DE LA RECHERCHE À L'INDUSTRIE





# Galaxy clusters

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Towards a next space probe for CMB observations and cosmic origins exploration 2016 May 19



### Hot gas

## Dark matter



 few % of total mass
 15 %
 80 %

Optical	X-rays, CMB	Indirect
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### Hot gas

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 few % of total mass
 15 %
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Optical X-rays, CMB Indirect



dust

### Hot gas

### Dark matter



SZ

few % of total mass 15 %

CMB halo lensing

80 %

# M4 proposal (60-800 GHz, 1.5m tel.)



# COrE+: Cluster Science The COrE+ Collaboration, Jean Baptiste Melin, James G. Bartlett, ...

Received ; accepted

#### ABSTRACT

This is the abstract.

Key words. Galaxy Clusters

#### 1. Introduction

Link to Mission and Instrument paper.

Study the *COrE*+ only and the *COrE*+ + CMB-S4 cases.

#### 2. Simulations

Link to the simulation paper.

### Improvement of the SZ component of the Planck Sky Model is required

Need for simulations of *COrE*+ missions (e.g. baseline and extended) + associated CMB-S4 maps (with realistic atmospheric noise included) Need to include other emissions than SZ for the clusters: dust.

#### 3. The cluster catalogue

### This section will contain thermal SZ and relativistic thermal SZ studies

Describe how the clusters are detected from the simulations  $\rightarrow$  use Planck algorithms.

Characterize the selection function of the catalogue.

# 4. Cosmological constraints from the *COrE*+ cluster catalogue

Fisher constraints assuming the selection function determined in Sect. 3.

#### 5. Cluster Mass Estimation

Link to the lensing paper.

## This section will contain cluster CMB lensing studies and comparison with Euclid shear studies

How well can we measure individual/stacked masses using CMB lensing with *COrE*+? see e.g. Melin & Bartlett (2015)

Compare Euclid shear measurements of COrE+ clusters with COrE+ CMB lensing measurements. Which one is better ? For which redshift range ?

#### 6. Velocity fields

#### This section will contain kinetic SZ studies

At which scale can we reconstruct the velocity field with COrE+? Bulk flow studies. Radial: thanks to the kSZ (individual and stacking)

Transverse: thanks to the polarized SZ (stacking only but how to determine the direction of the velocities?). The transverse velocity determination with the polarized SZ seems hope-

# **Context and Major topics**

- COrE and COrE & CMB-S4 cases
- More than just the gas (SZ) → dust and total mass
- Astrophysics

   z>1 & z>2 samples, space and space & ground?
   z>2 sample, gas and dust interplay in proto-clusters
- Cosmology cluster counts (sensitivity to uncertainties on Y-M normalization and evolution)
- Impact of telescope size (1.2 vs. 1.5 vs. 1.8m)
   [P. de Bernardis talk on Wednesday morning]

# **Additional topics**

• Astrophysics

z>1 & z>2 samples, space and space & ground? z>2 sample, gas and dust interplay in proto-clusters **cluster masses (M**<sub>500</sub>)

Cosmology

cluster counts (sensitivity to uncertainties on Y-M normalization and evolution) velocites (kSZ) T<sub>CMB</sub>(z)

 Synergy with other experiments (eROSITA, Euclid, LSST, WFIRST, Athena) M. Remazeilles J. Delabrouille J.-B. Melin

# **PSM simulations**

### Baseline COrE "SZ" simulations 60-800 GHz 1.5m tel.

Maps

http://www.jb.man.ac.uk/~cdickins/exchange/bpol\_sims/Mathieu/SZ/core+\_v4\_SZ\_sim\_v2/

SZ inputs

http://www.jb.man.ac.uk/~cdickins/exchange/bpol\_sims/Mathieu/SZ/core+\_v4\_SZ\_sim/components/sz/



- Astrophysics Need additional PSM CMB-S4 maps
   z>1 & z>2 samples, space and space & ground?
   z>2 sample, gas and dust interplay in proto-clusters
   cluster masses (M<sub>500</sub>)
- Cosmology
  - cluster counts (sensitivity to uncertainties on Y-M normalization and evolution) velocites (kSZ)  $T_{CMB}(z)$
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- Astrophysics

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Dust in clusters



(0.0, 90.0) Galactic

- Astrophysics z>1 & z>2 samples, space and space & ground? z>2 sample, gas and dust interplay in proto-clusters cluster masses (M<sub>500</sub>)
  - Cosmology
    - cluster counts (sensitivity to uncertainties on Y-M normalization and evolution) velocites (kSZ)  $T_{CMB}(z)$
  - Synergy with other experiments (eROSITA, Euclid, LSST, WFIRST, Athena)

# Cluster masses (CMB halo lensing)



See J. Bartlett's talk

• Astrophysics

z>1 & z>2 samples, space and space & ground? z>2 sample, gas and dust interplay in proto-clusters cluster masses (M<sub>500</sub>)

Cosmology

cluster counts (sensitivity to uncertainties on Y-M normalization and evolution)

velocites (kSZ)  $T_{CMB}(z)$ 

• Synergy with other experiments (eROSITA, Euclid, LSST, WFIRST, Athena)

# **Cluster detection probability**



- Astrophysics z>1 & z>2 samples, space and space & ground? z>2 sample, gas and dust interplay in proto-clusters cluster masses (M<sub>500</sub>)
- Cosmology

cluster counts (sensitivity to uncertainties on Y-M normalization and evolution)

velocites (kSZ) C. Hernandez-Monteagudo?

T<sub>CMB</sub>(z)

• Synergy with other experiments (eROSITA, Euclid, LSST, WFIRST, Athena)

- Astrophysics z>1 & z>2 samples, space and space & ground? z>2 sample, gas and dust interplay in proto-clusters cluster masses (M<sub>500</sub>)
- Cosmology
  - cluster counts (sensitivity to uncertainties on Y-M normalization and evolution)
  - velocites (kSZ)

 $\frac{T_{CMB}(z)}{G_{L} uzzi}$ C. Martins R. G. Santos

Synergy with other experiments (eROSITA, Euclid,

LSST, WFIRST, Athena)

# **Conclusions**

- Work on the cluster science paper recently restarted
- All-sky PSM simulations (with up-to-date SZ component) are now available for the baseline (1.5m) configuration. Soon for 1.2 and 1.8m configurations + CMB-S4
- Astrophysical and cosmological questions (sample characterization @ z>1 and z>2, cosmological constrains)
- Still a lot of work to do and science to explore. Volunteers welcome !