An absolute spectrometer for the M-class proposal ?

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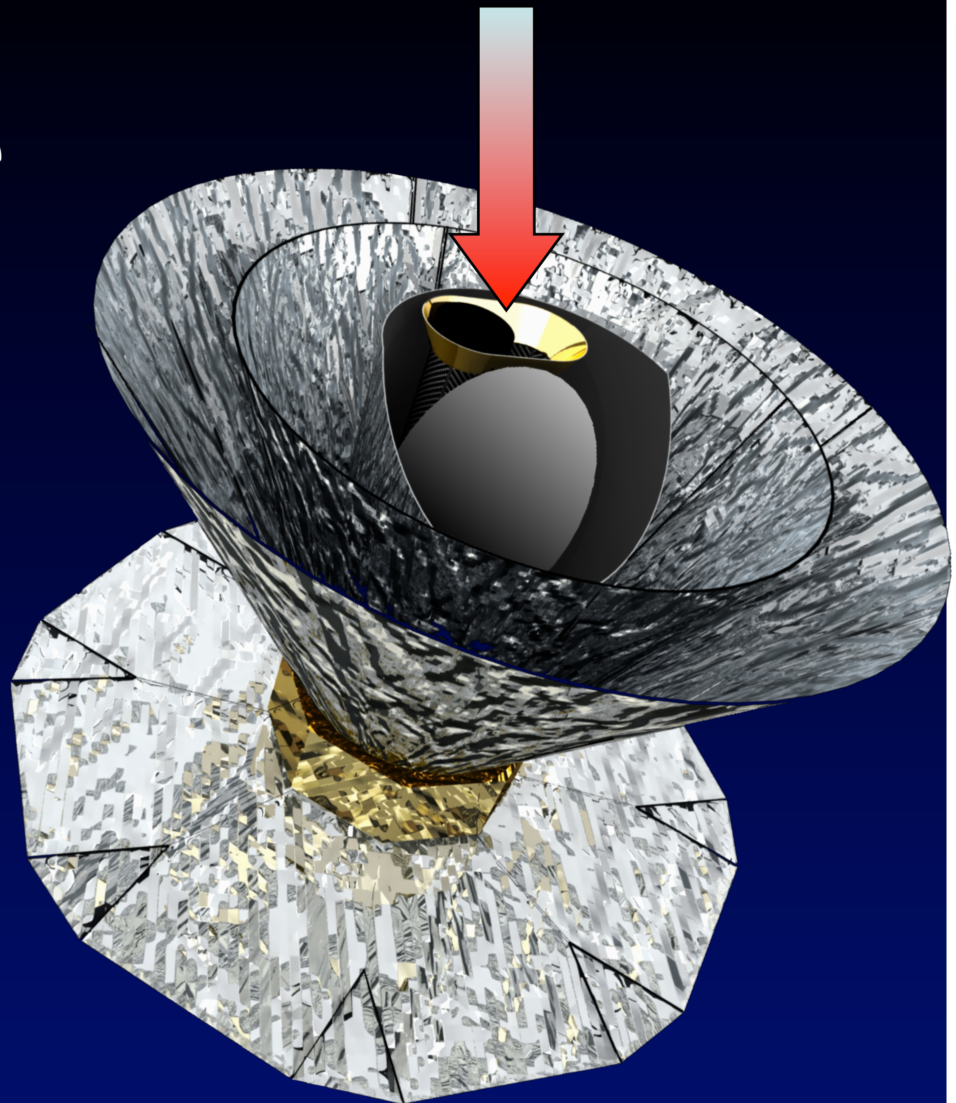
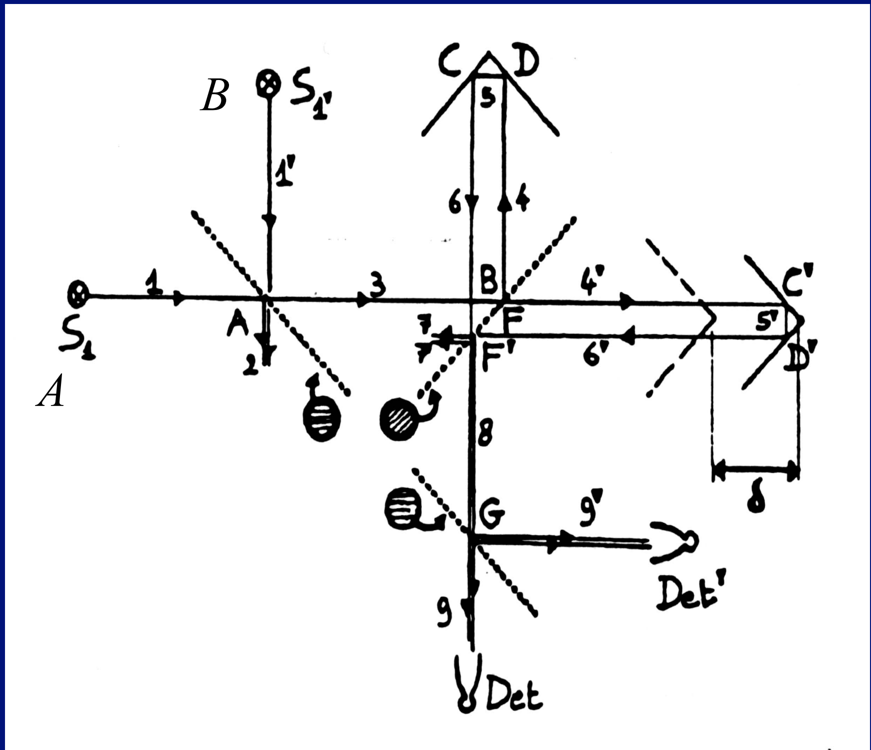


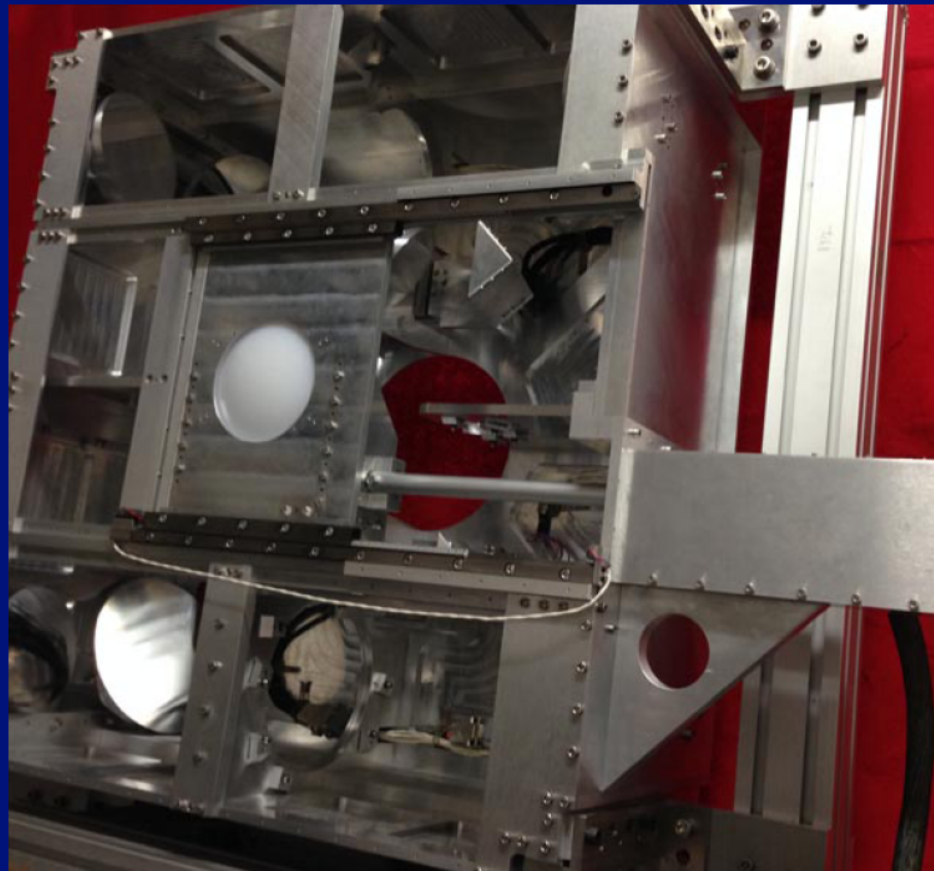
Absolute spectrometer

- To be accurate, the whole spectrometer should be cooled down to T close to 2.73K.
- So cannot share the larger (warmer) telescope used by the imager for CMB polarization studies.

- A Fourier Transform Spectrometer, and in particular the MPI configuration, is a good solution, because:
  - It is an imaging instrument
  - It is differential (measure directly the difference between 2 input ports > versatile instrument !)
  - It is smaller than a dispersion instrument and has higher throughput (however, it is a macroscopic piece of hardware)

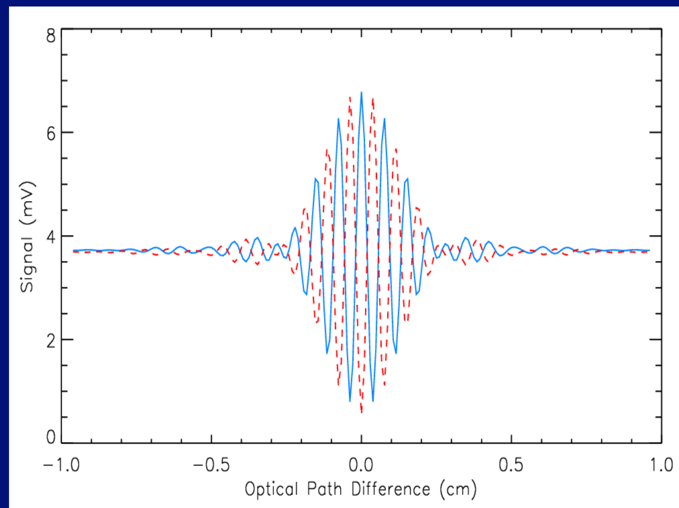
MPI



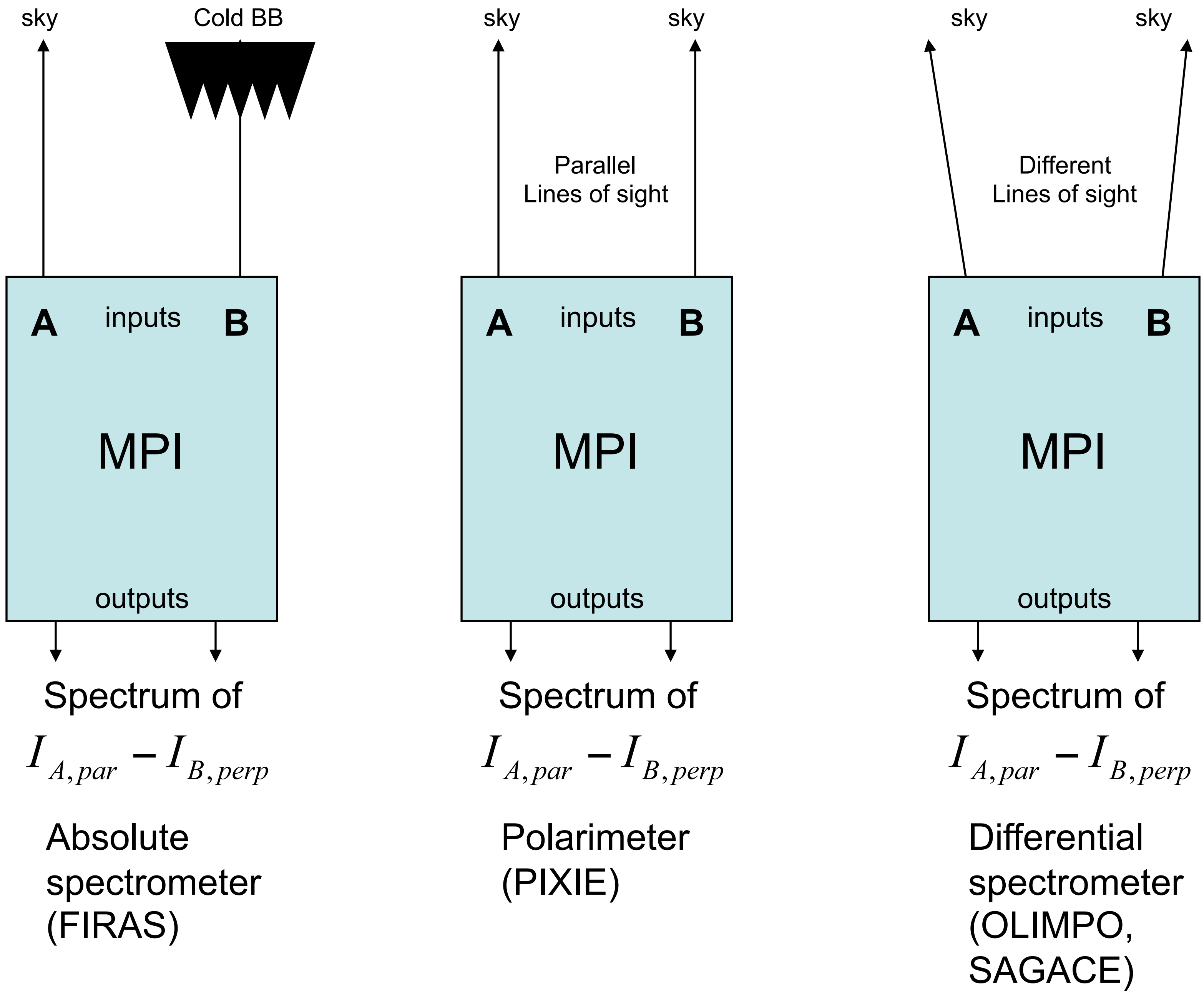


$$I_9 = \frac{1}{2}[A_x^2(1+\cos\delta) + B_y^2(1-\cos\delta)] = \frac{A_x^2 + B_y^2}{2} + \frac{A_x^2 - B_y^2}{2}\cos\delta$$

$$I_9^{'} = \frac{1}{2}[A_x^2(1-\cos\delta) + B_y^2(1+\cos\delta)] = \frac{A_x^2 + B_y^2}{2} - \frac{A_x^2 - B_y^2}{2}\cos\delta$$



See e.g. Schillaci et al. A Lossless Differential Fourier-Transform Spectrometer for precision Sunyaev-Zel'dovich effect measurements (2014)

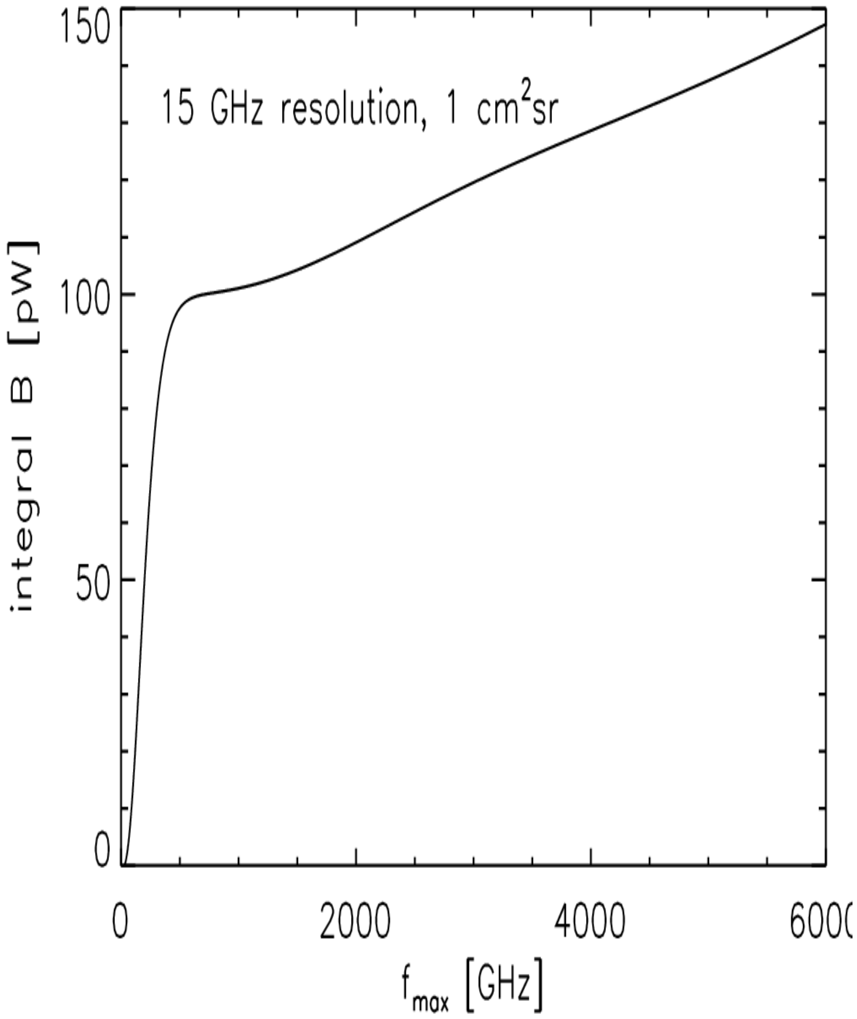

sky
Cold BB
sky
sky
Parallel
Lines of sight
sky
sky
Different
Lines of sight
A
inputs
B
MPI
outputs
Spectrum of
$I_{A,par} - I_{B,perp}$
Absolute spectrometer (FIRAS)
Polarimeter (PIXIE)
Differential spectrometer (OLIMPO, SAGACE)

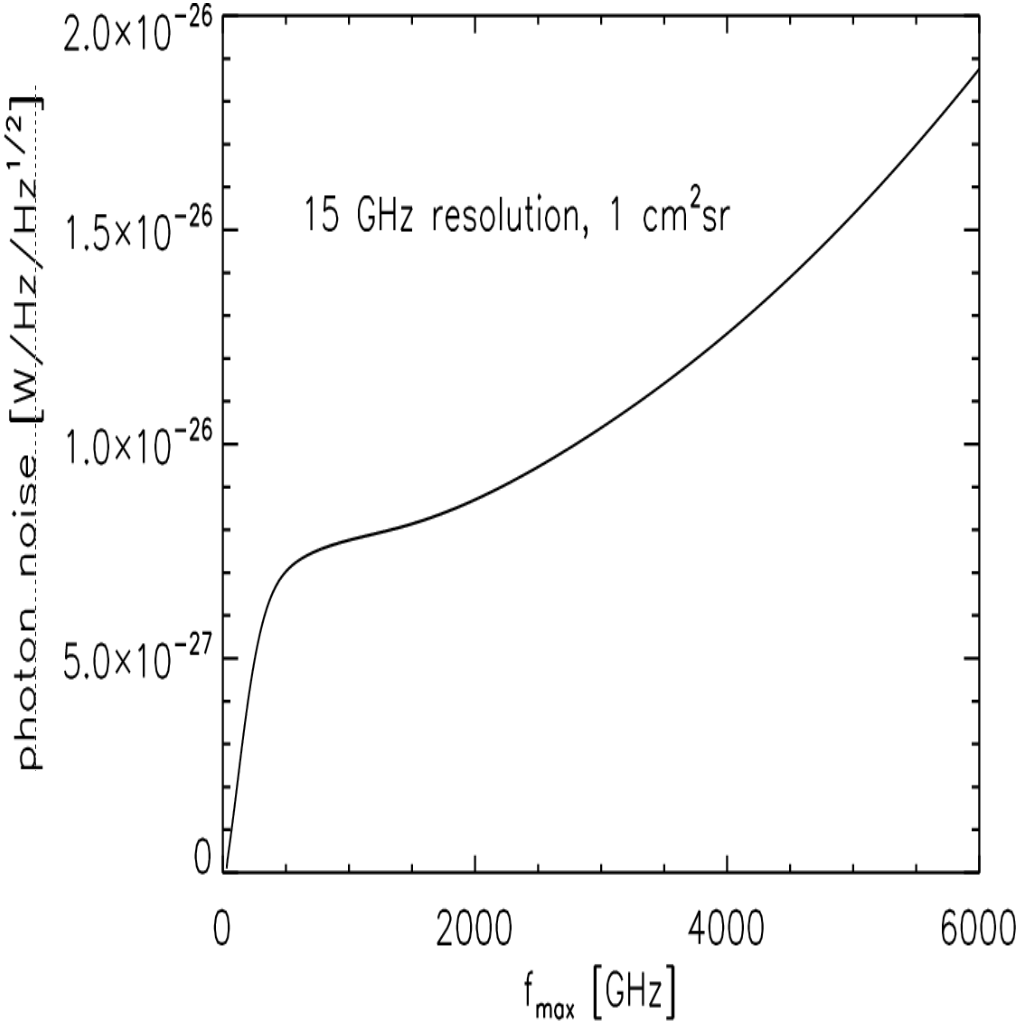
Accuracy is everything !

- Common mode rejection of MPI very good, probably > 50 dB (however, target is probably 60 or 70 dB …)
- Accuracy of reference BB to -70dB to be demonstrated over wide frequency range

  see e.g. Mather et al. Ap.J. 512 : 511-520, (1999) .
- Accuracy of local foregrounds removal to be demonstrated.

Astrophysical background + cold instrument





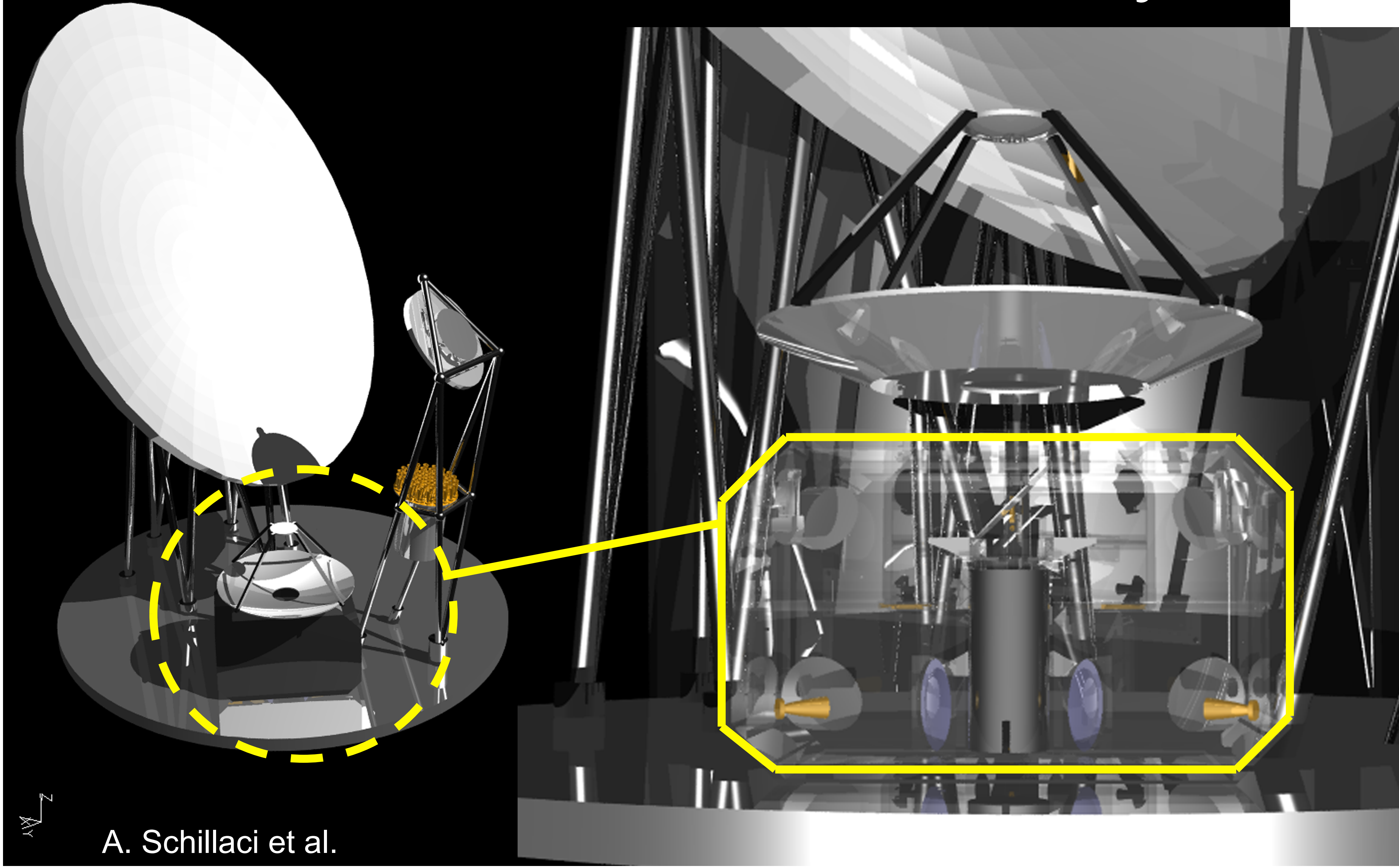
→ **Good idea : splitting coverage in a few sub-bands**

Optimized instrument performance

band (GHz)	resolution (GHz)	$A\Omega$ ($cm^2 sr$)	background (pW)	NEPν ($W/m^2/sr/Hz \times \sqrt{s}$)	global 4-yr mission sensitivity ($W/m^2/sr/Hz$)
30-6000	15	1	150	1.8×10^{-22}	1.8×10^{-26}
30-500	15	1	97	7.0×10^{-23}	7.2×10^{-27}
500 - 6000	15	1	70	1.7×10^{-22}	1.7×10^{-26}
30-180	15	1	42	3.5×10^{-23}	3.6×10^{-27}
180-600	15	1	57	6.3×10^{-23}	6.5×10^{-27}
600-3000	15	1	20	7.4×10^{-23}	7.6×10^{-27}
3000-6000	15	1	28	1.6×10^{-22}	1.6×10^{-26}

Table 3: Performance of the FTS, in three possible configurations, for photon-noise limited detectors, operating in a radiative background comprising CMB, high galactic latitude interstellar dust, CIB, and high ecliptic latitude interplanetary dust emission. With an entrance pupil 50 cm in diameter, the baseline throughput is $\sim 1\,cm^2 sr$, the angular resolution 1.4°. The theoretical sensitivity for each spectral bin is reported in the last column, assuming 4 years of observation and 75% useful sky. The actual sensitivity, taking into efficiency factors can be 2-3 times worse. The first line is a configuration with an ultra-wide spectral coverage obtained with a single detector in both output ports. In the next two lines the detectors at the two output ports are sensitive to different bands. Similar numbers apply if each output port is split in two sub-bands with identical dichroics on both outputs. In the fourth to seventh line each output port is split in two sub-bands using dichroics to minimize photon noise in the low-frequency bins.

PRISM study



A. Schillaci et al.

A smaller instrument for a medium mission ?

- Sensitivity already background limited.
- Size controlled by throughput.
- Smaller instrument with same sensitivity implies smaller entrance pupil with wider beam.
- For PRISM 1.4° with 50cm diameter.
- Wider beam implies > contamination from discrete sources.
- Tradeoff possible once the main instrument is defined.

Δ – budgets :

- Volume:
  - Depends on angular and spectral resolution. The beam must be parallel to the spin axis.
  - Volume > than beam to sky, due to cold blackbody
- Mass
  - Order of 50 kg cold + 10 kg warm
- Power
  - 10 mW cold (100 when moving calibration BB) + 10W warm
- TRL: very good (FIRAS, SPIRE etc.)
- Cost
  - Order of 30M€, using cryogenics of polarimeter and a small number of detectors
- **Is it *credible and sellable* a medium mission with two complex cryogenic instruments on-board ?**