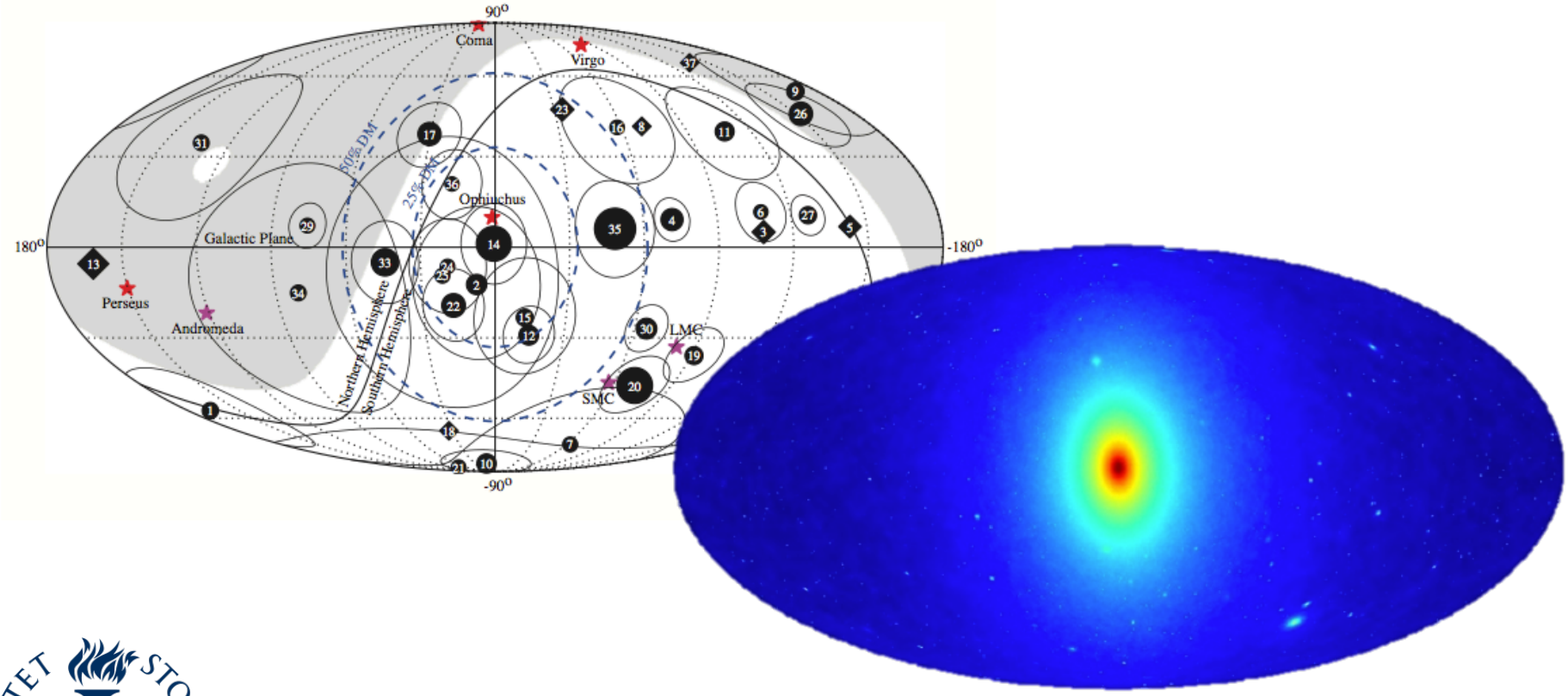
PeV Dark Matter Scenario for IceCube



Jon Dumm

OKC Dark Matter Meeting

April 21, 2015

Stockholm University

Oskar Klein centre

Context

- Explore very heavy DM interpretation of the IceCube diffuse neutrino flux
  - arXiv:1503.04663v1

Testing the Dark Matter Scenario for PeV Neutrinos Observed in IceCube

Kohta Murase,[1,2] Ranjan Laha,[3] Shin'ichiro Ando,[4] and Markus Ahlers[5]

- Compare with gamma-ray observations

- Future tests in IceCube
  - IceCube-Gen2 will test this scenario with Virgo and M31 in ~10 years from now
  - **Explore galactic halo test with current data?**

PeV Dark Matter

- Is that allowed?

Unitarity Limits on the Mass and Radius of Dark-Matter Particles

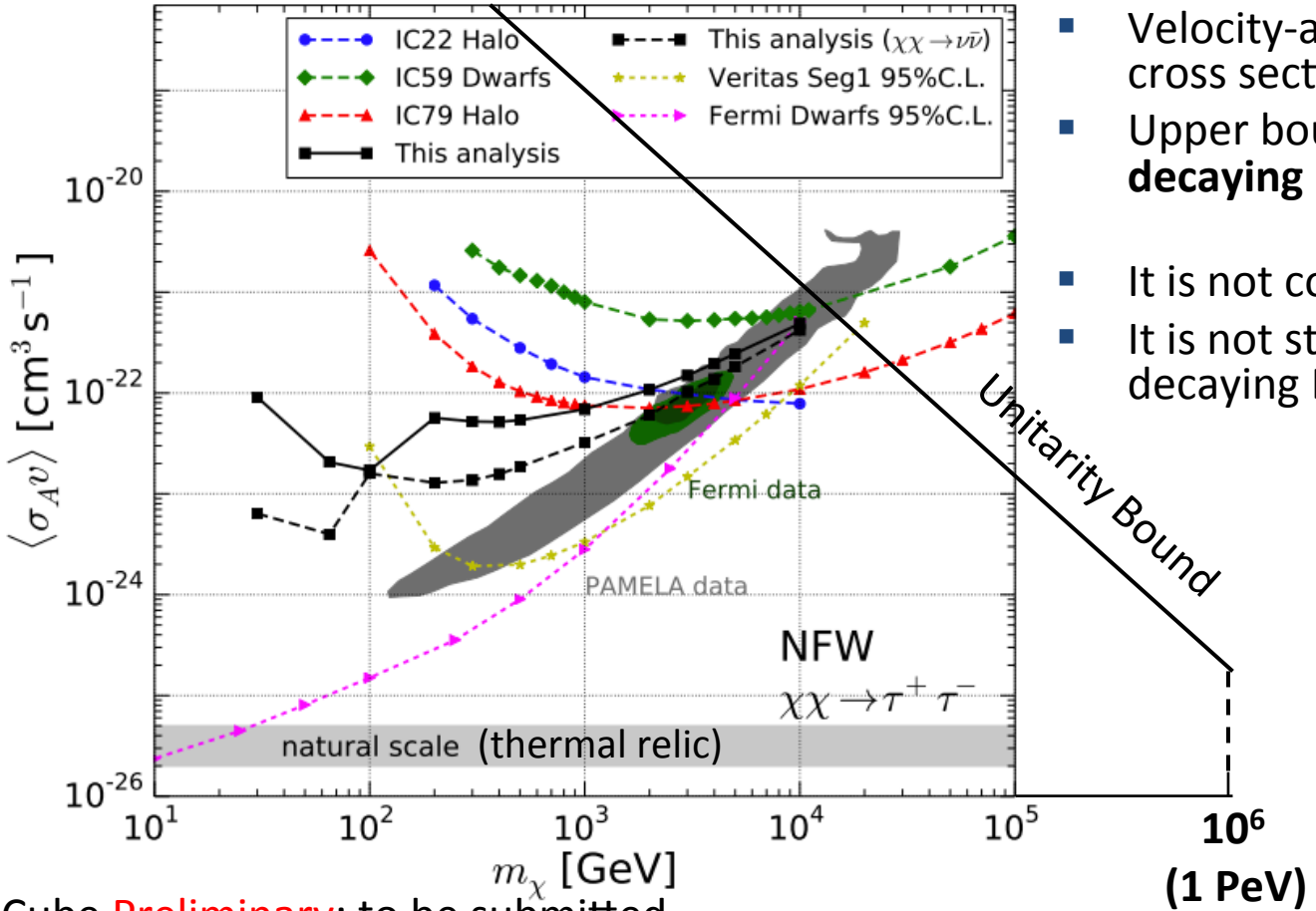
Kim Griest
Center for Particle Astrophysics, University of California, Berkeley, California 94720

Marc Kamionkowski
Physics Department, Enrico Fermi Institute, The University of Chicago, Chicago, Illinois 60637-1433
and NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500
(Received 5 October 1989)

Using partial-wave unitarity and the observed density of the Universe, we show that a stable elementary particle which was once in thermal equilibrium cannot have a mass greater than 340 TeV. An extended object which was once in thermal equilibrium cannot have a radius less than 7.5×10^{-7} fm. A lower limit to the relic abundance of such particles is also found.

PeV Dark Matter

- Is that allowed?



- Velocity-averaged **annihilation** cross sections
- Upper bound not valid for **decaying** dark matter
- It is not considered likely
- It is not strictly forbidden for decaying DM

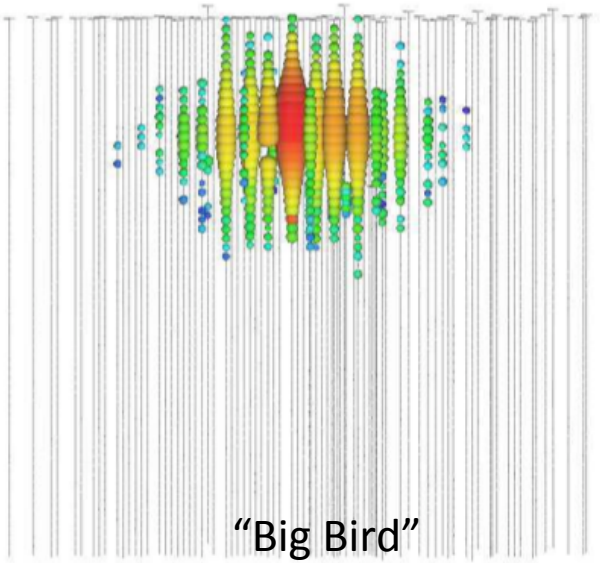
IceCube Preliminary: to be submitted

IceCube's Diffuse Neutrino Flux

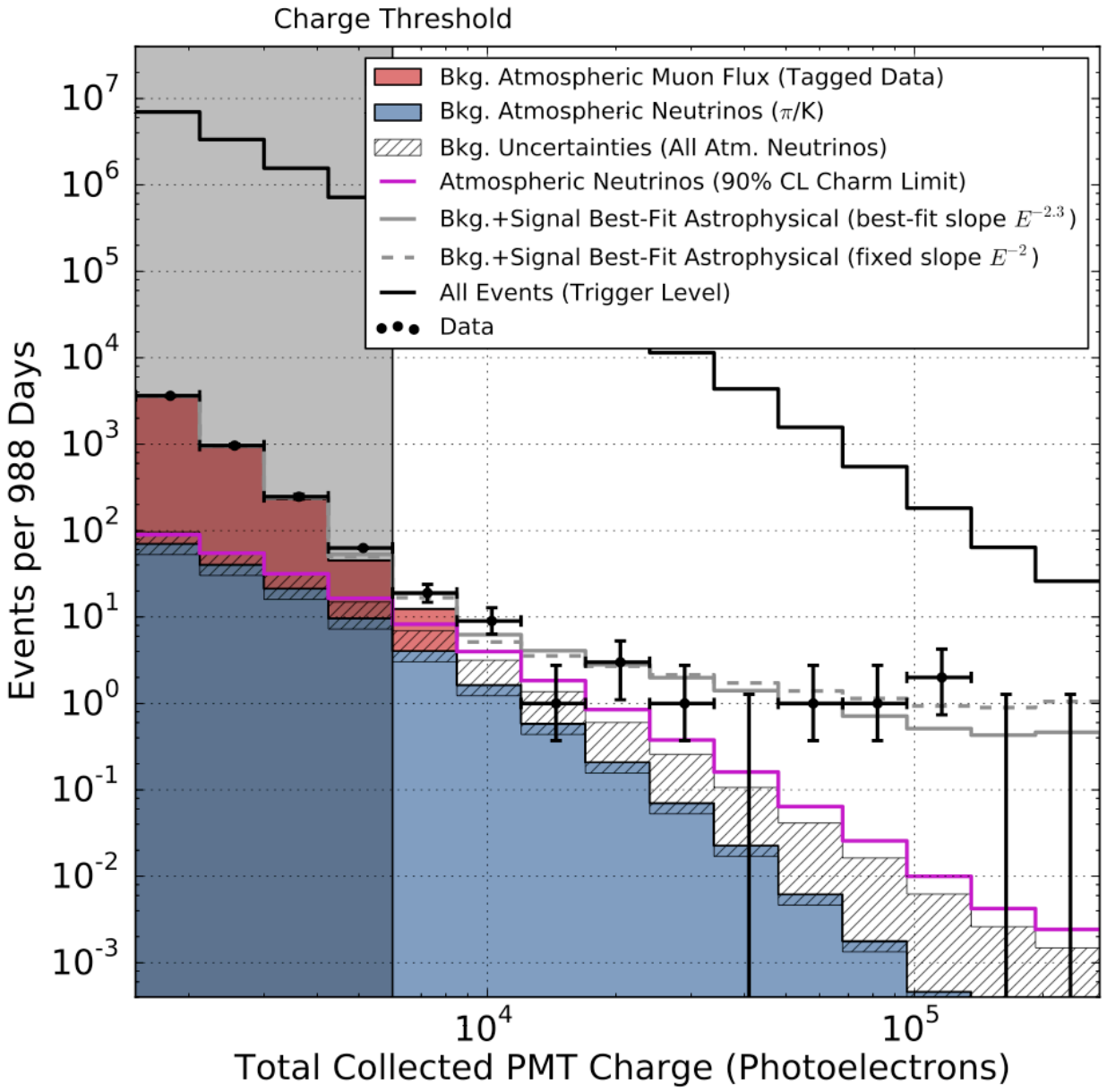
3-Year Analysis
PRL **113**, 101101 (2014)

36 events & **5.7 σ**
(~1/2 expected to be background)

Excess grows with deposited energy



"Big Bird"
2 PeV neutrino

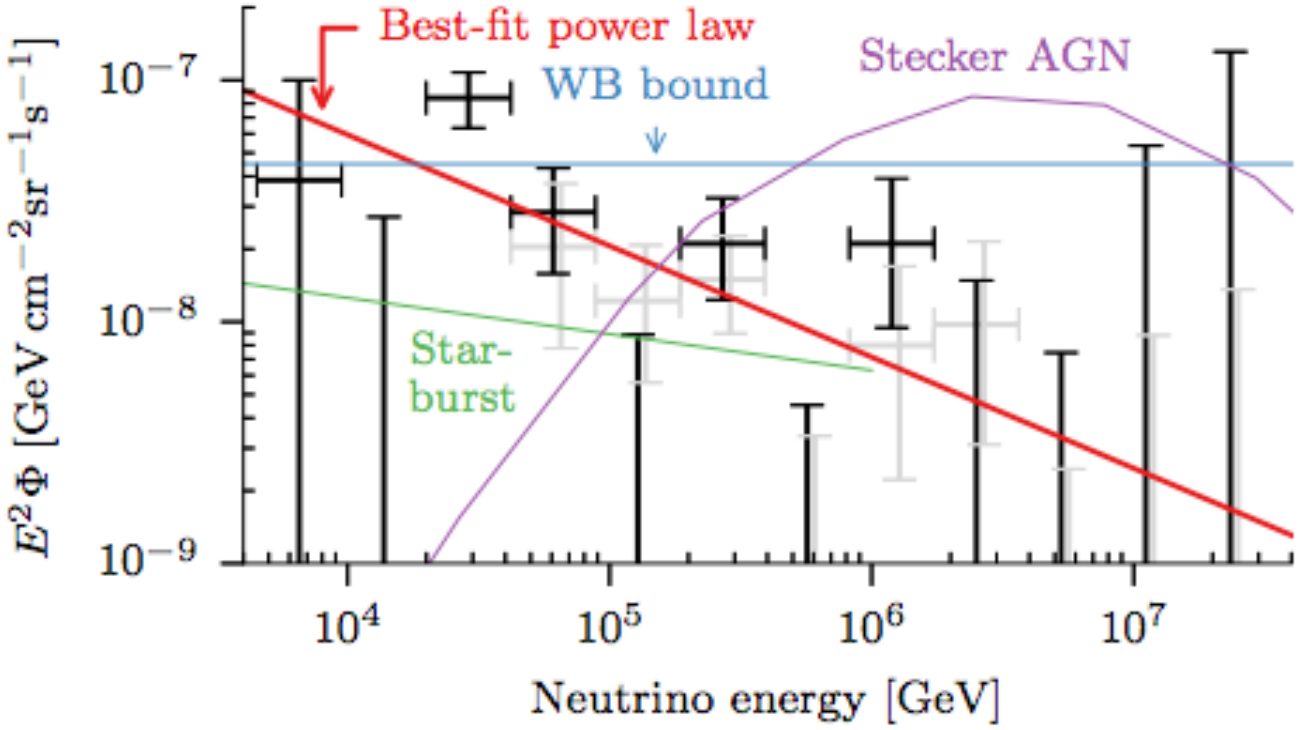


Latest Spectral Results

Latest spectral results: [arXiv:1410.1749]

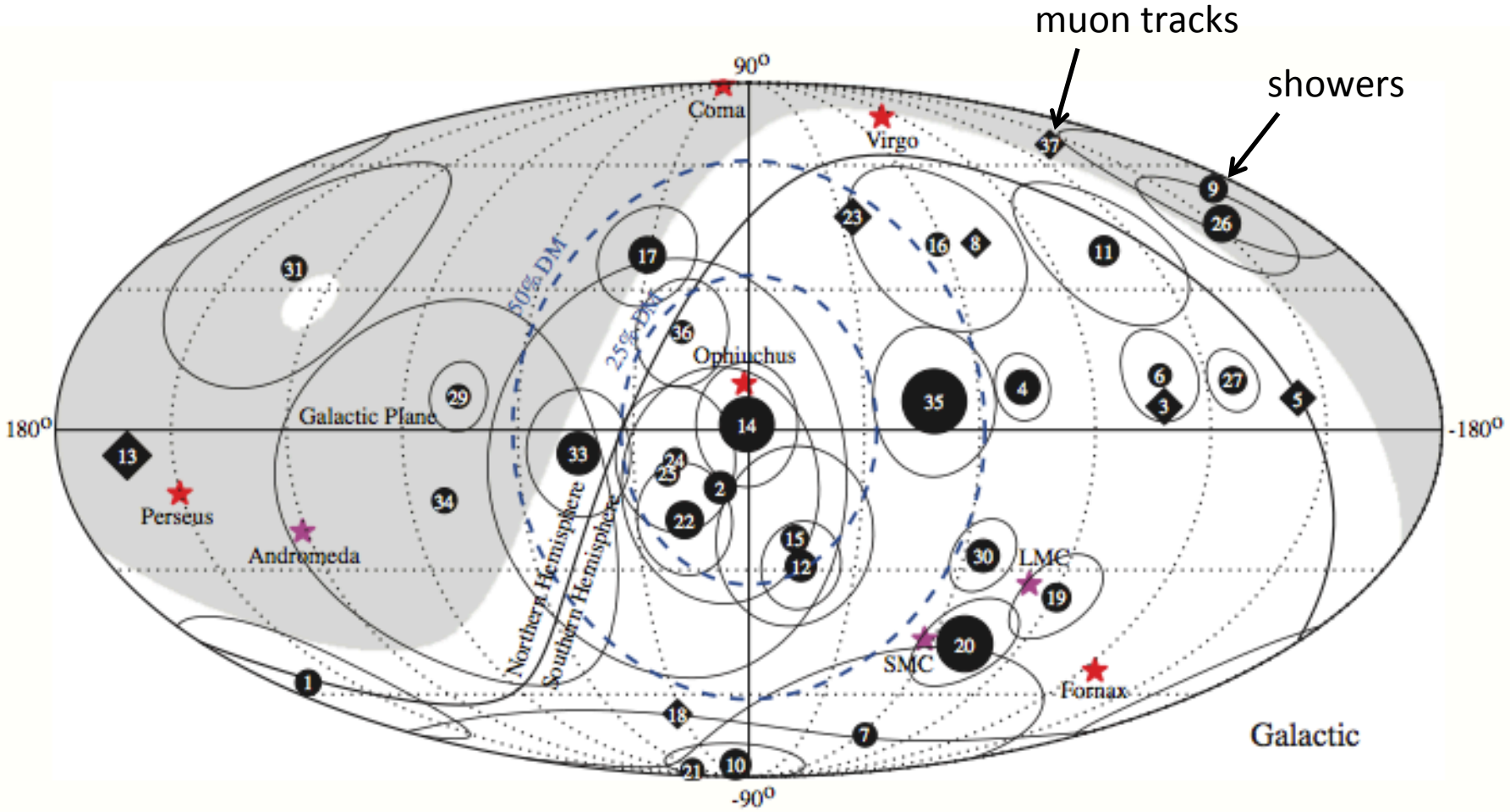
$$\Phi_\nu = 2.06^{+0.4}_{-0.3} \times 10^{-18} \left(E_\nu/10^5 \text{ GeV}\right)^{-2.46\pm0.12} \text{GeV}^{-1}\,\text{cm}^{-2}\,\text{sr}^{-1}\,\text{s}^{-1}$$

Assuming an unbroken power law, standard expectation of **E^{-2} disfavored at 99% CL**



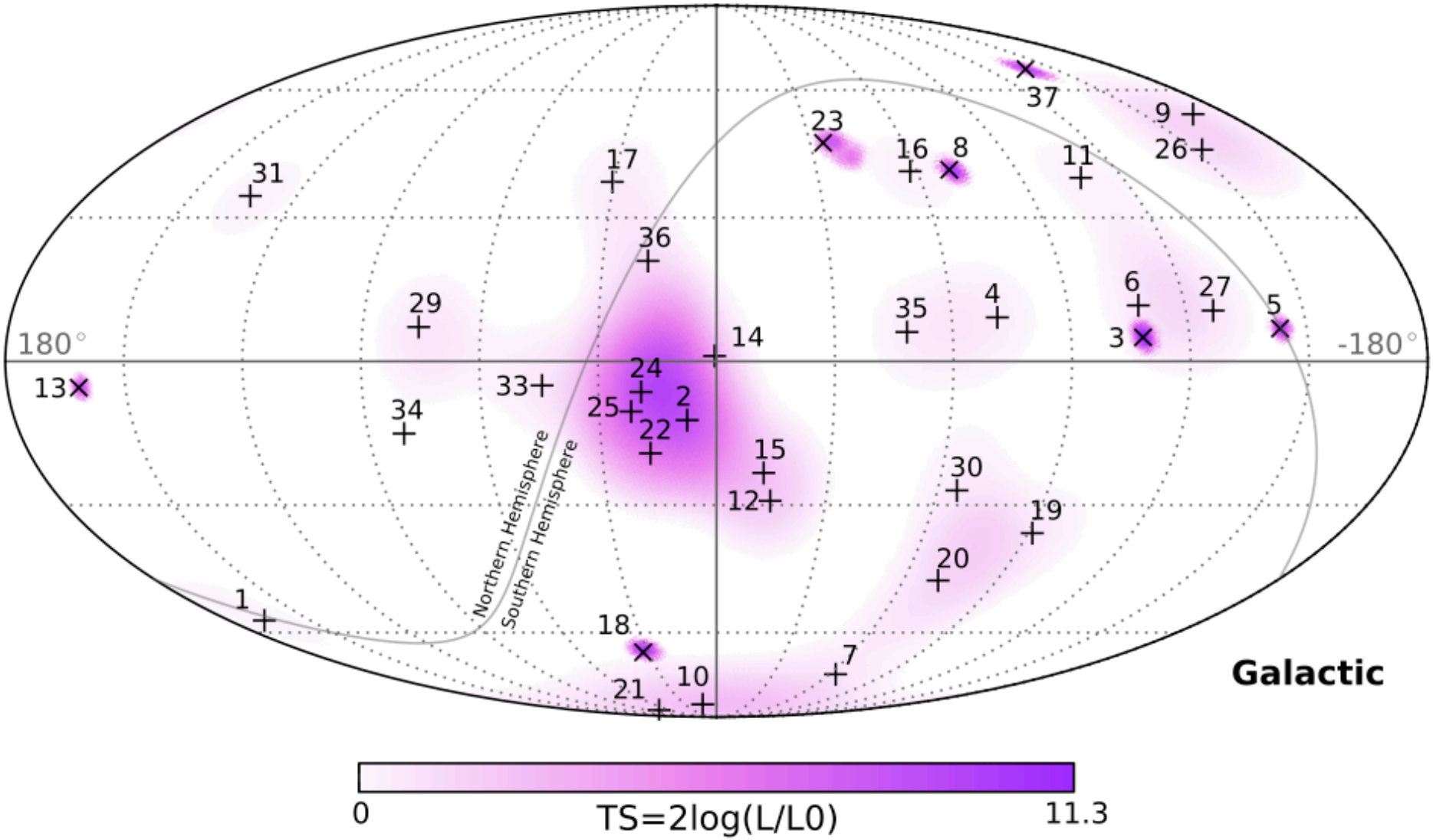
Many reasonable astrophysical explanations: SNR, AGN, Starbursts...

Latest Spatial Results



- Consistent with isotropy
- Consistent with equal flavor ratios (1:1:1) at Earth

Latest Spatial Results



- No significant clustering: Several variations on point-source hypotheses performed
- Some hint of clustering near the galactic center but not significant

The VHDM Models

- Authors simulate a couple of valid models, tuned to explain the neutrinos and stay within constraints from gamma-rays:

"**ES13**" parameters:

$$m_{\rm dm} = 3.2 \text{ PeV}$$

$\text{DM} \to q\bar{q}$ BR: 12%

$\text{DM} \to \nu_e\bar{\nu}_e$ BR: 88%

$$\tau_{\rm dm} = 3.0 \times 10^{27} \text{ s}$$

"**RKP14**" parameters:

$$m_{\rm dm} = 2.4 \text{ PeV}$$

$\text{DM} \to l^{\pm}W^{\mp}$ BR: 50%

$\text{DM} \to \nu Z$ BR: 25%

$\text{DM} \to \nu h$ BR: 25%

$$\tau_{\rm dm} = 3.5 \times 10^{27} \text{ s}$$

$$E_\nu^2\Phi_\nu = E_\nu^2\Phi_\nu^{\rm EG} + E_\nu^2\Phi_\nu^{\rm G}$$ (~equal gal. and extragal. contributions)

$$\approx \frac{ct_H\xi_z}{4\pi}\frac{\rho_{\rm dm}c^2}{\tau_{\rm dm}\mathcal{R}_\nu} + \frac{R_{\rm sc}\mathcal{J}_\Omega}{4\pi}\frac{\rho_{\rm sc}c^2}{\tau_{\rm dm}\mathcal{R}_\nu}$$

$$\sim 4 \times 10^{-8} \text{ GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$$

ES13 Model

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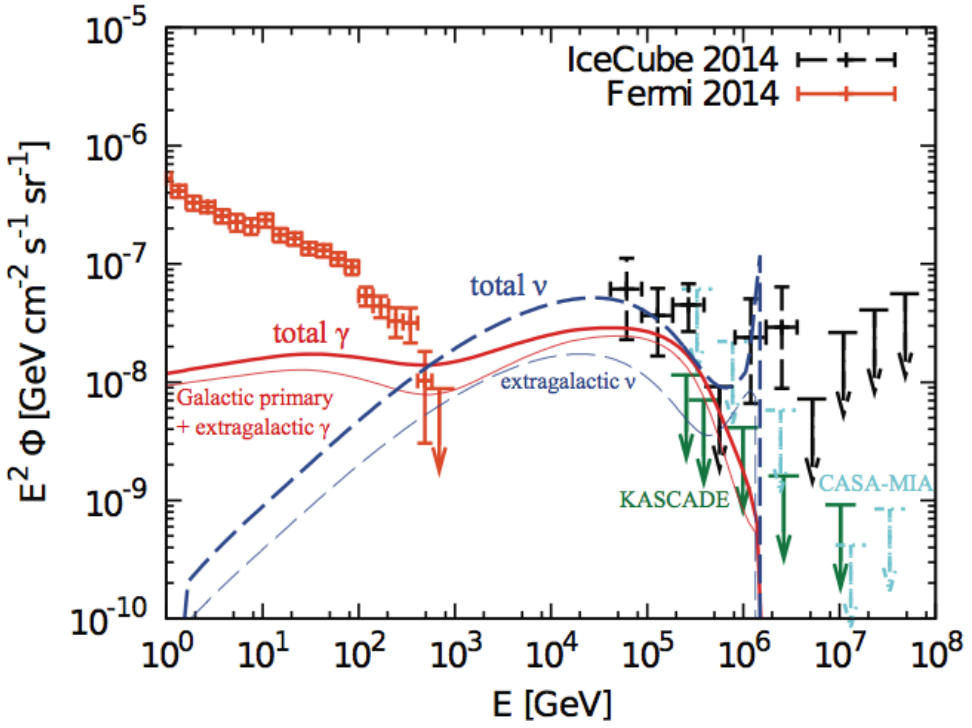
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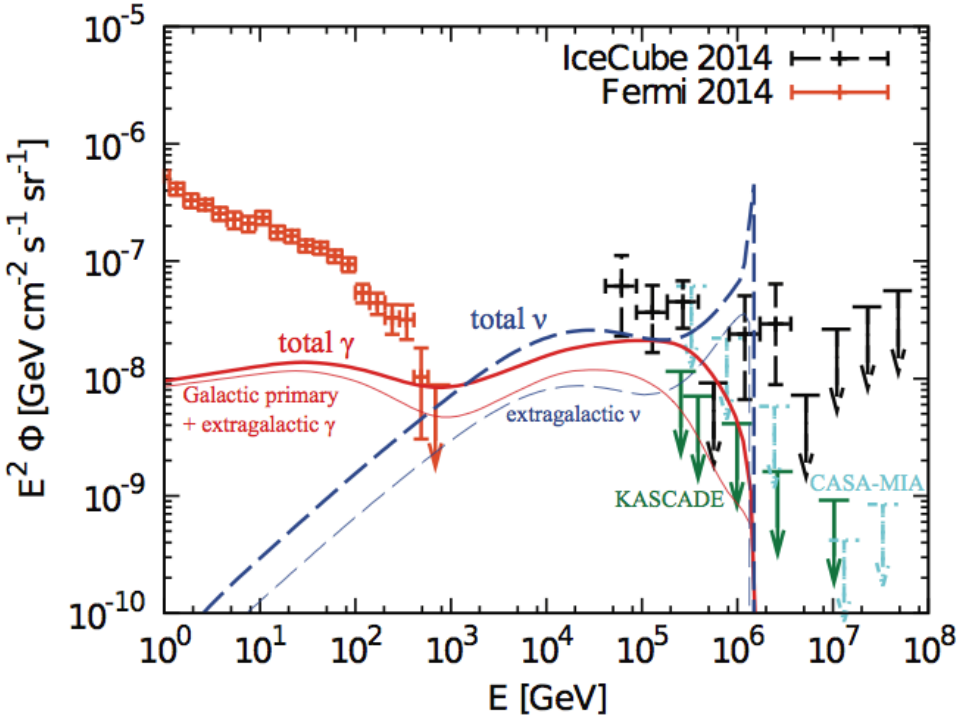
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Summary

- Models are marginally consistent with gamma-ray observations
  - Detailed shape analysis of Fermi data might show increasing anisotropy with energy
    - Tough in light of other flux components
    - Uncertainty in spatial profile (DM dist. & B_{Gal})
  - HAWC may see excess towards G.C.

- Models are testable with IceCube upgrade
  - IceCube-Gen2 will test this scenario with Virgo and M31 in ~10 years from now
    - The authors only considered northern sky sources
  - **Explore galactic halo test with current data?**