# Research Notes

## *Old Data, New Answers—I*

"Ill-posed" mathematical problems are those in which the answers are so sensitive to the accuracy of the data that they have been considered unsolvable. Any errors in the data are magnified to produce absurd and unrealistic answers. But now a method for solving them has been developed by Joel N. Franklin, professor of applied mathematics, and a whole array of scientific and engineering problems have become amenable to solution.

What Franklin has done is to restate the ill-posed problem so that the correct answer does not depend so heavily on the precision of the data.

One person who has already found the method useful, Don Anderson, director of Caltech's seismological laboratory, explains that one can describe statistically the data errors and plausible solutions and include those estimations in the calculations of a set of unstable equations.

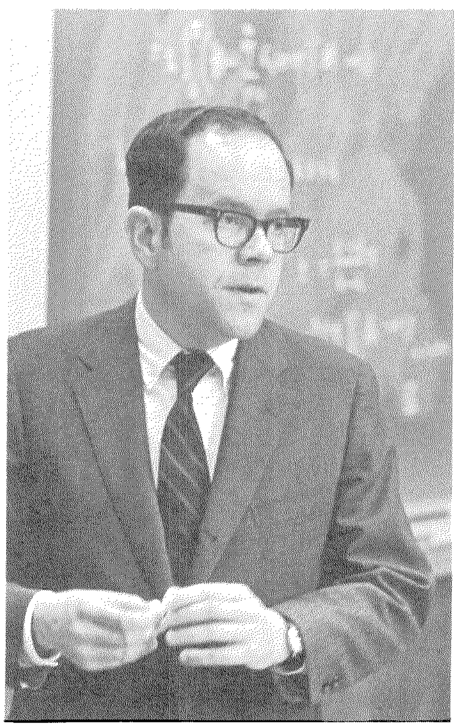
A graduate student working with Anderson, Tom Jordan, says that the data available about the changes of the properties of rocks with depth and increased pressures just don't give enough information to answer questions about the nature of the earth's interior. Franklin's theory lets them introduce new information—namely, educated guesses on what the properties will be.

The principal clues to the nature of the earth's interior are contained in the free oscillations of the earth caused by large earthquakes. If the structure of the earth were known, how it oscillates could be predicted. However, the geophysicists have to work the other way: They have the information about the free oscillations and want to determine the structure.

Their problem is to determine what the composition of the earth would be for it to oscillate as it does. The solution takes the form of a likely mathematical model of the earth, which is then tested in the computer to see if it oscillates the way the real earth does. If the computer shows the same oscillations, then the model is correct. If not, another model is made up and tested.

The computation job is immense. Billions of calculations are involved in what amounts to the solution of a system of linear equations.

The method is an extension of the prediction theory of Norbert Wiener and Norman Levinson. The general definition of ill-posed problems was first given in 1902 by French mathematician Jacques Hadamard, who regarded this class of problems as fundamentally beyond the practical reach of mathematics.



*Joel Franklin*

## *Old Data, New Answers—II*

The earth's mantle is an 1,800-mile-thick layer of material between the crust and the core that has been thought to be uniform in composition. But, according to Don Anderson, director of Caltech's seismological laboratory, it is now clear that the earth is layered most of the way down, and there are about ten separate layers in the mantle. The mantle layering consists of changes in crystal structures in the rock, with some crystals changing shape two or three times as heat and pressure increase with depth. Also, the mantle has perhaps 20 percent more iron at greater depths than was thought, more silicates with depth, and more magnesium at shallower levels.

Anderson's work, which results from the application of the Franklin method described above, implies that the earth has undergone a series of differentiations. Anderson now thinks that the upper 250 miles of the mantle developed out of the lower part, much as the earth's crust differentiated out of the upper mantle. Anderson also says that mantle temperatures are considerably lower than supposed, ranging from about 1,800 degrees Fahrenheit near the top to 5,400 near the base.

The new work confirms the finding that the upper mantle, about 30 to 90 miles down, seems to be at least partly molten. This is the region believed to supply the magma for volcanoes and to form the "sea" on which huge plates of the crust float. Most earthquakes occur at the boundaries of the plates where they are colliding or pulling apart.

Anderson says the next step is to determine how the mantle's composition varies horizontally, and how it varies under the oceans and continents. Variations down to 250 miles are known, but the region below that is still a mystery.

Anderson is assisted in the work by three graduate students. Thomas Jordan is involved in the over-all mathematics; Charles Sammis is working on atomic theory of solids; and Bruce Julian is examining the velocity of earthquake waves with depth.

## *Galactic Explosions*

What is the origin of the spiral arms of galaxies? And of the peculiar S-shaped pairs of streamers that some galaxies have instead of spiral arms? Also of galactic bridges, the streams of material linking two or more galaxies?

Halton Arp of the Hale Observatories has some answers, based on a study of the unusual celestial objects pictured in his *Atlas of Peculiar Galaxies*. In a recent scientific paper, Arp suggests that titanic explosions have ejected matter from such galaxies. The ejected material leaves trails of gas, dust, and stars; these appear as spiral arms or S-shaped arms in galaxies that are rotating. Occasionally they appear as galactic bridges.

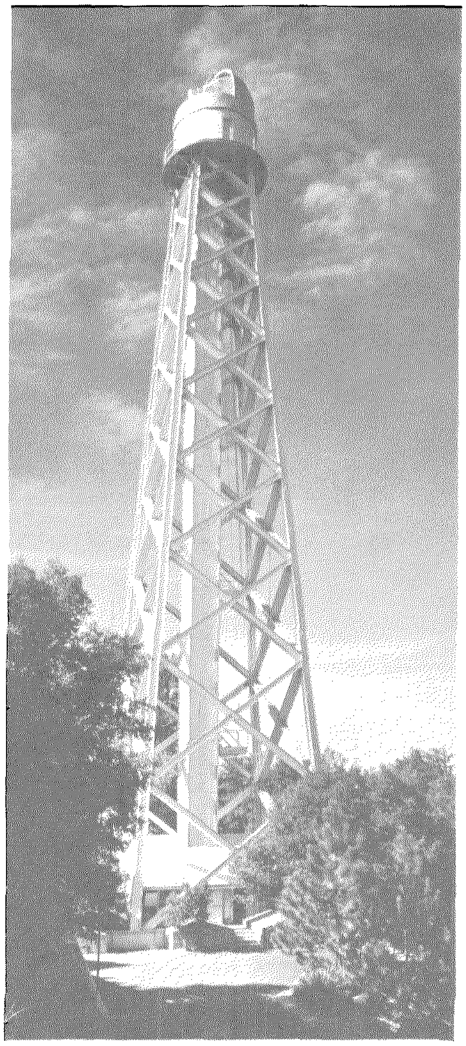
Arp, who earlier suggested that quasars were shot out of galaxies, does not attempt to explain why a galaxy, the largest unit of matter known, would become unstable enough to experience a king-sized explosion. However, an explanation is offered by Fred Hoyle, visiting associate in physics at Caltech and Plumian Professor of Astronomy and Experimental Philosophy at Cambridge University in England. It is possible, he says, that matter and antimatter are somehow generated in equal amounts in the cores of galaxies, with the matter being ejected and the antimatter remaining in the core.

## *Recoating the Mirror*

A delicate rebrightening operation performed on the 200-inch mirror has brought the Hale telescope on Palomar Mountain back up to near-maximum efficiency. A crew directed by Bruce Rule, Caltech's chief engineer for the Hale Observatories, dismantled the 14.5-ton mirror, washed it, then coated it with aluminum only 1/150,000 of an inch in thickness.

The high-temperature coating process was performed in a vacuum chamber at the observatory using 360 tungsten filaments to heat the aluminum until its atoms boiled off and condensed on the cold glass, forming a brilliantly reflective surface.

It was the seventh aluminizing of the 200-inch mirror since it was installed in 1948; the last time the job was performed was in 1960. This latest rebrightening is expected to last for about nine years.



*Mt. Wilson's 150-foot solar telescope*

## *Faster Solar Observing*

For the last 13 years the Hale Observatories' 150-foot tower telescope at Mt. Wilson has provided astronomers with nearly all the magnetic observations that are made of the sun. The telescope produces regular daytime records of the sun's shifting magnetic fields in the form of maps (magnetograms), and also records in pictures (dopplergrams) the large-scale motions in the solar atmosphere. The instrument scans back and forth across the sun, recording the polarity and measuring the strength of the magnetic fields with a magnetograph. At any one time it can observe an area 1/10,000 of the sun's disk—a square 12,000 miles on a side.

At present it takes about an hour to map the entire solar disk, but a new system will cut this time to 15 to 20 minutes when it goes into operation next fall. A computer and associated equipment to improve the performance and speed of the telescope are now being assembled in the Astro-electronics Laboratory at Caletch under the supervision of Edwin W. Dennison, staff member of the Hale Observatories. The computer will control and run the telescope as well as collect and analyze the data.

The new instrumentation may make it possible to learn whether there is any link between sunspots and possible long-term variations in the rotation of solar gases. The improved telescope also will be better able to measure and record the velocities of the gases that rise and fall in the solar atmosphere.

Magnetic observations of the sun are useful in developing methods of forecasting outbursts of activity on the sun's surface, such as solar flares. The speed and sophistication of the new equipment may well improve these forecasts, with the possible practical application of greater safety factors for astronauts, who can be endangered by high-speed atomic particles while in space.

Funds for the improvements, to cost $210,000, are being supplied by NASA and the Air Force Cambridge Research Laboratory.