



**Dick Bond**

**CITA = Cosmic Information Theory & Analysis**

from *SuperWeb simplicity to complex Intermittency in the Cosmic Web*  
*IT from BIT, from BITs in IT, Studying the Cosmic Tango*  
*Universe=System+Res, =Data+Theory en-TANGO-ment*

**CIFAR Cosmology & Gravity Program: >1985, Bond Director 2002-17 20 Sr Fellows & Fellows (5@UofT), 21 associates + 6 Advisory Board members; CITA: 6+ faculty, >20 PDFs & Sr RAs + ~15 grad students; Bond: projects 3 grad students, 2 SrRAs, 2 (++) PDFs**

**Cosmic standard model SMC =  $\Lambda$ CDM,  $\Lambda$ =dark energy+tilt: what is U made of? Planck15 dark energy, dark matter, baryons, CMB, CIB, CnuB, GW:  $\rho_{\text{dm}}/\rho_{\text{b}}=5.43$**   
 $\rho_{\text{de}}/\rho_{\text{dm}}=2.53$   $\Omega_{\text{m}}=0.32 \pm 0.009$ ,  $\Omega_{\Lambda}=0.68 \pm 0.009 \Rightarrow$

**BSMC Beyond the SMC** eg  $\Omega_{\Lambda}(t,x)$ , neutrino properties, inflation anomalies

**How Structure in the Universe Arose?: fluctuation generation in curvature from an early inflaton:  $P_{\text{POWER}}|_{\text{na, isoc}}$ ,  $\text{GW}(k)$ : isocurvature, Gravity Wave;**  
(coherence + quantum noise  $\Rightarrow$  incoherence via entropy/information generation) via nonlinear lattice simulations of multiple scalar fields at the end of inflation & “ballistics”  
 $\Rightarrow$  **CMB/LSS Anomalies and intermittent non-Gaussianity cf. perturbative non-Gaussianity, correlated & uncorrelated. probe with CMB + LSS large surveys**

**CMBology** precision cosmic parameters **Planck 2013-15-17 intensity + polarization + ACTpol + BKP + SPT + LSS  $\Rightarrow$  Spider, Advanced ACTpol  $\Rightarrow$  Simons Obs  $\Rightarrow$  CMB Stage 4, ..**  
**LSSology** CHIME, COMAP, Euclid ... cross correlations: **CMBxLSS**

**morphs** into the nonlinear **Cosmic Web: clusters SZ, filaments, voids; galaxies Mass-peak-patches, N-body, gas to “Mock Heaven” tSZ, kSZ, CIB, CO, HI, optical (HOD), CIB, CO, HI**

**What is the fate of the U: (coupled?) dark energy driving late inflation**



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Sr RAs + ~15 ...; Bond: projects 3 ... 2 SrRAs, 2 (++) PDFs

Cosmic ... model  $\Lambda$ CDM =  $\Lambda$ CDM + dark energy, dark matter, CMB, CIB ...  
what is U made of?  $\rho_{dm}/\rho_b = 5.43$   
 $\Omega_m = 0.32$ ,  $\Omega_\Lambda = 0.68$

**SAMPLE COLLABORATIONS & PROJECTS**  
B+Braden, Mersini  
3D bubble simulations  
Planck/AdvACT

B+Meyers+Wilson+Fuller+Grohs  
cosmic neutrino decoupling & BBN

B2FH: B+Braden, Frolov, Huang  
preheating, caustics, shocks-in-time  
Planck/AdvACT/Spider/LSS

B+Huang, Frolov  
In  $a(x,t)$  early U maps  
potential reconstructions  
acceleration histories  
Planck/AdvACT/Spider/LSS

B+ Alvarez+ Stein Battaglia, Berger, Hajian, Huang, Pfrommer, Sievers,  
Bahmanyar, Pu, Shaw  
hydro sims, peak-patches & potential pits, flows beyond 2LPT, 3D non-Gaussian  
Pen, Vanderlinde, Opperman, van Engelen, ... Planck/ACT/CHIME  
Netterfield, Padilla +, Nolta, van Engelen, Hlozek, ...  
CMB analysis: Planck/Spider/AdvACTpol

CMBology precision cosmology + ACTpol + BKP + SPT  
LSS

morphs into the ...  
peak-patches, N-body ...  
Mock Heaven ...  
SZ, CIB, CO, HI

What is the fate of the U: (coupled?) dark energy driven late inflation

**BSMc = SMc + primordial anomalies**

*sigh, Mother Nature puts her Anomalies @ low L where sample variance => tantalizing ~ 2σ's?*

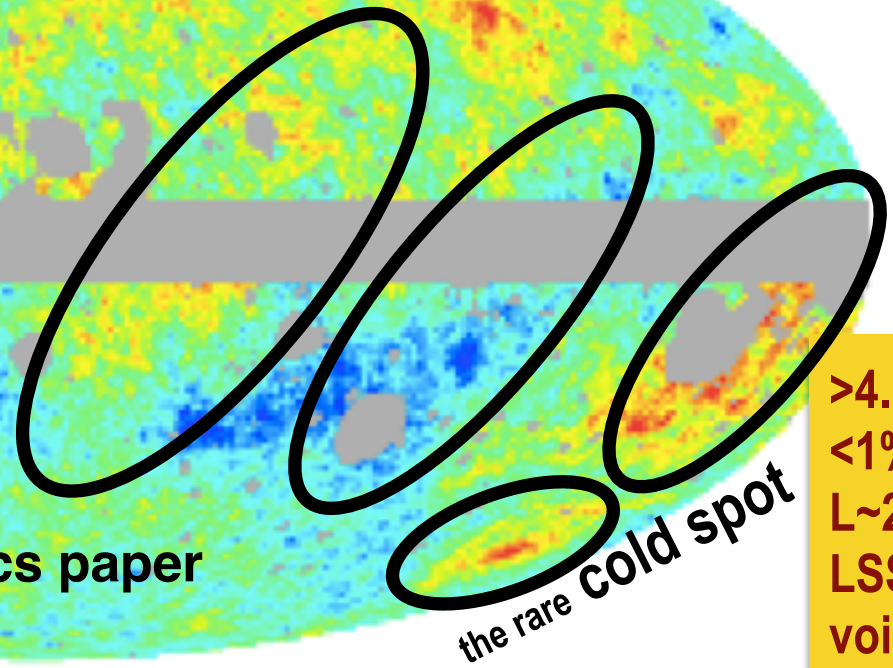
**early Universe maps of curvature fluctuations from CMB data**

**$\langle \zeta | T, E \rangle + \delta \zeta$ ,  $\zeta = \ln a(x, t) |_{\mathcal{H}}$  Planck 2015 XVII nonGaussianity paper**

40 arcmin fwhm

**B+Huang, Frolov**  
**In  $a(x, t)$  early U maps**  
**potential reconstructions**  
**acceleration histories**  
**Planck/AdvACT/Spider/LSS**

**Planck 2015 XX Inflation paper**  
**CMB anomaly in power**  
**Planck 2015 XVI Isotropy & Statistics paper**  
**hemisphere difference in**  
**power ~7% at low resolution**



**>4.5σ**  
**<1%**  
**L~20**  
**LSS**  
**void?**

**intermittent?**