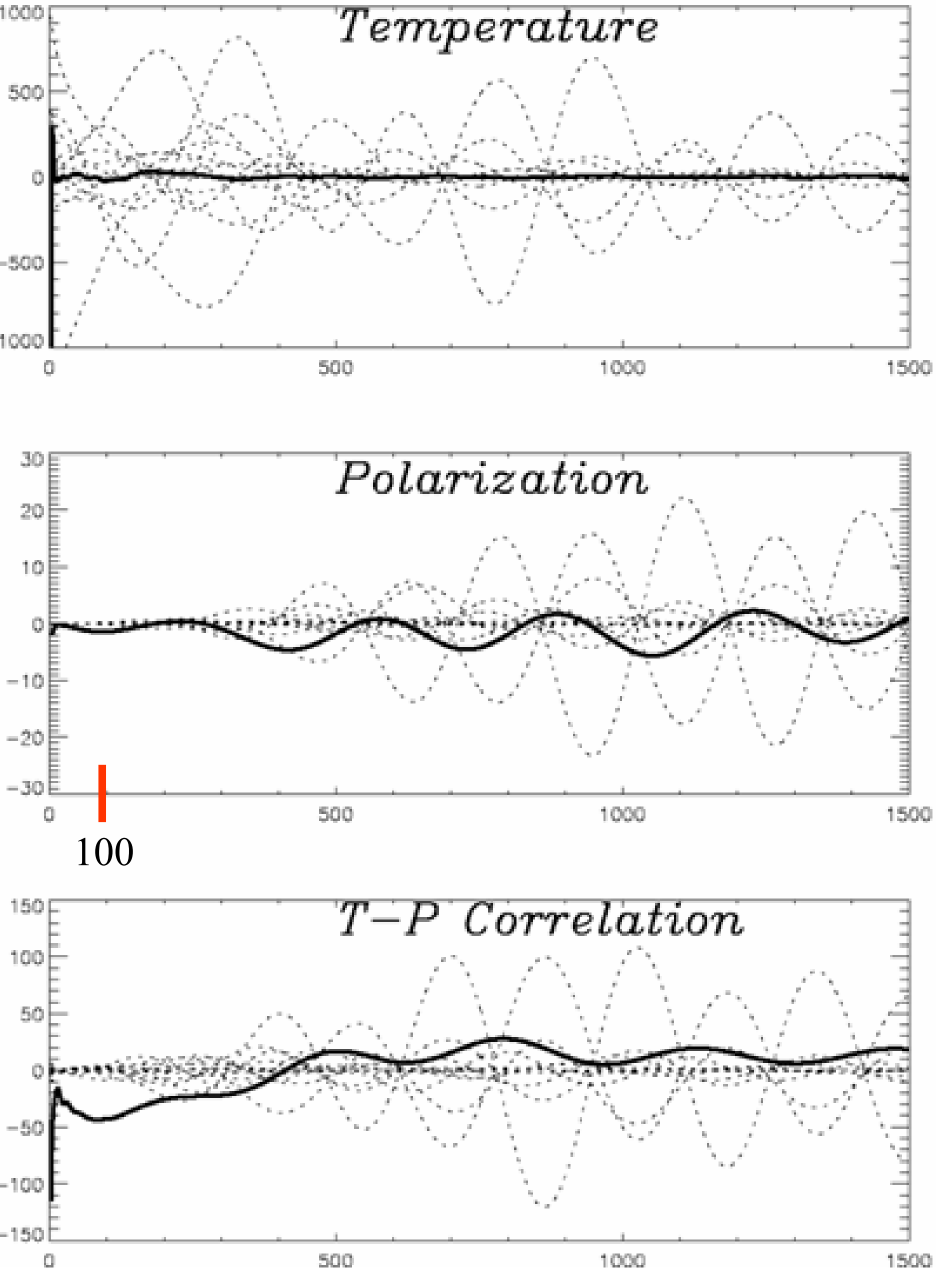
Bucher, Moodley, Turok, astroph/0012141

	M-T-A	M-TP-A	M-T-F	M-TP-F	P-T-A	P-TP-A	P-T-F	P-T+P-F	P-TP-F
V1	1.10^{-5}	4.10^{-9}	5	7.10^{-7}	2.10^{-8}	9.10^{-12}	5.10^{-5}	6.10^{-10}	5.10^{-11}
V2			3.10^{6}	1.10^{-4}			1.10^{-2}	3.10^{-11}	1.10^{-13}
VT			2.10^{7}	8.10^{-11}			6.10^{-7}	2.10^{-20}	7.10^{-24}

NB: Still assuming simple scale-invariant (initial) P(k)…

Contributions to $F_{ii}=1/\sigma_i^2$

for 4 worst principal directions



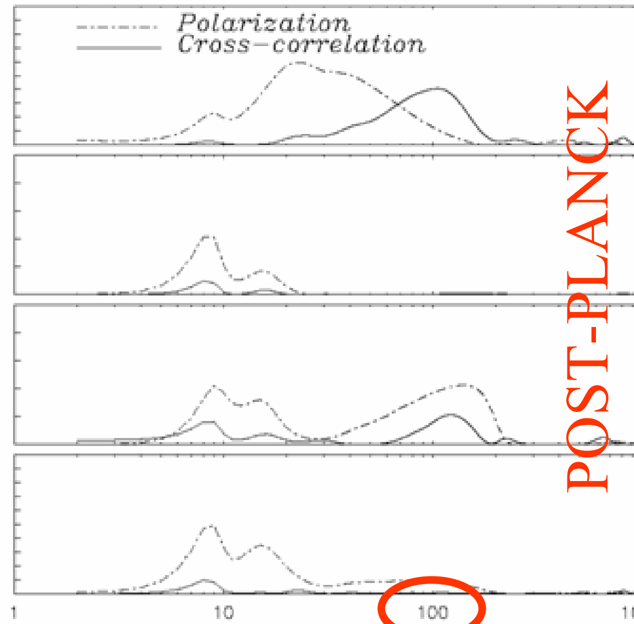
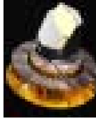


FIG. 3. When only temperature information from PLANCK is taken into account, the uncertainties in the four most poorly measured principal directions are 239%, 60%, 36%, and 23%. These numbers are the inverse square root of the corresponding eigenvalues of the Fisher matrix. When the polarization information anticipated from PLANCK is taken into account as well, these uncertainties are reduced to 11.1%, 10.3%, 6.6%, and 4.6%, respectively. The plots (from top to bottom, respectively) indicate the contributions of the polarisation information at each l to diagonal elements of the Fisher matrix in these directions. The cross correlation contribution is by definition the difference between the total and that obtained from polarisation and temperature information taken separately.

Bucher, Moodley, Turok, astroph/0012141

SECOND ARY EFFECTS

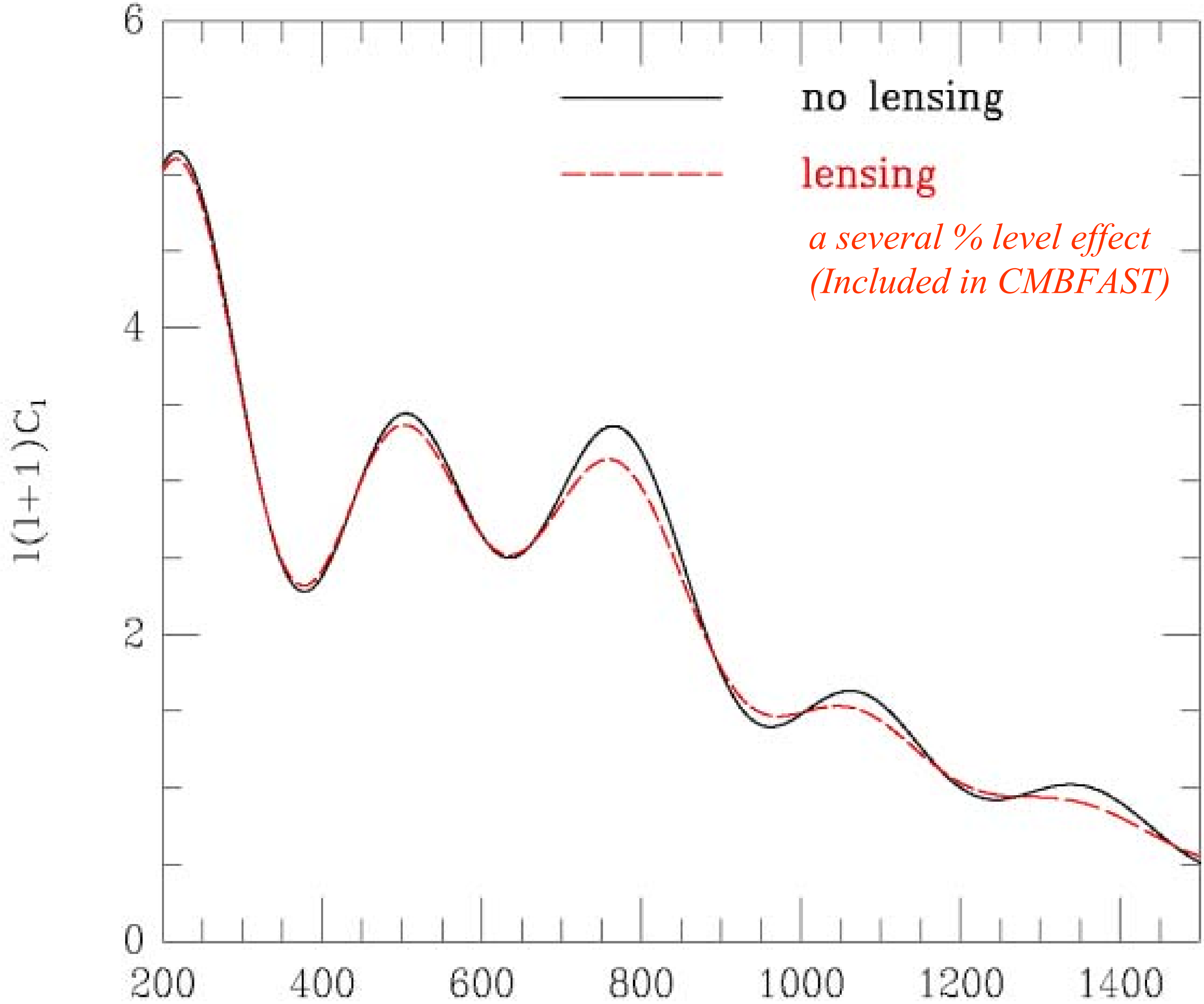
SECONDARY ANISOTROPIES

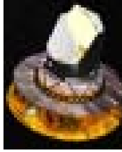


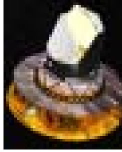
By definition, secondary anisotropies occur after recombination, via two broad types of mechanisms:

- Gravitational effects:
  - Photon path (relative) deflection through Lensing, a smoothing effect
  - Photon path through time-varying potentials
    - Integrated Sachs Wolf effect, or Late ISW (linear, large scales)
    - Rees-Sciama (non-linear, small scales)
    - "Moving lens" effect (Butterfly pattern from clusters, "Kaiser-Stebbins" from strings)
- Thomson (re-) scattering:
  - from Reionisation
    - Damping of the primary (homogeneous)
    - Vishniac-Ostriker (small scale, KSZ of weakly non-linear field)
    - Polarisation generation (large scales)
    - Inhomogeneous reionisation (KSZ from reionised bubble fronts)
  - from hot gas within LSS: (Late) Kinetic SZ (from clusters, filaments)

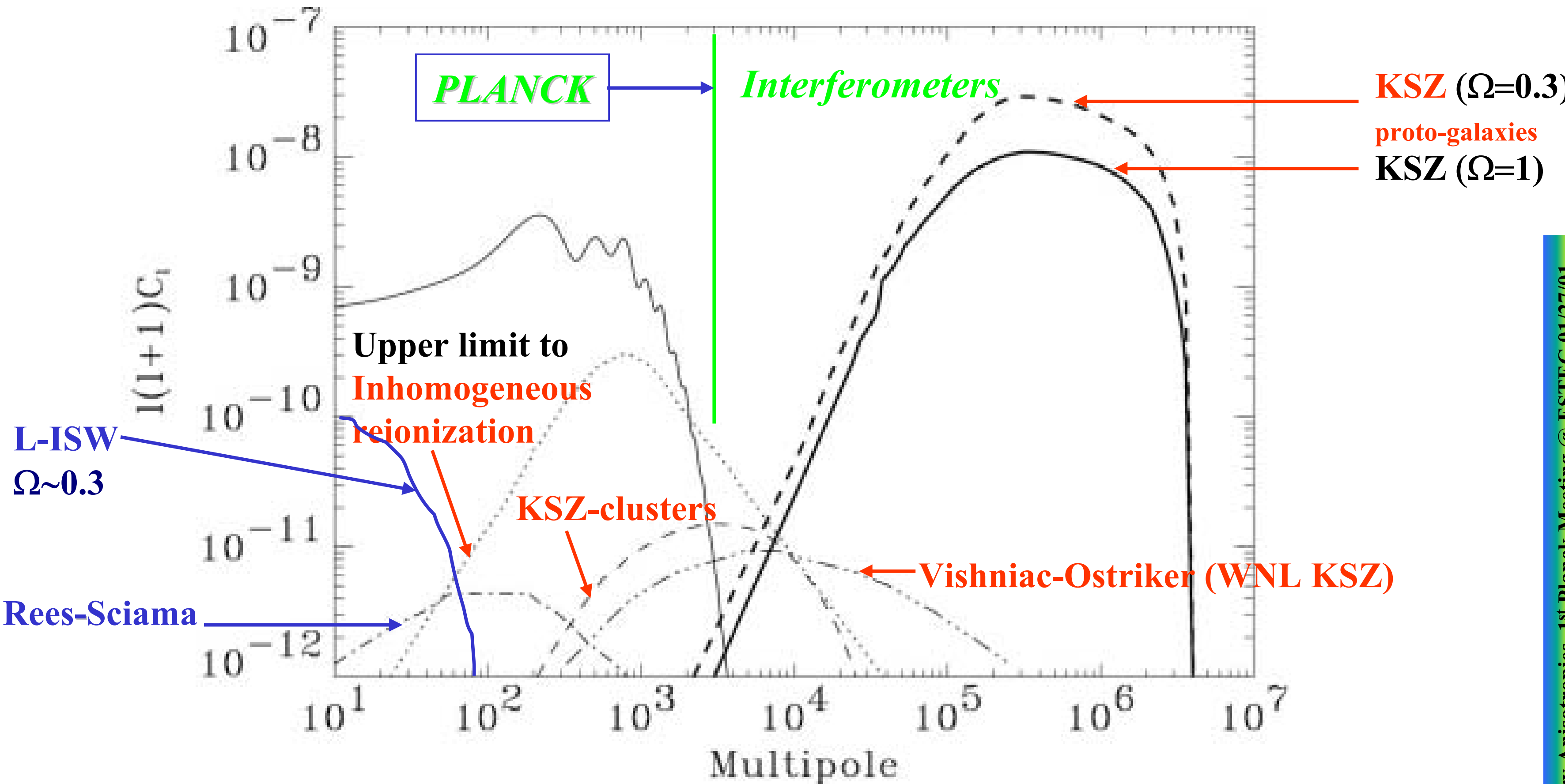
NB: Most effects are weak and are coming, or are traced by, from the same (low-z) structures. Analyses will thus be difficult, since effects will be intertwined, but we can (maybe) learn a lot…


no lensing
lensing
a several % level effect
(Included in CMBFAST)
l(l+1)C_l
0
2
4
6
200
400
600
800
1000
1200
1400





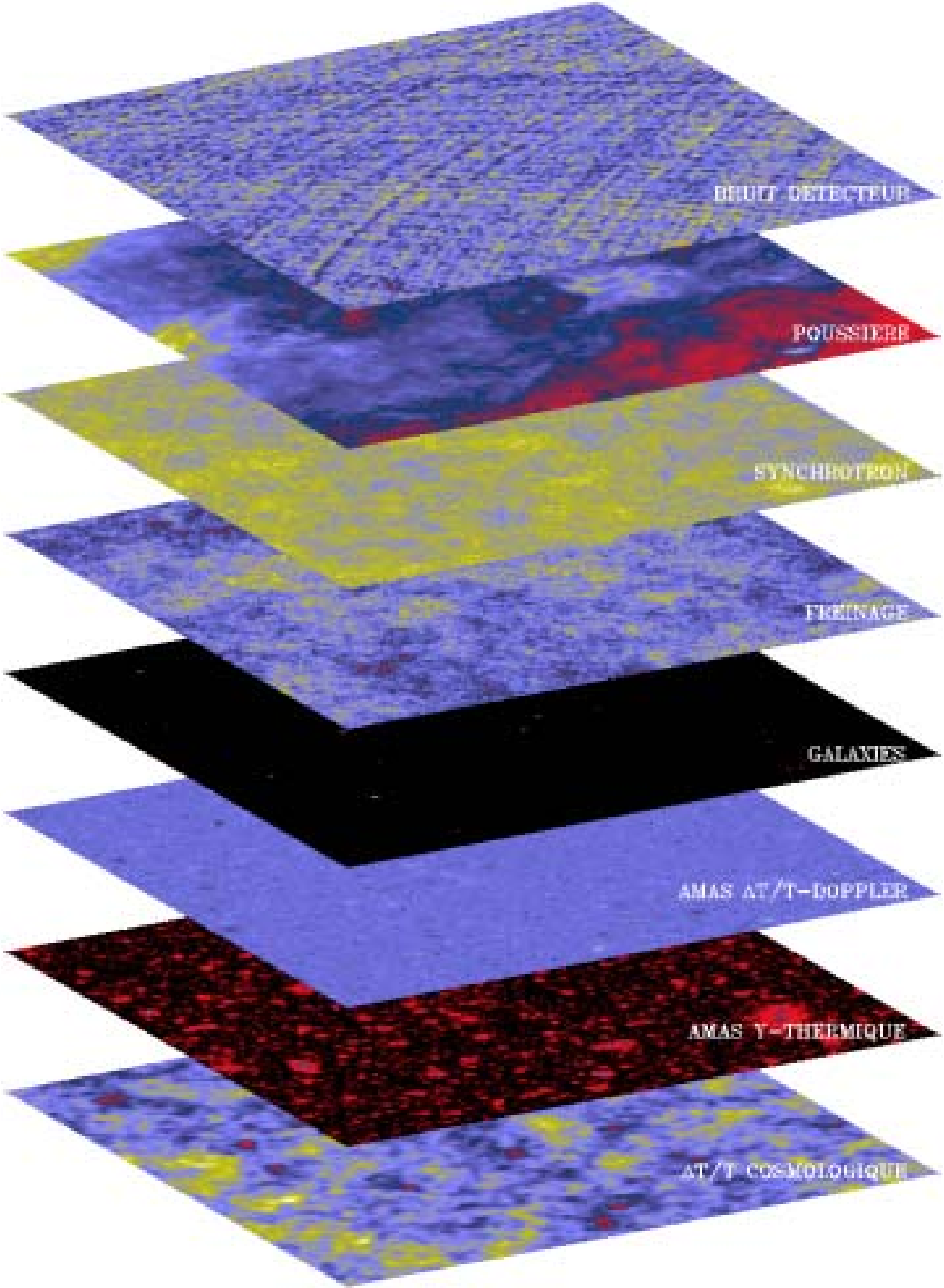
SOURCES of TEMPERATURE ANISOTROPIES



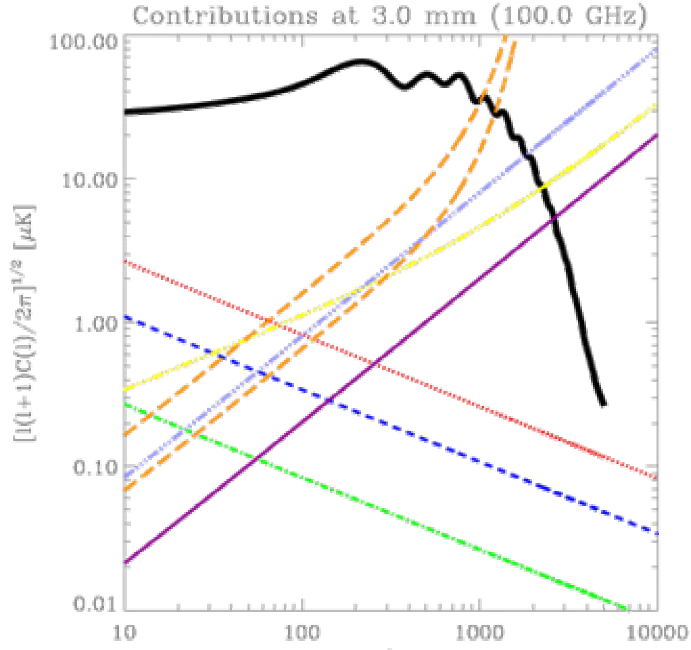
Power spectra of different sources of temperature anisotropies taken from the literature (Aghanim et al. 2000).

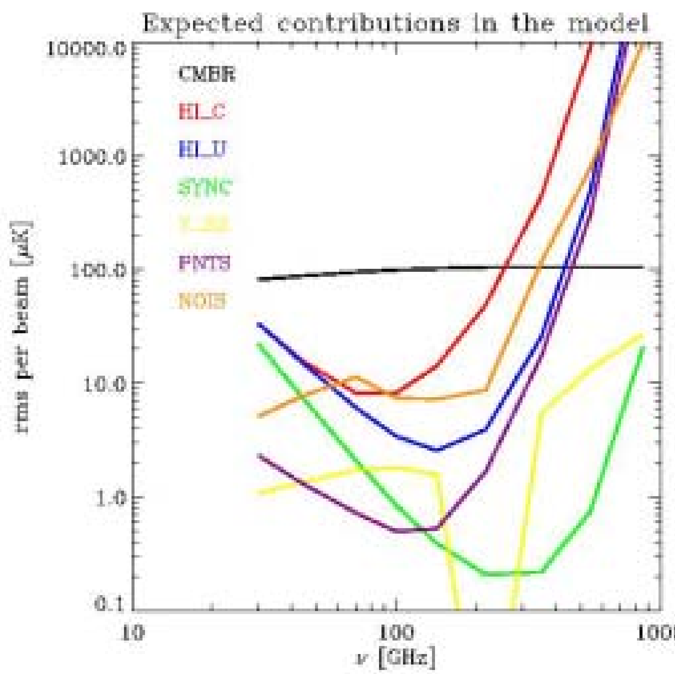
Upper limit to Inhomogeneous reionization by quasars from Aghanim et al. (1996). Rees-Sciama from Seljak (1996). Kinetic SZ from clusters from Aghanim et al. (1998). Vishniac-Ostriker from Hu & White (1996).

FORE-
GROUNDS



F.R. BOUCHET & R. GISPERT 1996





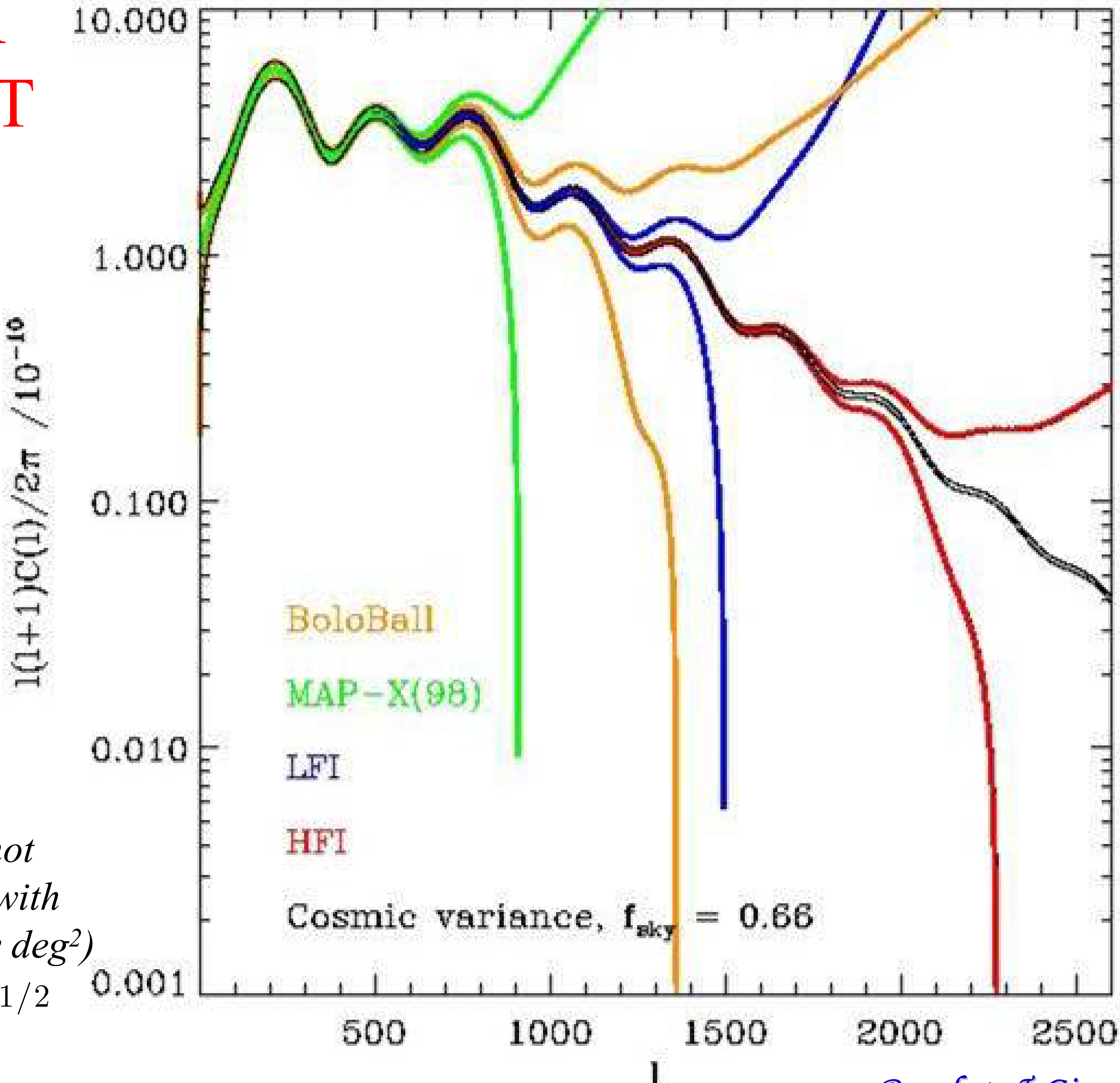
1σ ERROR FORECAST

Foreground separation errors included;

NO band averaging performed (l~2500 OK)

NB: a BoloBall cannot map 66% of the sky with that sensitivity (~few deg²)

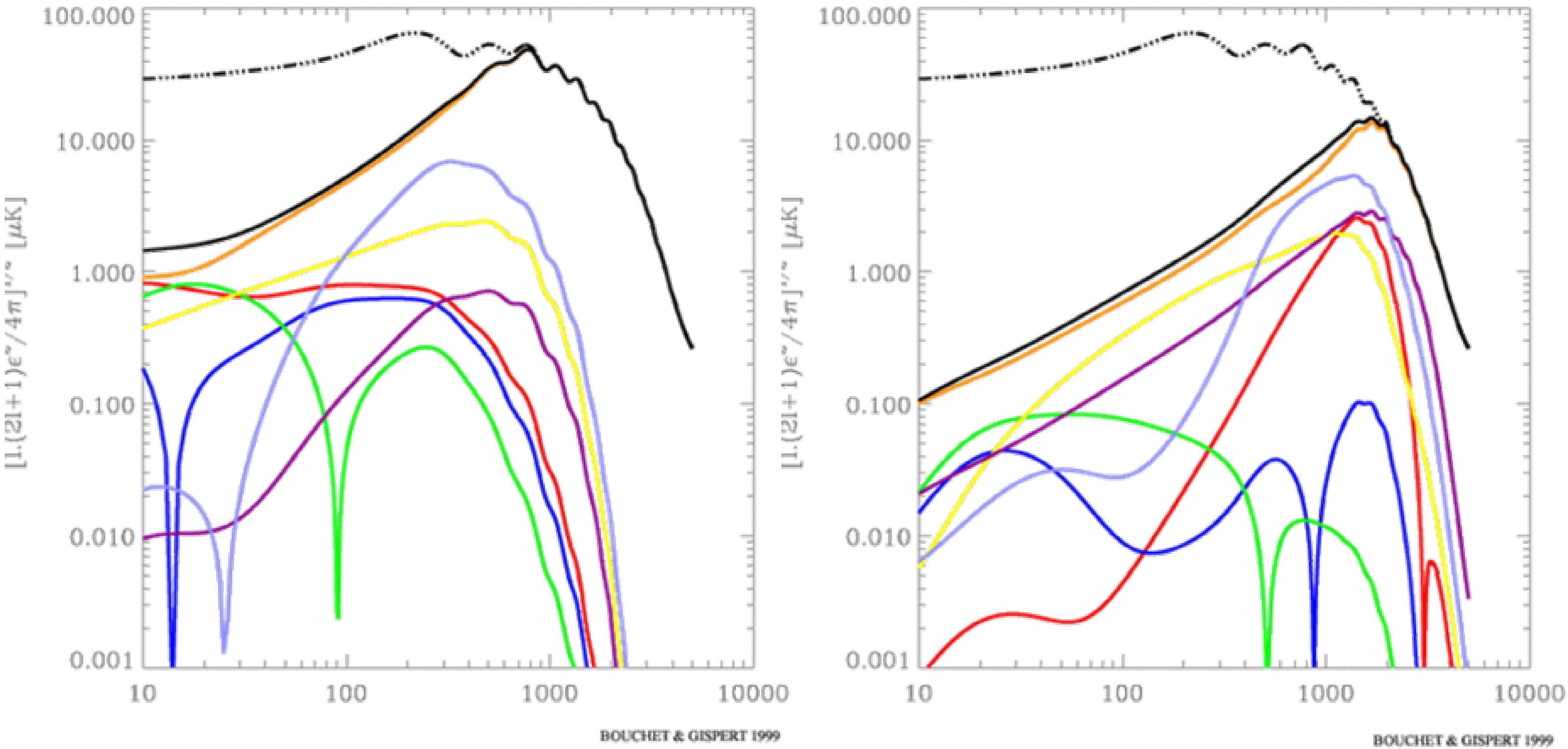
$$\Delta C \propto \left[\frac{2}{(2\ell+1)\,f_{sky}}\right]^{1/2}$$



Bouchet & Gispert 2000

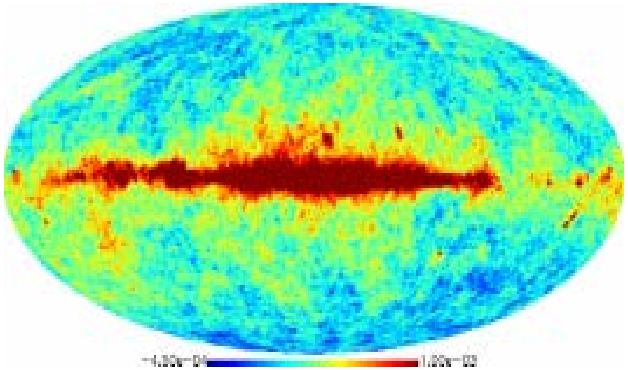
ANGULAR RESOLUTION, SENSITIVITY, FREQUENCY COVERAGE COMBINED EFFECT ON A FIDUCIAL SKY MODEL: RESIDUALS

MAP ***CMB case*** ***PLANCK***



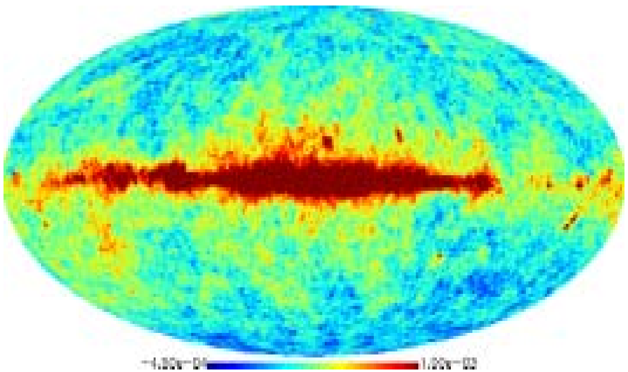
Results turn out to be rather robust vs. « reasonable » foregrounds model variations. But we might be wrong about reason…

MAP



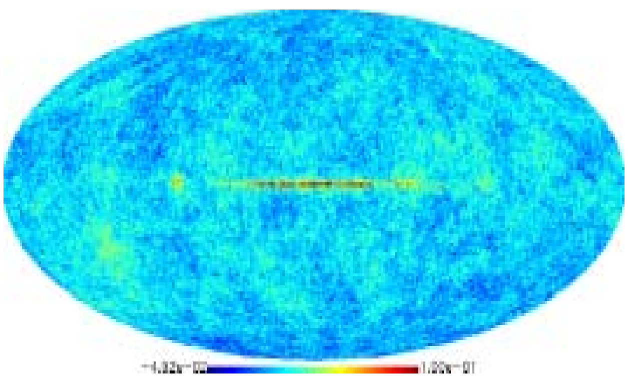
22GHz

(30GHz)



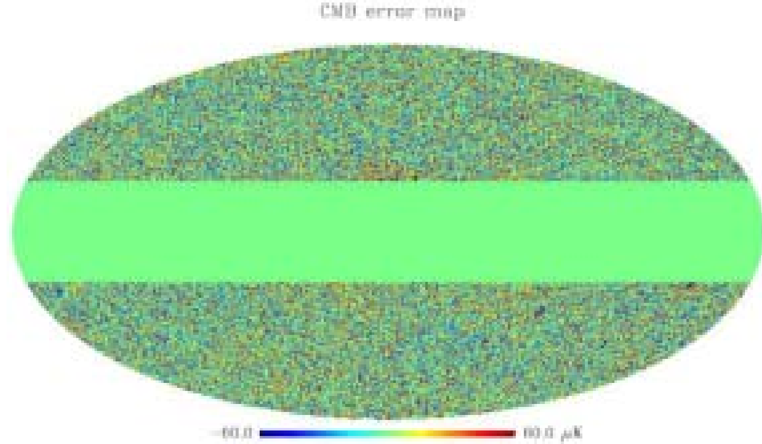
40GHz

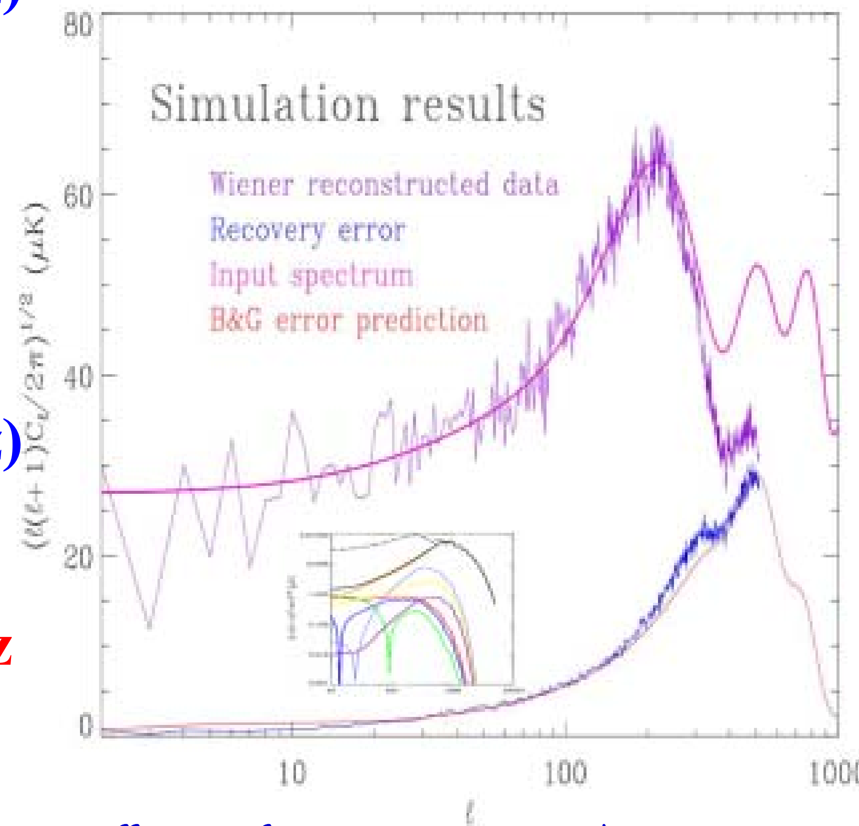
(60GHz)



90 GHz

Detector skies

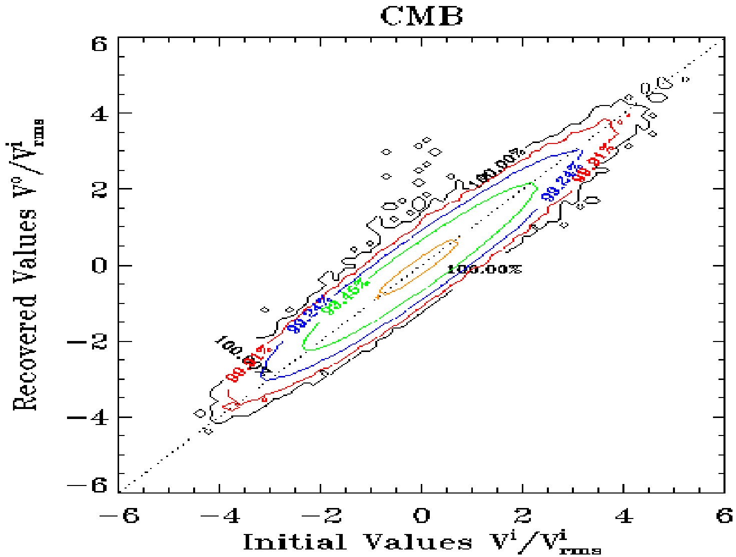


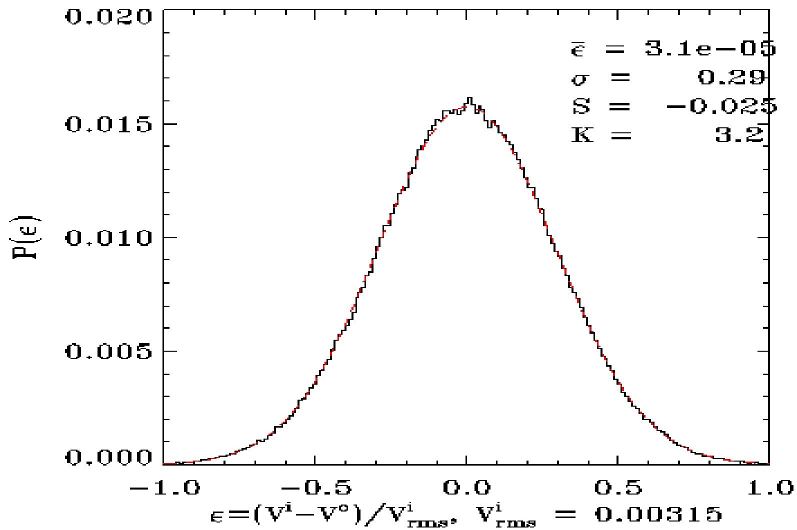


Prunet, Teyssier, Scully, Bouchet, Gispert, 2001A&A...373L..13P

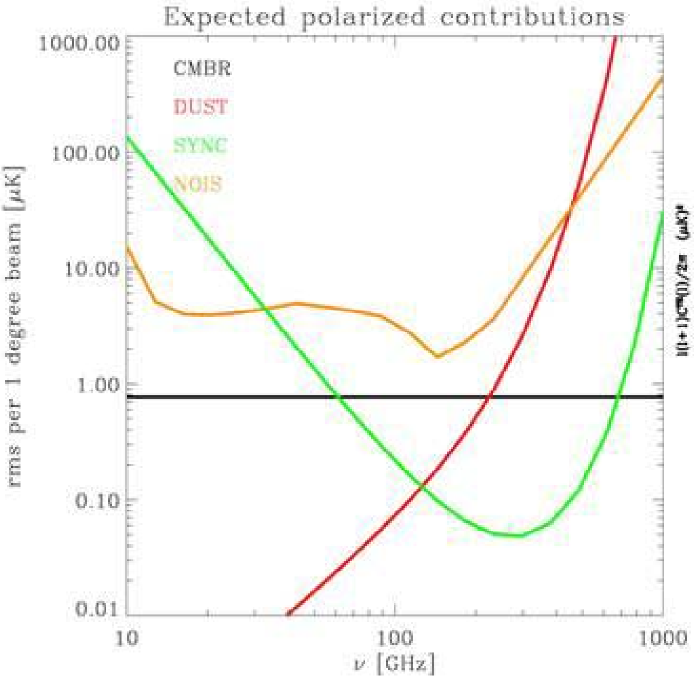
PRUNET - TEYSSIER - BOUCHET - GISPERT - 9/9/99

MAP

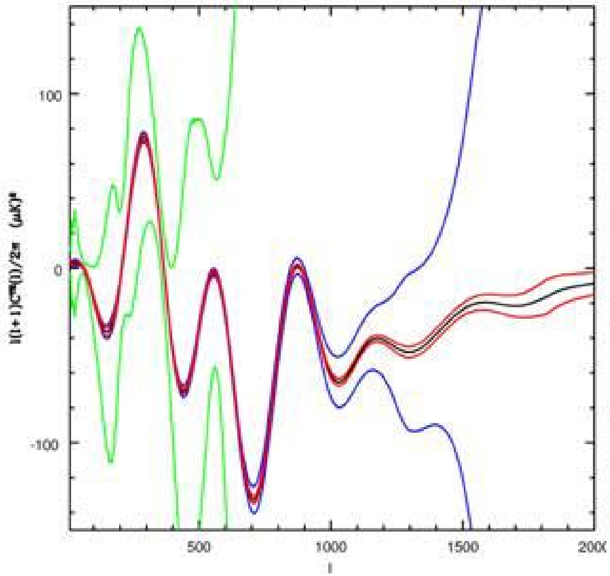




POLARISATION & FOREGROUNDS…



Dust model from *Prunet, Sethi, FRB, Miville-Deschene A&A98*



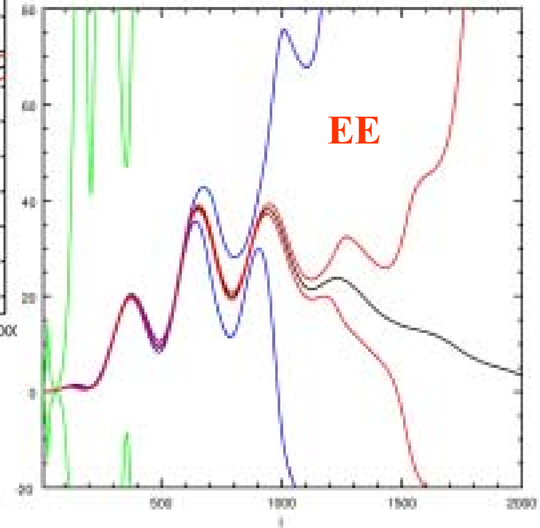
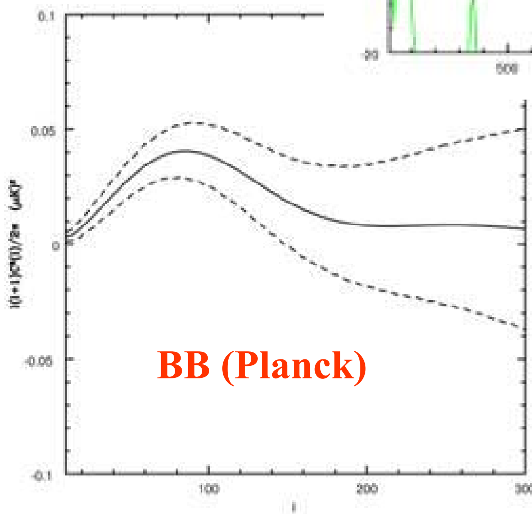


Table 2. Errors on parameters for a model with tensor contribution with or without the inclusion of B-mode polarization

Parameters	C_2	h	Ω_b	Ω_Λ	τ	n_S	n_T	T/S
Model	$796(\mu K)^2$	0.5	0.05	0.0	0.1	0.9	−0.1	0.7
Wiener (PLANCK)	8.7 %	1.6 %	2.7 %	0.045	5.5%	0.46 %	81 %	22.4 %
+ B-modes (PLANCK)	6.5 %	1.55 %	2.64 %	0.044	4.8%	0.43 %	57.1 %	17.5 %
Wiener (HFI)	9.4 %	1.63 %	2.8 %	0.05	7 %	0.47 %	87 %	24.1 %
+ B-modes (HFI)	7.7 %	1.6 %	2.7 %	0.05	6 %	0.45 %	70 %	20.6 %
Wiener (LFI)	9.8 %	5.3 %	8.6 %	0.15	11.3 %	1.65 %	91.6 %	32.4 %
+ B-modes(LFI)	9 %	4.6 %	7.5 %	0.13	9.6 %	1.42 %	83 %	28.2 %
Wiener (MAP)	12.3 %	22.3 %	40 %	0.67	52.5 %	7.5 %	91 %	91 %
+ B-modes (MAP)	12 %	20 %	36.5 %	0.60	46 %	7 %	90.4 %	81.6 %

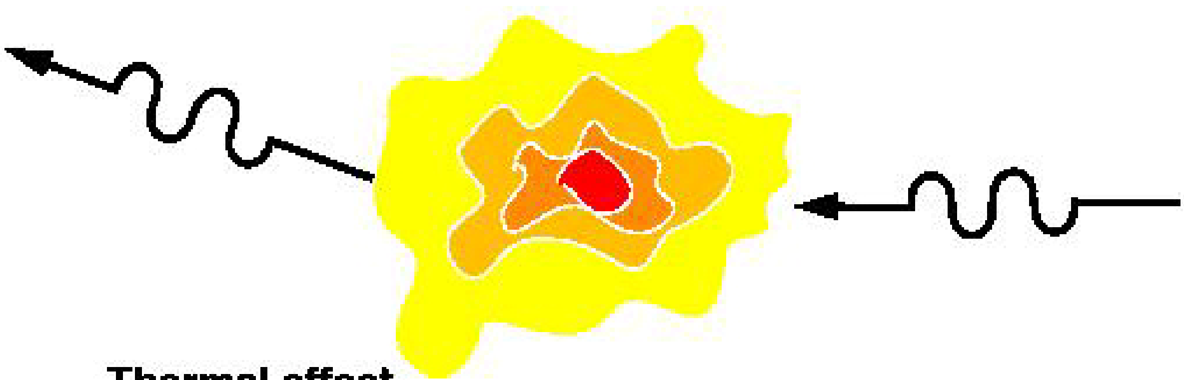
Implication for cosmological parameters (*Prunet, Sethi, FRB, MN00*)



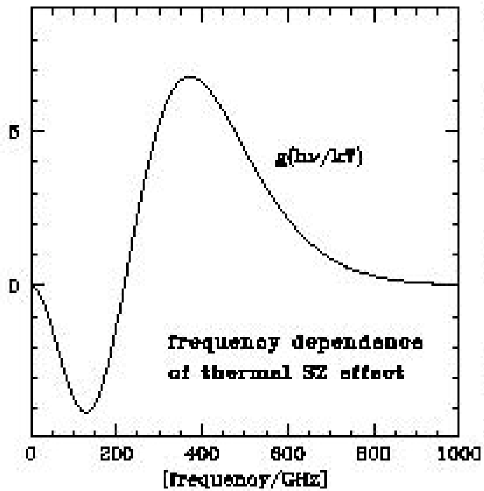
Wiener filtering polarization data…(*Bouchet, Prunet, Sethi, MN99*)
TE, E & B with Δl/l=0.2 "band averaging" for MAP, LFI & HFI

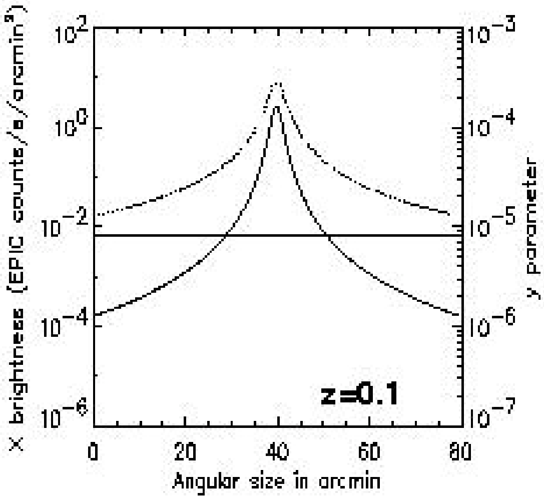
SZ

Sunyaev-Zeldovich effect



Thermal effect



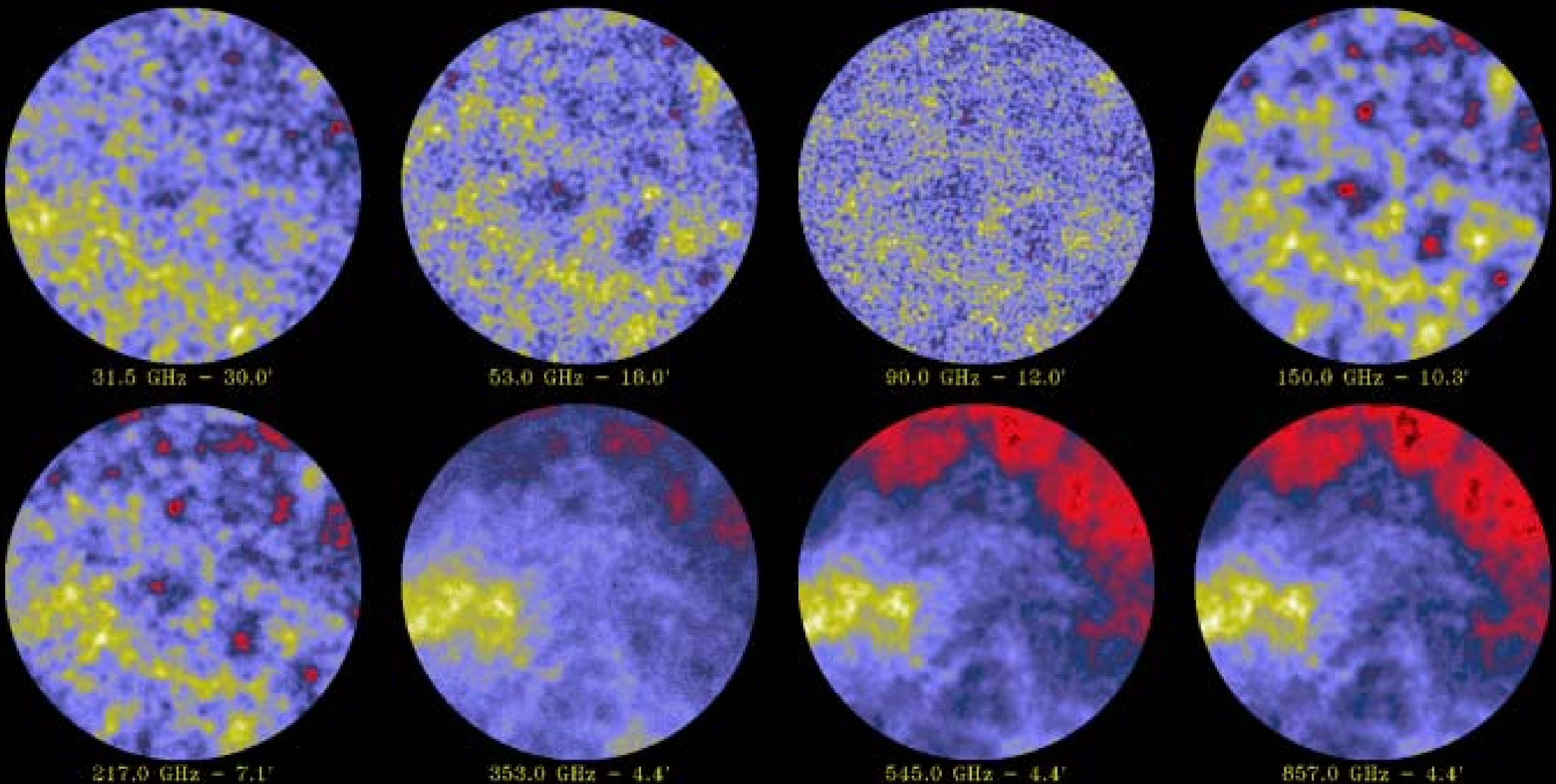


Kinematic effect

$$\Delta T \sim 30\left(\frac{n_e}{3\times10^{-3}\,cm^{-3}}\right)\left(\frac{r_c}{0.4\,Mpc}\right)\left(\frac{v_{pec}}{500k\frac{m}{s}}\right)\mu K$$

(typical cluster)

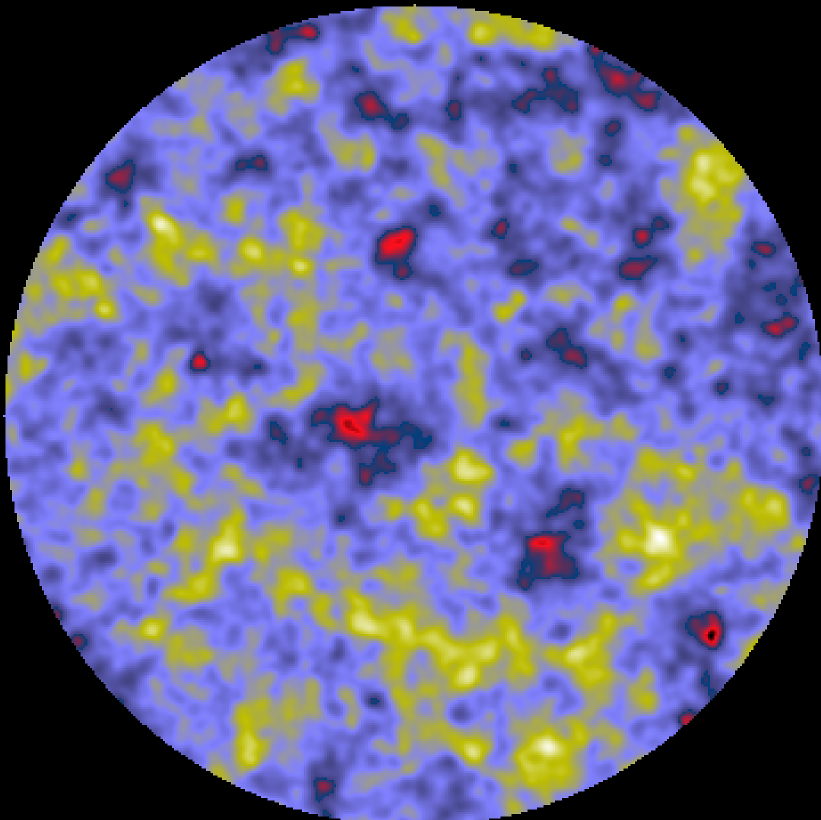
SIMULATIONS D'OBSERVATIONS PAR LE SATELLITE COBRAS-SAMBA



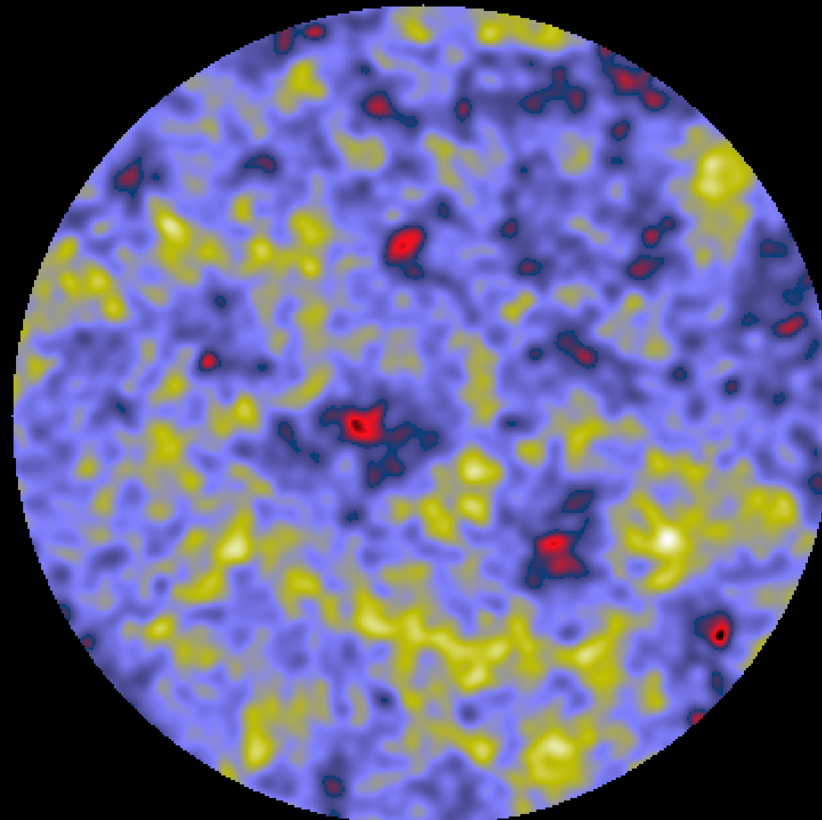
DIAMETRE DES CARTES : 9°

F.R.Bouchet & R.Gispert 1996

FLUCTUATIONS DU
CORPS NOIR COSMOLOGIQUE



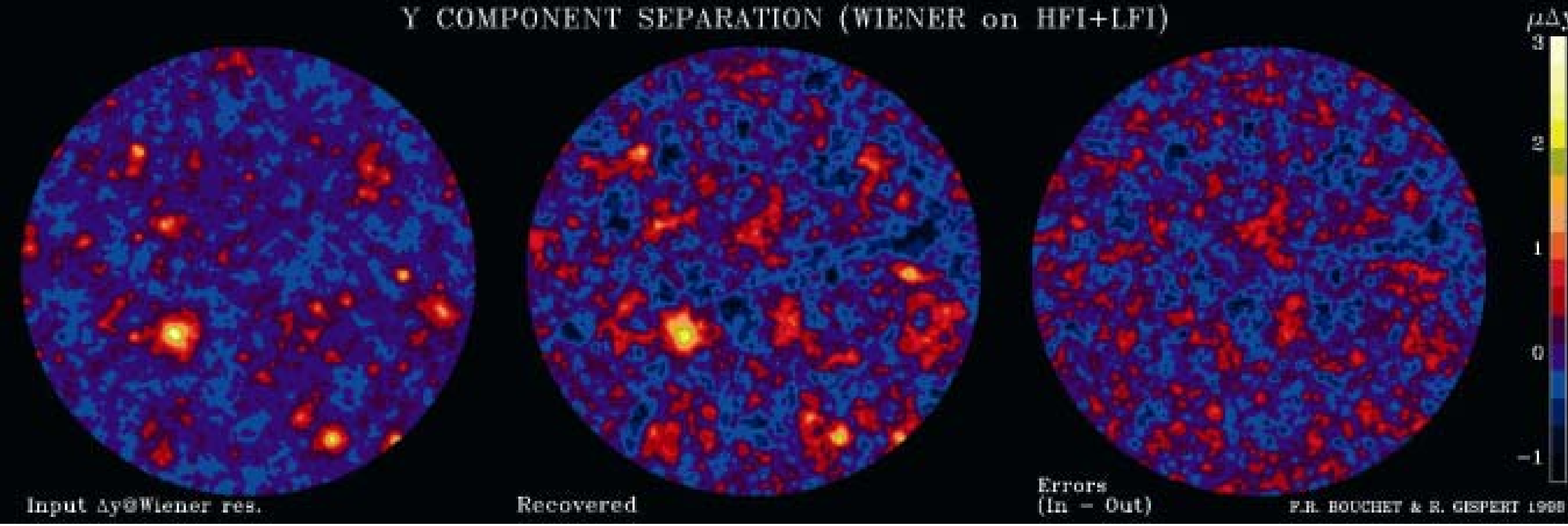
MODELE D'ENTREE



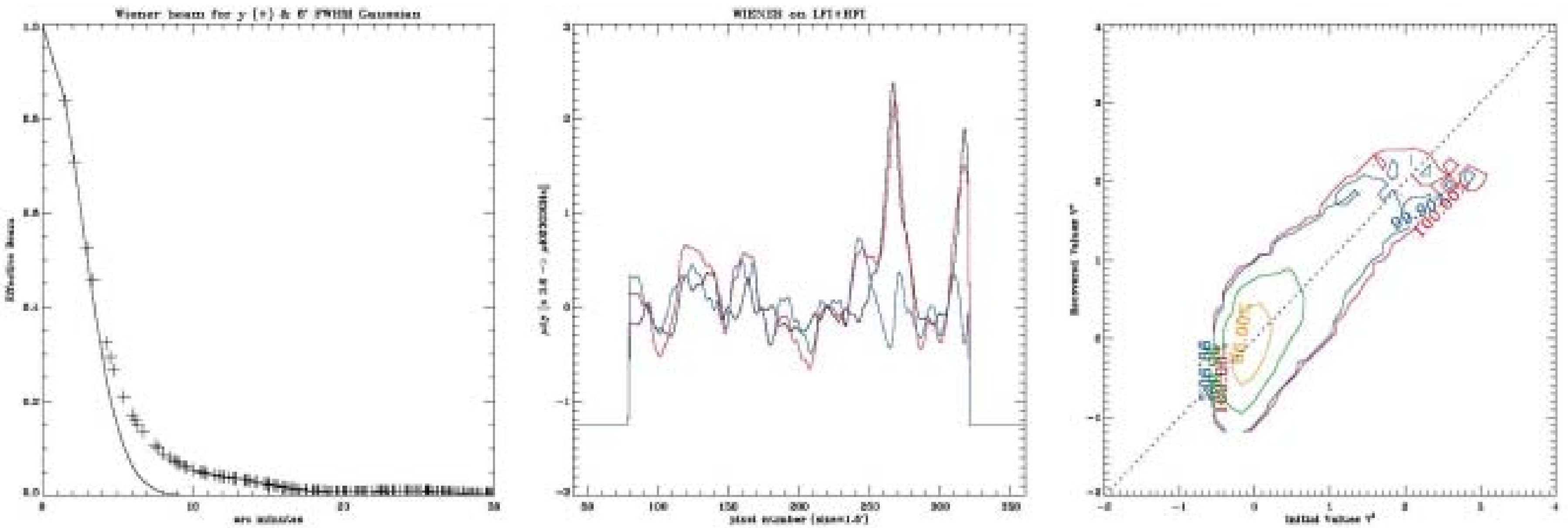
RESTITUTION

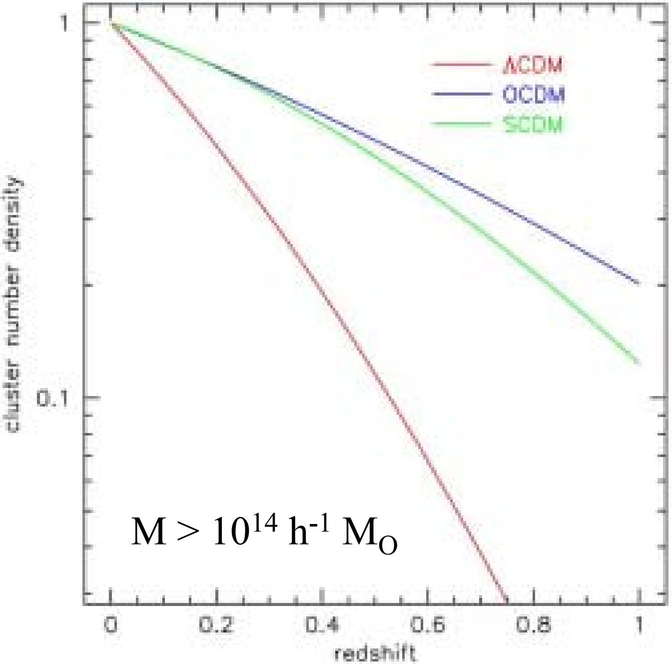
DIAMETRE DES CARTES : 9°

F.R.Bouchet & R.Gispert 1996



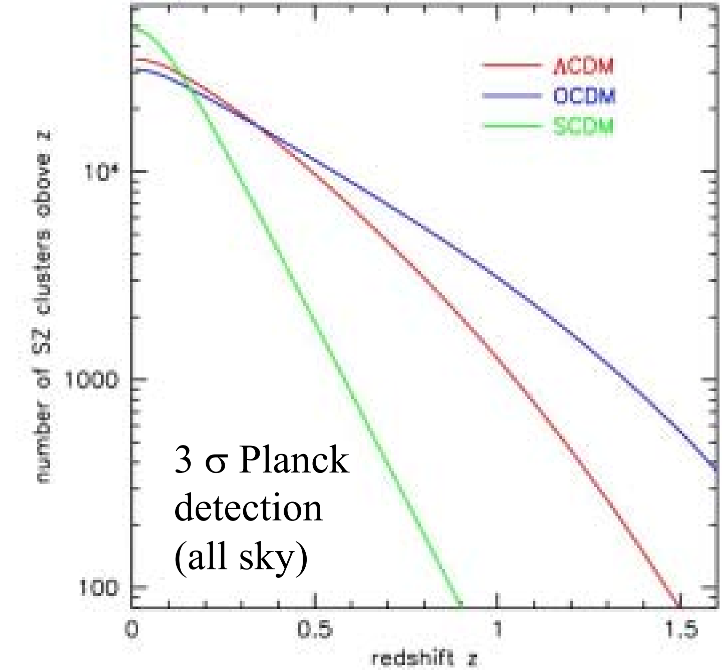
Of the order of (a few X) 10 000 clusters detected objectively





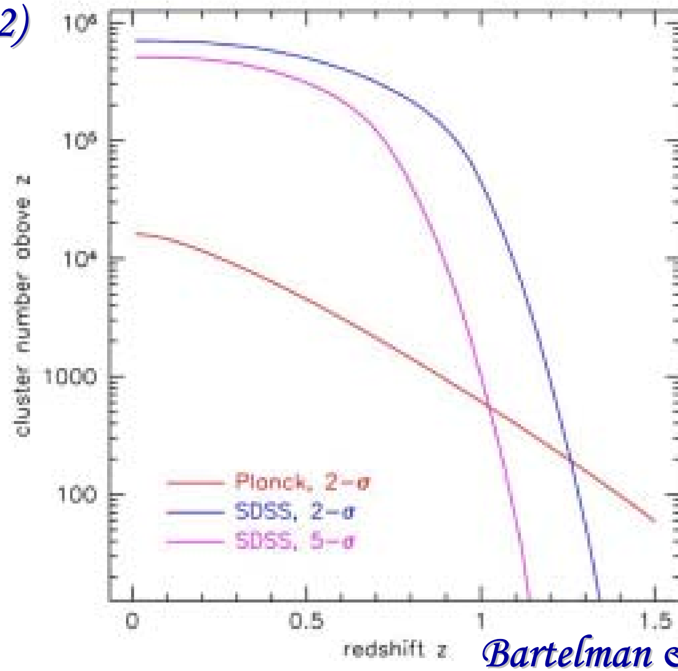
(As in Oukbir & Blanchard AA 92)

PLANCK SZ CLUSTERS



Bartelman 2001

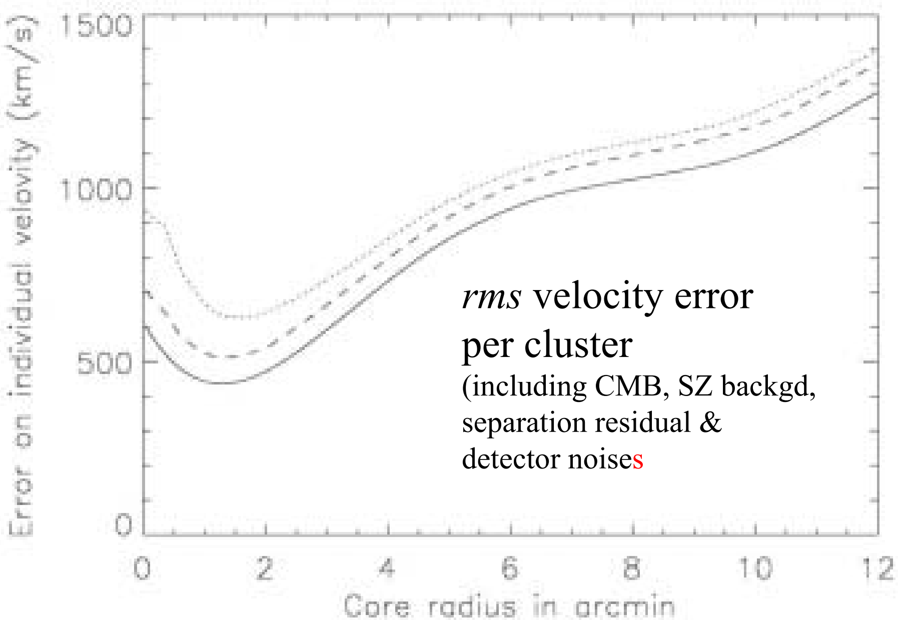
About 10^4 clusters in common in the SDSS area.

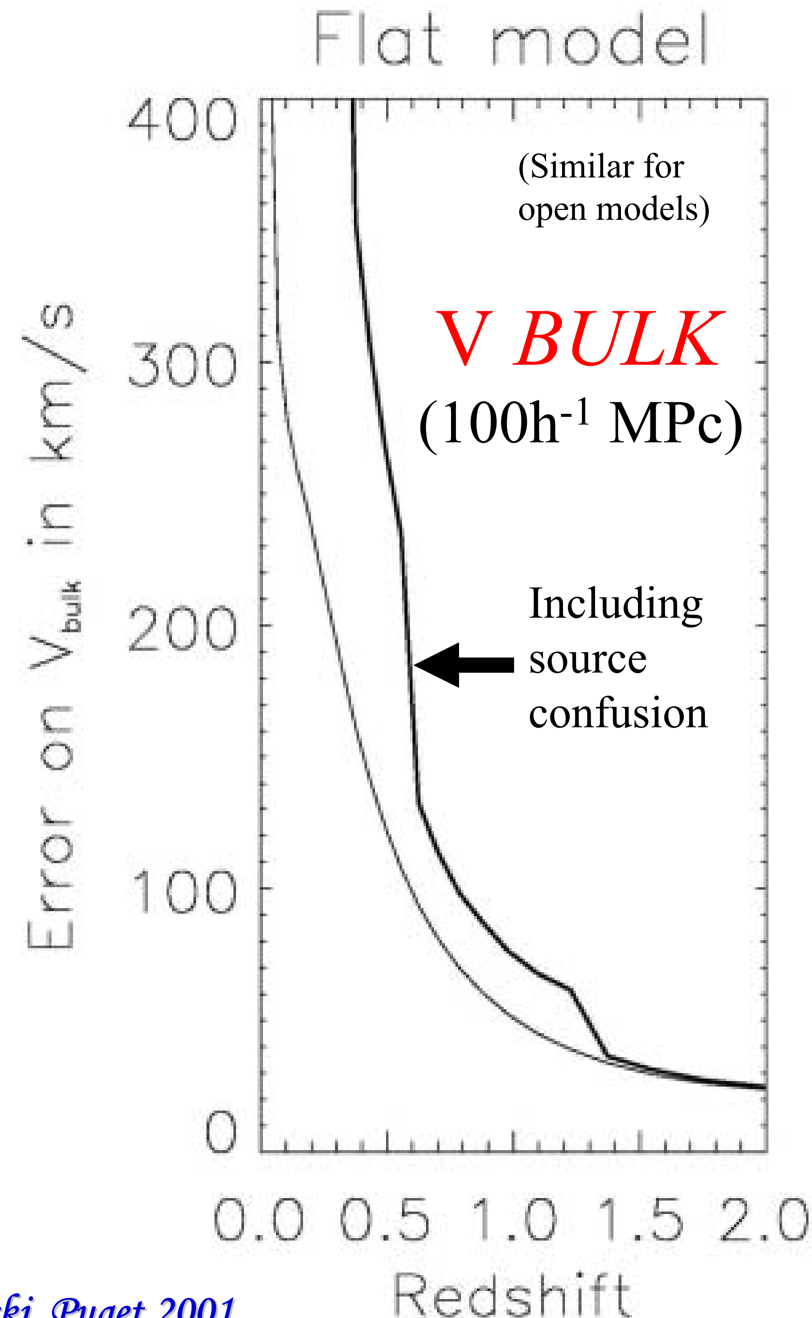


Bartelman & White 2002

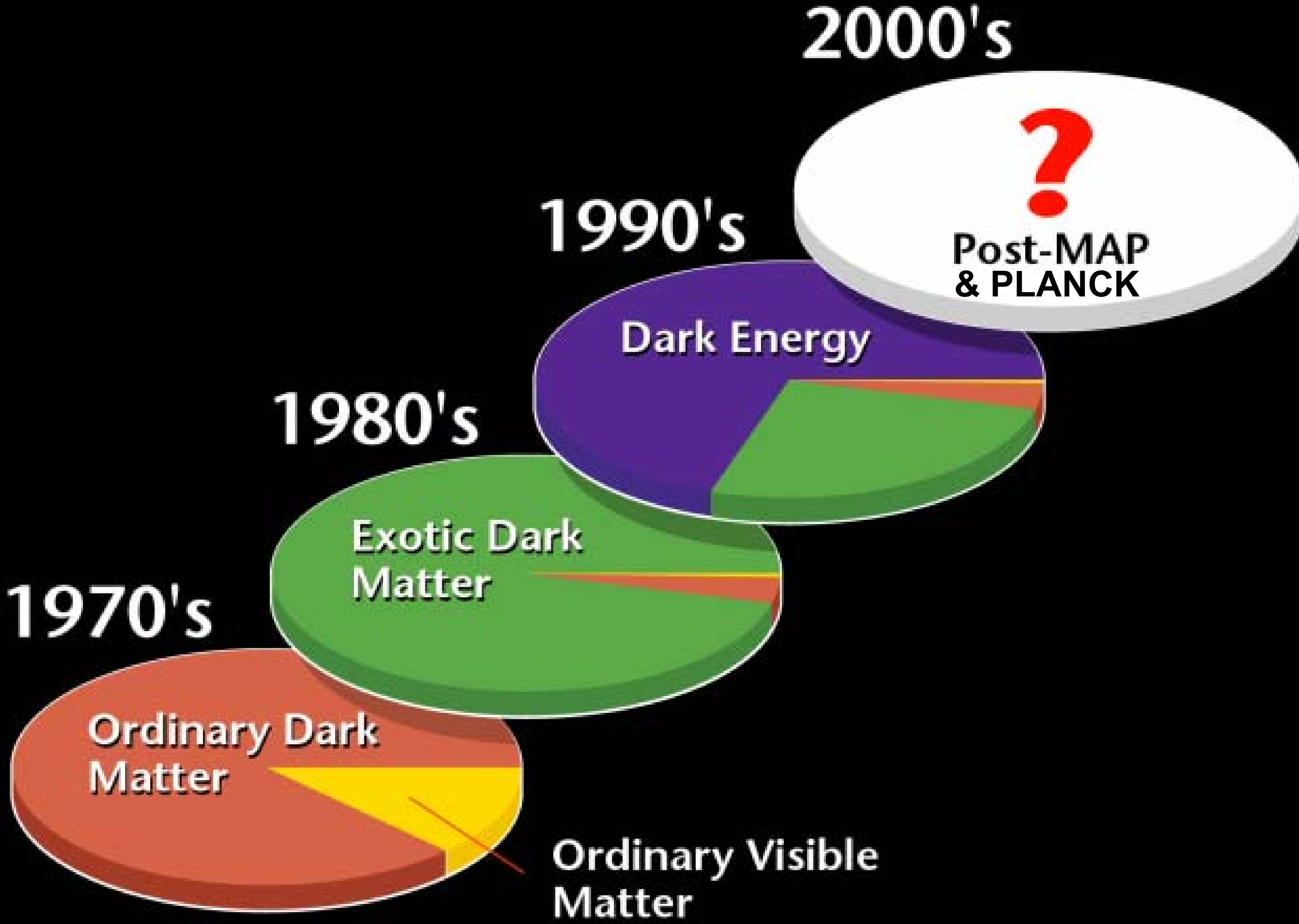
Those with no SDSS counterpart will be at high z...

The determination of a cluster velocity thanks to the *kinetic SZ effect* is noisy due to the confusion with other parasitic contributions like the primary CMB fluctuations, the contributions from other clusters, partly removed foregrounds and detector noise. BUT…





Aghanim, Gorski, Puget 2001


2000's
?
Post-MAP
& PLANCK
1990's
Dark Energy
1980's
Exotic Dark
Matter
1970's
Ordinary Dark
Matter
Ordinary Visible
Matter