Cosmic Microwave Background

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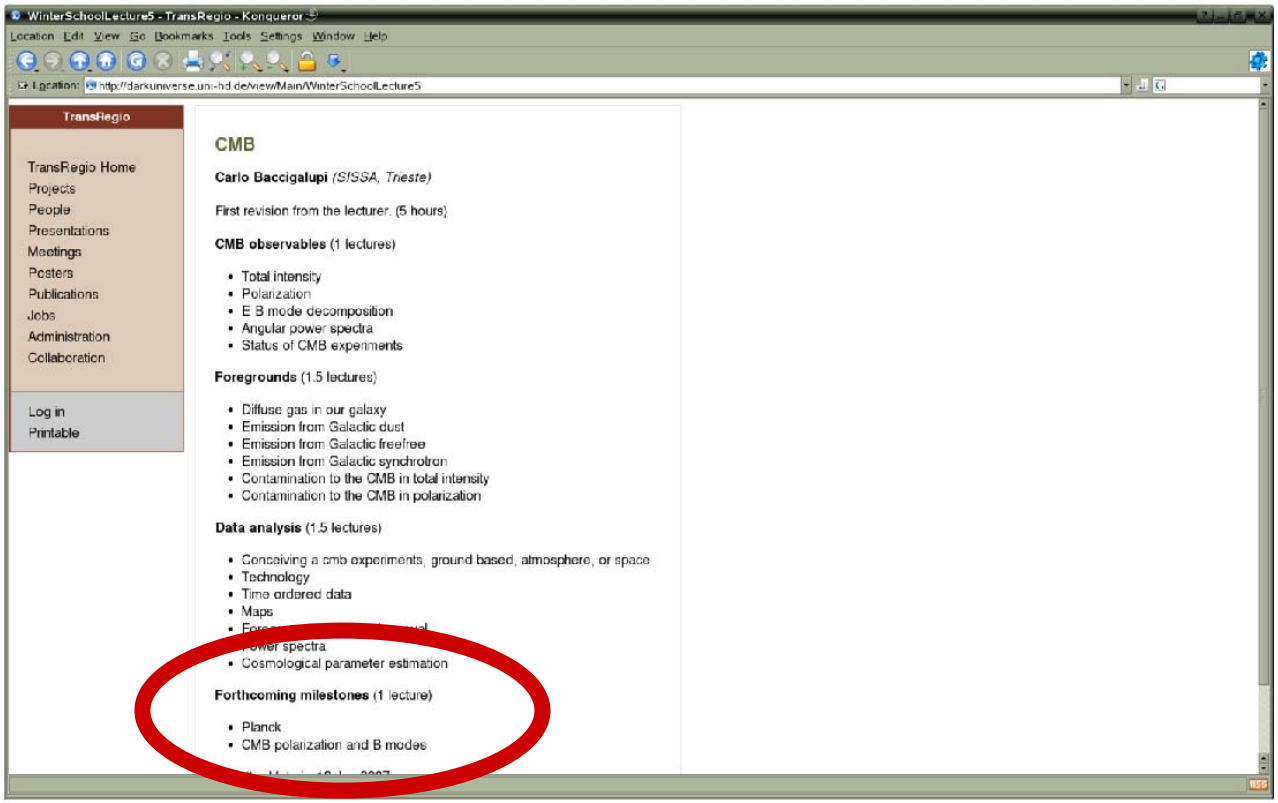
CMB lectures at TRR33, see the complete program at
darkuniverse.uni-hd.de/view/Main/WinterSchoolLecture5
These lectures are available in pdf format at
people.sissa.it/~bacci/work/lectures

Forthcoming milestones



Outline

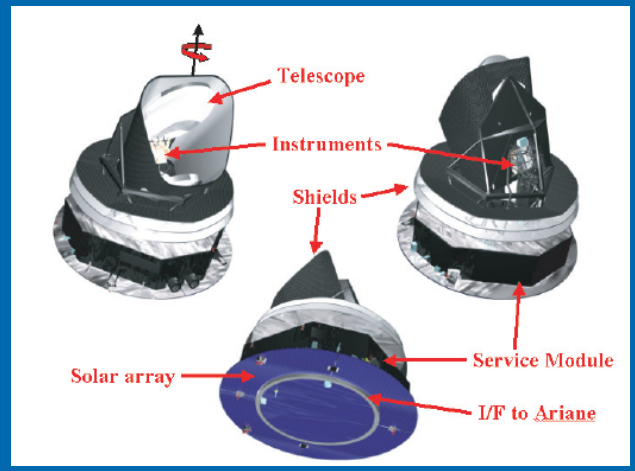
- The science goals of the Planck satellite
- B mode hunters, the example of the E and B experiment (EBEx, Oxley et al. 2004)
- Conclusions ☹/☺

The science goals of the Planck satellite

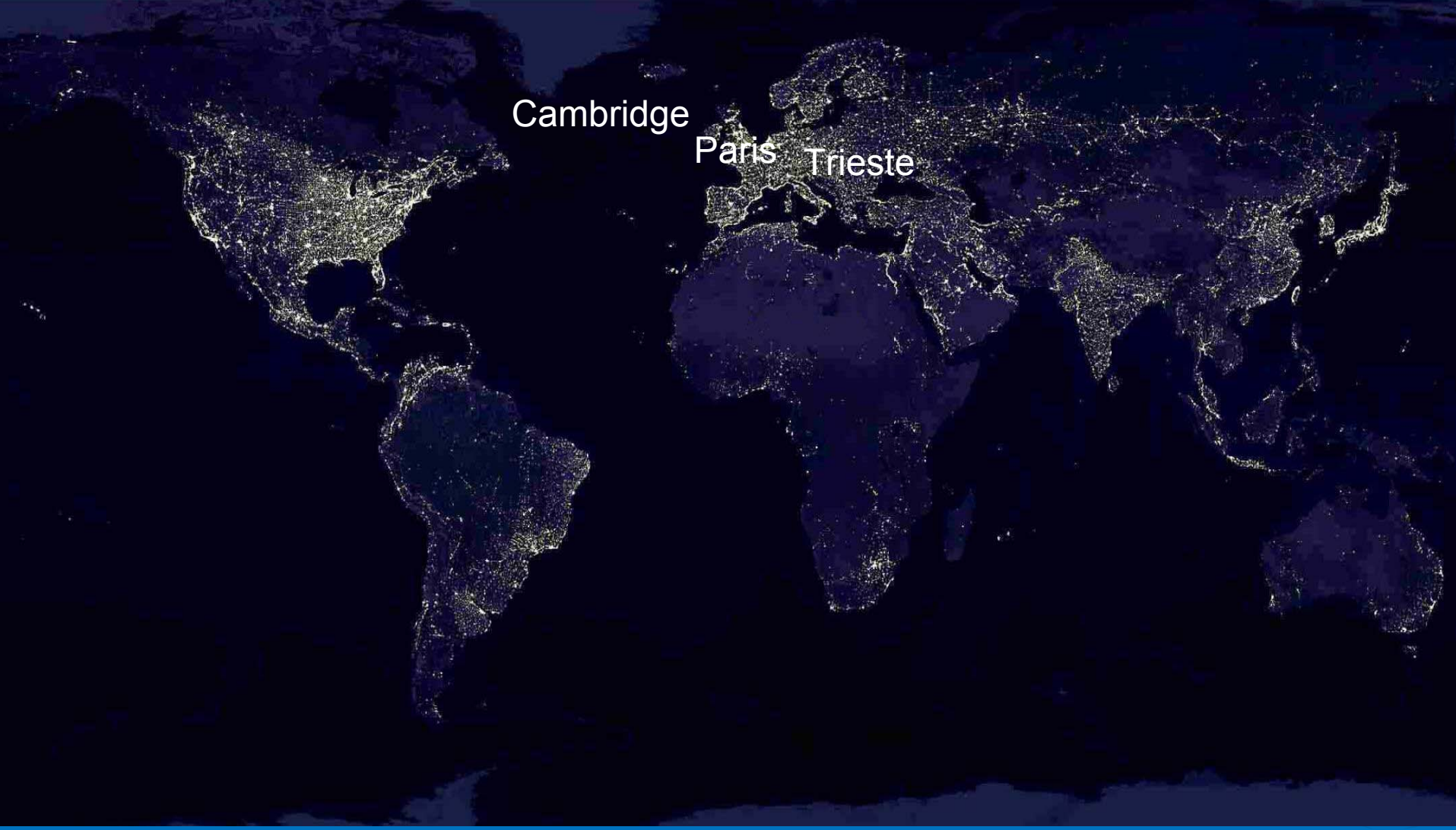
Source: Planck scientific program bluebook, available at www.rssd.esa.int/Planck

Planck

- A third generation CMB probe, ESA medium size mission, NASA (JPL, Pasadena) contribution
- Over 400 members of the collaboration in EU and US
- Two data processing centers (DPCs): Paris + Cambridge (IaP + IoA, data from 100 to 857 GHz), Trieste (OAT + SISSA, data from 30 to 70 GHz)
- The analysis proceeds in parallel at the two DPCs from time ordered data to maps, and joins afterwards for component separation, angular power spectrum estimation, point source and cluster extraction, etc.



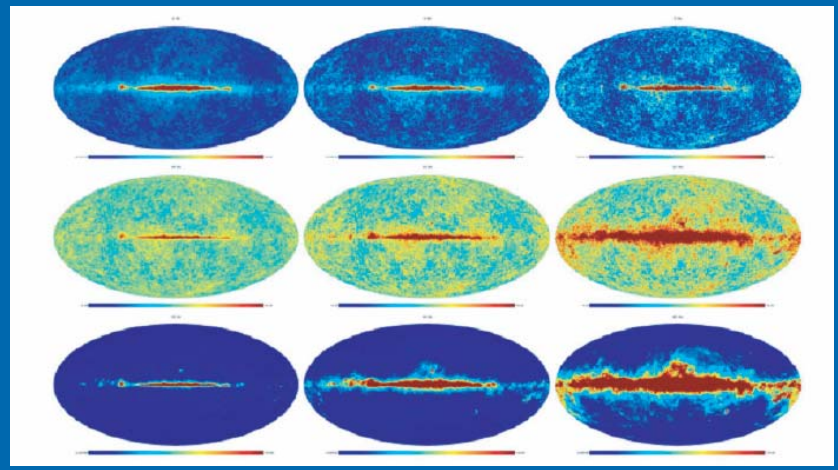
Planck contributors



Planck data processing sites

Planck deliverables

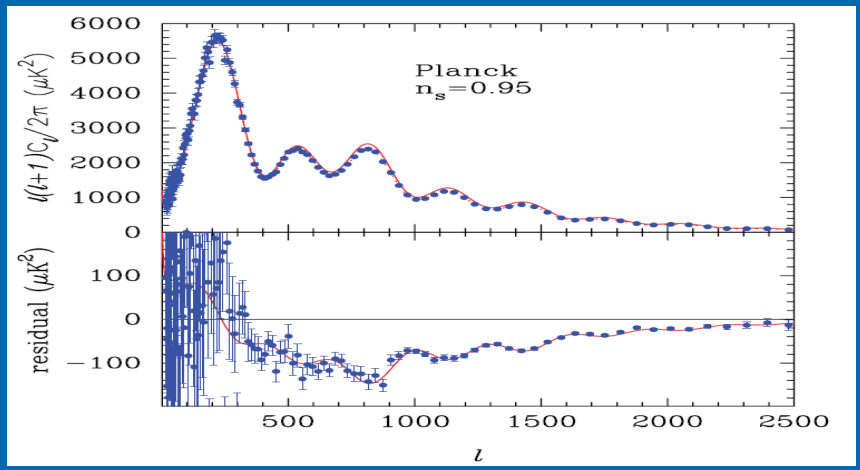
- All sky maps in total intensity and polarization, at 9 frequencies between 30 and 857 GHz
- Angular resolution from 33’ to 7’ between 30 and 143 GHz, 5’ at higher frequencies
- S/N ≈ 10 for CMB in total intensity, per resolution element
- Catalogues with tens of thousands of extra-Galactic sources

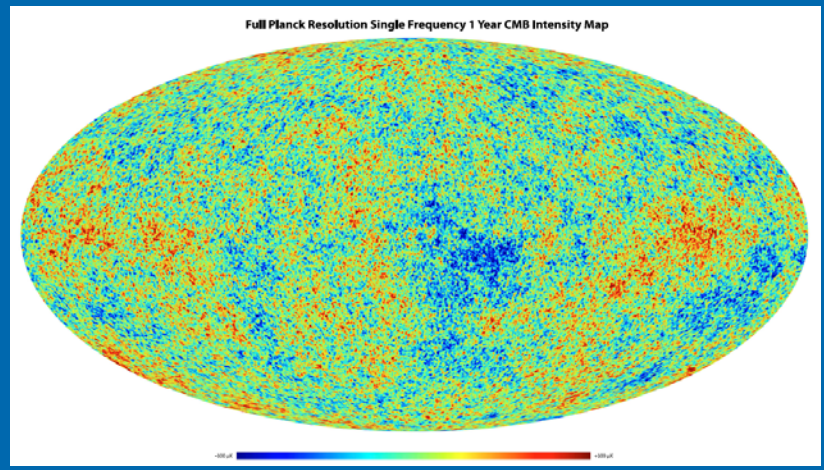


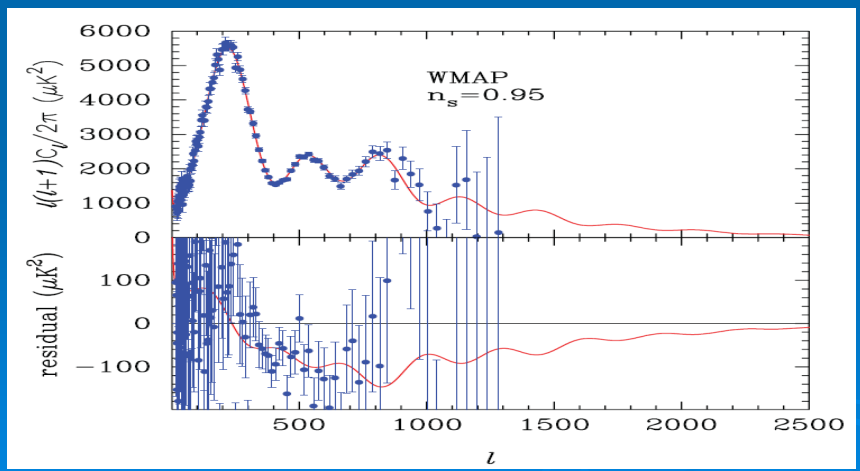
PLANCK GALAXY SURVEYS

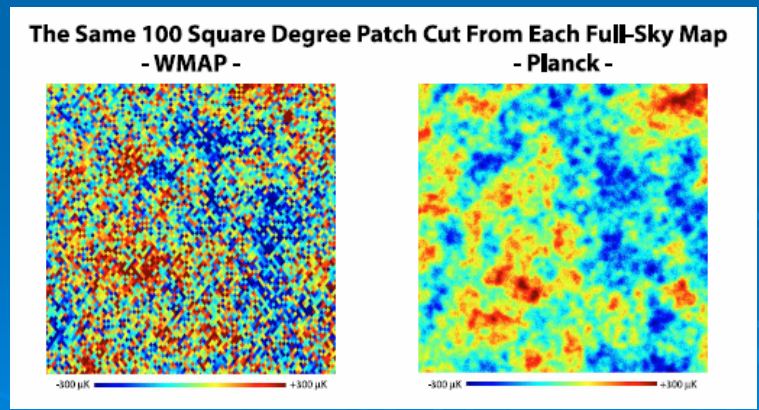
	FREQUENCY [GHz]				
	143	217	353	550	850
Confusion limit [mJy, 3σ]	6.3	14.1	44.7	112	251
Planck All Sky Survey sensitivity [mJy, 3σ]	26	37	75	180	300
Planck Deep Survey sensitivity [mJy, 3σ]	10	18.4	49	170	280
Number of galaxies [all sky]	570	860	1700	4400	35000

Planck deliverables: CMB total intensity and the era of imaging



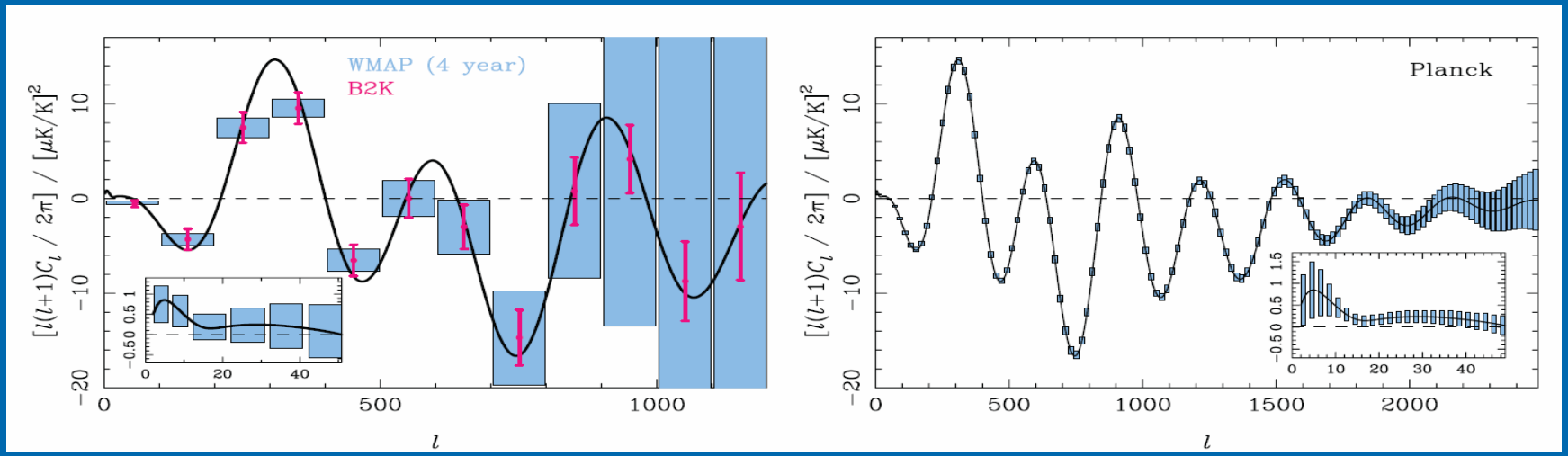


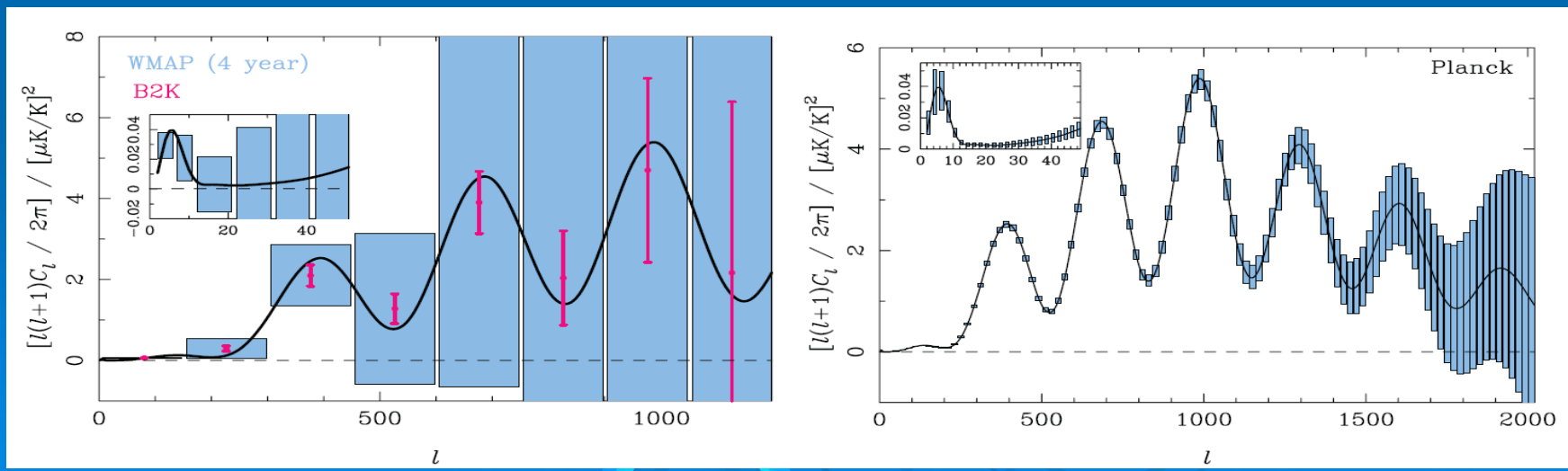




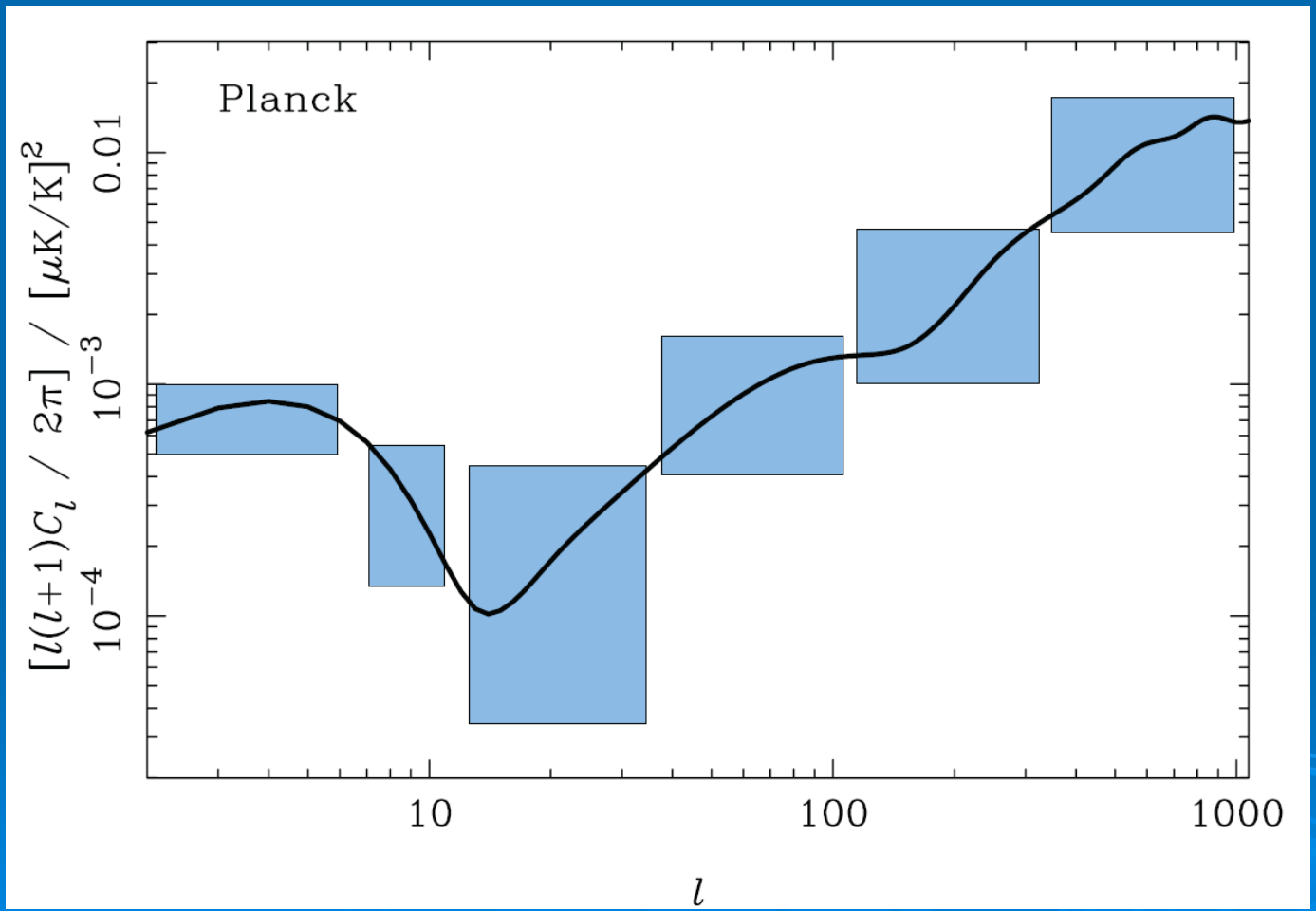
Simulation at NERSC, Berkeley

Planck deliverables: CMB polarization

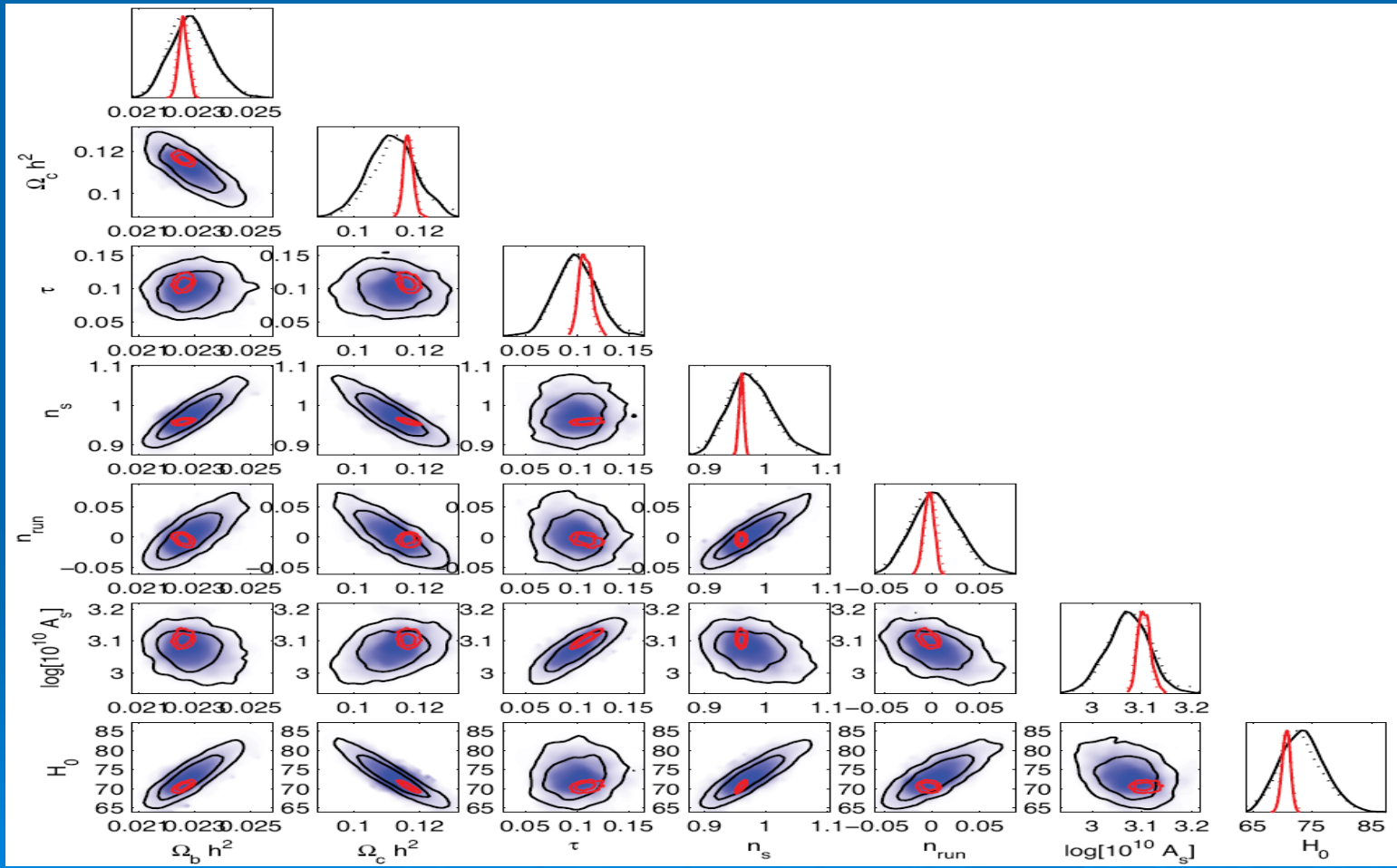




Planck and B modes



Planck deliverables: cosmological parameters



Non-CMB Planck deliverables

- Thousands of galaxy clusters
- Tens of thousands of radio and infrared extra-Galactic sources
- Mapping of the diffuse gas in the solar system and the Galaxy, from 30 to 857 GHz
- …

B mode hunters

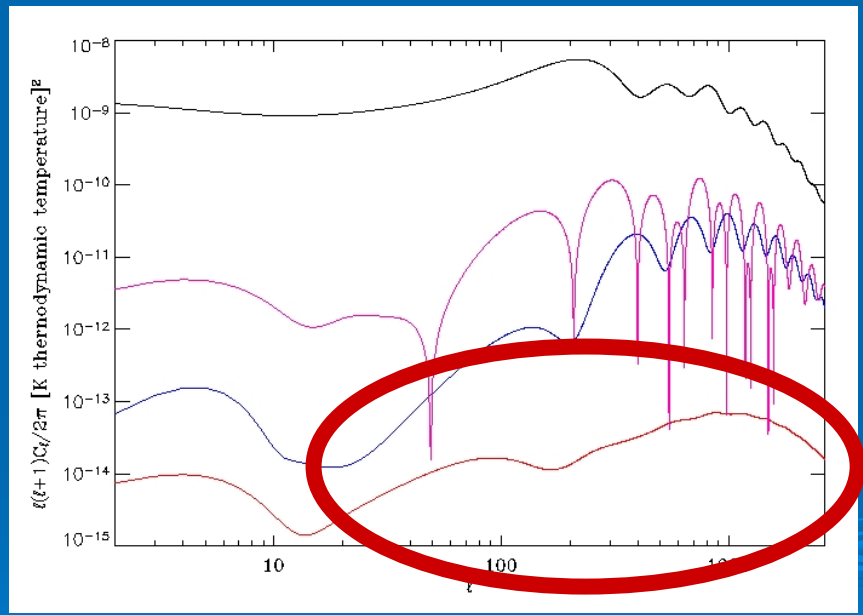
The case of the E and B Experiment,

on behalf of the EBEx collaboration,

groups.physics.umn.edu/cosmology/ebex

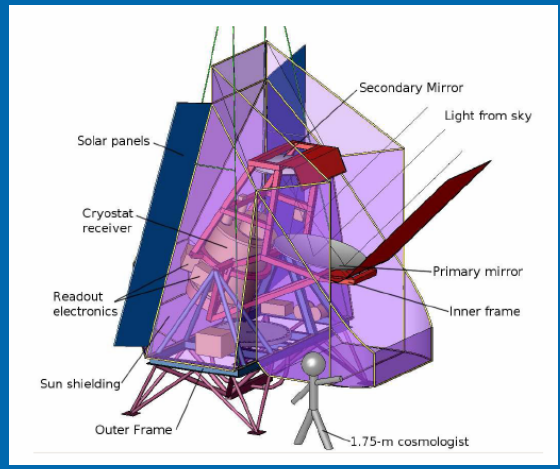
B modes hunters

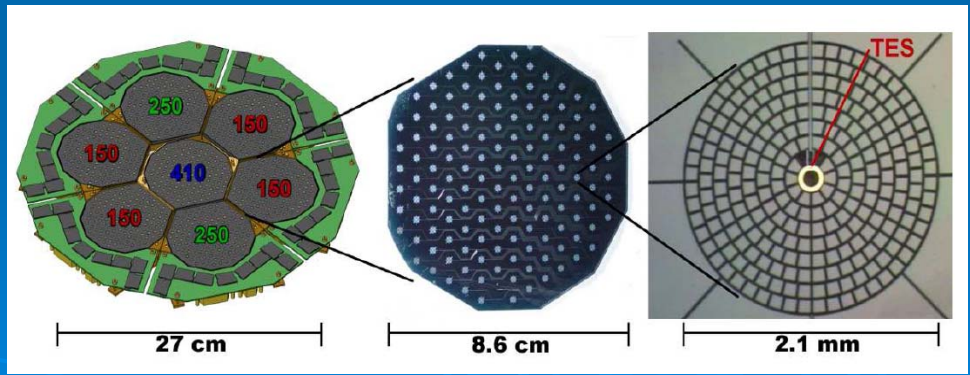
- Visit lambda.gfsc.nasa.gov for a complete list of all the ongoing and planned experiments
- Different technologies, ground based as well as balloon borne probes
- The instrumental sensitivity and angular resolution are high enough to get to a tensor to scalar ratio of about 10^{-2} via direct detection of cosmological B modes on the degree scale
- Some of the probes also are able to detect the lensing peak in the B modes
- All these experiments aim at the best measurement of CMB, although most important information is expected in particular for the B mode component of the diffuse Galactic emission
- The challenge of controlling instrumental systematics and foregrounds make these probes pathfinders for a future CMB polarization satellite



EBEx

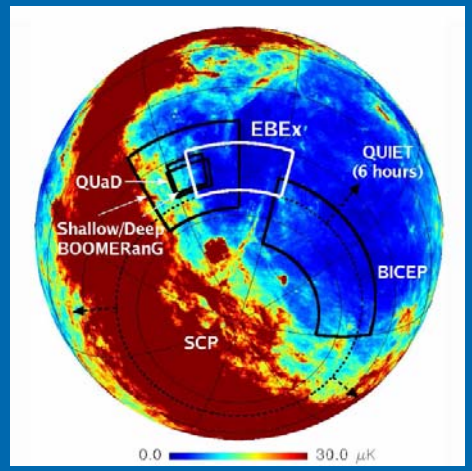
- Balloon borne
- Three frequency bands, 150, 250, 410 GHz
- About 1500 detectors
- 8 arcminutes angular resolution
- Sensitivity of 0.5 micro-K per resolution element
- Scheduled for flying from north america within 2008, and from antarctica afterwards

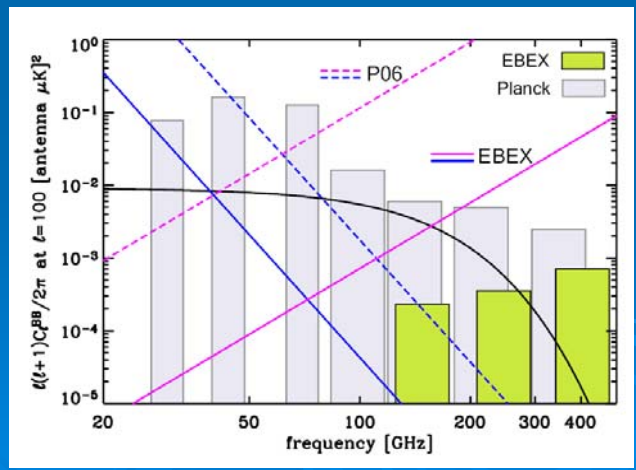




EBEx

- Targeting a low foreground area in the antarctica flight, already probed by previous observations for total intensity and E mode polarization
- Foregrounds, dominated by Galactic dust at the EBEx frequencies, are estimated to be still comparable to the cosmological signal for B
- Band location and number of detectors per band have been optimized for foreground subtraction

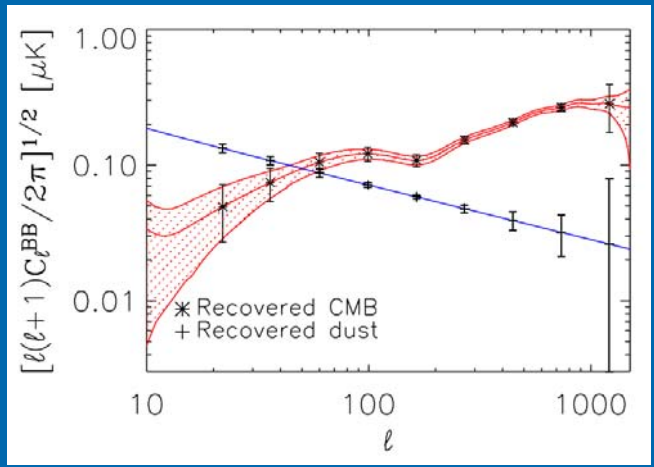


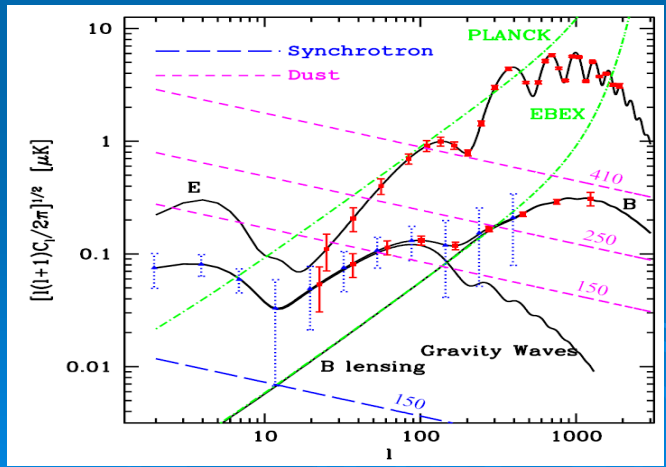


EBEx contributors

Expectations from EBEx

- Foreground parametrization and ICA foreground removal are going to be applied to the data to remove the contamination from the dust on the degree scale, also yielding most precious measures of the same Galactic signal for ongoing and future CMB probes
- The detector sensitivity should allow a detection of the tensor to scalar ratio equal to 0.1 with a signal to noise ratio of about 5, or setting a two sigma upper limit of 0.02, plus a mapping of the lensing peak in B modes





Conclusions

- The CMB will be the best signal from the early universe for long
- We have some knowledge of the two point correlation function, but most of the signal is presently unknown
- If detected, the hidden signatures might reveal mysteries for physics, like gravitational waves, or the machanism of cosmic acceleration
- We don't know if we will ever see those things, systematics and foregrounds might prevent that
- But we've no other way to get close to the Big Bang, so let's go for it and see how far we can go
- First go/no go criteria from Planck and other probes in just a few years, possible scenarios…

- Polarized foregrounds too intense, no sufficient cleaning, systematics out of control
- Increase by one digit the precision on cosmological parameters, constrain non-Gaussianity and lensing, mostly from improvements in total intensity measurements
- Time scale: few years

Theorist

- Modest or controllable foreground emission, systematics under control
- Cosmological gravity waves discovered from CMB B modes! Expected precision down to one thousandth of the scalar amplitude
- Percent measurement of the dark energy abundance at the onset of acceleration, from lensing detection on CMB and optical measurements
- Time scale: from a few to 20 years