

Active galactic nuclei

Pointing towards the source?

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QUASARS, like beauty, may be in the eye of the beholder. So suggests Peter D. Barthel in a paper in the latest *Astrophysical Journal*¹ that collates observations collected by his² and many other groups of astronomers. According to his version of the unified scheme for active galactic nuclei, radio-emitting quasistellar objects (QSOs) and powerful radio galaxies are the same sorts of objects, seen from different directions, and radio-quiet QSOs may be the similarly oriented subset of powerful galaxies with bright infrared sources (called IRAS galaxies after the satellite that measured their fluxes).

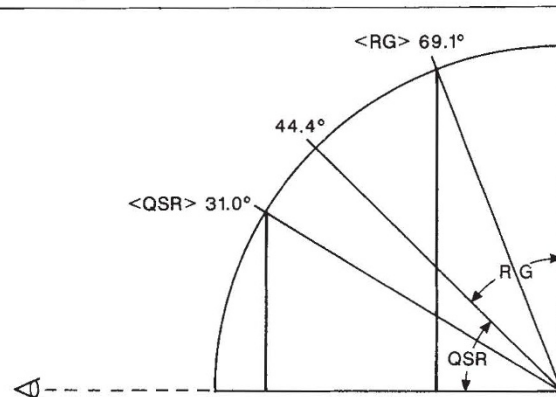
The generic name, active galactic nuclei (AGNs), indicates a long-standing recognition of some kind of unity within the zoo. The beasts on display include (a) quasars (an attempt at pronouncing the acronym QRS for quasi-stellar radio source), which are optically compact, show broad emission lines at large redshifts, and emit powerfully at radio wavelengths, (b) QSOs (much more numerous and not strong radio sources, but otherwise similar), (c) BL Lac objects (with rapid variability, strong polarization, and weak or no emission lines; named for their prototype), (d) radio galaxies, (e) optically violent variables (OVVs) and (f) Seyfert galaxies (bright nuclei and strong emission lines with moderate redshifts, named for their discoverer). The host galaxies are generally thought to resemble ellipticals for types (a) and (d), spirals for (b) and (f). Many are interacting galaxies.

All AGNs exhibit the astrophysical difficulty of producing lots of energy from small volumes with the capacity for very rapid change in both brightness and location of the emitting regions. And all are currently explained by a standard model^{3,4}. Its components are a massive black hole (10^5 – 10^6 times the mass of our Sun) at the centre of a galaxy; energy generation and transport by some combination of gas flowing inward and magnetic fields linking the hole to more distant gas; and one or two outgoing, well-collimated jets of particles, field and photons moving at speeds close enough to the speed of light that special relativity must be applied rather carefully to avoid inconsistencies in interpreting the observations⁵.

The model clearly provides a wealth of parameters that can be varied among assorted kinds of AGNs—the mass of the black hole, the rate of gas inflow (relative

to an upper limit set by radiation pressure), the field strength and configuration, the geometry of surrounding gas, the mechanism and precision of jet collimation, the dominant components of the jet (plasma of electrons and positrons or electrons and protons; magnetic field; photons), and the angle the jets make with our line of sight.

Earlier versions of a unified scheme^{6–9} attached considerable importance to the last, orientation, parameter. A jet seen more or less end-on was invoked to explain several phenomena that are common, but by no means universal, in quasars, including rapid flux variability



Orientation of the approaching jet of active galactic nuclei relative to the observer's line of sight. The dividing line between quasi-stellar and radio and infrared galaxies occurs at about 44° . Thus the average radio galaxy (RG) at 69° should have an apparent, projected radio diameter about twice that of the average quasar (QSR) at 31° as seems to be the case. (Courtesy of P. D. Barthel.)

and rapid outward motion of radio-emitting blobs along the jet direction (called superluminal motion because a naive analysis of it that neglects the effects of orientation and special relativity leads to apparent motion at velocity = 2 – 10 c). Such a picture successfully organizes a variety of observed features of quasars and their ilk.

The classification of some quasars as roughly end-on jets and some as roughly side-on, runs into a couple of difficulties, however. First, presence of superluminal motion should be correlated with small angular size of extended radio emission as projected on the sky. It is not. The paper by Barthel *et al.*² in fact reports apparent expansion at 2.5 c for the core of the quasar 4C 34.47, which has the largest projected size of any known (560 kiloparsecs assuming a Hubble parameter $H = 100$ $\text{km s}^{-1} \text{Mpc}^{-1}$). Second, the radio flux we see should be enhanced by beaming and the X-ray flux should not; yet the two

are rather well correlated. It is also sometimes hard to understand the non-detection of the expected, diametrically opposed, jet aimed away from us.

In Barthel's restructured scheme (see figure), all quasars are beamed within 44° at us (average, 31°), and the otherwise-directed objects are seen as powerful radio galaxies, whose projected sizes are indeed larger by about a factor of two. Radio-quiet quasistellar objects may be the corresponding end-on views of galaxies that we otherwise see as strong infrared sources (because dust absorbs and re-radiates much of the emission in the equatorial direction). The presence or absence of radio emission is then an intrinsic property of a particular hole-accretion-collimation combination, and X-ray emission must be somewhat enhanced by beaming effects. The Seyfert galaxies provide some supporting evidence. The two subtypes, Seyfert 1 and Seyfert 2

galaxies, have been attributed to pole-on and equator-on directions of view on the basis of other evidence¹⁰. And, indeed, Seyfert 1 galaxies are more often the strong X-ray emitters; and the most pronounced superluminal galactic source, 3C 120, resides in a Seyfert 1. Barthel suggests that all host galaxies will be found to be experiencing some degree of interaction with neighbours. The relationship with yet another kind of activity, also widely blamed on interactions and called star bursts (meaning bursts of rapid star formation), remains to be worked out.

Barthel provides eight additional predictions of his scenario, pertaining to polarization, optical emission line, counter-jet and infrared properties of the several classes of objects. He also proposes two kinds

of observations that could rule it out—evidence for systematic differences in the morphology or in the environments between the host galaxies of quasars and radio galaxies, or between QSOs and infrared galaxies. Curiously, the definitive test of going around to the other side of a few and looking is not mentioned. □

1. Barthel, P.D. *Astrophys. J.* **336**, 606–611 (1989).
2. Barthel, P.D., Hooimeyer, J.R., Schilizzi, R.T., Miley, G.K. & Preuss, E. *Astrophys. J.* **336**, 601–605 (1989).
3. Rees, M.J. *IAU Symp.* **119**, 1 (1986).
4. Blandford, R.D. *IAU Symp.* **119**, 359 (1986).
5. Rees, M.J. *Nature* **211**, 468–470 (1966).
6. Orr, M.J.W. & Browne, I.W.A. *Mon. Not. R. astr. Soc.* **200**, 1067 (1982).
7. Scheuer, P.A.G. & Redhead, A. *Nature* **277**, 182–185 (1979).
8. Blandford, R.D. & Königl, A. *Astrophys. J.* **232**, 34 (1979).
9. Kapahi, V.K. & Saikia, D.K. *J. Astrophys. Astron.* **3**, 465 (1982).
10. Antonucci, R.R.J. & Miller, J.S. *Astrophys. J.* **297**, 621–632 (1985).

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