

# *Planck and the CMB*

***Ken Ganguly  
APC***







# Planck is >20 Years of Work

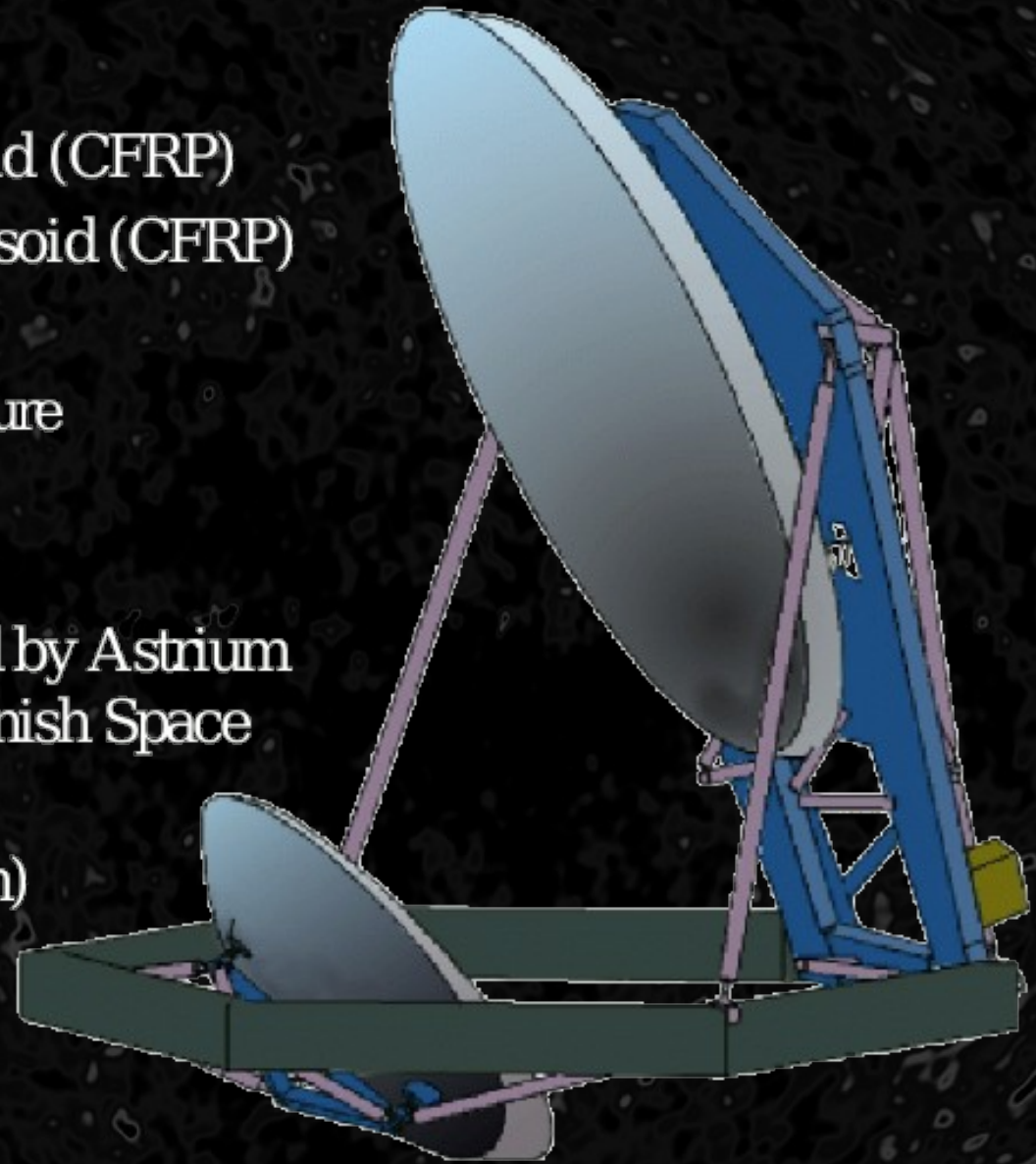






# Telescope

- Primary: 1.50 x 1.89 m ellipsoid (CFRP)
- Secondary: 1.02 x 1.04 m ellipsoid (CFRP)
- System:
  - 1.5 m circular projected aperture
  - Total MWFE  $< 40 \mu\text{m rms}$
  - Total  $\varepsilon < 0.01$
- Reflectors are being developed by Astrium GmbH, led by ESA and the Danish Space Research Institute  
(PI: Dr. H.U. Norgaard-Nielsen)



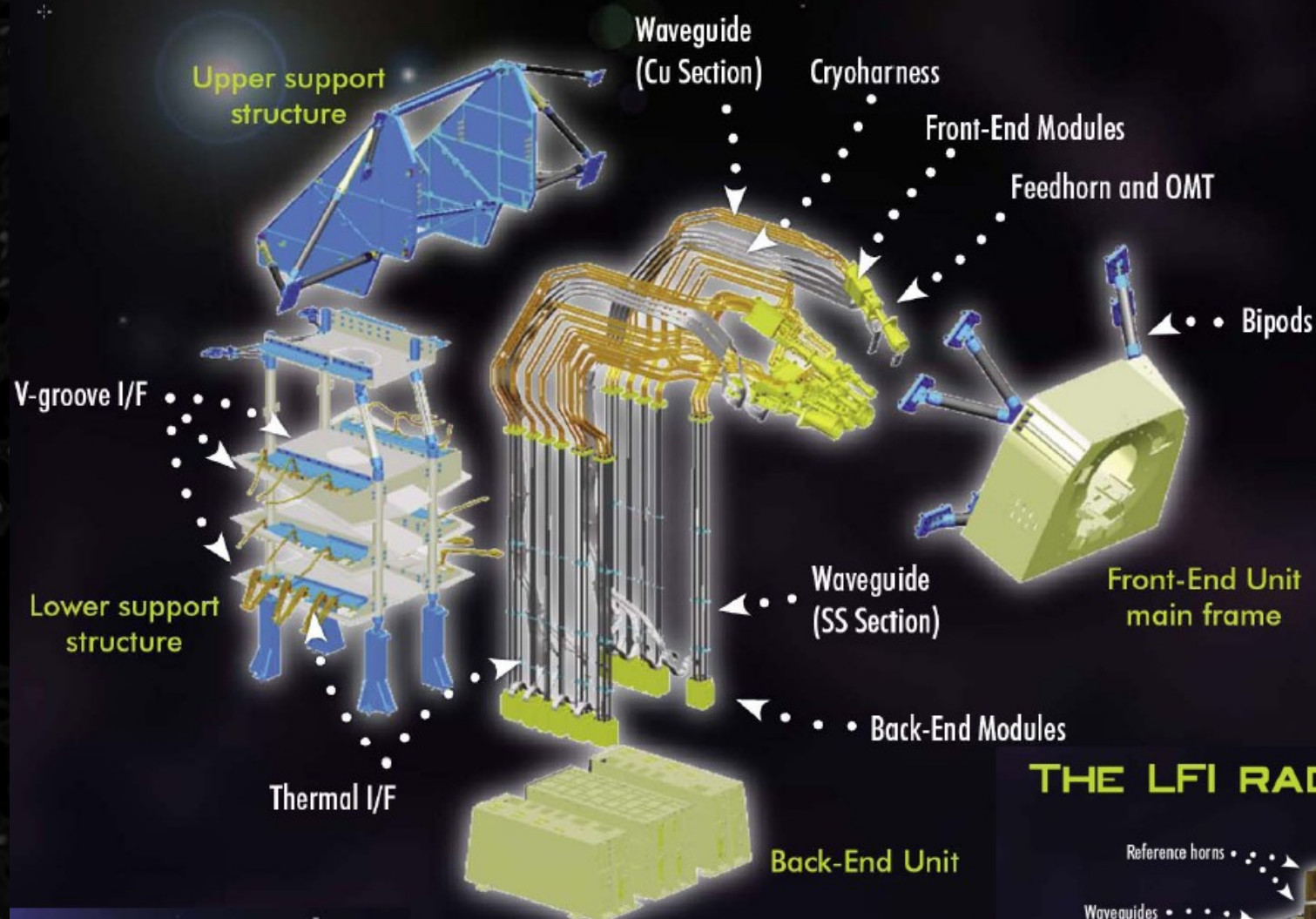
*PLANCK*

**esa**  
**ASTROPHYSICS**

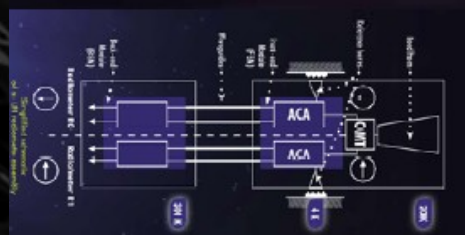
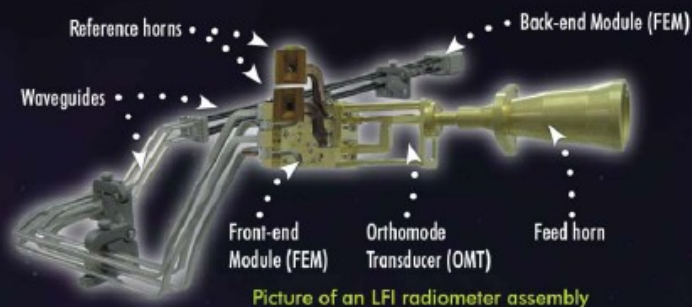




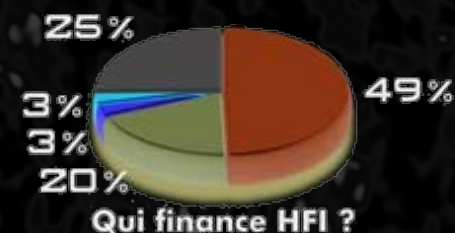
# The Low Frequency Instrument LFI



## THE LFI RADIOMETER CHAIN



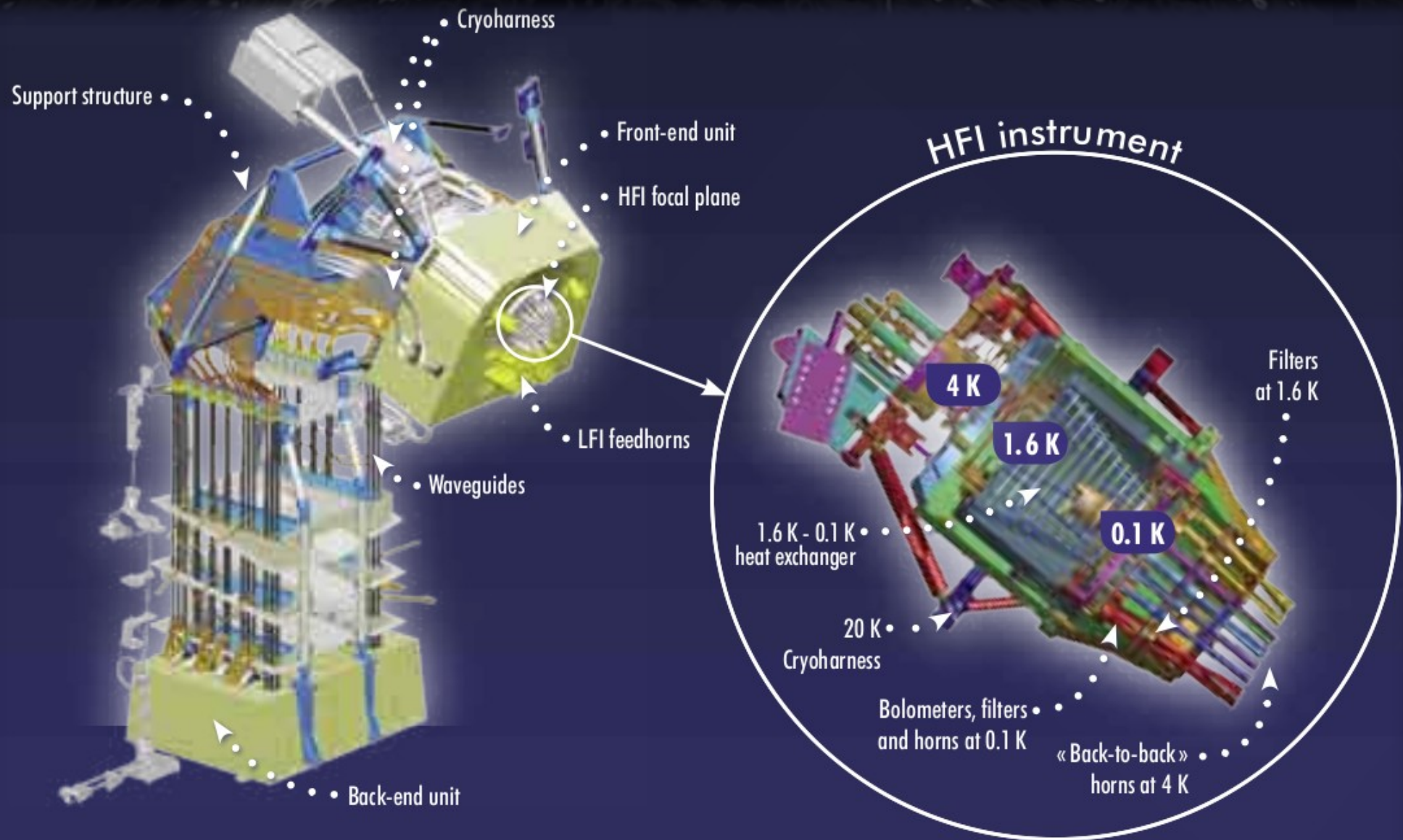








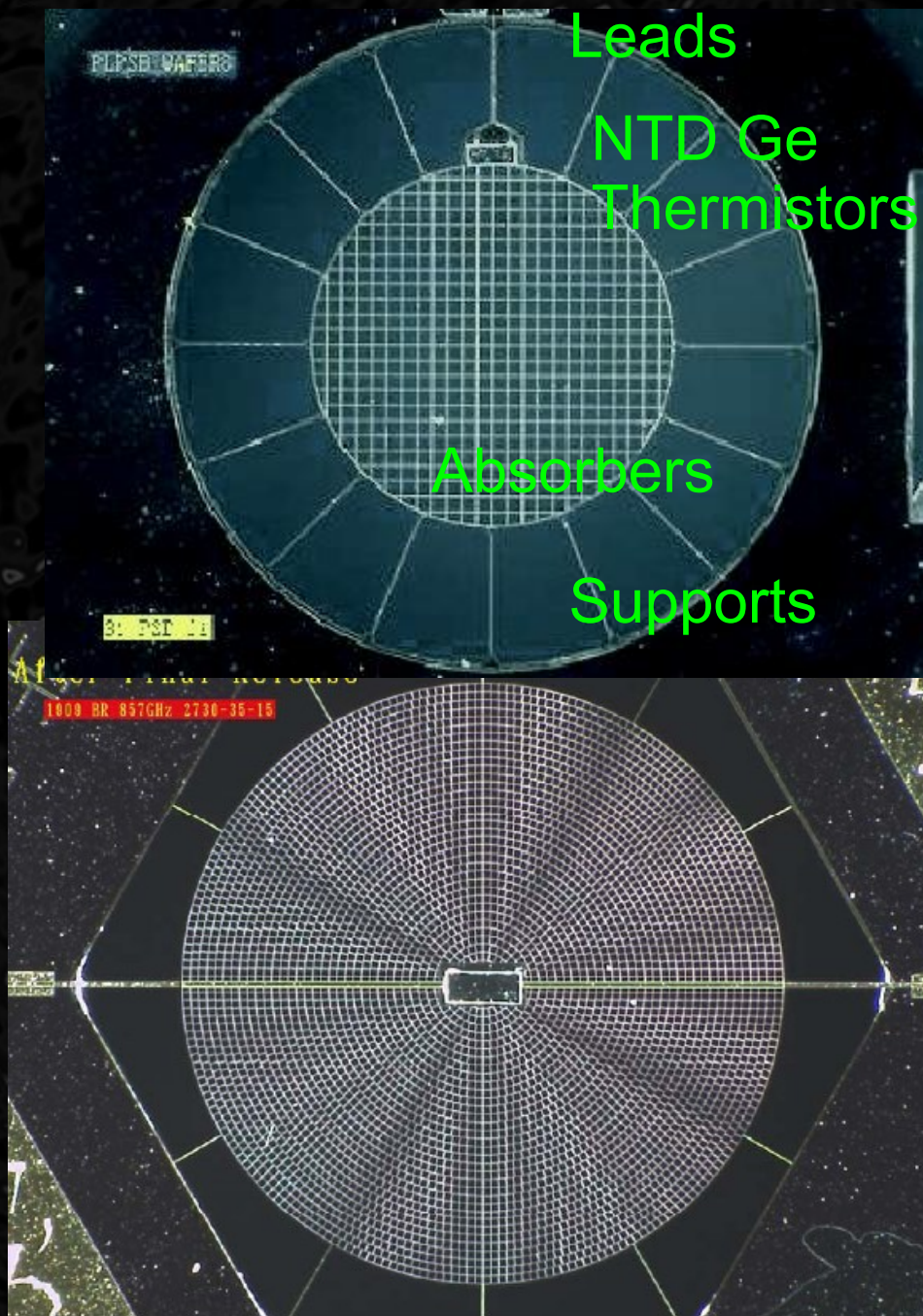
# The Coldest Thing in Space







# Polarization and Total Power Detect.



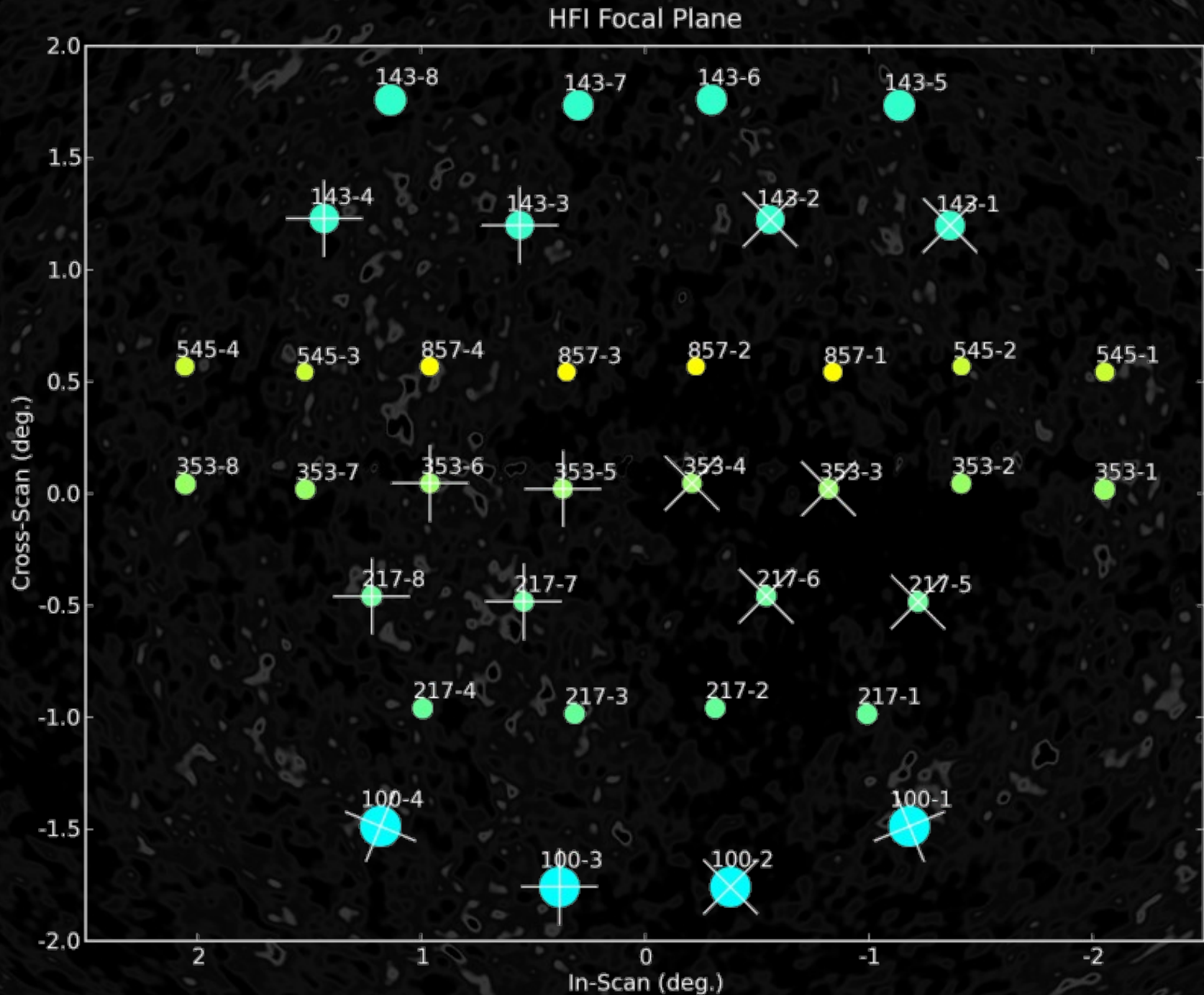
There are actually two detectors in the top figure to the left – each sensitive to a single linear polarization

Effort is required to understand the “cross-polarization” of the detectors





# The HFI Focal Plane: ~50 Detectors

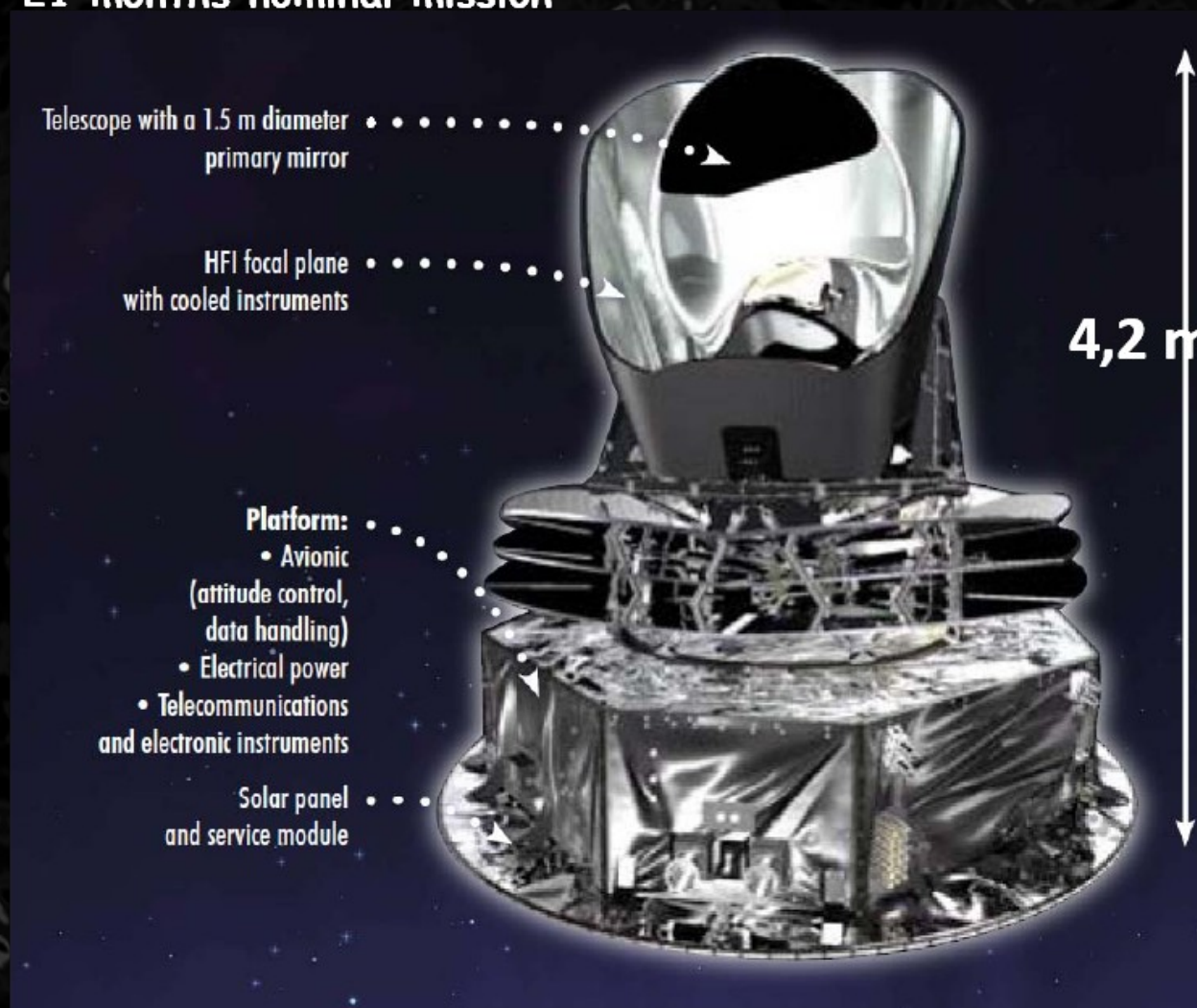






# Payload Summary

2000 Kg  
1600 W consumption  
2 instruments - HFI & LFI  
21 months nominal mission



50 000 electronic components  
36 000 l  $^4\text{He}$   
12 000 l  $^3\text{He}$   
11 400 documents  
20 years between the first project and first results (2013)

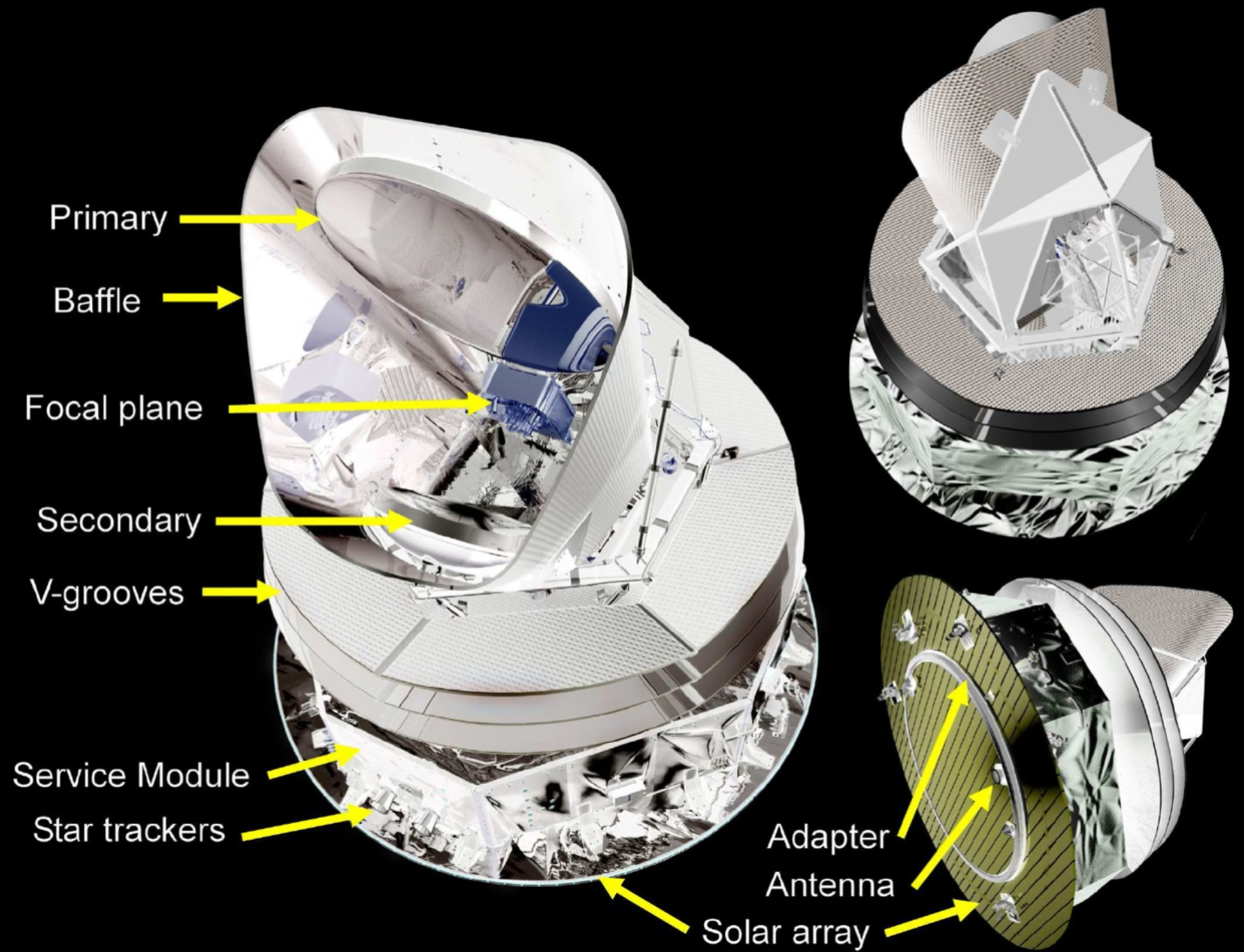
5c per European per year  
16 countries  
400 researchers among 1000



4,2 m

Ken Ganga



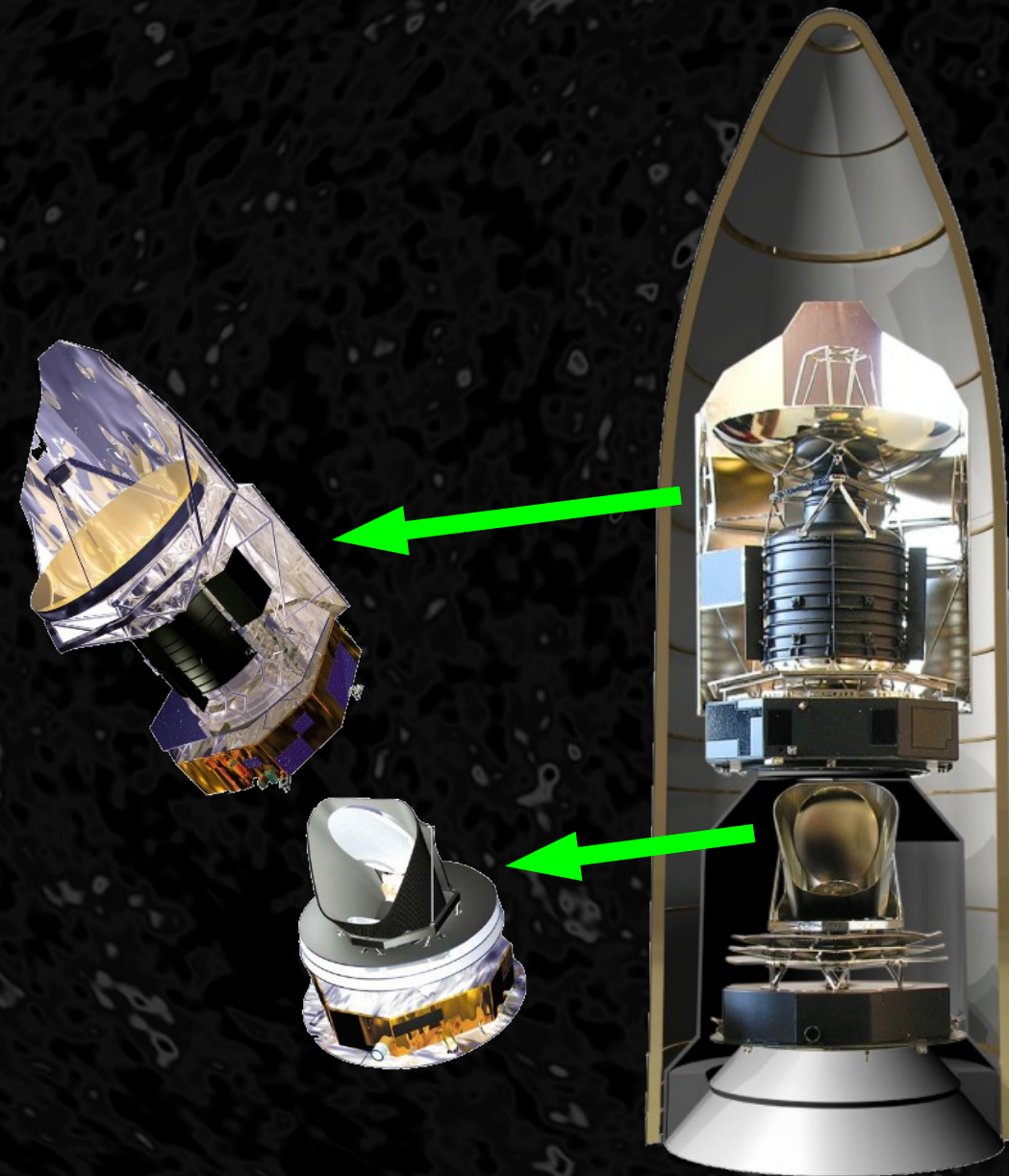






# Launch

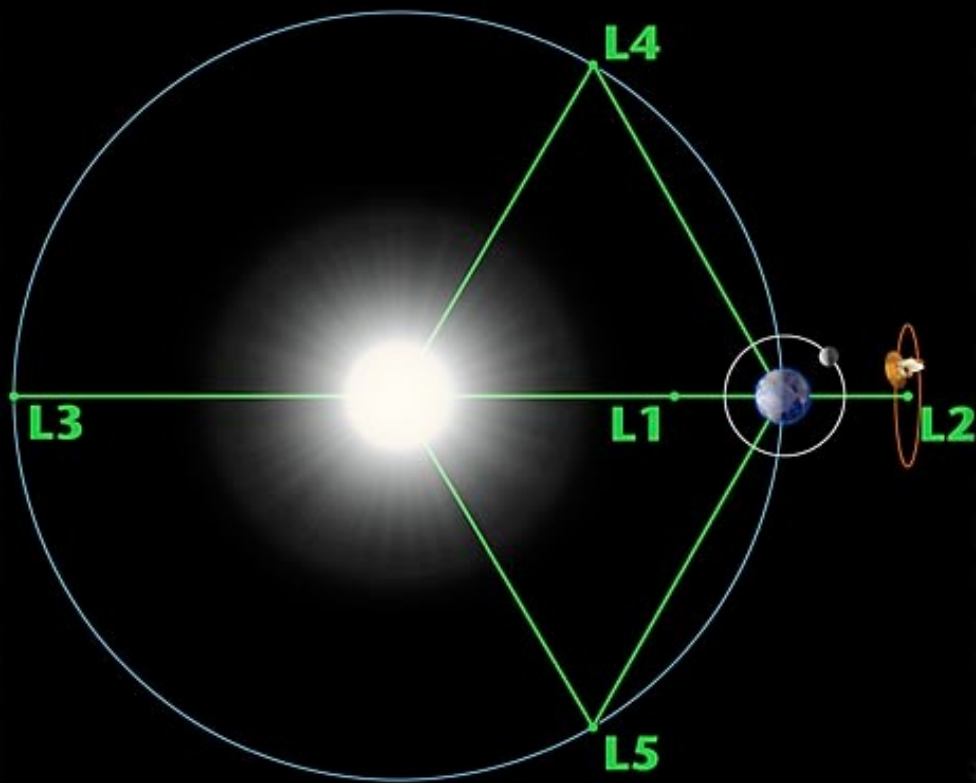
Launch was May 1 from  
Guiana Space Center,  
Kourou, French Guiana  
Ariane 5 Launch Vehicle  
With Herschel, which also  
is at L-2







# 2<sup>nd</sup> Earth-Sun Lagrange Point



- Radiation from the Earth and the atmosphere can contaminate our measurements
- Solution: Get as far from the Earth as possible
- L2 is  $\sim 1.5 \cdot 10^6$  km ( $\sim 0.01$  AU) from Earth

<http://map.gsfc.nasa.gov>





# Planck's Orbit and Scanning

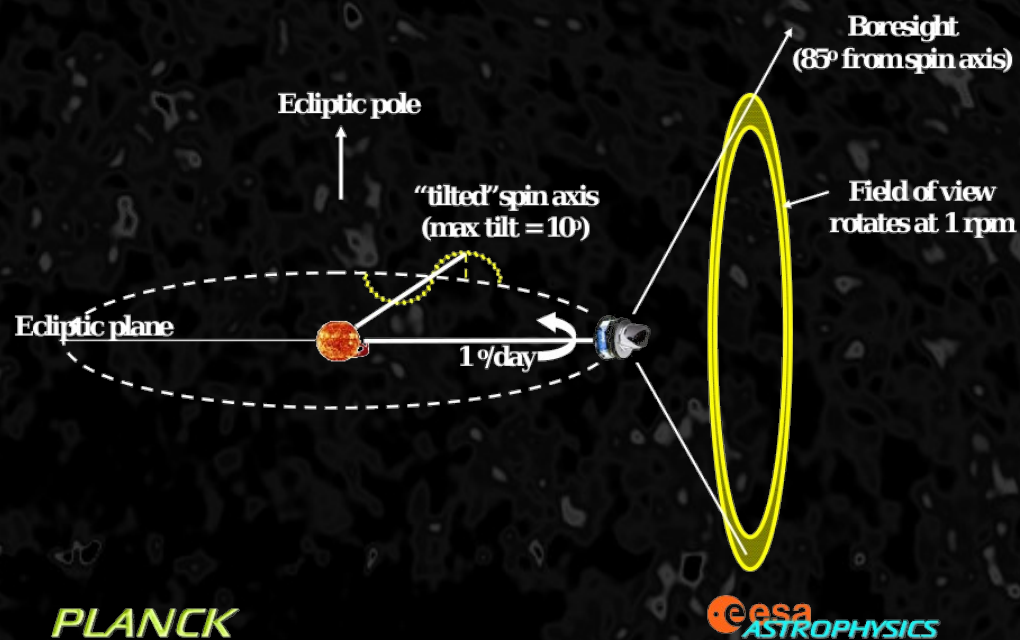
Orbits the Sun

Solar Panels always facing near Sun

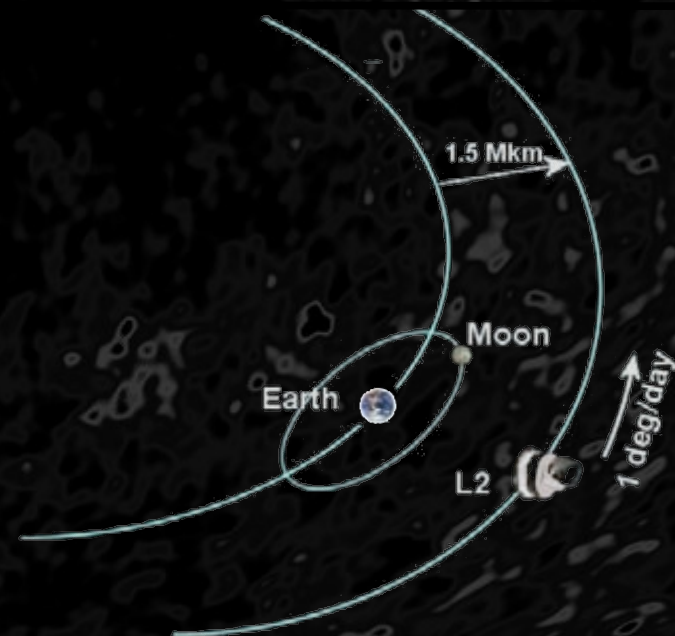
Antenna always facing near Earth

Detectors always  $\sim 95^\circ$  from Sun/Earth

We actually orbit *around* L2 (1.5 Mkm from Earth) in a Lissajous orbit



Sun

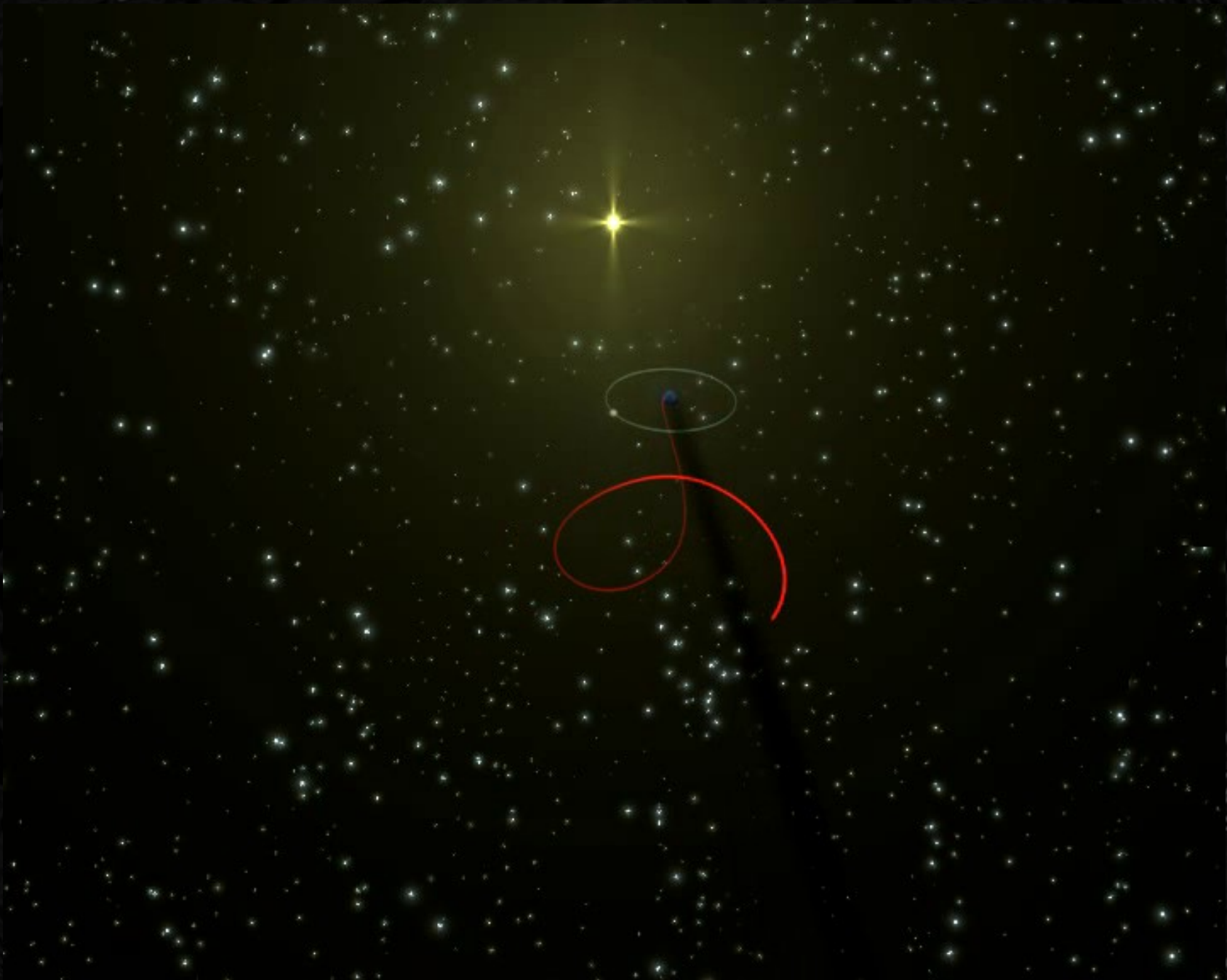


Planck Bluebook



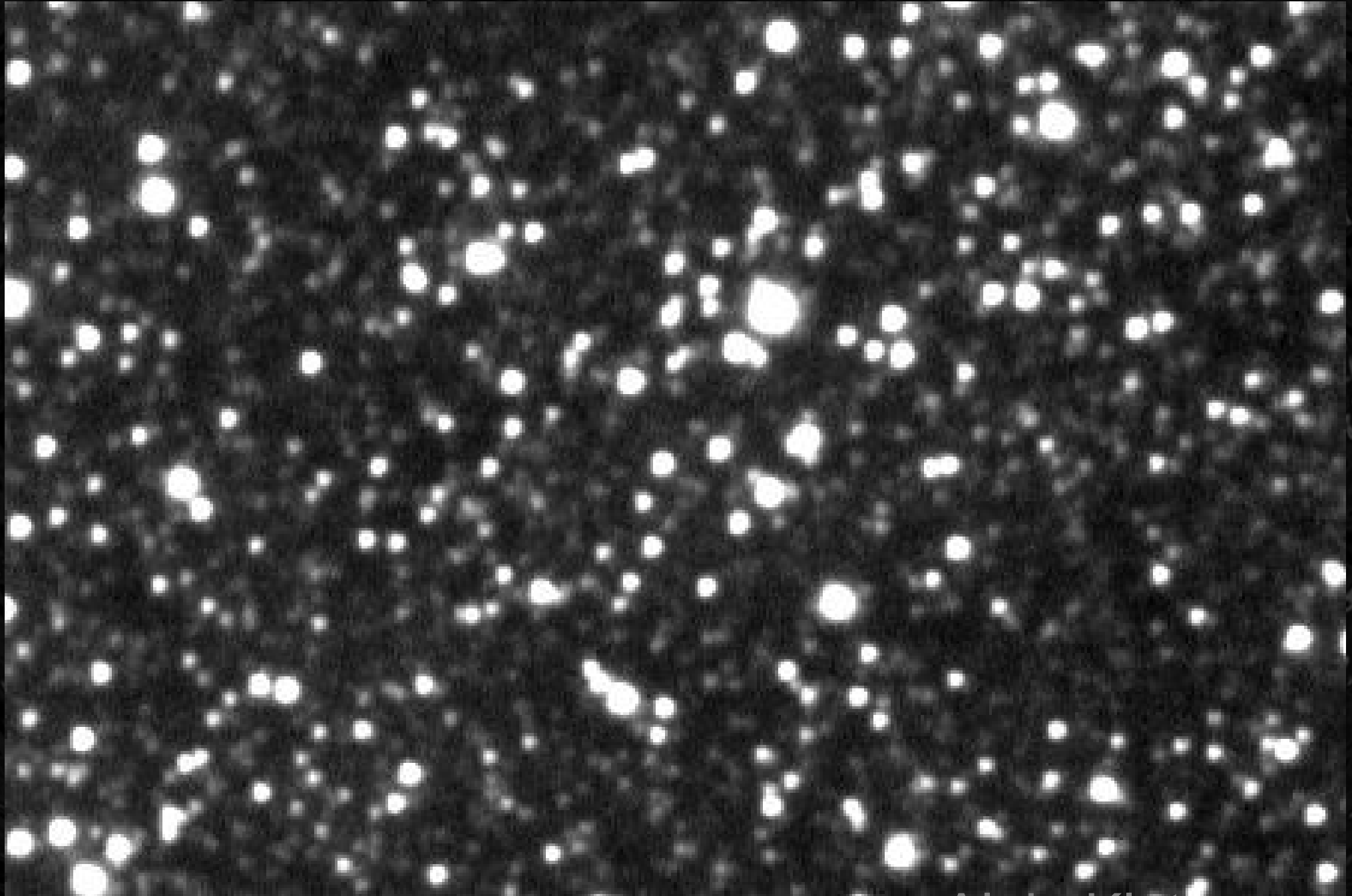


# Voyage to Orbit





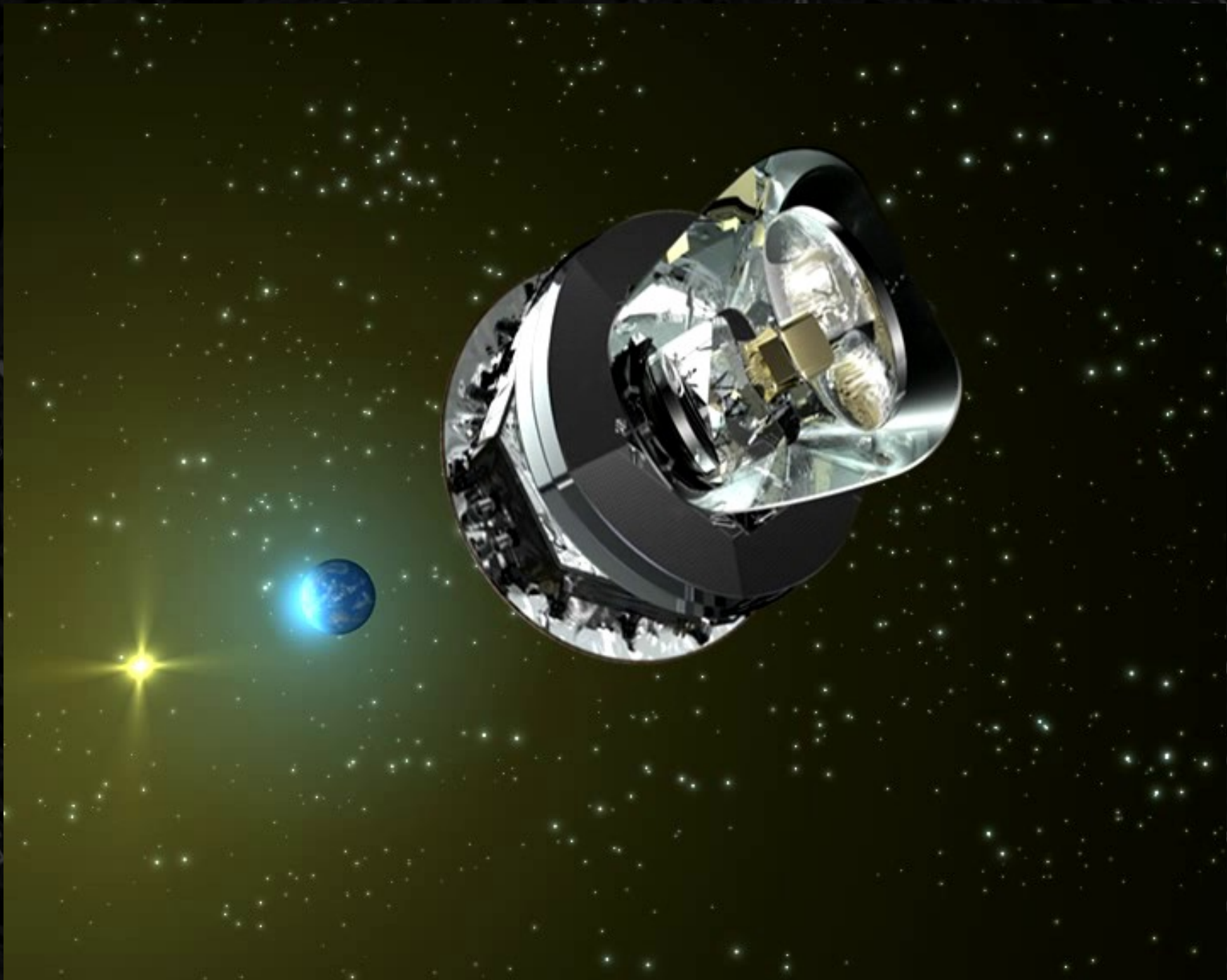
# Planck as Seen from Earth







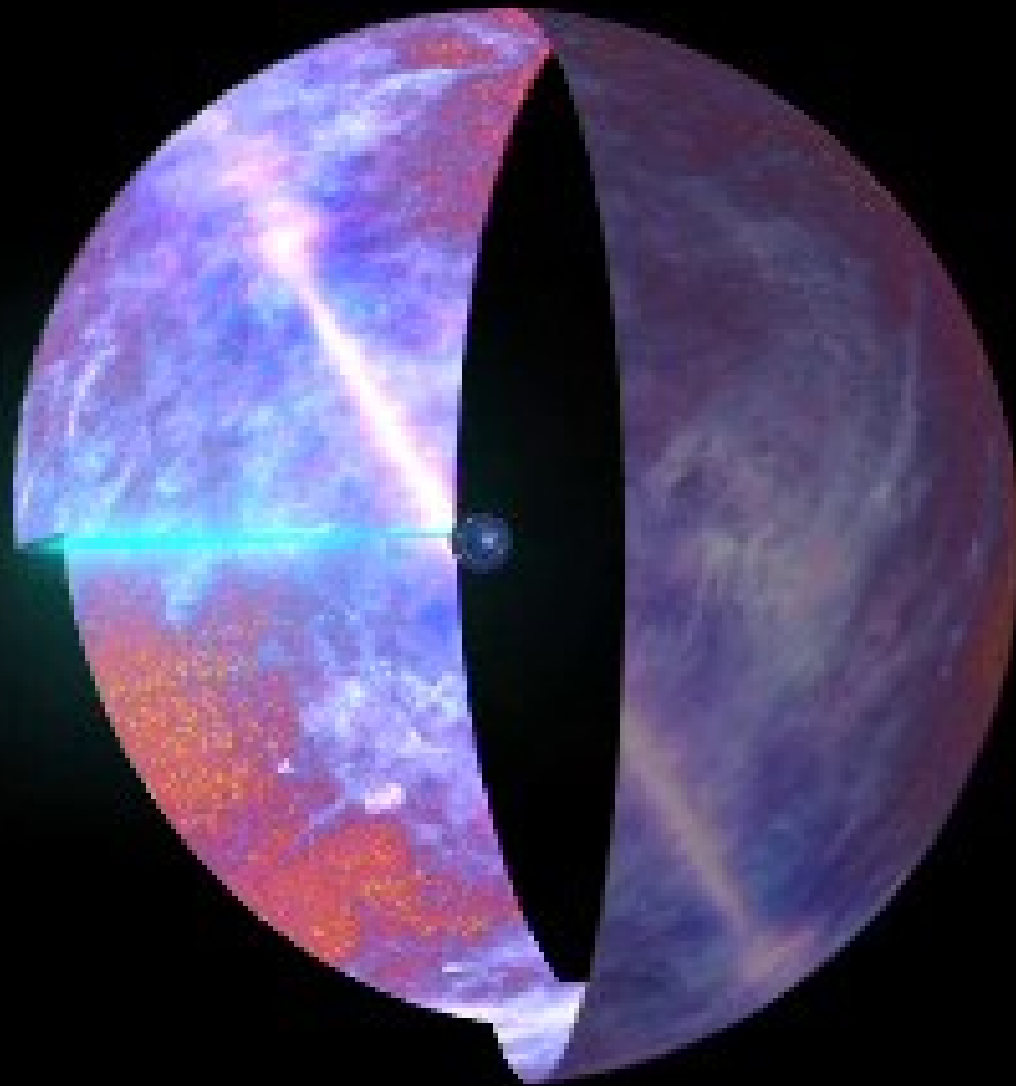
# Orbit







# Scan



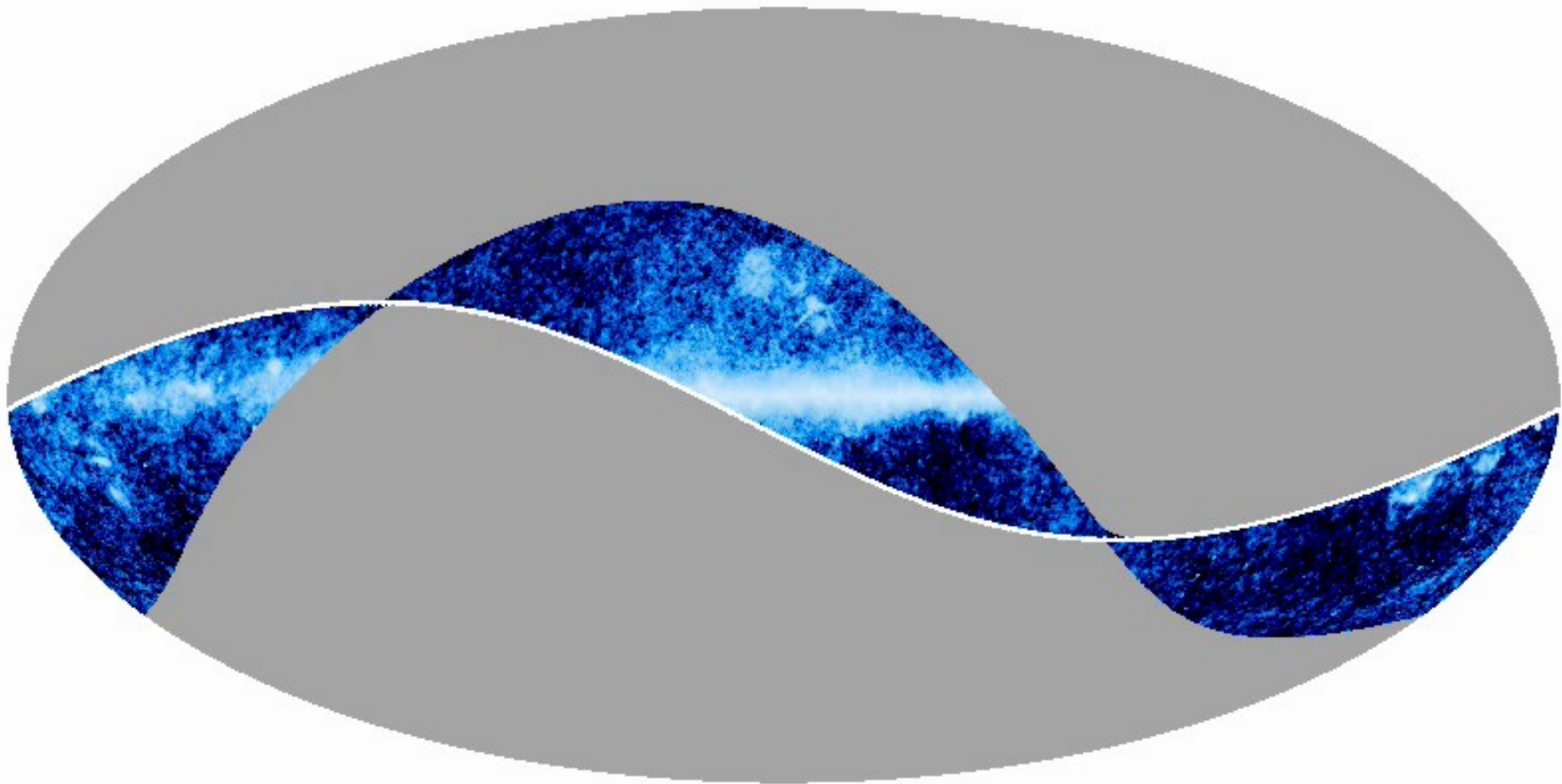




# Sky Coverage

Planck scanning

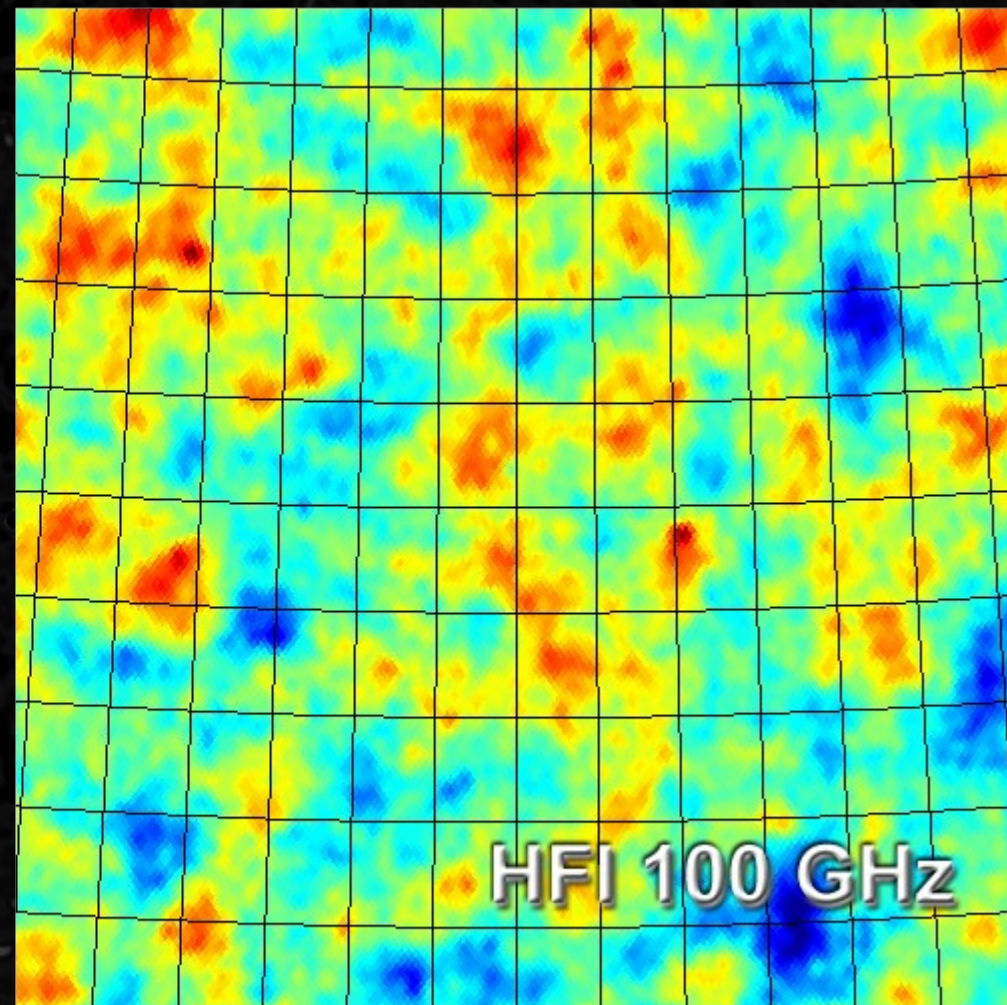
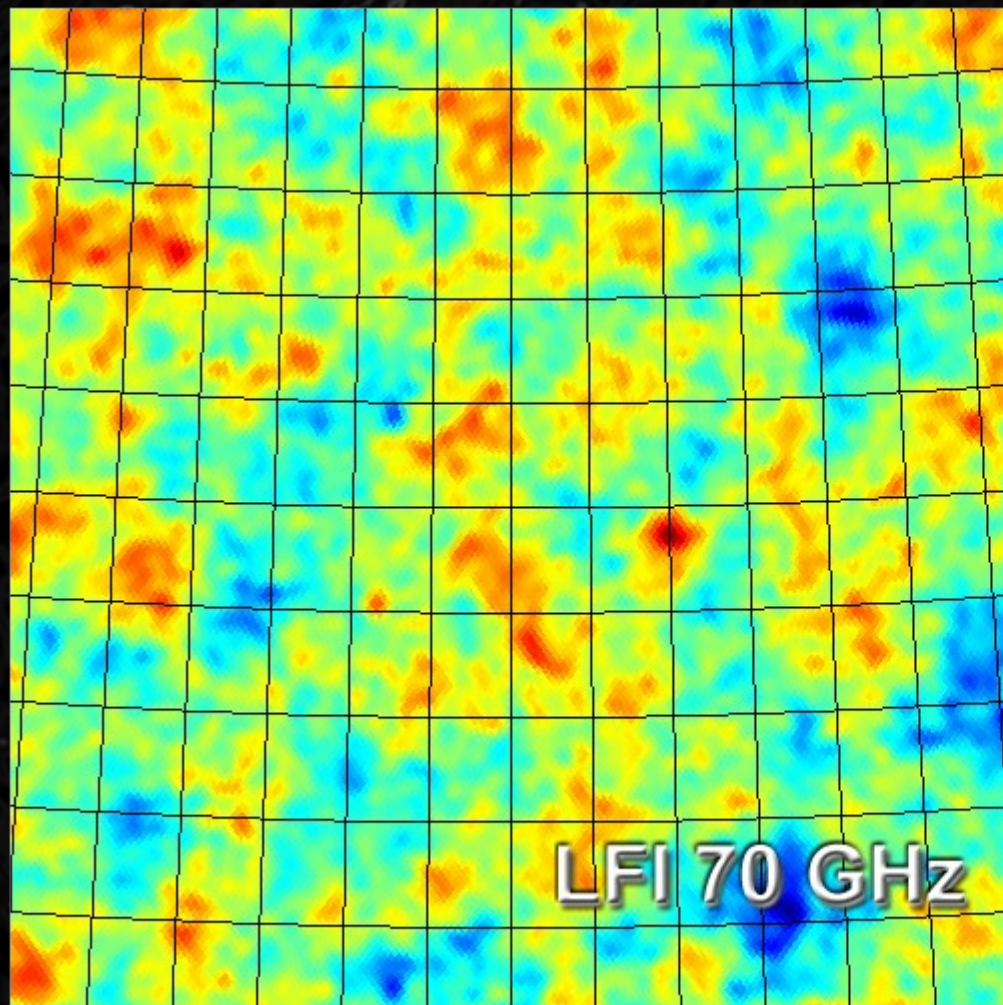
2009-09-20







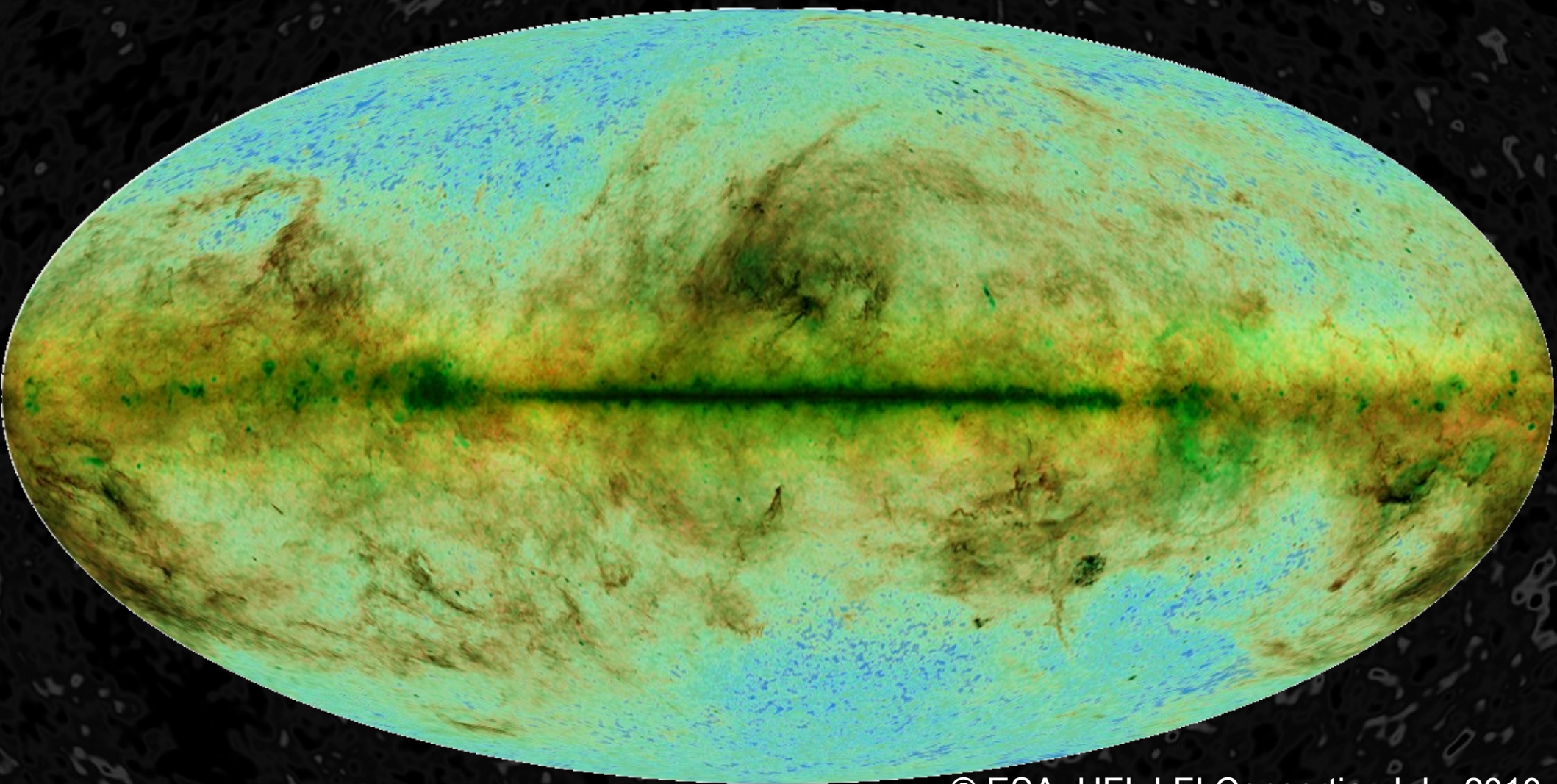
# HFI-LFI Consistency







# Planck One-Year All-Sky Survey

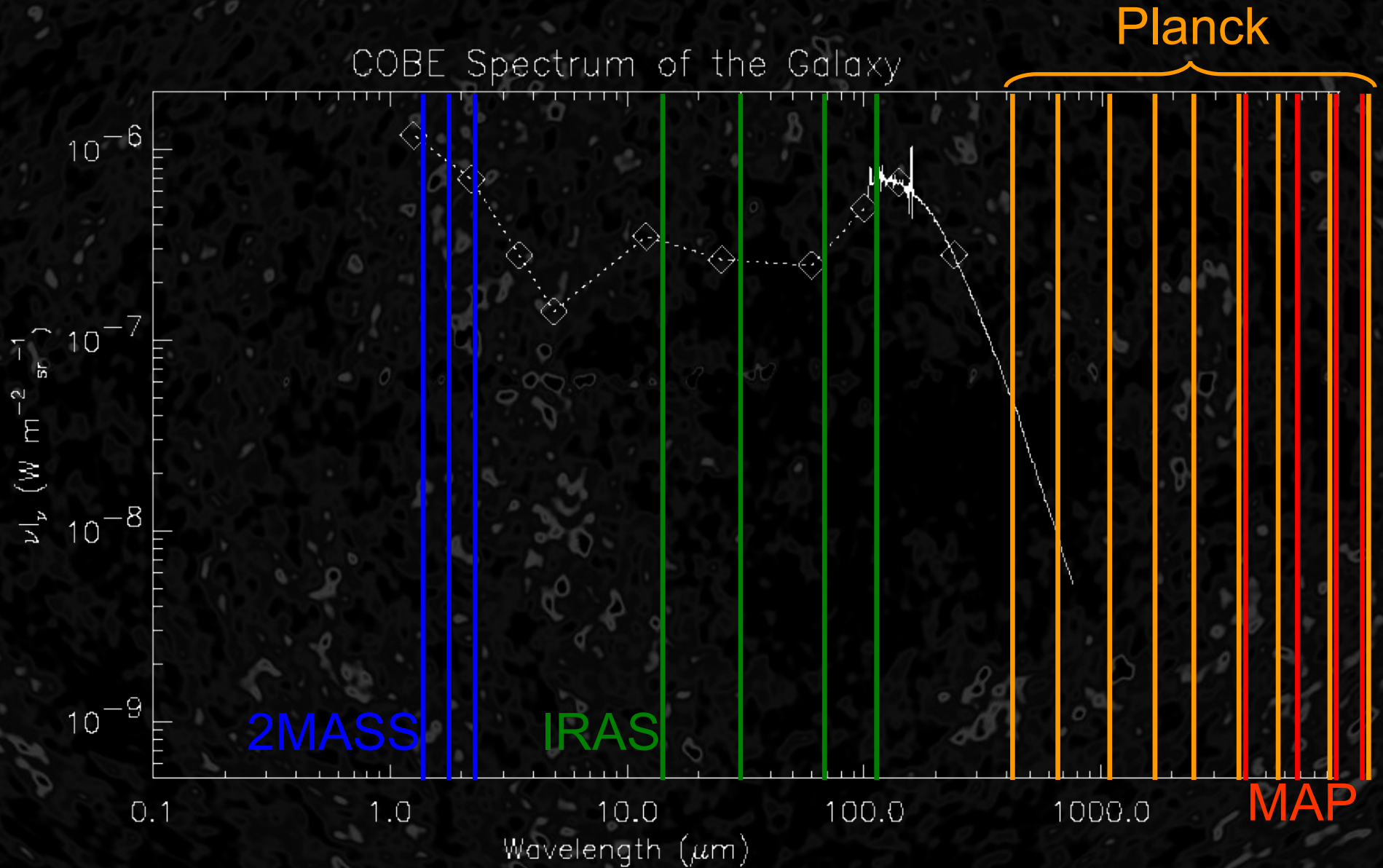


© ESA, HFI, LFI Consortia; July, 2010





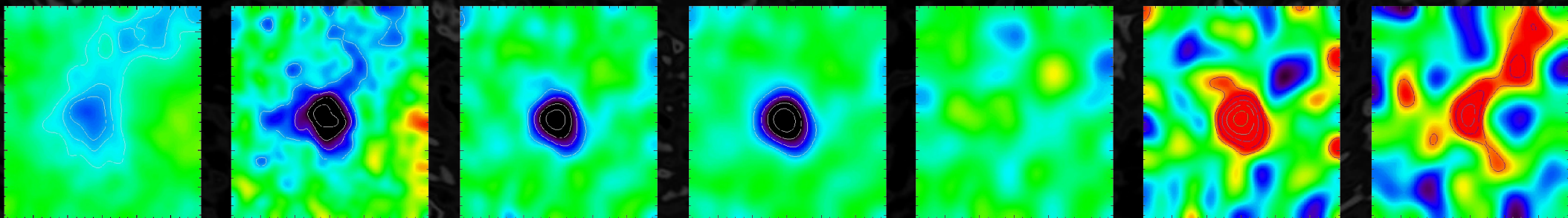
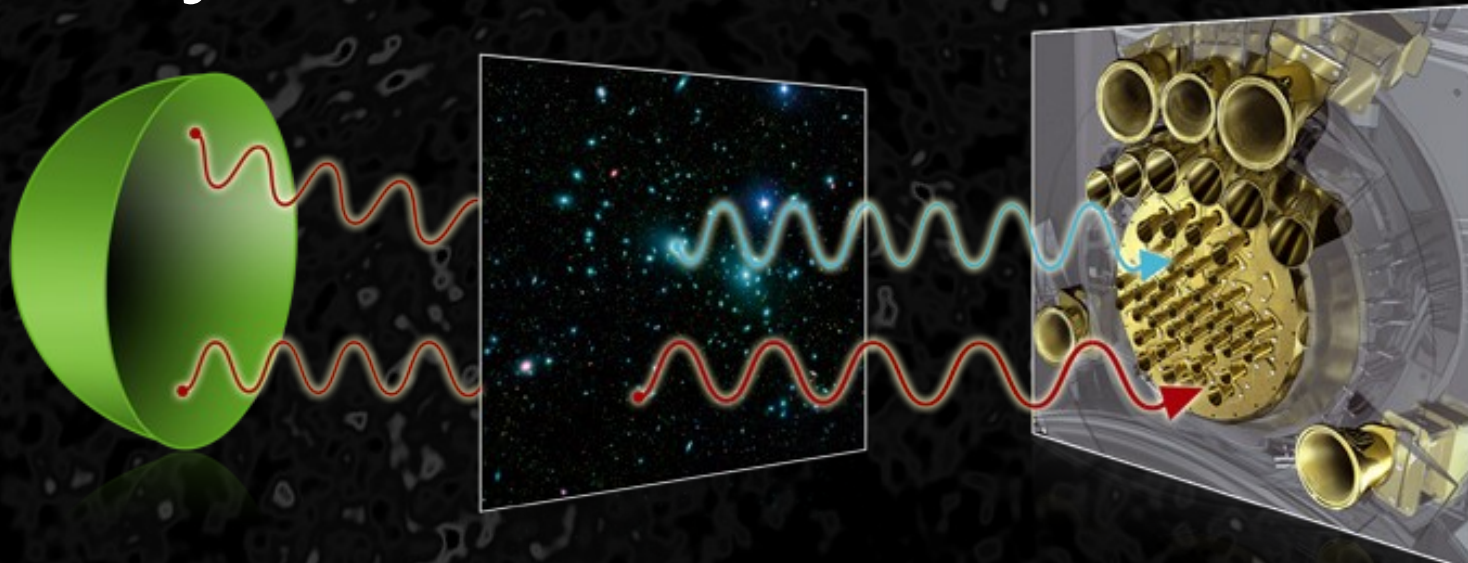
# Planck Frequency Coverage







# Galaxy Cluster Abel 2319 in the SZ



44 GHz

70 GHz

100 GHz

143 GHz

217 GHz

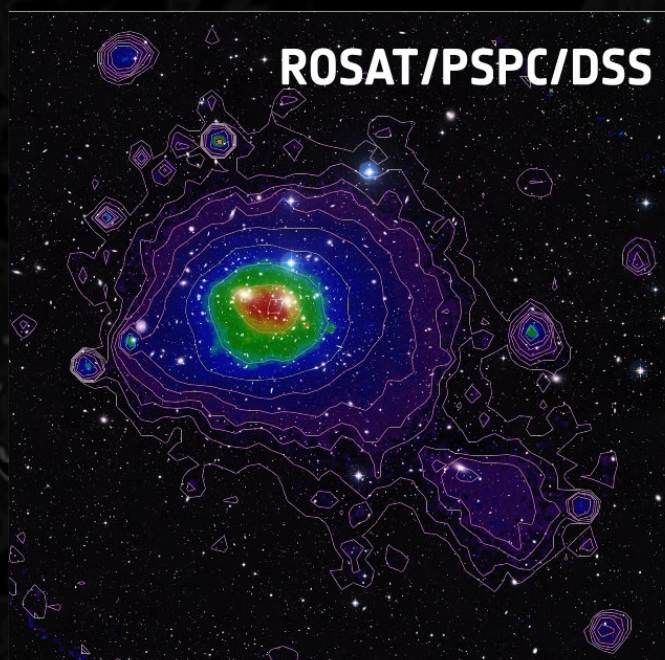
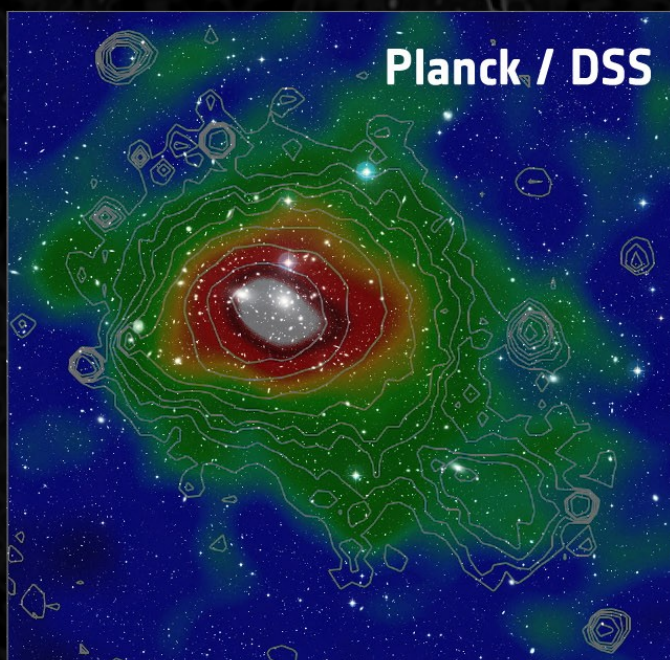
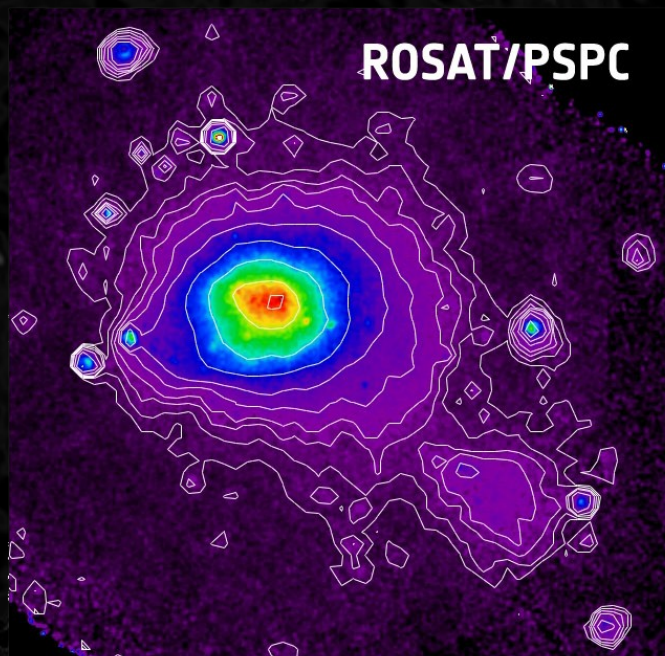
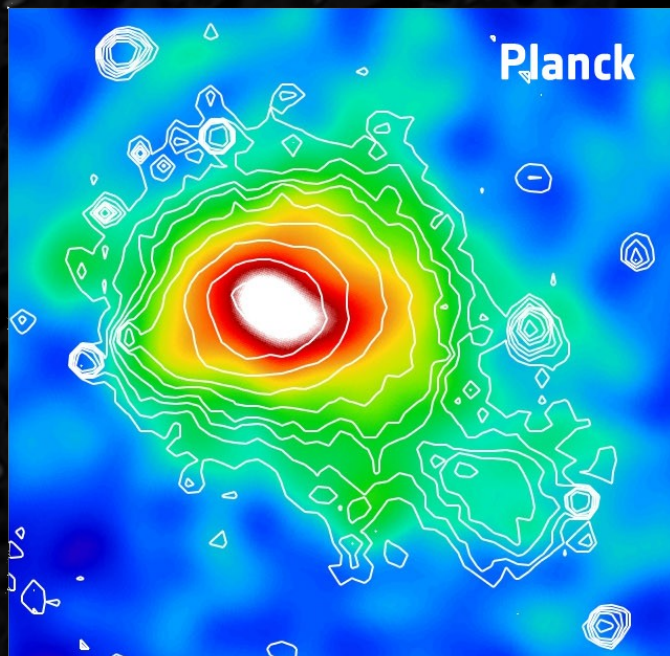
353 GHz

545 GHz



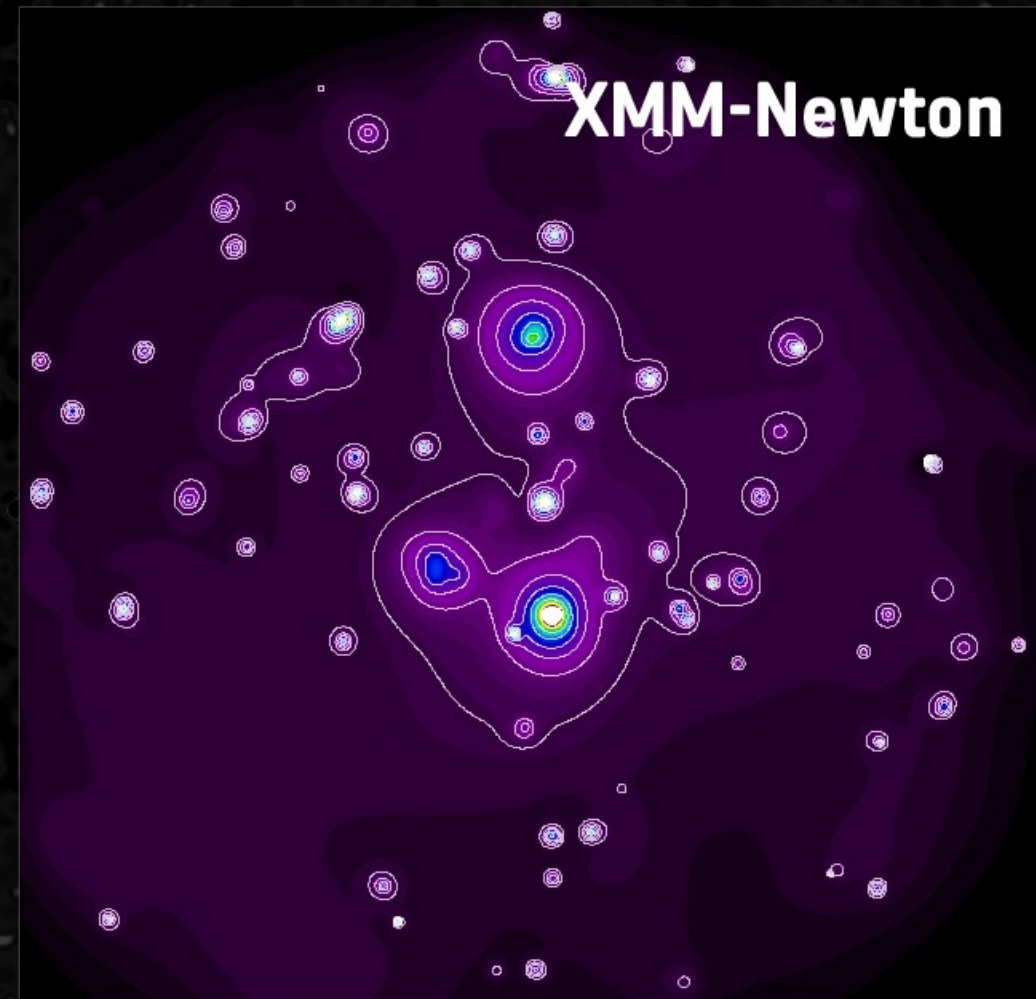
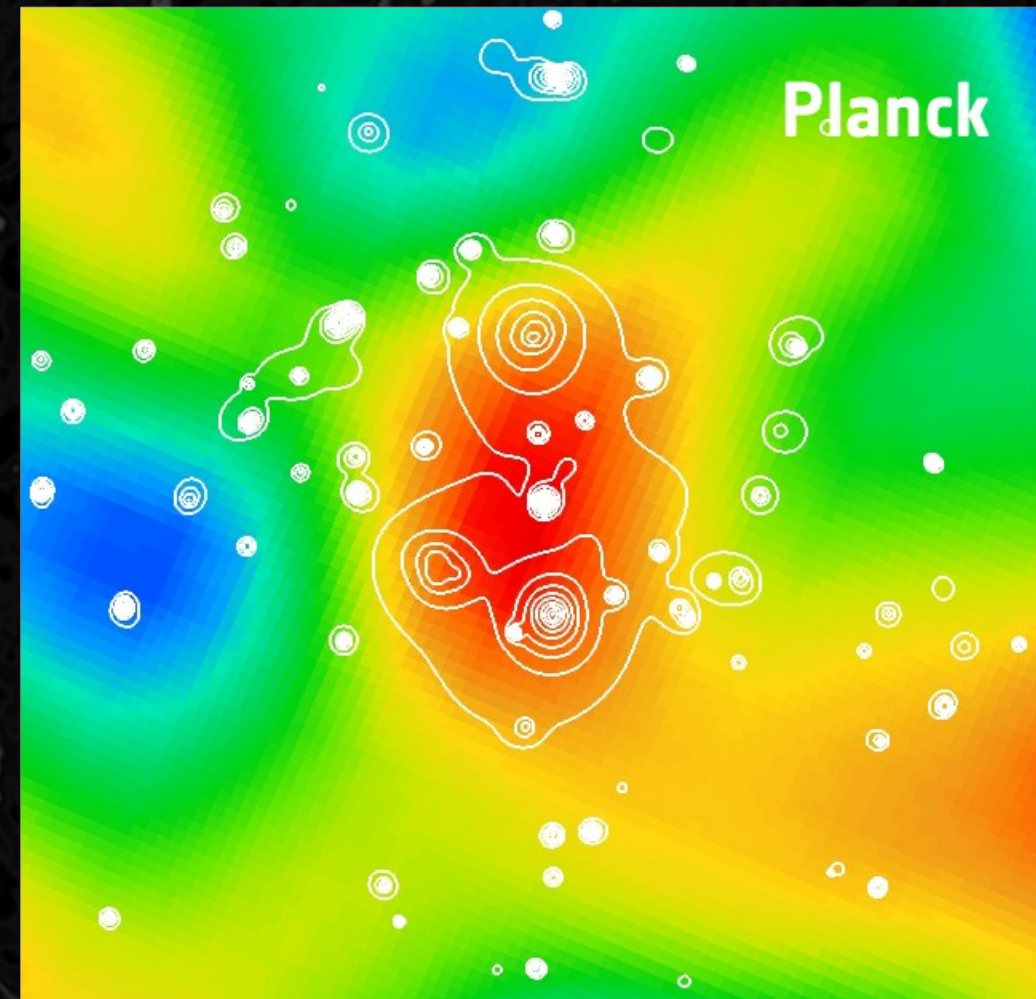


# The Coma Cluster





# A New Supercluster Seen By Planck

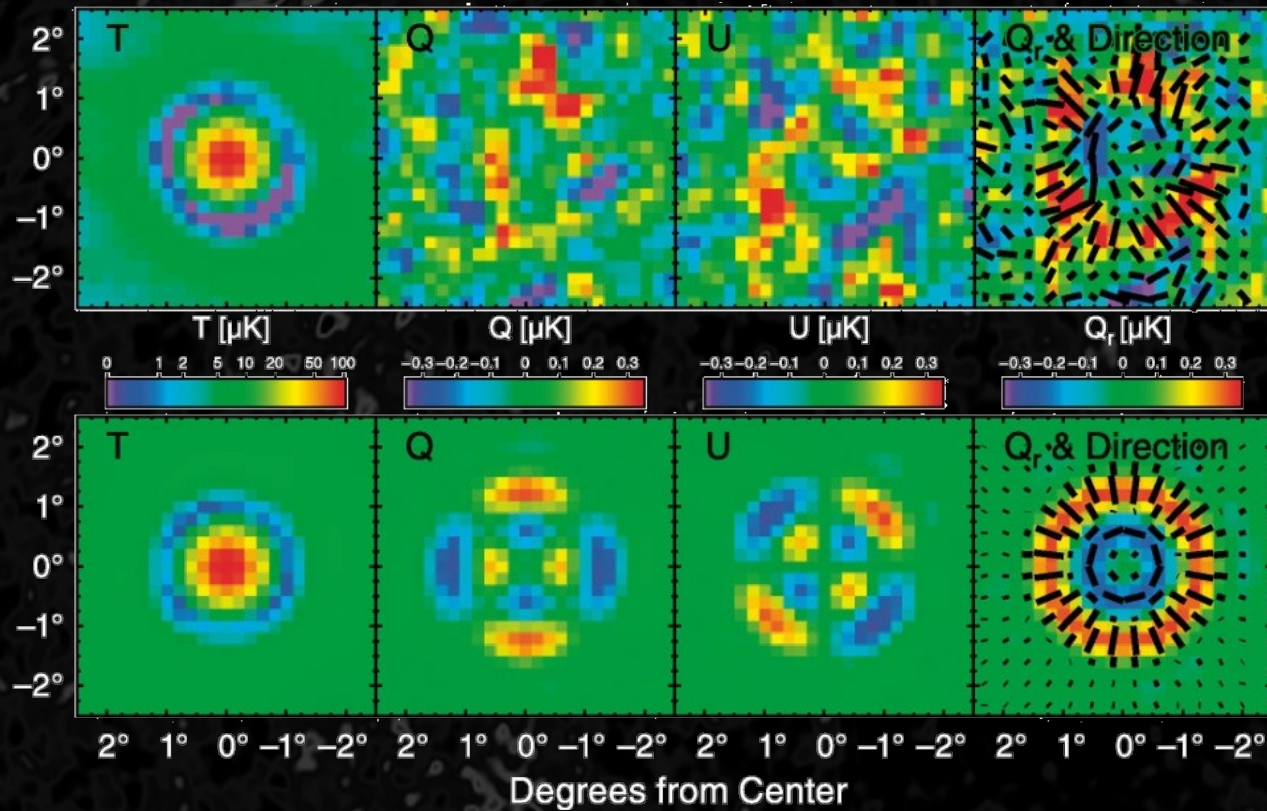






# Illustration of polarization sensitivity

WMAP 7years  
(Komatsu et al.  
preprint 2010)  
& simulations

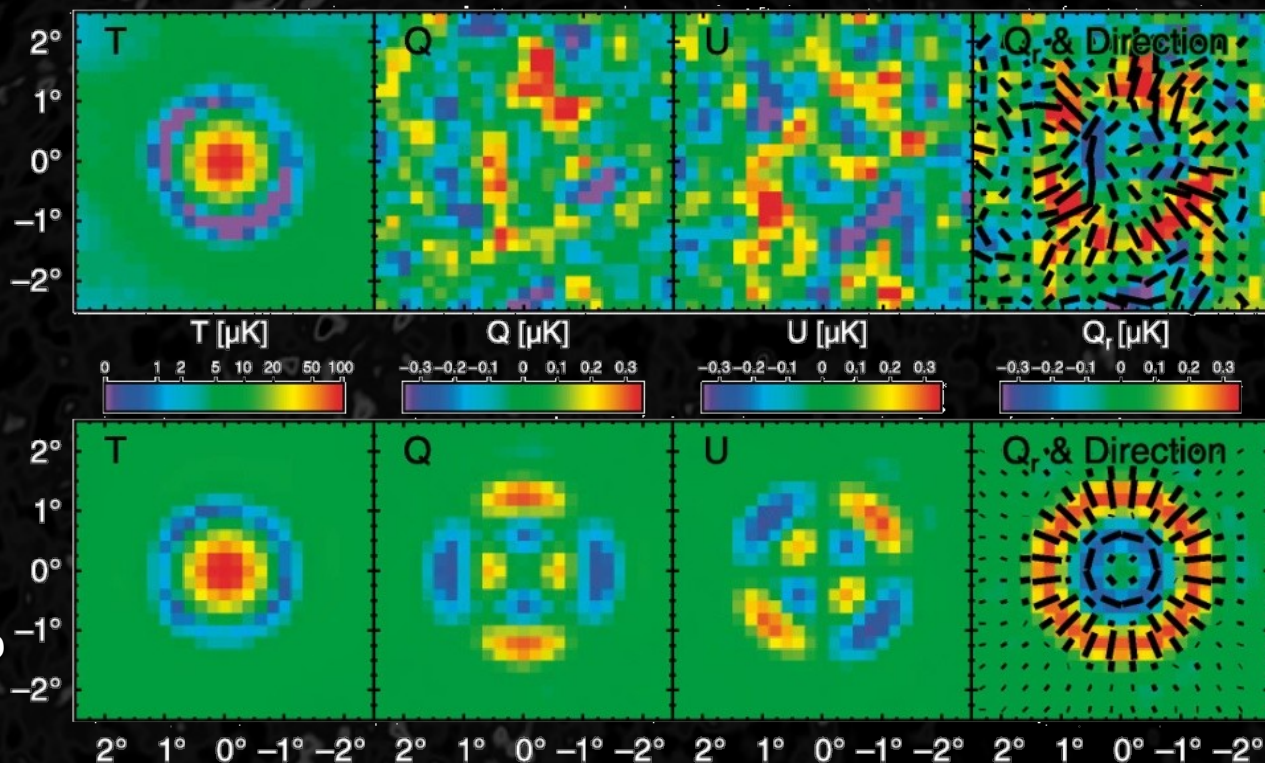






# Illustration of polarization sensitivity

WMAP 7years  
(Komatsu et al.  
preprint 2010)  
& simulations



**Health  
Warning: not  
assured yet  
whether  
systematic  
effects are  
controlled for  
“precision  
cosmology”**

ILLUSTRATIVE Planck PLOTS  
REMOVED FOR DISTRIBUTION





# WMAP/Planck E-Mode Polarization

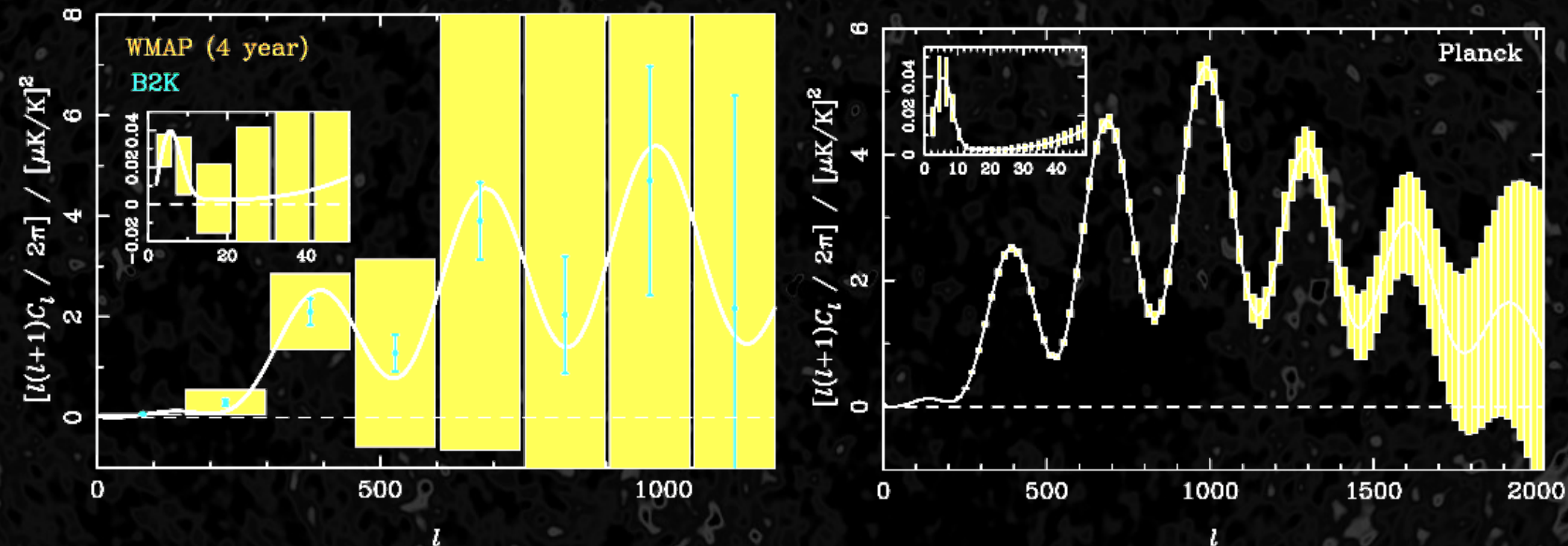


FIG 2.14.—Forecasts for the  $\pm 1\sigma$  errors on the  $E$ -mode polarization power spectrum  $C_\ell^E$  from *WMAP* and B2K (left) and *Planck* (right). The cosmological model, and the assumptions about instrument characteristics, are the same as in Figure 2.13. For *WMAP* and B2K, flat band powers are estimated with  $\Delta\ell = 150$  (with finer resolution on large scales for *WMAP* in the inset). For *Planck* we have used the same  $\ell$ -resolution as in Figure 2.13.





# Projected Tensor-to-Scalar Limits

## B-mode Detection with an Extended Planck Mission

G. Efstathiou<sup>†</sup> and S. Gratton

Kavli Institute for Cosmology Cambridge and Institute of Astronomy, Madingley Road, Cambridge, CB3 0HA.

**Abstract.** The *Planck* satellite has a nominal mission lifetime of 14 months allowing two complete surveys of the sky. Here we investigate the potential of an extended *Planck* mission of four sky surveys to constrain primordial *B*-mode anisotropies in the presence of dominant Galactic polarized foreground emission. An extended *Planck* mission is capable of powerful constraints on primordial *B*-modes at low multipoles, which cannot be probed by ground based or sub-orbital experiments. A tensor-scalar ratio of  $r = 0.05$  can be detected at a high significance level by an extended *Planck* mission and it should be possible to set a 95% upper limit of  $r \lesssim 0.03$  if the tensor-scalar ratio is vanishingly small. Furthermore, extending the *Planck* mission to four sky surveys offers better control of polarized Galactic dust emission, since the 217 GHz frequency band can be used as an effective dust template in addition to the 353 GHz channel.





# Schedule (unofficial)



<u>Date</u>	<u>Event</u>
2009-05-06	<b>Launch</b>
2009-06-27	<b>In orbit</b>
2009-08-14	Begin Routine Operations
2010-03-30	Sky covered ~once
2010-09-28	<b>ERCSC Delivered to DPCs</b>
2011-01-15	<b>ERCSC Made Public</b>
2010-08-14	Sky covered twice (1 year)
2011-03-30	Sky covered ~three times
2011-08-14	Sky covered four times (2 years)
2011-11-05	<b>HFI warms</b>
2012-08-13	<b>First-Year Data Release</b>
2013-08-13	<b>Second-Year Data Release</b>

Note that my dates might occasionally be off by about a week or so in some cases that have already occurred, and more in case of predictions...





# A First Planck Conference

THE MILLIMETER AND SUBMILLIMETER SKY  
IN THE PLANCK MISSION ERA

PARIS, FRANCE  
JANUARY 10-14 2011  
CITÉ DES SCIENCES



The Planck satellite has been operating with outstanding success since its launch on May 14<sup>th</sup> 2009. Reaching the ambitious goals of Planck in Cosmic Microwave Background (CMB) science will depend on the ability to remove all foregrounds (galactic and extragalactic) in intensity and polarization.

This conference will be aiming mostly at the physics and observations of the foregrounds and in particular of the lesser known polarized ones. The Planck flight performances will be presented and the implications of the cosmological goals for the CMB primary anisotropies in terms of the needed accuracy of the foreground removal will be reviewed.

#### SCIENCE ORGANIZATION

##### PLANCK SCIENCE TEAM

J.L. PUGET (CONFERENCE CHAIR, IAS, FRANCE)  
M. BERSANELLI (U DI MILANO, ITALY)  
F. BOUCHET (IAP, FRANCE)  
G. EFSTATHIOU (U OF CAMBRIDGE, UK)  
J.M. LAMARRE (OBS DE PARIS, FRANCE)  
C. LAWRENCE (JPL, USA)  
N. MANDOLESI (IASF-INAF BOLOGNA, ITALY)  
H.U. NORGGAARD NIELSEN (DNSI, DENMARK)  
J. TAUBER (PST CHAIR, ESTEC, THE NETHERLANDS)  
A. ZACCHEI (OSS DI TRIESTE, ITALY)

##### INTERNATIONAL ADVISORY COMMITTEE

N. AGHANIM (IAS, FRANCE)  
R. BOND (U OF TORONTO, CANADA)  
C. CESARSKY (CEA/DAPNIA-SAP, FRANCE)  
R. DAVIES (JODRELL BANK, UK)  
G. DE ZOTTI (INAF PADOVA, ITALY)  
J. DUNKLEY (U OF OXFORD, UK)  
E. FALGARONE (OBS DE PARIS, FRANCE)  
G. HELOU (CALTECH/IPAC, USA)  
S. MASI (U LA SAPIENZA, ROMA, ITALY)  
B. PARTRIDGE (HAVERFORD COLLEGE, UK)  
R. SUNYAEV (MPA GARCHING, GERMANY)  
L. TOFFOLATTI (U DE OVIEDO, SPAIN)

##### LOCAL ORGANIZING COMMITTEE

F. PAJOT (CHAIR, IAS, FRANCE)  
H. BLAVOT  
S. CAMINADE  
C. COUGRAND  
D. PRIVAL



[HTTP://WWW.PLANCK2011.FR](http://www.planck2011.fr)





# Planck Continues as WMAP Retires

NASA - NASA's WMAP Project Completes Satellite Operations - SeaMonkey

File Edit View Go Bookmarks Tools Window Help

Back Forward Reload Stop <http://www.nasa.gov/topics/universe/features/wmap-complete.html> Search Print

HOME NEWS MISSIONS MULTIMEDIA CONNECT ABOUT NASA

> Log In To MyNASA | > Sign Up

NASA Home > News & Features > News Topics > Universe > Features

Send Print Share

## News & Features

### News Topics

- Shuttle & Station
- Moon & Mars
- Solar System
- Universe**
- Aeronautics
- Earth
- Technology
- NASA in Your Life
- NASA People
- NASA History

### News Releases

### Media Resources

## Feature

Text Size + -

Tweet 36 Like 137 ★★★★★ ?

### NASA's WMAP Project Completes Satellite Operations

10.06.10

After nine years of scanning the sky, the Wilkinson Microwave Anisotropy Probe (WMAP) space mission has concluded its observations of the cosmic microwave background, the oldest light in the universe. The spacecraft has not only given scientists their best look at this remnant glow, but also established the scientific model that describes the history and structure of the universe.

"WMAP has opened a window into the earliest universe that we could scarcely imagine a generation ago," said Gary Hinshaw, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Md., who manages the mission. "The team is still busy analyzing the complete nine-year set of data, which the scientific community eagerly awaits."

> View larger image

This image is the detailed, all-sky picture of the infant universe created from seven





# Thank You!

