All four maps measure longitude westward from 0° to 360° and have a 0° central meridian representing the central meridian of the hemisphere facing Saturn. The coordinate grids are drawn at 30° intervals in latitude and longitude. Along the equator, the 60° parallels in the polar regions, and the 0, 90, 180, 270° meridians, marks are placed every 5°.

Planimetric control is based on measurements of the position of each satellite relative to the Voyager 1 spacecraft at the time the corresponding picture was taken. A grid of meridians and parallels in an external perspective projection was computed by K. F. Mullins and H. G. Morgan for each particular case and superimposed on the photograph; features were then transferred manually, each in its appropriate cell, to the projection being used for the map. The Mimas and Tethys maps are based on only two or three photographs each. The map authors estimate that the relative accuracy of placing the separate features is 20 km for Mimas (or 4 mm at the scale used), 50 km for Tethys and Dione (5 mm), and 70 km for Rhea (7 mm) over two-thirds of the territory mapped.

Preliminary names for some features are lettered on the maps. There are 31 names on Mimas: 27 craters have been named for personages from medieval Celtic legends about King Arthur and the Knights of the Round Table, while four canyons, or chasms, bear names from Greek myths about giants, for Mimas himself was one of those giants. Six features on Tethys are named for characters in Homer's epic, The Odyssey, and on Dione 29 names have been adopted from The Aeneid of Virgil. Names of 44 craters and two canyons on Rhea are taken from the folklore of various peoples, chiefly Asiatic, regarding the creation of the world. Crater-shaped formations are lettered in upright type and other features in sloping type, so that one can easily tell them apart.

In the map margins, 20-25 lines of explanatory text give particulars on the televised images, the map compilation procedure, the feature placement accuracy, the figure of each satellite adopted for calculating the projection, and the like. Both the main map and the polar charts are equipped with graphical scales for various latitudes, simplifying measurements taken on the maps.

As their title implies, these maps are provisional in character. They are not of high planimetric accuracy, their territorial coverage is incomplete, and their detail is not adequate to their scale. Further careful processing of the video imagery and the filling in of the blank spots with pictures taken by the Voyager 2 craft in August 1981 (especially urgent for the map of Tethys) undoubtedly will help improve the maps. Yet even in their Voyager 1 preliminary version they constitute a most valuable product of "cosmic cartography." For the first time these maps give an idea of what the terrain is like on the satellites of Saturn. They will be useful for preparing a variety of special-purpose maps for these distant celestial bodies, which in some ways can best be studied by means of cartography.

Translated by R. B. Rodman

Optical Jets in Galaxies*

Reviewed by V. G. Surdin

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Some noted astronomers contributed to this collection of 26 papers given at a workshop organized to plan operations with the Space Telescope, which is to be put in service by 1985. Comprising a Ritchey–Chrétien system of 2.4-m aperture, the telescope will have $0''.1$ angular resolution near λ6330 Å. The instrument field of view will be 18' in diameter; the spectral energy range will extend from 1150 Å to 1 mm, and the pointing stability will be accurate to $0''.007$. Provision will be made in this instrument to measure the positions of point sources in a 60 $(1')^2$ field to $\pm 0''.002$ precision. The Space Telescope will be equipped with a battery of photometric and spectroscopic apparatus that can perform intricate astrophysical experiments. In the high-speed photometry mode, for example, it will be feasible to measure the brightness of a star as faint as $m_V = 24$ to 0.2% accuracy with a time resolution of 16 μsec. The designers of the Space Telescope have hopes of recording objects all the way down to 28th visual magnitude.

The optical jets extending from the nuclei of galaxies have hitherto been difficult to study, as they are very small in angular size: the jet in 3C 66B is $50''$ long; in 3C 273, $20''$; and in M87, just $2''.2$. It is hard to inspect these structures with ground-based instruments, for the emission of the bright central part of the galaxy seriously interferes. In this respect the capabilities of the Space Telescope could scarcely be better suited to the task: it can provide not merely high angular resolution but also sharp-contrast images of jet structures in the far ultraviolet, where stellar emission is relatively weak while the nonthermal jet radiation is enhanced. So stable will the photometric parameters of the telescope instrumentation be on extremely small angular scales that the nonstable processes at work in jets can be investigated in detail.

Thus far the jets in active galaxies have been observed more intensively by radio than by optical techniques. One reason is the nonthermal spectrum of the jets themselves; another is the fine angular resolution furnished by aperture-synthesis systems (for the VLA, $0''.09$ at $\lambda = 1.3$ cm). Only in a few of these radio sources have features in the radio-jet structure been identified with optical irregularties (such as the six optical knots in the M87 jet). Optical instruments whose resolving power has been improved to $0''.1$ will undoubtedly disclose in jets many new features which often will not have been detected by radio telescopes at all. If a jet does contain bright optical features, then in principle their proper motion can be studied. At best, the Space Telescope will be able to record the relative displacement of point objects to $0''.002$ accuracy, which corresponds, in a galaxy 10 Mpc away, to motion at 10^4 km/sec for an interval of 10 yr. First-epoch measurements for objects of interest will have to be made as soon as possible in order that the requisite astrometric data can be acquired during the lifetime of the space telescope (perhaps 15 yr).

The technique of numerically deconvolving images has been in use for a while now to refine ground-based photographs of double stars and jets in galaxy nuclei. A similar procedure can be applied to enhance the resolving power of the Space Telescope. M. A. C. Perryman (ESA, Noordwijk) describes a method of maximum entropy for deconvolution purposes. It should be feasible to increase the instrument resolution fivefold, to $0''.02$! But while waiting for the Space Telescope astronomers are not sitting idle: they are perfecting photographic techniques that can be used on the ground. With a Lallemand electrographic camera, J.-L. Nieto et al. (Observatoire du Pic-du-Midi) have taken pictures of the M87 jet with very good resolution and high penetrating power. The reproductions clearly show that along with the faint parts far out from the center, the whole jet looks S-shaped.

Ordinarily it is the nucleus of an elliptical galaxy that spawns jets. In R. D. Wolstencroft's (Royal Observatory, Edinburgh) graphic paraphrase of G. K. Miley (Sterrewacht Leiden), "jets are the umbilical cords carrying the maternal energy needed to nurture the extended emission of the double radio lobes." All the more remarkable, then, that the barred spiral NGC 1097 should display enormous optical streamers—and not just a pair of them, but four! They are as much as 120 kpc long. Yet the galaxy has no extended radio lobes at all. No radio waves have been recorded from the optical jets, so their emission evidently is not of synchrotron origin. Although the galaxy does have a small elliptical companion, the jets are unlikely to have resulted from tidal effects. Probably they owe their development to processes in the nucleus of the spiral galaxy. The nucleus manifests signs of Seyfert activity: highly polarized optical radiation, a relatively strong x-ray flux; and it is surrounded by a ring with a nonthermal spectrum. Hence there is good reason to attribute the long streamers to activity in the nuclear region. In any event, the galaxy NGC 1097 is an altogether atypical spiral and warrants especially close study.

In a fine paper, H. Arp (Hale Observatories) assembles photographs and some recent findings for the optical jets protruding from the nuclei of M87, NGC 5128, 3C 120, 3C 66B, and 3C 273. The last of these, the quasar 3C 273, will be a particularly interesting object for the Space Telescope, since VLBI observations with $0''.001$ resolution have disclosed in its nucleus a radio jet rotated by 20°–30° from the position angle of the familiar optical jet. It will be valuable now to secure optical data in the $0''.01-1''$ range from the center so as to ascertain whether the source is continuously rotating in the quasar nucleus or whether it turns off from time to time and then resumes its activity in some other direction. Speaking of the possible relationship between quasars and galaxies, Arp points out a curious coincidence: we observe the two best examples of an optical jet in the objects associated with the radio sources 3C 273 and 3C 274 (namely M87). They are numbered successively in the radio-source catalog, and the objects themselves are not far apart in the sky, in the constellation Virgo. Is that an accident? Arp believes that if the quasar 3C 273 is really located in the Virgo cluster, as the galaxy M87 is, then some unexplained puzzles would be solved. In particular, the radio components of the quasar would not have an apparent expansion velocity of 10c, but only 0.2c. Arp does not particularly insist on such an interpretation, however.

An exceptionally interesting study has been carried out by W. van Breugel (Kitt Peak). He has examined the optical emission associated with the jet and the outer radio lobes of the galaxy 3C 277.3 (Coma A), whose redshift $z = 0.0857$. The brightest optical feature, coincident with the jet, has a 12% continuum polarization with the magnetic vector extending along the jet. Emission lines are observed in the outer radio lobes to ≈60 kpc from the center of the galaxy, indicating the presence of moderate-temperature gas there ($T_e \lesssim 17{,}000$°K) with a total mass of 10^5–10^9 $M_\odot$. It is this gas which is depolarizing the radio continuum. The low temperature and the large [O III]/[O II] intensity ratio rules out the chance that the gas is heated by shocks. Moving at speeds of ≈300 km/sec, the gas carries a kinetic energy of $\approx 10^{53}$–10^{57} erg, compared with at least 10^{58} erg for the relativistic plasma that produces the radio lobes. The kinematic age (size/velocity) of the hot gas is $\approx 10^8$ yr, comparable with the lifetime of the relativistic plasma in the radio source (both the extended regions and the compact source) with respect to synchrotron losses. Thus the radio-emitting relativistic plasma and the hot gas responsible for the optical emission undoubtedly have some genetic relationship, with the dynamics being controlled by the relativistic plasma. What the origin and ionization source of the hot gas may be is not yet clear.

Many of the papers in these Proceedings deal with the radio properties of the jets. A review of those properties is offered by A. G. Willis (Westerbork Radio Observatory). Generally speaking, the radio jets are substantially larger than the optical jets. Detailed study of the internal radio structure is facilitated both by the relatively large angular size and by the high resolving power of radio interferometers. Viewed in projection the radio jets range from ≈2 kpc long in M87 to ≈290 kpc in NGC 315 (for $H_0 = 75$ km·sec^{-1}·Mpc^{-1}). Jets usually have slightly flatter radio spectra than the integrated radio emission of the parent sources. Often the ends of radio jets will be wiggly or even curled, presumably because of precessional motion of the internal energy source or orbital motion of the whole galaxy if it is paired with a companion. A gap in radio emission several kiloparsecs wide is commonly observed between the central source and the inside end of the jet. It is generally believed that such gaps reflect a high degree of collimation in the relativistic beam, whose particles will travel for some length of time strictly parallel to the magnetic field lines, and thus will not radiate. But examples exist (as in the NGC 315 counterjet) where several gaps occur along the same jet; in such cases they might well owe their origin to cyclic activity in the nucleus.

In order to understand the physical processes in radio jets, one has to determine how the magnetic field is oriented relative to the jet axis. In some jets, such as those in M87, 4CT 74.17.1, and 4C 32.69, the magnetic field is aligned with the jet along its entire length. Among the radio sources with double jets there is a special group of "twin tail" sources like NGC 1265, formed through interaction of the relativistic plasma with hot intracluster gas. In such sources the magnetic field configuration is complicated, and an analysis would not help explain the jet. In the simple case of centrally symmetric jets, Willis points out the following regular behavior: a) close to the nucleus the magnetic field is always directed parallel to the jet axis; b) in twin-jet sources the field will be parallel to the axis of the brighter jet along the central part, but perpendicular to the jet near its outer end, or vice versa; c) in the counter jet (the fainter of the twins) the magnetic field is always perpendicular to the axis along the central portion, while at the edges it may have any orientation. Not one case has been discovered where the field is normal to the jet axis near the nucleus but becomes parallel farther out. It is not yet understood how the morphology of the jets is related physically to their magnetic field structure.

R. A. Perley (VLA) emphasizes that flat-spectrum radio sources show significantly more complicated structure than those with a power-law spectrum. In flat-spectrum sources the opposite radio lobes usually have a flux ratio greater than 5:1, and sometimes more than 20:1. Halo, linear jet, and blob structures are often observed simultaneously. At least 30% of these sources, once thought compact, contain extended radio structures, and in fact as new multiple-antenna interferometers have come into service, many seemingly compact sources have proved to display intricate structure. For example, R. Fanti and P. Parma (Bologna) have used the Westerbork aperture-synthesis system to investigate low-luminosity radio galaxies from the B2 catalog; they observed 17 galaxies, and 9 of them exhibit jets.

Many interesting results have been obtained with VLBI systems. These findings are summarized by E. Preuss (Bonn). With good angular resolution, sources having extended radio "vanes" will almost always exhibit asymmetry in the central structure, which will appear elongated (often in the form of diminutive radio vanes) nearly always in the same direction as the large outer radio vanes (jets). Extremely compact ($0''.001$) radio sources occur in all classes of active nuclei (but not in every individual nucleus). We observe one example of a very compact source in the nucleus of M87. At $\lambda = 2.8$ cm one-third of its total flux comes from a region ≈1.5 light-months across. Many if not all extended sources have a compact core (probably detectable whenever the sensitivity is adequate). Objects with a bright, compact nucleus show rapid variability, both in total flux and in structure. The most remarkable instances of variability are the objects displaying "superluminal" motions: 3C 120, 273, 279, 345. The components (relative brightness peaks) of these objects have mutual displacement rates corresponding to apparent velocities from 5c to 45c.

X-ray observations thus far have given information on only three jets: those in M87, Centaurus A, and 3C 273. A unified synchrotron mechanism would closely fit the radio, optical, and x-ray spectrum of each jet. The break observed in the spectrum at $\nu = 10^{13}$-10^{15} Hz suggests that the relativistic electrons have a short lifetime – shorter than the light travel time from the nucleus to the tip of the jet (in M87, for instance, the electrons survive about 100 yr, but the jet is thousands of light years long). Evidently some source of fast electrons exists inside the jets themselves.

Various theoretical problems concerning jets in galaxies are discussed by A. Ferrari et al. (Turin), A. S. Wilson (University of Maryland), and M. S. Longair (Edinburgh). We do not yet know whether the bright knots found in jets result from the interaction of the relativistic beam with dense interstellar gas clouds or from MHD instability in the beam itself. Longair makes an interesting point: drawing an analogy between active galaxy nuclei and active stars, he remarks that in the realm of stars material is generally ejected fairly isotropically; only in rare cases (SS 433, Scorpius X-1) is a highly collimated beam observed. Conversely one would like to learn of extragalactic systems in which relativistic (or merely hot) gas is being ejected from an active nucleus isotropically.

Reviewing the optical properties of the jets in NGC 5128, I. J. Danziger (ESO) states that radially elongated optical features are observed between about 4 and 40 kpc from the nucleus. All these structures are approximately collinear with the radio and x-ray jets. The optical emission in the jets resembles that of ordinary H II regions of normal chemical composition (even as far out as ≈40 kpc from the center), but their excitation and ionization mechanism is not yet clear. Relative to the galaxy the radial velocities of the optical jets are generally directed toward us and seem to approximate the Keplerian velocity at the corresponding galactocentric distance. The origin of the optical-jet material and the nature of its ionization source presumably are intimately tied in with the question of how the gaseous disk of NGC 5128 was formed.

If one compares the two radio galaxies closest to us, M87 and NGC 5128, one has to concede that optical studies of the central part of M87 have an appreciably better chance of success, even though this galaxy is farther away. Inspection of the optical jet structure in M87 is restricted solely by the angular resolution of our instruments; the situation soon will much improve, through the launch of space telescopes as well as the introduction of new techniques into ground-based astronomy.

Taken together, the Proceedings leave a good impression. Not only are the latest results collected, but tasks are outlined for future research using optical systems of high angular resolution. Selected review papers in this volume would be worth publishing in Russian.

Translated by R. B. Rodman