Péter and B. Tamain.[2] They bombarded Bi^{209} with 525-MeV Kr^{84} ions and measured a cross section for quasifission events of 0.5 barns, or more than 60% of the total reaction cross section. Another surprising feature of their data was that the angular distribution was sharply peaked at an angle of about 95 deg in the center-of-mass system.

Similar results were subsequently obtained by a group working at the SuperHILAC at the Lawrence Berkeley Laboratory. This team used a 600-MeV Kr^{84} on a Bi^{209} target and found that the cross section for strongly damped collisions had increased to about 1.5 barns or 80% of the total reaction cross section.[3] They, too, measured a peak in the angular distribution; however, the peak was shifted to a center-of-mass angle of 58 deg. In both experiments this peak occurs at an angle near the grazing angle for the corresponding energy. The grazing angle is the angle of scattering of a projectile that barely hits the outside edge of the target nucleus. Such a projectile has the highest angular momentum.

The group that used the SuperHILAC consisted of Kevin L. Wolf and John P. Unik of Argonne, John R. Huizenga and John Birkelund of the University of Rochester, Victor E. Viola of the University of Maryland and Hartwig Freiesleben of the University of Marburg, Germany, and formerly of the University of Rochester.

Both experiments were correlation experiments in which two detectors on either side of the beam measure events that occur in coincidence. The Orsay group used three surface-barrier detectors. One was fixed at a laboratory angle of 55 deg, whereas the other two formed a pair with an angular width of 10 deg in the reaction plane. This pair is moved step by step to cover the full range of angular correlation of fragments in a few measurements. This arrangement of detectors does not allow measurement of the angular distribution of fragments in general; that would require rotating the first detector from 55 deg through all angles. However, the Orsay group measured the singles spectra—one in which they do not impose a coincidence requirement—over a wide angular range, and they assume that the mass of the krypton-like product does not change with angle. On the basis of their coincidence data at one angle, the Orsay group argues that this singles angular distribution is representative of the fragment with mass near that of the projectile.

The experiment at the SuperHILAC used a similar technique, but one detector was a large position-sensitive detector that subtended an angle of 26 deg in the reaction plane. The other was an angle-defining detector that had a 2 deg acceptance angle. With this arrangement, the angles and energies of both fragments could be measured with a high geometry factor, allowing mass-identification over the entire angular distribution. A significant mass-exchange was found to take place at backward angles. This group performed coincidence measurements at five angles and showed that the low-energy peak in each singles spectrum was due to the lighter mass fragment of the strongly damped collision process.

Theoretical explanations. The Argonne-Maryland-Rochester group attempts to account for the large cross section for the strongly damped process in terms of the delicate balance between the nuclear, Coulomb and centrifugal forces for interactions between heavy target nuclei and projectiles as heavy as krypton. Their examination of nuclear potentials for various values of the angular momentum l shows that only a limited number of l waves have potential wells at some radius from the target nucleus. Those waves that do not have potential wells are not likely to form a compound nucleus, and hence the fusion cross section is low.

The variation in the radial dependence of the interaction potentials for the various l waves may also provide a clue to the sharp peaking of the angular distributions. The conservative force driving the nuclei apart is much weaker for low-l waves and gives sticking times for these waves that are much longer than the higher-l waves. On the other hand, the low-l waves rotate more slowly through larger angles of rotation than the high-l waves, and the general result may be for all waves to be emitted at nearly the same angle.

The findings of both groups have an important impact on heavy-ion research, particularly on the production of transactinide elements by the reactions with heavy ions. Certainly, the new results dim the hopes for producing new elements by complete fusion reactions with projectiles as heavy as krypton; however, reactions with projectiles lighter than krypton may still be productive. —BGL

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Correcting for atmospheric distortion in telescopes

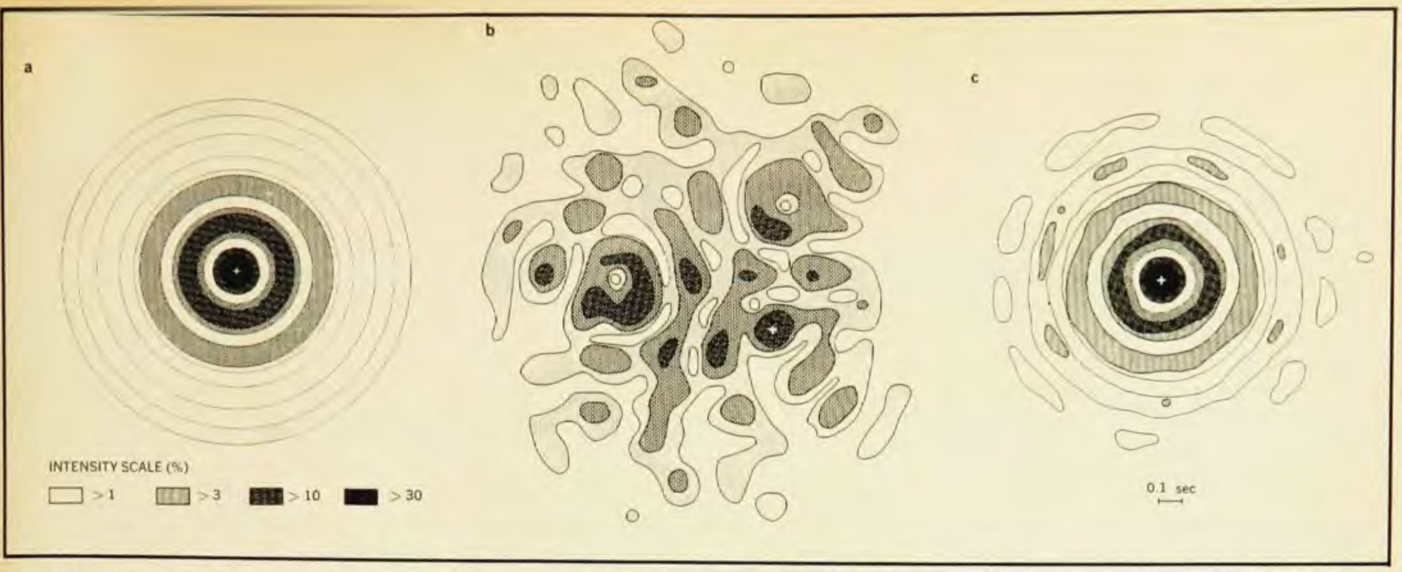
Optical astronomers are frequently hampered by atmospheric turbulence that distorts telescopic images by causing random phase shifts in the incoming light. These distortions often reduce the resolution of a telescope far below its diffraction limit. But the outlook may be brightened by new techniques now being developed to detect and correct for the phase error in real time. Until now most techniques to correct for atmospheric distortions have been post-detection compensation techniques: The effects of turbulence are extracted after the image data has been recorded. Three of the groups that are conducting major development efforts on real-time compensation described their work at a conference on Optical Propagation Through Turbulence that was sponsored by the Optical Society of America at the University of Colorado, 9–11 July. These three groups are from Hughes Research Laboratories, from Itek Corporation and from Lawrence Berkeley Laboratory[1] and the Institute for Advanced Studies.

The pre-detection compensation schemes all feature a component for detecting the errors introduced by turbulence, some active optical elements to correct for the errors and an on-line data processing system to calculate the desired response of the optical elements. All components must have extremely fast response times because the pattern of atmospheric disturbances changes typically every 20 msec. Beyond these general features lie interesting differences in approach.

At Itek, John Hardy, Julius Feinlieb and James Wyant use a shearing interferometer[2] to detect the phase errors in the wavefront arriving at the telescope aperture. The phase error introduced by turbulence changes over a region of roughly 10-cm square, so the interferometer essentially generates a wavefront map by measuring the phase error in each of these regions. The map is measured in about 1 msec, independent of the size of the telescope. The phase corrector is a monolithic piezoelectric mirror.[3] This solid slab is divided into regions, each driven electrically by a separate actuator. The measuring and data processing between the interferometer and the mirror are done in parallel.

The Itek group is the only group that has demonstrated its system in the laboratory. Working with thermal turbulence, they obtained a resolution close to the diffraction limit. Hardy told us that the Itek design is an add-on system that can be relatively small and has a high-frequency response.

Richard Muller and Andrew Buffington of LBL have developed an idea for a feedback system that continuously monitors and improves the image quality.[1] By contrast to the above two techniques, they do not directly measure the



Computer simulation of a ring-shaped telescope aperture (a), the speckle pattern caused by random atmospheric phase distortion (b) and the restored image after one iteration with 25 phase-shifter segments (c). The sharpness criterion was maximization of light through a small hole. These results from LBL resemble other work being done at Hughes Research Laboratory. (From reference 1.)

atmospherically introduced phase errors. Instead their feedback system continuously adjusts the positions of an array of separately movable mirrors in order to maximize a quantity that they call the "sharpness" of the image. They have proved analytically that maximization of the image sharpness will necessarily lead to a completely restored image. Muller and Buffington have investigated the effects of several different definitions of sharpness by computer simulations. A good definition would be the integral of the square of the intensity across the image, but a definition that is easier to implement would be simply maximizing the light through a small hole in a mask.

Freeman Dyson of the Institute for Advanced Studies collaborated with Muller and Buffington by laying the theoretical ground rules for general schemes of optical image improvement, establishing that diffraction-limited resolution in a large, ground-based telescope is in principle possible, and setting forth various expectations and limitations.

At Hughes Research Laboratory, Thomas O'Meara, Wilbur Brown and Larry Miller are applying some of the experience gained in work with transmitter control systems to the problem of optical image improvement, with modifications appropriate to the difference between coherent light and white light from astronomical objects. Like Muller and Buffington, they use image quality as a measure of atmospheric distortions, but differ in some of the definitions of image quality. O'Meara feels that they consider a different variety of maximization systems by using different control algorithms.

The Hughes team is working with analog as well as digital interface systems. For this purpose they are modifying a process of dithering, which is used in transmitter control to maximize the power arriving at a point target. So far they have found no intrinsic advantage favoring either analog or digital processors.

What is the reason for the sudden surge of progress in this field? A general scheme was proposed by Babcock as early as 1953[4] but was presumably never implemented because the technology was not then available. According to Hardy the Itek group first pointed out several years ago that the technology was ready and encouraged development of such systems. O'Meara felt that in addition to the great recent improvement in technology, a motivating factor has been the demonstration that similar systems work for transmitter control. —BG

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Quick-change negative-ion source for accelerators

A negative ion source that can provide high yields of nearly all known stable negative ions and enables the user to vary the ion species within minutes has been developed[1] by Roy Middleton and Charles T. Adams of the University of Pennsylvania, Philadelphia. The negative ions are formed directly from a solid surface by the sputter action of 30-keV positive cesium ions resulting in a negative ion current of the order of 10 microamps. A unique feature here is that a simple, long-lived surface ionization source (similar to a type used in thrusters for space satellites[2]) produces the cesium ion beam, rather than the duoplasmatron conventionally used in negative-ion sources, eliminating the problems caused by the presence of plasmas and gases. This new source, developed at the Penn Tandem Accelerator Laboratory, is particularly applicable to Tandem Van de Graaff accelerators, which must use negative ions and have, until now, been unable to live up to their full potential as universal accelerators of all varieties of ions. High-energy linear accelerators, as well as atomic-beam experiments, could also incorporate these sources.

There is now a great deal of interest in interactions between fast-moving heavy ions and matter, in nuclear as well as atomic physics, and the Tandem Van de Graaff appears very well suited to this kind of experiment. It was designed as a way of reaching higher energies with Van de Graaff accelerators of limited voltage. In the Tandem a negative ion at ground potential is accelerated through the maximum voltage, converted to a positive ion and then accelerated back to ground potential. If the accelerating voltage is, say, six million volts, then stripping off only the extra electron plus one other results in a 12-MeV positive ion. With a heavier ion, such as sulfur, not just two but seven electrons might be stripped and, at ground potential, the S^{6+} would have an energy of 42 MeV.

The catch, however, has been to form the negative ions. Two usual methods have been charge transfer to a positive ion in a donor gas, and direct extraction, from a plasma. Neither method is very efficient, and the gases present tend to clog and poison the ion sources, especially for many heavy ions. To eliminate the difficulties caused by gases, Middleton and Adams tried to