Executive summary

How did the universe evolve? The fine angular scale ($\ell > 1000$) temperature and polarization anisotropies in the CMB are a Rosetta stone for understanding the evolution of the universe. Through detailed measurements one may address everything from the physics of the birth of the universe to the history of star formation and the process by which galaxies formed. One may in addition track the evolution of the dark energy and discover the net neutrino mass.

We are at the dawn of a new era in which hundreds of square degrees of sky can be mapped with arcminute resolution and sensitivities measured in microKelvin. Acquiring these data requires the use of special purpose telescopes such as the Atacama Cosmology Telescope (ACT), located in Chile, and the South Pole Telescope (SPT). These new telescopes are outfitted with a new generation of custom mm-wave kilo-pixel arrays. Additional instruments are in the planning stages.

no mention in this "white Paper" of the terms "turbulence" or "planets", even though any physical model of primordial polarization requires both.
CHG 2014

1 Introduction

The primary CMB has been a gold mine for understanding the cosmos. Through the study of the CMB we have determined the geometry, age, and contents of the universe at the few percent level. Observations have reached the point where we now have a "standard model of cosmology." Yet there is much more to learn from the CMB. In the standard model there are new unanswered questions and more traditional questions are more sharply focused. The following are within our reach in the next decade:

1. What is the dark energy and what are its characteristics? Did the dark energy act differently before $z = 1$?

   Dark energy is an unnecessary concept: it doesn't exist, CHG
2. Did neutrinos leave an identifiable imprint on the cosmos and if so what is the sum of their masses? Measurements of neutrino oscillations show that the difference in the square of the masses is ~ 0.002 $(\mathrm{eV})^2$, indicating that at least one species must have a mass near 0.05 eV. This value can be determined with fine scale anisotropy measurements.

   Neutrinos weigh 10^-36 kg each, probably, (~30 times larger), CHG
3. Where are the missing baryons? Big Bang nucleosynthesis and CMB derived baryon densities are not in accord with the observational census.

   The dark matter of galaxies is planets. The planets are in clumps. CHG
4. How did the first stars turn on and what is their ionization history?

   When plasma turned ot gas the dark matter planets promptly formed stars.
5. Did the early universe have only Gaussian fluctuations or were there phase transitions that perhaps produced cosmic strings? The discovery of primordial non-Gaussianity would revolutionize cosmology.

   The big bang turbulence of the hot big bang nicely explains the observations, CHG
6. Are the fluctuations solely adiabatic or is there an admixture of isocurvature modes?

   See Sreenivasan and Bershadski papers for the best evidence of plasma epoch turbulence from the CMB, CHG

Eisenstein and Bennett 2008 Physics Today

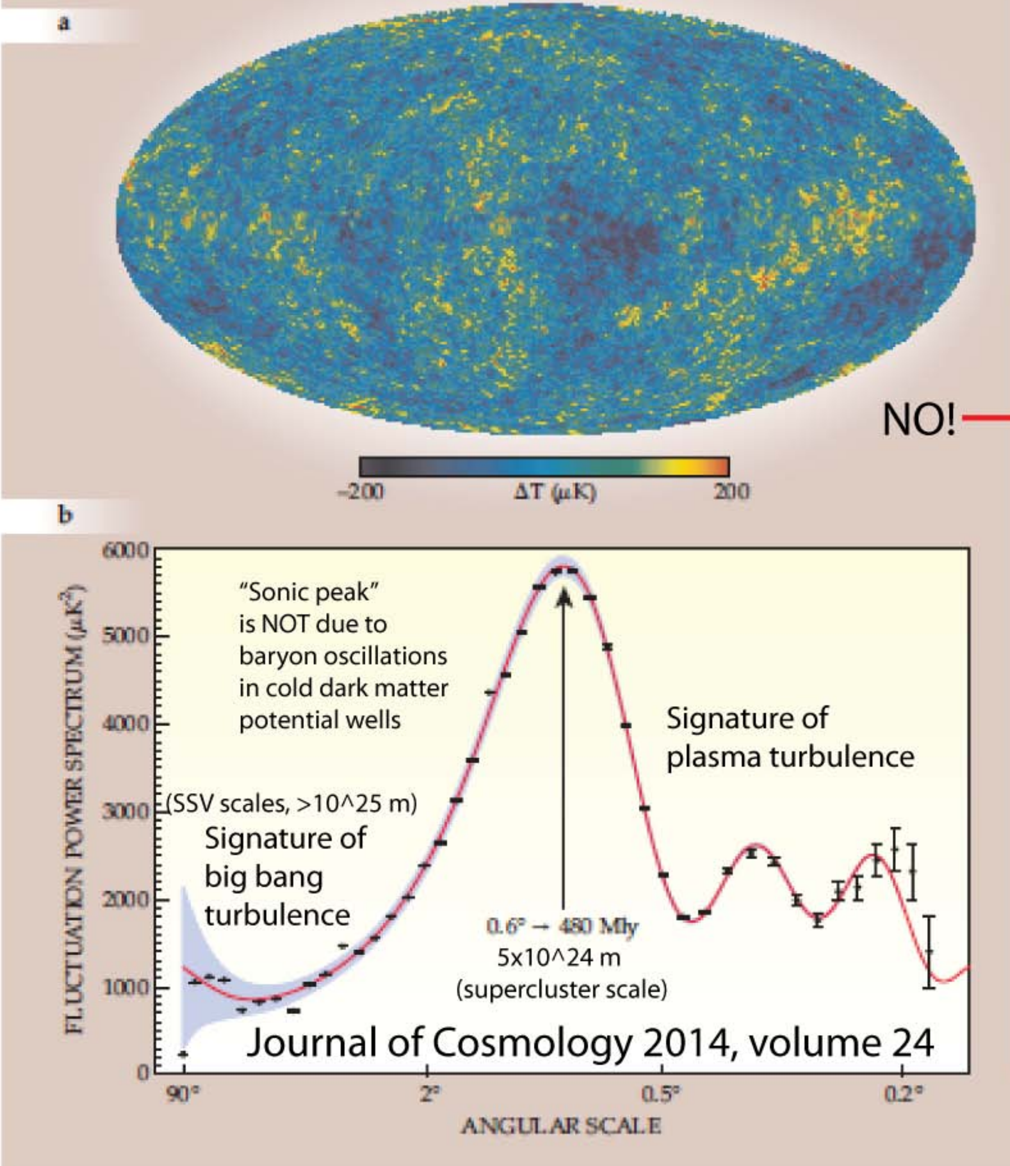

Figure 2. (a) Small spatial fluctuations ΔT in the almost perfectly isotropic 2.725 K temperature of the cosmic microwave background, as recorded by the *Wilkinson Microwave Anisotropy Probe.*[12] **(b)** The power spectrum of the temperature fluctuations, plotted as a function of their angular size on the sky, comes from a spherical-harmonic analysis of the *WMAP* data.[12] It reveals a harmonic sequence of acoustic peaks attributed to sound waves propagating in the hot primordial plasma that filled the cosmos for its first 380 000 years. The first acoustic peak, at 0.6°, manifests the distance a primordial sound wave could propagate before the abrupt end of the plasma epoch. In the subsequent thousandfold Hubble expansion of the cosmos, that characteristic distance has been stretched to 480 million light-years. The curve is the best cosmological-model fit to the data points, and the gray swath indicates the irreducible random variance for different cosmic vantage points.