

## THE HOMESTAKE SURFACE-UNDERGROUND SCINTILLATORS -- INITIAL RESULTS

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The first 70 tons of the 140-ton Large Area Scintillation Detector have been operating since Jan. 1985 at a depth of 4850 ft. (4200 m.w.e.) in the Homestake Gold Mine, Lead, S.D. A total of  $4 \times 10^4$  high-energy muons ( $E_{\mu} \geq 2.7$  TeV at the surface) have been detected. The remainder of the detector is scheduled to be in operation by the Fall of 1985. In addition, a surface air shower array is under construction. The first 27 surface counters, spaced out over an area of 270' x 500', began running in June, 1985. We describe the LASD performance, discuss the potential of the combined shower array and underground muon experiment for detecting point sources, and present the initial results of a search for periodic emission from Cygnus X-3.

## I. Detector Status

Underground, the Large Area Scintillation Detector will be used to detect high-energy muons, slow monopoles, and neutrinos<sup>1</sup>. The detector consists of 140 tons of liquid scintillator housed in 200 PVC boxes, each 30 cm x 30 cm x 8 m, placed around the outside of the <sup>37</sup>Cl solar neutrino detector of Davis et al.<sup>2</sup> at a depth of 4850 ft. in the Homestake Gold Mine (Fig. 1). The surface array currently consists of twenty-seven 3 m<sup>2</sup> x 4" thick liquid scintillation detectors, spaced by 15 - 25 m over an area of 80 x 150 m<sup>2</sup>. The surface and underground

detectors are currently being operated both independently and in coincidence in order to study the cosmic ray composition near  $10^{15}$  eV and to search for high energy sources. The detectors have been described elsewhere in these Proceedings<sup>1</sup>. Here we discuss the potential of the surface-underground telescope to see point sources with high angular resolution, and illustrate the initial

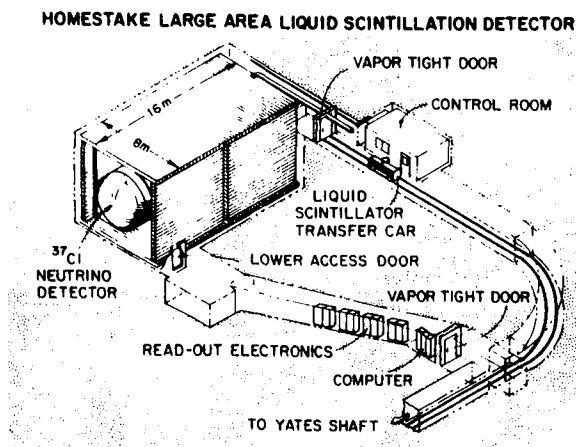


Fig. 1

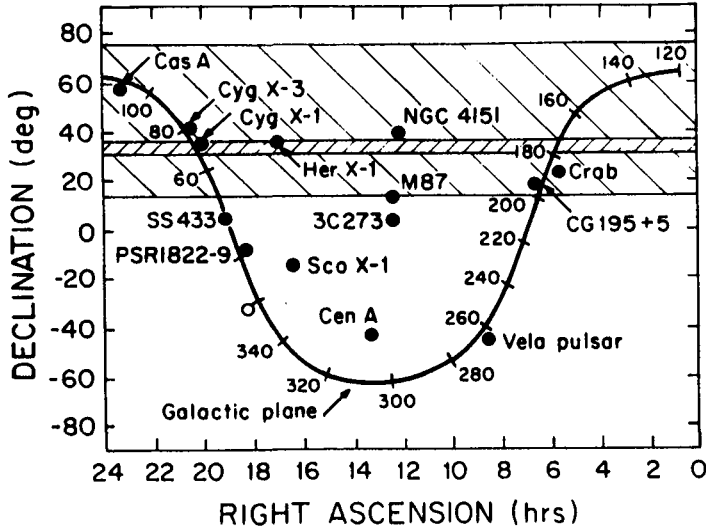


Fig. 2

performance of the system. In addition, we present the first results of a search with the LASD for a periodic muon signal from Cygnus X-3.

## II. The Surface-Underground Telescope

The latitude of the detectors is  $44^{\circ}21'$  N. Since the surface array operated independently has high efficiency for showers inclined at angles up to  $30^{\circ}$  from the zenith, a  $\pm 30^{\circ}$  band in the sky is shown in Fig. 2. Several interesting x-ray,  $\gamma$ -ray, and radio point sources are shown, together with the Galactic plane. A line connecting the underground LASD and the current 270' (north-south) by 500' (east-to-west) surface array is at an angle of  $11^{\circ}$  south of vertical. The band from  $31^{\circ}$  to  $35^{\circ}$  subtended by the surface array

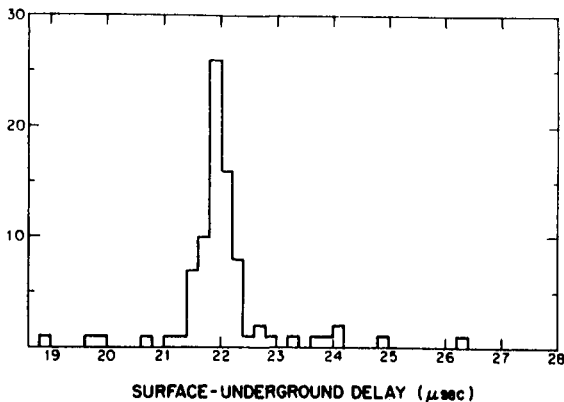


Fig. 3

is also shown in Fig. 2. The sources Cyg X-1 and Her X-1 lie within this band; Cyg X-3 and NGC 4151 lie less than  $6^\circ$  to the north, and will be covered by the next expansion of the surface array.

It should be noted that the existing surface array is comparable in size to the Kiel<sup>3</sup> and Haverah Park<sup>4</sup> arrays used to detect  $10^{15}$  eV showers from Cyg X-3, and the LASD is significantly larger than the Soudan I<sup>5</sup> and NUSEX<sup>6</sup> underground detectors which have also reported small flux excesses from near Cyg X-3.

The angular resolution of the combined surface and underground detectors is 3-10 mrad.

With the full area of the underground LASD in operation, we detect 5 surface-underground coincidences  $\text{day}^{-1}$ . In Fig. 3, we show the measured time delay between surface and underground for the first 83 detected coincidence events. The distribution is peaked at  $21.8 \mu\text{s}$  (corresponding to a  $5 \mu\text{s}$  muon travel time and  $17 \mu\text{s}$  cable delays), with a FWHM of  $0.6 \mu\text{s}$  (due largely to the spread in flight times for showers passing through different parts of the surface array). The delay time distribution shows very little background -- based on the independent surface and underground counting rates, we expect an accidental coincidence rate of  $1/30 \mu\text{s}^{-1} \text{day}^{-1}$ , in good agreement with the data. In Fig. 4, we show the observed shower size distributions (plotted as the number of surface counters above threshold) for events with multiple underground muons (top) and single underground muons (bottom).

### III. Search for Underground Events From Cygnus X-3

We have searched our data for the period 5/24/85 - 7/23/85 for events with a characteristic period of 4.8 hours from the direction of the binary pulsar Cygnus X-3. In order to minimize detector biases, the detector ran nearly uninterrupted during this interval, with a fractional live time of 98%. We analyzed the data by imposing fiducial cuts, by requiring that the measured flight time corresponded to a velocity  $\beta = 1$ , by requiring that the events arrived from within  $36^\circ$  of the vertical, and by requiring that the events came from within  $10^\circ$  of the known Cygnus X-3 position. We performed a phase analysis by folding the data using the x-ray ephemeris of van der Klis and Bonnet-Bidaut<sup>7</sup>. The result is shown in Fig. 5, where the solid line is the phase plot for potential source events, and the dashed line is the background distribution (where the background comes from the same declination band but from all right ascensions except those within  $30^\circ$  of the source). We see a  $1\sigma$  excess in the phase bin 0.7 - 0.8 (the same bin where the NUSEX excess was seen) and a  $3\sigma$  excess in the region  $\phi = 0 - 0.2$ . The arrival directions of the individual events in the  $3\sigma$  peak are plotted in Fig. 6; there is no noticeable enhancement at the position of Cygnus X-3. With a sample of  $1.2 \times 10^4$  events (half the size of the NUSEX sample), we feel that we have no evidence for significant positive excesses in our phase plot.

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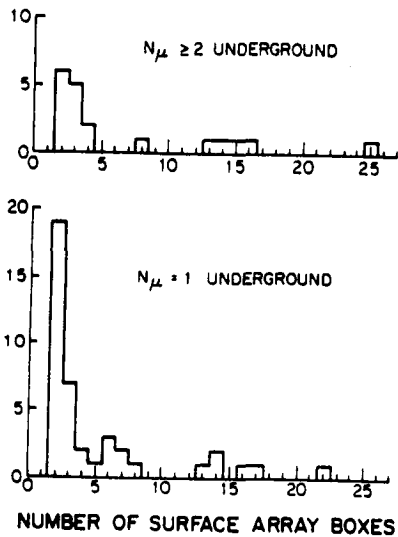


Fig. 4

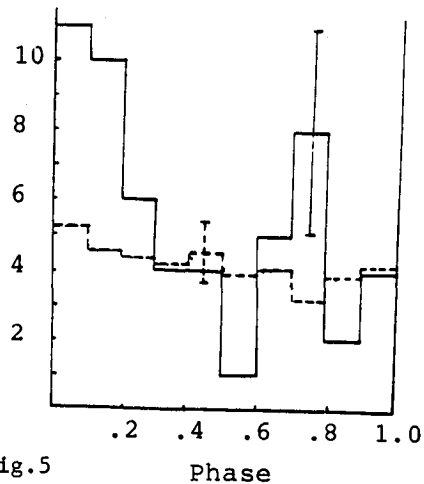


Fig. 5

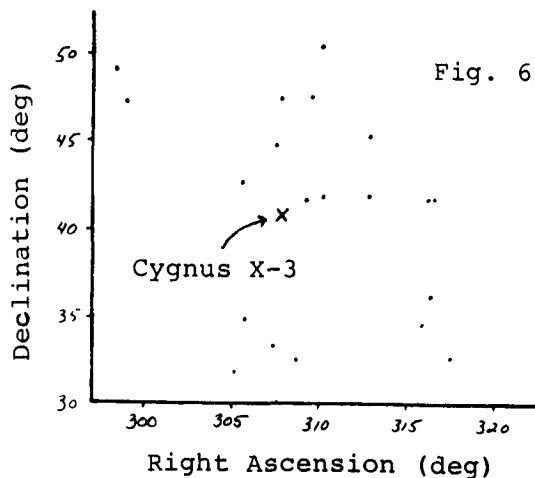


Fig. 6