CITA ICAT Canadian Institute for Theoretical Astrophysics L'institut canadien d'astrophysique theorique

25 years cifar

CIAR

# CITA = Cosmic Information Theory & Analysis:

## *IT from BIT, from BITs in IT,* Studying the Cosmic Tango

Dick Bond

*Universe=System+Res, =Data+Theory* **en-TANGO-ment**

*CIFAR Cosmology & Gravity Program: >1985, 22 fellows & scholars (5@UofT), 19 associates + 6 Advisory Board members; CITA: 6+1 faculty, ~26 PDFs & Sr RAs + ~15 grad students; Bond: projects with 3-1 grad students, 5-1 SrRAs, 2 (++) PDFs*

**Cosmic history: what is U made of?** $\Rightarrow \rho_{dm}/\rho_b = 5.1$

$\Rightarrow \rho_m/\rho_{de} = .30$ & $\Omega_m = 0.268 \pm .012$, $\Omega_\Lambda = 0.736 \pm .012$

**How Structure in the Universe Arose?:** ***fluctuation generation in curvature from an early inflaton: isocurvature, Gravity Wave, non-Gaussianity signatures***

**(coherence + quantum noise => incoherence via entropy/information generation)**

***morphs*** *into the nonlinear* ***Cosmic Web: clusters, filaments, voids; galaxies*** **(SZ)**

**What is the fate of the U: dark energy properties driving late inflation**

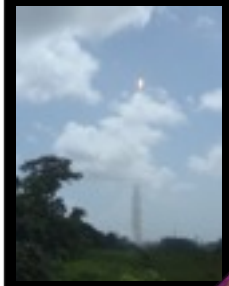
**CMB*ology*** **&** ***x*CDM, *x*=dark energy+*tilt*: the cosmic standard model**

**status@Sept11: uses WMAP7+ACT** (SPT)**, past: Boom, CBI, Acbar,..** (QuAD, ...)

***Planck* cosmology** Jan13 **ultra-precision on cosmic parameters** Jan11(25p), Feb12

***ACTpol, ABS, Spider,*** *Quiet-2, .. ALMA, CARMA, Mustang2 on GBT, CCAT*

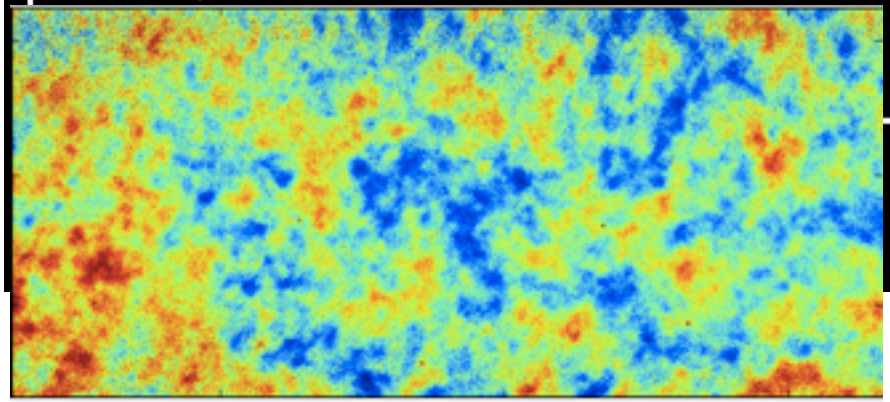
# Cluster Information from Compton Heating of the CMB: ACT, Planck & Theory

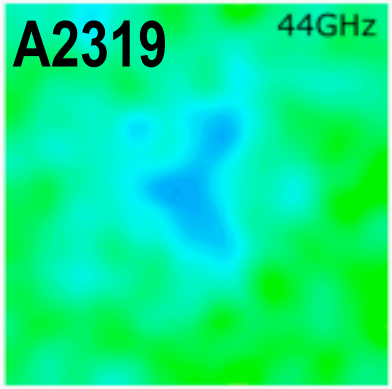


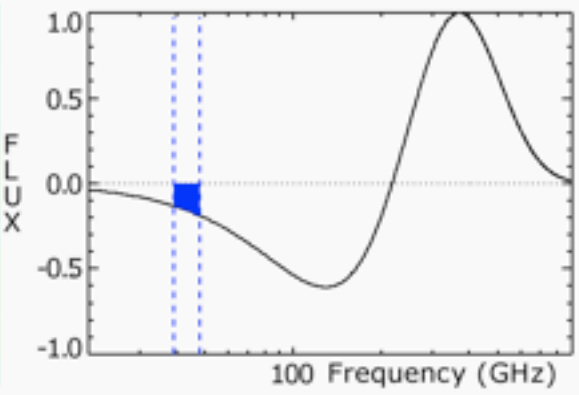


ACT+WMAP7 hajian+10
=>cosmological parameters +10

Planck all-sky surveys 2 Jan11
25 papers; 4+ cosmo Jan13





CITA ICAT Canadian Institute for Theoretical Astrophysics / L'institut canadien d'astrophysique theorique

# Current Projects

CIAR

25 years cifar

***Planck satellite, CMB all-sky, 9 frequencies, & polarization: ESA+NASA+CSA, B since 93, CSA since 02, launch may09, 4 full skies done, 5 in all, great data*** B+ Miville-Deschenes (SrRA), Nolta (SrRA), Netterfield (Prof), Marleau (DAA), Chluba (SrRA), Martin (Prof) + Contaldi, MacTavish, Crill, Dore (ex-CITAzens)+hundreds more - Europe+US ***P11 (ISM,SZ,CIB,sources,...), P12, cosmic: P13, P14***

***WMAP1,3,5,7*** all sky 5 frequencies Nolta (SrRA). stopped taking data Aug10 ***WMAP9*** winter12

s ***Early Universe non-Gaussianity:*** B+ Braden (GS), Huang (GS=>PDF), Frolov ex-CITAzen

***probing CMB non-Gaussianity:*** B+ Frolov, Nolta, Huang. Cold/Hot Spots; quadratic nonlinearities

***CMB@ hi res:*** CBI2 finished data in 09 - new cluster results, B+ Sievers (SrRA=>Princeton)

***Atacama Cosmology Telescope@very hires:*** B+ ***Hajian*** (PDF), ***Nolta, Sievers, Switzer*** (SrRA), ***Battaglia*** (GS), ***Hincks*** (SJ) ***finished taking data Jan11 => ACTpol Fall11*** neutrino masses, inflation, cluster physics, dark energy properties, ***lens*** ACTpol+Planck +... very powerful!

s ***Clusters & Cosmic Web Gasdynamical Simulations,*** & the Intracluster Radio Web: B+ Nick Battaglia (GS, PhD Aug11=>CMU PDF), Pfrommer (ex-SrRA), Sievers (SrRA=>Princeton) ACT,Planck, CBI (SPT,..,SKA)

***ABS; Quiet2;*** Chile-based ***Spider*** balloon-borne ***CMB expts targeting primordial gravitons via CMB pol*** B+ Nolta, Sievers B+ Sievers B+ Netterfield, Farhang (GS) +,Barth-team, ++ GW/scalar $r \approx 0.01 V/(10^{16}\text{Gev})^4$

***Probing Recombination epoch with the CMB***: B+ Chluba (SrRA), Farhang

s ***GW & Acceleration Trajectories:*** B+ Huang, Vaudrevange, Contaldi; B+ Farhang, Dore, Netterfield

s Post-Inflation ***Preheating:*** B+ ***Braden (GS).*** ***How Entropy Arose in U via a Shock-in-Time***

s ***Late-time Inflaton Trajectories & Dark Energy cf. CMB,LSS,SN now/future***: B+ Huang

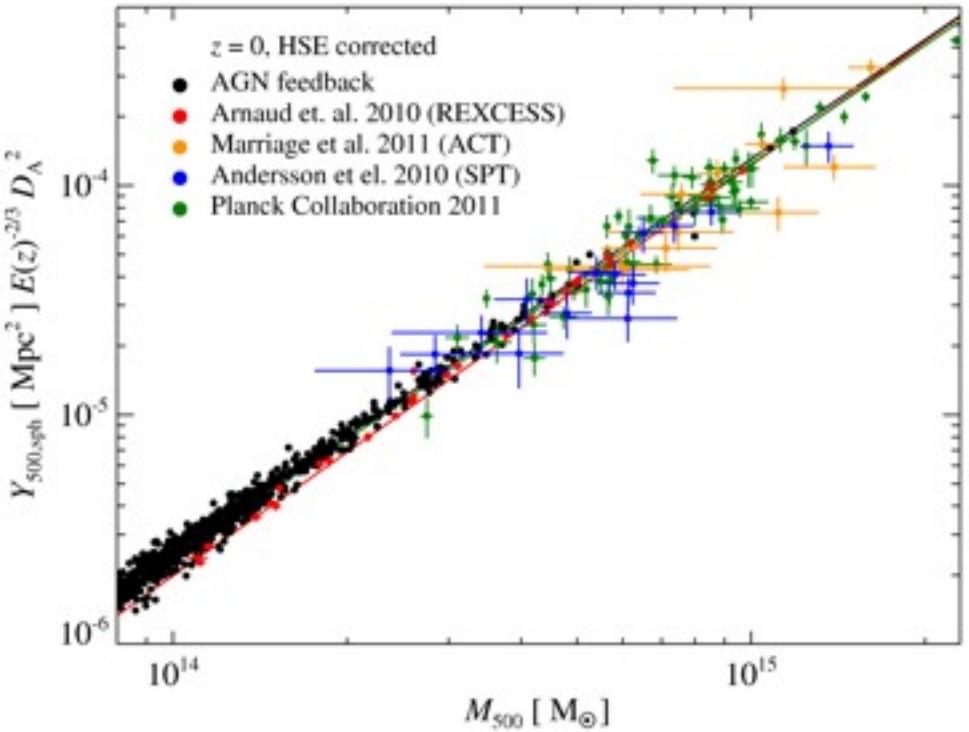
s ***Magnetohydrodynamical Turbulence Simulations & Polarized Dust,*** B+ Fahrang, Miville-Deschenes, +..., ..

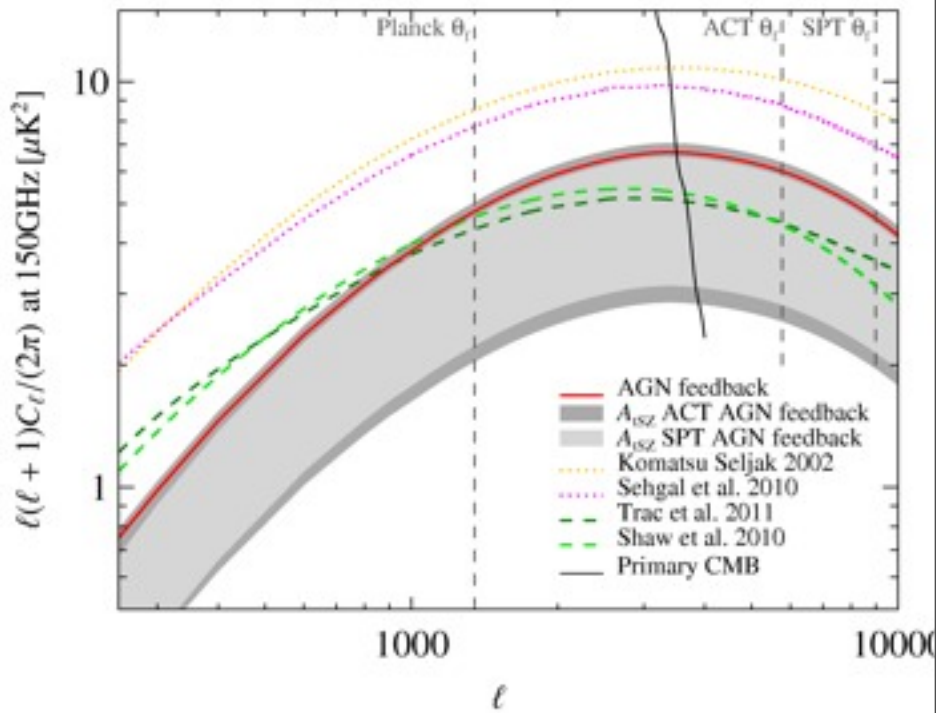
CHIME, neutral hydrogen via redshifted 21 cm Baryon Acoustic Oscillations & Dark Energy: Pen (Prof)++ B+ Canadian Consortium: site DRAO in BC

# Cluster Coarse-Grained Feedback Sims cf. SZ data ACT, SPT, Planck

## Cluster counts $n_{cl}(M(Y))dM$ + tSZ/kSZ Power spectrum

**Battaglia, Bond, Pfrommer, Sievers 2011: I,II,III,IV; BBPS+Sijacki 2010**



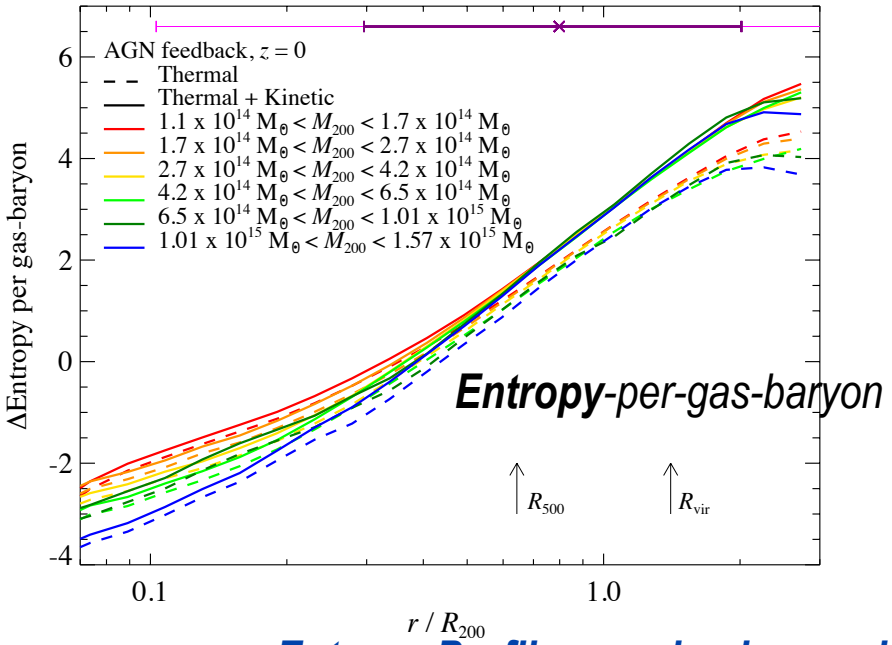

**"turbulence"** $p_{kin}/p_{th}$**~20% effect**

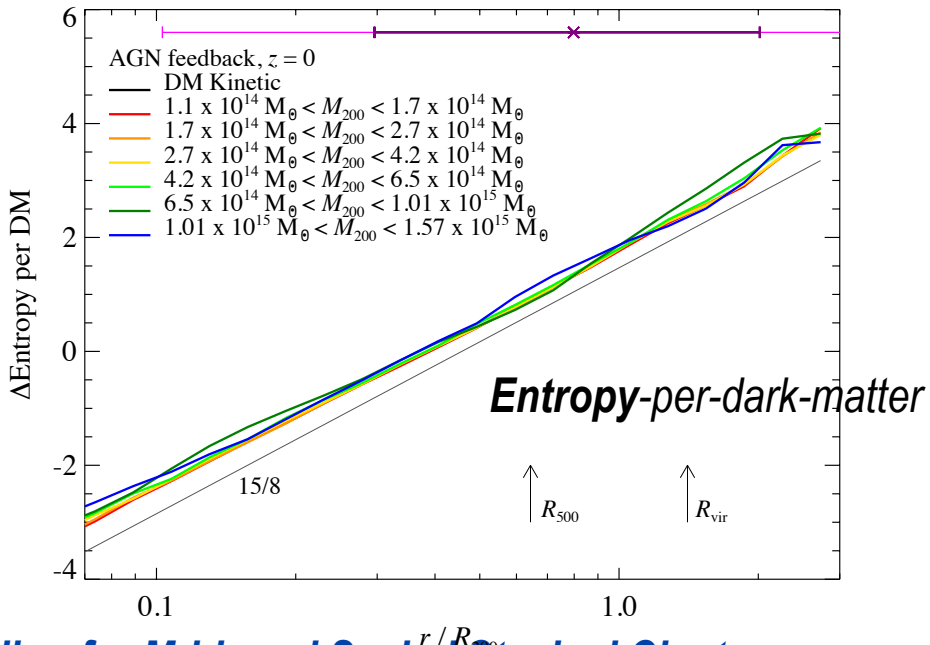
**asymmetry** long/short **<20% effect; cf.** spherical **~30%**

**Δ input physics ~30% effect**

**both are sensitive to gastrophysics:**
***resolution, feedbacks(M,z), kinetic <δVδV†> cf. thermal pressure, <δXδX†>anisotropy, p&ρ-clumping, non-equilibrium cluster-outskirts***

# Entropy Profiles (M/z=0) for M-binned Scaled Stacked Clusters




# Entropy Profiles vs physics modeling for M-binned Scaled Stacked Clusters