NEUTRON MODEL FOR THE FORMATION OF AGN JETS WITH CENTRAL RADIO GAP

F.B. Sigalo and M.A. Briggs-Kamara
Department of Physics, Rivers State University of Science & Technology, Port Harcourt, Nigeria

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Abstract

In this work, there has been an attempt to explain the formation of jets in some radio sources with gaps at their centers using the neutron "production-to-decay" process. The jet-light-up point is taken to coincide with the end of the lifetime of the neutrons. Calculated intrinsic opening angles for the jets of the selected Active Galactic Nuclei (AGN) sources have a correlation with the observed opening angles for those sources. There appear to be loose anti-correlation between jet-opening-angle and the neutron density number, making it difficult to confirm the luminosity connection.

Keywords: *Active galactic nuclei, radio sources with jets, neutron decay.*

1. Introduction

It is commonly reported that the extended radio sources are powered from the centre of their parent galaxies (Blandford and Rees, 1974, Junor et al., 1999). The opinion has been supported by the discovery of some radio galaxies with jets which tend to originate from the central engine, and traveling several kiloparsecs into large radio lobes (Burns and Christiansen, 1980; Butcher et al, 1980). The jets, which are collimated, are believed to have been produced through energy dissipation by relativistic particles (Sikora et at, 1987).

However, in some cases, a few parsecs from the central engine, there appear to be some kind of obscurity to the take off point of the jets from the central core (Perley et al., 1979; and Peck et al 1999). The question now arises as to what might have been responsible for the seeming obscurity or gap in the propagation of the jet from the central core.

Kirk and Mastichiadis (1989) emphasized the role of relativistic electrons and positrons originating in the central engine as agents of non-thermal radiations from the active galactic nuclei, stressing that such may have resulted from the collisions of relativistic protons with photons or ambient matter. Another consequence of such collisions they concluded is the production of relativistic neutrons. Giovanoni and Kazanas (1990), Ekejiuba et al (1992) and Atoyan and Dermer (2003) have reported that such relativistic neutrons could be the origin of energy transport mechanisms from the core of some active galaxies to the extragalactic radio sources (EGRS). They maintained that since neutrons are not affected by electromagnetic fields, no radiation would be detected on their route, until their decay into relativistic protons and electrons. In this paper we shall consider the neutron model in relation to the ultimate formation of the jets in some sources with noticeable central radio gap. In Section 2 we put forward the model, in Section 3 we evaluate the neutron number density, in Section 4 we discuss and compare some observational parameters and in Section 5 we conclude.

2. The Model

Here, we consider the central engine which habours a super massive black hole as the source of the production of relativistic particles, which include the neutrons. We assume the neutrons to form at some distance $R_0 = 20R_g$ (Sikora et al., 1989), from the central core, where

$$R_g = \frac{GM_{BH}}{c^2} \qquad (1)$$

is the gravitational radius, G is the

gravitational constant, M_{BH} is mass of the black hole and c is the velocity of light.

The gravitational force on the neutron at the surface R_0 is given by

$$F_n = \frac{G M_{BH} M_n}{(20 R_g)^2}, \qquad (2)$$

where M_n is the mass of the neutron.

The gravitational potential energy V_n will then become

$$V_n = \frac{G M_{BH} M_n}{20 R_g}. \qquad (3)$$

The neutrons having gained kinetic energy from the proton-photon collision process escape through the gap if they can overcome the gravitational potential. With the relativistic neutrons we set the energy E_n with which they travel through the gap before decaying as

$$E_n = \gamma_n M_n c^2 - \frac{G M_{BH} M_n}{20 R_g} \qquad (4)$$

where γ_n is the neutron Lorentz factor. We note that the effect of the gravitational potential on the neutron production surface is negligible; hence the effective energy of the neutron particles is kinetic. We therefore have neutron energy simply as

$$E_n = \gamma_n M_n c^2 \qquad (5)$$

The Lorentz factor can be obtained by considering the travel time t_n of the neutrons before decay, which relates to the neutron lifetime ($t_d \sim 10^3$s) as $t_n = t_d \gamma_n s \sim 10^3 \gamma_n s$ (Giovanoni and Kazanas, 1990). The relativistic neutrons therefore travel through a distance $r_n \sim 3 \times 10^{11} \gamma$ m. Using the observed central radio gaps (Butcher et al., 1980), see Table 1, as the travel distance of the neutrons before decaying we estimate the Lorentz factor for the neutrons in each source.

Table 1: Some radio galaxy sources with central radio gap (Butcher et al., 1980).

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Source object	Central Radio gap in kpc	Estimated Lorentz factor of neutrons x10^8
M87	0.3	0.31
3C 66B	1.5	1.55
3C 31	0.7	0.72
NGC 315	2.0	2.06
3C 449	3.0	3.09

in which case the velocity and density are taken to be constant over the length of the gap.

3. Evaluation of Neutron Number Density

As stated in Section 2, neutrons are formed at a distance about $20R_g$ from the central engine. We assume a unique radius r_0 (determined by the intrinsic opening angle from the centre) for a blob at A (Fig. 1), over which the number density of neutrons is N_0. The neutrons, which are, accelerated as a result of collision with high energy photons in the blob form into a flux of energy E_f given by

$$E_f = N_0 v_0 \pi r_0^2 m_n \gamma_n c^2 \qquad (6)$$

where v_0 is the initial velocity of the neutrons. The accelerated neutrons at velocity v_0 travel out of the blob through a distance h (representing the gap length) before decaying into protons and electrons together with anti-neutrino emissions. The flux of energy carried by the neutrons to the point B, which is the starting point of the jet) is therefore given as

$$E_f = N v_0 \pi r^2 m_n \gamma_n c^2 \qquad (7)$$

where N and r are number density and characteristic radius at B respectively. Evidently equations (6) and (7) are equal, hence

$$N = \frac{N_0 r_0^2}{r^2} \qquad (8)$$

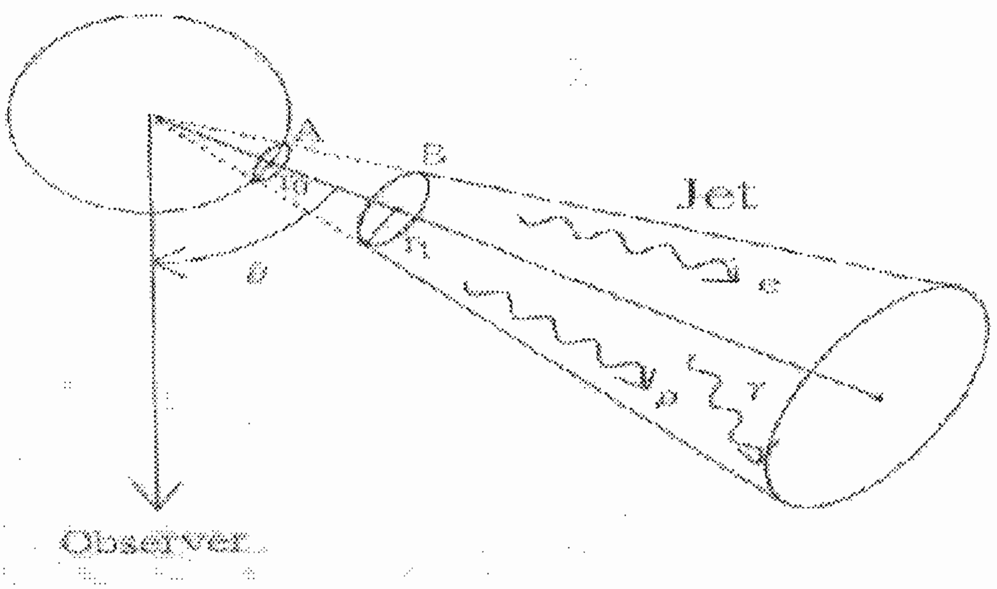


Fig. 1: Jet projected direction

The flux of energy in equation (7) is conservatively equal to the total observed luminosity L_k of the jet. This follows a major assumption here that all the energy carried by the neutrons and consequently the kinetic power is channeled into the jet through the decaying neutrons. With very highly relativistic neutrons (judging from the Lorentz factor, $_n \sim 10^8$), we take $v_0 \sim c$, hence the total kinetic power becomes.

$$L_k = Nr^2 m_{nnc}{}^3 \qquad (9)$$

where L_k is the observed luminosity per unit length multiplied by the total jet length. The observed luminosity also depends on the observed opening angle (Rudge and Raine, 2000). The observed opening angle relates with the angle of line of sight and the intrinsic opening angle, through the following expression:

$$\frac{\theta_o}{2} = \tan^{-1}\left(\frac{\tan\frac{\theta_i}{2}}{\sin\theta}\right) \qquad (10)$$

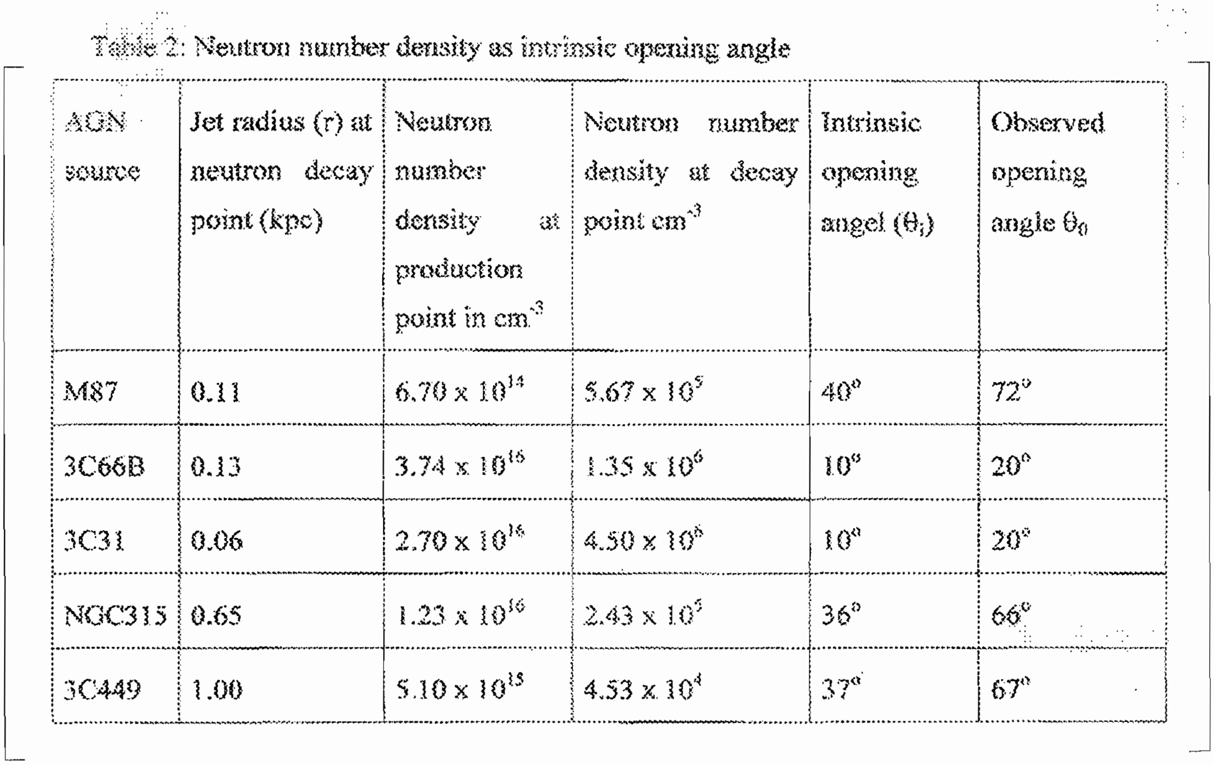
(Oppenheimer and Biretta, 1994), where $_0$ and $_i$ are the observed and intrinsic opening angles respectively, and is the angle of line of sight.

If we suppose a central super massive black hole of mass 3 x10^9 M (Junor et al., 1999), and taking this uniquely for the sources under consideration, we estimate the radii r_0 and r with the angle of line of sight as 30° (Sparks et al., 2001). The calculated intrinsic opening angles for the sources based on the angle of line of sight and the observed opening angles are given in Table 2.

We have taken the length of the jets to correspond to those observed by Butcher et al., 1980. Based on these quantities we evaluate the neutron density number at the decay point using equation (6) and (7). Our observations are as reported on Table 2.

Table 2: Neutron number density as intrinsic opening angle

AGN source	Jet radius (r) at neutron decay point (kpc)	Neutron number density at production point in cm^{-3}	Neutron number density at decay point cm^{-3}	Intrinsic opening angel (θ_i)	Observed opening angle θ_0
M87	0.11	6.70×10^{14}	5.67×10^5	40°	72°
3C66B	0.13	3.74×10^{16}	1.35×10^6	10°	20°
3C31	0.06	2.70×10^{16}	4.50×10^6	10°	20°
NGC315	0.65	1.23×10^{16}	2.43×10^5	36°	66°
3C449	1.00	5.10×10^{15}	4.53×10^4	37°	67°



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4. Discussion

Superluminal motion and sidedness in jets are results of relativistic beaming. We noticed through our estimates of the Lorentz factors for our sources (M87, 3C 66B, 3C31, NGC 315 and 3C449) that they have Lorentz factors ã ~ 10^8, meaning that the jets in these sources are highly relativistic. Another observation we have made from Table 2 is that the neutron density at the production point of the neutrons is higher for all the sources than the densities at the decay point.

At the decay point for M87 for example we have neutron density $5.67 \times 10^5 cm^{-3}$ which is in agreement with electron density in a typical jet at 5GHz (Paragai et al., 2001). The difference in neutron densities could be explained on the basis of free-free absorption, which takes place within the gap. The relation between jet opening angle and neutron number density is not clearly connected. However, for 3C66B and 3C31 sources we observed a seeming relationship between the intrinsic opening angle and the neutron density at the point of decay of the neutrons (Table 2).

5. Conclusion

We have shown that the jets reported in the sources are relativistic by the magnitude of their Lorentz factors. The fact that they may have been formed through a process of neutron decay remains possible since their take off point coincides with the lifetime of the neutron. However, an important parameter for all relativistic jets, the kinetic power or luminosity, remains to be evaluated for these sources. The constraint on the kinetic luminosity for the model borders on the lack of clear relationship between the opening angle of the jet and the neutron number density.

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