STIMULATED RAMAN SCATTERING IN ACTIVE GALACTIC NUCLEI

V. Krishan
Indian Institute of Astrophysics
Bangalore 560034, India

P. J. Wiita
Department of Astronomy & Astrophysics
University of Pennsylvania
Philadelphia, PA 19104-6394, USA

ABSTRACT. Stimulated Raman scattering (SRS) processes offer an attractive and efficient method for producing both essentially the entire non-thermal continuum as well as fast electrons in active galactic nuclei (AGN). In this picture, electrons are accelerated by Langmuir waves which are generated by Raman forward scattering (RFS); these electrons then rapidly radiate their energy by means of Raman back scattering (RBS) off of spatially periodic magnetic fields. Such periodic fields can be produced by magnetic modulational instabilities of the Langmuir field. The emission is envisaged to arise from an expanding region, with the highest frequency radiation originating from the smallest volumes at the core of the AGN. Time variability is dominated by density fluctuations in these magnetohydrodynamic flows.

1. INTRODUCTION

We argue that the bulk of the power emitted by active galactic nuclei, from the radio through gamma-rays, could be coherent SRS radiation produced when a pump field is scattered off the collective mode of a relativistic electron beam. Such a pump could be either electro-magnetic waves or static periodic electric or magnetic fields. In more standard models of AGN synchrotron photons are the pump and produce higher energy photons via inverse Compton scattering (CS; Wiita 1985). In SRS the scattering is off of Langmuir waves, which are collective excitations of high energy electrons. SRS is faster and more efficient than Compton scattering, since the Compton scattering rate is proportional to the square of the amplitude of the pump while the SRS rate is linear in that quantity (Hasegawa 1978). We propose RFS as the acceleration process and RBS as the emission mechanism in AGN, where the rate of loss of energy of the electrons via RBS is balanced by the rate of gain of energy in the Langmuir field generated by RFS. Details are in Krishan (1983, 1984, 1985) and Krishan and Wiita (in preparation).

G. Swarup and V. K. Kapahi (eds.), Quasars, 419–420.

2. ACCELERATION AND LOSS MECHANISMS

Langmuir fields can be generated when two electromagnetic waves beat at frequency $\omega_p = \omega_o - \omega_1$ producing a plasma wave of phase velocity $v_p \approx c[1-(\omega_p/\omega_o)^2]^{1/2}$. This wave saturates by trapping electrons, and since $v_p \approx c$ the electrons tend to remain in phase with the wave and are highly accelerated, via an induced electric field given by $E_p \approx m\omega_p cn'/(en)$; here the maximum value of the density fluctuation, $n' \approx n$, the ambient plasma's density. The time needed to gain energy γmc^2 is $t_a \approx \gamma/\omega_p$ (Krishan 1985).

Plasma oscillations with inhomogeneous phase distributions produce vortical currents which can increase the spontaneously generated magnetic field through magnetic modulational instabilities (Bel'kov and Tsytovich 1979). These fields have spatial periodicities between $\omega_p/c < \kappa_o < \omega_p/v_{th}$ with amplitude $B = eE_p^2/(4mc\omega_p)$.

RBS occurs when the difference of the frequencies and wave vectors of the pump wave and the scattered wave equal those of the plasma frequency of the electron beam. Equating the resulting rate of loss of energy to the gain from RFS one finds $n_b/n \approx 8/\gamma$, with n_b the electron beam density. While the ambient plasma takes part in the acceleration, only beam particles are responsible for the radiation.

3. APPLICATION TO AGN

The maximum amplitude of the scattered field is limited by the shift from RBS to CS, and yields the luminosity $L \sim 10^7 nA/\gamma^2$ at the frequency $\omega = 2\gamma^2\omega_p$, where A is the cross-sectional area of the beam. A plot of L/ω vs ω gives a spectral index of -1 as long as (nA) and γ are constant for all frequencies. This would define a density variation law $n \propto R^{-2}$, corresponding to an uniformly expanding region. If, in general, $n \propto R^{-\beta+2}$ and $\gamma^2 \propto R^{-\alpha}$ we find that the spectral index is given by $\Gamma = (2\alpha+1-\beta/2)/(\alpha+1+\beta/2)$.

Observations of quasars and other AGN (Wiita 1985) can be fit into this framework if we take $L_x = 5\times10^{45}$ erg/s at $\omega_x = 5\times10^{17}$Hz and assume $\alpha = 1$. Then, $n_x \approx 7\times10^{12}$cm^{-3} and $R_x \approx 10^{16}$cm. Extensions to the optical give $R_o \approx 22R_x$, $n_o \approx 10^{10}$cm^{-3}, and $L/\omega \approx 6\times10^{31}$erg/Hz/s at 10^{15}Hz; while in the radio, $R_r \approx 50R_o$, $n_r \approx 6\times10^2$cm^{-3} and $L_r/\omega \approx 10^{35}$erg/Hz/s at 5×10^9Hz. An AGN's typically flat spectrum in the radio implies dominance of SRS by synchrotron emission there; the usual cut-off in gamma-rays can be attributed to absorption by pair production.

REFERENCES

Bel'kov, S.A. and Tsytovich, V.N. 1979, Sov. Phys. JETP, **49**, 656.
Hasegawa, A. 1978, Bell System Tech. J., **57**, 3069.
Krishan, V. 1983, Astrophys. Lett., **23**, 133.
Krishan, V. 1984, Astrophys. Lett., **24**, 21.
Krishan, V. 1985, Astrophys. Space Sci., **115**, 119.
Wiita, P.J. 1985, Phys. Reports, **123**, 117.