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Astrophysical Limits on the Neutrino Electric Charge

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It was recently shown that the bunching in time of the neutrinos detected from SN1987A in LMC implies among other things that the neutrino electric charge q is 10^{-17} times as small as the electron charge. We point out that limits on q several orders more stringent than this can be obtained from other astrophysical considerations, for neutrinos with small rest mass.

The detection of about a dozen neutrinos of over 7 MeV all within about ten seconds from SN1987A in the LMC, 50 kpc away has been used by many authors to constrain the electron neutrino rest mass to less than 10 eV. However in a recent paper,[1] it was shown that the bunching in time of the neutrinos also indicates that their charge, q is about 10^{-17} times as small as the charge of the electron. For q larger than this limit the galactic magnetic field would lengthen the neutrino paths so that neutrinos with different energies could not arrive on the earth within a few seconds of each other, the radius of curvature of the trajectory is $\approx E/Bq$ for neutrinos of energy E so that there would be a difference in trajectory lengths and thus in arrival times. The time spread of a few seconds therefore enables a stringent limit of $q/e < 2\times10^{-17}$ to be placed on q, e being the electron's electric charge. This limit obtained from SN1987A neutrinos is substantially smaller than the limit $q/e \geq 10^{-13}$ obtained from arguments on solar energy losses.[2] We point out that limits on the neutrino charge several orders more stringent than the limits from SN1987A can be obtained if one assumes that neutrinos with small rest mass ($m_\nu \approx 10$ eV) constitute the bulk of the dark matter in galactic halos and clusters. As this matter is gravitationally bound, the simple requirement that the gravitational attraction of the system should be larger than the electrostatic repulsion due to the neutrino charge (if any) gives (i.e., the particles with charge q are assumed to cluster spherically with uniform density in the galactic gravitational field)

$$Gm_\nu^2 N_\nu^2 r^{-1} > q^2 N_\nu^2 r^{-1}\,, \tag{1}$$

N_ν being the total number of neutrinos assumed to contribute to the bulk of the matter. In terms of the electron's electric charge e this gives the constraint:

$$q/e < (Gm_\nu^2/e^2)^{1/2}\,, \tag{2}$$

which for $m_\nu \approx 10$ eV yields $q/e < 10^{-26}$, many orders more stringent than the tightest limit $q/e < 2\times10^{-17}$ calculated in Ref. 1) for SN1987A neutrinos. The above limit becomes even more stringent with smaller neutrino masses as q/e can be seen to scale linearly with m_ν (from Eq. (2)).

A somewhat more stringent limit can also be deduced by requiring the neutrinos having $m_\nu \approx 10$ eV and virial velocities of $V \approx 300$ km/sec to have radii of curvature

R of about 5 or 10 kpc in the galactic magnetic field so that they can cluster around at that distance and constitute the bulk of the dark matter in the galactic halo.

We thus have:

$$R \approx m_\nu V / B_G q\,, \tag{3}$$

which in terms of the electron charge e can be written:

$$q/e \approx \frac{m_\nu V}{B_G e R}\,. \tag{4}$$

For the galactic magnetic field $B_G \simeq 10^{-6}$ gauss, $R \simeq 10$ kpc $\simeq 3 \times 10^{22}$ cms and the above values of m_ν and V we get the limit:

$$q/e \simeq 2 \times 10^{-32}\,. \tag{5}$$

The limit given by Eq. (5) is 17 orders more stringent than that implied by the SN1987A neutrinos! This limit also scales linearly with m_ν so that it would become even more stringent with smaller neutrino masses and larger scale structures (as in Eq. (4)) if their mass is also assumed neutrino dominated. The limit given by Eq. (5) is comparable with the stringent bound on the net excess of charge per baryon, constrained to be below $\sim 10^{-30}$ from arguments involving the isotropy of cosmic rays, i.e., anisotropy induced by electric fields.[3] In these arguments for isotropy of high energy cosmic rays of energy E, one requires the product of the coherence length and the field to be less than E giving the constraint of $\sim 10^{-30}$.

Faraday rotation and scintillation effects as well as other related phenomena are too small by far in the case of neutrinos, to be measurable, and therefore for any useful limits to be put on q/e.

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1) G. Barbiellini and G. Cocconi, Nature **329** (1987), 21.
2) J. Bernstein and M. Ruderman, Phys. Rev. **132** (1963), 1227.
3) S. Orito and M. Yoshimura, Phys. Rev. Lett. **54** (1985), 2457.