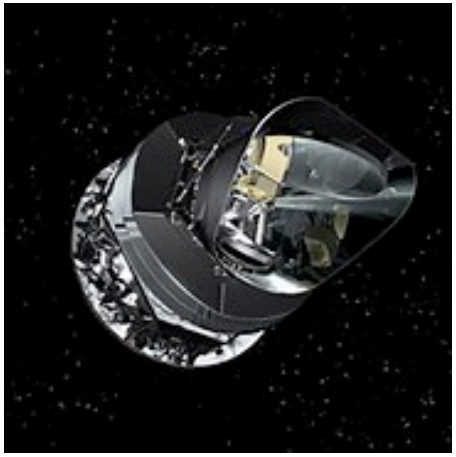
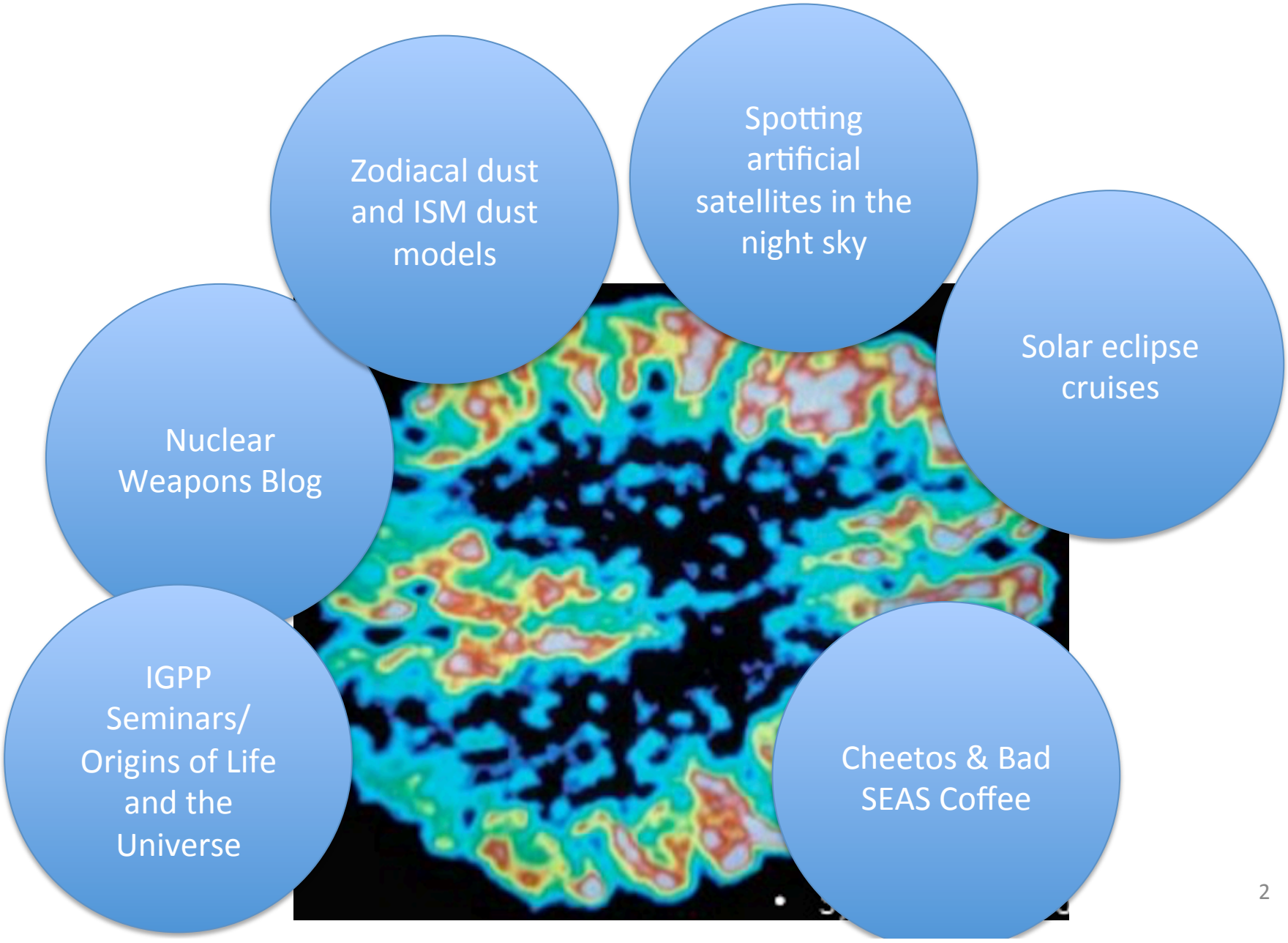


Caltech

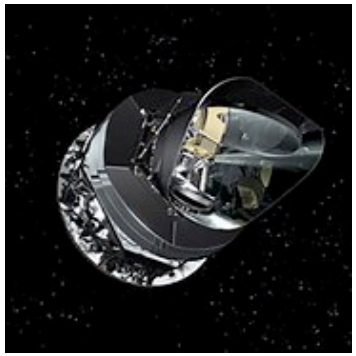
Ned's Multiverse: A Search for Spectral Distortions

Ranga Ram Chary
IPAC
California Institute of Technology


Zodiacal dust and ISM dust models
Spotting artificial satellites in the night sky
Solar eclipse cruises
Nuclear Weapons Blog
IGPP Seminars/ Origins of Life and the Universe
Cheetos & Bad SEAS Coffee

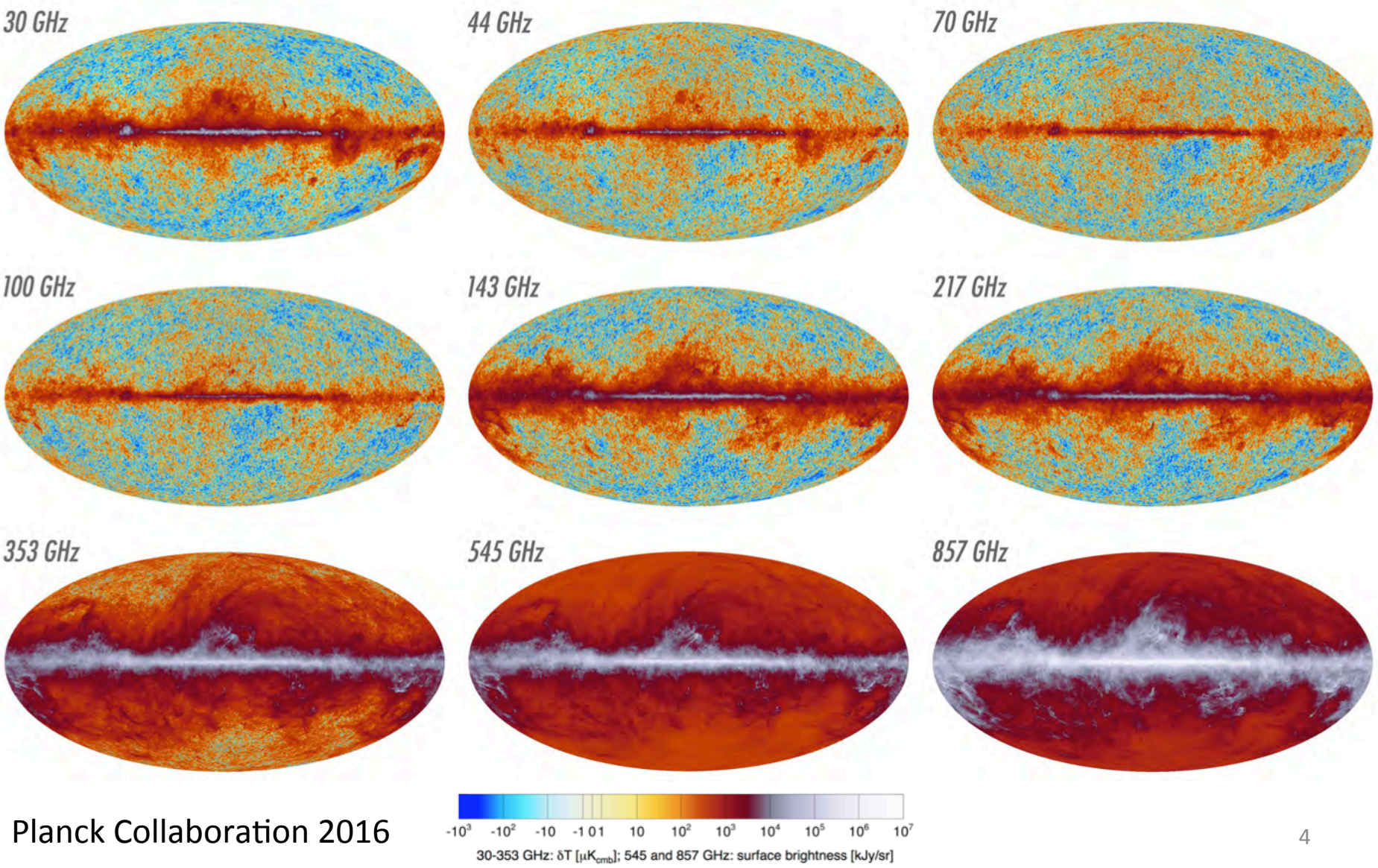
Requirements for study of Ned's Multiverse

- Need to observed Ned for extended periods of time
- Need to observe Ned closely i.e. highly sensitive data
- Need to interact with Ned in different environments i.e. separate foregrounds in a different way

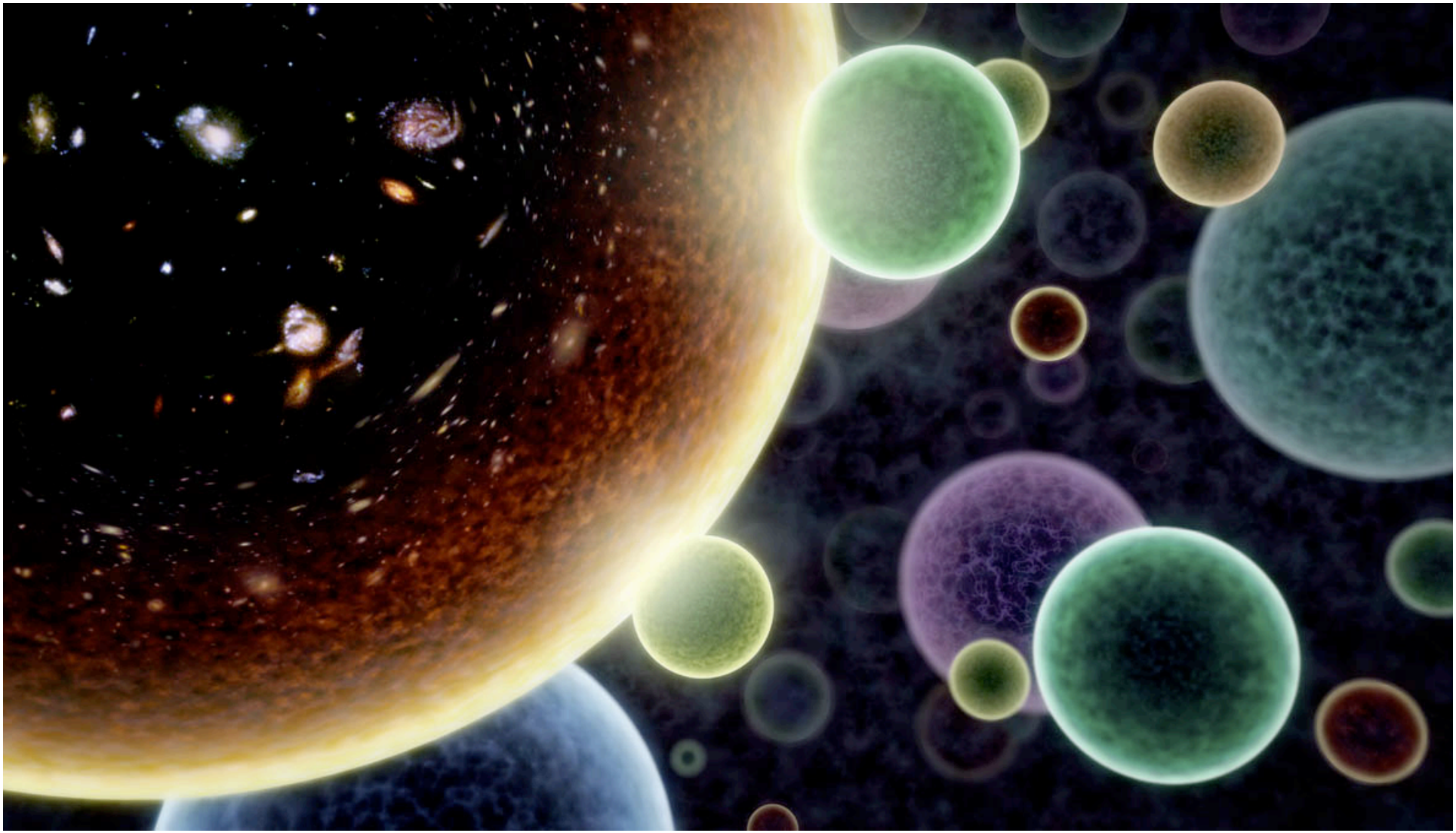


ESA's Planck Mission with NASA involvement

Planck Data: All-Sky Temperature Maps



Planck Collaboration 2016



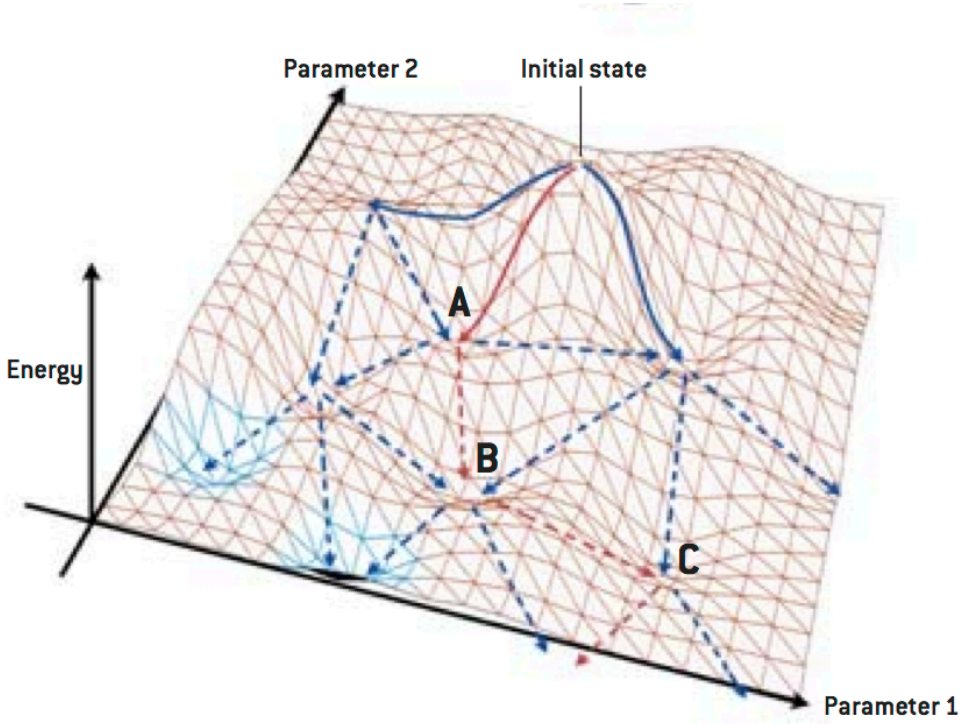
Planck Collaboration 2016 shows remarkable isotropy all over the sky!

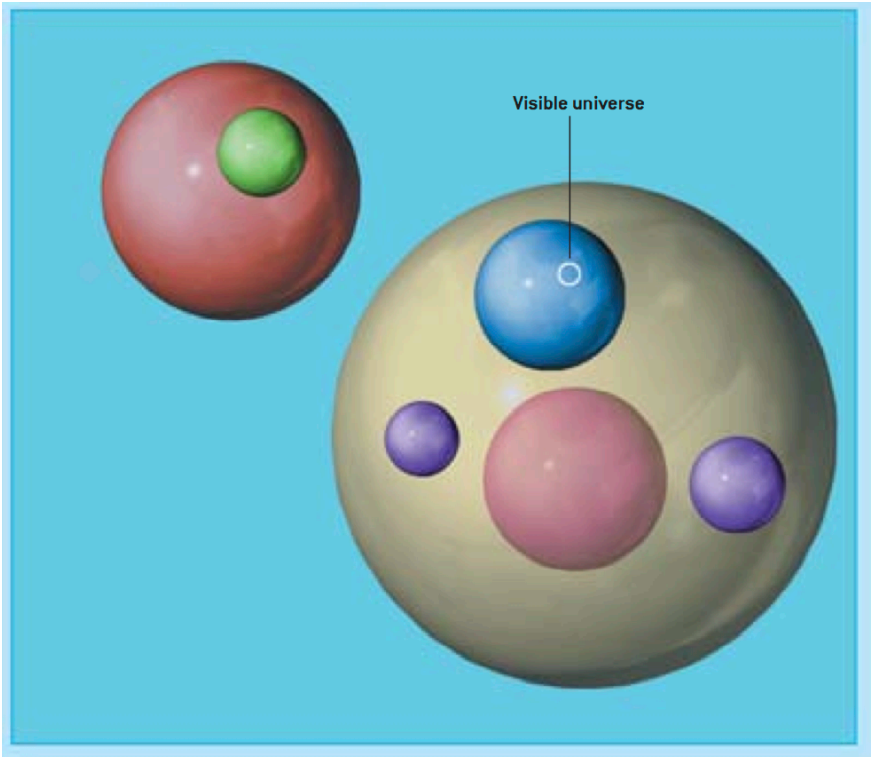
Past analysis insensitive to spectral distortions of CMB

- Any spectral variation of CMB absorbed into foreground models
  - dust has a very wide range of temperature and emissivity

- A differential analysis of foregrounds between nearby hot spots and cold spots is much cleaner

What causes the Big Bang and Inflation? From String Theory….

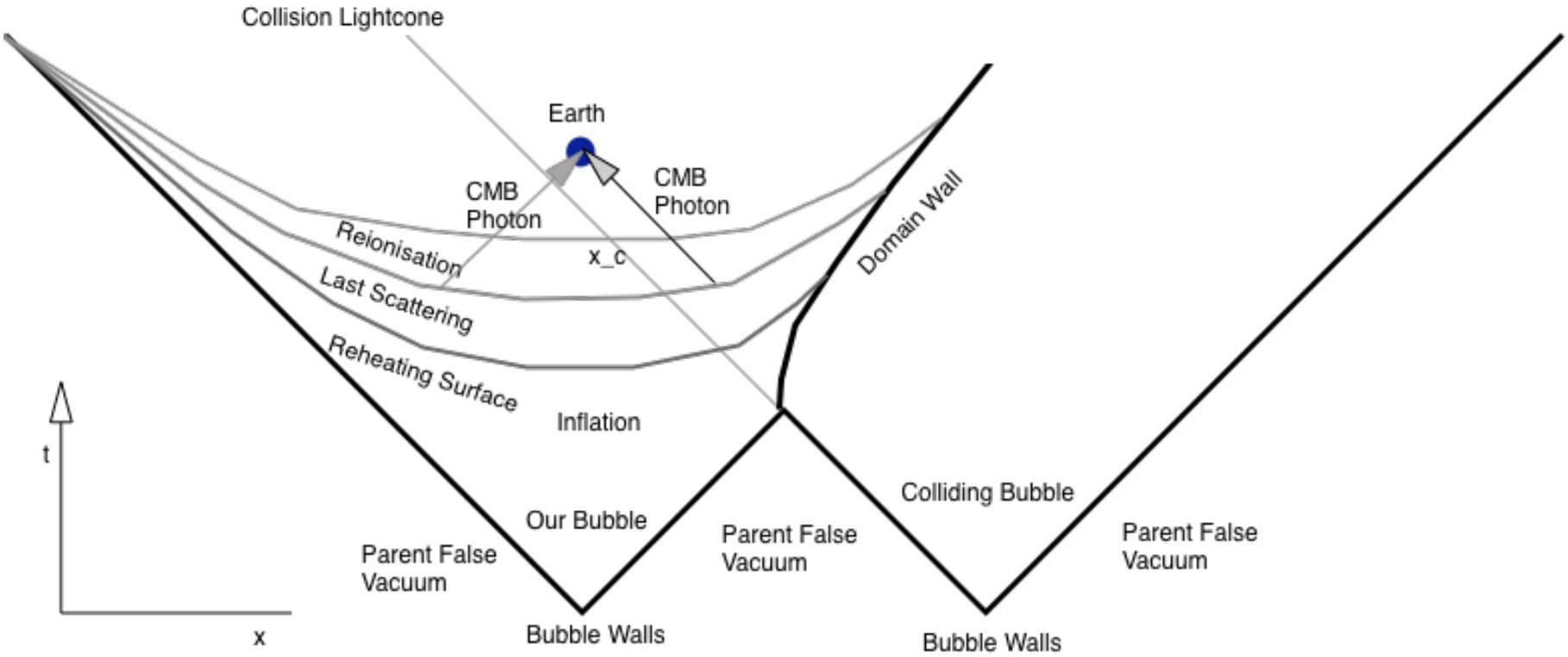




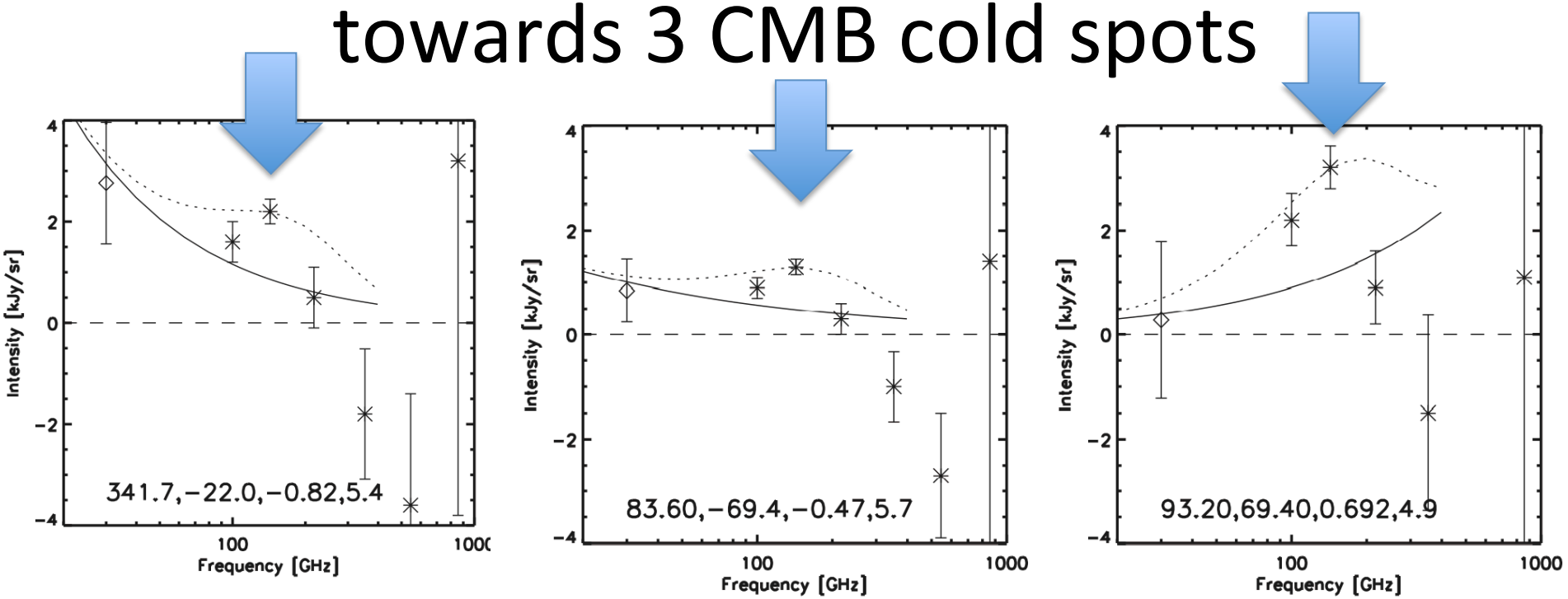
Phase transitions from multi-dimensional strings
If you don't want God, you'd better have a multiverse − Bernard Carr

Kallosh, Kachru, Linde, Trivedi (KKLT) 2003
Bousso & Pochinski

Lets look at it in space-time



~4-5σ Excess 143 GHz Emission towards 3 CMB cold spots



5sigma should occur only 1 in 70 maps

5.7sigma has a 1 in 70000 maps

Solid line is best fit residual foregrounds − the fit is NOISY!
Dotted line is adding a 3K continuum which violates 100 & 217 GHz
μ~3-9E-6, x30-100 below FIRAS constraints

Planck see spectral anisotropies on the sky - surprising!

1.8 deg Pixels with SNR>5 Excess at 143 GHz and low ISM emission

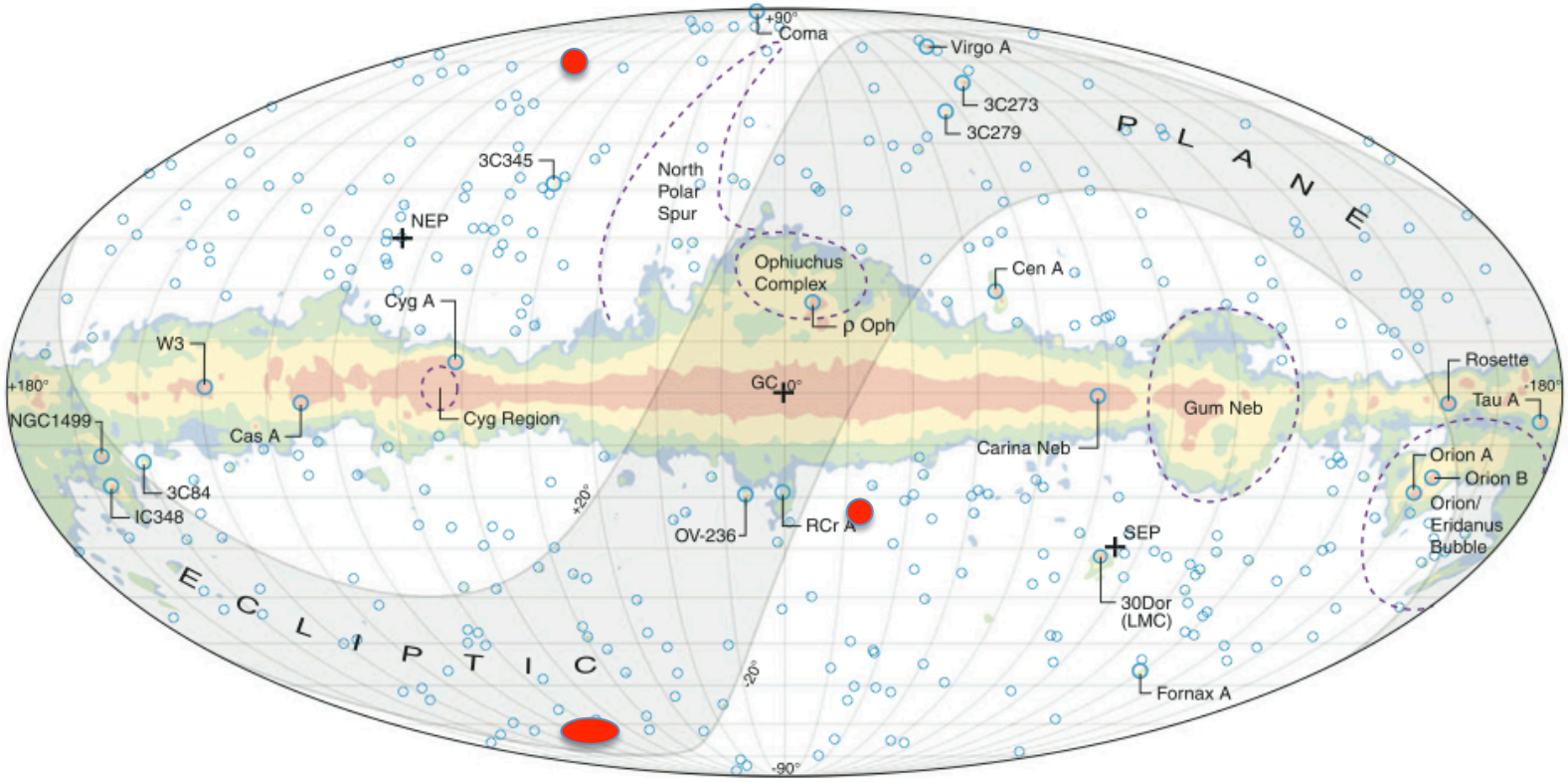
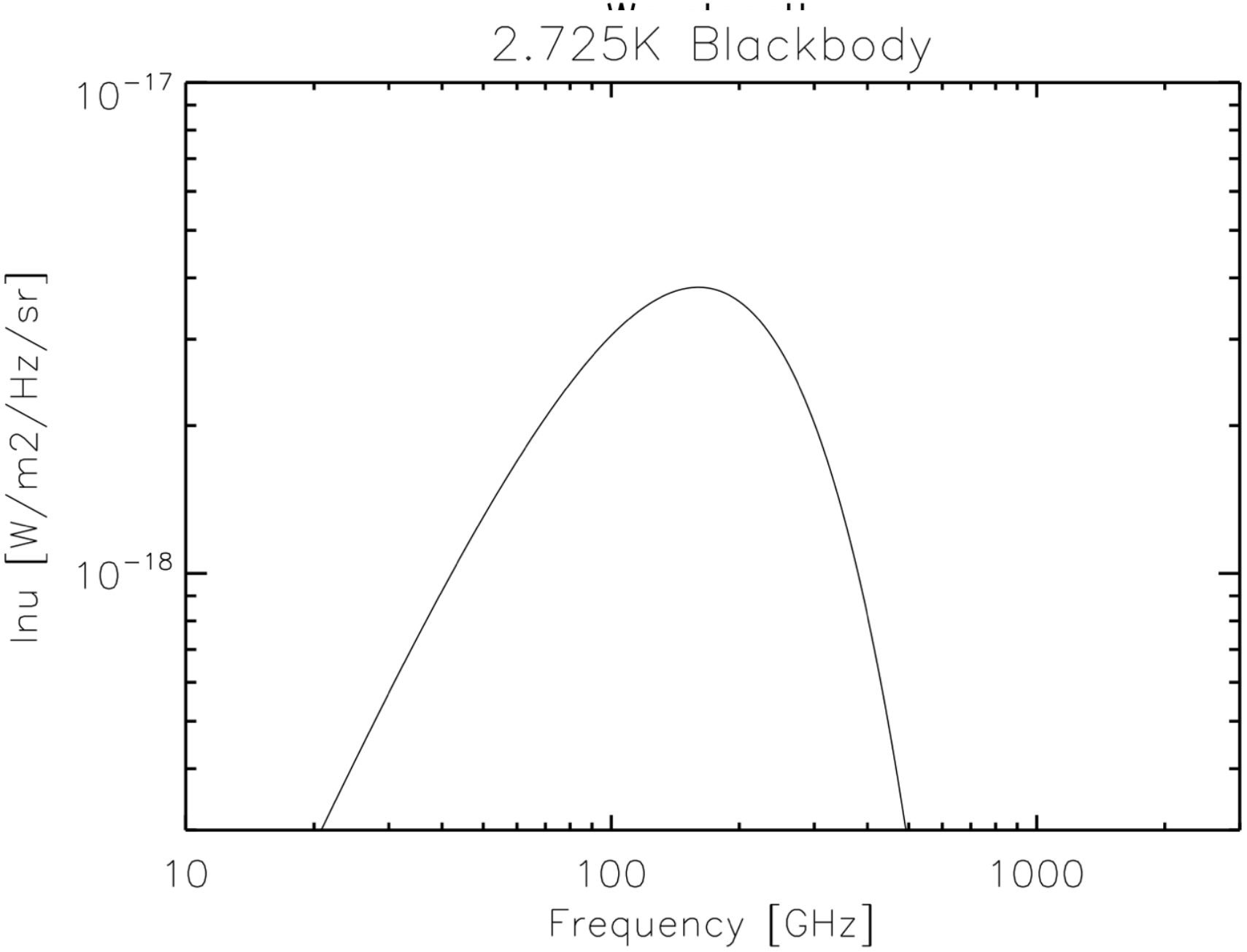


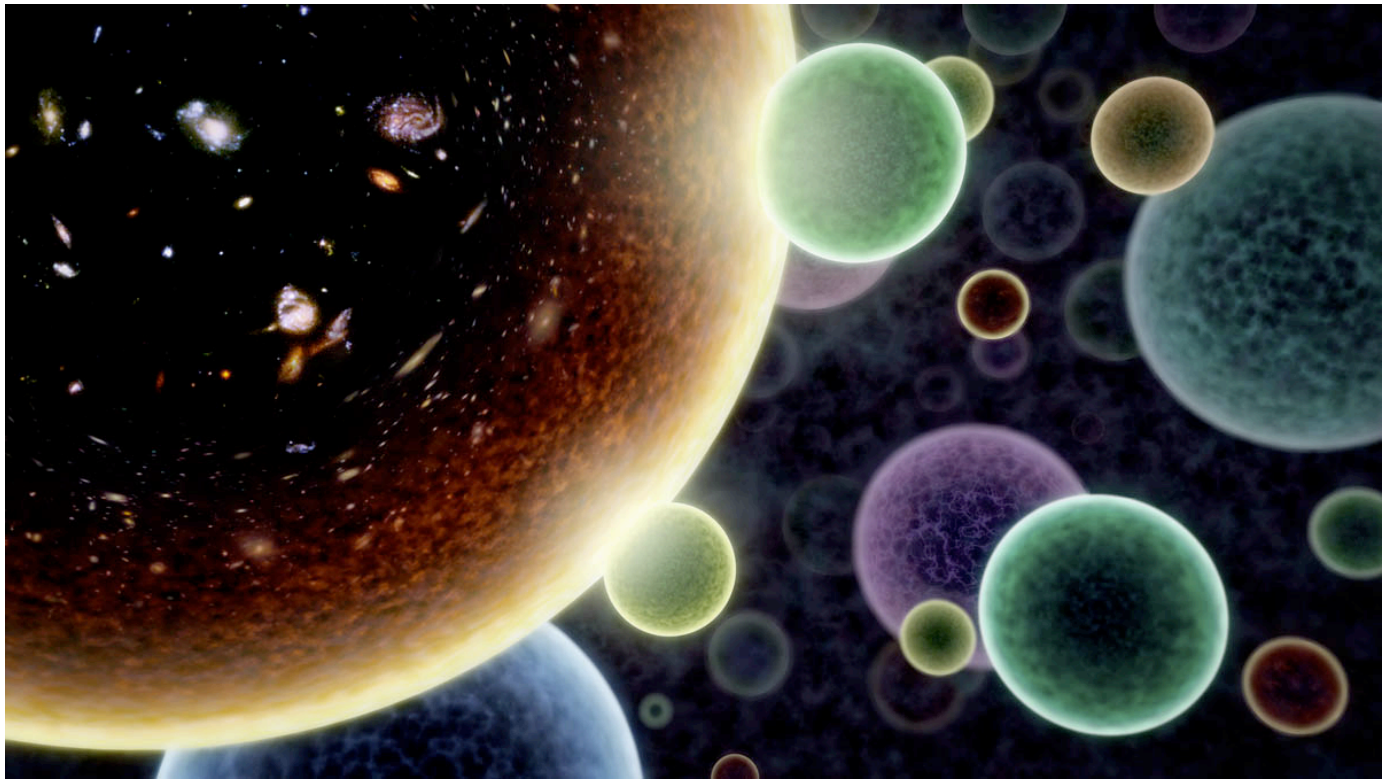
Figure 12. Microwave emission near the Galactic plane is traced by a *K*-band minus *W*-band difference map, which eliminates CMB anisotropy. A log scale is used for the color region and blue circles represent the positions of the brightest point sources, as seen by *WMAP*.

RC 2016, ApJ, 817, 33



Recombination model of Chluba & Sunyaev 2006, 2007; Rubiño-Martín et al. 2008

Enhanced Hydrogen Paschen-series lines from recombination?



- Stronger recombination signal in the direction of certain cold spots (~2-4 deg)?
- Requires a higher baryon density in those regions without affecting T power spectrum
- The region would have ~4500 more baryons/photons than our Universe
- Would have to be from collisions with our bubble inducing a localized isocurvature mode

RC, 2016, ApJ

Summary

- We are finding spectral anomalies ($\mu \sim 3\text{-}9\times10^{-6}$) in the direction of CMB cold spots at 143 GHz with Planck i.e. *excess emission in cold spots*.
  - Is the CMB not isotropic spectrally?
  - More than x10 below FIRAS constraints
  - Is there more noise in the Planck data that is unaccounted for?

- If due to Hydrogen Pa-alpha, requires x4500 enhanced baryon/photon ratio, which cannot be in our Universe and must be an alternate bubble.
  - Compensated isocurvature modes arising in bubble collisions?
  - Absence of signature in Temperature power spectrum.

- If true would favor eternal inflation models, with our Universe being a chance fluctuation among $\sim10^{500}$ and a way to test string theory.

Does she (Nature) play dice after all?

Lessons learnt from Ned (& Eric)

- Be generous with your time and funding (despite its sparseness) for students and postdocs.
- Trust your data.
- Build unique data analysis techniques.
- Think big thoughts because the 9^{th} decimal place of the Boltzmann constant only sheds marginally more light on nature.
- Play the lottery i.e. do Monte-Carlo simulations of the data.