giant arc, but the most distant cosmic object with measured redshift. Two similar red arcs, with redshifts of about 4.05, are seen in the cluster A2390 (R. Pello and G. Soucail, Obs. Midi-Pyrénées, Toulouse).

The mass distribution in the central part of galaxy clusters is still a matter of debate. Most simulations predict that clusters have sharply peaked central density, rather than a finite core where the mass distribution flattens. Fortunately, so-called radial arcs — linear images of background galaxies oriented in the direction to the cluster centre, like a spoke in a wheel — can precisely mark the size of such a core. A second radial arc found in the cluster MS2137 settles its core size at around 30,000 parsecs.

A striking feature of strong gravitational lenses is the formation of multiple images of a background source. In the cluster AC114, two five-image configurations have been discovered (J.-P. Kneib, Obs. Midi-Pyrénées), but even more impressive is the first septuple arc: seven images of the same background galaxy, lensed by the cluster CL2244. This abundance of high-multiplicity images tells us that the matter distribution in clusters is not smooth, but rather that the individual elliptical galaxies have massive dark haloes and hence produce complicated caustics (Fig. 1) and multi-image configurations (Kneib).

Giant arcs are produced only by the biggest galaxy clusters. Smaller clusters are much more numerous, but they only distort background galaxies slightly, stretching their images tangentially. This weak deformation cannot be detected in a single lensed object, but because this is a coherent shear effect on all background galaxies, hundreds or thousands of galaxies are tangentially aligned around the cluster. This weak-lensing signature contains a huge amount of information about the cluster potential[6]. Elegant reconstruction techniques[7] have now permitted quantitative determination of the shear and the total mass distribution in more than ten clusters (H. Hoekstra, Kapteyn Inst., Groningen; N. Kaiser, CITA, Toronto; Y. Mellier, Institut d'Astrophysique de Paris, Paris; P. Schneider, MPI für Astrophysik; G. Squires, Univ. Berkeley; L. van Waerbecke, Obs. Midi-Pyrénées). Measurement of shear at the one-per-cent level now seems possible — good enough to be another tool for distinguishing between cosmological models.

The University of Hawaii has built an 8,192-by-8,192-pixel CCD camera that made it possible to map three clusters with comparable redshift within one field. Mass reconstruction and subsequent comparison with each cluster's light distribution makes it clear that the mass-to-light ratios of clusters vary by at least a factor of two. A fourth cluster was discovered just by the statistical analysis of weak distortions — the first 'lens-selected' galaxy cluster (G. Luppino, Univ. Hawaii).

Another tool for determining the masses of galaxy clusters is X-ray observation, which only agrees to within a factor of two with the lens-based method. One reason for this apparent conflict may be the fact that clusters selected because of their strong lensing effect are preferentially dynamically active, with lots of substructure, whereas the X-ray based methods are most reliable for clusters with little substructure (M. Bartelmann, MPI für Astrophysik; H. Böhringer and S. Schindler, MPI für Extraterrestr. Physik, Garching).

A more recent application of gravitational lensing is the study of the effect of large-scale structure on background sources. Here, weak lensing comes in two guises: as well as distorting the shapes of extended sources, it affects the apparent brightness of unresolved sources. Inspired by Richard Feynman, Jim Gunn worked out the consequences of both effects 30 years ago[8]. The first effect will, in the next few years, allow us to determine the underlying primordial power spectrum of the matter distribution through measurements of this 'coherent shear' on large angular scales, and hence learn about the initial conditions of the early Universe (A. Stebbins, Fermilab; B. Jain, MPI für Astrophysik).

But not all aspects of lensing are considered a blessing by astronomers. Large-scale structures modify the apparent brightness of distant 'standard candles', which may make it more difficult than originally thought to determine the deceleration parameter (and so the density) of the Universe by measuring the apparent brightness of type-Ia supernovae as a function of redshift. Fortunately, it turns out that for most cosmological models this lens-induced dispersion is smaller than other observational uncertainties (J. Frieman, Fermilab; J. Wambsganss).

The workshop showed that the prospects for the future of lensing are good. Weak and strong lensing around clusters of galaxies and elsewhere will be one of the most useful tools in the next decade for the study of the matter distribution in the Universe. And it may be that in about a dozen years, most astronomers will have to deal with a gravitational-lens-distorted view of the Universe[9]. □

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Daedalus

Thinking makes it so!

Are electromagnetic fields a health hazard, and if so, why? One suggestion is ion cyclotron resonance. This effect is best known in plasmas, whose free ions can be excited to orbit around magnetic field lines by radio waves of the same frequency as the ionic orbits. By analogy, ions in the body might orbit around geomagnetic lines of force, if excited by a suitable a.c. field — in this case in the low audio range. Computer screens, power lines and so on emit in this range; and internal orbiting ions might well be bad for you.

This theory, says Daedalus, suggests a splendid new way of exploring the brain and nervous system. A nerve conducts by the sudden collapse of the voltage across its membrane, as sodium ions flood in from outside. Potassium ions are then promptly expelled again, restoring the resting potential ready for the next pulse. The ions traversing the nerve membrane will be constrained by its narrow channels; but the ones displaced on either side will be freely deflected by the magnetic field. At the fastest nerve-firing rate, the ions would be looping round almost continuous orbits at about 500 Hz. So they could absorb a 500 Hz a.c. signal by ion cyclotron resonance. Potassium ions are heavier than sodium ions, so the oscillation will not be exactly sinusoidal. Its absorption band will have a characteristic shape or overtone structure.

DREADCO technicians are now building a special headset to study the brain by ion cyclotron resonance. Its magnetic field gradient will be chosen so that only a specific slice of the brain can resonate at any given applied frequency, and its a.c. electrodes will be shaped to give a strong field only in a limited area of this slice. Accordingly, it will probe the state of activity in one small region of the brain. This region will be scanned round the brain by varying the field and frequency.

Ion encephalography will be far more informative than the old EEG. Not only can it probe very small regions; it can react as fast as the nerve cells themselves. Under computer guidance, it will soon be able to recognize the signatures of thousands of different brain states. The computer will then be accessible to purely mental control. The wearer of the headset will merely have to think of a command; the headset will detect it; the computer will recognize it and carry it out. At last that pestilent invention, the keyboard, will be vanquished. Lower back pain and repetitive strain injury will vanish from our lives; we will command our computers by thought alone.

David Jones