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Neutrinos from Active galactic nuclei to IceCube

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with

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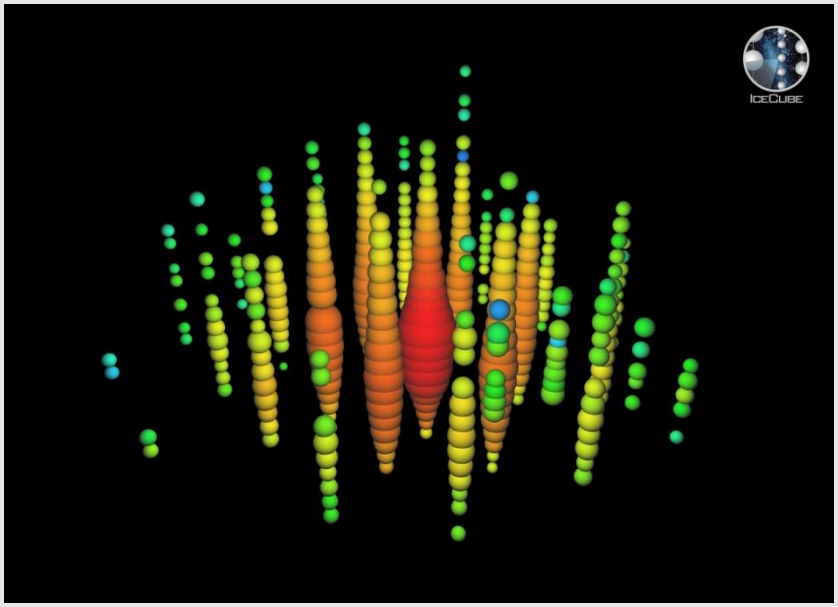
Motivation and a brief introduction to AGN

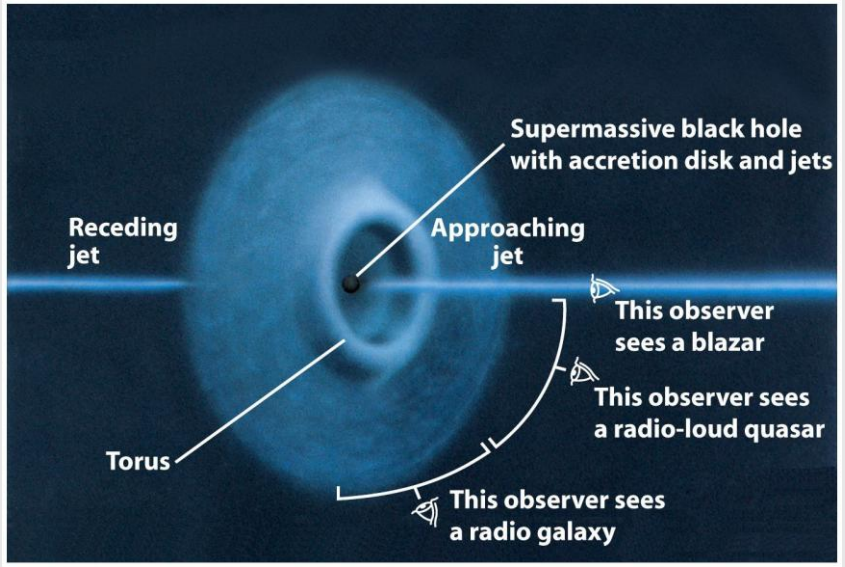
- IceCube recently reported detection of 28 highly energetic neutrinos [1]
- We assume:
  - highly energetic neutrinos are extragalactic
  - Active galactic nuclei (AGN) are sources these neutrinos

(a)



- A supermassive black hole is located in the center of the galaxy
- Gravitational energy as the source of the lumonsities
- Clouds surround the black hole
- Plasma jets accelerate particles

(b)



Our model

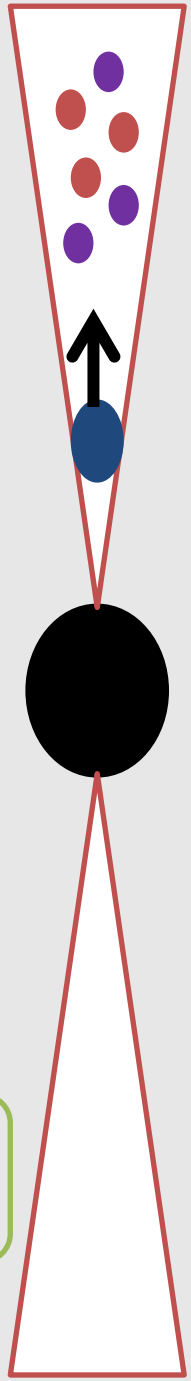
- Acceleration of plasmoid (protons+electrons) explained by shock model [2,3]
- Electrons emit synchrotron radiation, protons undergo inelastic proton-proton interaction and produce pions
- Charged pions decay into neutrinos
- The production rate is given by

$$q_{\pi^{\pm}} = 1.6 \cdot n_{\mathrm{H}} \cdot l \cdot \sigma_{\mathrm{pp}} \int_{E_{th}}^{\infty} \mathrm{d}E_{\mathrm{p}}\, j_{\mathrm{p}}\left(E_{\mathrm{p}}\right) \varepsilon_{\pi^{\pm}} \delta\left(E_{\pi} - \left\langle E_{\pi} \right\rangle\right)$$

↑ H-I, H-II, H_2

- Assumptions: cross section σ constant
  - Total proton energy is transferred to $\langle E_{\pi} \rangle$
  - Optical depth << 1

Delta function approximation



Neutrino flux on Earth

- **Assuming that the total pion energy is distributed equally, the total neutrino flux is:**

$$q_\nu^{\mathrm{tot}} \approx 20 \cdot l \cdot n_{\mathrm{H}} \cdot \sigma_{\mathrm{pp}} \left(\frac{6 \cdot E_\nu}{\mathrm{GeV}} \right)^{-\frac{4}{3}p+\frac{2}{3}} \quad l \cdot n_{\mathrm{H}} = N_{\mathrm{H}}$$

- **The normalization of the proton spectrum is obtained by considering the radio luminosity function:**

$$A_{\mathrm{p}} = \frac{\chi}{f_{\mathrm{e}}} \left[\ln\left(\frac{E_{\mathrm{max}}}{E_{\mathrm{min}}} \right) \right]^{-1} \cdot L \cdot \mathrm{GeV}^{-2} \text{ with } \begin{cases} f_{\mathrm{e}} = \dfrac{L_{\mathrm{e}}}{L_{\mathrm{p}}} \\ L_{\mathrm{e}} = \chi \cdot L_{\mathrm{radio}} \end{cases}$$

- **Neutrino flux on Earth assuming isotropic emission:**

$$\Phi_\nu = \int_{L,z} \frac{q_\nu^{\mathrm{tot}}}{4\pi d_{\mathrm{L}}(z)^2} \frac{\mathrm{d}n}{\mathrm{d}V\mathrm{d}L} \frac{\mathrm{d}V}{\mathrm{d}z} \mathrm{d}z\, \mathrm{d}L$$

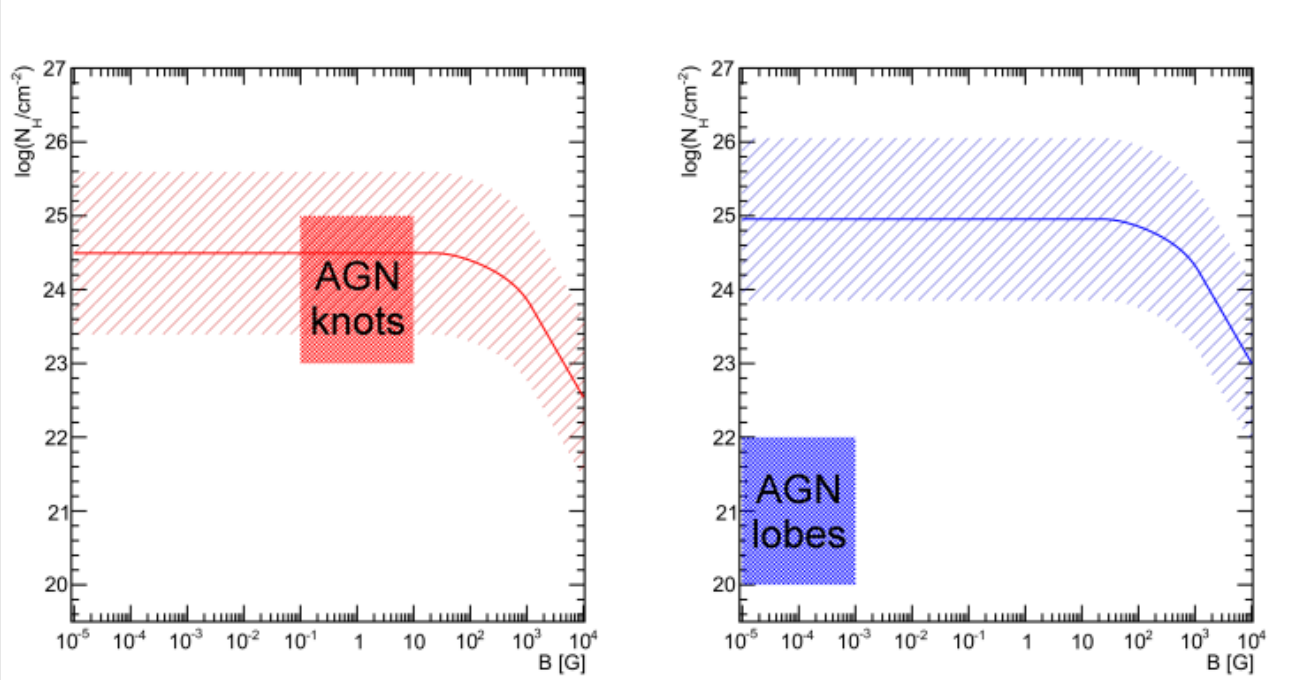
Our results

- **For different AGN types the column density for the plasmoid is:**

$$N_{\mathrm{H,\,FR-I}} = 10^{24.57\pm1.1}\left(\frac{f_e}{0.06}\right)\left(\frac{100}{\chi}\right)\mathrm{cm}^{-2}$$

$$N_{\mathrm{H,\,FR-II}} = 10^{25.03\pm1.1}\left(\frac{f_e}{0.06}\right)\left(\frac{100}{\chi}\right)\mathrm{cm}^{-2}$$

(d)



• Red and blue line = our results
• Red and blue box observations (d)

Discussion and outlook

- Uncertainties:
  - f_e can be calculated by using current observations
- Radio luminosity function
  - Division into two groups not sharp!
- Extend delta function approximation
- Using detailed gamma observation for Cen A and M 87 to calculate the neutrino flux
- Calculate neutrino flux for p=2.2

Thank You very much

☺

Question(s)?

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submitted