GALACTIC CENTERS AND TWIN-JETS

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Abstract. A schematic model is suggested to describe the various activities in the centers of massive galaxies. Basic assumptions are that (i) a uniform model can account for all the observed phenomena, such as quasars, blazars, radio galaxies, Seyferts, and the centers of normal galaxies (with disks), (ii) activity in galactic centers is repetitive, and (iii) in-situ-acceleration of highly relativistic electrons (other than by adiabatic compression) has an insignificant efficiency, i.e. is ignorable.

The central engine. At this meeting, Pacini has summarized the spinar model; see also [Morrison (1969)]. Its difficulties are that (i) after one active cycle, it collapses to a black hole, i.e. it cannot describe repetitive behaviour, (ii) the frozen-in transverse magnetic dipole moment would give rise to a distinctly periodic non-thermal output on the spin time scale, of order months for the strong sources, which is not observed, and (iii) it is not clear how a spinar could give rise to the (much more extended) narrow line emission regions.

Thorne, Blandford, and Rees have discussed features of the black hole model. Its difficulties are that (i) the unresolved central mass of nearby galaxies is typically of order several 10^6 $M_\odot$ [Bisnovatyi-Kogan & Blinnikov (1976), Duncan & Wheeler (1980)] and may be smaller than several 10^3 $M_\odot$ in the case of our own Galaxy [Parijskij (1981)] whereas the central black hole of a formerly active galaxy would be expected to have grown well beyond 10^9 $M_\odot$ by now, (ii) a black hole cannot anchor a transverse magnetic moment, and (iii) the large observed mass outflow rates from galactic centers, of order $M_\odot$/yr, would ask for much larger (supercritical) inflow rates into the black hole, and hence for excessive fuelling rates.

For these reasons, I have suggested the massive core of a supermassive magnetized disk (=SMD) as the central engine [Kundt (1979), and fig. 1]: Continual mass spiral-in into the extremely fast-spinning core, through the $\lesssim 10^5$ K warm disk [Sorrell (1980)], is balanced by an unsteady massive wind which supplies the material seen in the broad and - further out - narrow emission and absorption lines. This thermal

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component of the wind is driven by hydrogen burning; it has a small filling factor, between 10^{-5} and 10^{-10}. Most of the radiated power $\dot{E}$ is drawn from rotation via low frequency magnetic multipole radiation, with $\dot{E}=10^{45.5}\eta\, u_{-3}^{4}$ erg/s, where $\eta \lesssim 1$ is an efficiency factor for poloidal flux generation, $u:=R_S/R$ is the inverse radius in units of the Schwarzschild radius, and $u_{-3}:=u/10^{-3}$. This power is independent of the mass in the central core; the latter determines the spin period, and refilling timescale, and may fall between 10^2 and $10^7\ M_\odot$. Discharges outside the atmosphere give rise to pair production. As in pulsars [Kundt (1981), Kundt & Krotscheck (1980)], the $e^\pm$-plasma is post-accelerated by the forming (strong) low frequency waves, turns the thermal component into magnetized filaments in pressure equilibrium, and is eventually focussed into two antipodal beams by magnetic pinching.

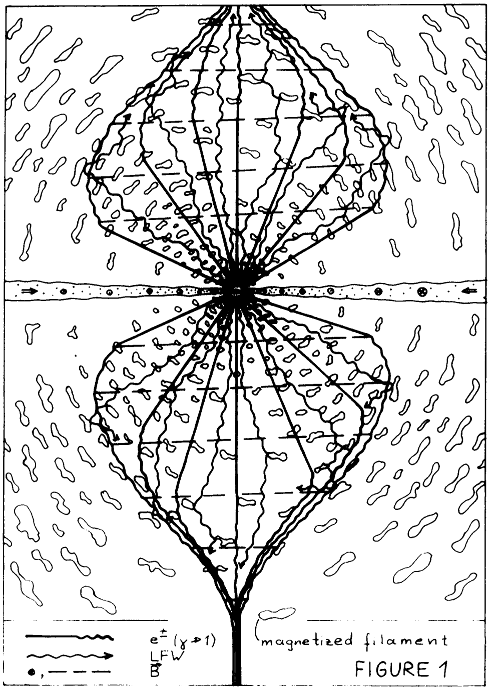

FIGURE 1

Fuelling. Geometrically, there are two preferred ways of fuelling the central engine: by spherical accretion or by accretion from a disk. A time-integrated energy output of 10^{63} erg, at a conversion efficiency ε of some 10^{-3} of the rest energy, corresponds to an average fuel demand of some 56 $M_\odot$/yr. This calls for an efficient and steady angular momentum loss mechanism. A massive gas disk stirred by large-scale turbulence can convect $\dot{M} \lesssim c_{sound} v_{turb}^2/G = 10 c_6 v_7^2$ ($M_\odot$/yr) to its center [c.f. Bailey & Clube (1979)]. Galactic-scale dust lanes have been detected in some 40 active elliptical galaxies, roughly at right angles to the radio axis; they may well originate from intergalactic accretion. Their huge mass and spin would explain the long-term steadiness, and direction stability of jets in extragalactic radio sources. Besides, accretion from a flat disk can greatly exceed the Eddington rate whereas spherical plasma accretion cannot.

Wind. Quasar emission lines reveal chemical compositions not very different from local galactic ones, i.e. we observe processed material. This suggests that we see the ashes rather than the fuel, as they are blown out from the burning core. The differences among the various types of extragalactic point sources may be largely due to different proportions of the thermal and relativistic component: a dense thermal shell gives rise to a compact, radio- and X-ray-quiet source whereas a more expanded (filamentary) shell becomes radio- and X-ray transparent and has a more uniform expansion velocity and larger volume, hence narrower and more intense emission lines.

Jet Formation. Focussing of the jets requires pressures $\dot{E}/Ac$ some 10^{10} times higher than galactic, (A=nozzle area). If these are provided by extrinsic plasma walls, as in various versions of the twin-exhaust model [c.f. Smith, Smarr, Norman & Wilson (1981)], there are the following difficulties: (i) the walls of the nozzles are in metastable dynamic equilibrium, hence must be continually replenished, (ii) the walls are hot ($T \lesssim 10^{10}$ K) and massive, hence are liable to be detected in emission, (iii) the walls could be detected through depolarization of the central radio source, (iv) the walls should filter out the (relativistic) jet component from the thermal component - which latter is observed e.g. through the forbidden lines. For these reasons, I prefer a model in which the expanding $e^{\pm}$-plasma is focussed by its frozen-in toroidal magnetic flux, i.e. by a magnetic pinch. Note that the extrinsic model needs a supermassive center to keep the scale height small whereas the intrinsic model does not.

Jet speed. Several estimates of the bulk speed of matter in the jets have been summarized by M. Rees at this meeting. These estimates are quite different in magnitude, depending on the specific assumptions made. In [Kundt & Gopal-Krishna (1980, 1981)] we have argued that the bulk Lorentz factor of the jet material is large, typically $\gamma \gtrsim 10^2$, because (i) the outward speed of the hot-spots in the outer lobes ($\gtrsim 0.1c$) must be subsonic w.r.t. the shocked material, (ii) the largest radio lobes would otherwise be intolerably old, (iii) beam bending via ram pressure poses problems for non-relativistic speeds in at least some of the sources, (iv) the frequent 1-sidedness of radio through X-ray jets, on scales between one pc and hundreds of Kpc, finds a simple explanation as forward-peaked synchrotron radiation caused by interactions with obstacles (such as channel walls), c.f. figure 2 and next section, (v) superluminal expansions are hard to explain without relativistic bulk motion, (iv) low frequency variability, absence of intergalactic scintillation, and absence of large inverse Compton contributions to the spectrum all indicate that relativistic beaming is important, (vii) the absence of boron lines from quasar spectra speaks against a significant fraction of ions in the emission volume [Baldwin et al (1977)], (viii) independent arguments have been given in [Kundt (1981)] that the corkscrew-shaped jets in the SS 433 system are beams of extremely relativistic $e^{\pm}$-plasma twisted because of a precessing injection direction.

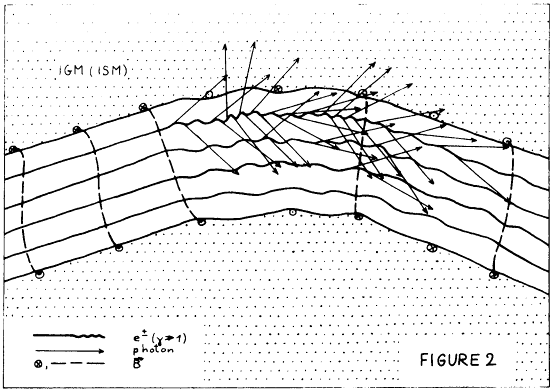

FIGURE 2

One-sidedness. Different explanations have been given for the frequent 1-sidedness of jet structures, among them: (i) isotropic radiation from expelled plasma clouds boosted in the direction of motion, (ii) al-

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ternating jet production, so that the observed 1-sidedness is intrinsic, and (iii) relativistic beaming caused by obstacles [Kundt & Gopal-Krishna (1981)]. A difficulty of interpretation (i) is that it implies implausibly small inclination angles. Difficulties of interpretation (ii) are that there are 2-sided jets (like in NGC 1265), that 1-sided structure is seen on largely different length scales (like in Cen A), and that for 1-sided emission to be sustained, the reflection symmetry of the feeding disk would have to be violated for many dynamic time scales of the central engine. Interpretation (iii), on the other hand, would explain why sometimes hot-spots are seen far removed from the outer edge of a lobe: they may be "knees", i.e. curved channel segments pointing towards us. In straight sources (e.g. Cyg A), most of the jet power is dumped in the heads of the outer lobes whereas in multiply bent sources (in particular head-tail sources), most of the power is dissipated by wall interaction. The degree of jet bending, in turn, depends on the ratio of jet power to relative velocities of the active galaxy w.r.t. its ambient medium.

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