Wampler *et al.* (**246**, 203; 1973) of a pair of quasars a few seconds of arc apart but with very different redshifts, and by Hazard *et al.* (**246**, 205; 1973) of several examples of quasars apparently in clusters of galaxies but with much larger redshifts than the cluster could have, must raise doubts in the minds of all but the most diehard cosmological redshifters (by no means a rare species).

Not so long ago Karlsson (*Nature phys. Sci.*, **245**, 68; 1973) was suggesting that the regular peaks in the distribution of quasar redshifts (Burbidge's 'periodicity') were absent from the quasars with extended radio sources, but present for the compact quasars. Unfortunately this was not established at a very significant level statistically.

This is again true for Plagemann's claim of anisotropy on the sky of compact quasars. When one works through his paper, past Fisher's method of statistical analysis of dispersion on a sphere, Monte Carlo computer algorithms, and topological considerations, it turns out that Plagemann's complete sample of compact quasars has only seven objects in it, and that the anisotropy disappears if three quasars at low galactic latitude have failed to be identified.

Clearly nobody is going to be moved from their favourite theory of quasar distances by that kind of statistics, or indeed by any kind of statistics. What is needed (as Wampler *et al.* point out) are good examples of associations of quasars and galaxies with different redshifts and signs of interaction. It is too much to hope to see a galaxy flare up, become a quasar, and change its redshift.

NUCLEAR STRUCTURE

New Giant Resonances

from our Nuclear Theory Correspondent

ONE of the most interesting events in recent years has been the discovery of new giant resonances in nuclei. The broad maxima in many reaction cross-sections around 20 MeV for light nuclei and at progressively smaller energies for heavier nuclei have long been known and are interpreted as E1 dipole resonances. They have been analysed microscopically as a coherent superposition of particle-hole excitations and more physically as the oscillation of the protons and neutrons in the nucleus against each other.

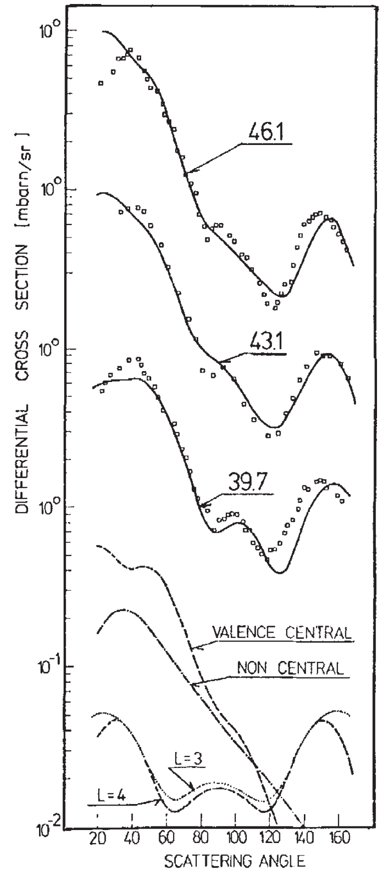
Enhanced cross sections have now been found at higher energies, and these are interpreted as giant multiple resonances of higher order. These resonances can be excited by inelastic proton scattering, and a particularly striking example has recently been analysed by Geramb, Sprickman and Strobel (*Nucl. Phys.*, **A199**, 545; 1973). They examined the differential cross sections for the ^{16}O(p,p′)^{16}O reaction to the $J^{\pi}=2^{-}$ state at 8.88 MeV for proton energies from 23 to 46 MeV. Such cross sections are usually analysed by the microscopic distorted wave theory using an effective interaction consisting of central, spin and isospin-dependent and tensor components. Such a calculation gives a good account of the forward cross section but falls rapidly in the backward direction and completely fails to account for the prominent peaks found experimentally. This indicates that another mechanism is contributing to the reaction.

The forward peaks that are well understood by the direct distorted wave theory are inhibited in reactions involving a parity change compared with those involving no parity change. The backward peaks are thus more prominent in parity-change reactions, so these provide a better test of models devised to account for them. In the ^{16}O(p,p′)^{16}O to the 2^{-}, 8.88 MeV state the conservation of angular momentum and parity require $S=1$ spin flip and parity change, implying a spin-dependent interaction or an exchange contribution.

The mechanism proposed is the excitation of a multipole giant resonance by the incident particle followed by decay of the resonance by proton emission. The nucleons remaining after emission combine with the proton initially responsible for exciting the resonance to give the final excited nuclear state. This process is called the core polarisation exchange mechanism. It is an exchange process because the emitted nucleon is not the same as the incident nucleon, as it is in direct processes. The direct core polarisation mechanism makes no contribution to the transitions involving a change of parity.

The cross section for this mechanism was calculated by the antisymmetrised distorted wave theory. The ground state of ^{16}O is a doubly closed shell, and the 2^{-}, 8.88 MeV state is represented by linear combination of particle-hole excitations. The incident and outgoing particles are represented by distorted waves generated by a complex optical model potential with spin-orbit coupling. The particle-core interaction is restricted to exchange contributions with isospins for the intermediate resonance states of $T=0$ or 1.

The data from 23 to 46 MeV were analysed assuming a direct contribution plus a core polarisation exchange contribution, and the amplitudes and energies of the giant resonance contributions were adjusted to optimise the fit to the inelastic scattering data. It was found that a good overall fit is obtained with giant quadrupole ($L=2$), octupole ($L=3$) and hexadecupole ($L=4$) resonances at 24, 35 and 42 MeV respectively, in addition to the familiar dipole ($L=1$) resonance at 22 MeV.



Differential cross sections for the ^{16}O (p,p′)^{16}O* (2^{-}, 8.88 MeV) reaction at 39.7, 43.1 and 46.1 MeV compared with distorted wave calculations including the $L=3$ and $L=4$ giant resonances. Also shown are the separate contributions of each reaction mechanism.

The experimental differential cross sections for the ^{16}O(p,p′)^{16}O (2^{+}, 8.88 MeV) reaction at 39.7, 43.1 and 46.1 MeV are compared with the calculations in the figure. Also in the figure are shown the contributions of the valence central and non-central interactions, which together account very well for the forward cross sections but not at all for the backward. In this energy range only the $L=3$ and $L=4$ giant resonances contribute appreciably, and as shown in the figure they are able to account very well for the backward peak in the experimental cross sections.

These higher order resonances have been found in several other reactions and in particular the (p,2p) reaction seems to provide a promising way of exciting them. These resonances have widths of several MeV, so they are not so easy to study as narrower ones; it is therefore desirable that they should be excited in as many ways as possible to ensure that all the data are consistent with the interpretation. It is likely that such data will soon be forthcoming and will enable thorough studies to be made of these new modes of nuclear excitation.