with adsorbed molecules by a cluster of metal atoms with attached molecules or ligands (*Science*, 20 May, p. 839). According to Plummer, photoelectron spectrums from molecular orbitals of carbon monoxide attached to clusters of as few as four or five metal atoms cannot be differentiated from those obtained from carbon monoxide on metal surfaces. This result indicates that, for properties that can be resolved by photoelectron spectroscopy, the metal cluster model of a surface may be valid.

Perhaps the biggest problem yet to be overcome is the development of a formalism for evaluating ARPES data from molecules other than carbon monoxide adsorbed on surfaces, especially those that have not been so extensively studied in the past that the answers are pretty much known ahead of time. Related to this problem is the need to discover the most efficient way to collect data. With possible variables being the angle of the incident photon beam, the polarization direction of that beam (if it is polarized), and the angle of the photoelectron detector, there is a bewildering volume of data that could be collected, much of it probably redundant or not of interest.

Theorists Dan Dill and Scott Wallace of Boston University have recently proposed that there is a much easier way of collecting data than that used now, when only the orientation of adsorbed molecules is sought. According to their calculations, it is enough to collect simultaneously photoelectrons emitted in all directions for a given orientation of the surface with respect to the incident photon beam, and then to repeat the measurement at many different orientations.

In certain cases, measurements at more than one direction of polarization of plane polarized ultraviolet light can provide geometrical information, even in the absence of angle-resolved measurements. Recently, for example, Jack Rowe of Bell Laboratories and his colleagues reported that chlorine molecules become adsorbed at different types of surface sites on silicon and germanium. (Angle-resolved studies by Smith and Paul Larson of Bell Laboratories have confirmed the results obtained for silicon.) The result is especially interesting because one of the primary reasons silicon, rather than germanium, is the mainstay of the microelectronics industry is its surface chemistry. Because of the different natures of semiconductors and metals, however, results such as these from purely polarization considerations are not in general possible.

In sum, ARPES is beginning to draw a good deal of attention as a way to discern the locations of atoms on a solid surface, but numerous questions are yet to be answered before it will be possible to say whether the technique will become a widely appreciated one or a passing fad.—ARTHUR L. ROBINSON

The Calabi Conjecture: A Proof After 25 Years

About 25 years ago, when Eugenio Calabi, who is now at the University of Pennsylvania, had just received his Ph.D., he began thinking about a difficult and provocative mathematical problem involving the geometry of surfaces of higher-dimensional spaces. Calabi developed a conjecture that had interesting geometrical consequences, but when he tried to prove it true, he ran into difficulties. In 1954, he published his conjecture, but, because he could not prove it, he published a heuristic argument in support of it. The full proof contained a gap that, until recently, no one could close. Now, S. T. Yau of Stanford University has completed the proof of the Calabi conjecture with an argument that mathematicians have described as "complicated and ingenious."

The Calabi conjecture specifies the relation between the concept of distance and the measurement of volume on surfaces in certain higher-dimensional spaces. Calabi speculated that there is a specific relation between the volume and a particular kind of distance function, or metric, on surfaces defined in terms of complex numbers. It is well established that, if a metric for one of these surfaces is known, there is a natural way to find the volume. Calabi proposed that if the volume is known, a particular kind of metric can be found. This metric, called the Kähler metric, reflects the geometry of the surface.

In the years following Calabi's publication of his conjecture, many mathematicians speculated about what would follow if the conjecture were true. They discovered a number of consequences of the Calabi conjecture and then tried to verify these results independently of it. In many cases, they were successful. Thus, as Calabi and others who worked on the conjecture stress, the conjecture is at least as significant for the research it inspired as for what it says about the relation between volumes and metrics of spaces.

In order to solve the Calabi conjecture, Yau had to solve some particularly difficult nonlinear partial differential equations, the solutions to which had eluded mathematicians for more than 20 years. Until recently, even Yau was not certain they could be solved. As of 4 years ago, he did not believe that the conjecture itself was true, because it appeared to be inconsistent with other conjectures that looked plausible. Consequently, Yau tried to prove the Calabi conjecture false, which would follow if the equations had no solutions.

Yau solved the equations by a procedure known as the method of continuity. Starting with a set of data for which a solution to the equations is known, investigators can continuously change the data from the initial set to the set of data for which the solutions are sought, "dragging" the solutions along to fit the changing data. This method, which had been used successfully many times before, requires, in each application, some very difficult calculations. These calculations, according to Calabi, "require a tremendous analytic skill as well as insight into the geometry of partial differential equations."

As a consequence of the truth of the Calabi conjecture, Yau proved true another long-standing conjecture. This conjecture provides a good characterization of the structure of complex surfaces. In particular, it says that the natural structure inherited by the projective complex space is unique.

Most mathematicians familiar with Yau's result predict that it will have ramifications in more than one area of mathematics. For example, some believe it will prove useful in elucidating the geometric structure of an important class of complex spaces, the K-3 surfaces (so called because they were intensively investigated by Kummer, Kneser, and Kodaira). Philip Griffiths of Harvard University thinks it will aid those studying nonlinear partial differential equations. These equations often turn up in applied mathematics and traditionally are extremely difficult to solve. It is too soon to predict exactly how Yau's result will be used. But the solution, after a quarter of a century, of an important problem in mathematics is an event to be noted.

—GINA BARI KOLATA