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### P4.034 Astrophysical probes of electromagnetic neutrinos

C Giunti<sup>1</sup>, K A Kouzakov<sup>2</sup>, Y-F Li<sup>3</sup>, A V Lokhov<sup>4</sup>, A I Studenikin<sup>5,6</sup> and S Zhou<sup>3</sup>

<sup>1</sup>INFN, Sezione di Torino, Italy, <sup>2</sup>Lomonosov Moscow State University, Russia, <sup>3</sup>Chinese Academy of Sciences, China, <sup>4</sup>Russian Academy of Sciences, Russia, <sup>5</sup>Lomonosov Moscow State University, Russia, <sup>6</sup>Joint Institute for Nuclear Research, Russia

The importance of neutrino electromagnetic properties was first mentioned by Pauli in 1930, when he postulated the existence of this particle and discussed the possibility that it might have a magnetic moment. Systematic theoretical studies of neutrino electromagnetic properties started after it was shown that in the extended Standard Model with right-handed neutrinos the magnetic moment of a massive neutrino is, in general, nonvanishing and that its value is determined by the neutrino mass. Detection of neutrinos from astrophysical sources can provide excellent probes of their electromagnetic properties. Large future liquid-scintillator detectors will improve the precision of low-energy solar neutrino measurements in the neutrino-electron scattering process and can give better limits on the neutrino magnetic moments. Supernova neutrinos are sensitive to the neutrino electromagnetic properties in the presence of strong magnetic fields. The spin-flavor process can constrain the neutrino magnetic moments. For Majorana neutrinos, non-trivial collective effects relating neutrinos and antineutrinos of different flavors can place stringent limits on transition magnetic moments as small as  $10^{-22} \mu_B$ . Therefore, with future observation of solar and supernova neutrinos with improved precision, the prospects of astrophysical probes of electromagnetic neutrinos appear to be very promising.