CMB projects for Voyage 2050

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(with inputs from Kaustuv Basu, Jens Chluba, Jean-Baptiste Melin, Mathieu Remazeilles)

On behalf of the Voyage 2050 CMB proposers

The Context : ESA science in 2035-2050

Voyage 2050 » Ho...

- Home
- Workshop registration
- Workshop programme
- Workshop: second announcement
- White Papers
- Senior Committee
- Call for Membership of Topical Teams
- Call for White Papers

VOYAGE 2050
LONG-TERM PLANNING OF THE ESA SCIENCE PROGRAMME

SCHEDULE FOR THIS CALL AND IMPORTANT DATES

Activity	Date
Senior Committee appointed	December 2018
Call for Membership of Topical Teams issued	4 March 2019
Call for White Papers issued	4 March 2019
Deadline for receipt of applications for Topical Team membership	6 May 2019, 12:00 (noon) CEST
Topical Team members appointed	July 2019
Deadline for receipt of White Papers	5 August 2019, 12:00 (noon) CEST
Workshop to present White Papers	**29 - 31 October 2019**
Topical Teams report to Senior Committee	February 2020
Senior Committee recommendations to Director of Science	Mid-2020

DOCUMENTATION

Letter of Invitation - White Papers (pdf)

Letter of Invitation - Topical Team membership (pdf)

Call for White Papers (pdf)

Call for Membership of Topical Teams (pdf)

The Context : outcome of the process

This process will decide what science will be done by the three next L-class missions!

The Director of Science has appointed the Senior Committee to guide the Voyage 2050 process. This Committee, composed of scientists working in institutions in ESA Member States, is tasked to:

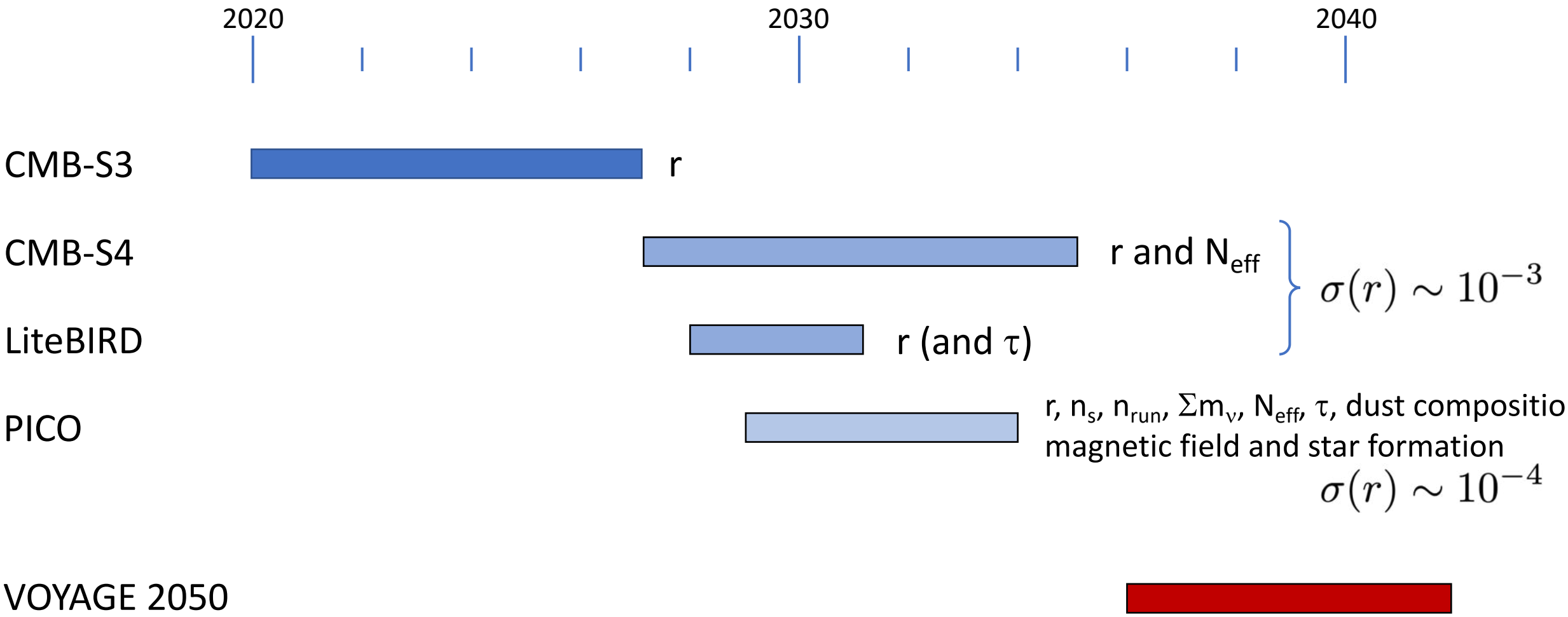
1. Recommend to the Director of Science the three science themes of the three L missions that will be part of the plan.

2. Identify a number of high-impact science themes that could be implemented through an M mission during the plan's time span. The actual M missions will be decided through open calls for missions issued in due time to retain flexibility in the Science Programme. However, the early identification of themes of interest will help the Agency in, e.g., developing key technologies.

But we are not asked for mission proposals!

White Papers are not proposals for specific missions; they should rather argue why a specific scientific theme should have priority in the Voyage 2050 planning cycle. At the same time, and to ensure realism in the resulting Programme, applicants should briefly illustrate possible mission profiles.

The Context : Ongoing and proposed efforts



Requirements / goals

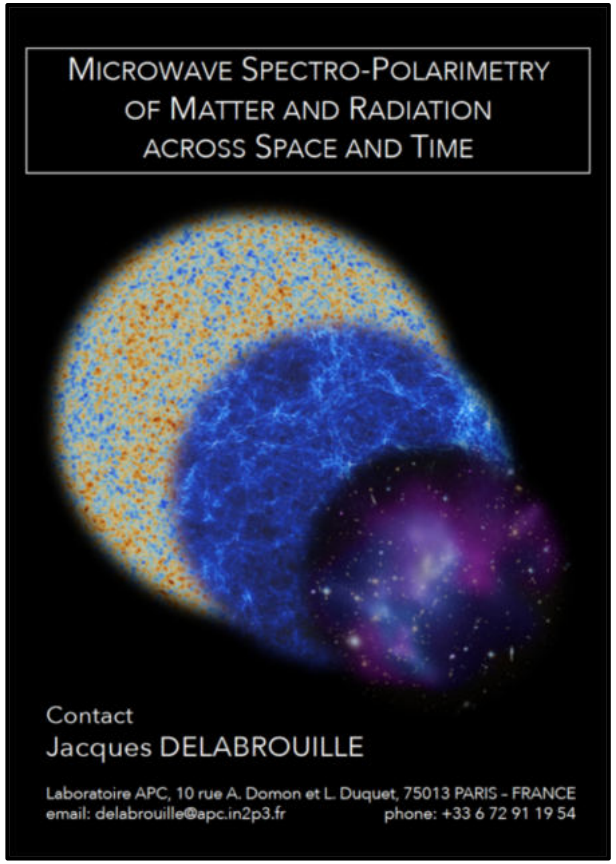
The proposed science programme must be attractive in 2035 for any scenario !

If primary B-modes are not detected it must make the ultimate attempt…

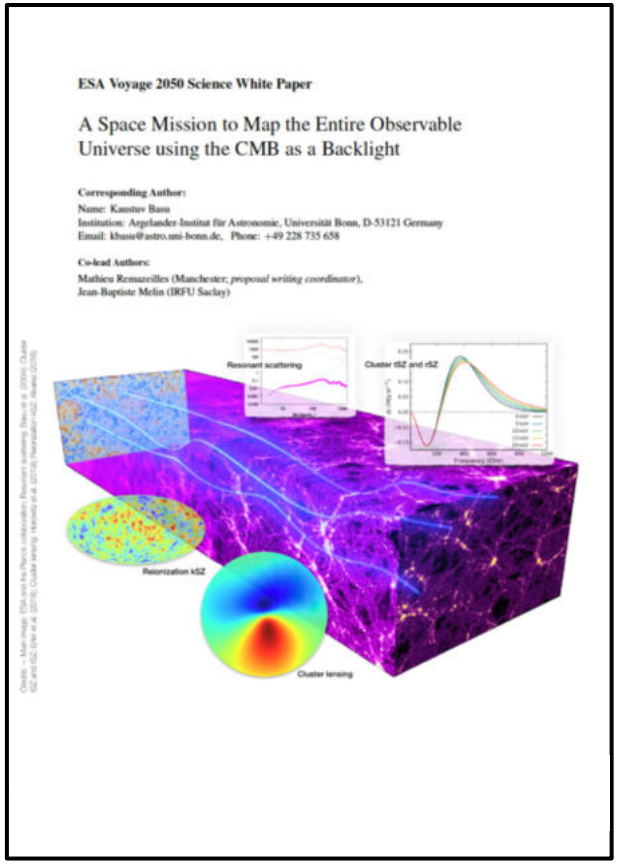
But this cannot be the main science goal (too uncertain)

- Go deeper than CMB-S4 over the full sky
- Get better angular resolution than PICO
- Do high angular resolution spectroscopy
- Do full-sky absolute spectroscopy
- Survey the full sky and ultra-deep patches

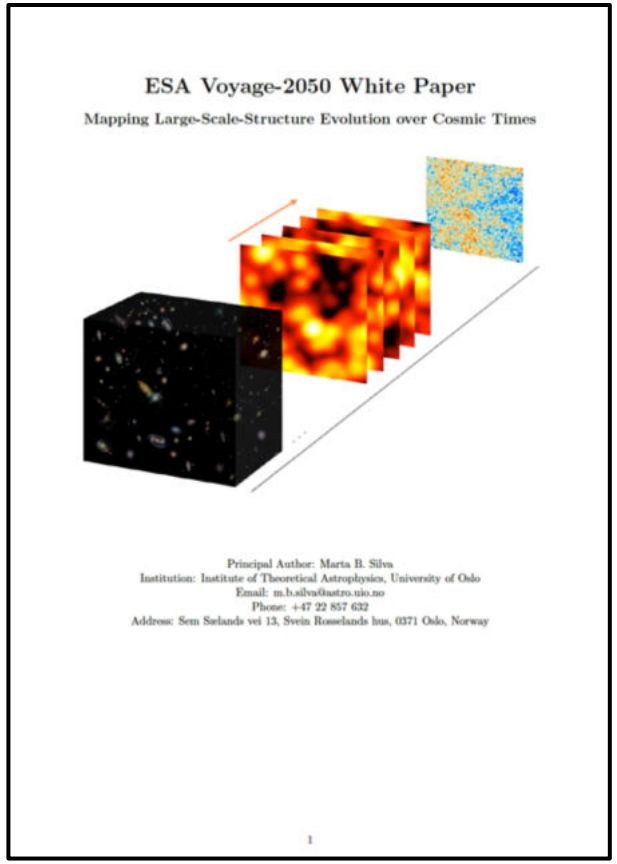
Four coordinated "CMB" white papers



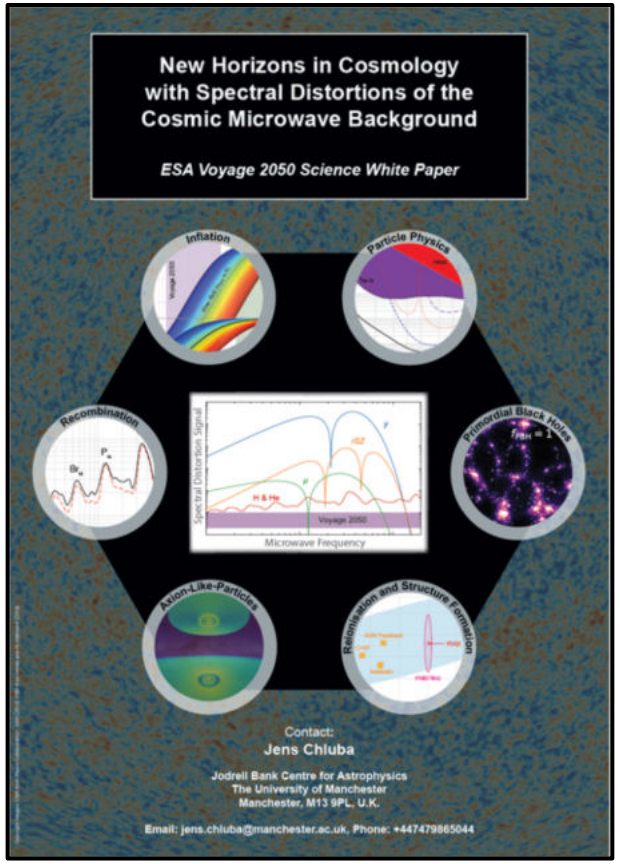
Microwave survey
Jacques Delabrouille et al.



CMB Backlight
Kaustuv Basu et al.



High redshift LSS
Marta Silva et al.



Spectral distortions
Jens Chluba et al.

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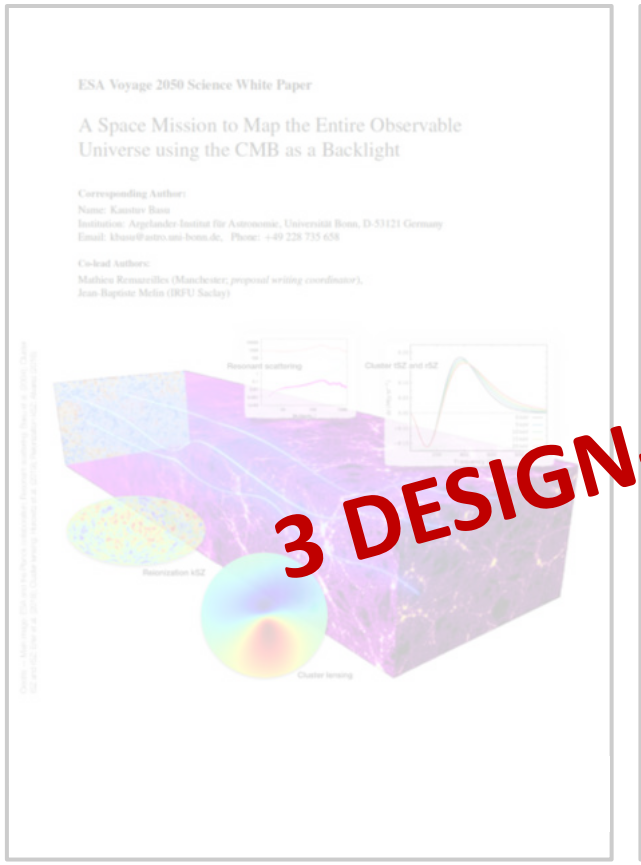

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3 DESIGN-DRIVING SCIENCE CASES

Read the papers (available on arXiv)

2019arXiv190901593C 2019/09

New Horizons in Cosmology with Spectral Distortions of the Cosmic Microwave Background

Chluba, J.; Abitbol, M. H.; Aghanim, N. *and 27 more*

2019arXiv190901592B 2019/09

A Space Mission to Map the Entire Observable Universe using the CMB as a Backlight

Basu, Kaustuv; Remazeilles, Mathieu; Melin, Jean-Baptiste *and 22 more*

2019arXiv190901591D 2019/09

Microwave Spectro-Polarimetry of Matter and Radiation across Space and Time

Delabrouille, Jacques; Abitbol, Maximilian H.; Aghanim, Nabila *and 77 more*

2019arXiv190807533S 2019/08

Mapping Large-Scale-Structure Evolution over Cosmic Times

Silva, Marta B.; Kovetz, Ely D.; Keating, Garrett K. *and 6 more*

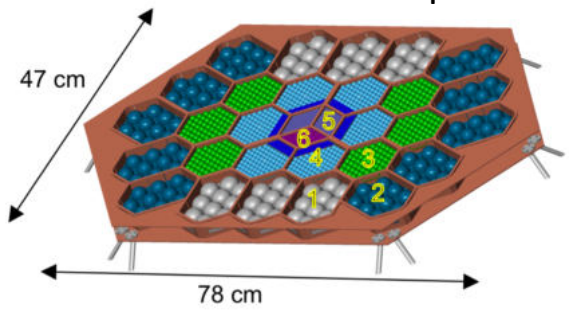
Large telescope for imaging and spectroscopy

Large (~3.5m) cold telescope with 2 focal plane instruments

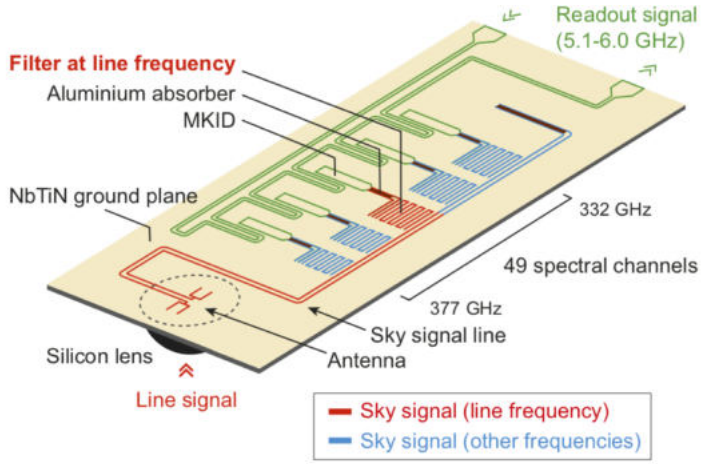
- A broad-band polarised imager optimised for CMB lensing and SZ science

	CMB sensitivity (μK.arcmin)	SZ sensitivity (*y*.arcmin)
full-sky 2 years	0.66	1.7×10^{-7}
5% sky 6 months	0.29	7.7×10^{-8}

PICO focal plane



- A spectrometer for mapping line emission



- Possibility of an additional guest instrument

- Must be an L-class mission

Absolute spectrometry

One or more small FTS modules

- Zero-level of intensity maps
- CMB spectral distortions
- Can be on a separate platform

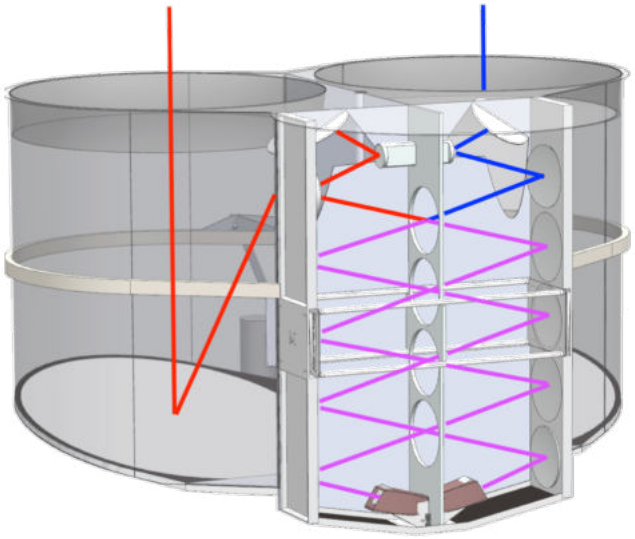


Table II: Multi-module absolute spectrometer; The mission sensitivity in the last column assumes 70% useful data and a 6-year mission.

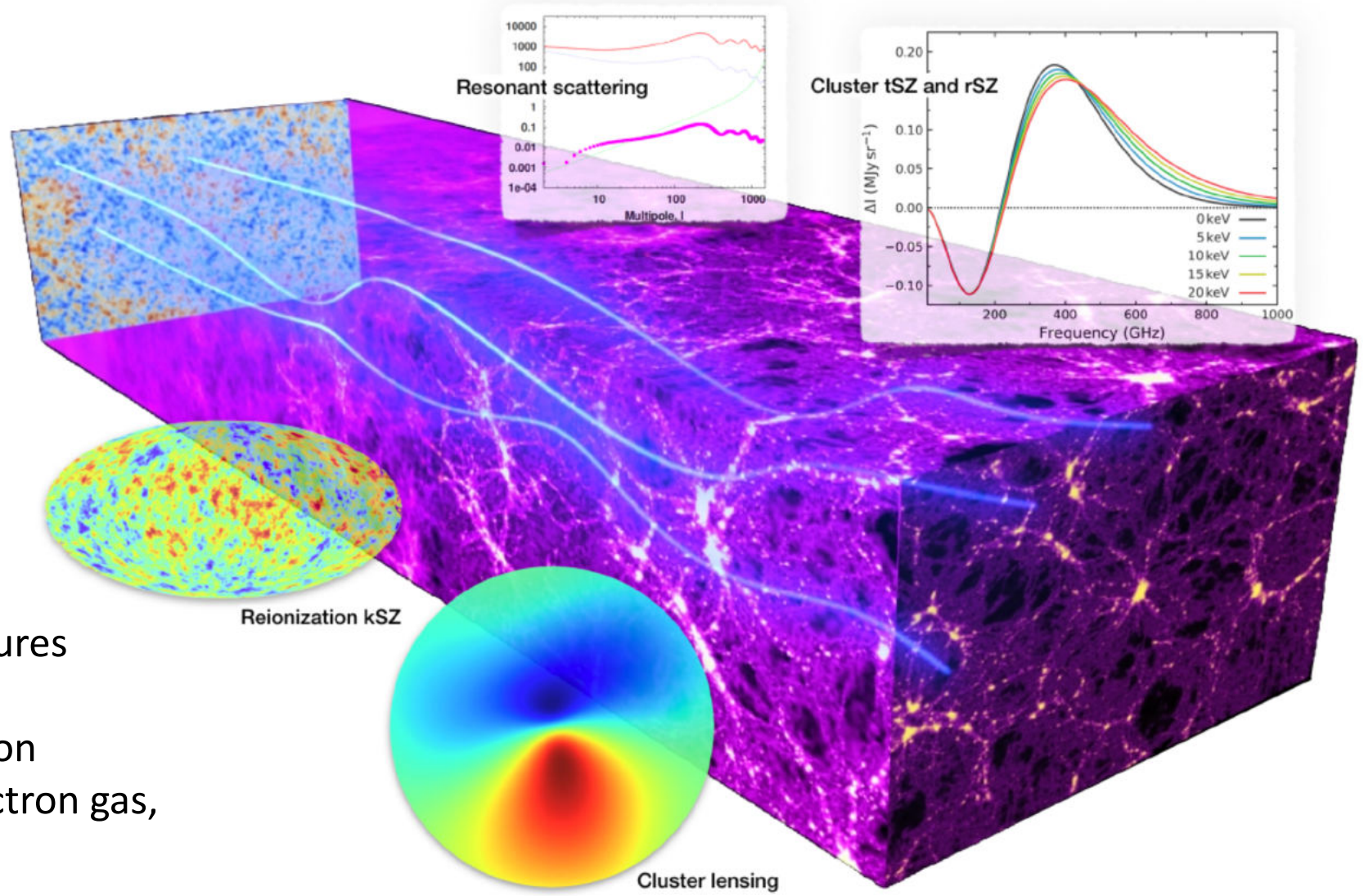
Module	$\nu_{\min}$ (GHz)	$\nu_{\max}$ (GHz)	$\Delta\nu$ (GHz)	Sensitivity (Jy.$\sqrt{s}$)	Mission sens. (Jy sr^{-1})
LFM	9.6	38.4	2.4	1435	0.12
MFM	20	600	20	6200	0.54
HFM	406	2000	58	2520	0.22

Observation modes

Optimize the spread of observing time

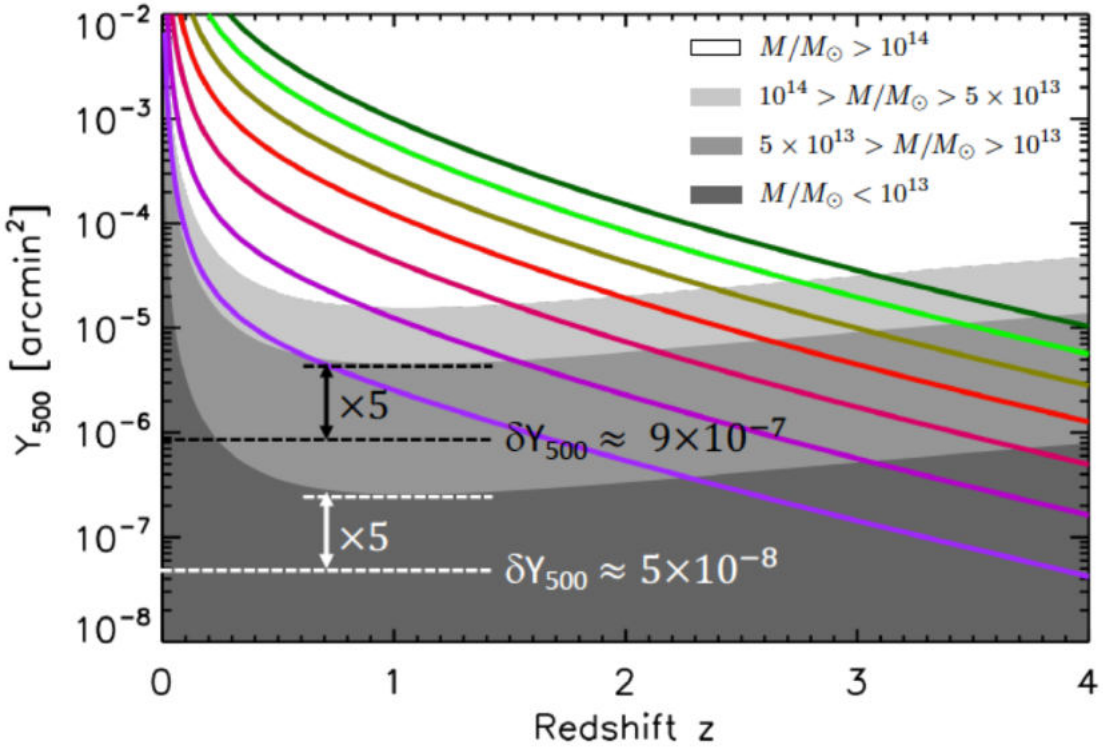
- Full sky survey for part of the mission lifetime
- Deeper survey of selected wide areas for part of the time
- Deep patches in observatory mode for part of the time

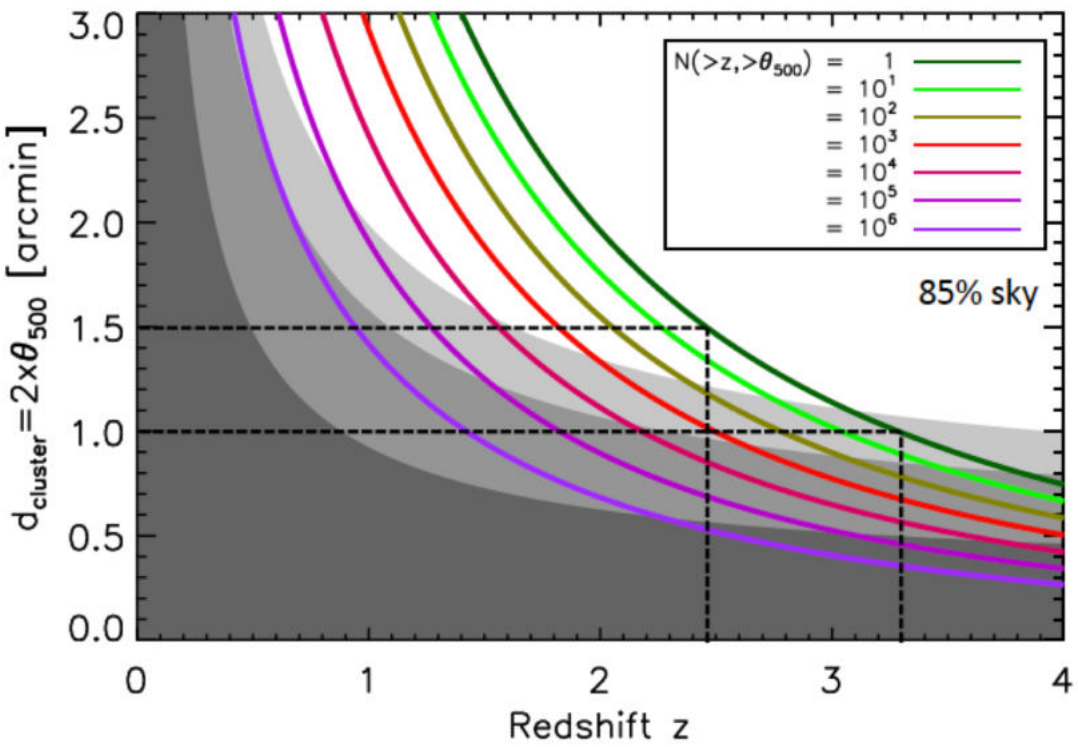
Backlight



The CMB is a backlight
that interacts with structures
in many different ways,
and probes the distribution
of mass, of atoms, of electron gas,
and of velocity flows
in the full Hubble volume.

Basu et al., Voyage 2050 White Paper





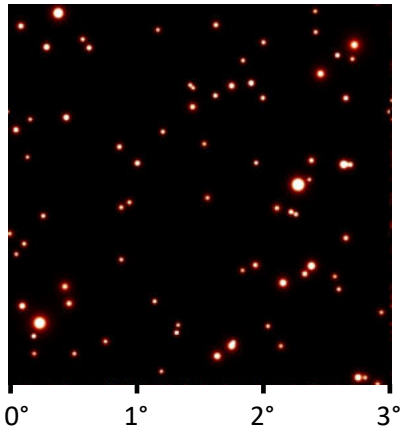
	SZ sensitivity (*y*.arcmin)
full-sky 2 years	1.7 x 10^{-7}
5% sky 6 months	7.7 x 10^{-8}

	Angular resolution
320 GHz	1 arcmin
220 GHz	1.4 arcmin

Ground complementarity for angular resolution <220 GHz

SZ and CIB confusion (even at 150 GHz)

Clusters only
$M > 10^{14} M_{sun}$



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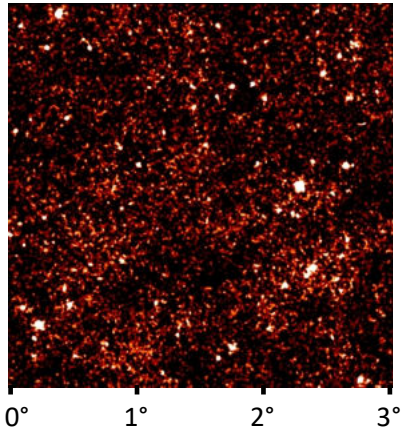
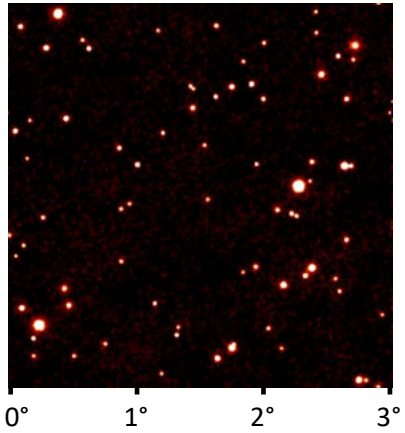
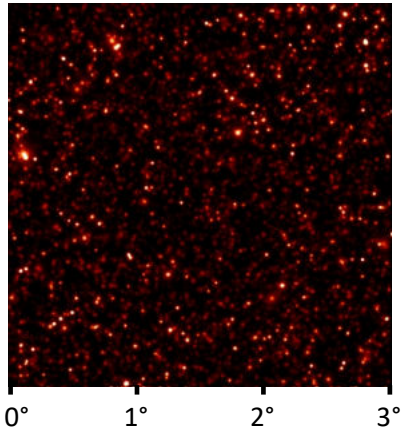


Clusters and 20% CIB
$M > 10^{14} M_{sun}$



Clusters only
$10^{14} M_{sun} > M > 5.10^{13} M_{sun}$



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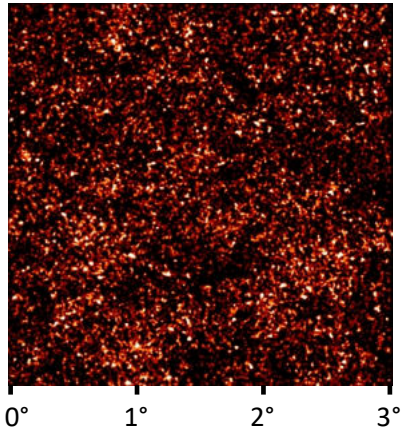

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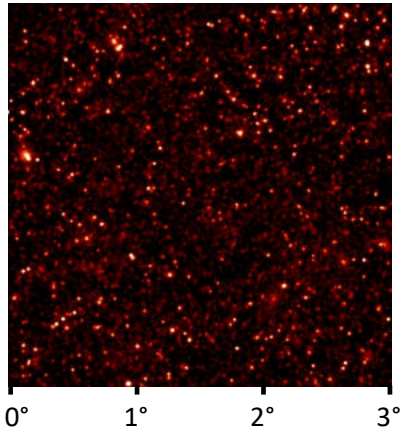
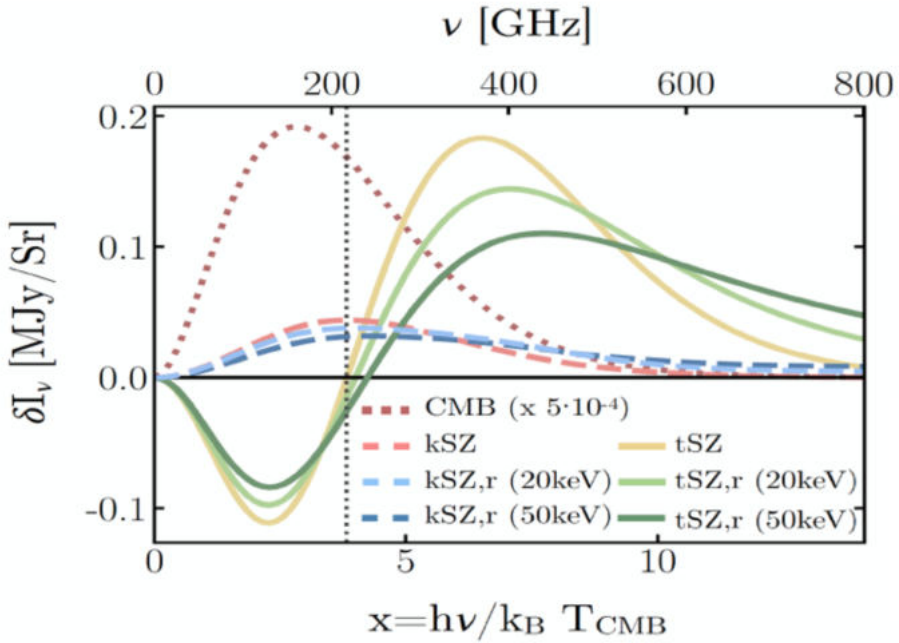


Need to reduce the level of CIB contamination by a factor of 5 at least (better for kSZ and for rSZ)…

+ Multifrequency signals of interest



Basu et al., Astro2020 White Paper

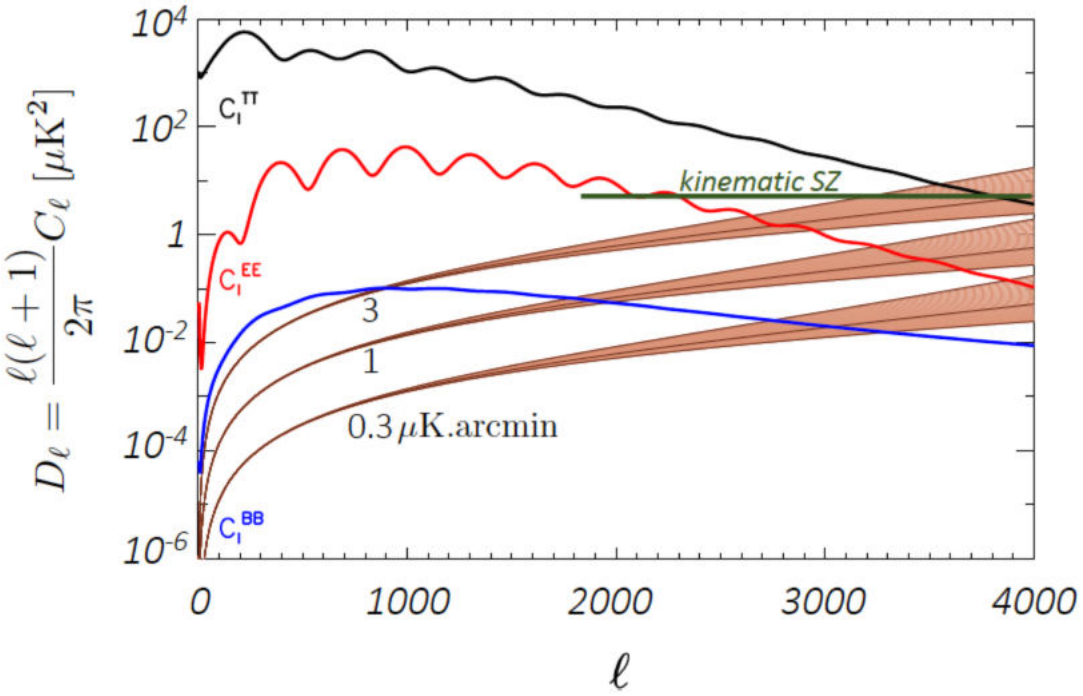
Requirements

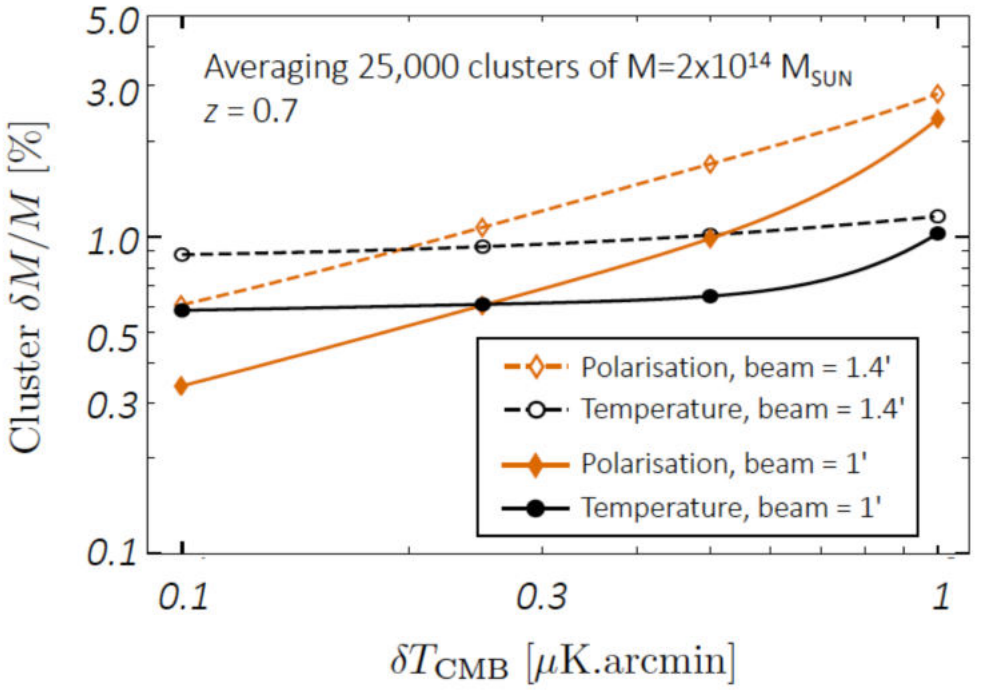
We need sensitive channels
above 300 GHz

We need many frequency channels

Possible only from space !

Measuring cluster velocities and masses





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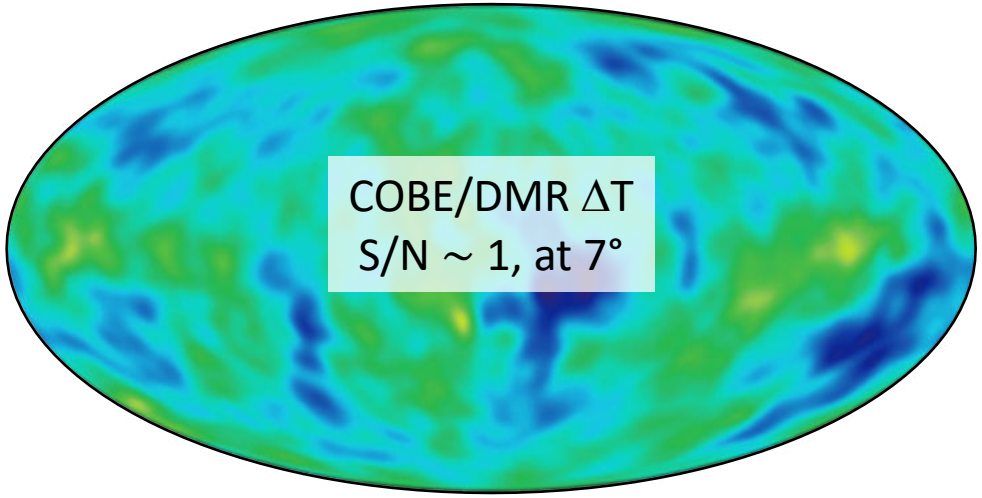
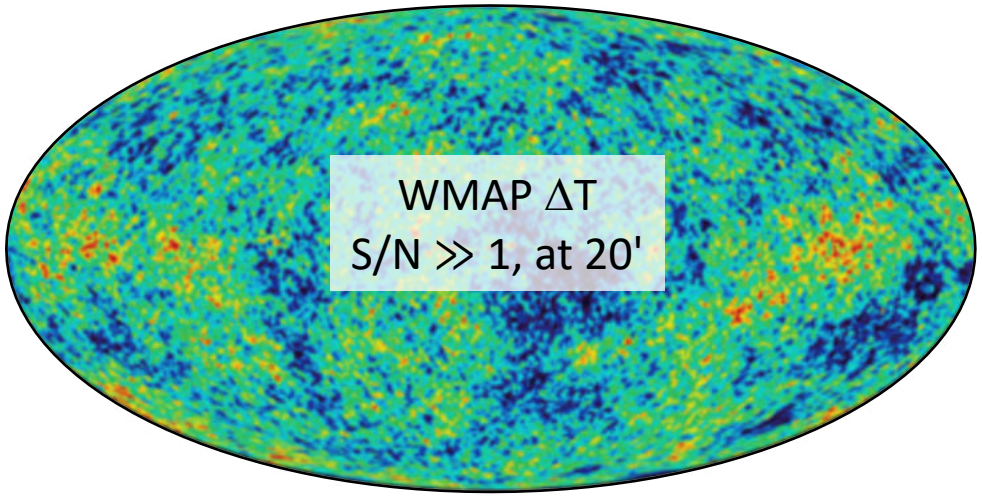
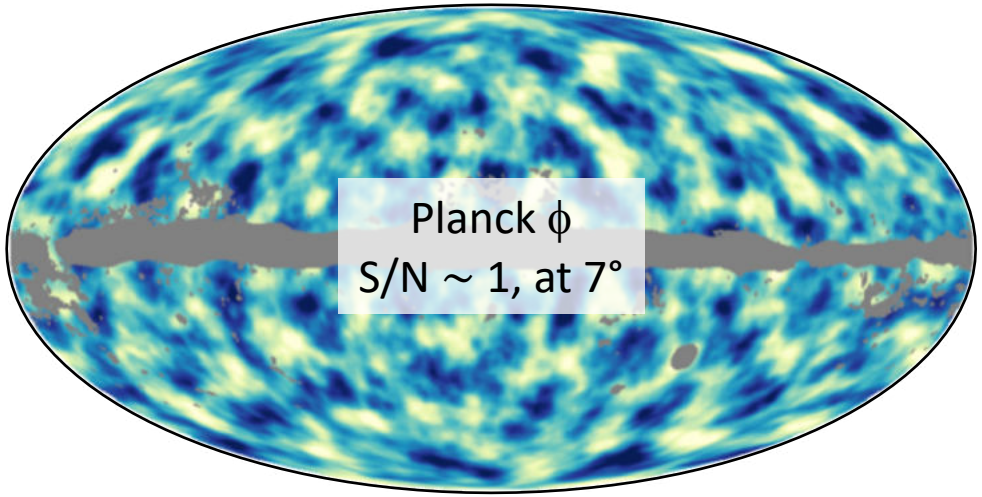
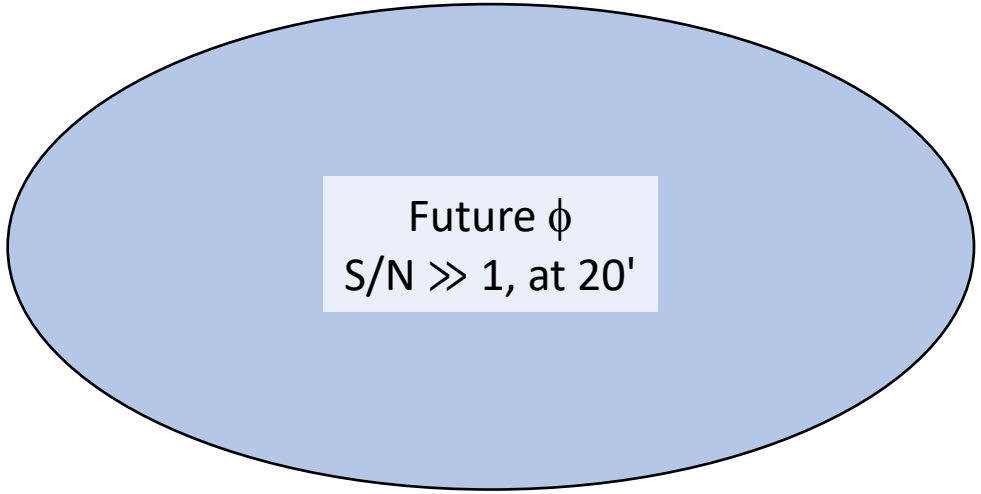
Mapping the Dark Matter



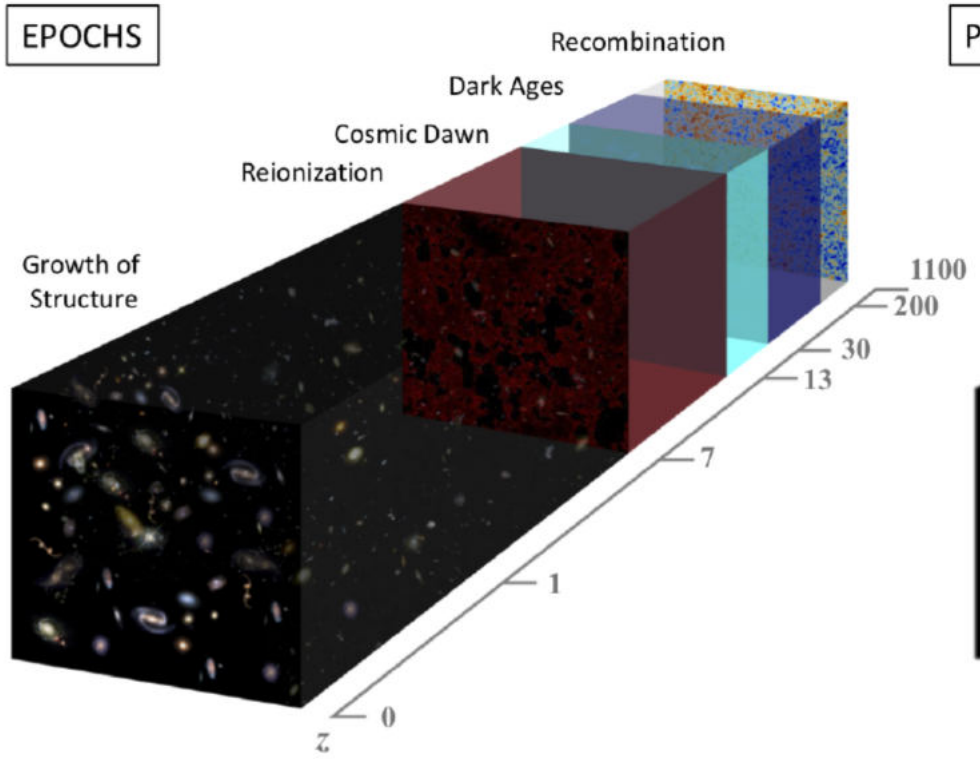


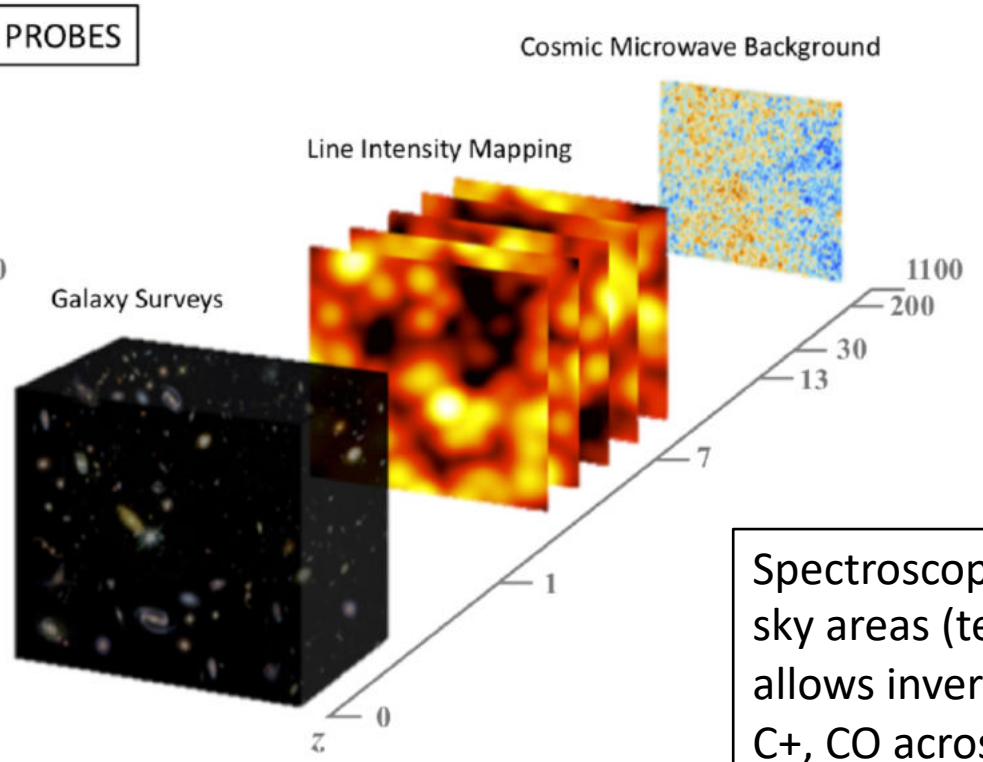




CIB tomography, Line Intensity Mapping

LIM gives access to "emission shells" for cosmological constraints across cosmic time.
(e.g. handle on cosmic expansion at high redshift)

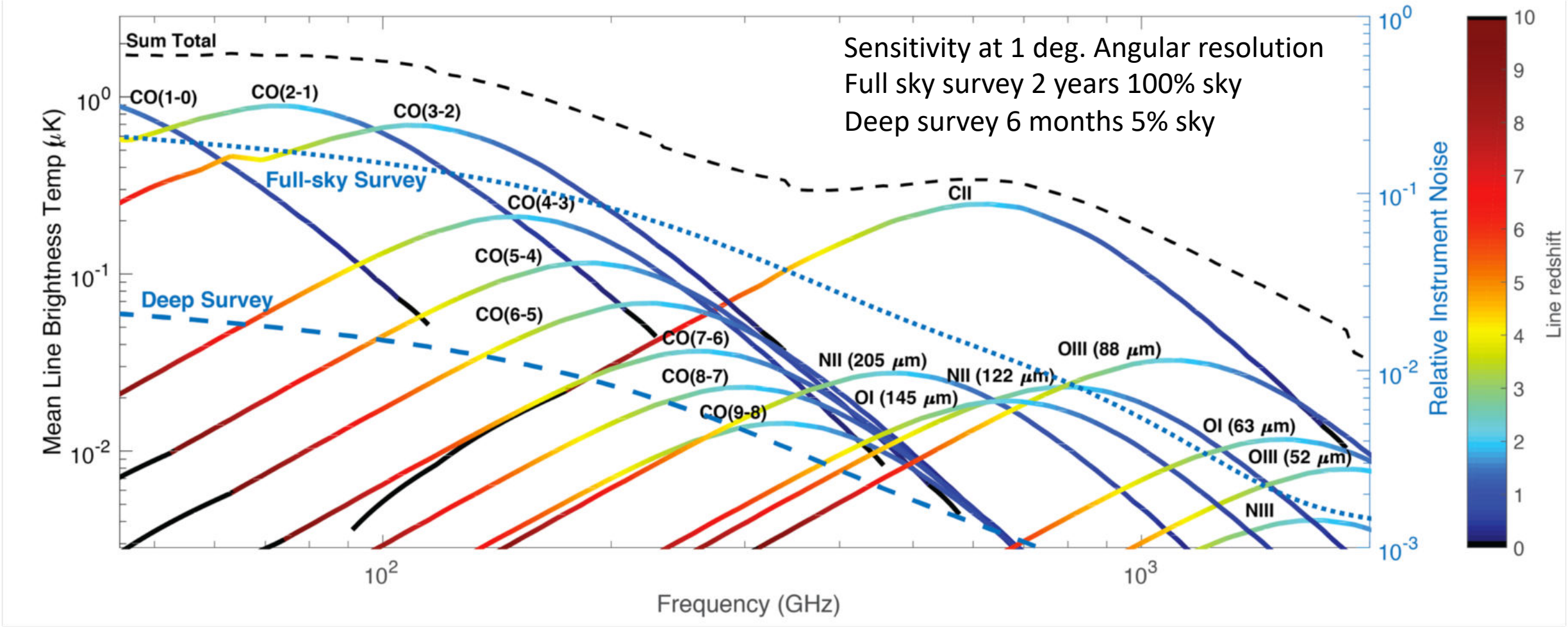




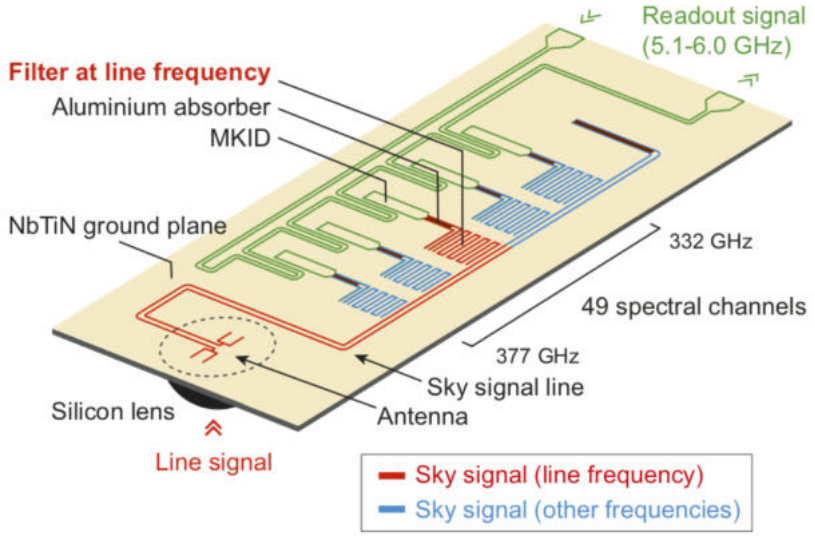
Spectroscopy on large sky areas (tens of %)
allows inversion $\nu \rightarrow z$
C+, CO across cosmic time
CIB in redshift shells

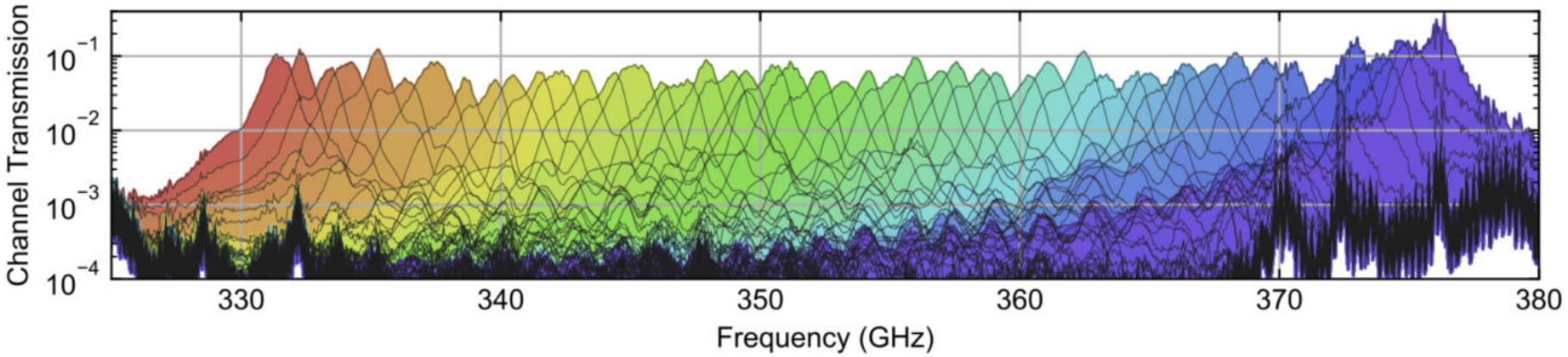
Kovetz et al., Astro2020 White Paper)

CIB tomography, Line Intensity Mapping



On-chip spectrometers

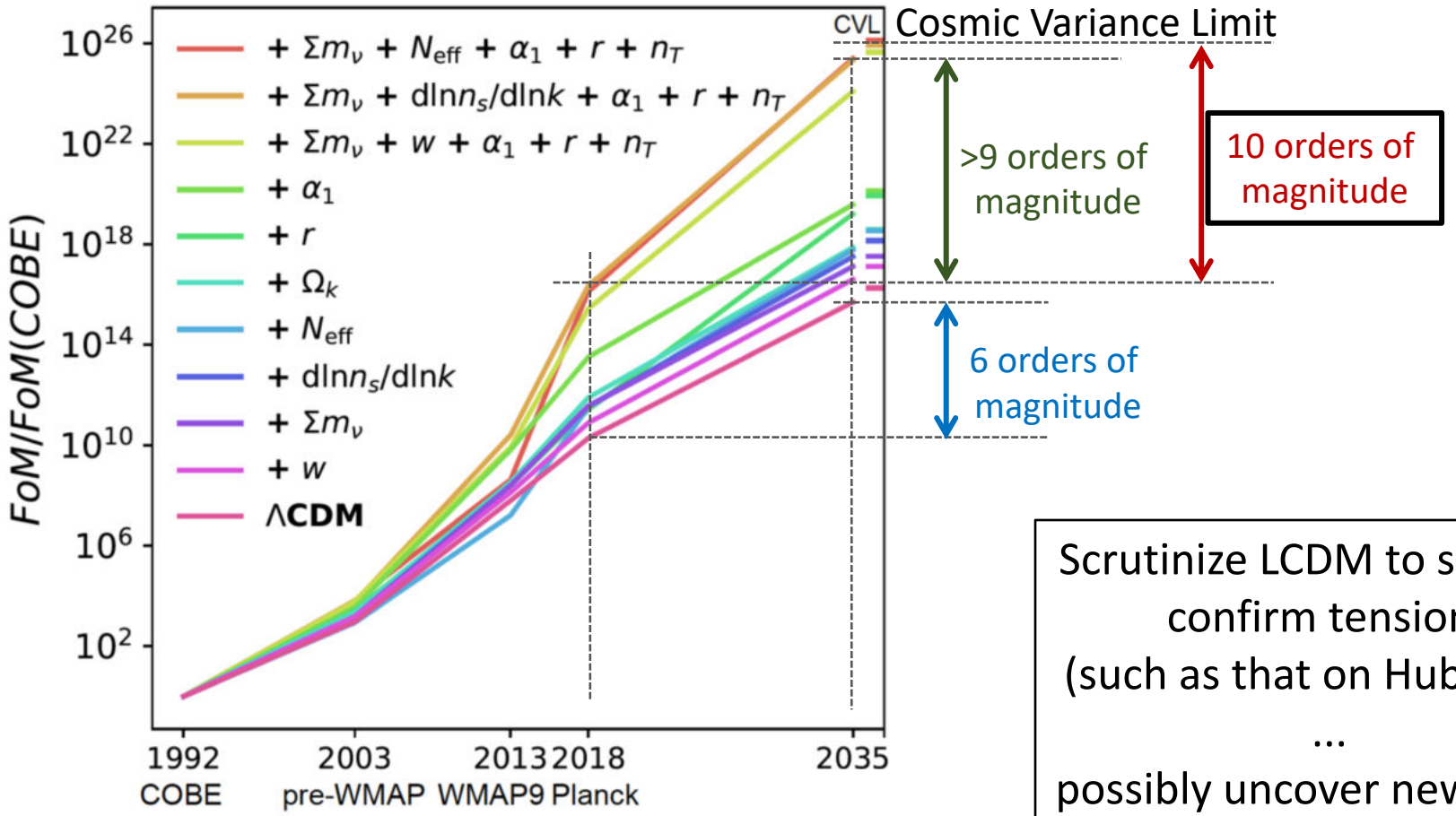




- Alternatives
  - Grating spectrometer with an array of detectors in the 20-2000 GHz range ?
  - FTS in the focal plane ?

Constraints on extended ΛCDM

$$\sigma(r) \sim 10^{-4}$$
$$\sigma(\Sigma m_\nu) \sim 10^{-2}$$
$$\sigma(n_s) \sim 0.0015$$
$$\sigma(N_{\rm eff}) \sim 0.016$$



Scrutinize LCDM to solve or confirm tensions (such as that on Hubble H_0) … possibly uncover new ones !

(figure from E. di Valentino)

Delabrouille et al., Voyage 2050 White Paper

Spectral distortions

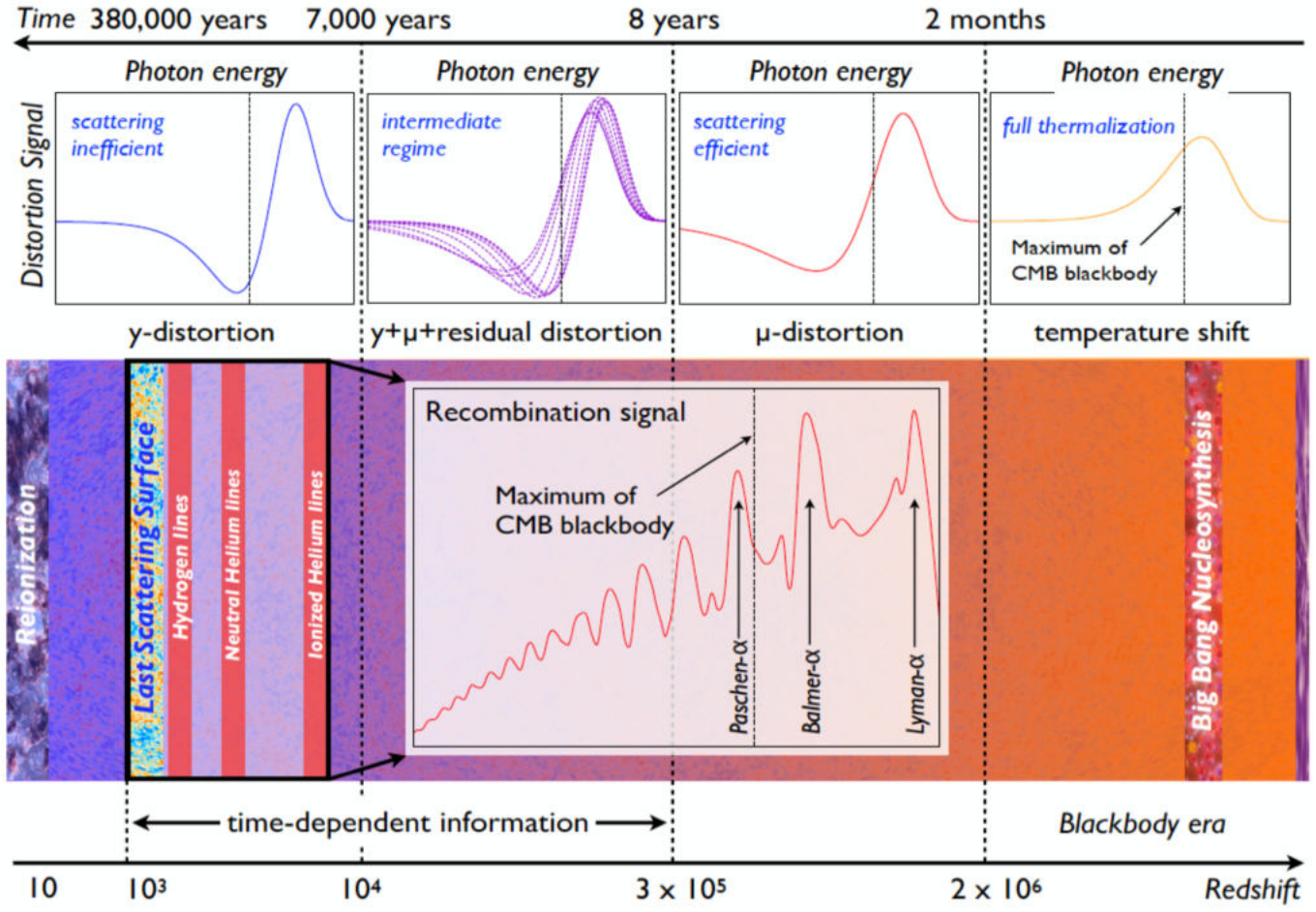
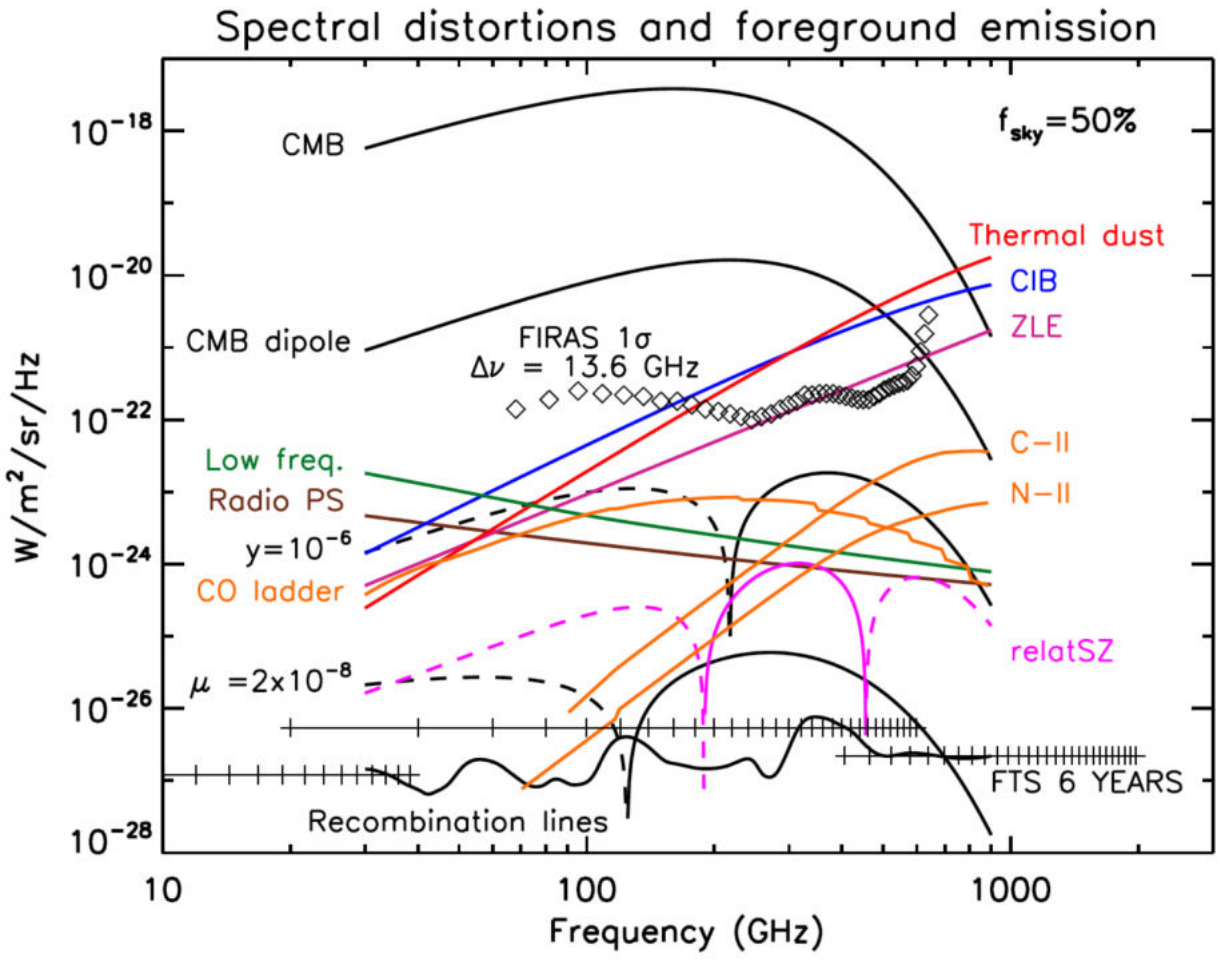


FIG. 1: Evolution of spectral distortions across time. Distortions probe the thermal history over long periods deep into the primordial Universe that are inaccessible by other means. The distortion shape contains valuable epoch-dependent information that allows distinguishing different sources of distortions.

see Chluba et al., Voyage 2050 White Paper

Spectral distortions



Constrain / observe

Inflation (small scale spectrum)
Total amount of hot gas in clusters
Average group/cluster gas temperature
Lines from primordial atoms

Foreground emissions

Small demonstrator along the way ?

see Chluba et al., Voyage 2050 White Paper

Next steps : get ready !

- Based on the proposed instrumental performance, forecast the capability of the mission (in particular for emerging science cases)

- Instrument definition and design

- Inputs from the community (i.e. you) needed
  - For the October 29-31 workshop in Madrid
  - For follow-up publications
  - For optimization – suggestions welcome !
  - For support and advertisement of this science.

Summary

- The Cosmic Microwave Background remains a key observable to understand the Universe
- In 2035+, an ambitious space mission can harvest a fantastic data set for Cosmology – very rich science case
- Observational objective : sensitive spectro-polarimetric full sky survey in 10-2000 GHz at all scales down to 1’
- Get involved and give support
- ESA recommendations expected mid-2020