Entropy, neutrino physics, and the lithium problem—why stars with no lithium in early universe exist

(And why the quark-gluon model is not the best analogy)

Abbreviated version—32 pages vs. 107

Dr. Andrew Beckwith

Part of material Presented at Chongqing University April 2009, with material from Rencontres de Moriond, Rencontres de Blois, and 12 Marcel Grossmann conferences 2009 added

重慶大學
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Topics in presentation

- **Basic assumption: neutrino-graviton intermixture affects early-universe nucleosynthesis of Lithium.**

- **Main point of the talk is:**

  <u>Why Lithium-free early stars?</u>

- **1st First few slides: Graviton- entropy linkage**

  (DM get perturbed via non Gaussian perturbations ?)

  [**Motivation: halo merging tree for galaxy formation breaks down**]

  2nd Next few slides: Neutralinos – Detector basics

  (The coupling of neutrinos to gravitons would be enhanced as their wave lengths would initially be quite similar)

3rd When neutrinos and gravitons inter mix in higher velocities

4th What the speaker is investigating :graviton – neutrino mixing may affect how and why lithium free stars may arise in the first place

Entropy Questions

- Infinite statistics compared to Glinka's version of graviton quantum gas involving the Wheeler De Witt equation directly
- Ng's quantum infinite statistics
- Is each "particle count unit" as brought up by Ng equivalent to a brane-antibrane unit in brane treatments of entropy?
- Is the increase in relic entropy due to relic graviton production?

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

Suggested downloads

- **Documents:**

  http://sites.google.com/site/abeckwithdocuments/

- **Put title of this document here**

  Chongquing - tabulated results 1a.pdf

Overview: does DM get perturbed via non-Gaussian perturbations? Linked to entropy

- **As presented in COMO Italy in July 2009 by Dr. Sabino Matarrese. Candidates for non –Gaussian perturbations:**

$$f_{NL} \equiv$$

- **Note linear Gaussian Gravitational potential**

$$\Phi_L \equiv$$

- **DM perturbations are from the overall gravitational potential**
- **DM perturbed by** $\Phi \equiv \Phi_L + f_{NL} \cdot \left[\Phi_L^2 + \left\langle \Phi_L^2 \right\rangle \right] + g_{NL} \cdot \Phi_L^3$

$$\delta \equiv -\left[\frac{3}{2} \cdot \Omega_m \cdot H^2 \right]^{-1} \cdot \nabla^2 \Phi$$

HFGWS in Quintessence inflationary models leads to

$$h_{rms} \sim 10^{-30} - 10^{-32} \Big/ \sqrt{Hz}$$

$$\nu \sim 10^{9} - 10^{10}\, Hz$$

Source: PRD article by Fangyu Li, et al. (2009)

- Next, we will refer to perturbations resulting due to the high frequency gravitational waves

Infinite Quantum statistics. Start with

$$Z_N \sim \left(\frac{1}{N!}\right)\cdot\left(\frac{V}{\lambda^3}\right)^N \qquad S \approx N\cdot\left(\log\left[V/N\lambda^3\right]+5/2\right)$$

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

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 , for volume

DM V (volume) for nucleation is HUGE. 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 $\Delta S \approx \Delta N_{gravitons}$

Some 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 $S \equiv \ln\Omega$

Derivation by Glinka explicitly uses the Wheeler De Witt equation Is there in any sense a linkage of Wheeler De Witt equation with String theory results ?

PROBLEM TO CONSIDER:

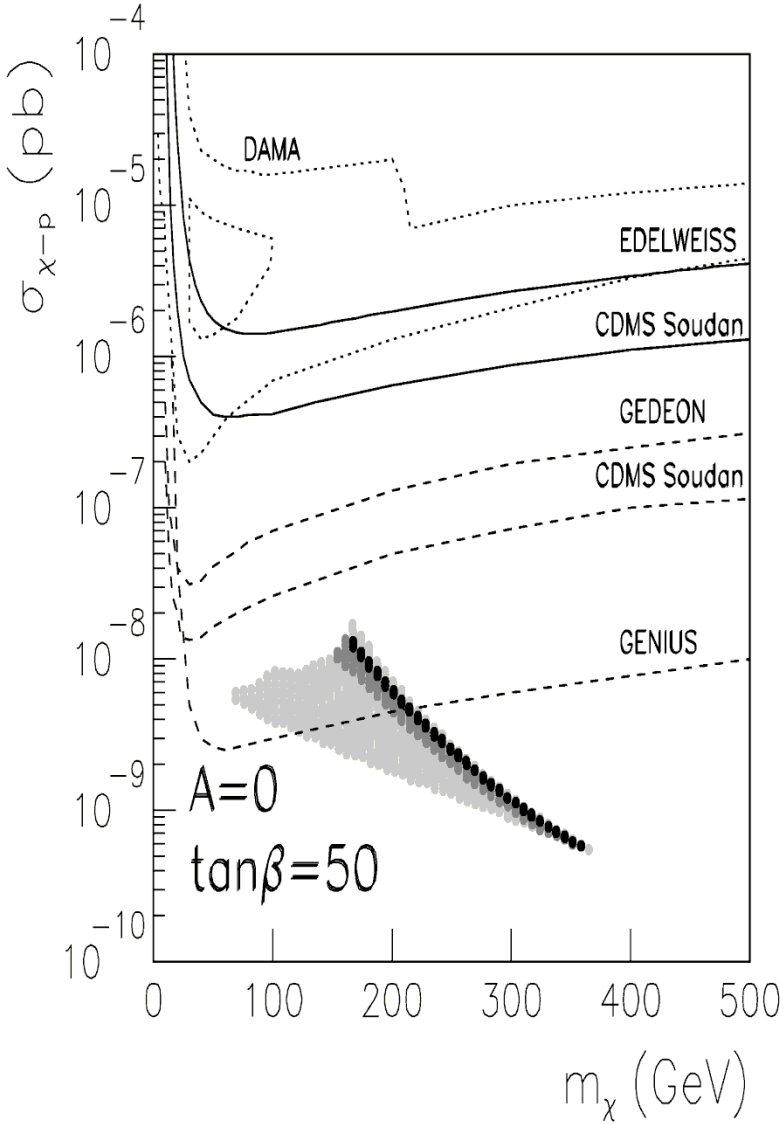
Ng's result quantum counting algorithm is a **STRING theory** result.Glinka is **Wheeler De Witt equation**. **Equivalent ?**

Questions to raise.

Can we make a linkage between Glinka's quantum gas argument, and a small space version/ application of Ng's Quantum infinite statistics ?

In addition, if the quantum graviton gas is correct, can we model emergent structure of gravity via linkage between Ng particle count, and Q.G.G argument?

Detection vs assumed mass of the DM



Consequences of this DM density variation, as discussed above. Partly due to damping due to GW and neutrino interactions (the halo merging tree for galaxy formation breaks down

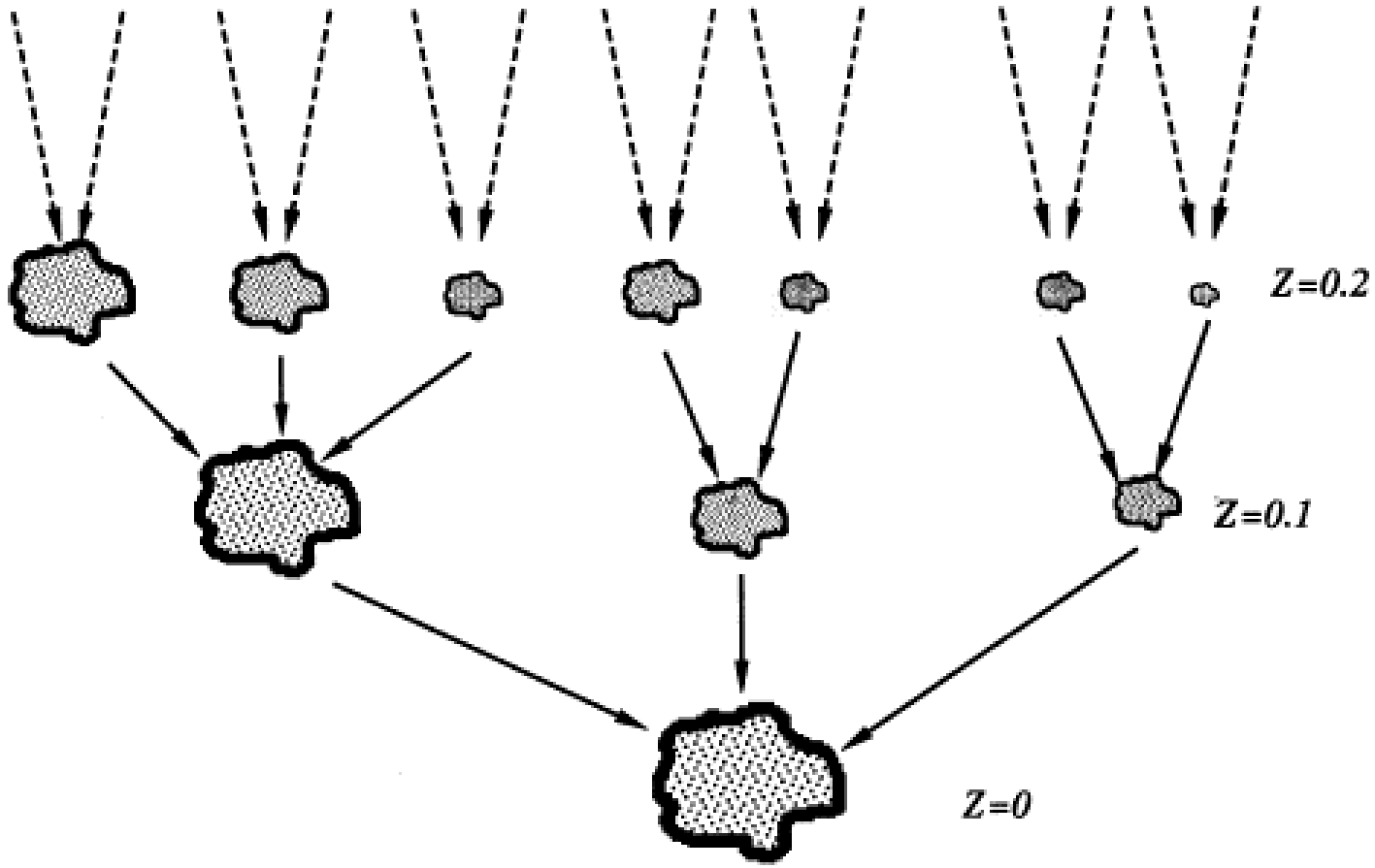


Figure 1. A schematic representation of a halo merging history 'tree'.

What is known

Experimental constraints:

Masses of the Higgs and superpartners, e.g. *mh* >114 GeV

$\sigma\big|_{Neutralino-DM}$ < 3×10^-8 pb

Supposition to investigate: consider a clump model of DM, as a profile density

- as given by **Berezinsky, Dokuchaev, and Eroshenko,** there is a power law for clumps of DM given, for galactic structure
- using
- $\tilde{\rho}$ as the mean clump density,

  R as mean radius of a clump , and r is spatial regions within the DM halo

- and

$$\beta \cong 1.8 - 2.0$$

- as a power law coefficient. This could be for MACHOS, which usually are ruled out via gravitational lensing. We are asking if the DM clump is composed of neutralinos. This would be a way of inferring an observational way of confirming

$$\rho_{\text{int}}(r) \equiv \frac{3-\beta}{\beta} \cdot \tilde{\rho} \cdot \left(\frac{r}{R}\right)^{-\beta}$$

Known

Neutralinos with masses **≈ (10-400) GeV** can be obtained within the reach of detectors. This may be sutiable for DM

- Can we use this to confirm-falsify the Ng hypothesis as given in slide 3 ?

- Can the neutralino candidates be part of the DM clumping as given in slide 7 ?

Neutrinos interacting with Gravitons

- Coupling enhanced -- wavelengths would initially be similar (short)
- Consequences for the Lithium problem in stars, due to stellar formation, and gravitational perturbation on DM
- The neutrino / gravitational wave interaction → damping relic GW intensity in CMBR

So what is the damping factor due to neutrinos interacting with GW, in CMBR perturbations?

According to Barvinsky (2005): a change on the order of

$$\left[1 - 5 \cdot \left(\rho_{neutrino} / \rho\right) + 9 \left[\rho_{neutrino} / \rho\right]^2\right]$$

First set of Open questions: Assume existence of SUSY neutralinos

- If a certain number of neutralinos of mass of at least 28 to 100 GeV is produced, as implied by G. Belanger (2004), the following needs to be investigated:

- Is there roughly a one-to-one correspondence between gravitinos, neutralinos , and relic gravitons, leading to in the first 1000 seconds ? $\Delta S \approx \Delta N_{gravitons} \approx 10^{20}$

  And if true, are there enough gravitinos and neutralinos to account for Jedamzik's (2008) data, indicating suppression of Lithium 6 and 7?

Second set of Open questions?

- Alejandro Jenkens, 2009, the author makes the same dimensional identification that of energy, and energy variation as carried by a graviton and as a way to show how gravitons are linkable to possible order of the Lorentz gravitational Lorentz violation.

$$p^0 \sim \bar{L} \cdot \mu \qquad \Delta E \sim \bar{L} \cdot \mu$$

- $$\bar{L} \sim (c - v)/c$$
- Note that for the degree of Lorentz violation which involve gravitons with a dispersion relationship of , where is a speed of propagation of the graviton. Note that the linkage of dispersion relationships of the graviton specifically are linked to a non relativistic treatment of the graviton. Also, left unsaid as a variance is how the strength of the energy interaction,occurs, and is set . Can the Lorentz gravitational
- Violation , as given below, lead to at high speeds,

$$\mu / M_{Planck} \sim \bar{L}$$

- and for physics approaching SM

$$\bar{L} \xrightarrow[approach-to-s\tan dard-\mathrm{mod}el-physics]{} 0$$

When velocity does not = c

- For low speeds,

$$\overline{L} \neq 0$$

(flat space not required)

Does this mean that initial emergence of gravitons was low energy, and then picked up energy due to massive projection of emergent space time at the beginning of a new universe:

UNKNOWN !

When neutrinos and gravitons inter mix in higher velocities, part 1

The graviton wave length shrinks in magnitude to the value of Neutrino Wave lengths which may aid in early universe actual inter mixture of graviton-neutrino physics in high velocity situations.

$$m_{graviton}\Big|_{NON-RELATIVISTIC} \leq 4.4\times10^{-22}\,h^{-1}eV/c^2 \Leftrightarrow \lambda_{graviton} \equiv \frac{\hbar}{m_{graviton}\cdot c} \sim 2.8\times10^{15}\,meters$$

$$m_{graviton}\Big|_{RELATIVISTIC} < 4.4\times10^{-22}\,h^{-1}eV/c^2 \Leftrightarrow \lambda_{graviton} \equiv \frac{\hbar}{m_{graviton}\cdot c} < 2.8\times10^{-8}\,meters$$

Leading to asking

Does higher velocity mean less graviton Lorentz invariance break down and

- $$\bar{L} \sim [(c-v)/c] \approx \left[\frac{\mu}{M_{Planck}}\right]$$

$$\xrightarrow[\substack{relativistic-conditions-for-graviton-speed,\\ \mu \to 0}]{} 0$$

When neutrinos and gravitons intermix in higher velocities, part 2

- As the wavelength of a graviton shrinks…

$$m_{graviton}\Big|_{RELATIVISTIC} < 4.4\times10^{-22}\, h^{-1} eV/c^2 \Leftrightarrow \lambda_{graviton} \equiv \frac{\hbar}{m_{graviton}\cdot c} < 2.8\times10^{-8}\, meters$$

- The wavelengths of gravitons, neutrinos in early relic conditions when they mix during the matter-radiation era may be approximately the same.

Consequences of neutrino-graviton wavelength overlap ?

Leading to actual **DAMPING** of perturbations, and also more structural complexity, which may lead to asking and answering the following question…

Why do some of the first stars have no lithium?

Changing nucleosynthesis?

MAIN QUESTION:

DO WE REALLY UNDERSTAND
THE BIG BANG?

What the speaker is investigating: Graviton-neutrino mixing may affect

- In addition, lithium free stars were referenced in Astronomy & *Astrophysics* (Vol 388(3), L53: June IV, 2002). **...** *LITHIUM-FREE STARS PLUG HOLE IN BIG BANG.*

- (after BBN, and prior to modification) different abundances of these nuclei ????

The question remains: what can be made of traditional nucleosynthesis theory and the big bang?

<u>The traditional story, which up to a point WORKS:</u>

- **1st Usually at a few MeV** values for decreasing early temperature after the big bang, it is expected, according to Matt Roos (2003), **that fusion reactions begin to build up light elements.**
- **2nd** Note that Big Bang Nucleosynthesis (**BBN**) is the **synthesis of the light nuclei, Deuterium, 3He, 4He and 7Li during the first few minutes of the universe.**

My final points

1st **Note that the datum Barvinsky brought up, in 2005, about neutrino - graviton intermixture damping is NOT usually brought up and needs to be INVESTIGATED**

2nd **In " Quantum Coherence of Relic Neutrinos" G. Fuller and C. Kishimoto (2009) presents 'Coherence scale of Neutrino flavor wave packets' as a way to quantify pre decoupling equilibrium, plus expansion of the universe**

These two ideas are inter related and need to be modeled properly. Will attempt to do just that.

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