Neutrino Telescopes and Tau Neutrino
Flux Number of Wider Astronomy

$$\log\left[\frac{\text{Flux}}{\text{cm}^{-2}\text{s}^{-1}\text{sr}^{-1}}\right]$$

-8 -4 0 4 8 12 16 20

$\log(E/\text{eV})$

$E\ dN/\text{dE} [\log_{10}(\text{cm}^2\text{s}^{-1}\text{sr}^{-1})]$
Galileo and the New Ten Astronomy

• Galileo Optics Astronomy ruled 4 Century
• Maxwell extensions ruled last Century
• UHECR p-He new Astronomy born in 2007
• (9) New Astronomy at the edge
• 1) Neutron Astronomy: GeV-PeVs-EeVs-GZK.
• 2) Anti-Neutron GZK by Anti-Galaxies (?)
• 3) Gravitational Waves (?) Astronomy
• 4) UHE SUSY Astronomy: Neutralino-??
• 5-6-7-8-9-10 Neutrino Astronomies
UHECR astronomy and UHE Neutrino Astronomy Connection
Remember: not one but 6 different Neutrino Astronomy at edge.
Different Cross-sections-DIFFERENT THRESHOLDS...and OPACITIES

Fig. 2

Venice NEUTEL 1998-99
Fargion: Neutrino Telescopes and Tau Neutrino
The lepton thresholds

\[ \sigma \left( 10^{-36} \text{cm}^2 \right) \]

\[ E_\nu \text{ (GeV)} \]

- \( \nu_\tau + p \rightarrow \bar{\nu}_\tau + \Delta^0 \)
- \( \bar{\nu}_\tau + p \rightarrow \mu + \Delta^0 \)
- \( \bar{\nu}_\tau + n \rightarrow \mu + \Delta^- \)
- \( \nu_\tau + n \rightarrow \mu + \Delta^+ \)
- \( \nu_\tau + p \rightarrow \tau + \Delta^+ \)
- \( \bar{\nu}_\tau + n \rightarrow \tau + \Delta^- \)
EeV AGASA MAP 1999: A UHE NEUTRON ASTRONOMY? Denied by AUGER.
Electron Neutrino ASTRONOMY inside huge Atmospheric Nu Noise: Sun +SN 1987A
Solar Flare atoms astronomy

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Fargion:Neutrino Telescopes and
Tau Neutrino
Neutron Astronomy: Solar Flare by OSSE 1991
Space Weather Aspects of the January 20, 2005 Solar Energetic Particle Event

Why so much interest for the January Solar Flare for Neutrinos?
The inner blowup of last January 2005 solar flare
Lower Bound by Observed gamma-pion bump

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Fargion: Neutrino Telescopes and Tau Neutrino
Solar Flare are nearby engine of Low energy Neutrinos: all the Flavor now
Megaton Must see their signal
ICDC in ICE Cube- 5 Megaton- may see Flare, but marginally the Tau see also0803.3044, maybe the Muons-
IMPORTANT POSSIBILITY FOR GRBs correlations
Anti-neutrinos are the best
Neutrino CROSS SECTIONS
Need for Large Volumes and Amplifiers

![Graph showing total cross sections vs. energy](image)

**Fig. 1**
Unstable tau versus muons at highest energy

A NEUTRINO AMPLIFIER D. Fargion et al. 1999-
Horizontal Tau air showers from mountains in deep valley: Traces of UHECR neutrino tau

D. Fargion ¹, A. Afello ², R. Conversano

ICRC-1999


Discovering Ultra-High-Energy Neutrinos Through Horizontal and Upward \( \tau \) Air Showers: Evidence in Terrestrial Gamma Flashes?
Why Horizontal – Upward Tau Showering is so much linked to neutrino mass and mixing?

Because mixing, even for minimal masses guarantee the flavour transformation from Muon Neutrinos to the Tau Neutrinos. Galactic and cosmic distances are huge respect oscillation lengths.

\[ L_{\nu_\mu - \nu_\tau} = 8.3 \text{ pc} \left( \frac{E_\nu}{10^{19} \text{ eV}} \right) \left( \frac{\Delta m^2_{ij}}{(10^{-2} \text{ eV})^2} \right)^{-1} \]
Long exhausted - Shortest Hardest
# Tau Air-Shower Channels

<table>
<thead>
<tr>
<th>Decay</th>
<th>Secondaries</th>
<th>Probability</th>
<th>Air-shower</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau \rightarrow \mu^- \bar{\nu}<em>\mu \nu</em>\tau$</td>
<td>$\mu^-$</td>
<td>$\sim 17.4%$</td>
<td>Unobservable</td>
</tr>
<tr>
<td>$\tau \rightarrow e^- \bar{\nu}<em>e \nu</em>\tau$</td>
<td>$e^-$</td>
<td>$\sim 17.8%$</td>
<td>1 Electromagnetic</td>
</tr>
<tr>
<td>$\tau \rightarrow \pi^- \nu_\tau$</td>
<td>$\pi^-$</td>
<td>$\sim 11.8%$</td>
<td>1 Hadronic</td>
</tr>
<tr>
<td>$\tau \rightarrow \pi^- \pi^0 \nu_\tau$</td>
<td>$\pi^-, \pi^0 \rightarrow 2\gamma$</td>
<td>$\sim 25.8%$</td>
<td>1 Hadronic, 2 Electromagnetic</td>
</tr>
<tr>
<td>$\tau \rightarrow \pi^- 2\pi^0 \nu_\tau$</td>
<td>$\pi^-, 2\pi^0 \rightarrow 4\gamma$</td>
<td>$\sim 10.79%$</td>
<td>1 Hadronic, 4 Electromagnetic</td>
</tr>
<tr>
<td>$\tau \rightarrow \pi^- 3\pi^0 \nu_\tau$</td>
<td>$\pi^-, 3\pi^0 \rightarrow 6\gamma$</td>
<td>$\sim 1.23%$</td>
<td>1 Hadronic, 6 Electromagnetic</td>
</tr>
<tr>
<td>$\tau \rightarrow \pi^- \pi^- \pi^+ \nu_\tau$</td>
<td>$2\pi^-, \pi^+$</td>
<td>$\sim 10%$</td>
<td>3 Hadronic</td>
</tr>
<tr>
<td>$\tau \rightarrow \pi^- \pi^+ \pi^- \pi^0$</td>
<td>$2\pi^-, \pi^+, \pi^0 \rightarrow 2\gamma$</td>
<td>$\sim 5.18%$</td>
<td>3 Hadronic, 2 Electromagnetic</td>
</tr>
</tbody>
</table>
Cosmic Ray Flashes above the Earth edges

- Atmosphere at Horizons is isis efficent suppressings filters for Cosmic Rays and a deep calorimeter for High Energy Neutrinos (PeVs -- EeVs energies)

- Horizontal versus Vertical Showers are spreading in a wider area (km2), becoming more detectable.

- Antineutrino electron may exhibit resonant interaction with electron in air column depth.

- Tau neutrino Earth -- Skimming may lead to Horizontal and Upward Tau Air -- Showers even more abundant than air because rock more dense than air.
Expected GZK neutrino flux
following most authors (Semikoz, Sigl...)

$E^2 [\text{eV cm}^{-2} \text{s}^{-1} \text{sr}^{-1}]$

$E [\text{eV}]$

- $\text{BAIKAL}$
- $\text{ANTARES}$
- $\text{ICECUBE}$, $1 \text{km}^3$
- $\text{AMANDA-II}$
- $\gamma$-ray bound
- $\text{TA}$, $0.5$
- $\text{ANITA}$, $0.2$
- $\text{EUSO}$
- $\text{VENUS}$, $30 \text{ days}$

$10^{12}$ $10^{14}$ $10^{16}$ $10^{18}$ $10^{20}$ $10^{22}$
Neutrino and Antineutrino ($\mu$ flavor) at Production

$E^2 \phi_{\nu} \left[ E_{\nu} \right]$ (GeV s$^{-1}$ cm$^{-2}$)

- GRB WB
- TD
- Atmospheric 90°
- Atmospheric 0°
- Prompt

Energy ($\nu_\tau$) (GeV)

10$^{-6}$
10$^{-7}$
10$^{-8}$
10$^{-9}$
10$^{-10}$
10$^{6}$
10$^{8}$
10$^{10}$
10$^{12}$
Earth Opacity by Inner Density Structures

Venice NEUTEL-11-03-09--
Siena-04-10-08-Fargon D, Vertical for Horizontal Tau Neutrino

\[ \rho \text{(g cm}^{-3} \text{)} \]

\[ R \text{ (km)} \]
Earth Opacity

Density $\rho$ [gm/cm$^3$]

Column depth $z(\theta)$ [$10^{10}$ cmwe]

Angle above nadir, $\theta$
Venice NEUTEL

Fargion: Neutrino Telescopes and Tau Neutrino

\[
dN_{\nu} \frac{dN}{d\theta dA dE} = \frac{E_{\nu}}{\text{cm}^{-3} \text{sec}^{-1} \text{sr}^{-1}}
\]

\[
\begin{align*}
0 & \quad 10^{-23} \\
0.25 & \quad 10^{-22} \\
0.5 & \quad 10^{-21} \\
0.75 & \quad 10^{-20} \\
1 & \quad 10^{-19} \\
1.25 & \quad 10^{-18} \\
1.5 & \quad 10^{-17}
\end{align*}
\]

\[
\begin{align*}
\frac{d\theta}{L} & = \frac{1}{10^{10}} \\
\frac{dL}{\phi} & = \frac{1}{10^{11}} \\
\frac{dE}{\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}} & = \frac{1}{10^{12}} \\
\frac{dE}{\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}} & = \frac{1}{10^{13}} \\
\frac{dE}{\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}} & = \frac{1}{10^{14}} \\
\frac{dE}{\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}} & = \frac{1}{10^{15}} \\
\frac{dE}{\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}} & = \frac{1}{10^{16}} \\
\frac{dE}{\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}} & = \frac{1}{10^{17}} \\
\frac{dE}{\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}} & = \frac{1}{10^{18}} \\
\frac{dE}{\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}} & = \frac{1}{10^{19}} \\
\frac{dE}{\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}} & = \frac{1}{10^{20}} \\
\frac{dE}{\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}} & = \frac{1}{10^{21}}
\end{align*}
\]
Expected Tau events at different angles.

**Water**

\[
\frac{dN_r}{d\theta d\phi dt dA dE} = E \text{ cm}^{-2} \text{ sec}^{-1} \text{ sr}^{-1}
\]

\[1 \times 10^{-20}, 1 \times 10^{-22}, 1 \times 10^{-24}, 1 \times 10^{-26}\]

\[0, 0.25, 0.5, 0.75, 1, 1.25, 1.5\]

**Rock**

\[
\frac{dN_r}{d\theta d\phi dt dA dE} = E \text{ cm}^{-2} \text{ sec}^{-1} \text{ sr}^{-1}
\]

\[1 \times 10^{-19}, 1 \times 10^{-21}, 1 \times 10^{-23}\]

\[0, 0.25, 0.5, 0.75, 1, 1.25, 1.5\]
The Inner Earth and the $\nu_{\tau}$
Tau Air-Showers is born also by Electron
Anti-neutrino- hitting electron in air or rock by Glashow 
W-resonance whose decay may produce Tau air-showers
$\nu_\tau$ Taus and Anti-$\nu_e$ into Taus: Testing CPT in our Universe

\[
\frac{dN_{\tau}}{d\theta dE} = E \left( \frac{1}{10^{21}} \right)^2 \frac{1}{10^{23}}
\]

\[
\frac{dN_{\tau}}{d\theta dE} = E \left( \frac{1}{10^{21}} \right)^2 \frac{1}{10^{23}}
\]

\[
\frac{dN_{\tau}}{d\theta dE} = E \left( \frac{1}{10^{21}} \right)^2 \frac{1}{10^{23}}
\]
Total rate in Auger for Tau Airshower
Fargion-2004-2006
Electromagnetic versus Muon bundle: No e.m. below 75-80° Only UHE Neutrinos and Upward Tau (10-50 more) at horizons
The Ande Mountains as a target for detecting UHE neutrino tau by Horizontal Air-Showers at AUGER: ANDE SHADOWs (ring mask at horizons) on GZK Cosmic Rays from West and Young Horizontal Tau Air-Showers at EeVs
The Ande Shadows on AUGER
Inclined Auger example

$\theta = 88^0$

CERN Courier
July 25 2006

MC simulation of an event with the same angle

2-lobed footprint on the ground due to muon deflection by the geomagnetic field

Ricardo A. Vázquez

Venice NEUTEL-11-03-09--
Fargion Neutrino Telescope, and
Tau Neutrino

Signal (VEM)
Fargion: Neutrino Telescopes and Tau Neutrino
The Radiography of the shower
First Answers in UHE neutrinos in AUGER: 10-20 years
TAU inclined Air showers mostly from the Andes

\[ E^2 f(E) \text{ [GeV cm}^{-2}\text{s}^{-1}\text{sr}^{-1}] \]

- GLUE'04 (e, \(\mu\), \(\tau\))
- FORTE'04 (e, \(\mu\), \(\tau\))
- ANITA-lite (e, \(\mu\), \(\tau\))
- RICE'05 (e, \(\mu\), \(\tau\))
- Auger ( \(\tau\) )
- AMANDA (e, \(\mu\), \(\tau\))
- AMANDA (\(\mu\))
- GZK, each flavor
- Balkal (e, \(\mu\), \(\tau\))
Second Auger: 2007 predictions

![Graph showing neutrino energy spectra and predictions for various telescopes and experiments.](image-url)
Last Tau updated NOW 08- Versus DF - RICAP 07

Flux limit

[Graph showing flux limits for different experiments, including Auger, AMANDA, Hires, and others, with energy on the x-axis and differential and integrated flux on the y-axis.]

Lukas Nellen - AUGER results, and implications for UHE neutrinos - NOW 08, Como, September 11, 2008
Counting Tau on clouds
(Also in Hess-Magic and Veritas) by AUGER via Cherenkov reflections

Figure 4: Upward Tau Air showering on the Auger clouds
UHECR versus Neutrino Astronomies

• Attention: Not just one UHECR: nuclei or nucleon
AUGER  Michael Unger , Pierre Auger  July
Composition puzzle

Composition puzzle

$\langle X_{\text{max}} \rangle$ [g/cm$^2$]

- Auger ICRC07

- proton

- iron

$E$ [eV]

- QGSJETII-03
- QGSJET01
- SIBYLL2.1
- EPOS1.6
Why an apparent UHECR-Super Galactic Correlation? Polarized-Radio show the link between Cen A (3.8 Mpc) - $B_{\text{Galactic}}$:
Map-Polarization2
UHE Nuclei energy losses

Pair production:
\[ A \gamma \rightarrow A e^+ e^-\]

Depletion of the flux:
- Iron
- Helium

Photodisintegration:
\[ A \gamma \rightarrow (A-1) N \rightarrow (A-2) 2N \]
Deflections inside our Galaxy and along Galactic Plane toward Cen A

Deflections inside our Galaxy and along the plane is \( \delta_{rm} \geq \):

\[
11.3^\circ \cdot \frac{Z}{Z_{He^4}} \cdot \left( \frac{6 \cdot 10^{19} \text{eV}}{E_{CR}} \right) \left( \frac{B}{3 \cdot \mu \text{G}} \right) \sqrt{\frac{L}{20 \text{kpc}}} \sqrt{\frac{l_c}{kpc}} (1)
\]

This Lightest Nuclei for Highest Cosmic Rays model implies and foresees among the other, additional clustering of UHECR events around the nearest AGN Cen-A (the lightest UHECR the more correlated to the source, the heavier and with larger charges, the most bent and spread ones). The model explains the absence or a poor signal from Virgo (too far for the fragile nuclei...
So lightest nuclei may trace nearer Universe not show Virgo and fit AUGER GZK imprint see astro-ph/0902.3290
CEN-A UHECRs
Conclusions: UHECR by He-like and UHE Tau at horizons

- The Lightest Nuclei UHECR may explain the AUGER anisotropy signal bent by vertical galactic field: No Virgo maybe due to early GZK for He and apparent Super Galactic correlation by unfortunate chance

- Future-present Auger UHECR must cluster around Cen A spread along B_gal. Axis. Mostly in NORTH side. The Ande Shadows in AUGER hides taus

- Neutrino apperance also the edge IN AMIGA AND HEAT lower edges
First new predictions for He
More at PeVs spread energy

three peaks like in the pure proton case but the third one is shifted to lower energies

Shape of the neutrino flux from nuclei different as the proton case
**MAGIC**, while pointing a GRB, SGR or BL Lac Below The Horizons (~ 1% of the GRB-SGRs events) on rock behave (near EeV $\nu\tau$ energy) as a 75 km$^3$ NEUTRINO TELESCOPE.

Horizons distance $d = 167$ km $\sqrt{(h/2.2 \text{ km})}$ Cerenkov Shower opening angle $\sim 0.3^\circ$

Inclined Conic Rock Base Area $A \sim 3\times 50 = 150$ km$^2$

Inclined Rock Cylinder depth $L_\tau \sim 10$ km

Rock Cylinder depth $l_t \sim 0.5$ km w.e.

$L_\tau = 10$ km w.e.

astro-ph/0511597
D. Fargion
AMIGA: Auger Muons and Infill for the Ground Array

Existing tank array 1500m

Infill array 750m
42 additional detectors
Area ~ 23.5 km²

Each of the 85 detectors:
pair of Cherenkov tank and muon counter

Infill array 433m
24 additional detectors
Area ~ 5.9 km²
In Conclusion, while Nuclei shine up Horizontally, up-ward Tau air-Shower rise by a Neutrino Sky under our own Sky: the Earth...Within a few 2-3 years in AUGER-AMI GA-HEAT.
Thank you for the invitation and your kind attention.
Fargion: Neutrino Telescopes and Tau Neutrino

•

If UHE neutralinos are born by UHECR at the same rate of UHE neutrinos (as in the topological evaporation model), then UHE neutralinos may show showers in Underground Km³.
Real Energy released per SUSY Showers: Imprint of Selectrons (and Squark) mass
UHE neutralino scattering onto relic light neutrino leading to Sneutrino - Burst

The UHE Neutralino-neutrino Showers
In a Sneutrino-Burst as neutrino-anti-neutrino
In Z-Burst model.
A remind for Z Burst model, able
To solve UHECR Puzzle by light relic 0.4-0.1 eV neutrino Mass.

25 APRIL 2008 : a huge Flare

- Wow! Satellite Catches Bright Solar Flare From a Another Star
- Satellite Catches Bright Solar Flare From a Another Star

- NASA's Swift satellite picked up one of the brightest solar flares ever seen — not from our own sun, but a star 16 light-years away. This flare packed the power of thousands of solar flares combined, and a flare of this magnitude from our own sun would have stripped Earth's atmosphere and sterilized the planet. Astronomers say the flare would have been visible to the naked eye on April 25, 2008 if the star had been easily observable in the night sky at the time. As it was, the flare's brightness caused Swift's Ultraviolet/Optical Telescope to shut down for safety reasons.
- But Swift was able to study the flare for over 8 hours with its X-ray capabilities.

- The Swift satellite normally searches for gamma ray bursts, and is surrounded with detectors that look for bursts of light.
- The spacecraft then "swiftly" and autonomously re-points itself to the location of the burst.
- However, this was no gamma ray burst, just a solar flare. But what a solar flare!

- The star, EV Lacertae, is a basic red dwarf, the most common type of star in the universe. It shines with only one percent of the Sun's light, and contains only a third of the Sun's mass. It's one of our closest stellar neighbors, but normally is not visible with the naked eye, as it holds a magnitude of -10.
Radio versus UHECR
UHECR versus IR: A clear Nearby Universe Signal?
Icecube might but marginally
Skimming meteorites and asteroids
We also propose today: NEVOD, ICARUS, FLARE or UNO in crown arrays on peak mountains tracing Upward Horizontal AirShowers.
Air Showers on the Crown array telescope
Muon Bundles by GZK ad Tau airShowers: more than atmospheric ones

\[
\frac{dN_\mu}{d\theta d\phi dt dA dE} \times E \text{ [cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}] 
\]

\[
E = 10^{10} \quad E = 10^{13} \quad E = 10^{16} \quad E = 10^{19} \quad E = 10^{21} 
\]

\[
\frac{dN_\mu}{d\theta} \times \frac{E}{dE} 
\]

\[
0 \quad 0.25 \quad 0.5 \quad 0.75 \quad 1 \quad 1.25 \quad 1.5 
\]

\[
\theta \text{ [rad]} 
\]
Gamma from GZK neutrino and Tau

\[
\frac{dN_\gamma}{d\theta d\varphi dt dA dE} \text{ [cm}^{-2} \text{ sec}^{-1} \text{ sr}^{-1}] 
\]

\[
\begin{align*}
E &= 10^{21} \\
E &= 10^{20} \\
E &= 10^{19} \\
E &= 10^{18} \\
E &= 10^{17} \\
E &= 10^{16} \\
E &= 10^{15} \\
E &= 10^{14} \\
E &= 10^{13} \\
E &= 10^{12} \\
E &= 10^{11} \\
E &= 10^{10} \\
E &= 10^{09} \\
E &= 10^{08} \\
E &= 10^{07} \\
E &= 10^{06} \\
E &= 10^{05} \\
E &= 10^{04} \\
E &= 10^{03} \\
E &= 10^{02} \\
E &= 10^{01} \\
E &= 10^{00} \\
\end{align*}
\]