Primordial Gravitational Waves and Inflation

CMB-S4 Collaboration Meeting

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Gravitational waves

- With CMB-S4 we hope to detect cosmological gravitational waves present at recombination.
- Such gravitational waves are a pristine relic of the primordial universe.
- In the foreseeable future, their imprint on the polarization of the CMB is our only way to detect them.
- These gravitational waves are statistically independent from density perturbations and a detection would provide a new window onto the early universe.

Gravitational waves

- Many models of inflation predict a gravitational wave signal large enough to be detected with CMB-S4.
- According to inflation, primordial gravitational waves arose as quantum fluctuations in the metric of spacetime.
- As a consequence, a detection of gravitational waves with CMB-S4 would provide insight into quantum gravity.
- In addition, a detection would measure the expansion rate and energy density during inflation.

Gravitational waves

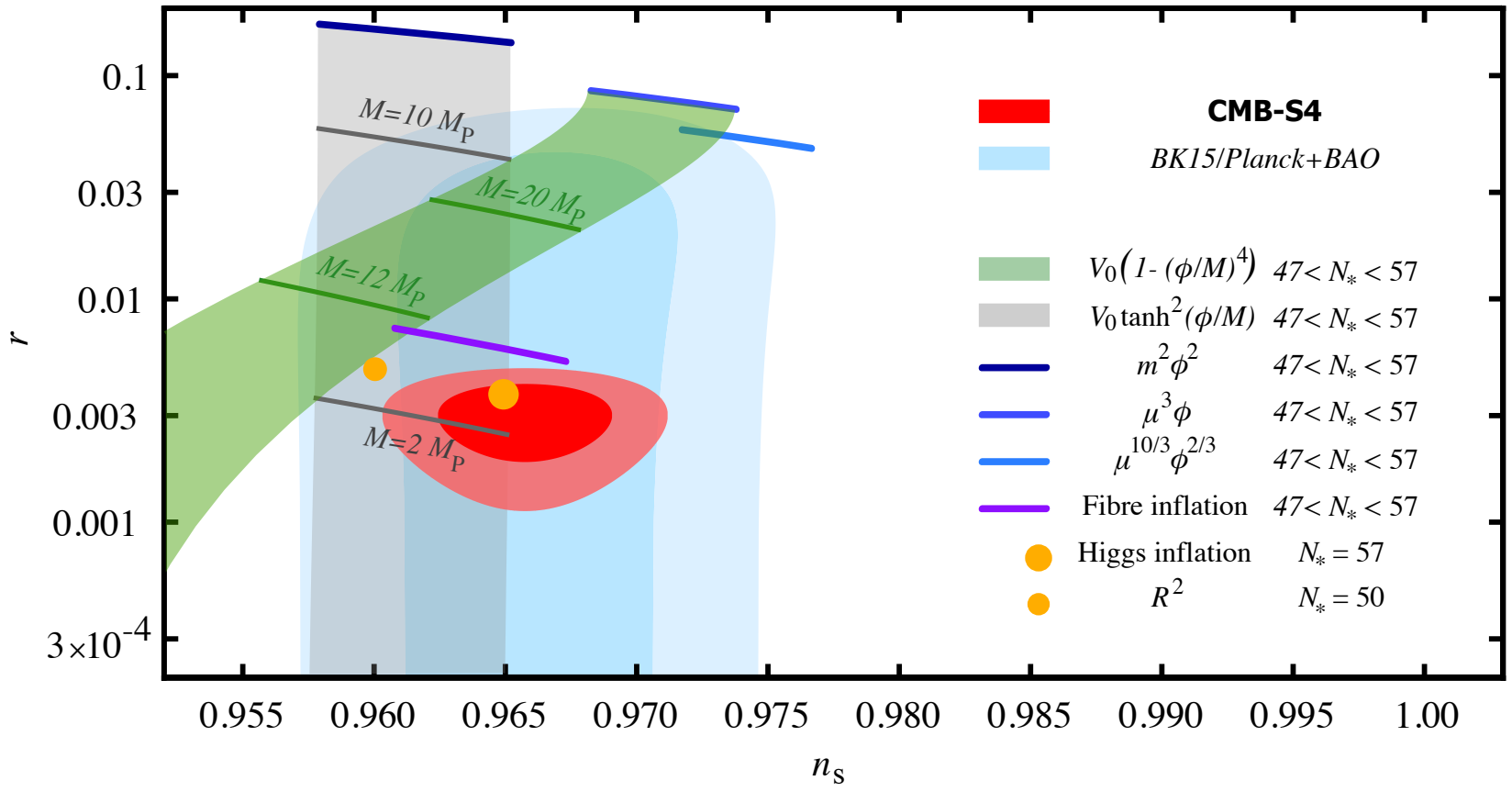
Science goals

- Detect gravitational waves provided $r \geq 3 \times 10^{-3}$
- Upper limit of $r < 10^{-3}$ at 95% CL otherwise

CMB-S4 will test many of the simplest models of inflation, including those based on symmetry principles, that occur at high energy and large inflaton field range.

Gravitational waves

Evidence for gravitational waves



Gravitational waves

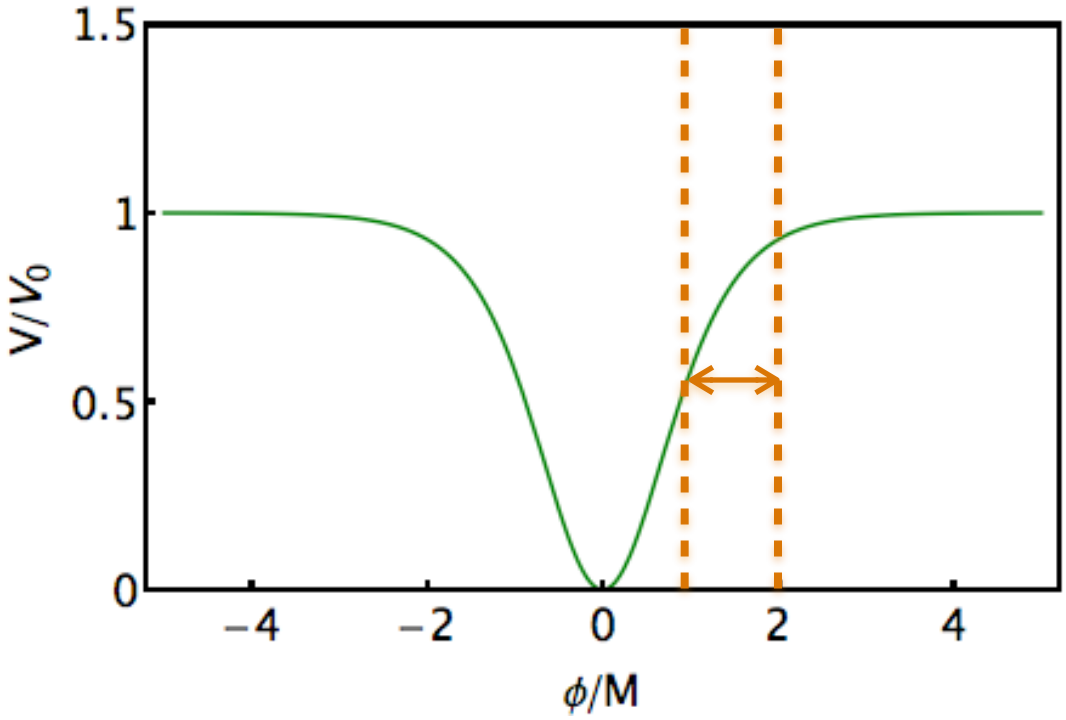
Implications of an upper limit

Models of inflation that naturally predict $n_{\rm s}$ fall into two classes

- monomial models: $r \gtrsim 0.01$
- hilltop and plateau models: prediction depends on characteristic scale of the potential (contains Starobinsky, Higgs inflation, …)

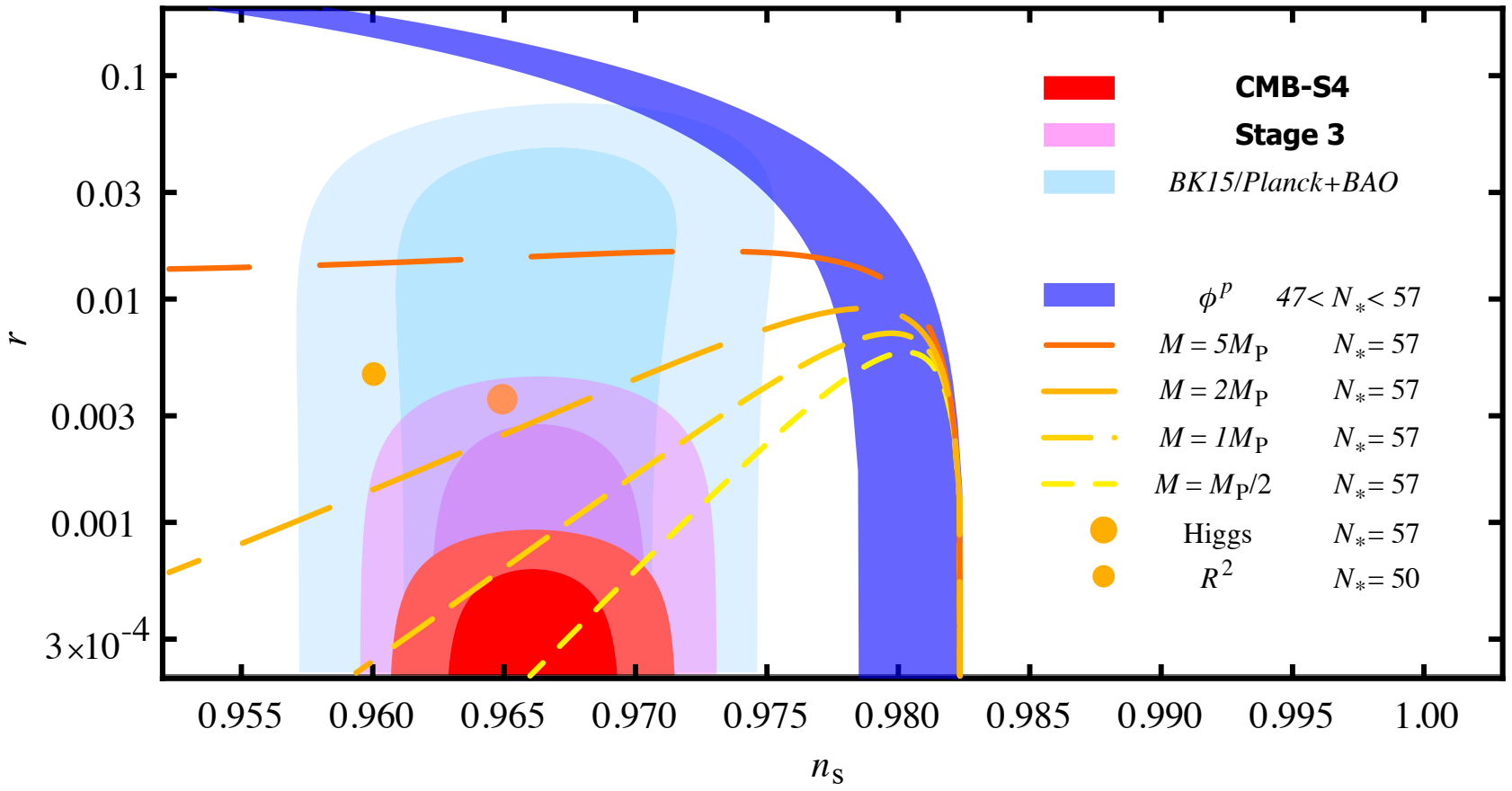
Gravitational waves

Characteristic scale



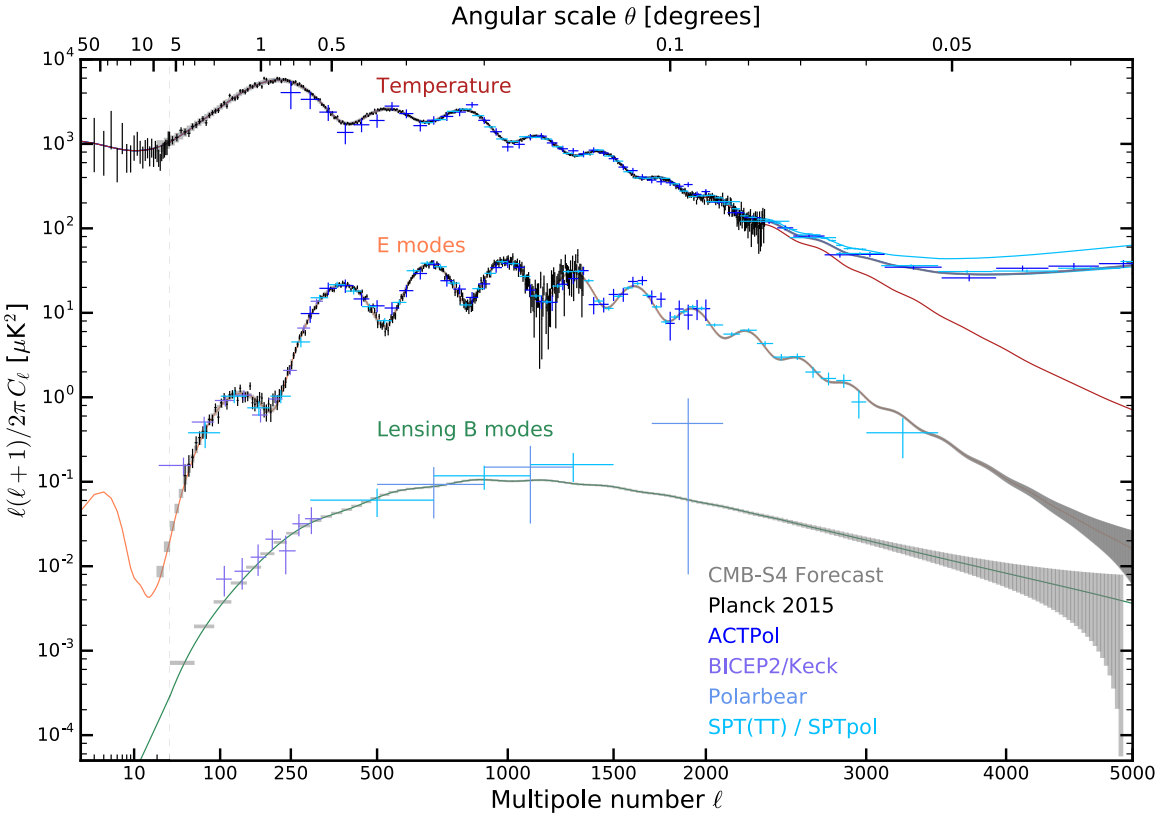
From a theoretical perspective, the characteristic scale is a key property of the inflaton potential.

Gravitational waves



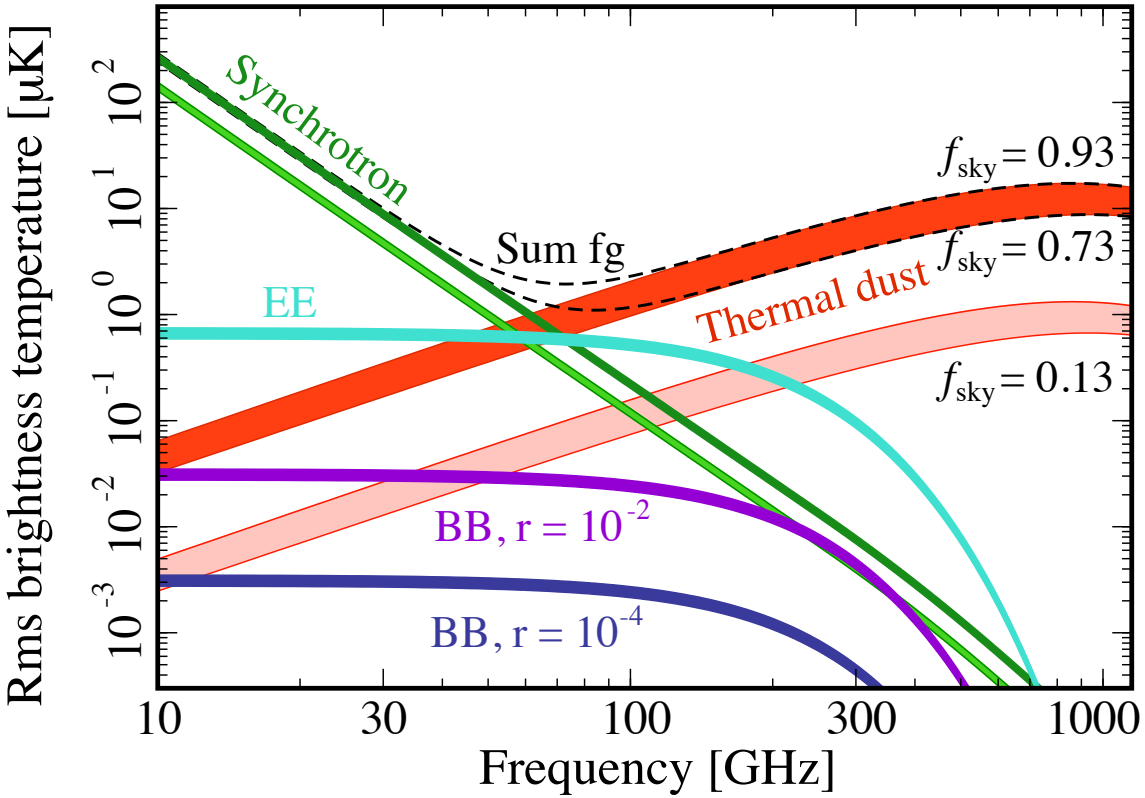
CMB-S4 will exclude models that naturally explain the observed n_S with super-Planckian characteristic scale M.

Inflationary observables beyond r



CMB-S4 will improve constraints on the spectral dependence, departures from adiabaticity, Gaussianity of primordial density perturbations by a factor 2-3.

Foregrounds



Foregrounds are brighter than the signal on all scales and at all frequencies.

Foregrounds

Contributors to work on forecasts

Colin Bischoff, Victor Buza, Tom Crawford, Alex van Engelen, Brandon Hensley, Colin Hill, Lloyd Knox, John Kovac, Clem Pryke, Ben Racine, Blake Sherwin, Caterina Umilta, …

over 50 telecons, over 150 postings on CMB-S4 wiki

- Studied numerous existing foreground models
- Developed new foreground models
- Studied different analysis techniques
- …

Delensing

The science goals require highly efficient removal of lensing B-modes (delensing)

Requires a dedicated large aperture telescope to accompany the small aperture telescopes

Forecasting currently in two steps

- forecast of effective noise curve for ILC map given the DSR reference design and foreground model
- spectrum based forecast for iterative delensing

Some reassuring map-based results, but more work is needed.

Summary and Conclusions

- CMB-S4 is exquisitely sensitive to gravitational waves present at recombination
- Gravitational waves present at recombination are a pristine relic of the primordial universe.
- Either a detection of, or an upper limit on, the amount of gravitational waves with CMB-S4 will provide invaluable information about the primordial universe
- CMB-S4 will improve precision for most observables related to primordial density perturbations by a factor of 2-3, more on certain observables

Summary and Conclusions

- To achieve the science goals, unprecedented control over foregrounds, delensing, and systematics is required
- Significant progress on foregrounds and delensing achieved within gravitational waves working group
- New, physically motivated foreground models have been developed and were first used for CMB-S4
- Two independent analysis pipelines provide consistent results
- More work is needed, but no show stoppers to achieve the science goals