The inflationary origin of the seeds of cosmic structure: quantum theory and the need for novel physics.

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100 years of Einstein in Prague, June 27, 2012

Plan: (Very condensed report of various years of work)

1) Comments on the inflationary account for the *emergence* of the seeds of cosmical structure.... and the problem.
2) The usual answers, and their shortcomings.
3) Our approach. Bring into inflation Dynamical Reduction Theories (collapse of the WF, or “the R process” as called by Penrose).
4) The formal implementation. (Very brief)
5) The practical implementation. (Brief)
6) Collapse schemes and detailed predictions. Comparing with observations.
7) Other recent results.

1) Cosmic Inflation:

We have seen that inclusion of an early inflationary stage in cosmology leads to a natural account for the seeds of cosmic structure in terms of quantum fluctuations and a correct estimate of the corresponding spectrum.

The starting point of the analysis is a RW space-time background

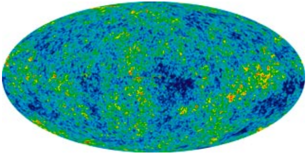
$$dS^2 = a(\eta)^2\{-d\eta^2 + d\vec{x}^2\}$$

inflating under the influence of an inflaton background field $\phi = \phi_0(\eta)$.

On top of this, one considers quantum fluctuations: $\delta\phi, \delta\psi, ..., \delta h_{ij}$ assumed to be characterized by the " vacuum state" (essentially the BD vacuum) $|0\rangle$.

From these, one argues, the primordial inhomogeneities and anisotropies emerge.

THE DATA: $\frac{\delta T}{T_0}(\theta,\varphi) = \frac{1}{3}\psi(\eta_D,\vec{x}_D)$, (to be precise there are other contributions) gives us a picture of the Newtonian Potential on the LSS.



We characterize this map in terms of the spherical harmonic functions, and write: $\frac{\delta T}{T_0}(\theta,\varphi) = \sum_{lm} \alpha_{lm} Y_{lm}(\theta,\varphi)$, so that

$$\alpha_{lm} = \frac{1}{3}\int d\Omega^2 \psi(\eta_D,\vec{x}_D) Y^*_{lm}(\theta,\varphi) \tag{1}$$

The quantity that is often the focus of the analysis is:

$$C_l = \frac{1}{2l+1}\sum_m |\alpha_{lm}|^2. \tag{2}$$

As we saw in the talk of Prof. Sasaki, the analysis leads to a remarkable agreement with observations. However, there is a difficulty that is not often addressed.

These are supposed to represent the primordial inhomogeneities which evolved into all the structure in our Universe: galaxies, stars planets, etc... As THEORY FITS VERY WELL WITH THE

OBSERVATIONS, one is then very tempted to say "well that is it. What else do we want?".

However, let us consider the following: The analysis starts with a H&I region, (both in the part that could be described at the "classical level", and the quantum level) that grows into our causal Universe. But we end up with a situation which is not H&I : It contains the primordial inhomogeneities which will result in our Universe's structure, and the conditions that permit our own existence.

How does this happen if the dynamics of the closed system does not break those symmetries?

Issue related to one considered by N.F.Mott in 1929. I.e. it is related to the "measurement problem", but, as we will see, in an aggravated form.

Simplified model: Mini-Mott

Consider a 2 level detector $|-\rangle$ (ground) y $|+\rangle$ (excited), and take two of them located at $x = x_1$ y $x = -x_1$. They are both initially in the ground state. Take a free particle with initial wave function $\psi(x, 0)$ given by a simple gaussian centered at $x = 0$ (so the whole set up is symmetric w.r.t $x \to -x$).

The particles's Hamiltonian: $\hat{H}_P = \hat{p}^2/2M$, while that of each detector is

$$\hat{H}_i = \epsilon \hat{I}_p \otimes \{|+\rangle^{(i)}\langle +|^{(i)} - |-\rangle^{(i)}\langle -|^{(i)}\}. \tag{3}$$

where $i = 1, 2$. The interaction of particle and detector 1 is

$$\hat{H}_{P1} = \frac{g}{\sqrt{2}}\delta(x - x_1\hat{I}_p) \otimes (|+\rangle^{(1)}\langle -|^{(1)} + |-\rangle^{(1)}\langle +|^{(1)}) \otimes I_2 \tag{4}$$

with a similar expression for the particle's interaction with detector 2.

Schrödinger's equation can be solved for the initial condition

$$\Psi(0) = \sum_x \psi(x,0)|x\rangle \otimes |-\rangle^{(1)} \otimes |-\rangle^{(2)}$$

and it is clear that after some time t we have

$$\Psi(t) = \sum_x \psi_1(x,t)|x\rangle \otimes |+\rangle^{(1)} \otimes |-\rangle^{(2)} + \sum_x \psi_2(x,t)|x\rangle \otimes |-\rangle^{(1)} \otimes |+\rangle^{(2)}$$

$$+ \sum_x \psi_0(x,t)|x\rangle \otimes |-\rangle^{(1)} \otimes |-\rangle^{(2)} + \sum_x \psi_D(x,t)|x\rangle \otimes |+\rangle^{(1)} \otimes |+\rangle^{(2)}$$

One can interpret the first two terms easily: no detection and double detection (involving bounce) which is small $O(g^2)$.
Thus, we could think the first two terms indicate the initial symmetry was broken with high probability: Either detector 1 was excited or detector 2 was.
We just use some kind of Copenhagen interpretation and everything seems fine, ... but as we will see, one in fact needs more...

Considering instead describing things in the: alternative state basis for the detectors (or "context")

$$|U\rangle \equiv |+\rangle^{(1)} \otimes |+\rangle^{(2)} \tag{5}$$

$$|D\rangle \equiv |-\rangle^{(1)} \otimes |-\rangle^{(2)} \tag{6}$$

$$|S\rangle \equiv \frac{1}{\sqrt{2}}[|+\rangle^{(1)} \otimes |-\rangle^{(2)} + |-\rangle^{(1)} \otimes |+\rangle^{(2)}] \tag{7}$$

$$|A\rangle \equiv |\frac{1}{\sqrt{2}}[|+\rangle^{(1)} \otimes |-\rangle^{(2)} - |-\rangle^{(1)} \otimes |+\rangle^{(2)}] \tag{8}$$

In fact, these are more convenient for describing issues related to the symmetries of the problem.

It is then easy to see that the $x \to -x$ and $1 \to 2$ symmetry of the initial setting, and of the dynamics, prevents the excitation of the asymmetric term.

One can explicitly find that :

$$\Psi(t) = \sum_x \psi_s(x,t)|x\rangle \otimes |S\rangle + \sum_x \psi_0(x,t)|x\rangle \otimes |D\rangle + \sum_x \psi_D(x,t)|x\rangle \otimes |U\rangle$$

And thus the issue is, can we or can we not describe things in this basis? And, if not, why not?
An experimental physicist in the Lab has no problem, he/she has many things that in practice (FAPP) indicate he should use the other basis (he knows that his detectors are always either excited or un-excited.. he never perceives them in superposition). The measurement problem is: exactly how does our theory account for that *experience* of our experimental colleague? Often, we just don´t care. However, if we now have a situation where there is no experimentalist.... and nothing else in the universe, we do not know what to do.
In that situation, why would we believe the conclusions drawn in the first context but not those of the second?. i.e. How do we account for the breakdown of the symmetry?

2) THE USUAL ANSWERS and their shortcomings:

a) As in all QM situations, take into account that "we perform a measurement".
Even ignoring all the issues that come with the measurement problem in Quantum Theory, taking this view amounts to saying that the conditions that made possible our own existence result, in part, from our own actions.

b)Environment-induced decoherence + many worlds Interpretations (MWI). i) Requires identification of D.O.F as an "environment" (and traced over). Entails using our limitations to "measure things", as part of the argument. ii) Does not tell us that the situation is now described by one element of the diagonal density matrix, but by all, and as such the situation is still symmetric. Need something like MWI. iii) But MWI relies on a mind whose state of consciousness determines the alternatives into which the world splits. How does the mind come about?.

In our case, the environment would correspond to DOF of other fields, or some particular modes of the inflaton field deemed to be“non observable”. That is .. ...non observable, by us!

Moreover, the whole state involving the full set of modes and all other fields) is symmetric (i.e. H&I).

In fact, one can not interpret this diagonal density matrix as generically indicating we have alternative “realizations” before measurements (See for instance Penrose’s “Shadows of the Mind” Ch 6) because it leads to conflict with Bell inequalities and EPR experiments (Aspect et. al.).

This fact is well known in the "Quantum Foundations" community (see for instance Joos in "Decoherence: Theoretical, Experimental, and Conceptual Problems", (2000, p. 14):
"Does decoherence solve the measurement problem? Clearly not. What decoherence tells us is that certain objects appear classical when they are observed. But what is an observation? At some stage, we still have to apply the usual probability rules of quantum theory".

Most people working on this topic compute the so called decoherence functionals, apparently without focussing too much on these issues.

However, even W. Zurek: "The interpretation based on the ideas of decoherence and ein-selection has not really been spelled out to date in any detail. I have made a few half-hearted attempts in this direction, but, frankly, I was hoping to postpone this task, since the ultimate questions tend to involve such "anthropic" attributes of the "observership" as "perception," "awareness," or "consciousness," which, at present, cannot be modeled with a desirable degree of rigor." (quant-ph/9805065)

3) OUR APPROACH: The situation we face here is unique (Quantum + Gravity (GR) + Observations).
We want to be able to point to a physical process that occurs in time as explaining the emergence of the seeds of structure. After all, emergence (in this context) means : Something that was not there at a time, is there at a later time. We need to explain the breakdown of the symmetry of the initial state: Collapse can do this.

Collapse Theories: Important existing work in this direction: GRW, Pearle, Diosi, Penrose, Bassi (recent advances to make it compatible with S.R. : Tumulka (Th. of flashes), Bedningham (Q F with stoch. dynamics)), and recently Weinberg.
However, we will NOT start from any of those, as we first want to learn what does the situation at hand require?. (Eventually, we will seek to connect).
We propose to add, to the standard inflationary paradigm, a quantum collapse of the wave function as a self induced process.

How would this fit with our current theoretical views? The big question. Let's recall some issues and conceptual difficulties still outstanding (which I think might offer some hope):

I) The Problem of Time. One often ends up with a timeless theory (canonical approaches).

II) More generally: how do we recover space-time from different approaches to QG ?.

Solutions to I) usually consider using some dynamical variable as a physical clock and then considering relative probabilities (and wave functions). However one recovers only an approx Schrödinger eq. with corrections that violate unitarity (Pullin & Gambini). Could something like this lie at the bottom of collapse theories?
Regarding II), it is worth mentioning that there are many suggestions indicating space-time might be an emergent phenomena... (T. Jacobson, R. Sorkin, N. Seiberg and many others...).
In that case, the level at which one can talk about space-time concepts, might well be the classical description. However some quantum aspects could remain as traces, and "look" like collapse.
Hydrodynamic analogy.

4) The Proposal:

The idea is that at the quantum level gravity is VERY different, and at large scales leaves something that looks like a collapse of the quantum wave function matter fields. (Inspired by Penrose and Diosi's ideas).

Thus, the inflationary regime is one where gravity already has a good classical description, but matter fields do still require a quantum treatment.

The setting will thus naturally be semiclassical Einstein's gravity (with the extra element: THE COLLAPSE): i.e., besides U we have sometimes, spontaneous jumps:

$$....|0\rangle_{k_1} \otimes |0\rangle_{k_2} \otimes |0\rangle_{k_3} \otimes .... \rightarrow ....|\Xi\rangle_{k_1} \otimes |0\rangle_{k_2} \otimes |0\rangle_{k_3} \otimes .....$$

There is an underlying Quantum Theory of Gravity, (probably with no notion of time).

But, by the "time" one recovers space-time concepts, the semiclassical treatment is a very good one, its regime of validity includes the inflationary regime as long as $R << 1/l^2_{Plank}$.

More precisely, we will rely on the notion of *Semiclassical Self-consistent Configuration* (SSC).

DEFINITION: The set $g_{\mu\nu}(x), \hat{\varphi}(x), \hat{\pi}(x), \mathcal{H}, |\xi\rangle \in \mathcal{H}$ represents a SSC if and only if $\hat{\varphi}(x)$, $\hat{\pi}(x)$ and $\mathcal{H}$ correspond a to quantum field theory constructed over a space-time with metric $g_{\mu\nu}(x)$ and the state $|\xi\rangle$ in $\mathcal{H}$ is such that:

$$G_{\mu\nu}[g(x)] = 8\pi G\langle\xi|\hat{T}_{\mu\nu}[g(x), \hat{\varphi}(x), \hat{\pi}(x)]|\xi\rangle.$$

It is, in a sense, the GR version of Shrödinger-Newton equation.

This, however, can not describe the transition from a H&I SSC to one that is not. For that, we need to add a collapse: However, a collapse will be a transition from one SSC to another, not simply from one state to another. So we need: $....SSC1.... \rightarrow ....SSC2....$ During the collapse eq. # must be modified (as in W. Israel's matchhings)!.

In particular they will describe a transition from an H&I SSC to one that is not. That involves changing the state, and thus the space-time, and thus the Hilbert space where the state "lives" and is non trivial (arXiv:1108.4928, in press at JCAP), but seems to teach us something about the required modifications in #.

5) PRACTICAL TREATMENT:

As we said, space-time is thus treated in classical language, and in our case (working in a specific gauge and ignoring the tensor perturbations) the metric is:

$$ds^2 = a^2(\eta)\left[-(1+2\Psi)d\eta^2 + (1-2\Psi)\delta_{ij}dx^i dx^j\right], \Psi(\eta, \vec{x}) \ll 1$$

But now, in the practical approach the field is split $\phi = \phi_0 + \delta\phi$: The homogeneous scalar background $\phi_0(\eta)$ and a perturbation $\hat{\delta\phi}$ to be treated with QFT. In the previous, more precise treatment, the former corresponds to a specific mode (or combination) of the quantum field.

During Inflation (slow roll regime), we will have $a(\eta) \approx \frac{-1}{H_I \eta}$.

We will set $a_{today} = 1$, and assume that inflationary regime ends at a value of $\eta = \eta_0$, negative and very small in absolute terms.

Semiclassical Einstein's equations, at lowest order lead to

$$\nabla^2\Psi = 4\pi G\dot{\phi}_0\langle\delta\hat{\dot{\phi}}\rangle = s\langle\delta\hat{\dot{\phi}}\rangle, \tag{9}$$

where $s \equiv 4\pi G\dot{\phi}_0$.

Now, we consider the quantum theory of the field $\delta\hat{\phi}$. It is convenient to work with the rescaled field variable $\hat{y} = a\delta\hat{\phi}$ and its conjugate momentum $\hat{\pi} = \delta\hat{\dot{\phi}}/a$. (Set the problem in a box of side L, which can be taken to ∞ at the end of all calculations).

We decompose the field and momentum operators as:

$$\hat{y}(\eta,\vec{x}) = \frac{1}{L^3}\sum_{\vec{k}} e^{i\vec{k}\cdot\vec{x}}\hat{y}_k(\eta), \qquad \hat{\pi}_y(\eta,\vec{x}) = \frac{1}{L^3}\sum_{\vec{k}} e^{i\vec{k}\cdot\vec{x}}\hat{\pi}_k(\eta),$$

where

$$\hat{y}_k(\eta) \equiv f_k(\eta)\hat{a}_k + \bar{f}_k(\eta)\hat{a}^{+}_{-k}, \qquad \hat{\pi}_k(\eta) \equiv g_k(\eta)\hat{a}_k + \bar{g}_k(\eta)\hat{a}^{\dagger}_{-k}$$

with the usual choice of modes: $f_k(\eta) = \frac{1}{\sqrt{2k}}\left(1 - \frac{i}{\eta k}\right)\exp(-ik\eta)$ $g_k(\eta) = -i\sqrt{\frac{k}{2}}\exp(-ik\eta)$, which leads to what is known as the Bunch Davies vacuum: the state defined by $\hat{a}_k|0\rangle = 0$.

Note that $\langle 0|\hat{y}_k(\eta)|0\rangle = 0$ and $\langle 0|\hat{\pi}_k(\eta)|0\rangle = 0$.
The collapse will modify the state, and thus, the expectation values of the operators $\hat{y}_k(\eta)$ and $\hat{\pi}_k(\eta)$.

We need to specify the "rules" according to which collapse happens. That is: the state $|\Theta\rangle$ after the collapse. This is thought to be controlled by novel physics, so we must try to make an "educated guess", and later contrast results with the data.

We will assume, that after the collapse, the expectation values of the field and momentum operators in each mode will be related to the uncertainties of the pre-collapse state (these quantities for the vacuum are NOT zero).

In the vacuum state, $\hat{y}_k$ and $\hat{\pi}_k$ characterized by Gaussian wave functions centered at 0 with spread Δy_k and $\Delta \pi_{y_k}$, respectively.

6) For their generic form, associated with the ideas above, we assume that at time η_k^c the part of the state corresponding to the mode $\vec{k}$ undergoes a sudden jump, so immediately afterwards:

$$\langle \hat{y}_k(\eta_k^c) \rangle_\Theta = \alpha \;\; x_{k,1} \sqrt{\Delta \hat{y}_k}$$
$$\langle \hat{\pi}_k(\eta_k^c) \rangle_\Theta = \beta \;\; x_{k,2} \sqrt{\Delta \hat{\pi}_k^y}$$

where $x_{k,1}, x_{k,2}$ are selected randomly from within a Gaussian distribution centered at zero with spread one.

Here, we consider two "Models" :

Model 1): *the symmetric model*: $\alpha = \beta = 1$.

Model 2):*the Newtonian model*: $\alpha = 0$, $\beta = 1$.

Finally, using the evolution equations, we obtain $\langle \hat{y}_k(\eta) \rangle$ and $\langle \hat{\pi}_k(\eta) \rangle$ for the state that resulted from the collapse for all later times.

Analysis of the Phenomenology

The semi-classical version of the perturbed Einstein's equation that, in our case, leads to equation
The Fourier components at the conformal time η are given by:

$$\Psi_k(\eta) = -(s/ak^2)\langle\hat{\pi}_k(\eta)\rangle$$

Prior to the collapse, the state is the vacuum and $\langle 0|\hat{\pi}_k(\eta)|0\rangle = 0$ so we would have: $\Psi_k(\eta) = 0$

But after the collapse we have:

$$\Psi_k(\eta) = -(s/ak^2)\langle\Theta|\hat{\pi}_k(\eta)|\Theta\rangle \neq 0$$

And thus we can reconstruct the Newtonian potential (for times after the collapse)

$$\Psi(\eta, \vec{x}) = \frac{1}{L^3}\sum_{\vec{k}} e^{i\vec{k}\cdot\vec{x}}\Psi_k(\eta)$$

The quantity of interest is the “Newtonian potential” on the surface of last scattering: $\Psi(\eta_D, \vec{x}_D)$, where η_D is the conformal time at decoupling and $\vec{x}_D$ are co-moving coordinates of points on the last scattering surface corresponding to us as observers.
This quantity is identified with the temperature fluctuations on the surface of last scattering.Thus:

$$\alpha_{lm} = \int \Psi(\eta_D, \vec{x}_D) Y^*_{lm} d^2\Omega.$$

Now, we have

$$\Psi(\eta, \vec{x}) = \sum_{\vec{k}} \frac{sU(k)}{k^2} \sqrt{\frac{\hbar k}{L^3}} \frac{1}{2a} F(\vec{k}) e^{i\vec{k}\cdot\vec{x}}$$

where $F(\vec{k})$ contains the information about the type of collapse scheme one is considering as well as the time at which the collapse of the wave function for the mode $\vec{k}$ occurs.

The factor $U(k)$ represents the modification of the primordial fluctuations by known physical effects, like the acoustic oscillations of the plasma (i.e. are transfer functions).

Now, putting all this together we find,

$$\alpha_{lm} = s\sqrt{\frac{\hbar}{L^3}}\frac{1}{2a}\sum_{\vec{k}}\frac{U(k)\sqrt{k}}{k^2}F(\vec{k})4\pi i^l j_l(|\vec{k}|R_D)Y_{lm}(\hat{k}), \qquad *$$

where $j_l(x)$ is the spherical Bessel function of the first kind, $R_D \equiv ||\vec{x_D}||$, and $\hat{k}$ indicates the direction of the vector $\vec{k}$.

Thus α_{lm} is the sum of complex contributions from all the modes, i.e. the equivalent to a 2-dimensional random walk, whose total displacement corresponds to the observational quantity.
We then evaluate the most likely value of such quantity:

$$|\alpha_{lm}|^2_{M.L.} = \frac{s^2\hbar}{2\pi a^2}\int\frac{U(k)^2C(k)}{k^4}j_l^2((|\vec{k}|R_D)k^3dk$$

The function $C(k)$ encodes information contained in $F(k)$. For each model of collapse it has a slightly different functional form.
It turns out that in order to get an exactly featureless primordial spectrum, there is a single simple option: z_k must be almost independent of k, That is: $\eta_k^c = z/k$.

This result shows that the details of the collapse have observational consequences!! Note: usual treatment has no analog of $*$!!

In particular, we do not expect the time of collapse to follow strictly the pattern: $\eta_k^c = A/k$. How precise must this be ?

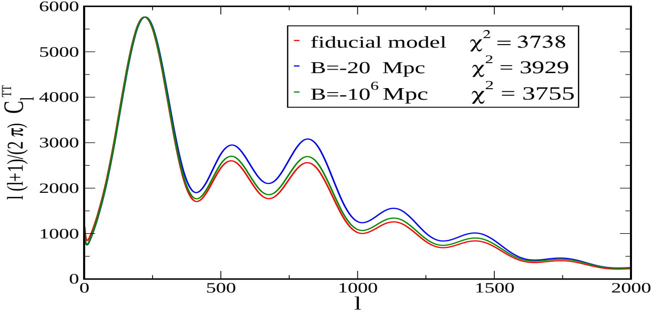
We have explored departures from the pattern $\eta_k^c = z/k$, but assuming $\eta_k^c = A/k + B$.

[*PRD* **78**, 043510, (2008) arXiv:0801.4702 [gr-qc]

& *PRD* **85**, 123001, (2012) arXiv:1112.1830 [astro-ph.CO].

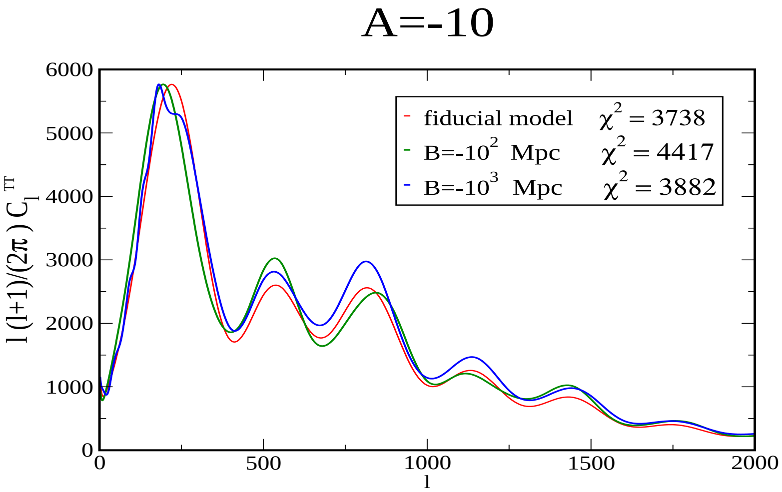
Next, we show a sample of the results detailed analysis incorporating the well understood late time physics (acoustic oscillations, etc) and comparing directly with the observational data:

A=-10

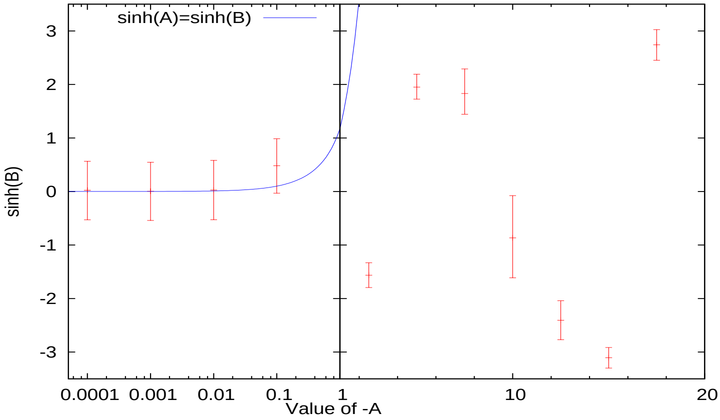


6000
5000
4000
3000
2000
1000
0
l (l+1)/(2 π) C_l^TT
0
500
1000
1500
2000
l
fiducial model χ² = 3738
B=-20 Mpc χ² = 3929
B=-10⁶ Mpc χ² = 3755

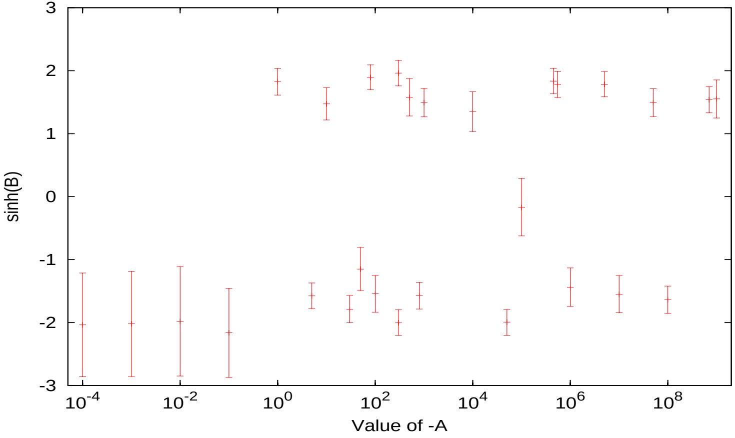
For Model 2


A=-10
fiducial model $\chi^2 = 3738$
B=-10^2 Mpc $\chi^2 = 4417$
B=-10^3 Mpc $\chi^2 = 3882$
l (l+1)/(2π) C_l^{TT}
l
0
1000
2000
3000
4000
5000
6000
500
1500

For Model 1



For Model 2



We still need to fully explore the significance of these results.

7) MORE ON THE COLLAPSE IN THE EARLY UNIVERSE.

i) No tensor modes. (In the semiclassical approach we favor. This can also be tested.)

ii) Might offer a solution to the Fine Tuning problem for the inflaton Potential. [CQG, 27, 225017 (2010)].

iii) Multiple collapses. More information about the post-collapse states [CQG, 28, 155010 (2011)]

iv) New views on the study of Non-Gaussianities. Novel possibilities, and approaches *Sigma* **8**, 024, (2012). [arXiv:1107.3054 [astro-ph.CO].]

v) Very Speculative Ideas connecting with QG and the problem of time: Wheeler de Witt or LQG are timeless theories.
Can the recovering of time be connected with collapse theories? In what direction would the connection be?

On going research:

i) Framing Inflation within explicit collapse theories. CSL:

$$|\psi,\eta\rangle_w = \mathcal{T}e^{-\int_0^{\eta} d\eta' [i(\hat{H}_k) - w(\eta')\hat{A}_k + \lambda \hat{A}_k^2]} |\psi,\eta_0\rangle \qquad (10)$$

adapted to QFT.

ii) Performing detailed statistical analysis.

iii) Non gaussianities, and novel forms thereof. Numerical simulations, etc.

OPEN ISSUES

a) The precise analysis led to jump in extrinsic curvature at the SSC junction. Can this be resolved in a QG theory? Perhaps in analogy with the BH singularity resolution in LQG?

b) Framing within a fully covariant approach (which might involve no locality) but which ensures no conflicts with causality.

When in Prague, Einstein attended the First Solvay Conference, which apparently influenced him very strongly with preoccupations about the nature of quantum theory.

He (and his friend Michelle Besso) referred to that meeting as 'the Witches' Sabbath'. Einstein: "The h-disease looks ever more hopeless," he wrote to Lorentz, after the conference.

Today, in many places, students (and young –or not so young – researchers) are often advised against worrying about these issues.

Perhaps, this is because we have all grown used to employing Quantum Theory, by following, in practice, the Copenhagen Interpretation or some other FAPP kind of approach (as described by John Bell). We can, in fact, do this quite generally when dealing with laboratory experiments where there are no doubts about ... what is being measured? .. when? and .. by whom?.

F. Goya.

The fact that we are nowadays applying QT to cosmology forces us, in my view, to reconsider such approach.

We could see this as a problem, but it might be an opportunity instead!.

Could it lead to fundamental new insights on the Quantum & Gravity interface?

Perhaps these issues can help rekindle, 100 years later, the “awe” of that ‘ Witches’ Sabbath’ ?

Perhaps at Charles Bridge..?

tonight?... midnight? ...anyone?

Thank you.