tween 350 and 2500 psi (1 psi = 6.89×10^4 dyne/cm^2) and temperatures between 225° and 350°C (again depending on the particular coal). The chemicals are then filtered off, regenerated and recycled, and the coal, after washing and drying, is ready for burning.

According to Battelle, this treatment is sufficient to remove nearly all inorganic sulfur and about half of the more tightly held organic sulfur. In experiments with six different types of bituminous coal, the extraction efficiency for organic sulfur varied from 24 to 72 percent. The treatment also removes part of the ash, some of the toxic metals present in coal (including lithium, beryllium, vanadium, arsenic, lead, and thorium), and about 5 percent of the coal itself. An additional treatment step, rinsing the coal with a dilute acid, would make it possible to extract most of the re-

Quasars Flare Sharply: Explaining the Energy Gets Harder

During the last two decades, astronomers have realized that extraordinarily powerful and violent events are commonplace occurrences in the universe. The enormous energies of quasars, large radio sources, and other peculiar objects are continuing puzzlements. Recent research at Harvard University has magnified the problem of the quasars by showing that one of the brighter ones underwent a previously unsuspected flare in 1937, and for a period of several months was the most luminous object known in the universe.

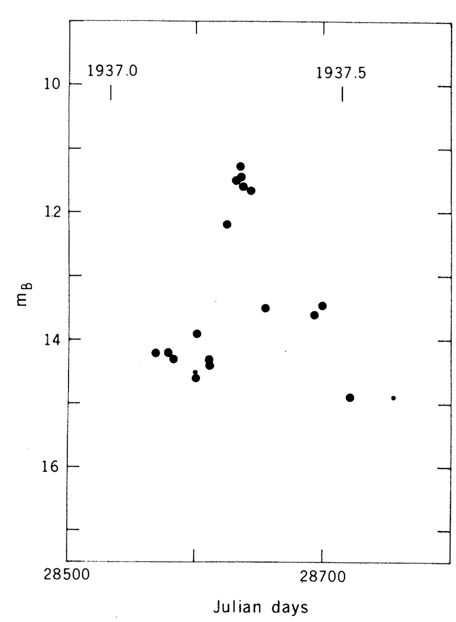
In April of 1937, quasar 3C279 intensified very quickly from its normal optical brightness of 15th or 16th magnitude until it reached a maximum brightness of magnitude + 11.3. The quasar is thought to be more than 5 billion light-years away, assuming that its red shift (0.536) is equally as good a measure of distance as are the red shifts of normal galaxies. At such a distance, the absolute magnitude of 3C279 at the peak of its flare must have been − 31.4. (The magnitude scale of optical brightness is logarithmic, with negative values brighter than positive ones, and five magnitudes equivalent to a factor of 100.) At such a high optical luminosity, the quasar would have been emitting 10^{48} erg/sec.

For comparison with other objects in the universe, the absolute visual magnitude of the sun is + 4.7, that of the entire Milky Way is − 20; the absolute magnitude of a giant elliptical galaxy is typically −22, and that of a bright quasar −26. The flare that occurred in 1937, shown in the figure below, was a phenomenon equivalent in effect to turning on thousands of giant galaxies in a matter of months and then turning them off again. But because the event happened so quickly, the short distance that light could have traveled in that time suggests that it occurred in a region far smaller than a single giant galaxy. "The flare was absolutely huge," according to Harry van der Laan at Leiden Observatory, Netherlands, and constitutes a whole new limit for the energy problem in astronomy.

The photographic plates that contained the record of the depression-era flare of 3C279 were recorded as part of a systematic observing program pursued by the Harvard College Observatory for almost 70 years, from 1885 to 1954, and recently renewed. From the observatory site in Cambridge, Massachusetts, and from the Agassiz station about 40 miles away, Harvard astronomers conducted a regular patrol of the Northern Hemisphere. Regular coverage of the Southern Hemisphere was carried out at the Harvard southern station, which was located in Arequipa, Peru, until 1924 and then moved to Bloemfontein, South Africa. About 500,000 plates were made during the time the sky patrol was active. Every portion of the sky was typically photographed with wide-angle cameras several times a year.

The plates have been carefully stored on three floors of the old observatory building, which now adjoins the building of the Smithsonian Astrophysical Observatory. Two years ago, with the encouragement of George Field, who sits as director of both institutions, Harvard astronomers began looking into the plate collection for data that would be relevant to some of the newer scientific frontiers—particularly high-energy astrophysics. William Liller and associates at Harvard found evidence for a regular optical period in the brightest x-ray source in the sky, Sco X-1, and also began a survey of the variability of the optical emissions of the brighter quasars. William Liller, Martha Liller, and Lola Eachus found evidence for flares not only in 3C279, which exhibits the most pronounced flare discovered so far, but also in quasar PKS 1510-089, and in the quasar-like object MA 0829 + 047. There is also some evidence from the Harvard plates that quasar 3C279 flares regularly every 7 years, since brightness peaks were recorded in 1944 and 1951.

The power produced by quasar 3C279 peaked at a value greater than that known for any other object. Over one period of 13 days in 1937, the quasar emitted an average of 10^{41} watts, assuming it is at the cosmological distance given by its red shift. This is an enormous power, comparable to that discussed in trying to explain the double radio sources (*Science*, 27 June 1975). The radio sources continually emit 10^{37} watts. But Geoffrey Burbidge, at the University of California, San Diego, suggests that it may be just as much of a problem to explain how radio sources can emit 10^{37} watts for millions of years as to explain how quasars can emit 10^{41} watts for a few days or months.



As one of the school of astronomers who question whether the red shifts of quasars are indicators of their cosmological distances, Burbidge also questions whether 3C279 really became as bright as magnitude − 31.4. But he thinks that the discovery is nonetheless significant. Either 3C279 is much closer, according to Burbidge, or else "you cannot appeal to the evolutionary processes of normal stars" to explain it.—William D. Metz