RELATIVISTIC JETS AS RADIO AND X-RAY SOURCES

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ABSTRACT: Various predictions and implications of the relativistic-jet model for compact extragalactic sources are reviewed in the light of recent radio and X-ray observations.

According to the relativistic-beaming hypothesis (Scheuer and Readhead 1979, Blandford and Königl 1979), the radio emission in most of the bright, compact extragalactic sources originates in relativistic jets, and can be detected only when the observer is located within the beamed "emission cone" of the jet. In this picture, the sequence: radio-quiet quasars, radio-loud quasars, and optically violently variable quasars (OVVs) corresponds to similar sources which are viewed at progressively smaller angles to their jet axes. Except for the absence of strong emission lines, BL Lac objects are similar to OVVs in their spectra, high degree of variability and strong linear polarization, and may represent the strongly beamed sources (the analogs of radio-loud quasars) among giant elliptical galaxies. An immediate consequence of the beaming hypothesis is that, for every relativistic core-dominated source with Lorentz factor γ, there are $\sim\gamma^2$ extended double sources in which the central components are radio quiet. In sources which are viewed nearly along the jet axis, the extended outer lobes should appear as low-surface-brightness, steep-spectrum halos around the bright flat-spectrum cores. Recent low-frequency observations (e.g., Browne et al. 1981) have verified that most core-dominated sources are indeed surrounded by such halos, and that the source statistics are consistent with the values of $\gamma(\gtrsim 6)$ that are inferred in a number of these sources from apparent superluminal motions (e.g., Cohen 1982). It is suggestive that Lorentz factors in this range can also explain the frequent occurrence of low-frequency variability in core-dominated sources (Blandford and Königl 1979).

The relativistic-jet model provides a natural interpretation of the phenomenon of apparent superluminal expansion, and particularly of the fact that the separating components have comparable flux densities. In this picture (Blandford and Königl 1979), one of the components is identified with the stationary, optically thick "core" of the jet, while the other components are associated with shock waves which either propa-

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gate in the jet or which form behind dense clouds that are accelerated by the flow. The core component is expected to have a flat radio spectrum and a relatively constant flux density, whereas the other components could have steeper spectra and would diminish in brightness as they separated from the core. These predictions appear to be borne out by recent high-resolution VLBI observations (e.g., Unwin 1982).

Radio-loud quasars are different from radio-quiet quasars also in their X-ray properties, having on the average a higher ratio of X-ray to optical luminosity (e.g., Ku, Helfand, and Lucy 1980). The differences are most noticeable for OVVs which, together with BL Lac objects, appear to form a distinct class of sources, much as they do in the radio and optical regimes. In the context of the relativistic-jet model, these observations suggest that the X-rays in these strongly polarized and highly variable sources could be associated with the beamed emission component which produces the strong radio flux. It is, in fact, possible to account for the main spectral characteristics of this class -- the flat radio spectrum and the two-component X-ray spectrum -- with a simple model of an unresolved, inhomogeneous jet, in which the local emission spectrum breaks as a result of synchrotron radiation losses (Königl 1981). This model implies that all of these sources will be found to have a hard X-ray component (attributed to synchrotron self-Compton emission) at sufficiently high frequencies. On the basis of this model one can, in principle, deduce various source parameters from the detailed shape of the spectrum. An example of a source for which a reasonable set of parameters could be inferred in this fashion is the BL Lac object PKS 2155-304 (Urry and Mushotzky 1981). Relativistic beaming in this source is suggested independently by arguments involving the inverse-Compton "catastrophe."

Quasars are now believed to account for a large fraction of the diffuse X-ray background in the few-keV range (e.g., Tananbaum 1982). The radiation is most likely associated with the unbeamed emission component. The only quasar identified so far as a high-energy ($\geqslant$ 100 MeV) γ-ray source is 3C273, which is also a radio-loud "superluminal" quasar. If 3C273 is a typical quasar, then it is possible to argue on statistical grounds (Königl 1981) that the high-energy γ-rays in quasars also originate in the beamed emission component, and that radio-loud quasars contribute most of the diffuse $\geqslant$ 100 MeV background.

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