A new, Gravity Symmetric view of the Universe

GSU

Repulsive gravity between matter and antimatter

We may live in a universe that is half anti-gravitating anti-matter
and
<u>only neutrinos will reveal the symmetry</u>

<u>Warning… whole talk may be speculative phantasy, but fun to contemplate!</u>

Still a Fundamental Question even if GSU wrong

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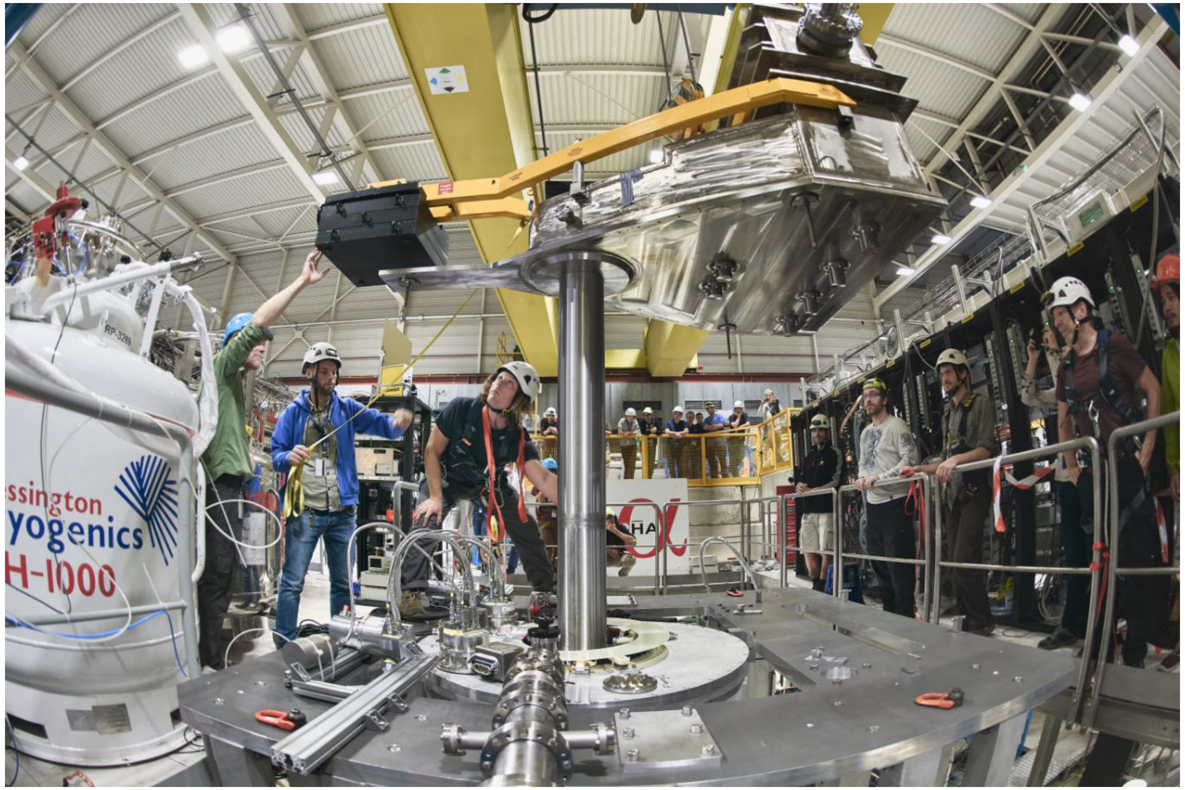
With maximal credit for Massimo Villata of U. Turin, Italy, for the founding ideas herein

Key Idea

For this speculative idea to work, **anti-protons must repel ordinary protons.**

The notion of anti-gravity has been debated for decades. The notion of anti-matter having anti-gravity is new (and due to Italian astrophysicist Massimo Villata about 20 years ago)



Installing ALPHA-g at CERN 2018

This is now under test at CERN and Fermilab
In the ALPHA experiments. Results are long past due. (Prelim results last year, indecisive. Lack of publications.) Recent report of 97% chance gravity normal… (now is 2 sigma, claim 1% test in 2024) but no details, no publication.

All of the following hinges on the rising or falling of anti-hydrogen in earth gravity.
If antihydrogen falls you can forget the rest of this presentation with respect to a GSU.

If it rises, then we are heading towards a great revolution in astrophysics and cosmology.
Key: then half the universe probably anti-gravitating anti-matter, and only neutrino observations can resolve this quandry.

Theory does not tell us <u>how gravity couples to protons and anti-protons.</u>

We cannot calculate the <u>gravitational</u> or inertial mass of the proton (nor anti-proton) from first principles.

a) Lattice QCD folks claim inertial mass calculation, but they employ known meson masses

b) We have no quantum gravitational field theory in any event

If anti-hydrogen rises, all matter and anti-matter should annihilate or segregate itself into <u>zones of matter and antimatter</u>, assuming the initial singularity symmetrically makes matter and anti-matter.

One then suspects that from a symmetric Big Bang, the universe will have <u>begun to segregate</u> into regions of matter and of anti-matter (just as with BAO) <u>prior to the CMB</u>.

Present theory has baryon annihilation to ~10^-9 matter being left over. No easy “baryogenesis” mechanism found.

As gravity and antigravity zones accumulate mass, <u>pressure barriers</u> form between them, shutting down annihilation.

Accepted limits on the amount of anti-matter in the universe do not apply: these <u>limits assume mutual attraction.</u>

(Krauss L M, Glashow S L and Schramm D N 1984 Nature 310 191)

If half the universe is indeed anti-gravitating antimatter, that we live in a GSU: <u>How can we discern this?</u>

In sum attraction with antimatter is like E&M, but Opposite Pattern

m = matter charge
M = anti-gravity matter charge
+ = normal positive electrical charge
- = normal negative electrical charge
A = Attractive
R = Repulsive

Villata antigravity:

	m	M
m	A	R
M	R	A

E&M: (plasmas)

	+	-
+	R	A
-	A	R

Quantum Field Theory relies upon CPT Symmetry

C = charge and anti-particle
P = parity, left or right handed
T = forwards and backwards in time

All QFTs rely upon locality, causality, unitarity, and CPT symmetry

(extended) GRAVITATION

Geodesic equation (equation of motion):

"Negative Mass in General Relativity"
H. Bondi Jul, 1957 5 pages
Rev.Mod.Phys. 29 (1957) 423-428 10.1103/RevModPhys.29.423

$$\frac{\mathrm{d}^2 x^\lambda}{\mathrm{d}\tau^2} = \mp \frac{m_{(\mathrm{g})}}{m_{(\mathrm{i})}} \frac{\mathrm{d}x^\mu}{\mathrm{d}\tau} \Gamma^\lambda_{\mu\nu} \frac{\mathrm{d}x^\nu}{\mathrm{d}\tau}$$

- for attraction
+ for repulsion

$m_{(g)}/m_{(i)}$ = 1 (Equivalence Principle holds)

where the ratio $m_{(g)}/m_{(i)}$=1 (the Equivalence Principle) added for a useful comparison with electrodynamics.

Four **(C)PT**-odd quantities (el. charges in ED are replaced by additional ranks here), so that the equation is **CPT**-invariant.

But, if we **CPT**-transform only the charge or the field, we get a change of sign in the equation (both ED and GR), meaning that attraction becomes repulsion, and the generalized Newton law is then:

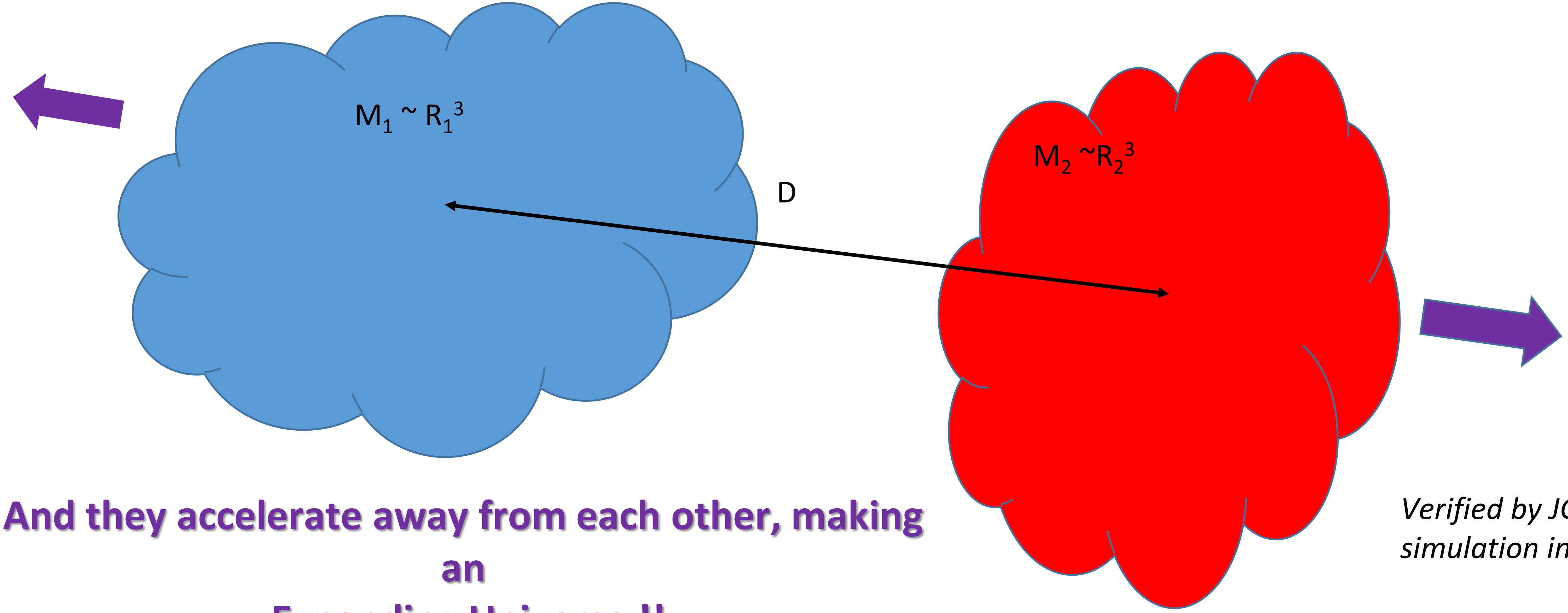
Hence Generalized Newton Law:

$$F(r) = -G(\pm m)(\pm M)/r^2 = \mp GmM/r^2$$

"CPT symmetry and antimatter gravity in general relativity" M. Villata 2011, *EPL* 94, 2001

As the self attractive matter and antimatter regions grow and incorporate more mass they repel each other ever more strongly!

$F = \color{red}{+}\ \dfrac{G\, M_1\, M_2}{D^2}$ Take R_1 and R_2 to be ~D/2 Then $F \sim D^3 * D^3 / D^2 \sim D^4$ => **Pressure** $P \sim F/A \sim D^4 / D^2 = D^2$



Verified by JGL simulation in 2010

And they accelerate away from each other, making an

Expanding Universe !!

GSU Implications call for major revisions in our cosmology

Yes, this whole hypothesis is going to be hard to sell, but has many wonderful implications:

- No tricks needed to get Hubble flow from simple numerical calculations

- No mystical metric expansion…

- No need for mystical Dark Energy and of cosmological constant problem

- No need for tricky scheme to yield slight excess of matter over antimatter

- No need for mystical inflatons to give fast universe expansion

- No Universe age of 14 billion years: Perhaps t = 0 was infinite time in past

- Maybe no need for mystical Dark Matter either (neutrinos?)

<u>If</u> anti-hydrogen rises, we are in for a great rethinking of cosmology

But what remains alright? <u>Almost everything we observe is same!</u>

First off, <u>General Relativity</u> remains intact… only need extended Equivalence Principle

All of <u>Particle Physics</u> is unaffected… gravity plays negligable role

<u>Nothing</u> changed (as far as I see) within <u>solar system scale</u>, or even local galactic scale

All of <u>Optical Astronomy</u> remains untouched, except that we are observing some antigravitating antimatter galaxies and clusters, which look just the same.

<u>Photons are bent to follow the geodesic</u> in gravitational fields, and must be same for lensing and antimatter lensing.

<u>ISW and such</u> unchanged.

This of course is our trouble with the GSU: <u>How can we test it astronomically?</u>

A good question anyway: Of what are distant galaxies composed?

Are all galaxy center black holes of only matter?

Should there not have been primordial black holes of matter and anti-matter?

What has become of the primordial black holes? Evaporated early on?

Where did the AGN come from?

I dunno the answers to any of these questions,
but seems that this reinforces the initial question of this talk.

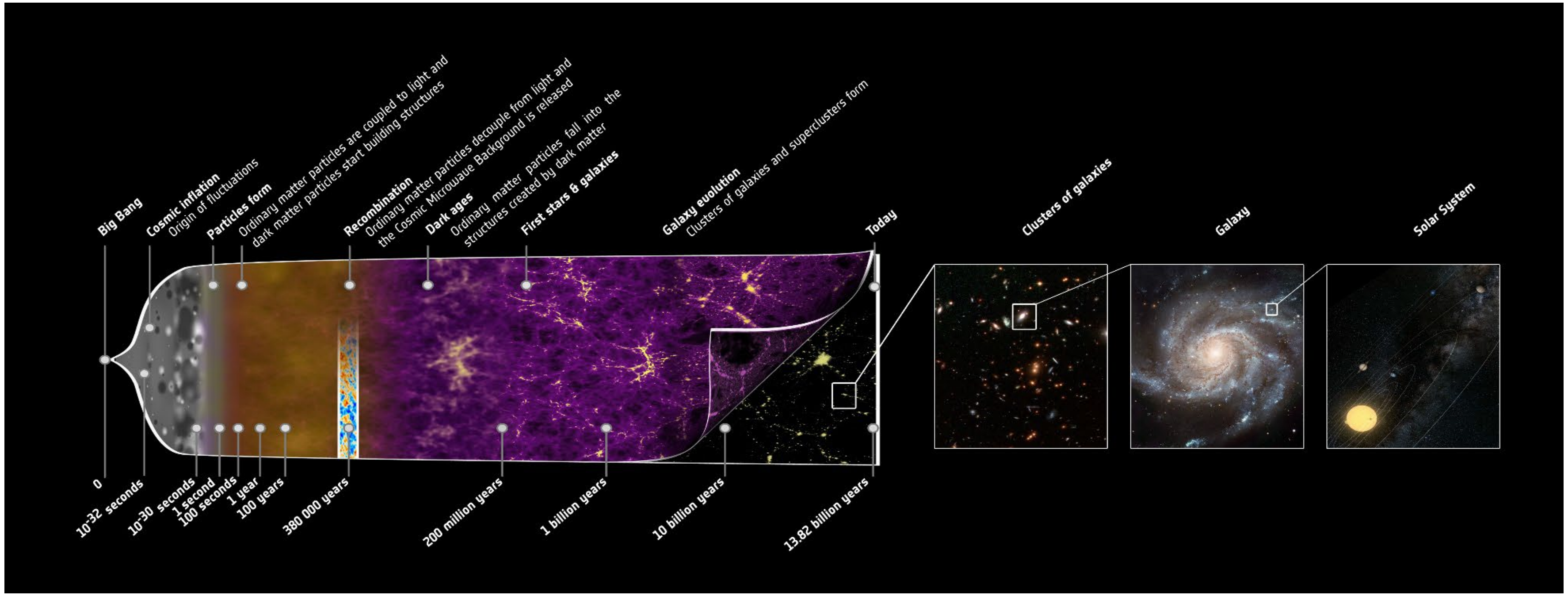
Now to the meat of the presentation: If Anti-hydrogen rises I am claiming that

Only neutrinos can reveal this Cosmic Symmetry

Traditional astronomy utilizes photons, but it appears to be impossible to discern a matter galaxy from an antimatter galaxy with photons (light, Xrays, gamma rays, radio)… they all look alike to optical, radio and gamma ray telescopes.

Weak interactions do indeed have a handedness, and hence we should look at neutrinos for possible revealing the situation?

For the rest of this talk I will focus upon how we might accomplish this distinction



IceCube has clearly begun High Energy Neutrino Astronomy

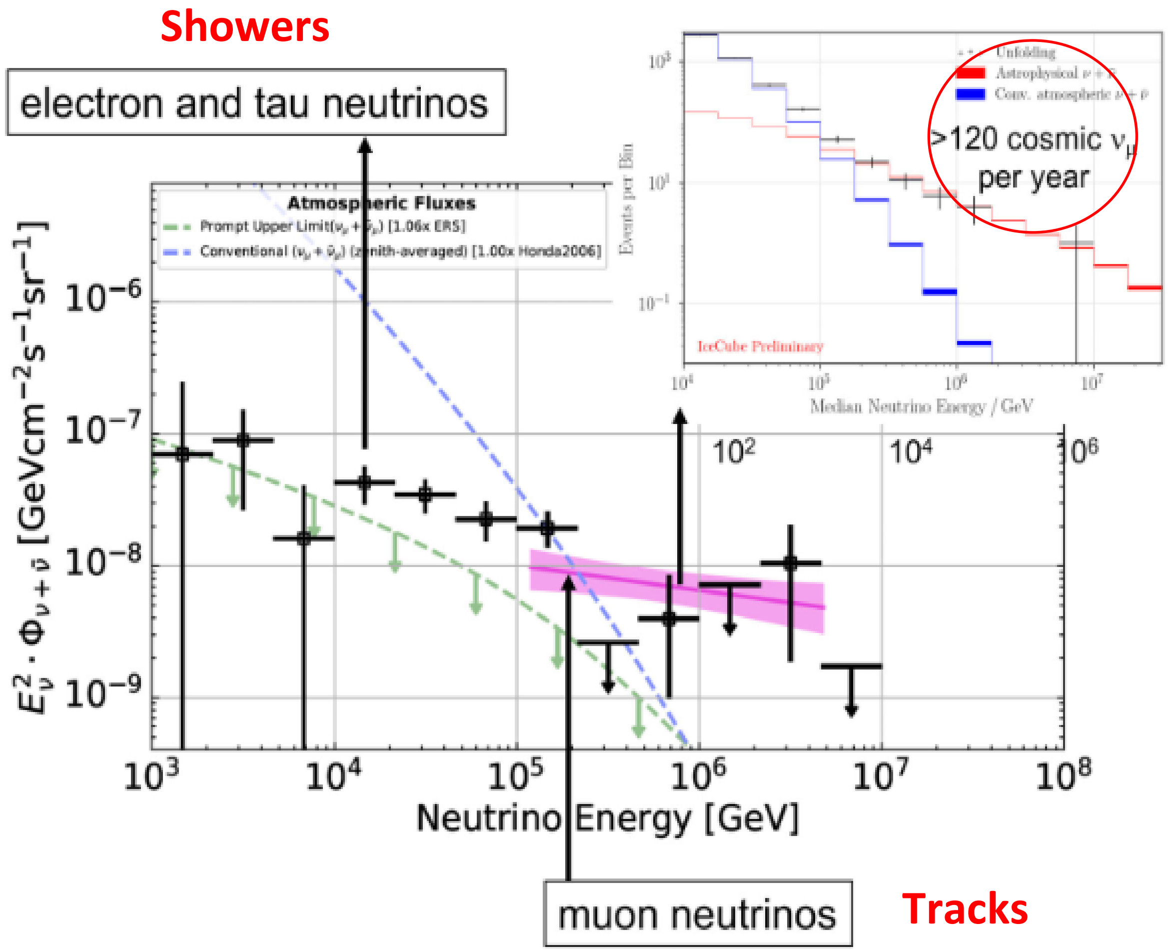


Figure 8. The flux of cosmic muon neutrinos[19] inferred from the 8 year upgoing-muon track analysis (red solid line) with 1σ uncertainty range (shaded range; from fit shown in upper-right inset) is compared with the flux of showers initiated by electron and tau neutrinos.[27] The measurements are consistent assuming that each neutrino flavor contributes an identical flux to the diffuse spectrum

IceCube webpage

Newly reconciled Gamma, Cosmic Ray and Implied Neutrino Fluxes

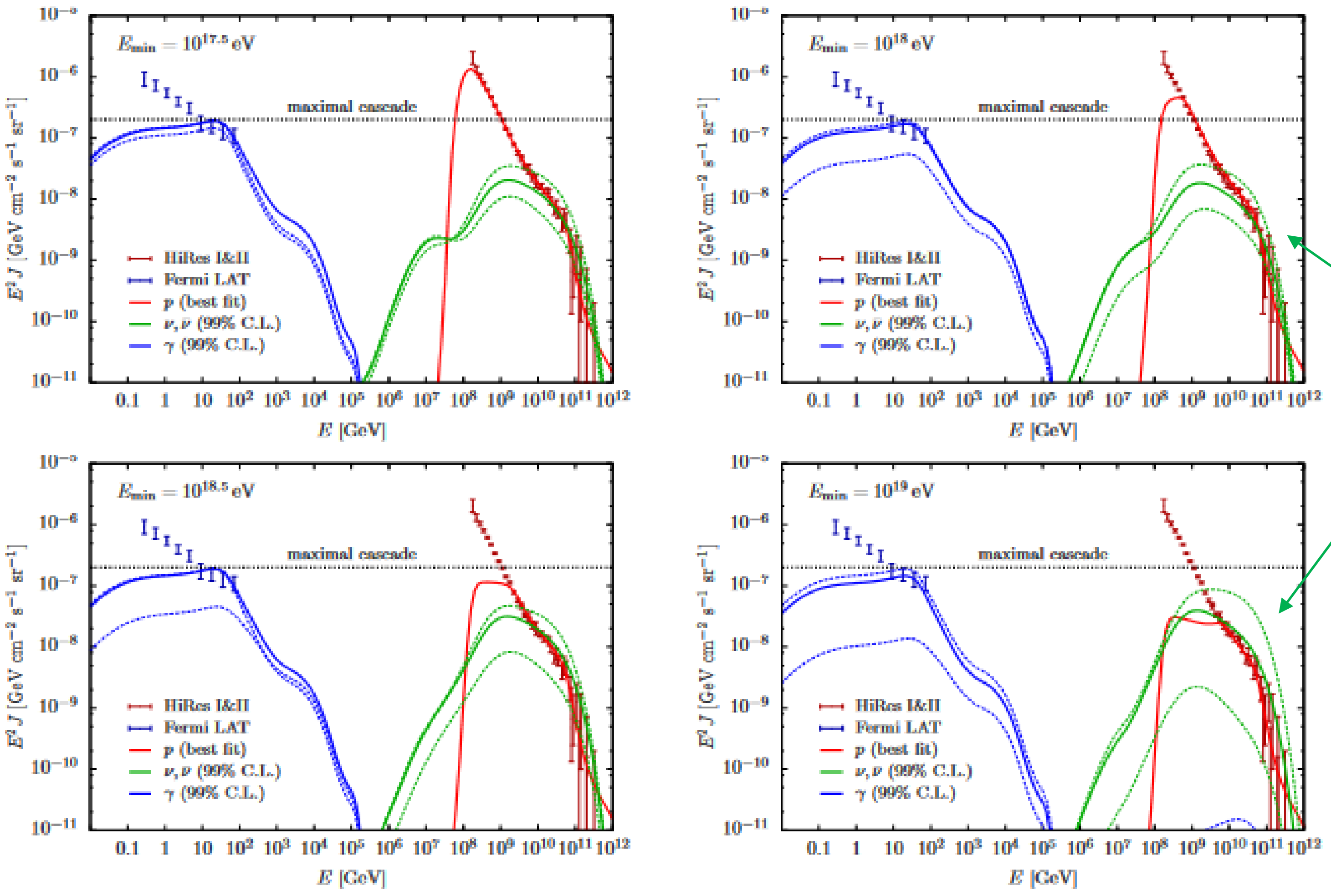


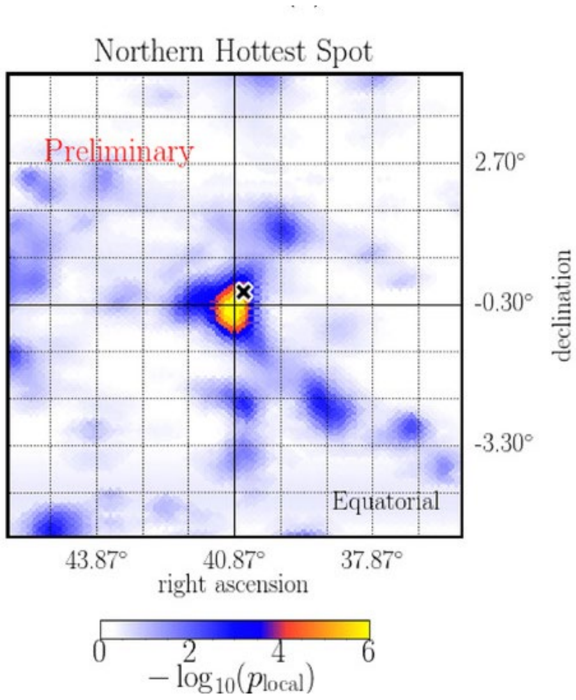
Figure 6: Comparison of proton, neutrino and gamma ray fluxes produced in interactions on the CMB by cosmic-ray protons fitted to HiRes data. We repeat the calculation for 4 values of the crossover energy marking the transition to the extragalactic cosmic ray flux. We show the best fit values (solid lines) as well as neutrino and gamma-ray fluxes within the 99% C.L. with minimal and maximal energy density (dashed lines). The γ-ray fluxes are marginally consistent at the 99% C.L. with the highest-energy measurements by Fermi-LAT. The contribution around 100 GeV is somewhat uncertain, due to uncertainties in the cosmic infrared background.

Highest CR Energies may be Neutrinos

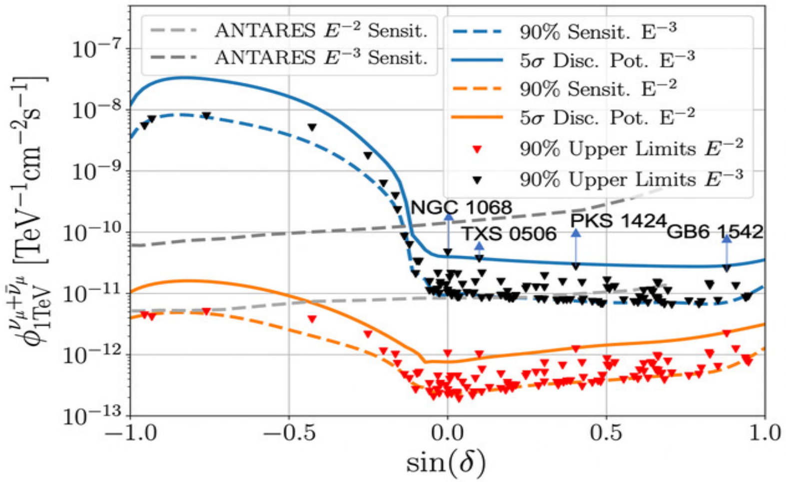
IceCube page

IceCube at the South Pole starting to see many Cosmic Point Sources

NGC 1068 seen by IceCube



IceCube sensitivity



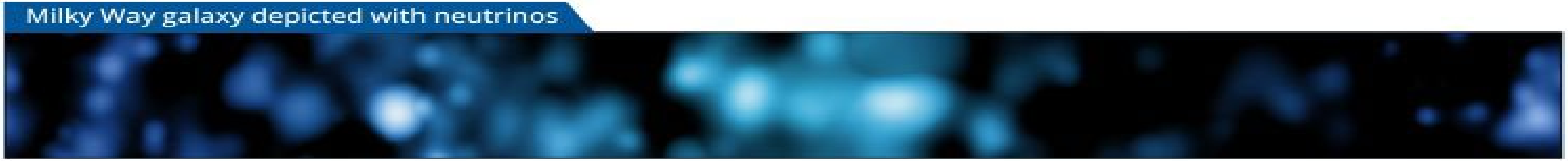
Implication: New larger detectors will find many cosmic neutrino sources

Halzen and Keirandish arXiv:2202.00694v1

IceCube also sees Neutrinos from our Galactic Plane

Multiple unresolved neutrino point sources in our galactic plane, near Galactic center

Many unidentified galactic plane gamma sources seen by Fermi Satellite



Implication is that if our unremarkable galaxy produces many point sources of high energy neutrinos then

the sum of all galaxies' neutrino output must be enormous.

R. Abbassi, et al. arXiv:/2307.00247

OK, so now (in last few years after 40 years of hunting with ever better instruments)
we know there are Lots of Cosmic Neutrinos!

But, can we discern if half come from anti-matter galaxies?

Follows: 6 possible regions to test with neutrinos:

1) Diffuse Supernova Neutrinos from the sum of all past Supernovae (DSNB) (SRN)

- Calculations indicate that we are not far from detecting this background (SK->HK)

- Supernova models have been changing in recent times

- Previously expected a big leading burst of electron nus ($\nu_e / \bar{\nu}_e / \nu_x = 2.4/1.6/1.0$)

- Modern calculations indicate more nearly equal proportions of neutrino types.

- Whatever the flavor mix, best sensitivity at lower energies <GeV is to electron anti-neutrinos:

  nuebar + p -> n + e+

  Due to double signature (n & e+, and not just one e- as from nue)

  Poor sensitivity to electron neutrinos, flux dominated by solar neutrinos.

- Largely below threshold for muon and tau neutrinos, <100 MeV/c

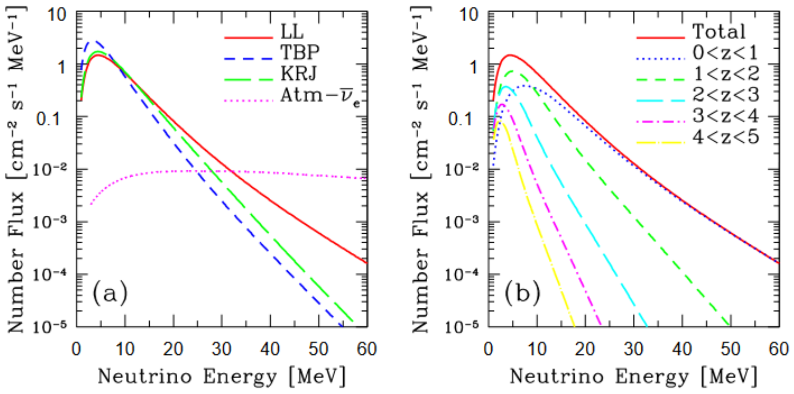


Figure 2. (a) SRN flux in units of f_* cm^{-2} s^{-1} MeV^{-1} calculated with three reference models of original neutrino spectrum: LL, TBP and KRJ. The flux of atmospheric neutrinos [66, 67] is also shown for comparison. (b) The same as (a), but indicating contribution from various redshift ranges. LL is adopted as the supernova model. These figures are taken from [17].

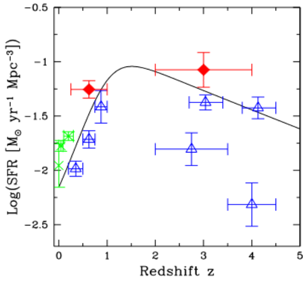


Figure 1. Cosmic star formation rate as a function of redshift. Data points are given by rest-frame UV (*open triangles*) [22, 23, 30], NIR Hα (*crosses*) [33, 34, 35], and FIR/sub-millimeter (*filled diamonds*) [31, 32] observations. The solid curve represents our reference model given by equation (4) with $f_* = 1$. The standard ΛCDM cosmology is adopted ($\Omega_m = 0.3, \Omega_\Lambda = 0.7, H_0 = 70$ km s^{-1} Mpc^{-1}) .

Ando and Sato https://doi.org/10.48550/arXiv.astro-ph/0410061, New J. Phys. 6 (2004)

Gloomy Prospects for GRU Confirmation via DSNB (SRN)

Search Region
~18-35 MeV/c

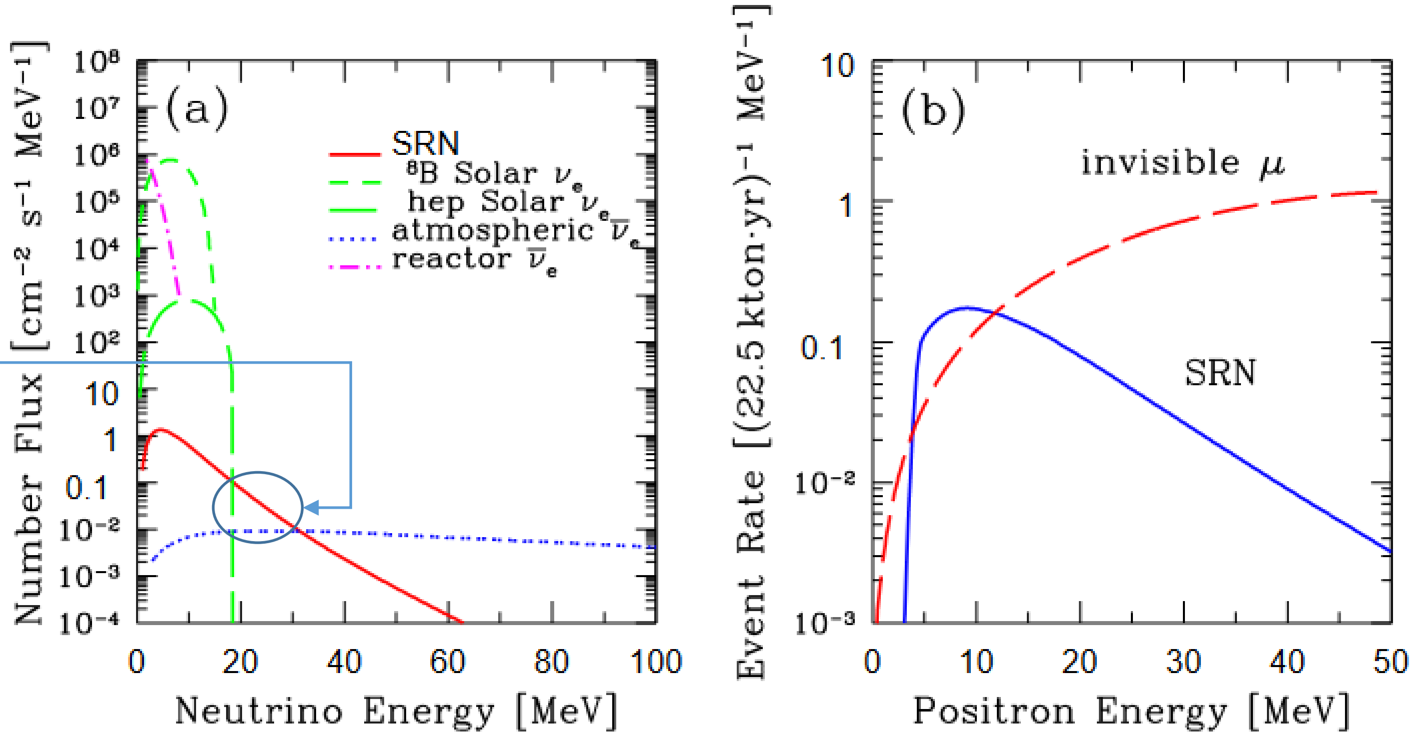


Figure 4. (a) Number flux of SRNs compared with other background neutrinos. (b) Event rate of SRNs and invisible muon decay products. In both panels, LL is adopted as the original neutrino spectrum. These figures are taken from [12].

(12) Ando S, Sato K and Totani T 2003 Astropart. Phys. 18 307

2) Big Bang Relic Neutrinos (or "CNB")

- 3 types of neutrinos left over from the Big Bang ought to be symmetric in numbers including the effects of oscillations, and initially equal neutrinos and anti-neutrinos.

m = milli

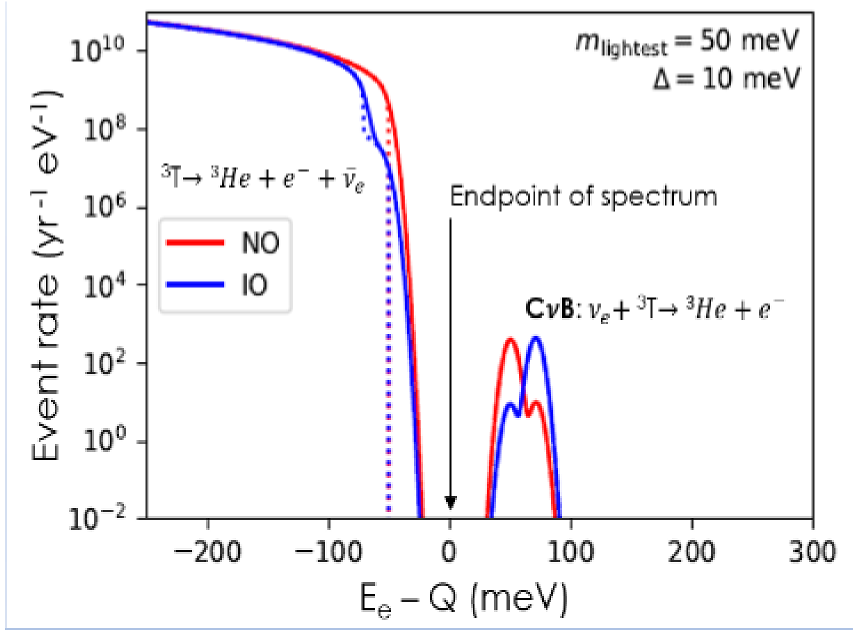
- There should be a cosmic neutrino background (CNB) that is exactly (4/11)^(1/3) of the cosmic microwave background (CMB) temperature. And present energy ~$10^{-(4-6)}$ eV…. (Decoupled ~2.5 MeV)   Now ~56/cm^3.

- **Cross sections for interaction so small scattering detection not possible.** (<10^-10 of usual observations: forget using accelerators, etc.)

- With **GSU it seems we must be sitting in a soup of Neutrinos** (not Anti-Neutrinos) of all flavors.

- The initial flavor wave packets will all have decohered, so what?

- **Ptolemy experiment under development may detect these: $\nu_e + {}^3H \rightarrow {}^3He + e^-$**



Interlude: Low Energy Mystery ~ 100 eV

Anomalous low energy deposition is well known in experiments with a low threshold, <keV, developing awareness over a decade

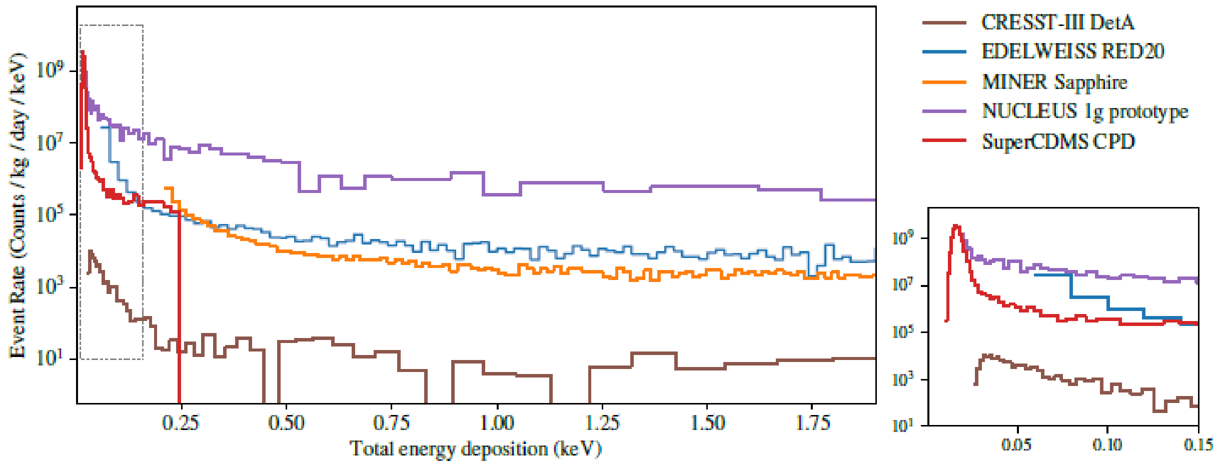
“Many low-threshold experiments observe sharply rising event rates of yet unknown origins below a few hundred eV, and larger than expected from known backgrounds” from the EXCESS Workshop 4/22 summary*.

Some of this apparently arises from release of stored energy which can be discharged by IR illumination, but not all **

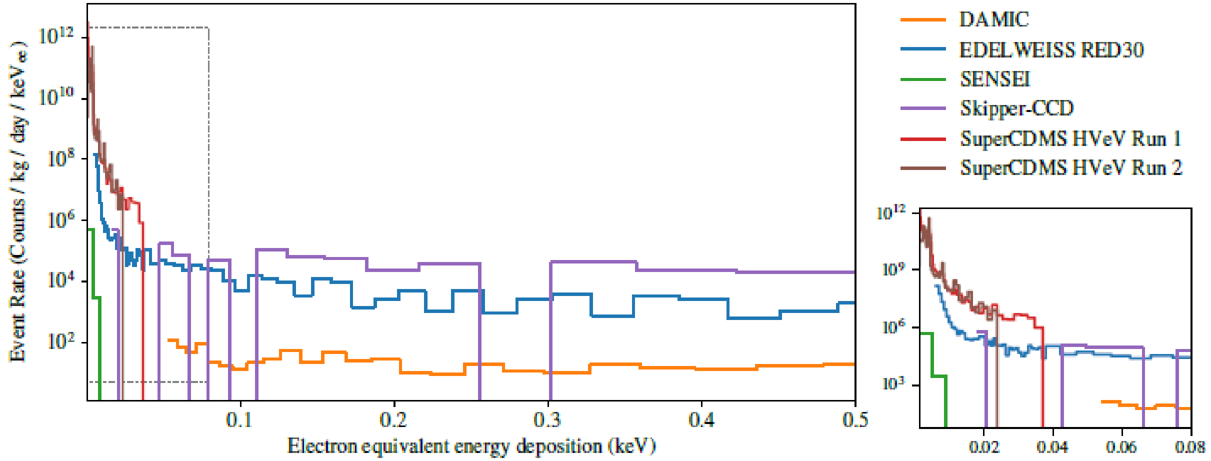
Hence, **could this be due to very low energy neutrino scattering?**

Origin unclear… much activity Fermilab and elsewhere.

(Way too much energy for relic nu’s so ?????????????
But Dark Energy maybe???)



(a) Energy spectra of measurements with units of total energy deposition. The apparent peaks in the CRESST (SuperCDMS CPD) data at 30 eV (20 eV) are caused by the trigger threshold and discussed in the main text.

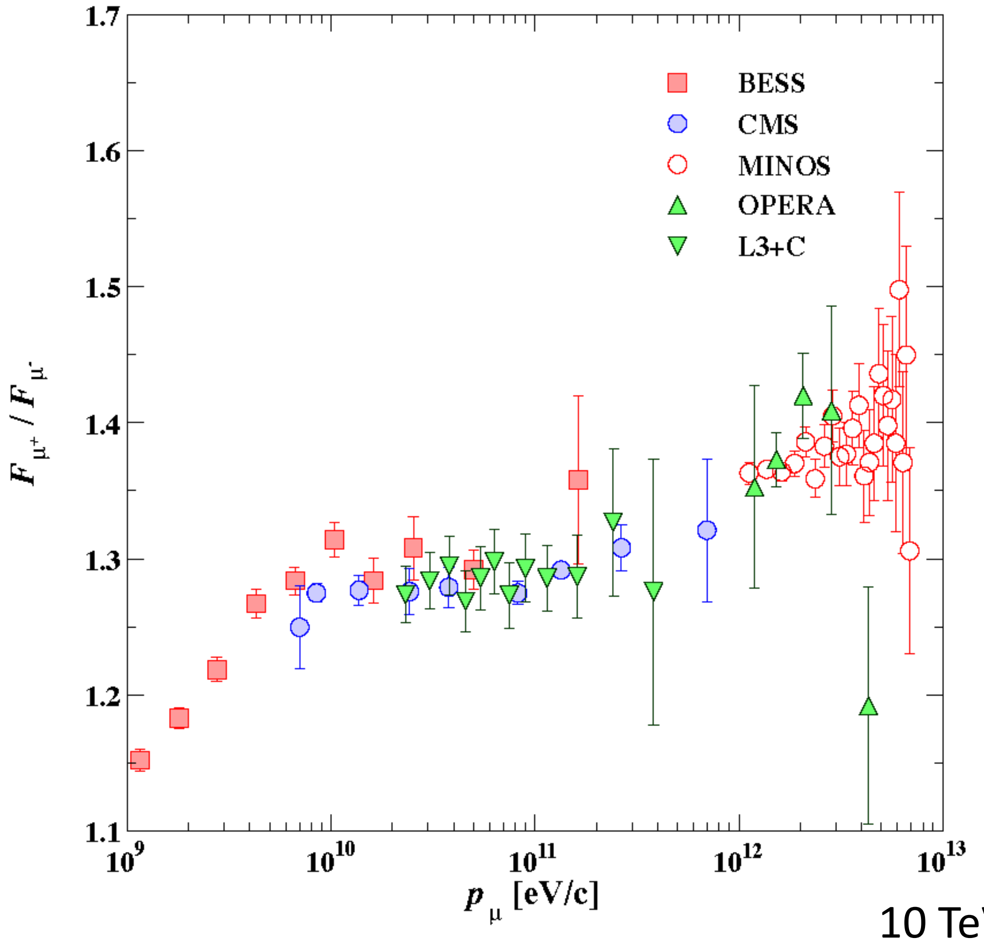


(b) Energy spectra of measurements with units of electron equivalent energy deposition. Note that this energy scale can only be approximated for SuperCDMS HVeV data (see Sec. 2.1.5).

Figure 20: (a, b) (left, large) Energy spectra of excess observations from the individual experiments . In all energy spectra, the rise at low energies is visible. (right, small) Zoom into the excess region of the spectrum [15].

3) Probably no GSU help from < PeV cosmic ray observations

- Ordinary cosmic rays wind up with many muons penetrating to deep detectors, such as SuperK
- Around 1/s stop in the SK detector, and mu+ stop and often get captured on water nuclei, whence underground experiments measures the mu+/nu- rate in CRs…. ~ 1.4
- Detectors with magnets can directly measure sign of incoming muon, up to MDM typically 1 TeV
- (AMS measures antiprotons but below ~1 TeV)
- All these probably from our galaxy, so no surprise.
- Probably would need 100 PeV muons to see effects of extragalactic particles
- Impractical



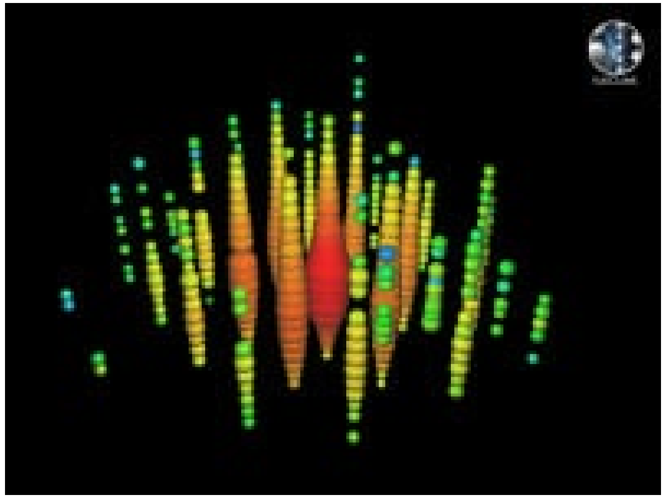
10 TeV

Allkofer et. al. Phys. Lett. B36, 425 (1971)
Jokisch et. al. Phys. Rev. D19, 1368 (1979)

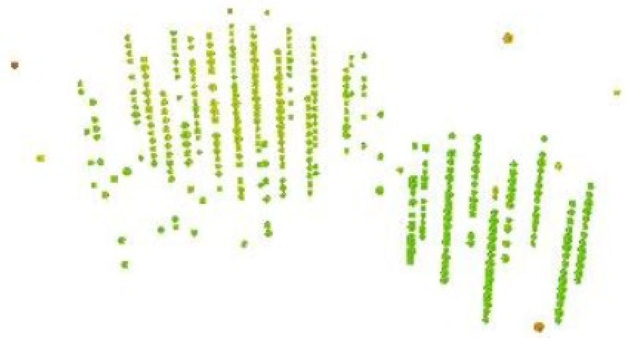
4. IceCube to the Rescue?

- Can we tell if these very high energy events in IceCube result from neutrinos or anti-neutrinos?
- 2023 hints of other (AGN) sources emerging in the IceCube data. It seems unlikely that even in the optimistic case for GSU we will find anti-matter galaxies in our neighborhood, <~ 100 mly.
- Thus, this seems like a conceivable route, though with some luck needed in the extant sources, and much study of the events in IceCube and new detectors.
- Can IceCube and the like (big ocean neutrino detectors such as KM3Net, Trident,…) distinguish the initial interaction type?
- Hi X particles retain initial particle information.
- At present no, at least in the TeV range, but very sophisticated machine learning methods have shown surprising progress of late in tagging types if initial interaction?

- Question: Can Double Bang (nu_{tau} : initial CC interaction followed by tau decay shower at some distance) be employed? *(SP & JL predicted and now IC has observed DB events). (Tau- through earth favored?)*



Large IC Event

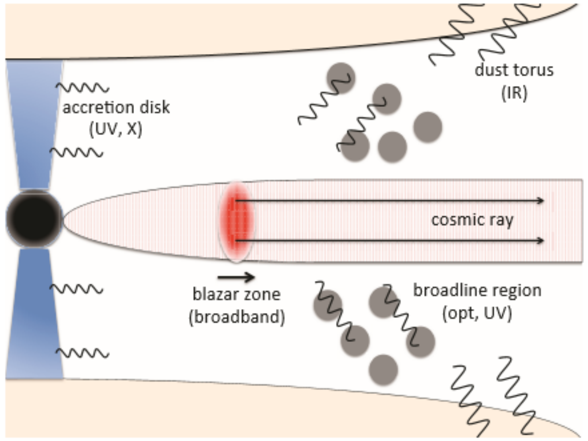


Simulated DB event

Boyer, Penn State, 2010

Example of how Neutrinos can Reveal the Matter State of the Source

Interacting proton jets (as from an AGN) with normal matter makes decay chain ending in Electron anti-neutrinos



P -> P + stuff -> P + pions + gammas

Gammas get scattered and absorbed

end of decay chain in electron anti-nuetrinos

The protons lead to a potential nuebar tag that the source was matter not antimatter

But how to detect high energy neutrino types? One sure way via Glashow resonance.

5) PeV Anti-Neutrinos and Glashow Resonance

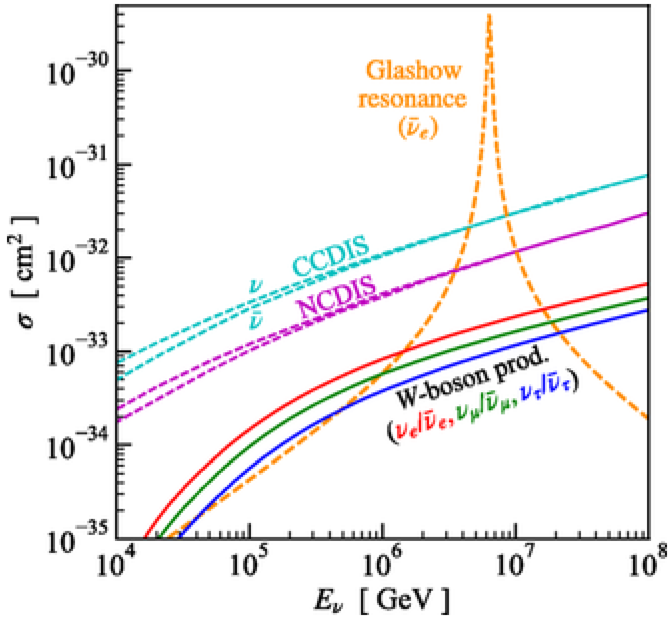
- AntiNu_e of about 6.2 PeV can tickle the so-called Glashow resonance, where the center of mass energy is at the (80,260 MeV/c^2) mass of the weak interaction carrier particle the W-. AT resonance (like a tuning fork of a given pitch) the cross section shoots up by at least a factor of a thousand.

- On December 8, 2016 IceCube observed such an event.

- The key to anti-galaxy detection comes from distinguishing a rate due to more electron anti-neutrinos than electron-neutrinos.

- Ten times present IceCube sensitivity might be getting close, and 100 x present sensitivity prove definitive.

- Obviously we require more calculations and most importantly bigger neutrino experiments along with IceCube (KM3 and Trident for example). PeV neutrinos may ultimately decide the game.



6) GZ Neutrinos should have excess electron anti-neutrinos

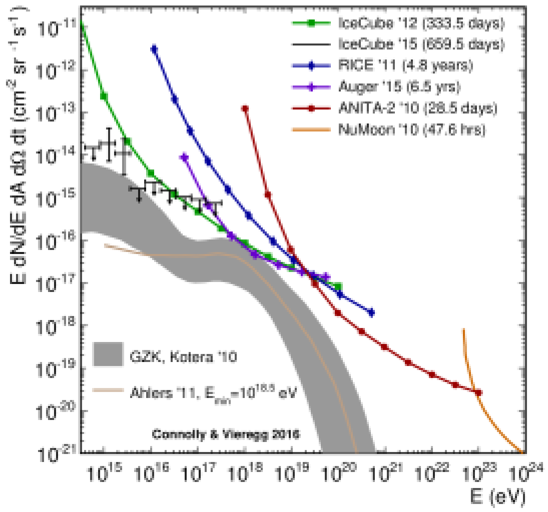
- GZK (BZ) electron anti-neutrinos neutrinos should be present due to >10^20 eV protons interacting on microwave background photons producing pions which decay to electron anti-neutrinos (and other particles).

- ANITA, PUEO, and other radio detection experiments, have sensitivity into this region (EeV) but probably not enough exposure.

- Not observed yet, but possibly fruitful.

- Weiler Z-bursts could be asymmetric too.

Berezinsky-Zatsepin Neutrinos



Weiler Z Bursts

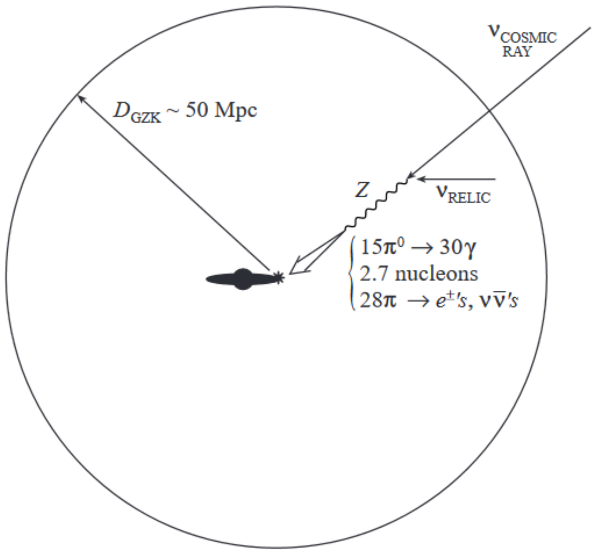
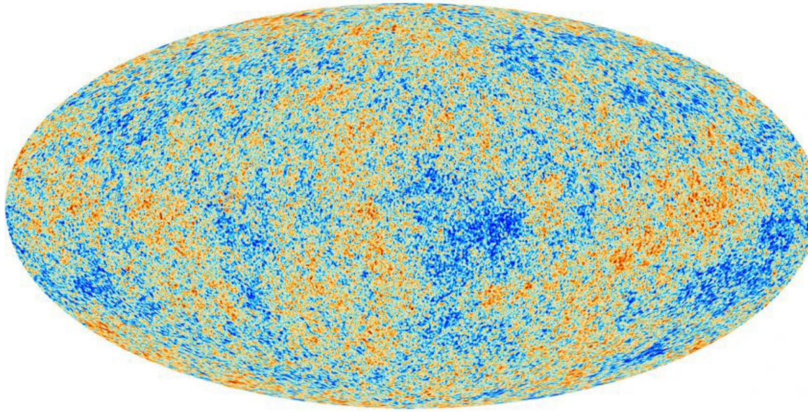


Figure 1. Schematic diagram showing the production of a Z–burst resulting from the resonant annihilation of a cosmic–ray neutrino on a relic (anti)neutrino. If the Z–burst occurs within the GZK zone ($\sim$ 50 to 100 Mpc) and is directed towards the earth, then photons and nucleons with energy above the GZK cutoff may arrive at earth and initiate super–GZK air–showers.

Tom Weiler https://doi.org/10.48550/arXiv.hep-ph/9910316

Aside: Electron Neutrinos as Dark Matter?)



- The GSU removes the need for the hypothetical Dark Energy.
- But, what of Dark Matter, which allows stars to circle galaxies faster than apparent stellar mass would predict?
- Due to a hypothetical new particle? (being theorists panacea for everything)

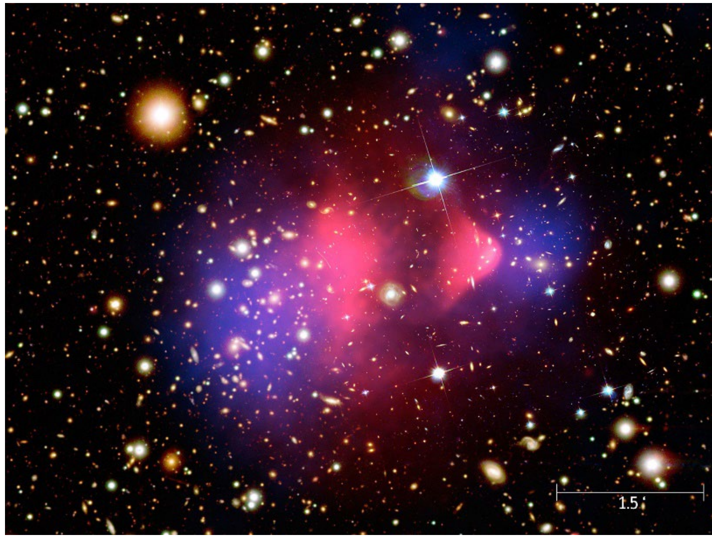
- Proposed modifications to Newtonian Gravity (just a tiny tweak at long distances would do the job) -> **MOND theories**.
- But **none** of these seem to explain the facts very well.

- Graphically, see the Bullet Cluster, which appears to favor a particle solution, not MOND.
- **Suppose however that the Dark Matter consists of Big Bang Relic neutrinos!**
- They will have segregated, and ours should be a cloud of nus not anti-nus

- Beyond the scope of today's talk but it could be the elephant in the room since we know that dark matter must total something like 5 times the mass of the galaxies it stabilizes.

Can these be detected?

- Ptolemy experiment under development may detect these: $\nu_e + {}^3H \rightarrow {}^3He + e^-$



Summarizing the Several Considered GRU Tests with Neutrinos

1 DSNB	Was good, but new calculations make nearly equal flavor fluxes
2 BB Relics	Maybe possible with Ptolemy
3 Underground CR Obs	Observations mostly of <TeV energies, all galactic not likely AM bias
4 IceCube	But perhaps IC learn to distinguish electron vs anti-electron showers in TeV regime?
5 Glashow Events	Clear signal of nuebar neutrinos, issue will be rate
6 BZ Neutrinos	SHE Protons should make more muon neutrinos, but how to distinguish?

Curiosities with UHE Cosmic Rays?

- Peculiarities in highest energy cosmic rays seen as Extensive Air Showers at earth

- Depth of atmosphere penetration significantly decreases at highest energies.

- Other peculiarities in EAS zenith angle dependence and in muons near horizon

- EAS community interprets as trend from proton to heavier nuclei

- However, recent flux predictions indicate growing fraction of neutrinos compared to charged particles in EEV range.

- But, I do not see why there should be sign difference?

Summary

If present experiments show that anti-hydrogen rises in earth gravity => vast implications

Likely then that **half the universe is made of antigravitating antimatter:** implications follow, yet not disturbing most of particle physics and astronomy

Photons cannot distinguish if we are seeing matter or antimatter stars, so as of now we do not know if there are antimatter stars galaxies or clusters of galaxies out there.

Only neutrinos appear to be able to clarify the situation.

We have discussed 6 channels for neutrino observations some of which may yield results

But none seem easy if indeed possible, except Ptolemy for relic neutrinos: much needs to be studied

New ideas needed

Meanwhile if antihydrogren falls we can forget all this interesting alternative cosmology, though whether all galaxies are matter remains a good question.