Title: Who Is The Inflaton?

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Abstract: It is argued that space-time is discretized on the basis of the gravitational interactions among the degrees of freedom of quantum fields.Configurations of fields fall into 2 classes,propagating (cisplanckian in length scale) and those that are transplanckian, sequestered in the space-time that is localized in discrete elements.Only the former determine the hubble expansion parameter and are therefore used to construct the inflaton.The model used for discretization is Sorkin\'s causet construction.From this the covariant massy Klein Gordon equation can be rationalized.The mass is encoded as an exchange matrix element between the sequestered (bound) degrees of freedom and those that propagate,presumably by tunneling thereby exlaining why m<<1.

An Enquiry on the Concept of

THE INFLATON = ϕ

ϕ a scalar field that evolves in an expanding space

1 foot in established physics QFT GR

1 foot in terra incognita (i.e. enigma

1] To have inflation (exponential expansion)

ϕ must condense: $\langle \phi \rangle \neq 0$ in a homogeneous patch (it can start small)

To inflate, $\langle \phi \rangle = O(1)$

(>6 to attain our world)

2] ϕ must be massy, but m is small

$m = 10^{-6}$ works

3] In inflation, modes are created!!

With $m = 10^{-6}$ → { CMBR fluctuation spectra
Large scale structure

Point of view adopted here

Traditional conservative

↓

Push it into failure, inconsistencies *

↓

Elaborate "reasonable" hypotheses **

* Failure must be anticipated because inflation physics is phase change hence strong coupling physics

Usual QFT will not work !!

But know it fails gives key to →

** Reasonable hypotheses

Def. of reasonable.

Analogy to known science, hence intelligible. But not derived

↓

Extended, open ended phenomenology

Begin from the Beginning

The Hebrew text - circa 700 B.C.

And the earth was without form and void
and darkness was on the face of the deep [1)]

And God said, Let there be light
and there was light [2)]

1) Vacuum = chaos before form

Even before big bang form arose from chaos
$\langle \phi \rangle \neq 0$ is form

→ Exponential separation to the
big bang homogeneous space-like surface

2) Hebrews liked the Big Bang not Inflation
But, Babylonians + Sumerians ⇒ causal emergence
(2000 B.C.)
- preferred "inflation" i.e growth

- Inflation was conceived in 1977-79 by Englert, Gangui, R.B. as growth from a seed out of chaos which fed on itself self-consistently

[Pre-universe chaos is natural
Sokal in Vienna (1978) said
"After all, one must begin somewhere"]

- Inflation was our response to the need for causality. It also explained flatness (Casher, Englert 1980), Starobinsky (1980)
- Its implementation by ϕ (Mukhanov, Linde, Steinhardt) explains large scale structure, CMBR fluctuations

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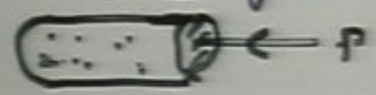
- Alternative hypothesis, naturally at sniquantum

We want to interpret "ϕ-ness", so think about fluids

<u>Usually</u> $p > 0$, $dE = -p\,dV$



Force exerted externally

If expansion, $dV > 0$, $p > 0$; $dE < 0$

System works and loses energy

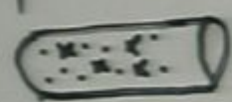
(e.g. steam engine

see Carnot: Encl. Britannica)

<u>Cosmology in inflation</u>

$p < 0$; $dV > 0$, $dE > 0$

Implies internally distributed engines



X = engine

homogeneously distributed

X delivers E to system

$dV > 0$ ∴ Number of X increases → exponential in

ϕ-vevs describes a density of energy-giving entities within the system

<u>Model</u>: QFT

To start, QFT as we practice it

Take massless scalar field, φ

because we want planckian scale and known masses $\ll 1$

Modes of φ (φ is not ϕ) are momentum eigenstates

$$\nu(\Lambda) = \text{mode density} = \int^{\Lambda} k^2 dk$$
$$= \Lambda^3$$

$$\rho(\Lambda) = \text{energy density} = \int^{\Lambda} |k|\, k^2 dk$$
$$= \Lambda^4$$

for free fields

$\rho \to \infty$, as $\Lambda \to \infty$: OK no coupling

Introduce gravity

Field configurations of φ have self gravitational interactions

e.g. Newtonian $\int \hat{d^3k} \int \hat{d^3k'} \frac{|\vec{k}||\vec{k}'|}{|\vec{k}-\vec{k}'|^2}$

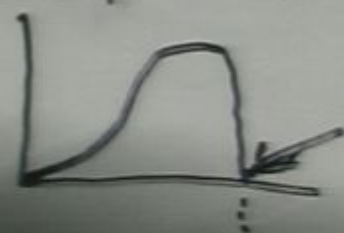
$$\sim \Lambda^6$$

= contribution to ρ from modes with $|\vec{k}| \leq \Lambda$

So $\rho(\Lambda) = \Lambda^4 - \Lambda^6$

($m_{Pl} = 1$, constant $O(1) = 1$)

Untenable for $\Lambda > \Lambda_0$ where $\rho(\Lambda_0) = 0$



Λ_0 | $H^2 = \rho(\Lambda) > 0$

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= contribution to ρ from modes with $|\vec{k}| < \Lambda$

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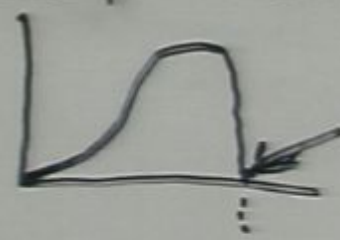
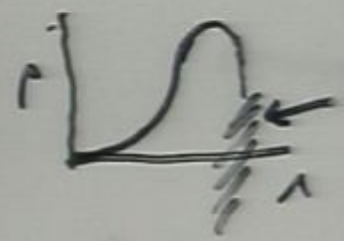


Λ_0 | $H^2 = \rho(\Lambda) > 0$

$\rho(\Lambda)$ cannot be calculated for Λ near Λ_0 because of strong coupling

Describing field configurations in terms of modes must change



$\rho(\Lambda)$ for $\Lambda > \Lambda_0$ goes negative because of gravitational attraction

→ Hypothesis

At planckian scale, fields come in bound state aggregates as well as modes

One can find a model for ϕ and $p \leq 0$

in a discretized space or space-time

For definiteness choose space-time

$\rightarrow$ Causal Discretization

Bound state aggregates are centered

about causal-sites

i.e.

Transplanckian field configurations

are ephemeral bound state

aggregates that come up in the

action integral

[Lorentz abstract is foam on

space-like surfaces, but

Lorentz invariance not manifest]

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terpreting ϕ and m

$\nu(\Lambda)$ = density of propagating degrees of freedom (modes)

$= 0 \quad \Lambda > \Lambda_0$

$\rho(\Lambda) = 0 \quad \Lambda > \Lambda_0$ where ρ = energy density due to modes

n many body theory (like superfluids) one defines

$$\nu = |\phi|^2$$

dopt this definition up to a constant

$|\phi|^2$ = density of modes / space-time volume.

(if $m_{pl} \neq 1$ then replace ϕ^2 by $\phi^2 m_{pl}^2$)

Parametrize cis-trans communication

$$g\,|\phi|^2 |\psi|^2$$

hence $m^2 = g\,|\psi|^2 |\phi^2|$

s in QFT

$\sim\sim$ = unperturbed ϕ propagator $= G^{(0)}$

$\sim\sim\sim\sim$ $= G^{(0)} m^2 G^{(0)}$

Interfacing ϕ and π

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Parametric cis-trans communication

$$g\,|\phi|^2 |\psi|^2$$

where $m^2 = g\,|\psi|^2 |\phi^2|$

as in QFT

m = unperturbed ϕ propagator $= G^{(0)}$

$$\underset{g}{m} = G^{(0)} m^2 G^{(0)}$$

$G^{(0)}$ [illegible] is from round trip π charge

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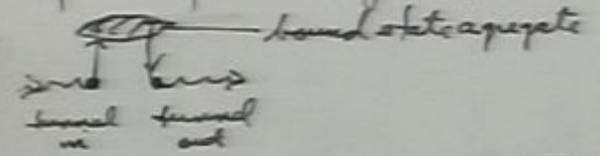
as in QFT

$\sim\sim$ = unperturbed ϕ propagator $= G^{(0)}$

$$\sim\sim\sim\sim\sim\sim - G^{(0)} m^2 G^{(0)}$$

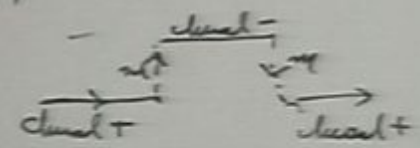
$G^{(0)}$ comes from hopping; g from round trip exchange

calculate g = square of tunneling amplitude $= |t|^2 \ll 1$



10^{-6} is "reasonable" : $(e^{-4\pi} \sim 10^{-5})$

If ϕ depends on $\vec{x}$ as well as t, it propagates in two ways (like the Dirac wave function



Replace classical − by the reservoir)

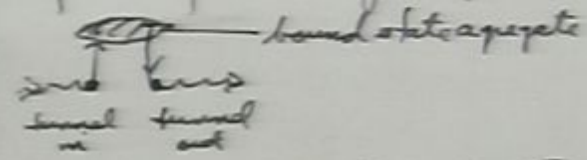
<u>Importance of m for cosmologists</u>

- For ordinary fluids density fluctuations are massless fluctuations (Formally from conservation.
- Also common sense: what is up here is down here

no $\vec{k}=0$ mode

and $\lim_{k\to 0} \omega(k) = 0$

calculate g = square of tunneling amplitude $= |t|^2 \ll 1$



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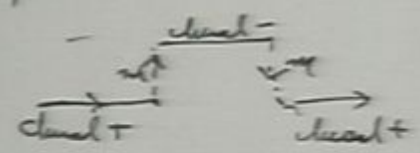

Replace chiral − by the recursion)

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With $m \neq 0$; $\lim_{k \to 0} \omega(k) = m$

related to non conservation

— A fluctuation  results

some $\phi^2 \cdot \psi^2$ can result in pair annihilation of modes

— i.e. If $\nu = \nu(\Lambda_0)$ and $\rho(\Lambda_0) = 0$ $\therefore$ $H^2 = 0$

modes can "fall into" planckian aggregate

$\nu(\Lambda_0) \to \nu(\Lambda)$ with $\Lambda < \Lambda_0$

ρ increases (less gravitational attractive energy in cis-planckian sector)

$H^2 \neq 0 \to$ cosmogenesis if initial fluctuation is sufficiently extensive and homogeneous

---

By same token: If $\phi \neq 0$ (i.e. $\Lambda < \Lambda_0$)

$\therefore$ planckian reservoir make modes, $\phi \to 0$, $H \to 0$

$\nu(\Lambda)$ can be created from behind H^{-1} during

— A fluctuation  secrete

some ϕ^2, ψ^2 can result in pair annihilation of modes

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modes can "fall into" plenum aggregate

$v(\Lambda_0) \to v(\Lambda)$ with $\Lambda < \Lambda_0$

ρ increases (less gravitational attractive energy in coplanar vectors)

$H^2 \neq 0 \to$ cosmogenesis if initial fluctuation is sufficiently extreme and homogeneous

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$\therefore$ plenum reservoir nodes erodes, $\phi \to 0$, $H \to 0$

$v(\Lambda)$ can be created from behind H^{-1} during inflation $\to$ scale invariant fluctuation spectrum

Resumé:

- Chaotic and expanding vacuum is a cis-trans equilibrium with $\langle v(\Lambda_0) \rangle$ determined from $\langle \rho(\Lambda_0) \rangle = 0$
- The trans reservoir is the pump that delivers $\rho < 0$
- Cosmogenesis develops [illegible] linearly homogeneous fluctuat[illegible] to $H^2 = \rho$, and [illegible]
- Reheating is mos[illegible] Exponential expo[illegible] as $\langle \phi \rangle \to 1$ (i.e. [illegible]
- Smooth evolution is so[illegible] because $\dot{\phi}^2$ competes wit[illegible] i.e. evolution by hopping co[illegible]

→ Program: look for cascades of "eddy[illegible]

Resumé:

- Chaotic and expanding vacuum is a dis-trans equilibrium with $\langle v(\Lambda_0) \rangle$ determined from $\langle \rho(\Lambda_0) \rangle = 0$
- The trans reservoir is the pump that delivers $\rho < 0$
- Cosmogenesis develops out of a sufficiently homogeneous fluctuation, expands due to $H^2 = \rho$, and requires to reheating
- Reheating is most likely a turbulent phenomenon. Exponential expansion ($H > 0$) goes out as $\langle \phi \rangle \to 1$ (i.e. as $\Lambda \to \Lambda_0$)
- Smooth evolution is no longer possible because $\dot{\phi}^2$ competes with $m^2 \phi^2$ i.e. evolution by hopping competes with tunneling

→ Program: look for cascades of "eddies"