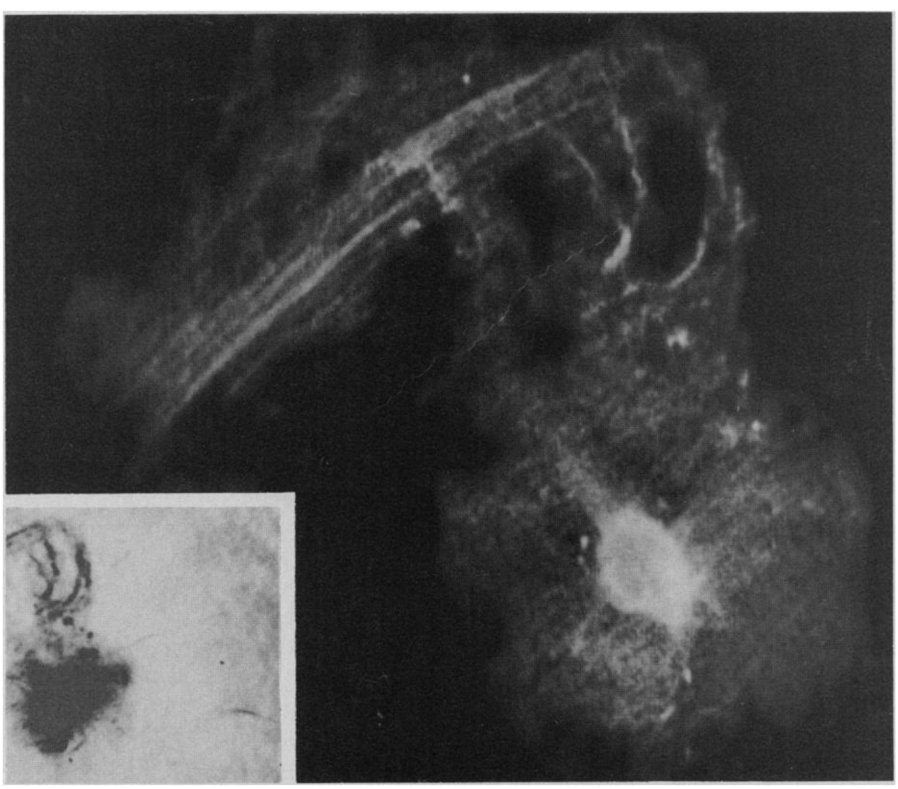
New Mysteries at the Galactic Center

In addition to a massive black hole, the center of the Milky Way exhibits bizarre magnetic structures, "threads," and possibly a jet

Even as astronomers are focusing their attention on what seems to be a massive black hole at the core of the galaxy (*1*), a series of broad-scale radio surveys has begun to reveal a striking variety of activity surrounding the core. The features seen to date include a large-scale magnetic field of unknown origin, a possible jet emanating from the central black hole, and a series of "threads"—smooth, narrow lines of emission that seem to correlate with nothing else in the central region, and that resemble nothing else in the galaxy.

The first suggestion of a large-scale magnetic field came in 1984, when Mark Morris of the University of California, Los Angeles, his student Farhad Yusef-Zadeh, now at Columbia University, and Don R. Chance of Columbia were able to observe the fine structure of the so-called Continuum Arc. Originally detected in 1959, the arc had previously seemed to be just a narrow strip of radio emission lying perpendicular to the plane of the galaxy about 40 parsecs out from the center, and extending roughly 20 to 30 parsecs above and below the plane. (A parsec is 3.26 light years.) However, data taken by Morris, Yusef-Zadeh, and Chance at the Very Large Array (VLA) in Socorro, New Mexico, revealed that the arc actually consists of thin, parallel filaments (*2*). Furthermore, at the northern end of the arc the filaments merge with a second, less regular set of filaments that curve back down into Sagittarius A West, the radio source that marks the center of the galaxy. More recent work suggests that the arc may be part of a still larger structure (*3*).

The filaments mean that the arc is almost certainly shaped by a magnetic field, say the researchers. For one thing the filaments are strikingly uniform over large distances, which makes it hard to see how they could have formed as part of an interstellar shock wave, for instance. More important, independent polarization measurements of the arc made recently by Japanese and by German radio astronomers are consistent with synchrotron radiation, which is produced by electrons spiraling around magnetic field lines.



The Continuum Arc

Shown here in an image produced by the VLA at 20 centimeters wavelength, the arc is clearly resolved into thin, parallel filaments, which are presumably organized by a magnetic field. The central core of the galaxy lies in the blob of emission at lower right. Recent observations have also revealed faint "threads" of emission extending to the north of the arc (inset; courtesy of Astronomical Journal*).*

The polarization measurements also give an estimate of the magnetic field: 10^{-4} gauss, which is very large relative to the overall magnetic field of the galaxy. Thus the central question: what is producing the field?

One obvious candidate is the black hole itself, which could certainly produce a magnetic field if it were spinning and had a substantial electric charge. However, the size of the arc makes the black hole origin implausible. Much more likely, say the researchers, is the same kind of dynamo process that produces magnetic fields in the sun, the earth, and the other planets. Indeed, the dynamo effect seems to be quite common in astrophysics. All that is required is a rotating, electrically conducting fluid—the metallic core of the earth, for example, or the hot plasma of the sun—and a random trace of magnetic field threading through the fluid. Calculations show that the field will then be twisted, recombined, and magnified by the motions of the fluid until it becomes quite substantial, and self-sustaining.

However, that still does not explain where this particular dynamo resides. Are the fields being generated in a hot disk of matter around the black hole? In a cooler disk of gas farther out? Or in turbulent material scattered over a considerably wider range? Only further observation will tell.

In more recent work, Morris, Yusef-Zadeh, and their colleagues have found a faint ridge of emission beginning at the nucleus itself and extending to the south about 30 parsecs perpendicular to the plane of the galaxy. The ridge is especially intriguing because it resembles the high energy jets of matter commonly seen in quasars and other active galactic nuclei. Moreover, the existence of such a jet in our galaxy is certainly plausible: the million-solar-mass black hole that seems to lie at the core of the Milky Way differs only in size from the billion-solar-mass black holes that are thought to power the quasars. (The energy output of a quasar seems to come from gas and dust spiraling into the hole, and the jets seem to consist of superheated gas squirting out the axis of the spiral, along the path of least resistance.)

On the other hand, the observation is still ambiguous. "We're quite sure we see a ridge of emission," says Morris, "but we're not sure that it's a jet." Not only does it fail to line up exactly with the center, he cautions, but it only appears in an image made at the relatively low frequency of 160 megahertz. Such a ridge might easily be the result of an accidental gap in the intervening galactic material. However, the VLA will soon have the capability to take data at 327 megahertz, where the ridge should also show up clearly. "And then," says Morris, "we'll go at it hammer and tongs."

The threads resemble nothing else in the galaxy

Finally, there are the central region's most mysterious new features, which Morris and Yusef-Zadeh have dubbed "threads" (*4*). The name is apt. The threads—there are at least three of them—are more than 30 parsecs long and less than 0.5 parsec wide. They are dim, gently curved, and quite smooth. And they differ from the filaments of the arc in that they are isolated. Indeed, although they do appear to cross the arc, they are not obviously associated with anything else in the region.

So what are they? Aside from some vague guesses about magnetic fields, says Morris, "We've essentially thrown up our hands." If the threads are shock fronts, why are they so long and uniform? If they are jets, where is the source? If they are the wakes of fast-moving objects of some kind, why do they bend away from the nucleus? One would expect the paths of moving objects to bend *toward* the nucleus because of the concentration of mass there.

Of course, it is always possible that the threads are actually much closer to us than the galactic center, and just happen to lie along the same line of sight. But that implies that a unique set of objects just happens to lie in front of a unique region in the galaxy, says Morris, which seems an outrageous coincidence. And in any case, it still would not explain what the threads are.

—M. MITCHELL WALDROP

References

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Predictable Quake Damage

The elements that combined to create the Mexico City disaster are all too familiar to earthquake engineers and seismologists. Indeed, the devastation there might have been predicted almost 30 years ago; observers had recognized the vulnerability of the central city after the 1957 earthquake. This time, the shock was stronger and lasted a bit longer than usual, but the sequence of events followed the expected pattern.

If there was anything unusual about the earthquake itself, it was how mildly it shook the ground along the coast where it was centered, 300 kilometers from Mexico City. James Brune and John Anderson of the University of California at San Diego and their Mexican colleagues Jorge Prince and Krishna Singh managed to capture this great earthquake (magnitude 8.1) in a network of seismographs designed to record the strongest shaking without going off-scale. That is a first in strong motion seismology. Surprisingly, the maximum acceleration of the ground as it shook back and forth was only 0.16 that of gravity. Seismographs that had happened to be triggered by other large earthquakes in subduction zones, where ocean crust dives beneath continental crust, had recorded peak accelerations as high as 0.8*g*.

Brune suspects that the relatively low acceleration may be typical of a subduction fault rupture buried 25 to 30 kilometers below the surface that fails to touch off other ruptures near the surface. In part because of this relatively mild shaking, there was little damage along the coast. With increasing distance from the earthquake epicenter, the seismic waves became weaker, the peak acceleration dropping to 0.03*g* 100 kilometers outside Mexico City.

Such attenuated shaking could have done little damage without being amplified, but, as observed after the 1957 earthquake, Mexico City is all too effective an amplifier of certain seismic waves. The key to the amplification is the matching of fundamental modes of vibration of the soil beneath the city and of the buildings with certain of the seismic waves. As an example of a fundamental period, an A tuning fork vibrates with a period of 1/440 of a second that is determined by its size, mass, and composition. However it is hit, the fork vibrates with that period. A building behaves much the same way, flexible 5- to 15-story buildings swaying with a period of around 2 seconds when struck by wind or earthquake. By chance, a column of lake-bed sediments in central Mexico City also had a fundamental period of about 2 seconds by dint of its effective depth and composition.

When 2-second seismic waves begin shaking such soil, a resonance exists that amplifies the shaking, just as properly timed, periodic pushes of a swing will drive it into larger and larger arcs. Thus, the waning 0.03*g* acceleration jumped to 0.2*g* on the old lake bed, throwing the ground back and forth 40 centimeters every 2 seconds, a total of 15 to 20 times. That is a lot of shaking for Mexico City, but other great earthquakes have struck the neighboring coast. The only distinctive characteristic of this earthquake may be its complexity, according to Hiroo Kanamori and his colleagues at the California Institute of Technology. This event had two pulses instead of one, which might have lengthened the time of strong shaking.

Once resonance between intermediate-height buildings and the soil further amplified the shaking, the next element in the disaster, inadequate construction, came into play. Edwin Johnson of Atkinson, Johnson, and Spurrier in San Diego, a member of the U.S. team that surveyed the damage, lists at least 20 design and construction practices that contributed to the damage. It is a litany ranging from inadequate foundations—a crucial failing in Mexico City's soft, subsiding ground—to unreinforced masonry that is familiar from reports following the 1957 earthquake and others elsewhere. "What we really had was a recitation of old lessons that we have learned time and time again," he says.

Although staggering when viewed through the camera lens, the Mexico City disaster was a limited one. Only 250 buildings collapsed out of a total of 600,000 or more structures in the city; about 1 percent of the city suffered heavy damage. A great earthquake can be much worse.—RICHARD A. KERR