PRODUCTION AND INTERACTION OF HIGH ENERGY NEUTRINOS IN CLOSE X-RAY BINARIES

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ABSTRACT. Reports of air showers with $E > 10^{15}$ eV from Cygnus X-3, LMC X-4, Vela X-1 and Hercules X-1 have been interpreted as requiring production of neutral secondaries by cosmic rays accelerated by the compact partner in these systems. If neutral pions are the source of photons that produce the observed air showers, then charged pions must also be produced, and they will give rise to neutrinos. We consider limits that may be placed on binary systems like Cygnus X-3 in which a neutron star is a strong source of ultra-high energy (UHE) particles that produce photons, neutrinos and other secondary particles in the companion star through nuclear interactions. The highest energy neutrinos (> 1 TeV), which have the largest interaction cross sections, are absorbed deep in the companion. From a detailed numerical calculation of the hadronic cascade induced in the atmosphere of the companion star, we estimate the neutrino production spectrum from an isotropic flux of monoenergetic 10^{17} eV protons and we estimate the resulting neutrino absorption in the stellar core. In the case of Cyg X-3 and LMC X-4, the cosmic-ray luminosities required to produce the observed gamma rays would result in energy deposition from neutrino absorption exceeding the intrinsic stellar luminosity of the companion. Over a timescale of 10^4-10^5 yr, the star would absorb its own binding energy and be disrupted. On shorter timescales, the energy deposition will cause significant expansion of the star, perhaps leading to quenching of high-energy signals from the source. From these results, we conclude that systems requiring intense UHE proton fluxes are either very young or the companion star is not the site of observed gamma-ray production. Alternatively, if the gamma-ray source is highly variable, the proton flux requirements would be lower, providing some relaxation of the above constraints.
[See Gaisser et al. 1986, Ap. J. (Oct. 15), in press].

D. J. Helfand and J.-H. Huang (eds.), The Origin and Evolution of Neutron Stars, 552.