Planning for the Decadal: Space, Balloons and CMB-S4

August 2017

Broad Context - Prep for Decadal 2020

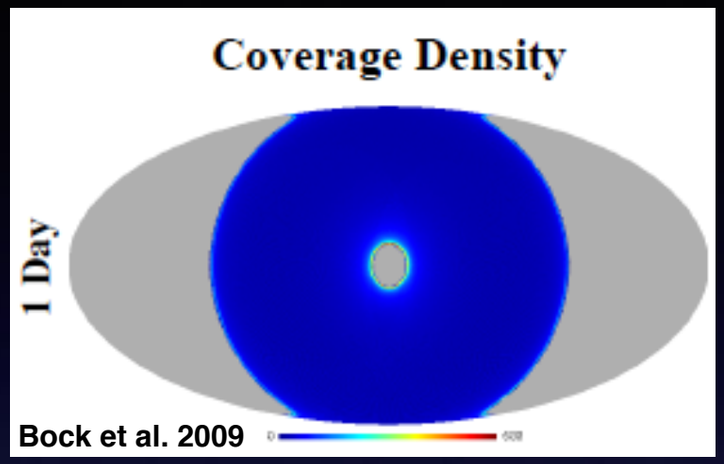
- Communicate breadth of science goals: those we own (r, Neff), those that also appeal to the broader astrophysics community
- Present a compelling plan to the agencies, specifically both NSF and NASA
- Present a coherent plan - how all components work together, ground, balloons, space

Broad Context - Prep for Decadal 2020

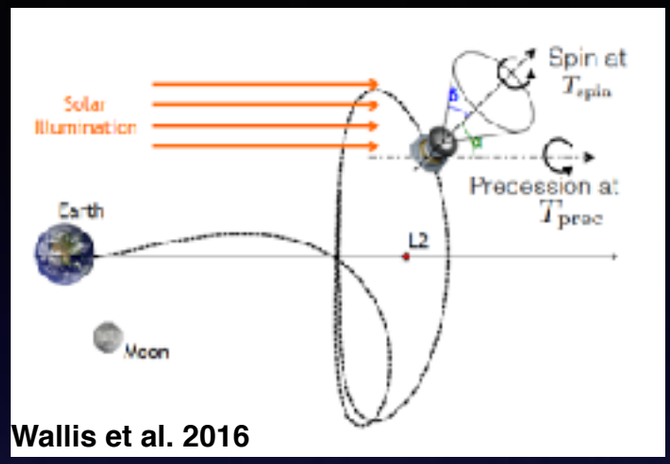
- NASA only invests in technology development or balloon payloads that lead to a future space mission.
- Over the years NASA has spent significant resources in CMB activities (space, balloons, tech development) because there was a mission in the future.
- NASA invests only in what the decadal panel recommends
- Many of us (most? all?) recognize the strengths of a future CMB space mission, the complementarity with sub-orbital, and of keeping NASA engaged with CMB

Strengths of a Space Mission

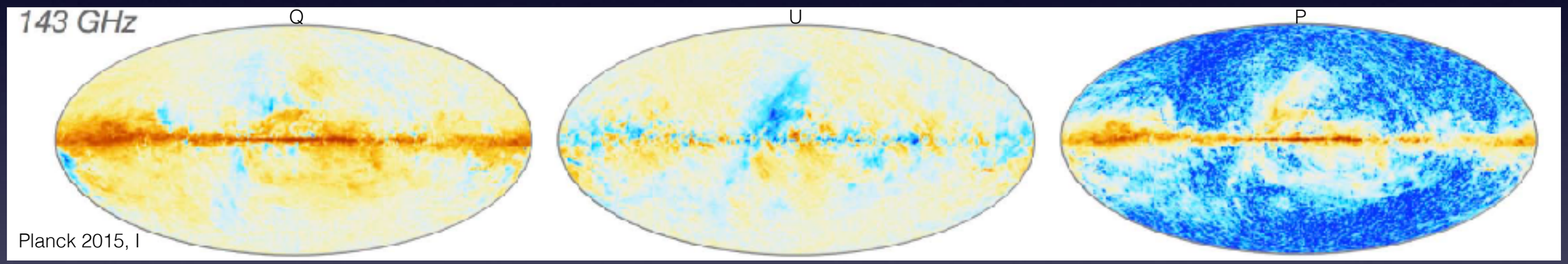
- Unparalleled view of the entire sky➡
  Access to the lowest ℓ



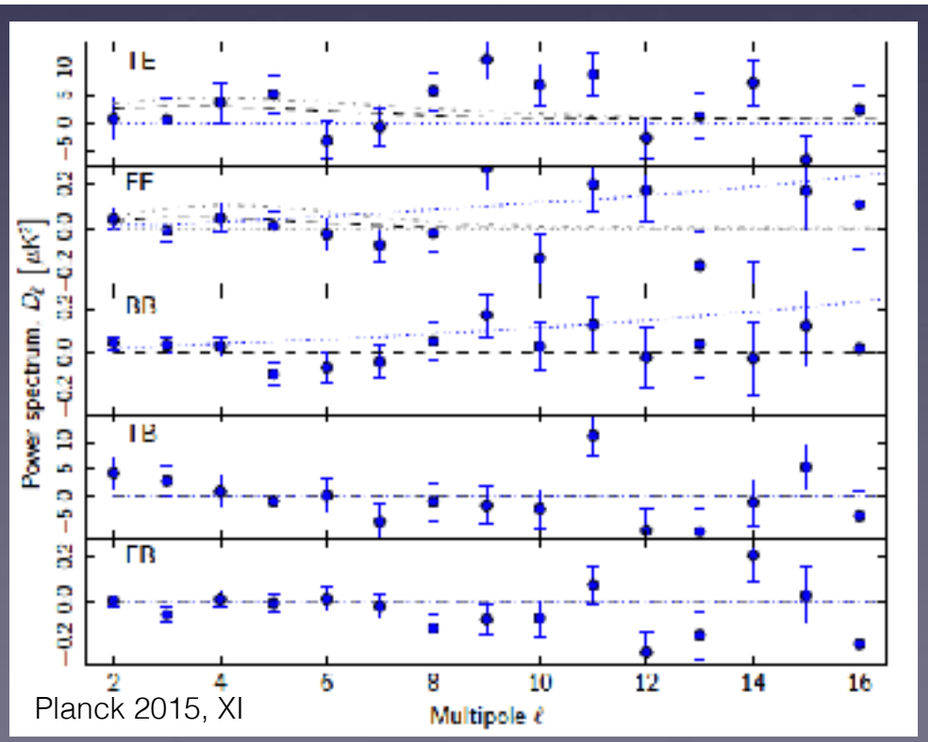
Bock et al. 2009



Wallis et al. 2016



Planck 2015, I



Planck 2015, XI

Strengths of a Space Mission

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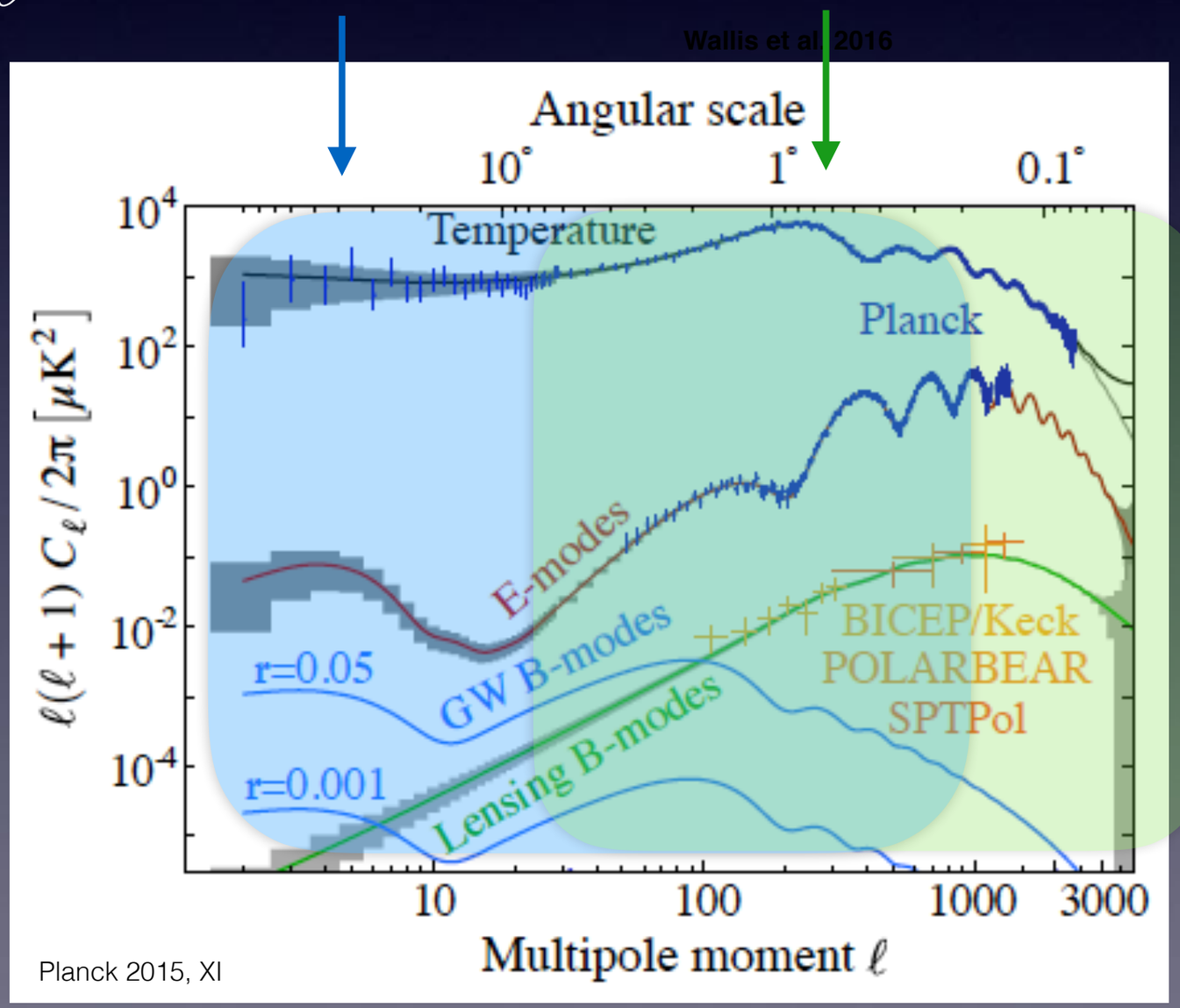
Strength of ground: high ℓ



Planck 2015, XI

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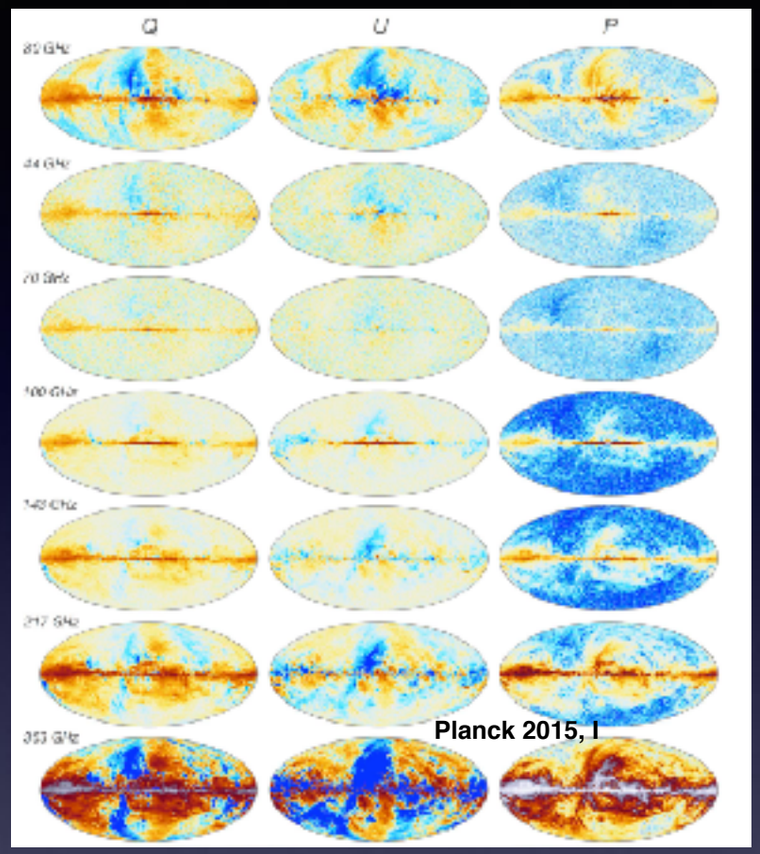
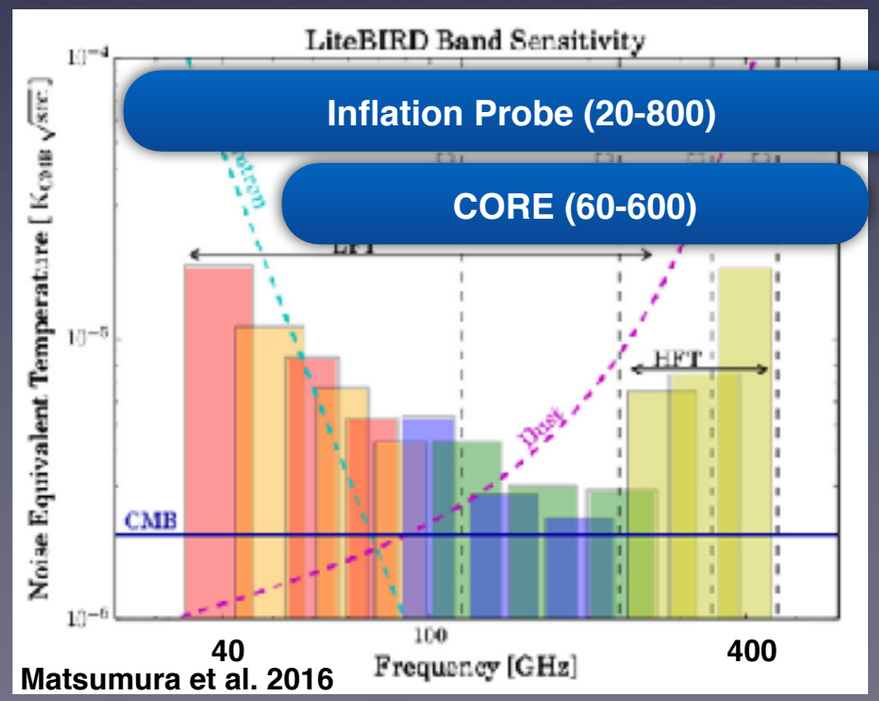


Bock et al. 2009

Q U



Matsumura et al. 2016

Strengths of a Space Mission

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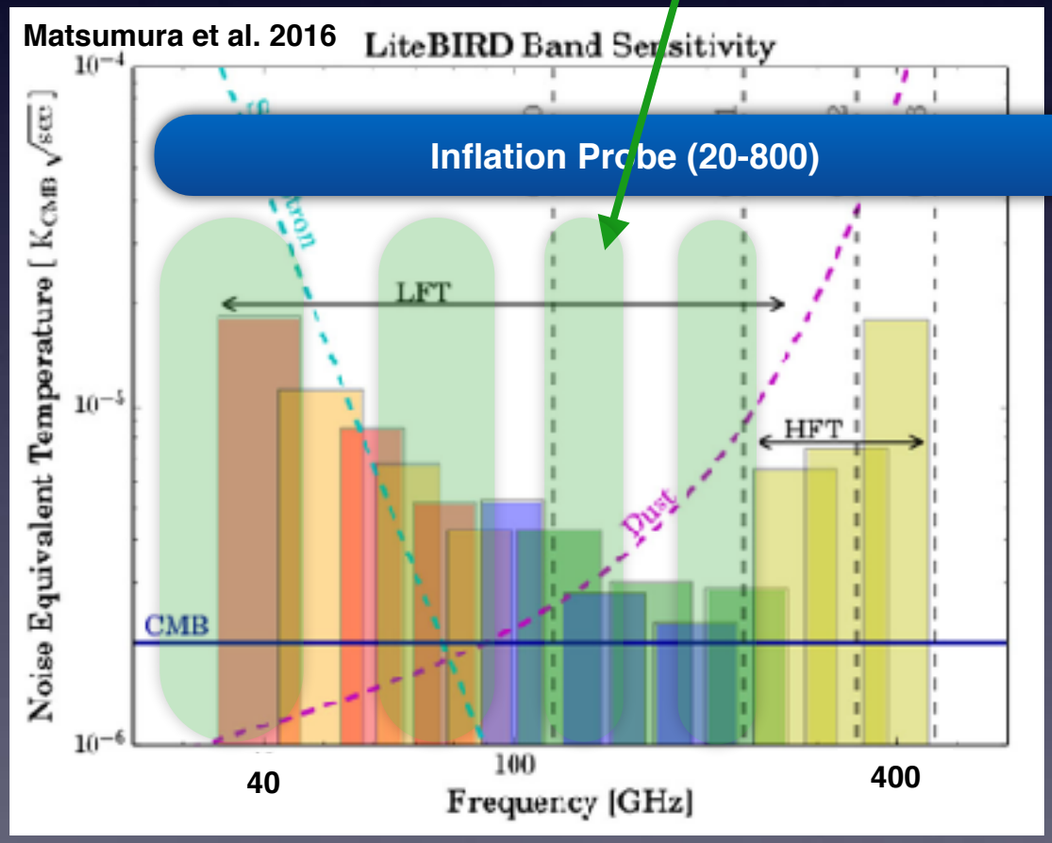
Ground

Wallis et al. 2016

Matsumura et al. 2016



Strengths of a Space Mission

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- Unparalleled frequency coverage all in one instrument/data set

- Unparalleled stability + high sensitivity ➡ characterization of systematic uncertainties

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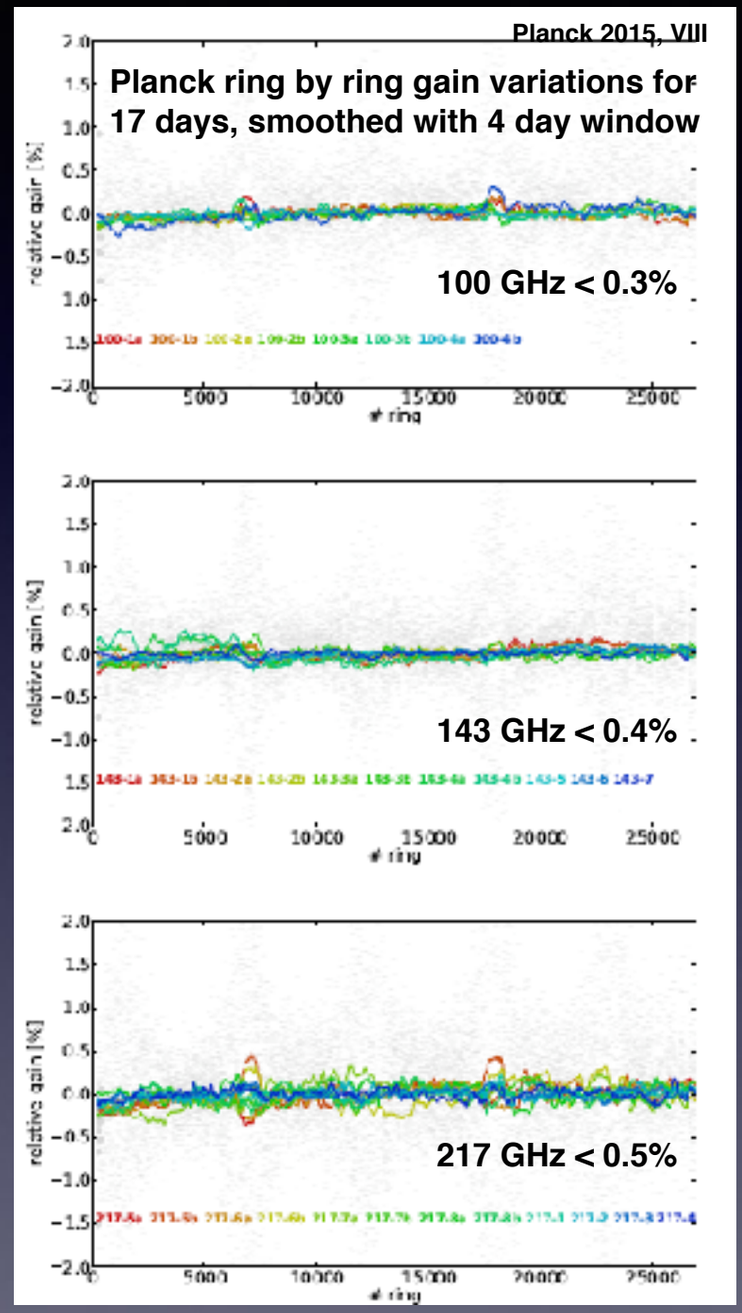

WMAP: nondetectable spin-synchronous radiometer thermal variation over 1 month (< 8 uK RMS)

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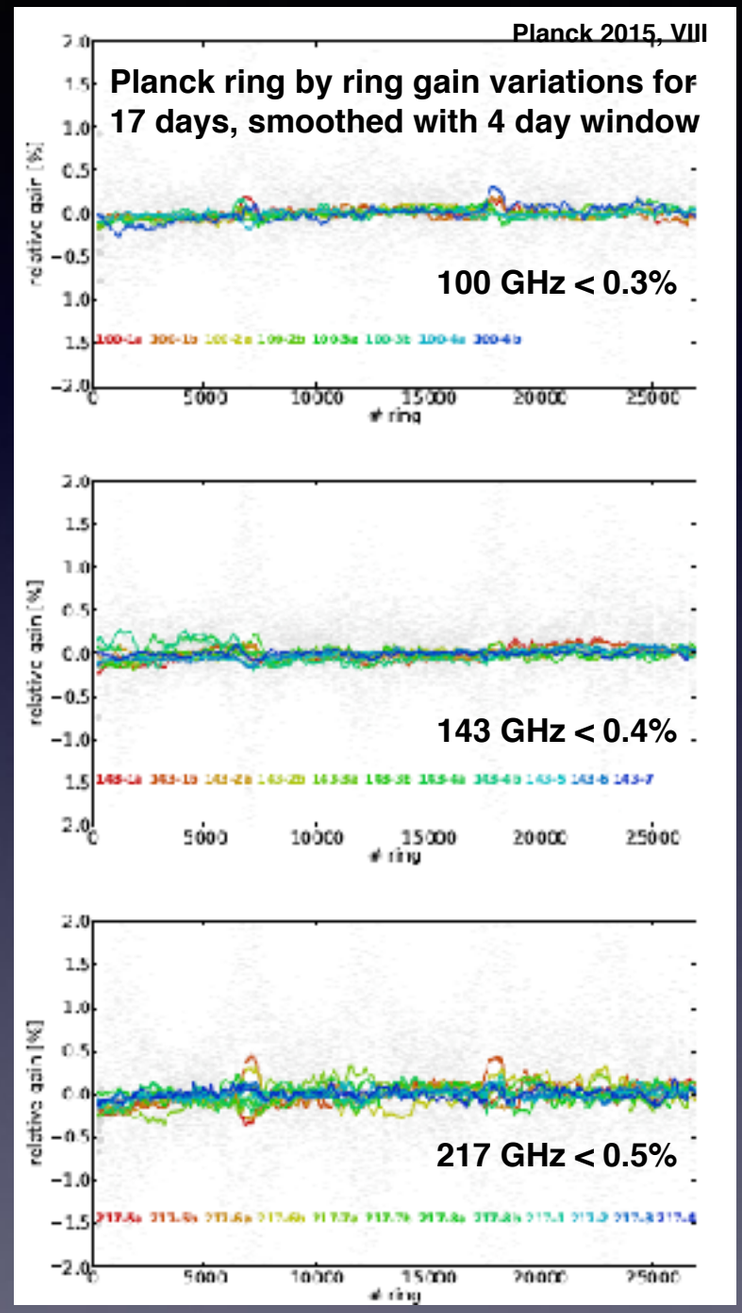

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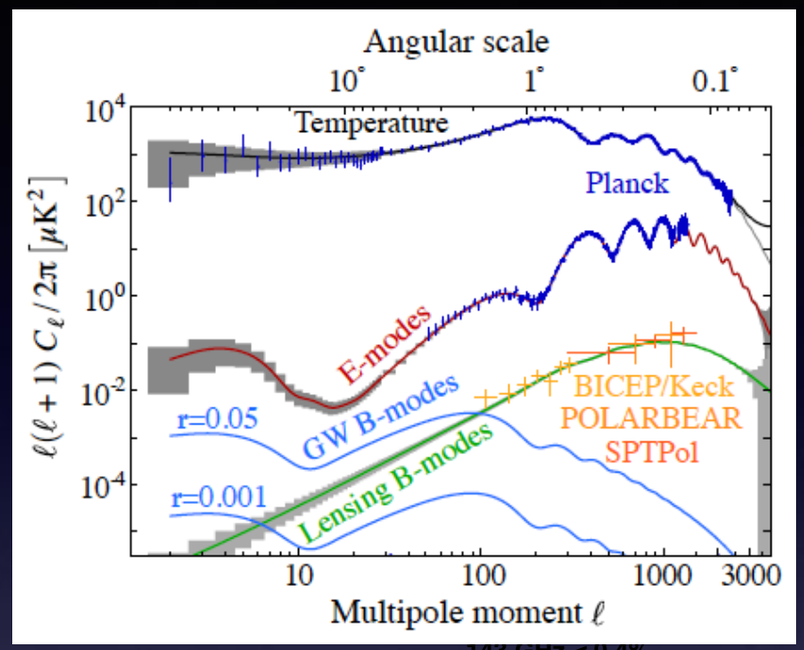
Strength of ground - long integration, flexibility to characterize / fix / adapt

WMAP: nondetectable spin-synchronous radiometer thermal variation over 1 month (< 8 uK RMS)

Leading to Compelling Science

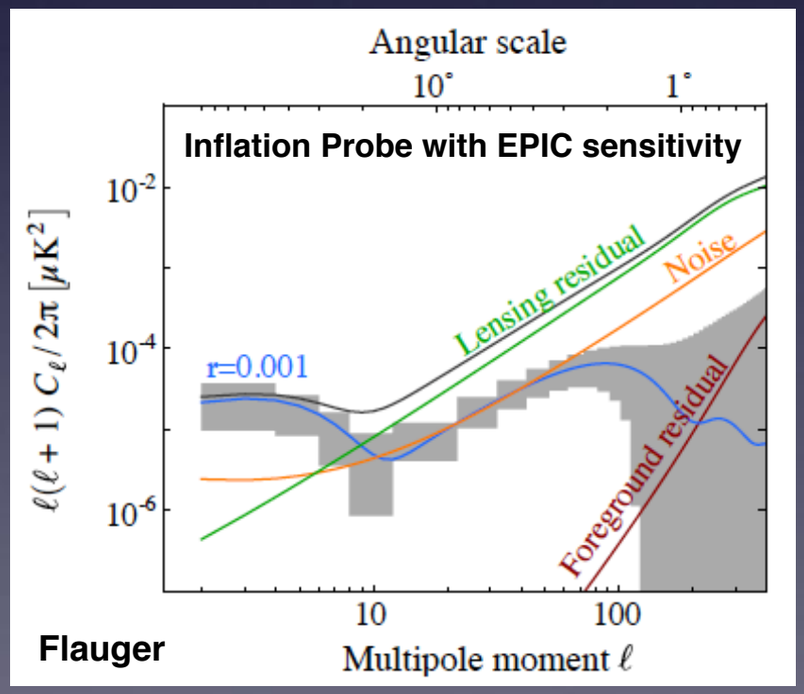
- σ_r :10^{-3} - 10^{-4}
  - PIXIE: <4x10^{-4} (95%)
  - LiteBIRD: σ_r ~0.001



Bock et al. 2009

U

143 GHz < 0.4%



Flauger

Leading to Compelling Science

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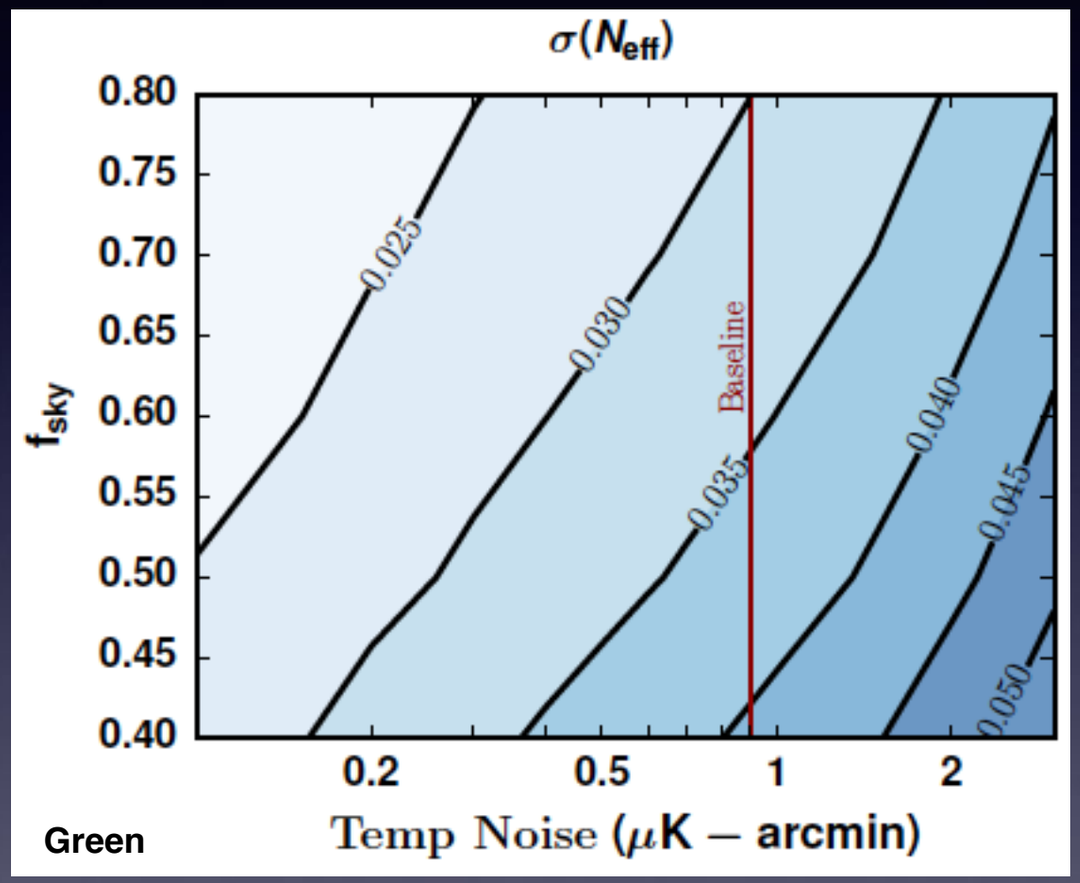
- Reach $\sigma_{N_{eff}} = 0.027$?

Bock et al. 2009

U

Planck 2015, VIII

100 GHz < 0.3%



Green

217 GHz < 0.5%

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- $\sigma_\tau = 0.002 \Rightarrow$
  $\sigma_{\sum m_\nu} < 15\,\mathrm{meV}$ (with DESI)

Bock et al. 2009

U

Planck 2015, VIII

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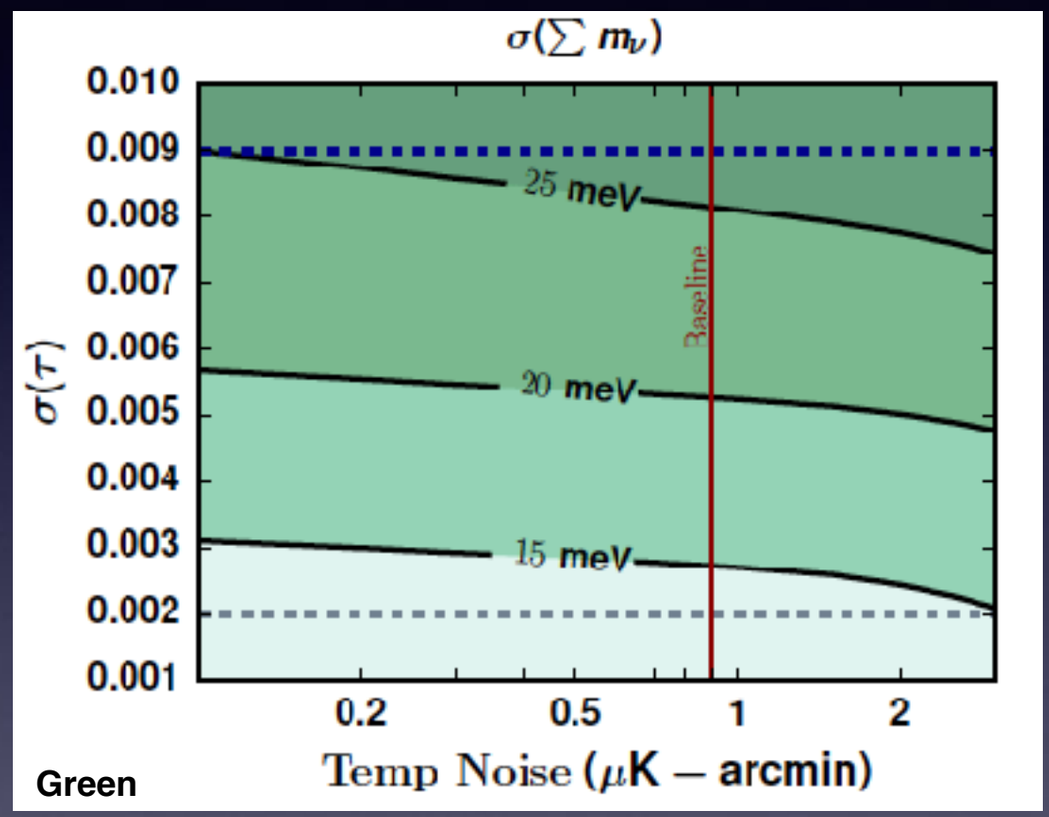

Green

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Leading to Compelling Science

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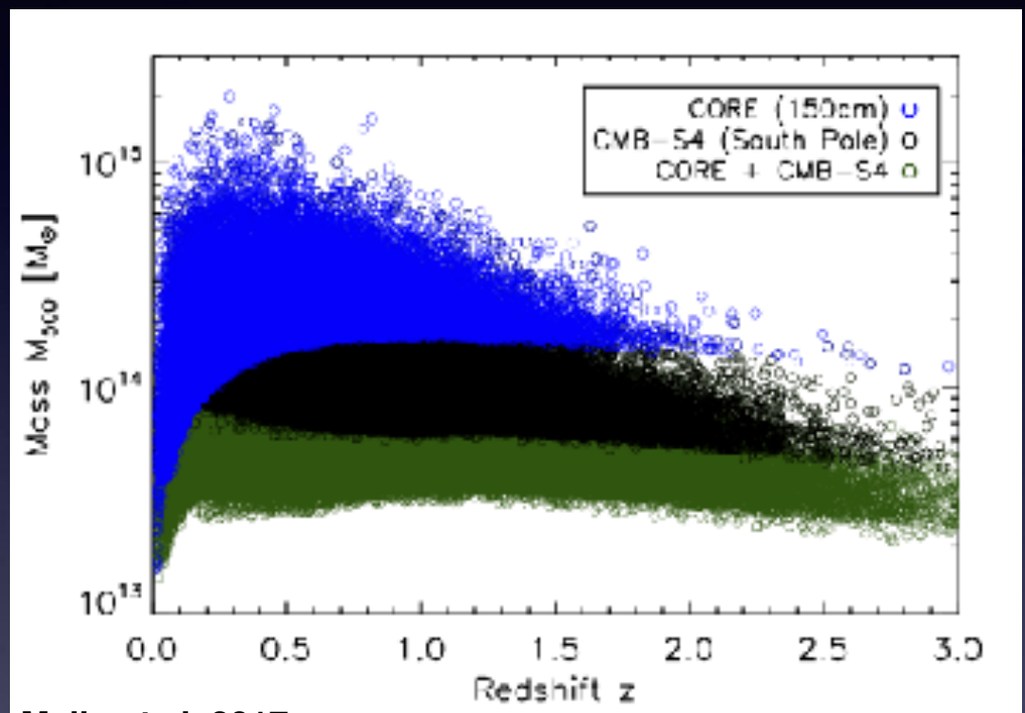

Melin et al. 2017

- Reach $\sigma_{N_{eff}}$ = 0.027 ?
- $\sigma_\tau = 0.002 \Rightarrow$
  $\sigma_{\sum m_\nu} < 15\,\mathrm{meV}$ (with DESI)
- Increase in cluster count

Melin et al. 2017

Experiment	$N_{\rm clus}$	$N_{\rm clus}/{\rm deg}^2$	$N_{\rm clus}(z > 1.5)$
CORE-120	38,000	1.1	200
CORE-150	52,000	1.5	500
CORE-180	65,000	1.85	800
CMB-S4 (Atacama)	10,700	0.47	70
CMB-S4 (South Pole)	71,000	6.9	5,000
CORE-150+CMB-S4 (Atacama)	56,000	2.5	850
CORE-150+CMB-S4 (South Pole)	222,000	21.5	20,000

NASA Prep for 2020

- Set up 8 Probe Mission Studies
  - Probe= $400M-$1000M
  - One `Inflation Probe' (CMB) study: Probe of Inflation and Cosmic Origin = PICO (?)
- Studies will produce 50 pg. reports + cost estimates that will be submitted to NASA and to the Decadal Panel
- Desired/Likely outcome: Panel recommends a funding wedge. Probes are competed later.

PICO Information

- Steering Committee: Bennett, Dodelson, Page
- Executive Committee: Borrill, Bock, Crill, Devlin, Flauger, Jones, Hanany, Knox, Kogut, Lawrence, McMahon, Pryke, Trangsrud - Weekly Telecons
- 7 working groups: fundamental physics (Flauger), extragalactic science (Battaglia), galactic science (Chuss), data challenge (Knox), Imager (Hanany), Spectrometer (Kogut), Systematics (Crill), [Technology (McMahon)] - Weekly/Periodic Telecons
- Wiki: https://z.umn.edu/cmbprobe
- Mailing list: cmbprobe@lists.physics.umn.edu

Developing a Decadal Panel Strategy

- We should give the panel a coherent story otherwise it would write the story for us.
- When you give it a coherent story, it listens
- A candidate story is
    - S4 will produce great science and should move forward immediately.
    - A space probe would also probe fantastic science and is compelling on its own
    - The two data sets would robustly extract all science possible from the CMB
    - The agencies should continue to support the technologies needed to field these experiments, and for balloons to make supporting measurements.

Developing a Decadal Panel Strategy

- Option: common workshop to develop the complementarity case
  - part of next S4 meeting? (April / May?)
  - 1 of 2.5(?) days
  - describe design of PICO, science capabilities + targets, discuss science complementarity (what can be achieved with both data sets), discuss technology development for both efforts
- Highlight complementarity in relevant reports
  - CDT; PICO study; S4 Science Book V2; S4 whitepaper; …
- Highlight common technologies + cross-fertilization in technology development; recommend participation of all agencies in developing the technologies

Additional Slides

Additions

- Decadal: NASA is the third leg
- Coordinated message:
    - AI: real concern is when we're interfacing with S4. Both S4 and Probe concept need to be careful to give the same message, lest NASA HQ decides that only one is needed. Including things ground doesn't get us that space does. Don't want HQ to think that the CMB community thinks a ground mission alone can get the full range of science.
    - AI: It is important that both ground based and NASA side are saying the same thing. Don't want mixed messages. Maybe be best couched in terms of sigmas - sigmar, sigmanf