Origin of Ultra High-Energy Neutrinos via Heavy-Meson Synchrotron Emission in Strong Magnetic Fields [1]

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We studied the generation of heavy-meson synchrotron emission due to the acceleration of ultra-relativistic protons (and possibly nuclei) in the presence of strong magnetic fields ($H \gtrsim 10^{15}$ G) in transient astrophysical environments such as magnetar flares. We then discovered that, in addition to the well known pion synchrotron emission, heavy vector mesons like ρ, D_S, J/Ψ and Υ could be generated with high intensity (~10^3 times the photon intensity) through strong couplings to the ultra-relativistic nucleons in the strong magnetic field.

We propose in particular the synchrotron emission and subsequent cooling and decay of the heavy ρ^0 and $\Upsilon(1S)$ mesons by the burst of energetic neutrinos, via $p \rightarrow p' + \Upsilon(1S)$, $\Upsilon(1S) \rightarrow \tau^+ + \tau^-$, $\tau^- \rightarrow \mu^- + \bar{\nu}_\mu + \nu_\tau$ and $e^- + \bar{\nu}_e + \nu_\tau$. We evaluate the spectra of escaping ν_e, ν_μ and ν_τ due to the decay of short lived τ-mesons.

We conclude the possible event rate in a terrestrial PeV neutrino detector like ICECUBE [2]. We estimate that neutrinos produced from the heavy vector-meson synchrotron radiation from a strong magnetar SGR burst will only be detectable with the current generation of detectors if the source is very nearby (< 30 pc). Nevertheless, if ever detected, the existence of heavy meson synchrotron emission might be identifiable by the unique signature of energetic tau neutrinos.

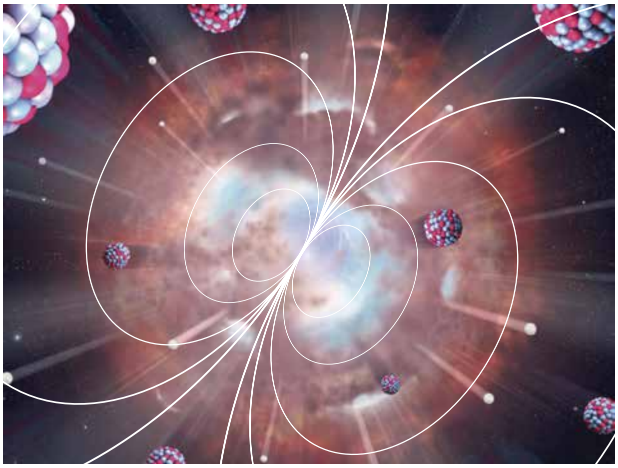

Figure 1: Illustration of meson synchrotron emission from magnetar flares that interact with ultra-relativistic baryons. Heavy mesons like $\Upsilon(1S)$ eventually decay to emit a burst of energetic neutrinos, via $p \rightarrow p' + \Upsilon(1S)$, $\Upsilon(1S) \rightarrow \tau^+ + \tau^-$, $\tau^- \rightarrow \mu^- + \bar{\nu}_\mu + \nu_\tau$ and $e^- + \bar{\nu}_e + \nu_\tau$.

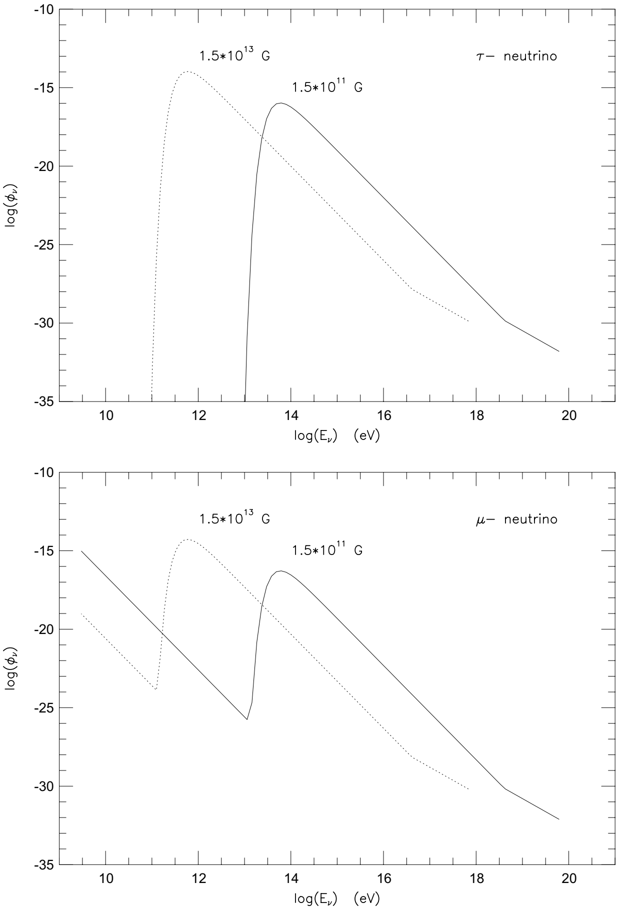

Figure 2: Upper (lower) graph is the calculated flux at the source of τ-neutrinos (μ-neutrinos) and their anti-particles as the decay product of $\Upsilon(1S)$-mesons. The solid curve shows the spectrum for an injection energy of $E_{\Upsilon(1S)} = 10^{20}$ eV with a magnetic field of $H = 1.5 \times 10^{11}$ G, and the dashed curve is for $E_{\Upsilon(1S)} = 10^{18}$ eV with $H = 1.5 \times 10^{13}$ G. In μ-neutrino spectrum the hard- and soft-energy components arise from the decay of $\tau^\pm$-leptons and dissipated $\mu^\pm$-leptons, respectively.

References

[1] Kajino, T., et al.: 2014, *ApJ*, **782**, 70.
[2] Aartsen, M. G., et al. (The IceCube Collaboration): 2013, *Phys. Rev. Lett.*, **111**, 021103.