Planck Lessons learned
Memories Issues Gratification

International Conference

CMB@60

Accademia delle Scienze di Torino
28-30 May 2025

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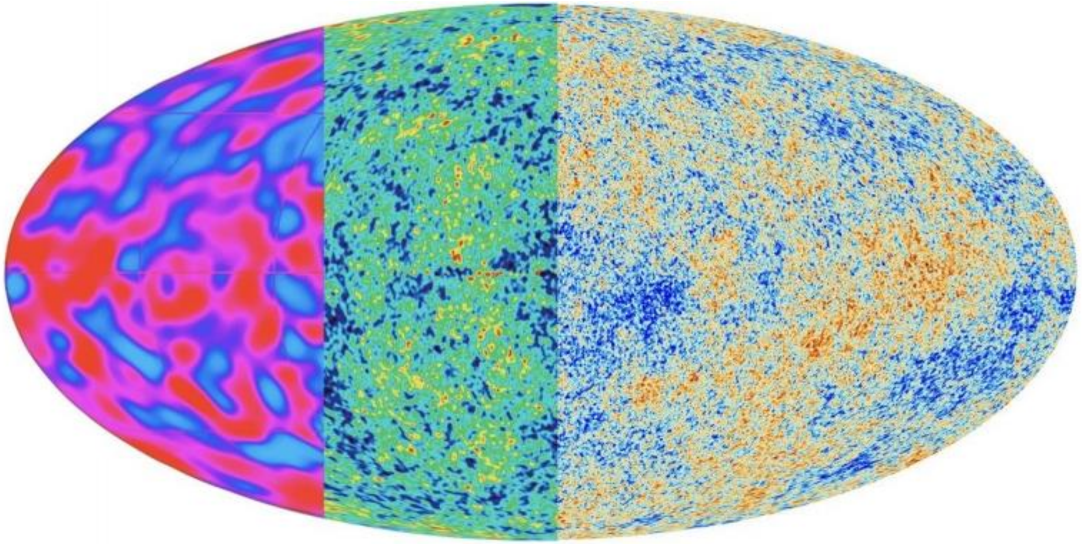


Personal memories not to forget

- Early '70s: First Approach to CMB
- Late ’70s: Early experiments dreaming reasonable $\delta T/T$
- ‘70s - ‘80s: CMB Spectrum -> Best T before COBE FIRAS

1992: Preparation to COBRAS proposal

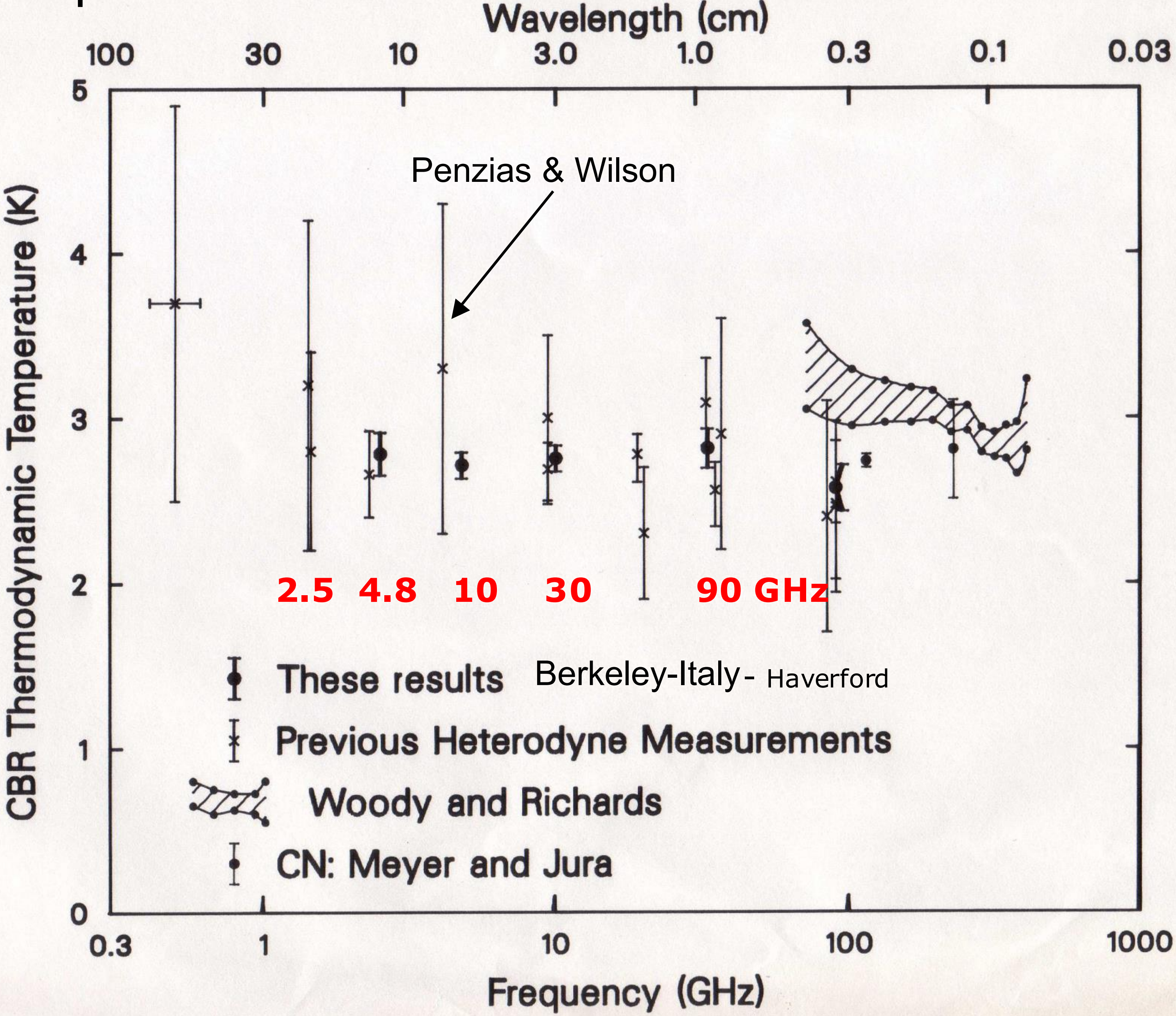
CMB @ Berkeley

- **Joe Silk - theory - 1967, start @ UCB in 1970**
- **Paul Richards took on graduate students John Mather & Dave Woody - beginning 1974**
  - Develops bolometers and Michelson Interferometer
  - precursor for COBE FIRAS
- **Anisotropy & Polarization - beginning 1974** —Ground-based, aircraft, balloons, and spacecraft
- **Berkeley-Italy spectrum collaboration joined by Haverford College - 1977**
  - Long Wavelength coherent receiver observations
  - Develop reference loads
- **Competition - with head start**
  - Rainer Weiss & Dirk Muehlner @ MIT
  - Dave Wilkinson @ Princeton - theory & motivation Jim Peebles

Spectrum : Collaboration at White Mtn.

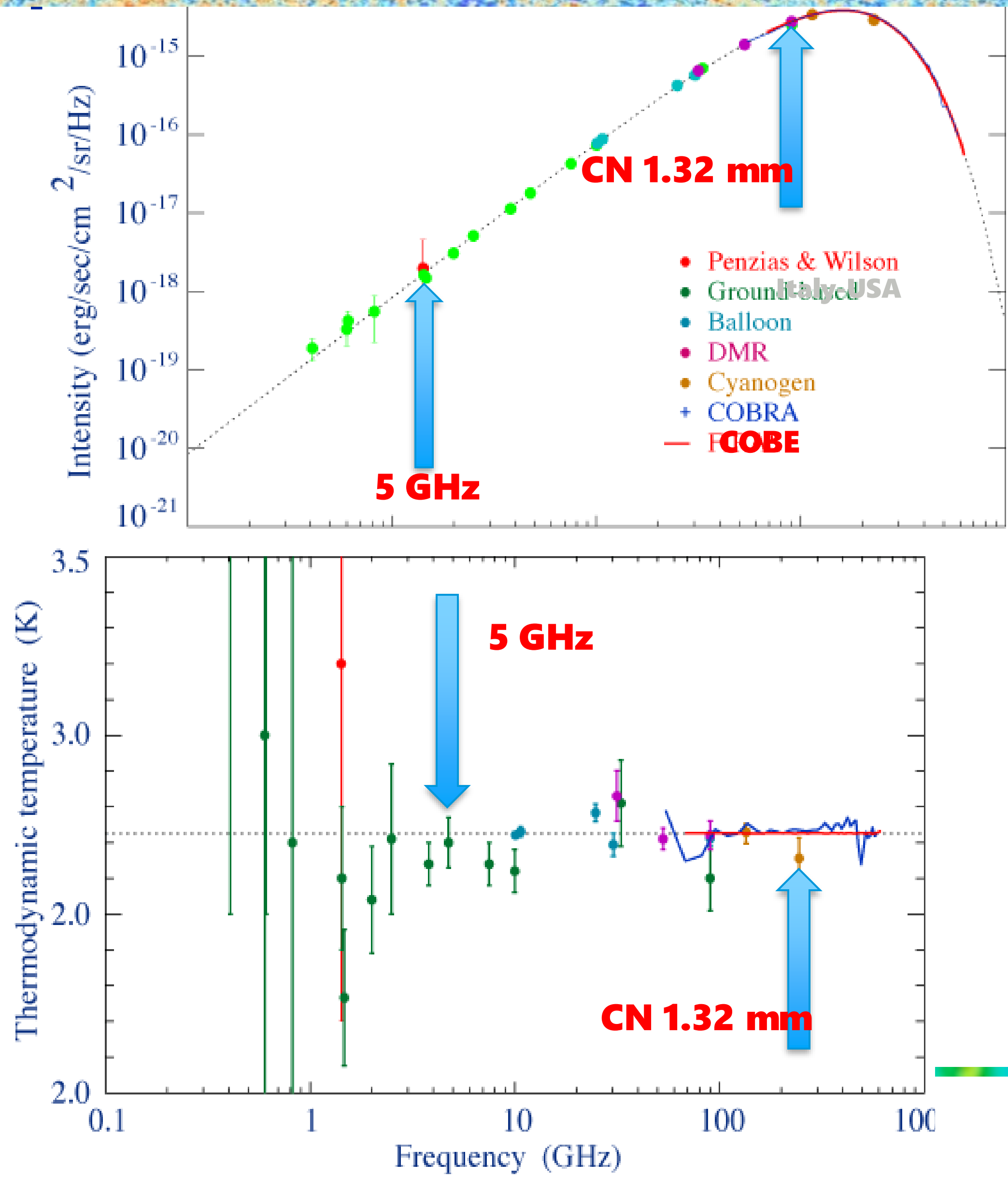
Berkeley – Italy – Haverford Team

CMB Spectrum ca 1984



- EX LABORE FRUCTUS -

Bologna White Mountain & CN results

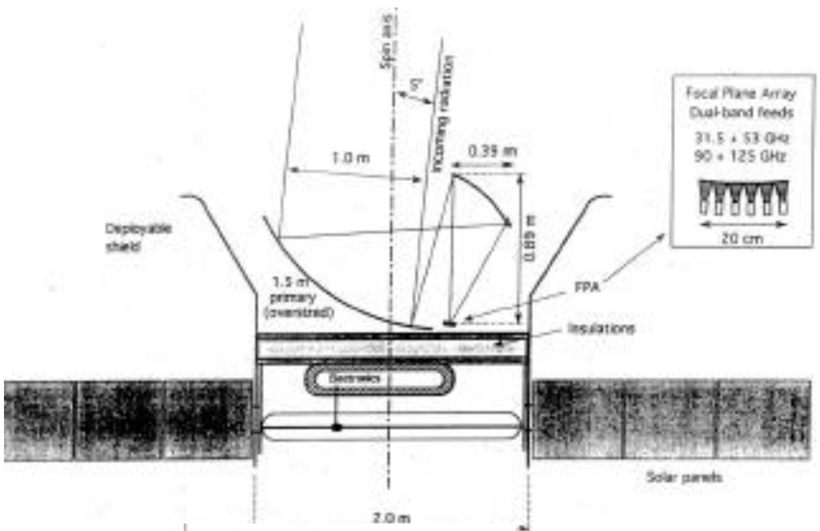


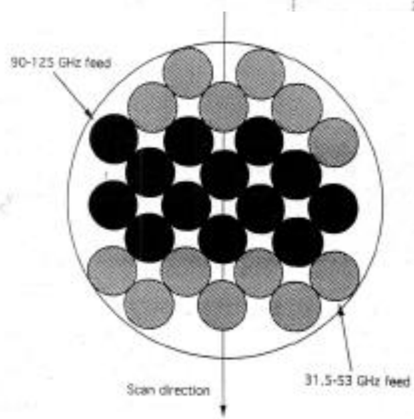
Then COBRAS-SAMBA and Planck

A proposal submitted in response to ESA M3 Call for Mission Ideas (May 1993)

COBRAS

COsmic Background Radiation Anisotropy Satellite



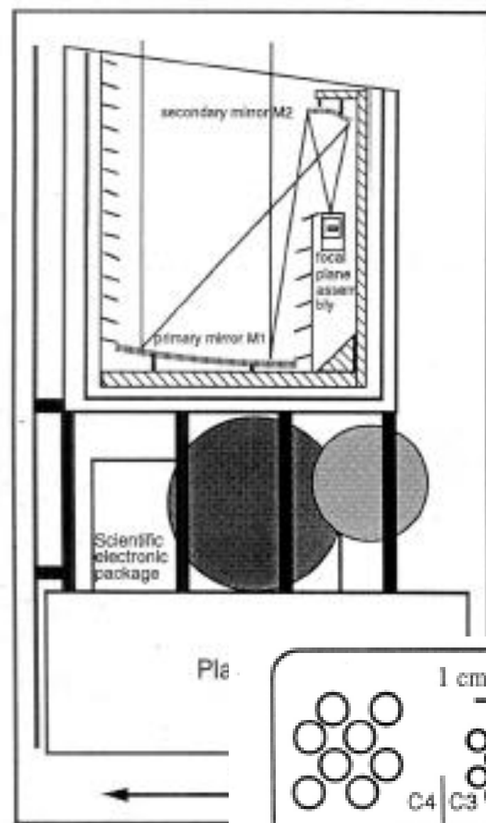


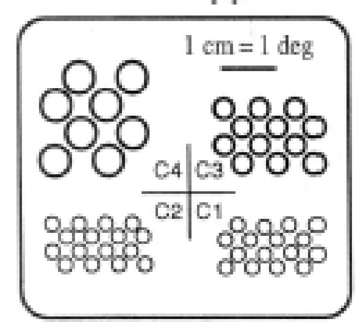
ian optical system assumed in our
set from the spin axis (here assumed
the details of the scan strategy. The
lelobe pickup and cooling efficiency.
feeds. Placing their apertures on a

Figure 7 - The proposed geometrical disposition of the feed elements in the focal plane array is shown. The higher frequency elements (90–125 GHz) are more sensitive to beam distortion effects and have been clustered near the center of the array. Our preliminary study shows that coma lobes of the most de-centered elements are expected to be below -40 dB (10^{-4}) at 125 GHz and below -55 dB ($10^{-5.5}$) at 30 GHz.

SAMBA

Satellite for Measurements of Background Anisotropies





Planck: Success Story

“high risk - world class science” mission

- Instrumentation not off the shelf
- the data processing had to be fine tuned during the overall mission and data analysis lifetime

But ……..

the H/W, the S/W and….

the science objectives have been highly successful

Lessons Learned

Many areas of Lessons Learned

- Management (development, operations, science)
- Technical (satellite, payload)
- Operational (satellite, instruments)
- Data processing
- Documentation

Management 1/2

1. Managing Structure too complex: ESA project team, instrument development teams, ESA-led industry and Consortia led industry….
2. PI-PM meetings and Science Team: the right answer? And the day-to-day activities management?
3. Dedicated Working Groups: OK
4. Lack of continuity in PM
5. Funding: Problematic, no certainties of funding during the full mission - PI-PM-ESA-Funding agencies useful but not enough.
6. Support from national Agencies: controversial/not ideal

Management 2/2

7. Schedule: too many sleeps – longest launch delay among ESA missions
8. Instrument organizations (based on academics/postdocs) with ESA/industrial professionals): Messy
9. Academic/Research personnel would have needed to be trained in evaluating/managing costs/risks/schedule/changes
10. Consortia with hundreds of Institutes, each with different funding, manpower, schedule problems
11. Inflation of meetings/telecons/bottle neck of key people
12. Communication and Information: not ideal
13. Documentation: huge number of documents -> all necessary ?
14. Lack of first author in papers – damage carriers of young people

Technical Challenges

- **The thermal design**
  - Passive cooling + three levels of active coolers
  - Cooling chain: 4 K cooler non redundant, sorption cooler technology not tested sufficiently in space, V-grooves not easily accepted by industry (under ESA contract)
  - Testing on the ground of in-flight conditions

- **The optical design**
  - A large and demanding telescope
  - Extreme control of straylight
  - Highly accurate prediction of performance – requiring very demanding on-ground measurements

- **The instruments**
  - High performance (sensitivity, stability)
  - Difficult test environment

Technical Challenges: Risks

- Planck was a risky mission with, not only, several single-point failures
- A risk assessment with Planck's level of risks would not be ready to fly today
- The success of Planck is certainly attributed to the technical excellence of all the teams involved in the development but…..

some luck helped

Planck was conceived as a “simple” survey satellite

The most important drivers turned out (unexpectedly) to be:

- Long and complex Commissioning and PV ops
- Contingency operations

This required more manpower and a different setup than initially planned

Data processing challenges

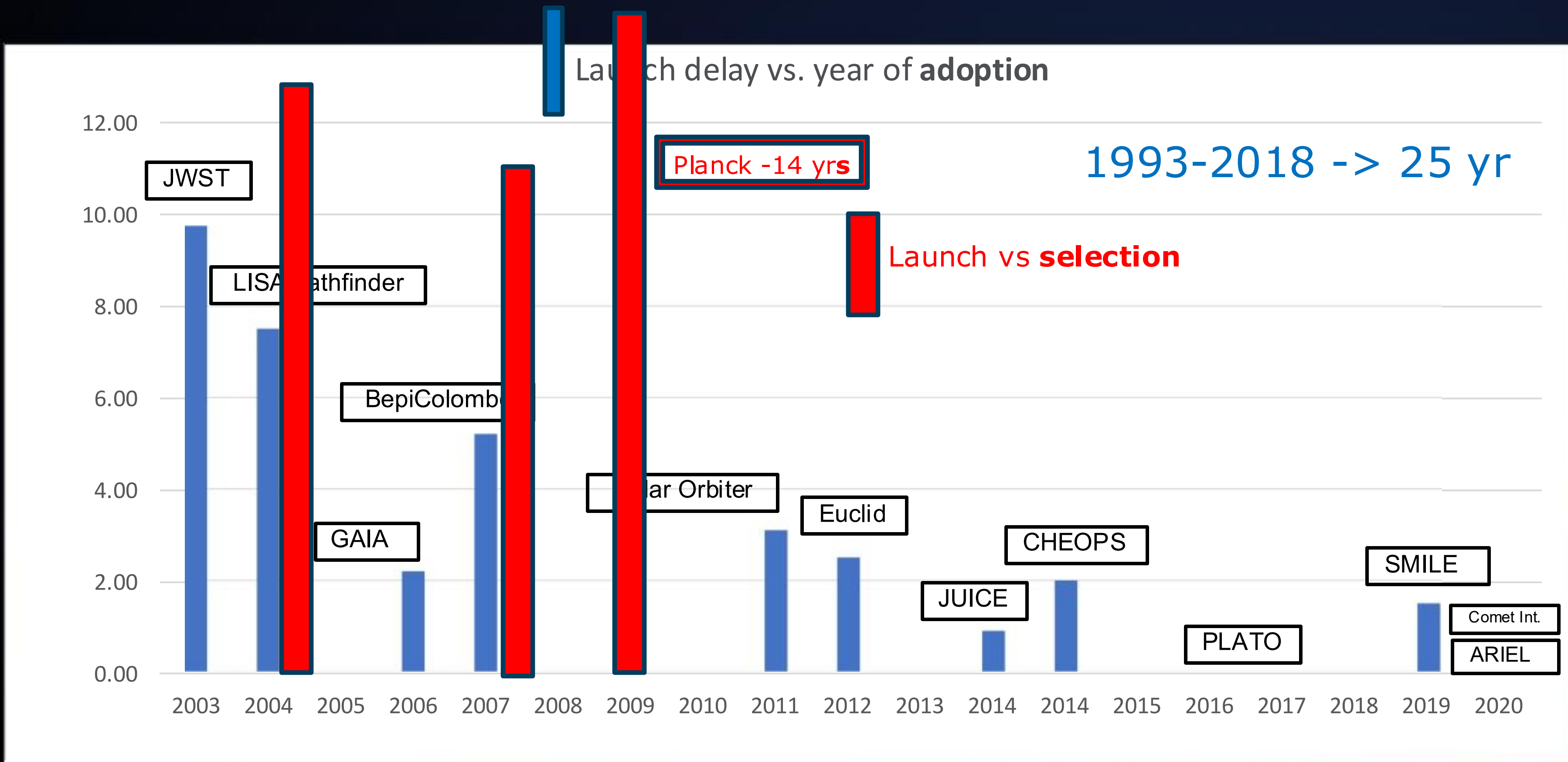
Understanding and control of systematic effects from many different sources was a great effort. It involved data processing at many different levels in a manual and iterative process with deep understanding of instruments It also means a lot of parallel streams of work

Removing the first level of systematics (when single effects dominate) is relatively straightforward – at the second and third levels, when several effects compete it becomes very difficult… Improvements in knowledge are exponential – not linear.

A huge amount of computing effort and a significant organization and management was required (difficult task within the non-hierarchical scientific community)

Comparison of Launch Delays

Science Project Performance



Beginning

End

Planck is a great success !

And we hope that we can learn from it and build even better experiments in the future…

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.


Thank you