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On the Existence of a Giant Monopole Resonance in ^{208}Pb and ^{197}Au*

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ABSTRACT

Evidence recently presented concerning possible E0 giant resonance states in ^{208}Pb and ^{197}Au is discussed. It is shown that these states may be equally well of E2 character.

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In a recent letter[1] evidence for the first observation of a giant monopole (E0) resonance is presented. States were located in both ^{197}Au and ^{208}Pb at $E_x \sim 53A^{-1/3}$ by decomposition of a complicated spectrum of inelastically scattered electrons. The widths were found to be 2.2 and 1.8 MeV, and the strengths appear to exhaust a large fraction of the E0 sum rule. The states show an angular distribution consistent with either E0 or E2, but the DWBA calculations give a somewhat better fit if an E0 is assumed rather than an E2. The main argument with which the authors rule out a E2 assignment is, however, based on the nonappearance of the state in (γ,n) excitation. However, the arguments presented below indicate that if the state was E2, it would not be visible in (γ,n).

The (γ,n) argument in the letter is apparently based on an incorrect calculation. Using the energy weighted sum rule,[2] which is not model dependent,

$$\int \frac{\sigma(E)\,dE}{E^2} = 4.3 \times 10^{-4} \frac{Z^2}{A^{1/3}} \text{ MeV}^{-1} \text{-mb.}$$

We find that an E2 state at $E_x = 9$ MeV in ^{208}Pb which exhausts 100% of the sum rule would possess a total cross-section of 50 MeV-mb. But we know that this state could not exhaust more than 16% of the sum rule since it is less than one fifth of the strength of the known E2 state at 10.5 MeV according to the decomposition of the authors. The peak height, σ_{peak}, of a Lorentzian with width Γ and area σ_{total} is given by

$$\sigma_{total} = \frac{\pi}{2} \Gamma \sigma_{peak}$$

The cross section, σ_{peak}, at the peak of the resonance therefore comes out to be 3 mb not 30 mb as found by the authors. The (γ, n) cross section[3] in this region is smooth and about 50 mb, and therefore it would easily obscure a 1.8 MeV wide 3 mb high peak. In fact, the five times stronger E2 state at 10.5 MeV is only weakly evident. We, therefore, conclude that the contention of an E0 state far from proven.

It is interesting to discuss the implications of a strong E0 state at 9.2 MeV. The monopole energy is related to a fundamental property of nuclear matter, the compressibility. According to the hydrodynamic model,[4] a breathing mode in ^{208}Pb depends on compressibility according to

$$E_{monopole} = 0.95 \sqrt{\kappa}$$

where the compressibility is defined in terms of the binding energy per particle E/A and the radius characterizing the volume per particle, r_o, as

$$\kappa = r_o^2 \frac{\partial^2}{\partial r_o^2} \left(\frac{E}{A}\right)_{r_o} \quad \text{(MeV)}$$

This model is borne out by microscopic calculations with Hartree-Fock theories.[5] If the monopole strength were centered at 10 MeV, the compressibility would be about κ = 110 MeV. Extrapolating to higher density, a prediction could be made the heavy ion collisions might produce complete overlap of the nuclei at center-of-mass energies as low as 6 MeV per nucleon. However most current theory favors a much higher compressibility $\kappa \sim 200-400$ MeV.[6,7]

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