# Map-making, power spectrum and likelihood tools (a survey)

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many inputs from
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# Map-making, PS and likelihood

- Various independent activities in the last years. Mainly to characterize systematic effects and propagate them to cosmological parameters
- Simple approaches adopted
  - **binning map-making**
  - **Pseudo-$C_l$**
  - **exact likelihood (fullsky, white noise)**
- New group just created, lead by Yuji Chinone.
- Objectives (email sent last wednesday)
  - “define **the guidelines** to be met when **establishing requirements and making recommendations for the tools**”
  - “assess "off-the-shelf" **packages available within the LiteBIRD Collaboration** and the general CMB community, and **determine their suitability for the task at hand**”
  - “In the long-term, **dedicated R&D** will seek **to improve on these tools or develop new tools to meet LiteBIRD-specific requirements**, i.e. scientific requirements, feasibility, computational resources and in terms of ease-of-integration into the LiteBIRD frameworks”

# Map-making - current status

- What is available at hand?
  - Binner
    - **Natively implemented** in lbs
  - Madam
    - **Destriper** built for Planck, used for LFI and, with few changes, for NPIPE analysis
    - “Interfaced” with lbs. lbs produces inputs files for madam in the proper format then the map-maker is called as external code
    - Used in the **post-PTEP simulations**
    - Library with python interface available. Interface provided through toast
  - Toast map-maker (see next slide)
- Other approaches:
  - **GLS implementation** with SANEPIC
    - Used in BLAST, PACS, SPIRE, HFI
    - Used in PTEP paper for HWP systematic studies
  - Commander
    - **running on post-PTEP simulations**

# Map-making - options

- Toast map-maker
  - Implemented in Toast2
  - Implements a **destriper and supports for systematics templates**
  - Ibs interface coded, some debug still necessary
- dacapo
  - Implementation of the **calibration algorithm used in LFI**
  - **Calibration + destriper map-maker**
  - Python interface available
  - Ibs interface missing but easily achievable (local expertise)
- ROMA
  - **GLS implementation**
  - Developed for BOOMERanG and Planck, used for Hi-GAL and SWIPE simulated data
  - Ibs interface missing (local expertise)

# Map-making - activities

- From Yuji's email:
  - "What is the **optimal map-maker to achieve enough sensitivity at lower ell ranges with continuously rotating half-wave plates**? Is there any difference: **map-making after demodulation or map-making by solving the map-making equation w/ modulation information**? Which is better?"
- Priorities:
  - Have at **least a destriper and GLS implementation** stably interfaced with lbs
    - toast map-maker and/or libmadam (directly or through toast)
    - Consider the options we have for the GLS. Preferably ROMA
  - Start **development/optimization activity**
- A small group already formed for pursue this activity:
  - Avinash, Giuseppe, Maurizio, Marco, Nicolò, Margherita, Thejs, PaoloC, PaoloN, Luca
- Specific task on LiteBIRD map-making within the Spoke 2 Centro HPC
  - People involved Thejs (RTDa), Paolo, Luca

# Power spectrum - status and options

- What is available at hand?
  - cROMAster
    - Implements the **Master algorithm**. Developed for **BOOMERanG** and **Planck**
    - No interface with python. **No pure implementation**
    - Competitors: NaMaster (widely used in LiteBIRD), PolSPICE (use in Planck)
  - BolPol.
    - Implements the **QML** algorithm for the **auto-spectrum**.
  - pse_qml.
    - Implements the **QML** algorithm for the **auto and cross-spectrum**.
  - Loris' QML
    - Implements the **QML** algorithm with the **SMW approximation**
- Common issues:
  - Lack of **high level interface**
  - No **documentation**
  - Not **public** (except pse_qml and Loris' QML)

# Power spectrum - activities

- From Yuji's email:
  - "Which type of power-spectrum approach is suitable for LiteBIRD, **auto spectrum vs. cross spectrum**? How do we **estimate noise bias** precisely for the auto spectrum? Which kind of data splits are useful to mitigate certain systematics in cross-spectra?
  - Which kind of power-spectra estimator is **optimal for the cross-correlation** of these splits? Which kind of estimator is more adequate for LiteBIRD  for a given ell-range and accuracy demand? E.g., **pseudo-Cl, pure-Cl, QML** (auto- vs cross-)."
- Priorities:
  - Select one or two codes on which we want to invest development time. Mainly for: **high level interface**, **documentation** and **public release**
  - **QML** seems the most **promising candidate** for this
  - Compete with NaMaster is difficult. But having a modern interface for cROMAster and a public repository might be valuable

# Likelihood - status and options

- What is available at hand?
  - Several implementations of **exact likelihood**
    - Suited for estimating biases on cosmological parameters
  - **Pixel-Based** implemented for Planck
    - For reionization peak
    - Requires estimation of noise covariance
- Hybrid likelihood, combining reionization and recombination peaks
- Options:
  - **Multi-frequency $C_l$ likelihood**
  - **$C_l$ likelihood on component separated maps**
  - **Map based likelihood on component separated maps**
  - **Likelihood free inference** (e.g. NN)

# Likelihood - activities

- From Yuji's email:
  - "Which **interfaces** should be prepared **between component separation and map-making, power-spectra estimator, and likelihood**? **map-based** component separation, **power-spectra-based component separation**?"
  - "Which **likelihood algorithms are best for LiteBIRD**, Gaussian approximation, (Q)ML, or (Bayesian) sampling? Depending on ell ranges?"
- Priorities:
  - Build a **pipeline for multi frequency cross-$C_\ell$ likelihood** based on HL (Gaussian) approximation, for r estimation
  - Build a **pipeline for $C_\ell$ likelihood based** on HL (Gaussian) approximation, for both τ and r