



CIFAR Cosmology & Gravity Program: >1985, 20 Sr Fellows & Fellows (5@UofT), 17 associates + 6 Advisory Board members; CITA: 6+1 faculty, ~25 PDFs & Sr RAs + ~15 grad students; Bond: projects with 3-2 grad students, 4-1 SrRAs, 2 PDFs (++)

Cosmic history: what is U made of? Planck13 $\Rightarrow \rho_{dm}/\rho_b=5.4$

$\Rightarrow \rho_{de}/\rho_{dm}=2.7$ & $\Omega_m=0.31 \pm 0.01$, $\Omega_\Lambda=0.69 \pm 0.01$

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

(coherence + quantum noise \Rightarrow incoherence via entropy/information generation)

via nonlinear lattice simulations of multiple scalar fields at the end of inflation

\Rightarrow Anomalies and intermittent non-Gaussianity

CMBology & λ CDM, λ =dark energy+tilt: the cosmic standard model

Planck cosmology Mar13 precision on cosmic parameters 2011-12; 14-15 pol ACTpol, ABS, Spider, GLP, .. ALMA, CARMA, Mustang2 on GBT, COMA, CCAT.. CHIME 21cm

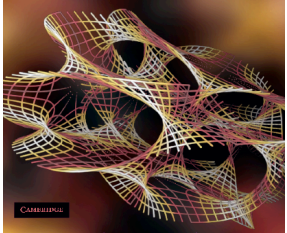
morphs into the nonlinear Cosmic Web: clusters t/k SZ, filaments, voids; galaxies CIB, CO, HI via hydro sims with feedback tSZ; PeakPatch mocks 1st *, dG, Gals, cls/gps, Xcorr, nonG++

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

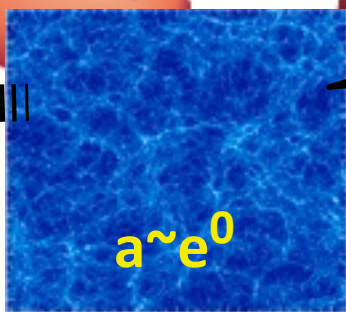
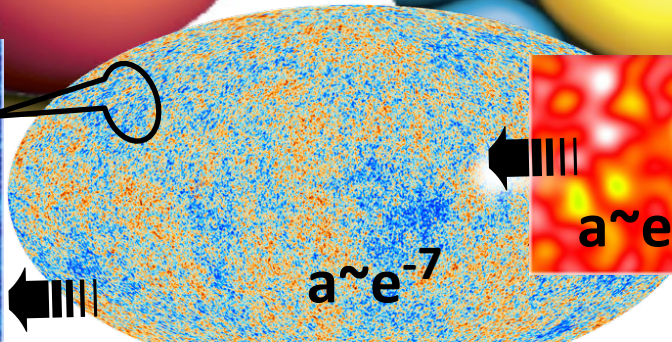
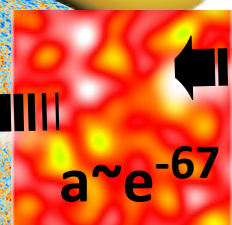
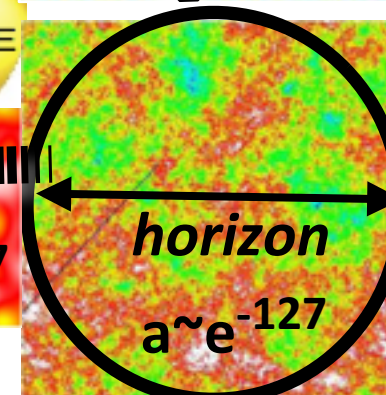
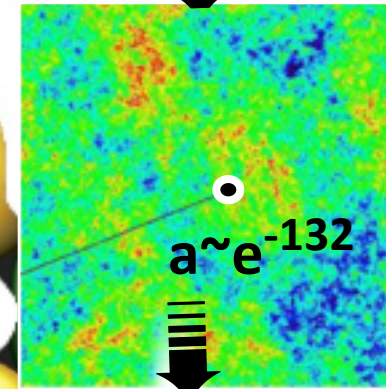
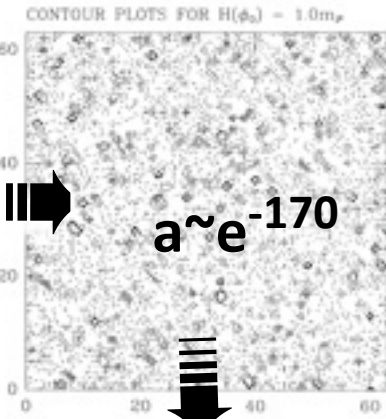
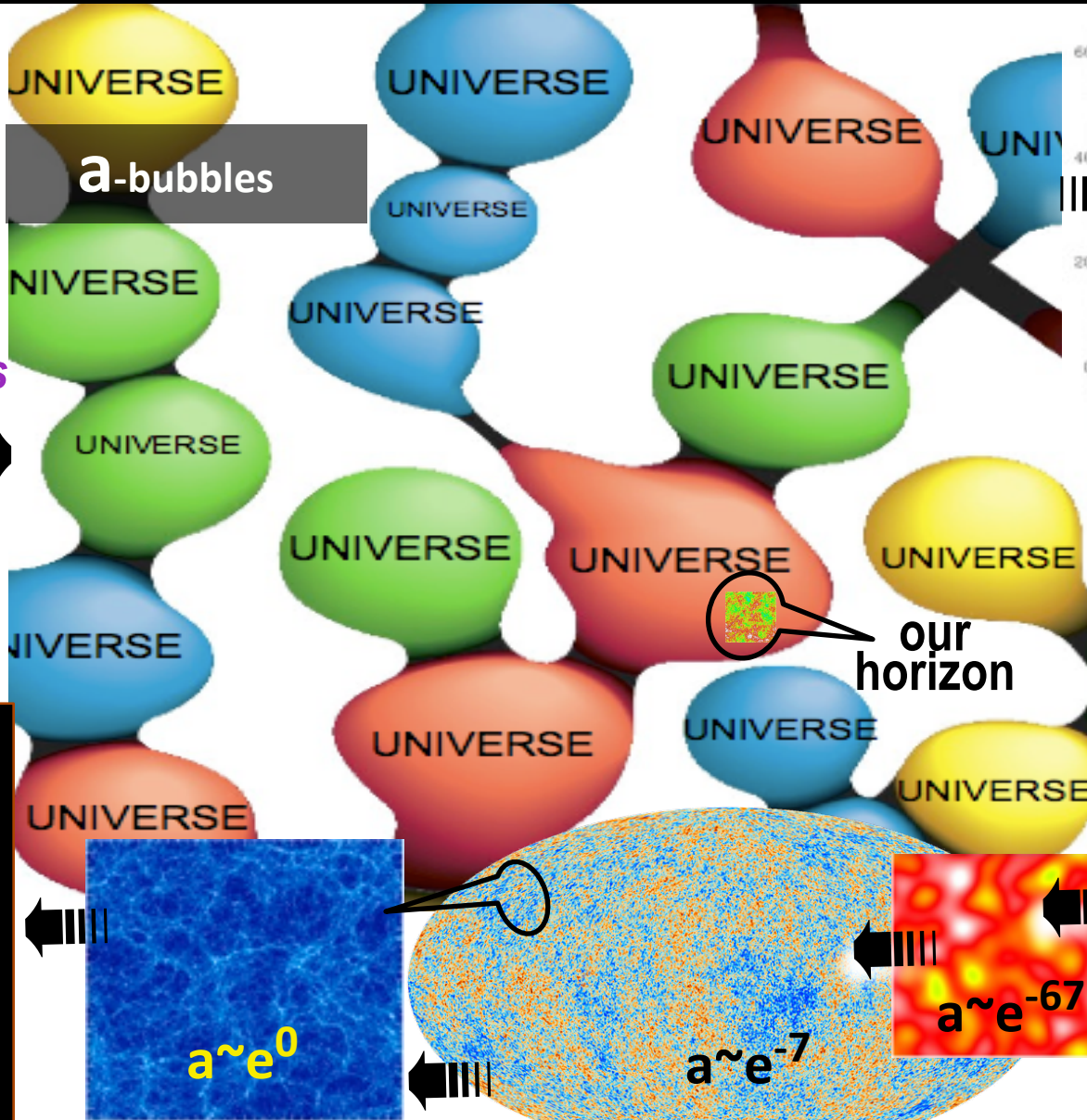
ultra-Ultra Large Scale Structure of the Universe

Horizons: the ultimate-speed constraint on light & information

Universe or Multiverse?
Edited by Bernard Carr



quantum tunnels = bubbly-U



END
a future DE-Void

CITA-ICAT

$a \sim e^{+++}$

SIMPLICITY

at $a \sim e^{-7} \sim 1/1100 \Rightarrow$
at $a \sim e^{-67-60} \sim 1/10^{30+25}$

reveals *primordial sound waves in matter*

\Rightarrow learn **contents & structure** at 380000 yr, $a \sim e^{-7}$

\Rightarrow infer the structure far far earlier $a \sim e^{-67-60}$

7⁺ numbers

Early Universe **STRUCTURE**

“red” noise in phonons/strain: 2 numbers at $a \sim e^{-67-55}$

$$\ln \text{Power}_s \sim \ln 22.0 \times 10^{-10} \pm 0.025$$

$$n_s = 0.9608 \pm 0.0054 \quad 5\sigma \text{ from } 1$$

TBD: Full Mission + Polarization, Planck2014-15 + ACTpol, Spider, ..

$$-0.014 \pm 0.009$$

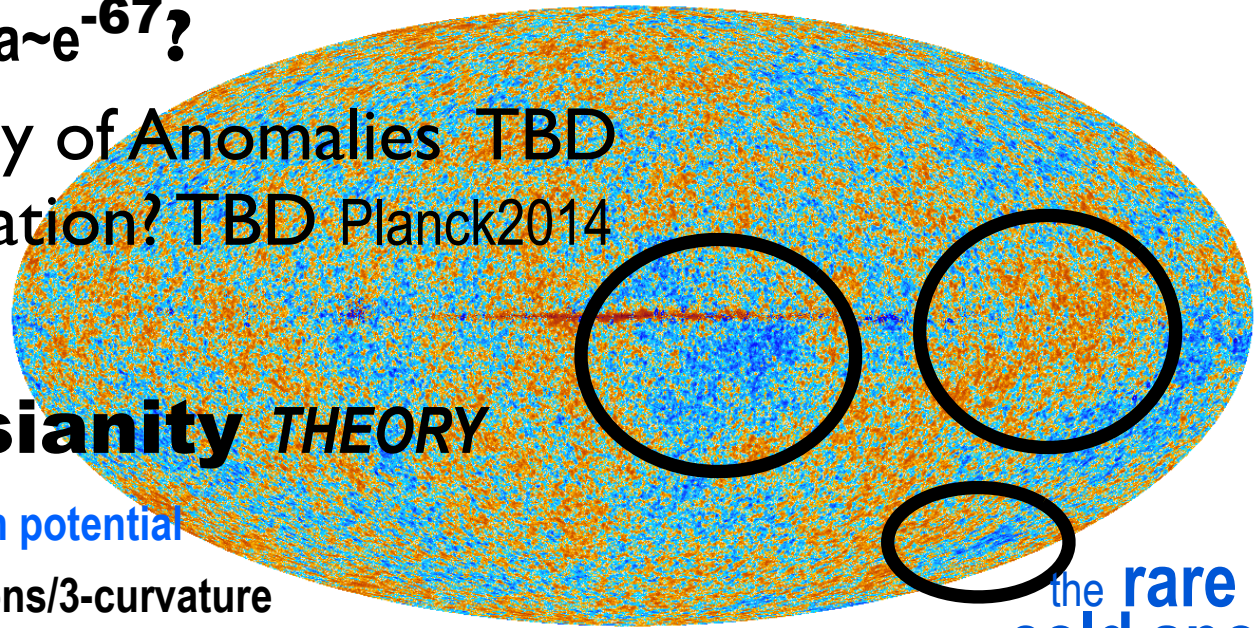
$$r < 0.12$$

95% CL on *running* $dn_s/d\ln k$, *running of running*, r = Tensor-to-Scalar ratio (GW), **isocurvature modes** for axions (<3.9%), baryons, neutrinos, curvatons (<0.25%)

COMPLEXITY at $a \sim e^{-67}$?

Grand Unified Theory of Anomalies TBD

Anomalies in Polarization? TBD Planck2014



primordial **nonGaussianity** THEORY

f_{nl} : 2.7 ± 5.8 local for Newton potential

$\Rightarrow f_{NL^*} = 0.44 \pm 3.5$ for phonons/3-curvature

from end-of-inflation & preheating chaos

the rare cold spot

intermittent CMB power bursts from super-bias of a

$\chi_b(x), g(x)$ modulating Gaussian field landscape scan

$$\zeta_{NL}(x) = \zeta_G(x) + \mathbf{F}_{NL}(\chi_b(x), g(x))$$

ANALYSIS

bubble collisions CMB

Euclidean $SO(4) \Rightarrow$ real $SO(3,1) \Rightarrow$
 $SO(2,1)$ collisions, oscillon broken

WHITEN \Rightarrow MASK \Rightarrow FILTER BANK \Rightarrow

EXTRACT hierarchical **PeakPatches**

filter = extra dimension: **scale space** analysis

hot & cold peaks agree with BE87 Gaussian stats $n_{pk}(<v)$

PLANCK2013: 826', 105 peaks, coldest -4.97σ 1:497