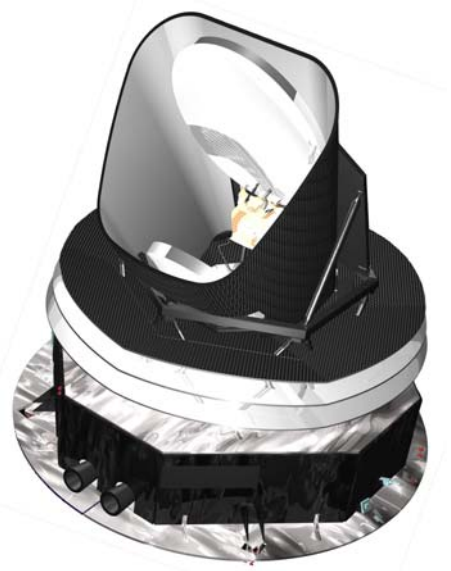
Cosmology and the PLANCK mission



J. Tauber
European Space Agency

Topics

- Modern Cosmology
- The Cosmic Microwave Background
- The Planck satellite

Cosmology

- Describes our Universe at large scale
- The pillars of the current model:
  - Observations
  - The General Theory of Relativity
  - High energy theories
  - Inflation
- A cosmological model may be synthesized with only a dozen parameters

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Observations

- The spatial structure and dynamics of matter
- The expansion of the Universe
- The abundances of light elements
- The age of the Universe
- The Cosmic Microwave Background

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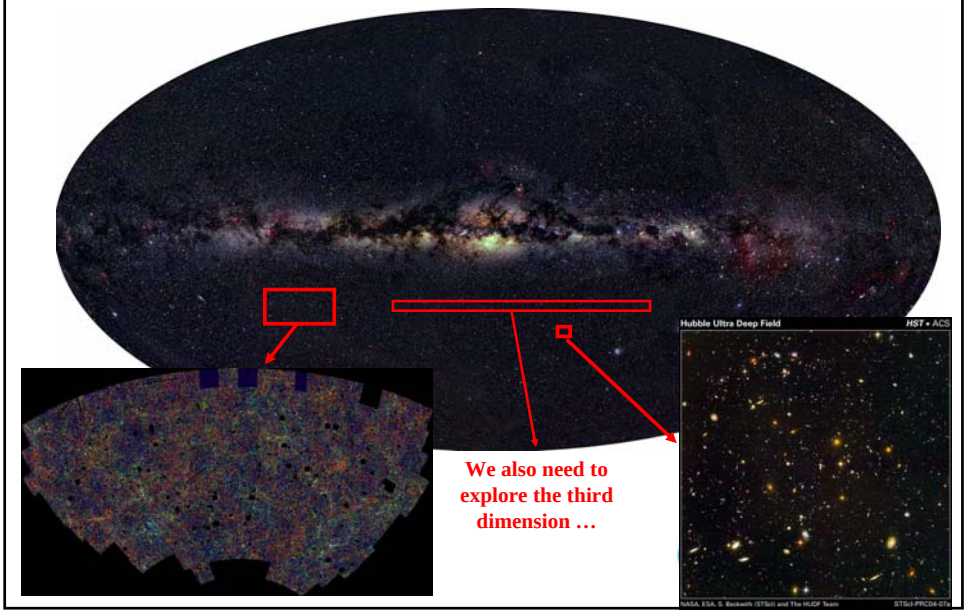
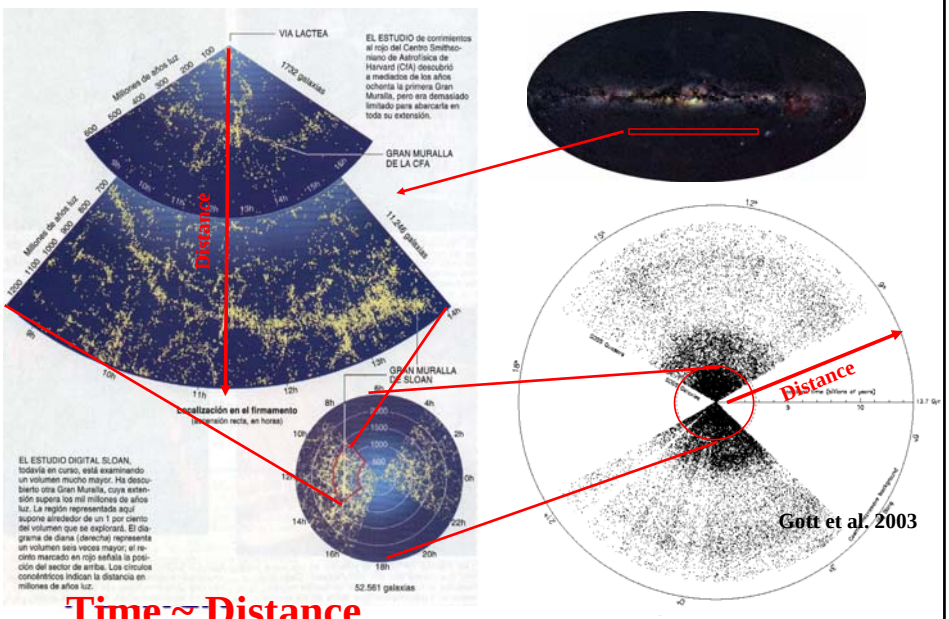
Our environment

The structure of luminous matter



We also need to explore the third dimension …

The structure of luminous matter

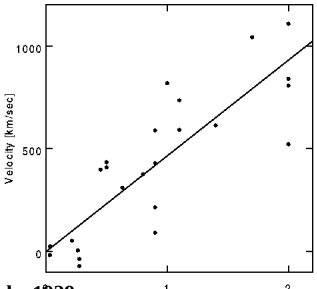


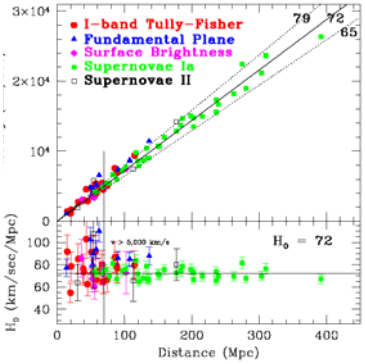
Time ~ Distance

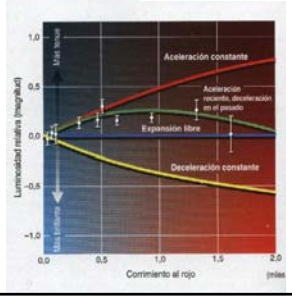
1 pc ~ 3 light-years
The Milky Way ~ 100000 light-years ~ 30 kpc
The visible Universe ~ 4 Gpc

Expansion of the Universe

Edwin Hubble, 1929



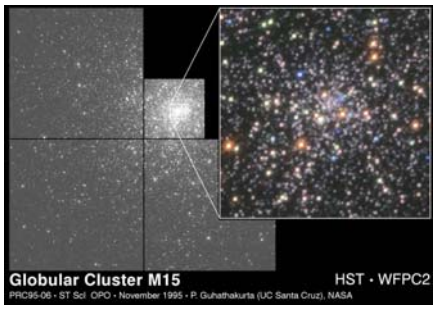




The observation of distant supernovas indicates that the expansion velocity is increasing.
The origin of this acceleration is referred to as Dark Energy.

The age of the Universe

The expansion of the Universe and the Cosmic Microwave Background indicate an age of ~13700 million years



The age of globular clusters can be estimated at 12-18000 million years.

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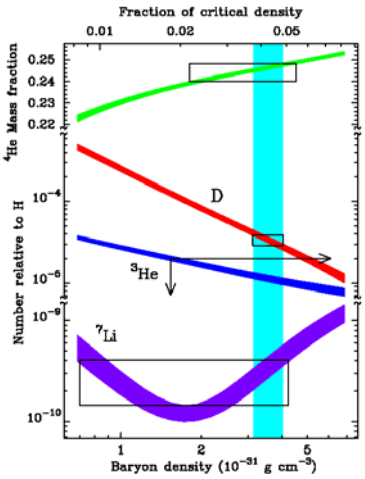
The abundance of light elements

George Gamow

Primordial nucleosynthesis



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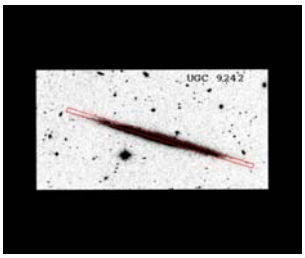
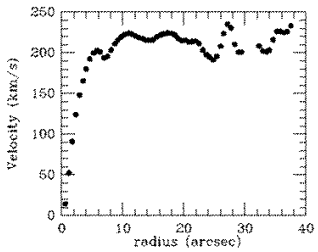
The dynamics of luminous matter





The rotation curves of spiral galaxies show that there Is matter which influences motions through gravity but is not visible. It is called Dark Matter.

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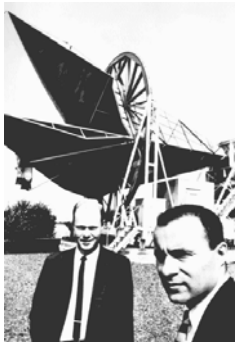
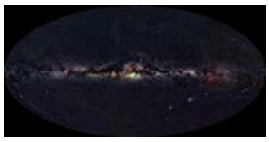
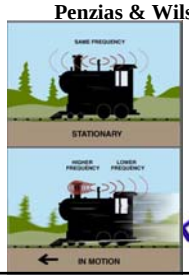
The Cosmic Microwave Background



Penzias & Wilson 1965

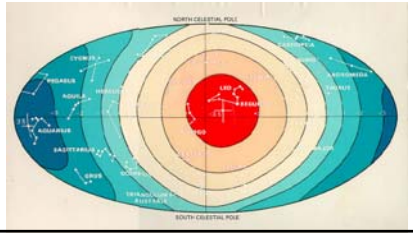
Discovery of a radiation which is present all over the sky - of cosmological origin



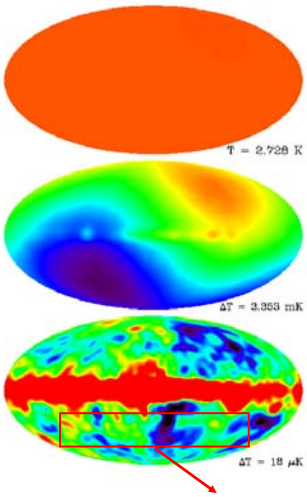


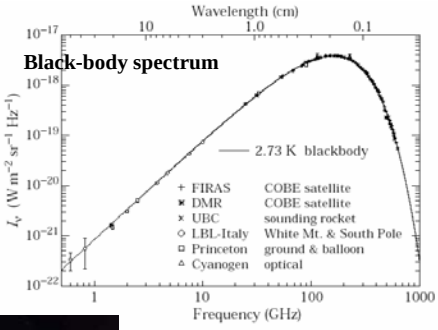
The dipole

U2 experiment 1970's



The Cosmic Microwave Background





T ~ 2.7 K = -270.3 °C

COBE
1992

These small deviations of the temperature of the CMB trace the origin of luminous structure in the Universe.

The Cosmic Microwave Background

COBE 1992

WMAP 2003

Searching for the origin of luminous structure

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Summary: the “Hot Big Bang”

- In the distant past, the Universe was much more compact, dense and hot than it is today.
- From its birth, the Universe is expanding, and becomes colder and less dense as time increases
- Today the Universe is homogeneous and isotropic at large scales
- At small scales, local physical processes give rise to a high degree of structure
- The laws of physics that we can test locally are the same everywhere
- It is necessary to postulate a “special” initial phenomenon: inflation

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Formation of structure

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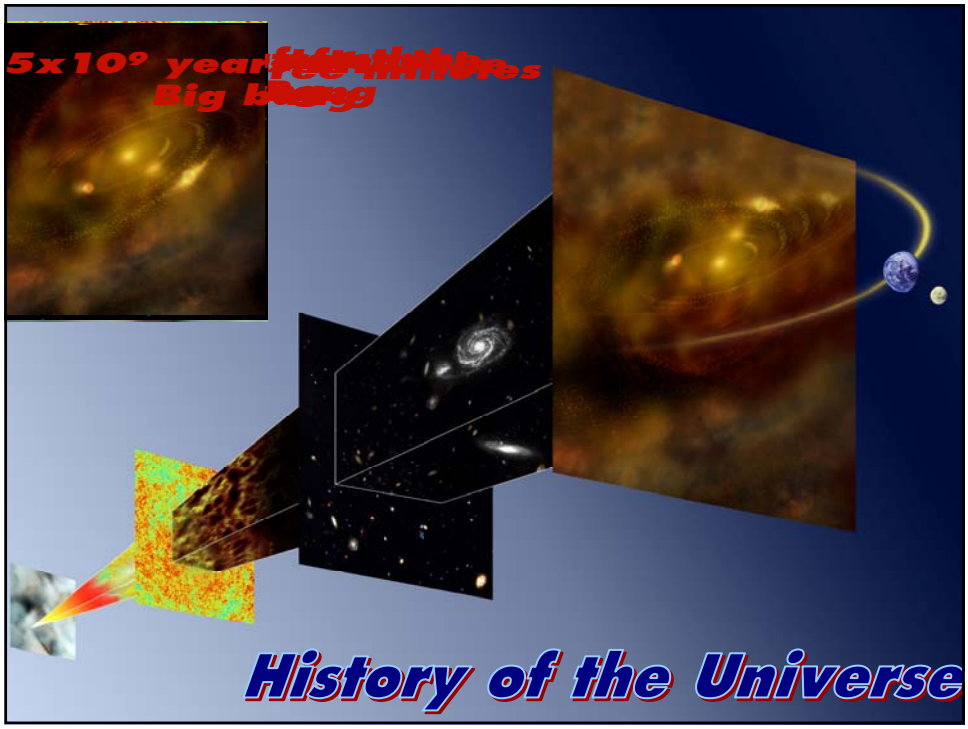
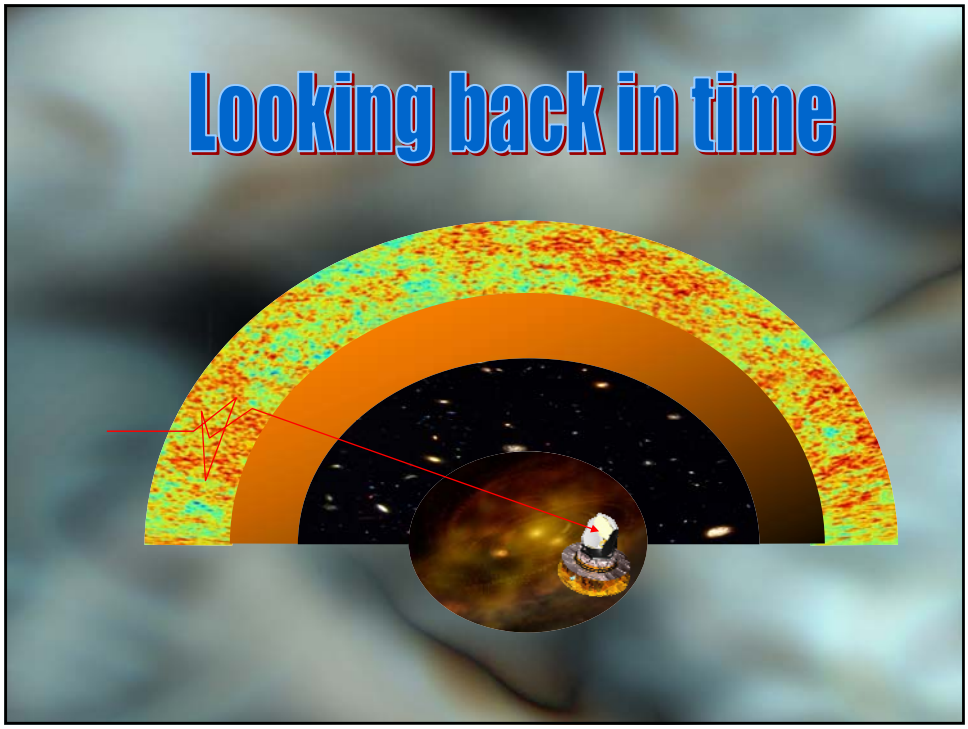
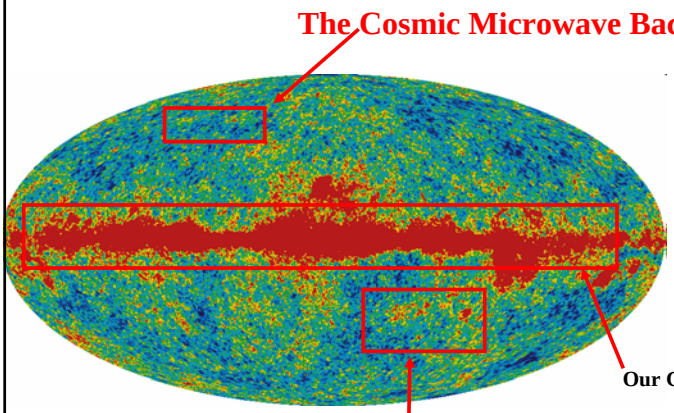

5x10⁹ years
Big bang
History of the Universe


Looking back in time

The sky seen in microwaves



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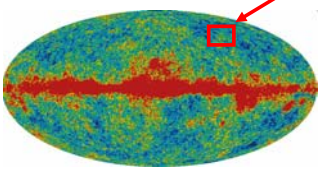
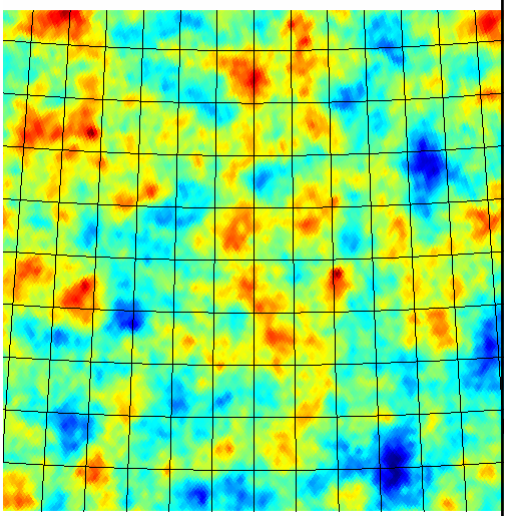
Why do we care about these small deviations in the temperature of the CMB ?





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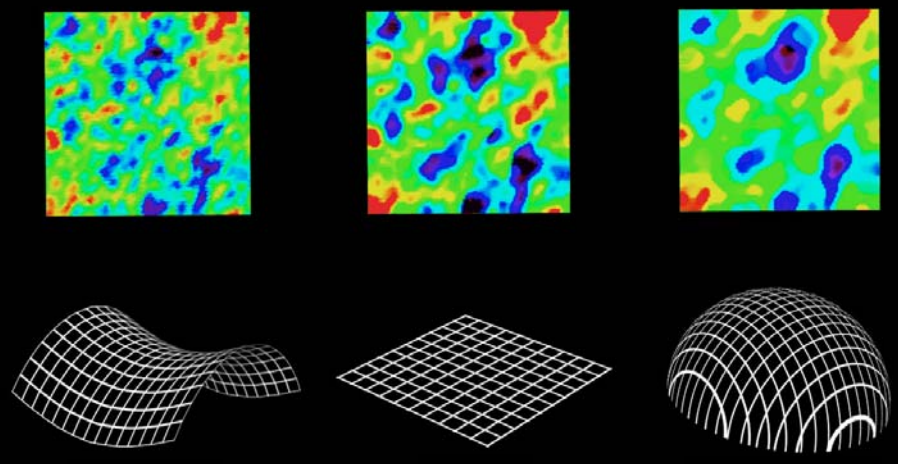
Example: Geometry of the Universe



We have an algorithm to try to understand the Universe

- The Universe is a rather simple object a few hunderd thousand years after the Big Bang
- The Cosmic Microwave Background gives us a faithful image of that time, which reflects the properties of the Universe
- At large scale, we can synthesize the properties of the Universe with a dozen parameters
- The Cosmic Microwave Background allows us to measure these parameters with great precision

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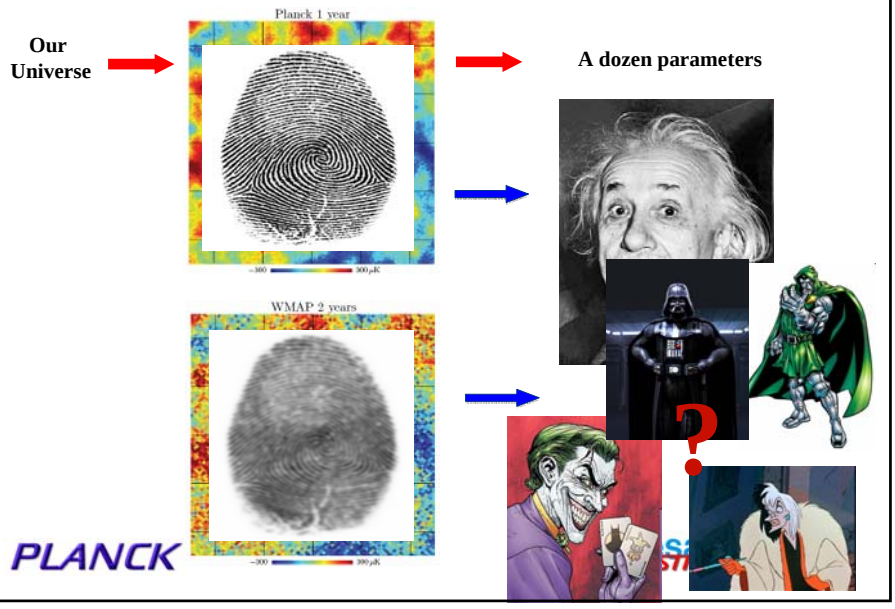
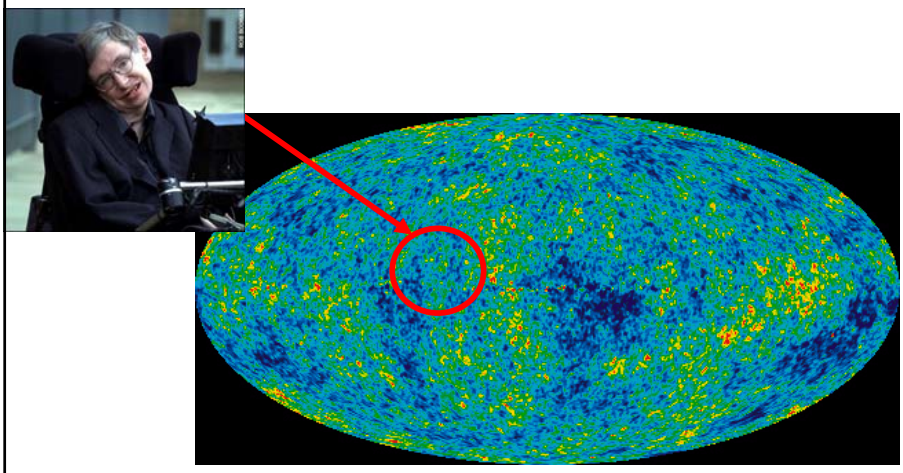
Reconstructing parameters



Reconstructing parameters



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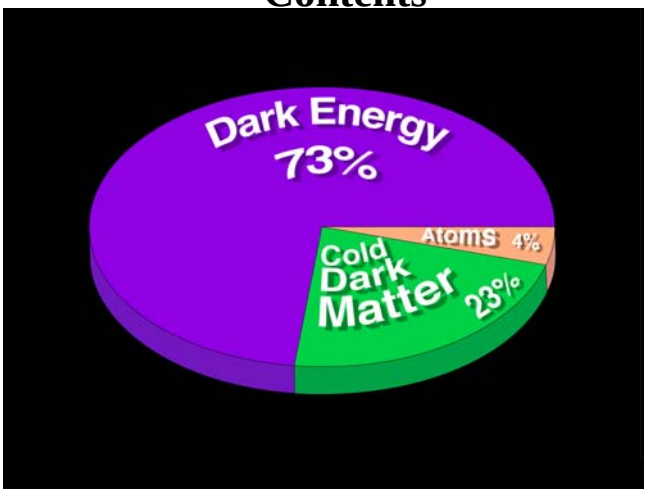

Description of the Universe, based on WMAP

Ω_0 ~1

Flat Geometry

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Age ~ 13700 Mill. years

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Parameter	Value[a]	Description	WMAP[b]
		Ten Global Parameters	
h	0.72 ± 0.07	Present expansion rate[c]	$0.71^{+0.04}_{-0.03}$
q_0	-0.67 ± 0.25	Deceleration parameter[d]	-0.66 ± 0.10[e]
t_0	13 ± 1.5 Gyr	Age of the Universe[f]	13.7 ± 0.2 Gyr
T_0	2.725 ± 0.001 K	CMB temperature[g]	
Ω_0	1.03 ± 0.03	Density parameter[h]	1.02 ± 0.02
Ω_B	0.039 ± 0.008	Baryon Density[i]	0.044 ± 0.004
Ω_{CDM}	0.29 ± 0.04	Cold Dark Matter Density[i]	0.23 ± 0.04
Ω_ν	$0.001 - 0.05$	Massive Neutrino Density[j]	
Ω_X	0.67 ± 0.06	Dark Energy Density[i]	0.73 ± 0.04
w	-1 ± 0.2	Dark Energy Equation of State[k]	< -0.8 (95% cl)
		Six Fluctuation Parameters	
$\sqrt{S}$	$5.6^{+1.5}_{-1.0} \times 10^{-6}$	Density Perturbation Amplitude[l]	
$\sqrt{T}$	$< \sqrt{S}$	Gravity Wave Amplitude[m]	$T < 0.71S$ (95%cl)
σ_8	0.9 ± 0.1	Mass fluctuations on 8 Mpc[n]	0.84 ± 0.04
n	1.05 ± 0.09	Scalar index[h]	0.93 ± 0.03
n_T	—	Tensor index	
$dn/d\ln k$	-0.02 ± 0.04	Running of scalar index[o]	-0.03 ± 0.02

Expansion speed

Expansion acceleration

Age of the Universe

The temperature of the CMB

The density and geometry of the Unverse

Density of normal matter

Density of dark matter

Density of neutrinos

Density of dark energy

Equation of state of dark energy

Fundamental parameters

} **First order deviations**

[a]The 1-σ uncertainties quoted in this table represent our combined analysis of published data.
[b]Bennett *et al.*, 2003.
[c]Freedman *et al.*, 2001; note: $H_0 = 100h$ km sec^{-1} Mpc^{-1}.
[d]Supernovae results combined with measurements of the total matter density, $\Omega_M = \Omega_\nu + \Omega_B + \Omega_{CDM}$ and Ω_0, assuming $w = -1$ (Perlmutter *et al.*, 1999; Riess *et al.*, 1998).

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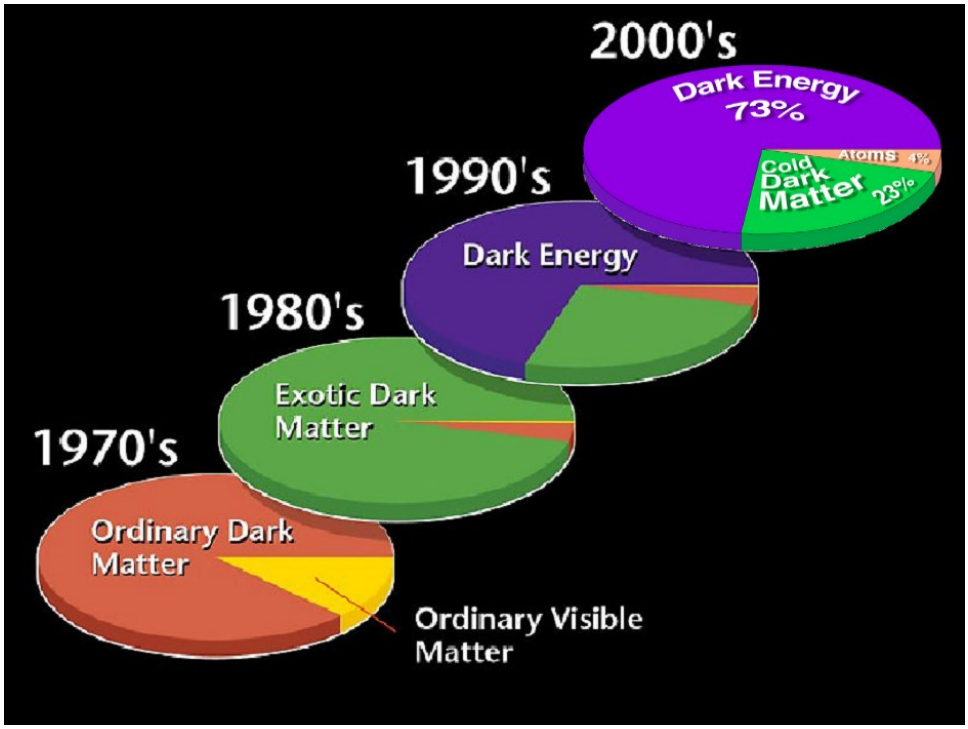
From Freedman and Taylor 2004



Many open questions

- Did inflation happen ?
- What were the characteristics of inflation ?
- What is dark matter ?
- What is the nature and origin of dark energy ?
- Why do we live at a time when the Universe starts to accelerate ?
- Are there “defects” such as magnetic monopoles, cosmic strings, etc ?
- .....

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The Cosmic Microwave Background contains lots of new information that will help us to answer some of these questions.

A space experiment is required that can:

- Detect structures at very small scale
- Detect very weak signals
- Measure the polarisation of the CMB

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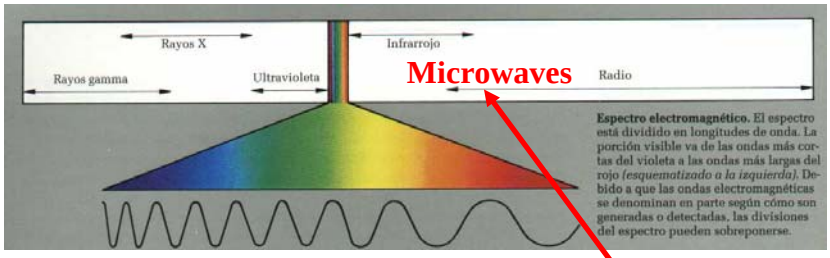
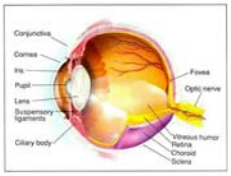
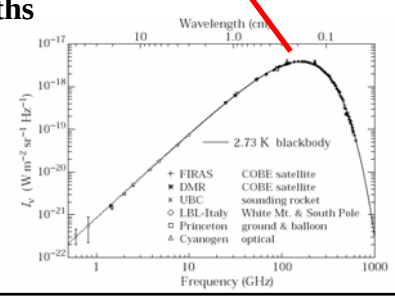
The "color" of the CMB

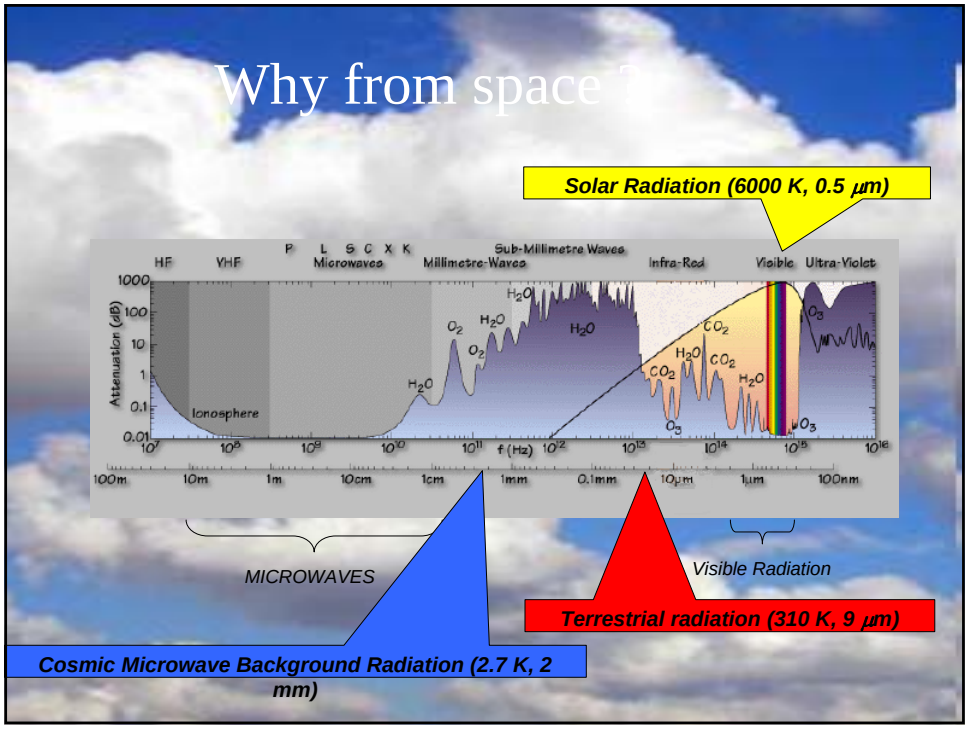


The CMB radiates at wavelengths typical of microwaves

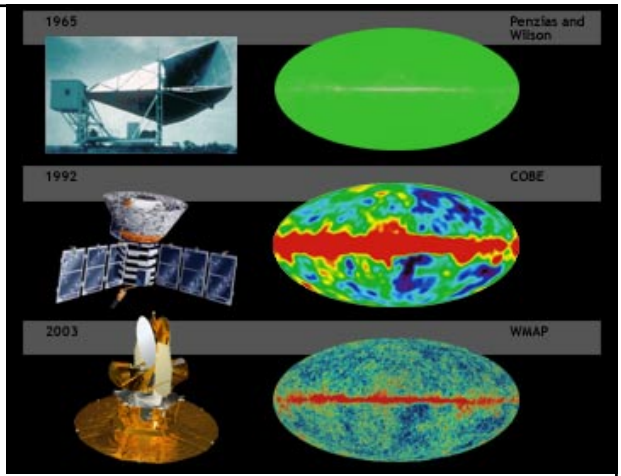


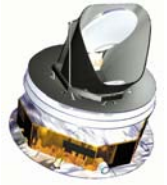


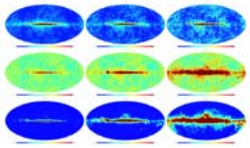
Why from space ?



Planck: a third generation project







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HERSCHEL SPACE OBSERVATORY

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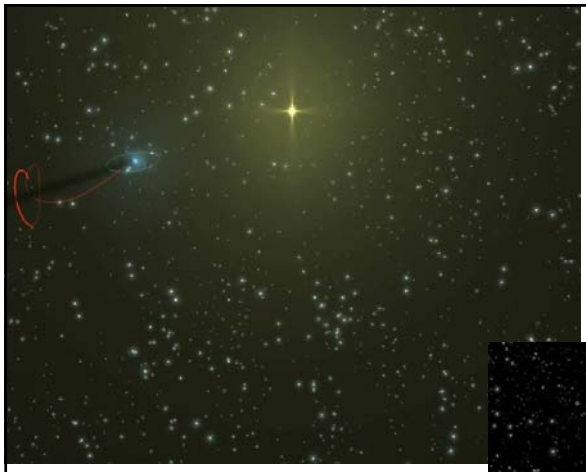
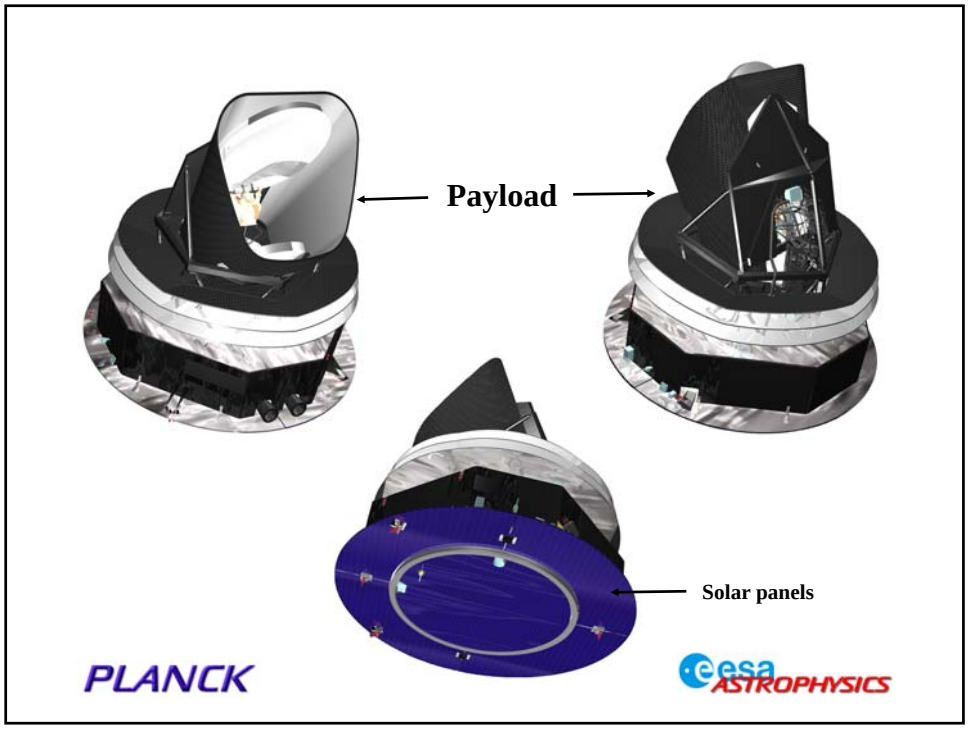


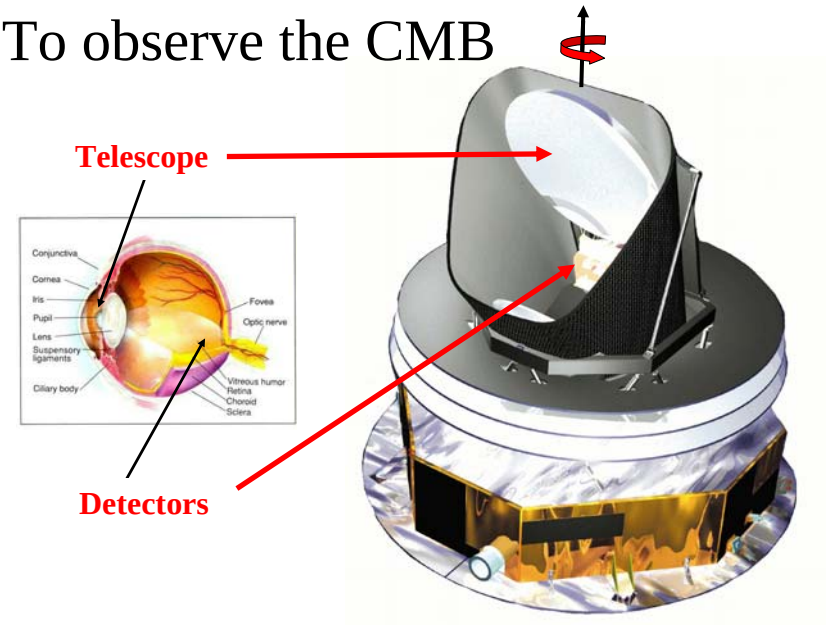
Mission duration
= 15 months
= 2 full maps
of the sky

Mission ends: Dec 2010

PLANCK



To observe the CMB



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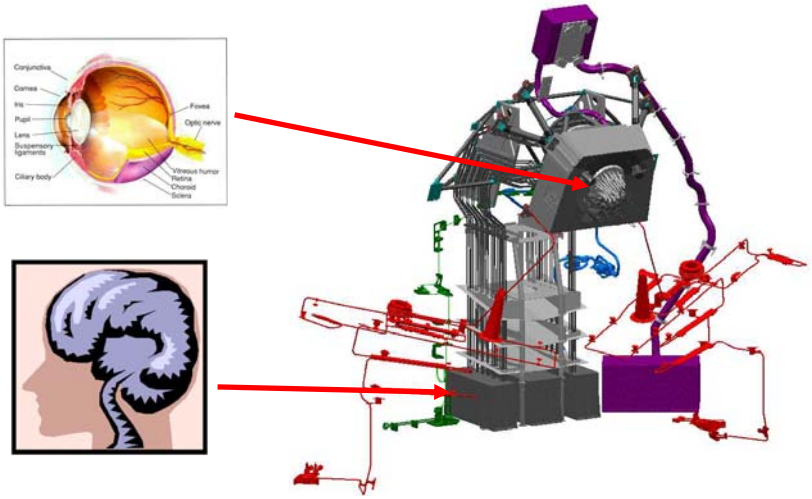
To map the CMB



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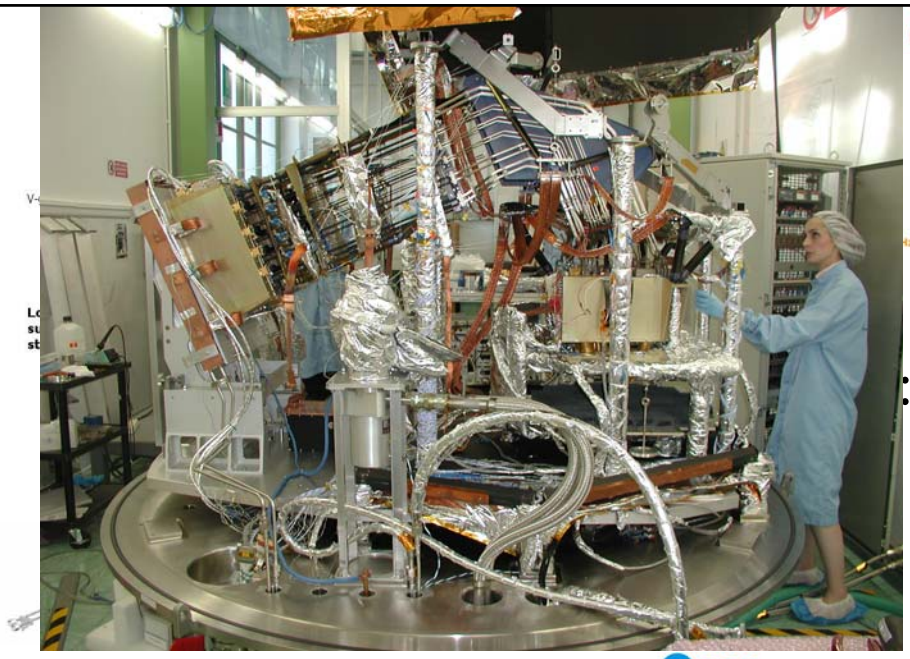

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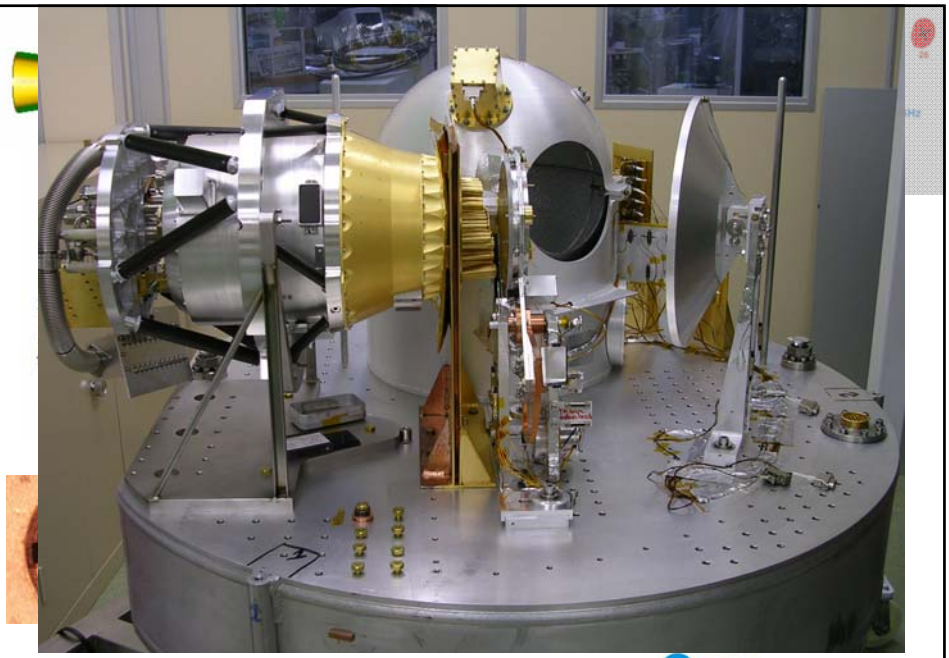

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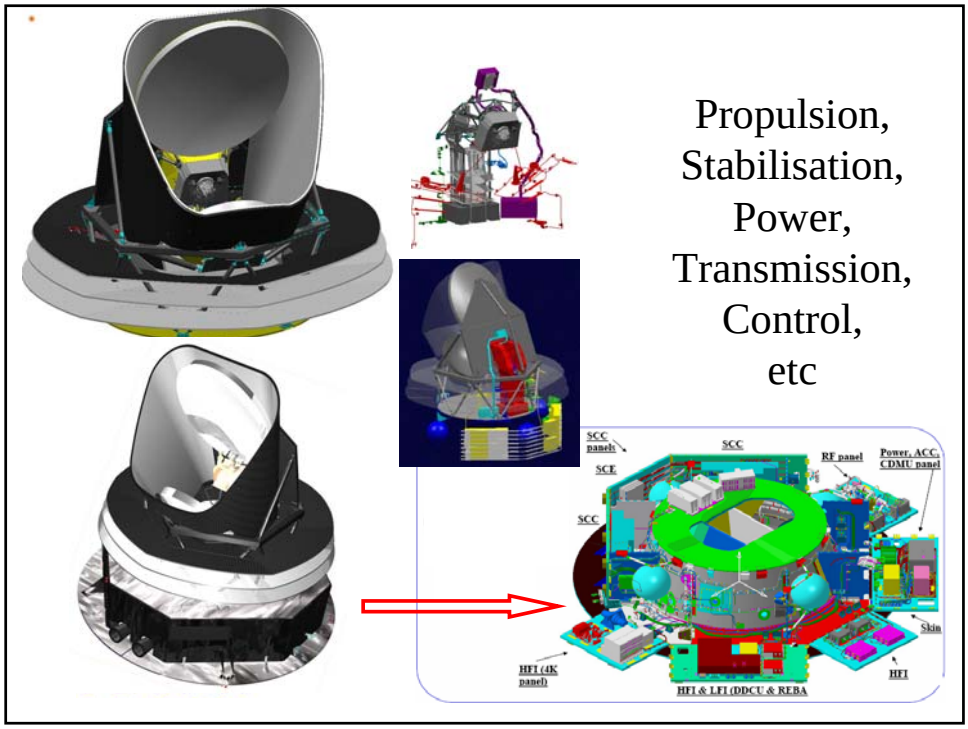
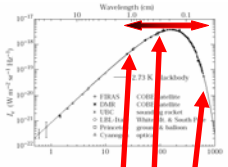
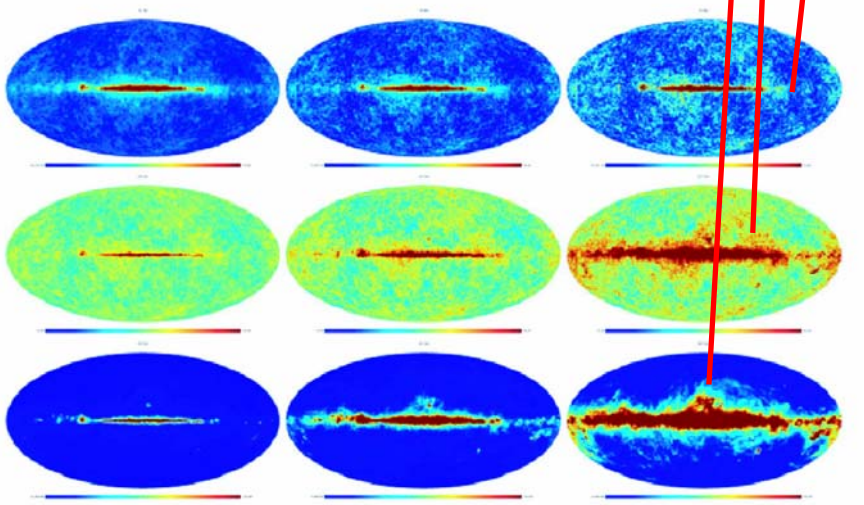
ors
Dilution cooler
Control unit
PLAN
HFI JFET
LFI-FPU
HFI-FPU
0.1K Pipes
LFI BEU
HFI PAU
ROPHYSICS


Propulsion,
Stabilisation,
Power,
Transmission,
Control,
etc
SCC panels
SCC
SCE
SCC
RF panel
Power, ACC, CDMU panel
Skin
HFI (4K panel)
HFI
HFI & LFI (DDCU & REBA

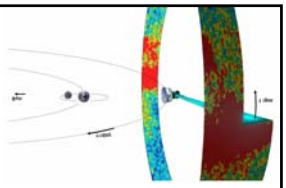
What will Planck see

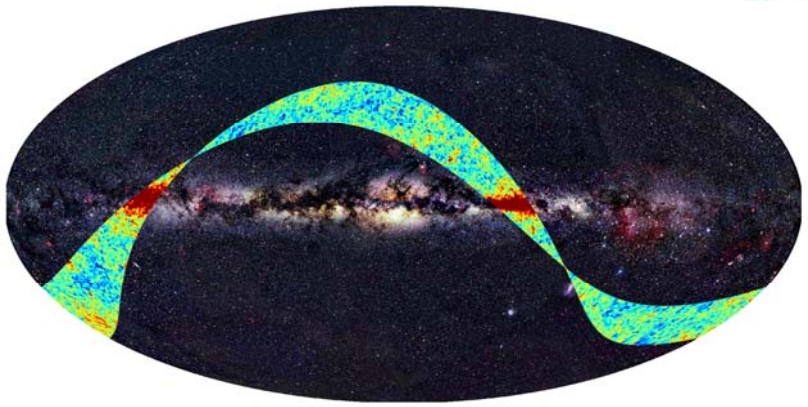


Using the spectral information if all these maps, Planck can measure The temperature of the CMB very precisely at each point of the sky



First images





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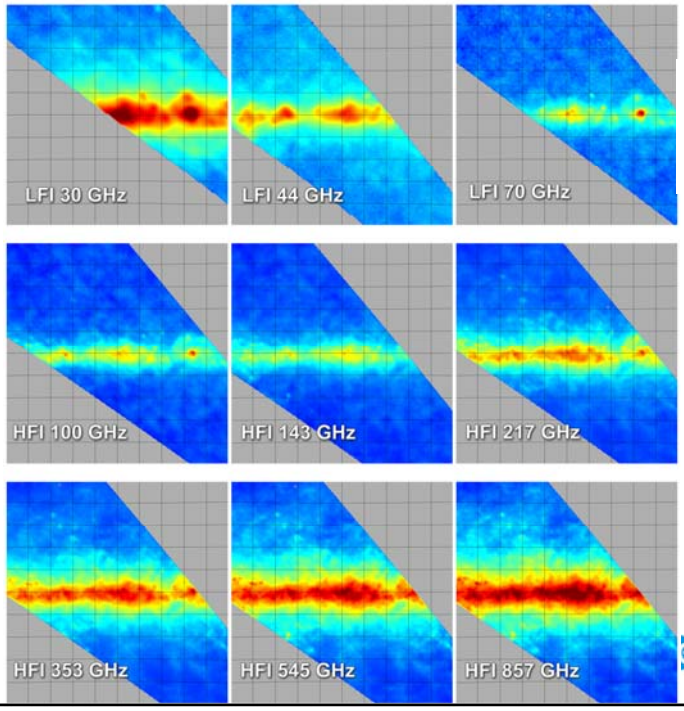

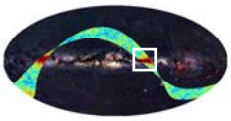

The Milky Way

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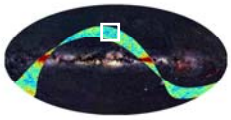
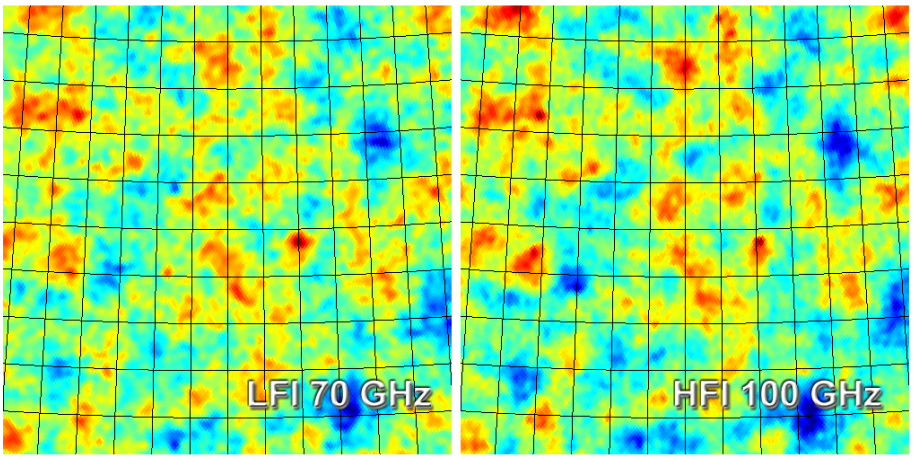


The Cosmic Microwave Background



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Thank you !