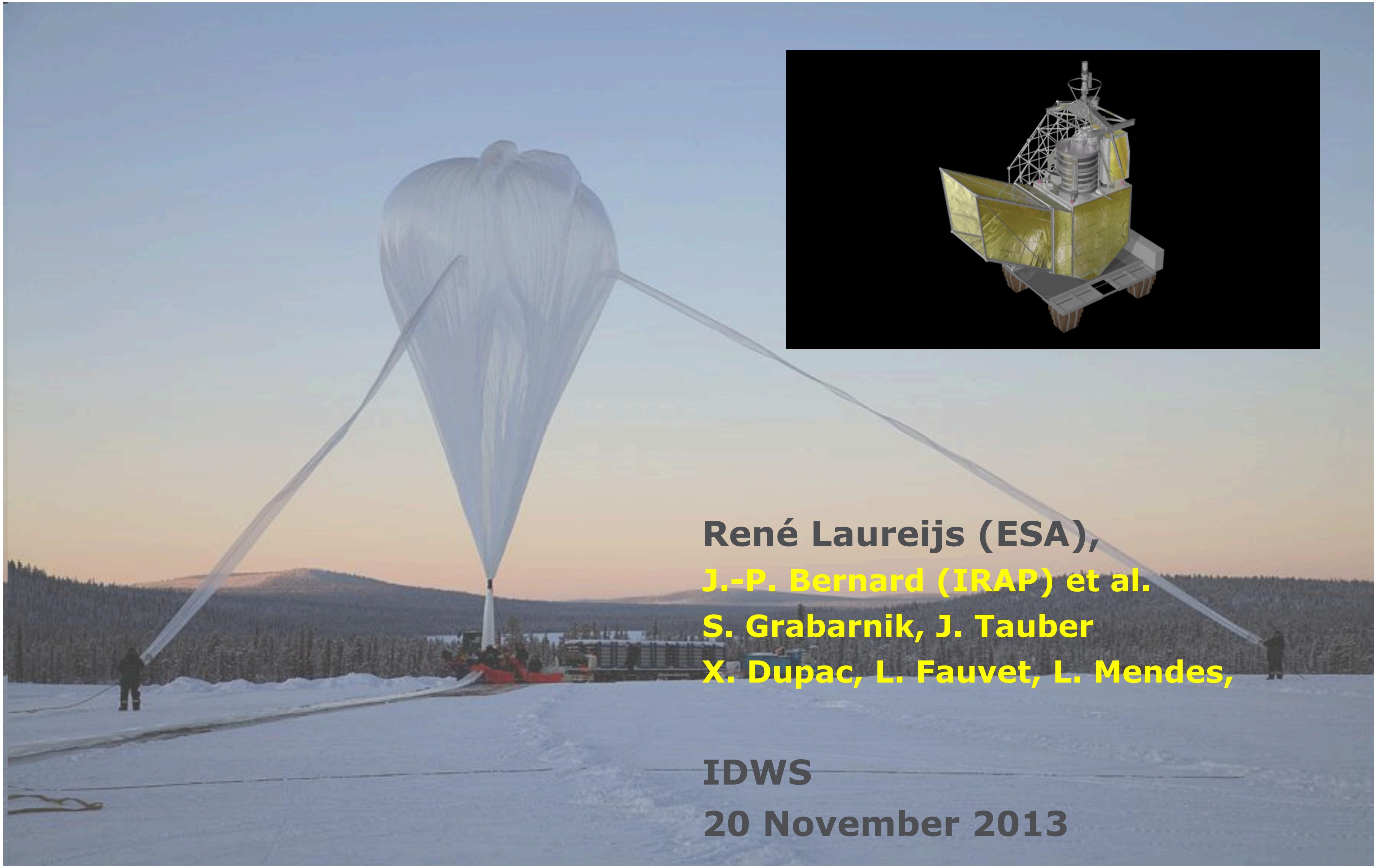
Status of the FIR polarisation mapping experiment PILOT



René Laureijs (ESA),
J.-P. Bernard (IRAP) et al.
S. Grabarnik, J. Tauber
X. Dupac, L. Fauvet, L. Mendes,

IDWS
20 November 2013

Context

PILOT: ***P**olarised **I**nstrument for **L**ong wavelengh **O**bservation of the **T**enuous interstellar medium*

Faculty supported project

- Initially: support design of the cryogenic part of the payload
- Present: analyse/design the PILOT baffling system, based on straylight analysis methods

Actors:

- ✓ **CNES:** Project Team
- ✓ **PI:** J.-P. Bernhard (IRAP, Toulouse)
- ✓ **Co-Is**: IAS Orsay CEA Saclay, Rome, Cardiff, ESA

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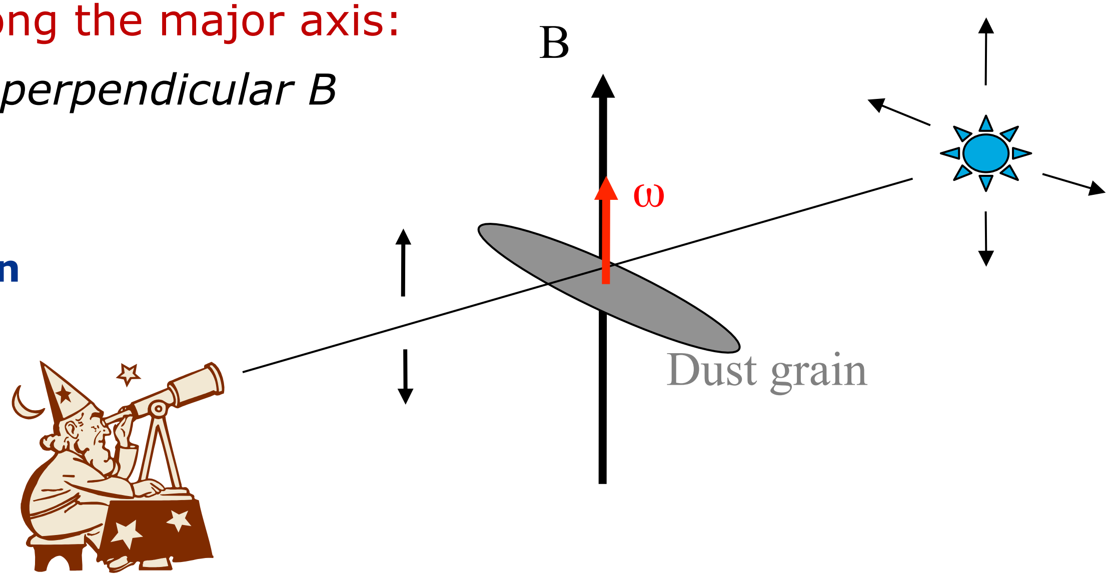
Polarisation of interstellar dust

Elongated (large) dust grains:

- ❑ Rotate due to their absorption and emission of light
    - ➢ Rotation quickly aligns with small axis of the grain
    - ➢ Rotation slowly aligns with the **magnetic field B**
- ❑ Absorb preferentially along major axis:
    - ➢ *Polarisation in extinction parallel to B*
- ❑ Radiate preferentially along the major axis:
    - ➢ *Polarised emission perpendicular B*

Large grains: 0.01 – 0.2 micron



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PILOT Science Objectives

- Measure *linear* polarisation of interstellar dust emission in the FIR
- Investigate the geometric and magnetic properties of interstellar dust grains (size, shape, magnetic susceptibility)
- Reveal the structure of the galactic magnetic field
- Complement Planck Observations

Eventually:

- Learn about the dusty foregrounds affecting CMB polarisation observations, including spectral dependence

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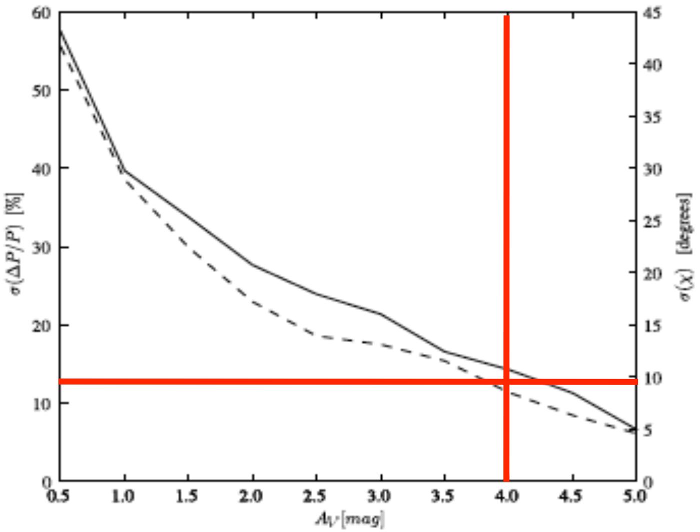
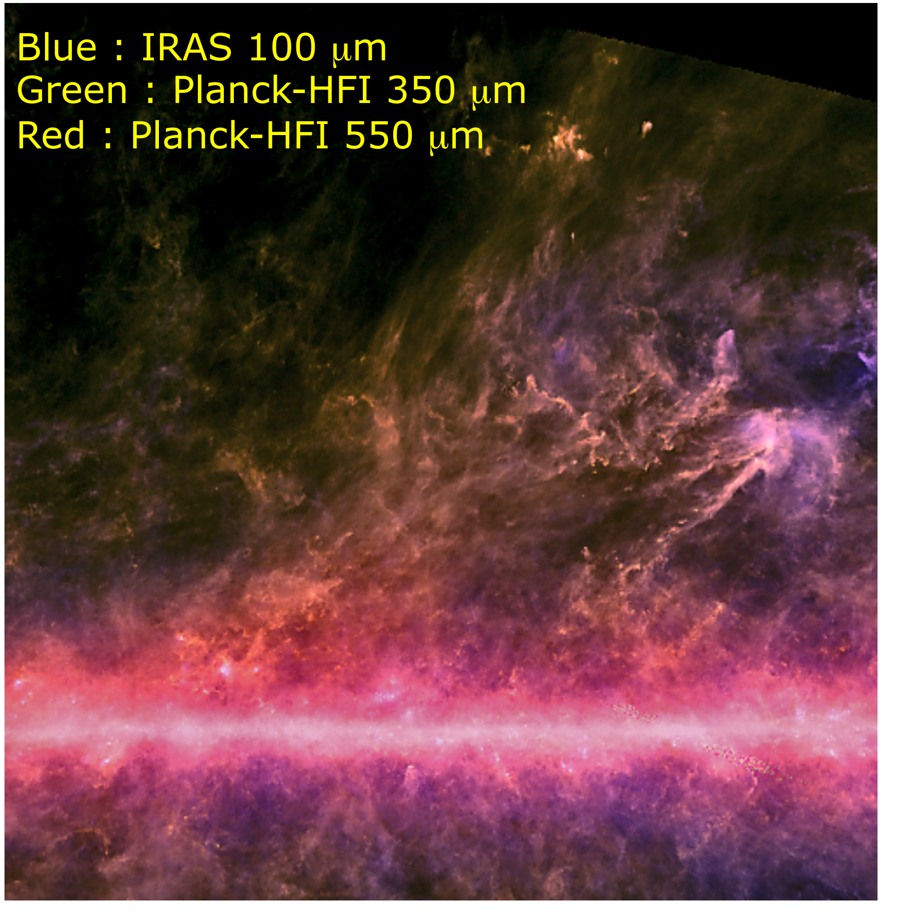
PILOT vs Planck

- Planck: dust polarization over the full sky at 353, 217, 143, 100 GHz
- Planck: Limited sensitivity to very low surface brightness (Av>4 mag) at 10% accuracy.
- Pilot: higher angular resolution
- A factor of 10-50 can be gained by going to higher frequencies
- Variations with λ important for dust models





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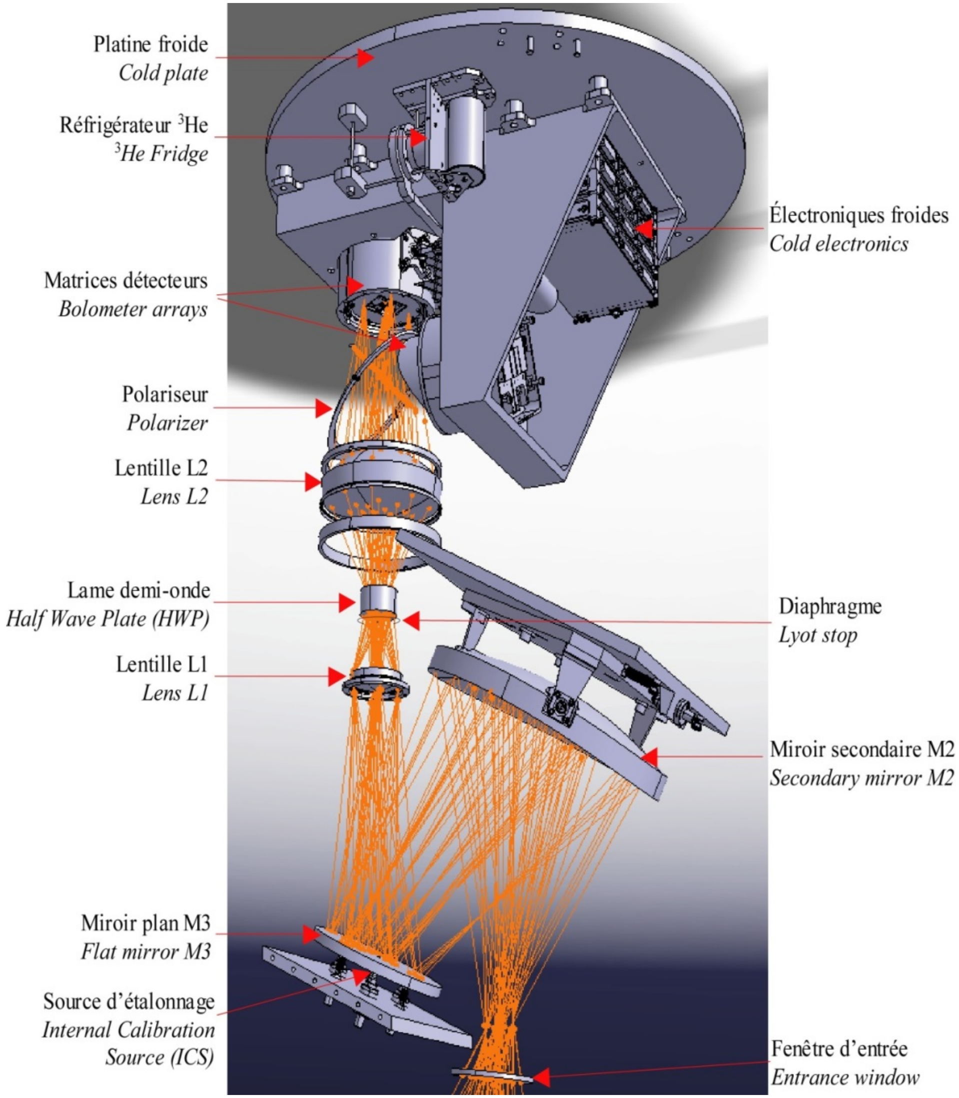
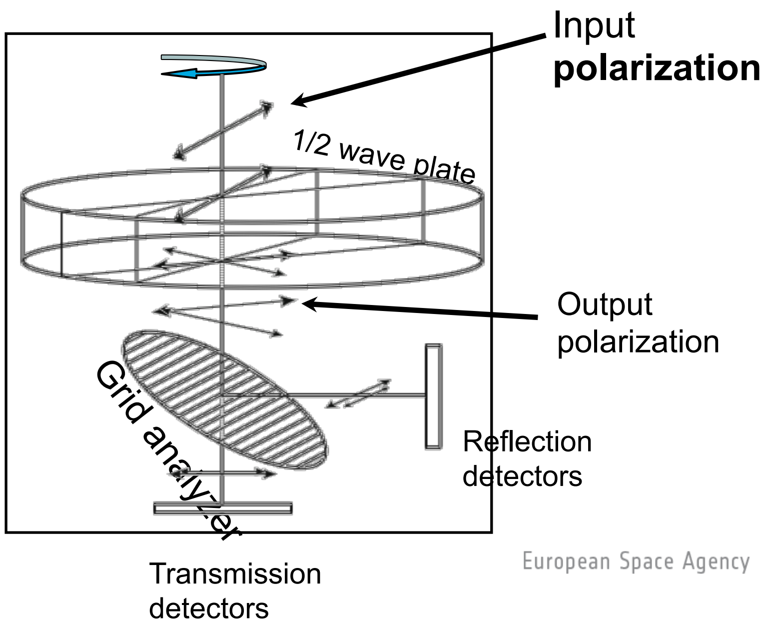
PILOT Experiment



- M1 diameter: 700 mm
  → Resolution: 1.4'/3.3'
- Photometric Channels:
  - 240/550 microns Detection limit: S(3σ) ~ 0.3/0.4 MJy/sr
- FOV: 46'*23'

- Gondola mass: ~ 700 kg
- Flight altitude: ~ 40 km



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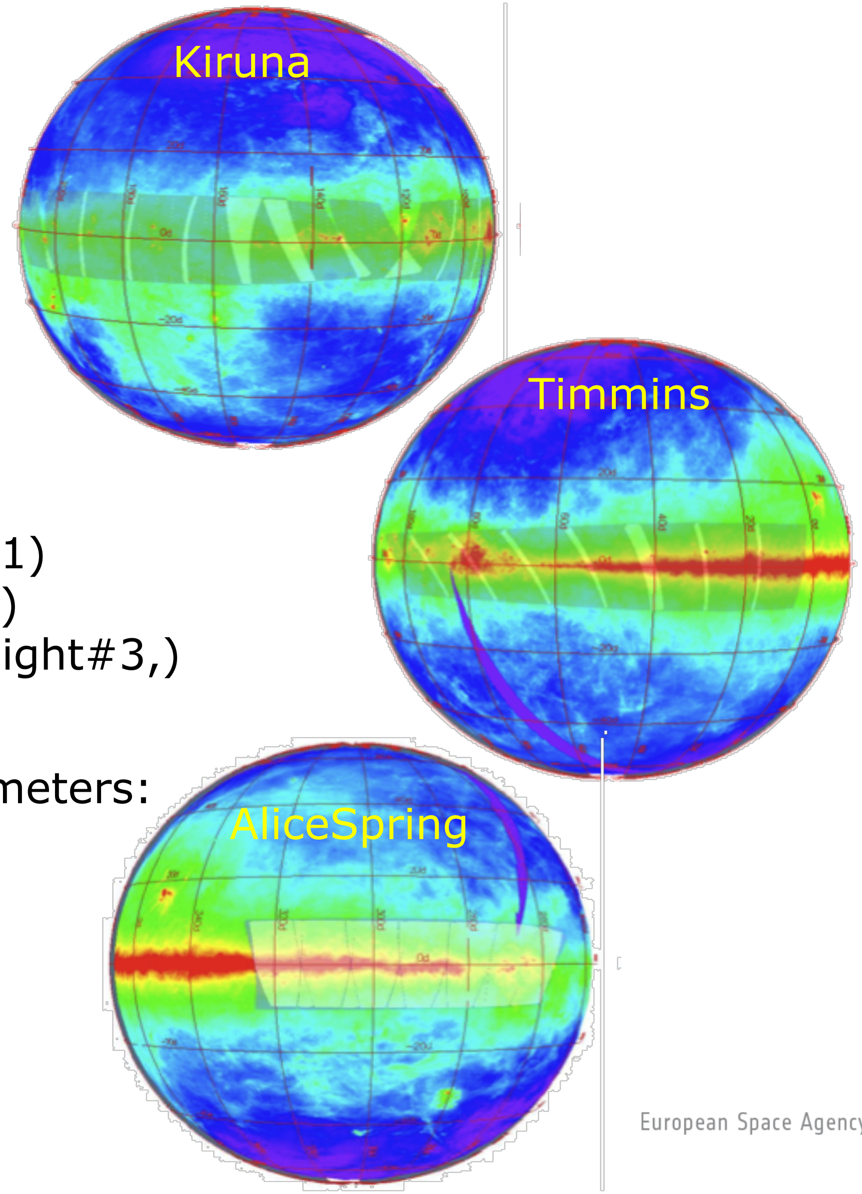
Planning

- ❑ Objective on astronomical targets
  - Galactic plane survey
  - Deep field on cirrus clouds
  - Large and Small Magellanic Clouds

- ❑ Source visibility requires combination of 3 flights from different launch sites (different latitudes)

- ❑ Preliminary launch sites, night time only:
  - ➢ Timmins - Canada (lat 48.5°, flight #1)
  - ➢ Kiruna - Sweden (lat = 60°, flight #2)
  - ➢ Alice Spring – Australia (lat = -23°, flight#3,)

- ❑ Simulations performed with realistic parameters:
  - ➢ mapping speed: 300 sq deg/h
  - ➢ Slew speed =24'/s
  - ➢ Scan amplitude=20°



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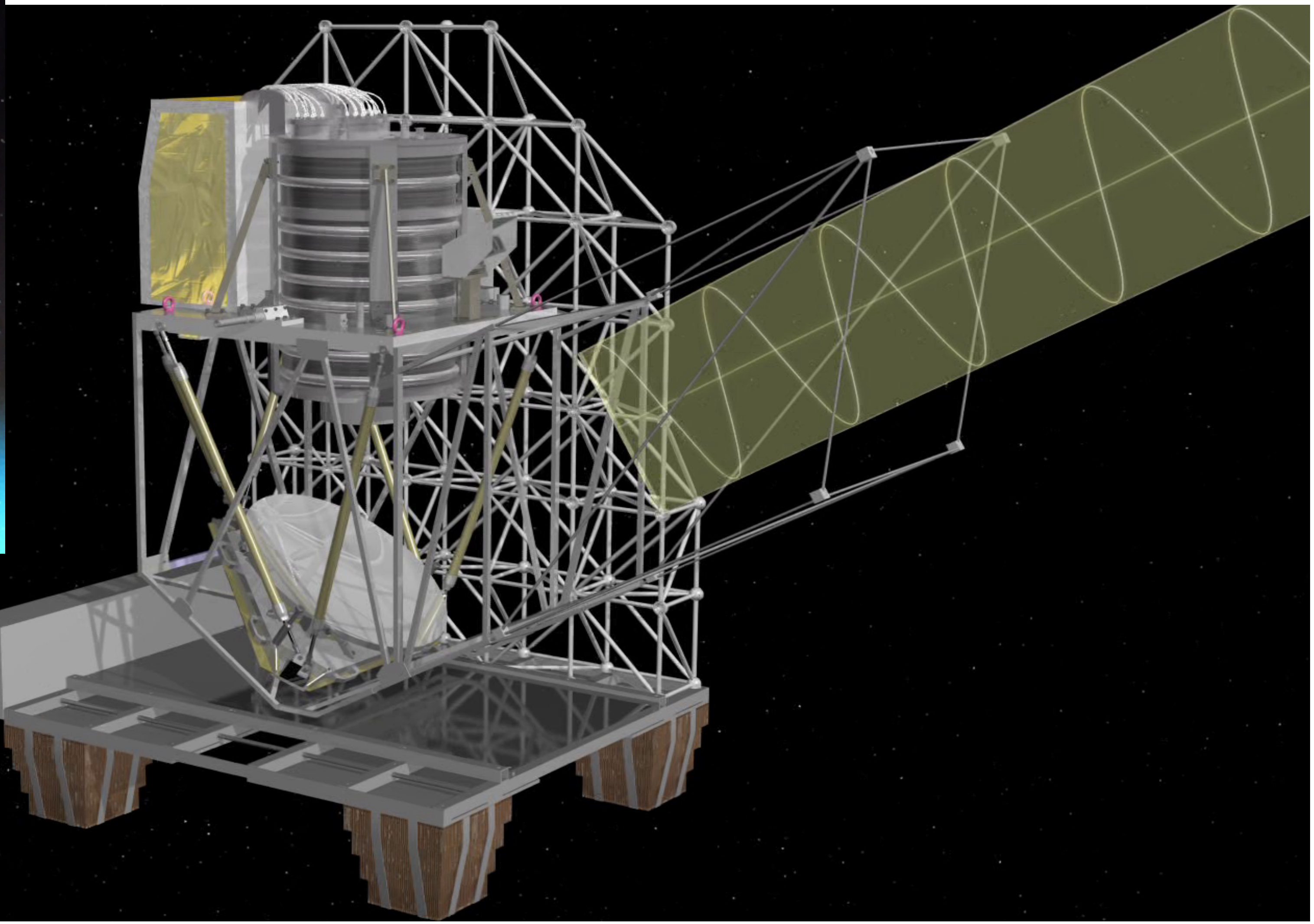
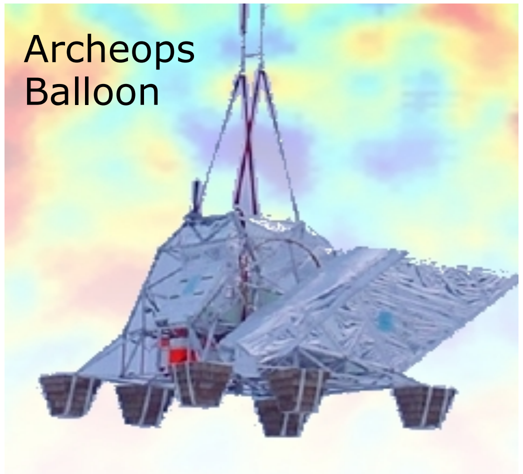
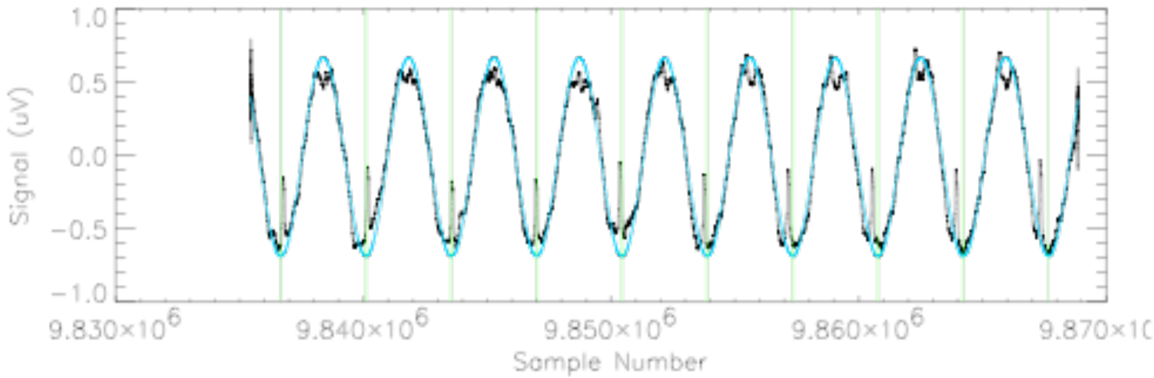
Baffle designs and Straylight

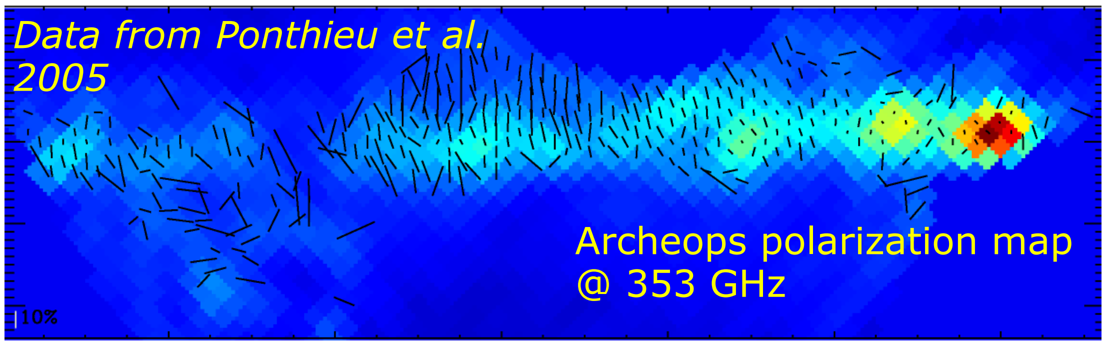


Balloon and Earth: strong submm straylight sources





The balloon skin caused an unexpectedly strong systematic signal



Archeops balloon experiment measured dust polarization at 353 GHz (850 μm) of a fraction of the galactic plane

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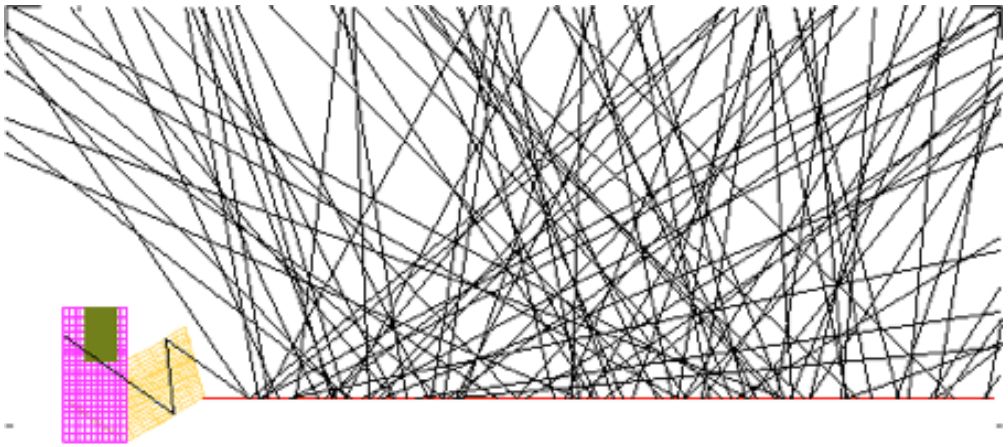
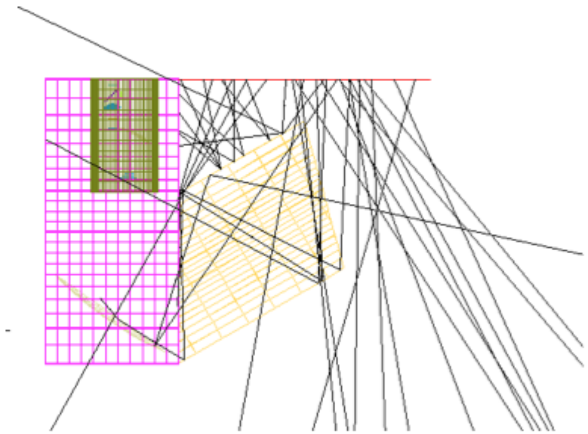
Straylight Analysis

- Computations initially sequential Zemax, later using ASAP software, taking into account instrument optics
- Include Earth and balloon contributions
- Demonstrated superiority of reflective baffles
- Investigation of various baffle geometries

Earth Straylight



Balloon Straylight



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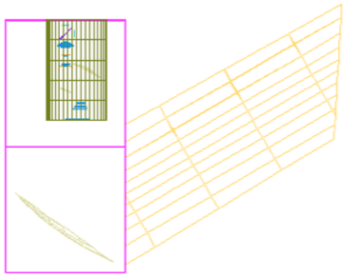
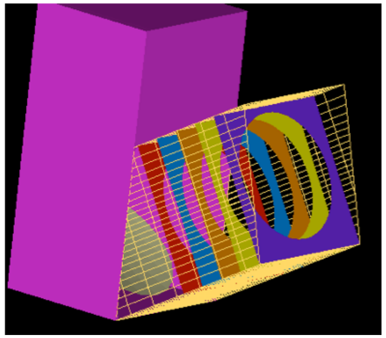
Investigations





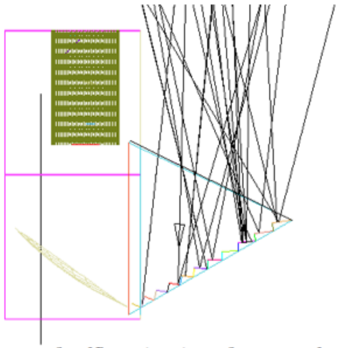


Table 2. Simulation results coparison: updated versus initial baffle designs.

Stray light power [W]	**30° elevation**		**53° elevation**	
	Initial design	*Updated design*	*Initial design*	*Updated design*
From balloon	2*10^-12	1.37*10^-12	2.9*10^-11	1.13*10^-11
From Earth	4*10^-11	4.62*10^-11	6.8*10^-12	7.3*10^-12

Elevation angle, degrees	30	42	53
For balloon stray light:			
Stray light signal as compared to baffle without vanes	23%	56%	34%
For Earth stray light:			
Stray light signal as compared to baffle without vanes	25%	24%	22%

Table 3. Simulation results comparison: updated versus initial baffle designs.

Stray light power [W]	**30° elevation**		**53° elevation**	
	Initial design	*Staircase design*	*Initial design*	*Staircase design*
From balloon	2*10^-12	0.87*10^-12	2.9*10^-11	2.6*10^-11
From Earth	4*10^-11	1.5*10^-12	6.8*10^-12	0

	Fixed straylight	1 mag ISM	Δ straylight (Archeops)
W/m^2	10^{-8}	$2.14\ 10^{-10}$	$5.2\ 10^{-10}$
pW/pix	$5.6\ 10^{-3}$	$1.2\ 10^{-4}$	$2.9\ 10^{-4}$
MJy/sr	812	17.4	42.2

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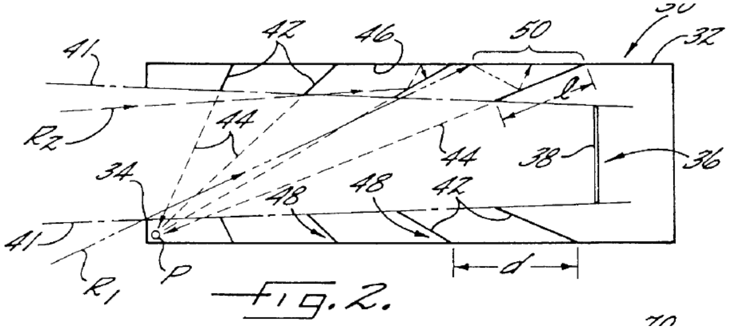
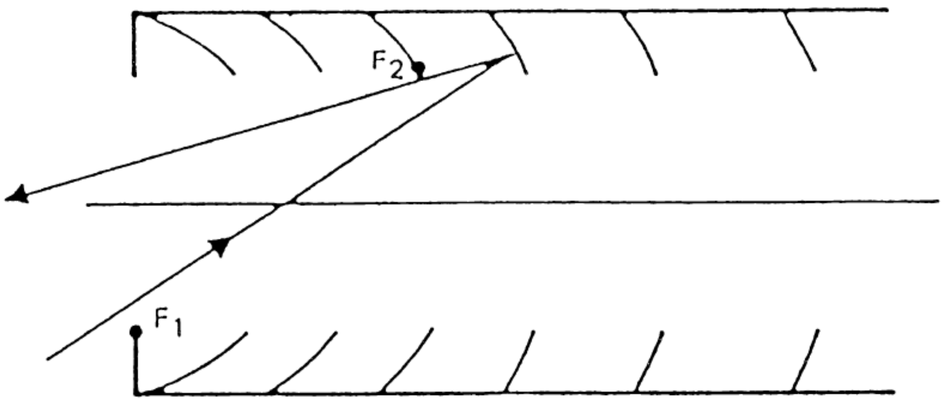
Near Future work

- Tilted vanes: no improvement
- Redo Calculations with 3 vanes
- Investigate elliptical vanes:
  The vanes in this baffle are sections c
  on the tip of the preceding vane and the other focus on the edge of the baffle entrance aperture





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PILOT Outlook

- First testflight was done in September this year to validate the new CNES navigation and communication system.
- First science flight expected in April 2015 – from Timmins, Canada
- ….finally start scientific interpretation

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