Quasars and BL Lac Objects as Active Nuclei of Giant Galaxies

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Are we beginning to understand the nature of the quasars and the equally mysterious BL Lacertae objects? Are they nothing but extraordinarily bright galaxy nuclei? Dr. Jacqueline Bergeron, now with the ESO Scientific Group in Geneva, summarizes the most recent findings in this exciting field.

The observed similarity and continuity between the active nuclei of Seyfert type I, broad-line radio galaxies and quasars began to be fully exploited only around five years ago. The possibility of intrinsically similar physical processes in both types of objects was raised earlier, but the basic idea of quasars and BL Lac objects as very powerful nuclei of large galaxies is only a recent one and not yet entirely accepted.

The similarity between the Seyfert type I galaxies and the quasars are (i) in their optical line spectra characterized by very broad allowed lines (typical velocities of (0.5–1.5) $\times 10^4$ km sec^{-1}) variable on a time-scale of months, and narrower forbidden lines with a large range of ionization stages, and (ii) in their variability at optical frequencies on a time-scale of weeks. The radio sources are also found to be very variable. The BL Lac objects have a featureless optical continuum spectrum (yet in some cases very weak emission lines have been detected) and they are characterized by an extreme variability at radio frequencies, down to time scales of days.

The current definition of quasars (which also applies to BL Lac objects) is that they have star-like images on direct plates. Yet nebulosities or "fuzz" associated with quasars were known since the beginning of quasar research, i. e. around TON 256 and 3C 48, and were the subject of discussion and puzzlement. In particular the large extent of 100 kpc (for $H_0 = 50$ km $Mpc^{-1} sec^{-1}$) for the nebulosity accompanying 3C 48 illustrated in the Figure did not suggest a normal galaxy.

A photographic programme was undertaken by J. Kristian to attempt to detect underlying galaxies centered on quasars. The quasars are so bright that their light could swamp that of the underlying galaxy. Thus the latter could be detected only for quasars of small redshift and if its image size is greater than that of the quasar. These observations were consistent with the hypothesis of quasars as active nuclei in galaxies. Indeed those quasars which were predicted to show underlying galaxies did so and those which were predicted not to show underlying galaxies did not, with the exception of 3C 48.

However, photometric studies of faint envelopes of galaxies, also in progress in the early 1970's confirmed the existence of *large* envelopes. Both elliptical and spiral galaxies were found to be surrounded by large envelopes, $\gtrsim 100$ kpc for elliptical galaxies and not significantly smaller (by a factor of 2) for spiral galaxies (when compared at same integrated luminosities).

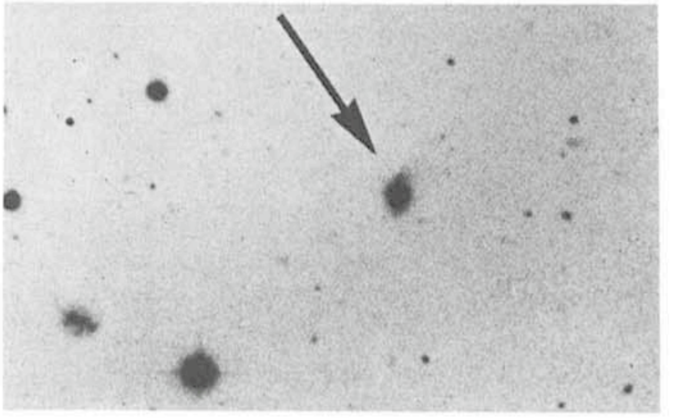
Further one must emphasize that less attention was devoted to Seyfert galaxies than to quasars before 1968. Few "extreme Seyfert galaxies" of redshift above 0.01 were studied then. Some extreme Seyfert-type galaxies at redshift close to 0.05 were observed by W.L.W. Sargent among the objects in the Zwicky lists. All these active nuclei were indeed surrounded by nebulosities. Yet for most of them, a galaxy of stars and cold interstellar gas was not brought into evidence.

The next step necessary to definitively solve the problem of underlying galaxies required spectroscopic observations of these nebulosities.

Recently, such observations have revealed two types of nebulosities: (i) those dominated by a strong emission-line spectrum, and no detection of an intrinsic continuum (typically 3C 48), (ii) those characterized by a spectral enery distribution and absorption lines consistent with that of a normal galaxy of stars (typically BL Lacertae). In all cases, the redshift for this nebulosity is very close to that of the active nucleus. This appears to rule out gravitational redshifts for quasars.

Spectroscopic observations of the nebulosity around the quasar 3C 48 were reported in 1975. Other quasars, and also the Seyfert galaxy 3C 120 were studied and their nebulosities exhibit the same type of strong emission-line spectrum. The two more intense optical lines are [O II] λ 3727 and [O III] λ 4959, 5007; [O III] is stronger than [O II] and much stronger than Hβ, with in some cases [O III]/Hβ as high as 20. This type of spectrum is unusual for a galaxy. It cannot be accounted for by H II regions heated by main-sequence stars, whatever the abundances of heavy elements. Hard UV or collisional heating is required. The hard radiation, $\gtrsim 50$ eV, emerging from the active nucleus is a possible energy source for the nebulosity. The observed line spectrum could then be achieved if the gas density is low, from 0.03 to 3 cm^{-3}. At a cosmological distance the nebulosity is then similar in dimensions and mass to the extended neutral H disks around spiral galaxies. Other possible models involve denser gas, thus very clumpy material, i.e. dense filaments, heated by the emerging UV radiation from the active nucleus.

A strong controversy about spectroscopic observations of the nebulosity associated with BL Lacertae took place in 1974–75. The intrinsic continuum spectra of such nebulosities are very difficult to observe, due to their weakness and to the strong contamination of nucleus light in the observed annular apertures. The detection of typical absorption features, such as Ca II K and Mg I is a crucial point. At least



200-inch Hale reflector photograph of 3C 48. The quasar is shown by the arrow. North is up, west is right. The field is 3' EW and 2'30'' NS.

two such detections have been made: for BL Lacertae and for the quasar PHL 1070. In both cases the extended light surrounding the active nucleus is consistent with a luminous galaxy of stars. There is a large number of nebulosities for which only a featureless continuum spectrum has been detected. The magnitude of the nebulosity is then consistent with that of a large galaxy.

Quasars and BL Lac type objects can now be more firmly identified as active nuclei of giant galaxies. For BL Lac type objects and some quasars, the surrounding nebulosity is entirely consistent with a giant elliptical galaxy. For quasars such as 3C 48, or Seyfert galaxies such as 3C 120, the nature of the "surrounding galaxy" is not as clear. The emission from the ionized gas is much larger than would be that of the stars and only a very high sensitivity would allow the detection of the intrinsic continuum and of absorption lines. Another possible approach, possible with present-day techniques for extreme Seyfert galaxies, would be the determination of a rotation curve within the nebulosity from the brighter emission lines.

CHIRON: A New Planet in the Solar System

Last October, Charles T. Kowal of the Hale Observatories in Pasadena, California, found a new planet in the solar system. Comparing two plates from the 48-inch Palomar Schmidt telescope in a blink microscope, he noticed a small trail of a moving 18th-magnitude object. From these plates and others which were obtained on the following nights, it soon became obvious that the new planet had an exceptionally slow motion. At opposition the motion of a planet is inversely proportional to the distance and a first estimate put 1977 UB (as it was designated) at about the distance of Uranus, almost 3,000 million kilometres away.

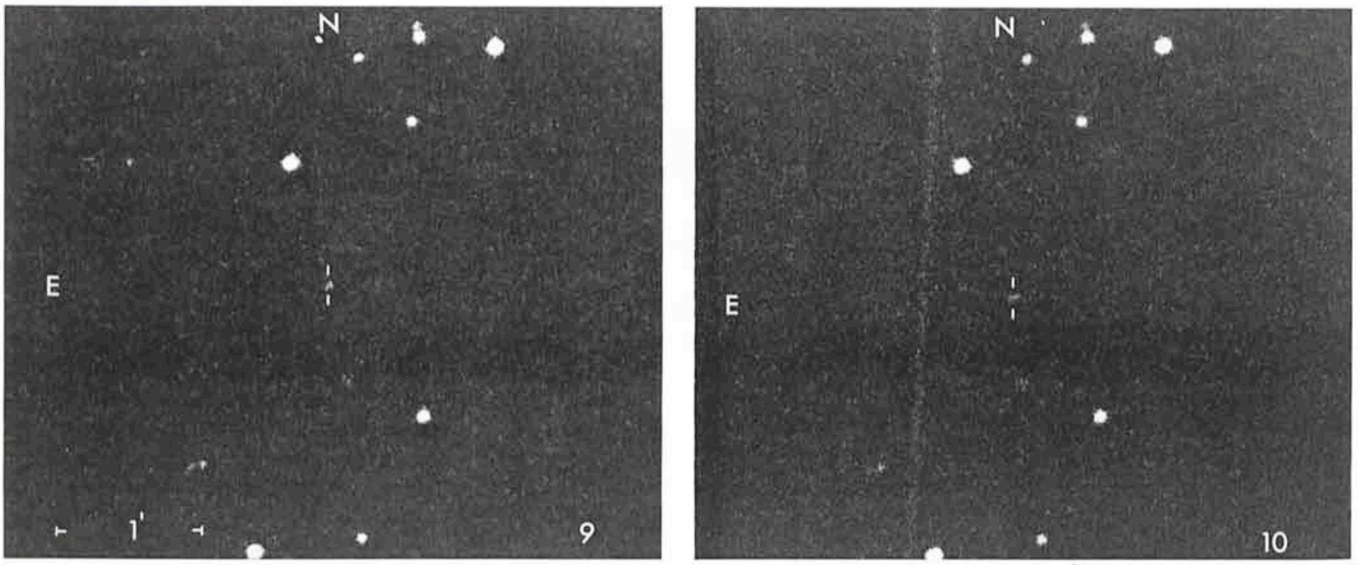
When more observations became available, it was possible for Dr. B. Marsden at the Smithsonian Observatory to confirm this distance and to establish the orbit. Extrapolating backwards, Mr. Kowal and Dr. W. Liller found 1977 UB on old plates in the Harvard plate library, obtained in 1895, 1941 and 1943. Some further observations from Palomar helped to improve the orbit, and it is now known that 1977 UB is a unique object in the solar system.

It moves in a rather elliptical orbit ($e = 0.38$) with perihel just inside the orbit of Saturn and aphel close to that of Uranus. It was actually discovered a few years after it had passed through the aphel and will become as bright as magnitude 14.5 in 1996 when it again reaches perihel. The orbital period is just over 50 years.

For the benefit of the eagle-eyed readers of the *Messenger,* we here show two plates of 1977 UB, obtained with the ESO Schmidt telescope on 1978 January 9.05209 and 10.04936 UT. The plates were exposed during 30 minutes rather low in the western sky, just after sunset. At that time the planet was nearly stationary, near its smallest right ascension. The seeing was bad, probably around 4–5 arcseconds on both occasions and the images are therefore somewhat fuzzy, in particular on the 10th.

But it does not move! exclaims the (slightly inattentive) reader. Sorry, it does. On the left hand photo (from the 9th) the position was $1^{h}55^{m}16^{s}.04$; $+11^{\circ}08'21''.1$, and on the 10th $1^{h}55^{m}15^{s}.80$; $+11^{\circ}08'16''.4$. This corresponds to a movement of only $3''.6$ to the west and $4''.7$ to the south (0.05 mm and 0.07 mm, respectively, on the original plate). You can see it if you measure the distances to the surrounding stars on the figures.

From the magnitude it can be estimated that 1977 UB has a diameter of a few hundred kilometres. It is most likely the first known member of a new class of asteroids outside the orbit of Jupiter, and Kowal has proposed the name CHIRON (a centaur in Greek mythology). There is, however, still the possibility that it is a comet; at very large distances, it can be very difficult to tell the difference, when no tail shows up and the "head" is perfectly stellar-like.



Two 30-minute exposures on 103a–O emulsion behind a GG385 filter with the ESO Schmidt telescope demonstrates the extremely slow motion of the new, distant planet CHIRON (1977 UB). The left plate was obtained on 1978 Jan. 9.05, the right on Jan. 10.05. At that time, the distance to CHIRON (from the Earth) was 2,623 million kilometres. The scale is indicated. The (near) N–S trail on the 10th is an artificial satellite.