THE NEXT STAGE OF DUMAND

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ABSTRACT

Observations of PeV γ-rays from Cygnus X-3 and other binary X-ray systems imply that ν_μ's of comparable levels are also being emitted from these sources. A flux of one event per year per 1000 m^2 is estimated from Cygnus X-3, implying the need for detector areas above 10^4 m^2. The DUMAND collaboration is proposing a Stage II array which should approach the desired minimum goal of 10^4 m^2.

1. **Introduction**. The PeV γ-rays which have been reported from Cygnus X-3, and with less confidence from other x-ray binary systems [1], strongly imply that *hadronic* processes are responsible. That is, the neutron stars in these binary systems are *natural accelerators* of protons to energies as high as 10^{17} eV; the observed γ-rays result from the decay of π^0's which are produced when these protons strike matter in the companion star or pulled from the star by the gravitational attraction of the neutron star. It follows that fluxes of ν_μ's comparable to the observed γ fluxes exist from these sources, resulting from the decay of the charged mesons which will also be copiously produced [2]. Those ν_μ's above 1 TeV can interact in the earth producing muons with ranges of hundreds of meters w.e. Thus any underground or undersea muon detector is a potential neutrino telescope.

Calculations for Cygnus X-3 indicate that one can expect an event rate of about one event per year per 1000 m^2 of effective muon detection area from this highly-studied source [3]. Most of the muons will have energies above 100 GeV and be within a fraction of a degree of the original neutrino's direction. Thus a neutrino telescope with an area of the order of 10^4 m^2 and a muon angular resolution of 1^o would have an excellent prospect for making the first detection of neutrinos from beyond the solar system. Smaller detectors may have a chance if Cygnus X-3 is significantly more productive in ν_μ's than γ-rays or if there are other more powerful sources.

Current underground cosmic ray and proton-decay experiments also double as neutrino telescopes, although the latter emphasize volume rather than area and so tend not to be well-optimized for this purpose. The largest of these is the IMB proton decay detector in Cleveland, with an effective area for through-going muons of about 400 m^2 [4]. No neutrino source detections have been reported by this or the other smaller experiments. Of the next generation underground experiments being developed at this time, only the MACRO experiment at Gran Sasso [5] has greater area, 1400 m^2.

2. DUMAND: The Second Stage. The 1982 DUMAND proposal [6] envisaged an array of 748 photomultiplier detector modules in a 250X250X500 m^3 volume located at a depth of 4500 m at the bottom of the ocean off the coast of the island of Hawaii. The 10^5 m^2 effective area of this array would give 100 neutrino vents per year from Cygnus X-3, according to the calculations mentioned in the previous section. Stage I of the project , the *Short Prototype String (SPS)*, is now complete; the results are reported elsewhere in these proceedings.

For the next stage, the DUMAND Collaboration proposes to build upon what we have learned and deploy an instrument on the ocean bottom. One proposal is to simply replicate the string of seven detector modules and associated instrumentation developed for the SPS and deploy three similar strings on the ocean bottom. This configuration has been dubbed the **TRIAD**. If the optical detectors are moved further apart vertically, to 15 m, and the strings are spaced about 20 m apart, then an effective detection area of 3000 m^2 and muon angular resolution of perhaps 5° are estimated [7].

However, a more desirable design goal would be 10^4 m^2 effective area and 1° muon angular resolution. The latter would be comparable to multiple scattering and achieve the best possible directional information on the source. Further, this detection area is an order of magnitude better than any other existing or planned experiments and would make the detection of neutrinos from sources such as Cygnus X-3 possible, if the predictions mentioned above are reliable. Preliminary Monte Carlo simulations indicate that these requirements can be accomplished with fewer than 100 detector modules of the type already developed, arranged on 4-6 vertical strings

In one example which has been studied in some detail, 64 optical detectors are arranged in four vertical strings 30 m apart, with a vertical 15 m spacing of the 16 modules on each string. Using a triggering scheme which reduces the rate of accidental triggers and fake muons from the various backgrounds to an acceptable level, an effective area of 7000 m^2 and angular resolution of 2° in zenith and 6° in azmuth is achieved [8]. Further work is in progress to determine how much this configuration must be expanded to achieve the desired goals and whether such a plan is feasible for the next stage. Also under study is the the possibility of other configurations not based on the string concept [9].

In all these Stage II schemes, a single electro-optical cable with multiple optical fibers would connect the array to shore, carrying power and commands from the shore laboratory and transmitting signals to that lab at an extremely high data rate. Such a cable is currently under design. Deployment will be difficult but appears feasible, at least for the string-based configurations. Fortunately, these are the only elements requiring extensive development in this case since the basic detector modules and the other instrumentation to be placed on the strings have already been built for the SPS. It is anticipated that these can be produced without significant changes in design.

*DUMAND is a collaboration of the University of Hawaii, the Instutute for Cosmic Ray Research of the University of Tokyo, Caltech, University of California at Irvine, Scripps Institution of Oceanography, University of Wisconsin, Purdue University, Vanderbilt University, Kiel University and Bern University.

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