



**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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IT from **bits** in IT, Studying the Cosmic Tango  
Universes, =Data+Theory **en-TANGO-ment**

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

**B+Braden, Mersini**  
**3D bubble simulations**  
Planck/AdvACT

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

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

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

**CMBology** precision cosmology + **ACTpol + BKP + SPT**  
**LSS** galaxy clustering

**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

**B+Huang, Frolov, Chluba, Farhang**  
**Netterfield, Padilla +, Nolta, van Engelen, Hlozek, ...**  
**CMB analysis: Planck/Spider/AdvACTpol**

**Web: voids, filaments, voids**  
**Mock Heavens** LSZ, CIB, CO, HI

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