Proposal for using mix of analytical work with data analysis of early CMB data obtained from the JDEM NASA - DOE Investigation

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Sent to :

Rocky Kolb, *Chair of the JDEM Dark matter search panel*

&

Laurence Pinsky, *Chair of the U. of Houston Physics department*

To whom it may concern,

I. Introduction of the problem I wish to have analyzed in this document.

As of May 2nd , 2005, ***Kenji Kadota*** of FNAL gave a talk at Pheno 2005 called "***Reconstructing inflaton potentials***" which talked about a data related scheme for giving classes of potentials as would fit how to reconstruct the dynamics of cosmological inflationary activity after the big bang. As is commonly known in cosmology circles, one would expect a flat Friedman – Walker universe after 60 e-foldings, but beforehand one could expect sharp deviations as to flat space geometry, which I do think is detectable. The moment one would expect to have deviations from the flat space geometry would closely coincide with ***Rocky Kolb's*** model for when degrees of freedom would decrease from over 100 degrees of freedom to roughly ten or less during an abrupt QCD phase transition. As was mentioned by ***Joe Lykken*** , the CMB model should yield a distinct 'signal' which is lending toward a non flat cosmological metric space potential which can be seen to be initiating a phase transition at about the end of the 60 e-folding regime of cosmological expansion. My own model as provided for in the paper I present here, "***Using Di quark pairs at the beginning of nucleation of a new universe, and setting initial conditions which permit the onset of variations of a nucleation rate per Hubble volume per Hubble time***" is useful for such QCD phase transitions, while Kenji's potential reconstruction scheme is not specific as to a **UNIQUE** potential structure. It would be enough in itself to try to combine the two techniques as to go before the thousand year mark Kenji mentioned as to data sets permitting potential reconstruction, and to find evidence as to CMB background as to the initial phases of CMB generation leading to the datum ***Rocky Kolb*** mentioned as to the decrease in cosmic microwave radiation to its present value as a result of a QCD phase transition in the expansion of the early universe.

As this is meant at its heart to be an experimental investigation, it is important to point out that effective field theories as presently constructed require a cut off value for applicability of their potential structure, but often at the costs of , especially in early universe theories, of clearly defined baryogenesis , and of a clearly defined mechanism of phase transitions. The phase transition issue is extremely important in lieu of ***Rocky Kolb's*** stated result of a dramatic reduction of degrees of freedom during the QCD phase transition, and as of the present there are no experimental/ phenomenological studies as to the particulars as of this transformation to more classic inflationary cosmology. This study, among other things, intends to fill in this gap. And to provide researchers pointers as to how to re-construct potential systems pertinent up to the big bang itself. In particular, getting a handle of how phase transitions affect the 60 e-folding transformation of the initial onset of non curved, flat space reconstruction of a big bang model, using di quark pairs forming a background for a scalar potential model.

II. Brief presentation of analytical method given by Kenji Kadota as of mid 2005 for inflaton potential reconstructive methods

Let us now refer to how one can use re constructive methods to analyze potential structures. This discussion uses three papers, the first being

1. **Precision of Inflaton Potential Reconstruction from CMB Using the General Slow-Roll Approximation**

by ***Kenji Kadota***, ***Scott Dodelson***, ***Wayne Hu***, and ***Erwin D. Steward***

This is arXIV:astro-ph/0505185 v1 9 May 2005

2. **On the reliability of inflaton potential reconstruction**

By ***Edmund J. Copeland***, ***Ian J. Grivell***, and ***Edward W. Kolb***

This is arXIV : astro-ph/9802209 v1 15 Feb 1998

3. **Using Di quark pairs at the beginning of nucleation of a new universe, and setting initial conditions which permit the onset of variations of a nucleation rate per Hubble volume per Hubble time**

By ***Andrew Beckwith***

In process of evaluation by the U. of Arizona journal of astronomy and astrophysics

4. Matching Scherrer's k essence argument with behavior of scalar fields permitting derivation of a cosmological constant

By *Andrew Beckwith*

ArXIV math-ph/0412002 paper being evaluated by one of World Press Scientific journals with Scott Dodelson as editor overseeing referee review

Kenji Kadota of FNAL in Pheno 2005 talked of comparing two graphs, one with a combination of scalar potential terms $\left[3\cdot\left(\frac{V'}{V}\right)^2-2\cdot\frac{V''}{V}\right]$ against $[(\xi)]$ (Mpc) with a graph of

$m(j)$ against ***mode numbers***. Here, in this situation,

$m(j)=$ linear combination of $\{P(j)\}$ (1)

And when we set t_{END} = the demarcation of the end of time for the inflation , for a scale factor a leads to

$$\xi\equiv-\int_t^{t_{END}}\frac{dt'}{a(t')} \tag{1a}$$

In this situation, the $\{P(j)\}$ refer to pixel data slices which show up in

$$\left[3\cdot\left(\frac{V'}{V}\right)^2-2\cdot\frac{V''}{V}\right]\equiv\sum_i p_i\cdot B_i(\ln\xi) \tag{2}$$

We should identify the left hand side of equation 2 with the derivative of a function $G(\xi)$, i.e.

$$\frac{dG(\xi)}{d\xi}\equiv\sum_i p_i\cdot B_i(\ln\xi) \tag{2a}$$

This is when ***Kadota*** et al defined

$$B_i(\ln\xi)=\begin{cases}1\\0\end{cases}\text{ with a value of 1 iff }\ln\xi_i<\ln\xi<\ln\xi_{i+1} \tag{3}$$

In the most recent arXIV article, ***Kadota*** defined a procedure as to how to identify useful entries as to acceptable $\{P(j)\}$ values as to a simplified scalar potential structure which is $V(\phi) \equiv \left(V_0 \cdot e^{\lambda\cdot(\phi-\phi_0)}\right)\cdot \left[1 + c\cdot e^{-\nu\cdot(\phi-\phi_0)^2}\right]$ for a perturbation centered at $\phi \equiv \phi_0$ where this has $|\lambda|, c << 1,\ |\nu| >> 1$, so then after ***Kadota et al*** defined

$$\phi \cong \lambda \cdot \ln \xi \tag{4}$$

so one could write

$$\phi_0 \equiv \lambda \cdot \ln \xi_0 \tag{5}$$

he obtained graphical behavior as seen in his figure 8 and figure 9 of his arXIV article. An even simpler situation graphically emerged when ***Kadota*** set the left hand side of equation 1 equal to a constant which permitted him, using equations 2 and 3 above to give constant values to the p_i pixels, which was equivalent to his figure 7 which was for a potential system leading to a constant spectral index value, *n* when he defined via linking *n* – 1 to the derivative with respect to *k* of an expression of the primordial power spectrum $\mathrm{P}(k)$ via

$$n - 1 = \frac{d\mathrm{P}(k)}{dk} \tag{6}$$

Here, in this situation we have that if we interpret $\vartheta(1)$ as an order of magnitude constant of about 1 < $\vartheta(1)$ < 10. We should also note that often $\vartheta(1)$ is often set very close to 1 itself.

$$k = \vartheta(1)\cdot a \cdot H \equiv a \cdot H \tag{7}$$

The exact particulars of the power spectra $\mathrm{P}(k)$ are in **Kadotas** well written arXIV paper, but it suffices to say that the natural logarithm of the power spectra $\mathrm{P}(k)$ is equal to an integral over ξ values from zero to infinity, with part of the integrand involving a so called 'window function' times the power spectra $\mathrm{P}(k)$, for $G(k)$ of equation 2a above. In conclusion one can say the following:

Kenji Kadotas methodology permits the general reconstruction of potentials as up to about 1000 years after the big bang. The issue at stake though is if or not re constructive methodology using some of these same methods could be countenanced going up to the end of the 60 e-folding period commonly viewed as the demarcation between flat and curved space, with a curved space milieu being the regime of active nucleation of our universe. This would entail, among other things, finding traces in CMB data of the initial signature of the big bang itself and tying it into a QCD style phase transition, via the potential system which will be discussed briefly in the next section.

III. Presentation of very early di quark nucleation potential behavior as could be analyzed by the above methods.

This section starts off with several premises (assumptions) about a nucleation of baryonic states which would play a role in the formation of model building permitting a bridge to an inflaton scalar field , permitting the formation of a potential which could give experimentally observable signatures to the CMB problem which could be analyzed experimentally.

0th , that a C-P violation in initial states would lead to an initial Baryon condensate of matter separating into di quark (S-S’) pairs leading to :

1st ,that for times less than or equal to Planck time t_P the potential system for analyzing the nucleation of a universe is a driven Sine Gordon system, with the driving force in magnitude far less than the overall classical Sine Gordon potential.

2nd premise lies in having topological charges for a soliton – anti soliton di quark pair $(S - S')$ stem prior to Planck time t_P for this potential system cancel out, leaving a potential proportional to ϕ^2 minus a contribution due to quantum fluctuations of a scalar field being equal in magnitude to a classical system , with the remaining scalar potential field contributing to cosmic inflation in the history of the early universe.

The **3rd** assumption is that a vacuum fluctuation of energy equivalent to $\Delta t \cdot \Delta E = \hbar$ will lead to the nucleation of a new universe, provided that we are setting our initial time $t_P \approx \Delta t$ as the smallest amount of time which can be ascertained in a quantum universe.

What has to be kept in mind is the following. If a phase transition occurs right after our nucleation of an initial state, it is due to the time of nucleation actually being less than (or equal to) Plancks minimum time interval t_P , with the length specified by reconciling the fate of the false vacuum potential used in nucleation with a Bogomol'nyi inequality specifying the vanishing of topological charge . In any case, I specified three regimes for analysis of this problem. Which are as follows:

$$\begin{array}{lll} V_1 & \rightarrow V_2 & \rightarrow V_3 \\ \phi(increase) \leq 2 \cdot \pi & \rightarrow \phi(decrease) \leq 2 \cdot \pi & \rightarrow \phi \approx \varepsilon^+ \\ t \leq t_P & \rightarrow t \geq t_P + \delta \cdot t & \rightarrow t >> t_P \end{array} \tag{8}$$

$$V_1(\phi) = \frac{M_P^2}{2} \cdot (1 - \cos(\phi)) + \frac{m^2}{2} \cdot (\phi - \phi^*)^2 \tag{8a}$$

$$V_2(\phi) \approx \frac{(1/2) \cdot m^2 \phi^2}{(1 + A \cdot \phi^3)} \tag{8b}$$

$$V_3(\phi) \approx (1/2) \cdot m^2 \phi^2 \tag{8c}$$

Although not directly stated, the **1st** potential system would be equivalent to the conditions ***Rocky Kolb*** specified as of a multiple degrees of freedom system, which after a QCD phase transition would transform, via the **2nd** potential to the chaotic potential regime specified as of ***Guths*** normal chaotic inflationary model, as given by the **3rd** potential written here. The specifics of forming a S-S' pair would be due to ***Zhitiniskys*** construction of QCD "balls" forming S-S' pairs which would be separated by a distance as created by a C-P violation for forming di quark pairs. The di quark pairs would be essential in the set up of the scalar field ϕ of what eventually would be a typical inflaton scalar field for a chaotic inflaton potential as given in equation 8c. The entire ethos of this proposed project would be in trying to ascertain signals which could be re constructed by CMB data analysis along the lines given by ***Kenji Kadotas*** arXIV article, in a manner to give more definition to the transformation alluded to in equation 8 above. In addition, the model referred to above would be useful as a way to

IV. Discussion of differences in this approach with standard methodology as well as what to look forward to from an explicit experimental point of view:

What would be required would be two fold.

1st determining from experimental considerations what would be an optimal way to put in data for the power spectrum which could be used to analyze , as ***Kadota*** wrote up

$$\ln P(k) = \int_0^\infty \frac{d\xi}{\xi} \cdot \left[-k \cdot \xi \cdot W'(k \cdot \xi)\right] \cdot G(\ln \xi) \tag{9}$$

This will require , if we set $k \cdot \xi = x$ what ***Kadota*** et al call a window function as being

$$-x \cdot W(x) = -3 \cdot \frac{\left(5x^2 - 3\right)}{2 \cdot x^3} \cdot \sin(2 \cdot x) + 3 \cdot \frac{\left(x^2 - 3\right)}{x^2} \cdot \cos(2 \cdot x) \tag{10}$$

More to the point will be filling in the details of what to put into $G(\ln \xi)$ assuming that equations 2 and 2a are valid. In particular, using the derivation of behavior for a linkage between a scalar field ϕ and ξ would be essential. The model which I derived in the paper I wrote above has a simplified linkage right for di quark behavior in the regions of the potential system in equations 8a to 8b which would be helpful in this analysis, but in truth the main issue would be in obtaining what would be a realistic set of recoverable $G(\ln \xi)$ inputs via equations 2 and 2a above, which in the end would be finding p_i s from CMB data.

The differences with contemporary approaches would be in re construction of signals as to look for gravitational wave signatures from a QCD phase transition initializing the end of the 60 e-fold curved space regime prior to the transition to the flat space regime where the ***Guth*** style inflaton potential as given by equation 8c would be dominant. As ***Kadota*** stated in his Pheno 2005 talk, current re construction of acceptable potentials are well within the regime of flat space, for typical times as of the order of about 1000 years after the big bang itself. Refining this methodology may allow us to systematically search for data permitting a resolution to the particulars of the big bang problem itself, as well as address the particulars of how dark cold matter played a role in the initial phases of nucleation of the scalar field itself leading to the typical inflaton potentials modeled by ***Guth*** . The slow roll hypothesis would make it unfeasible to model potential behavior of the region given by equation 8a, but we could look at the after effects of potential system behavior at or right after the phase transition implied by equation 8b above, which is in the vicinity of nucleation of di-quark pairs at or right after Plancks time t_P as a contribution to CMB data recoverable by experimentally collected signatures from the big bang itself.

V. Linking this discussion with JDEM requirements for Dark Matter signal and data collection requirements

Essentially, I have no background as to the actual signal evaluation done in the JDEM satellite. This would require that I would interface with regards to members of the DETF panel who are aware of exactly how the analysis of the data has been done in earlier Hubble telescope observations, as an example, and to also discuss the precise instrumentation requirements specified as to the new mission.

Due to circumstances I have no control over, what is presented in this document is a conceptual pitch for a different form of data analysis. ***Rocky Kolb*** doubtless knows of how to use electronic data collection so as to make the Fisher matrix set up of data as ***Kenji Kadota*** and ***Scott Dodelson*** are aware of and used in their May 2005 arXIV paper a refined tool to parse data collected by astronomical observations collected by the JDEM satellite feasible.

VI. Whom would be involved in any JDEM analysis of data

The first step would be to refine the analytical algorithms of ***Kenji Kadota*** and ***Scott Dodelson*** into something which would be able to , for one , give reliable data inputs into the right hand side of $\frac{dG(\xi)}{d\xi} \equiv \sum_i p_i \cdot B_i(\ln \xi)$, where the left hand side of this equation actually could use , in a modified format the procedure given in equations 8 to 8c, and this done to obtain a match up of the acceptable p_i entries with CMB data.

This would entail use of Monte Carlo simulations as well as far more developed analysis of how to obtain acceptable p_i entries in a more realistic manner than the toy problem analyzed by ***Kadotas*** toy problem example which he presented in figure 7 of his arXIV article.

Afterwards, once acceptable procedures are outlined as to finding acceptable p_i entries for potentials other than the potential given by $V(\phi) \equiv \left(V_0 \cdot e^{\lambda \cdot (\phi - \phi_0)}\right) \cdot \left[1 + c \cdot e^{-\nu \cdot (\phi - \phi_0)^2}\right]$ were obtained, would come discussions with , most likely, ***Rocky Kolb*** himself as to instrumentation requirements as to putting data directly into the entries into the Fisher matrix used by ***Kadota*** and ***Dodelson*** for equation 2a above.

IF the committee buys this as a legitimate start into Dark matter/ dark energy searching, then the following could be participants as to whom should be involved.

(1) ***Kenji Kadota***, of FNAL . It is HIS arXIV paper and algorithm which started this analysis in the first place.

(2) ***Rocky Kolb***, of FNAL. A person who knows data collection techniques for inflaton potential reconstruction, and who wrote a pioneering paper as of 1998 as to the necessary and sufficient conditions needed for inflationary cosmology potential reconstruction.

(3) ***Scott Dodelson***, of FNAL. A person who is intimately aware of the CMB problem and whose research field involves use of statistical data analysis of CMB data for all sorts of astrophysical model building .

(4) Myself, ***Andrew Beckwith***. For what it is worth, I am proposing what I think is a no nonsense initial nucleation model for precursors of the inflationary phase of cosmology which I do think would be a useful initial condition start as to how to make sense of CMB data up to the point of the big bang itself, and also to analyze the role of what dark matter/ dark energy would play in the formation of inflaton potentials at or before the 60 e-folding limit (when curved space conditions morphed into Friedman Walker flat space)

I would frankly need to be assigned a base institution to work with, should this analysis and proposal to initiate inquiry into this problem be accepted. Dr. ***Leon Pinsky*** of the U. of Houston has graciously permitted myself to use the U. of Houston as a reference point. This can be continued if Dr. ***Pinsky*** thinks that the project will benefit the U. of Houston physics department, or it can be altered if members of an investigative team looking at this proposal recommend another institutional flagging of myself for purposes of this proposal are in order.

VII. Final conclusions and summary of the proposal, and whom would be involved with it if accepted.

1. The four people in order who would be doing the work would be as follows:

1a. ***Kenji Kadota*, of FNAL** .

1b.***Rocky Kolb*, of FNAL**..

1c. ***Scott Dodelson*, of FNAL**..

1d. ***Myself, Andrew Beckwith***.

2. Host institution

2a. **Largely FNAL,** but if the U. of Houston wishes to put in its involvement with myself as representing the U. of Houston, pending an agreement with Dr. ***Lawrence Pinsky***, that would be fine with me.

3. Budget :

3a. **I expect that the first task would be to initially extend Kadotas potential reconstruction work to a wider version of potentials so that CMB data could be matched with potentials corresponding to initial nucleation conditions.**

This would require NO additional outlay of funds for the first three participants. If or not the panel wishes to pay **me** for involvement is a decision which would be made by a funding agency as they saw fit. <u>I expect this would take half a year to finalize</u>. A lot of analytical work, but no major investment of engineering resources

3b. After agreed upon reconstruction techniques were identified, extensive work with fisher matrix elements, and CMB data from prior astronomical data would have to be initiated, involving consultation with Dr. Kolb and members of the panel most familiar with satellite data. The idea would be to find ways to obtain data sets via techniques most congruent to reliable potential reconstruction of the early inflationary cosmos. Before the 1000 or so year limit specified by ***Kenji Kadota***. This realistically might take a year to implement. Still though the budget requirements for this would be quite small

3c. IF these two stages were successfully completed, would come the hard part. Mainly a discussion with manufacturers of the satellite used for dark matter searching as to tailor made electronics which would be acceptable for obtaining sufficient data sets. I am assuming that this investigation would be one out of many being used in the upcoming satellite mission.

VIII . Relevance of the cited articles above to this proposal.

The **first article**, by ***Kenji Kadota et al*** is a template for cosmological potential reconstruction. A simplified result with respect to a 'bump potential' linked to data reconstruction issues has already been derived. Considerably more work needs to be done with this in early universe potential models. The **second article**, of which ***Rocky Kolb*** is an author is the original template as to necessary and sufficient conditions permitting a reconstructive algorithm to work for cosmological potentials. The **third article**, written by myself, ***Andrew Beckwith***, is a template for early universe nucleation which I do believe should be heeded and which ties in the CMB early universe data in with dark matter and dark energy constructions. The **fourth article** , written by myself, ***Andrew Beckwith*** is a use of the k essence model given by ***Scherrer*** to argue for the existence of a phase transition from a dark matter-dark energy initial state to the situation represented by chaotic inflaton potentials as seen in standard cosmology models.