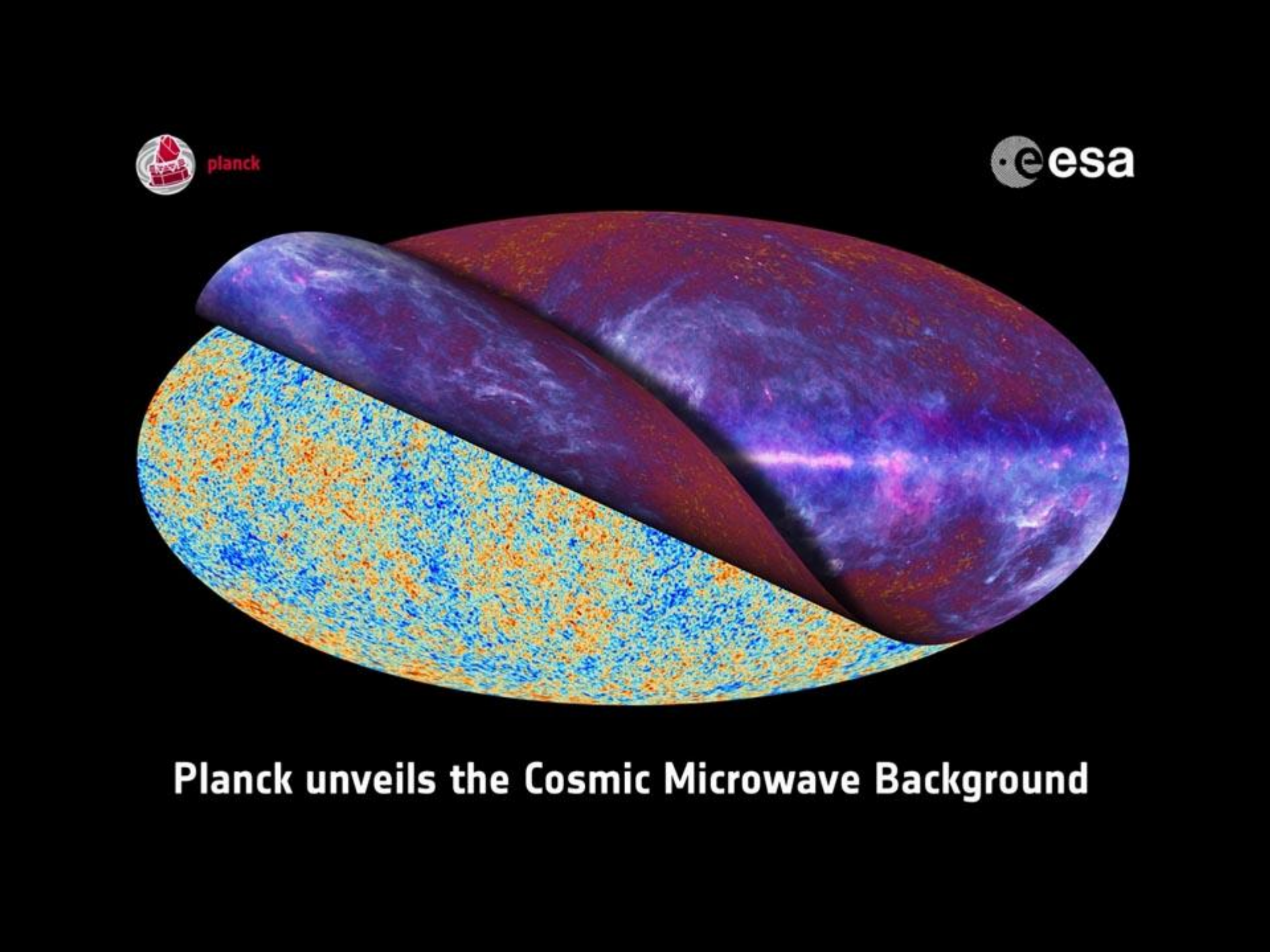
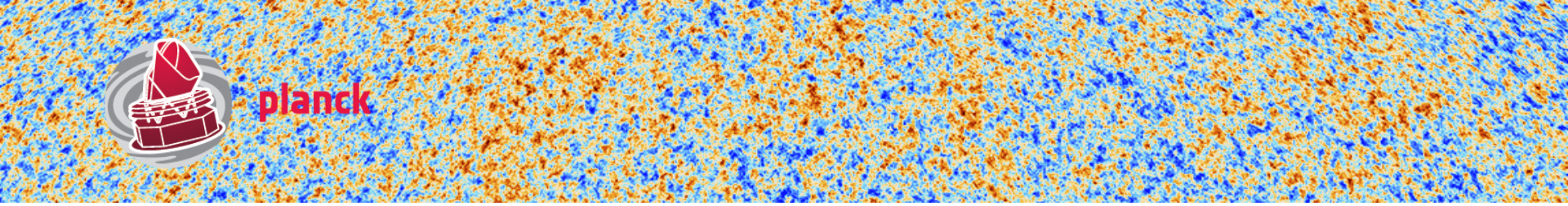

planck
esa
Planck unveils the Cosmic Microwave Background




# L'eco del BigBang misurato da un satellite Italo/Francese, PLANCK

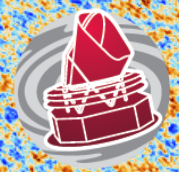
A. Zacchei

INAF-OATs

on behalf of the Planck Collaboration



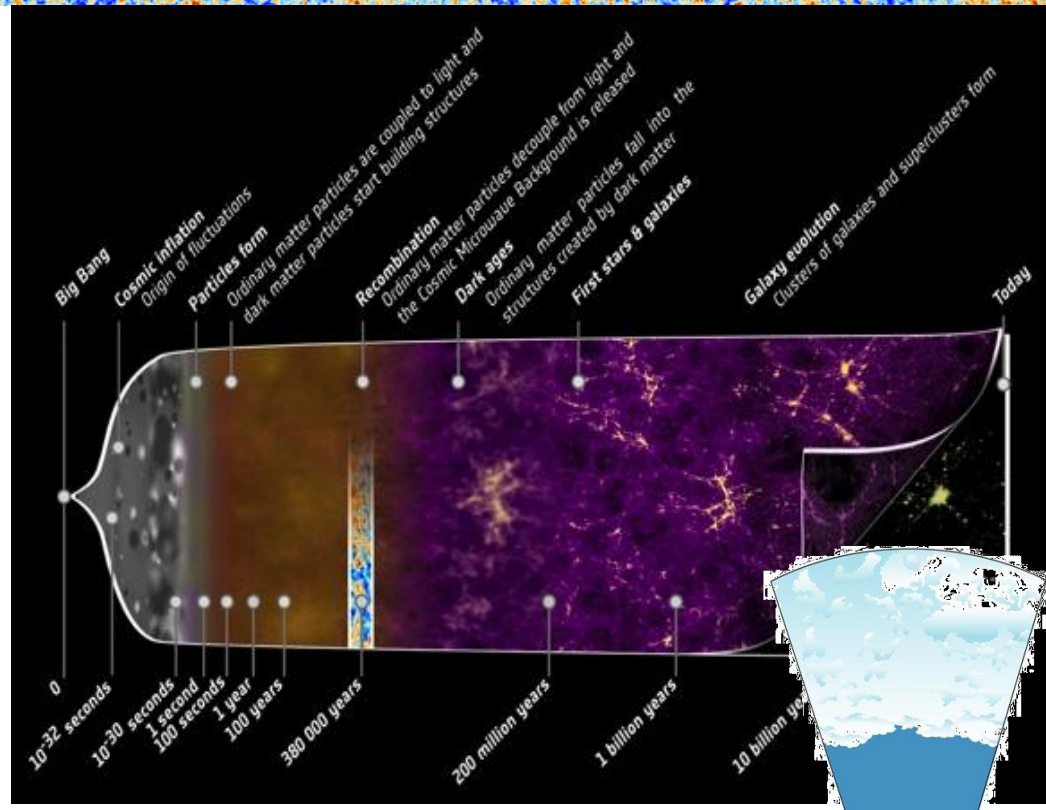
# Overview



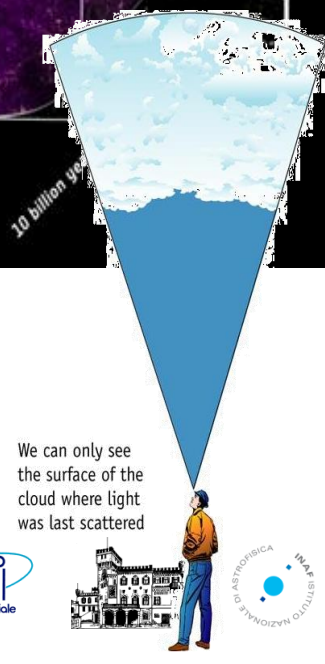
1. La CMB
2. Il Satellite Planck
3. L'acquisizione ed analisi dei dati
4. I primi risultati pubblici

# Il Big Bang

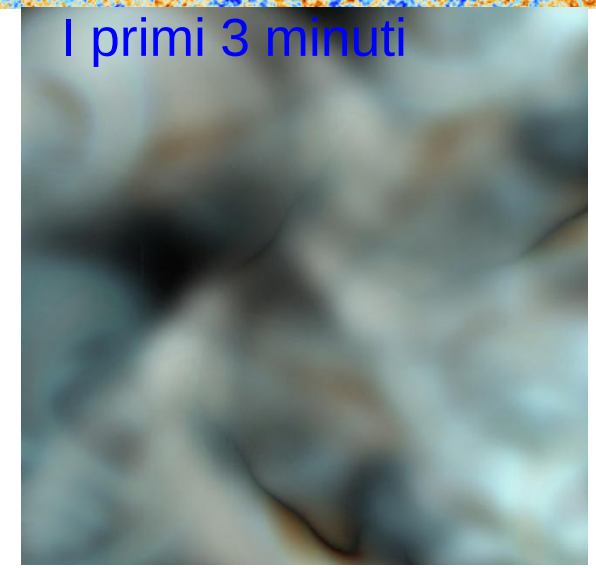
- Universo Primordiale: opaco, plasma caldo e ionizzato ad altissima densita'
  - Fotoni interagenti, elettroni, quarks, il tutto in equilibrio termico
- Universo in espansione
  - Scattering di Thomson
  - Il plasma si raffredda formando atomi di Idrogeno

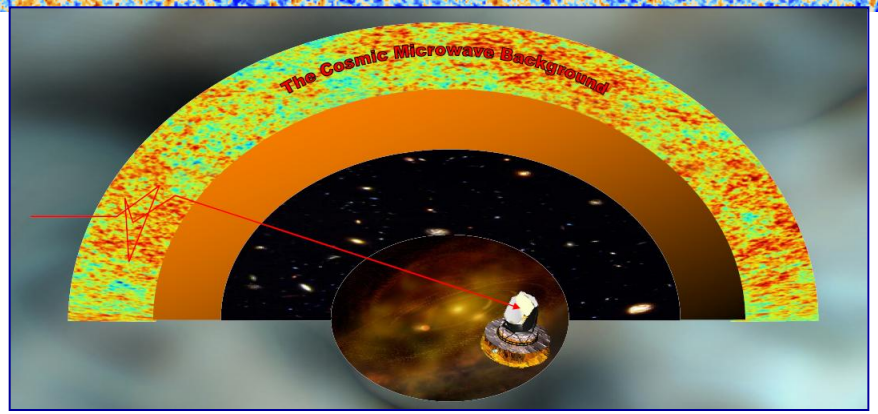



- T ≈ 3000 K ricombinazione (disaccoppiamento)
  - t ≈ 380000 anni dopo il Big Bang
- La materia diventa trasparente alla radiazione, la luce e' libera di viaggiare…



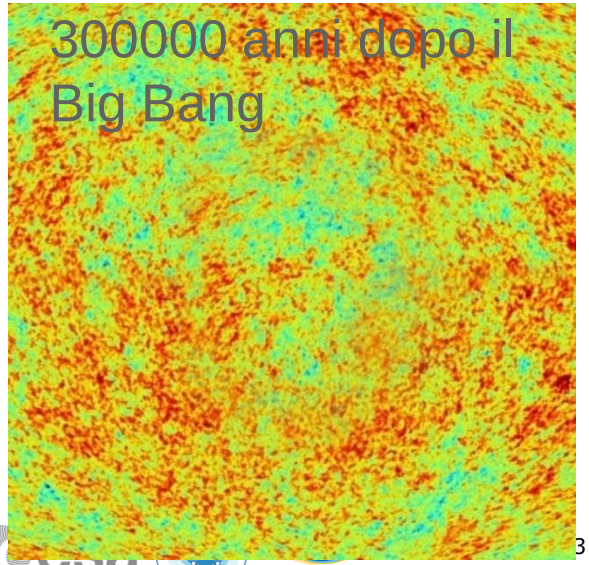
# Uno sguardo nel passato… da 3000 a 3 k




Strutture a piccola scala: risoluzione

Necessita' di rilevare radiazioen molto debole: sensibilita'



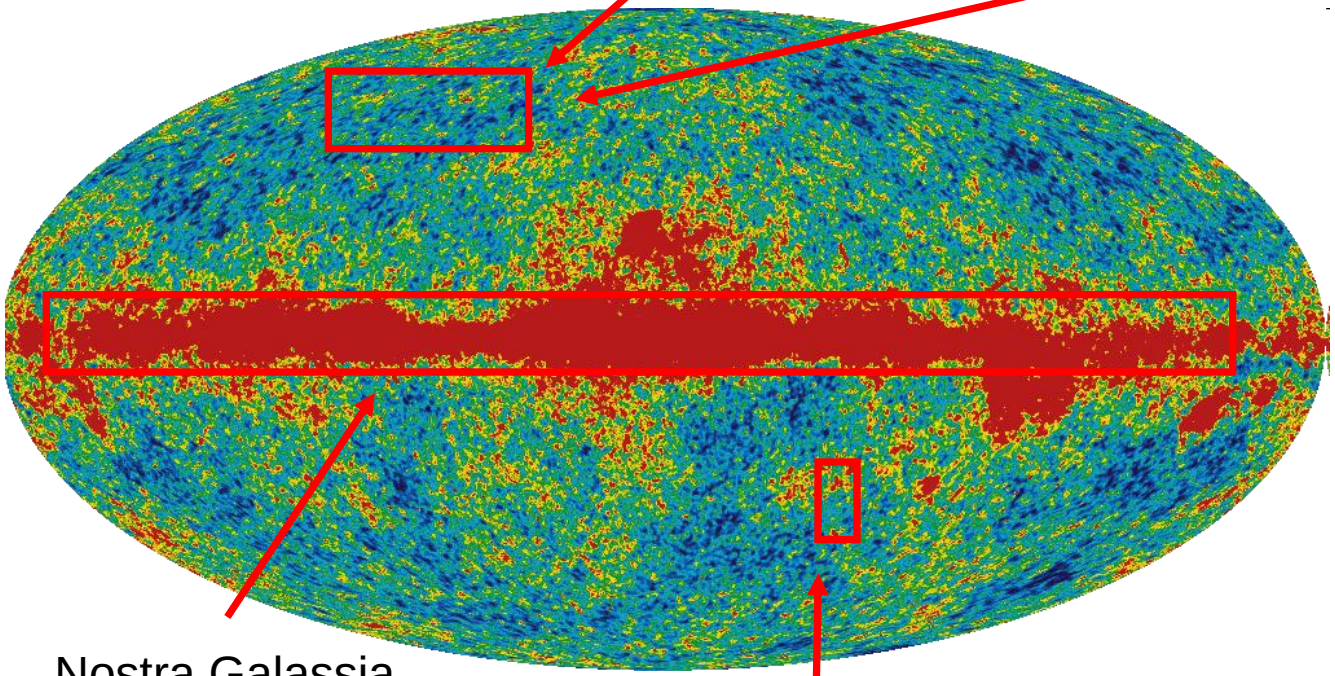


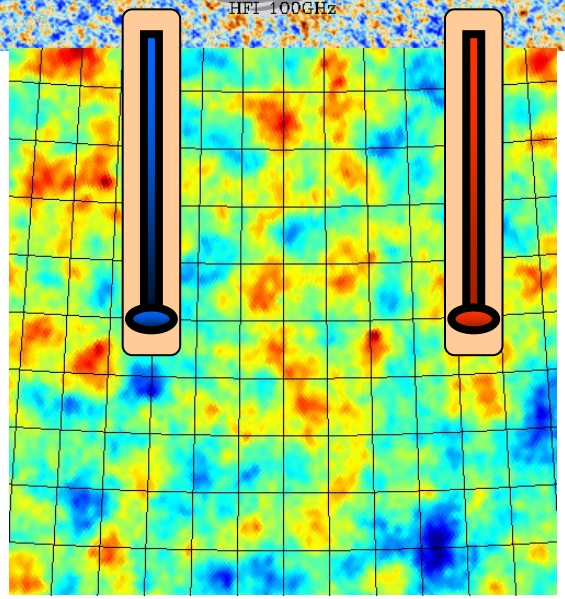
# The CMB

Abbiamo una formula per capire il nostro Universo;

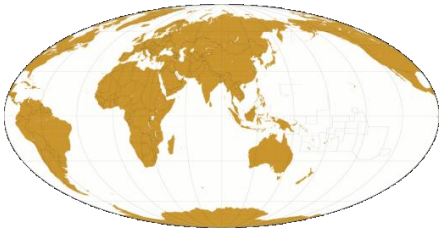
1. L'Universo, subito dopo il big bang, e' un oggetto piuttosto semplice (assomiglia ad un corpo nero perfetto);
2. La CMB (Cosmological Microwave Background) ci da' l'immagine dell'Universo al tempo della ricombinazione
3. Proprieta' dell'Universo a larga scala non sono cambiate dall'epoca della ricombinazione e possono essere sintetizzate in pochi numeri;
4. Usando la CMB questi numeri descrittivi del nostro universo possono essere misurati con elevata accuratezza.

# Le anisotropie della CMB

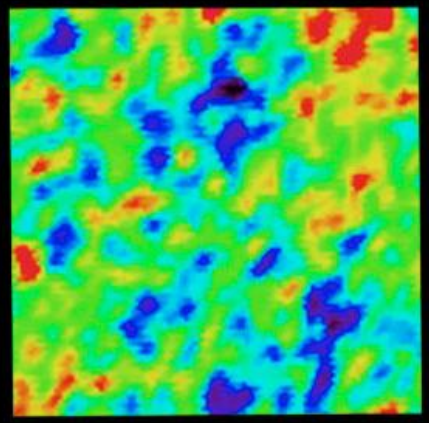


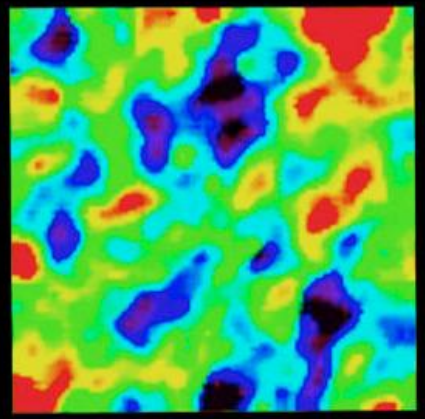



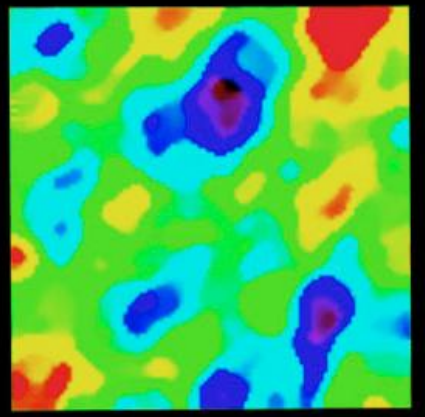

70 μK

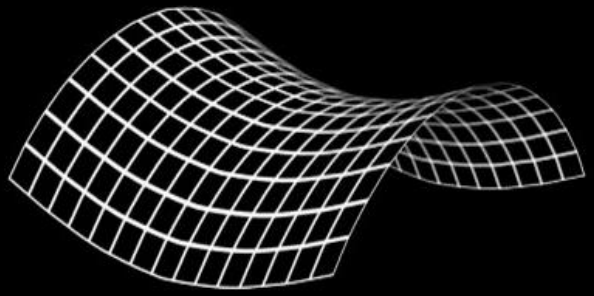


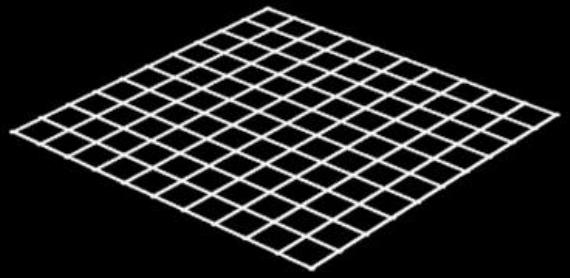
# La CMB e la Geometria dell'Universo

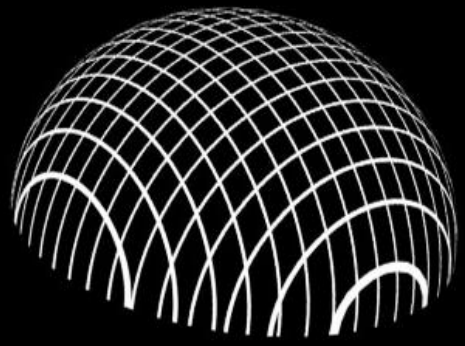










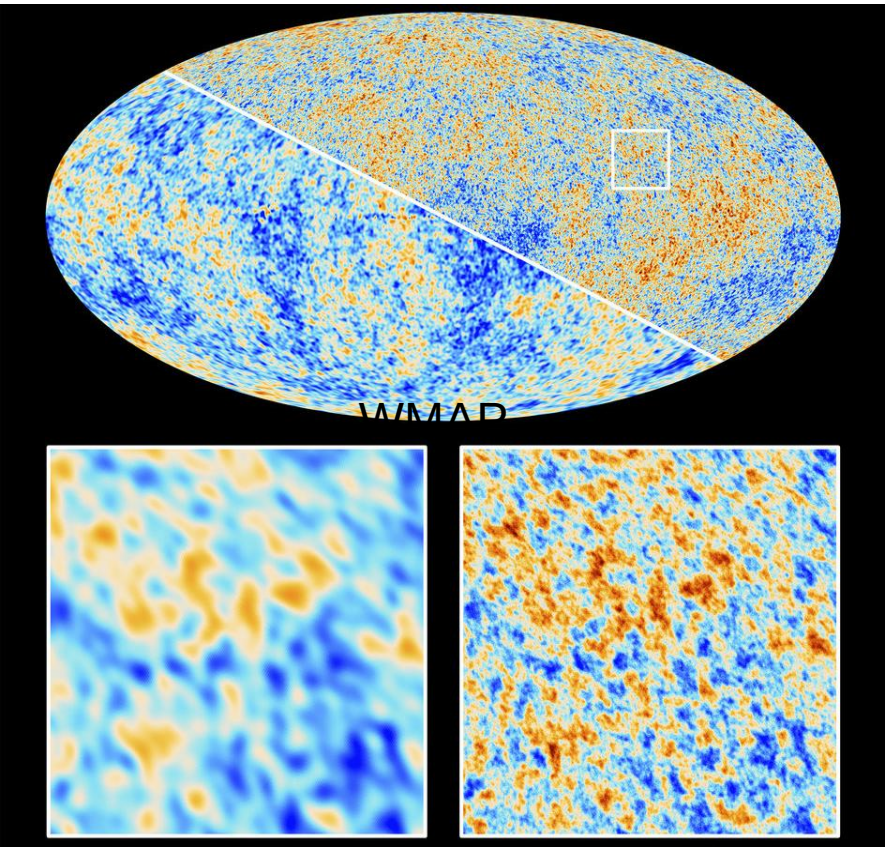


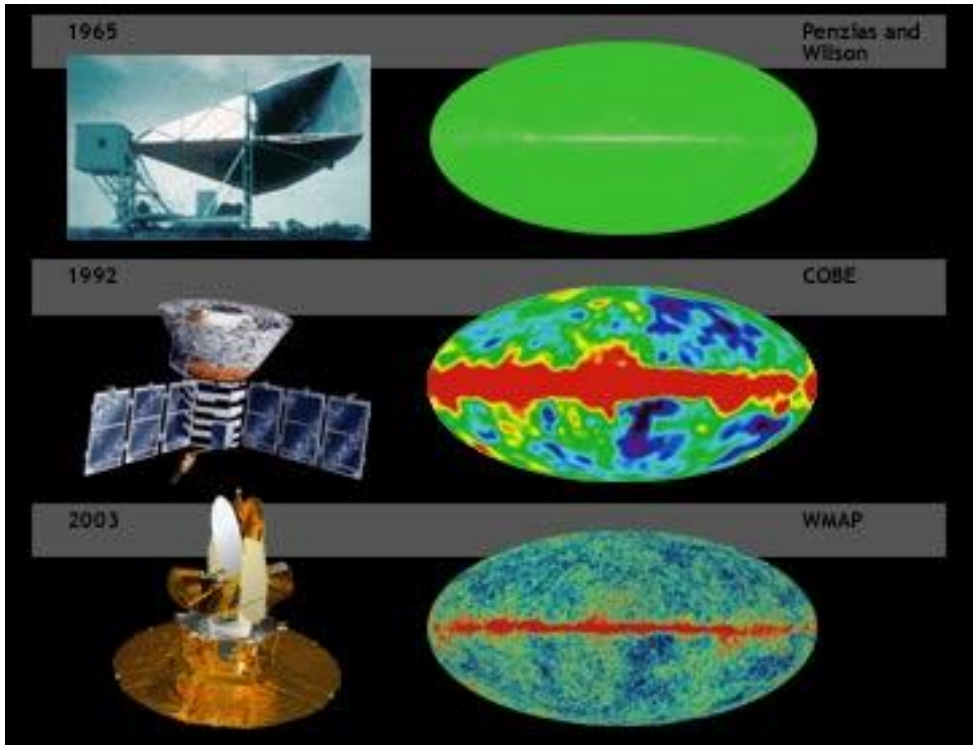
Open

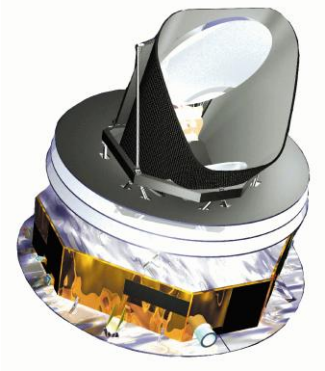
Flat

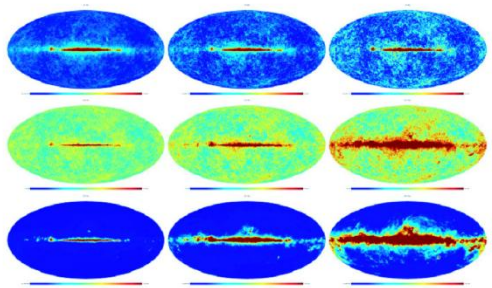
Closed

# Planck vs WMAP

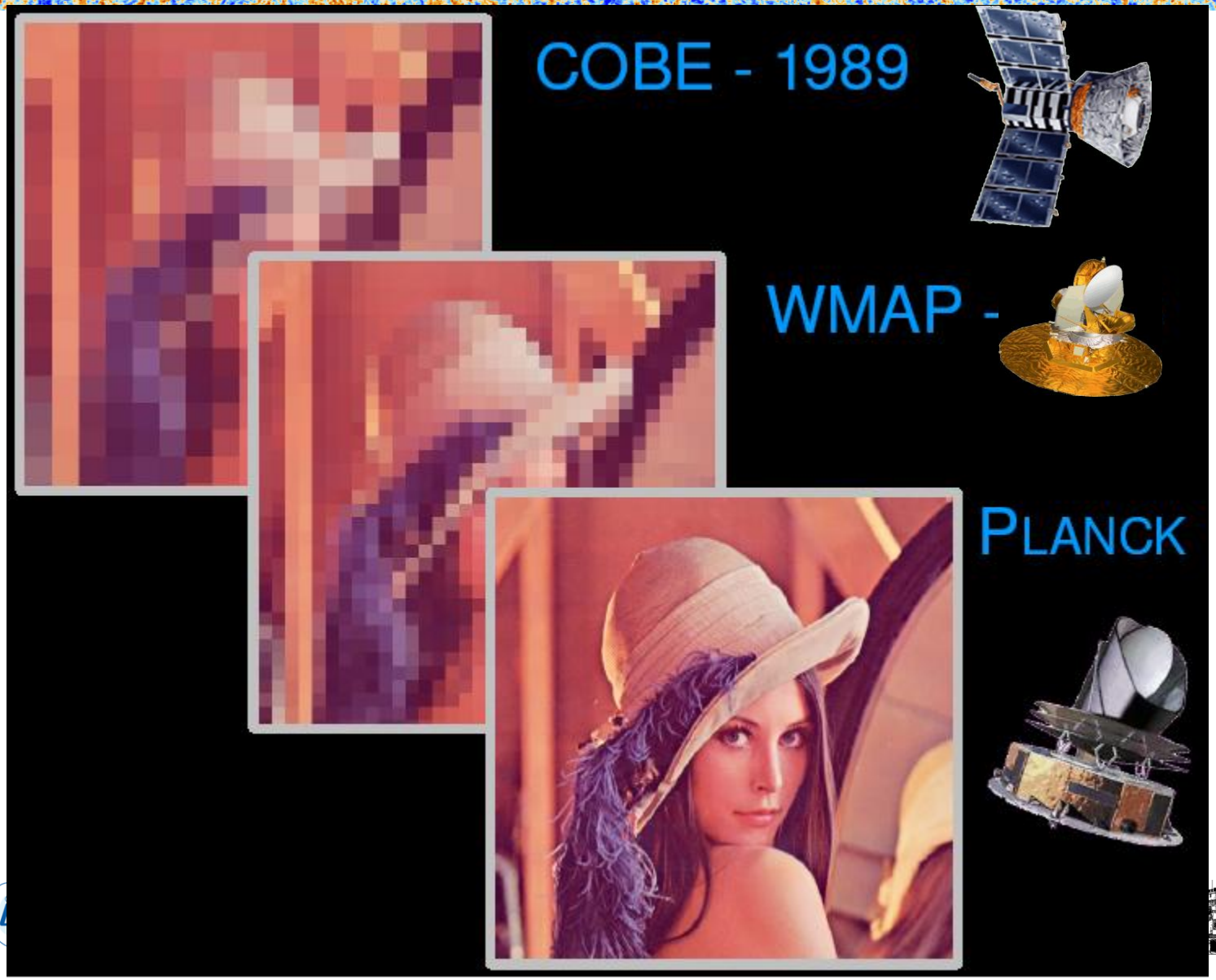




# Why Planck?



# Planck in pillole


1. Missione ESA, è stata lanciata il 14 Maggio 2009 (con Herschel).

2. Oltre a ESA, ci sono due Consorzi internazionali ognuno con la responsabilità della costruzione degli strumenti e l'analisi dei dati
   a. LFI, 22 radiometri raffreddati a 20 K, PI: N.Mandolesi - INAF/IASF Bologna.
   b. HFI, matrice di bolometri raffreddati a 0.1 K, PI: J.L.Puget - IAS Orsay.
   c. Sistema di Raffreddamento (Sorption Cooler), PI: C. Lawrence – NASA/JPL.

3. La vita nominale (14 mesi dopo il raggiungimento del punto L2) è stata estesa di tre anni ⇒ cinque survey complete del cielo; tre survey "LFI-only". Durata complessiva: 51 mesi.

4. Costo COMPLESSIVO della missione circa 800 milioni di Euro.

5. Scopo scientifico: ricavare le mappe a tutto cielo di tutte le maggiori sorgenti che emettono dalle microonde sino al lontano infrarosso, mappe delle anisotropie nella RADIAZIONE DI FONDO COSMICO ⇒ valutare i principali parametri cosmologici.

# Il satellite Planck


3rd CMB space mission - 1st ESA in collaboration with European, US and Canadian scientific community

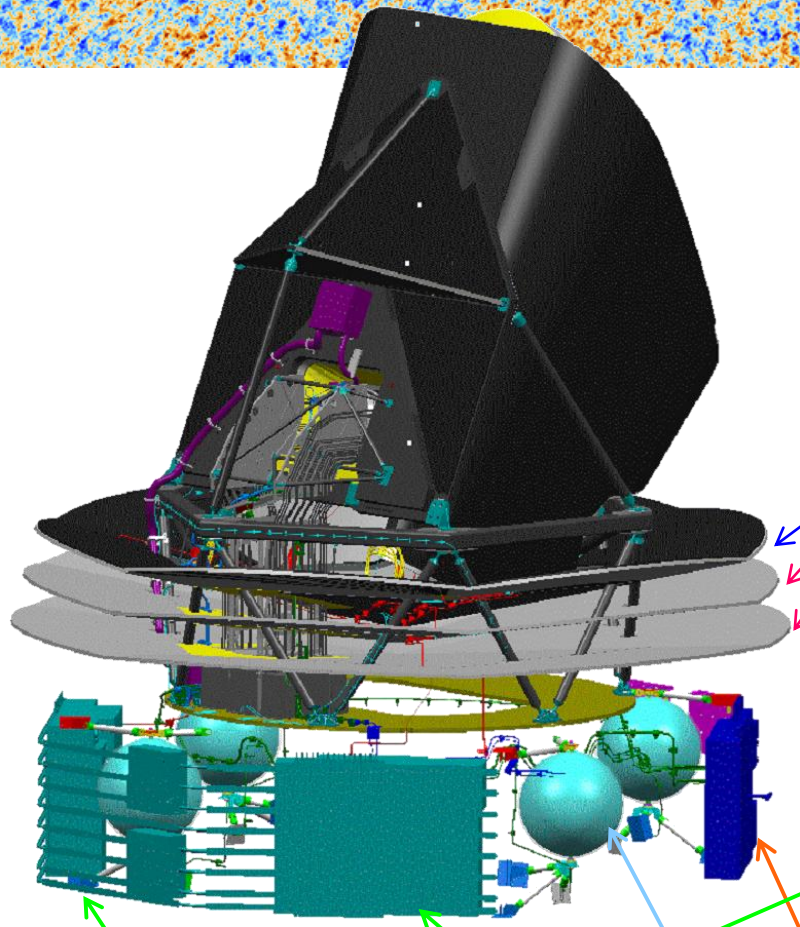
| | |
|---|---|
| Mass | 2˙000 kg |
| Power | 1˙600 W |
| Size | 4.2 × 4.2 m |
| Cost | 800×10$^6$ € |

50˙000 Electronic components
36˙000 l $^4$He
12˙000 l $^3$He
11˙400 Documents

20 yrs between project & results

2 instruments & consortia
16 countries
400 researchers

# Il frigorifero …. L'oggetto piu' freddo mai costruito

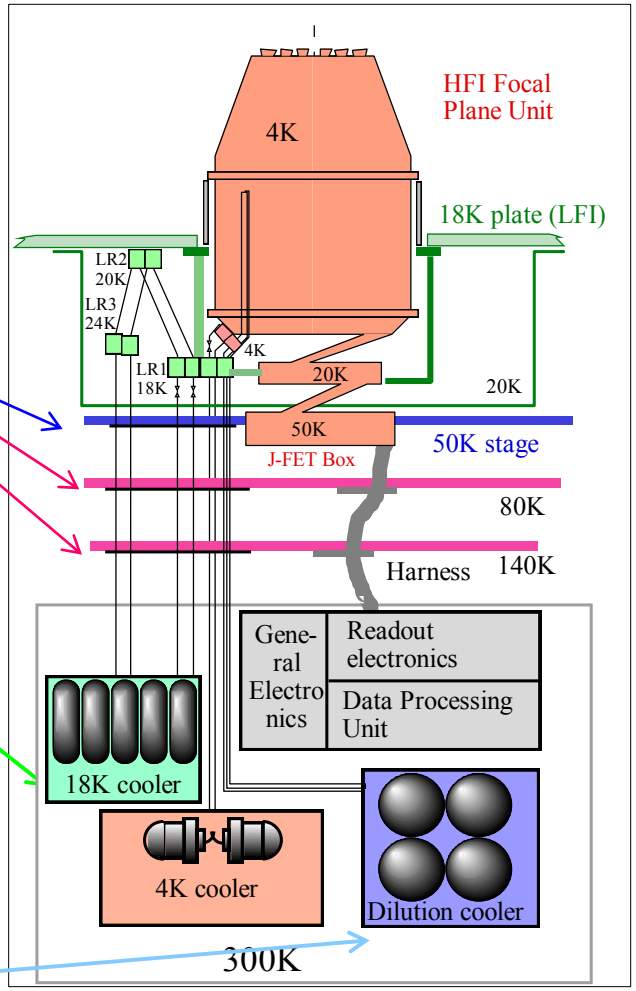


V-grooves

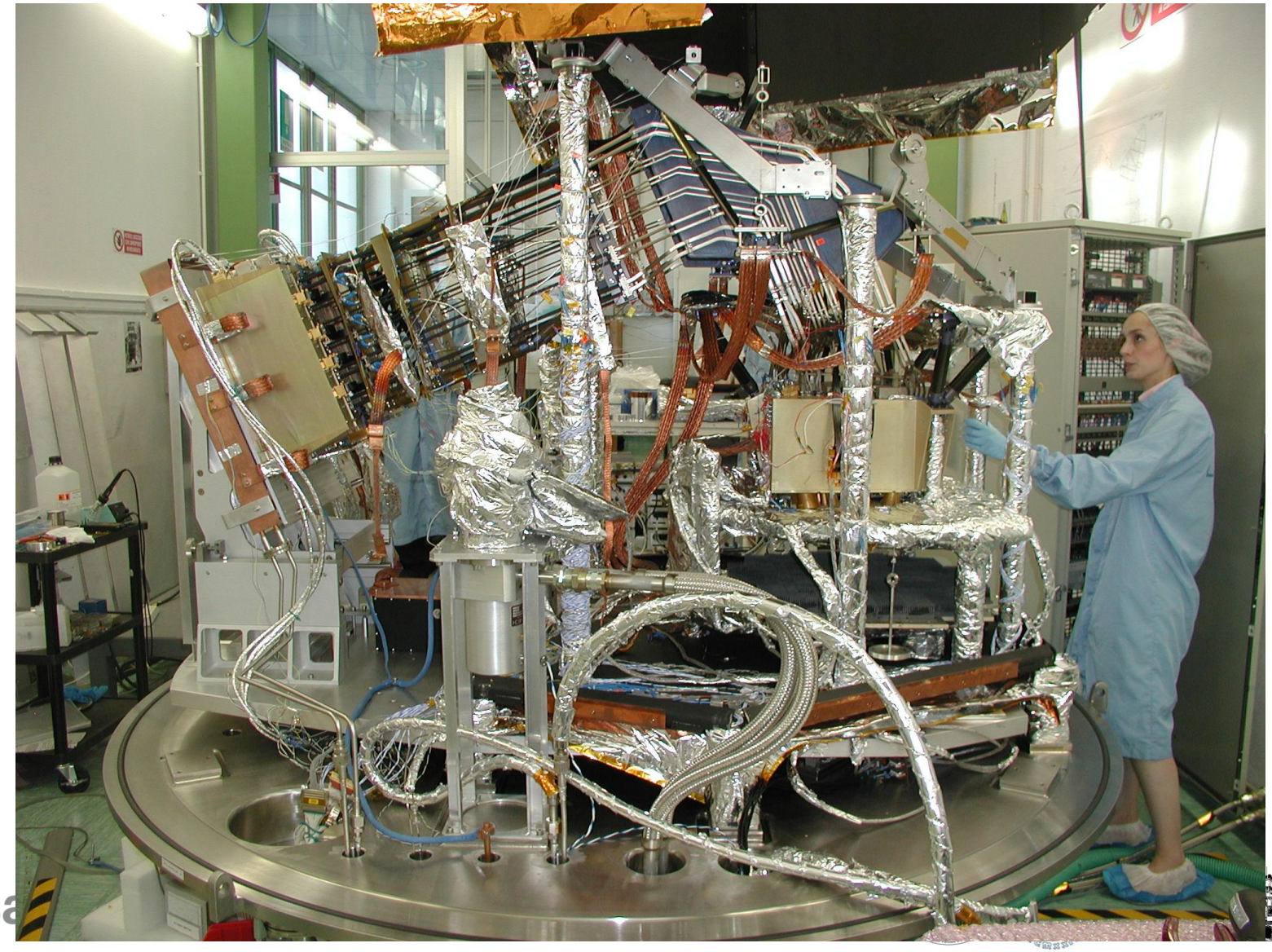
18-20 K H2 sorption coolers (JPL)

4 K Stirling cooler (RAL)

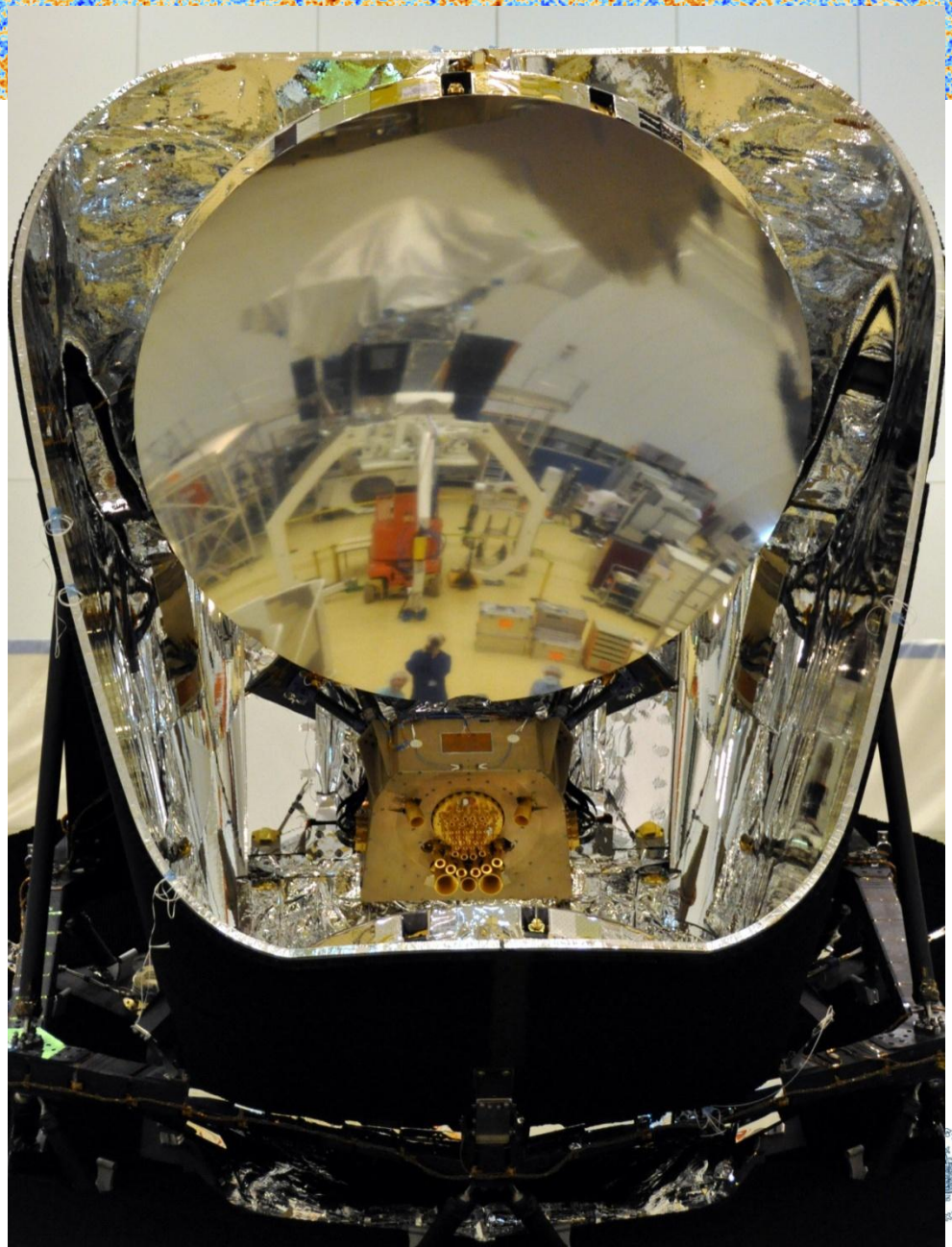
0.1 K $^3$He/$^4$He dilution cooler (CRTBT)



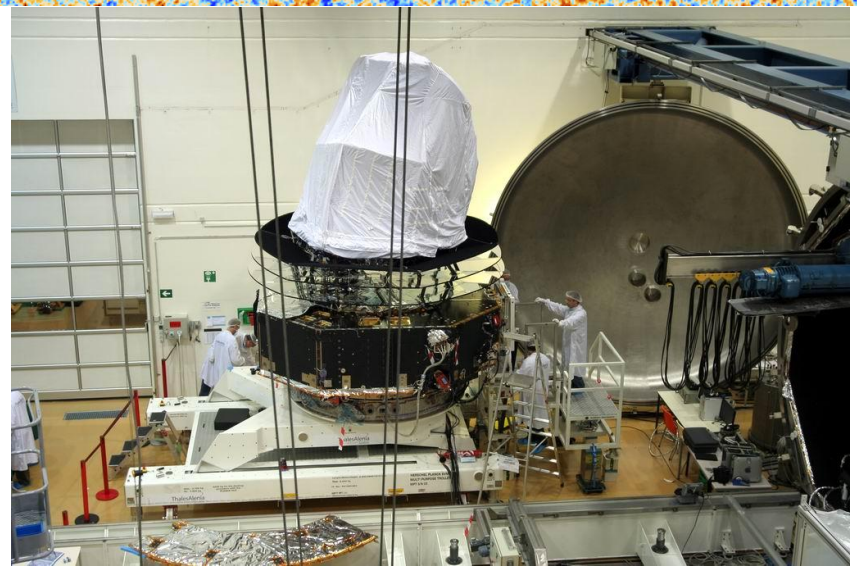
# Lo strumento Italiano e' stato integrato a Milano



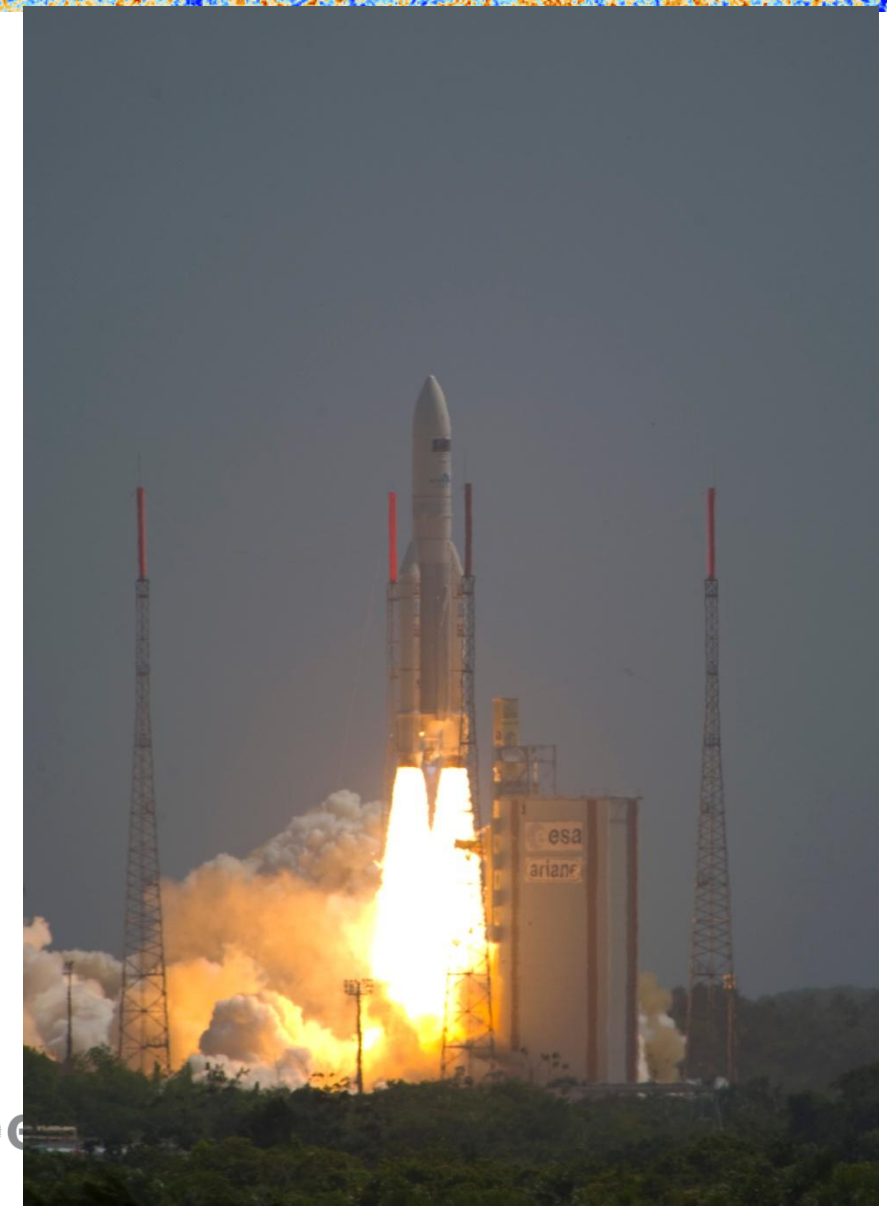
# L'Occhio di Planck

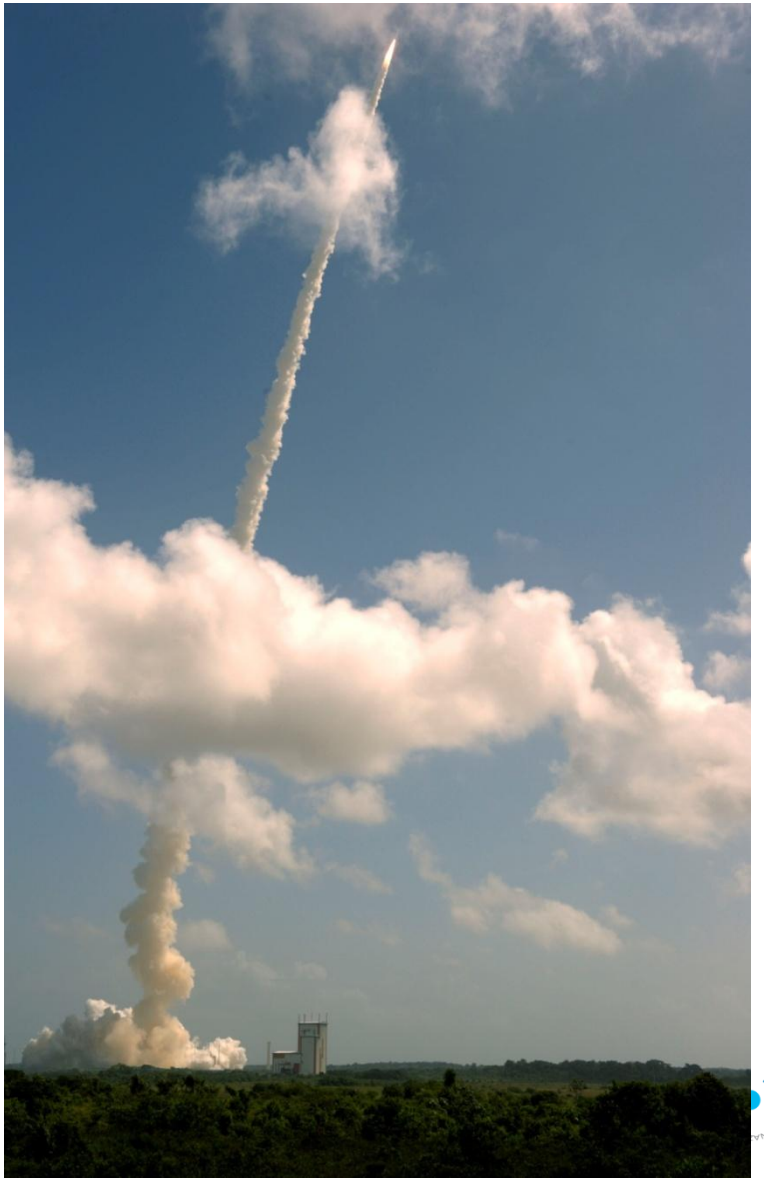


# Ultimi test e Planck fa il pieno …

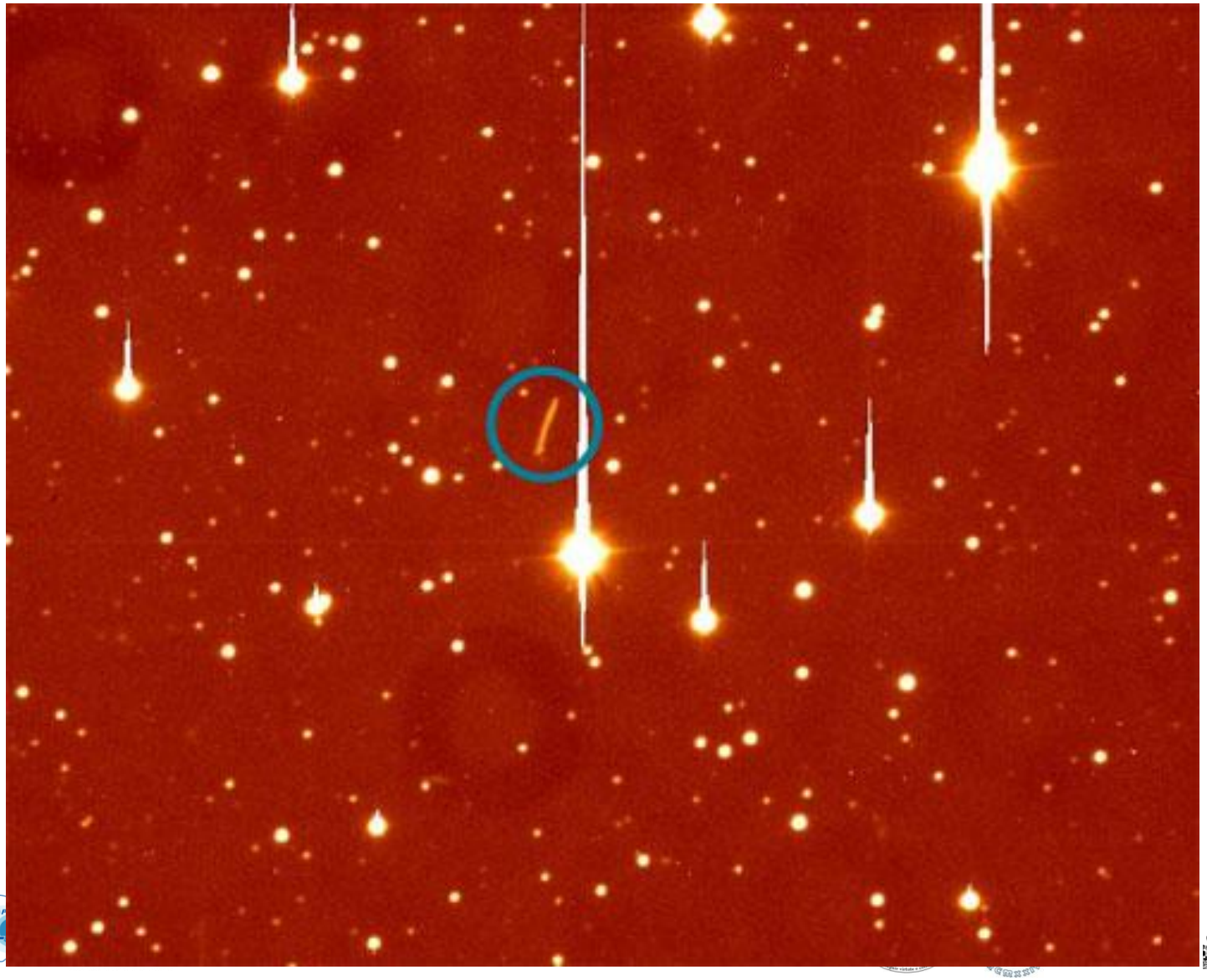



# Il Lancio (14 Maggio 2009)

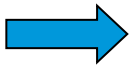


# Ma siamo sicuri ???



# Acquisizione dei dati



0110101

1110110

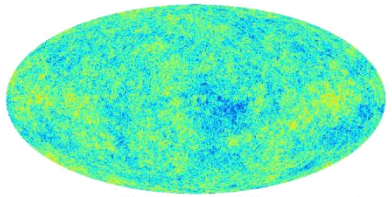


MOC

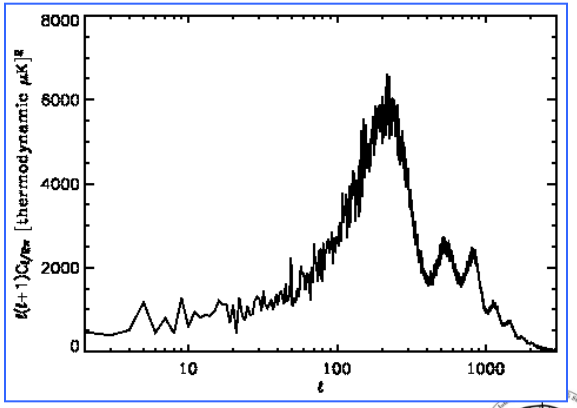


Parigi e Trieste

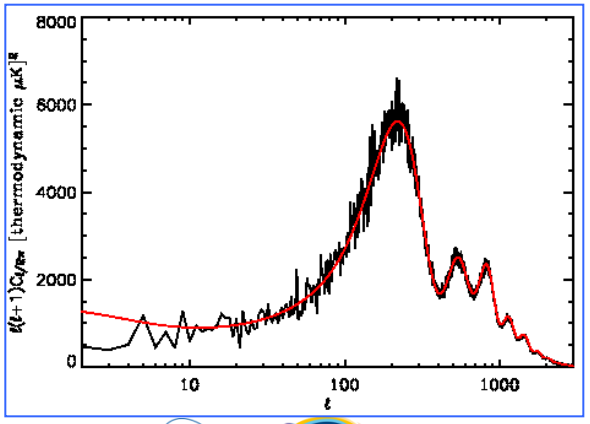








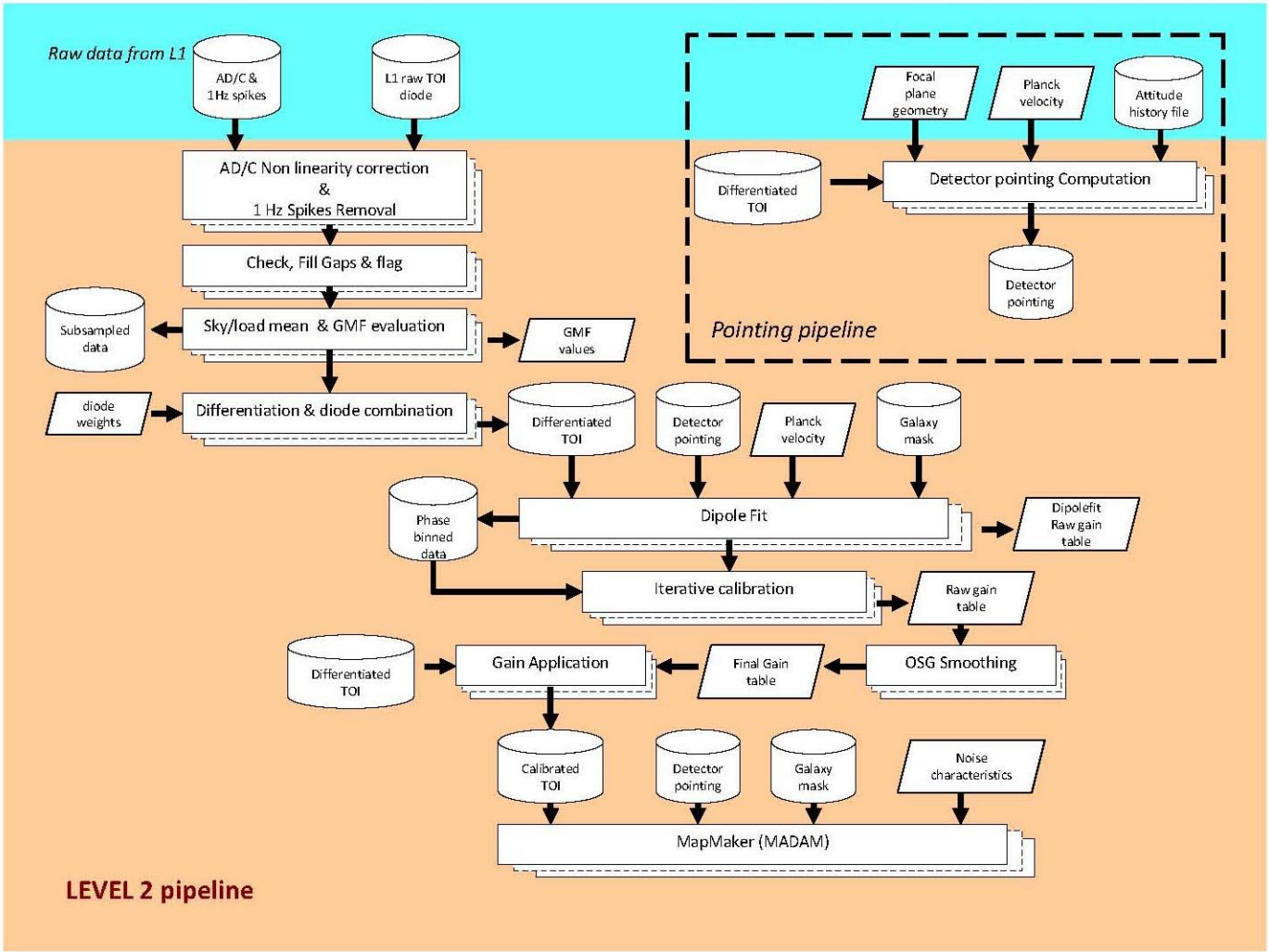


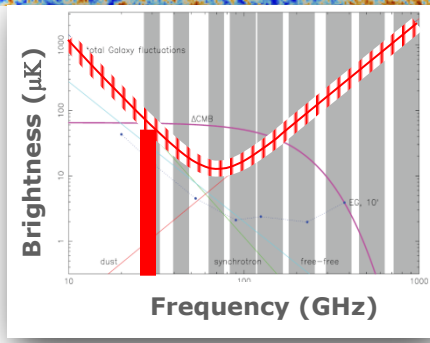
# LFI Pipeline

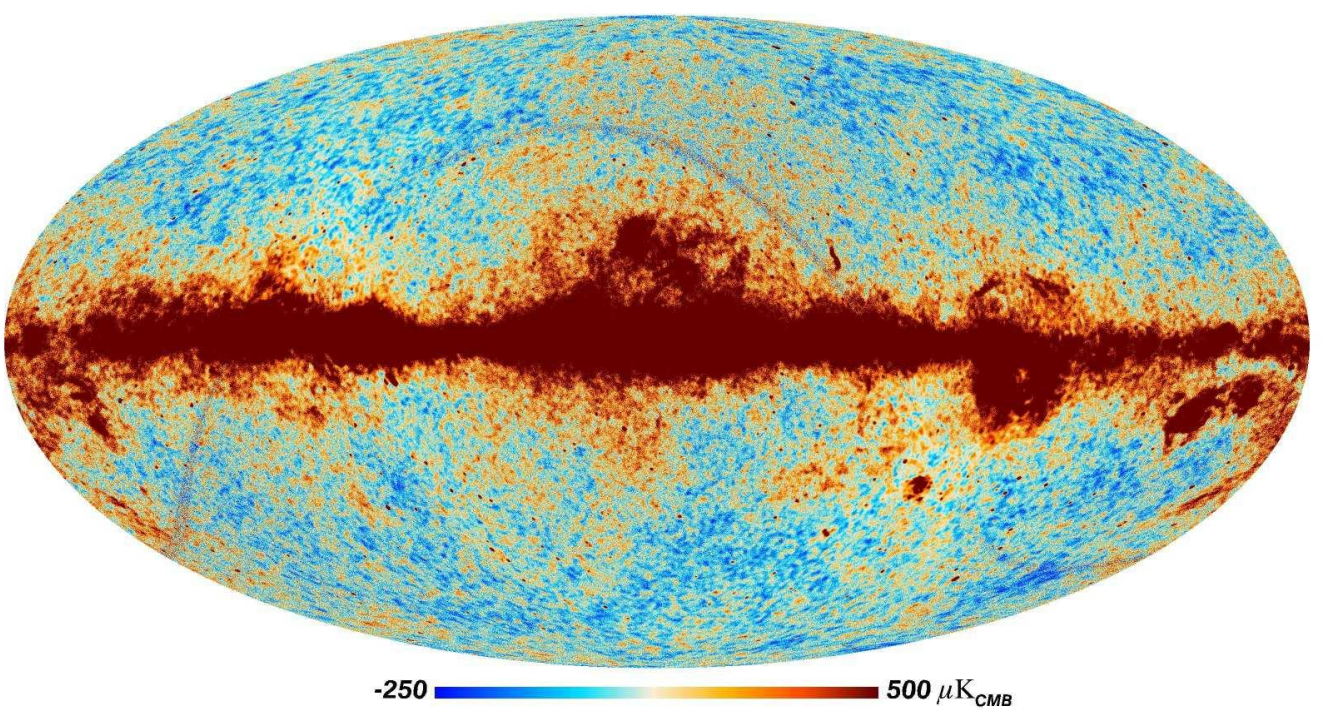
Tutto il software usate e' stato realizzato all'interno della collaborazione Planck.

Si tratta di centinaia di moduli di analisi scritte in C++ che lavorano su cluster(250/10000 CPU) in ambinete linux.

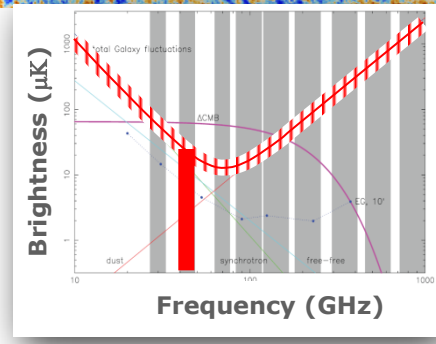


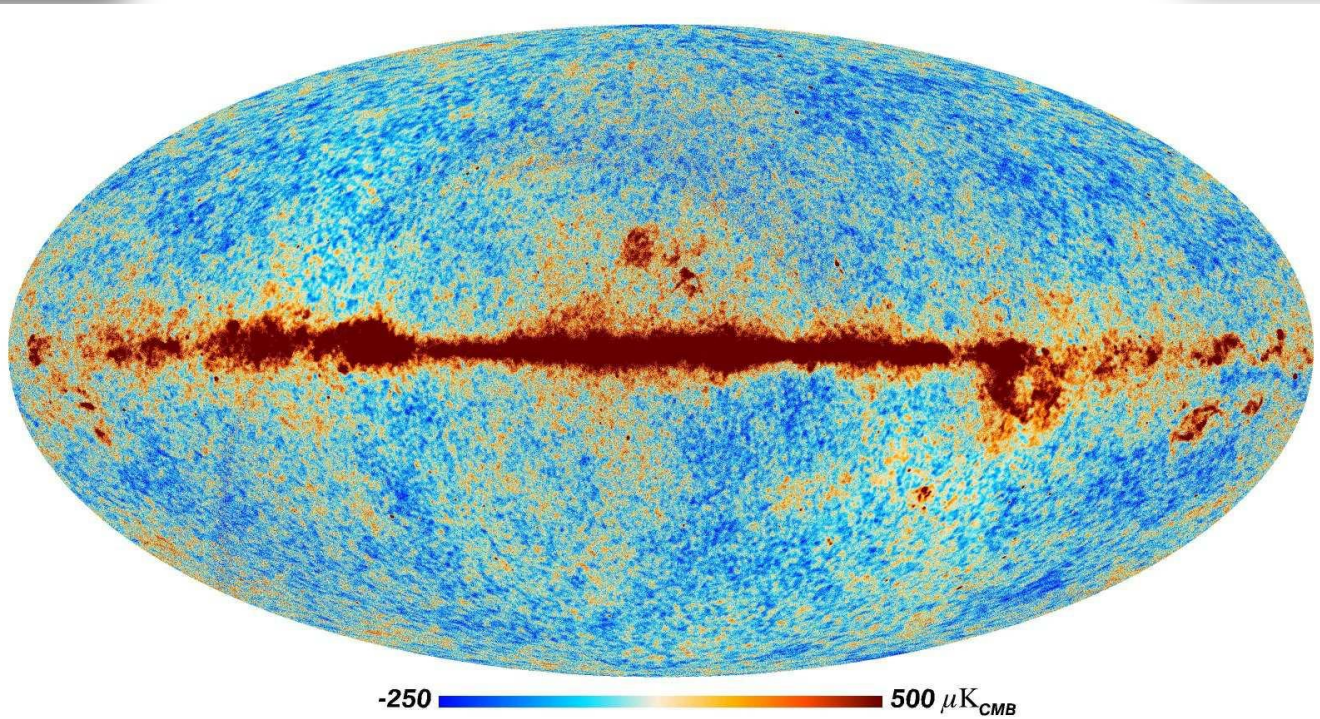
# Planck-LFI – 30 GHz frequency map



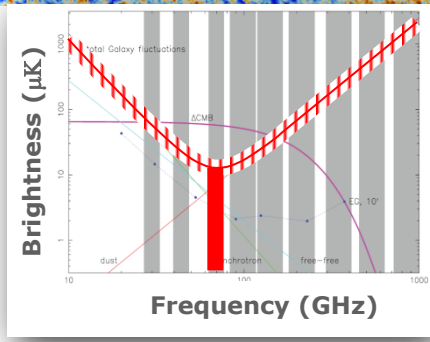



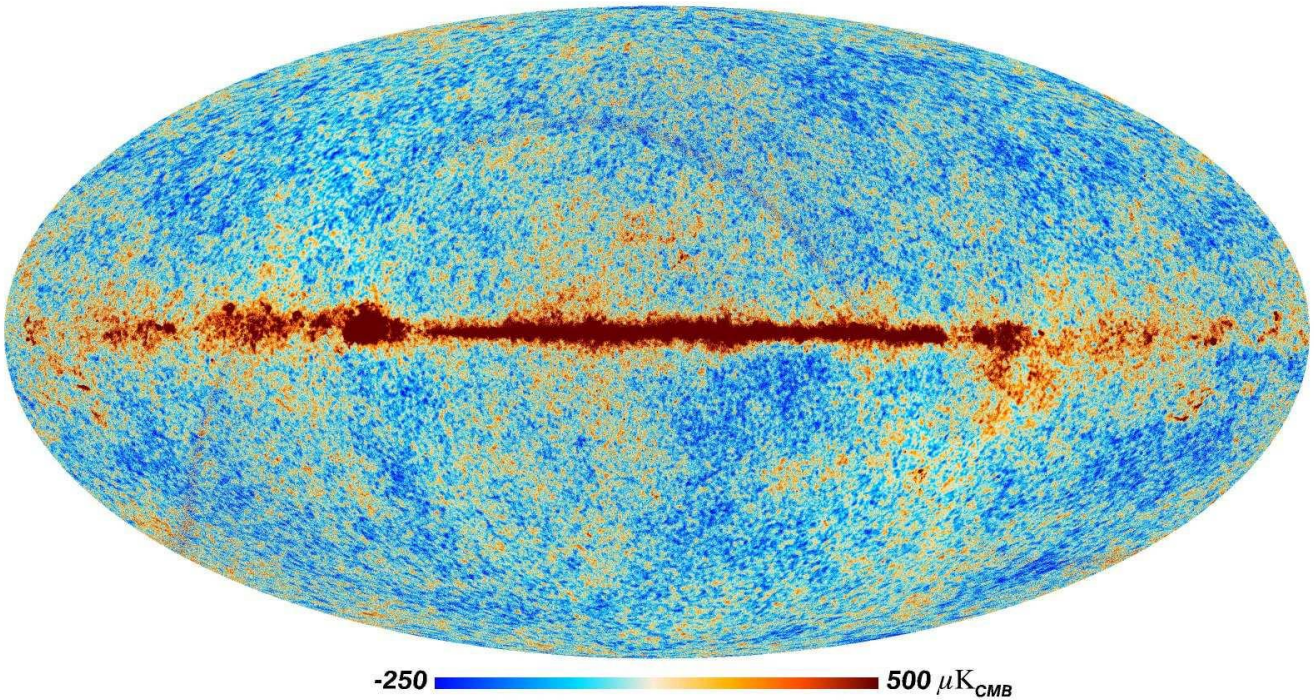
# Planck-LFI – 44 GHz frequency map



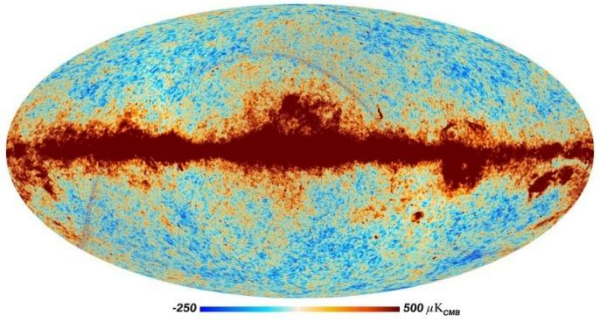



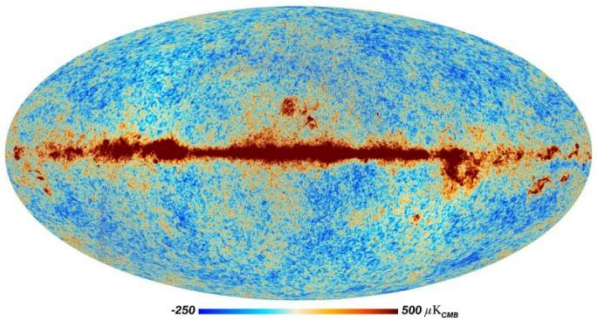
# Planck-LFI – 70 GHz frequency map

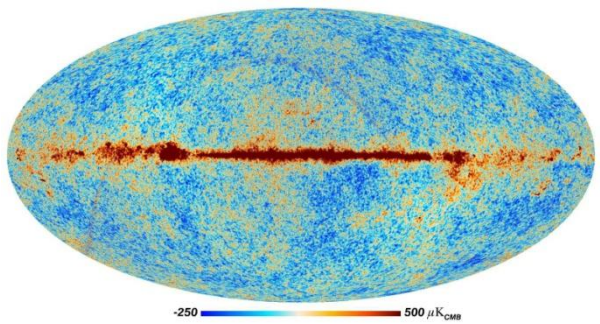


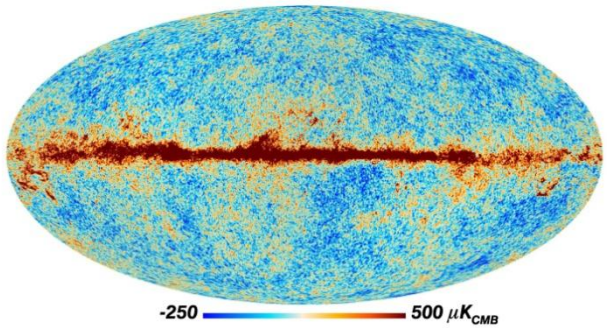



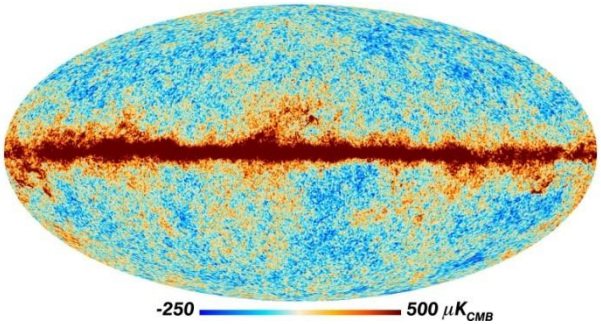
# Planck le Mappe in frequenza

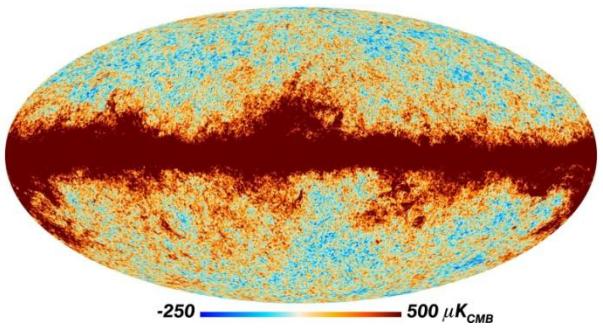


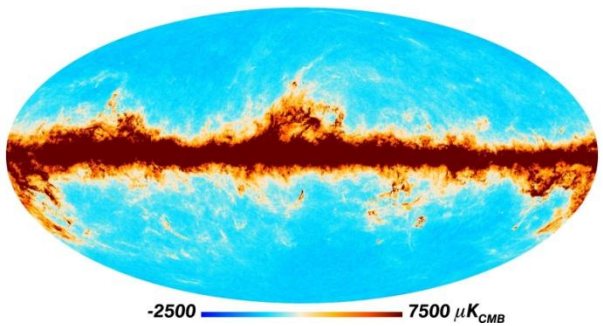



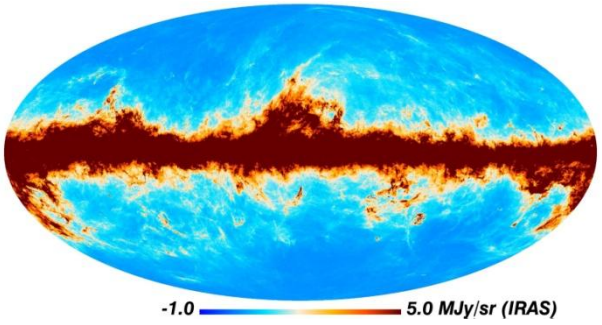



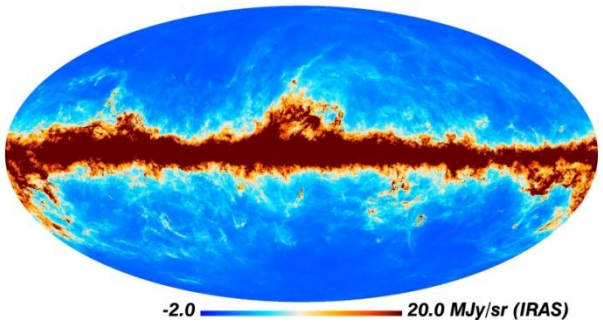



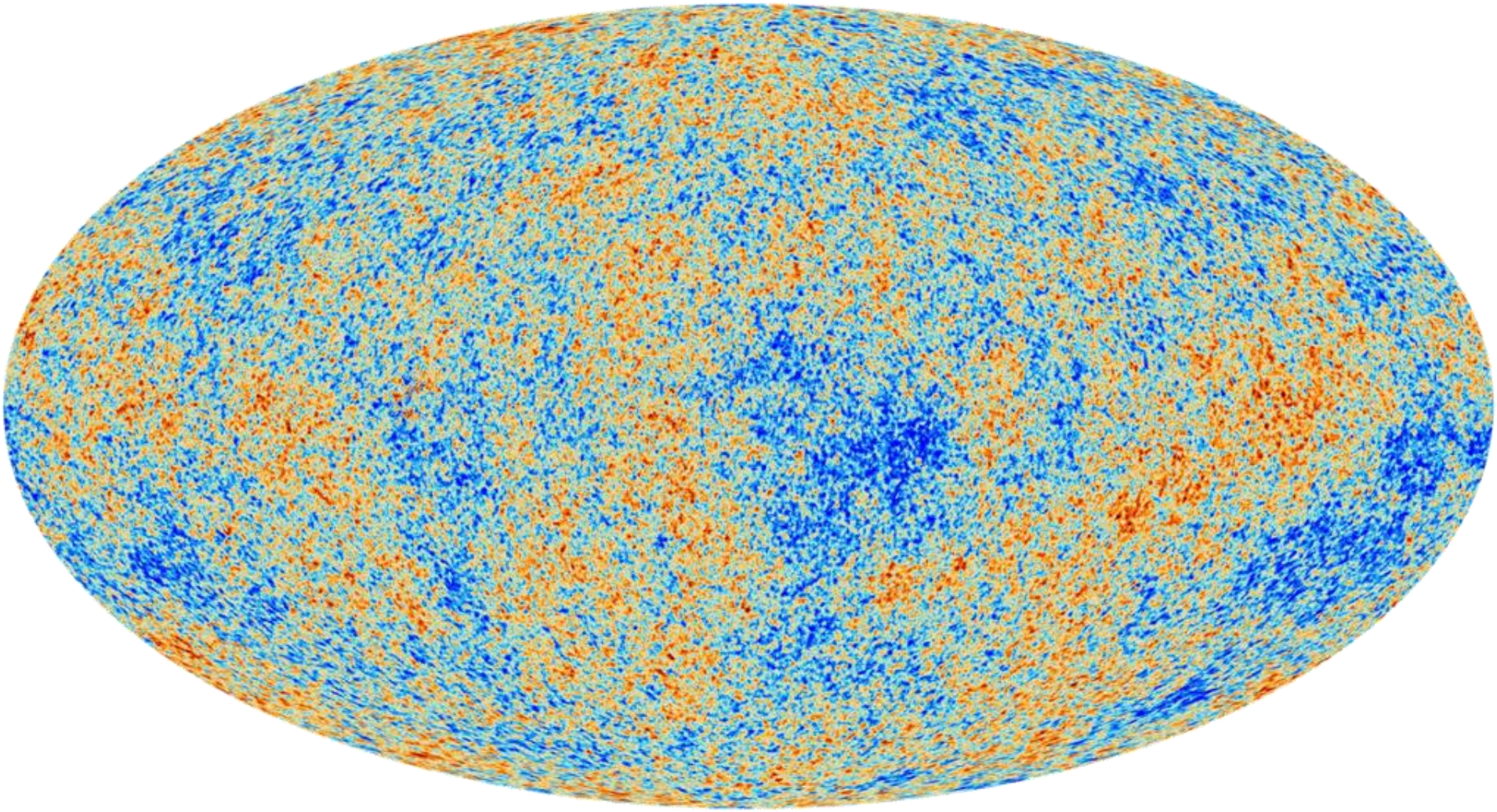



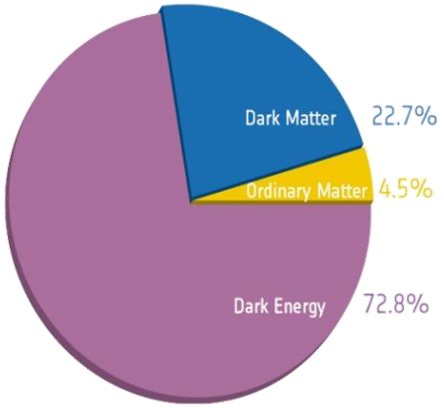
# Planck CMB Map



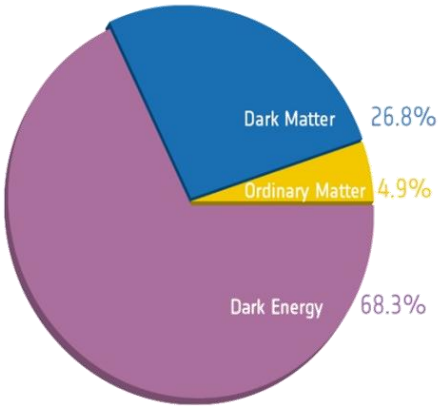
# I primi risultati: di cosa e' fatto l'universo ?

- Eta' dell'universo: $13.82 \times 10^9$ anni

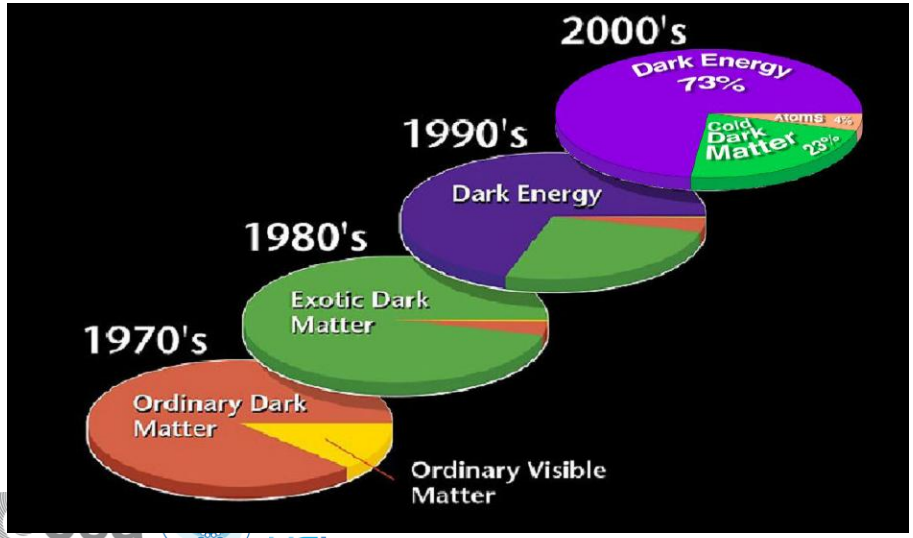
- Composizione
  - 4.9% Materia ordinaria
  - 26.8% Materia Oscura
  - 58.3% Energia Oscura




Before Planck




After Planck



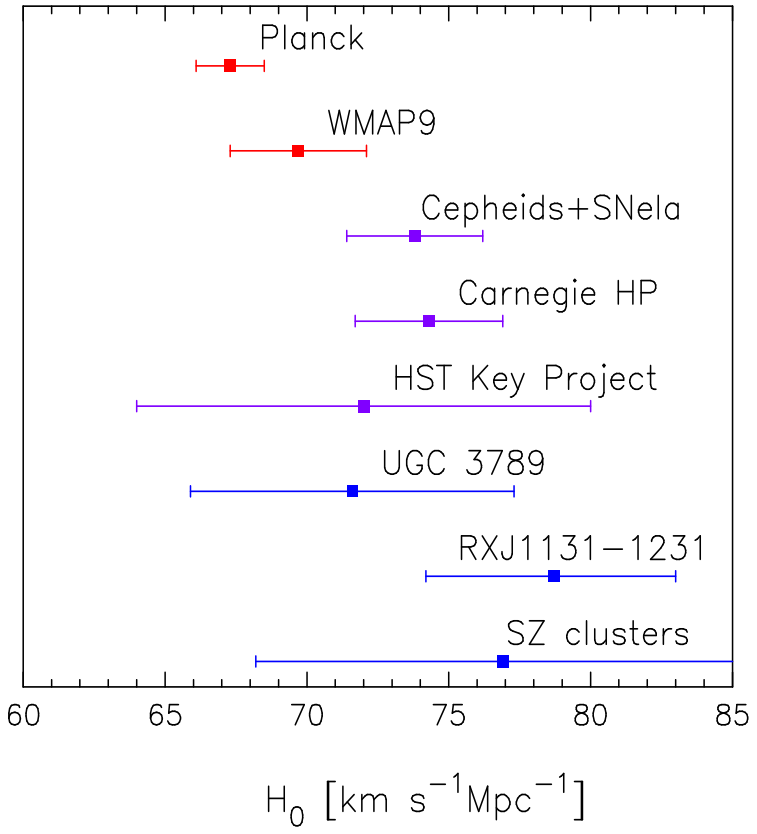
# I primi risultati: di cosa e' fatto l'universo ?

Geometria dell'Universo

- $\Omega_0$=1: Universe e' piatto, in continua espansione

Hubble constant (velocita' di espansione):

- $H_0$ = 67.3 ± 1.2 km $s^{-1}Mpc^{-1}$
- Prima di Planck era 72 ± 8 km $s^{-1}Mpc^{-}$

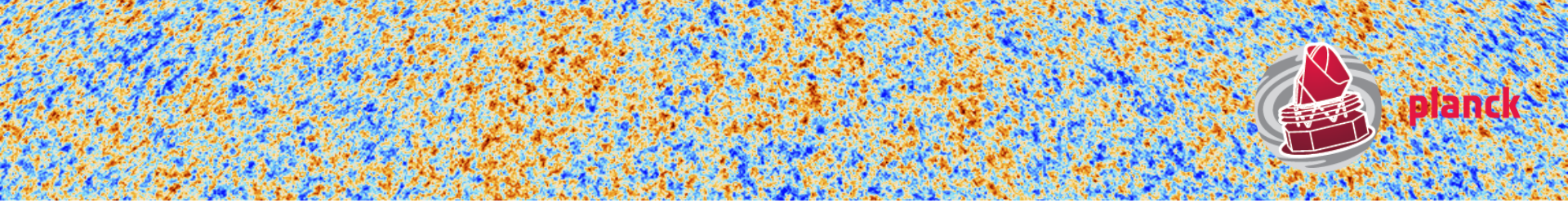


# Domande ancora aperte....

- Che cosa e' la Materia Oscura?
- Che cosa e' l'energia Oscura
- Perche' propio nel momento in cui viviamo l'accelerazione dell'Universo sta aumentando ?
- Quanto pesano i neutrini ?

# The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada

Planck is a project of the European Space Agency, with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.


planck

# Domandone Finale ...

Filosofico:

- Perche' l'ente Spaziale Europeo (ESA) e quindi NOI tutti spendiamo 800 Milioni di Euro per conoscere l'Universo ?

Tecnico

- Perche' quasi tutti I siti di Lancio dei satelliti si trovano vicino all'Equatore  e in zone costiere ?