The Ninetieth Annual Scientific Meeting of the A.S.P.: Quasars and Active Galaxies

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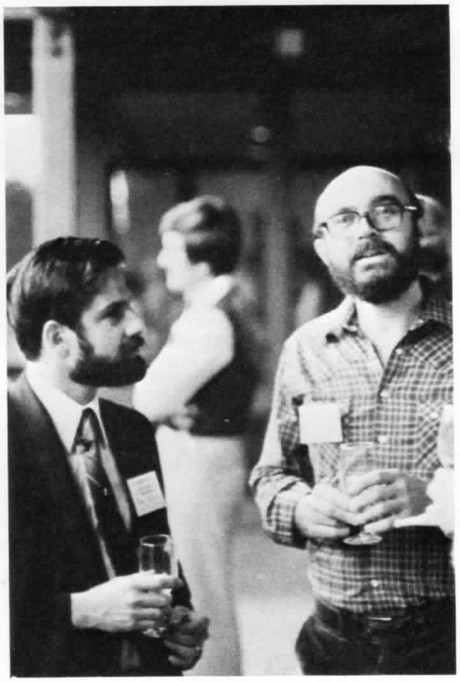
Editor's Note: Below, Dr. Tenn, one of the hosts for the A.S.P.'s 90th annual meeting, reports on the symposium on quasars and active galaxies around which the meeting was organized. Readers who are not familiar with the current controversy which surrounds these objects may want to consult the following three *Mercury* articles: "Quasi-Stellar Objects" by H. Smith (Mar/Apr 1978), "Exploding Galaxies and Supermassive Black Holes" by W. Kaufmann (Sep/Oct 78), and especially "Cosmic Distances and QSO's" by J. Tenn (Jul/Aug 79).



Astronomers Joe Tenn and Gordon Spear of Sonoma State University were hosts for the Meeting. (Photo by A. Fraknoi)

Quasars and active galaxies dominated the discussion at the Society's 90th annual meeting (held June 26-30, 1979, at Sonoma State University) but there was much more: Jupiter and its satellites, wine and cheese tasting, a 3-D film of Mars, and the presentation of the Catherine Wolfe Bruce gold medal to William A. Fowler.

There were 20 invited lectures, two award lectures, and 32 contributed papers featuring work in radio, infrared, optical, ultraviolet, and x-ray astronomy, as well as astronomical theory and nuclear physics. There were accounts of quasars in and near galaxies, and of material coming out of, and falling into, galactic nuclei.

The meeting featured something for every category of A.S.P. member: the professional astronomer, the amateur, the armchair astronomer, and the teacher. Some events, such as Halton C. Arp's public lecture on active galaxies, David Morrison's profusely illustrated account of the Jovian system, and Ken Jones and Elliott Leventhal's 3-D film of the surface of Mars undoubtedly appealed to all.

The Symposium

The scientific portion of the meeting began with a symposium on "Active Galaxies and Quasars" organized by Halton C. Arp, Joe S. Miller, and Holland Ford. The symposium consisted of eighteen invited papers. After one and one-half days of these, everyone was convinced of the existence of both active galaxies and active astronomers. However, the connection between active galaxies and quasars remained a matter of controversy.

The symposium opened with Alan Stockton (Univ. of Hawaii) announcing, "I am going to try to persuade you that there is a good chance that virtually all quasi-stellar objects are associated with small groups of galaxies."

Stockton reported that he now has 14 galaxies in the fields of 9 quasars having essentially the same redshifts. [See Dr. Tenn's article "Cosmic Distances and QSO's" in our previous issue — *Ed.*] Stockton emphasized that he has made a *systematic* survey of the fields around a *complete* sample of quasars in a certain range of magnitudes, redshifts, and declinations.[1] The magnitudes and redshifts were chosen so that luminous galaxies at the assumed redshift distances of the quasars would be bright enough to have measurable spectra. He pointed out that if the Local Group were observed from a distance corresponding to a redshift of .15 to .45, only the Andromeda galaxy, our galaxy, and possibly M33 could be detected. It is unlikely that an observer from such a distance would be able to discern that our galaxy is a member of a group. Thus, only those groups which are both rich and compact should be detectable by his method. Yet he found groups around 9 quasars out of the 27 in the survey. Ten quasars had no galaxies within 45 seconds of arc on the red Palomar Sky Survey, and eight had galaxies in their fields whose redshifts differed from those of the quasars.

Stockton believes that if his survey could be extended sufficiently, all QSO's might be found to be in small groups of galaxies.

Stockton did find a possibly disturbing difference between quasars with steep radio spectra and those whose

1. Magnitudes are units used by astronomers to measure the brightness of cosmic objects; the smaller the magnitude, the brighter the object looks to us. Redshifts are changes in the color of light toward longer wavelengths. Declination (together with right ascension) forms a coordinate system which astronomers use to define the position of objects in the sky. — *Ed.*

Symposium organizer and A.S.P. vice-president Halton C. Arp gave the 1979 public lecture of the Society at the Sonoma meeting.

radio fluxes are relatively flat when plotted versus frequency. (Setti and Woltjer showed a few years ago that QSO's with steep radio spectra are more likely to obey the Hubble Law than those with flat spectra or no radio emissions.) The quasars with steep radio spectra were much more likely to have associated galaxies than those with flat spectra.

This could imply the existence of two kinds of quasi-stellar objects, one with steep spectra, at the cosmological distances, and the other possibly possessing anomalous redshifts. Stockton doesn't think so. He quoted Einstein, "God is subtle, but he is not malicious," and then stated that, to him, the existence of two kinds of QSO's would be clear evidence of malice.

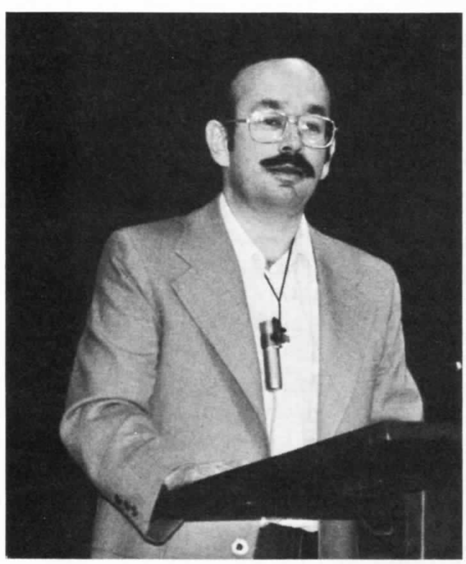
After presenting further evidence, Stockton issued the provocative challenge, "You give me a quasi-stellar object that is observationally tractable, and I'll find a galaxy near it with the same redshift."

He concluded with some criticisms of Arp's work (which was presented at an earlier conference). Stockton questioned Arp's method of calculating probabilities by asking how many fields Arp has inspected — all those he has examined on Sky Survey plates, or only those selected for detailed investigation because of blue objects found nearby on these plates?

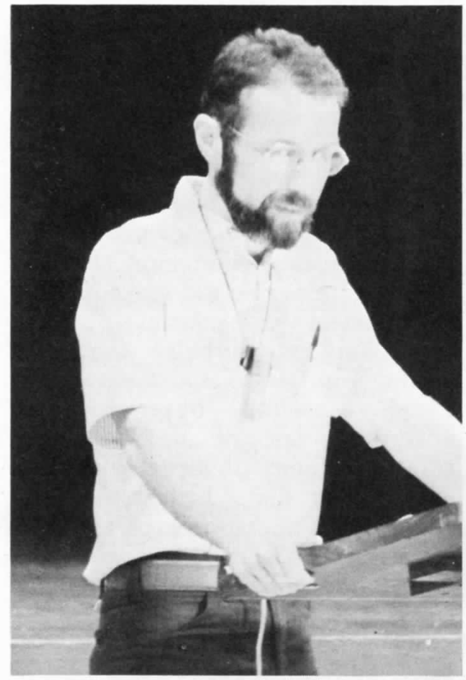
The next speaker was Joe S. Miller (Lick Observatory), who discussed the evidence that quasars are located *in* galaxies. He pointed out that it is widely assumed that this is the case (1) because of the continuity of properties from quasars to Seyfert galaxies to N galaxies to galaxies, and because BL Lacertae objects, believed to be similar to QSO's, have definitely been shown to be in galaxies; (2) because QSO's appear to have common elemental abundances (the heavy elements whose lines appear in their spectra were presumably manufactured in stars); and (3) because most QSO's seem to "hang around" with galaxies.

What is the direct evidence? Attempts have been made to find "fuzz" around QSO's and some successes have been reported. Spectroscopic examination, however, showed that the fuzz does not consist of starlight.

Miller, working with Howard French and Steve Hawley, has been observing the spectra of QSO's and N-systems, following the methods they developed for examining BL Lac objects. They had found that all BL Lac objects up to redshift 0.07 are in giant elliptical galaxies. They further believe those with higher redshifts are probably similarly located, but the dim galaxies are not detectable. Also, the double radio sources characteristic of many radio galaxies are always associated with giant ellipticals. In the hope that QSO's also behave this way, they are seeking a spectrum dominated by late-type stars around these compact objects.



Joe Miller of the Lick Observatory.



Alan Stockton of the University of Hawaii was the first invited speaker at the symposium.

In a long, careful program of observations with the 3-meter Shane telescope of the Lick Observatory, Miller and his colleagues searched for the underlying spectra of elliptical galaxies in the spectra of BL Lac objects, N galaxies, and QSO's.

All but two of the nine N galaxies for which they have good data show surrounding galaxies. In each case, these are giant ellipticals, but not giant ellipticals of the first rank. They find the galaxies to be less luminous than had been previously reported by Allan Sandage.

They failed to detect any galaxies around the QSO's, despite better data than was used to detect galaxies around some of the N systems. If there are galaxies surrounding quasars, "They are certainly not first rank giant ellipticals. They're certainly not even luminous galaxies within a magnitude of first rank giant ellipticals. They may be lower luminosity ellipticals or they may not even be ellipticals at all." If they were spirals, for example, the spectral features sought by Miller would not be present, and the QSO emission lines would hide their absorption features.

Miller concluded, "So we really can't answer the question, 'What kind of galaxies are they in?' leaving aside the even more fundamental question, 'Are they in galaxies?' but at least we can say they are *not* in very luminous . . . giant ellipticals." The similarities between the double radio sources associated with quasars and with radio galaxies still lead Miller to believe that quasars are in giant elliptical galaxies, but this cannot be shown with currently available equipment. Perhaps the space telescope will make it possible to detect these galaxies.

E. Margaret Burbidge (Univ. of Calif., San Diego) spoke on recent "high resolution" observations of absorption spectra of QSO's and related 21-cm observations. She pointed out that "high resolution" should be in quotation marks because the resolution she obtains with 18th and 19th magnitude quasars would be called low resolution by those who observe much brighter objects such as stars.

Absorption lines are seen in 60 to 120 QSO's[2] and sometimes there are absorption lines at several different redshifts. When, as is usually the case, the absorption redshift is lower than the emission one, the spectrum can be interpreted in terms of ejection of material from the QSO towards the observer or absorption by material between the observer and the QSO. If the former is correct, ejection velocities of one-tenth to one-half the speed of light are required; if the latter theory is correct, some galaxies must have enormous halos, several hundred kiloparsecs[3] in size, to provide enough material to do the absorbing.

However, she remarked, "As an observational person, I never like to throw away an observation because the theorists can't explain it." She presented a variety of quasar spectra and discussed the interpretation of some as evidence for "cloudlets" absorbing the Lyman alpha line of hydrogen. Presumably such cloudlets surround the quasi-stellar objects. Weymann, *et al* have deduced the existence of three separate sources for the hydrogen absorption: a cluster of clouds, perhaps protogalaxies, surrounding the QSO; a long tail of material ejected from the QSO; and an intervening cluster to account for the largest velocities (with respect to the QSO).

Dr. Margaret Burbidge chats with Dr. and Mrs. Gerard deVaucouleurs during a break in the sessions.

Halton C. Arp (Hale Observatories) presented a number of new observational results, although he reminded the audience that he has been finding associations between high redshift quasars and low redshift galaxies since 1966. In recent years he has found that disturbed galaxies are often companions to large spirals. For example, M82 is a companion to M81. He is now concentrating on these disturbed galaxies and their environs, where he finds an extraordinary number of quasars. He presented a table of 43 quasars associated with 30 different galaxies. Twenty-one of these, he said, have probabilities of less than 0.01 of being found where they are if quasars are distributed uniformly about the sky. (For these calculations, he assumes the largest proposed background of 10 quasars per square degree brighter than or equal to 20th magnitude.)

There are 150 galaxies in the Shapley-Ames catalog which are candidates for his search. Fifty of these have companion galaxies. To date he has looked at seven and has found quasars near all seven. The improbability of this is stated to be 10^{-14}. Even if the other 43 turn out negative, he will have a correlation whose probability he estimated to be one chance in a million if the objects are not related.

Following a suggestion made at the Ninth Texas Symposium on Relativistic Astrophysics, held at Munich last December, Arp used the Hale 5-meter telescope to search for additional companion galaxies. Some galaxies have several disturbed companions — NGC 2859 has four, for example. Nearby, he found four high redshift compact objects, at least three of them quasars.

Perhaps the most surprising results Arp presented were the strange cases of pairs of quasars aligned across galaxies, one on each side. In some cases, the redshifts of the quasars, interpreted as Doppler shifts, yield similar but opposite velocities with respect to the central galaxy, as if they had been ejected in opposite directions from the galaxy. There is also a small residual redshift, which Arp believes to be intrinsic.

In at least three cases, there are pairs of quasars with almost exactly the same redshifts, aligned on opposite sides of a galaxy.

Arp also discussed the survey of the southern hemisphere which Osmer and Smith have made with the Curtis Schmidt telescope. The survey is complete for a certain strip of sky. The highest redshift quasars are found to be associated with the brightest and nearest galaxies. This is the opposite of what is to be expected if quasars obey the Hubble law.

Arp concludes that quasars are correlated in space on a scale which is consistent only with their being much nearer than the cosmological interpretation of their redshifts would indicate. In some cases they are correlated in redshift as well. These conclusions, of course, are the opposite of Stockton's.

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2. A technical review of this subject by Perry, Burbidge and Burbidge appeared in the *Publications of the A.S.P.* Vol. 90, p. 337 (1978).

3. A kiloparsec is 3,260 light years. A megaparsec is a thousand kiloparsecs. — *Ed.*

Donald Osterbrock, Director of the Lick Observatory, next discussed the optical spectrum of the radio source OQ 208, which is seen optically as the compact galaxy Markarian 668. The spectrum shows both broad hydrogen emission lines and narrow forbidden lines. This object varies in brightness in less than one year and Osterbrock and R. Cohen have studied the variation in the spectrum over the past year. The large difference in redshift between the narrow lines and broad lines, and the change in this difference in only nine months make this object unique. His model, published earlier, is that the narrow lines come from a large volume, of the order of hundreds of parsecs in diameter, while the broad lines must come from a very small region, no larger than 0.1 parsec in size. It is these lines which vary over such short periods.

Is the redshift difference due to a gravitational redshift of the light from the inner region? If so, the compact source must have a mass of six billion solar masses, a figure thought to be unlikely. Instead, Osterbrock believes that he is seeing asymmetric line profiles, an indication of the motions of clouds within the emitting region. He exhibited such profiles in other Seyfert galaxies. The study of these line profiles continues.

Patrick Osmer of the Cerro Tololo Inter-American Observatory described the surveys made there which have found a large number of new quasars. He recalled that "classic" quasars were defined as objects having the following properties: starlike objects; radio, infrared, and/or x-ray emissions; variable in light; large ultraviolet flux; broad emission lines; and, of course, large redshifts.

Now the use of the Curtis Schmidt telescope (which was moved to Chile from Michigan) makes it possible to search economically for quasars in bunches. The wide field of the telescope, coupled with sensitive emulsions, has enabled Osmer and his colleagues to use transmission gratings to find QSO's from their emission line properties. And the use of the larger 4-meter telescope of CTIO with transmission gratings makes quasar-hunting really "profitable."

The result is that there are now more than 1300 quasars known, and that most of them are radio-quiet objects. Many fail to meet all of the "classic" definitions and would not have been discovered by earlier methods. Some are quite red.

H.E. Smith of the University of California, San Diego.

Using the Curtis Schmidt telescope, Osmer and Malcolm Smith surveyed fifteen fields each 5° square, and found 120 candidates, of which 108 were found to be quasars. The 4-m telescope was used to survey small regions around quasars previously found, and 66 more quasars were discovered.

The most important result of this work is the estimate that there are 5.5 quasars per square degree down to magnitude 19.5. Systematic errors make this figure a lower limit, uncertain to within a factor of two. There appears to an unusually large number of quasars with redshifts between 1.8 and 2.5, but the technique is best suited to the discovery of quasars with redshifts higher than 1.8, and selection effects bias the survey against the discovery of faint high redshift quasars. Osmer noted that high redshift objects tend to be brighter than the others. Arp had called this fact significant, but Osmer believes it can be explained by the magnitude system used and the selection effects.

Osmer closed with the question, "Where are the 'redshift four' quasars?" He believes that it will soon be possible either to find them or to show that the density of quasars changes radically at this redshift, a discovery which would have profound cosmological consequences.

Harding E. Smith (Univ. of Calif., San Diego) discussed hydrogen line ratios in QSO's. The first spectra obtained suggested that photoionization[4] is the energy source for the emission line region and that the hydrogen lines are due to photoionization and recombination similar to what is found in ionized hydrogen clouds and planetary nebulae in our own galaxy.

Since the work of Jack Baldwin, in 1975, it has been known that in interpreting these lines one must take into account reddening by dust within the emitting regions of the quasars. Now the situation is even more murky. With rocket flights bringing in observations from above the atmosphere, it is possible to observe the entire spectrum of a QSO. Infrared, optical, and ultraviolet spectrophotometry are being combined by groups at UCSD, Caltech, and Cambridge. Smith noted that a redshift of 2.05 to 2.7 will bring the hydrogen lines into the infrared "window" in the Earth's atmosphere at 2.3 microns.

Dust within clouds can be a very efficient absorber but cannot explain all of the line ratios. External dust (between the QSO and the observer) also fails to account for them. Another possibility is that radiative transfer effects are important. Smith revealed that his colleagues at UCSD have found that they can explain the spectrum by assuming very great optical depths[5] in the emission line regions — depths which imply electron densities of a billion particles per cubic centimeter and electron temperatures of 10,000° K.

Three speakers presented results of observations of quasars in invisible regions of the electromagnetic spectrum: Richard Green (Caltech) described observations in the ultraviolet with the International

4. In photoionization, a passing photon is absorbed by an electron which thus acquires the energy to leave its parent nucleus. In the recombination process, a free electron is captured by an ionized nucleus and its unneeded energy is given off as a photon. — *Ed.*

5. Optical depth measures the opaqueness of a given material. — *Ed.*

Ultraviolet Explorer (IUE) satellite; David Ennis (Caltech) presented one-millimeter observations; and J. Patrick Henry (Harvard-Smithsonian Center for Astrophysics) reported on x-ray observations from the Einstein orbiting observatory.

Green enthusiastically reported that the IUE detectors are much more sensitive than had been expected.[6] He, Maarten Schmidt, and a team at the Jet Propulsion Lab are working on quasar observations with the satellite. They have been examining the Lyman alpha line of hydrogen and note that there is no observable intergalactic absorption of this line. There is also no intergalactic absorption by helium. This implies that if there is an intergalactic medium, it must be very hot.

Ennis described the first observations of quasars made at 1 mm wavelength, corresponding to 300 gigahertz, the highest frequency at which radio observations have been attempted. This work was done at the prime focus of the 5-meter Hale telescope on Mt. Palomar during twilight and night hours. Ennis and his colleagues in the Caltech infrared group looked at 27 quasars, 10 of which were radio-quiet. (The others they call "radio-active.") They detected signals at 1 mm wavelength from six of these, all of them radio-active. They found no correlation between the flux densities at 1 mm and the densities at 10 microns in the infrared. They then compared the 1 millimeter fluxes with those previously detected at longer radio wavelengths. Several of the radio-active quasars show a smooth linear transition in flux density from the radio to the millimeter range; it is quite possible that all do so. There is no excess radiation at 1 millimeter for radio-active quasars.

Henry discussed observations of active galaxies and quasars made with *Einstein,* formerly known as HEAO 2, (High Energy Astrophysical Observatory) which was launched in November, 1978. He and his colleagues intend to obtain a complete x-ray survey of quasars with redshifts up to 4. They have already determined that quasars are contributing a large fraction of the cosmic x-ray background. They have increased the number of quasars known to emit x-rays from 3 to 30. Some, such as the first quasar discovered, 3C 273, vary their x-ray emissions in times as short as one day. There were hints that its x-rays might be produced by cloudlets falling into a massive black hole — one of several hundred million solar masses.

Alan Marscher, a bold young theorist from the University of California, San Diego, then presented an attempt at a theoretical reconciliation of Arp's and Stockton's observations. He assumes that QSO's originate in the nuclei of galaxies in numbers which drop off steeply with increasing QSO luminosity and mass. The light, low luminosity QSO's are shot out of their galaxies with high velocities, leading to high Doppler shifts. For reasons not made clear, those with blue shifts are not observed. The luminous, massive QSO's stay in their galaxies. Thus, Arp observes QSO's with non-cosmological redshifts which have been shot out of galaxies, and Stockton observes QSO's with cosmological redshifts which have remained in their galaxies.

The Second Day: Active Galaxies

The second day of the symposium was devoted primarily to the discussion of active galaxies. Optical and radio astronomers presented pictures of jets of luminous material emerging from, or perhaps falling into, a large number of quasars and active galaxies. The first jet discovered, that in the giant elliptical galaxy M87 (also known as the radio source Virgo A) came in for much discussion. Although discovered by Heber D. Curtis of Lick Observatory in 1918, this jet is still very much in the news.

The first speaker of the morning was François Schweizer, of the Cerro Tololo Inter-American Observatory in Chile. He showed some dazzling photos taken with the 4-m telescope, as he presented photometric and spectroscopic observations of NGC 1316 (Fornax A). This object, the third nearest radio galaxy (after Centaurus A and Virgo A), is only 33 megaparsecs away. It has giant radio lobes, extending hundreds of kiloparsecs, and a very compact radio source at its center.

Short exposure photographs by Schweizer reveal a bright, pointlike nucleus. Deeper plates reveal much structure — a spheroid with dust lanes, knots which may be bright globular clusters, and ripples. The galaxy is basically an elliptical one, a cD, with an abnormally small core. It also has a disk of gas perpendicular to the ellipsoid. Schweizer believes that NGC 1316 has swallowed a small spiral galaxy; if true, this is direct evidence of galactic cannibalism![7]

Marshall H. Cohen (Calif. Inst. of Technology) described some very long baseline interferometry,[8] using four or five telescopes up to 8000 kilometers apart. Such an array yields an angular resolution as small as one two-thousandth of a second of arc, or half a parsec at a distance of 100 megaparsecs.

This array has been used to examine hot spots in the outer lobes of radio galaxies. These may be produced when extragalactic matter is struck by jets ejected from the centers of the galaxies. In some, but not all cases, the spots are situated symmetrically opposite the center of the galaxy. Observations of the jet in NGC 6251 reveal that there have been a series of ejections over ten million years, all in the same direction. Cohen interprets this as evidence of rotation around an axis fixed in space. He believes that the "slingshot" model of ejection can be ruled out by these observations. In the discussion, Gérard de Vaucouleurs pointed out that this galaxy is much like M87.

Harvey Butcher (Kitt Peak National Observatory) presented new optical observations of radio jets, made with the 4-meter telescope at Kitt Peak. Electrons emitting synchrotron radiation[9] do so in the visible region of the spectrum for only a few years; they emit radio waves for many millions of times longer. Hence optical observa-

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6. See the article on IUE by E. Bohm-Vitense in the Mar/Apr 1979 *Mercury,* as well as the "Noted in the Current Journals" column in that issue. — *Ed.*

7. See "Noted in the Current Journals" in the Sep/Oct 1978 issue of *Mercury.* — *Ed.*

8. An interferometer uses connected radio telescopes to obtain more detailed information about the source than a single telescope can provide. — *Ed.*

tions tell us which regions are currently active. Butcher, with George Miley and Will van Breugel (Leiden), has observed four galaxies which have radio jets. These galaxies are about four times as distant as M87. If they possess similar optical jets, the jets should be detectable. Optical jets were found in two of the four: 3C 66B and 3C 31. Jets were not detected in NGC 315 or 3C 449.

After all the talk about material being shot out of galaxies, it was an interesting change of pace to hear Holland Ford (Univ. of Calif., Los Angeles) present "The System of Filaments of M87: Evidence for Matter Falling into an Active Nucleus." Ford gave what he called a weather report for M87: "It is raining in M87." The rain is due to a hot intergalactic medium (30 million degrees K) which has thermal instabilities. The pressure gradient in the gas can no longer support the material, so it falls in toward the center of M87. The pressure causes shock waves in the infalling material, and the shocks produce the luminescent filaments which are observed. Ford showed photographs and maps, produced in collaboration with Harvey Butcher, in which they used special photographic techniques to make the galaxy disappear and the faint emission features show up. Spectrophotometry of the filaments near the jet and the counterjet show that the ionization is not due to starlight, the jet itself, or electrons and protons in the radio lobes. The only explanation which appears feasible to Ford and Butcher is that the ionization comes from low velocity shock fronts. The filaments contain heavier elements which must have been produced in stars. The speculation is that they were produced inside stars in the giant elliptical galaxies of the Virgo cluster and lost by some mechanism such as galactic winds. It is also speculated (for other reasons) that there is an engine (a massive black hole) in the center of M87. The infalling filaments could provide the fuel that drives this engine.

The remaining speakers on M87 returned to the discussion of the outflowing material in the jet itself. Gérard de Vaucouleurs (Univ. of Texas) presented a quantitative analysis of the jet. He and J-L. Nieto (Pic-du-Midi) have found that the center of the galaxy is well represented by a black hole plus a nonthermal point source. The point source, which is seen superimposed on the center of the galaxy, is believed to be part of the jet. De Vaucouleurs and Nieto examined the jet, subtracting out the galaxy behind it and found that the knots in the jet are gaseous. They are expanding, with the size of the blob directly proportional to the time elapsed since it was ejected. The observations reveal three new knots in the jet, bringing the total number to eleven. There is no continuous component to the jet: nothing is observed between the knots after the underlying galaxy is subtracted.

Dr. William Fowler accepts the 1979 Bruce Gold Medal from A.S.P. President Leonard Kuhi.

Jack Sulentic (Sierra Nevada College), working with Arp and Jean Lorré (Jet Propulsion Laboratory), then made the exciting suggestion that the blobs emitted by M87 are, or are becoming, BL Lacertae objects.

They repeated observations made by Walter Baade at Mt. Palomar in 1956, using exactly the same equipment and methods. They found a change in the brightness and polarization in at least two of the knots over the 22 years. There was no evidence of spectral lines or of proper motion. Both old and new plates were digitized and image-processed at JPL to bring out the maximum possible amount of information. Sulentic maintains that if the knots were isolated in the sky they would have been classified as BL Lac objects. There was some discussion over how accurately they could have duplicated Baade's work. When challenged that he must have used a different developer, Sulentic conceded, "A different batch." Donald Osterbrock recalled that Baade always used filter GG 1, and that is the filter Sulentic had used.

The next question asked by Sulentic *et al* was, "Are the BL Lac objects associated with galaxies?" They did a survey of the association between galaxies in the Shapley-Ames catalog and BL Lac objects. The correlation is weak, but then the list of BL Lac objects is very incomplete at present. If the knots emitted by active galaxies are indeed BL Lac objects, they may be quite massive, up to ten million solar masses. Sulentic emphasized that more effort must be made to detect spectral lines in the knots.

The last invited paper in the symposium was "The Structure of Radio Jets in 3C 449 from VLA Observations" by Richard A. Perley, Anthony G. Willis, and John S. Scott. The Very Large Array, not yet complete, already has the highest resolution and sensitivity of any interferometer in the world. It has been used to map a dozen jet galaxies, the most spectacular of which is 3C 449, a compact radio galaxy which is a member of a Zwicky cluster and which has two close companions less than 1 second of arc away. It was mapped at high resolution at wavelengths of 6 and 20 centimeters. The main features are an unresolved nucleus, gaps in emission on each side, and two jets which are straight but have sharp bends. The jets can be resolved into lumps. The favorite interpretation is a model, by Blandford and Ickey, which postulates a gravitational encounter between 3C 449 and its near neighbors. Speaking just one week after the VLA acquired the instrumental capability to measure polarization at 20 cm wavelength, Perley reported on earlier measurements of the polarization (high!) at 6 cm. The magnetic field is perpendicular to the jet axis.

It is clear that a new era of high resolution radio astronomy is coming

9. Synchrotron radiation is produced when fast-moving electrons spiral around strong magnetic fields. — *Ed.*

as the VLA, 27 telescopes spread over a Y-shaped track in southern New Mexico, nears completion.

The Trumpler Award Lecture

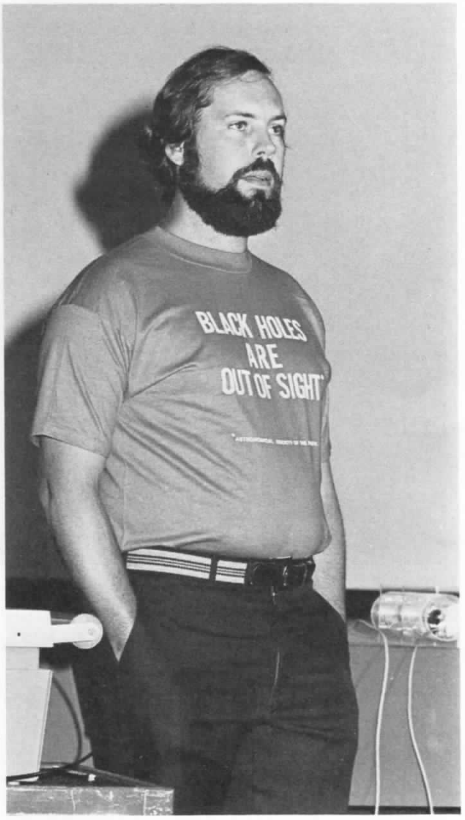
The 1979 Robert J. Trumpler Award for an outstanding Ph.D. thesis in astronomy was awarded to Gary Schmidt for research performed as a graduate student under J. Roger Angel at the University of Arizona. Schmidt, now at the Lick Observatory, presented his work in an invited lecture, "The Optical Polarization of Jets in Active Galaxies." It was a delightful coincidence that this year's Trumpler Award lecture fit in so well with the symposium.

Schmidt built the first multichannel imaging polarimeter and used it to observe — what else? — the optical jets of M87 and 3C 273. He also observed some other objects, most notably the Crab nebula.

Detailed polarization maps of the jets of M87 in both radio and visible light reveal their structure. There is Faraday rotation of the polarization due to passage of the radio waves through a plasma in a magnetic field. This plasma is uniform and surrounds the galaxy to a distance of at least 1.5 kiloparsecs, the length of the jet. This medium is associated with M87 and is much smaller than the Virgo cluster of galaxies of which M87 is part. Two possible sources of the medium are the x-ray halo around M87 and the large radio lobe which contains the jet. Schmidt prefers the radio lobe, as it is known to have a magnetic field and produces uniformly-polarized radio emission in regions which do not contain the jet.

The jet in M87 can be resolved into knots only because it is so close. (The Virgo cluster is only about 20 megaparsecs distant). If the jets in the quasar 3C 273 and various other objects are similar in size, it is currently impossible to resolve them or to detect polarization in individual knots.

Schmidt is now working with Joe Miller at Lick to develop a spectral polarimeter using the image dissection scanner on the Shane 3-meter telescope. They will be able to obtain polarization at each wavelength as they obtain spectra. Some of the first data from this new system were presented briefly; it is already clear that it can make polarization measurements of dim quasars with unprecedented speed.



William Oegerle discusses V861 Sco, a black hole candidate.

Contributed Papers on the Symposium Topic

Bruce Balick (Univ. of Washington) presented the first monochromatic video camera images of ionized gas around the nuclei of active galaxies. This work was done with Tim Heckman (now at Leiden) at Kitt Peak. Pictures made through 50-Angstrom wide filters centered on emission lines of doubly ionized oxygen, etc. revealed some beautiful structure around the nuclei of Seyfert galaxies.

H.K.C. Yee (Calif. Inst. of Technology) discussed optical continuous and emission line spectra of active galactic nuclei and quasars. He examined the spectra of 104 of these, from his own observations and from the literature, and found a strong correlation between the flux of the second Balmer line of hydrogen (H-beta) and the nonthermal luminosity of the object. Quasars in this respect behave very much like active galaxies.

Gregory A. Shields (Univ. of Texas) presented "Thoughts on the Broad Line Regions of QSO's." This theoretical work was performed at the Lawrence Livermore Laboratory of the University of California, in collaboration with Jon Weisheit and C. Bruce Tarter. They studied the physical conditions in the clouds which (presumably) emit the broad spectral lines and showed that these clouds could be absorbing the missing low-energy x-rays and re-emitting the energy in the visible and ultraviolet.

James M. Shuder (Univ. of Calif., Santa Cruz) reported on a study, made with Donald Osterbrock, of narrow-emission line galaxies which are also x-ray emitters. They found broad H-alpha profiles in these galaxies.

The next paper was "Implications of the Hydrogen Line Ratios in Quasi-Stellar Objects" by Richard Puetter and Richard Canfield (Univ. of Calif., San Diego). Canfield discussed the multilevel, depth-dependent, radiative transfer calculations they performed in order to model the QSO clouds. In their dust-free model, heating is by photoionization. They are able to calculate hydrogen line strength ratios.

Stephen W. Hinch, Gordon G. Spear, and Miriam Carolin (Sonoma State Univ.) presented the results of photographic photometry of the Seyfert Galaxy Markarian 509. They found that Mrk 509 varied by 1.3 magnitudes in just two weeks.

Another Seyfert galaxy, Arakelian 120, was examined by H. Richard Miller (Georgia State Univ.). Photoelectric photometry reveals that the galaxy has, in a sudden outburst, brightened by as much as 0.24 magnitudes in three weeks, implying that the emitting region is quite small.

Two Other Papers

Two of the many fine contributed papers delivered at the meeting may be of special interest to *Mercury* readers.

William Oegerle and Ronald S. Polidan (Princeton Univ.) presented strong evidence for the existence of another black hole in our galaxy. They analyzed ultraviolet and x-ray data to show that the variable star V861 Sco probably has a black hole as its companion. Since the star is of magnitude 6.2 in the visible, they suggested that amateur astronomers might wish to monitor it. It has undergone an extremely energetic event in terms of its ultraviolet emission, and varies over very short times in x-rays.

Perhaps the most exciting contributed paper was the one by Bruce Margon and Holland Ford (UCLA) on the large amplitude periodic Doppler shifts in the bizarre object SS 433. Ford used a flashlight as a model of a "blowtorch." He asked participants to imagine that it was emitting very energetic particles (with speeds about one-fourth the speed of light) from each end. He moved it around to simulate rotation about an axis inclined to the line of sight, and then showed how this might explain the extremely large red *and* blue shifts recently discovered in the spectrum of this star. Estimated to be only 3500 parsecs away, SS 433 has been called a "theorist's delight;" it is certain that we will hear a great deal more about it in the future. [See article below. —**Ed**]

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A report on the non-technical sessions at the meeting will appear in the next issue of *Mercury*. — *Ed.*

Photographs for this article were taken by John Fruhbauer, a professional photographer and A.S.P. member who generously donated his time to the Society. Members who need photographic work may want to show their appreciation by using Mr. Fruhbauer's services. He can be contacted at: Fruhbauer Films and Fotos, 1383 Colette Way, Woodland, CA 95695. — *Ed.*