The biggest discovery in cosmology in over a decade?

Primordial gravitational waves detected by BICEP2?

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BICEP2

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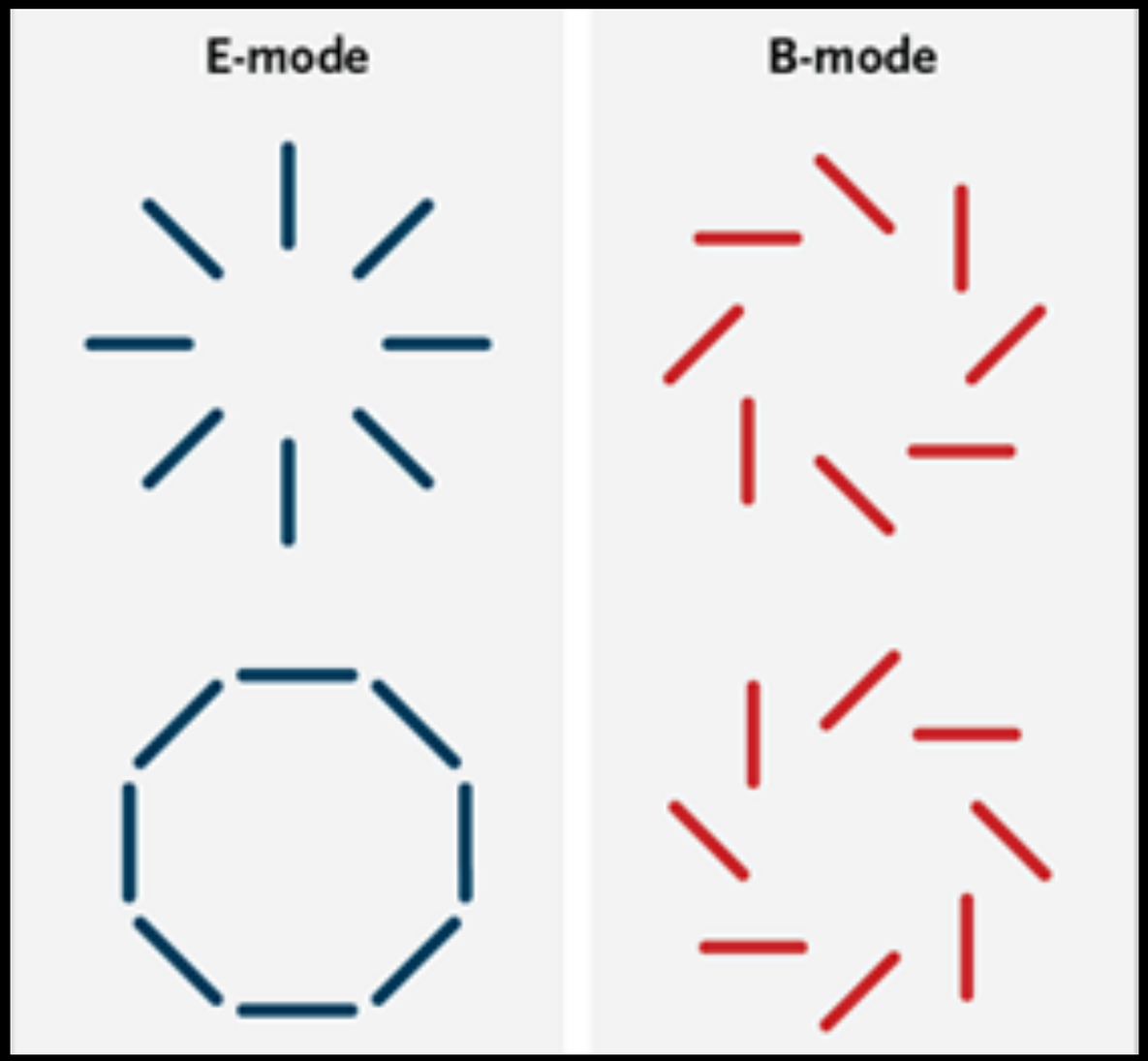
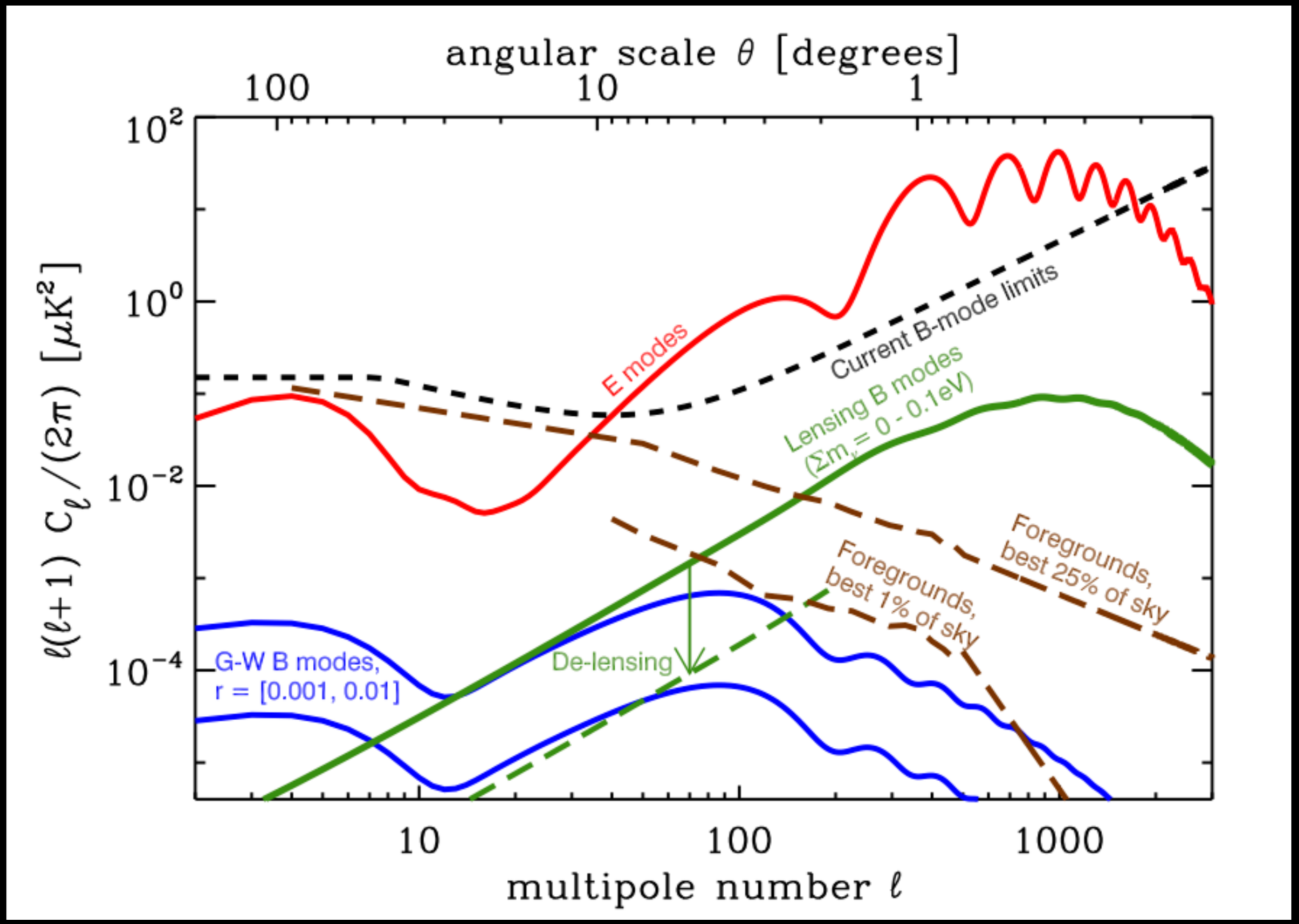
E and B modes



Theory Spectra



Raw Data

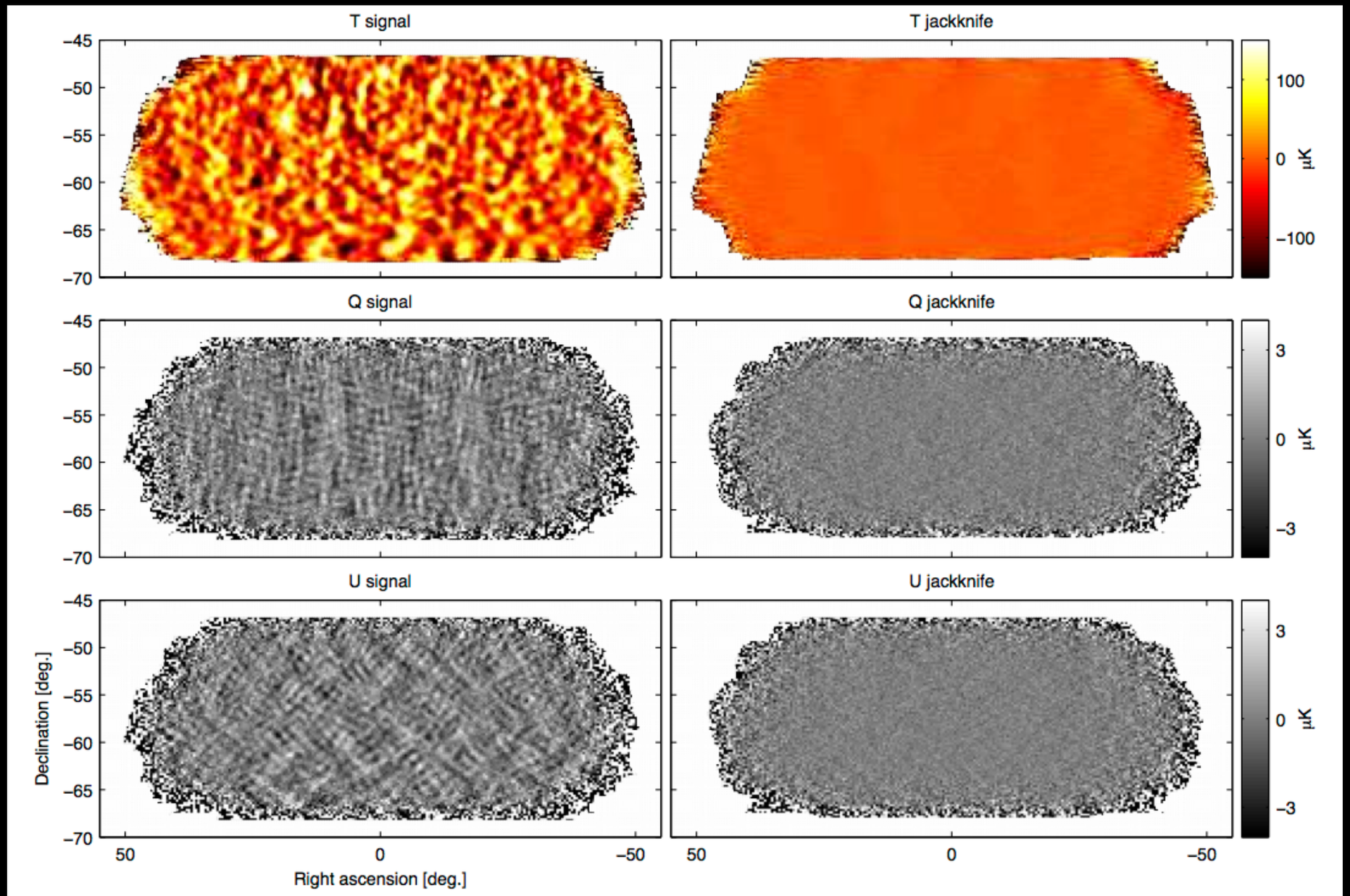


FIG. 1.— BICEP2 T, Q, U maps. The left column shows the basic signal maps with 0.25° pixelization as output by the reduction pipeline. The right column shows difference (jackknife) maps made with the first and second halves of the data set. No additional filtering other than that imposed by the instrument beam (FWHM 0.5°) has been done. Note that the structure seen in the Q&U signal maps is as expected for an E-mode dominated sky.

Recovered E/B Maps

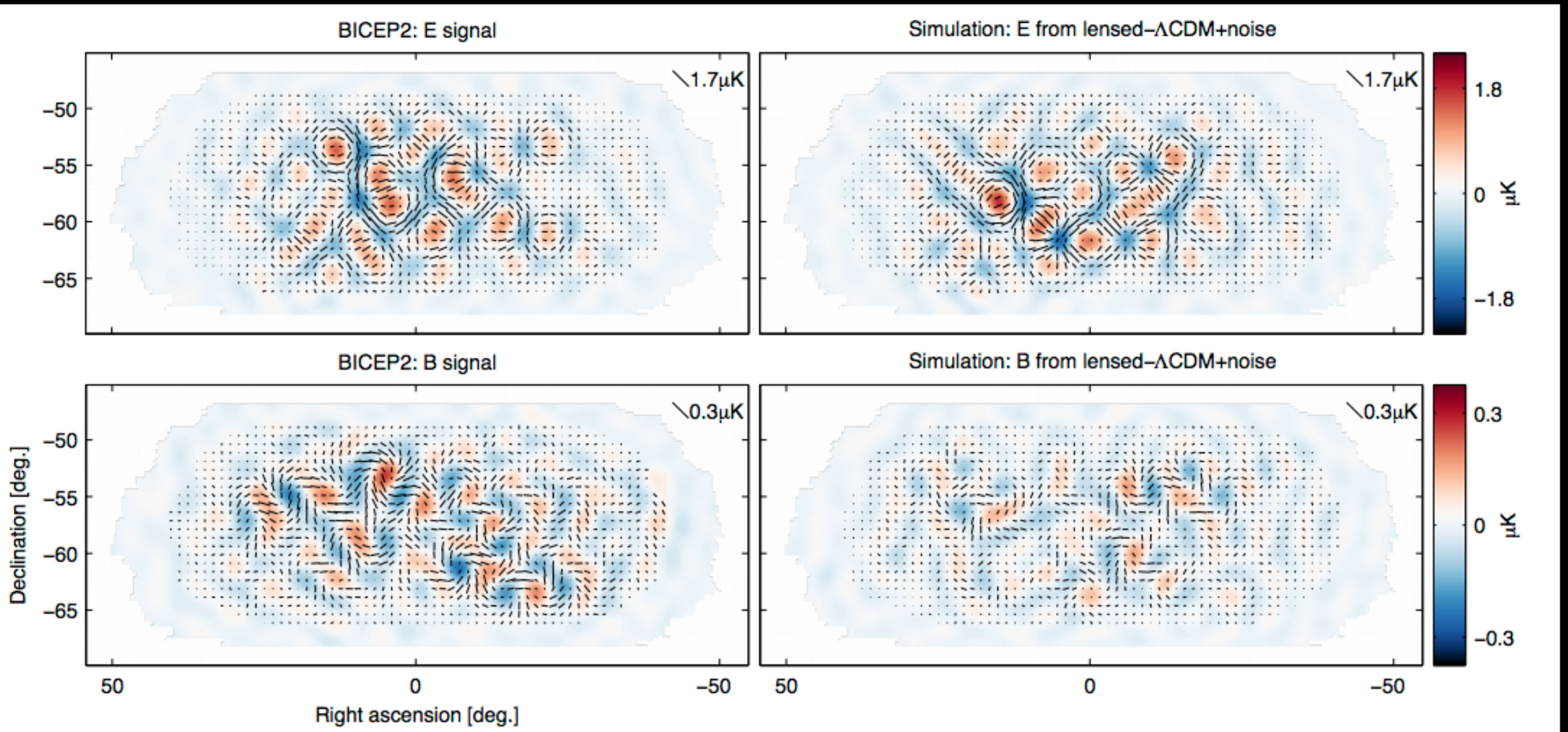


FIG. 3.— *Left:* BICEP2 apodized E-mode and B-mode maps filtered to $50 < \ell < 120$. *Right:* The equivalent maps for the first of the lensed-ΛCDM+noise simulations. The color scale displays the E-mode scalar and B-mode pseudoscalar patterns while the lines display the equivalent magnitude and orientation of linear polarization. Note that excess B-mode is detected over lensing+noise with high signal-to-noise ratio in the map ($s/n > 2$ per map mode at $\ell \approx 70$). (Also note that the E-mode and B-mode maps use different color/length scales.)

Full Spectra

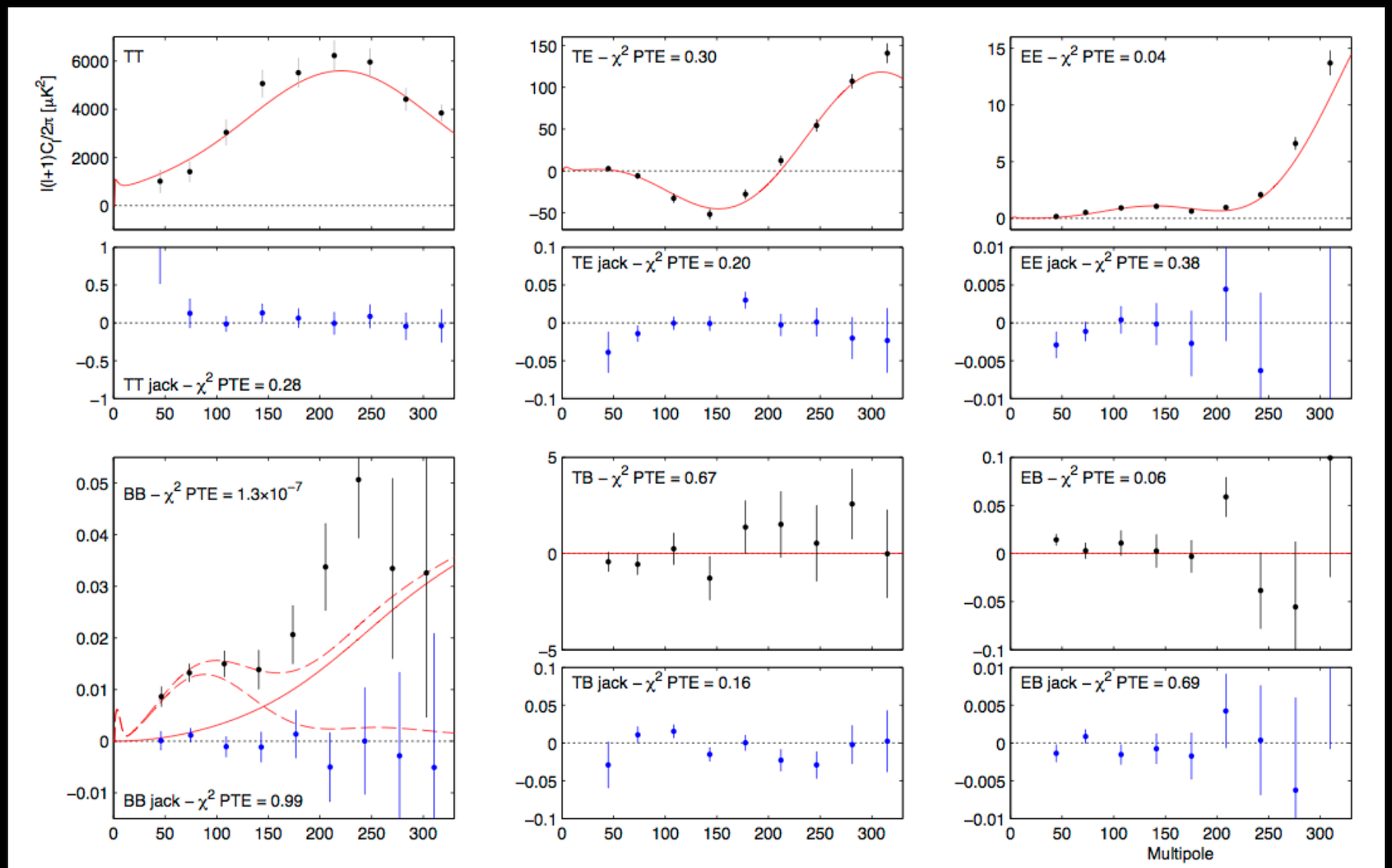


FIG. 2.— BICEP2 power spectrum results for signal (black points) and temporal-split jackknife (blue points). The red curves show the lensed-ΛCDM theory expectations — in the case of *BB* an $r = 0.2$ spectrum is also shown. The error bars are the standard deviations of the lensed-ΛCDM+noise simulations. The probability to exceed (PTE) the observed value of a simple χ^2 statistic is given (as evaluated against the simulations). Note the very different y-axis scales for the jackknife spectra (other than *BB*). See the text for additional discussion of the *BB* spectrum.

Tensor-to-Scalar Ratio

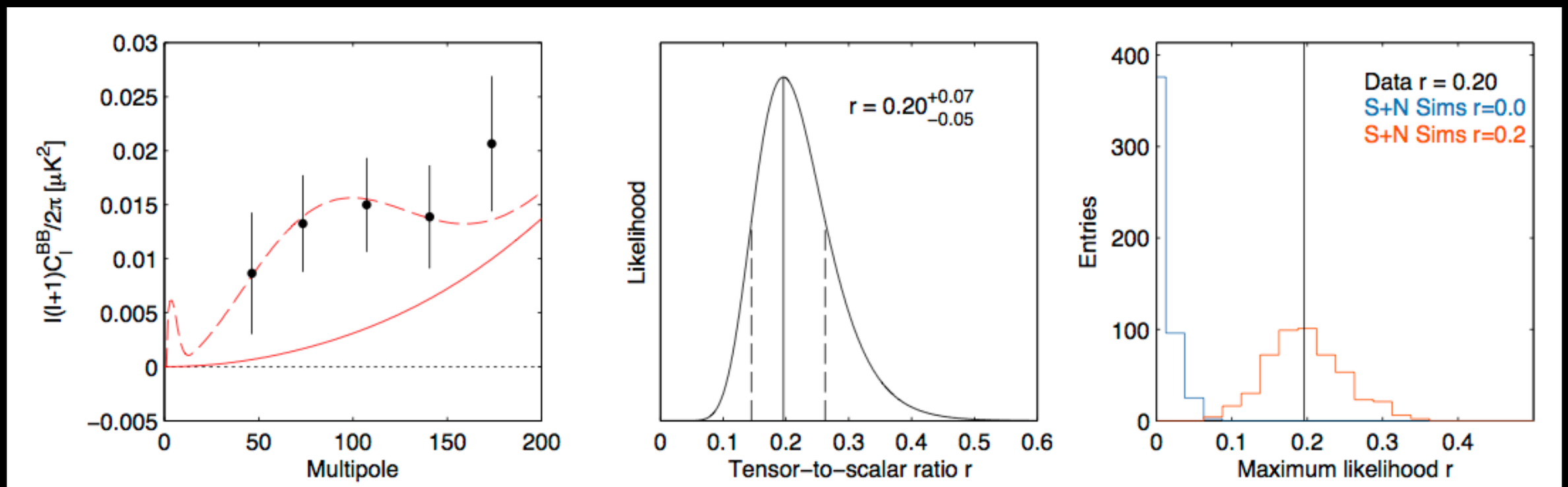


FIG. 10.— *Left:* The BICEP2 bandpowers plotted with the maximum likelihood lensed-ΛCDM+$r = 0.20$ model. The uncertainties are taken from that model and hence include sample variance on the r contribution. *Middle:* The constraint on the tensor-to-scalar ratio r. The maximum likelihood and $\pm 1\sigma$ interval is $r = 0.20^{+0.07}_{-0.05}$, as indicated by the vertical lines. *Right:* Histograms of the maximum likelihood values of r derived from lensed-ΛCDM+noise simulations with $r = 0$ (blue) and adding $r = 0.2$ (red). The maximum likelihood value of r for the real data is shown by the vertical line.

Robustness

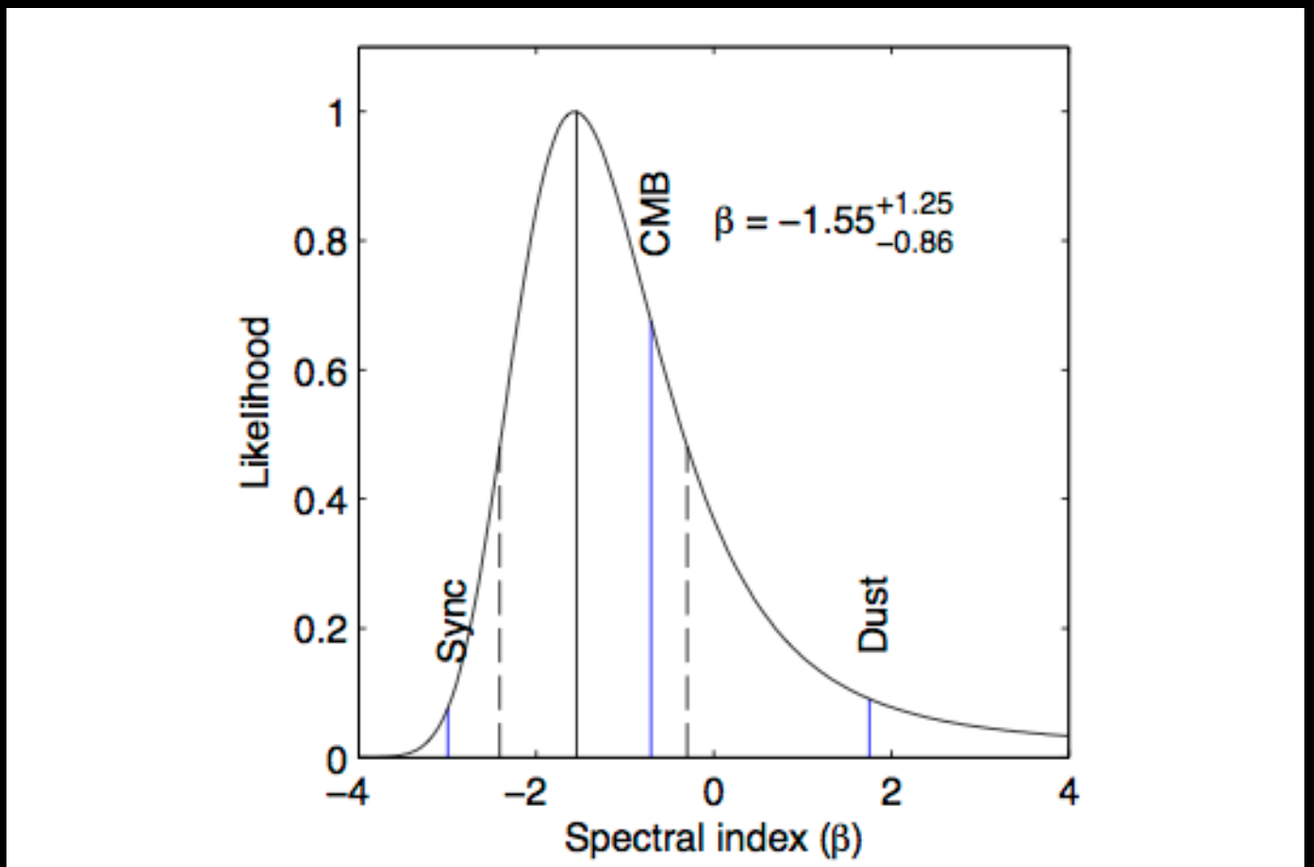


FIG. 8.— The constraint on the spectral index of the *BB* signal based on joint consideration of the BICEP2 auto, BICEP1$_{100}$ auto, and BICEP2×BICEP1$_{100}$ cross spectra. The curve shows the marginalized likelihood as a function of assumed spectral index. The vertical solid and dashed lines indicate the maximum likelihood and the $\pm 1\sigma$ interval. The blue vertical lines indicate the equivalent spectral indices under these conventions for the CMB, synchrotron, and dust. The observed signal is consistent with a CMB spectrum, while synchrotron and dust are both disfavored by $\gtrsim 2\sigma$.

Comparison with Planck

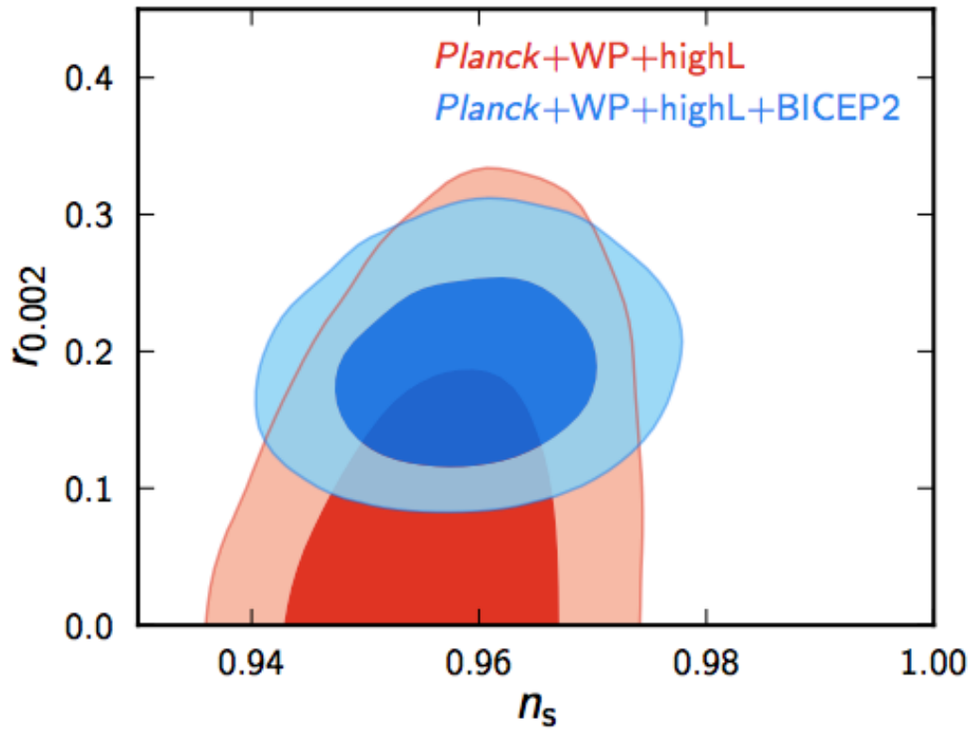


FIG. 13.— Indirect constraints on r from CMB temperature spectrum measurements relax in the context of various model extensions. Shown here is one example, following Planck Collaboration XVI (2013) Figure 23, where tensors and running of the scalar spectral index are added to the base ΛCDM model. The contours show the resulting 68% and 95% confidence regions for r and the scalar spectral index n_s when also allowing running. The red contours are for the "Planck+WP+highL" data combination, which for this model extension gives a 95% bound $r < 0.26$ (Planck Collaboration XVI 2013). The blue contours add the BICEP2 constraint on r shown in the center panel of Figure 10. See the text for further details.

Constraints from other Experiments

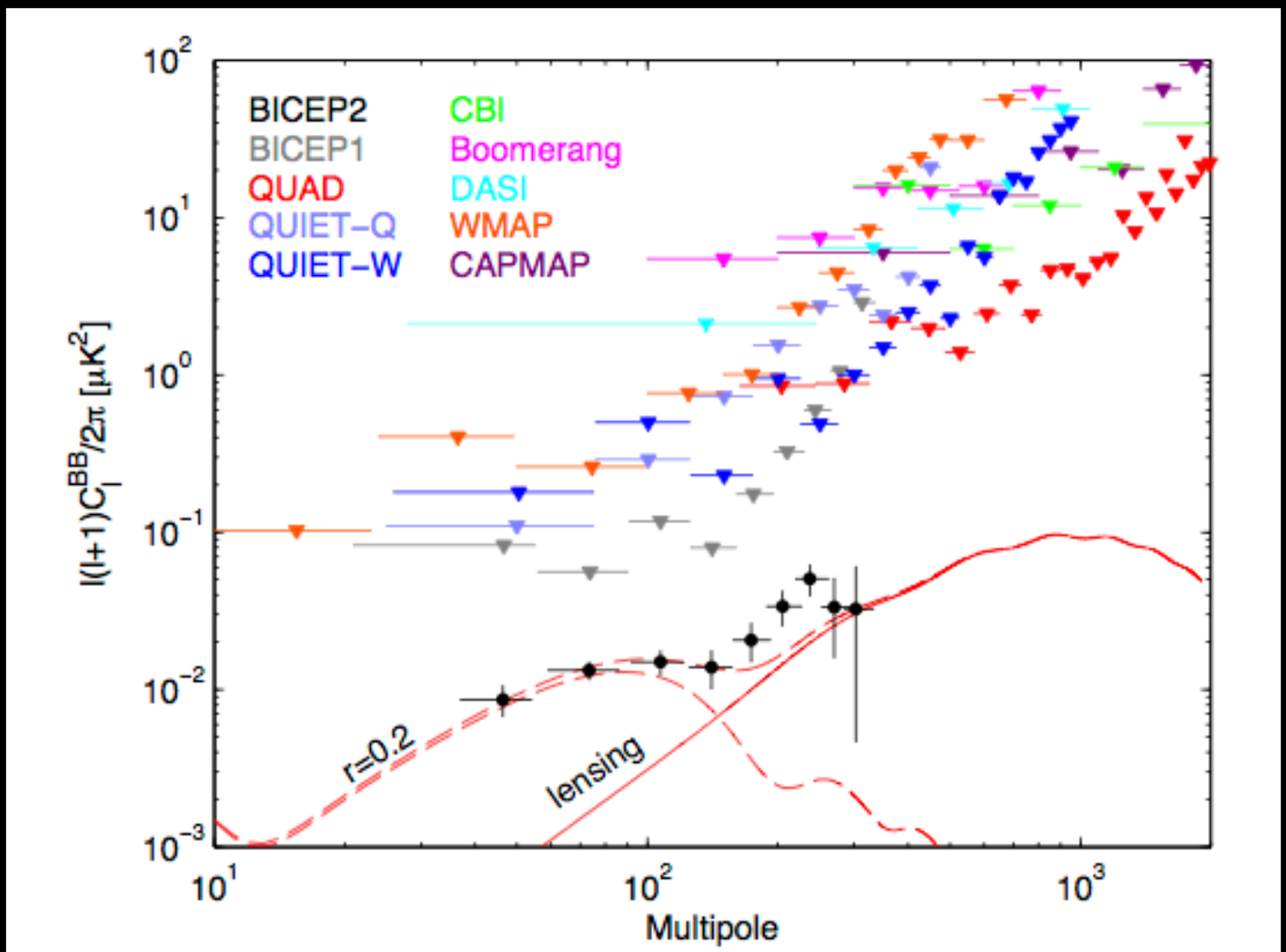
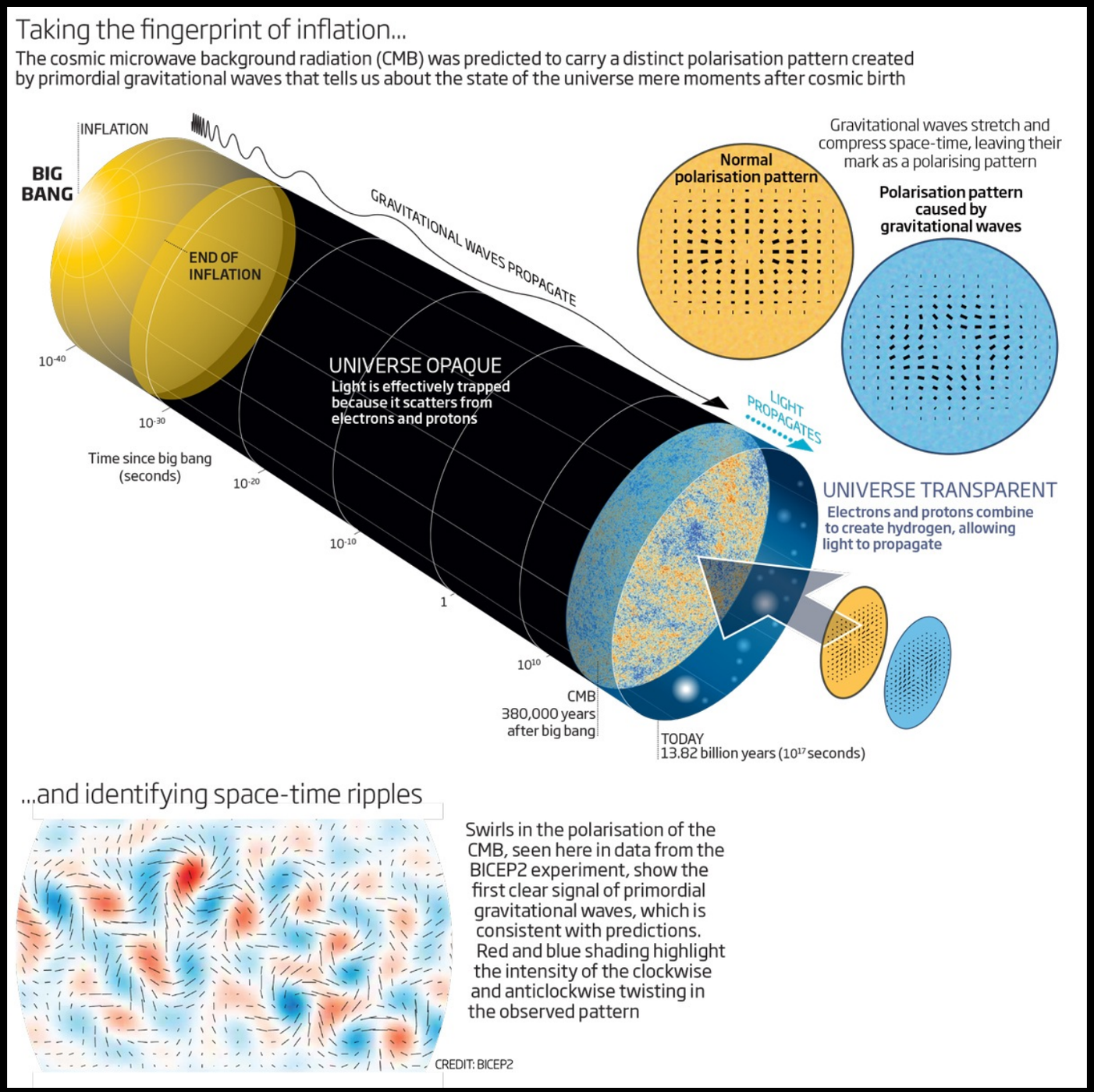


FIG. 14.— BICEP2 *BB* auto spectra and 95% upper limits from several previous experiments (Leitch et al. 2005; Montroy et al. 2006; Sievers et al. 2007; Bischoff et al. 2008; Brown et al. 2009; QUIET Collaboration et al. 2011, 2012; Bennett et al. 2013; Barkats et al. 2014). The curves show the theory expectations for $r = 0.2$ and lensed-ΛCDM.

A new Window into the Cosmos



Probing Fundamental Physics

- Inflation ~10^16 GeV, whereas LHC ~10^3 GeV
- Potential to probe fundamental physics at energy scales a trillion times larger than with particle accelerators!

Credits

- http://bicepkeck.org/
- BICEP2 2014 I: Detection of B-mode Polarization at Degree Angular Scales, The BICEP2 Collaboration, 2014
- http://www.preposterousuniverse.com/blog/2014/03/16/gravitational-waves-in-the-cosmic-microwave-background/
- http://arxiv.org/abs/1309.5381
- www.newscientist.com/article/dn25235-first-glimpse-of-big-bang-ripples-from-universes-birth.html#.UydKc-dUg6o