

# Additional Cosmology For Euclid Italia 2023

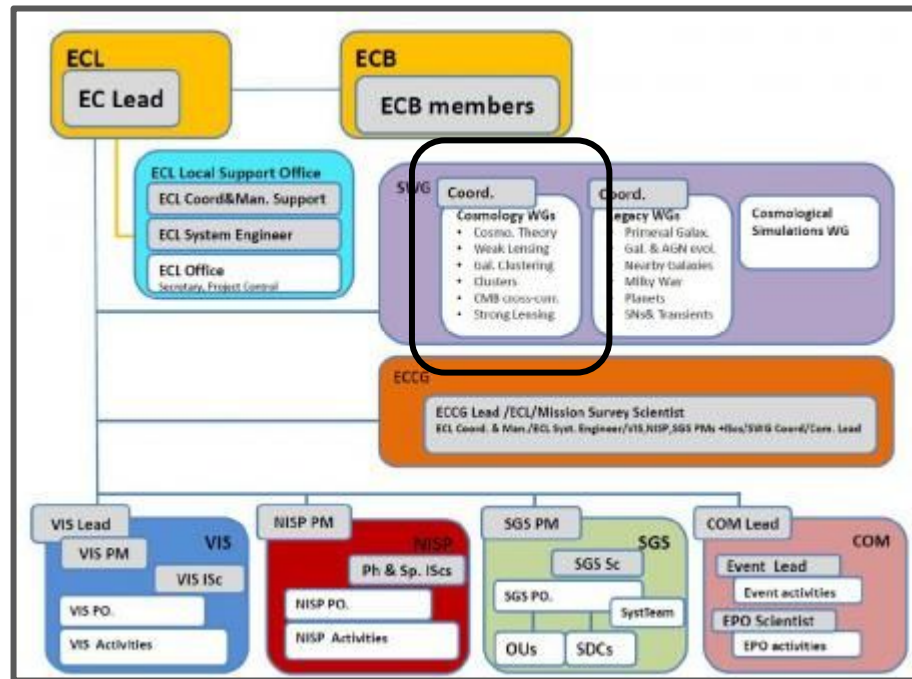
Carlo Baccigalupi, Fabio Finelli, Massimo Meneghetti, Lauro Moscardini on  
behalf of the CMBXC, Theory, Strong Lensing, Clusters WGs

# Outline

- **General Remarks on Additional Cosmology**
- **From Small to Large Scales**
  - Strong Lensing
  - Clusters
  - CMBX
  - Theory
- **Pre-Launch Considerations**
  - KPs
  - Coordination
  - Common Interfaces
- ...

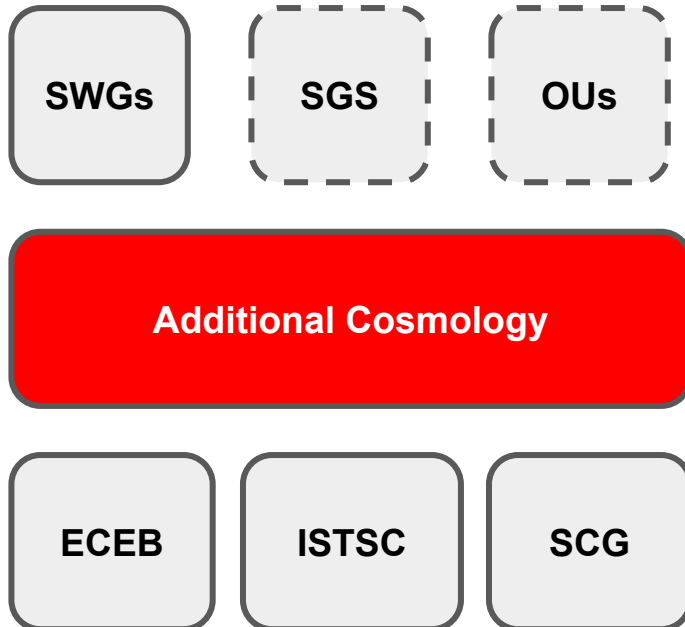
# Additional Cosmology: Structure & Goals

- **Definition:** Cosmology Science for Euclid, Complementary and Coordinated with Primary Probes
- **Additional Cosmology WGs**
  - **Strong Lensing:** Lens Dark Matter, Background Sources, Cosmography, ...
  - **Clusters:** Dark Matter Profile, Hot Gas Properties, Arc Statistics, Weak Lensing, ...
  - **CMBX:** Integrated Sachs Wolfe, Lensing, Thermal and Kinetic Sunyaev Zel'dovich, ...
  - **Theory:** Dark Energy & Modified Gravity, Dark matter, Initial conditions, ...
- **Observables, Models, Codes**
- **Coordination with Primary Probes, Cosmological Simulations**



# Additional Cosmology: Consortium Interface & Organization

- **Additional Cosmology** absorbs Information from **SWG**s through **Regular Monthly Teleconferences**
- **Information flows from and to**
  - Editorial Board, monitoring Consortium Papers, Organizing Internal Referees, Coordinate Publication
  - Inter-Task Force Science Coordination
  - Science Coordination Group
- **Examples:**
  - Choices for Internal Paper Referees with **SWG** Leads,
  - Coordination of **CLOE** Development within **IST** Likelihood and Non-Linear Coordinated with Model Building and Modules in **SWG**s,
  - **SWG** Lead Rotation Plan, ...
- Information from and to **SGS**, **OU**s is spontaneous and functional to needs, the **Launch** offers the opportunity to make these links stronger, structural.



# Strong Lensing: Organization

SWG coordinators: **R. Gavazzi (LAM, Marseille), M. Meneghetti (INAF-OAS, Bologna), J.P. Kneib (EPFL, Lausanne, rotating off)**

OU-SHE-SL coordinator: **F. Courbin (EPFL, Lausanne)**

Active members: ~25 people (I, CH, F, UK, US, NL, S, B, D)

Two active KPs (pre-launch) with dedicated working sub-groups for each ongoing paper.

Telecons and meetings:

- One general telecon per month (usually on the last thursday of each month, details of the redmine)
- Telecons dedicated to each KP (once per month)
- In person meetings: resumed last summer (Leiden), second meeting in December (Marseille). Next meeting likely in May (TBD)

Communications:

- **Wiki:** <https://euclid.roe.ac.uk/projects/slswg/wiki/Wiki> (being re-styled)
- **Mailing list:** [ecsls@googlegroups.com](mailto:ecsls@googlegroups.com)
- **Slack:** [ecslsworkspace.slack.com](https://ecslsworkspace.slack.com)

# Strong Lensing: KP Plan

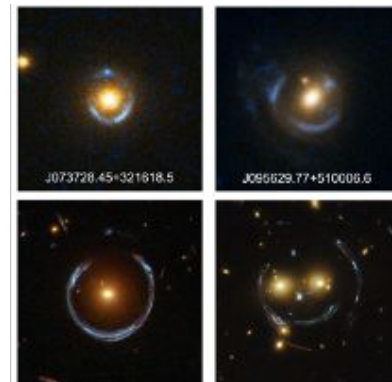
Two Key Projects coordinated by the SLWG (and ongoing paper leading authors, **purple=italian leadership**):

○ **KP-SL-1: Galaxy-scale Strong Lenses (G. Despali, G. Vernardos)** (GAEV-SWG, OU-SHE)

- Realistic image simulations of strong lensing galaxies (B. Metcalf)
- Algorithms for finding strong lensing galaxies (B. Clément, L. Leuzzi)
- Lens modeling techniques (J. Nightingale)
- Information content on the galaxy evolution model (A. Sonnenfeld)

○ **KP-SL-2: Cluster-scale Strong Lenses (L. Moustakas, G. Mahler)** (WL-SWG, CL-SWG, GAEV-SWG, OU-SHE)

- Realistic image simulations of strong lensing clusters and groups (P. Bergamini)
- Algorithms to find strong lensing features in galaxy clusters and groups (G. Angora)
- Lens modeling techniques (G. Mahler)
- Strong lensing by cluster substructures (M. Meneghetti)



# Strong Lensing: Consortium Interfaces & Coordination

- Report to ECB last June 2022
- Very strong connection with OU-SHE-SL and SDC CH to build the SL processing functions (e.g. sharing person power; actively participating in the coding activity)
- Good interface with other SWGs. Sharing tools (e.g.: image euclidization tool HST2Euclid with LU-WG; image simulations of double AGNs with GE-WG; lens mapping tools with CL-WG) and expertises.

# Strong Lensing: Status of Activities

- **Completion of the Pre-launch KPs:** 1 paper completed and to be submitted to ECEB in the next days (**led by L. Leuzzi**); overleaf existing for other 2 papers; other papers planned to be completed by June
- Largest effort dedicated to **developing, testing, and validating the SL lens finding and modeling pipeline:** ongoing work, but in advanced stage
- **Definition of Q1 and DR1 projects**
- **Readiness for Q1:** Aim at quick release of automated lens finding (trained with sims with their own limitations); involvement of citizen science to validate lens detections (ZooUniverse?)
- **Planning follow-up observations:** e.g. spectroscopy on 8m class telescopes (to be discussed and coordinated with other WGs); T. Collet led a joint Euclid/Rubin 4MOST proposal (4SLSLS, now absorbed into TiDES) to follow-up Euclid and LSST lens candidates: southern sky, 36000 fiber hours granted



# Clusters: Organization

- ~150 Members: ~30% both **Italy** and France, 13% Germany, 7% both UK and Spain, 5% USA, plus few more people in Canada, Japan, Netherlands, Finland, Norway, Austria, Portugal...
- 11 Working Packages, **7 of them with an Italian co-lead**
- 6 pre-launch KPs (see below)
- Communications:
  - General bi-weekly zoom calls, alternating a general SWG telecon and one reserved to the KP/WP leads
  - Wiki: <https://euclid-redmine.roe.ac.uk/projects/cgswg/wiki>
  - Strong connection/overlap with OULE3-Clusters (**IT-lead**)
- Meetings:
  - Twice per year (spring and fall), plus possible splinters at Consortia
  - next one, in Bologna, March 14th-16th, 2023
- ...

# Clusters: KP Plan: 6 KPs, 28 'papers', 4 already completed

- **KP-CG-PL-1: Validation of the Cluster Cosmology Pipeline (managed by CG-WP3 IT-lead)**
  - Paper 1.1: The HSC AMICO cluster catalog
  - Paper 1.2: Modelling of Euclid Cosmological likelihood-systematics and statistics (IT-lead)
  - Paper 1.3: Constraints from the AMICO HSC Cluster catalogs with the Euclid cluster cosmology pipeline (IT-lead)
- **KP-CG-PL-2: Establishing the Cluster Selection Function (managed by CG-WP9 IT-lead Jointly with OULE3)**
  - Paper 2.1: Comparison of Euclid Cluster selection function to other surveys
  - Paper 2.2: Preliminary evaluation of the Euclid cluster selection functions
  - Paper 2.3: Data-driven evaluation of the Euclid cluster selection function
  - Paper 2.4: Definition of the cluster sample for cosmology
- **KP-CG-PL-3: Precision Simulations for Cluster Cosmology (managed by CG-WP9 IT-lead)**
  - Paper 3.1: Calibration of the cluster halo mass function in vanilla LCDM models (IT-lead): **PUBLISHED**
  - Paper 3.2: Characterization of the covariances for cluster halo mass function and halo bias (IT-lead): **2 PUBLISHED**
  - Paper 3.3: Baryonic effects on halo mass function and bias (IT-lead)
  - Paper 3.4: Halo mass function and bias in non-standard models (IT-lead)
  - Paper 3.5: 3D and 2D profiles and concentrations in LCDM and non-standard models
  - Paper 3.6: Convergence and shear maps of simulated clusters: calibration of WL masses (IT-lead): **SUBMITTED**
  - Paper 3.7: Impact of hydrodynamical modelling on the WL signal of massive halos
- **KP-CG-PL-4: Euclid galaxy clusters legacy science (managed by CG-WP7 and CG-WP11, both with IT-lead)**
  - Paper 4.1: Astrophysical properties of selected/unselected clusters: X-ray simulations
  - Paper 4.2: Optical counterparts of the X-ray selected clusters
  - Paper 4.3: The X-ray counterpart of the optical clusters
  - Paper 4.4: Impact of cluster physics on the cluster selection
  - Paper 4.5: Tools and forecasts for ICL detection
  - Paper 4.6-4.9: Definition and optimization of algorithms for the identification of clusters at  $z > 1.5$  and protoclusters (more papers, IT-lead)
- **KP-CG-PL-5: Cluster mass-observable relation (managed by CG-WP5)**
  - Paper 5.1: Covariance of ICM and optical/NIR observables in simulations (IT-lead)
  - Paper 5.2: Constraining WL mass-richness covariance from ICM observables
  - Paper 5.3: Mass calibration from galaxy kinematics (IT-lead)
- **KP-CMBX-6: Meta-catalogues for Euclid Cluster science (managed by CG-WP8)**
  - Paper 6.1: Velocity dispersions meta-catalogues
  - Paper 6.2: Consistency of masses in optical, X-ray, and SZ meta-catalogues

# Clusters: Consortium Interfaces & Coordination

- The main SWG strength is coming from the **strong collaboration/synergy/overlap with OULE3 Galaxy Clusters**, where Italy is also having a strong leading role: a large fraction of the OULE3 processing functions necessary for cluster science are developed by Italian researchers who are at the same time very active members of SWG  $\Rightarrow$  most of them are leading the pre-launch KP papers planned inside OULE3 (KP-LE3-CL-1,2,3).
- Good interfaces with the rest of the Consortium:
  - SWG**s: mainly with Strong Lensing, Galaxy clustering, Weak lensing, Cosmological simulations and Galaxy evolution;
  - IST**: -Likelihood and -Nonlinear

# Clusters: Status of Activities

- **Completion of the Pre-launch KPs:** 4 papers completed, **all with Italian leads** (Fumagalli, Tiago, again Fumagalli, Giocoli); overleaf existing for other 4-5 papers; preliminary results for the majority of the rest; few cases of delays due to missing person-power
- The largest effort is to apply the whole Euclid cluster cosmological pipeline (cluster detection, abundance and clustering measurements, mass-richness calibration, likelihood, final inference of the cosmological parameters, ...) to the best existing public data: **Hyper Suprime Cam (HSC)**
- **Definition of Q1 and DR1 projects**
- **Detailed plans for specific external data:** eRosita, SPT, other surveys.... (necessity of new MoUs? Public data only? Observational proposals?)

# Theory: Organization

- **117 Members (Jan. 20):** approx. 26% from **Italy**, 18% France, 10% UK, 9% both Portugal and Switzerland, 6% Germany and Spain, plus few more people distributed in Netherlands, Finland, Japan, Norway, Sweden, US...
- **10 Work Packages**, 7 of them with an Italian co-lead
- **3 pre-launch KPs** (see below)
- **Communications:**
  - Monthly calls, general one alternate with WP-leads one, plus biweekly calls for each WP.
  - Wiki: <https://gitlab.euclid-sqs.uk/SWG/SWG-TWG>
  - Mailing list: [swg-cosmo-theory-group@euclid-projects.org](mailto:swg-cosmo-theory-group@euclid-projects.org)
- **Meetings:**
  - One per year, plus possible Splinter at Consortium
  - Last one (first hybrid after the pandemy), in Bologna, October 10-11, 2022, next one TBD

- **KP-TH-1: Forecasts for beyond-standard models in cosmology and fundamental physics**
  - **KP-TH-1 P1** Euclid preparation: xx. Forecast constraints on dark energy and modified gravity **(IT-WP co-led)**
  - **SP-TH-[WP1/2]-P1** Euclid: Constraints on f(R) cosmologies from the spectroscopic and photometric primary probes **(w/ ECEB)**
  - **SP-TH-[WP1/2]-P2** Euclid: Constraining linearly scale-independent modifications of gravity with the spectroscopic and photometric primary probes **(IT-WP co-led)** **(w/ ECEB)**
  - **SP-TH-[WP1/2]-P3** Euclid: Constraints on model independent parametrizations of gravity **(IT-WP led)**
  - **KP-TH-1 P2** Euclid preparation: xx. Forecast constraints on neutrinos in LCDM and beyond **(IT co-led)**
  - **SP-TH-[WP3]-P1** Euclid: Particle Dark Matter
  - **SP-TH-[WP3]-P2** Euclid: Generalized Dark Matter
  - **SP-TH-[WP3]-P3** Euclid: Primordial Black Holes
  - **SP-TH-[WP3]-P4** Euclid: Validation of MontePython
  - **KP-TH-1 P4** Euclid preparation: xx. Forecast constraints on initial conditions and implications for inflation **(IT-WP led)**
  - **SP-TH-[WP4]-P1** Euclid: The search for primordial features **(IT-WP led)**
  - **SP-TH-[WP4]-P2** Euclid forecasts for early Universe: Bayesian inference of cosmic initial conditions
  - **KP-TH-1 P6** Euclid preparation: xx. Impact of non-linear clustering on beyond-LCDM constraints with Euclid
- **KP-TH-2: Relativistic effects **(IT co-led)****
  - **KP-TH-2 P1** The impact of wide-angle, lensing, and the ‘finger of the observer’ effects on two-point statistics for the Euclid spectroscopic sample **(IT-WP led)** **(published in MNRAS)**
  - **KP-TH-2 P2** Euclid preparation - XIX. Impact of magnification on photometric galaxy clustering **(published in A & A)**
  - **KP-TH-2 P3** Euclid preparation: xx. Impact of lensing magnification on the spectroscopic sample of the *Euclid* mission
  - **SP-TH-[WP9]-P1** Relativistic effects beyond the  $\Lambda$ CDM model **(IT-WP led)**
  - **SP-TH-[WP9]-P2** Relativistic effects: the dipole of the correlation function **(IT-WP led)**
- **KP-JC-6: Simulations and non-linearities beyond LCDM **(IT co-led)****
  - **KP-JC-6 P1** Simulations and non-linearities beyond LCDM
  - **KP-JC-6 P2** Scientific results results from non-standard cosmological simulations
  - **KP-JC-6 P3** Cosmological constraints on non-standard cosmologies from simulated Euclid probes **(IT-WP Led)**
  - **KP-JC-6 SP1** Exact title TBD (MCMC constraints on extended cosmologies from Euclid photometric survey)

# Theory: Consortium Interfaces & Coordination

- Interfaces and coordination:

**SWG**s: mainly with Galaxy clustering, Weak lensing, Cosmological simulations (see WP 12 and joint pre-launch project) and CMBX;

**IST**: -Likelihood and -Nonlinear

# Theory: Status of Activities

- **KP Progress:**
  - A full day was dedicated to the status of KPPs and SPPs in the SWG meeting last October
  - Progress monitored by different KP and WP leads in WP dedicated and general telecons, also supervised by SWG leads
- **Contribution to CLOE:**
  - Interface with IST:L and IST:NL settled
  - New WP11 (Likelihood interface) co-lead appointed fully dedicated to CLOE implementations in the last fall
  - An heritage of models investigated with Fisher within pre-launch KPPs to be implemented in CLOE with manageable adjustments due to the evolving specifications/theoretical modelling
  - An internal release of CLOE v2.0 is needed to proceed
  - A clear schedule and wise choice of contents of IST:L KPPs is needed to better motivate work in the direction of CLOE implementation of cosmology beyond LCDM within TWG
  - Joint meetings and/or hands on meetings with IST:L would be highly desirable (was Heidelberg 2016 the only one organized?)
- **DR1**
  - The discussion of the science which could be extracted from DR1 has started in the last Theory meeting and is proceeding.



# CMBX: Organization

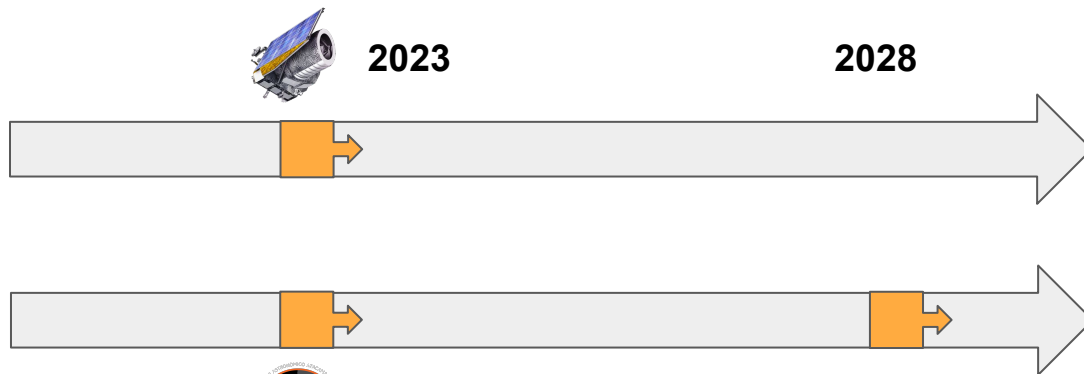
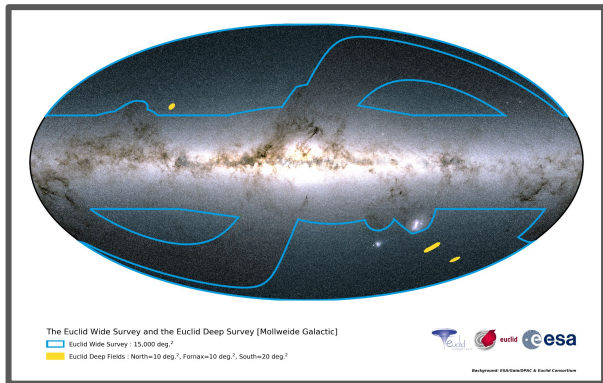
- **Members: 70% equally splitted between France, Italy, 15% in UK, 5% Germany, 3% Spain, 3% Switzerland , 3% the Netherlands, 1% US, Gender Balance at 20%**
- **Communications:**
  - **General bi-weekly zoom calls: 705 - 044 - 4609**
  - **WP dedicated calls: Likelihood, Simulations, ...**
  - **Wiki: [euclid.roe.ac.uk/projects/cxswg/wiki](https://euclid.roe.ac.uk/projects/cxswg/wiki),**
  - **Slack Channel: [euclid-cmbx.slack.com](https://euclid-cmbx.slack.com)**
- **Meetings:**
  - **Twice per year, Italy (fall), France (Spring)**
  - **Splinters at Consortia,**
  - **next one, in Marseille, March 23rd, 24th, 2023**

...

# CMBX: KP Plan

- **KP-CMBX-1: Forecasts for CMBX**
  - Paper 1.1: Forecasts validated on simulations [[Series to KP 2.2](#)]
  - Paper 1.2: Fisher based forecasts for cross-correlated Euclid and CMB data [[Published](#)]
  - Paper 1.3: Extended forecasts for CMBX [[Summer](#)] **IT-WP Lead**
- **KP-CMBX-2: Simulations for CMB-LSS cross-correlations**
  - Paper 2.1: Lightcone comparison project [[Published](#)]
  - Paper 2.2: CMBX Mock Simulations [[Spring](#)] **IT-WP Lead**
- **KP-CMBX-3: ISW-GC Cross-Correlation**
  - Paper 3.1: Estimators of the ISW-GC cross-correlation [[Spring](#)] **IT-WP Lead**
- **KP-CMBX-4: tSZ/CMBL-WL Cross-Correlation**
  - Paper 4.1: Estimators for tSZ-WL cross-correlation [[Series to KP 4.2, Link to CWG](#)]
  - Paper 4.2: Estimators for CMBL-WL cross-correlations [[Fall](#)] **IT-WP Lead**
- **KP-CMBX-5: tSZ/CMBL-GC Cross-Correlation**
  - Paper 5.1: Estimators for tSZ-GC cross-correlations [[Series to KP 5.2, Link to CWG](#)]
  - Paper 5.2: Estimators for CMBL-GC cross-correlations [[Fall](#)] **IT-WP Lead**
- **KP-CMBX-6: Estimators for the reconstruction of kSZ signal**
  - Paper 6.1: Methods for reconstructing the kSZ effect of galaxy clusters from Euclid-CMB cross-correlations [[Series to KPs 4.1, 5.1](#)]

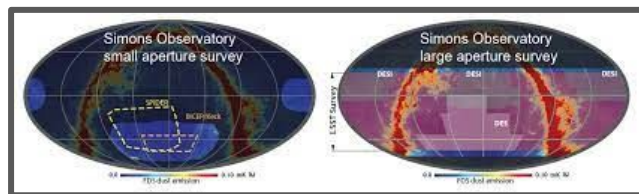
# CMBX: External Datasets



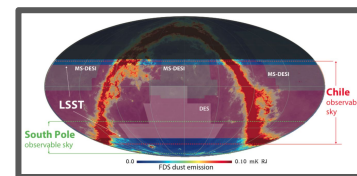
Simons Observatory



LiteBIRD



**CMB-S4**  
Next Generation CMB Experiment



# Activities and National WPs

## Activities

- Aosta: CMB-N-Body & Ray Tracing, Simulations and Analysis
- Trieste: Analysis of CMB-N-Body Simulations
- Milano: Production of CMB-N-Body & Ray Tracing Simulations, Analysis
- Padova: Implementation of Estimators, Analysis, Theory
- Ferrara: Implementation of Estimators & Likelihood
- Bologna: Production of CMB-N-Body Simulations, Analysis, Estimators & Likelihood, Theory
- Rome: Productions of Estimators & Likelihood, Simulations, Analysis



## National WPs:

- Trieste [ASI-INAF, Baccigalupi]: Simulations
- Milano [INFN, Guzzo]: Simulations, Estimators & Likelihood
- Padova [INFN, Stanco]: Estimators & Likelihood
- Ferrara [ASI-INAF-INFN, Lattanzi, Natoli], Estimators and Likelihood
- Bologna [ASI-INAF, INFN, Finelli, Sirri]: Estimators & Likelihood, Simulations, Theory
- Support for Computing Facilities (INFN)

# CMBX: Status of Activities

- **KP Schedule:**
  - Drafting 1.3, 2.2, 3.1,
  - Starting 4.2, 5.2
- **Increasing Integration:**
  - e2e Simulation Pipeline Finalizing,
  - Estimators are Operational (ISW-G), Implemented (CMBL-Main Probes)
  - Likelihood Modules under Implementation
- **Robust Interfaces through Group Members:**
  - Simulation WG,
  - IST-L,
  - IST-NL,
  - Clusters,
  - Theory,
- ...
- **Near Term Goals:**
  - Delivering KPs,
  - Completing Sets of Estimators & Validation on e2e Simulations,
  - Interface with SGS Objects,
- **Interface with CMB Probes:**
  - Science Oriented, Performance Assessments in Papers, see KP1.2
  - Using Public Objects, see KP1.2,
  - Cross-Membership with CMB-S4, LiteBIRD, LSPE, SO,
  - Consortium Level
- **Meetings:**
  - Orsay, March 23rd, 24th
  - Splinter at Consortium Meeting
- ...

# Pre-Launch Considerations

- **Completion of Pre-Launch KP Plan**
  - Capitalizing Significant Leadership of the Italian Community
  - Charting Inter-WG KPs
  - Discussing Post-Launch KPs,
  - Transition to Analysis Tools, Support to OUs, SGS,
  - ...
- **Coordination**
  - Success of the Consortium through the Italian Community
  - Areas of Improvement: OUs, SGS, Possibility for Discussing Stable Links
  - Plan for Hand-On Joint Meetings?
  - ...
- **Common Interfaces & Needs: Numerical Simulations**
  - Simulations are Supported through CINECA
  - Study Plan for post-Launch Support for Calculus
  - Catalogue of non-Standard Cosmological Simulations: Marco Baldi's [non-Standard Cosmologies Simulation Chart](#),
  - ...
- ...