

**ASTROSIESTA**



**RADIOMETRI 3.0  
PER LA PRIMA LUCE DELL'UNIVERSO**

**Paola M. Battaglia**

**INAF-IASF Milano  
9 Marzo 2017**

# Advanced Modelling of the Planck-LFI Radiometers

**J**inst

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THE PLANCK LOW FREQUENCY INSTRUMENT

## Advanced modelling of the Planck-LFI radiometers

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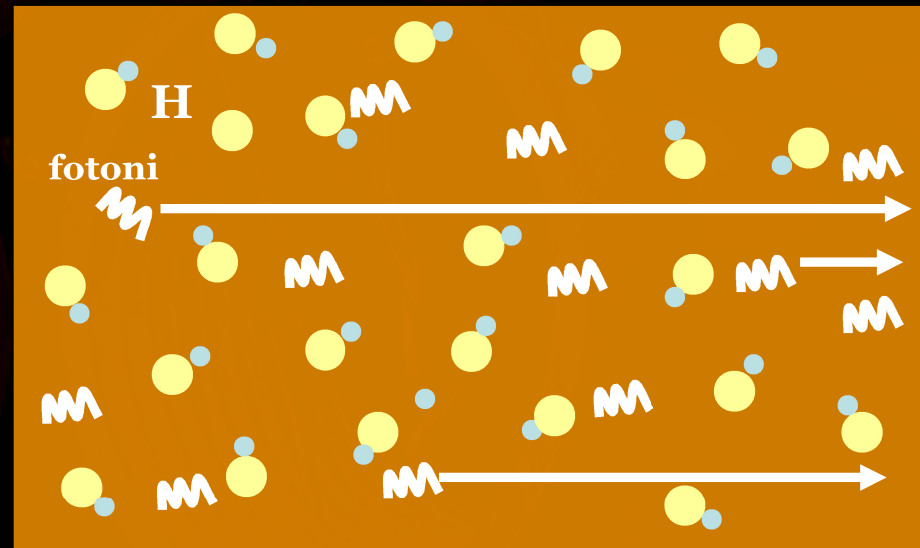
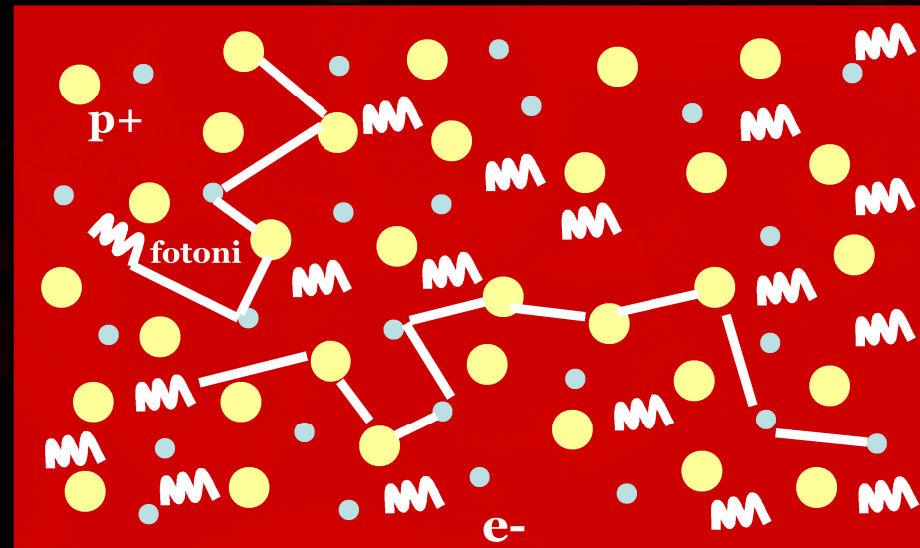
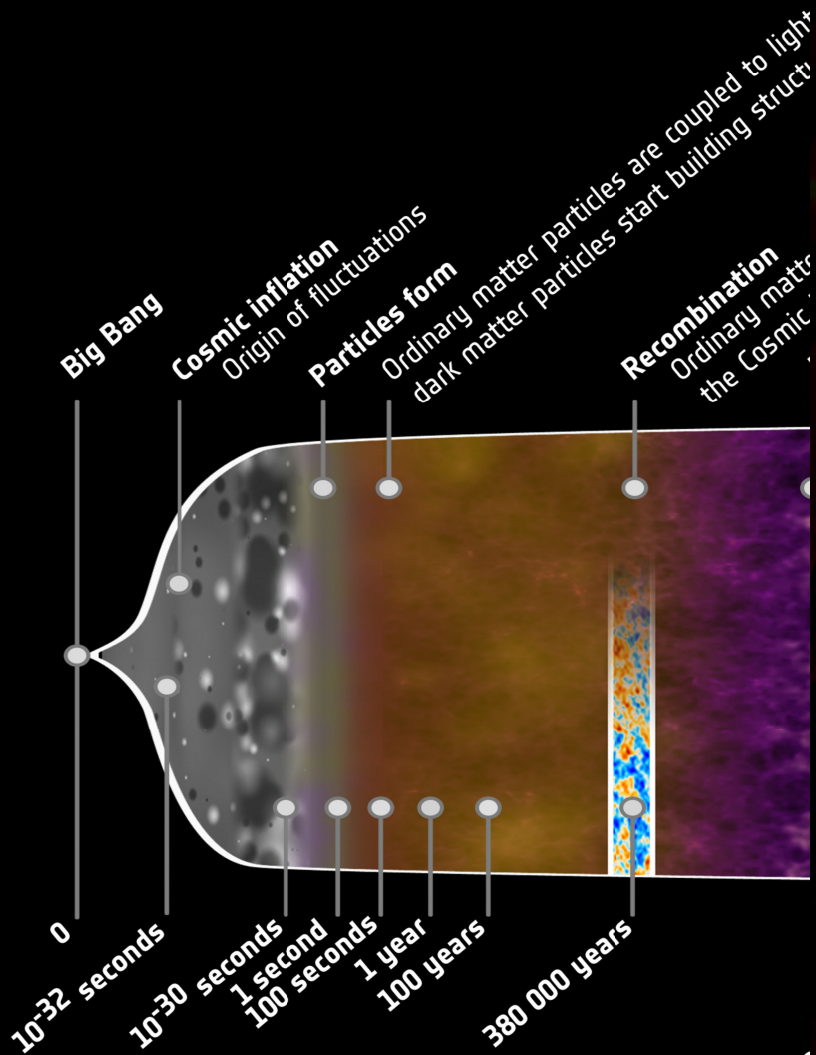
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# Radiazione Cosmica di Fondo...



# ...nelle Microonde

L'Universo, dalla ricombinazione si è espanso di un  
fattore 1000



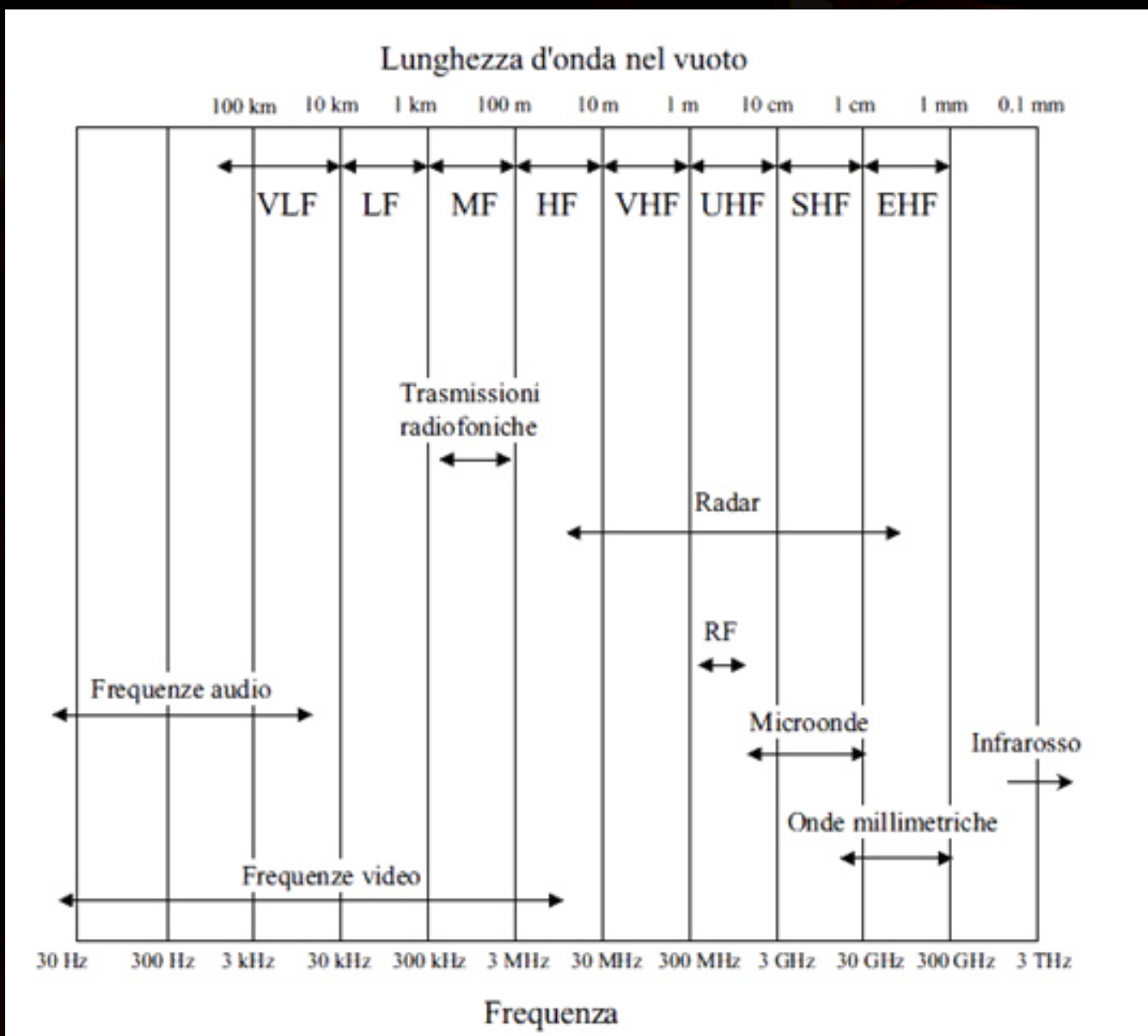
**RICOMBINAZIONE**

t= 380.000 anni dopo Big Bang  
T= 3000K  
Fotoni infrarossi

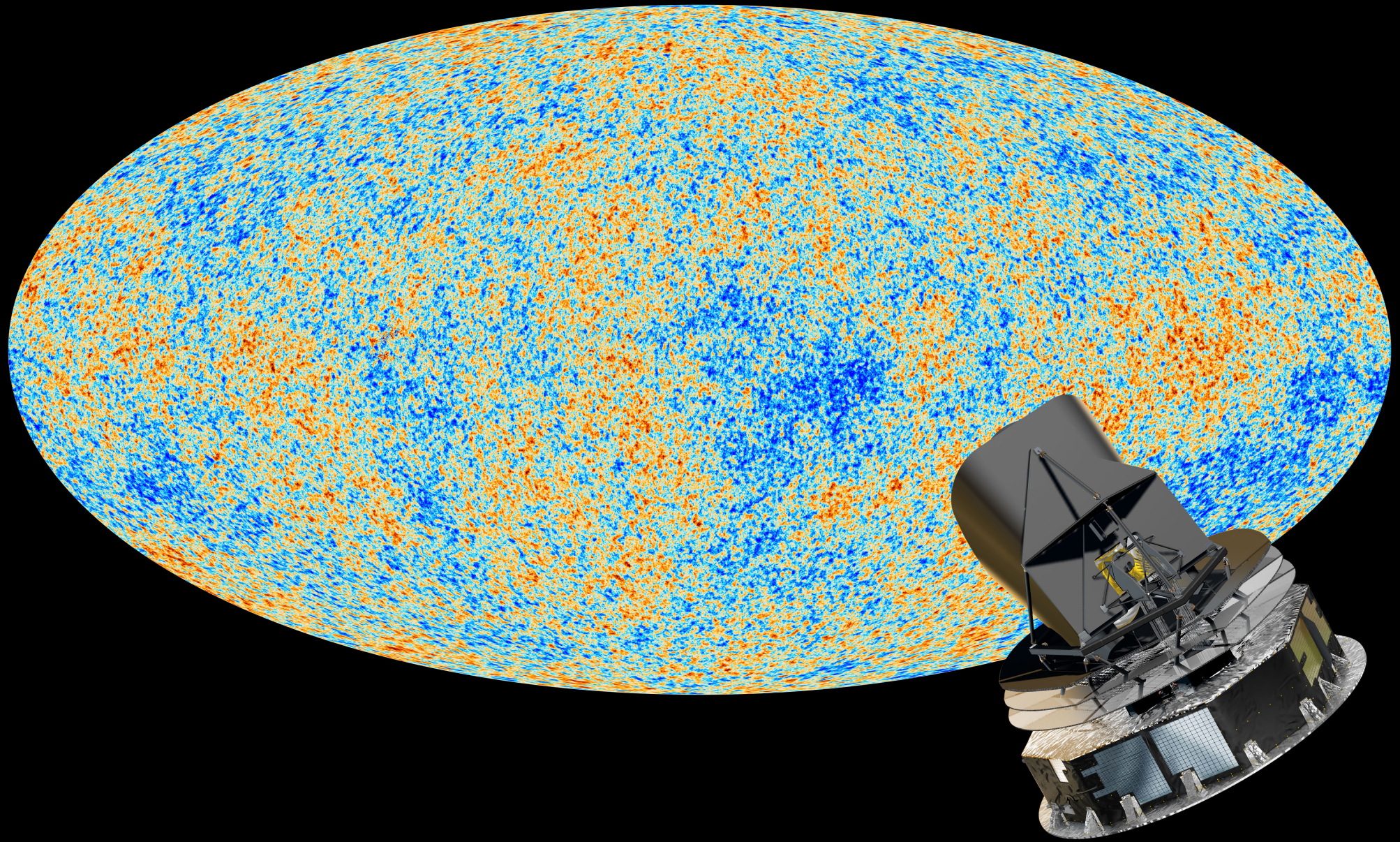
**OGGI**

t= 13,8 mld anni dopo Big Bang  
T= 3K  
Fotoni microonde

# RF, MW, Onde Millimetriche

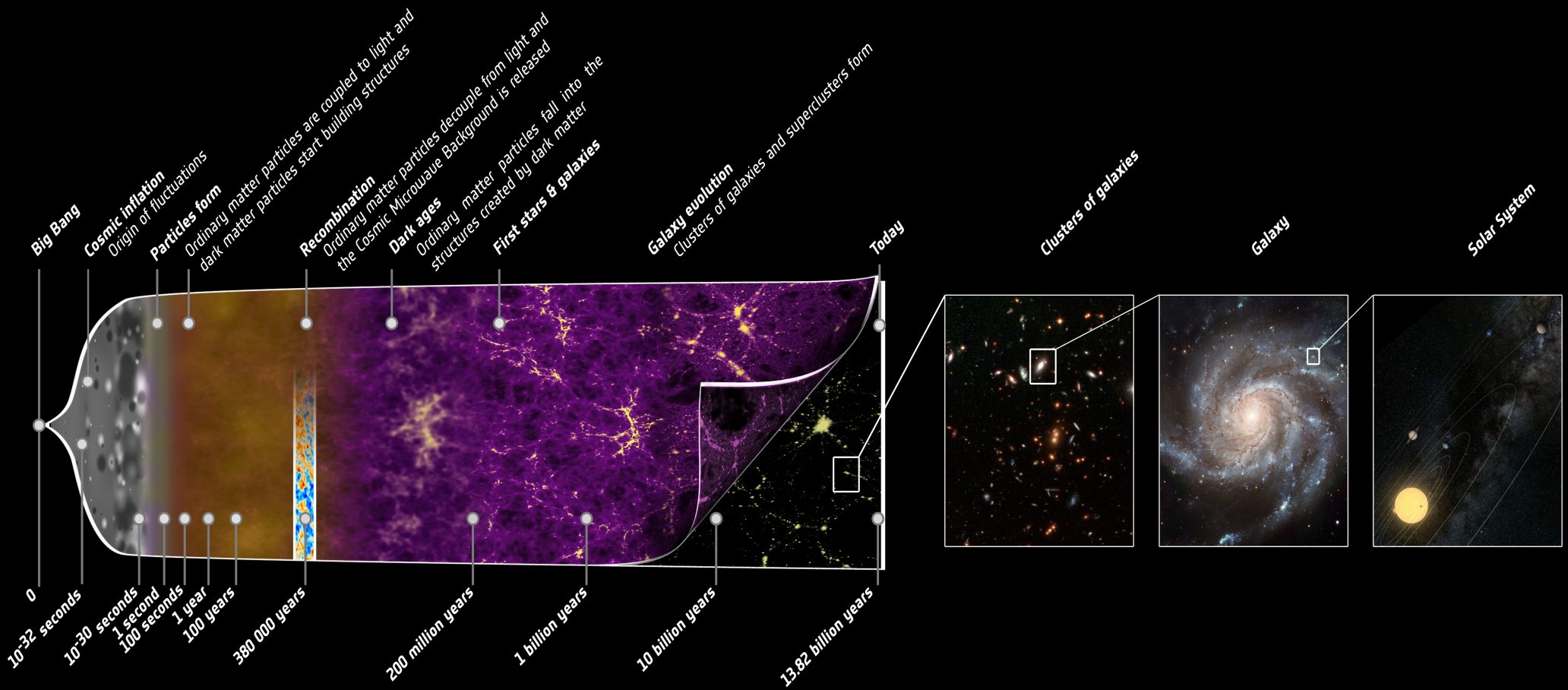


# Il cielo di Planck

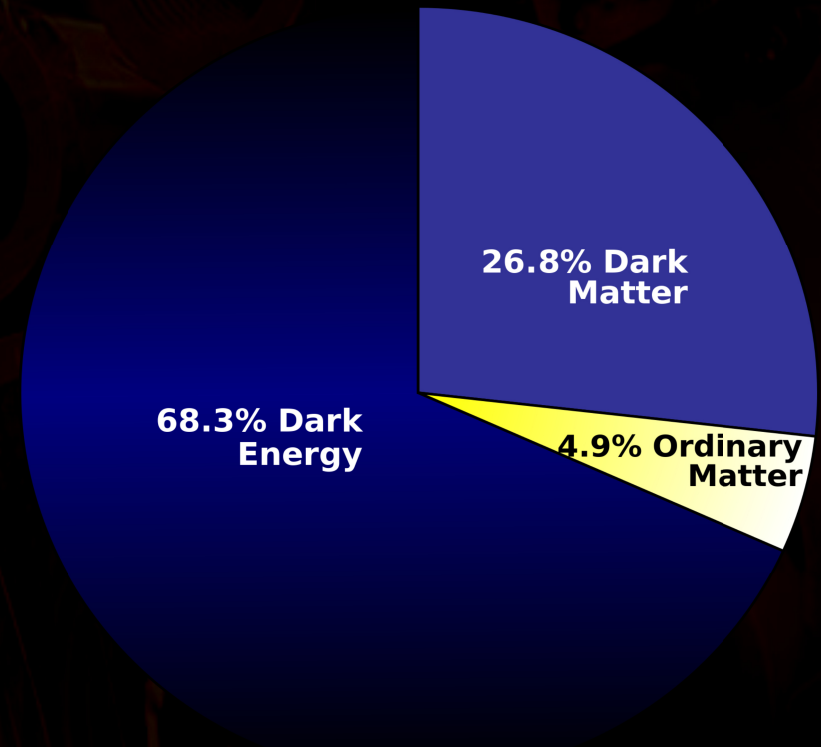
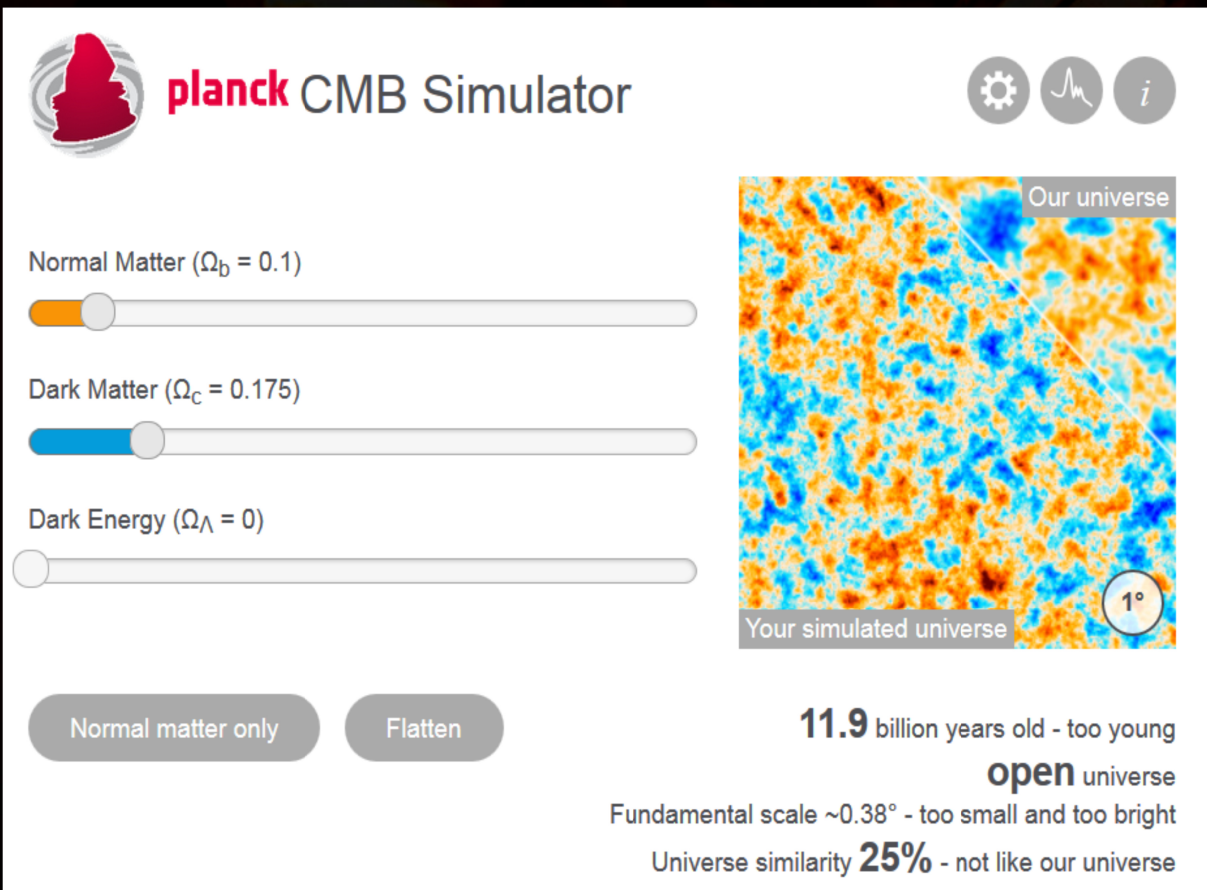


**P.M. Battaglia**  
**Astrosiesta - 9 Marzo 2017**

# I "Semi" delle Strutture

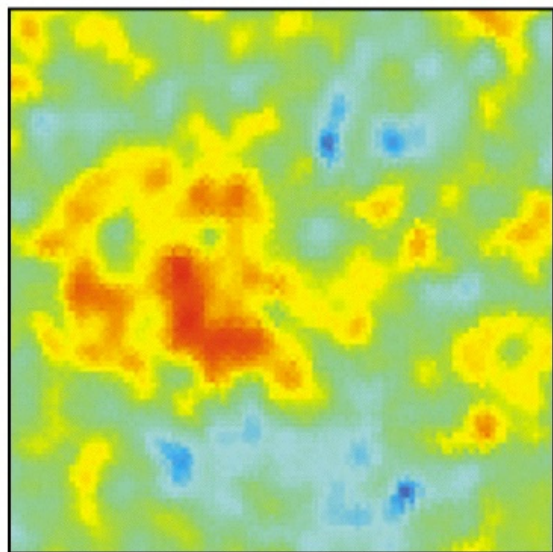
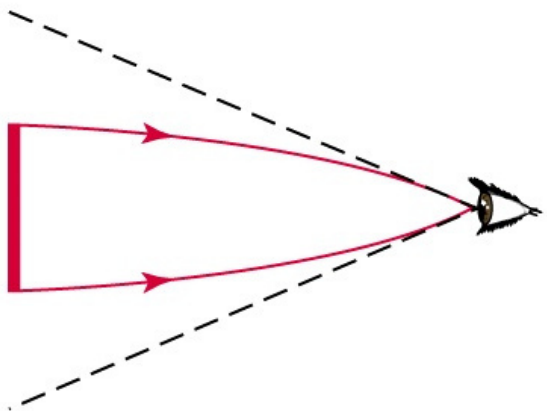


# Una Luce Ricca di Informazioni

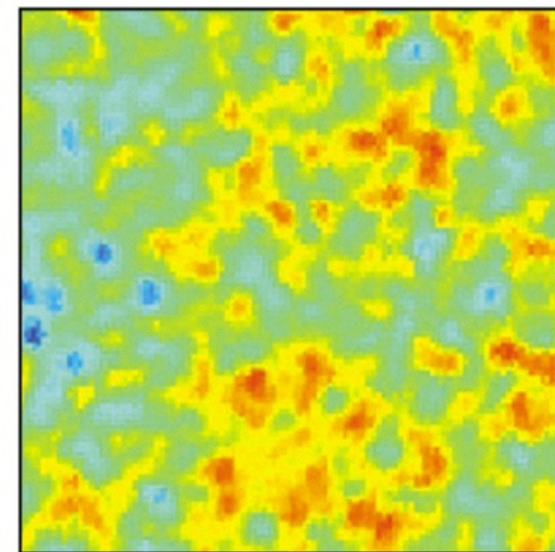
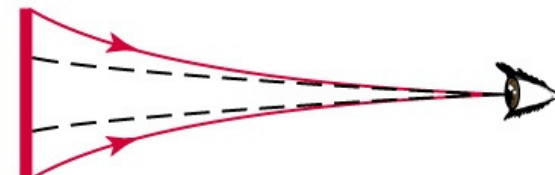
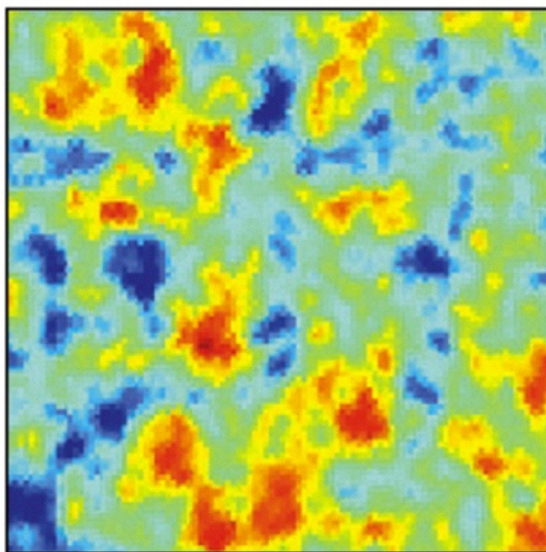
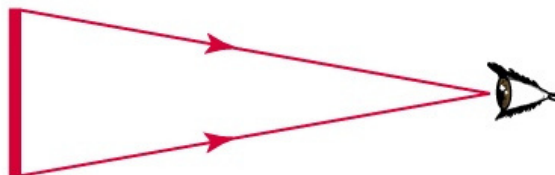




# Una Luce Ricca di Informazioni



**Universo chiuso:**  
le zone calde appaiono  
più ampie del reale



**Universo aperto:**  
le zone calde appaiono  
meno ampie del reale

# Planck



**Terza missione** dedicata allo studio della Radiazione Cosmica di Fondo.

**Nome originale:** COBRAS/SAMBA. Cambiato nel 1996 in PLANCK.

**Lancio:** 2009 da Guiana Space Centre (Kourou, Guiana Francese), assieme al telescopio Herschel verso L2.

**Lanciatore:** Ariane V

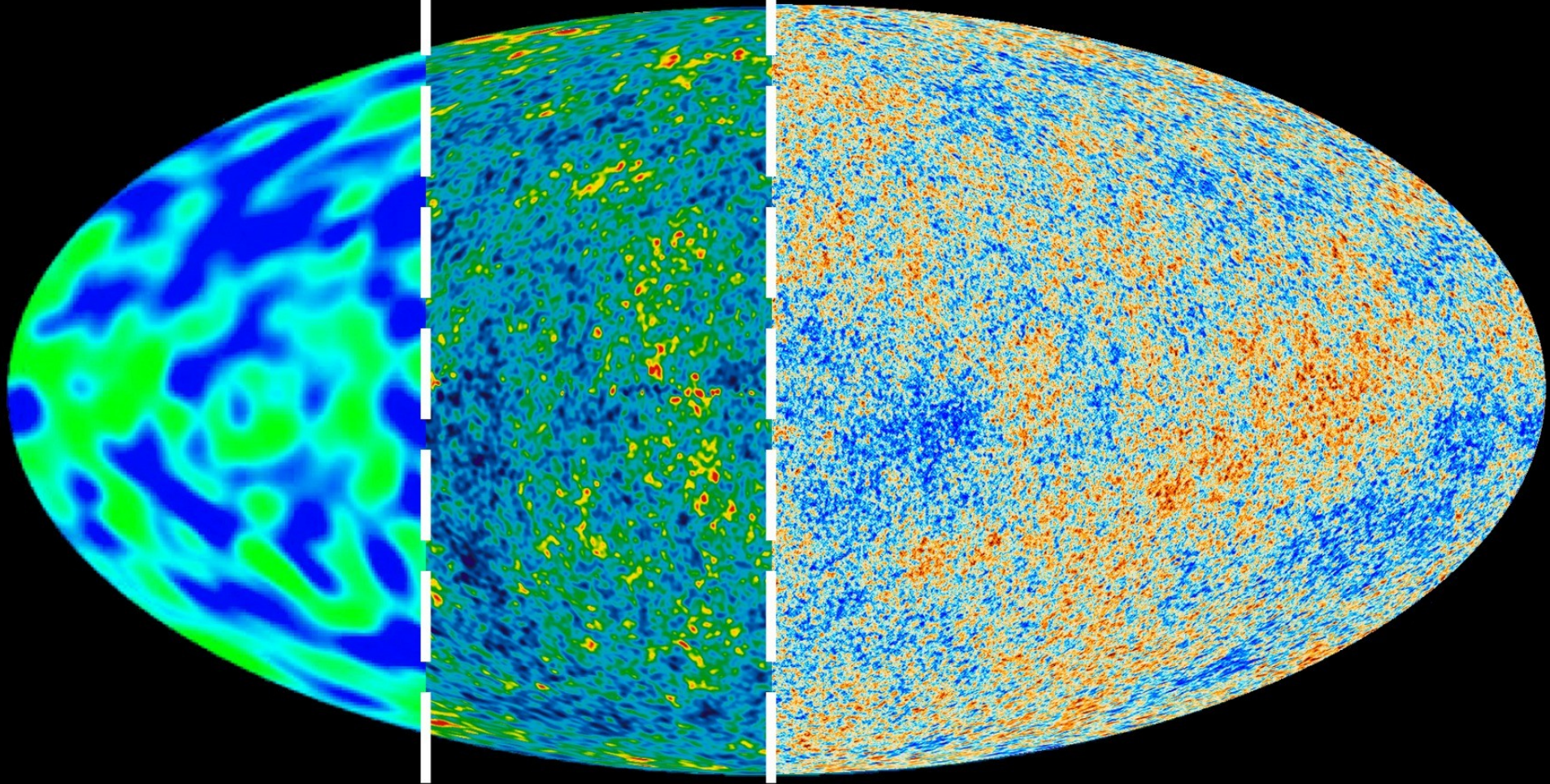
**Massa totale di lancio** (per il solo PLANCK): 1800 kg circa

# Planck

COBE (1989-1993)

WMAP (2003-2012)

Planck (2009-2013) (ongoing)

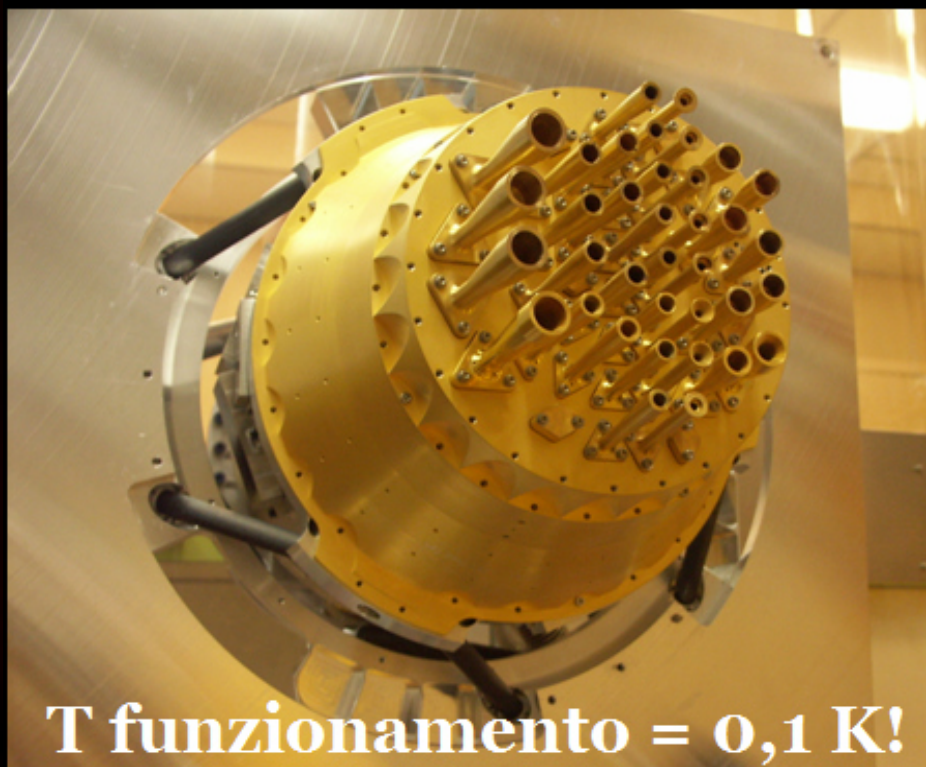


P.M. Battaglia  
Astrosiesta - 9 Marzo 2017

# Bolometri e Radiometri

Planck è stato un satellite ad altissima tecnologia, molta della quale è stata realizzata in Italia.

**High Frequency Instrument  
(100 GHz – 857 GHz)**



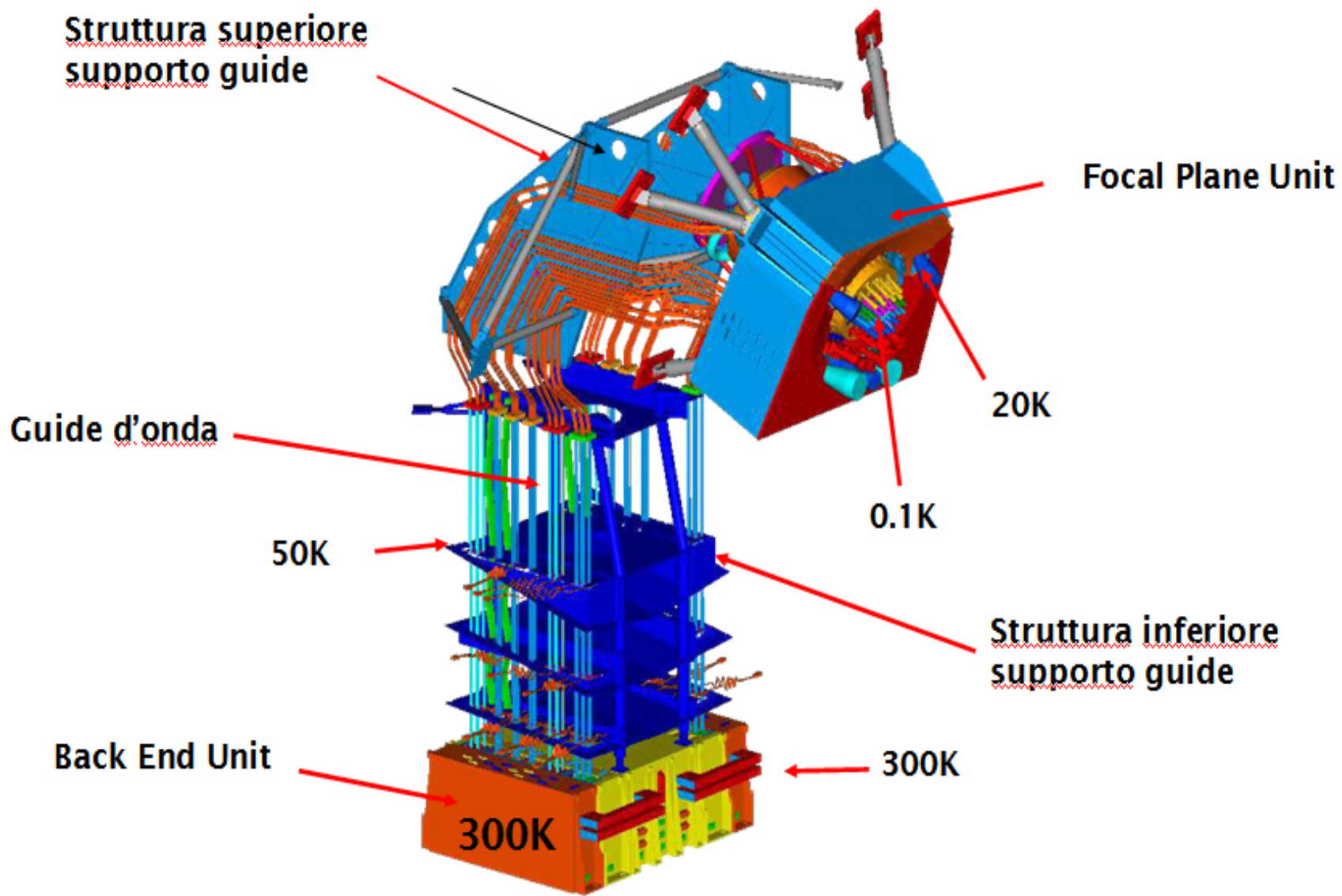
**T funzionamento = 0,1 K!**

**Low Frequency Instrument  
(30 GHz – 70 GHz)**

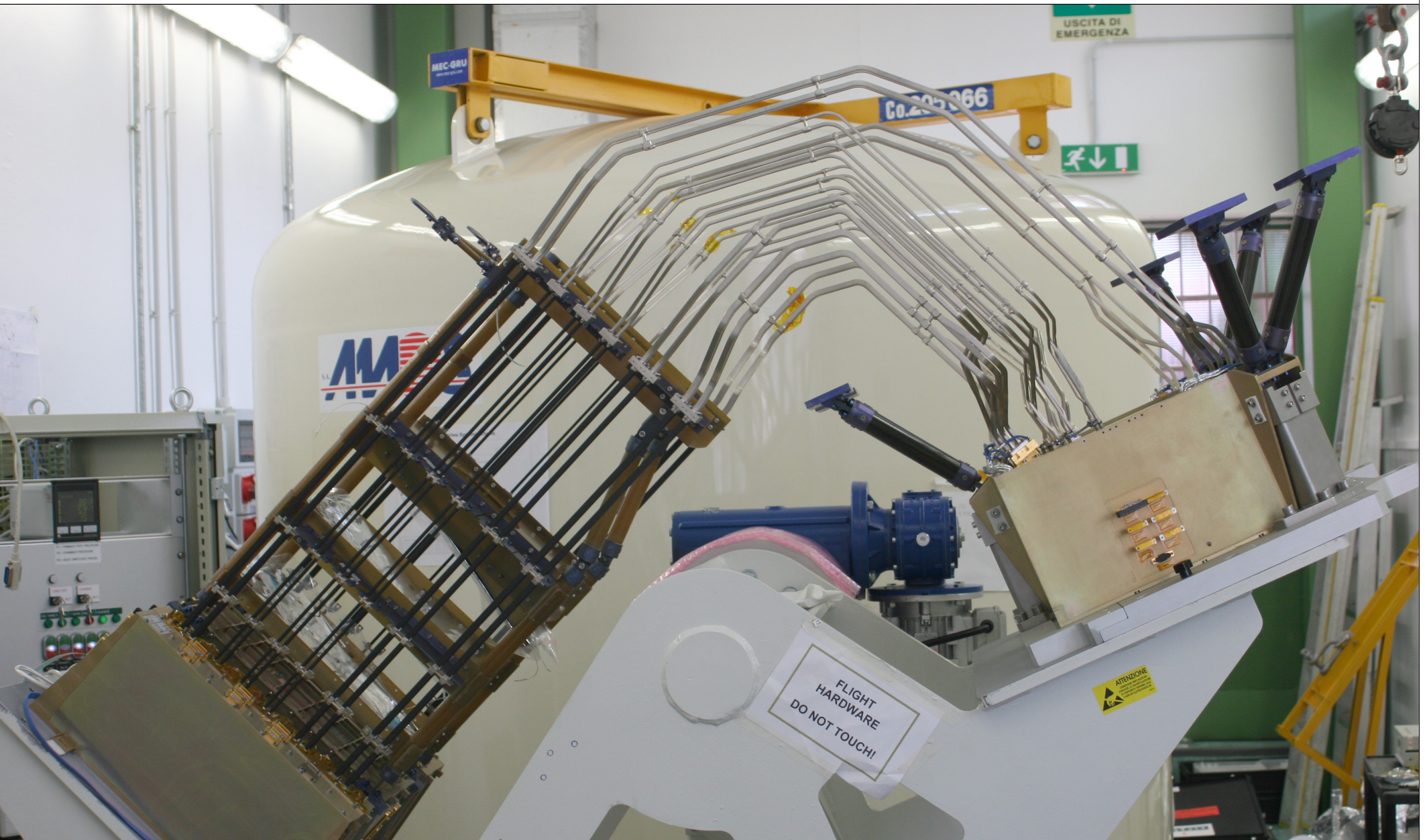


**T funzionamento = 20 K!**

# Low Frequency Instrument

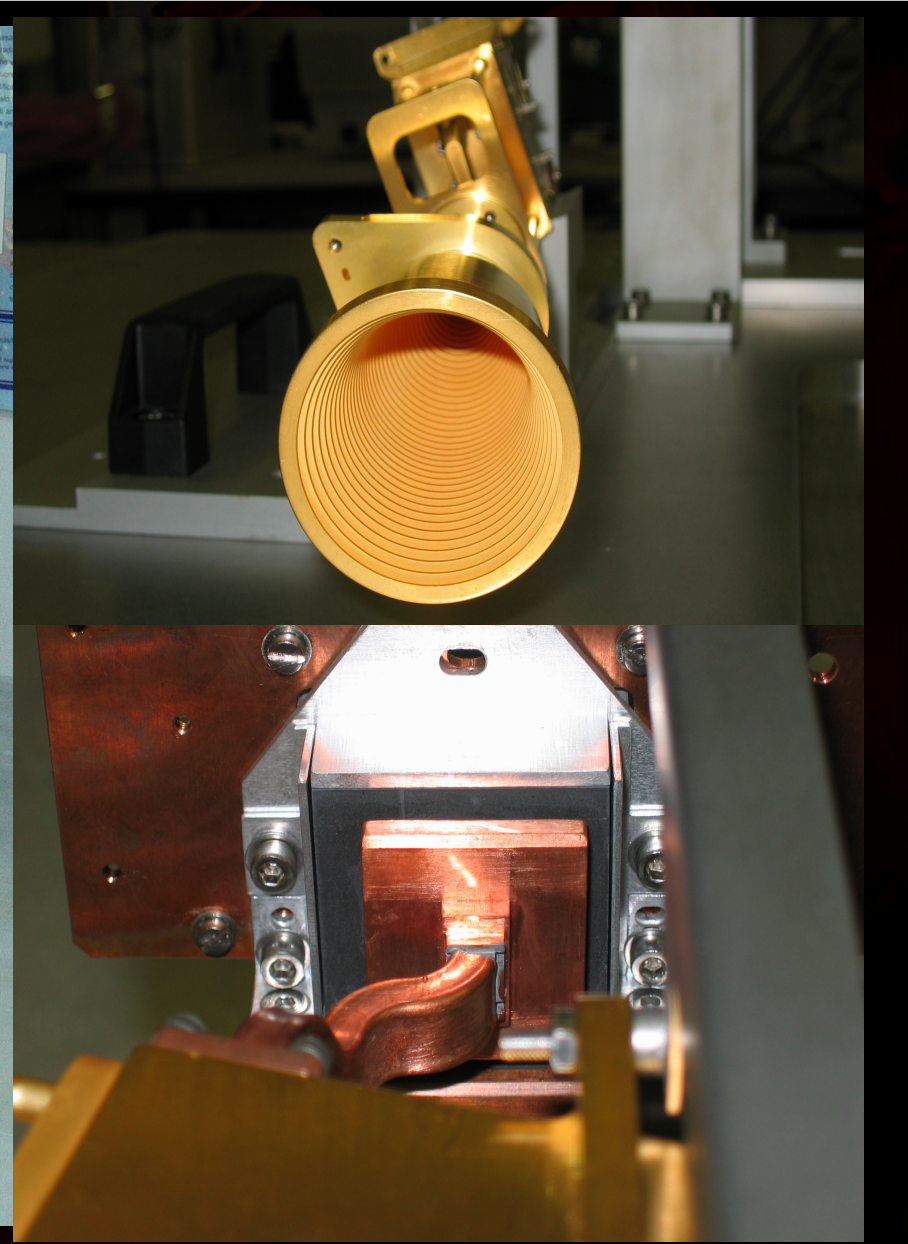


# Low Frequency Instrument



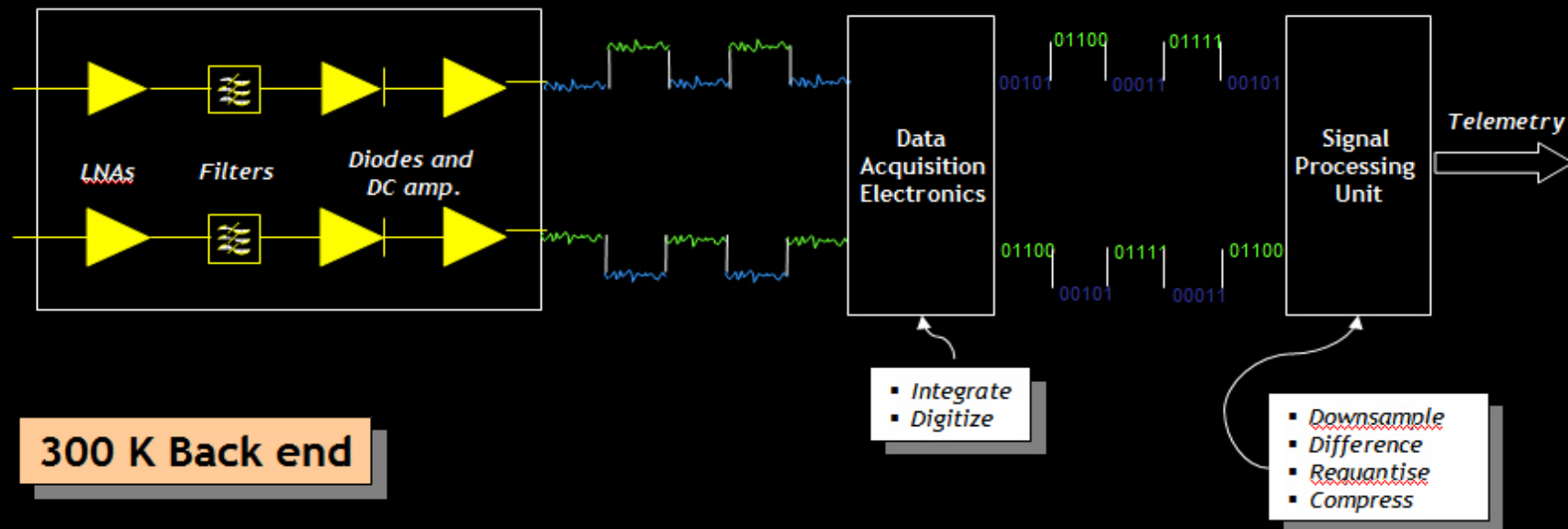
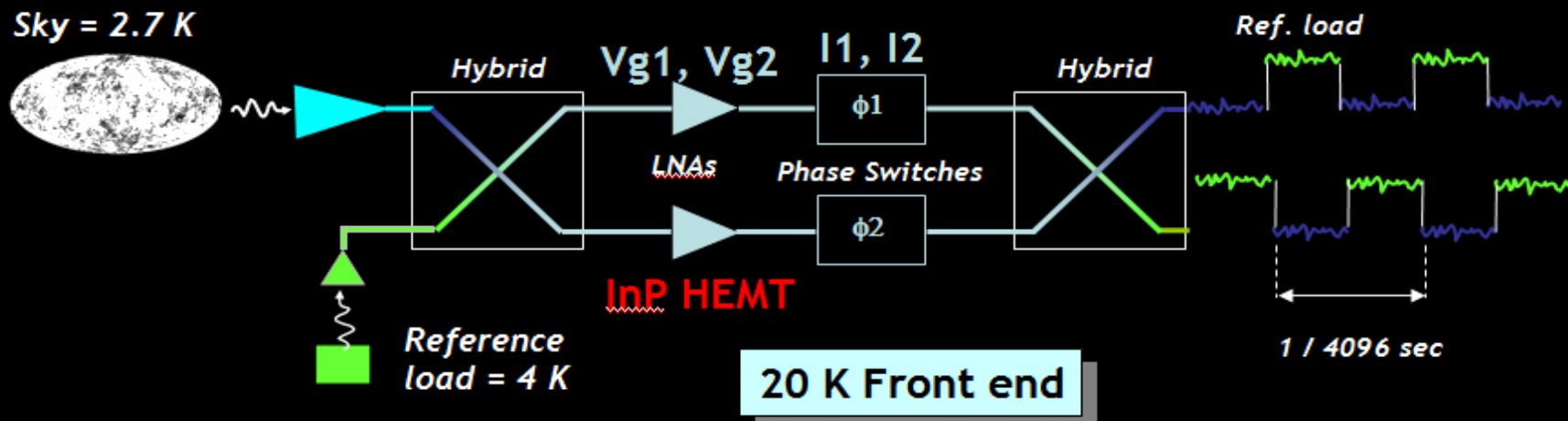
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**Astrosiesta - 9 Marzo 2017**

# Radiometri di LFI



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**Astrosiesta - 9 Marzo 2017**

# Pseudocorrelazione

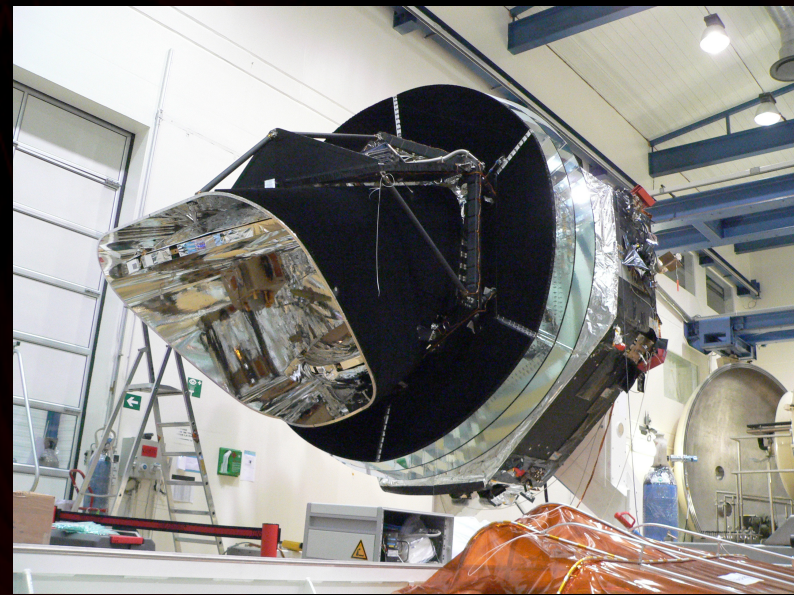
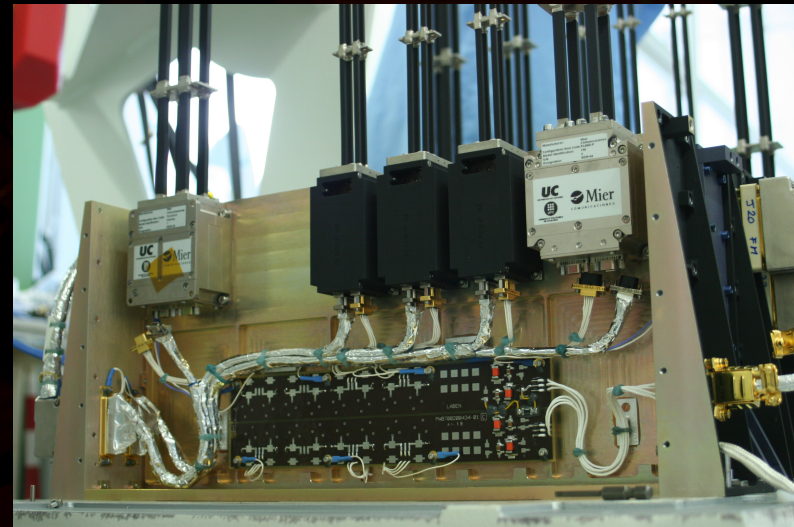




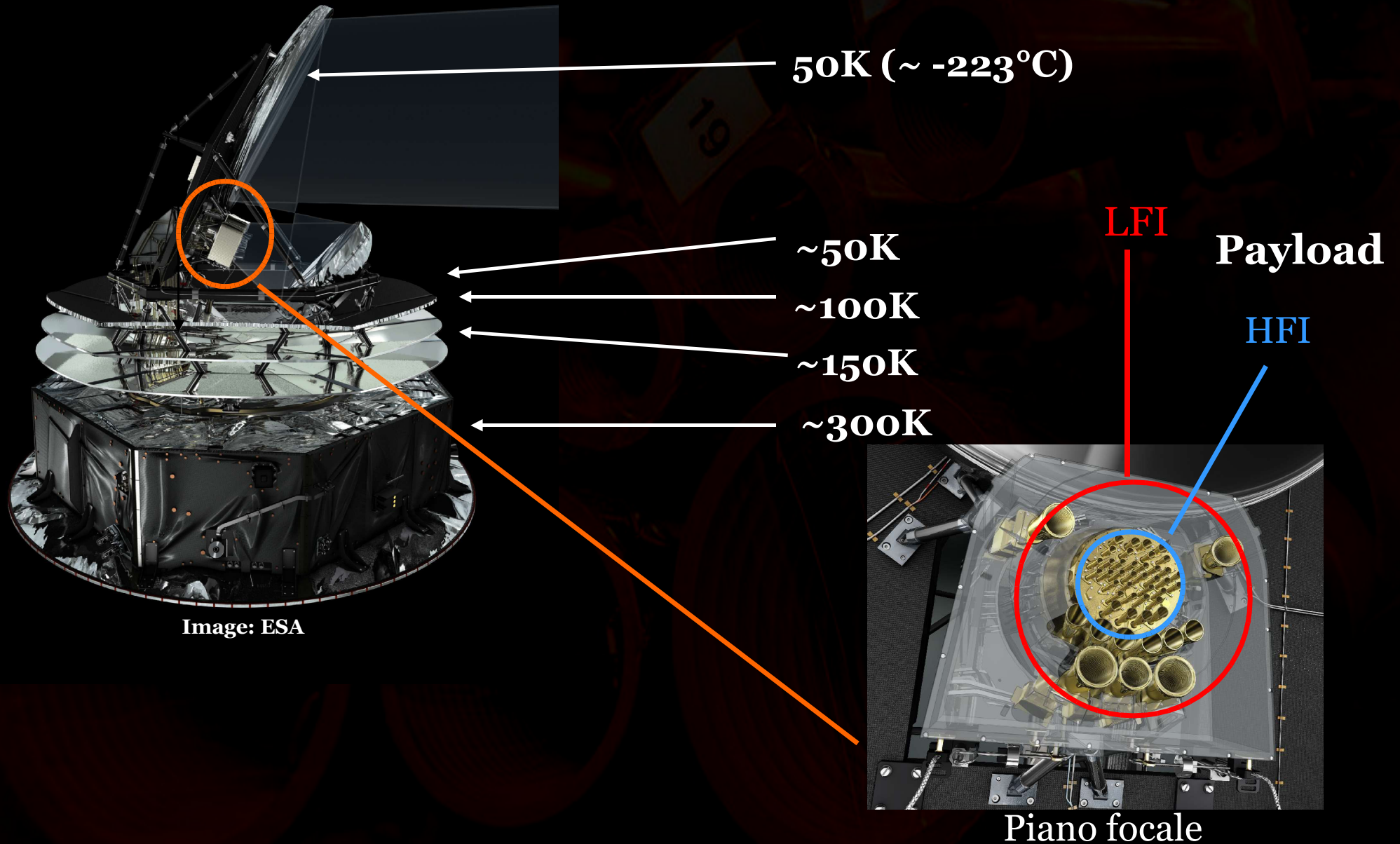
# 3 Frequenze

11 radiometri, 44 canali

- 70 GHz (6)
- 44 GHz (3)
- 30 GHz (2)

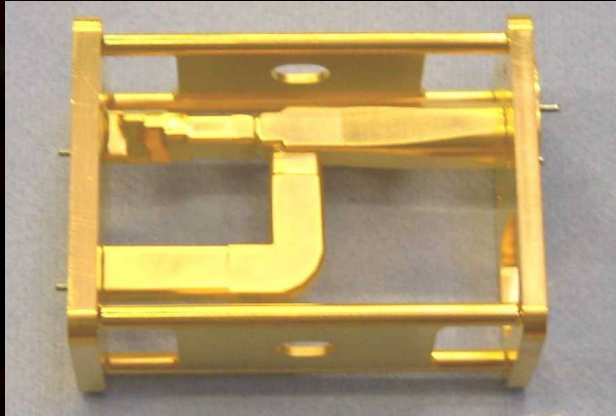


# Satellite Criogenico



# Componenti Passivi

- Feed Horns @ 30, 44, 70 GHz
- OMT @ 30, 44, 70 GHz



Images:  
TAS-I Vimodrone

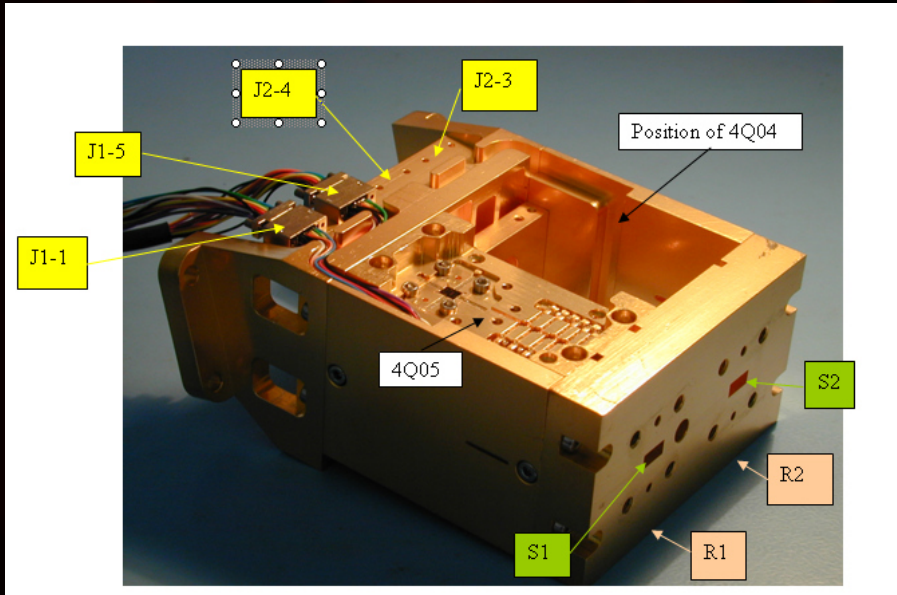
# Componenti Passivi

Image: TAS-I Vimodrone



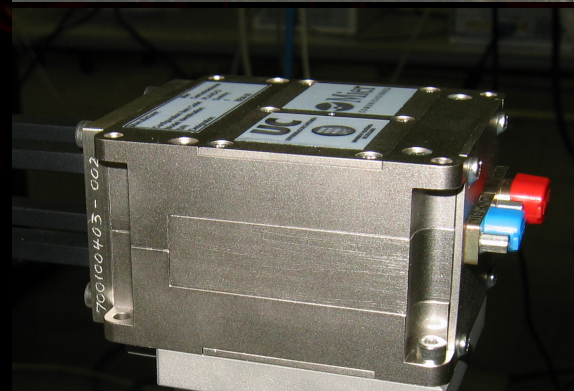
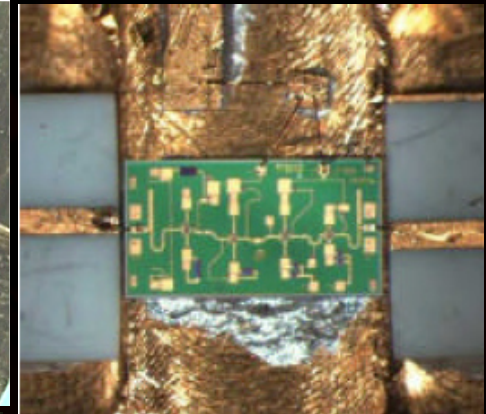
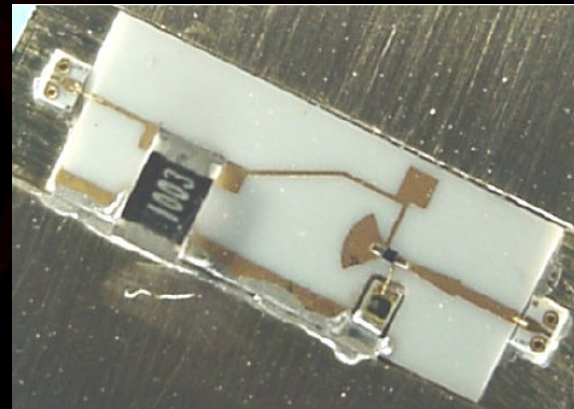
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# FEM & BEM



**FEM @ 30, 44, 70 GHz**

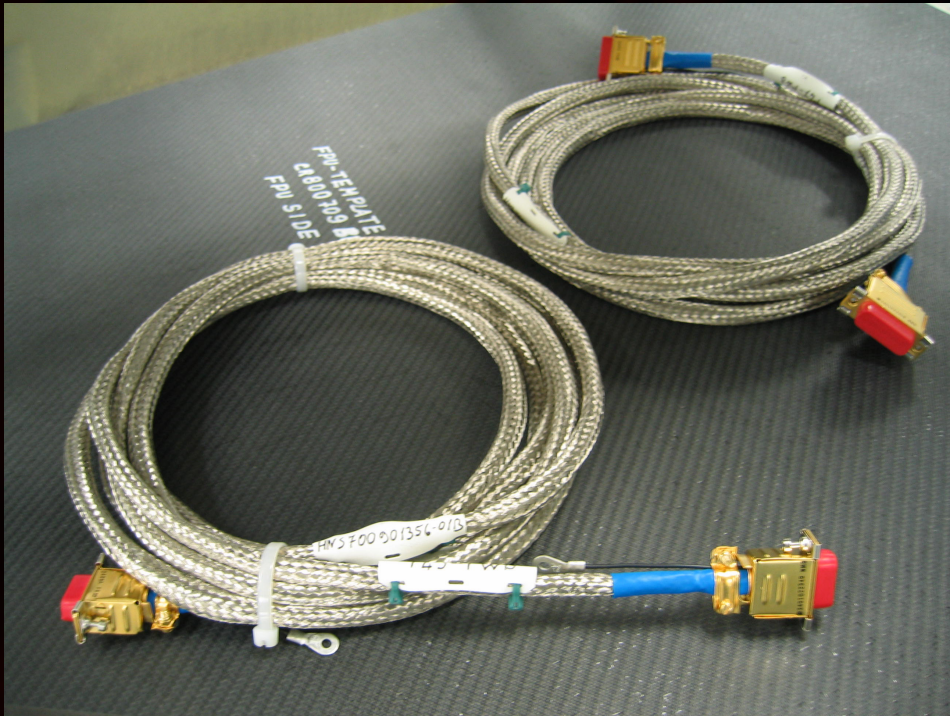
**BEM @ 30, 44, 70 GHz**



Images: TAS-I Vimodrone

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**Astrosiesta - 9 Marzo 2017**

# Cryo & Warm Harness



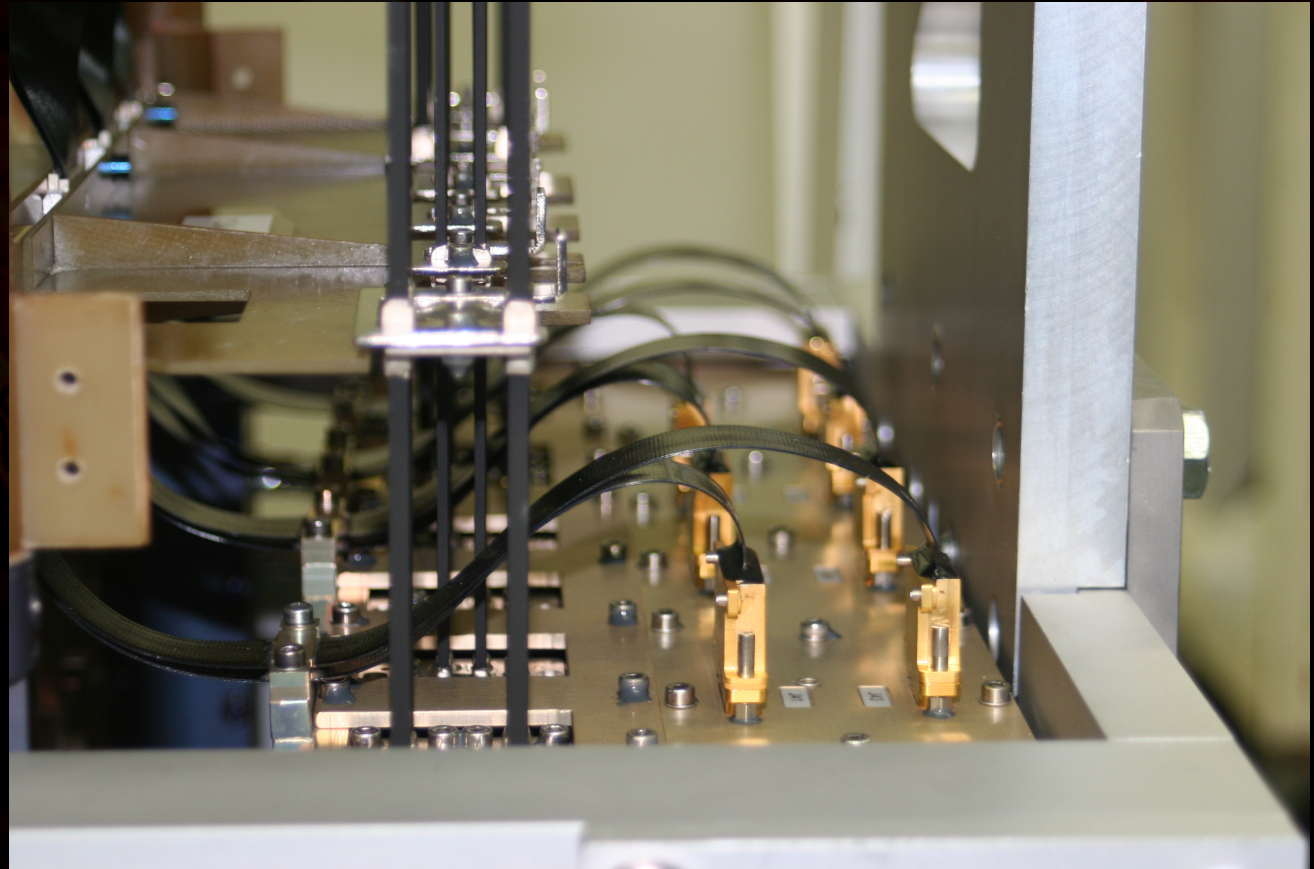
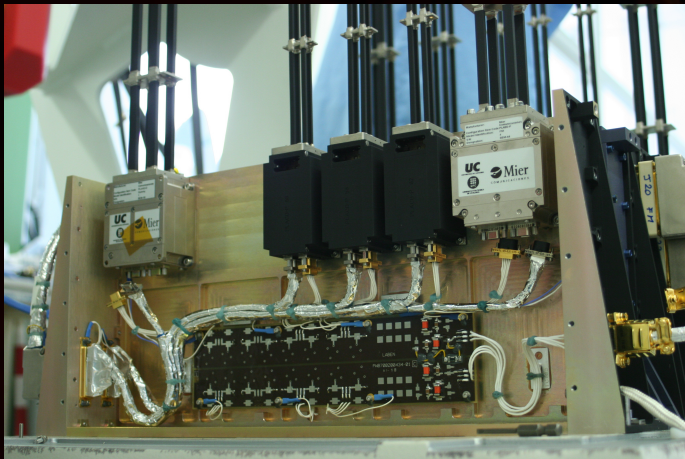
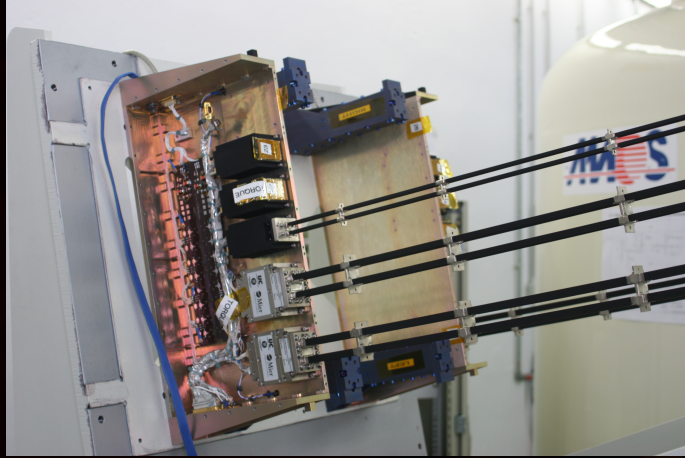
**Warm Harness  
(TAS-I Vimodrone)**

## Cryo Harness



Images: TAS-I Vimodrone

# Elettronica di Acquisizione

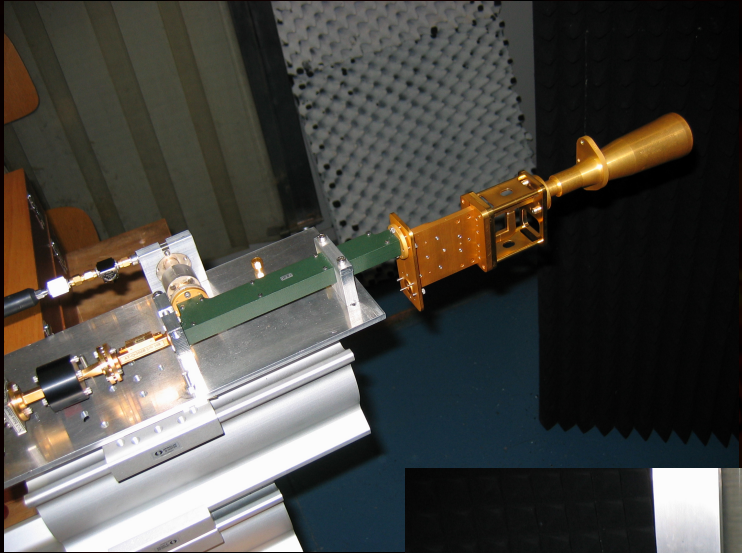


Images: TAS-I Vimodrone

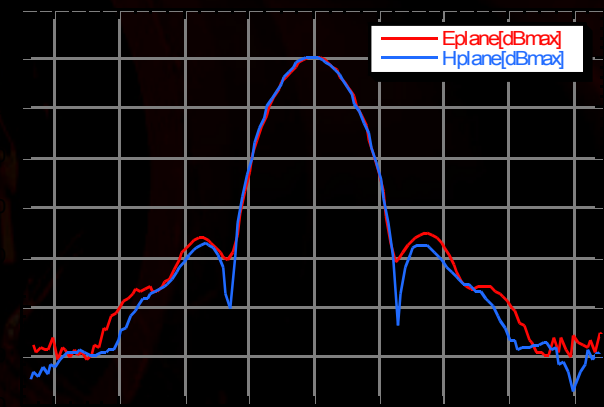
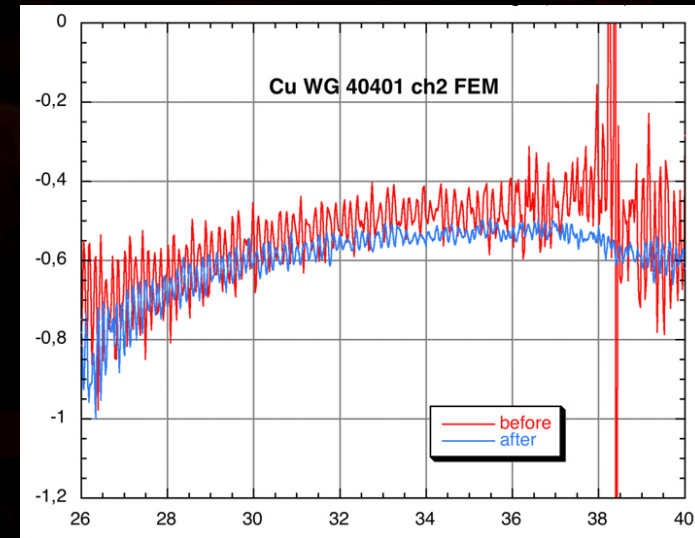
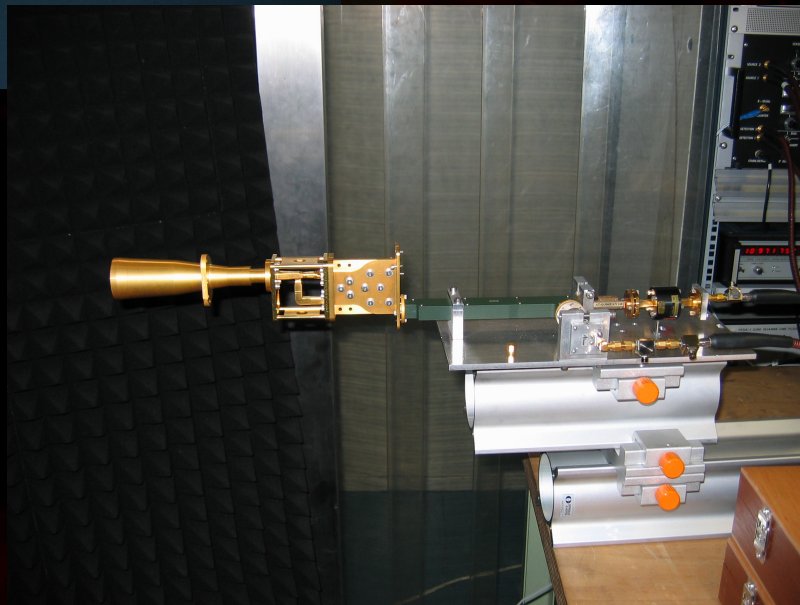
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# Test Componenti Passive

Attività di test condotti con supporto CNR – IFP –  
Milano Bicocca



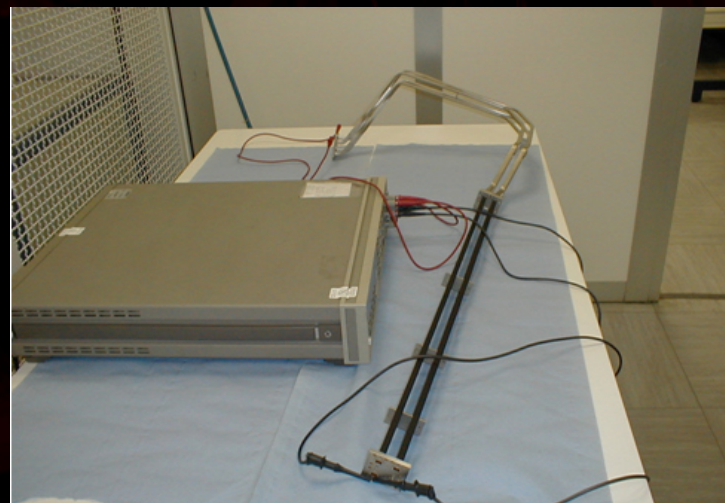
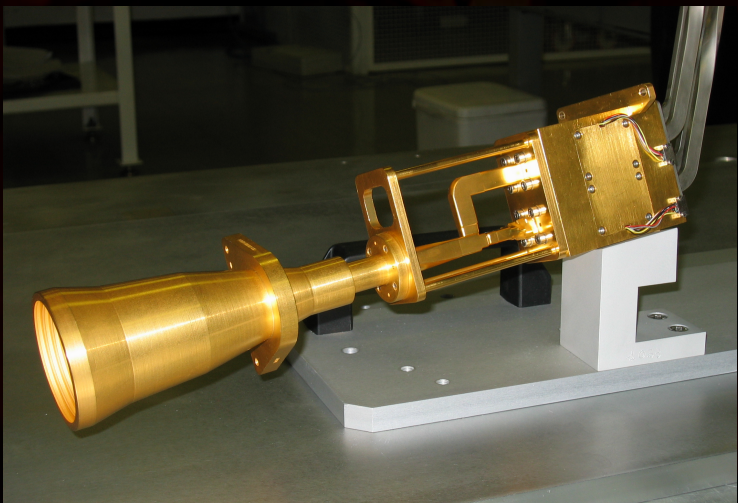
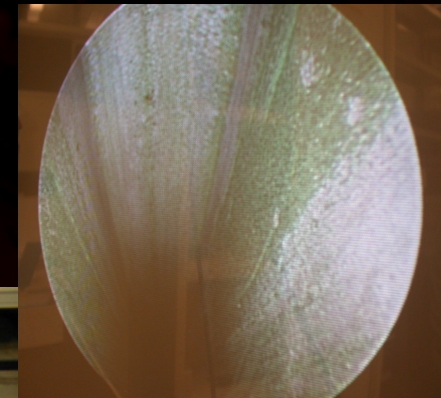
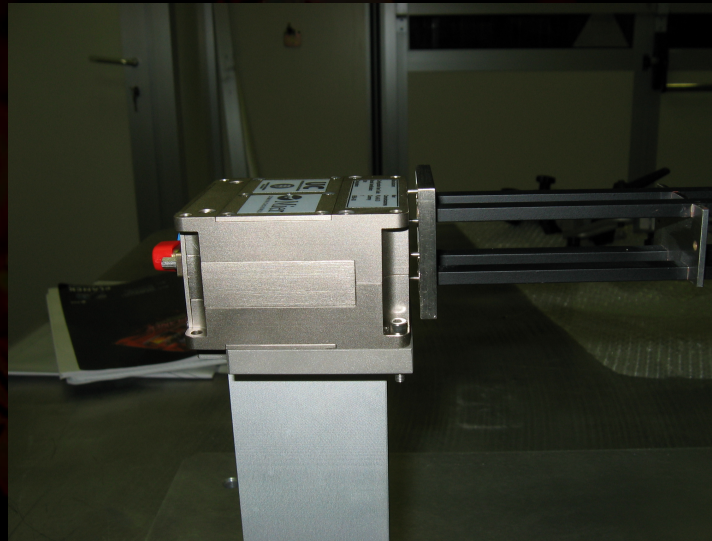
Images: TAS-I Vimodrone





# Integrazione Meccanica

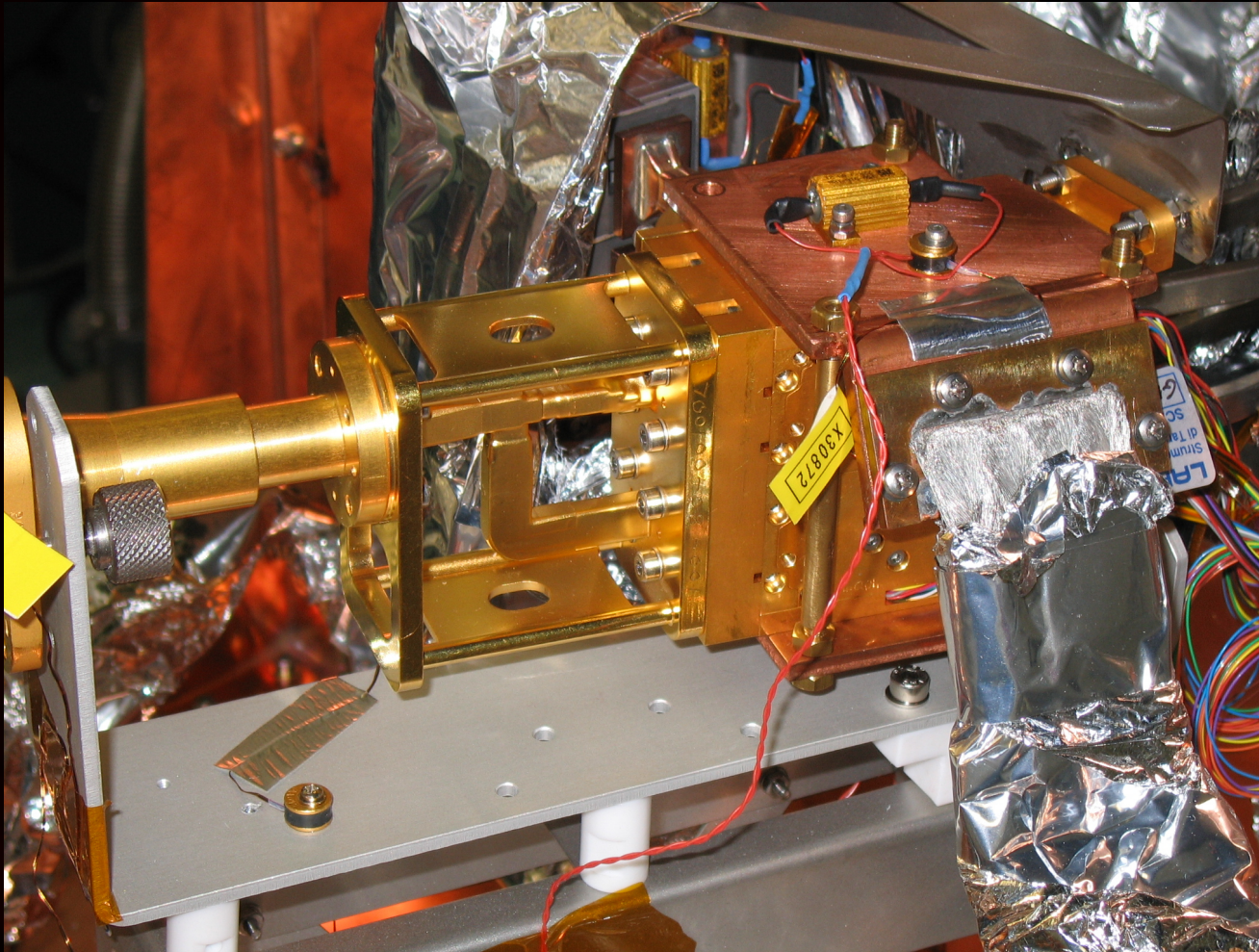
Test di caratterizzazione e verifica (misure resistenza elettrica guide, ispezione endoscopica, ...)



Images: TAS-I Vimodrone

# Test Criogenici Singolo Radiometro

**Riprodurre funzionamento nello spazio!**



Images: TAS-I Vimodrone

Progettazione e  
costruzione RCA Cryo  
Facility

Procedure  
Esecuzione test  
funzionali/calibrazione

Acquisizione/storage  
dati

Analisi dati preliminare  
(valutazione  $T_N$ ,  
Isolamento, Linearità,  
Risposta spettrale)

# Calibrazione Radiometri

Verifica stato dei PS/SW

Bilanciamento dei PS/SW

Tuning  $V_{gate1}$ : minimizzare  $T_N$

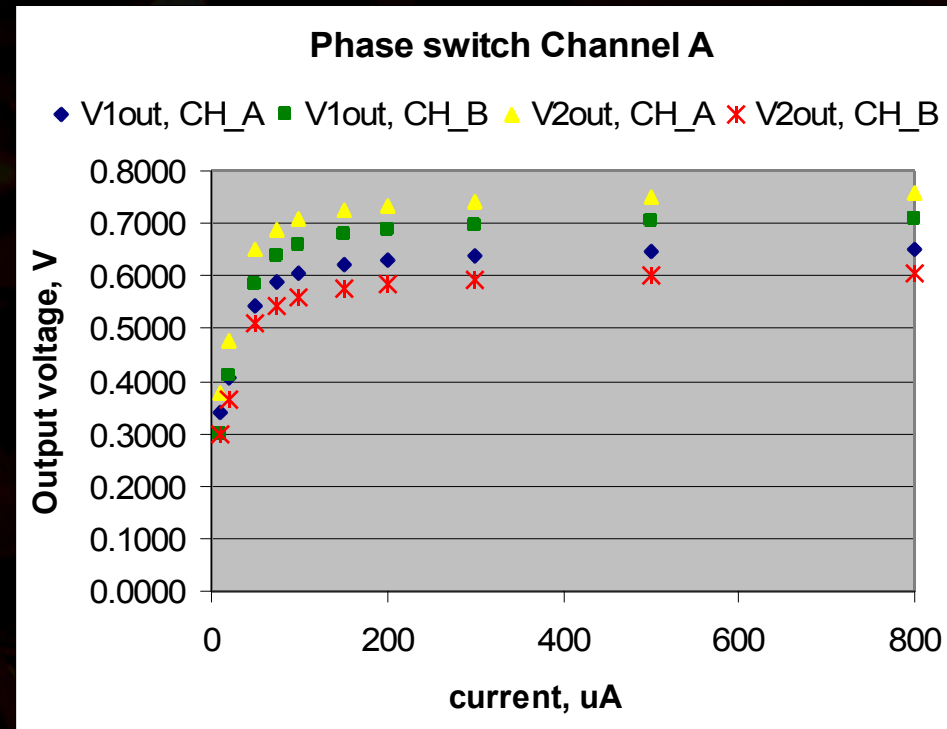
Tuning  $V_{gate2}$ : ottimizzare  
isolamento

$$T_{NOISE} = \frac{T_{HOT} - Y T_{COLD}}{Y - 1}$$

$$Y = \frac{V_{HOT}}{V_{COLD}}$$

Isolation(dB) =

$$10 \log_{10} \frac{(outputA_{sky, Tref\_low} - outputA_{sky, Tref\_high})}{(outputA_{sky, Tref\_low} - outputA_{sky, Tref\_high} + outputA_{ref, Tref\_low} - outputA_{ref, Tref\_high})}$$



# Calibrazione Radiometri

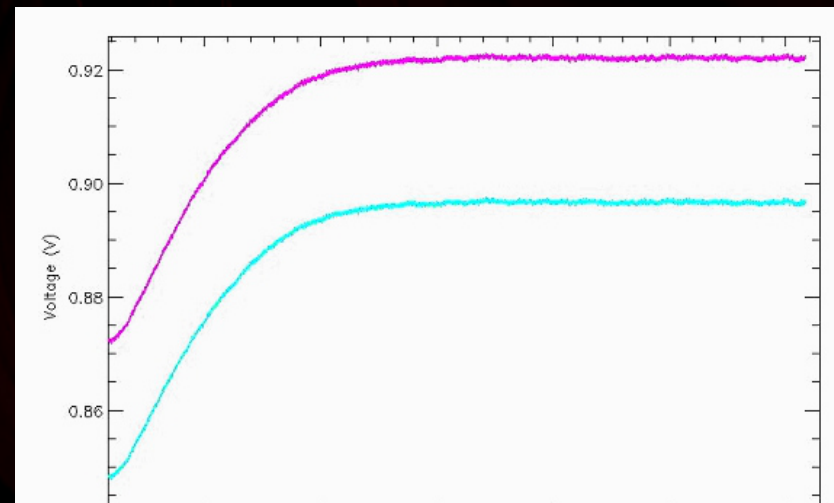
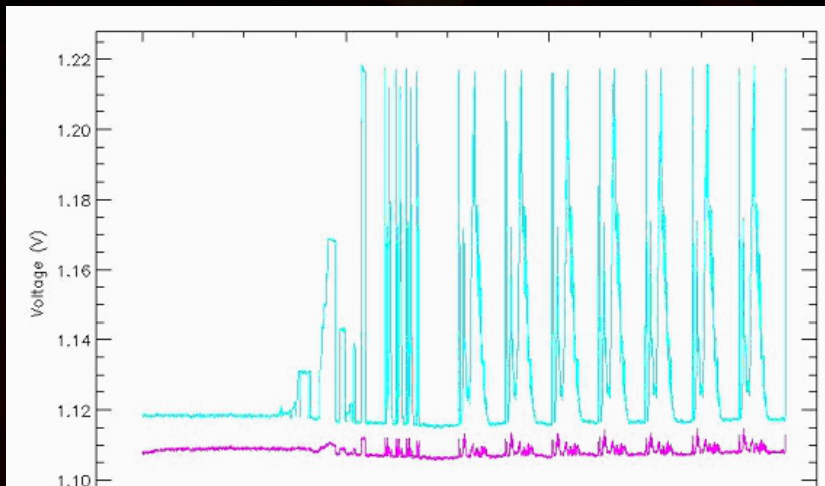
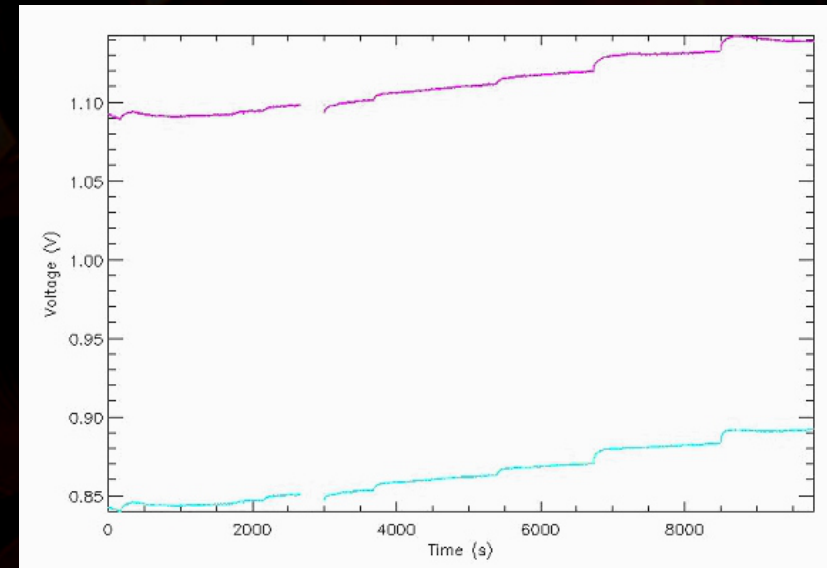
RCA\_THF: sensibilità ai cambi di temp.  
sul FEM

RCA\_THB: sensibilità ai cambi di temp.  
sul BEM

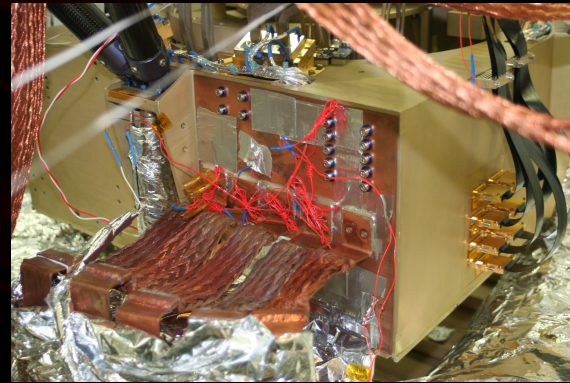
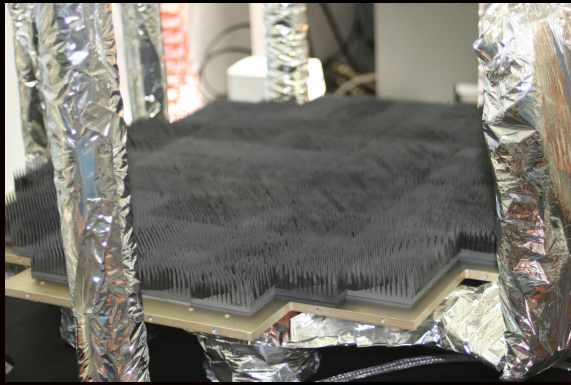
RCA\_THV: sensibilità ai cambi di temp.  
sui V-grooves

Swept source test

RCA\_ELE: disturbo sinusoidale (1 mV p-  
p) su gate e drain lines



# Test Criogenici – Strumento Integrato



Images: TAS-I Vimodrone

Progettazione/procurement  
Cryo-Facility

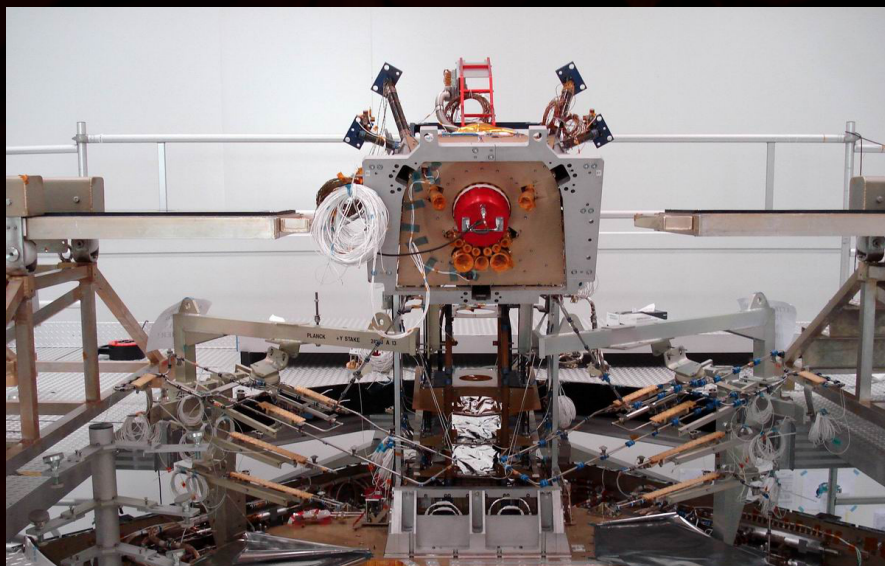
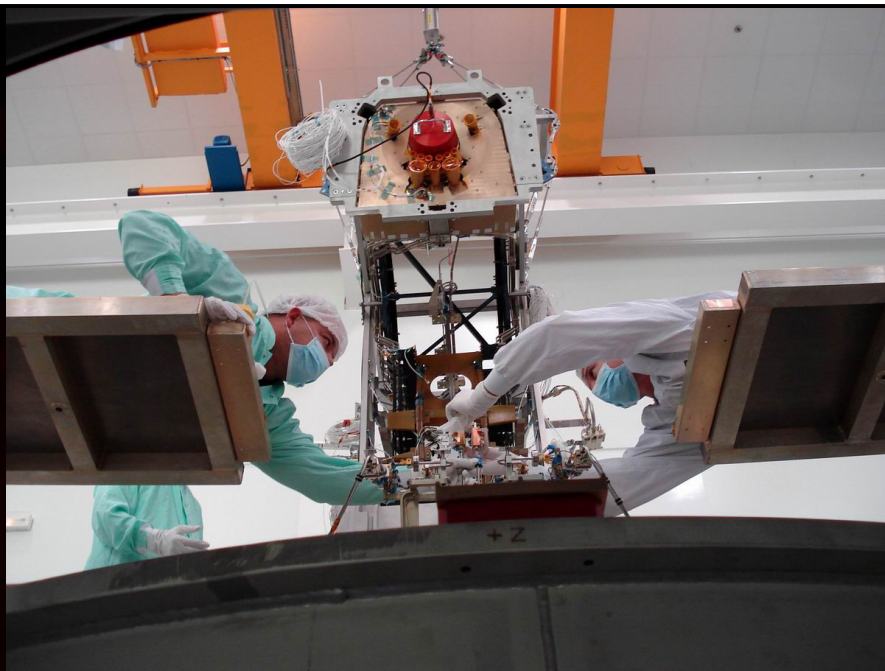
Progettazione LFI EGSE (ISU,  
ICOE)

Procedure

Esecuzione Test c/o TAS-I  
Vimodrone (Funzionali, EMC,  
Acquisizione Dati,  
Calibrazioni)

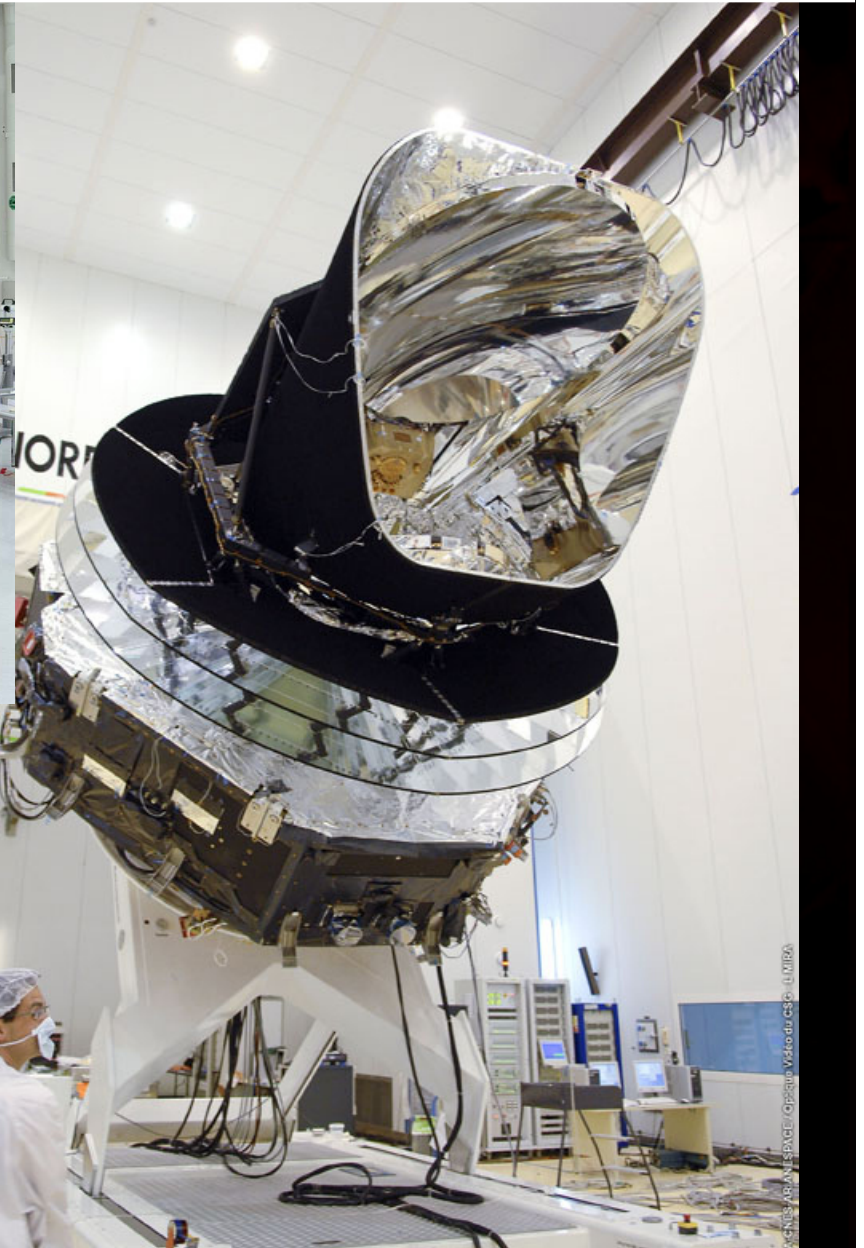
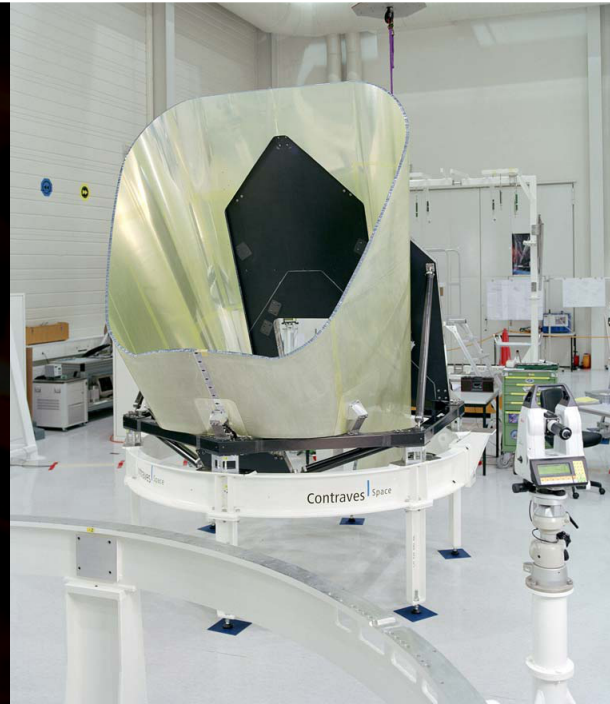
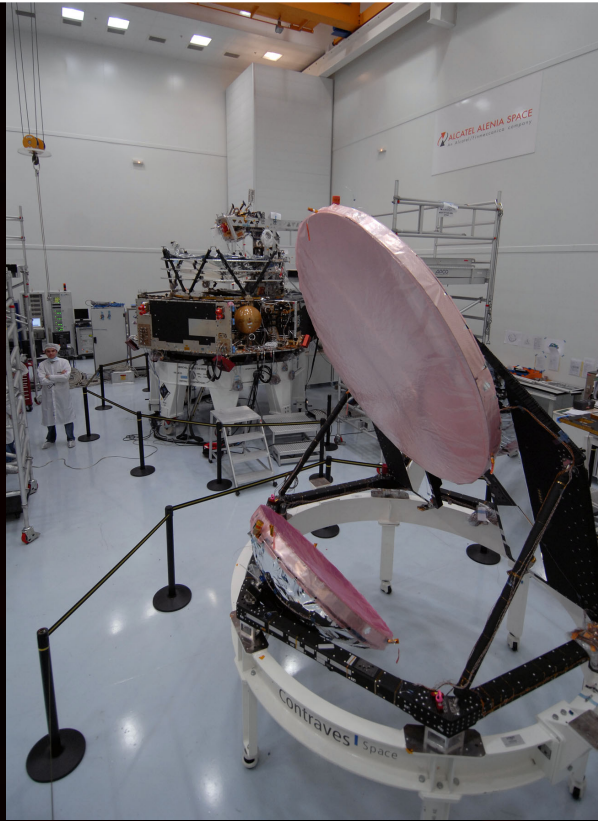


# Integrazione su Satellite



**P.M. Battaglia**  
**Astrosiesta - 9 Marzo 2017**

# Integrazione Planck



Images: TAS-F Cannes

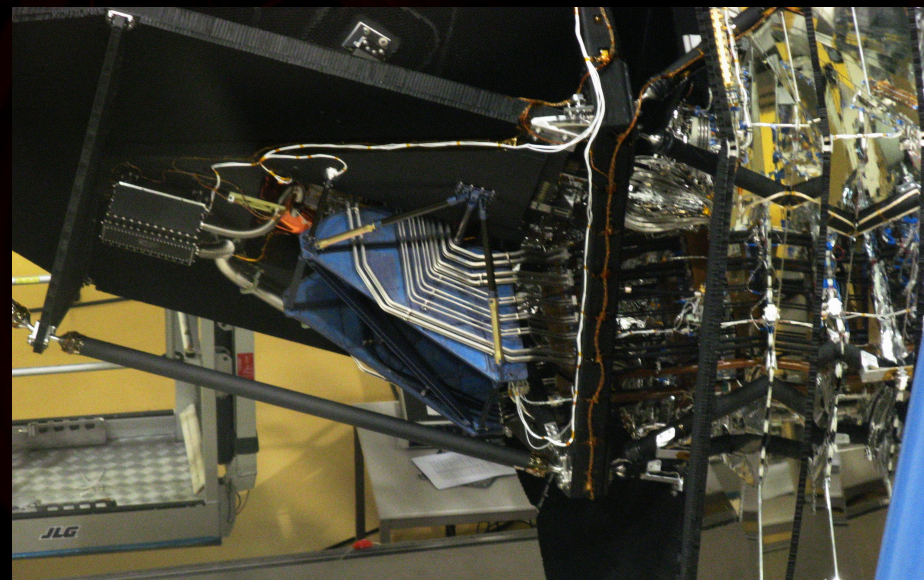
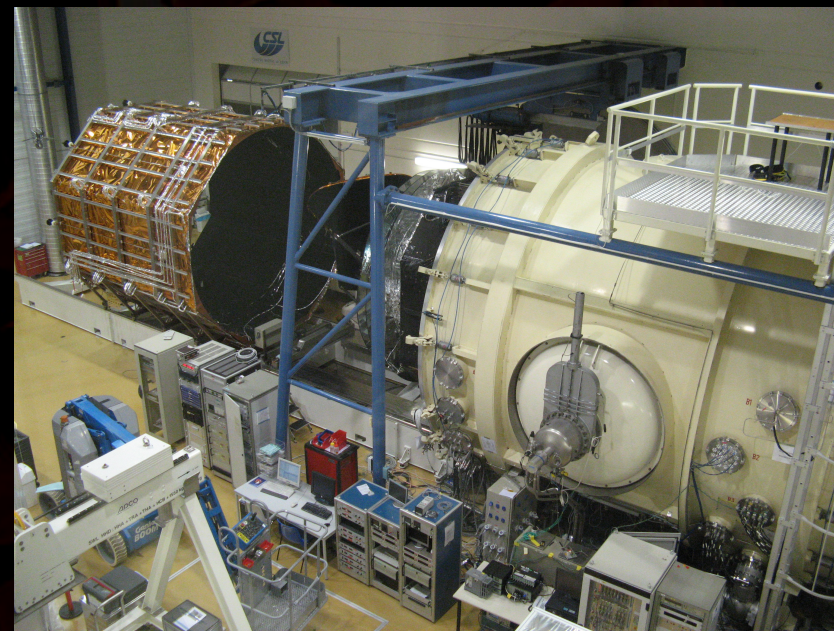


**P.M. Battaglia**  
Astrosiستا - 9 Marzo 2017

AGENCE AERIAN SPACE / Opération Vidéo du CSG - L'IMRA

# Test Criogenici su Satellite

## Centre Spatial de Liege



P.M. Battaglia  
Astrosiesta - 9 Marzo 2017



# The LFI Daily Telegraph

Carabinieri Spagnoli dei Lingua Editoria, basato daily

## The LFI Daily Telegraph

### FREE LIFE IS NOW

PLANCK DATA ANALYSIS SOFTWARE INSIDE

sol.esa.int/planck EUROPE'S BEST SELLING PLANCK DAILY Thursday, July 3, 2008 No 4 42 billion

### J-T finally reaches 40 Kelvin

LFI CSL Team jubilant that CRYO1 will start soon

By Planck Skripten Coder  
Largo, Belgium

The world may be suffering from global warming but ESA's Planck experiment is suffering from dramatic "spacecraft cooling". The cool-down has been occurring for the past few weeks under careful monitoring by European and US scientists. Scientists in the European Space Agency (ESA) confirm that the rate of cooling is now starting to accelerate after reaching a critical point.

The J-T temperature is now at 39 K, and the temperature across the Low-Frequency Instrument are as low as 42.2 K. With the roughly "40 K" approaching for LFI, the start of the CRYO1 tests will soon be able to begin. Instrument scientist Francesco Cutina, Maurizio Tomasi and Paola Battaglia will be first to begin once the tests begin and are currently preparing themselves for the important work ahead.

EURO 2008: Scientists happy about Spanish win

www.lfi.esa.int

Carabinieri Spagnoli dei Lingua Editoria, basato daily



Baguette and pasta demand surges in Belgium

Demand for pasta and baguettes has seen a 20% increase in the Largo area of Belgium during the past week. The Carabinieri reported in Brussels, Belgium and the Torino sandwich shop in Italy. The Carabinieri are both reporting huge increases in demand. The demand has sustained supply and on Sunday the LFI team were forced to serve in only four baguettes. In an attempt to study demand Daniele Morosini (US) attempted to freeze 10 baguettes. However, after several poor attempts at defrosting, Morosini admits that "it was wrong about the baguettes" improvements are being made to supply lines with daily visits to the local sandwich shop being formalized with official European Space Agency (ESA) procedures and interface control documents (ICD) being drafted.

Planck, 30 June 2008, the supply of Baguettes was increased to the LFI team at Centre d'Etude Spatiale de Nivelles, in Belgium.

Carabinieri Spagnoli dei Lingua Editoria, basato daily

## The LFI Daily Telegraph

### FREE LA CHAUFFRE

MADE FROM REAL GNOMES

sol.esa.int/planck EUROPE'S BEST SELLING PLANCK DAILY Saturday, July 5, 2008 No 4 42 billion

CRYO-1 SUCCESS!

By Marco Polo  
Largo, Belgium

For over two years, a team of the highly motivated LFI software engineers have seen the release of more and more features into version 1.0. The team's success is now being celebrated after an annual team picnic. The team's success is now being celebrated after an annual team picnic. The team's success is now being celebrated after an annual team picnic.

morning. The entire LFI CSL team were overcome with emotion when they realized that the first test was complete. Celebrations lasted many seconds with a program of La Chouffe opened to commemorate the event.

Local residents in Sart Tilman, Largo had arranged a separate party at a nearby nightclub to celebrate the test milestone.

In other news, the recently reported baguette and pasta shortages are now being exacerbated by pizza shortages which started on Friday night.

www.lfi.esa.int

Carabinieri Spagnoli dei Lingua Editoria, basato daily

Carabinieri Spagnoli dei Lingua Editoria, basato daily

## The LFI Daily Telegraph

### COUGHS & SNEEZES

FREE ILLNESS FOR EVERY READER

sol.esa.int/planck EUROPE'S BEST SELLING PLANCK OCCASIONAL DAILY Wednesday, July 16, 2008 No 8 42.5 billion

### LFly tuning

Tuning analysis aided by insect?

By Daniele Morosini  
Largo, Belgium

These small 100-compound insects have been appearing late at night through the opening of external Windows™. Lines and Man has been off-fused last.

It is thought that such insects are not just a nuisance but also a source of inspiration for the design of LFI.

Planck is designed to be the most precise of instruments. Eight days has not been used for real data. However, progress may be being a challenge. An annual team picnic is now being celebrated after an annual team picnic.

www.lfi.esa.int

Carabinieri Spagnoli dei Lingua Editoria, basato daily



More people than RCAs

By Daniele Morosini  
Largo, Belgium

Scientists at the Centre d'Etude Spatiale de Nivelles, Belgium, have been working on a new method for measuring the temperature of the Cosmic Microwave Background (CMB) using a technique called "LFI tuning".

The LFI tuning method is a new way of measuring the temperature of the CMB. It is based on the fact that the CMB is not perfectly uniform. There are small variations in temperature across the sky. These variations are caused by the presence of galaxies and other objects in the universe.

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P.M. Battaglia  
Astrosiesta - 9 Marzo 2017

# The LFI Daily Telegraph...edizione speciale!

Centre Spatial de Liège Edition, issued daily.

## The LFI Daily Telegraph

THE TOP 10 PLANCK NCRs  
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EUROPE'S BEST SELLING PLANCK OCCASIONAL DAILY Sunday, July 20, 2008 No 10 €2.7 billion

By Wedding Correspondent, Milano, Italy

The crowds cheered and a weekend of celebrations began in Milano, Italy on Saturday as Paola Battaglia and Filippo Rizzo were married. Paola, an expert SCOS/TQE operator, had been at CSL for the Planck tests until early in the week when she left to prepare for her big day. She may have given her heart to her husband Filippo but he knows that he competes for her affections with a large spacecraft in Belgium. Following a day of married life, Paola returns to CSL to continue with the LFI test campaign. They will start their normal honeymoon after the tests are over. The destination is being kept secret to protect the couple from Thales separation. Paola and Anna return on Monday as Peter and Rodrigo leave.

19.7.2008



Happy couple Paola & Filippo Rizzo after wedding on Saturday.

### Cooler is "like an eagle in a cage"

Wildlife experts at Cnespace have expressed their concern for the well being of one of Europe's rarest species. The lesser spotted scapular cooler (*Frigidarius albaeus*) has been kept in a captive cooling programme within the PICALO vacuum chamber at Centre Spatial de Liège for over a month. On Sunday afternoon cooler spokesman Gianluca Morgante described it as "like an eagle in a cage." "It doesn't like to be in the chamber... it needs to be in the wild, free" he added. It is hoped that a planned release into its natural L2 habitat next year will improve its spirits.

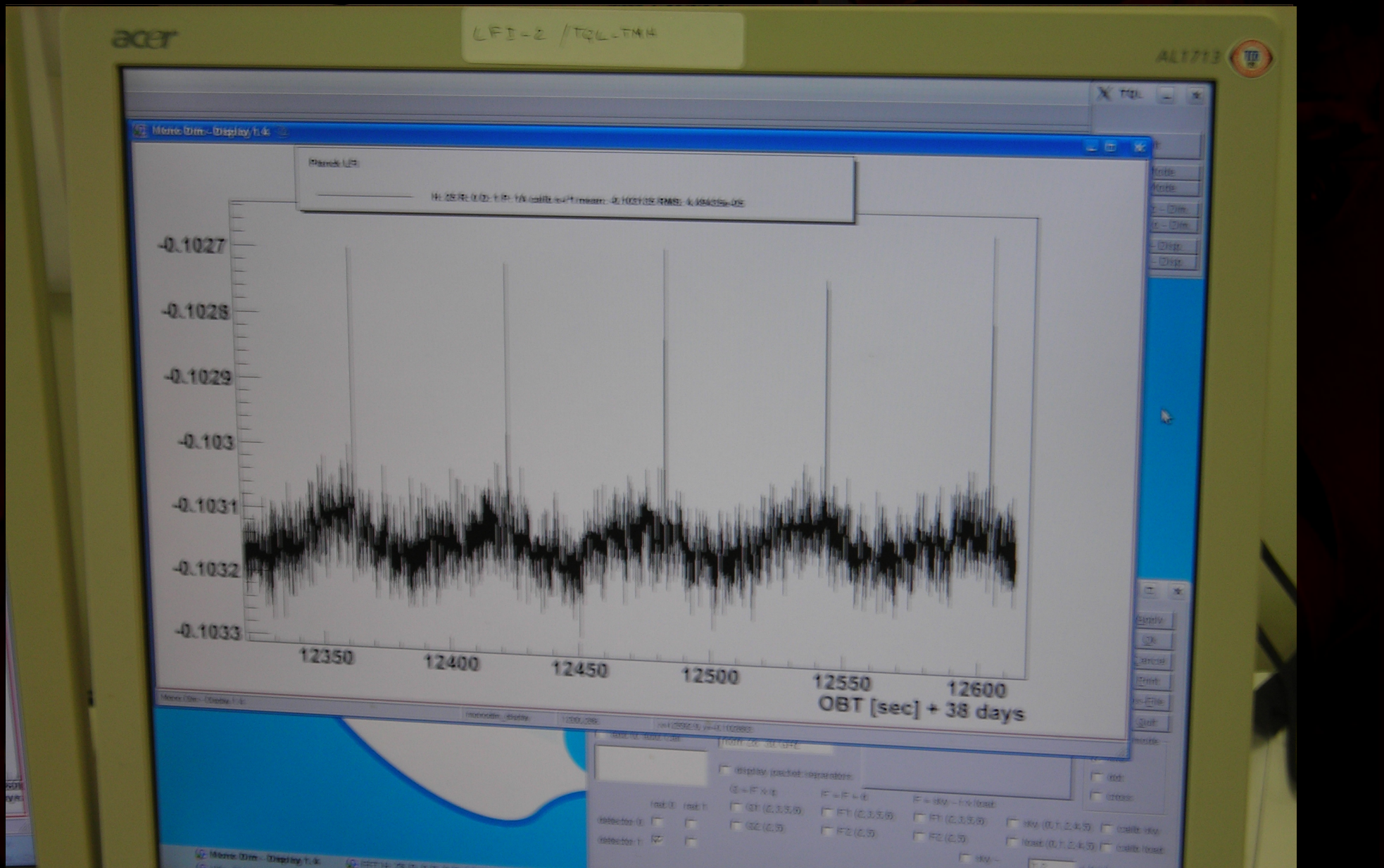
### 'Tornado' hits CSL

Reports are coming in of a tornado ripping through the Planck LFI team. It is thought that the tornado hit at 9:30 local time on Sunday morning. A high pressure system formed at the end of the 10° 4K cooler PID tuning and meteorologists warn that the oncoming saving verification will keep things 'whirling for a couple of days'.

Paola Battaglia and Filippo Rizzo in Milan marks the good news that the ACA testing has been completed 18th July 2008. (MAGP) Stefano De Marco

P.M. Battaglia  
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# Calibrazione in Volo



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# 23 Ottobre 2013: Planck Switch Off



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**GRAZIE!**



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**Astrosiеста - 9 Marzo 2017**