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# Atoms that barely exist (APS April 2008)

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There are a lot of atoms out there that live on the verge of existence. These are called rare isotopes and tend to only be created in experiments designed to specifically create them. Most of them almost immediately decay back out of existence in tiny fractions of a second. But these short-lived creatures can tell us a lot about other areas of science, and also have many applications. The rare isotopes are unusual and unstable because they have a either a strange number of neutrons or protons in the nucleus.

Witold Nazarewicz of the University of Tennessee, Knoxville, and Oak Ridge National Laboratory said in the opening plenary talk (http://meetings.aps.org/Meeting/APR08/Event/82722) here, "The study of rare isotopes makes the connection between the Standard Model, complex systems, and the cosmos."

In a whirlwind 36 minutes, Nazarewicz crammed in an overview of many hours worth of material that left me reeling with fascinating ideas and information.

Here are a few highlights for me.

**The alpha-knife for cancer treatment**

Radioactive nuclei can be used for a bunch of different purposes, including a host of medical applications. One example that is now being explored is the "alpha-knife". (The name plays off the gamma knife (http://en.wikipedia.org/wiki/Gamma_knife).)

Terbium-149 emits alpha particles (the nucleus of helium, with two protons and two neutrons) which can be used to target tumors. Test on mice at the ISOLDE (http://isolde.web.cern.ch/isolde/)facility at CERN have shown that applications of the alpha-knife have extended the lives of mice with cancer remarkably well. It's early days but this could be a new application of radioactive particles for cancer treatment

**How to skin an atom: Pygmy dipoles and neutron stars**

Some neutron-rich nuclei develop an outer skin of neutrons, with the protons more confined in the center. For example, consider the isotopes that have a total of 100 neutrons and protons. Sn-100 (tin with 50 protons and 50 neutrons) has the protons and neutrons distributed in the same way through the nucleus. However Zn-100 (zinc with 30 protons and 70 neutrons) has a very identifiable skin of neutrons. This can even be measured.

Many nuclei wobble about in various ways and a nucleus like Sn-100 has the bulk of protons and neutrons slightly separated on average (called a dipole) and it oscillates back and forth. A nucleus like Zn-100 has an additional kind of dipole caused by the neutron skin. This has been called a "pygmy dipole".

The useful part of the pygmy dipole is that it reveals a lot of information about what a dense collection of neutrons is like, and so can tell us about what neutron stars must be like, without having to try to measure a neutron star itself. Neutron stars are fascinating objects and I mentioned them in a previous post (http://www.symmetrymagazine.org/breaking/2008/04/01/smallest-black-hole/) about black holes. This is just one of the cosmic implications of nuclear physics!

## When the laws of physics go pear-shaped

Radium-225 (88 protons, 137 neutrons) has a configuration of protons and neutrons that makes the whole nucleus have the shape of a pear. Experiments on this nucleus allow physicists to test fundamental properties of the laws of nature including CP violation. (See our 60 seconds on the topic (http://www.symmetrymagazine.org/cms/?pid=1000194)). This is an area that is usually studied through the decay of particles (http://www.symmetrymagazine.org/breaking/2008/04/03/a-crack-in-the-standard-model/) in collider experiments but this different approach give other complementary information.

## Has magic gone awry?

A long-standing understanding of nuclear structure suggests that certain nuclei are more stable than others. These happen when the number of protons or neutrons is one of the so-called "magic numbers (http://en.wikipedia.org/wiki/Magic_number_%28physics%29)"--2, 8, 20, 28 for example. A bunch of new experiments have shown that perhaps these numbers aren't as magical as previously thought. Experimenters are finding nuclei that are more stable with 14, 16, or 32 protons or neutrons in the nucleus. It's not quite time to rewrite the textbooks but it is enough to cause a rethink of just how magical the magic numbers really are. And it will lead to a better understanding of what makes a nucleus stable in the first place.

With all this physics in just one talk, I'm not sure my brain will be able to keep it all in, but it's been a great start to the conference!

*See all posts from the American Physical Society April 2008 conference here (http://www.symmetrymagazine.org/breaking/category/this-conference-life/aps-april-2008/).*