cosmology forecasts for PlanckEXT

$n_s(k)$, GW $r(k)$, nonG f_{NL}++, $\rho_{de}(t)$, m_ν, strings, isocurvature, ...

current CMB+LSS+WL+SN1a+Lyα **PEXT=**Planck2.5yr + low-z-BOSS + CHIME + Euclid-WL + JDEM-SN

Huang, Bond, Kofman 2010

$n_s = 0.963 \pm 0.011 \Rightarrow \pm 0.002$ **(Pext)**

Power$_s$~25×10^{-10} $\ln A_s = \pm 0.03 \Rightarrow \pm 0.008$ **(Pext)**

Farhang, Bond, Dore, Netterfield 2011 ***forecasting QU not EB***

Spider $2\sigma_r \sim 0.013 \Rightarrow \sim 0.02$ for $0.02 < f_{sky} < 0.15$

Planck2.5yr $2\sigma_r \sim 0.02 \Rightarrow \sim 0.05$ (foregrounds)

quadratic local nonG $-10 < f_{NL} < 74$ (+- 5 Planck)

the emergence of the collective from the random:
coherence from driven zero-point vacuum fluctuations ⇨ V **inflaton**, gravity waves; decohere

let there be heat: entropy generation in **preheating** from the coherent inflaton (origin of all matter)

Standard Parameters of Cosmic Structure Formation

$\Omega_b h^2$ $\Omega_{dm} h^2$ Ω_Λ Ω_k τ_c

$\ln A_s$ n_s $r = A_t/A_s$ $dn_s/d\ln k$ n_t

$\Omega_{er}h^2$ $\Omega_{m\nu}h^2$ X_{He}

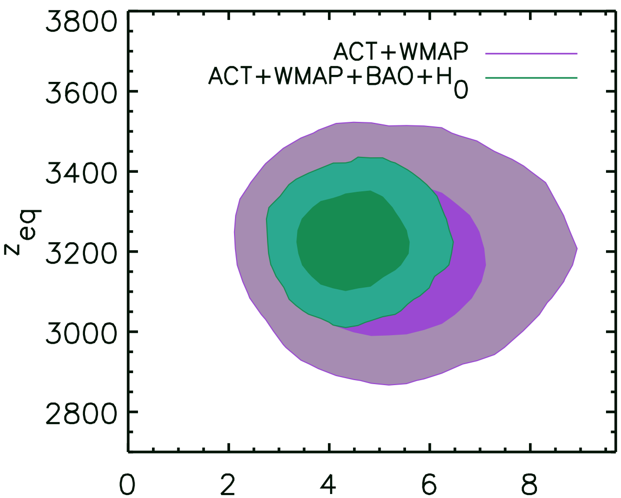
$1+w_0, w_a$ $\theta \sim \ell_s^{-1}$ $n_e(a)$ $\sim \ln \sigma_8^2$

new parameters: **trajectory probabilities for early-inflatons & late-inflatons**

(partially) blind cf. informed "theory" priors

$\Omega_{er}h^2$ Number of Relativistic Species

WMAP7+ACT08+BAO+HO =4.56±0.75; 3 still OK

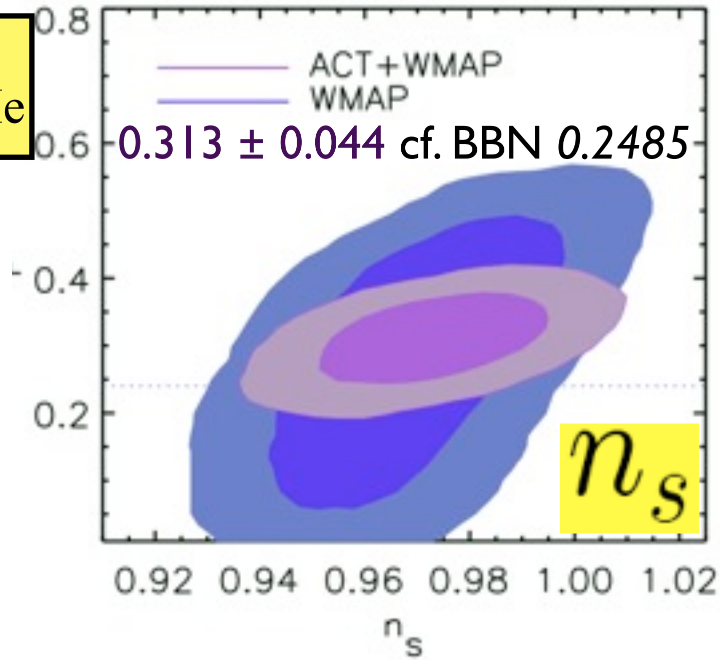


to ±0.11 Planck+ACTpol

$N_{\nu,effective}$

Abundance of Primordial Helium

X_{He}



n_s

Studying the Cosmic Tango

en-Tango-ment, the dance of S+R=U
Universe=System(s)+Reservoir,
=Signal(s)+Residual *noise*,
=Effective Theory+*Hidden variables,*
observer(s)+observed,
ruled by (information) entropy, entangled. *the fine grains in the coarse grains*

the coherent and the entropic, in all its forms, from ultra-early-U to ultra-late-U

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information in **nearly-Gaussian** random **fields** of U: spatial coarse-grained **CMB entropy** & how we capture it. **dark matter entropy, cluster & protocluster & cosmic web entropy. MHD turbulence entropy** with cooling & grain polarized emission - a CMB fgnd. *How Shannon info-entropy flows from CMB bolometer timestreams to marginalized cosmic parameters via* ***Bayesian chains from prior to posterior.***

Shannon entropy ~ von-Neumann entropy
= Trace $\varrho \ln \varrho^{-1}$ = full non-equilibrium S
$\varrho(U) = \varrho(S,R) = \varrho(R|S)\,\varrho(S)$ entanglement of phase & probability

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resolution dimension **λ = -*ln* r/r_0**
S(λ |coarse-grained-measures) deals with the **non-equilibrium & non-thermal S** in clusters, includes DarkMatter coarse-grained S - and **of preheating configurations**.

gravitational entropy remains a **mystery, horizon needed? gravo-thermal catastrophe** = negative specific heat, what gravity wants is to localize concentrating mass into black holes and make accelerating voids to straighten out U.

25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work flawlessly** with great results on ERCSC (~15000 sources, 189 SZ clusters), CIB, SZ, AME & the dusty MW, & much more, so many areas, enabled by so many frequencies. more **Veils Feb 2012**, **primary CMB & pol TBD, Jan 2013, 14, .**

- **SZ - 189 SZ clusters. SZ scaling relations appear as expected for X-ray clusters , apparent SZ deficit for optical clusters (jury out on cause, ACTxSDSS-LRGs too}**
- **CIB - clustering clearly detected at 217-857 GHz, in power spectrum & images Sources in halo model fits the spectra. BLAST, ACTxBLAST, Planck agree, Herschel a little higher, still an interpretation uncertainty.)**
- **Spinning dust - clearly seen in Perseus and rho-Ophiuchus regions with a spectrum in excellent agreement with spinning PAH theory.**
- **Radio sources: Planck counts consistent with ACT/SPT; local IR galaxies: cold dust component.**
- **beautiful Milky Way dust maps, all sky and for selected regions - see extra emission from 'dark gas' not in HI or CO, could be H_2 that survives when CO does not.**

ACT+WMAP7: **tilted ΛCDM still works well**, modest basic 6 parameter improvement, separated power components CIB, tSZ+kSZ; 7+ peaks seen; **running =-0.024±0.015; r <0.19 40%** stronger, **cosmic strings 60%** more constrained, primordial **Helium** (electron number/baryon) **0.313±0.044 cf. ~*0.25* BBN, $N_{\nu,eff}$ =4.56±0.75, so 3 OK;** CMB lensing @4σ via 4pt function Das+11 => Ω_{de} @3.3σ via just CMB Sherwin+11

ACTpol+**Planck2.5**+SPTpol+**ABS+Spider**+..**$n_s(k)$**, GW **$r(k)$**, nonG **f_{NL}++, $\rho_{de}(t)$, m_ν,..**
~25x ACT&Pol, ~1000clusters, CMB lens for DE isocurvature, strings,..

end of inflation @ε=1

through **preheating**

(linear resonance, nonlinear backreaction $\delta\psi,\delta\chi$)

to **thermal equilibrium**

$ln(n_k^{-1}+1) \Rightarrow k/T, \rho_k \sim E_k(n_k+1/2)$

from coherent "background" field with nearly-Gaussian linear fluctuations to incoherent heat bath through a not-that-turbulence-like cascade: development of complexity: information (multi-scale entropy) b+braden 11

@

$k > H_{end}^{-1}$

=> no effect on k-observed? MAYBE:

relics (e.g., strings, isocons), HF gravity waves (kHz-GHz cf. 10^{-19}Hz), isocon modulation & non-Gaussianity

Old view: Theory prior = delta function of THE correct one and only theory

New: Theory prior = probability distribution of late-flows on an energy LANDSCAPE

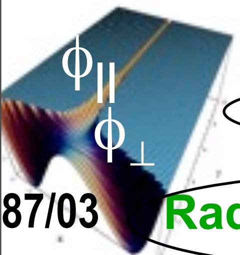
6/7 tiny extra dimensions

1980

R^2-inflation

Old Inflation

Chaotic inflation



New Inflation

Power-law inflation

Double Inflation

SUGRA inflation

87/03

Radical BSI inflation

running (nee variable M_P) inflation

Higgs inflation

Extended inflation

1990

Natural pNGB inflation

Hybrid inflation

KLS94 preheating

SUSY F-term inflation

Assisted inflation

SUSY D-term inflation

Brane inflation

2000

SUSY P-term inflation

Super-natural Inflation

K-flation

2003 KKLT

N-flation

ekpyrotic/cyclic

D3,D7 brane inflation

DBI inflation

moving brane separations

Racetrack inflation

Tachyon inflation

Warped Brane inflation

moduli fields

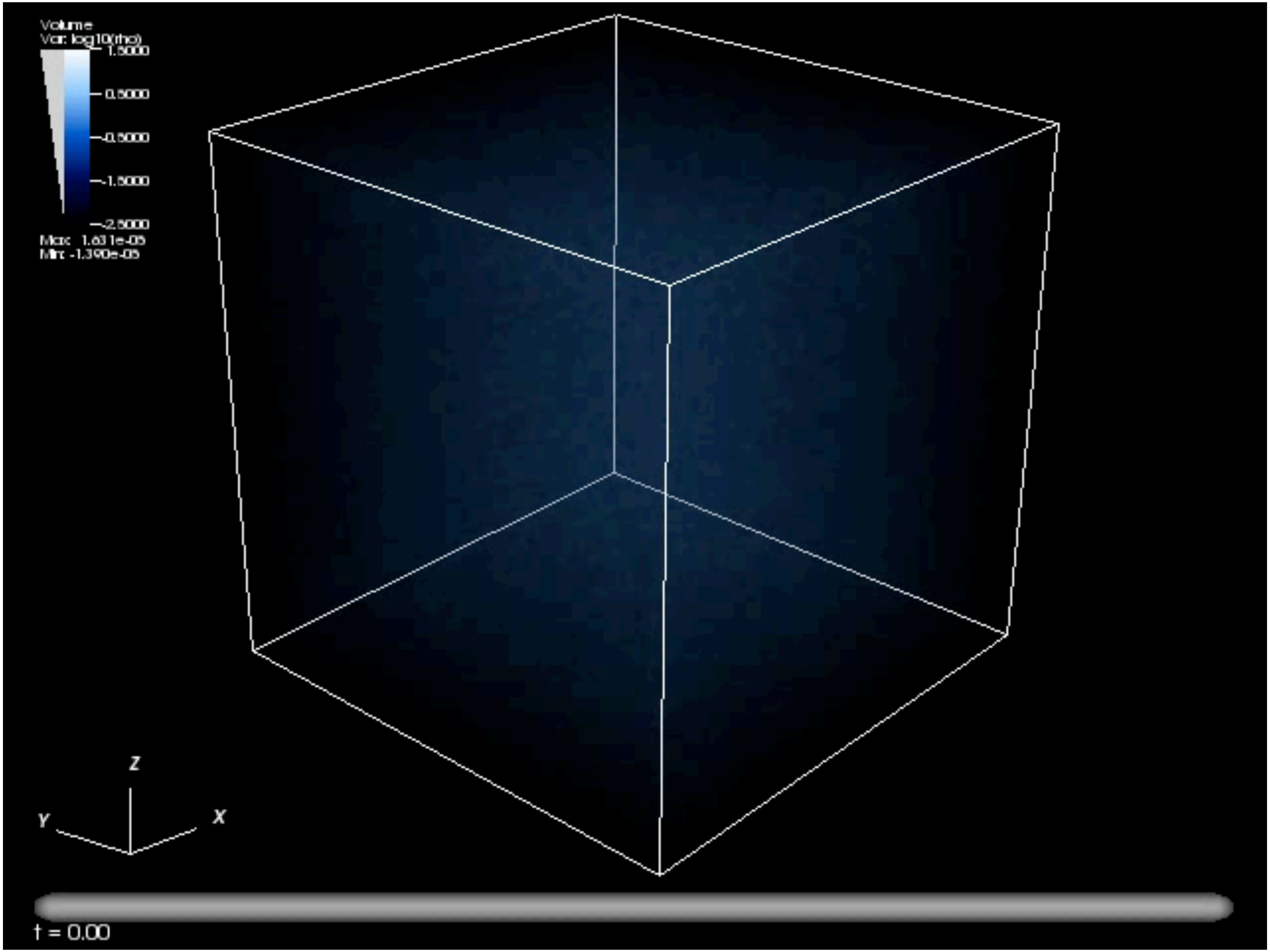
monodromy

Higgs inflation

Roulette inflation Kahler moduli/axion

fibre inflation

Andrei Frolov, Defrost code $V(\phi,\chi)=1/4\,\lambda\,\phi^4 + 1/2\,g^2\,\phi^2\,\chi^2$



Preheating = Shock-in-time Jonathan Braden + B 2011

Initial State = Nearly Homogeneous Inflaton

Low entropy (vac fluc.), information encoded in a few parameters

Preheating

Instabilities result in nonlinear transition to an incoherent state
KLS 94, 97,e.g. Tkachev, Felder, Garcia-Bellido, ...

Transition Regime

Complex slowly evolving nonlinear, nonequilbrium state e.g. Micha and Tkachev 2004, turbulence analogy??? not quite

the shock-in-time is the sharp mediator between the linear & the highly nonlinear transition
a fascinating non-Gaussianity through a

Thermal Equilibrium

Maximum spreading of information in modes subject to energy and particle number constraints.

A Shocking End to Post Inflation Mean Field Dynamics

Shock-in-space t = const

$v_{bulk}^2 > c_s^2 \Rightarrow v_{bulk}^2 < c_s^2$

supersonic ⇒ subsonic

Characteristic spatial scale

Jump Conditions: $\Delta T^{\mu\nu}$

Randomizing Shock Front: ΔS

Mediation: width via viscosity or collisionless dynamics

post-shock evolution, slow, of temperature, etc.

Shock-in-time x = const (deviations for nonG)

$\langle\rho\rangle \gg \delta\rho \Rightarrow \langle\rho\rangle \ll \delta\rho$

Homogeneous ⇒ Fluctuations

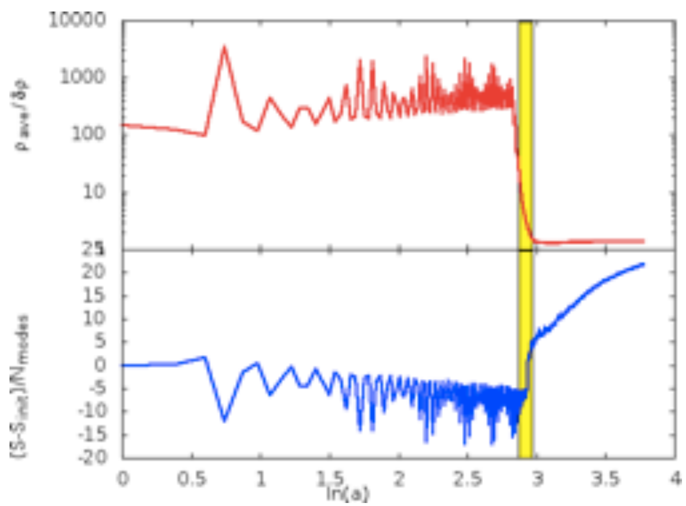
Characteristic temporal scale

Jump Conditions: $\Delta T^{\mu 0}$

Randomizing mode cascade & Particle Production: ΔS

Mediation: width via gradients and nonlinearities

post-shock evolution, slow, of fluctuations



Preheating is a shockingly efficient entropy source

nonequilibrium Shannon (~von Neumann) entropy

$S = -\mathrm{Tr}\, P[f] \ln P[f] \Leftarrow -\mathrm{Tr}\, \rho \ln \rho$

$P[f]$: probability density functional, ρ density matrix

classical $\Leftarrow$ quantum

$\varrho(U) = \varrho(S,R) = \varrho(R|S)\, \varrho(S)$ entanglement of phase & probability

Coarse Graining & Entropy Production

we have explored many ways of treating non-eq S. max S constrained by measurements we theorists make on the medium

Field$\Rightarrow$ Correlation Functions

Measurements: Constraints (information) on Correlators

Maximize entropy subject to given constraints

Generation of higher order correlators $\Rightarrow$ entropy generation

Entropy & Correlator Constraints & Gaussian Distributions

if only power spectrum is constrained $\Rightarrow$ multivariate Gaussian maximizes S

$$\mathbf{S/N = 1/2N\ \mathrm{Tr} \ln P(k) + 1/2 + 1/2 \ln(2\pi)}$$

$\ln = \log_e$ measure info in nats, $\mathrm{lb} = \log_2$ measure info in bits

$P(k)$ dimensionful, so ΔS relative to a S_i, counting states $\Rightarrow$normalize to =1 state

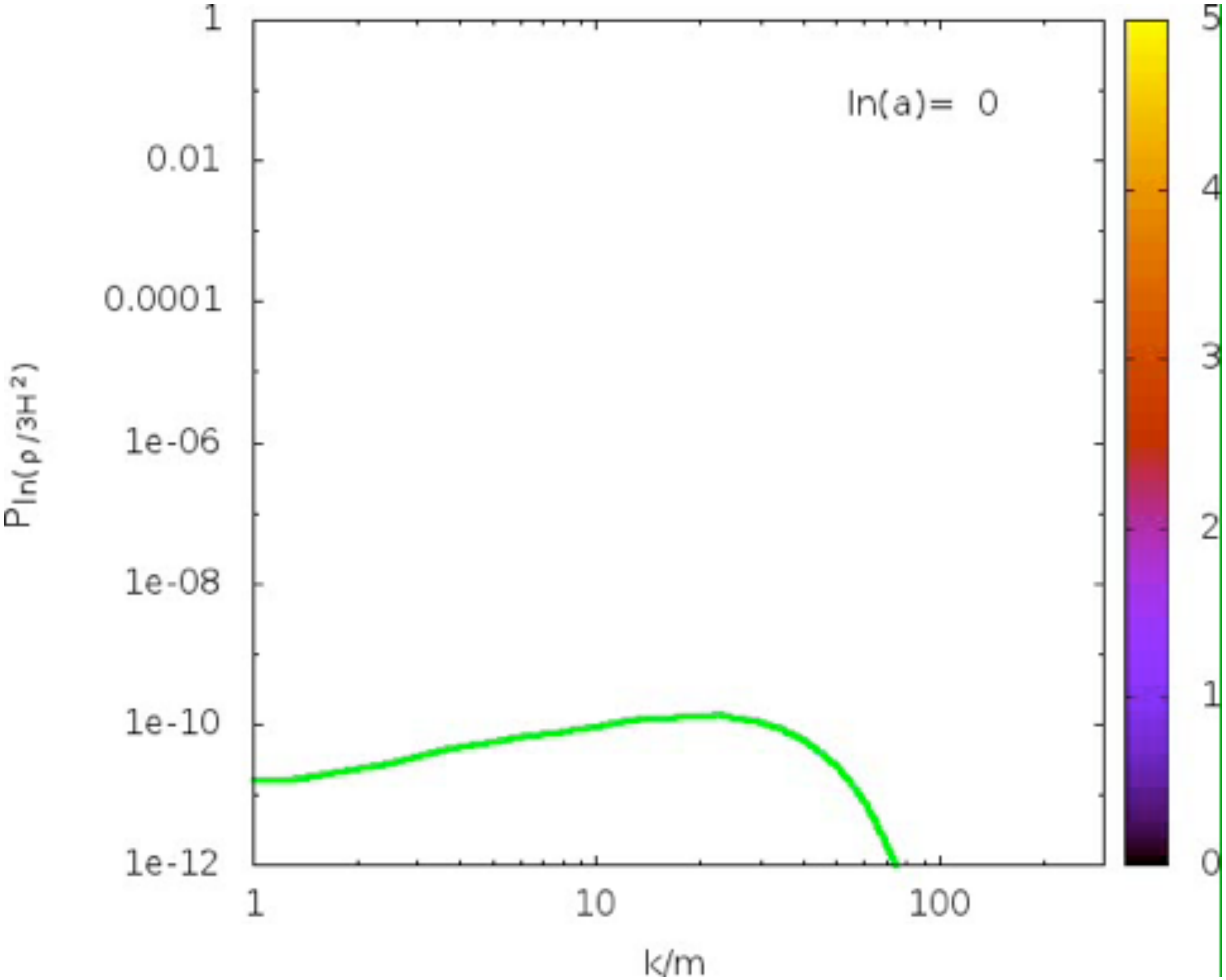
Power Spectrum

Nonlinear dynamics via large parallel lattice simulations using modified version of DEFROST Frolov 2008

log is more Gaussian

$\ln(\rho/3H^2) \sim \ln(\rho/\langle\rho\rangle)$ as the dynamical random field.

$$V = \frac{m^2}{2}\phi^2 + \frac{g^2}{2}\phi^2\chi^2$$

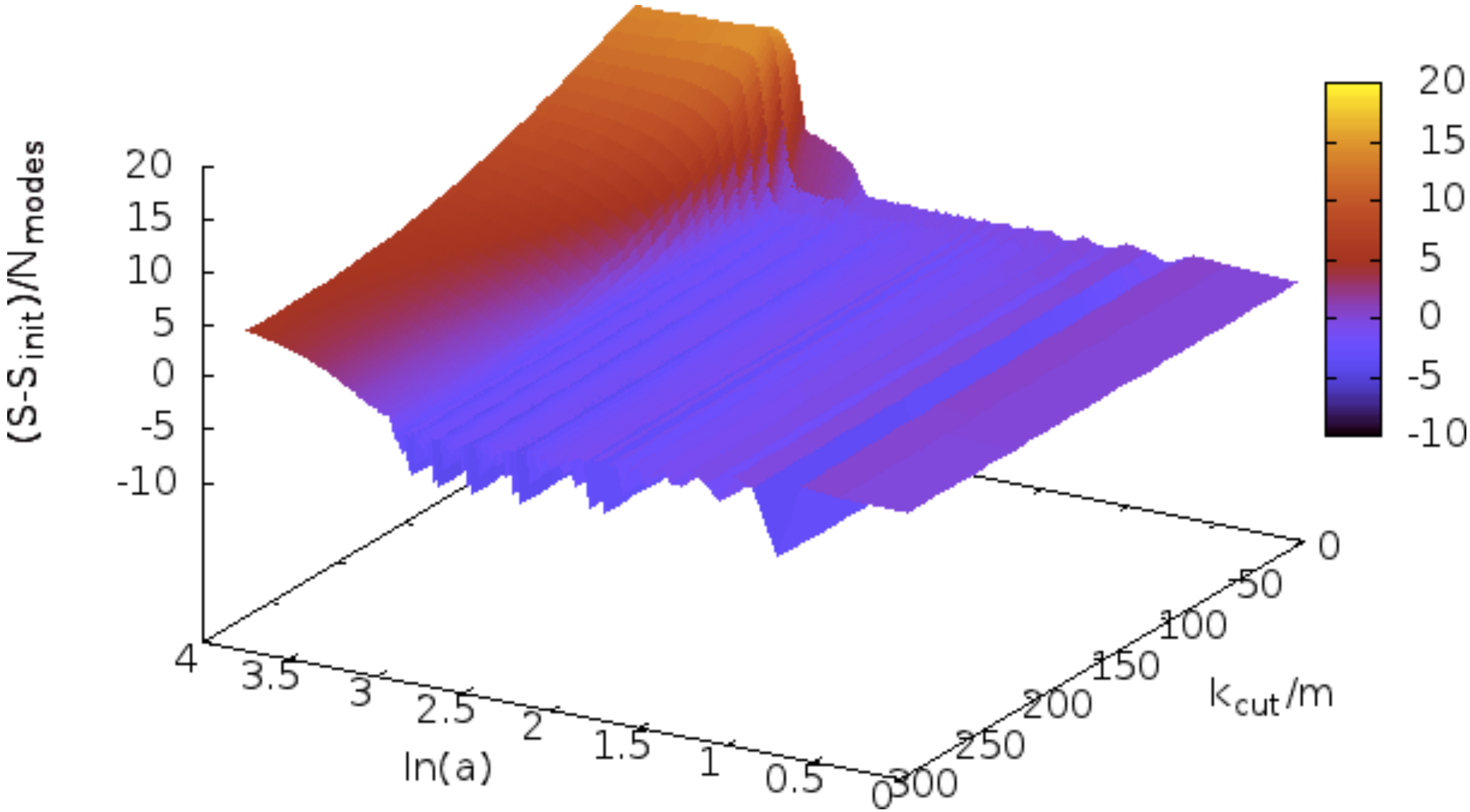


$m/M_P=10^{-6}$, $g^2=10^{-5}$

low entropy initial state: uniform inflaton + simulated vacuum aka quantum fluctuations, initial isocon field rapid classical increase in nonlinear fluctuation power through mode-mode coupling ⇒ shock-in-time.

post shock evolution of power is relatively slow *(coupling to standard model?? accelerates particle production at very high k? subgrid phenomenology a la eddy viscosity.)*

Scale Dependence of Shock-in-Time



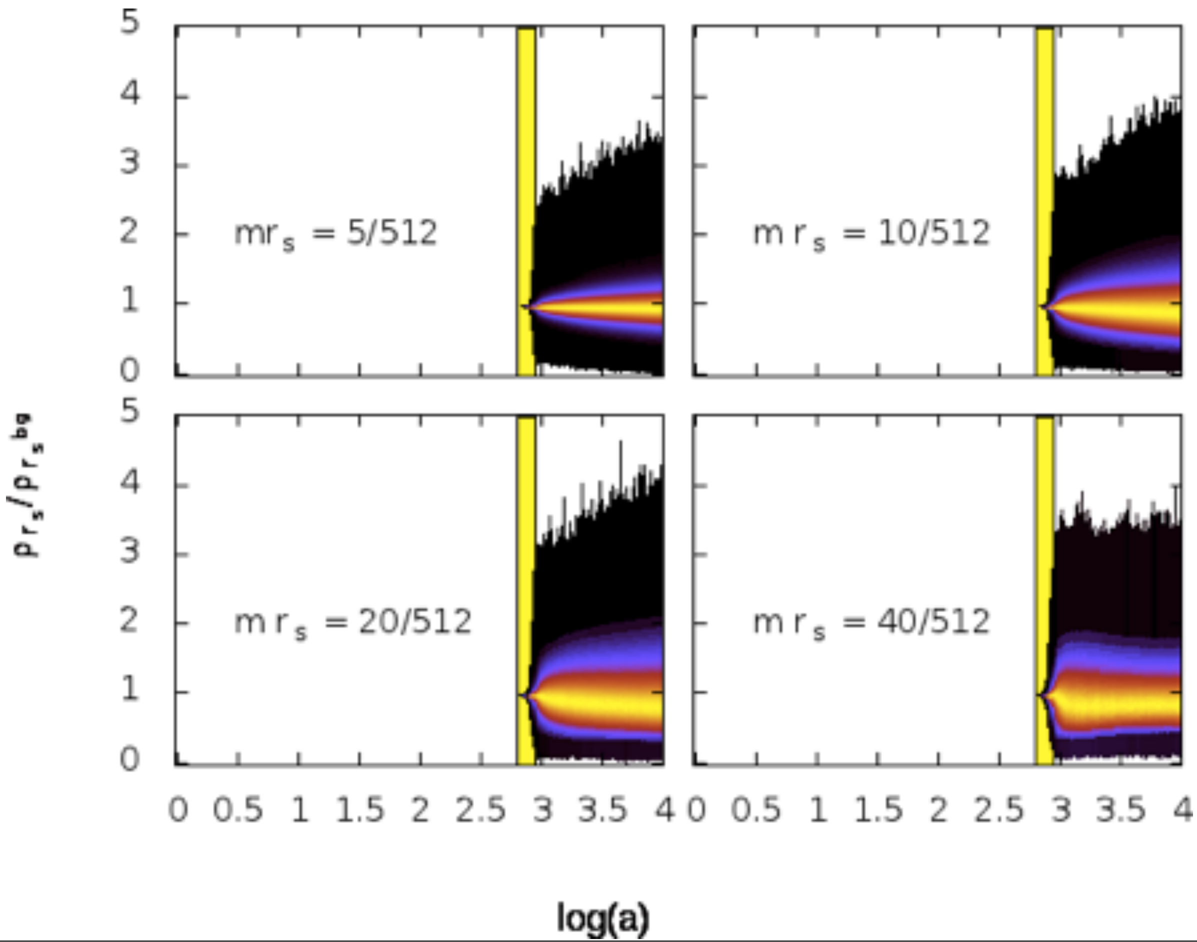
entropy production is not scale-localized. resolution of the field = kcut (sharp k space cut). Rapid spread in k, but not a turbulence-like cascade, slower movement to high k. Suggests ***Renormalization Group Flow picture***.

Renormalization and Scale Dependence via Wilsonian RG Blocking

Sequence of smoothed fields ρ_S defined by averaging over groups of 8 nearest neighbours with $r_S = 2^S \delta X_{lat}$ the smoothing scale.

Define local background for $\rho_S(x)$ by ρ_{S+1}

idea: fluctuations *layered on* fluctuations *layered* on fluctuations ...

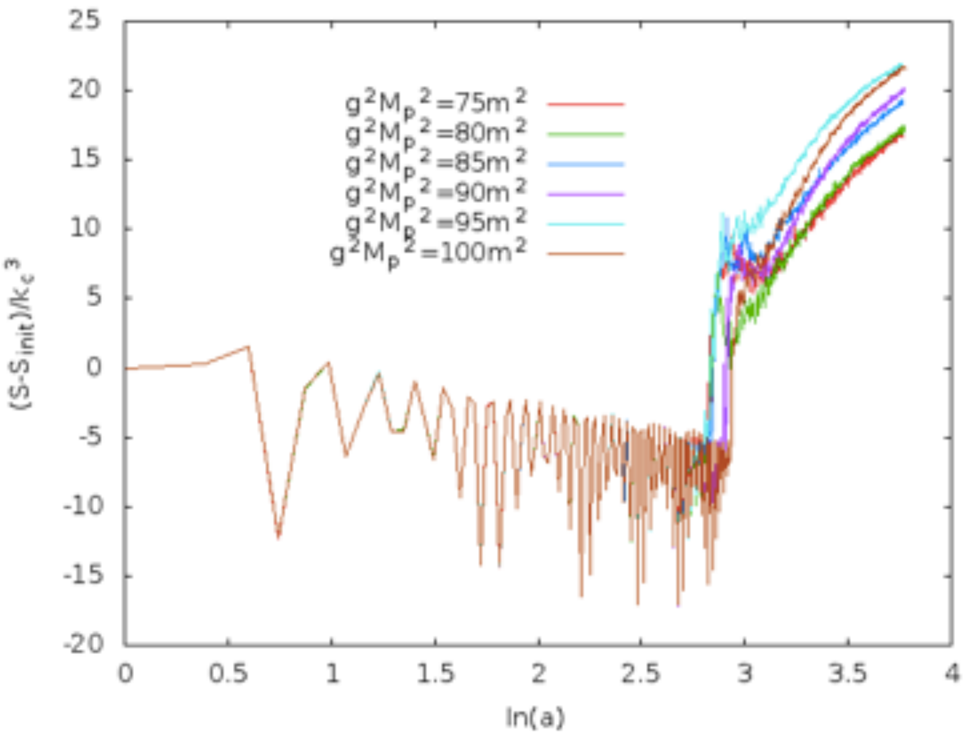


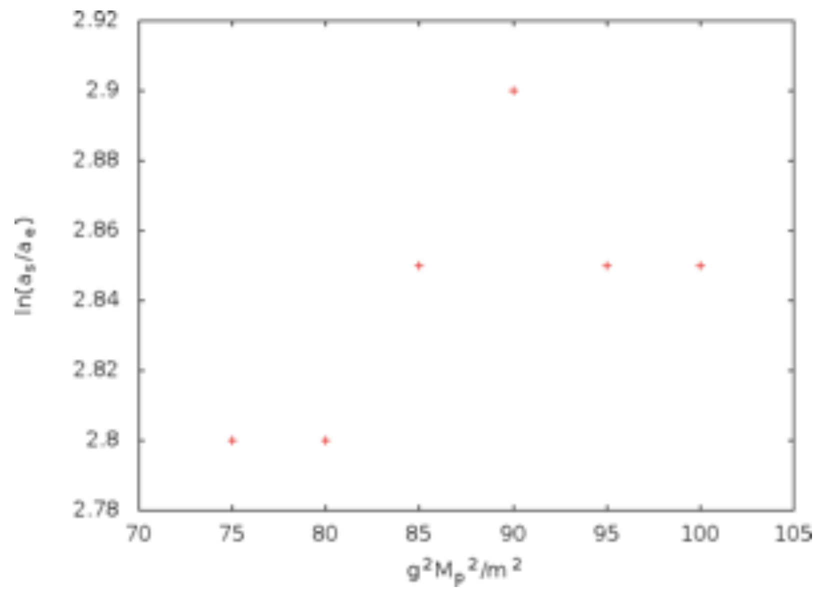
The shock-in-time has a more pronounced effect on larger scales

At late times, local fluctuation PDFs evolve more slowly on larger scales than on small

White bounds the extremal values in the simulation box.

Relation to Nongaussianities entropy change as coupling changes





dependence of $\ln(a_{shock}/a_{end})$ on parameters (coupling constants,$\langle x_{init}\rangle$, ...)

relationship to nongaussianities from preheating

Bond,Frolov,Huang,Kofman (2009), and e.g. Chambers and Rajantie (2008)

The spatial structure of $\ln(a_{shock}/a_{end})$ (x) from modulated initial conditions encodes information about the perturbation spectra including nongaussianities.

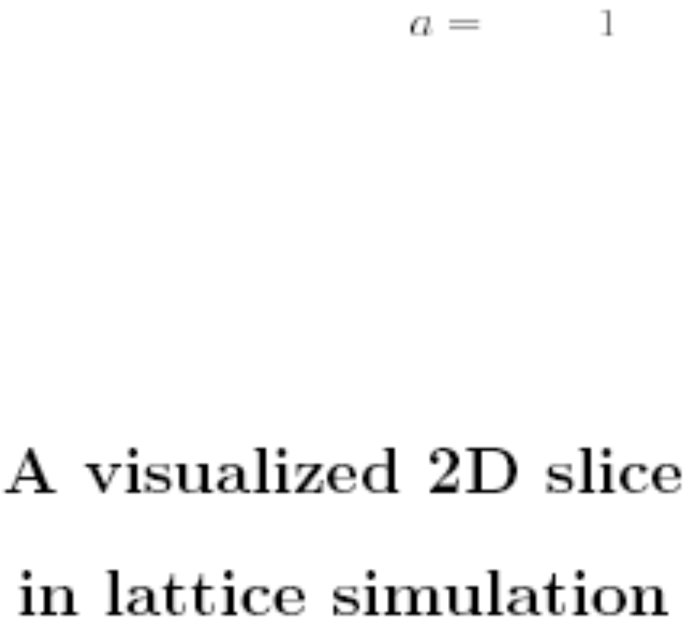
a case with small post-shock nonG??

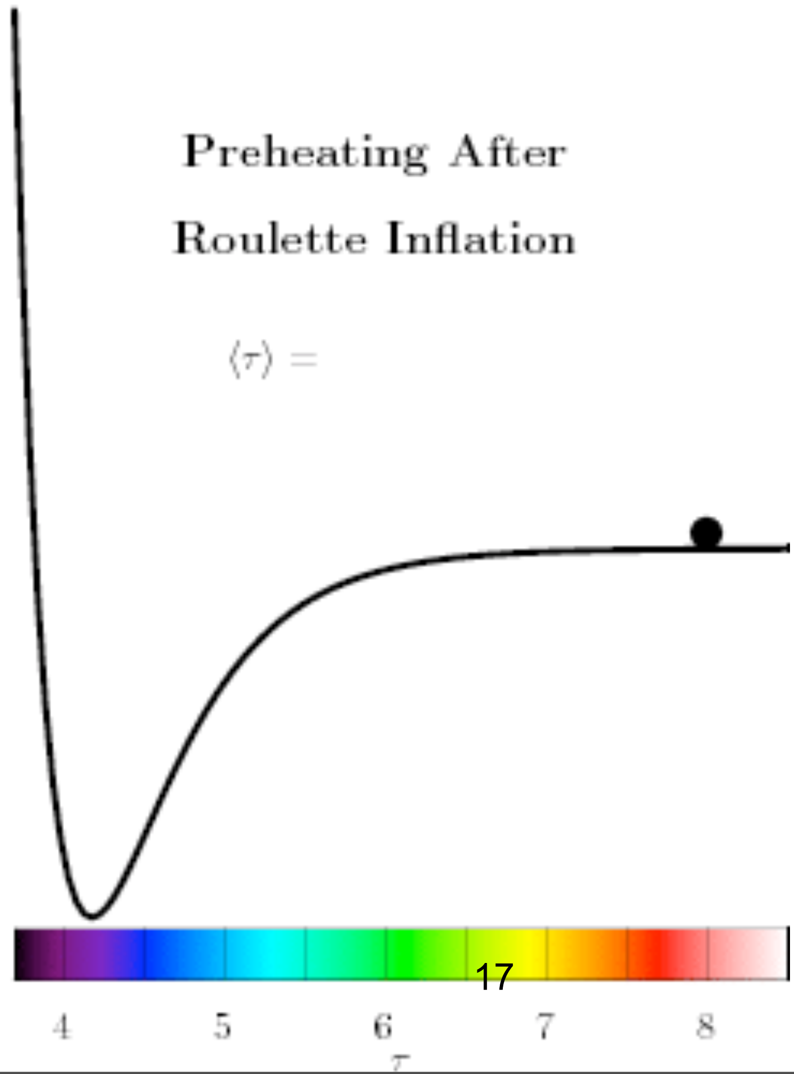
Preheating After Roulette Inflation

pre-heating patch (<1cm)

Barnaby, Bond, Huang, Kofman 2009

HLattice code: arbitrary number of fields, hybrid symplectic, to ~ trillionth accuracy!
Huang 2011 added full metric back action





www.youtube.com/watch?v=FW__su-W-ck&NR=1

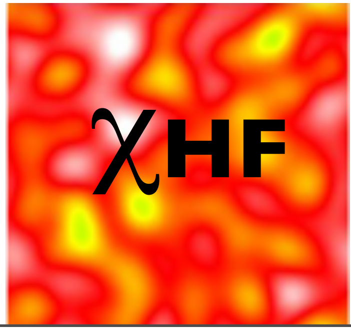
large post-shock nonG??

trying to prove that $\ln a_{final}/a_{end} \sim \ln a_{shock}/a_{end}$

curvature $F_{NL}(\chi(x,t)) = \delta \ln a|_H (\chi_i)$

highly nonlinear function of a Gaussian random 'isocon' field

$\chi(x,t)=$



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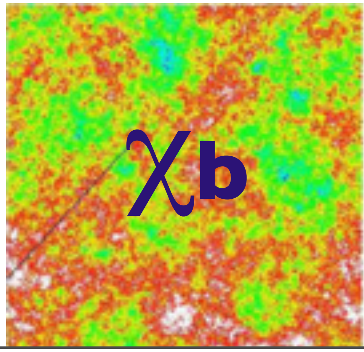

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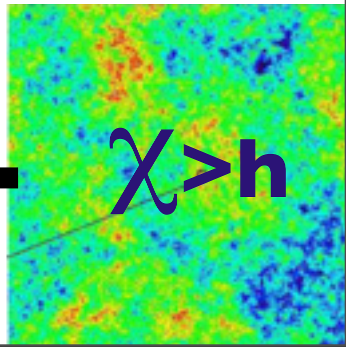
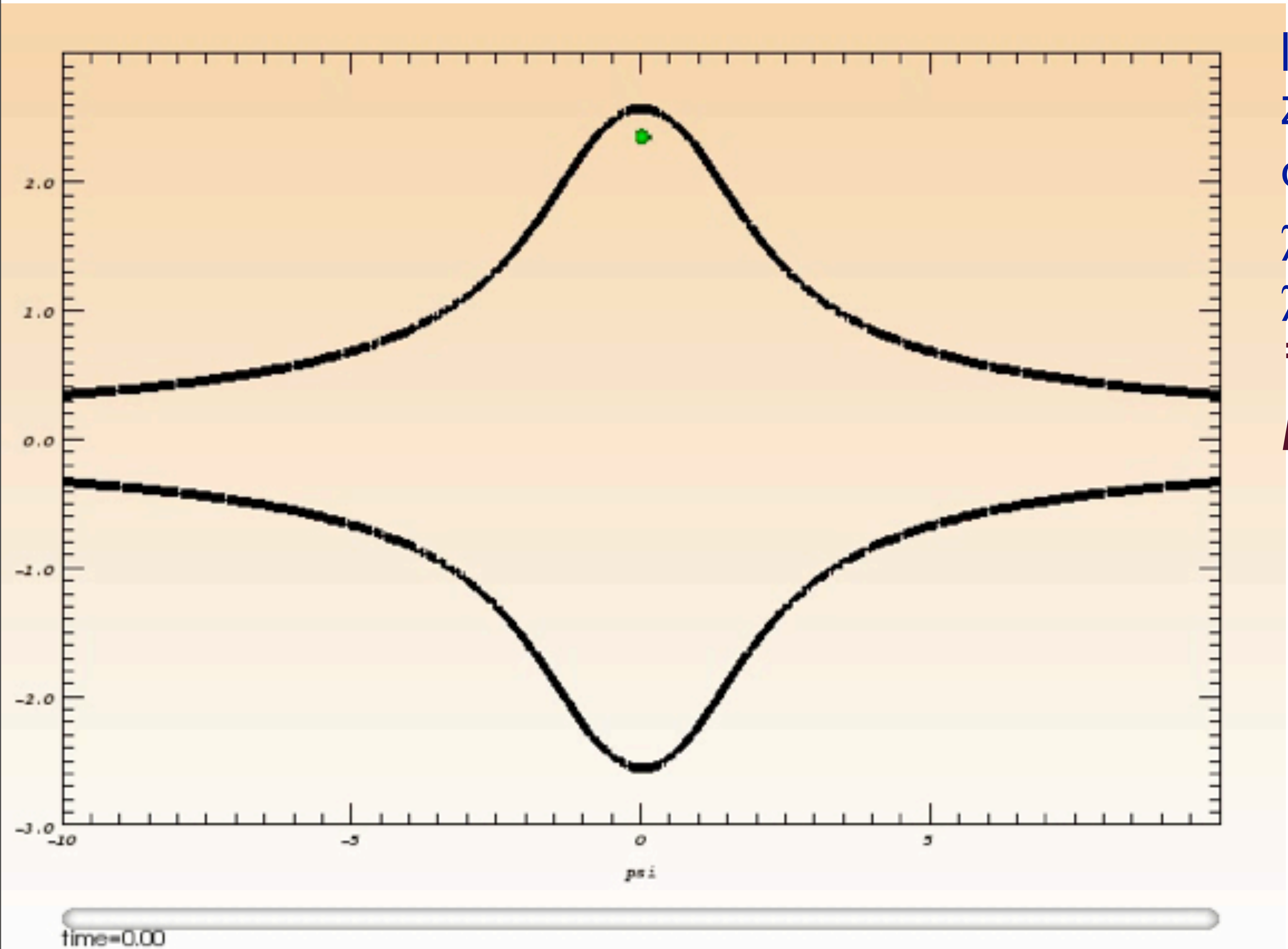


large post-shock nonG??

calculate $\delta \ln a[\chi_i(x,t)]$ *from* **ε=1** *(end of inflation)* ***through preheat***
(copious mode-mode-coupling aka particle creation) ***to thermal equilibrium***

Bond, Andrei Frolov, Zhiqi Huang, Kofman 09



linear regime of zero-modes:

$\phi_0(t+T) = \phi_0(t)$

$\chi_0(t+T) = \chi_0(t) \exp[\mu_0 T]$

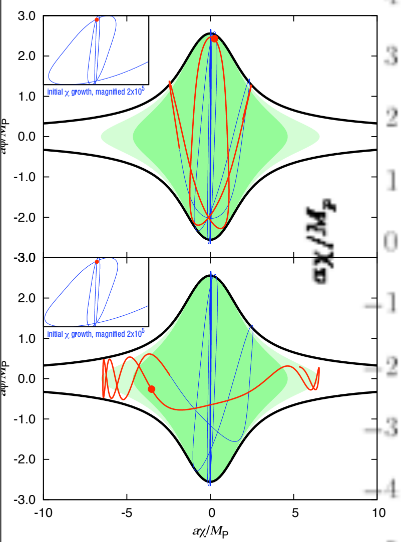
⇒ ***spikes are***

log χ_i ***spaced***

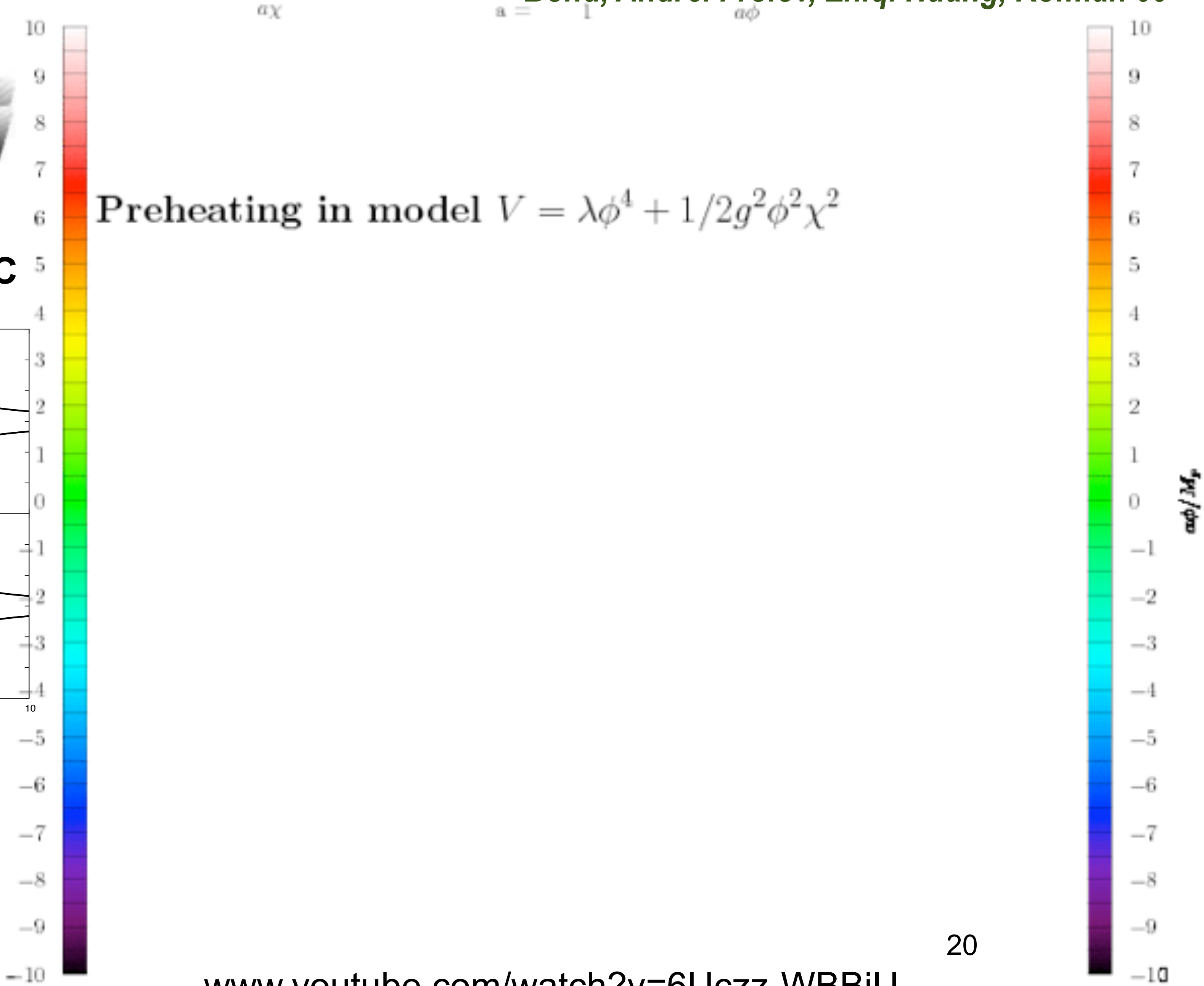
Cosmic Chaotic Billiards: NonGaussianity from Parametric Resonance in Preheating

Bond, Andrei Frolov, Zhiqi Huang, Kofman 09

non-spike IC



spike IC



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www.youtube.com/watch?v=6Uczz-WBBjU

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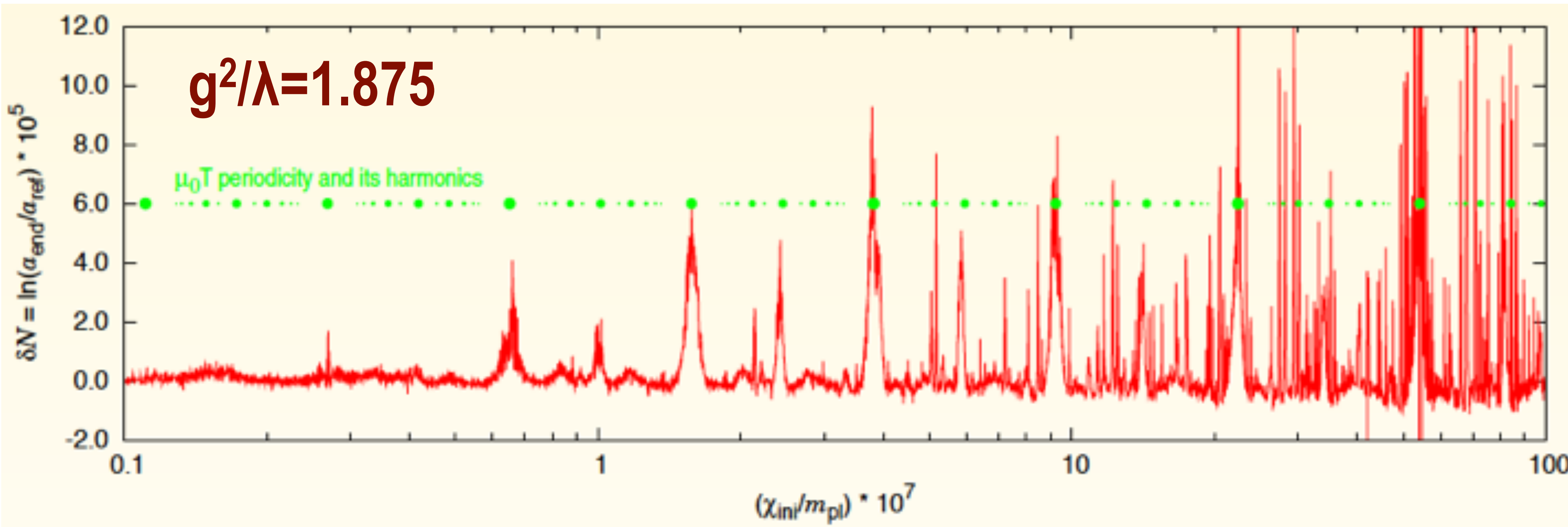
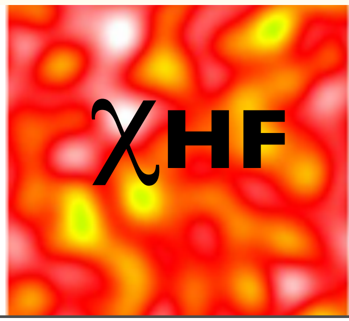


$\chi(x,t) =$



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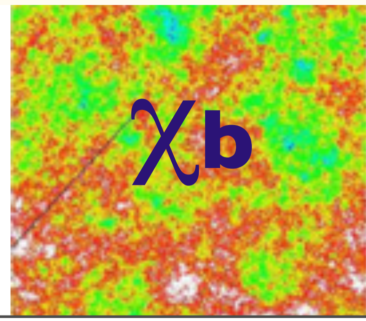

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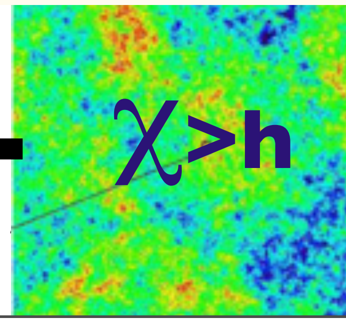

large post-shock nonG??

to develop the $\ln a(\chi_i)$ response curve, we perform > 10^4 lattice simulations for each g^2/λ

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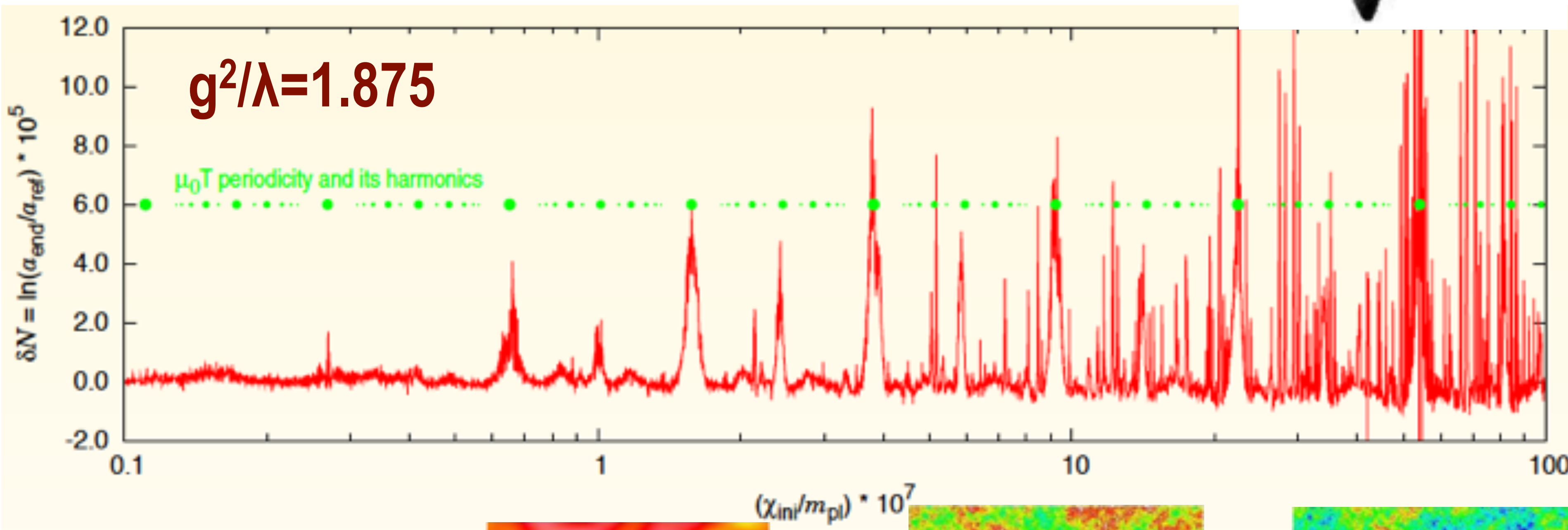
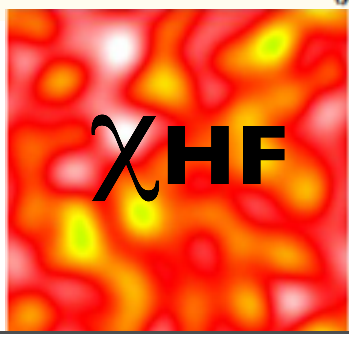
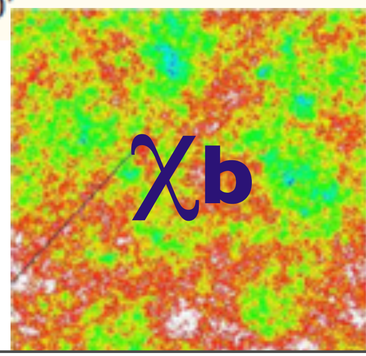
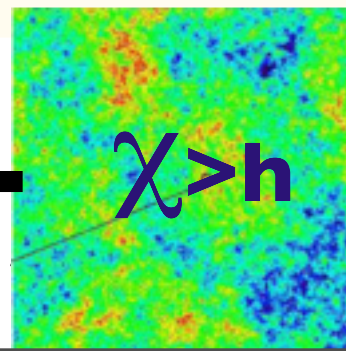


$\chi(x,t) =$ 

+ 

+ 

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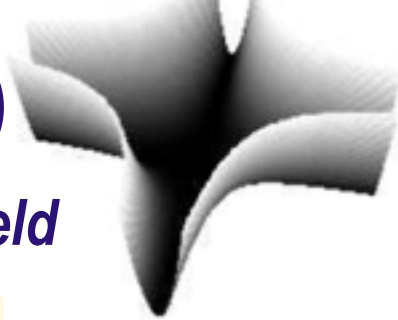

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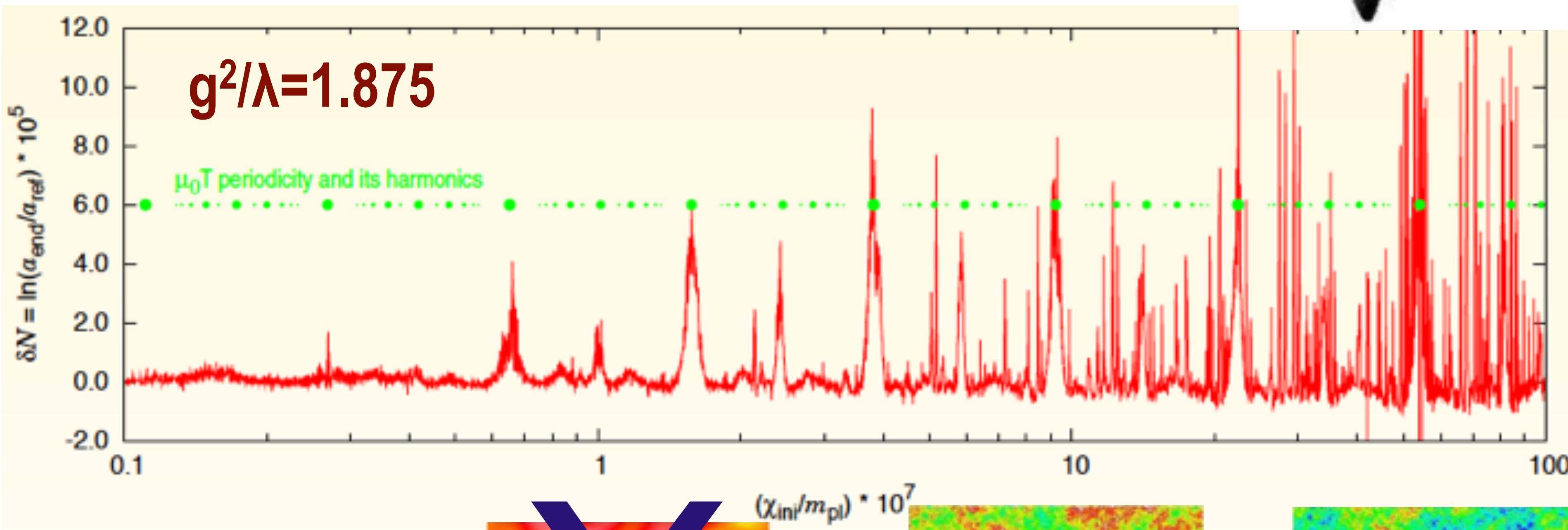
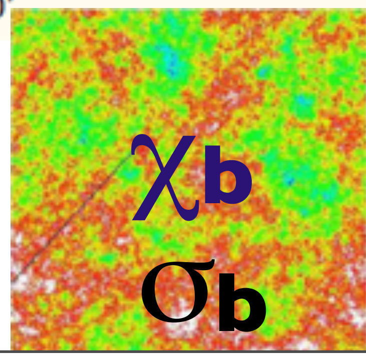
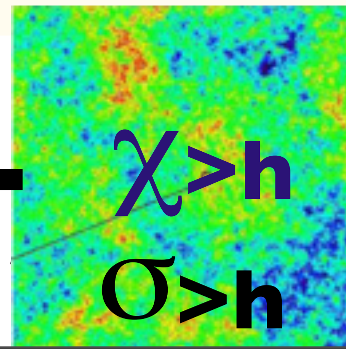


effective field theory

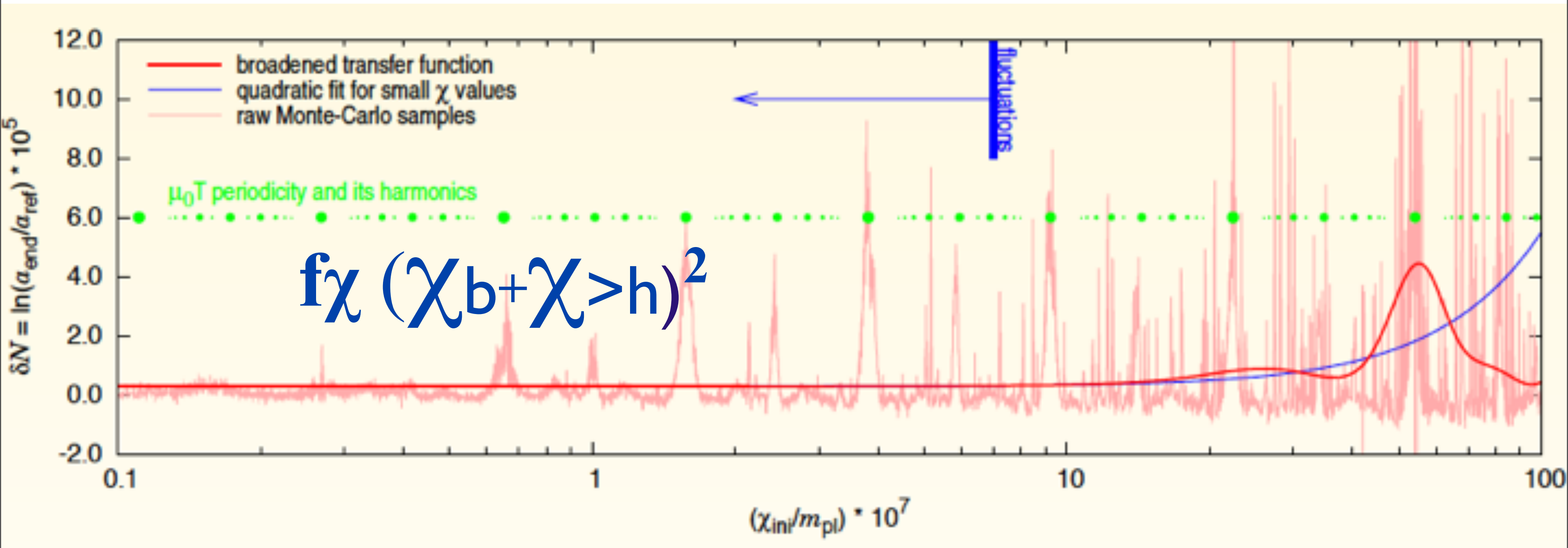
$\chi_{eff}(x,t) =$  +  + 

field smoothing over χ_{HF}

field smoothing over χ_{HF} over ~50 e-folds of HF structure

$$< F_{NL} | \chi_b + \chi_{>h} > \sim \beta(\chi_{>h})\, \chi_b + f(\chi_{>h})\, \chi_b^2 + \ldots$$

cf. $F(x) = F_G(x) + f_{NL}\, F_G^2(x)$



field smoothing over χ_{HF} over ~50 e-folds of HF structure

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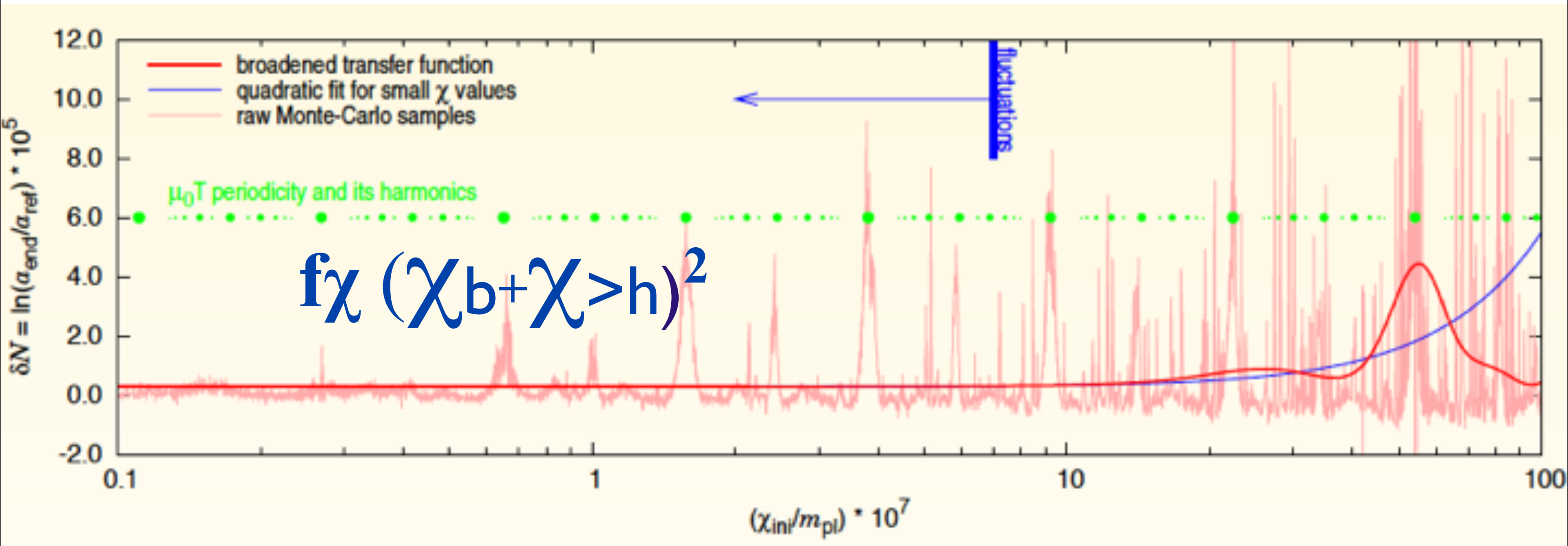


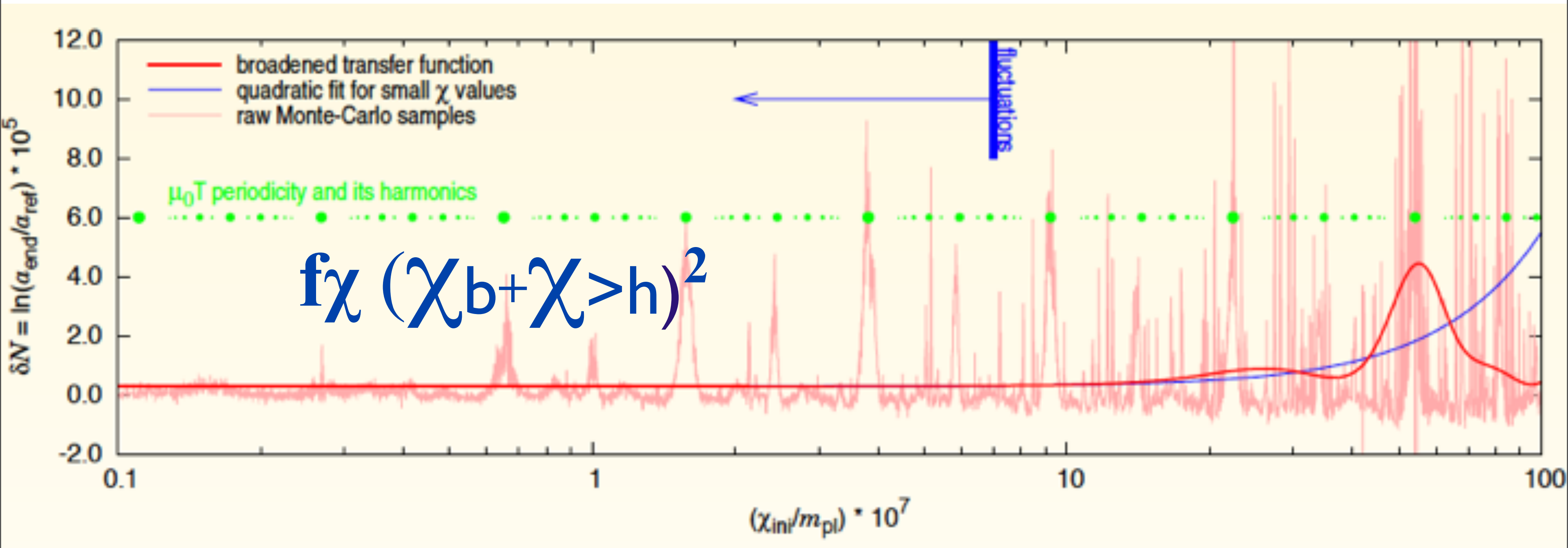
$$f_{NL}^{equiv} = \beta^2 f_\chi\, [P_\chi/P_\phi]^2(k_{pivot})$$

=> constrain $f_\chi^3\, \chi_{>h}^2$ ($P_\chi/P_\phi \sim 2\varepsilon$ => *relaxed limit*)

field smoothing over χ_{HF} over ~50 e-folds of HF structure

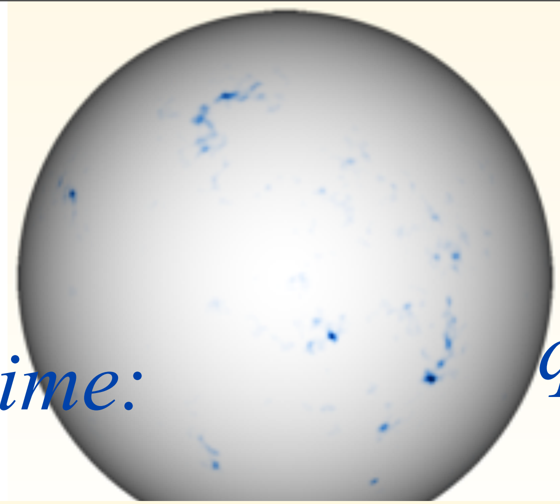
$$< F_{NL} | \chi_b + \chi_{>h} > \sim \beta(\chi_{>h})\, \chi_b + f(\chi_{>h})\, \chi_b^2 + \ldots$$

cf. $F(x) = F_G(x) + f_{NL}\, F_G^2(x)$

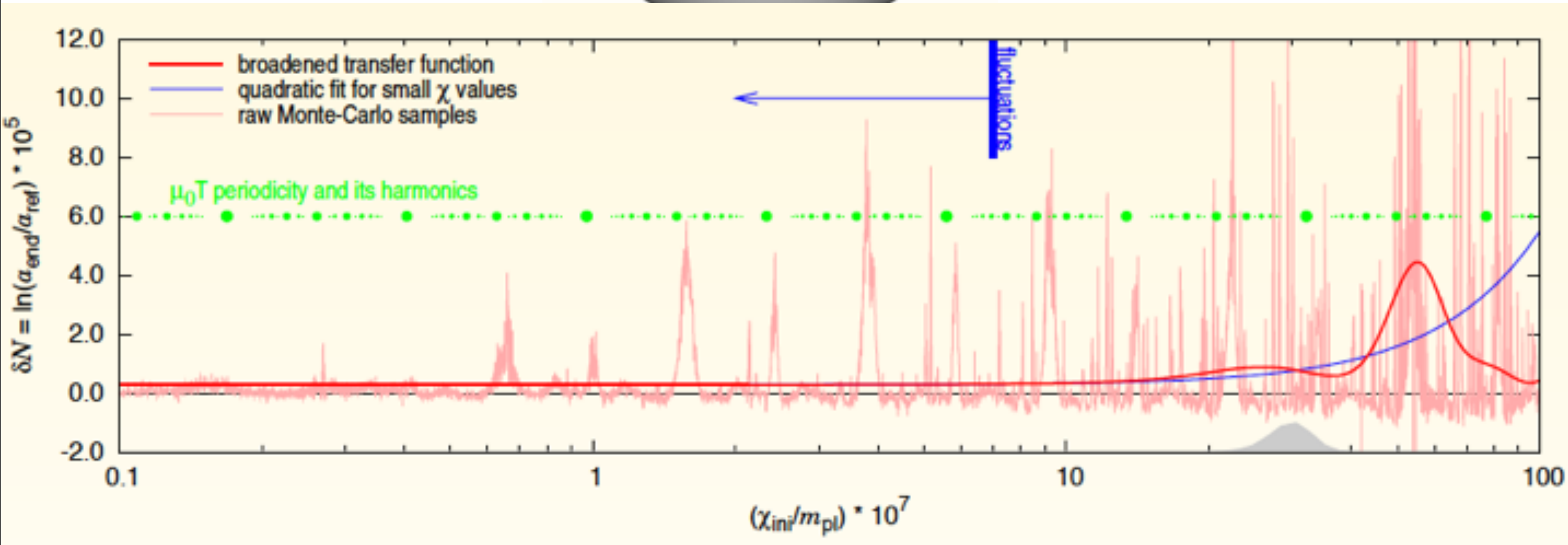


$f_{NL}^{equiv} = \beta^2 f_\chi\, [P_\chi / P_\phi]^2 (k_{pivot})$ **$-10 < f_{NL} < 74$ WMAP5 (± 5 Planck)**

=> constrain $f_\chi^3\, \chi_{>h}^2$ ($P_\chi/P_\phi \sim 2\varepsilon$ => *relaxed limit*) *large-ish* χ>h *regime:*



*quadratic+**cold spot***
“rare events”

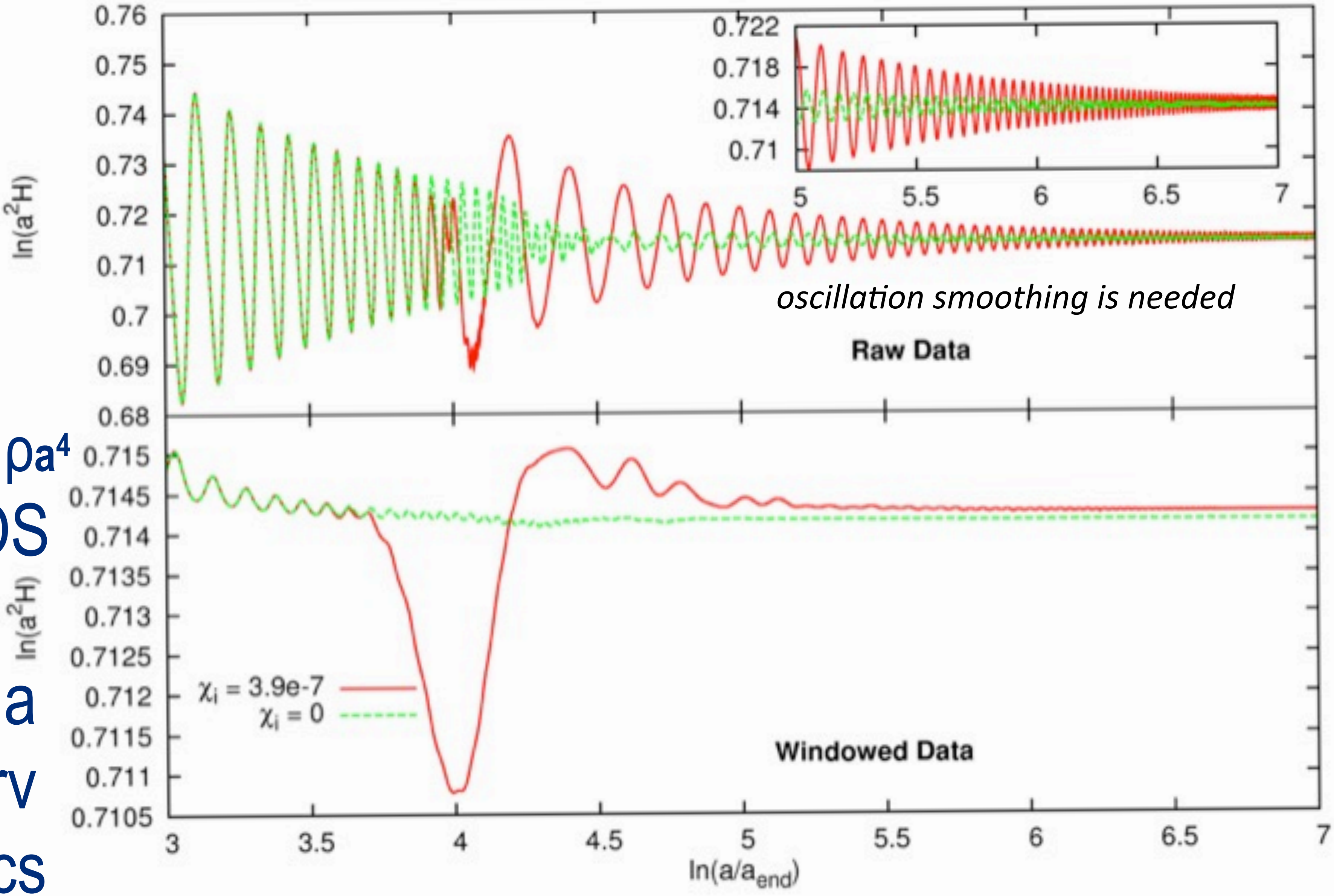


B+Frolov+Nolta, motivated by B+Braden+Frolov+Huang, B+Braden nonG

long aside: novel ways of **finding hot & cold spots in the CMB vs. resolution**; probing their interior structures; **their polarization & relation to anisotropic T-strain**; **use of L-statistics** (L-mean, L-skewness, L-kurtosis, ..) less biased than conventional central moment estimators

Relation to Nongaussianities smooth in time over oscillations gives EOS change ρa^4

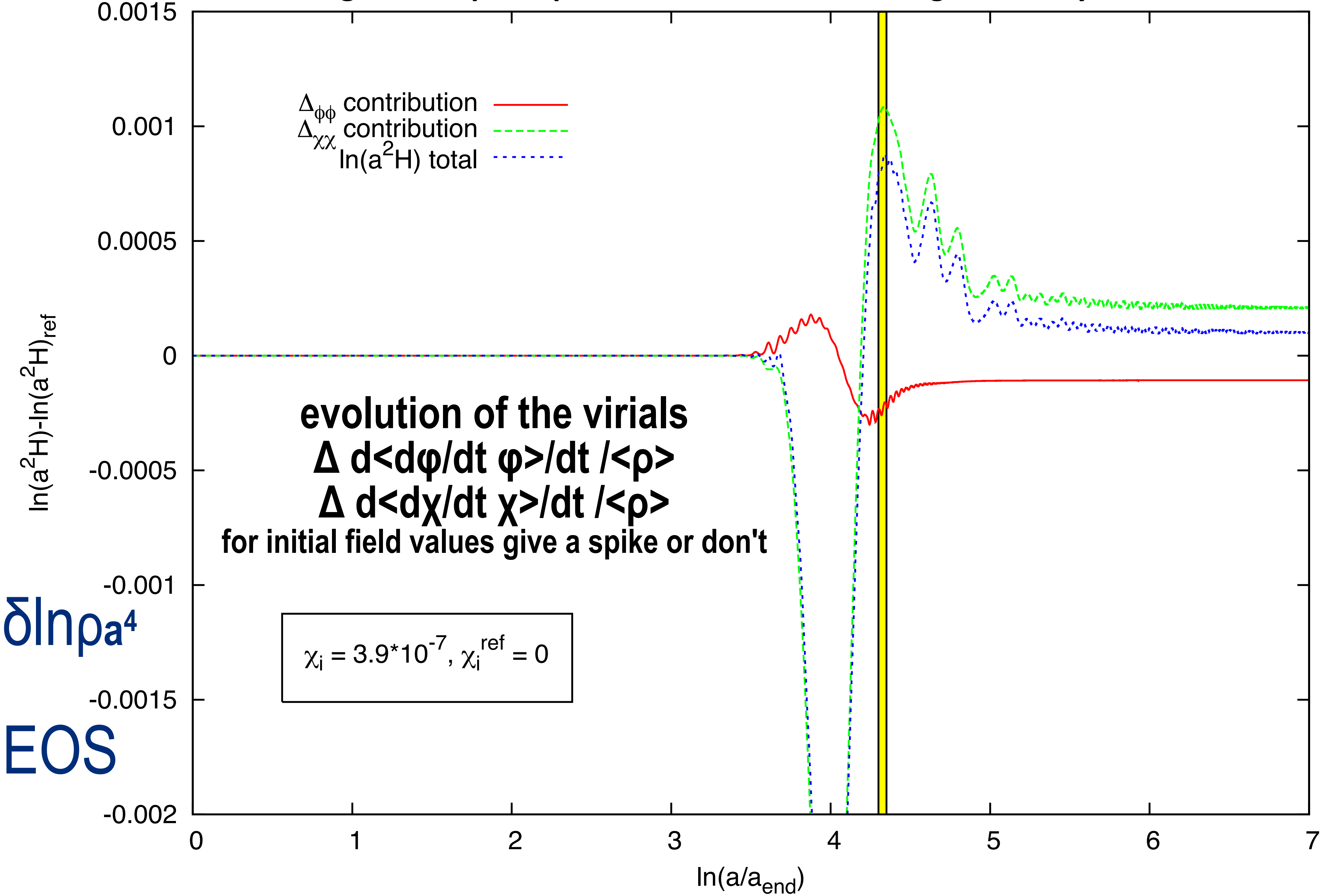
looking for sub-parts-per-million deviations so high accuracy fundamental



$\delta \ln \rho a^4$ EOS ~ $\delta \ln a$ curv flucs

Relation to Nongaussianities smooth in time over oscillations gives EOS change ρa^4

looking for sub-parts-per-million deviations so high accuracy fundamental



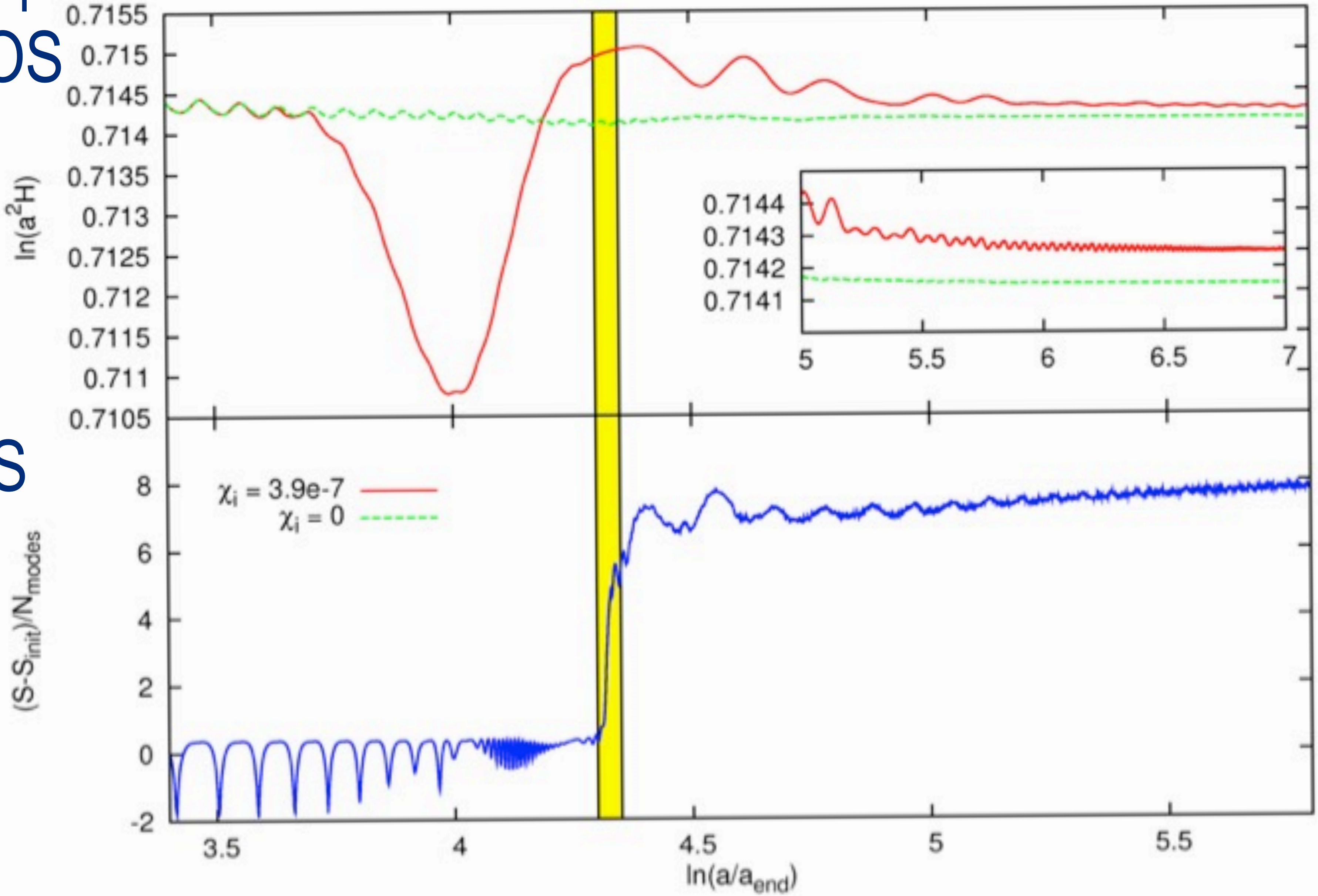
Relation to Nongaussianities EOS change ρa^4 near the entropy jump

looking for sub-parts-per-million deviations so high accuracy fundamental

$\delta \ln \rho a^4$

EOS

δS



Conclusions

new language for preheating with complex information measures at its core: the shock-in-time = randomization front, an efficient entropy source

Spatial block RenormGp smoothing indicates that PDF's of fluctuations around local values evolve slowly post-shock

nearly Gaussian PDF for $\ln \rho$ **& v hydro/phonon regime**

Observable preheating nongaussianities can be encoded in the spatial structure

of the shock-in-time, characterized by $\ln a_{shock}(x)/a_{end}$ &

the mediation width. reasonable case made for ~ $\ln a_{final}(x)/a_{end}$

TBD: solidify the case for nonG from shock-in-time(x | couplings, isocon, ...) & explore the parameter dependence, and thus the **variety of nonG** that can arise.

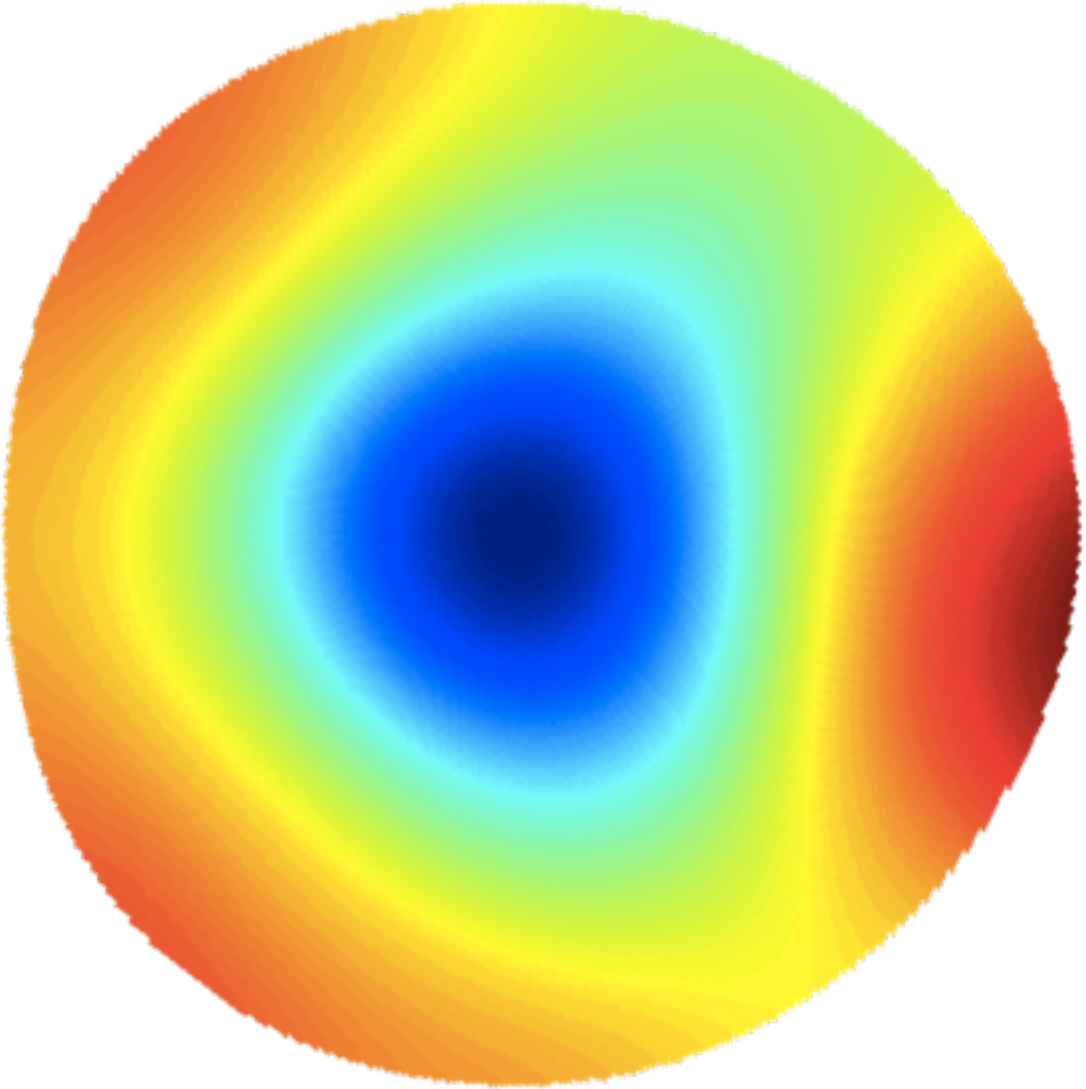
constrain/detect with Planck. ***explore more short-astro-distance exotica of spiky potential pits***

whence opening of large number of particle dofs & standard model? can this kick in earlier, aka warm inflation. anyway, we are having fun with the high k drain

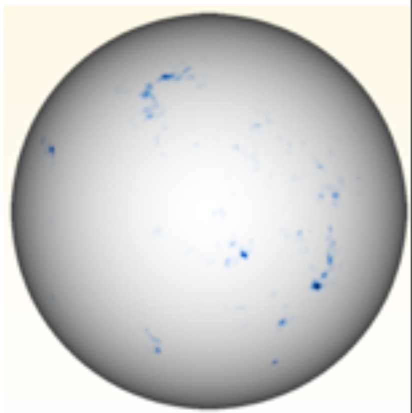
publish all of our cold spot /quadratic constraints nonG-S stuff

end

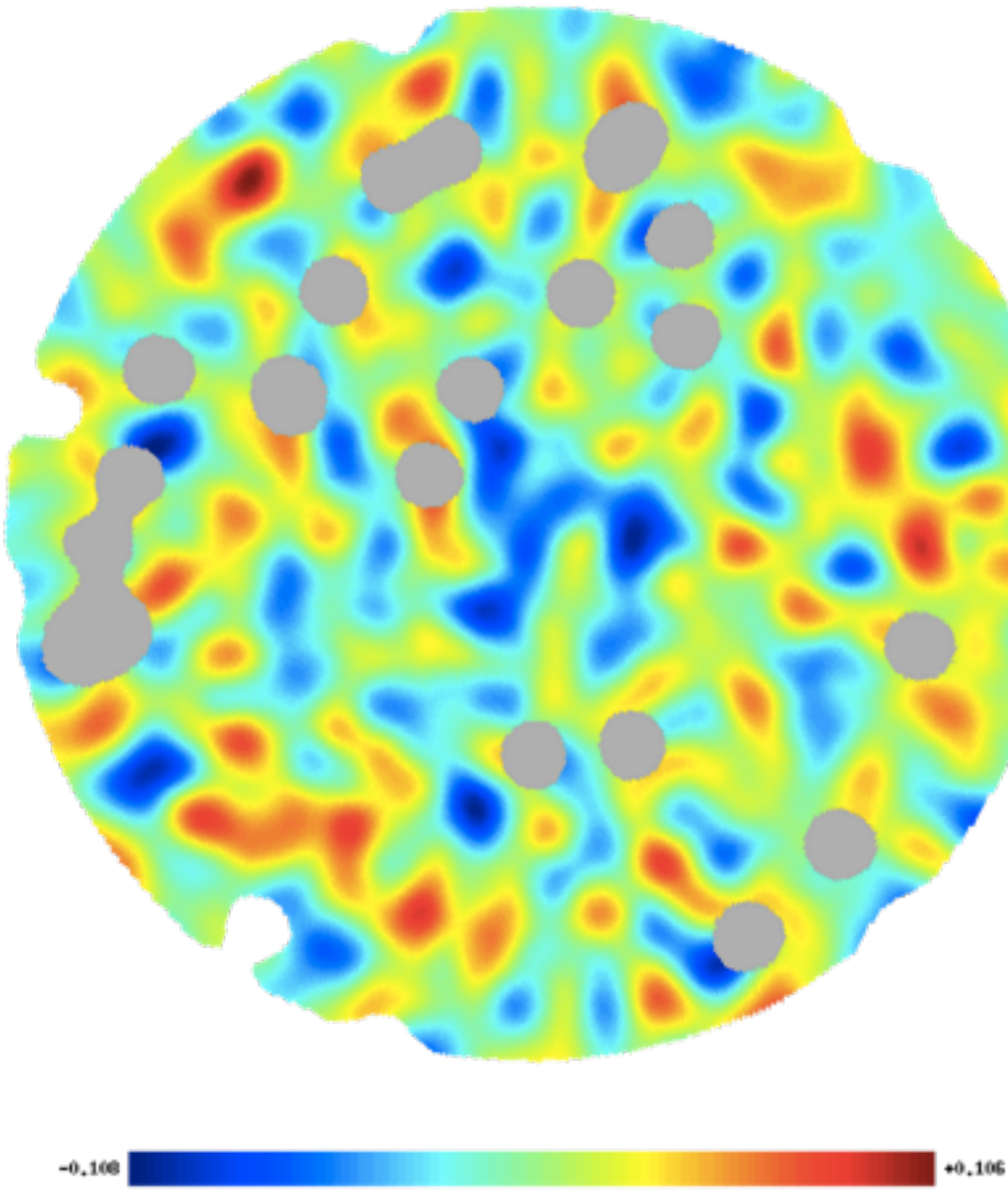
closing in on cold spot structure *(resolution)*



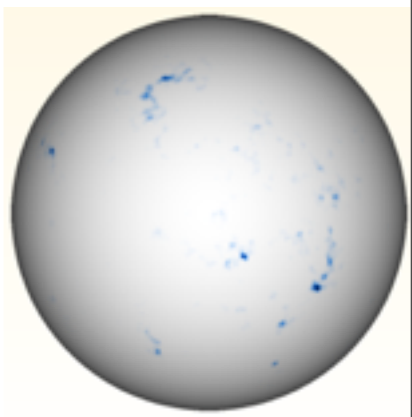
13 deg



closing in on cold spot structure *(resolution)*



2 deg

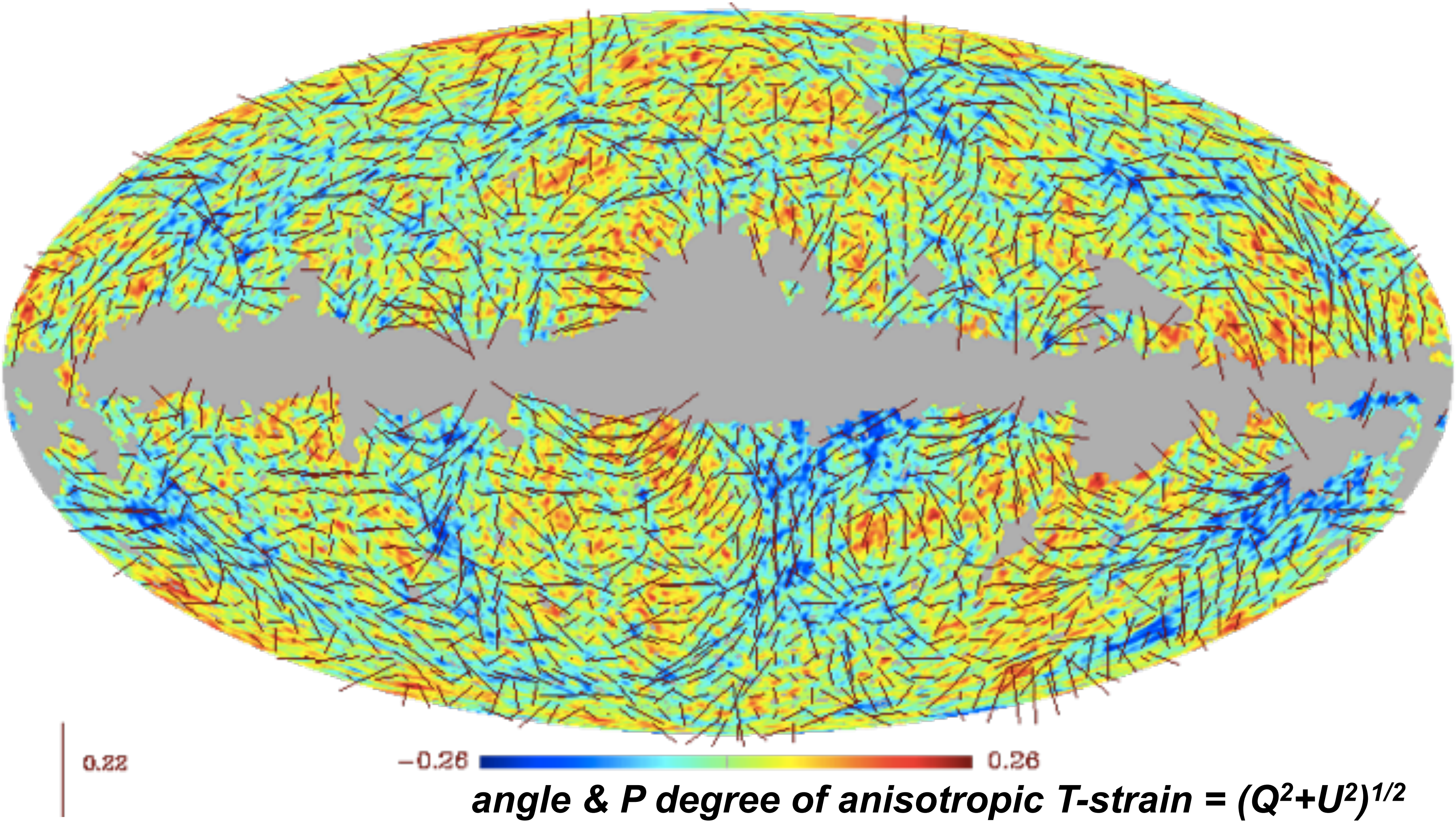


$$K_{ab} \equiv \Delta^{-1} \nabla_a \nabla_b T$$

isotropic T-strain: = I Stokes

anisotropic T-strain: K_{11}-K_{22} ~ Q E-like Stokes

anisotropic T-strain: K_{12}+K_{21} ~ U E-like Stokes

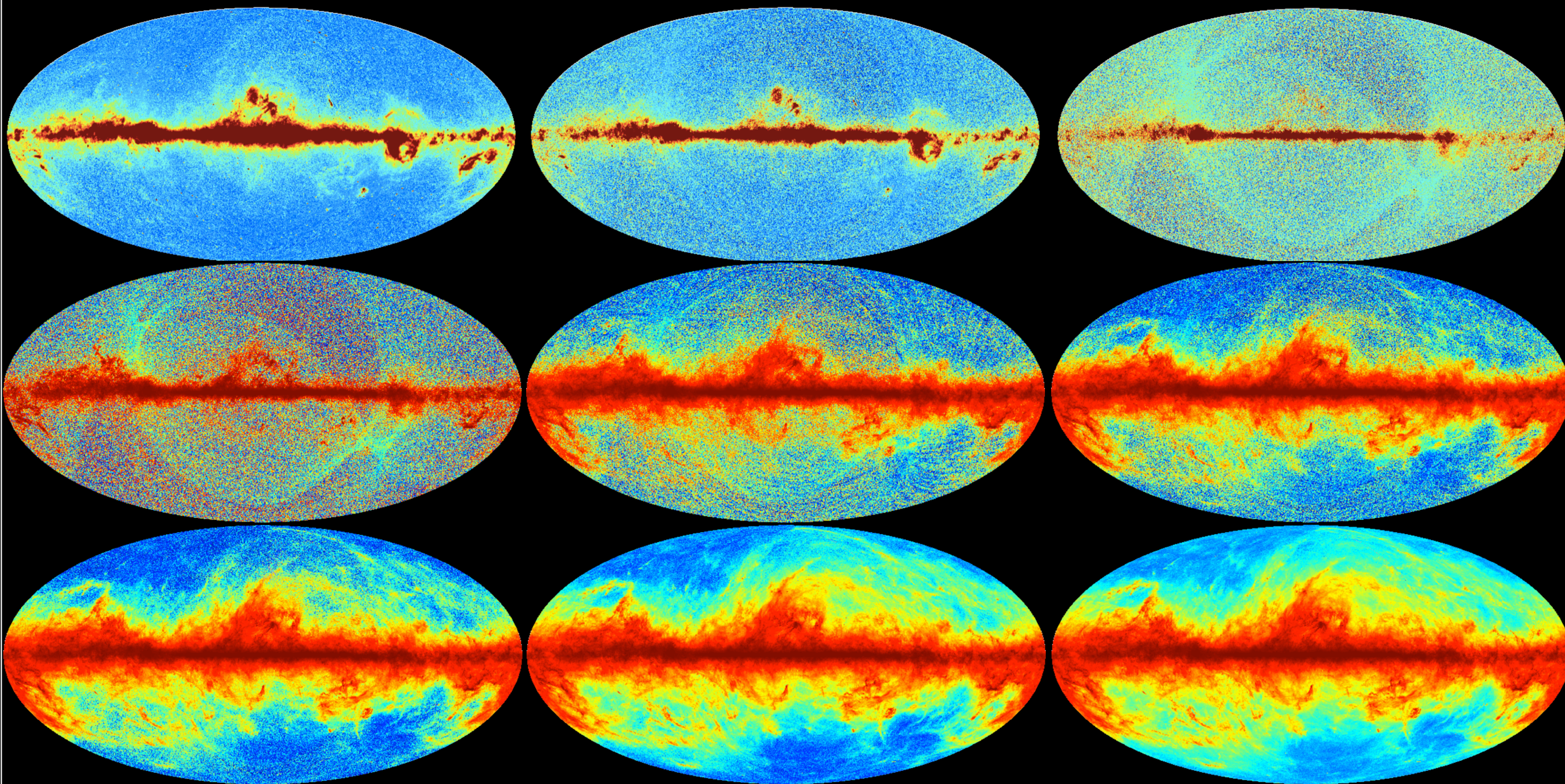


angle & P degree of anisotropic T-strain = $(Q^2+U^2)^{1/2}$

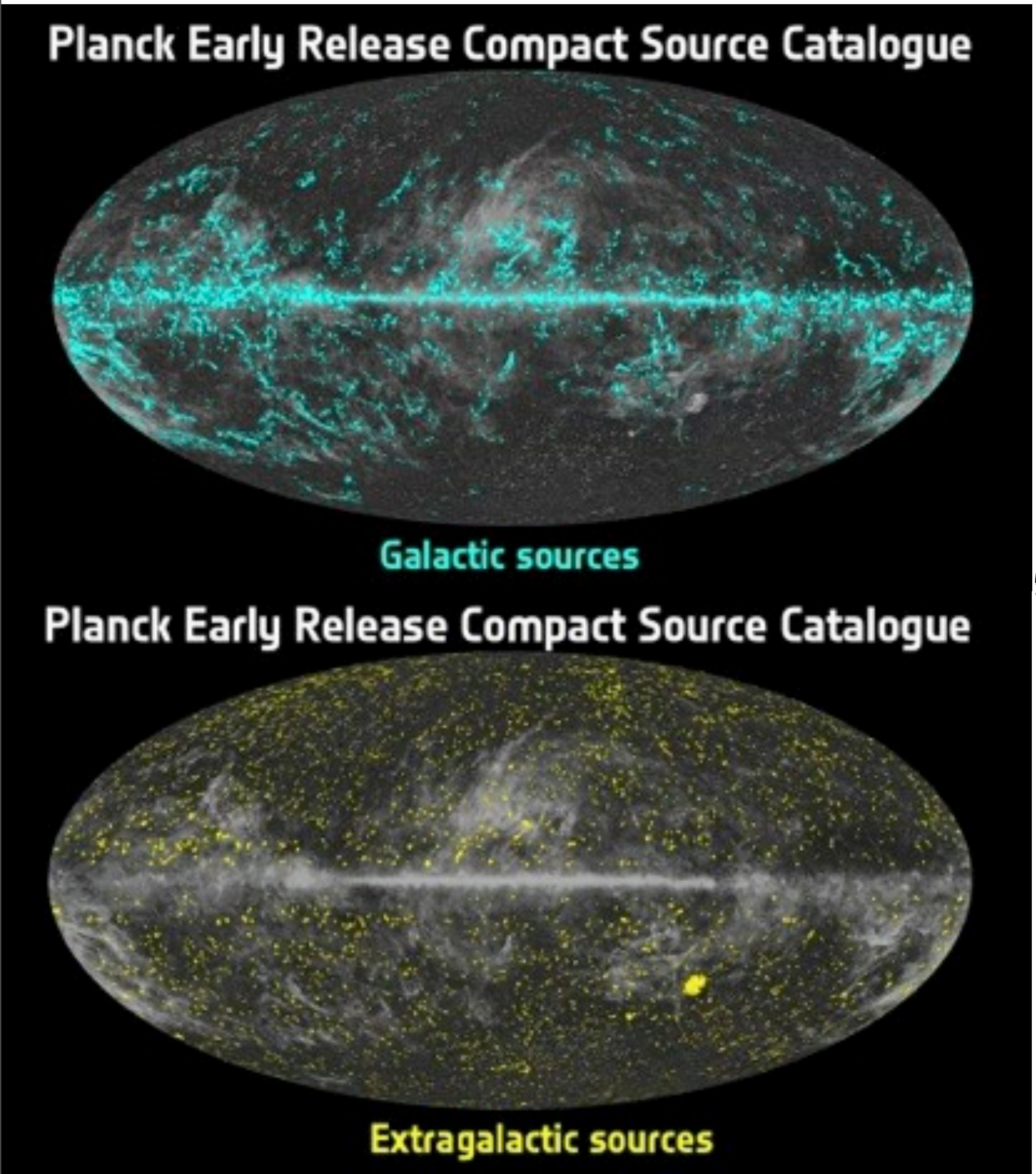
veils(ν) +CMB-CMB

The Planck Foregrounds sky

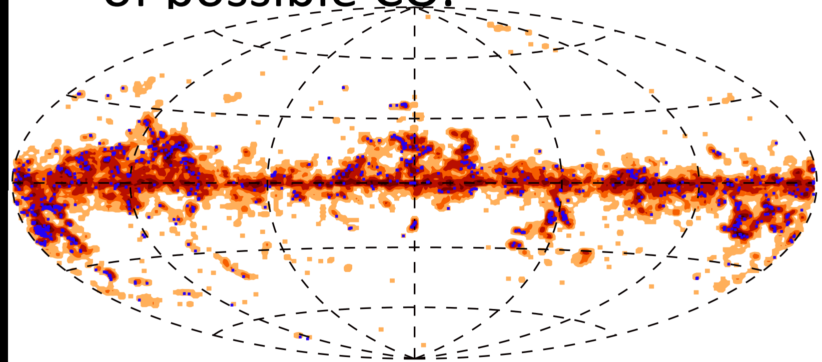
data Aug 13 09 to Jun 7 10: all-9-frequency maps + maps-CMB produced & delivered to consortium Aug 2 10



Needlet ILC method chosen to remove CMB for HFI. so many separation methods - great, so many templates. localized removals won out in some early papers. lessons learned?



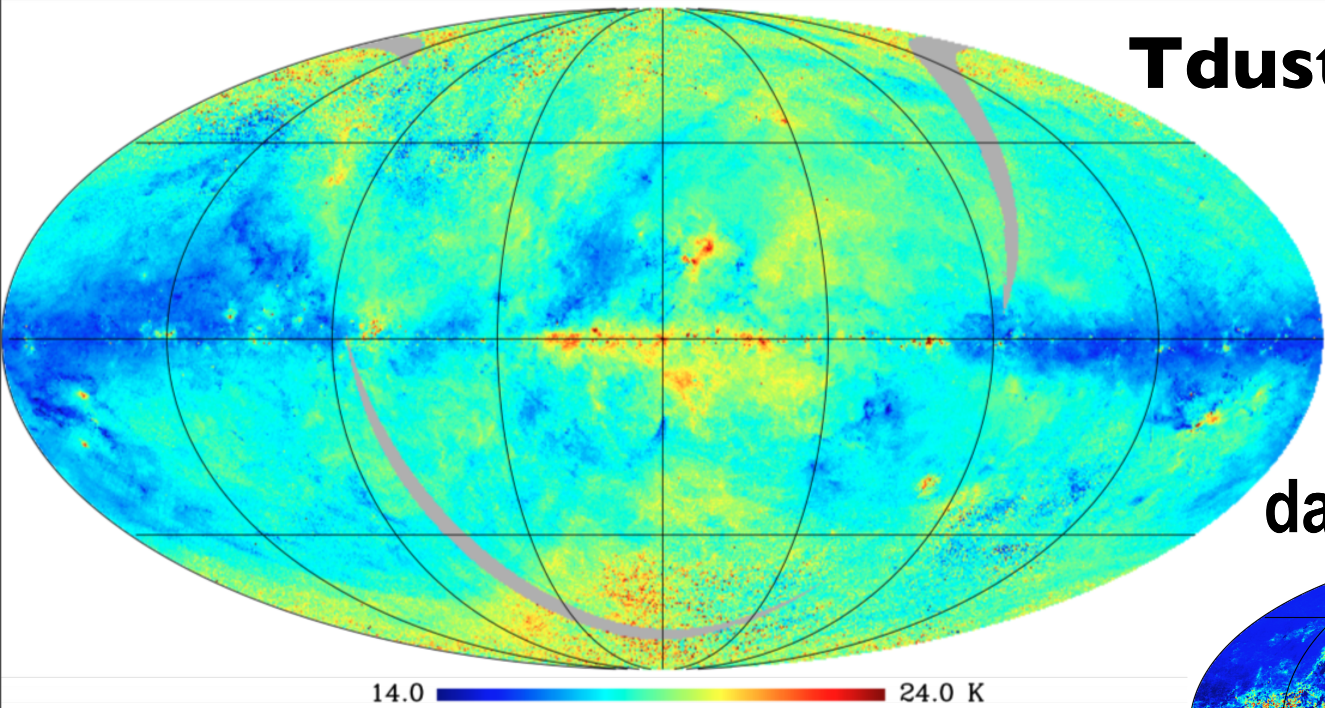
- 15000 sources. Reliability > 90% (using MC) with photometric accuracy <30%, no completeness stats and not flux limited.
- => radio/submm extragalactic sources, Galactic sources, +
- Have to take care at 100 GHz of possible CO.



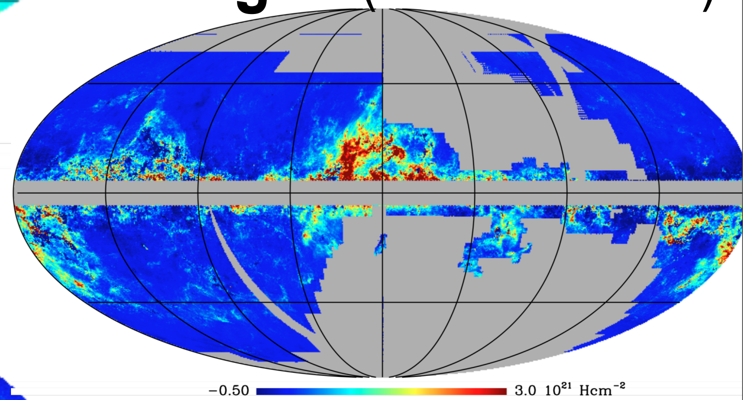
- **915 cold cores** in catalog **ECC** (7-17K, 1.4<beta<2.8), **10783 (C3PO)** seen in maps, most within 2kpc
  Herschel follow-up, some done
- precursors of pre-stellar cores, up to 1e5 Msun
- *Cold Clumps aka cold cores* in groups & filaments, on edges of H1/IRAS loops

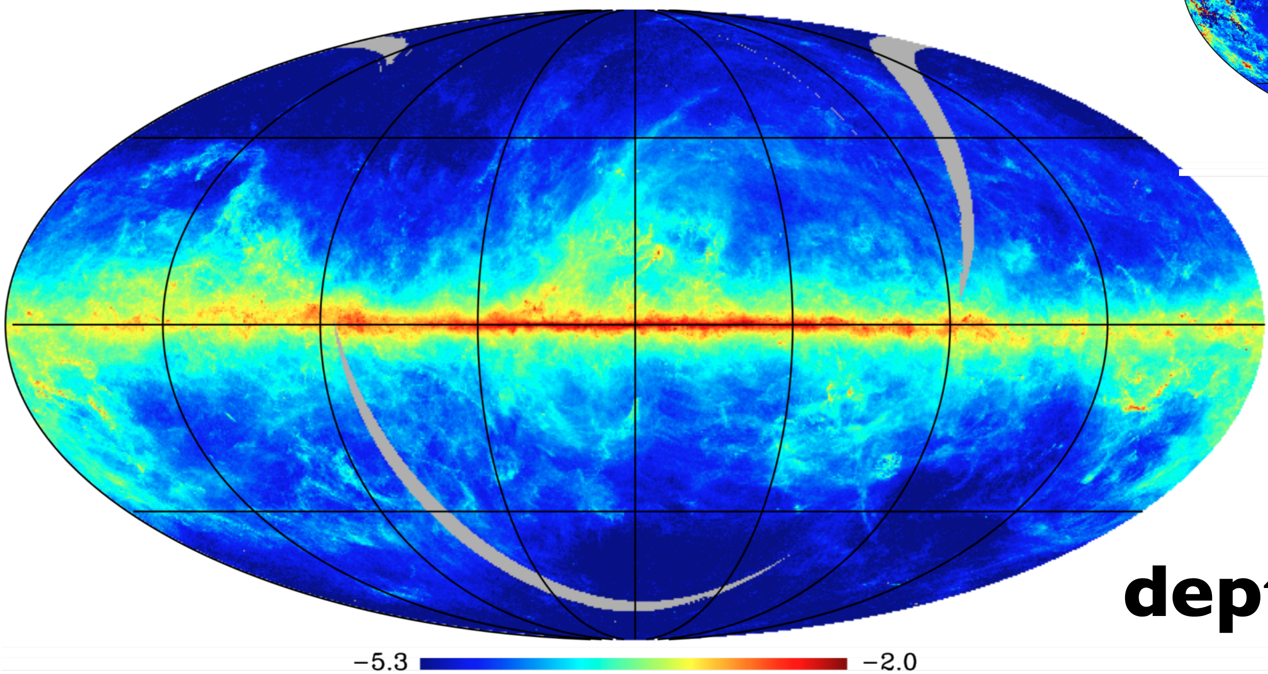
Tdust β fixed @1.8

Planck+*IRAS*



dark gas (no HI/CO corr)





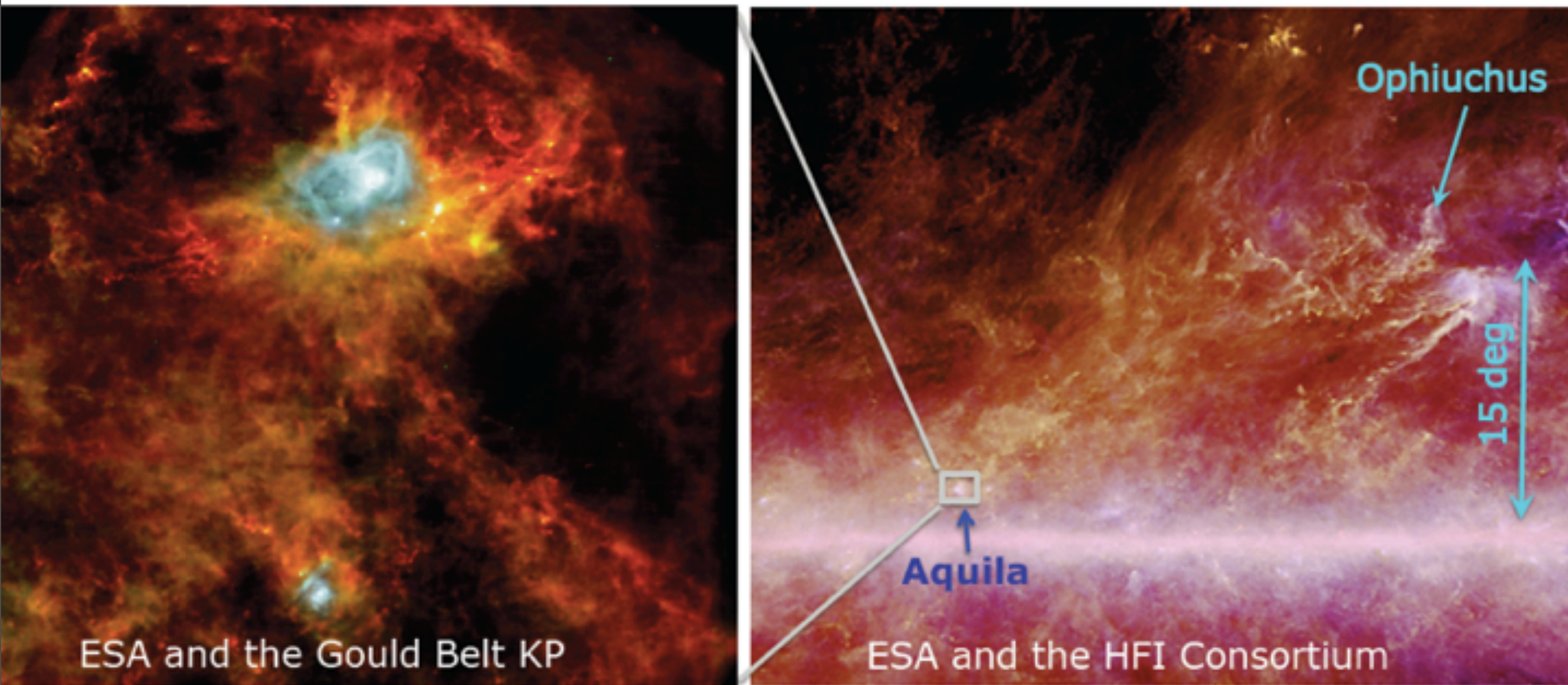
depth τdust

the GALAXY WIDE WEB

Filaments permeate the ISM on all scales

(3.5m telescope) **Herschel** — (1.5m telescope) **Planck**

SPIRE 500 μm +PACS 160/70 μm — **HFI 540/350 μm + IRAS 100 μm**



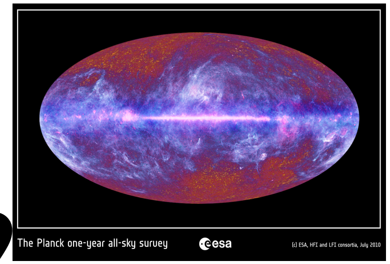
Göran Pilbratt | Planck 2011: The mm & submm sky in the Planck era | Paris | 10 January 2011 | vg #16

Herschel ATLAS is a key legacy survey of 550 sq deg, 300 sq deg & lots of science done

gastrophysics

= gastrointestinal disorder? or

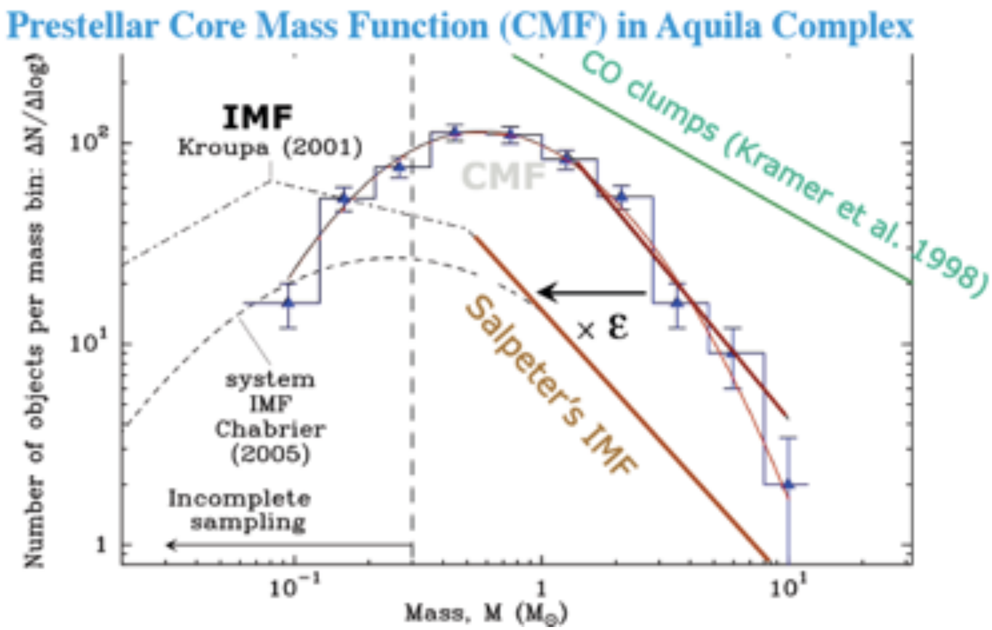
interplanetary dust

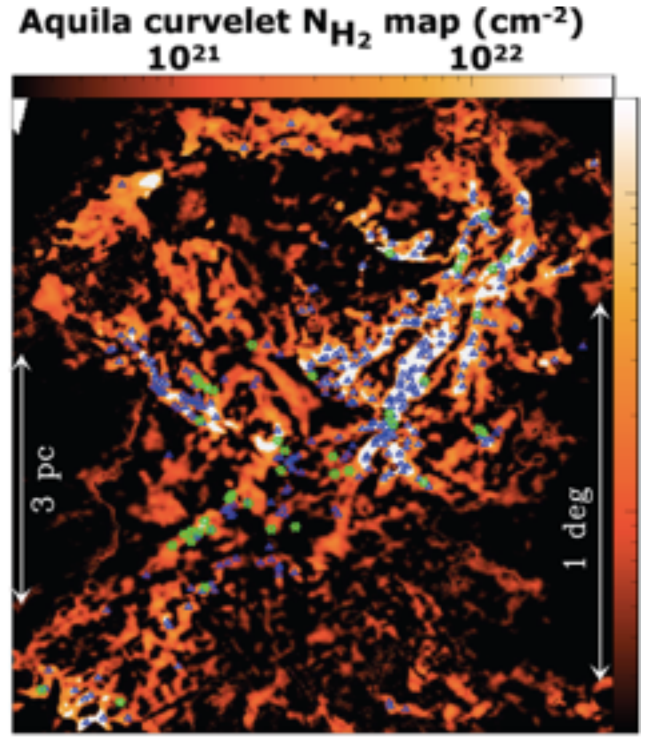


= gourmand's paradise?

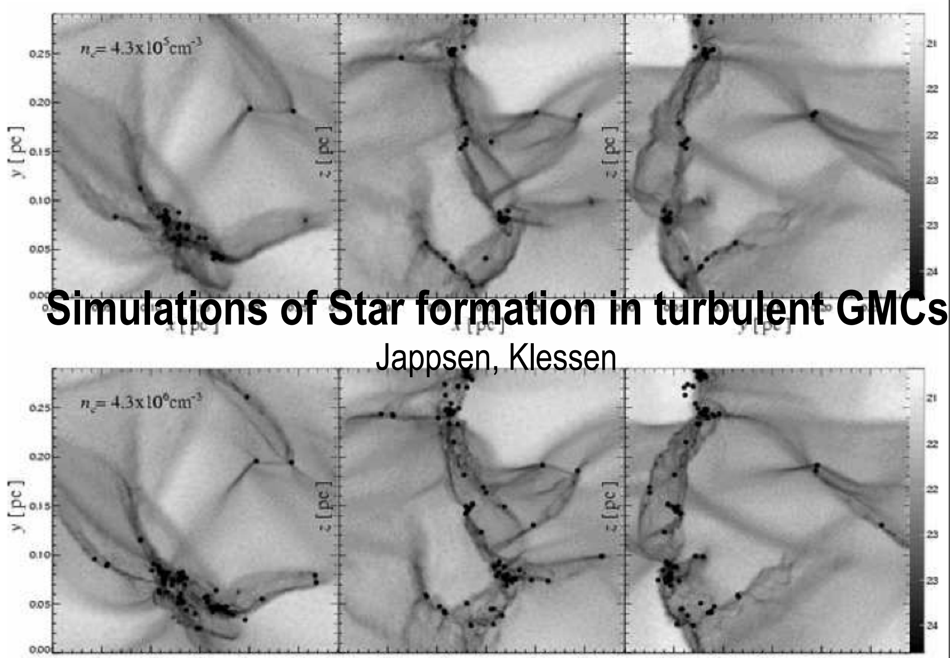
in paris, the latter @planck2011

∃beauty in complex information, but how best to measure it - compress into fewer bits of high Quality (cf. entropy) - what art our science should/must be





André et al. 2010, A&A special issue



Simulations of Star formation in turbulent GMCs
Jappsen, Klessen

ISMer-cosmologist cross talk is good and increasing, stimulated by Planck etal

n(M)dM, morphology of filaments, clustering/power spectra, "bulk/turbulent flows"

SIMPLICITY in COMPLEXITY?

but so much chemistry etc

25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work**

- **Galactic dust and templates. MW maps! - see extra emission from 'dark gas' component not in HI or CO, could be H_2 that survives when CO does not. (linear response to templates of all sorts. Planck & Herschel maps beautiful. Tdust vs dust depth/N_H trend) the PlanckEXT extinction model will rule (sometime)**

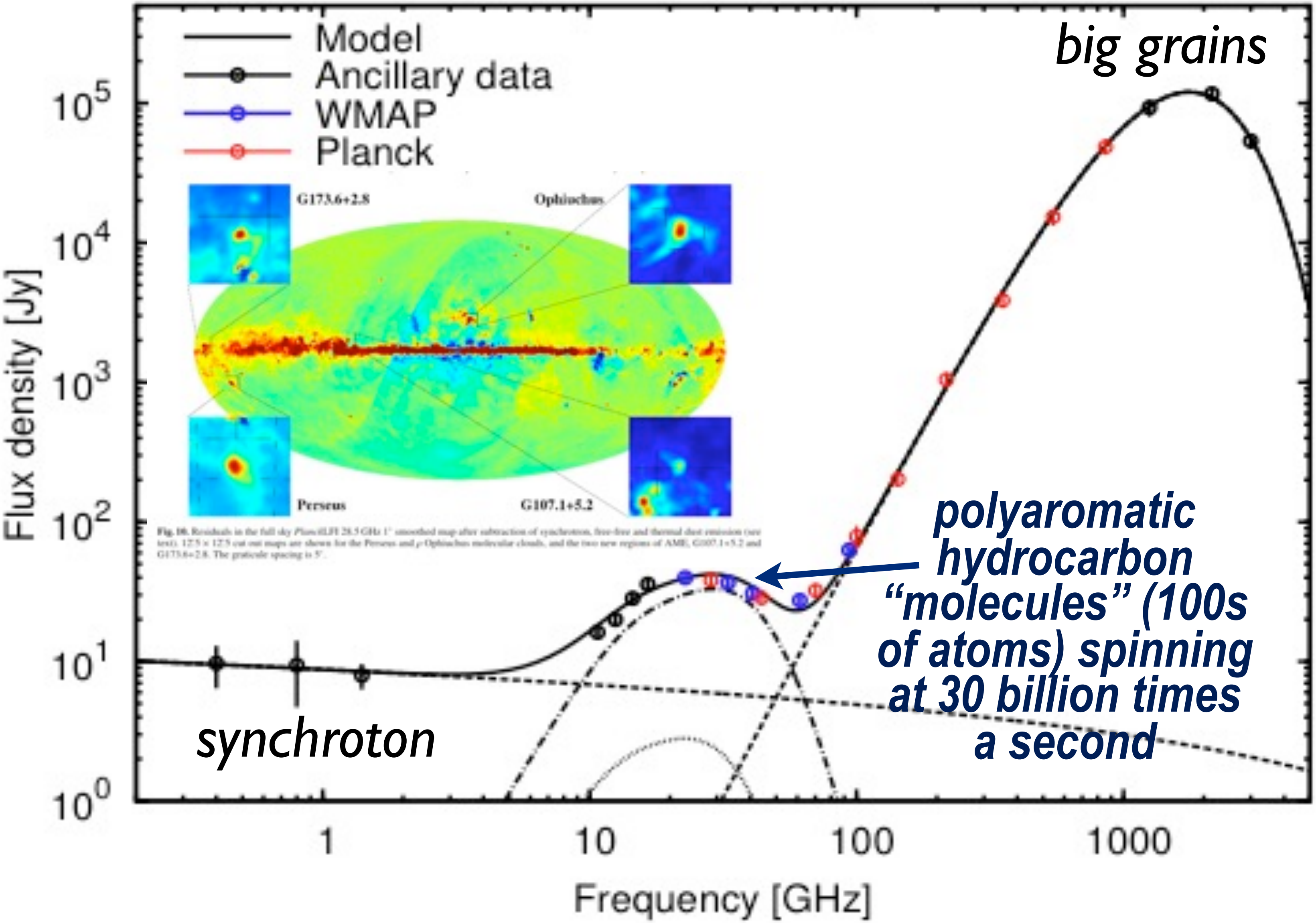


Fig. 4. Spectrum of G160.26-18.62 in the Perseus molecular cloud. The

25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work**

- **Spinning dust - AME clearly seen in Perseus and rho-Ophiuchus regions with a spectrum pulled out in excellent agreement with Draine & Lazarian theory from the 90s, a long journey from the OVRO AME discovery & a leap forward**

Delta T over Tea Toronto May 1987: first dedicated CMB conference, exptalists+theorists, primary+secondary DT/T

an early CITA/CIFAR collaboration, 65 participants

*e.g., **Bond, Carlberg, Couchman, Efstathiou, Kaiser, Page, Silk, Tremaine, Unruh**; Bennett, **Halpern**, Lange, Mather, **Wilkinson**, ...*

A tentative list of topics organized according to angular scale, with theory and observation intertwined, is:

• very small angle anisotropies - VLA results, secondary fluctuations via the Sunyaev-Zeldovich effect, primeval dust emission, and radio sources

• small angle anisotropies - current results, optimal measuring strategies, statistical methods for small signals in larger noise, which universes can we rule out, the reheating issue, future detectors and techniques, CMB map statistics, polarization

• intermediate and large angle anisotropies - $5^o - 10^o$ results, future experiments at $\sim 1^o$, COBE and other large angle analyses, theoretical $C(\theta)'s$ and their angular power spectra, Sachs-Wolfe effect in open Universes, the isocurvature CDM and baryon stories, $\Delta T/T$ from gravitational waves, the cosmic string story.

25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work**

radio source counts **Planck, ACT, SPT, WMAP**

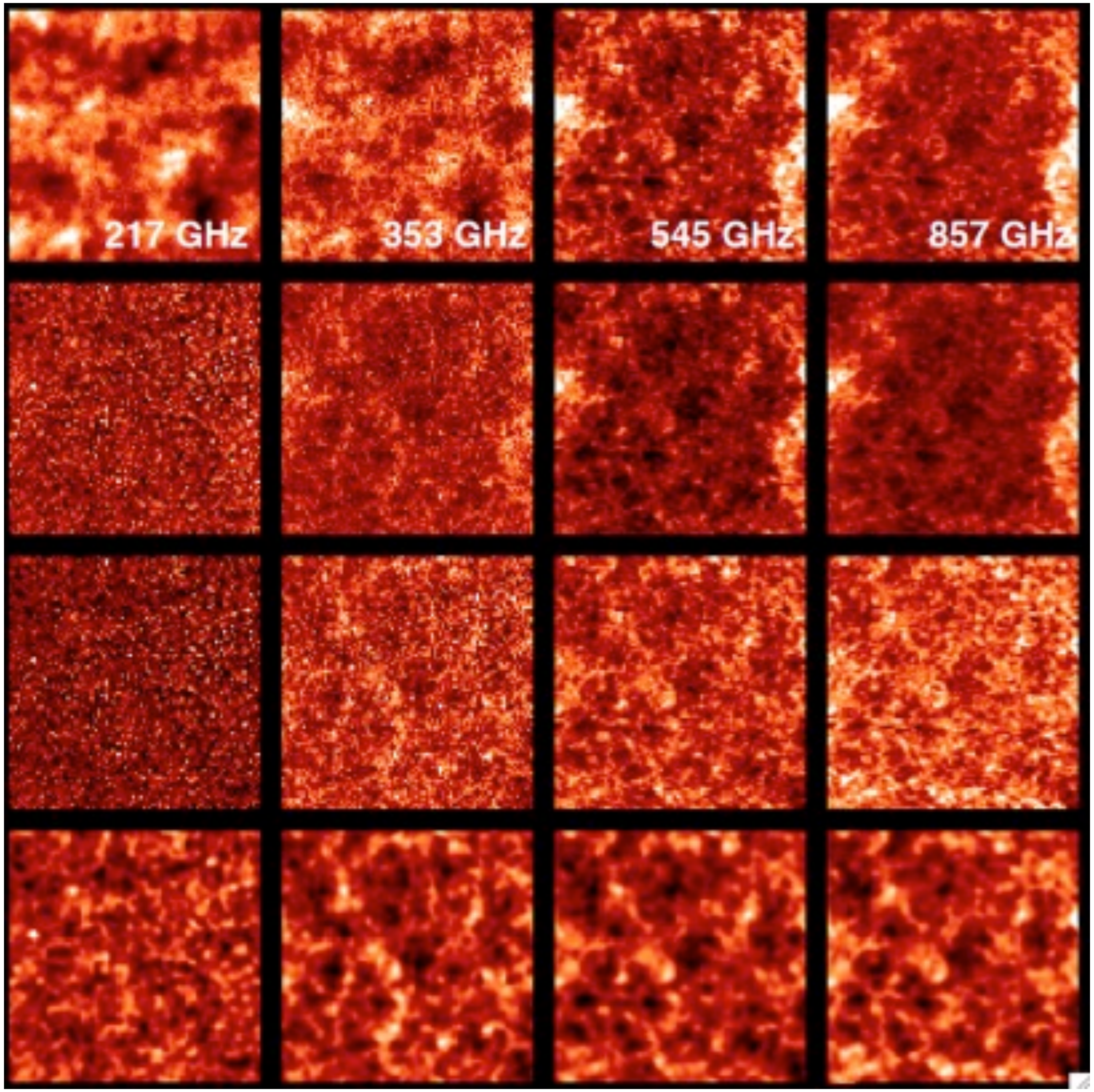
- **Radio src - counts consistent with ACT/SPT (at higher flux range), & WMAP, lower than prior model. there is spectral steepening above 70 GHz.**
- **IR src – possible evidence for cold dust component in local IR galaxies (T<20K).**

dusty gals **Planck, ACT, SPT, ACTxBLAST, Herschel**

gg-clustering term is much more important than for clusters, resolution needed to see both,

Planck Early Results: The Power Spectrum Of Cosmic Infrared Background Anisotropies

exquisite information on Galactic foregrounds from the Green Bank telescope (H from 21 cm) & other data, and the Planck point sources +CMB, allows one to dig out an underlying CIB



Planck-HFI Raw maps
26.4 sq. deg.

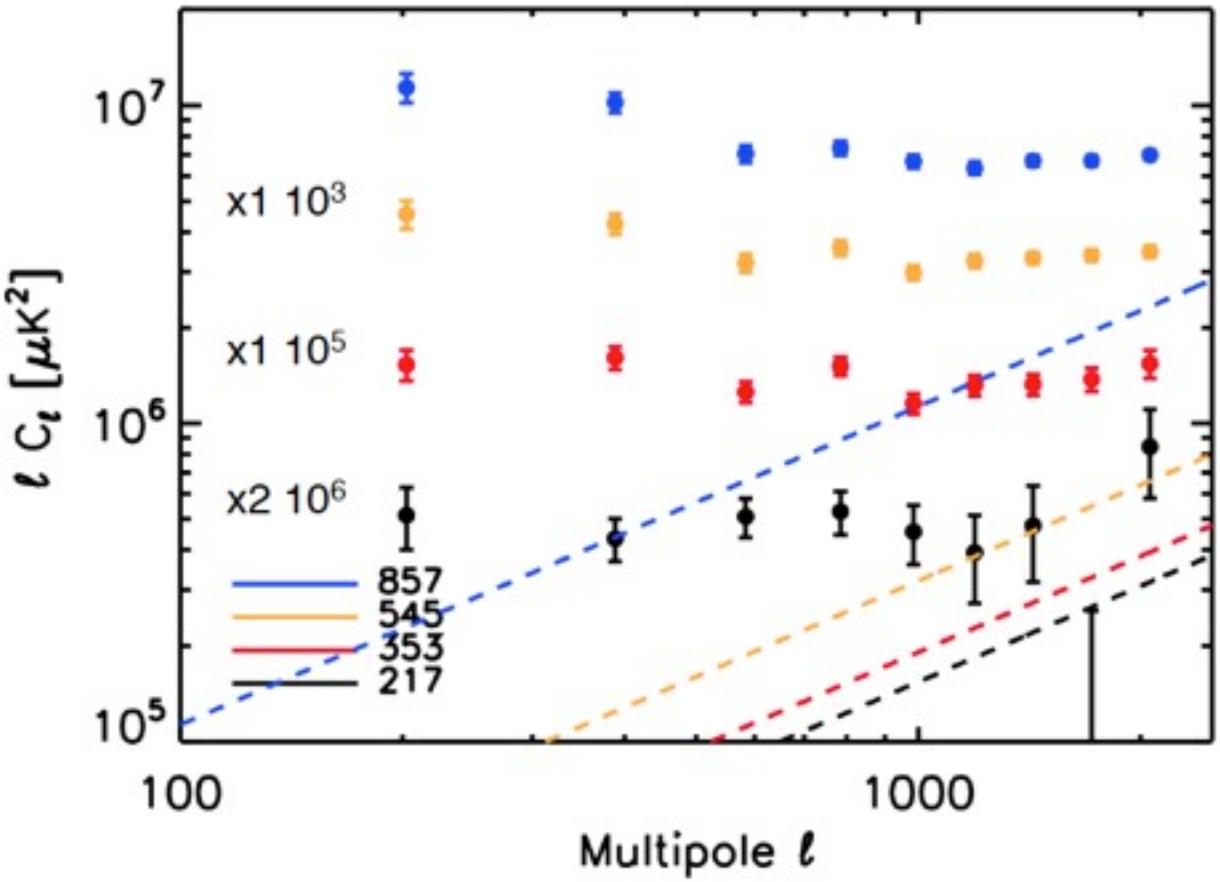
Raw maps
- CMB
- ERCSC point sources

Raw maps
- CMB
- ERCSC point sources
- Galactic dust

CIB maps @ 10 arcmin

Planck Early Results: The Power Spectrum Of Cosmic Infrared Background Anisotropies

clustering of luminous infrared galaxies at high redshift: starbursts, dust-shrouded AGNs, etc



- Planck measures the CIB anisotropies from 10 arcmin to 2 degrees at 217, 353, 545 and 857 GHz
- *Half of power comes from z<0.8 at 857 GHz and z<0.9 at 545 GHz. 1/5 and 2/3 come from z >3.5 at 353 GHz and 217 GHz*
- *Results depends strongly on the HI data & Toronto GBT results*

consistent with $\xi gg \sim r^{-1.8}$ (or even r^{-2}) & linear bias, but halo model with 2-halo dominant, ***sources are exactly what?*** shot noise not (really) measurable with Planck, need higher res expts cf. ***ACTxBLAST, BLASTxBLAST, SPT/ACT CL separation, Herschel*** ***(higher)***

25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work**

- **CIB - clustering term clearly detected at 217-857 GHz, with diminishing correlation as band separation increases. imaged (BLAST, ACTxBLAST, Planck agree, Herschel a little higher). Source halo model fits the spectra, so does usual galaxy clustering with <bias>. source population is exactly what? => uncertain interpretation**

25 papers & a large fraction of the papers at Planck2011 were unveiled for 10 months & 9-freq T data, + a press conference, highlighting: **HFI & LFI work**

ambient/blank-field tSZ effect from **clusters & gps**

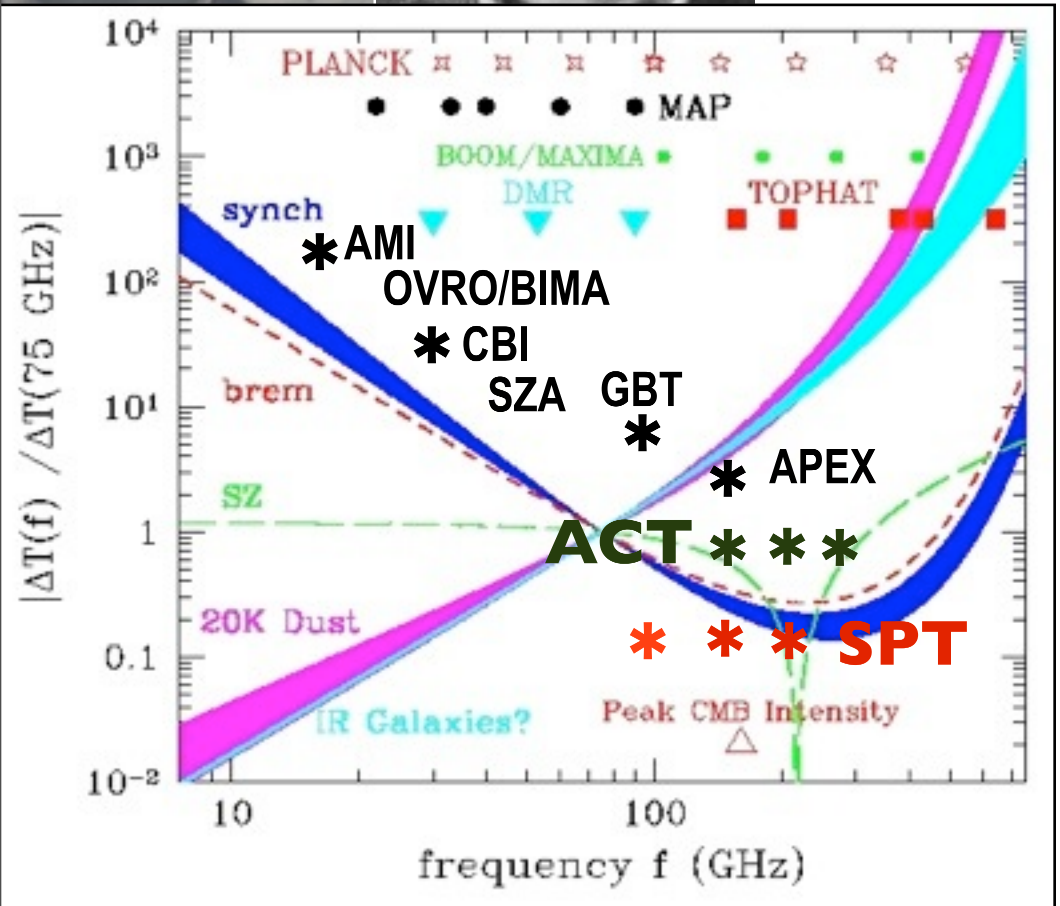
- **SZ - 189 SZ clusters. SZ scaling relations appear as expected for X-ray clusters (no deficit, assuming universal profile), apparent SZ deficit for optical clusters (jury out on cause, but seen in ACTxSDSS-LRGs as well)**

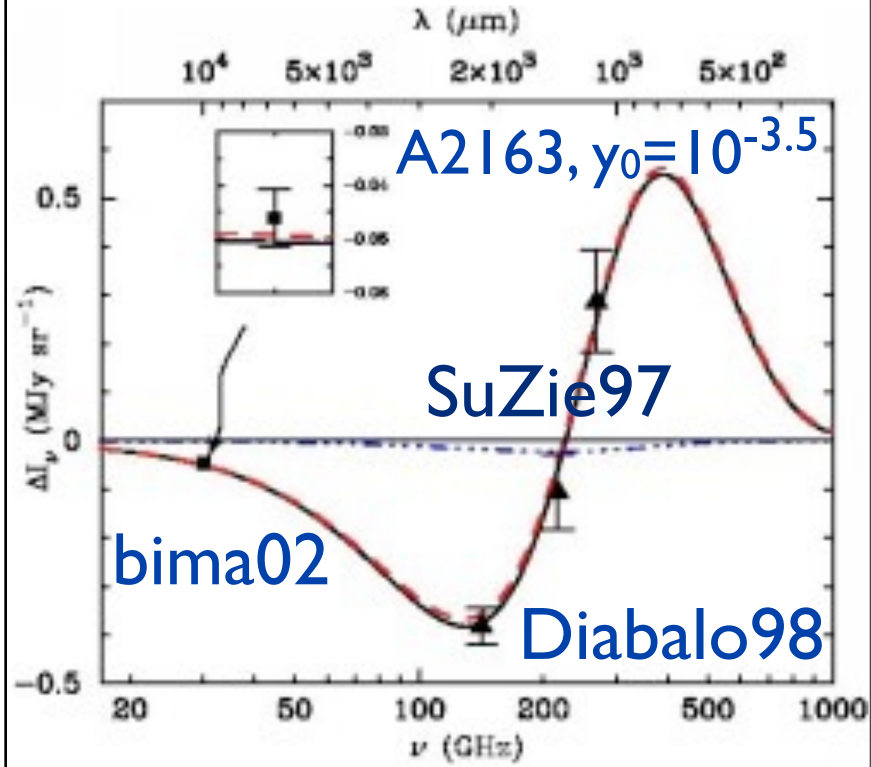
Planck & the thermal Sunyaev-Zeldovich Probe of Gas in the Cosmic Web: $y \sim \int p_e \, d\text{line-of-sight}$

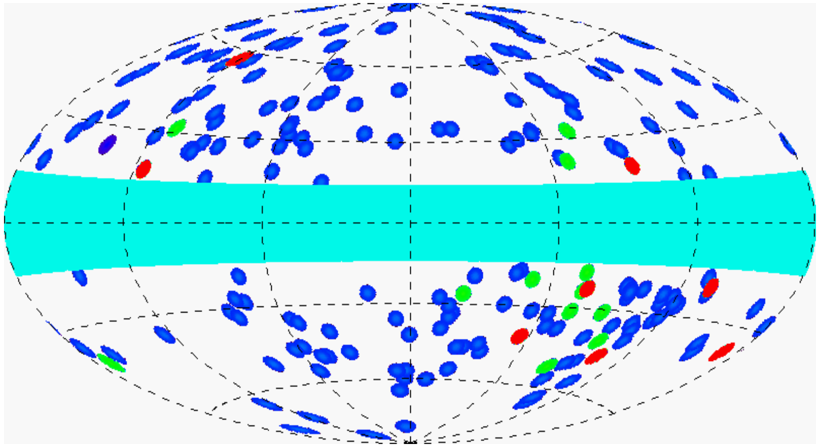
$\Delta T/T = y * (x(e^x+1)/(e^x-1)-4)$, $x = h\nu/T_\gamma$

$= -2y$ to xy, 0 @ $\nu = 217$ GHz

$\Delta I_\nu = \Delta T/T * x^4 e^x/(e^x-1)^2$







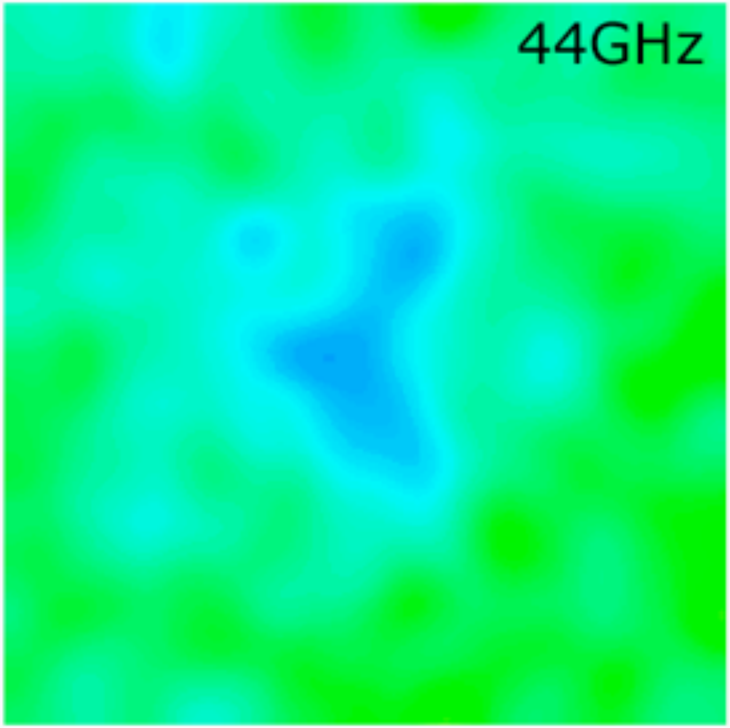
ESZ 20 new + 169 in X/Opt cats

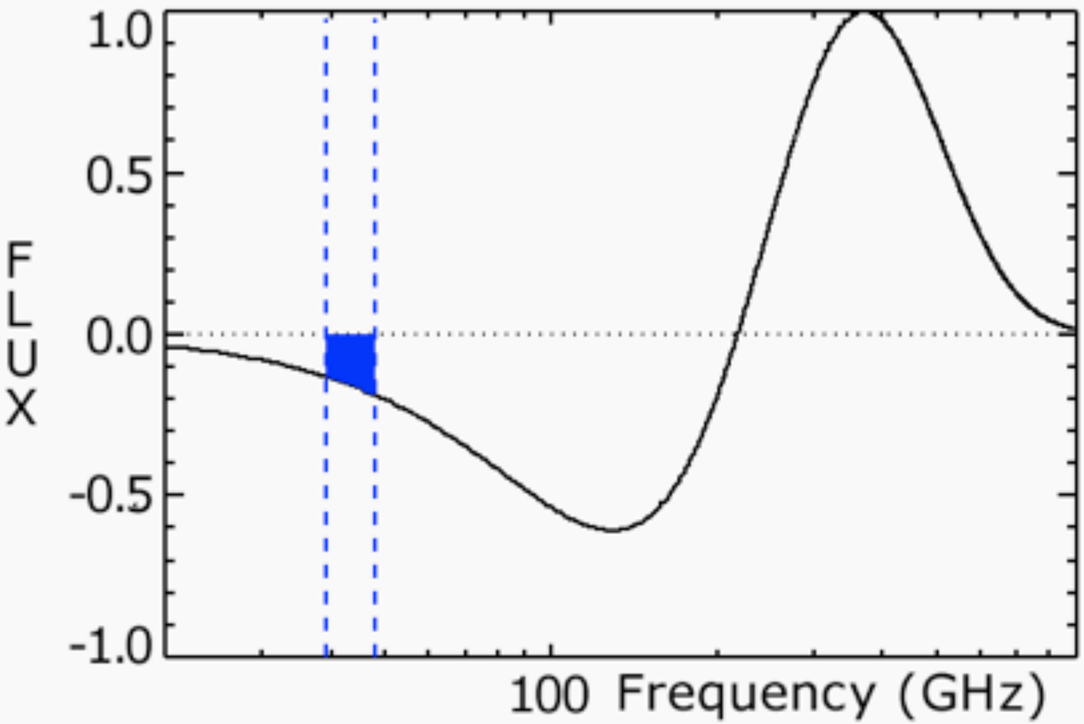
(& ~80% new in SZ, $E_{thermal}$ view)

Planck**XMM** dedicated time on newbies
~95% reliable, validation, S/N ~ 6 cut
+ cross-correlate with X/SDSS cats, Y-"M" scaling OK in shape, puzzle in amp for optical maxBCG/LRG

new SZ cluster detections reported by ACT (~50), SPT (~50), AMI, .. more coming

A2319

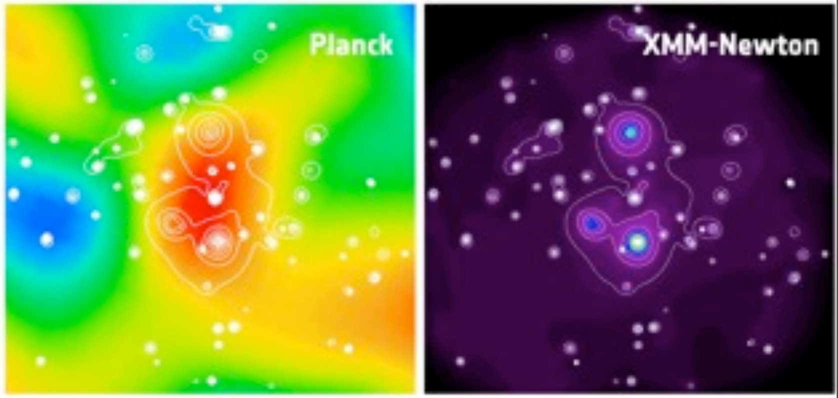


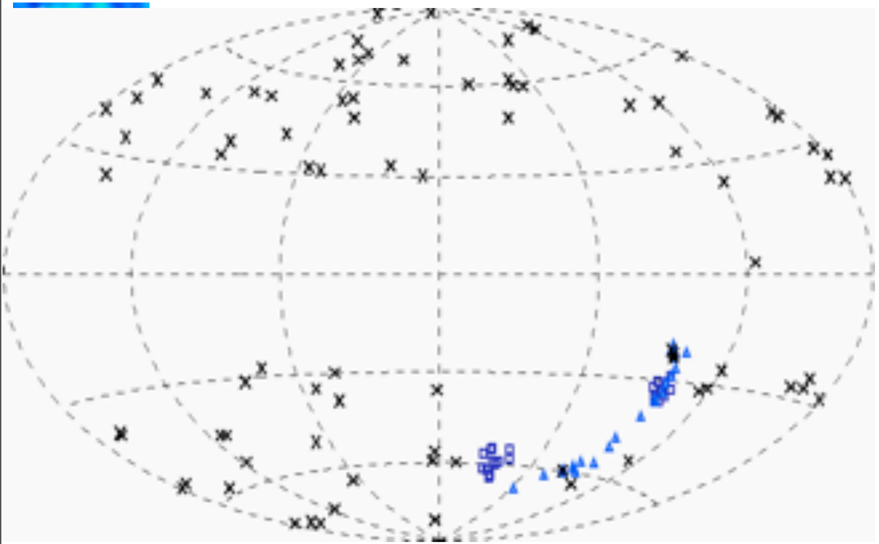


Planck sees the rarest & most massive clusters over the whole sky:

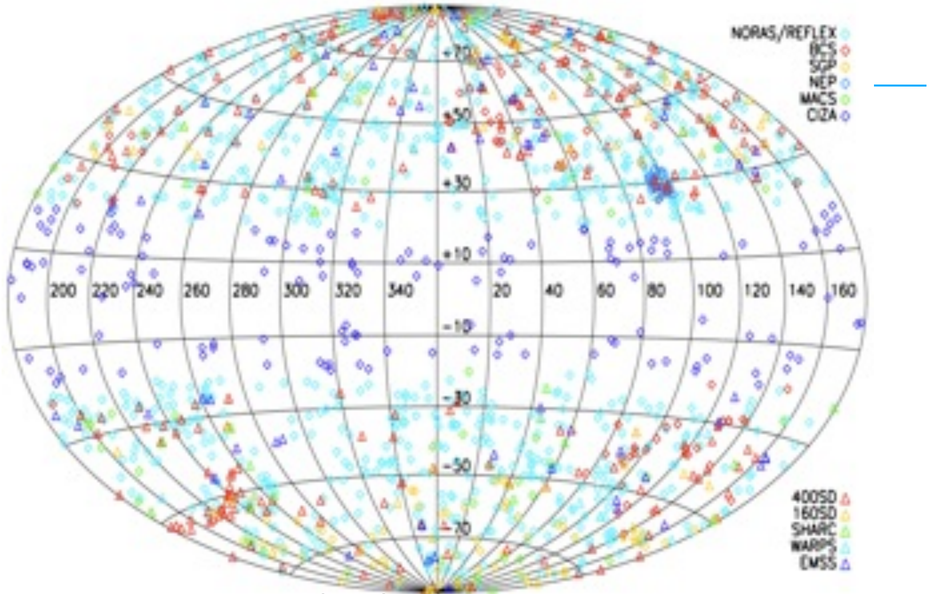
small/moderate redshifts (86% with z<0.3); masses to 1.5 × 10^{15} M_{sol}. 90% of the RASS above M > 9 × 10^{14} M_{sol} detected by blind ESZ, 5/21 of new Planck clusters have M > 9 × 10^{14} M_{sol}.

Feb10 targets for XMM-*Newton* - **25 candidates observed:** DDT time, eg, pilot 10 targets from 62% of sky coverage, in 4 < S/N < 6 range (EZ > 6); high S/N (>5) programme 15 targets. **21 confirmed** → ***~85% success rate; 17 single clusters, most disturbed; 2 double systems; 2 triple (super-cluster) systems; 0.09 < z < 0.54***

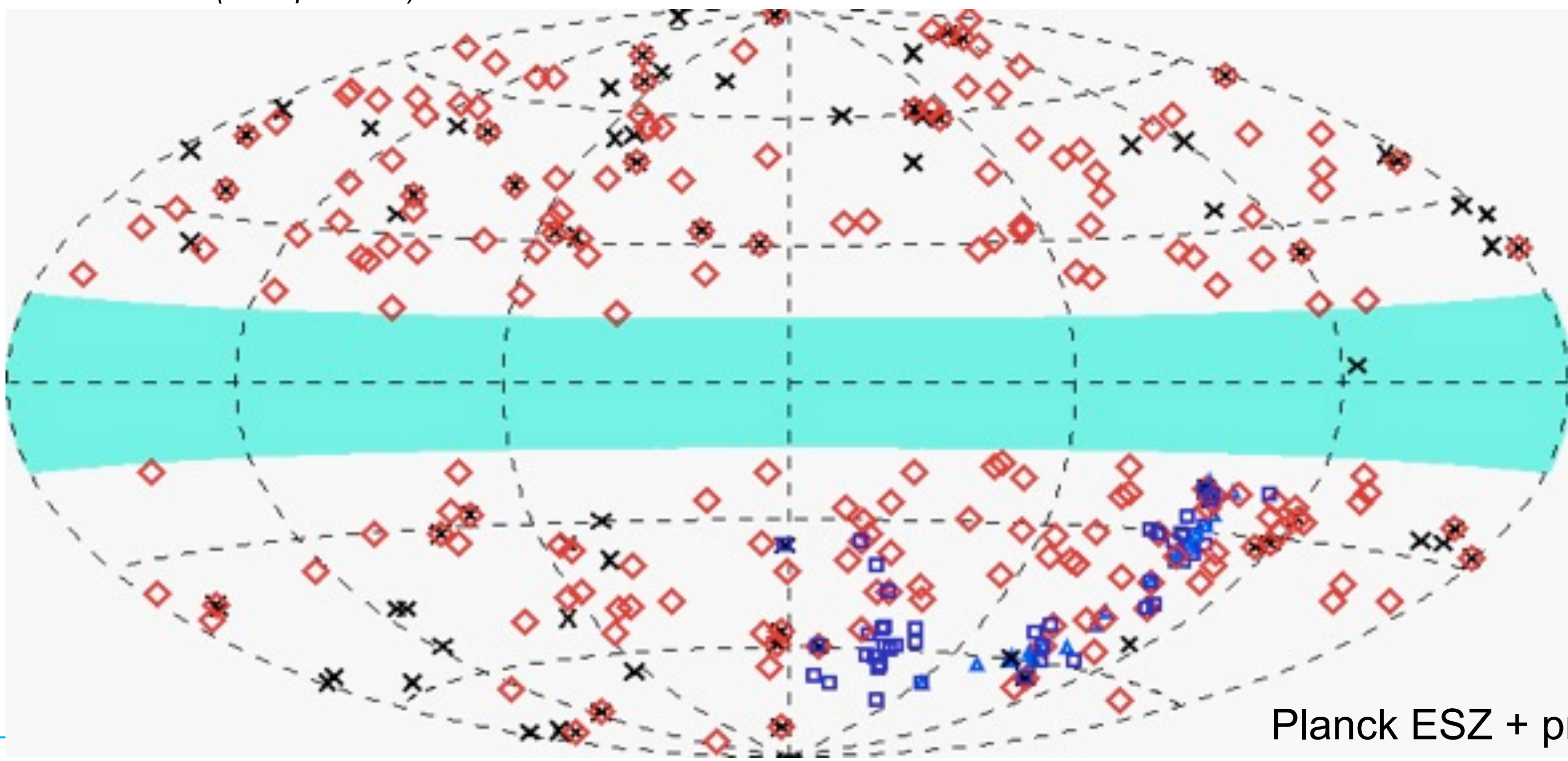




All-sky compilation of first generation SZ clusters
(Douspis et 11)



All-sky distribution of MCXC clusters ~1600 *(Piffaretti et 10)*



$n_{cluster}$

$(Y_{SZ}, M_{lens}, Y_X, L_X, T_X, L_{cl,opt}, R_{ich}, \ldots$ | z, gold-sample, thresholds)

+ C_L^{SZ}(cuts) + $\xi_{cc}(r|n_{cl})$ will deliver

valuable cosmic gastrophysics for sure.

Will it deliver fundamental physics

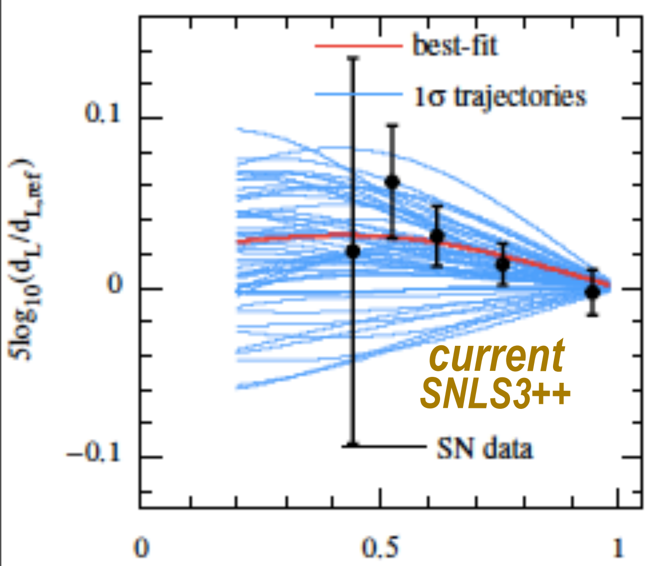
e.g., the dark energy EOS, primordial non-Gaussianity??? σ_8 even?

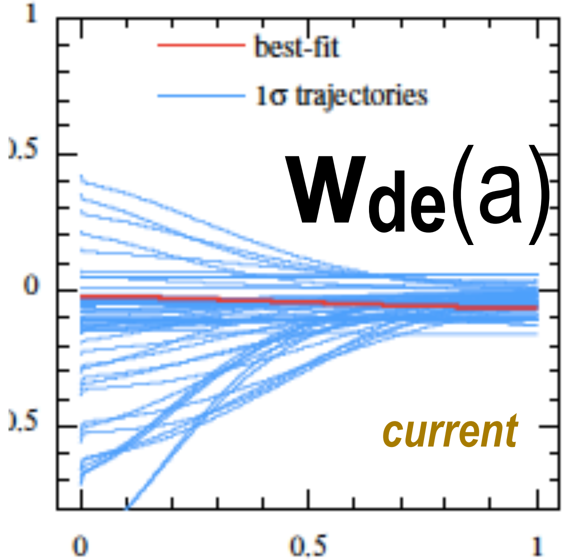
cluster/gp system used since 80s: Xtra power ξ_{cc} ξ_{cg} => xCDM

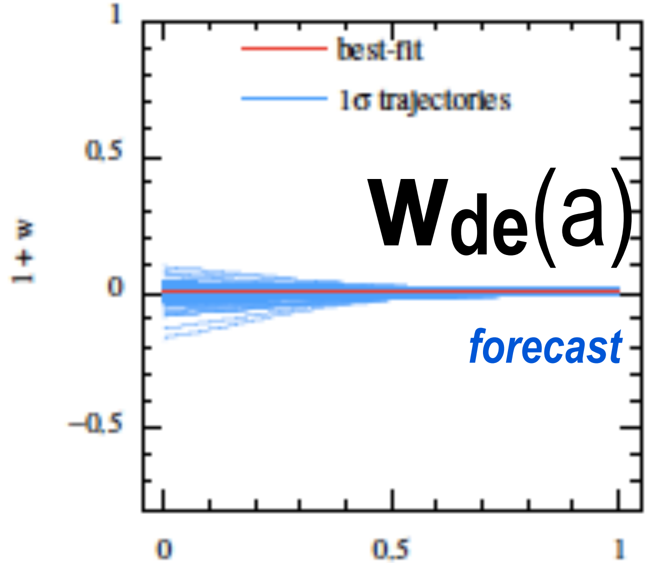
$P_{\rho\rho}$(.25h/Mpc) aka σ_8 via n_{cl} *are we really ready for prime time? mock-ing!!*

NOW & future DE equation of state trajectories

$(1+w_{de}) = -\, d\ln\rho_{de} / d\ln a^3 = 2/3\, \varepsilon_\psi$ & $\varepsilon = \Omega_\psi \varepsilon_\psi + \Omega_m \varepsilon_m$ & $\varepsilon_m = 3/2$







3-parameter w_{de} (z|V(ψ),IC) paves well late-inflaton trajectories

Huang, Bond, Kofman 2010; Bond, Huang 2011

Current Data

CMB: **ACT+WMAP7**, **Acbar** (2009), QUAD (2009), BICEP (2009), **CBI** (2008), **Boomerang**-pol, VSA, MAXIMA

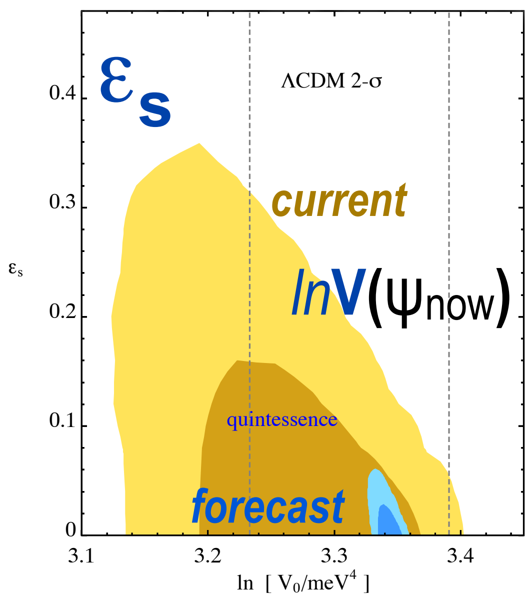
Type Ia Supernova 472: 123 low-z+ 242 SNLS3yr +93 SDSS1yr + 14 HST

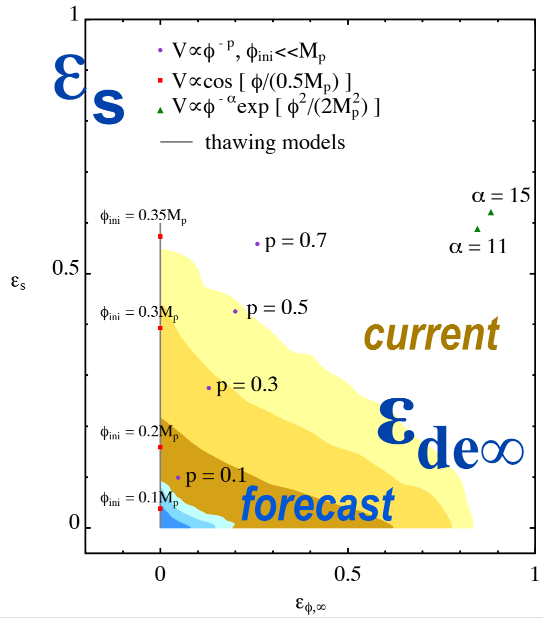
HST constraint H0 = 73.8 +-2.4 km/s/Mpc

Weak Lensing: COSMOS + CFHTLS-wide + RCS +VIRMOS +GaBoDS

LSS: SDSS-DR7 LRG (2009)

Lya Forest: SDSS





Forecast Data

CMB: Planck2.5yr, LSS: EUCLID spectroscopic redshift survey; **21-cm CHIME BAO survey: EUCLID** weak lensing survey

Studying the Cosmic Tango

the **Cosmotician**'s *agenda*

the ***Bayesian chain***

posterior P(cosmic parameters|D,T)
Likelihood P(D | cosmic params,T)
prior P(cosmic params|T)
evidence P(D|T) = *partition function*
P(q|D,T) =P(D|q,T)P(q|T)P(T)/P(D|T)
posterior Shannon entropy
$S_f(D,T) = - \int dq\, P(q|D,T) \ln P(q|D,T)$

D=CMB,LSS,SN,...,complexity, life
T=baryon, dark matter, vacuum mass-energy densities,...,
early & late inflation as low energy flows on a (string) landscape *(point process of vacuua, river-flow trajectories),* $L(g_{\mu\nu},\phi,\chi_i,\psi,A_\mu,\rho_m,p_m)$*, structure of manifolds (extra dims compactifying 7+3+1, holes, branes, fibres, coupling 'constants')*

Anthrostatician=superHorizon measurer

V. Acquaviva [1,2]
P. Ade [3]
P. Aguirre [4]
M. Amiri [5]
J. Appel [6]
E. Battistelli [7,5]
J. R. Bond [8]
B. Brown [9]
B. Burger [5]
J. Chervenak [10]
S. Das [29,6,1]
M. Devlin [2]
S. Dicker [2]
W. B. Doriese [11]
J. Dunkley [12,6,1]
R. Dunner [4]
T. Essinger-Hileman [6]
R.P. Fisher [6]
J.W. Fowler [6]
A. Hajian [6]
M. Halpern [5]
M. Hasselfield [5]
C. Hernandez-Monteagudo [13,2]
G. Hilton [11]
M. Hilton [14, 15]
A. D. Hincks [6]
R. Hlozek [12]
K. Huffenberger [16,6]
D. Hughes [17]
J. P. Hughes [18]
L. Infante [4]
K.D. Irwin [11]
N. Jarosik [6]
R. Jimenez [19]
J.B. Juin [4]
M. Kaul [2]
J. Klein [2]
A. Kosowsky [9]
J.M. Lau [20,6]
M. Limon [21]
Y.T. Lin [22,1,4]
R. Lupton [1]
T.A. Marriage [1,6]
D. Marsden [2]
K. Martocci [23,6]
P. Mauskopf [3]
F. Menanteau [18]
K. Moodley [14]
H. Moseley [10]
B. Netterfield [24]
M.D. Niemack [11,6]
M.R. Nolta [8]
L.A. Page (PI) [6]
L. Parker [6]
B. Partridge [25]
H. Quintana [4]
B. Reid [19,1]
N. Sehgal [20,18]
J. Sievers [8]
D. Spergel [1]
S.T. Staggs [6]
O. Stryzak [6]
D. Swetz [2]
E. Switzer [23,6]
R. Thornton [26,2]
H. Trac [27,1]
C. Tucker [3]
L. Verde [19]
R. Warne [14]
G. Wilson [28]
E. Wollack [10]
Y. Zhao [6]

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[5] University of British Columbia (Canada)
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[8] CITA, University of Toronto (Canada)
[9] University of Pittsburgh (USA)
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[11] NIST Boulder (USA)
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[14] University of KwaZulu-Natal (South Africa)
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[16] University of Miami (USA)
[17] INAOE (Mexico)
[18] Rutgers (USA)
[19] Institute de Ciencies de L'Espai (Spain)
[20] KIPAC, Stanford (USA)
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[22] IPMU (Japan)
[23] KICP, Chicago (USA)
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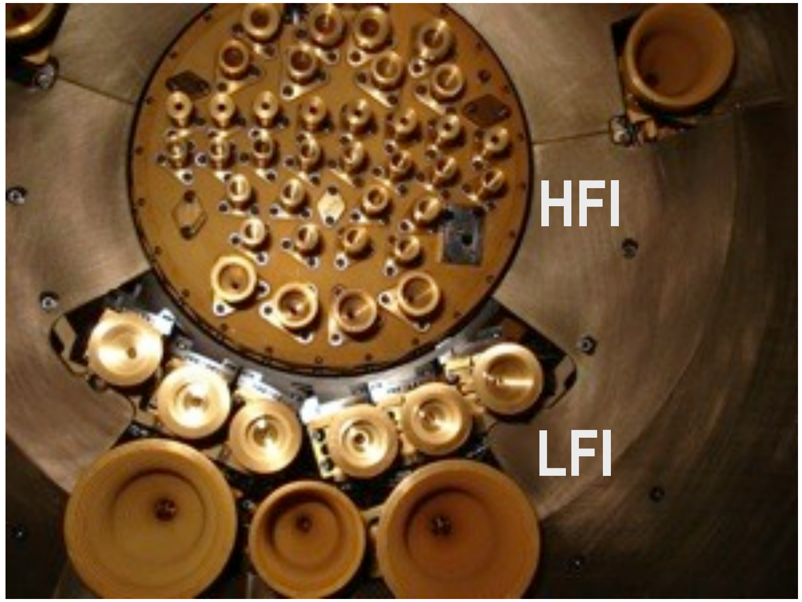
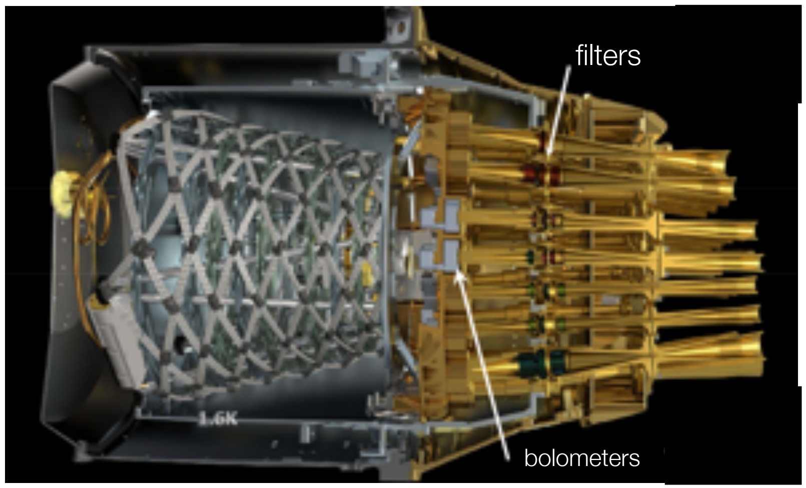
[25] Haverford College (USA)
[26] West Chester University of Pennsylvania (USA)
[27] Harvard-Smithsonian CfA (USA)
[28] University of Massachusetts, Amherst (USA)
[29] BCCP UC Berkeley and LBL (USA)

Planck

Focal plane

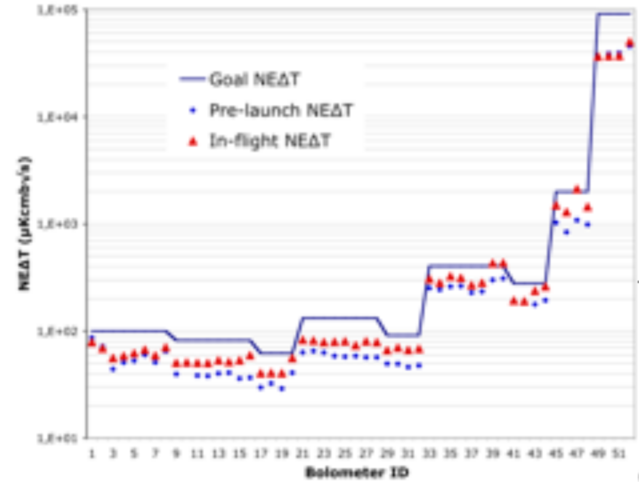


HFI cut view

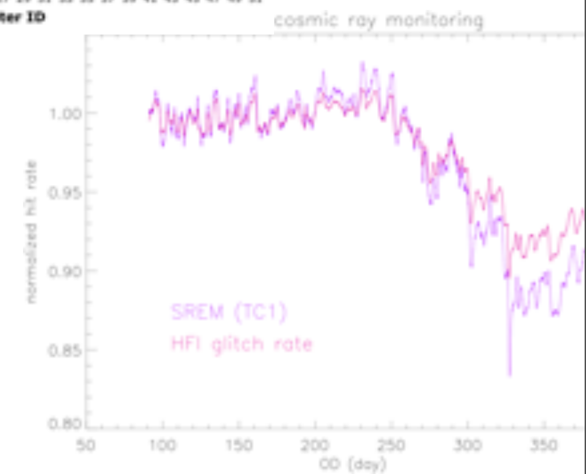


HFI performance

- **Thermal performance**
  - 100 mK HFI detectors behave exactly as during ground tests. Set for minimum Helium flow, enough for 5 sky coverages (until ~Jan 2012 +-x)

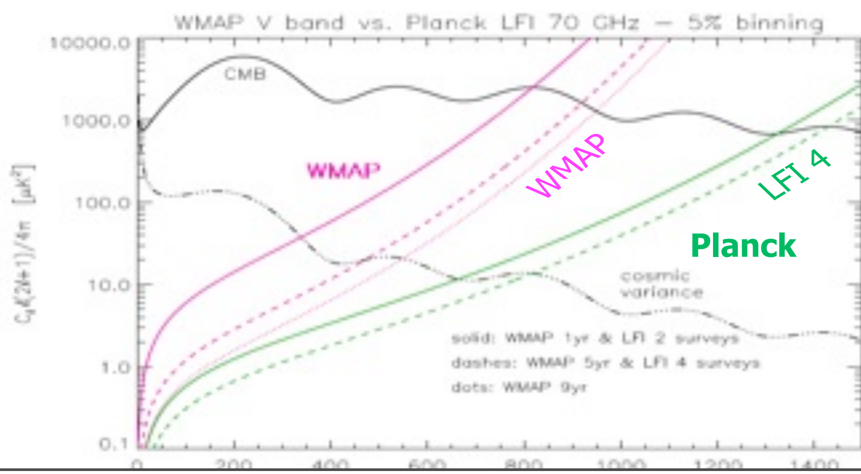


- **CosmicRays: Glitch** rate at ~80/min on each bolometer=>thermal fluctuations
  - contribute to 1/f noise (significant CSA-HFI role in discovering and characterizing the effect)



- **Sensitivity and Beams:** a little better than Blue Book widely used for forecasts. (CR thermal fluctuations make it a little higher than ground measurements). Anticipated “aggregated” sensitivity (100-217 GHz) for 30 months is 0.33 microK-deg ie, **~1000 years of WMAP** *(60-94 GHz = 10.8 microK-deg in 1 yr)* + >2 smaller beam

- **CarbonMonoxide lines** in 100 and 220 GHz complicates modelling, a problem becomes a strength? with separation of components, could get an all-sky CO map



LFI performance

- **Sensitivity and Beams:** ~ Blue Book widely used for forecasts. Beams to - 20 db understood.

cluster ENTROPIES with INTERNAL BULK KINETIC ENERGY

s per particle = $\int$[-f ln f +f] dVdV_p / $\int$f dVdV_p *(MB corrected for BE/FD)*

$\Delta s_{th} = Y_T\,(3/2\, ln <p_{th}/\rho_g> - ln\, \rho_g)$, particles per baryon $Y_T = \sum Y_A$

Sackur Tetrode formula $117 + Y_T(3/2\, ln T/\mathrm{kev} - ln\, n_b/\mathrm{cc})$, $Y_T \sim 1.7$

*constant involves abundances,.. gps-**cls** ~150-**190 bits/baryon,** Δs_{th}~12 bits/b*

a coarse-grained entropy, turbulence + bulk interior flows

$\Delta s_{k+th} - \Delta s_{th} = \sum Y_A\, 1/2\, \mathrm{Trace}\, ln(\, I + m_A/m_p\,(p_{kin}\, I + \Pi_{kin})/p_{th}\,)$

kinetic pressure p_{kin} anisotropic pressure tensor Π_{kin}

how coarse? our decision. e.g., cluster interior R_{500}, R_{200} R_{vir} $s_{k+th} - s_{th} \sim 1 \mathrm{bit/b}$

(generalized) way of looking at **phase-space density $<f>_p \sim n/\sigma_v^3$**

entropy-per-DM-particle cf. entropy-per gas-baryon

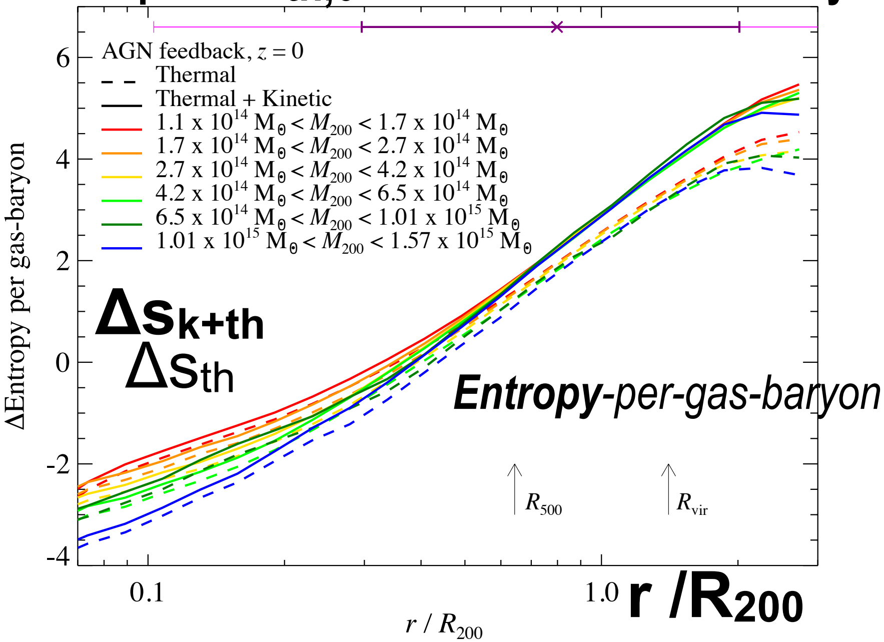
$\Delta s_{dm} = 1/2\, \mathrm{Tr}\, ln<(p_{kin}\, I + \Pi_{kin})/\rho_{dm}> - ln\, \rho_{dm}$ *~7 bits/DM*

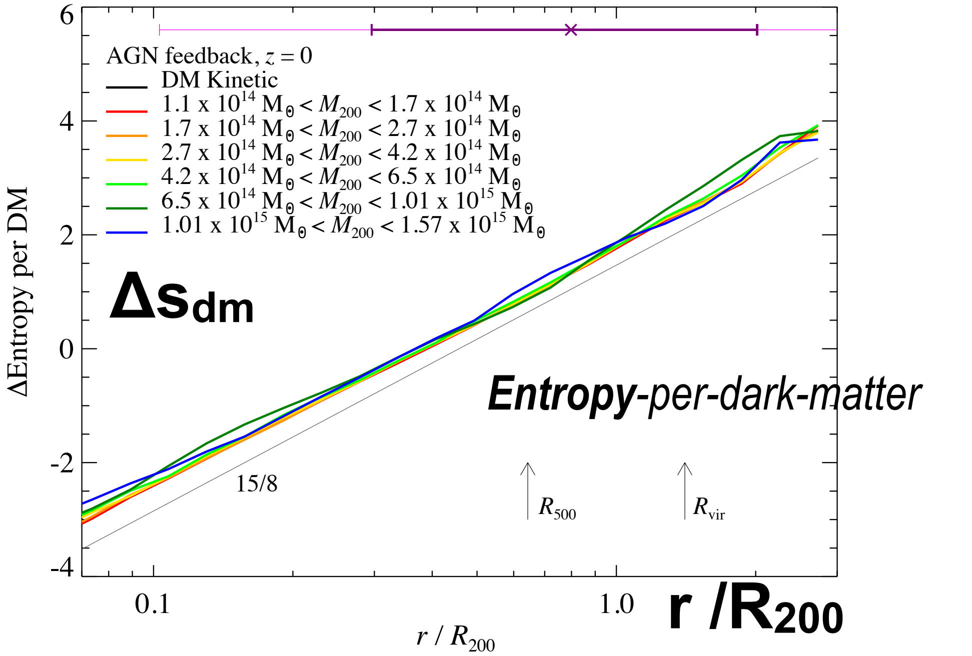
zero point depends on type of DM, WIMP or axion or ...

$s_t / n_b \sim 1.66\times10^{10}/(1+\delta_b)$ bits/b; s_γ / n_γ = ***5.2 bits/Y*** = *2130/411*; $s_\nu = 21/22\, s_\gamma$

AGN's black hole entropy $S_{bh} = M_{bh}^2/2M_P^2 \sim 10^{22}\, S_b$; but $\tau_{bh} \sim 10^{120}$yrs non-equilibrium and non-thermal ***Entropy Profiles (M | z=0) for Mass-binned Scaled Stacked Clusters***

zero point $S_{th,0}$ ~ 130 nats ~ 190 bits/baryon





slope~3.04 =X-ray Voit

slope~15/8 =self-similar radial infall Navarro

better-than-NFW fit to DM-only simulation density profiles.

gas/star effect affect NFW-ism.

ongoing mystery - why halos have this entropy growth law

P_{kin} / P_{th}~0.1-0.6!

$<(\Delta v)^2>/c_s^2$ affects hydrostatic equilibrium

S(resolution λ=-*ln* r/R200 |coarse-grained-measures) $P_{tot,ij}$ ~ $<\delta V_i\, \delta V_j \mid \lambda>$, $I_{,ij}$ ~$<\delta X_i\, \delta X_j \mid \lambda>$ $<\delta ln\rho\, \delta ln\rho \mid \lambda>$

kinetic pressure tensor & turbulent cascade; space-space fluctuations & ... pressure & density clumping

fine-*macro-small*-grain 10^6 baryons in cubic metres sph--*macro-large*- grain 10^{65} baryons. ~26 dims per sph-grain, huge dimensional reduction, scaled-radial-*resolution*-grain further dim reduction. entanglement of fine & coarse & EFT. feedback.

gravitational entropy, a **mystery**: the **gravo-thermal catastrophe** = negative specific heat, what gravity wants is to localize concentrating mass into black holes and make accelerating voids to straighten out U.

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

25 years cifar

CITA = Cosmic Information Theory & Analysis:

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

Dick Bond CIAR

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

the ***Cosmotician's*** *Agenda: Statistical Paths in Cosmic Theory & Data*

we compress the Petabit++ observed cosmic info into a precious few bits encoding 6+ parameters of the Minimal Cosmic Standard model (LCDM)

ρ_{dm}/ρ_b=5.1 ρ_m/ρ_{de} =.30 Ω_m=0.268 ±.012 Ω_Λ=0.736 ±.012

Power$_s$=25x10^{-10} *Tilt*$_s$ =0.963±0.013 **running=-0.024 ± 0.015 r=T/S<0.19**

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

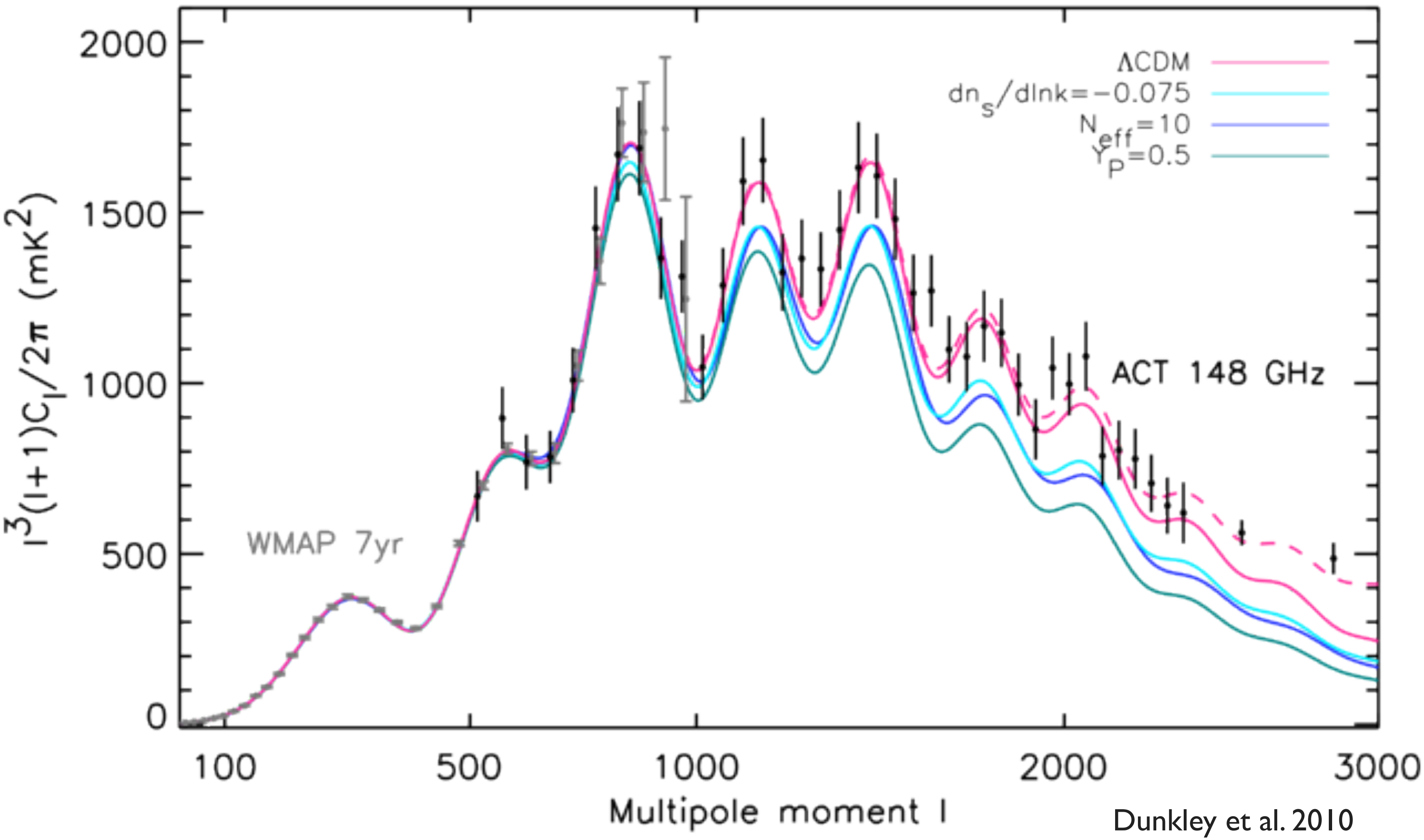
(coherence + quantum noise => incoherence via entropy/information generation)

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

Entropy/Information Generation in Post-inflation Preheating: A Shock-in-Time

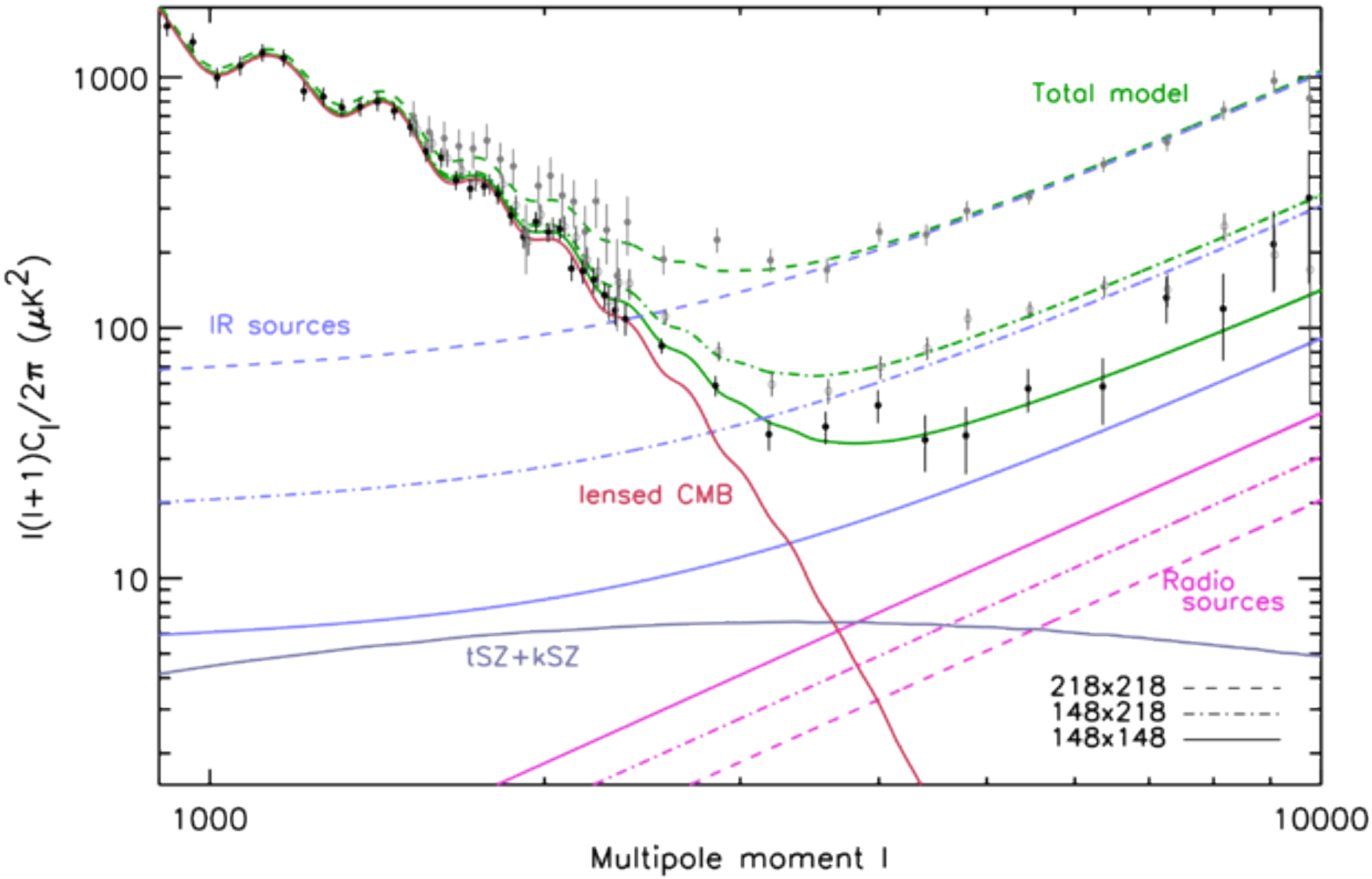
the **fate** of the **U?**: **dark energy** properties driving late inflation, ***S in asymptotic dS?***

'low-L' part of ACT's power spectrum



Dunkley et al. 2010

primordial (lensed) CMB + veils, ***the veils = radio sources, the CIB, tSZ and kSZ (& Milky Way dust and synchrotron at lower multipoles)***



Dunkley+. 2010