Tethered Balloons for Radio Detection of Neutrinos?

Rachel Scrandis and Cosmin Deaconu

University of Chicago

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Introduction

- Almost every time someone gives an ANITA/PUEO talk, somebody asks "why don't you simply tether the balloon?"
- This is (obviously) not a new idea, see e.g. D. Besson et al.'s proceeding from ARENA 2010 (!!)
- In this talk I'll discuss some more recent studies on sensitivity and feasibility of a radio tethered balloon (aerostat) UHE neutrino detector.
- Start with "why" and then mostly talk about "how" and challenges

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Tethered balloons for radio detection of ultra high energy cosmic neutrinos in Antarctica

D. Besson[a], R. Dagkesamanskii[b], E. Kravchenko[b], I. Kravchenko[c,*], I. Zheleznykh[d]

[a] Department of Physics and Astronomy, University of Kansas, Lawrence 66045, KS, USA
[b] Radio Astronomy Observatory LPI RAS, Pushchino 142290, Moscow Region, Russia
[c] Department of Physics and Astronomy, University of Nebraska, Lincoln, 68588, NE, USA
[d] Institute for Nuclear Research RAS, Moscow 117312, Russia

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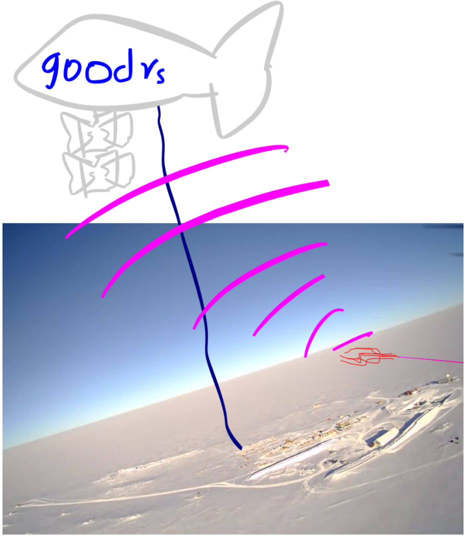
ABSTRACT

We present a brief overview of experimental efforts in Antarctica to search for radio pulses from electron–hadron cascades produced by cosmic ultrahigh-energy neutrinos in Antarctic ice. Thus far, the essential features (energy thresholds, effective recording volumes, etc.) of Antarctic neutrino radio experiments can be classified according to the deployment scheme employed: either (1) on the surface of the glacier—RAMAND-type, (2) in holes in the ice at depths of several hundred meters—RICE-type or (3) on board of a stratospheric balloon at an altitude of 40 km—ANITA-type. We herein propose an alternative possibility, namely to use tethered balloons for placing the radio antennas at modest (compared to ANITA) altitudes above the ice surface (1–2 km). This configuration of antennas will reduce (as compared to ANITA) the energy threshold for detection of neutrinos and increase the observation time.

From ARENA 2010 proceedings

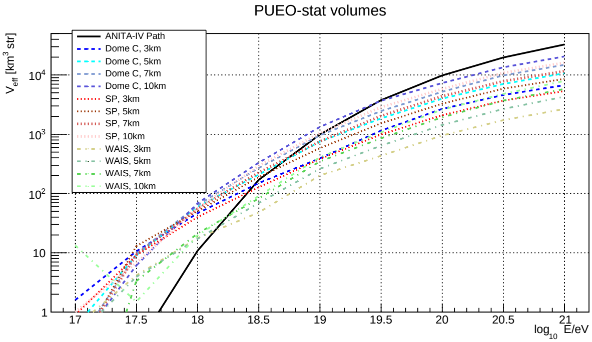
Tethered Askaryan Detector Concept

- Similar in concept to ANITA or PUEO, but significantly lower (likely several km), more stationary and with longer livetime
- Lower altitude not necessarily a downside, depending on interesting energy range
  - Dial the altitude for energy range you care about
- Dominant backgrounds for ANITA/PUEO are anthropogenic; single location helps with that
- Could be in Antarctica or Greenland (Antarctic ice is better, but Greenland is easier)



Dramatization

Tethered Askaryan Detector Sensitivity



- **Take the scaling more seriously than the actual values here, since depends strongly on assumptions about trigger sensitivity**
  - This projection assumed an E-field threshold 2.5x lower than ANITA-IV over 300MHz-1GHz. PUEO now has a lower threshold, and many tethered-specific optimizations could be made
  - This was actually considered for PUEO in 2020

Tethered ν_τ Detector Concept?

The Dream

- For ν_τ, don't need to go to the ice sheet.
- Analogous to BEACON concept (though with full 2π coverage and different antenna constraints).
- But, RFI-clean practically accessible mountaintop sites rare
- A tethered balloon in a valley / Fjord geometry has some potentially compelling features:
  - ν_τ can convert in valley walls, adding volume compared to flat geometry
  - Valley walls also act as RFI shielding
  - Valley floor (or fjord) much easier to access than mountaintop
- Not clear exactly what the best topography is; valley walls can't be too close together, to give the τ room to decay.
  - Full terrain-based simulation optimization studies needed
  - Preliminary naive attempts at using GRAND tools suggest perhaps 2x terrain factor in a random valley in Nevada

General aspects of tethered platform design

- Looks more like a blimp than a balloon (so it can take advantage of wind lift and be mostly stationary)
- For lower altitudes (up to a few km), can get power from tether (at highest altitudes, power cable too heavy so must use solar)
- Can bring data down tether as well (in fact, can use RFoF to have almost all electronics on ground, where easily serviced/upgraded).
- Generally must be brought down in too high winds, though can stay up for weeks at a time if weather is good.
  - This also imposes design requirements on how antennas are suspended

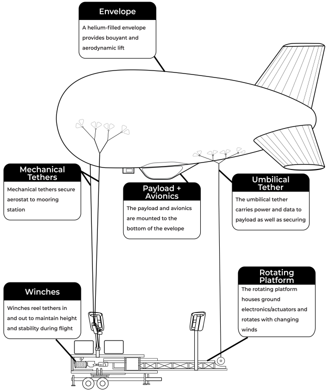


Figure: General Aerostat Layout; Source: Altaeros

Previous Aerostat Science Cases

Publ. Astron. Soc. Aust., 1996, 13, 48–59

POST: A Polar Stratospheric Telescope for the Antarctic

Michael A. Dopita[1], Holland C. Ford[2],
John Bally[3] and Pierre Bely[4*]

[1]Mount Stromlo and Siding Spring Observatories, Institute of Advanced Studies,
Australian National University, Private Bag, Weston Creek PO, ACT 2611, Australia
Michael.Dopita@anu.edu.au
[2]Johns Hopkins University, Baltimore, MD 21218, USA
[3]Astrophysical, Planetary, and Atmospheric Sciences Department,
University of Colorado, Boulder, CO 80309, USA
[4]Space Telescope Science Institute, Baltimore, MD 21218, USA

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Abstract: The tropopause, typically at 16 to 18 km altitude at the lower latitudes, dips down to only 8 km in the polar regions, allowing access to the cold, dry and nonturbulent lower stratosphere by tethered aerostats. These can float as high as 12 km, have long operating lifetimes, and are extremely reliable. In contrast to free-flying balloons, they can stay on station for weeks at a time, and payloads can be safely recovered for maintenance and adjustment and relaunched in a matter of hours. We propose to use such a platform, located first near Fairbanks, Alaska, and later in the Antarctic, to operate a new-technology 4 m telescope with diffraction-limited performance in the near infrared. Thanks to the low ambient temperature (~200 K), thermal emission from the optics is of the same order as that of the zodiacal light in the 2–3 μm band. Since this wavelength interval is the darkest part of the zodiacal light spectrum from optical wavelengths to 100 μm, the combination of high-resolution images and a very dark sky make it the spectral region of choice for observing galaxies, QSOs and clusters of galaxies at the formation epoch of galaxies.

Keywords: Antarctic astronomy — atmospheric effects — balloons — infrared: general — telescopes

Figure: POST experiment idea

- The Polar Stratospheric Telescope (POST) was a proposed near-IR and optical telescope planned to fly on a tethered aerostat in the Arctic and/or Antarctica.
  - Eventually transitioned to the Stratospheric Observatory For Infrared Astronomy (SOFIA) experiment, which had the same science goal but flew on a 747.
  - Change was driven at least partially by the stringent stability requirements of the experiment (telescope FOV needed to be stable to within 12 mas)
- Atmospheric Radiation Measurement (ARM) facilities have used small aerostats for atmospheric monitoring and research.

Modern Use Cases: Telecom and electronics surveillance

- Tethered aerostats get most of their applications in the commercial and government sectors.
  - World Mobile uses tethered aerostats as semi-permanent communications infrastructure to bring internet to unconnected areas
  - Disaster relief efforts use tethered aerostats as fast response communications coverage while impacted area is being cared for
  - Government agencies, such as U.S. Customs, use tethered aerostats for border protections from low-flying illegal aircrafts

Figure: World Mobile aerostat in Zanzibar

ATLAS-LTA Aerostat Portfolio

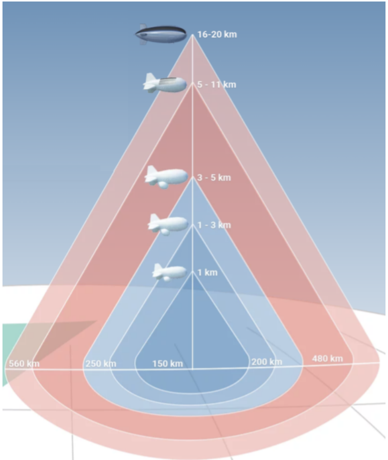

Figure: ATLAS-LTA

- Standard aerostats fly from 1-5km, carrying 100kg up to 3,000kg. They fly for 15-45 days before needing refilling.
  - In the several $M range
- High altitude aerostats drop the heavy power tethers and produce all their power onboard via solar panels.
  - This allows them to fly between 5-11km high, holding up to 300kg
  - Flies 50-100 days
- In the case Jeff Bezos wants to get involved, there is the Propulsion Assisted High Altitude Platform.
  - No power tether, flies 16-20km above the surface
  - Onboard propulsion system allows it to withstand heavy winds
  - Flies year round

Autonomous Aerostats

- Unlike long duration balloon platform, aerostats can land multiple times, refuel, and relaunch. It is therefore desirable to have autonomous control of aerostats.
- Altaeros, another aerostat company, has demonstrated autonomous launch, control, and landing of their balloons.
  - Ground mooring system is anchored to a center point, and winch is allowed to pivot around circle to adjust for winds and improve stability
  - Their current products don't go over 1 km, but if they can figure this out, may greatly improve feasibility

Figure: Altaeros autonomous mooring system

Applications of very small aerostats?

Small aerostats are very cheap, can be a good alternative to a drone for e.g. air shower calibrations for radio arrays.

Skyhook Helikites

Helikite Type	Helium Capacity Cubic Metres	Balloon Material Thickness Thou/Inch	Lift in no wind KG	KG Lift in 15km wind (approx)	MPH Max Speed (approx)	Max FT Unloaded Alt (approx)	Length in FT	Width in FT	Price UK £ Excludes VAT/Delivery
Skyhook	1.0	2	0.2	2	28	2,000	5	4	£ 770.00
Skyhook	1.6	2	0.3	3	30	2,500	6	4.5	£ 980.00
Skyhook	2.0	2	0.8	4	30	3,000	7	5	£ 1,150.00
Skyhook	2.5	2	1.1	5	30	3,500	8	5	£ 1,300.00
Skyhook	3.0	2	1.5	6	35	4,000	9	5.5	£ 1,450.00
Skyhook	4.5	2	1.9	7	36	4,200	10	6	£ 1,770.00
Skyhook	6.0	3.5	2.9	9	38	5,000	11	7	£ 2,360.00
Skyhook	7.0	3.5	3.5	10	40	5,500*	11.5	8	£ 2,500.00
Skyhook	9.0	3.5	4.5	10	42	5,800*	11.7	9	£ 2,990.00
Skyhook	11	3.5	6	12	40	6,000*	12	9.5	POA
Skyhook	16	3.5	9	16	40	7,000*	13	10	POA
Skyhook	21	3.5	12	20	40	7,500*	16	11	POA
Skyhook	25	4	14	25	40	8,000*	20	13	POA
Skyhook	34	6	14	30	40	7,000*	22	15	POA
Skyhook	45	6	20	40	40	7,500*	24	18	POA

Figure: www.helikites.com

Conclusion

Figure: Tethered Aerostats on an Icy Moon (Adobe Firefly AI Generated)

- Tethered aerostats could provide an ideal platform to measure the UHE neutrino flux
  - Aerostats could fly for longer periods over Antarctic ice than weather balloon counterparts with competative V_{eff}
  - Deployment in valley or fjords could represent a lower RFI alternative to the ν_τ channel
- Modern aerostats can reach the desired flight altitudes and have potential autonomous capabilities to make such an experiment realistic
- Easy deployment and autonomous control opens up a wide paramter space for possible deployment locations (Europa anyone...?)