COLLECTIVE NEUTRINO OSCILLATIONS ACCOUNTING FOR NEUTRINO QUANTUM DECOHERENCE

V.BOKOV[1], K.STANKEVICH[1], A.STUDENIKIN[1,2]

[1]*MOSCOW STATE UNIVERSITY*
[2]*JOINT INSTITUTE FOR NUCLEAR RESEARCH, DUBNA*

KL.STANKEVICH@PHYSICS.MSU.RU

40th International Conference on High Energy Physics (2020)
30 Jul - 5 Aug, Prague, Czech Republic

July 29, 2020

Supported by the Russian Foundation for Basic Research under grants No. 20-52-53022-GFEN-a

QUANTUM DECOHERENCE IN THE NEUTRINO PHYSICS

Neutrino quantum decoherence is the effect engendered by the violation of the superposition of different neutrino states.

Experimental studies of the neutrino quantum decoherence

Reactor neutrinos

A.Capolupo,S.M.Giampaolo,G.Lambiase, Phys.Lett.B 792 (2019)298
J.A.B.Coelho, W.A.Mann, S.S.Bashar, *Phys.Rev.Lett.118* (2017)221801
Y.Farzan, T.Schwetz, A.Y.Smirnov, J. High Energy Phys. (2008) 067
G.Barenboim et al, *Nucl.Phys.B* 758 (2006) 90

Solar neutrinos

P.C. de Holanda, *JCAP 03* (2020) 012

Atmospheric neutrinos

E.Lisi, A.Marrone, D.Montanino, *Phys.Rev.Lett.85* (2000) 1166

Theoretical studies of the neutrino quantum decoherence

Matter fluctuations

C.P.Burgess, D.Michaud, *Ann. Phys.* (1997) 256
F. Benatti, R. Florianini, *Phys. Rev. D 71* (2005) 013003

Neutrino radiative decay

K. Stankevich, A. Studenikin, *Phys.Rev.D 101* (2020) 056004
K. Stankevich, A. Studenikin, *J.Phys.Conf.Ser.* 1468 (2020) 012148
K. Stankevich, A. Studenikin, *J.Phys.Conf.Ser.* 1342 (2020) 012131
K. Stankevich, A. Studenikin, *PoS ICHEP2018* (2019) 925
K. Stankevich, A. Studenikin, *PoS EPS-HEP2017* (2018) 645

Non-forward scattering

J.F.Nieves, S.Sahu, *Phys. Rev.D 100* (2019) 115049
J.F.Nieves, S.Sahu, *Phys.Rev.D* 99 (2019) 095013

INFLUENCE OF THE NEUTRINO QUANTUM DECOHERENCE ON COLLECTIVE NEUTRINO OSCILLATIONS

Master equations for neutrino density matrix

$$i\frac{d\rho_f}{dt} = [H, \rho_f] + D[\rho_f]\,, \qquad i\frac{d\bar{\rho}_f}{dt} = [\bar{H}, \bar{\rho}_f] + D[\bar{\rho}_f]$$

Hamiltonian

$$H = H_{vac} + H_M + H_{\nu\nu}$$

Dissipative term (in the Lindblad form)

$$D\left[\rho_{\tilde{m}}(t)\right] = \frac{1}{2}\sum_{k=1}^{3}\left[V_k, \rho_{\tilde{m}}V_k^{\dagger}\right] + \left[V_k\rho_{\tilde{m}}, V_k^{\dagger}\right]$$

Linearized (in)stability analysis

D.Väänänen, G.McLaughlin, *Phys.Rev.D* 93 (2016) 1050

Supernovae model

C.J.Stapleford et al, Phys. Rev. D 94 (2016) 093007

Stability equation

$$(\omega - i\Gamma_1)\begin{pmatrix}\rho'_{12}\\ \bar{\rho}'_{21}\end{pmatrix} = \begin{pmatrix}A_{12} & B_{12}\\ \bar{A}_{21} & \bar{B}_{21}\end{pmatrix}\begin{pmatrix}\rho'_{12}\\ \bar{\rho}'_{21}\end{pmatrix}$$

Conditions for collective neutrino oscillations (bipolar/nutations)

$$\begin{cases}(A_{12} - \bar{A}_{21})^2 + 4B_{12}\bar{B}_{21} < 0,\\ \mathcal{I}m\left((A_{12} - \bar{A}_{21})^2 + 4B_{12}\bar{B}_{21}\right) > \Gamma_1.\end{cases}$$

Elements of the stability matrix

$$A_{12} = (H^0_{11} - H^0_{22}) - \frac{\partial H_{12}}{\partial \rho_{12}}(\rho^0_{11} - \rho^0_{22}),$$
$$B_{12} = \frac{\partial H_{12}}{\partial \bar{\rho}^0_{21}}(\rho^0_{22} - \rho^0_{11}),$$
$$\bar{A}_{21} = (\bar{H}^0_{22} - \bar{H}^0_{11}) - \frac{\partial \bar{H}_{21}}{\partial \bar{\rho}_{21}}(\bar{\rho}^0_{22} - \bar{\rho}^0_{11}),$$
$$\bar{B}_{21} = \frac{\partial \bar{H}_{21}}{\partial \rho^0_{12}}(\bar{\rho}^0_{11} - \bar{\rho}^0_{22}).$$

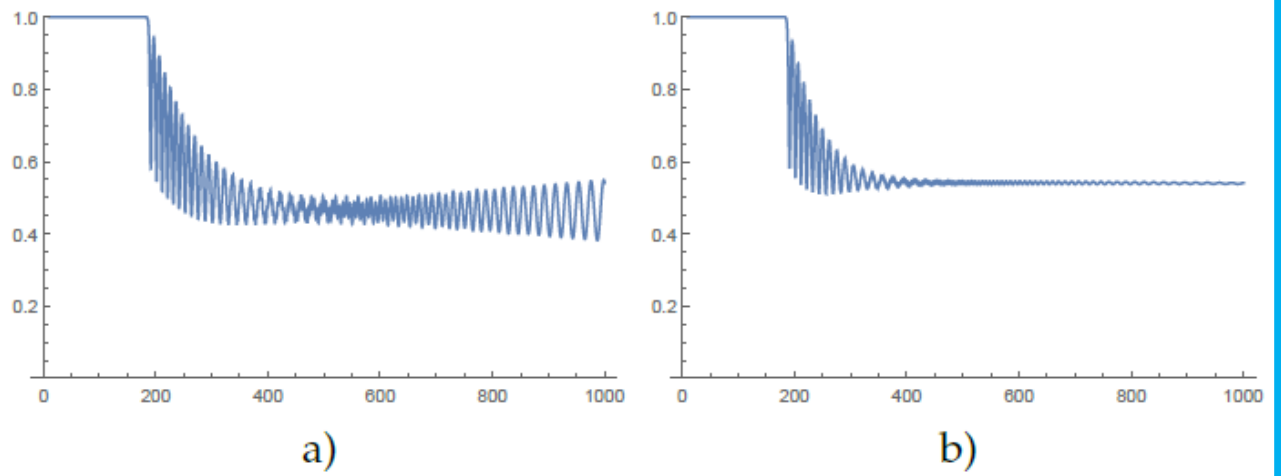

Figure 1: The survival probability of the electron neutrino in the absence of quantum decoherence (a) and for the case when the neutrino decoherence parameter is $\Gamma_1 = 10^{-21}$ GeV (b).

CONCLUSION

1) We considered for the first time the **interplay** of two effects: **neutrino quantum decoherence** and **collective neutrino oscillations**.

2) We derived **new conditions** of the existence of the **collective bipolar neutrino oscillations** that accounts the **neutrino quantum decoherence**.

3) The **importance** of the neutrino quantum decoherence studies are highlighted by new opportunities for a searching of **physics beyond the standard model** in astrophysical and terrestrial neutrino fluxes.