RELATIVISTIC NEUTRONS IN ACTIVE GALACTIC NUCLEI

Marek Sikora
N. Copernicus Astronomical Center, PAN
00-716 Warszawa, Bartycka 18, Poland

Bronisław Rudak
N. Copernicus Astronomical Center, PAN
87-100 Toruń, Chopina 12/18, Poland

Mitchell Begelman
Joint Institute for Laboratory Astrophysics, National Bureau of Standards and Univ. of Colorado Boulder, CO 80309-0440

PROLOGUE. A substantial fraction of the radiation from an active galactic nucleus (AGN) is apparently nonthermal in origin, and is probably produced by ultrarelativistic electrons. How much energy goes into relativistic protons is uncertain, but it is likely to be comparable to the electron energy or larger. Indeed, several authors (Sikora et al. 1987; Kazanas and Ellison 1986; Zdziarski 1986) have shown that proton-photon and proton-proton collisions can be efficient sources of relativistic pairs in the central engine of an AGN. Thus it is not necessary for electrons to be accelerated directly in AGNs, provided that protons are accelerated with high enough efficiency.

1. NEUTRON PRODUCTION AND ESCAPE

A natural byproduct of proton acceleration in AGNs is the production of relativistic neutrons. Approximately one-quarter of the inelastic proton-proton collisions and half of the reactions leading to photo-meson production result in the conversion of a proton to a neutron. Whereas even the most relativistic protons likely to be present are coupled magnetically to the ambient plasma and are advected on a hydrodynamical time scale, the neutrons travel ballistically until they either decay or suffer a collision. We show below (Fig. 1) that a significant flux of relativistic neutrons can stream out of the central regions of AGNs and escape up to distances ~1-100 pc before decaying.

2. DYNAMICAL EFFECTS

The relativistic protons created by neutrons couple immediately to the background plasma, and their energy becomes available for producing both dynamical and radiative effects. The dynamical effects can be rather dramatic, since the neutrons suffer no adiabatic losses before they decay, and because the specific gravitational binding energy of material is much smaller at the decay radius than it is close to the

D. E. Osterbrock and J. S. Miller (eds.), Active Galactic Nuclei, 215–216.

https://doi.org/10.1017/S0074180900140902 Published online by Cambridge University Press

black hole. Therefore, a relatively small energy flux in neutrons (compared to the luminosity of the AGN) can drive an outflow with speeds well in excess of the local Keplerian speed and with a mass flux much larger than the accretion rate necessary to power the AGN. We suggest that such outflows may be associated with the broad absorption line systems in quasars and with the velocity fields in the broad emission line regions. The fact that a small neutron flux can reverse a sizable spherical accretion flow suggests that the accretion flow which powers the AGN must either be disk-like, or highly inhomogeneous.

3. RADIATION SIGNATURES

Much of the energy lost through pp collisions is radiated as very energetic γ-rays. We predict that the γ-ray spectrum will cut off at energies $h\nu_{max} \sim 10^3 (L_{Edd}/L)(R_o/10R_s)$ GeV, where $R_s = 2GM_{BH}/c^2$. If the central source has a luminosity exceeding 10^{44} erg s^{-1}, then the spectrum should also exhibit a break, due to γ-γ absorption, at $h\nu_{\gamma\gamma} \sim L_{46}^{-1}\, h\nu_{max}$. The ratio of the two frequencies provides a test of the theory, whereas their individual values can be used to estimate the radius of the central engine.

This research was supported in part by NSF grant AST83-51997 and by NASA Astrophysical Theory Center grant NAGW-766.

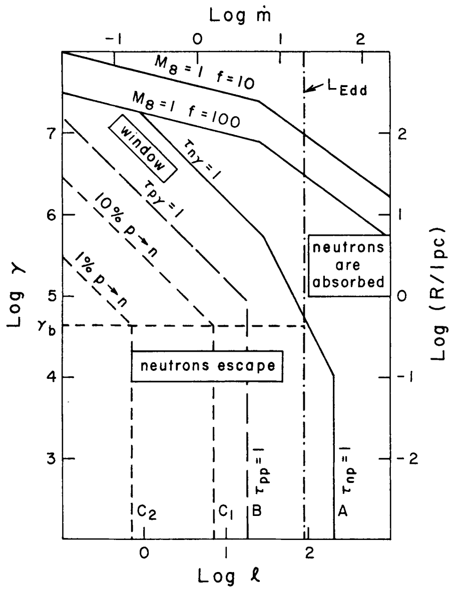

Fig. 1. Dependence of neutron escape efficiency on the neutron Lorentz factor, γ, and on the compactness of the central source, ℓ. Above line A all neutrons are trapped in the accretion flow via np and nγ interactions. In the "window" about 50% of protons injected above the $\tau_{p\gamma} = 1$ line and ~25% of protons injected to the right side of $\tau_{pp} = 1$ line are converted to neutrons and almost all of them escape. (See details in Sikora, Begelman and Rudak, submitted to Nature.)

REFERENCES

Kazanas, D., and Ellison, D. C. 1986, Ap. J. 304, 178.

Sikora, M., Kirk, J. G., Begelman, M. C., and Schneider, P. 1987, Ap. J. Lett. 320, L81.

Zdziarski, A. A. 1986, Ap. J. 305, 45.