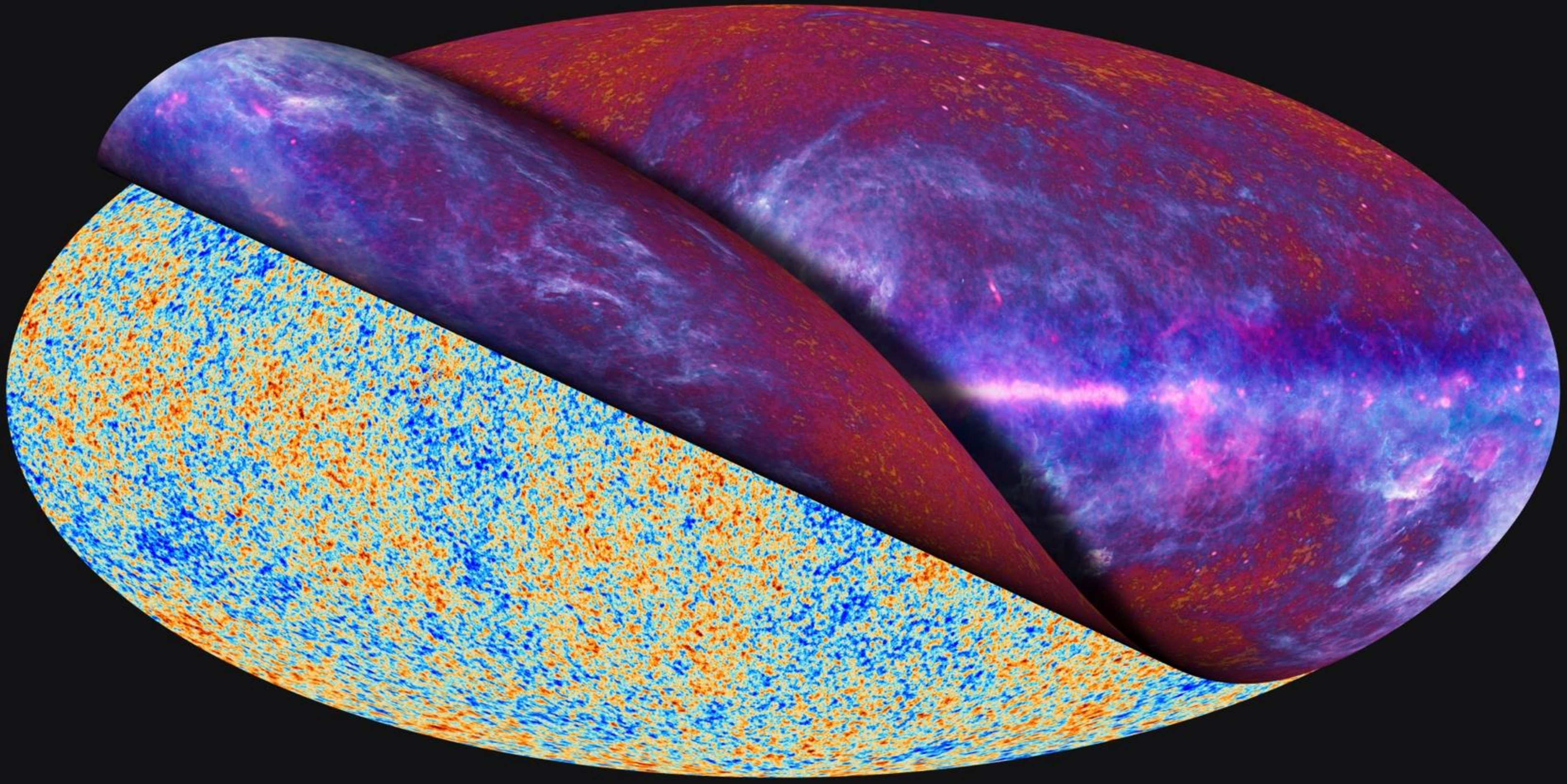
planck [redacted]



Planck unveils the Cosmic Microwave Background

planck

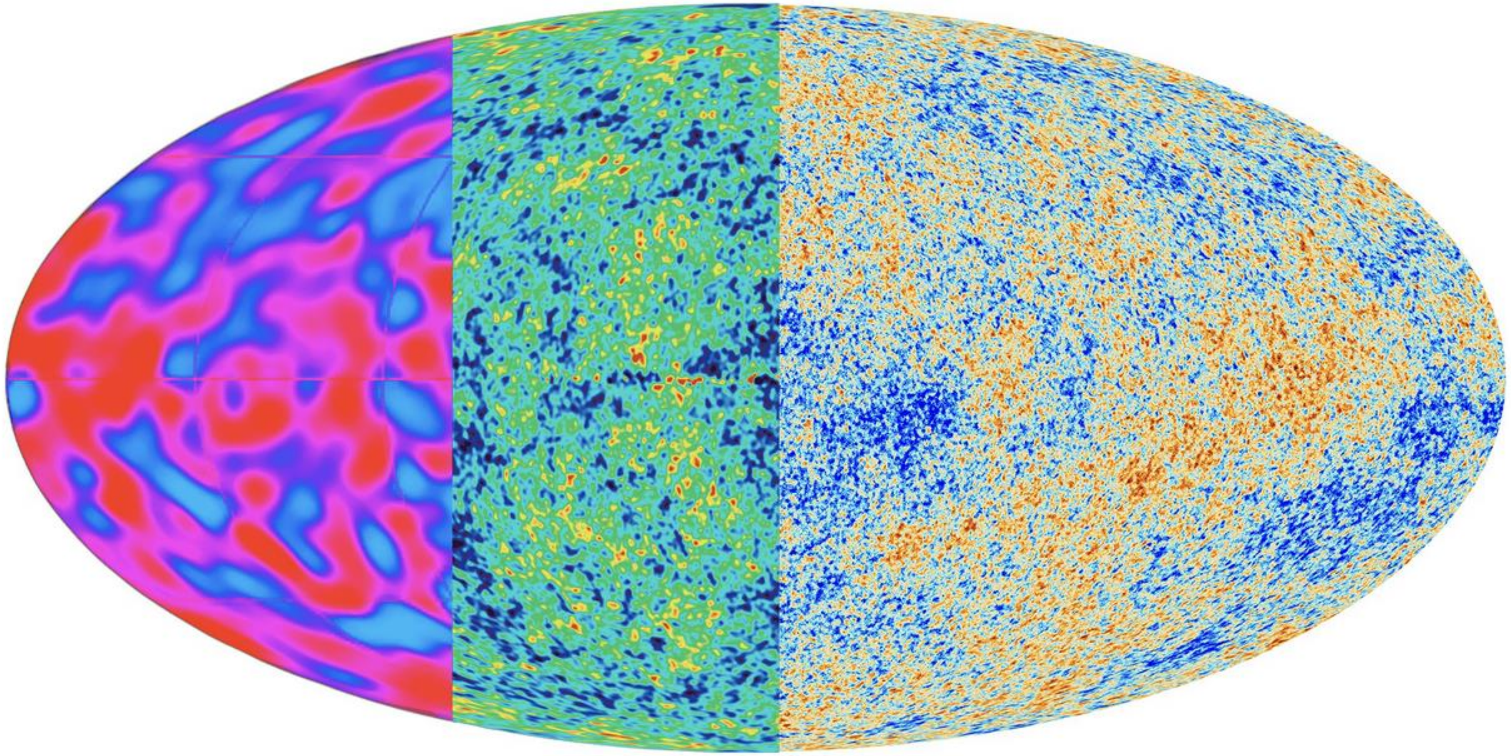
International Conference

CMB@60

Accademia delle Scienze di Torino
28-30 May 2025

Lessons Learned from Planck

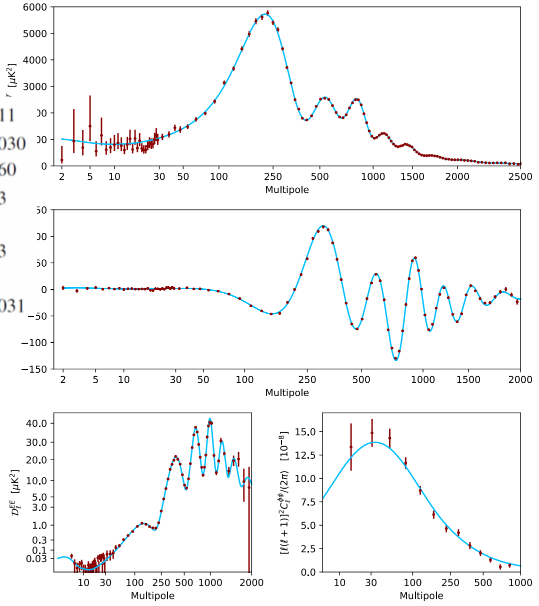
Jan Tauber
Leiden Observatory



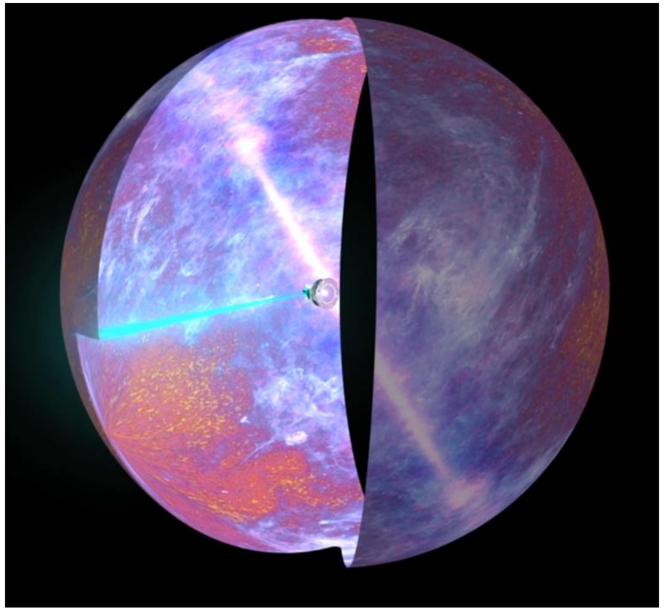
Planck - overview

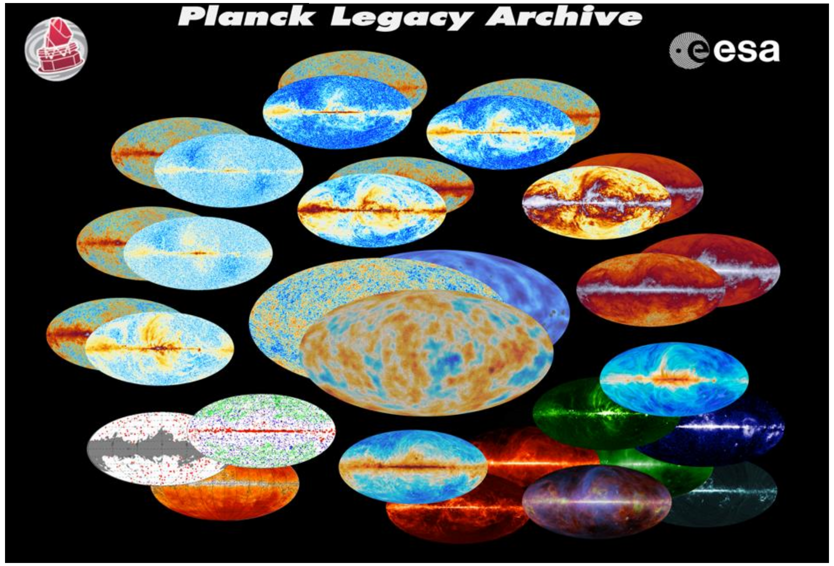
- First proposals – COBRAS & SAMBA – in 1993
- Start of Planck in 1996
- Launch in May 2009
- Operations Aug 2009- Oct 2013
- First data release March 2013
- Second data release Feb – July 2015
- ***Legacy*** data release: 2018-2020

$\Omega_m h^2$	0.1430 ± 0.0011
$\Omega_m h^3$	0.09633 ± 0.00030
σ_8	0.8111 ± 0.0060
$\sigma_8(\Omega_m/0.3)^{0.5}$ . . .	0.832 ± 0.013
z_{re}	7.67 ± 0.73
Age[Gyr]	13.797 ± 0.023
r_*[Mpc]	144.43 ± 0.26
$100\theta_*$	1.04110 ± 0.00031

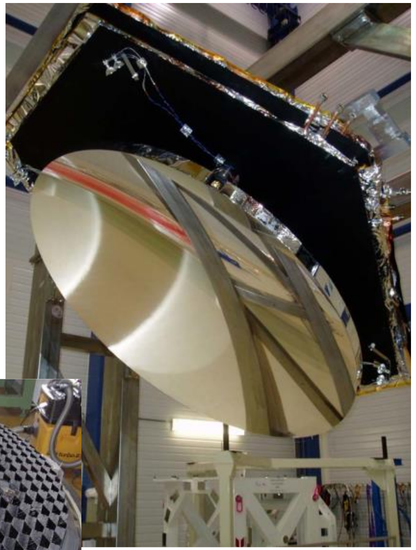


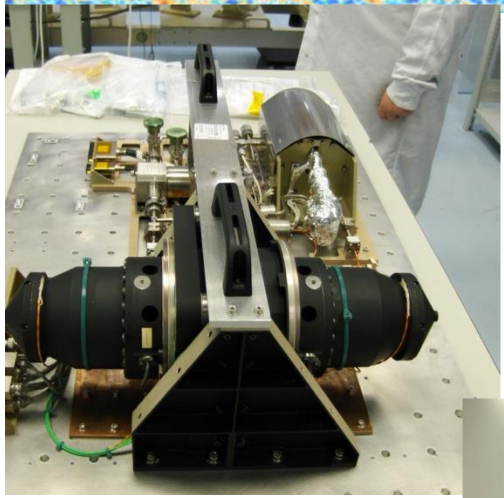
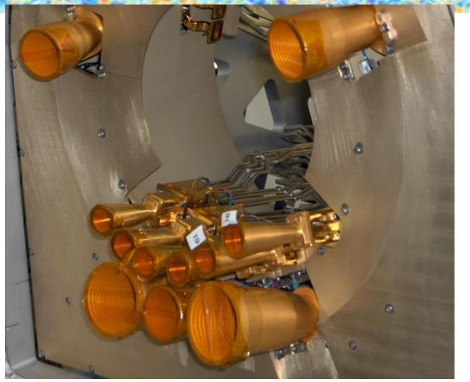
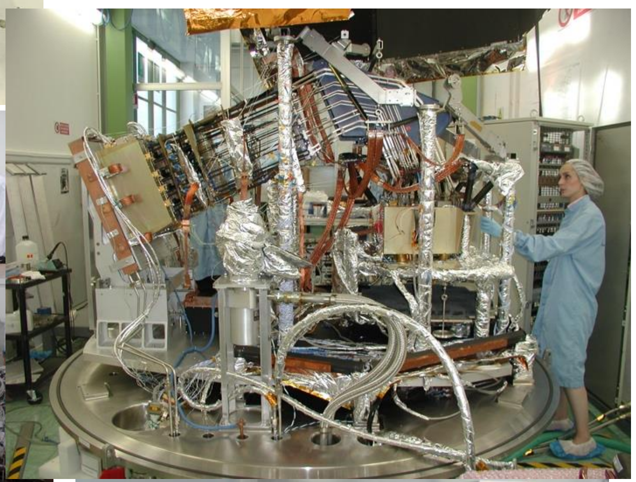
ISSI Gamechanger series, 26 Nov 2020

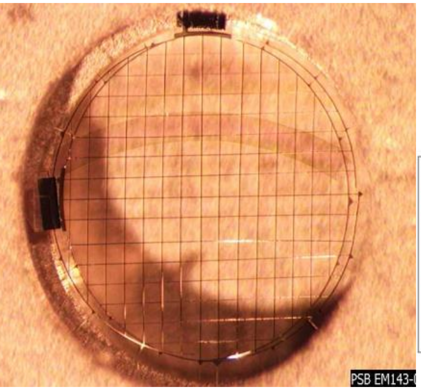
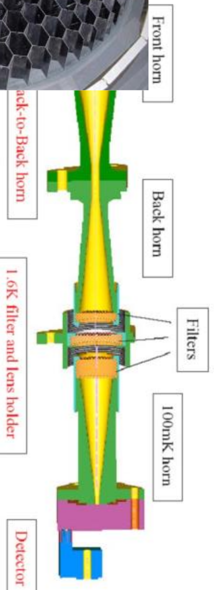


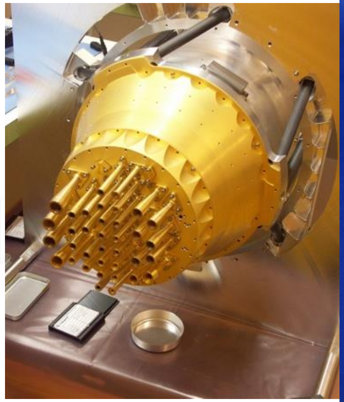


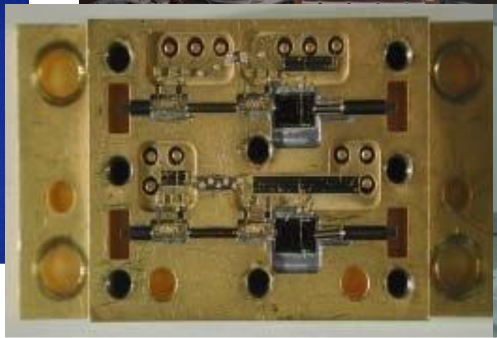
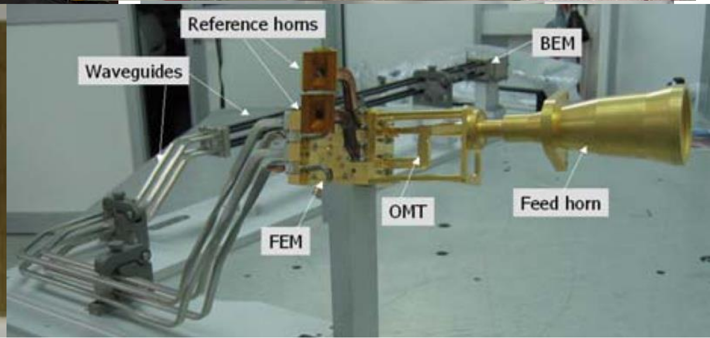
Planck payload: 1990's technology



Lessons learned from a space mission ?

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https://www.cosmos.esa.int/web/planck/lessons-learned

- Payload: *1990's technology*
  - Cryogenic Focal plane <100 detectors
  - Cryogenic CFRP telescope
  - Bespoke 4-stage cooling system
- Operations
- Data processing
- Scientific analysis
- Management approach

Particularities of space science:

- High risk aversion
- Very long timeline
- Intricate relations between funding agencies, industry, and science
- Very large international scientific collaboration
- …

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European Space Research
and Technology Centre
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands
www.esa.int/Planck

DOCUMENT

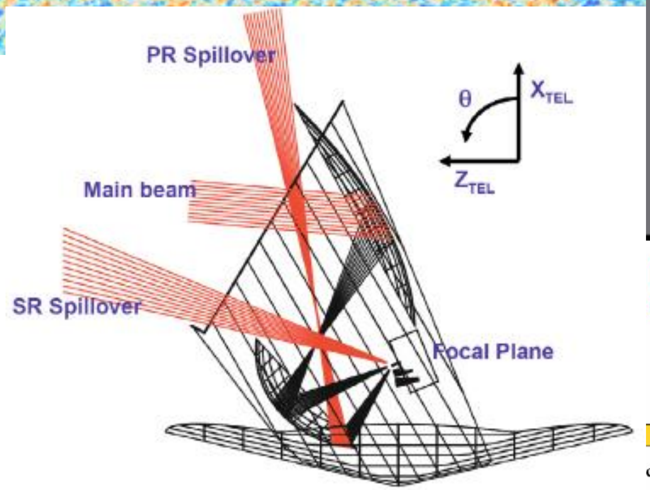
Planck Lessons Learned

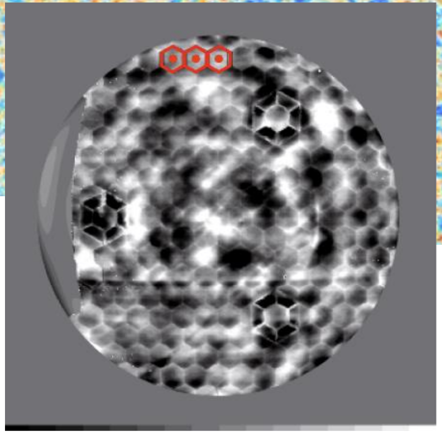
2017

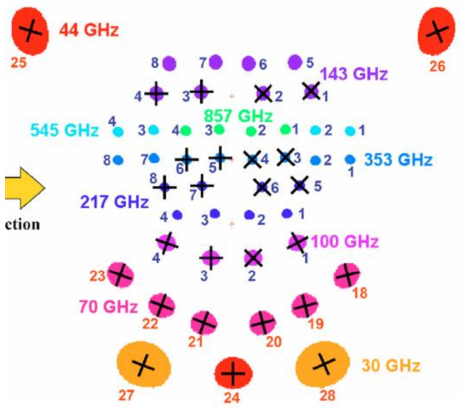
Prepared by	Jan Tauber
Reference	SCI-S/2016.236/jt
Issue	2.0
Revision	
Date of Issue	21-08-2017

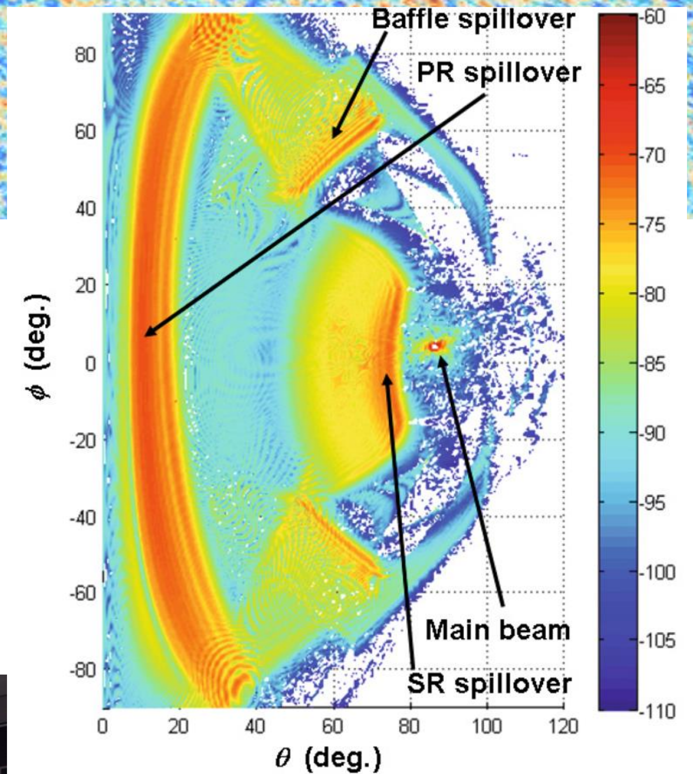
European Space Agency
Agence spatiale européenne

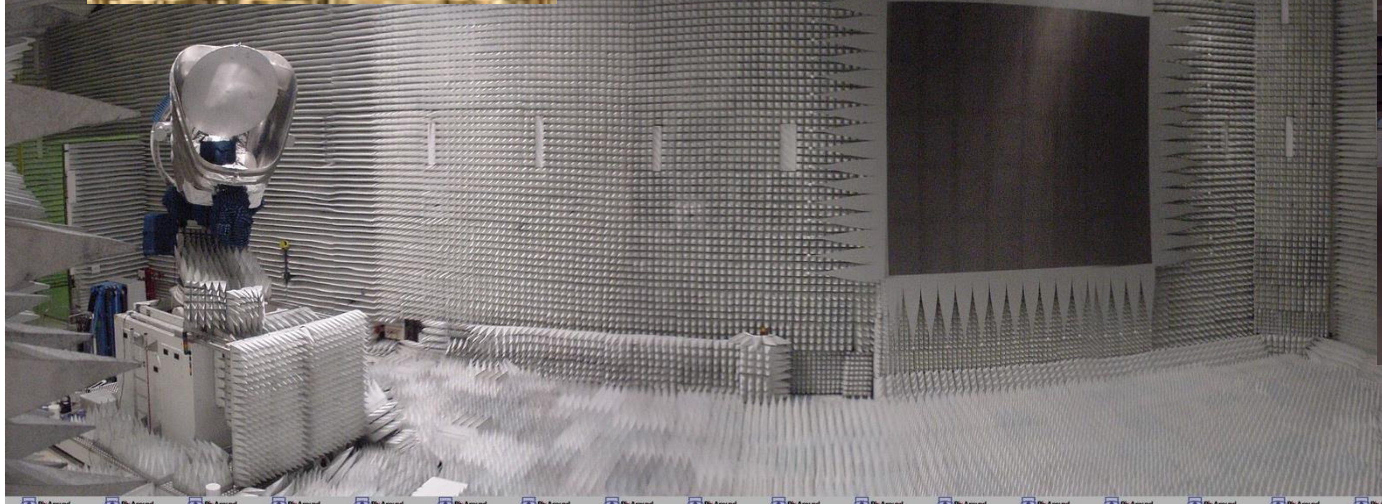
Optics


PR Spillover
Main beam
SR Spillover
Focal Plane
θ
X_{TEL}
Z_{TEL}

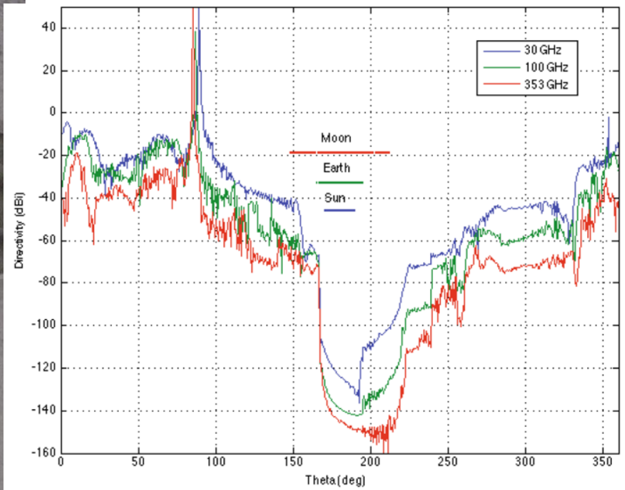



44 GHz
25
26
143 GHz
857 GHz
545 GHz
353 GHz
217 GHz
100 GHz
70 GHz
30 GHz
23
18
22
21
20
19
27
24
28


Baffle spillover
PR spillover
Main beam
SR spillover
ϕ (deg.)
θ (deg.)




esa
Contraves Space


30 GHz
100 GHz
353 GHz
Moon
Earth
Sun
Directivity (dBi)
Theta (deg)

Optics Lessons Learned

- Extremely challenging requirements, performance, knowledge
    - Different quality metrics: engineering – data processing – science analysis
- Demonstrate performance
    - Modelling
        - Language (radio/ir/optical; science/eng)
        - Coordinate systems - polarization
        - Including all elements in the optical chain
        - Tools require engineering expertise (GRASP, Code V, ASAP, Zemax, …)
        - Computing power: never enough
            - Extrapolation
            - How much is really needed ?
        - Assessing uncertainties
    - Ground measurement
        - reproducing the flight situation (cryogenic testing) impossible
    - Combining modelling with ground testing data: requires engineering/physics understanding
- Understand the uncertainties towards the actual in-flight performance
    - Estimation uncertainties
    - Operational aspects, e.g. scanning, pointing

Optics Lessons Learned

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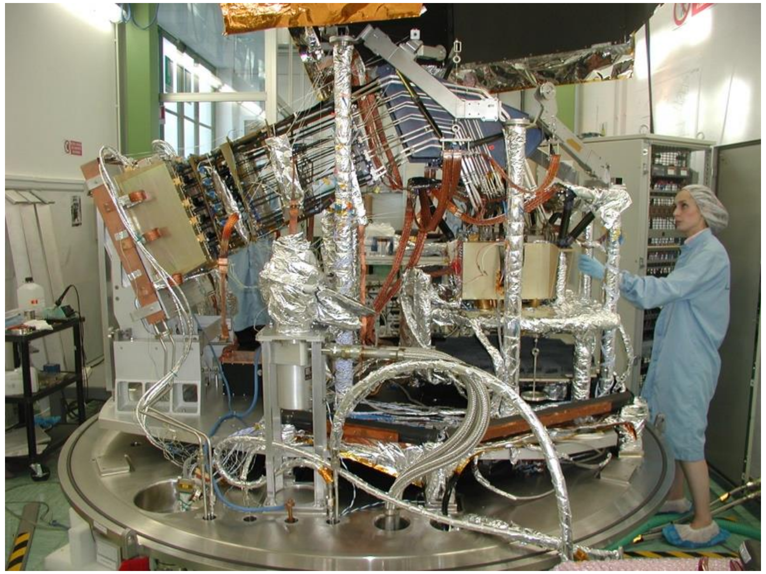
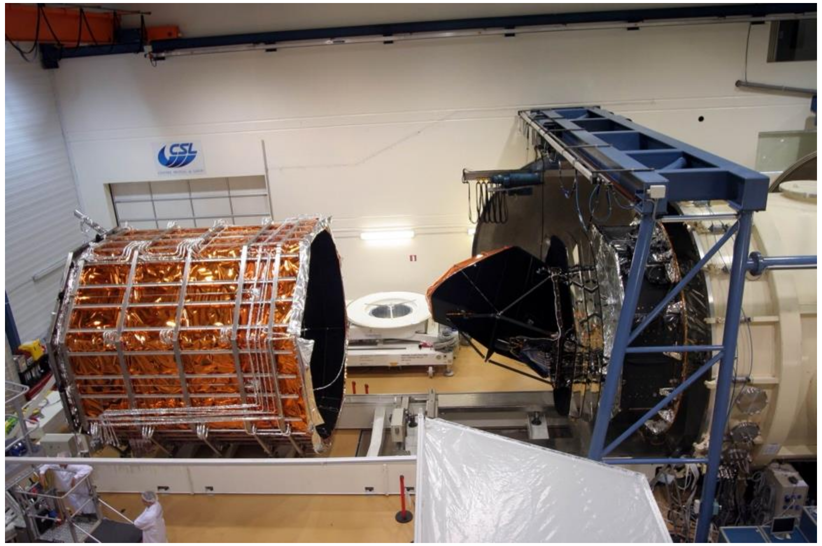
- Flight performance **estimation** will result from a combination of modelling and ground testing
    - A single team to oversee this system-level effort from Day 1
- Develop the means to **measure** the performance ***in flight*** and **use** this knowledge in the data processing and scientific analysis
    - Dedicated measurements are likely needed

Operations





- Autonomous ops
- Initially planned for two all-sky surveys
- Goal: maintain instrument stability

Operations Lessons Learned

- Operations start long before launch
    - "smooth transition between phases"
    - Ground testing teams transition to flight operations teams
    - Tools, procedures, and data transition from Ground to Space systems
- Survey ops = simple ops ?
    - Decentralized teams means lots of interfaces
        - Formal vs informal interfaces (file vs human)
    - Performance verification in space can be quite complex
        - Payload and satellite intricately intertwined
    - Contingency planning can be a system driver
        - simpler to plan for longer ops ?
    - Survey ops *not necessarily simple* ops !

Operations Lessons Learned

- Ground testing is **key** preparation for flight operations
  - Spend as long as possible on system-level ground ops
  - Ensure the ground testing tools and teams transition "smoothly" into flight ops
- **Formal interfaces** are often cumbersome but **important**
- the **human** interfaces have to work well
- Plan well in advance for **all** kinds of operations (perfo verif, contingency,…)

Information management

- Where many entities and teams are involved, information has to be closely managed
    - Formal systems are needed to record status and uncover problems: meetings, reporting, reviewing, etc – based on *documents*
    - Informal systems are used for short-time-scale exchange of info: human, meetings, email, wiki, etc
- A good balance has to be found to ensure no useful information is lost
- A system to manage documentation must be implemented which allows information to be found !
    - Widely accepted and used
    - Widely available - secrecy must be minimal

Data management

- Useful data is being generated long before operations begin
- It must remain available throughout the life of the mission
    - A common Archive should be developed which is used by all parties from an early time
- "Understanding the data" is fundamental to doing good science
    - Scientific analysis is an integral part of understanding
- (Internal & External) Science data products must be well defined, documented and produced on a clear schedule known to all parties
    - As data processing advances, the data processing cycle becomes very long
    - Detailed documentation of all iterations is needed

Information and Data management Lessons Learned

- Information and Data exchanges, storage, and distribution must be **actively** managed from an early time
    - This requires **significant** dedicated effort

People management

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- This is the hardest problem of all !
- Experiments like Planck are made up of a huge number of semi-independent teams of people with widely varying objectives, expertises, timelines, obligations, needs, wishes, and expectations
- Some kind of hierarchy of decision making is needed to manage this
    - Usually this is determined by top-level formal relationships ("contractual" & financial obligations)
    - Must be streamlined yet effective
- Success in people management is critical to mission success
    - Obligation to cater to the needs of young scientists
- As for Info & Data management, People management requires **a lot of dedicated effort**

Recognition of Individuals in Large Collaborations

Summary Report

12-05-2022

APPEC-ECFA-NuPECC (JENAS) working group

Djamel Boumediene, Emmanuel Gangler, Nasser Kalantar, Karl-Heinz Kampert, Bogna Kubik, Marcel Merk, Gerda Neyens, Eberhard Widmann

Astroparticle Physics European Consortium https://www.appec.org

Thank you