Influence of a gravitationally induced phase on neutrino oscillation and Baryogenesis

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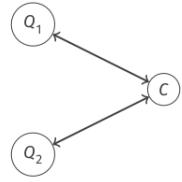
Outline

- Motivation
- Basics
- Phase shift of neutrino oscillation due to entanglement
- Baryogenesis via neutrino oscillation
- Outlook

Motivation

- No uncontroversial proposal for quantum gravity
- Does gravity have to be quantized at all?
- Experimental evidence that gravitational field has quantum properties?

Entanglement as a hint for quantum effects



- If two Systems get entangled due to interaction with mediator →Mediator has to be quantum![1]
- Now: Gravitational interaction of two heavy, sterile neutrinos in the early universe!
- Interaction should change phase in transition probability
- Evidence for quantum gravity effects in neutrino oscillation?

[1] C. Marletto, V. Vedral und D. Deutsch. In: (2018).

General transition probabilities of neutrino oscillation

- For one neutrino in gravitational interaction with a neutrino background

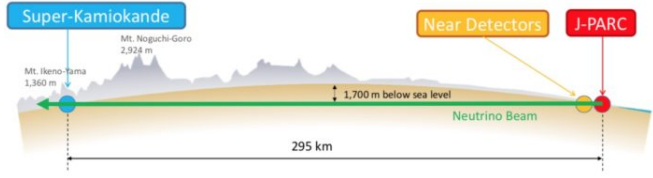
$$\bar{P}_{\alpha\to\beta} = \delta_{\alpha\beta} - 4\sum_{A>C} \mathrm{Re}\left(U^*_{\alpha A}U_{\alpha C}U_{\beta A}U^*_{\beta C}\right)\sum_B p_B \sin^2\left(\Delta\epsilon^{BB}_{AC}\frac{t}{2}\right) + 2\sum_{A>C} \mathrm{Im}\left(U^*_{\alpha A}U_{\alpha C}U_{\beta A}U^*_{\beta C}\right)\sum_B p_B \sin\left(\Delta\epsilon^{BB}_{AC}t\right)$$

- P_B: Probability that mass eigenstate B occurs in background
- Energy eigenvalue differences:

$$\Delta\epsilon^{BB}_{AC} = \epsilon^B_A - \epsilon^B_C = E^{(1)}_A + E^{(2)}_B - \frac{G}{d}m_A m_B - E^{(1)}_C - E^{(2)}_B + \frac{G}{d}m_C m_B$$

Difference of the transition probability

- Phase shift of transition probability due to gravitational interaction!
- Effects are very small but may be measurable →Formula needs to be modified to apply for experiment. →For example T2K.
- Influence on Baryogenesis?



https://t2k-experiment.org/t2k/

Baryogenesis via neutrino oscillation

- Big question: Origin of baryon asymmetry[2]
- One possiblity: Baryogenesis via neutrino oscillation
- New formula for baryon asymmetry with modified neutrino oscillation
  $\rightarrow$Very little effect on baryogenesis

[2] E. Kh. Akhmedov, V. A. Rubakov und A. Yu. Smirnov. In: (1998). arXiv: hep-ph/9803255.

Summary and Outlook

- Influence of gravitationally induced phase on neutrino oscillation
- If phase is experimentally detectable $\rightarrow$Confirmation of quantum gravity
- Very little effect on baryogenesis.
- To be studied: Comparison of experiment sensitvity with phase. $\rightarrow$Mass limit for neutrinos?
- Effect of a reduced Planck scale, e.g. in theories with large extra dimensions.