Where, when and how SUSY is showering in the sky

D. Fargion,
ROME UNIV 1 and INFN
SUSY signals into sky

- *Cosmic Rays and UHECR are reaching highest energy well above LHC ones. Because photopion production they might hide UHE GZK neutrino that may airshower at Earth Horizons. These Airshowers mostly are Tau induced ones.*

- *SUSY traces might be also searched inside the same UHECR shower occurring on Earth. Indeed UHE neutralino and other surprising SUSY secondaries may offer a novel Astronomy at the edge by inclined airshowering.*

- *But also UHE SUSY and Neutrino traces maybe originated inside the sources and discovered in present Telescopes, as Magic one.*
Where, when and how SUSY traces maybe revealed and disentangled from Neutrino?

- Assume a sharp event occur in the Universe, as the blazing of a BL Lac or of a GRB: it may be a trigger of a Gamma burst as well as of a UHE neutrino event. (Possibly its tau event may escape the earth and arise as a Tau Air-Showers)

- The same event may contain a rare neutral SUSY particle (UHE Neutralino, UHE gluino) whose masses are above hundred GeV value. Being neutral it may flight in line and in time correlation.
The SUSY imprint

- The SUSY production is source of a signal *delayed respect of the BL Lac- GRB event.*
- Indeed an EeV (or 0.1 EeV) UHE Neutralino or Gluino may reach the observer at a Lorentz factor (10 or 1 million) and its delay (for a cosmic source at Universe edge) ranges from half and hour to a couple of days: Therefore **SUSY rise as a Neutralino or Gluino BURST a day after.**
The UHE SUSY versus UHE Neutrino air Showering

- The UHE Neutralino scattering on electron making s-electrons, behaves as a resonant PeVs Glashow anti-neutrino electron interacting via W boson:
- a difference, SUSY goes into electromagnetic air-showers always, while W has most hadronic channel decays
If UHECR hides (as most model require) SUSY secondaries than UHE Neutralino scattering with fermions in matter must occur: Selectrons-Squarks-Sneutrino Resonances
The simplest, the best

- The neutralino SUSY resonance at UHE PeV-EeV energies

\[ \chi_1^0 + e \rightarrow \tilde{e}_R \rightarrow \chi_1^0 + e, \]

The Selectron resonance behave like the well known Glashow W one:

\[ \bar{\nu}_e + e^- \rightarrow W^- \rightarrow X \]

\[ E_{\nu}^{\text{peak}} = \frac{M_W^2 - m_{\nu}^2}{2m_e} \approx \frac{M_W^2}{2m_e} \approx 6.3 \times 10^6 \text{ GeV}, \]
The Neutralino versus Neutrino cross sections for equal energies

Set : I
- $\tan\beta = 2$
- $\mu < 0$
- a: $m_{\chi_1^0} = 61$ GeV
- b: $m_{\chi_1^0} = 99$ GeV
- c: $m_{\chi_1^0} = 178$ GeV

$\sigma$ (nb) vs $\log_{10}[E_{X_N} \text{ (GeV)}]$

Set : II
- $\tan\beta = 10$
- $\mu > 0$
- a: $m_{\chi_1^0} = 60$ GeV
- b: $m_{\chi_1^0} = 93$ GeV
- c: $m_{\chi_1^0} = 174$ GeV

$\sigma$ (nb) vs $\log_{10}[E_{X_N} \text{ (GeV)}]$
Resonant Cross Section

\[ \sigma_{\text{peak}} = \frac{8 \pi}{m_f^2} \left( \frac{m_f^2}{m_f^2 - m_\chi^2} \right)^2 B(\tilde{f} \rightarrow f \chi_1^0) B(\tilde{f} \rightarrow X). \]
Different Squark – Selectron and Sneutrino masses

→ Different Neutralino UHE Resonant Energies

\[ E_\chi \gtrsim \frac{m_{\tilde{q}}^2}{2m_p} \sim 10^5 \text{ GeV} \]

\[ E_\chi \sim \frac{m_{\tilde{e}}^2}{2m_e} \sim 10^7 \div 10^9 \text{ GeV} \]

\[ E_\chi \sim \frac{m_{\tilde{\nu}}^2}{2m_{\nu}} \sim 10^{14} \text{ GeV} \]
UHE neutralino scattering onto relic light neutrino leading to Sneutrino Resonance channel, like Z-Burst

Range of SUSY parameters: Neutralino maybe among us making most of the dark matter
Updated narrow Neutralino allowed Areas

\[ \tan \beta = 10, \, \mu > 0 \]

\[ m_h = 114 \text{ GeV} \]

\[ m_{\chi^\pm} = 104 \text{ GeV} \]

Olive 2005
### mSUGRA Benchmark Scenario: the test points (J. Ellis et all 2003)

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Narrower range of Neutralino mass parameters following W-Map, LEP and g-2 constrains
Consequent resonant Neutralino electron-Selectron cross sections along the main SUSY points
Neutralino Fluxes
in agreement with WB flux

- Assumed Spectra
- Comparable with the Neutrino power law

one at exponent -1.5 for Fragmentation:

\[ E^2 \frac{dN}{dE_{\chi}} = 10^{-7} \text{ GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1} \left[ \frac{E_{\chi}}{10^7 \text{ GeV}} \right]^{0.5} \]

Or a Fermi-like power law at exponent -2:

\[ E^2 \frac{dN}{dE_{\chi}} = 10^{-7} \text{ GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1} \]
Spectra Fluxes

Excluded Region

ACASA + Fly's Eye

Index -1.5

GLUE + FORTE

Index -2

Luis Anchordoqui,* Haim Goldberg†, and Pran Nath‡
Constrained best Neutralino parameters

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<td>0.35</td>
<td>3.0</td>
<td>1.1</td>
<td>0.52</td>
<td>1.3</td>
<td>0.08</td>
<td>1.5</td>
<td>0.17</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>0.22</td>
<td>2.6</td>
<td>0.89</td>
<td>0.36</td>
<td>1.1</td>
<td>0.04</td>
<td>1.2</td>
<td>0.09</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Table 1: Definition of different mSUGRA scenarios and corresponding event-number expectations $\mathcal{N}_{\tilde{e}_R,\tilde{q}_R}$, for resonant neutralino scattering in ice. In all scenarios, we assume $A_0 = 0$. The resonance decay widths and peak cross sections for the right selectron and right squark are also shown. The upper of the two entries in the $\mathcal{N}_{\tilde{e}_R,\tilde{q}_R}$ rows corresponds to the event number calculated by the neutralino flux in eq. (4) ($\beta_0 = 1.5$), while the lower entry refers to eq. (5) ($\beta_0 = 2$). When computing the squark event rates, an incident neutralino energy threshold of 1 PeV is assumed. The relic DM density $\Omega h^2$ corresponding to each scenario is also shown.
### Number of events expected for Cubic Km/year

<table>
<thead>
<tr>
<th>Model</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_{1/2}$ (GeV)</td>
<td>600</td>
<td>280</td>
<td>400</td>
<td>525</td>
<td>375</td>
<td>935</td>
<td>350</td>
<td>750</td>
<td>450</td>
</tr>
<tr>
<td>$m_0$ (GeV)</td>
<td>107</td>
<td>57</td>
<td>77</td>
<td>101</td>
<td>110</td>
<td>233</td>
<td>180</td>
<td>298</td>
<td>303</td>
</tr>
<tr>
<td>$\tan \beta$</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>35</td>
<td>35</td>
<td>47</td>
</tr>
<tr>
<td>sign($\mu$)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>$\Omega h^2$</td>
<td>0.128</td>
<td>0.123</td>
<td>0.122</td>
<td>0.116</td>
<td>0.110</td>
<td>0.123</td>
<td>0.117</td>
<td>0.119</td>
<td>0.113</td>
</tr>
<tr>
<td>$m_{\chi}$ (GeV)</td>
<td>243</td>
<td>107</td>
<td>158</td>
<td>212</td>
<td>148</td>
<td>388</td>
<td>138</td>
<td>309</td>
<td>181</td>
</tr>
<tr>
<td>$m_{\tilde{e}_R}$ (GeV)</td>
<td>254</td>
<td>128</td>
<td>175</td>
<td>226</td>
<td>184</td>
<td>423</td>
<td>227</td>
<td>412</td>
<td>349</td>
</tr>
<tr>
<td>$\Gamma_{\tilde{e}_R}$ (MeV)</td>
<td>9.13</td>
<td>57.2</td>
<td>29.7</td>
<td>16.3</td>
<td>103</td>
<td>53.4</td>
<td>448</td>
<td>396</td>
<td>931</td>
</tr>
<tr>
<td>$\sigma^{peak}_{\tilde{e}_R}$ ($\mu$b)</td>
<td>21.1</td>
<td>6.58</td>
<td>9.34</td>
<td>13.3</td>
<td>2.57</td>
<td>2.17</td>
<td>0.477</td>
<td>0.301</td>
<td>0.150</td>
</tr>
<tr>
<td>$N_{\tilde{e}_R}$</td>
<td>28</td>
<td>32</td>
<td>26</td>
<td>23</td>
<td>8.5</td>
<td>2.3</td>
<td>1.9</td>
<td>0.55</td>
<td>0.42</td>
</tr>
<tr>
<td>(km$^{-3}$ yr$^{-1}$)</td>
<td>37</td>
<td>45</td>
<td>34</td>
<td>30</td>
<td>7.7</td>
<td>1.4</td>
<td>1.1</td>
<td>0.20</td>
<td>0.14</td>
</tr>
<tr>
<td>$m_{\tilde{q}_R}$ (GeV)</td>
<td>1194</td>
<td>596</td>
<td>825</td>
<td>1057</td>
<td>781</td>
<td>1798</td>
<td>748</td>
<td>1487</td>
<td>961</td>
</tr>
<tr>
<td>$\Gamma_{\tilde{q}_R}$ (GeV)</td>
<td>2.45</td>
<td>1.23</td>
<td>1.70</td>
<td>2.17</td>
<td>1.61</td>
<td>3.65</td>
<td>1.55</td>
<td>3.04</td>
<td>1.99</td>
</tr>
<tr>
<td>$\sigma^{peak}_{\tilde{q}_R}$ (nb)</td>
<td>7.43</td>
<td>28.6</td>
<td>15.3</td>
<td>9.46</td>
<td>17.1</td>
<td>3.32</td>
<td>18.5</td>
<td>4.81</td>
<td>11.3</td>
</tr>
<tr>
<td>$N_{\tilde{q}_R}$</td>
<td>0.35</td>
<td>3.0</td>
<td>1.1</td>
<td>0.52</td>
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Real Energy released per SUSY Showers: Imprint of Selectrons (and Squark) mass in Cubic Km. Similar Consequences in Horizontal Air-Showers
SUSY Points of interest
SUSY $S$-electron may air-shower at Horizons

- In air the $s$-electron may arise as a Glashow resonant event. At best at Horizons
- In air also Gluino may air shower at best.
- The UHE Neutrino Tau must also appear and airshower at greater rate. Therefore we show a brief summary of UHE Neutrino tao astronomy at the Earth edge.
The near future detection of prompt neutrino maybe correlated with GRB activities:
however the SUSY masses may induce delayed events: half an hour for $z=1$ and EeV event and a SUSY 100-200 GeV Gluino mass. A coincidence?
THE SUSY VERSUS UHE NEUTRINO SIGNAL at HORIZONS

The UHECR Ultra High Energy Cosmic Ray airshower in peculiar way at the horizons with splitting signature due to geomagnetic fields. This offer a novel spectroscopy of UHECR.

- Neutrino Astronomy may arise by upward-horizontal airshowers:
  - anti- \( \nu_e \) Glashow resonance and-or by Tau Neutrino Earth Skimming Air showers may split into sky. The \( \tau \) airshower are mostly GZK guaranteed and oscillated neutrinos at EeV energy.

- Magic is already looking for Horizontal Tau Air Showers at PeVs-EeV.

- AUGER may look Neutrino Showering by three ways:
  1) \( \tau \) airshower by Young Airshowers signature
  2) \( \tau \) airshower in Ande Shadows
  3) \( \tau \) airshower inside AUGER (cloudy) skies.
May UHE Neutrinos trace UHECR and solve the never ending puzzles of UHECR?

*There is not just 1 neutrino but 3*2 = 6 different Neutrino Astronomies*

Electrons are very dissipating and short.

Muons are very penetrating ones.

**BUT**

* Tau are the most penetrating, short at small, but longest at highest energies*
Unstable tau versus muons at highest energy

Why Horizontal – Upward Tau air-showers are easier to be revealed than muon tracks?

Because an air-shower is amplified by its huge secondary number and in large area.

Millions muons, billions gamma, e-pairs, trillions or more Cerenkov photons.

An Unique Muon is single and shine little.
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 (otherwise very difficult to produce) Tau Neutrinos.

Galactic and cosmic distances are huge respect the neutrino oscillation lengths. Even at UHE energies

\[ L_{\nu_\mu - \nu_\tau} = 8.3 \text{ pc} \left( \frac{E_\nu}{10^{19} \text{eV}} \right) \left( \frac{\Delta m_{ij}^2}{(10^{-2} \text{eV})^2} \right)^{-1} \]
Horizontal Tau air showers from mountains in deep valley: Traces of UHECR neutrino tau
Effective Volume Areas for Uptaus
Expected GZK neutrino flux
following most authors (Semikoz, Sigl..)
GZK neutrino and Upward Tau

\[
\frac{dN_{\tau}}{d\theta \, dE \, dA \, dE} \propto E \left[ \text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1} \right]
\]

\[
E = 10^{17} \quad E = 10^{18} \quad E = 10^{19} \quad E = 10^{20} \quad E = 10^{21} \quad E = 10^{15} \quad E = 10^{16} \quad E = 10^{17} \quad E = 10^{18} \quad E = 10^{19} \quad E = 10^{20} \quad E = 10^{21}
\]

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

Following Fargion et al. 2004

Following Zas 2005

High Energy Neutrino Astronomy: Inclined Air Showers

MAGIC, while pointing a GRB, SGR or BL Lac
Below The Horizons (~ 1% of the GRB-SGRs events) on rock behave (near EeV energy) as a 75 km$^3$ NEUTRINO TELESCOPE

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

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

Inclined Rock Cylinder depth $L \sim 10 \text{ km}$

Rock Cylinder depth $l \sim 0.5 \text{ km w.e.}$

$l_t = 0.5 \text{ km w.e.}$

astro-ph/0511597
D. Fargion
UHECR Mirror air-showers and their polarization: an Useful test for UHECR meter

Reflection on the Sea of UHECR air-Showers Cherenkov lights
MAGIC, while pointing a GRB or a SGR Burst at Horizons (~ 3% of the GRB-SGRs events) behave as a km³ NEUTRINO and SUSY NEUTRALINO and GLUINO TELESCOPE

Horizons distance \( d = 167 \text{ km} \sqrt{\frac{h}{2.2 \text{ km}}} \)

Cerenkov Shower opening angle \( \theta \sim 1° \)

Conic Air Base Area \( A \sim 30 \text{ km}^2 \)

Truncate Air Cone height \( h \sim 100 \text{ km} \)

Truncate Air Cone Volume \( V \sim 1000 \text{ km}^3 \)

Truncate Cone Mass \( M \sim 1 \text{ km}^3 \)

astro-ph/0505459

Neutrino Astronomy beyond and beneath the Horizons: D. Fargion

The Ande Mountains as a target for detecting UHE neutrino tau by Horizontal Tau Air-Showers at AUGER: MOON AND SUN Shadows difficult to observe- ANDE SHADOWs must be OBSERVED (within the 2008 ?)
Tau Young Air-Showers versus Hadron Old ones in AUGER

Pierre Billoir, AUGER 2006 NOW

The Ande Shadows on AUGER

height (m)

longitude (°)

latitude (°)

Pastor et al. 2005

AUGER SKY EDGES and THRESHOLDS
Long life Horizontal AirShowers
with no Surface Detector event

A Novel way to Neutrino and SUSY Astronomy
THE FLUORESCENCE lightening by TAU and SUSY: NO SD Trigger
Predictions

- Auger tracing Ande Shadows may reveal there an event in two years. Both Tau, Glashow and SUSY may be born.

- Auger detector fine-tuned to EeV may see Fluorescent air-showers at ten km altitude and Should reveal Tau Air-showers at 1-2 Event a year. ALSO a few Cherenkov flash On Clouds in Auger Sky-ALSO by SUSY sources.
AUGER showering into clouds:

**Tau and SUSY a few event a year**

SUSY Showering-D.Fargion-
SUSY2007-Karlsruhe-26-July-2007
Conclusions

1. \(\tau\) Neutrino Earth Skimming Astronomy is at the edges within the Earth horizons and within our lives.

2. MAGIC and Veritas and Hess might discover taus within horizons tracing active GRB- BL Lac sources

3. AUGER may and MUST.. find \(\tau\) GZK in inclined events WITHIN 1-2 years from NOW.

4. A DIFFERENT TRIGGER for fotopluorescent UPTAUS and HORTAUS with NO Surface Detector event : 1-2 event a year. Just beyond a corner

5. SUSY may arise at Tens PeVs on MAGIC-HESS pointing at horizons or at a few degrees below the edge.

Tau Neutrino and SUSY sky lay just beyond our own sky …the EARTH
Thank you DF