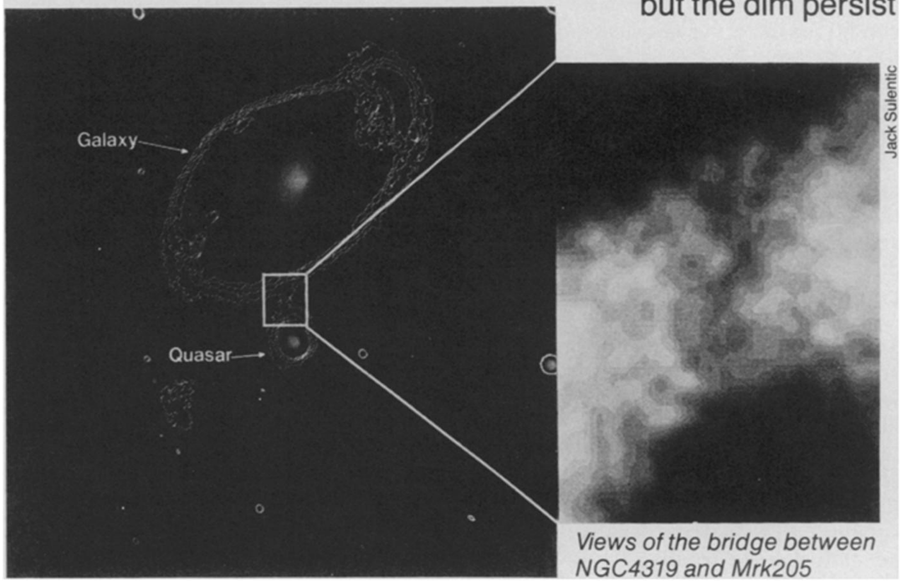
Quasar Evolution: The Fate of the Brightest

As eons go by, the bright quasars seem to fade, but the dim persist



Views of the bridge between NGC4319 and Mrk205

By DIETRICK E. THOMSEN

Quasars (quasistellar objects or QSOs) have been known to astronomers for 20 years. They are compact objects. On most sky photographs they look like stars. They are not stars, however. In light, radio and X-rays they radiate energy at rates proper to whole galaxies.

The light spectra of many quasars show large redshifts. In fact the largest redshifts known are seen in quasars. Astronomers usually interpret redshifts as measures of velocity. These velocities are then attributed to the overall expansion of the universe and become measures of distance. If this is done for quasars, then the most distant objects known are quasars, and quasars as a class are a window into conditions in the early history of the universe: We see distant objects as they were billions of years ago.

The question that then naturally arises is: Do quasars evolve over time? Do the more distant ones look different from the nearer ones? Are the distant ones more numerous per unit volume than the nearer ones or vice versa? Do the surroundings of quasars appear to change with time?

Recently reported studies bring evidence for evolution in quasars in both light and X-rays and for evolution in their surroundings. There is also evidence that they evolve in numbers. However, interpretation of such evidence is complicated by the insistence of a few astronomers that quasar redshifts are unreliable as measures of distance. Earlier this year one of that band brought forward what seems the best evidence yet that at least some quasar redshifts are not to be trusted.

Another kind of objection that quasars are not where they seem to be surfaced a few years ago. It suggested that many apparent quasars might be a kind of optical illusion. Gravitational lens effects, it proposed, were throwing images of quasars where nothing really was (SN: 11/21/81, p. 325). If that were true, any statistics relating to quasar evolution would be rendered both confused and confusing. However, the failure of several surveys to find widespread examples of gravitational lenses has damped down that objection.

The way to find evidence of quasar evolution, most scientists agree, is to gather statistics on a sizable sample of the objects. In a survey of a quarter of the sky (everything north of 30° galactic latitude) Maarten Schmidt of California Institute of Technology in Pasadena and Richard F. Green of the Kitt Peak National Observatory catalogued 92 previously unnoticed quasars. This Palomar Bright Quasar Survey took 11 years to complete; it started while Green was a graduate student at Caltech.

The survey, combined with several earlier ones, yielded statistics that show both that there were more quasars in the distant past and that there were more luminous ones too. The total number of quasars increases with increasing distance. As one looks farther and farther back, the rate of increase for bright quasars gets larger and larger, but the faint quasars appear not to increase at all. Thus this is evidence for two classes of quasar, the bright and the faint, that behave differently with respect to evolution over time. Schmidt and Green say they now want to study overall distribution of the energy output of these 92 quasars in order to learn details of how this evolution goes. The statistics have been published in the ASTROPHYSICAL JOURNAL (Vol. 269, p. 362).

General agreement with Schmidt and Green is found in a survey of X-ray brightness of 31 quasars and Seyfert galaxies by Tommaso Maccacaro and Isabella M. Gioia of the Harvard-Smithsonian Center for Astrophysics and the Istituto di Radioastronomia del CNR in Bologna, Italy. Seyfert galaxies are believed by many astrophysicists to be close relatives of quasars. Maccacaro and Gioia refer to all the members of their survey as Active Galactic Nuclei (AGNs). Many astrophysicists believe that quasars are galactic nuclei that never developed galaxies.

Maccacaro and Gioia told the recent 24th Liège International Astrophysical Symposium held at Liège, Belgium, that they have found evidence for luminosity evolution: Quasars were more luminous, in X-rays as well as in light, in the past. The sample is too small, however, for them to say anything definite about evolution in numbers.

At the same Liège symposium, Wallace L.W. Sargent of Caltech and Alec Boksenberg of University College, London, reported a study of evolution of gas clouds in the neighborhoods of quasars. When the spectrum of a quasar's light is spread out by a prism or grating, there appear — superimposed on the continuous rainbow background—both bright lines representing resonant emissions at some fairly sharp wavelength caused by some physical process in the quasar, and dark lines representing resonant absorbtions by some material between the observer and the quasar. By comparing the redshifts of the emission lines and the absorption lines, astronomers can tell where the absorbing material is with respect to the quasar.

Sargent and Boksenberg studied a particular pattern of absorption lines called Lyman alpha, which are deleted from quasar spectra by clouds of hydrogen. The Lyman alpha pattern can appear several times at different redshifts in the spectrum of the same quasar, due to different clouds. The lines become so numerous in some spectra that observers talk of the "Lyman alpha forest." Sargent and Boksenberg find that the forest has more trees in the more distant quasars. This means that such hydrogen clouds were more numerous in the early epochs of the universe. Indeed, they say, a quasar known to be very near, 3C273, has none at all.

Spectroscopy also shows that the clouds are all or very nearly all hydrogen. No evidence for heavy elements is seen, so if they are there, their incidence must be very small. Thus the clouds are probably primordial. Sargent and Boksenberg find that the hydrogen clouds are also fairly evenly distributed. They do not cluster as galaxies do, and the observers conclude that they avoid galaxies: Places where galaxies form don't have them. The hydrogen clouds thus seem to be a way to study conditions in the very earliest moments of the universe.

Of course all this works only if redshifts are reliable guides to the distances of quasars. Two decades of observation and discussion have ruled out other known causes of redshift than velocity, but still there are astronomers who try to find instances where quasar velocities are not due to expansion of the universe and so not related to distance.

Anticipating objections of this sort, Schmidt and Green did a statistical analysis of quasar distribution beginning with the assumption that quasars are nearby, and that their observed velocities (as calculated from redshifts) are due to some cause other than the expansion of the universe. They found that for this assumption to be true, the density of quasars per unit volume would have to increase very rapidly going away from the earth, and the earth would be located in a very special position, "a deep density minimum," where quasars are unusually scarce. Cosmologists would rather not have the earth in a special place. The only non-cosmological way to explain such a minimum is to adopt the hypothesis that quasars are objects ejected by our galaxy. This has been proposed by reputable astrophysicists, but is not widely accepted. The easiest thing to do, Schmidt and Green say, is to assume that quasar velocities are due to the universal expansion, not ejection from our galaxy.

Nevertheless, Halton "Chip" Arp of Caltech has put forward several instances that look rather like such ejection. Galaxies and quasars of quite different redshifts appear to be related to each other. If the spatial relationship is true, whether or not the galaxies in question actually had ejected the quasars, the quasar velocities as calculated from redshift would not be a guide to the quasars' locations. In one such instance, the galaxy NGC 4319 and the Markarian object 205, Arp showed something that looked like a bridge of luminous material between them. (Markarians are in many ways similar to quasars and may be part of the same general class of AGNs.)

Critics immediately jumped all over this, insisting that the bridge was either an artifact of image analysis or a third, unrelated, object that happened to be in a position to look like a connector. Earlier this year Jack W. Sulentic of the University of Alabama at University, published (in the ASTROPHYSICAL JOURNAL Vol. 265, p. L49) the results of a program of detailed photometry of these two objects. Sulentic's work convinces him that the bridge is real.

Thus, after 20 years of observation, discussion and debate, quasar observers continue to march resolutely forward—in opposite directions. □