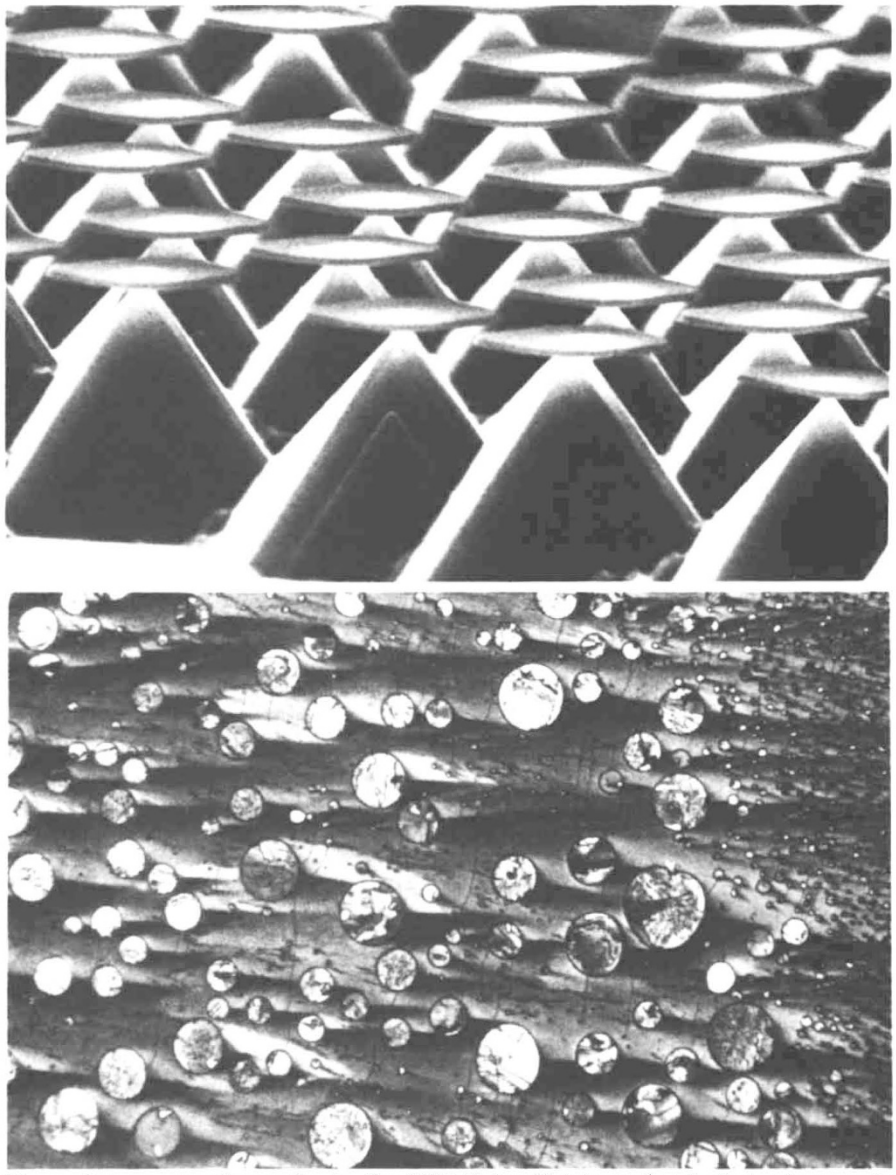

These pictures won first prize in the 1985 Polaroid international photomicrography competition. The top picture of a recrystallized mixture of sulphur and ketone was taken by William E. Schadel of Raleigh, North Carolina, using a Nikon polarizing microscope and a 35mm camera (1,680×). The bottom picture of etched silicon was taken by Anita Brandes of the Gould Research Center, with a Jeol scanning electron microscope (10×).

Distant galaxies

Pushing back the redshift limit

from C. Martin Gaskell

THE search for ever more distant galaxies has become one of the main challenges of observational cosmological research. The more distant a galaxy the greater its redshift because of the overall expansion of the Universe; astronomers generally prefer to speak of the redshift of an object rather than its distance. In this issue, J.S. Dunlop *et al.* (*Nature* **319**, 564; 1986) report the discovery of a new quasar, PKS1351−018, with a redshift (z) of 3.72. And also just recently, S. Djorgovski *et al.* (*Astrophys. J. Lett.* **299**, L1; 1985) have discovered the most distant non-quasar galaxy known. What do these discoveries mean?

Last year in these columns (*Nature* **313**, 628; 1985) I commented that the greatest known redshift for quasars had crept from 3.53 in 1974 to 3.78 in 1982, while in the same period the greatest known redshift for non-quasar galaxies shot from 0.46 to 1.82. The recent discoveries continue this trend. Djorgovski *et al.* have pushed the redshift record up to 3.218, while the quasar discovered by Dunlop *et al.* is the second most distant quasar known. There are now more than 70 quasars with redshifts greater than 3.0, but the distribution still cuts off sharply at around 3.7.

It has required much effort to measure the redshift of PKS1351−018. Dunlop *et al.* had to obtain an accurate radio position of a compact source in an apparently blank region of the sky; then deduce from infrared colours obtained with the UK infrared telescope that the object was probably a high redshift quasar; and finally obtain an optical spectrum with the Anglo−Australian telescope. It is of interest that although PKS1351−018 is considerably fainter that the previously discovered quasars with redshifts greater than 3.5, it proved to be no more distant. Does $z=3.8$ represent some sort of 'turn-on' epoch for quasars? The suspicion is that it does, but it will take more painstaking work to establish this.

Quasars are located in the nuclei of galaxies. Does $z=3.8$ represent some critical time for galaxy formation? A normal galaxy at a redshift greater than 3 is exceedingly difficult to find but the task is much easier if one knows just where to look. Extrapolating from common experience with low redshift galaxies, Djorgovski *et al.* reason that the best place to look for a galaxy is next to another galaxy. Because quasars are located in the nuclei of galaxies they decided to use quasars as signposts or beacons for their normal companion galaxies. They chose a small sample of distant quasars and used an interference filter to look for objects emitting Lyman alpha at the redshift of the quasar. In their first 20-minute exposure with the 3-metre telescope at Lick Observatory they discovered an object emitting strong Lyman alpha near a quasar. The object has the sort of spectrum expected from a mildly active galaxy at high redshift but not the sort one sees from a quasar.

The interest of this galaxy is that it is observed when the Universe was only some 14 per cent of its present age (if we assume a critical density Universe). This galaxy is probably less than 9 per cent of the present age of galaxies depending on just when galaxies formed. If galaxies formed more recently than $z=4$ then the Djorgovski *et al.* galaxy could be a good approximation to a 'primeval' galaxy.

The nature of this galaxy is still unknown, but perhaps the most important thing is that the method, using interference filter images of high redshift quasars to find extremely distant young galaxies, works. The technique promisies to expand studies of distant galaxies to redshifts as high as as those of the most distant known quasars and opens the door for studies of galaxies beyond $z=3$. □

C Martin Gaskell is in the Department of Astronomy, Ohio State University, 174 West 18th Avenue, Columbus, Ohio 43210, USA.