Distorted nuclei spinning to the same beat

"Only occasionally in any area of science is something really unexpected found, but that seems to be the case in nuclear-structure physics just now."

This arresting assertion introduces a report in the July 16 PHYSICAL REVIEW LETTERS concerning the spectra of gamma rays emitted by certain atomic nuclei spinning so rapidly that their shapes become extremely elongated. Unexpectedly, different kinds of "superdeformed" nuclei often produce spectra representing virtually identical sequences, or bands, of energy transitions – despite having different numbers of protons or neutrons.

"I think it's one of the most unusual things we've seen in a long time," says Frank S. Stephens of the Lawrence Berkeley (Calif.) Laboratory, the report's lead author. "As far as I know, nothing in our current understanding explains this behavior. There are lots of reasons why it shouldn't happen."

"It's a very hot topic at this moment," adds John F. Sharpey-Schafer of the University of Liverpool in England. "Why do you get such beautifully identical bands, and why are they so pervasive?"

The typical superdeformed nucleus is the product of an off-center collision between two moderately sized nuclei. The colliding bodies fuse to create a single, whirling entity. If a rapidly spinning nucleus has a mass that falls within a certain, well-defined range, it tends to settle into an elongated shape with a length roughly twice its width (SN: 5/28/88, p.346).

These spinning nuclei slow down in steps, losing energy and angular momentum by emitting a pair of gamma rays at each step. Filtering and analyzing the signals received by an array of gamma-ray detectors reveals a characteristic spectrum, or band, consisting of as many as 20 equally spaced lines.

Researchers have detected such bands for a variety of superdeformed nuclei, and a given nucleus may have as many as six bands, each one representing a different configuration of protons and neutrons but all having the same, extreme deformation. The surprise is that different superdeformed nuclei sometimes produce bands that are strikingly similar.

"That's something we don't expect because just the fact that you've added a nucleon or two nucleons ought to change the moment of inertia [rotational inertia] by quite an appreciable amount," Stephens says. In other words, the additional neutrons or protons should change the mass distribution enough to noticeably alter the way the nucleus spins.

So far, researchers have identified several apparently related sets of bands among dysprosium and related isotopes and at least nine among mercury and lead isotopes. "That doesn't look at all like an accident," Stephens says.

However, the reason why nuclei should behave in this way is "still up in the air," says Richard R. Chasman of the Argonne (Ill.) National Laboratory. Although theorists are hard at work, no single, coherent explanation to account for all the results has yet emerged.

Moreover, the quantum-mechanical calculations needed to make predictions about the behavior of nuclei are horrendously complicated. In fact, nuclear physicists usually rely on simpler theoretical models that merely approximate nuclear behavior. Studying superdeformed nuclei is one way to probe the strengths and weaknesses of these models. The unexpected experimental results show that these simplified models miss a potentially important aspect of the way nuclei are organized.

"In terms of the sorts of calculations that we can do, it's very hard to explain the [spectral] similarities down to the level [of precision] to which they're seen experimentally," Chasman says. "The calculations are just a little too crude."

"We have this astoundingly loud and clear signal that we don't understand," Stephens says. "The similarities are so striking, my feeling is that the answer can't elude us for very long." *—I. Peterson*

Space base heads back to the drawing board

NASA sent its space station designers back to work upgrading their ideas last week after an internal study warned that without major modifications to the $37 billion project, astronauts would have to devote well over 3,200 hours a year in spacewalking activities just to maintain the earth-orbiting base.

NASA released the study July 20, along with a second report that offered 100 recommendations that its engineers estimate would cut the need for time-consuming and potentially dangerous extra vehicular activities (EVA) to 485 hours a year. These include modifying some parts to last longer and need less repair; redesigning certain components so astronauts inside the station can fix them with robots; removing nonessential systems to lessen repair needs, and developing ways to reduce the time required to prepare for a spacewalk.

The space station remains in the design phase, with the fabrication of its parts still several years away. NASA says its astronauts will begin orbiting and assembling the station's components in 1995.

"The maintenance problem starts the day of the first element launch," notes John E. Pike, director of the Space Policy Project at the Federation of American Scientists in Washington, D.C. One NASA official says repairs required during the station's assembly pose a major concern, because astronauts must use the space shuttle for both living and as a work base.

Coming so soon after NASA's troubles with the Hubble Space Telescope and the grounding of the three space shuttles, the need for significant design revisions inevitably renewed questions about the need for the space station and NASA's ability to succeed with such a complex and costly project.

Pike, for one, envisions no abrupt end to congressional support for the space base. "But it does mean NASA will have to get its act together," he says. An aide says Sen. Jake Garn (D-Utah), who has orbited Earth aboard the space shuttle, and other members of the Senate appropriations subcommittee that handle NASA's budget, are "not thrilled" with the report. But Garn views NASA's planned corrections as "what the agency should be doing."

The surprising estimate on the space station's maintenance requirements came from a panel headed by astronaut William F. Fisher and robotics specialist Charles R. Price of NASA's Johnson Space Center in Houston.

Considering the time needed to prepare for a spacewalk, the actual time outside the space station, and the uncertainity of how long specific repairs may take, the Fisher-Price panel concluded that maintaining the permanently occupied space base would require 3,276 astronaut hours a year, or an average of nearly nine astronaut hours a day. The six-month, $1 million study's figure nearly doubles that of an earlier NASA study, which estimated a need for 1,732 hours of EVA-related maintenance annually.

One factor affecting the EVA-related hours is the need for astronauts to breathe extra oxygen for several hours before entering space. Currently, NASA uses space suits pressurized to 8 pounds per square inch and plans to operate the space station at 14.7 psi. To avoid the bends, astronauts must spend about five hours pre-breathing oxygen for a one hour EVA. NASA engineers estimate it would cost $300 million to develop space suits pressurized at 14.7 psi. Reducing the station's pressurization to 8 psi would require costly retesting of equipment to make certain it would not fail at that pressure level.

The Fisher-Price report also notes that the space station design includes some 8,000 individual items that will either need scheduled or unplanned maintenance. And, it says, the designs for most of these components remain "too immature" to determine how much time it will take to service them.