Unified Schemes and Relations with other Types of Objects

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ON THE DIFFERENCE BETWEEN RADIO LOUD AND RADIO QUIET AGN

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Abstract. Nuclear jets containing relativistic "hot" particles close to the central engine cool dramatically by producing high energy radiation. The radiative dissipation is similar to the famous Compton drag acting upon "cold" thermal particles in a relativistic bulk flow. Highly relativistic protons induce anisotropic showers raining electromagnetic power *down* onto the putative accretion disk. Thus, the radiative signature of hot hadronic jets is x-ray irradiation of cold thermal matter. The synchrotron radio emission of the accelerated electrons is self-absorbed due to the strong magnetic fields close to the magnetic nozzle.

1. Jets and accretion disks: Castor and Pollux?

A puzzling mystery for AGN theorists is the relation between the big blue bump emission component, which is believed to originate as thermal emission from matter surrounding a supermassive black hole and the emission related to the morphological appearance of jets. Recent γ-ray observations have shown that the blazar spectrum from the subparsec jet is quite different from a thermal one and extends over almost twenty orders of magnitude in frequency with an almost constant level νS_ν. Amazingly, the properties of the big blue bump alone never show any indication of whether or not the AGN also has a powerful jet. On the other hand, BL Lacs show no sign of a big blue bump at all. On the basis of these facts one is tempted to assume that there are two hearts in AGN: one beating for the thermal processes (high entropy) and one for the nonthermal processes (low entropy). But then we remember our aim as physicists is to simplify and not to secularize the physical world. Could there be a relation between the two phenomena, in the sense that one is, perhaps, more fundamental than the other? This question has been around for some time during which the paradigm changed from the nonthermal origin of activity to the thermal one, the accretion paradigm. If the latter is correct, then viscosity must be totally robust with respect to the generation of a powerful jet.

In this context I find two new results most challenging to our understanding of AGN. Firstly, γ-ray measurements teach us that the prime radiation mechanism in jets seems to favour extremely high energies: Mkn421 was observed at an energy of 1 TeV with a $\nu S_\nu \propto$ const. spectrum. Secondly, a fairly robust relation $Q_\mathrm{j} = 100 L_\mathrm{nlr} \approx L_\mathrm{bb}$ between the kinetic power of jets Q_j and the narrow line luminosity, resp. the photoionizing luminosity of the big blue bump, in radio galaxies and quasars has been found by Rawlings & Saunders (1991) and Celotti & Fabian (1993). They tell us that whatever links nonthermal and thermal components does this independent of the total luminosity and the presence of broad lines or a big blue bump. The existence of pure objects of either class then appears inconsistent.

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In fact, radio quiets do have weak radio jets and a nonthermal optical/x-ray continuum. So, one should perhaps take a different point of view: assuming *all* AGN have powerful jets with $Q_{\rm j} \approx L_{\rm bb}$, could their radiative appearence be different enough to account for all AGN classes (Camenzind & Courvoisier, 1983)? In particular, this requires that the jets in radio quiets must dissipate most of their kinetic power witin the central parsec, because further out they would unescapably show strong radio emission. The momentum, however, is still there and, indeed, radio quiets do show high speed nuclear outflows, most spectacularly in broad absorption line quasars. From this heuristic starting point the following questions arise: (i) if jets in radio loud sources generally start out with relativistic speeds (which can plausibly be assumed with $\gamma_{\rm j} \leq 10$), is this a prerequisite for the jets to emerge out of the central parsec without suffering much from radiative losses? If so, (ii) what is it that lets some jets start out slower, (iii) why do slower jets dissipate so much of their power in the central parsec and (iv) why is this connected to the properties of the host galaxy?

In this contribution I will attack question (iii), while leaving the answers to the other questions open. My personal guess would be that question (i) must be answered affirmatively, probably because relativistic bulk motion protects the jet from shock acceleration too close to the disk. Concerning (ii) it is quite natural for any jet forming mechanism to generate something like an inverse power law distribution for the speeds of jets, so that one easily gets 90% mildly relativistic jets and 10% relativistic jets. And finally, (iv) may have to be reversed in order: different jet properties make different host galaxies because jets can trigger star formation via cosmic rays and shocks. Remnant winds in quiets would sweep out interstellar matter above the disk leaving behind a torus.

2. Beamed γ-rays: a fingerprint from accelerated protons

In an effort to empirically answer the question whether jets contain an ordinary mixture of protons and electrons, Mannheim *et al.* (1991) investigated the radiative signature of highly relativistic protons accelerated at shock fronts. Photoproduction of pairs and pions injects electromagnetic power into the acceleration zone which is further reprocessed by an (unsaturated) synchrotron cascade. This proton initiated cascade (PIC) should operate at shocks of all sizes: starting from kpc Hot Spots (cf. Harris *et al.*, this volume) down to the shocks at the subparsec scale thought to be responsible for "proton blazar" emission (Mannheim, 1993). An essential parameter is the distance of the proton blazar from the source of the big blue bump photons, because local photons compete with thermal photons from outside the jet as a target. As the proton acceleration zone moves closer in, the γ-ray spectrum steepens as shown in Fig.(1) until cooling is entirely dominated by the anisotropic thermal target photons.

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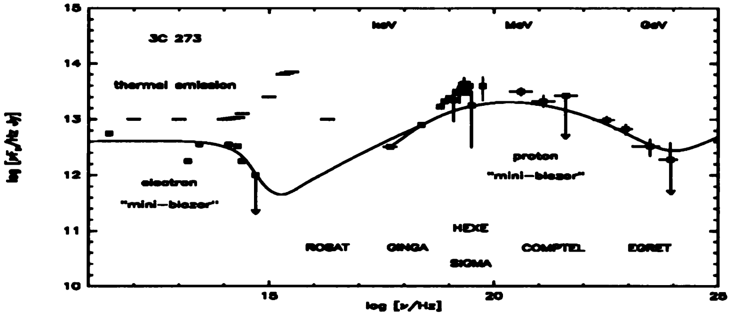

Fig. 1. The proton blazar model for 3C273 with a proton/electron ratio of $\eta = 15$, see Mannheim, *Phys. Rev. D*, Vol.48, No.4 (1993). Note the steepening of the γ-ray spectrum due to the additional blue bump target photons.

3. Dying jets: hadronic shower precipitation and nuclear winds

Protons exposed to an anisotropic target field cool via photoproduction mostly in the direction of the source of the target photons. They prefer head-on collisions with $\mu = -1$ because of the threshold condition $\gamma_p x(1 - \beta_p \mu) \geq x'_{k,th}$ where $\mu = \cos\theta$ is the cosine of the angle between proton and target photon momentum, $x = h\nu/m_e c^2$ the photon energy and $x'_{k,th}$ the photon threshold energy in the proton rest frame to create particle k= $e^{\pm}, \pi$ on the mass shell. Thus, head-on collisions require the lowest γ_p and thus produce the strongest flux for a proton distribution $n_p \propto \gamma_p^{-2}$ cooling on an almost monoenergetic photon target $x \approx 2 \times 10^{-4}$. The required proton Lorentz factor is $7 \cdot 10^5$ for pion production. Figs.(2) shows the emergence of this *natural anisotropy.* Maximum efficiency of the irradiation is obtained at the distance to the disk of $z_o = 200\sqrt{r_o/100}$ (in units of the Schwarzschild radius) where the photoproduction optical depth becomes unity for a jet radius of r_o, but $\tau_{pp} \ll 1$. At this location the magnetic field has the strength $B_o = 1.6 \cdot 10^3 M_A^{-1} m_8^{-1/2} r_o^{-1} \beta_{0.3}^{-1/2}$ and the target radiation compactness is $l_o = 3m_8^{-1} r_o^{-1/2}$. Here it was assumed that $L_{edd} = L_{bb} + Q_j + L_B + L_{rel} \simeq L_{bb} + L_B\,(M_A^2 + 2)$ with equipartition $L_B = (B^2/8\pi)\,A_j c\beta_j = L_{rel}$ and the kinetic power $Q_j = M_A^2 L_B$. The irradiation spectrum is a powerlaw with $\alpha \simeq 1$ from eV up to GeV (because of a lack of x-ray photons to reprocess γ-rays from MeV to GeV) and $L_{pic} = L_{bb}(1 + M_A^{-2})/\,(0.5 + M_A^2)$. A mildly relativistic jet suffering from such severe radiative losses rapidly expands. The surviving momentum is shared to the surrounding thermal matter driving a high speed nuclear wind. Radio emission from the accelerated electrons is synchrotron-self-absorbed up to the frequency $\nu_s = 4 \cdot 10^{13} m_8^{-1/3} r_o^{-1} M_A^{-4/3} \beta_{0.3}^{-2/3}$ which makes such dying jets radio quiet. There is some radio emission associated with the remnant wind and the low emissivity reflects its large opening angle.

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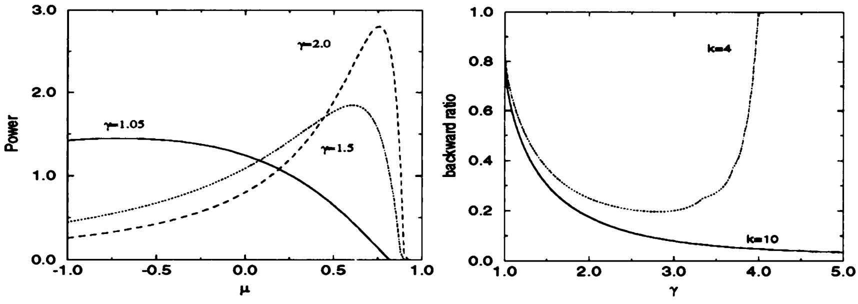

Fig. 2. **Left panel:** The angular distribution of cascade power. Note the transition from emission into the forward Doppler cone $\mu = \beta$ to emission into the backwards hemisphere when the bulk Lorentz factor γ decreases. At very small angles no emission is produced because there are no photons satisfying the threshold condition. **Right panel:** The backward/total luminosity ratio as a function of jet Lorentz factor. A maximum value of $\approx 90\%$ irradiation is possible. The label $k = 4$ denotes the curve for a proton maximum energy four times the threshold energy for head-on collisions. Thus, for $\gamma > 4$ no photoproduction ocurrs. Close to the limit the total luminosity is small, but emitted solely towards the backward hemishere.

4. Critique and conclusions

In this contribution I have proposed that powerful jets are ubiquitous in AGN. Radio quiets are equipped with mildly relativistic jets which cannot emerge from the central parsec because of severe radiative losses and rapid expansion. Relativistic protons in these jets induce electromagnetic showers which irradiate the accretion disk with hard radiation and which have very weak emission towards the observer. An *experimentum crucis* is the detection of the neutrino signature of the hadronic processes which is feasible with experiments currently under construction (Stenger *et al.*, 1992). The model needs a high efficiency of converting kinetic energy into radiation which is difficult to reconcile with statistical acceleration mechanisms (Mastichiadis & Kirk, this volume). Magnetic dissipation could resolve the problem, but could it yield proton Lorentz factors of 10^6?

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