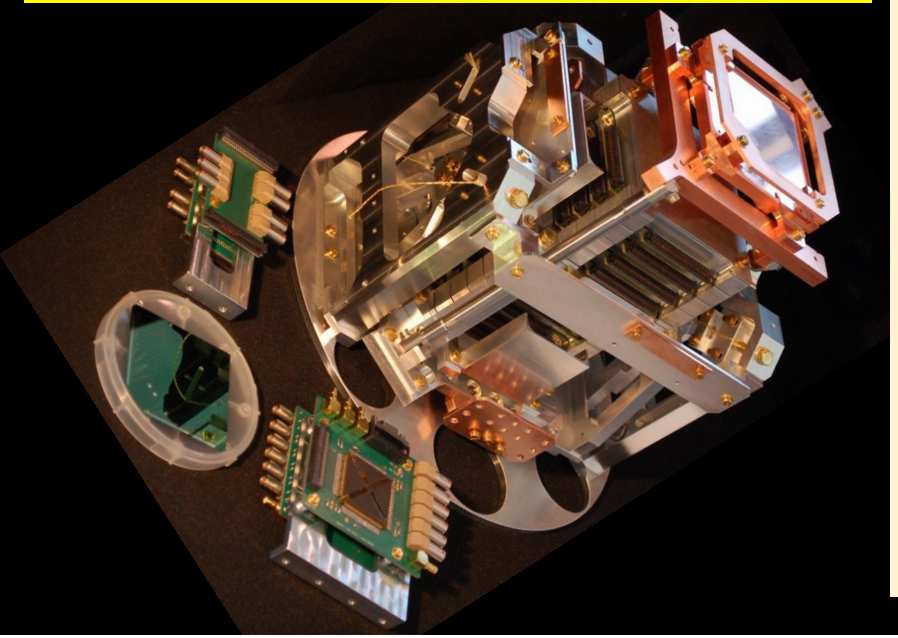
Experimental Activities and Instrumentation Developments for the **CMB**

- Scientific Priorities
- State of the art of the Italian scientific community
- Actions to be implemented



SCIENTIFIC PRIORITIES

red: large experiments

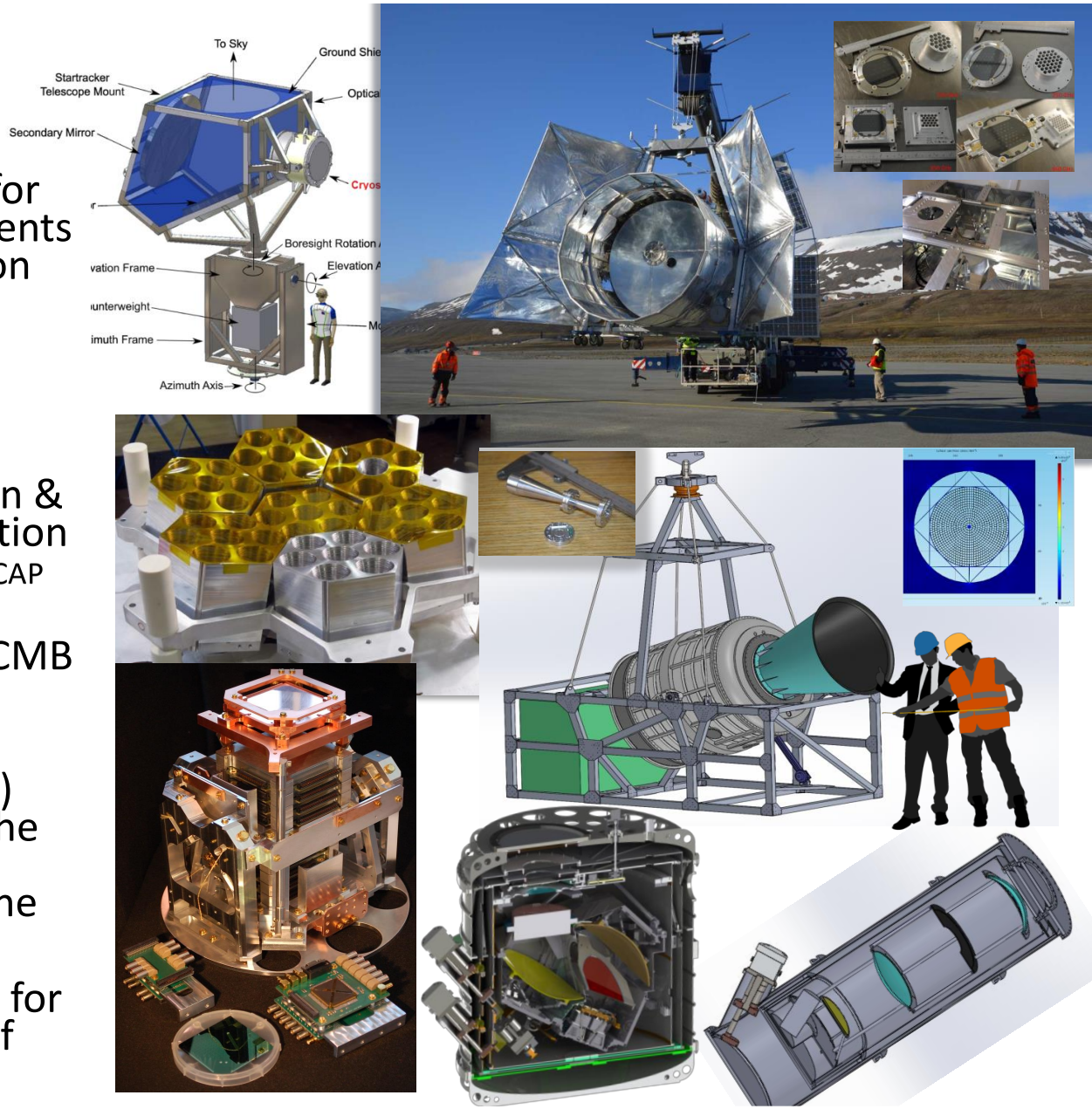
- CMB polarization / B-modes
  - High sensitivity
    - Mapping speed: multiplication of detectors & telescopes (SO, S4)
    - Massive cryogenics - minimization of radiative loads
    - Atmospheric removal techniques (QUBIC, STRIP, Polarbear, BICEP/KECK ARRAY) - space-based measurements (SWIPE, LiteBIRD)
  - High accuracy
    - Calibration procedures and specialized hardware
    - Polarization modulators, Polarization purity, Cryomechanisms.
    - Foregrounds removal capabilities
    - Careful study and mitigation of systematic effects – space-based (LiteBIRD)
- CMB spectrum
  - Isotropic (spectral distortions)
    - Ultra-high accuracy spectroscopy (COSMO)
    - Reference standards
    - Space-based missions (BISOU, PIXIE)
  - Anisotropic (SZ in clusters and in the LSS)
    - Large telescopes. Cold/dry sites (ACT, SPT, NIKA, MUSTANG, MISTRAL)
    - Imaging spectroscopy
    - Ground-based & Balloon borne imaging spectrometers (OLIMPO, KISS, CONCERTO)
    - Satellite-based imaging spectrometers (Millimetron)
- CMB statistics
  - Gaussianity
  - Photon statistics

State of the art in Italy : Enabling Instrumentation

- RF test facilities (UniMI, INAF/Bo, UniMIB, Sapienza)
- High polarization-purity antennas and OMTs (UniMI, CNR-IEIIT)
- Polarization modulator cryogenic mechanisms (Sapienza)
- Multimode TES bolometers (INFN-Ge + Sapienza)
- TES readout, cryogenic electronics (INFN-Pi, INFN-Ge)
- Kinetic Inductance Detectors (Sapienza + CNR-IFN) for space & ground
- Large throughput imaging spectrometers (Sapienza)
- Reference loads (INAF-Bo, UniMI, UniMIB, Sapienza)
- KIDs readout (Sapienza, UniMIB)
- Cryogenic telescopes & Optical systems (Sapienza, UniMI, INAF/BO)
- Ground segments (ASI/SSDC, INAF/OA-TS)

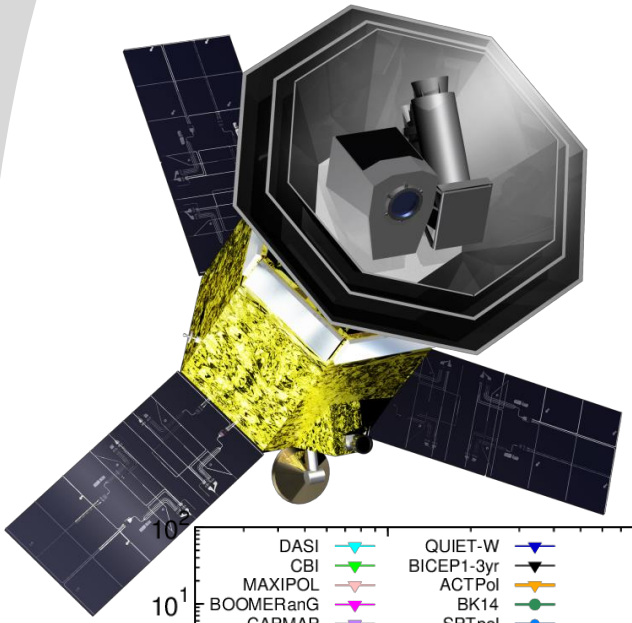
State of the art in Italy: Funded Experiments

- **OLIMPO** – a balloon-borne 2.6 m telescope, for precision, unbiased spectroscopic measurements of the SZ in clusters. 2018 flight: first validation of KID arrays in near space (Masi & JCAP 2019).
- **LSPE-STRIP** – ground-based (Tenerife) CMB polarization & low-frequency polarized foregrounds (Piacentini & JCAP 2020 to be submitted)
- **LSPE-SWIPE** – balloon-borne CMB polarization & high-frequency polarized foregrounds. Validation of multi-mode TES arrays in space (Piacentini & JCAP 2020 to be submitted)
- **QUBIC** – ground based (Argentinean Andes) CMB polarization – validation of bolometric interferometry (Mennella & Universe 2019)
- **COSMO** – Ground based (Dome-C, Antarctica) measurement of the absolute brightness of the CMB. Validation of atmospheric removal performance, in view of a future balloon-borne experiment (COSMO-Balloon ? BISOU ?).
- **MISTRAL** – a W-band KID camera (400 pixels) for SRT (facility instrument – PON-INAF. Survey of Extragalactic sources & SZ)

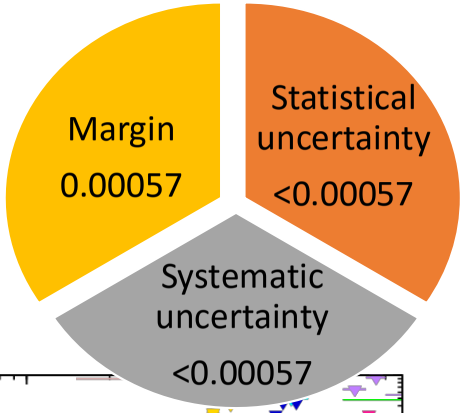


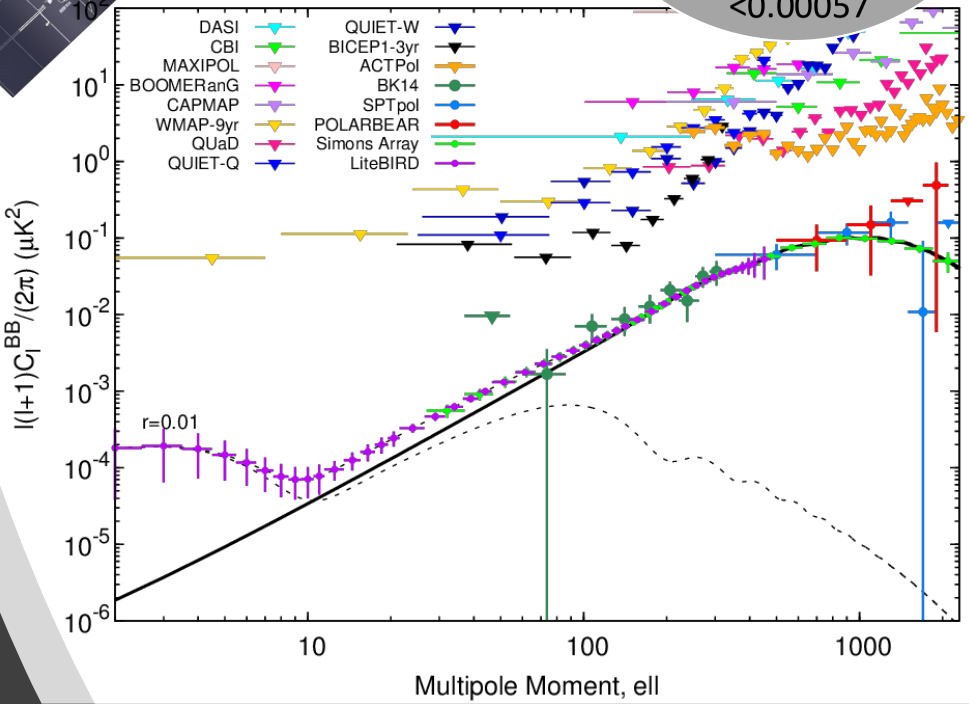
State of the art in Italy : LiteBIRD

- A large fraction of the Italian CMB community involved. Support from ASI & INFN
- Significant Presence in the Interim Governance Board and Working Groups
- To date, working hard to provide
  - Expertise in theory and data analysis
  - Ground Segment
  - Cryogenic mechanism for MHFT PMU
  - Calibration facility for the HWPs (component-level)
  - Cold-stop design and manufacture
  - Absorbers design and manufacture
  - RF tests of MFT and HFT (subsystem and system levels)
  - Warm electronics (SQUID control) for the detector readout chains



Full Success :
$\delta r < 1 \times 10^{-3}$ (for r=0)
$2 \leq \ell \leq 200$





Actions to be implemented for Experimental CMB

- Support to instrumentation developers : two main issues
  - Funds for laboratory activites
  - Recruitment barrier for instrumentation specialists (FIS/05-02C1 includes everybody, from theorists to data analysis specialists to instrumentation scientists.)
- Support for ground-based activities : no national agency specifically committed – weakness in the European community
- Flight support for italian balloon-borne experiments : no national service, international providers expensive.
- Balance between Italian contributions to international efforts and Italian flagship experiments