Planck Thermal Control System.

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April 12, 2024

Heat transfer and thermal control

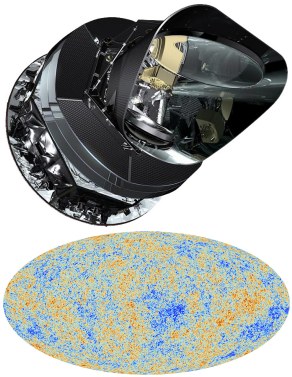
MUSE IDR-UPM-ETSIAE

Outline

Introduction

What is Planck?

- Planck is the third generation space mission to measure the anisotropy of the cosmic microwave background (CMB).
- It orbits the second Lagrange point (L2)
- It observes the sky in nine frequency bands covering from 27GHz to 1THz.
- It has two main instruments:
  1. The Low Frequency Instrument (LFI).
  2. The High Frequency Instrument (HFI).



Mission requirements and constrains

Thermal requirements

Operating temperatures of the main equipments.

Instrument	Solar Panel	SVM	LFI	HFI
T [K]	385	275	20	0.1

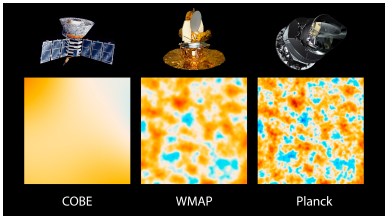
- HFI environment temperature ¡ 2K.
- LFI environment temperature ¡ 60K.
- 0.5 W heatlift in the LFI.

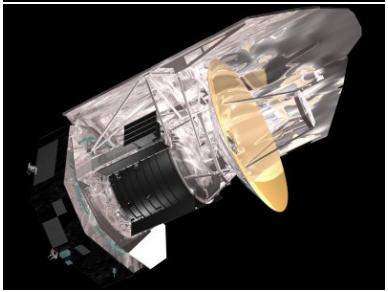
Other requirements

- No deployables.
- No optical elements such as windows with warm edges between the feed horns and telescope
- 1.5 yr minimum total lifetime.
- A spinning spacecraft.

Precedents

Background



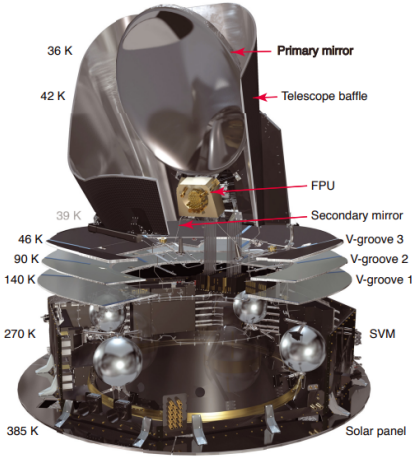


- COBE ($T = 2.725$K): used a 650 l He cryostat to cool the IR spectro-photometer to 2 K .
- WMAP ($T = 90$K): used passive cooling. A lot simpler, but unable to reach sub-Kelvin operating temperatures.
- Herschel ($T = 1.65$K): used 2 He cryostats of 2300 l each to cool the HIFI.

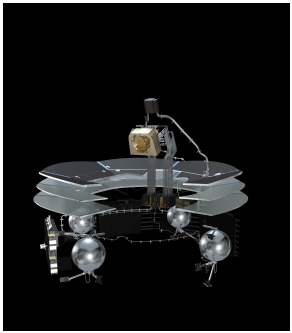
Thermal control instruments

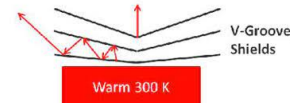
Thermal control instruments

1. Passive Elements
   - Telescopic Baffle: provided radiative shield.
   - 3 V-groove radiators.
2. Active Elements
   - Hydrogen sorption cooler.
   - Helium Joule Thompson expansion cooler.
   - He-He dilution cooler.



Passive elements

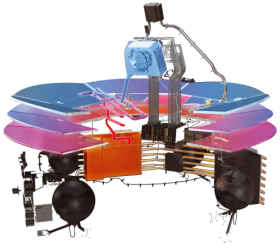




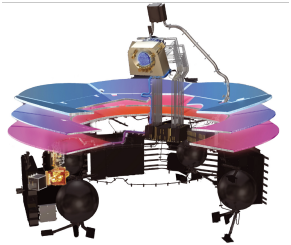
- Telescopic Baffle: provided radiative shield.
- 3 V-groove radiators: provided thermal isolation and radiative cooling

Allows to reach the precooling temperature $\leq$ 60K.

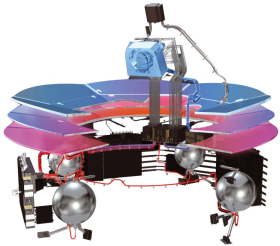
Active elements



H-Sorption cooler

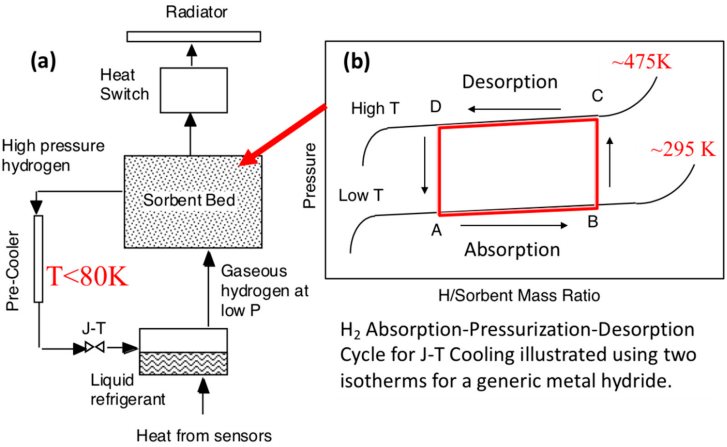


He-JT Expansion cooler



He-He dilution cooler

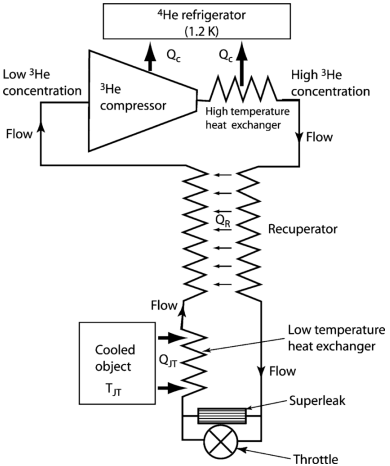
Active elements: H-Sorption Cooler



H_2 Absorption-Pressurization-Desorption Cycle for J-T Cooling illustrated using two isotherms for a generic metal hydride.

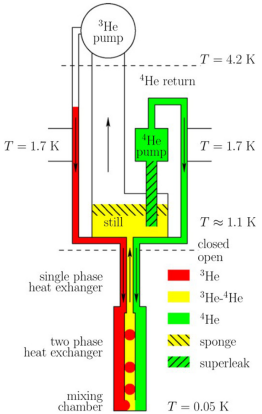
Functioning of an sorption cooler

Active elements: He-JT cooler



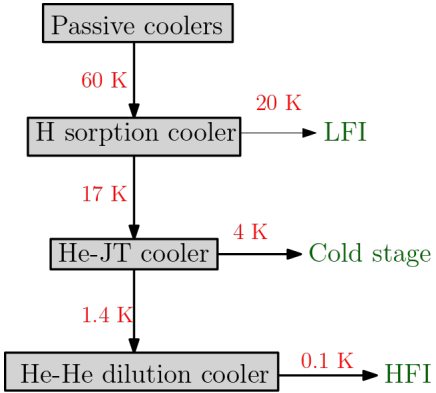
- JT He cooler works by expanding helium gas through a small orifice, resulting in a temperature drop.
- Cold He recirculates through a heat exchanger to cool down a target object.
- He is compressed back to its original pressure to start the cooling cycle again.

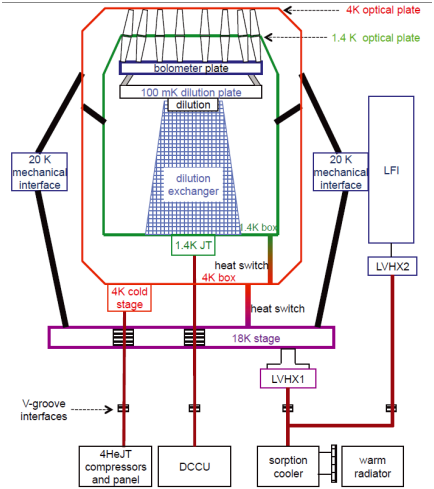
Active elements: He-He Dilution cooler



- Cooling medium is a mixture of Helium-3 and Helium-4 gradually cooled down to temperatures approaching 0 K.
- Uses the superfluid helium-4 to carrying heat away from the target object, as it flows without any resistance.
- Can achieve extremely low temperatures, down to a few millikelvin.

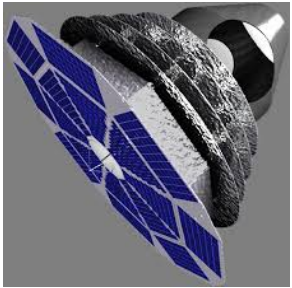
Complete system



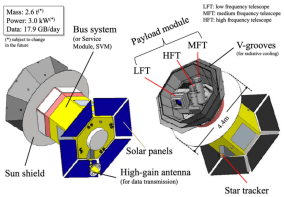


Future missions

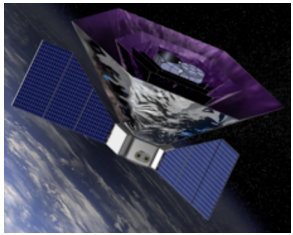
Active Elements



COrE+
Cosmic Origins Explorer, ESA



LiteBird
Primordial B modes mission, JAXA



Pixie Absolute Spectrophotometer, NASA

References

References

- López-Caraballo, C. H., Suárez, et al. (2011). On the stability and performance of the Planck satellite's radiometers. Astronomy & Astrophysics, 536, A12. doi: 10.1051/0004-6361/201116486.
- Leroy, C., Arondel, A., Bernard, J., ..., & Planck-HFI Instrument Team. (2011). Performances of the Planck-HFI cryogenic thermal control system. Astronomy & Astrophysics, 536, A22. doi: 10.1051/0004-6361/201116486
- Bhandari, P., Moore, B., Bolton, D., & Aboobaker, A. (n.d.). Design and Analysis of V-Groove Passive Cryogenic Radiators for Space-borne Telescopes & Instruments. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109.
- Ranajoy Banerji. Optimisation of a 4th generation CMB space mission. Cosmology and Extra-Galactic Astrophysics. Université Paris Diderot .

Thank you for attending

Questions?