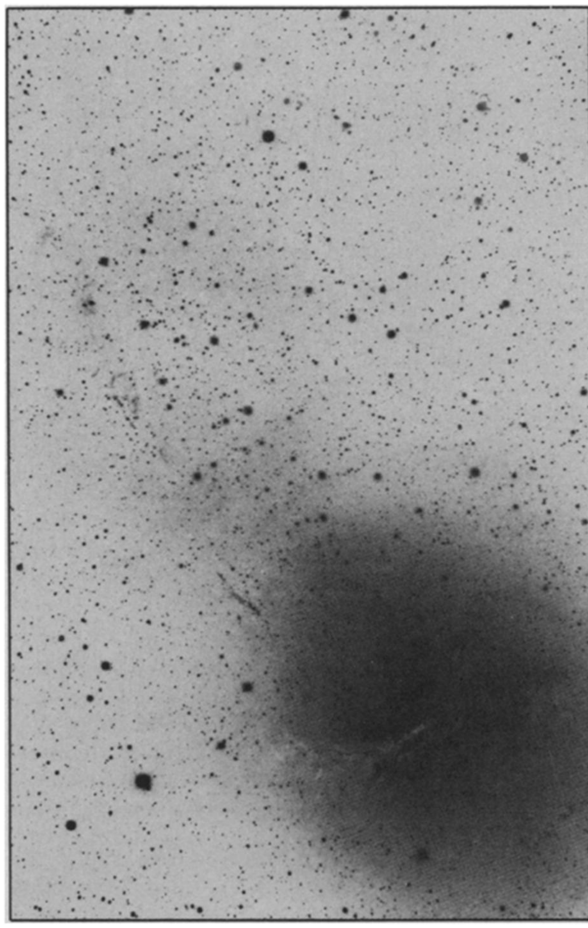
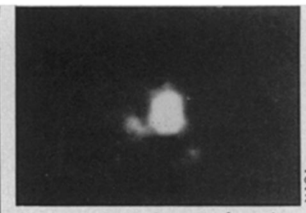
A HOLE IN THE MIDDLE OF THE GALAXY

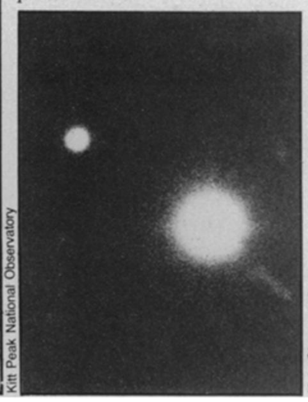


Kitt Peak National Observatory



NASA

A negative view (taken in visible light) of the radio galaxy Centaurus A by the four-meter telescope at Cerro Tololo (left). The nucleus of a Seyfert galaxy (above) and a representative quasar, 3C273 (below). All these objects may be powered by similar black-hole phenomena.



Hale Observatories

Martin Rees proposes that quasars are manifestations of phenomena common to galaxies: supermassive black holes in their nuclei

BY DIETRICK E. THOMSEN

Astrophysical mysteries are so numerous nowadays that one almost needs a Dewey decimal system to catalog them for easy remembrance. The way things are going with astronomers lately a 14-year-old mystery is practically hoary with antiquity, yet quasars continue to generate as much interest and spirited discussion as they did when first found. Some of the current mysteries that hit the headlines may turn out to be literal flashes in the pan, but quasars have an apparent cosmological and astrophysical importance that guarantees them a perennial good box office rating.

Quasars are objects that look the right size to be stars, but emit energy at rates characteristic of galaxies. The astrophysical question is what sort of process could generate so much energy in such a small volume of concentrated matter? Furthermore, if one believes that the redshifts in the quasars' light are accurate indicators of distance—there is a spirited argument on that question—then quasars are generally quite distant. A few of them would be the most distant objects known.

Looking out in space is always looking back in time. Quasars therefore appear to be largely relics of the early days of the universe and the cosmologist must ask what they have to say about its early histoty and evolution.

Both the astrophysical and the cosmological conundrums have led astronomers to suggest that quasars are something qualitatively different from other celestial phenomena with a physics and meaning all their own. If one starts from this axiom, one can spin various theories constrained only by the general laws of physics—and in some cases not even so constrained. And in the end it may all come down to Chico Marx's famous question: "Why a duck; why not a chicken?"

One of the more prominent scientists interested in quasars, Martin Rees of Cambridge University, now suggests that quasars are not at all qualitatively different phenomena but happenings common to the centers of galaxies. We see the most spectacular of these as quasars, he says, but since the less energetic don't stick out quite so obviously, we miss the general connection. The idea that quasars have to do with the centers of galaxies is not unique to Rees. A number of observers have suggested that quasars may be an early stage in the evolution of galaxies (before the extended parts of the galaxies formed) or galactic centers that never developed galaxies—a kind of evolutionary freak or cosmological birth defect. Rees, however, addresses the astrophysical problem by proposing that the basis of the quasar phenomenon is a gigantic black hole inhabiting the heart of a galaxy. Rees spelled out his hypothesis at the recent Eighth Texas Symposium on Relativistic Astrophysics.

Rees bases his belief on the things that have been learned in recent years about the structure and radiation mechanisms of quasars and of conditions in galactic centers. "Quasars are not qualitatively different from other manifestations in galactic nuclei," he says. "There are lines of evidence that do converge on a tentative hypothesis that black holes of a million times the sun's mass lurking in galactic centers get fuel by capturing gas and even whole stars."

These black holes would form out of supermassive star clusters in the galactic centers. Once such a black hole is formed, its gravitational attraction tends to increase the density of stars around it.

The next part of the theory parallels the more popular theories of pulsars and X-ray sources, and gains plausibility from the ease with which those theories have received wide acceptance. For pulsars and X-ray sources the popular theory suggests that disks of matter form around a small compact object (maybe a black hole). The matter for these accretion disks comes from a nearby source, such as a binary companion star, and as it falls into or onto the compact object it is heated by collisions and possibly other means and so yields the observed radiation.

For the supermassive black holes in his quasar hypothesis Rees suggests an accretion sphere, rather than a disk. The matter to continually replenish the disk, replacing what falls down the hole, comes from the dense group of stars surrounding the black

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needed, he says, but the central problem is a moral one. "The world dilemma is whether or not to redistribute wealth—making the rich nations very much poorer while doing relatively little for the huge numbers of the very poor. And *that* is what may create an 'enclave.' "

A Retrospective

In the late 1960s, Snow again turned his attention to this subject, in a lecture glumly entitled "The State of Siege." He reemphasized that "The Two Cultures" had been a call for action, to marshall both great intellectual traditions of the West to meet the worldly challenges of the future. He noted the easing of Cold War tensions and said that all-out war seemed less likely. But otherwise he had grown even more pessimistic, particularly in one crucial area he had earlier failed to pursue:

"In the 'Two Cultures' lecture there was a curious and culpable omission. . . . I was talking about world crises and I made only the slightest reference to the growth of population. . . . I didn't want this major problem to dominate the discussion: Partly because it seemed to me then to make social hope even more difficult; partly because I didn't want to hurt other people's religious sensibilities." In "Siege" he no longer yielded to such scruples. Warning about the dangers of famine and overpopulation "is the plain duty of churchmen of all kinds."

He also noted the rapid increase in global communications but he was far less sanguine about their effect than Lewis Branscomb. "Television bombards us with communication about the world outside. . . . We know so much—and we can do so little." The West is not only making itself an enclave, he wrote, but many groups of its people are making small ones of their own. Even the young: "They too have turned inwards—into their own customs and often their own language."

Once again he made a call for action, this time with little specific reference to academic disciplines of either stripe: "One hears young people asking for a cause. The cause is here. . . . Peace. Food. No more people than the earth can take. That is the cause." But then he concluded on a somber note. "I should be less than honest if I told you that I thought it was likely to succeed."

Leaving aside several specific details, Snow's original analysis and call for action have weathered the two last decades rather well. The schism between the Two Cultures is at least a matter still hotly debated, and the complex social-technical problems that must be solved in order to relieve human suffering are still with us. Some recent studies (SN: 11/13/76, p. 316) have indicated that world population may not be growing as quickly as most feared a few years ago, but the gap between rich and poor nations is demanding even more attention as terrorism and resource embargoes threaten the West.

While some educators still strive for what Gerald Holton calls "double literacy" in the sciences and the humanities, most recent attention has been focused on whether schools are even training children to be literate enough to function in day-to-day life. To Snow's concern for teaching professionals enough about each others' work that they can serve well in government must now be added a concern for educating the public enough to preserve democracy in an increasingly technical age.

Each of the Two Cultures thus faces a growing set of challenges that may make more cooperation a necessity. Both social problems at home and economic ones abroad call for solutions that go beyond the reach of any single family of disciplines. Partly as a result, a Third Culture—the social sciences—which Snow only briefly mentioned, may now mature. But if society's intellectual framework has any practical significance for the preservation of civilization—as Snow passionately believed—a fundamental new paradigm must emerge, built on a more holistic view than that of either the traditional scientific disciplines or the humanities.□

. . . Quasars

hole and coming under the influence of its gravitational field, but in this case the feeding methods are more spectacular than those for a pulsar.

"Stars of solar mass could be swallowed whole," Rees says. Larger stars might be disrupted by tidal forces or collisions with other stars and swallowed piecemeal. Rees estimates it would take a feeding rate of one solar mass per year to produce an energy radiation rate of 10^{40} ergs per second, which is about par for a quasar.

The accretion sphere forms a kind of photosphere around the black hole, similar to the light-producing layers of stars. How the object looks depends a good deal on how efficient the mechanisms are that cool this photosphere and dissipate the energy generated by collisions in it. If the cooling mechanisms are efficient, one would not be able to see very far down into the photosphere. It may be, Rees says, that the BL Lacertae objects, which have some resemblances to quasars but don't look quite as condensed and energetic, have inefficient cooling mechanisms in their photospheres so that one sees closer to their central black holes.

Rees finds that he can begin to explain various features of quasar spectra by reference to such accretion spheres. First, there is much nonthermal radiation in the background spectrum of a quasar, and this requires particles accelerated to relativistic speeds for its production. Instead of relying on gravitation (falling), which is unlikely to produce such speeds, Rees invokes electromagnetic phenomena. If the object or objects that originally formed the black hole possessed a magnetic field, that field would not only be preserved during collapse to a black hole, it would be strengthened. The ultimate result would be electric and magnetic fields that could produce the necessary acceleration. Thus the energy for the nonthermal parts of the spectrum would come ultimately from the energy associated with the black hole's rotation (stars rotate, and that too is not lost in black-hole collapse) mediated by its magnetic field.

The narrow absorption lines seen in quasar spectra could come from particles rather far from the black hole, Rees suggests. The broad emission lines that are seen in some quasars and Seyfert galaxies probably come from high-density regions of the accretion sphere. The radio qualities of quasars would come from electrons very near the black hole. These would be part of collimated beams of relativistic plasma that would form near the hole and blast outward in two jets, thus producing the two-lobed shape of radio sources associated with quasars and many galaxies. If the black hole formed initially from an object (stellar cluster or aggregation) of ten billion or so solar masses it could also emit gravitational radiation, although for the moment there are no data of that sort.

Beyond such oddities as quasars, BL Lacertae objects and Seyfert galaxies is the general question that extends to more "normally" behaved galaxies. "It may be that black holes lurk in the centers of little galaxies that are not big radiators," Rees proposes. It may be that the famous radio source Centaurus A once had such an active center, but has by now radiated away most of its energy and is only slowly accreting more matter. There is now no general, comprehensive theory of all these things.

Rees concludes by saying that perhaps quasars were discovered too soon. In 1963 everybody thought they were something qualitatively different. In the intervening time pulsars and X-ray sources have been found, and the accretion models developed. Astrophysicists now see that gravitation (acting in the infall of matter and in the enhancement of electromagnetic effects produced in the black-hole collapse) can be "an energy source that is relatively efficient. Had quasars been discovered later, this would have seemed a natural mechanism." Rees proposes that "now the time has come for an investigation," for the gathering of "a much larger body of high-quality systematic data." The ultimate hope then is the elaboration of a comprehensive and detailed theory along the lines of this hypothesis. □