Entropy growth in the early universe and confirmation of initial big bang conditions

(Why the quark-gluon model is not the best analogy)

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Presented at Chongqing University
April 2009
(a few slides removed)

Part 1

Limitations of the Quark-Gluon analogy and how such limitations impact AdS/CFT correspondence applications

Speculation on early universe entropy frequently makes analogies to the quark-gluon plasma to link viscosity to entropy

1. Is QGP strongly coupled or not? Note : Strong coupling is a natural explanation for the small (viscosity)

   Analogy to the RHIC: J/y survives deconfinement phase transition

2. What is the nature of viscosity in the early universe ? What is the standard story?

   (Hint: AdS-CFT correspondence models)

What happens to the viscosity-entropy ratio values of cosmology if AdS/CFT correspondence breaks down due to quark - gluon plasma physics no longer holding at the onset (beginning) of inflation ?

Viscosity/ entropy is < 1/(4pi)

How realistic is this assumption?

Mauro Brigante et al. in “The Viscosity bound and Causality Violation” write:

Something very different from the AdS/CFT correspondence value:
Guass Bonnet gravity has to preserve casuality $\lambda_{BG} \leq \frac{9}{100}$

If $\lambda_{BG} \neq 0$

$$\frac{\eta}{s} \equiv \frac{1}{4\pi} \cdot \left[1 - 4\lambda_{GB}\right] \leq \frac{1}{4\pi}$$

Very different from AdS/CFT values involving an alleged lower bound for all materials

True even for liquid helium. The use of a non-zero Gauss Bonnet gravity term gives change from

$$\frac{\eta}{s} = \frac{1}{4\pi}$$

Typical RHIC viscosity model

The standard story:

$$T_{\mu\nu} = pg_{\mu\nu} + (e+p)u_\mu u_\nu + \tau_{\mu\nu}$$

$$\tau_{\mu\nu} = -\eta\left(\frac{\partial u_\mu}{\partial x^\nu} + \frac{\partial u_\nu}{\partial x^\mu} + u_\mu u^\sigma \frac{\partial u_\nu}{\partial x^\sigma} + u_\nu u^\sigma \frac{\partial u_\mu}{\partial x^\sigma}\right)$$

$$-\left(\zeta - \frac{2}{3}\eta\right)\frac{\partial u_\sigma}{\partial x_\sigma}\left(g_{\mu\nu} + u_\mu u_\nu\right)$$

η : shear viscosity

ζ : bulk viscosity

More Collisions implies less viscosity

More Deflections ALSO implies less viscosity

The more Momentum Transport is prevented, the less viscosity value becomes

Viscosity due to Turbulent Fields

Perturbatively calculated viscosities:
due to Collisions

Has been known as *Anomalous Viscosity* in plasma physics

(this is going nowhere, from pre-big bang to big bang cosmology)

RHIC models for viscosity assume:

$$\frac{1}{\eta} \approx \frac{1}{\eta_A} + \frac{1}{\eta_C}$$

Our problem with the AdS-CFT picture

- The inverse of [anomalous viscosity] plus the inverse of [collision viscosity] gets smaller

- But we really do not know how to model [anomalous viscosity] in early-universe cosmologies

- No equality or real stated bound exists in early universe cosmology for improving upon:

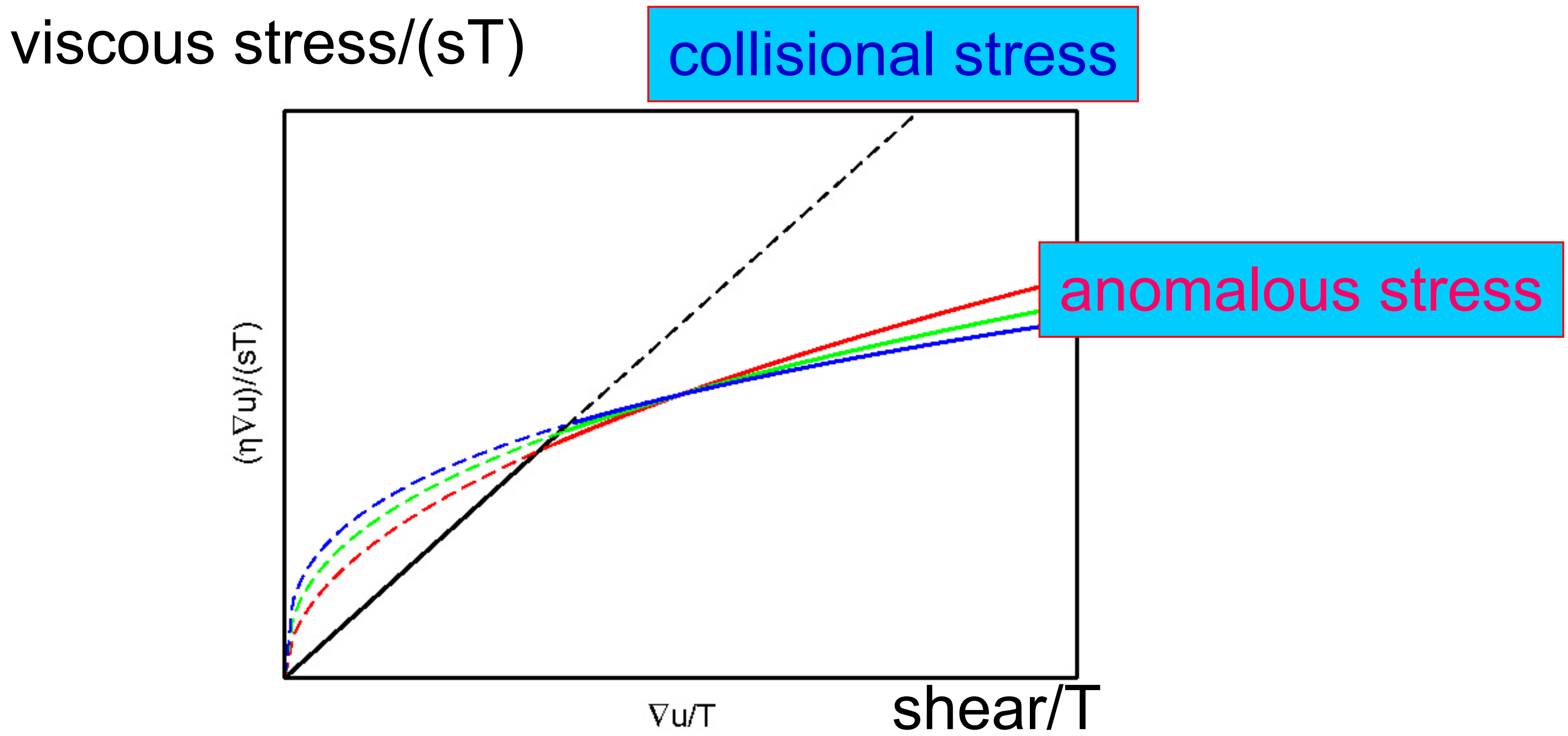
Entropy / viscosity is < 1/(4pi)

Mission impossible: why we need a different argument

- Even for the RHIC, and in computational models of the viscosity for closed geometries—what goes wrong in computational models
- Viscous Stress is *NOT* $\propto$ *shear*
- Nonlinear response: impossible to obtain on lattice (computationally speaking)
- Bottom line: we DO NOT have a way to even define SHEAR in the vicinity of big bang!!!!

Even for closed geometries (devices)

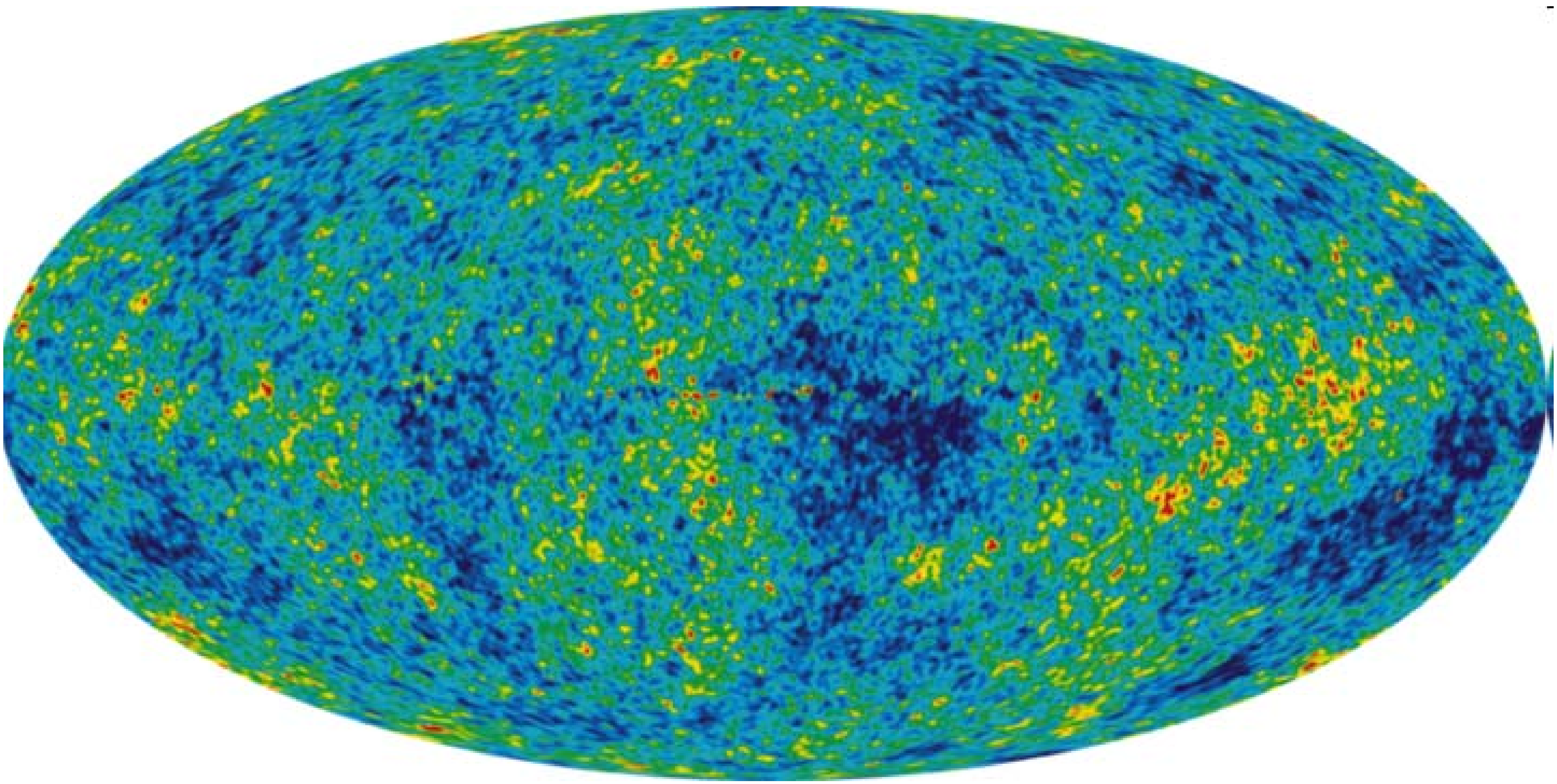
Mission impossible for (typical computational messes)



For RHIC , in CLOSED geometries

$$\frac{\eta_A}{s} = \bar{c}_0 \left(\frac{T}{g^2 \left| \nabla u \right|} \right)^{\frac{2n-1}{2n+1}} \quad \Longleftrightarrow \quad \frac{\eta_C}{s} = \text{const.}$$

Question: Did "God" put a RHIC reactor in the heart of the CMBR at the onset of inflation? NO

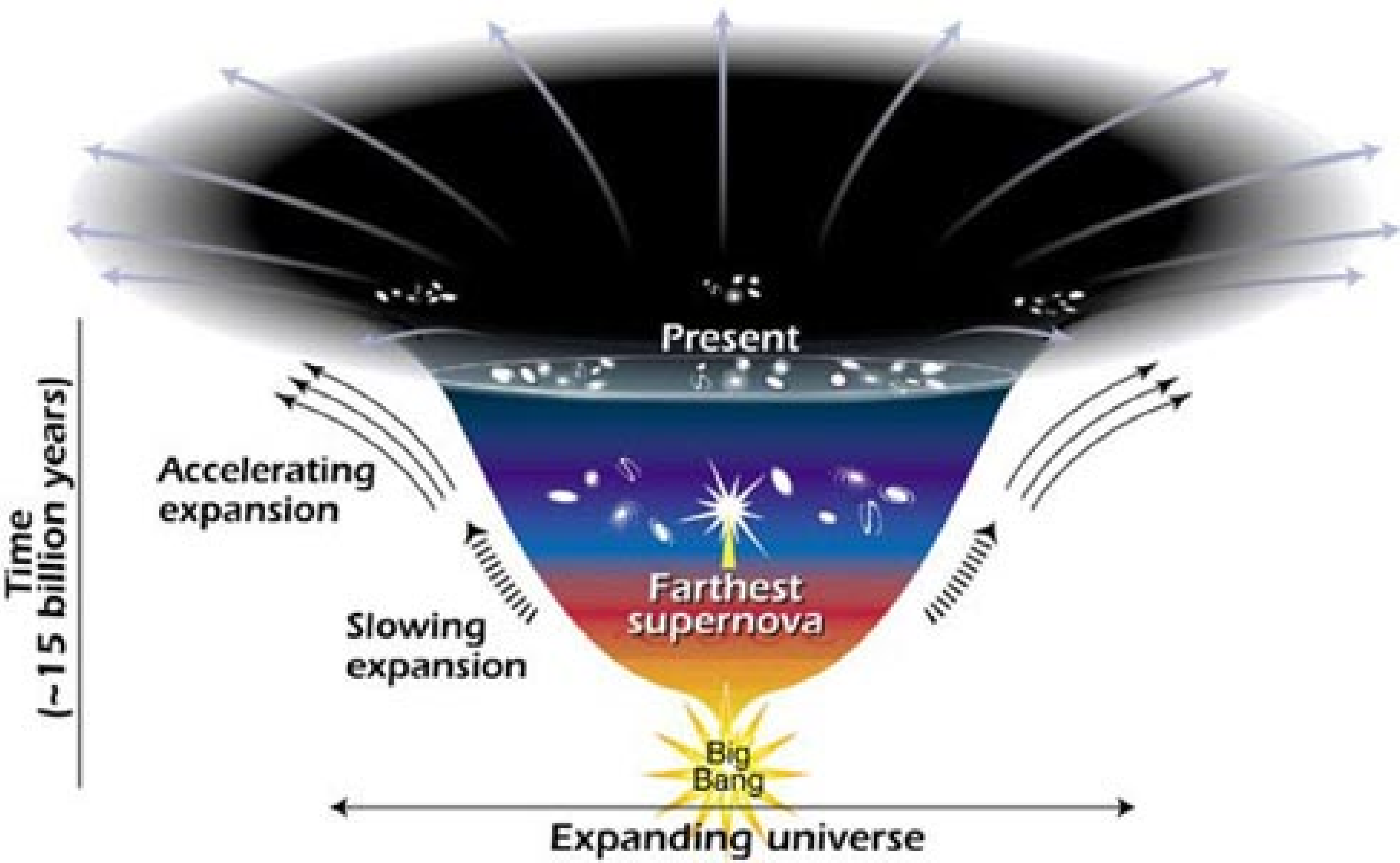


If wildly varying temperatures, T, exist before and after the big bang…

There is NO WAY to even make such an assertion, given the linkage between entropy and viscosity

So does a different way to think of entropy exist?

Our search has to match with cosmological dynamics



Part 2

Ng's infinite quantum statistics

Is there a linkage of DM and Gravitons?

Ng's quantum infinite statistics

- Question1 : Is each "particle count unit" as brought up by Ng, equivalent to a brane-antibrane unit in brane treatments of entropy?

- Question 2 : Is

$$\Delta S \approx \Delta N_{gravitons}$$

Infinite Quantum statistics

Start with a simple function

$$Z_N \sim \left(\frac{1}{N!}\right)\cdot\left(\frac{V}{\lambda^3}\right)^N$$

This, according to Ng, leads to entropy

But… there is a change in the formula: the N in the denominator goes, thereby obtaining **‘quantum infinite statistics’** as given by Y.J. Ng

$$S \approx N \cdot \left(\log\left[V / N\lambda^3 \right] + 5/2 \right)$$

$$S \approx N \cdot \left(\log\left[V / \lambda^3 \right] + 5/2 \right)$$

$$V \approx R_H^3 \approx \lambda^3$$

Assumptions we will use in analyzing Ng's infinite statistics

We wish to understand the linkage between dark matter and gravitons

To consider just that, we look at the "size" of the nucleation space, V

1. DM. V for nucleation is HUGE.

2. Graviton space V for nucleation is tiny , well inside inflation

Therefore, the log factor drops OUT of entropy S if V chosen properly for both 1 and 2. For small V, then

$$\Delta S \approx \Delta N_{gravitons}$$

For gravitons, the wavelength is tiny, and N is replaced by <n>

Especially true if V is well within inflation ‘grapefruit’ size dimensions

Here, <n> is a graviton density value to be identified experimentally via the Li-Baker detector

$$S \approx \langle n \rangle \Big|_{gravitons}$$

For DM, the wavelength is enormous. Implications?

Is there any construction which can link DM to gravitons? Or something similar ?

We are working on it. I.e., updates, refinements to

McElrath, Bob, “Emergent Electro weak Gravity”, http://arxiv.org/PS_cache/arxiv/pdf/0812.269v1.pdf

Supposition to investigate

IF Certain species of neutrinos/ DM play the role of Goldstone gravitons as implied by Bob McElrath (2009) then the counting algorithm of Ng (2008), which can do double duty as both a DM and a neutrino 'candidate' may in fact be also part of a continuum of results leading to relic gravitons playing an important role as to avoiding $dS/dt = \infty$ at $S=0$

Why is $dS/dt = \infty$ at $S=0$ so bad?

1. **Removes any chance that early universe nucleation is a quantum based emergent field phenomena**

2. **Goldstone gravitons would arise in the beginning due to a violation of Lorentz invariance. I.e. we have a causal break , and merely having the above condition does not qualify for a Lorentz invariance breakdown**

Part 3

Quantum gas and applications of Wheeler De Witt equation to forming Partition fctn

Photons and Gravitons as Goldstone Bosons, and the Cosmological Constant

[Per Kraus](), [E. T. Tomboulis]()

Some basic considerations about the partition function

Glinka (2007): if we identify

$$\Omega = \frac{1}{2|u|^2 - 1}$$

as a partition function (with u part of a Bogoliubov transformation) due to a graviton-quintessence gas, to get information theory-based entropy

$$S \equiv \ln \Omega$$

Glinka (2007) uses bosonification of his quantum graviton gas

1. Derivation by Glinka explicitly uses the Wheeler De Witt equation

2. Is there in any sense a linkage of Wheeler De Witt equation with String theory results ?

PROBLEM TO CONSIDER:

Ng's quantum counting algorithm is a STRING theory result

Part 4

Brane-antibrane 'pairs' and a linkage to Ng's quantum infinite statistics ?

Beginning to tally string theory entropy results. Here are two

Mathur (2007) gave the basic result of

$$S \sim E^{\left(D-1/D\right)}$$

Now for the brane-antibrane entropy

Lifschyztz (2004) codified thermalization equations of the black hole, which were recovered from the model of branes and antibranes

Can we link black hole entropy to early universe entropy ?

- It is VERY difficult to do. We are working on it.
- Big issue : making a linkage between number of brane-antibrane pairs and energent field ‘objects’, e.g. gravitons.
- One picture to toss out. The simple view of a new universe nucleating from a so called ‘white hole’

Part 5

Entropy, comparing values from T(u,v) stress energy , black holes, and general entropy values obtainable for the universe.

Vacuum energy and entropy

This suggests that entropy scaling is proportional to a power of the vacuum energy, i.e., entropy ~ vacuum energy, if is interpreted as a total net energy proportional to vacuum energy:

$$\frac{\Lambda_{Max} V_4}{8 \cdot \pi \cdot G} \sim T^{00} V_4 \equiv \rho \cdot V_4 = E_{total}$$

Black hole entropy and the Universe's entropy

From Sean Carroll (2005), the entropy of a huge black hole of mass M at the center of the milky way galaxy. Note there are at least a BILLION GALAXIES, and M is ENORMOUS

$$S_{Black-Hole} \sim 10^{90} \cdot \left[\frac{M}{10^{6} \cdot M_{Solar-Mass}} \right]^{2}$$

But Carroll (2005) estimates

The abelian group style conundrum, which refuses to go away. It is off by SEVERAL ORDERS OF MAGNITUDE from the PRIOR RESULT

$$S_{Total} \sim 10^{88}$$

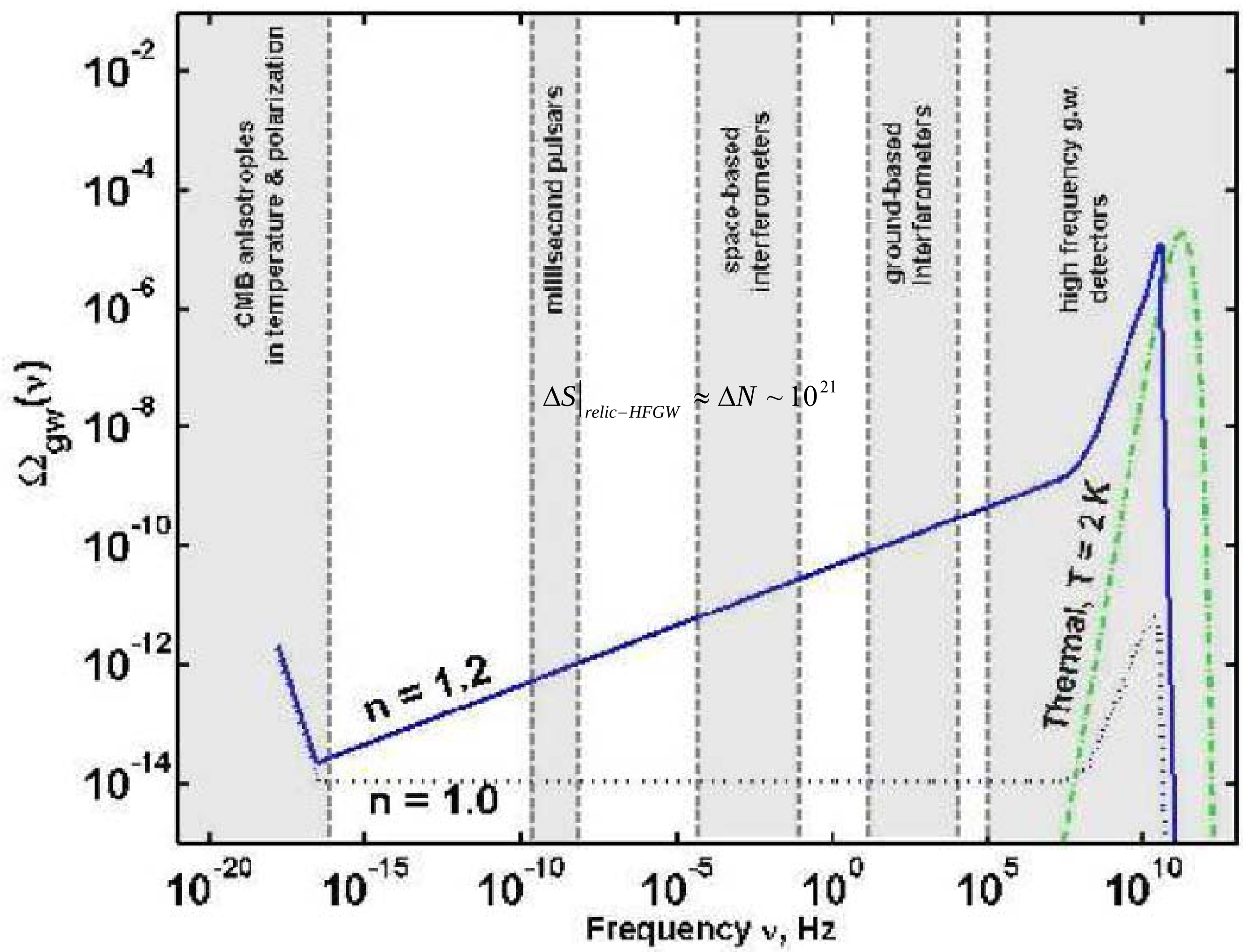
What NOT to do with gravitons and Entropy. As presented by Giovanni, what if all graviton production from the beginning to the present contributed?

$$S_{gw} = V \cdot \int_{\nu_0}^{\nu_1} r(\nu) \cdot \nu^2 d\nu \cong \left(10^{29}\right)^3 \cdot \left(H_1 / M_P\right)^{3/2} \approx 10^{87} - 10^{88}$$

This should be compared with HFGW production in relic conditions right after the onset of nucleation of a new universe

$$\Delta S\Big|_{relic-HFGW} \approx \Delta N \sim 10^{21}$$

Relic gravitons-entropy linkage benefits from HFGW production in the beginning of early universe (Grishchuk, 2007)



What is needed to explain that enormous HFGW spike?

- Relic gravitational waves will allow us to make direct inferences about the early universe Hubble parameter and scale factor ("birth" of the Universe and its early dynamical evolution). According to Grishchuk:

- Energy density requires that the GW frequency be on the order of

10^{10} Hz (10 GHz)

- Sensitivity required for that frequency on the order of

10^{-30} $\delta m/m$

Equipment issue

The theoretical ultimate sensitivity for GHz frequencies as a result of the optimization:

$$h_{min} \simeq 2.2 \times 10^{-22}\ \mathrm{Hz}^{-1/2}\ \delta m/m.$$

Part 6

Seth Lloyd’s incomplete hypothesis

Preferred venue to get the Li-Baker gravitational detector entropy analysis off the ground

Adding substance to Seth Lloyd's

$$\left|S_{Total}\right| \sim \left|k_B \cdot \ln 2\right| \cdot \left[\# operations\right]^{3/4}$$

What is a quantum nucleation operation, as given by Seth Lloyd?

- **Our supposition, such an operation is linked to a formation of a kink- antikink "assembly" of a graviton , and the emergence of a graviton from a properly constituted emergent field at the onset of inflation**.

- Kuchiev, M. Yu, "Can gravity appear due to polarization of instantons in SO(4)gauge theory?", *Class. Quantum Grav.* **15** 1895-1913 doi: 10.1088/0264-9381/15/7/008

Similarities, and differences with Zero point energy ? How does our energy ~ entropy compare with extraction of ZPE from a nucleated background ?

The problem with the ZPE, especially lies with a PROPER evaluation of the stress energy tensor, which we present again, in

$$\frac{\Lambda_{Max} V_4}{8 \cdot \pi \cdot G} \sim T^{00} V_4 \equiv \rho \cdot V_4 = E_{total}$$

For CASIMIR energy and the stress matter tensor we have device / closed geometry to work with

- See the following references
- Bismonete, G. Calloini, E. Esposito, G. and Rosa L.” Energy-Momentum Tensor for a Casmir Apparatus in a Weak Gravitational field”, PRD , Vol 74, 2006,085011
- Numerous corrections up to 2007

ZPE conundrum

ZPE application people wish to avoid a maximization of ENTROPY, but both seek to extract energy from a nucleation process.

Issue of closed device geometry for ZPE, vs. different geometry for OUR problem, especially in the early universe

How to compare stress energy tensors properly ? For HFGW ? New development

It was fortunate that Dr. Beckwith visited the ISEG 2009 conference. The crown jewel of that conference is now put up for review of the scientific community

http://www.tifr.res.in/~iseg/

If this presentation is understood and applied properly, it may help make a linkage between proper statement of T(u,v) , vacuum energy, and HFGW production.

C. S. Unnikrishnan: The One-way speed of light and implications to relativity theories

http://www.tifr.res.in/~iseg/presentations/Unni-iseg-velocity.pdf

Assertion to be vetted and tested

Beckwith claims, that if slides on the two way versus one way light speed presentation of the ISEG 2009 conference are properly analyzed with respect to early universe metrics, and PROPERLY extrapolated to today that ZPE energy extraction, as pursued by many, it will be a way to link early universe graviton nucleation to entropy production .

Some things to keep in mind about Stress tensors and Curved space

From Robert M. Wald : “Quantum Field theory in Curved Space time and Black Hole Thermodynamics”. If metric g(a,b) is for curved space time, the simplest matter energy stress tensor is (Klein Gordon)

$$T_{ab} = \nabla_a \phi \cdot \nabla_b \phi - \frac{1}{2} \cdot g_{ab} \cdot \left(\nabla_c \phi \cdot \nabla^c \phi + m^2 \phi \right)$$

Part 7

Simple relationships to consider

Expectation value of stress energy tensor leads to

$$G_{ab} = 8 \cdot \pi < T_{ab} >$$

This can be generalized to cover unitary equivalence as follows

More general treatment of the Stress energy tensor, with Klein-Gordon equation solutions ψ_1, ψ_2

$$T_{ab}(\psi_1, \psi_2) = \nabla_{(a}\overline{\psi_1} \cdot \nabla_b \psi_{2)}$$

$$-\frac{1}{2} \cdot g_{ab} \cdot \left(\nabla_c \overline{\psi_1} \cdot \nabla^c \psi_2 + m^2 \overline{\psi_1} \psi_2\right)$$

Put in projection map K as well as sympletic structure

Define the following operation, where A is a bounded operator, and < > an inner product

$$\mu(\psi_1, \psi_2) = \operatorname{Im}\widetilde{\Omega}(K\psi_1, K\psi_2) = \frac{1}{2} \cdot < \psi_1, |A| \cdot \psi_2 >$$

$$< \psi_1, |A| \cdot \psi_2 > = \int_{\Sigma} [T_{ab}(\psi_1, |A|\psi_2)] \xi^a \eta^b \sqrt{h} \cdot d^3 x$$

The structure of unitary equivalence is foundational to space time maps

$$C\mu_1(\psi,\psi) \leq \mu_2(\psi,\psi) \leq C'\mu_1(\psi,\psi)$$

This last issue ties in with whether or not the causal structure of space time is always maintained

Regarding information theory:

This is closely tied in with data compression and how much 'information' material from a prior universe is transferred to our present universe.

Part 8

Data compression, continuity, and Dowker’s space time sorting algorithm

Dowker postulated causal ordering in space time, an issue which may need to be revisited at or near the nexus point of the big bang.

This is an issue that the author is seriously working with, and trying to reconcile with the traditional singularity theorems of cosmology.

This also ties in with unitary equivalence and space time maps, and may have to be considered when looking at C. S. Unnikrishnan's hypothesis and its implications for revision of the metric g(u,v)

C. S. Unnikrishnan's change in the space time metric will necessitate careful reworking of equivalence relationships

Does that lead to bad physics ? NO.

It does mean that in order to preserve equivalence relationships as we know them that more structure, and more rethinking and refinements of the

$$T_{ab}\left(\psi_1,\psi_2\right)$$

One overriding caution

The claim of ZPE similarities to emerging quantum fields at the onset of inflation is NOT the same as the nucleation of dark energy!

Part 9

Controversies of DM/ DE applications to cosmology. How HFGW may help resolve them.

What we should keep in mind

Measured vacuum energy density (= dark energy density) is 10^{-9} J/m^3.

This translates into a measured cosmological constant Lambda = 2.07×10^{-52} m^{-2}.

These are present-day values and are valid going back to at least 10 billion years

Time for the headache pills. Not everyone buys dark energy

P. Hunt and Subir Sarkar,“Much ado about nothing: Do we live in a void ? ”
arXiv 0807.4508

This article though does NOT specifically break with DE

‘The cosmic void hypothesis’.

See Timothy Clifton, Pedro G. Ferreira and Kate Land

“Living in a Void : Testing the Copernican Principle with Distant Supernovae”

PRL 101, 131302, Sept 26,2008.
http://arxiv org/abs/0807.1443

Clifton raises the following question- can cosmology get to the bottom of this ?

"Solving Einstein's equations for an averaged matter distribution is NOT the same as solving for the real matter distribution and then averaging the resultant geometry"

("We average, then solve when in effect we should solve, then average")

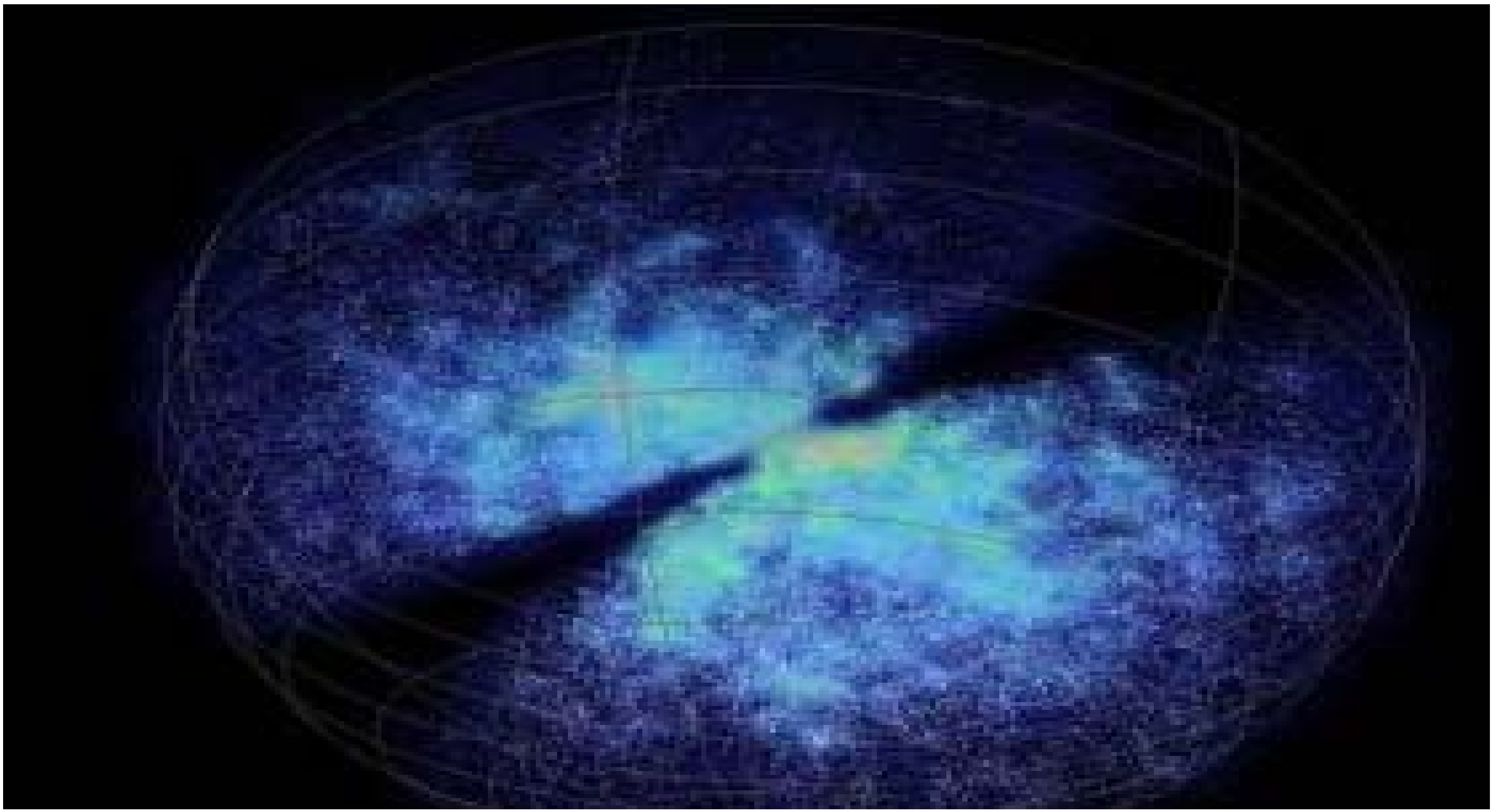
One of the alternatives

Using the Lemaitre-Tolman-Bondi model one can benchmark the following:

1. The more supernovae that astronomers observe, the more accurately they can reconstruct the expansion history of the Universe

2. A void, if identical to DE, would have density of matter INCREASING sharply from us in EVERY direction.

New cosmic map (galaxies) reveals colossal structures



“The new survey mapped the positions of more than 100,000 galaxies. The black strips are areas the survey did not cover because matter in our own galaxy blocked the view.”

“Enormous cosmic voids and giant concentrations of matter have been observed in a new galaxy survey, one of the biggest completed so far. One of the voids is so large that it is difficult to explain where it came from.”

Source: http://www.newscientist.com/article/dn16903-new-cosmic-map-reveals-colossal-structures.html

Do I need to say it ?

- If there EVER was a good reason to use HFGW as a way to test for matter distribution, THIS LAST SLIDE MAKES THE CASE FOR IT.

- What is at stake: The contrast between the VOID picture of expansion, and DE is so stark that this is a guaranteed NOBEL PRIZE in the offering for the first person to falsify either DE, or the VOID hypothesis

Galaxy formation issues….
Hierarchical Galaxy Formation

The smallest objects collapse first, bigger objects form by the merger of smaller ones

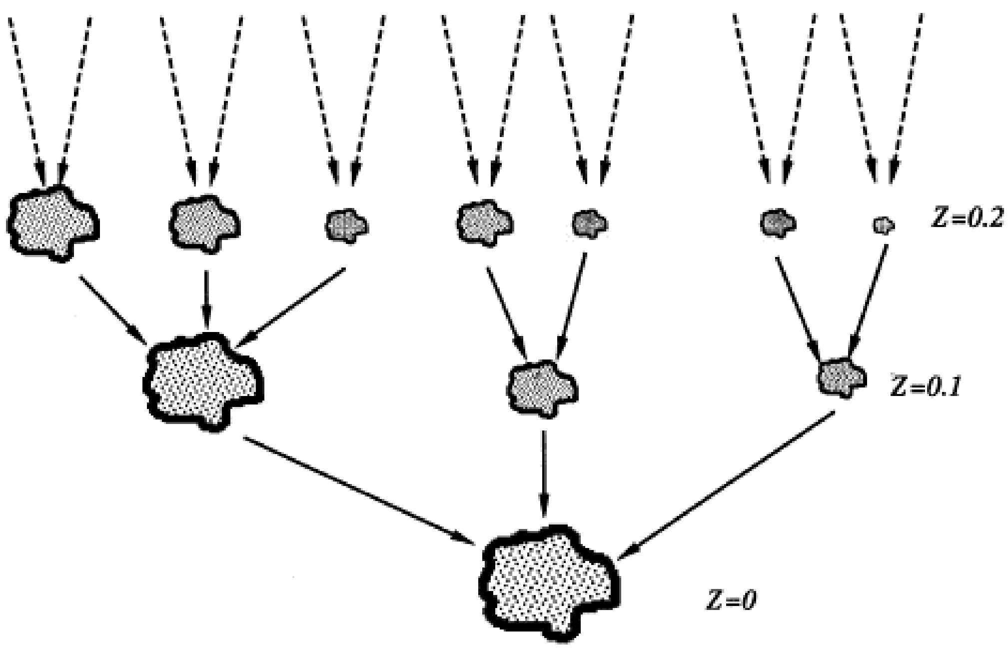


Figure 1. A schematic representation of a halo merging history 'tree'.

Dwarf Galaxies as cosmological probes

Since dark matter is typically dominant even in the central regions, the dark matter density distribution in dwarfs should reflect that predicted by numerical simulations

Details of ‘baryon physics’, e.g., the mass-to-light ratio of the stellar population, feedback from baryonic cooling and collapse on the structure of the Dark Matter Halo make it difficult to accurately determine the dark matter density profile in big galaxies.

Baryons are easily lost from the shallow dark matter potential wells of small galaxies

Reheating during the epoch of reionization, as well as from feedback from star formation should lead to dwarf galaxies having baryon fractions smaller than the cosmic mean.

Dark matter density profiles: standard story. It may have to be altered.

Traditionally used (phenomenological) dark halo models have constant density cores (‘*psuedoisothermal*’ halos)

$$\rho(r)=\rho 0/[1+(r/rc)2]$$

Numerical simulations of hierarchical CDM models predict cusped density core ("NFW") dark matter halos

$$\rho NFW\ (r)=\rho i\ /\ [(r/rs)(1+r/rs)2]$$

(Navarro et al. 1997 ApJ 490 493)

From measurements of the circular velocity as a function of galacto-centric radius (“rotation curve”), one can reconstruct the underlying mass distribution

Rotation curves of FIGGS galaxies can be used to check if dark matter density distribution matches numerical predictions

Although this ‘story’ for DM seems to be well established

Just ONE little problem: DM appears to be fattening up young galaxies, allowing for far-earlier-than-expected creation of early galaxies.

“A clutch of massive galaxies that seem to be almost fully-formed just 5 billion years after the big bang challenge models that suggest galaxies can only form slowly. Tendrils of dark matter that fed the young galaxies on gas could be to blame (NASA/CXC/ESO/P Rosati et al)”

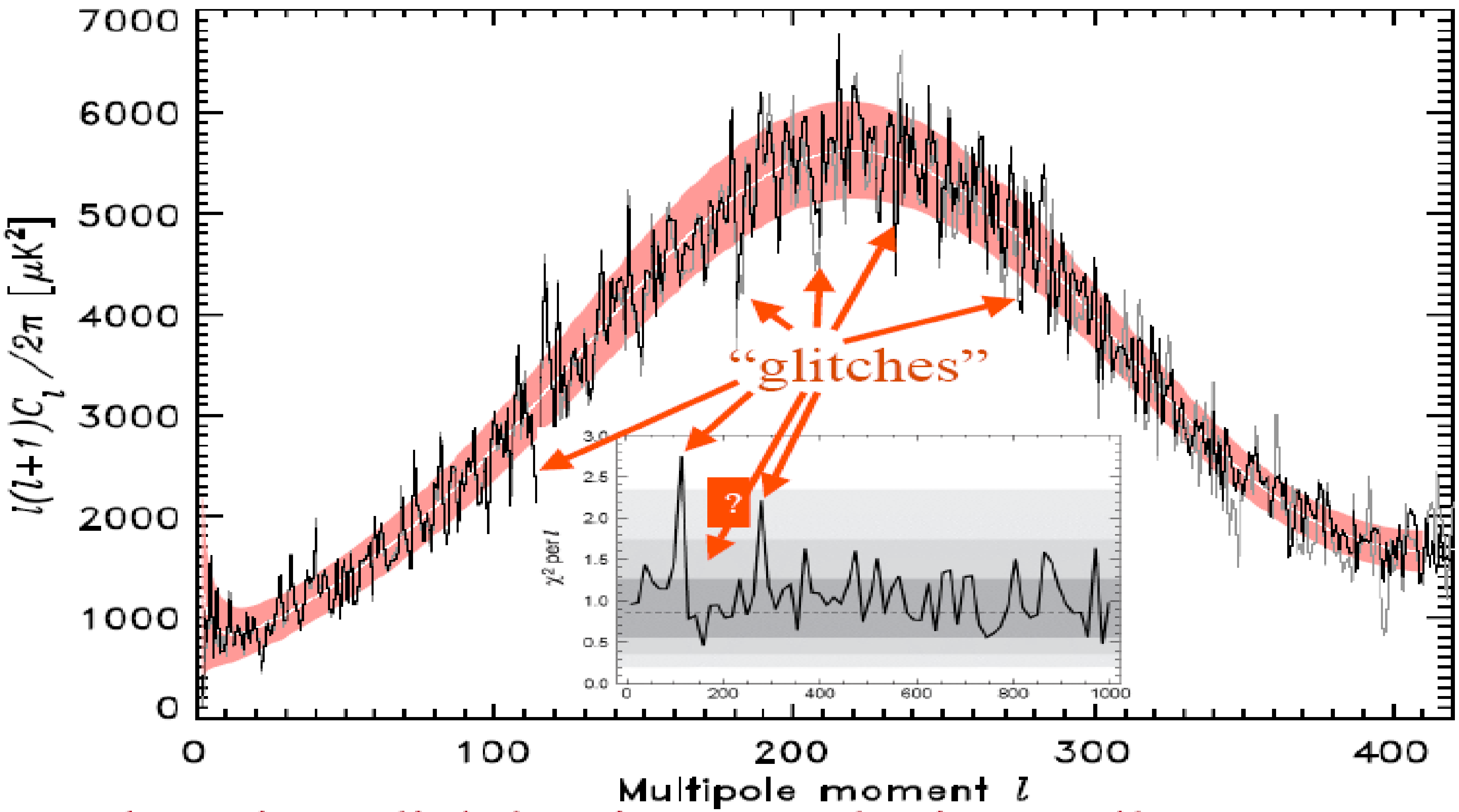
Source: http://www.newscientist.com/article/dn16912-overweight-galaxies-forcefed-by-dark-matter-tendrils.html

Interrelationship of DM and DE issues ? Or Void issues?

1. The growth of galaxies by mergers is driven by the gravity of non baryonic DM
2. The DM halo from the baryonic structures (star components of galaxies, etc.) is much larger.
3. We can assume that DM is on much firmer observational grounds than DE, for now.

We get CMBR glitches, and we need to examine if DE, or other reasons for voids are responsible

The excess χ^2 comes mostly from the *outliers* in the TT spectrum

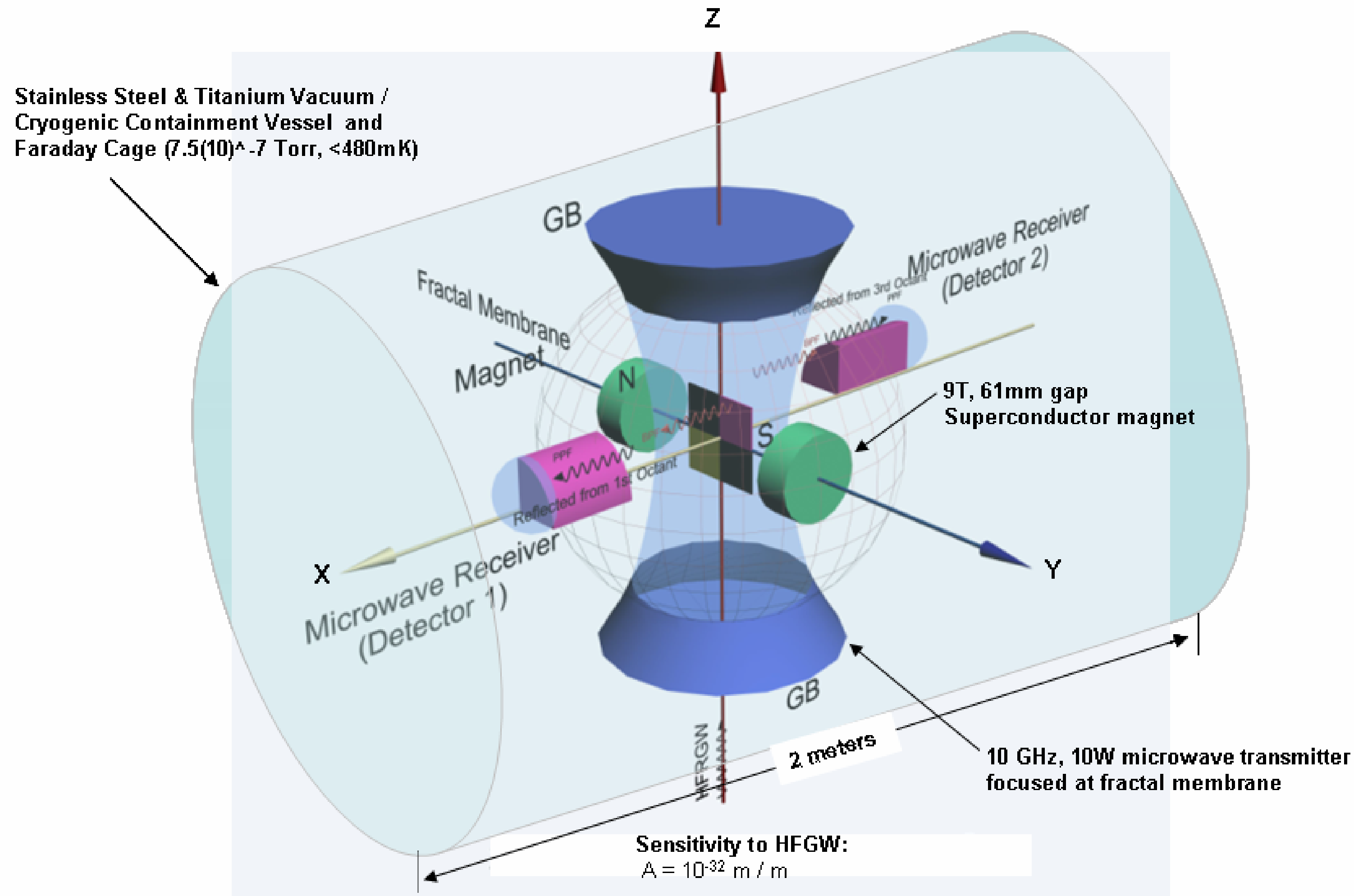


Is the primordial density perturbation really **scale-free**?

We have a LOT of work ahead of us -- especially if Sarkar is correct

"Quasi-DeSitter spacetime during inflation has no "lumpiness" -- it is necessarily very smooth. Nevertheless one can generate structure in the spectrum of quantum fluctuations originating from inflation by disturbing the slow-roll of the inflaton. In our model this happens because other fields to which the inflation couples through gravity undergo symmetry breaking phase transitions as the universe cools during inflation."

A practical HFGW detector as presented / designed by Dr. Li Fangyu and Dr. Baker



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