CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY

http://cyclotron.tamu.edu

Simple Oscillations of the Nucleus of the Atom: Can We Predict Them?

How well do monopole, dipole, quadrupole and octupole shape oscillations of the nucleus agree with predictions using an otherwise very successful interaction between nucleons (neutrons/protons) in the nucleus?

THE SCIENCE

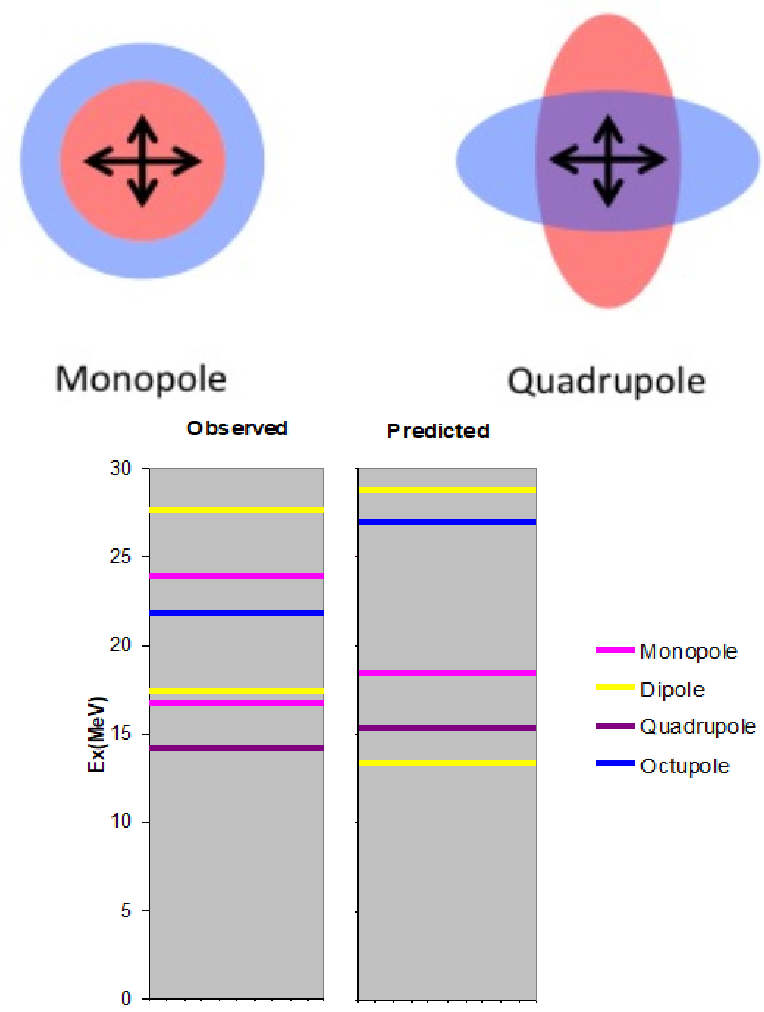
The atomic nucleus can be excited into shape oscillations where many of the neutrons and protons oscillate together, forming particular shapes as they oscillate. The simplest of these can be speherical (monopole), stretched alternately about two axes (quadrupole) or three axes (octupole), or a more complicated shape (dipole). The frequencies of oscillation of these simple modes can be measured in the laboratory and compared to predictions using an interaction between the nucleons that successfully predicts many other nuclear properties.

THE IMPACT

By measuring the frequencies of these oscillations in nuclei of the same element, but containing different numbers of neutrons, we can compare with predictions for these nuclei and test how the model works as you change the relative numbers of neutrons and protons. The different modes are sensitive to different parts of the interaction, permitting separate measures of individual parts of the interaction.

SUMMARY

Monopole, dipole, quadrupole and octupole shape oscillations of the nucleus were measured for zirconium and molybdenum isotopes at the Texas A&M Cyclotron Institute. Predictions of the frequencies of these modes were then done using an interaction between nucleons in the nucleus that has worked very well when predicting other nuclear properties. On average, the predictions for the dipole are in reasonable agreement with the data. The predictions for the quadrupole and octupole were consistently high for all the isotopes, suggesting a parameter in the interaction called the "effective mass" is too high. Except for the isotopes having 92 total proton and neutrons, the average monopole frequency was well reproduced, however experimentally two monopole oscillations with slightly different frequencies are seen in each nucleus. Only one is predicted. This, and the differences in frequencies for the isotopes with 92 nucleons suggest some important aspect of the nuclear properties is not included in the prediction.



Top: Two shape oscillations of the nucleus. **Bottom:** Observed and predicted energies of different shape oscillations for the nucleus of the Molybdenum isotope with 50 neutrons.

David H. Youngblood

Yiu-Wing Lui

PUBLICATIONS

Krishichayan, Y.-W. Lui, , J. Button, D.H. Youngblood, G. Bonasera, and S. Shlomo, "Isoscalar giant renosances in $^{90, 92, 94}$Zr," Phys. Rev. C 92 (2015).

D.H. Youngblood, Y.-W. Lui Krishichayan, J. Button, G. Bonasera, and S. Shlomo, "Isoscalar E0, D1, E2 and E3 strength in $^{92, 96, 98, 100}$Mo," Phys. Rev. C 92, 014318 (2015).

FUNDING

This work was supported by the U.S. Department of Energy.

ABOUT THE CYCLOTRON INSTITUTE: *Dedicated in 1967, the Cyclotron Institute serves as the core of Texas A&M University's accelerator-based nuclear science and technology program. Affiliated faculty members from the Department of Chemistry and Department of Physics and Astronomy conduct nuclear physics- and chemistry-based research and radiation testing within a broad-based, globally recognized interdisciplinary platform supported by the United States Department of Energy (DOE) in conjunction with the State of Texas and the Welch Foundation. The facility is one of five DOE-designated Centers of Excellence and is home to one of only five K500 or larger superconducting cyclotrons worldwide.*