Even mice bred from a 3R parent, the classic nonproducer, could make I-J^k, if the second parent contributed the non-MHC gene. Not only do the results suggest that 3R and 5R differ outside the MHC, they also indicate that 3R has the appropriate k gene in its MHC, just as 5R does. All of this is contrary to what was previously thought.

If both 3R and 5R mice have the appropriate k gene in their MHC's, then the DNA's in the region between I-E and I-A should be the same in both strains. The Hood group has found that the critical DNA segments from the two mouse strains are identical, as determined by restriction mapping—which might miss subtle differences. The investigators are determining the nucleotide sequences of the two DNA's and expect to know in a few months if they are the same.

To pin down the location of the non-MHC gene, Hayes and her colleagues turned to a series of 18 mouse strains, produced by Benjamin Taylor of the Jackson Laboratory, by crossing AKR mice with C57L mice. The Hayes group had found that AKR mice have the MHC-encoded gene needed for I-J^k molecule production but lack the non-MHC gene. The reverse is true for C57L mice. Some of the hybrids between the two strains produce I-J^k; others do not.

The distribution of several of the parental chromosomes in the hybrids has been worked out by other investigators. According to Hayes and her colleagues, hybrids that produce I-J^k consistently carry portions of chromosomes 4 and 7 from the C57L parent, but in nonproducers these chromosome segments are of the AKR type, a finding which suggests that one of the two chromosomes might carry the non-MHC gene needed for I-J production. The distribution of some of the parental chromosomes was not known, but the investigators eventually showed that chromosome 4 carries the gene, which they designated *Jt*.

What is now needed is an explanation of how two genes might collaborate to produce I-J molecules. "There is still more than one model that can account for the available data," Hayes points out. Conceivably the I-J molecule might be a modified I-E molecule, in which case the product of the *Jt* gene might be the enzyme that carries out the modification. This would be consistent with the Hood group's finding that the I-J region carries sequences coding for E_β. Moreover, the Hayes group has found that all of the I-J^k producing mice carry the k variant of the I-E genes. And Klein and his colleagues have also obtained recent evidence suggesting that I-J suppressor factors contain modified forms of I-E or I-A molecules.

Hood notes a problem with theories suggesting that the I-J molecule is a modified form of I-E, however. "If that is the case, the messenger should be there." But his group has been unable to detect messenger RNA transcripts of the DNA region between I-E and I-A in suppressor cells that make I-J.

Another, perhaps more likely, way in which the two genes might cooperate to produce I-J molecules involves the regulation of one by the other. For example, the *Jt* gene might code for the I-J structure and be controlled by the gene from the MHC. As already mentioned, the I-J molecule may be a component of T cell receptors, which can recognize a foreign antigen only in conjunction with an appropriate histocompatibility molecule—such as I-E. During development then, suppressor T cells might be selected on the basis of their having the right I-J molecule to recognize the I-E molecules carried by the immune cells with which the suppressors react.

The genes for the suppressor molecules could then appear to map to the MHC in classical genetic studies, even though they are located elsewhere, because their structures would in effect be determined by those of the corresponding histocompatibility antigens. There would have to be a way to generate the repertoire of suppressor molecules needed for the several I-E variants, but both the antibody and histocompatibility gene families provide a wealth of precedents for such generation of diversity.

This hypothesis, involving control of the *Jt* gene by one from the MHC, is not without problems of its own, however. For example, there are strains of mice that apparently do not express I-E molecules but do express I-J.

Although more work will be needed to confirm the findings of the Hayes group, the investigators have provided a valuable lead to the location of the elusive suppressor genes. Finding those genes and their products could help to solve some major problems in cellular immunology.—**Jean L. Marx**

Additional Readings

1. C. N. Baxevanis, Z. A. Nagy, J. Klein, *Proc. Natl. Acad. Sci. U.S.A.* **78**, 3809 (1981).
2. Z. Ikezawa, C. N. Baxevanis, B. Arden, T. Tada, C. R. Waltenbaugh, Z. A. Nagy, J. Klein, *ibid.* **80**, 6637 (1983).
3. J. A. Kobori, A. Winoto, J. McNicholas, L. Hood, *J. Mol. Cell. Immunol.*, in press.
4. M. Kronenberg, M. Steinmetz, J. Kobori, E. Kraig, J. A. Kapp, C. W. Pierce, C. M. Sorensen, G. Suzuki, T. Tada, L. Hood, *Proc. Natl. Acad. Sci. U.S.A.* **80**, 5704 (1983).
5. M. Steinmetz, K. Minard, S. Horvath, J. McNicholas, J. Srelinger, C. Wake, E. Long, B. Mach, L. Hood, *Nature (London)* **300**, 35 (1982).

Through a Lens Darkly

When the first gravitational lens system was discovered, in 1979, it seemed to promise a whole new window on cosmology. Here was nature's demonstration of an effect first predicted by Sir Arthur Eddington nearly 60 years before: light from a far-distant quasar was being deflected by the gravitational field of a foreground galaxy, and was focusing into a tight little cluster of quasar images for astronomers on Earth. With luck, said the optimists, such systems might allow them to map the mass distribution in the lensing galaxy, probe the intergalactic medium, or make a more accurate determination of cosmological parameters such as the Hubble constant.

The pessimists, however, noted that the effect was both very subtle and very difficult to study, and predicted that nothing much would ever come of it. "So far the pessimists have the edge," says Irwin I. Shapiro, head of the Harvard-Smithsonian Center for Astrophysics. While the situation is far from hopeless, he adds, "the universe is an *extraordinarily* dirty laboratory."

Last month, as he reviewed the status of gravitational lens research for the American Astronomical Society (AAS),* Shapiro supported that point with a look at the five lenses that have been discovered to date. Some curiosities:

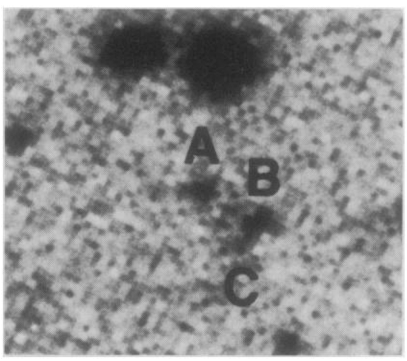
- All the quasar images come in pairs, even though the theory of gravitational optics demands an odd number of images. Perhaps the third image is just getting lost in the glare of the lensing galaxy, said Shapiro—but in all five cases? One hope for finding the lost images, if they are there at all, is with ultrahigh-resolution radio maps produced by very long baseline interferometry.
- None of the lensing galaxies lie in a straight line with their quasar images. This means that none of them has a spherically symmetric distribution of mass. Unfortunately, it also means that there is no way to deduce what the mass distributions really are because the same imagery can arise from radically different configurations. Complicating the analysis even more is the likelihood that some of the lens-

*The 163rd meeting of the American Astronomical Society, 8–11 January 1984, Las Vegas.

ing galaxies are embedded in clusters of galaxies.

• All the known lenses have relatively wide image separations, with values ranging from 2 seconds of arc to 7 seconds of arc. Yet recent theoretical calculations done at Princeton University by Edwin L. Turner, Jeremiah P. Ostriker, and J. Richard Gott indicate that on the average most lensed quasars should have images *closer* than 2 seconds of arc. Perhaps the wide separations are just a selection effect, said Shapiro, or the result of small sample size. Or perhaps we still do not understand something.

For all of that, said Shapiro, it is important to keep working on gravitational lenses no matter how dirty the cosmic laboratory. Eventually, for example, some lensed quasar will oblige us by fluctuating in brightness, and we will see its images flare up one after the other—with a time delay that is proportional to the distance of the quasar. Since the redshift of the quasar is directly observable, the effect could thus yield a sensitive measurement of the Hubble parameter, which relates the distance of an object to its velocity of cosmic expansion.



The newest gravitational lens

2016+112 is seen here through the Palomar telescope as twin quasar images (A and B) and the lensing galaxy (C).

By the same token, said Shapiro, the images should show subtle differences in their spectra, simply because one set of photons has taken a slightly longer path through the intergalactic medium and has thus suffered more absorption and scattering. This path difference is directly proportional to the time delay measured above, so lens systems could also give us a sensitive probe of the intergalactic medium.

Shapiro and other speakers at the AAS meeting agreed, however, that for gravitational lens research to make any great headway, observers are going to have to compile a much better statistical sample. That will not be easy: Turner, Ostriker, and Gott estimate that only 2 to 5 quasars out of every thousand will be lensed by a foreground galaxy. And since most of those will have very narrow image spacing, it will be tough to find them.

Still, an important step has been taken in that direction with a systematic survey of the radio sky conducted by Bernard F. Burke and his colleagues at the Massachusetts Institute of Technology, using the National Radio Astronomy Observatory's 100-meter antenna at Green Bank, West Virginia.

The survey started on a small scale in 1979 as a graduate student's thesis project, Burke explained to the AAS. But it quickly came to encompass a broad band of sky lying just north of the celestial equator. "At this point it was simply a general survey of radio sources at 6-centimeter wavelength," says Burke. "We only had crude positions." However, the discovery of the first gravitational lens that year helped convince them to dig deeper.

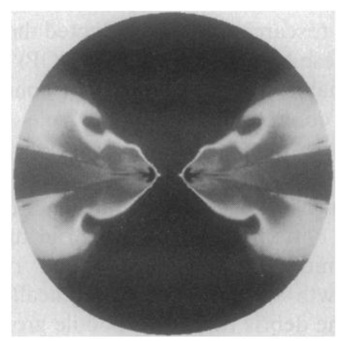
The next step was the Very Large Array (VLA), which was just then coming on line in New Mexico. In 1981 and again in 1982, Burke and his colleagues used the VLA to make detailed maps of 1000 sources chosen from their catalog at random. Several dozen proved to be compact, multiple sources and were thus candidates to be gravitational lenses. "Ten of these were really 'hot' candidates, good enough to justify optical telescope time," said Burke. There accordingly followed two observing runs at the Palomer 5-meter telescope: during the first, in August 1983, the team made very long exposures of the source region to identify optical counterparts; during the second, in October 1983, they attempted to obtain spectra.

The result was the identification of the newest gravitational lens, 2016+112, a triplet of 23rd-magnitude objects lying in the constellation Delphinus just to the left of the bright star Altair (*Science*, 6 January, p. 46). Two of the objects show a redshift of 3.27; presumably they are images of a quasar roughly 2 billion light-years distant. The third object, which has not been measured spectroscopically, appears to be the lens itself: its optical properties are consistent with a giant elliptical galaxy at redshift 0.8.

The MIT–Green Bank survey is far from exhausted, Burke told *Science*. There may well be more lenses found as other double radio sources are examined. And this particular survey covers only part of the sky. There is still a great deal to be done.

Splashdance

Astrophysicists, forced to grapple with horrendously complex phenomena and even more horrendous equations, are turning more and more to numerical modeling and the supercomputer. A case in point is the problem of matter spiraling into a black hole. The process is thought to power the quasars and the so-called active galaxies: given a black hole of, say, 10^8 solar masses, the infalling material will be heated by turbulence, compression, and viscosity until it radiates a large fraction of its mass as thermal energy. The problem is to understand the details well enough to compare the model with observation.



Shown here is an example of recent numerical studies performed on a Cray 1 supercomputer by University of Illinois astronomer Larry L. Smarr and doctoral student John Hawley. Around the black hole (center) orbits a thin, axially symmetric disk of cold gas. The disk is seen in cross section as a pair of dark wedges approaching from the left and the right. As the gas spirals in, however, it suddenly strikes a superheated shock front (dark cap) and splashes back across the surface of the disk. Only some of it enters the hole. This splash-back effect has not been considered before, and should shed some light on how energy escapes from the disk.

—M. MITCHELL WALDROP