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ANITA status

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ABSTRACT

I will review the status of ANtarctic Impulsive Transient Array (ANITA), an Antarctic long-duration balloon experiment designed to search for ultra-high energy (UHE) neutrinos through their radio Cherenkov signature in the ice. The first ANITA flight took place in the 2006–2007 Antarctic summer and ANITA II will fly this December 2008. I will report on first results from the first flight and the status of ANITA II.

1. Introduction

Neutrinos are the only cosmic particles that have the potential to probe the ultra-high energy (UHE) universe at cosmological distances and point to their sources undeflected by magnetic fields. A near-guaranteed flux of UHE neutrinos is expected from cosmic ray interactions with cosmic microwave background photons, known as the Greisen–Zatsepin–Kuzmin (GZK) process [1]. Ultra-high energy neutrinos are also expected to originate from the same sources that are emitting the extremely energetic charged cosmic rays up to above 10^{20} eV. No UHE neutrinos have yet been observed, but experiments are beginning to be sensitive to mainstream models for the neutrino flux from the GZK process.

ANtarctic Impulsive Transient Array (ANITA) is an Antarctic balloon-borne experiment that is launched under NASA's long duration balloon program from McMurdo station. ANITA views the Antarctic ice sheet from its in-flight altitude of 37 km where it is in view of 1.5×10^6 km^2 of ice surface. It searches for neutrino interactions in the ice by seeking their radio Cherenkov signature. ANITA has the greatest sensitivity of any experiment to UHE neutrino flux models in the energy range ($\sim 10^{19}-10^{23}$ eV).

2. Technique

Fig. 2 demonstrates the technique used by ANITA. A neutrino interacting within the horizon of the payload would produce a particle cascade and emit the radio Cherenkov pulse. A down-going neutrino would not be detectable by ANITA since the signal emitted at the Cherenkov angle would be absorbed by the bedrock below the ice. ANITA is not sensitive to up-going neutrinos either since at the energies of interest neutrinos are absorbed as they propagate through the earth. Therefore, ANITA is sensitive to neutrinos that skim the surface within approximately 10° of the horizon.

The radio Cherenkov signal was predicted by Gurgen Askaryan in 1962 [2]. A high energy neutrino interaction induces a particle cascade, which develops a 20% charge asymmetry as electrons in the medium become part of the shower, and likewise positrons in the shower are annihilated by electrons in the medium. The Cerenkov signal originates from the net current in a shower. Since the transverse size of the shower is of border 10 cm, the Cerenkov radiation is coherent for wavelengths longer than that (frequencies $< \mathcal{O}(1\,\mathrm{GHz})$). This effect was confirmed experimentally in accelerator beam tests for the first time in 2000 [3].

Antarctic ice is an ideal medium for this type of experiment due to the volume of ice found on the continent and its clarity for the frequencies of interest. Along the path of a typical balloon launch under NASA's long duration balloon program, depths of

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2.5 km are not atypical below the payload. In 2004, Barwick et al. measured the attenuation of the South Pole ice at radio frequencies by transmitting broadband signals from the surface and measuring their reflections from the ice-bedrock interface [4]. They measured field attenuation lengths above 1 km in the 200–700 MHz frequency range.

3. ANITA experiment

ANITA is pictured in Fig. 1 just before the launch of its first flight in 2006. It consists of an array of 32 broadband (200–1200 MHz) dual-polarization quad-ridged horn antennas with beam widths of approximately 50° across the bandwidth. The antennas are arranged in two layers, with 16 antennas on each layer separated in azimuth by 22.5°, and are canted 10° downward to view the horizon where the volume of ice is highest. Solar panels power both the science electronics and the NASA communications equipment aboard the payload. GPS antennas track the payload position and orientation during the flight, and additionally eight low gain antennas monitor any payload-generated noise and transmitted calibration pulses during the flight.

Fig. 1. ANITA I just before its first launch in December 2006.

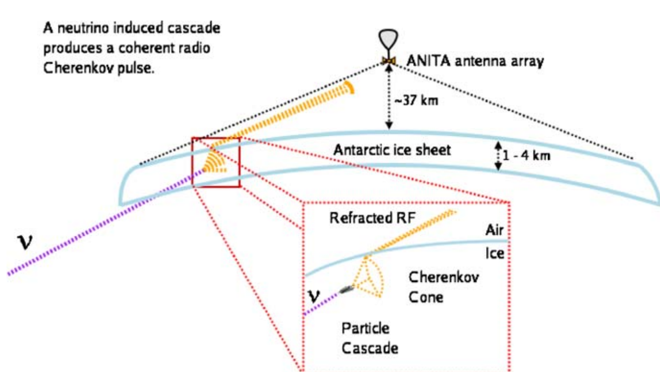

Fig. 2. This figure demonstrates the concept behind the ANITA experiment. An incident neutrino interacting in the Antarctic ice would emit a radio Cherenkov signal which would be refracted at the surface and observed at the payload, up to 700 km away.

The ANITA trigger splits the signal into frequency sub-bands and a coincidence requirement among bands provides a powerful rejection against narrow bandwidth backgrounds and thermal noise. A global trigger requires that four of a block of six neighboring antennas measure a signal that exceeds approximately five times the thermal noise level to trigger an event. Accidental thermal noise hits trigger the payload at a rate of approximately 4–5 Hz which allow us to continuously monitor the instrument health. These events are easily rejected offline since they are incoherent in phase, unlike the coherent signals expected from neutrino events.

The first full ANITA flight was launched from Williams Field, Antarctica near McMurdo Station on December 15th, 2006, taking $3\frac{1}{2}$ trips around the continent in 35 days before terminating on the Antarctic Plateau. Due to unusual wind patterns that were present that season, ANITA's flight path was largely over the western half of the continent where the ice is not as deep, and the payload was in view of either the South Pole or McMurdo stations approximately 50% of the time, both sources of anthropogenic electromagnetic interference. Still, the ANITA flight included 18 days of good livetime and the average depth of ice in view was 1.2 km. ANITA II has been approved and is scheduled to fly during the 2008–2009 season.

A test instrument with two antennas called ANITA-lite was flown in the 2003–2004 Austral summer, piggybacking on the TIGER experiment. ANITA-lite constrained the UHE neutrino flux and ruled out Z-burst models, which could have led to cosmic rays with energies that exceed the GZK cutoff [6,7].

Before its first flight in 2006, we performed a calibration test run at the Stanford Linear Accelerator Center (SLAC) in End Station A [5]. We constructed a 28.5 GeV electron beam with 10^9 particles per bunch incident on a $2 \times 1.5 \times 5$ m ice target to reproduce the signal that we would detect from neutrino interactions in Antarctica. The field strengths detected by the ANITA payload while suspended approximately 10 m from the ice target were consistent with those expected from theoretical predictions. In addition, the measured power increased quadratically with energy, as one would expect from a coherent signal.

4. Results

During the flight, calibration pulses were sent to the payload from above and below the surface both from McMurdo and a field camp at Taylor dome. These multi-purpose signals allowed us to quantify our resolution on the direction of incident pulses. ANITA reconstructs the direction of the RF signals through an interferometry technique, by measuring the difference in time of arrival between neighboring antennas. Preliminary results from borehole pulses show an angular resolution of 0.2° in azimuth with respect to the center axis of the payload and 0.8° in zenith angle.

Here we summarize the results of a preliminary search for UHE neutrinos in ANITA data, first presented at Neutrino '08 in Christ Church, New Zealand. This analysis requires an observable signal in six neighboring antennas, making the analysis threshold high and thus the sensitivity lower than other ongoing analyses. The analysis cuts were tuned on a 10% random sample of the data set before unblinding the remaining 90% of the data.

The analysis requires a waveform in one polarization of an antenna to surpass a threshold at three times the RMS noise voltage. Using the interferometry technique mentioned above, the direction of any incident RF signal is determined using the waveforms in the triggered antenna and its five neighboring