A NOVEL INTERPRETATION OF THE COSMIC CONSPIRACY IN AGNs*

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ABSTRACT. The flat radio spectra of core dominated AGNs are often attributed to a superposition of optically thick synchrotron components. This is known as the cosmic conspirac A radio index $p_r \sim 0$ is not a natural consequence of this model, and an alternative model proposed here interprets the source components as regions in which relativistic electrons stream along a magnetic field. Stream collimation is determined by plasma instabilities, and components are assumed to be optically thin, with cyclotron turnover at low frequencies. An appealing feature of this model is that radio photon index depends only upon electron energy distribution, which may be obtained from the photon index above the turnover frequency. An energy power-law with index $s \gtrsim 3$ is typical for these sources, and implies a flat radio spectrum with $p_r = (4/3) - p \sim 0$.

Relativistic particles streaming through a non-relativistic plasma are most effectively scattered by Alfven (A) mode oscillations propagating parallel to the magnetic field (Achterberg, 1980). This remains true for a strongly magnetized plasma, in which magnetic energy density exceeds rest mass energy density (Coleman, 1986a). The A-mode dispersion relation for parallel propagating oscillations is given by:

$$n^2 = 1 + \omega_P^2/\omega_B(\omega_B - \omega) \qquad (1)$$

with $n = kc/\omega$ the refractive index, ω_P the plasma frequency and ω_B the proton cyclotron frequency. This dispersion relation breaks down near the proton cyclotron frequency due to thermal proton motion, where A-mode waves are strongly damped by proton cyclotron resonance absorption.

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Proton cyclotron damping certainly precludes A-mode propagation in the frequency band (Akheizer et al., 1975):

$$(\omega_B^2 - \omega^2) \;/\; 2k^2\beta_p^2c^2 \; < 1 \qquad (2)$$

where $\beta_p c$ is the average thermal proton velocity. In this band, real and imaginary parts of the refractive index are of a similar magnitude, and hence damping is strong. Damping is not effective over a much broader frequency band because the co-efficient falls off exponentially with decreasing frequency. Substitution of dispersion relation (1) provides an estimate of the maximum weakly damped A-mode frequency:

$$\omega_d \sim \omega_B \; (1-\surd 2\beta_p) \qquad (3)$$

which corresponds to a propagation velocity specified by the Lorentz factor:

$$\Gamma_d^2 \sim 1 + \surd 2\beta_p \; (\omega_B^2/\omega_P^2) \qquad (4)$$

Nuclear jets in AGNs may be sufficiently hot and strongly magnetized for all undamped waves to propagate at a high Lorentz factor. The physical parameters required do not contravene virial limits on the field strength near a 10^8 $M_\odot$ compact object, nor the density estimates obtained from Faraday depolarization measurements and other arguments. In such a plasma relativistic electrons with pitch angles $\alpha \gtrsim 1/\Gamma_d$ are not scattered by plasma waves, and the force due to a field gradient causes them to develop into streams propagating with approximate Lorentz factor Γ_d. During this process the energy index s of an initial power-law distribution is increased by unity to s+1 (Coleman, 1986b).

The optically thin non-thermal spectrum of relativistic electrons streaming at small pitch angles is a power-law with low frequency cyclotron turnover. The turnover frequency ν_t is given by (eg. Pacholczyk, 1977):

$$\nu_t \sim \nu_B \;/\; \sin(\theta) \qquad (5)$$

The angle θ between magnetic field and line of sight is identified with the average electron pitch angle $\bar{\alpha} \simeq 1/\Gamma_d$. The strong fields and small pitch angles envisaged here are responsible for promoting the cyclotron turnover to high radio frequencies, where the cosmic conspiracy operates.

Equations (4) and (5), and the fact plasma density scales with field strength B in the case of perfect MHD flow, indicate that turnover frequency $\nu_t \sim B^{3/2}$. For a superposition of several electron stream sources in regions of different field strengths, flux densities at the turnover

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frequency scale as B^2 and the composite low frequency spectrum has the general form:

$$F_\nu \sim B^2 \nu_t^{-p} \sim \nu^{\{(4/3)-p\}} \qquad (6)$$

A flat radio spectrum clearly requires a high frequency spectral index $p \simeq 4/3$, which is consistent with the mean infrared spectral index of blazars (Gear, et al., 1985). If electrons are initially injected with energy index $s \gtrsim 2$ ($p \gtrsim 1/2$), the effect of a field gradient is to produce a steepening to $s \gtrsim 3$ ($p \gtrsim 1$), and the typical continuum spectrum of strong core AGNs is obtained.

In any synchrotron self-absorbed source, circular polarization undergoes a marked sign change near the turnover frequency. It is a firm prediction of this model that no such sign change be found in core dominated AGNs. Furthermore, individual source components (which have been identified with superluminal knots in several objects) must not exhibit strong spectral evolution, since synchrotron and adiabatic cooling processes have little effect upon the energy distribution of relativistic electrons streaming with small pitch angles. Both these predictions could be settled by making careful observations using current or planned instrumentation.

References:

Achterberg, A., 1980 Astron. Astrophys., 98, 161.

Akhiezer, A.I., Akhiezer, I.A., Polovin, R.V., Sitenko, A.G. and Stepanov, K.N., 1975 "Plasma Electrodynamics", Vol. I, Pergamon Press.

Coleman, C.S., 1986a "Structure and Evolution of AGNs", ed. Giuricin, G. et al., Reidel.

Coleman, C.S., 1986b Mon. Not. R. astr. Soc. (in press)

Gear, W.K., Robson, E.I., Ade, P.A.R., Griffin, M.J., Brown, L.M.J., Smith, M.G., Nolt, I.G., Radostitz, J.V., Veeder, G. and Lebofsky, L., 1985 Astrophys. J., 291, 511.

Pacholczyk, A.G., 1977 "Radio Galaxies", Pergamon Press.

https://doi.org/10.1017/S007418090015315X Published online by Cambridge University Press