NEUTRINO EMISSION FROM GALAXIES AND MECHANISMS FOR PRODUCING RADIO LOBES

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ABSTRACT

In the context of the proposed DUMAND-type detector for high-energy neutrinos, it is important to estimate the neutrino fluxes from powerful radio galaxies. This would indicate whether a detectable event rate can be expected, and would help choose among possible mechanisms for generating the radio lobes associated with many such galaxies. Among the models that have been proposed are: (a) a beam from the galactic core that interacts with the extragalactic medium; (b) ejection of clouds of plasma, particles, and magnetic fields into the lobes, either in an explosive burst, or by diffusive escape; (c) black holes or spinars ejected from the galactic nucleus by a gravitational slingshot mechanism.

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Many large elliptical galaxies have a prolific central energy source that gives rise to a pair of radio lobes. The total energy estimates for the relativistic particles and magnetic fields in these lobes are $\approx 10^{56}$ to 10^{61} ergs. Various models have been proposed for the generation of radio lobes:

(a) A relativistic beam of particles emitted along the axis of rotation (Scheuer 1974; Blandford and Rees 1974; Wiita 1978). A beam model invoking a massive black hole as the power source (Lovelace 1976). (b) Two oppositely directed clouds of thermal plasma, relativistic particles and magnetic fields that are confined by ram pressure (DeYoung and Axford 1967; Sturrock and Barnes 1972; Sanders 1976). Two special cases of this model have been suggested, one in which a large amount of energy builds up at the galactic nucleus and is then ejected in explosive bursts, and another in which the particles within the plasmons are emitted diffusively from the galactic nucleus. (c) Massive condensed objects are ejected from the galactic nucleus by a gravitational slingshot mechanism (Saslaw, Valtonen, Aarseth 1974). We shall here explore how observations of neutrinos can help to discriminate among the various models.

As an example we calculate the neutrino flux from Cen A. We shall try the alternative proton energy spectra characterized by exponents $\alpha = 2.35$ and $\alpha = 2.0$ at energies > 1 GeV. For each of these power laws,

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we shall assume alternative values of 1 and 10 for the ratio q_{pe} of energy input into protons to that into electrons. For confinement prior to the outburst, we adopt the conservative value $\bar{x} = 4$ g/cm^2. This could be considerably higher.

A value of $\bar{x} \approx 4$ g/cm^2 can be inferred in the case of diffusive escape of protons. DeYoung (1976) reports that the extended radio sources have separation velocities of ∿ 0.1. Assume that the outward diffusion of the cosmic-ray gas from the galactic center proceeds with the same velocity, though the emission velocity of the radio lobes vs. distance from the galaxy is model dependent. We adopt 0.2 g/cm^2 as the path length for straight-line escape (Sanford and Ives 1976), a value based on observed X-ray absorption. Then we get a mean path length $\bar{x} = 4$ g/cm^2. For relatively free escape, we assume a path length of 0.4 g/cm^2, twice the value for linear traversal from the source to our galaxy.

Table 1 shows how observations with DUMAND could help differentiate between models of proton confinement with explosive bursts (or with diffusive escape).

Table 1.

Annual Event Rates of Neutrinos ($E > 4 \times 10^{12}$ eV) from Cen A for Two Models* (I and II) of Radio-Lobe Production

Parameter Values		Neutrino Events per Year	
α	q_{pe}	I: ($\bar{x} = 4$ g/cm^2)	II: ($\bar{x} = 0.4$ g/cm^2)
2.35	1	∿2	∿0.2
2.35	10	∿20	∿2
2.0	1	∿100	∿10
2.0	10	∿1000	∿100

*Model I: Confinement and explosive burst, or diffusive escape.
Model II: Free escape in a beam. (The detector is assumed to have an effective volume of 10^{10} tons of water for observing ν_μ and $\bar{\nu}_\mu$, and a volume of 10^9 tons for ν_e and $\bar{\nu}_e$).

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