Observational Summary or: A Theorist Looks at Observations

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How Did I Get This Job?

- 1. Eiichiro Komatsu could not come...
- 2. I started in particle physics and gravity: $\Omega_k = 0$ or ~ 0.7
 - Planck, string and GUT scale physics
- 3. 2006: I was compiling HEALPIX and likelihood code
 - Worrying about convergence statistics for MCMC
- 4. 2010: Ω_k =-0.0023 (-0.0058,+0.0054)
 - My interests are much the same; but the world is different
 - And I am not giving a retirement speech!

Look For Features...

"Happy families are all alike; every unhappy family is unhappy in its own way"

Leo Tolstoy

Look For Features...

"Smooth universes are all alike; every lumpy universe is lumpy in its own way"

not Leo Tolstoy

Primordial Features...

- Universe today is *full* of features...
 - Stars, galaxies, people, planets, halos, voids
- Takes a very special person to see the sky as smooth...
 - Why CMB not immediately seen as astronomical
- Contrast: pre-discovery of pulsars: 23hr56 minute periodicity.
 - US Air Force radar technician: Charles Schisler
- Default is a smooth primordial universe: seeking exceptions



Planck Data...

- Time stream data from Bouchet's talk
 - Dipole: sinusoidal modulation across sky during scan
 - Planck detects CMB dipole in real time [how cool is that?]



Concordance Parameters

A _{sz}	Sunyaev-Zeldovich Amplitude	Scattering of photons by hot gas in clusters	Emorgont	
т	Reionization	First stars (gastrophysics, nuclear physics)	Emergent	
h	Hubble's "constant"	When we are looking	Timing	
$\Omega_{ m b}$	Baryon fraction (Mass known, #??)	Baryogenesis (? - GUT, Electroweak?)		
$\Omega_{\rm CDM}$	Dark matter (Mass ??, #??)	TeV Scale physics?? Supersymmetry? LHC?	Composition	
Ω_{Λ}	Cosmological constant	Quantum Gravity Magic?		
A _s ,n _s	Primordial Perturbations	Inflation GUT/string physics?	Primordial	

What is a "Feature"?

- One definition
 - Anything not explained by concordance cosmology?
 - \bullet But that may (one day) include e.g. neutrino physics / Y_{He}
- Feature / background is a matter of perspective
 - Symmetry: argues for pure Harrison-Zel'dovich spectrum?
 - Slow roll inflation prefers $n_s \neq 1$ (to give us a clock)
 - Brings us to priors

Someone (oddly) not invited...

- Reverend Bayes...
 - $\bullet~n_{s}$ fitted in WMAP1
 - Question of model selection

- Not clear this image is Bayes
 - Got it from Wikipedia
 - Misidentification not just for astronomy





December 15, 2010, 12:55 AM

A Bayesian Take on Julian Assange

Suppose that you are taking the bullet train from Kyoto, Japan to Tokyo, as I

Another thing we missed...

Possible Priors

UCL Ċ from: Ringeval **Theoretical proposals** Background induced features Non-standard perturbations Motivatio Non-vacuum initial state [Martin 00] ♦ Inflation + steps CMB measurements Primordial vs astrophysical [Starobinsky 92, Covi 06, Joy 08, Hazra 10] Theoretical proposals Modified dispersions Generating oscillations Multiple inflation [Barriga 01, Hunt 04] [Corley 96, Brandenberger 01, Niemeyer 01] Observing oscillations and features Quantum deformations ◆ Oscillating pot. [Wang 05] Conclusion [Kempf 01, Easther 01, Hassan 03, Sriramkumar 06] ◆ Variable mass fields [Langlois 05] Non-commutative geometry Multifieds inflation [Achucarro 10] [Lizzi 02, Tsujikawa 03] Bouncing universe models Decaying modes [Amendola 05] [Martin 03b, Falciano 08, Brandenberger 09] Higher order op. [Armendariz-Picon 09] ♦ Warm inflation (Barnaby 09) WKB violations [Kinney 08, Lorenz 08] Monodromy inflation [Flauger 10] Defects during inflation [Tseng 09] Cyclic inflation [Biswas 10] Minimal trans-Planckian effects: non-standard initial conditions [Danielsson 02, Niemeyer 02, Easther 02, Martin 03a, Kaloper 03, Brandenberger 05, Greene 05]

+ Bubble collisions

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Perhaps the Key Lesson Here...

- We are learning how to think about anomalies / correlations
 - Any dataset will have "features" at some level
 - Weirdest universe would a perfect fit to CAMB spectrum.
 - Would have no idea how to explain that!
 - Cannot "repeat the experiment" in cosmology
- Could not have this discussion without superb data
 - Concordance cosmology becomes "foreground"
 - Subtract that, see if anything is left over...





Possible Oddities in Data

A non-exhaustive list of WMAP anomalies					
Cold spot	$1–2.4\sigma$	Cruz et al 05 Cruz et al 07 Zhang & Huterer 09			
Large-angle correlation function	$2 extsf{}3.5\sigma$	Hinshaw et al 96 Spergel et al 03 Bunn & Bourdon 08 Copi et al 09			
Quadrupole-octopole alignment	$2.1–2.8\sigma$	Tegmark, de Oliveira-Costa & Hamilton 03 de Oliveira-Costa et al 03 Gordon et al 05			
Dipole power asymmetry	up to 3.8σ	Eriksen et al 03 Gordon et al 05 Dvorkin, Peiris & Hu 08 Hoftuft et al 09 Erickcek, Hirata & Kamionkowski 09 Hanson & Lewis 09			
Quadrupolar two-point anomaly	$\approx 9\sigma$	Ackerman, Carroll & Wise 07 Groeneboom & Eriksen 08 Hanson & Lewis 09			

Kendrick Smith

Three Possible Outcomes...

- Anomaly is an artifact (quadrupolar 2-point)
- Anomaly is "present" in the sky
 - e.g. cold spot, axis of evil, Penrose circles [Amir Haijan]
 - But not at the level we feel required to explain it
- Anomaly is "present" and needs to be explained
 - Could be a posteriori, but at very high significance
 - Or a prediction of a well-worked out theory
 - So far nothing seen that crosses this threshold



Suppose Planck saw this

A posteriori we can live with...

Position-based anomalies (not k-based)

- High redshift clusters [Hotchkiss, Gordon]
 - Significance (or otherwise) of this result will change quickly
- Bubble collision signatures: [Peiris, and collaborators]
 - NOT claiming a detection
 - Identifying candidate features
 - Confirmed / excluded with better data
 - Calibrated against simulations

"Fourier space" features...

- Anomalies in the power spectrum / 2 point
 - Low ¿ Cosmic variance limited [WMAP can't do better]
 - Does not seem to be systematics
 - Will be tested by better polarization data + 3-point
- 3-point function / non-Gaussianity: Yadav, Chen
 - Non-Gaussianity: already bounded at 0.1% level
 - Consistent with zero. (Foreground extraction key)
- Statistical isotropy

Concluding Thoughts...

- Overview idiosyncratic...
 - Apologies to anyone overlooked
 - Split between observations and theory not always clear
- Many thanks to HRI, local organizers [and India!]