Astronomy

A means to sharper images

E. Keith Hege

INTRICATE details of the astronomical systems observed with Earth-bound telescopes are destroyed by atmospheric distortion. But advances in our understanding of the Earth's atmosphere, together with recent image-reconstruction techniques, promise to make available distortion-free images commensurate with the light-gathering capabilities of modern apparatus. On page 229 of this issue, L.A. Thompson and C.S. Gardner describe an artificial star, produced by a laser beam scattered in the upper atmosphere, that may enable astronomers to unscramble atmospheric effects in distorted images. This technique could have applications in high-energy-beam defence systems.

Until recently, the giant telescopes of modern astronomy, used as cameras that record the images of distant objects, could see no more sharply than Isaac Newton's telescope. The large instruments are used to gather more light, and thus to look at greater distances, but their intrinsic ability to produce sharp images is seriously impeded by the turbulence of the atmosphere, through which all ground-based instruments must view the sky. This turbulence limits the sharpness of a directly-recorded image from any large telescope to that of a small telescope with an aperture of only 10–15-cm diameter, except during the very rare moments of exceptionally low turbulence, which astronomers call 'good seeing'. Even in those rare moments the resolution is insufficient to reveal details on the surface of the nearest stars, other than the Sun. The full, diffraction-limited resolution of the largest ground-based telescopes can be exploited, however, by using fast computers that execute complex image-reconstruction algorithms. For this, short-exposure images are required, obtained with highly efficient detectors capable of recording individual photons.

These image-reconstruction methods are limited to objects of sufficient brightness that several correlated photons can be recorded in the time during which the atmospherically distorted image does not change by more than the telescope's limit of resolution — typically 5–50 ms. Correlated photons are those that arrive within the 10–15-cm subaperture of the telescope's pupil that determines the sharpness produced in the conventional camera mode. These requirements limit these methods to sources brighter than visual-magnitude 17, independent of the size of the telescope, corresponding only to the closest galaxies with active nuclei

and the brightest quasi-stellar objects.

Fortunately, optical physics enables us to unscramble the atmospheric distortions if the image field of view contains an unresolvable (point) source, but very few objects of interest are matched with such bright point sources. The field of view to which any of these methods can be applied, the so-called isoplanatic field of view, is very limited — typically about 2 arc seconds. For the cases in which a sufficiently bright point is present, two methods are available to remove or reduce the atmospheric blurring. Adaptive-optics systems can measure and correct for the atmospheric distortion; deconvolution methods, related to holography, can correct a sequence of simultaneous short-exposure images of the point source and the object of interest. If the point source is bright enough, it should be possible to correct the image of any source in the isoplanatic field of view.

The results of the experiment reported

by Thompson and Gardner are therefore of great relevance in the quest for high-resolution images. The artificial star they create by scattering a laser beam off sodium vapour in the upper atmosphere is an alternative to a genuine natural point source that can always be put in the field of view of the telescope.

It seems unlikely that it will be possible to project a 'star' sufficiently point-like to be the perfect key to deconvolution. The mesosphere is neither infinitesimally thin nor infinitely distant, and the 'star' will have a size determined by diffraction in the projector itself (which could be the telescope). Nevertheless, the experiment shows that it is possible to project a source that is sufficiently bright to be useful. The approximate key to deconvolution provided by the guide star should increase the size of the effective correlated aperture and the effective atmospheric correlation time. These two benefits, in a system using adaptive optics to provide optimum data to the image-reconstruction methods otherwise available, can extend the highest resolving powers to even fainter targets in the early Universe. □

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Molecular neurobiology

Channel families in the brain

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MANY in the molecular neurobiology business have suspected all along that channels — membrane proteins mediating transmission of information in the brain — would fall into genetically related families, but this expectation has been based on analogies to other systems, such as the rhodopsin/ β -adrenergic/muscarinic receptor family¹, rather than on direct information. Now, suddenly, it has been shown in four different laboratories that the expectation is correct and family structures are beginning to emerge. Specifically, the glycine (page 215 of this issue²) and GABA_A (page 221³) receptors share similarities in amino-acid sequence with the nicotinic acetylcholine receptor channel, and a mammalian muscle calcium channel⁴ and a *Drosophila* (fruitfly) potassium channel⁵ are similar to the sodium channel.

Up until now, the taxonomy of channels has been based on their functional properties. Two main groups of channels have been identified: ligand-gated channels, proteins located in postsynaptic membranes that bind specific neurotransmitters and open a pore to function in synaptic transmission; and voltage-gated channels, integral membrane proteins designed to sense the transmembrane electrical field and open ion-specific pores to produce

nerve impulses and other forms of electrical excitability. Each of these two groups has perhaps dozens of members. In the past, ligand-gated channels were classified pharmacologically (according to which substances they bind), whereas the voltage-gated channels were distinguished by the ionic selectivity of their pores and by properties related to the manner in which they open and close. The new data mean that channels can be classified according to their structure.

The first ligand-gated channel to have its structure determined was the nicotinic acetylcholine receptor (AChR) (see the letter to *Nature* by Noda *et al.*⁶). Various AChRs, both from muscle and from brain, are known, and these molecules themselves form a family tied together by strong similarities. Their important characteristics are that each receptor is constructed from multiple distinct subunits (four in muscle but perhaps only two in brain^{7,8}) that are closely related genetically; and each subunit is structurally similar to others in that they all have a very similar pattern of alternating hydrophilic and hydrophobic regions (*a* in the figure). In particular, there are four domains, each with around 20 consecutive hydrophobic amino acids, in all of the known AChR