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# Studies on different halo nuclei models

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**A B S T R A C T**

In the present work were showed different existing halo nuclei models and compared their results. It also includes the necessity of the research on the halo nuclei. Previous Discovery, Recent discovery and the remarkable points about the limitations in the research. The differences in the properties of halo nuclei are also concluded in paper. The study of heaviest halo carbon22 nuclei, Be, He, Oxygen23 and calcium are also incorporated in the present study. This paper also includes Historical back ground. Recent discovery of the Heaviest Halo carbon nuclei-22, Comparative description of Be, He, Halo Oxygen23 and calcium etc.

## Introduction

Halo nuclei are very weakly-bound exotic states of nuclear matter in which the outer one or two valence nucleons (usually neutrons) are spatially decoupled from a relatively tightly bound core such that they spend more than half their time beyond the range of the binding nuclear potential. In this sense, the halo is a threshold phenomenon in which the 'halo' nucleons quantum tunnel out to large distances, giving rise to extended wave function tails and hence large overall matter radii. The halo nucleons tend to be in low relative orbital. The field of halo nuclei represents a paradigm shift in the study of nuclear structure and is still regarded as a 'hot' topic almost twenty years after their discovery. But when did the field actually begin? The consensus view is that this was in 1985 with the Berkeley experiments carried out by Tanihata and his group in which they measured the interaction cross sections of He (Tanihata, 2001) and Li (Kanungo et al., 2002) isotopes and found much larger values for the rms matter radii than would be predicted by the normal A dependence.

A less obvious but more appropriate landmark would be the 1987 paper by Hansen and Jonson (Zhukov, 2002) that first proposed the large size of these nuclei as being due to the halo effect. They explained the large matter radius of Li by treating it as a binary system of Li core plus a di-neutron and showed how the weak binding between the pair could form an extended halo density.

## Crucial years

In the science of halo nuclei three fundamental ideas are formulated in the short period of one year i.e. 1950-1951, with the formulation within a short time span of one year three fundamental ideas and this is major revolution. Hence the two years 1950 and1951are called crusial revolutionary years. The three ideas formulated by different scientists are as follows:

1) In 1950 Fred Whipple formulated the first idea i.e the icy conglomerate (`dirty snowball') model of the cometary nucleus.

2) In1950 Jan Hendrik Oort formulated the second idea i.e. the identification from kinematic studies of the existence of a distant reservoir of comets, now known as the Oort cloud. Where as

3) In 1951 Ludwig Biermann formulated the third idea i.e. the explanation of the motions in cometary plasma tails as due to interaction with the *solar wind*. But the important parts of them had been proposed earlier and the real fact is that among all these ideas no one of the ideas resulted directly from new observational evidence.

## Recent advance Carbon-22

An exotic form of carbon has been found to have an extra large nucleus, dwarfing even the nuclei of much heavier elements like copper and zinc, in experiments performed in a particle accelerator in Japan (Physical Review Letters *by* Kirby Kemper and Paul Cottle). Carbon-22, which has a nucleus comprised of 16 neutrons and 6 protons, is the heaviest atom yet discovered to exhibit a **"**halo nucleus**".** In such atoms, some of the particles that normally reside inside the nucleus move into orbits outside the nucleus, forming a halo of subatomic particles. Because atoms like carbon-22 are packed with an excessive number of neutrons, they are unstable and rapidly break apart to form lighter atoms, but they are more stable than scientists had previously expected. The extra stability is a surprise because the three particles-- two neutrons and a proton in a nucleus, that form a halo nucleus interact in a way that is difficult for physicists to model due to the complicated mathematics necessary to describe so-called "three body" problems.

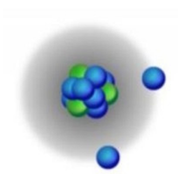

**Figure 1.1**: $C^{22}$ halo nucleus

Recently, Japan have discovered an exotic form of carbon, in which central region of this atom is so large, that it even puts to shame the nuclei of heavier chemical elements such as copper and zinc.

However, the new material does not exist in nature, as it was produced by researchers inside a particle accelerator. In fact, the team behind the finding says, Carbon-22 is the heaviest atom discovered to exhibit a halo nucleus, with its 16 neutrons and six protons. Kirby Kemper and Paul Cottle of Florida State University suggested that, particular class of atomic nuclei very interesting is that the particles that should have usually remained inside each individual nucleus exit its confines, and take up orbits around the remnants of the central structure. This results in a halo of subatomic particles enveloping the nucleus. (Physical Review Letters *by* Kirby Kemper and Paul Cottle). In the particle accelerator, it was demonstrated that this exotic form of carbon was more stable than previously thought. The Japanese team reveals that one of the reasons why the carbon form remained stable for so long lies in the two neutrons and a standard nucleus group, which are the main components inside the halo nucleus.

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**Figure.2.2** Schematic structure of 22C Borromean rings

The unexpected stability has led to such halo nucleus atoms being labeled Borromean atoms in reference to an ancient pattern depicting three rings interlocked such that the removal of any one ring would cause all three to be disconnected as shown in fig.

## Applications of C-22

The matter C-22 possesses high resistance to corrosion. In cases of the strong acidic areas and storng oxidizing chemicals the ordinary matter gives more pollution in the product of the pharmaceutical industries, who manufacture products with very high value and low tolerance to contamination**.** To avoid the effects of such a storng acidic areas central Industres care going to prefer C-22 due to its resistivity and of choice in a wide variety of process equipment **.**

Chemical Process Industries to avoid the contamination piping systems are installed with C-22. To avoid contamination caused by corrosion related failures, high purity processors are choosing C-22 sanitary fittings and tubing offered by Central States Industrial Flue gas scrubbers. As shown in fig.

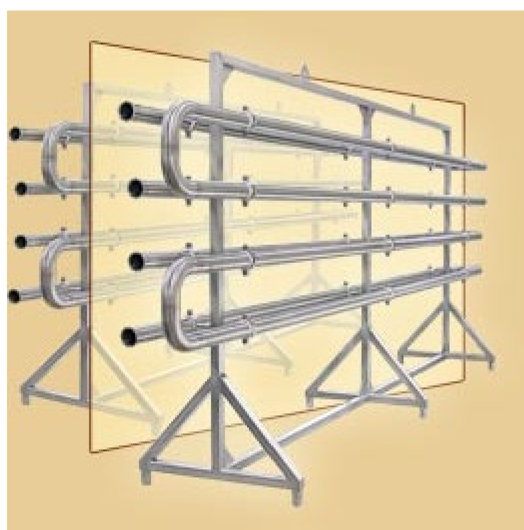

**Figure 3.3**: Piping systems are choosing C-22 by Central States Industries

Some common applications are in:

1. 1.Chlorination systems
2. 2.Acid production and pickling systems
3. 3.Outlet ducting and stack liners for power plants
4. 4.Sulfur dioxide scrubbers
5. 5.Pulp and paper bleach plants
6. 6.Weld overlay of less corrosion resistant metals
7. 7.Pesticide and other
8. 8.agrichemical production
9. 9.Tubular heat exchangers
10. 10.Plate heat exchangers
11. 11.Nuclear fuel reprocessing
12. 12.Incineration scrubber systems

## Oxygen-23

The oxygen-23 isotope is rare and transient. This is not the oxygen that keeps your body running. It exists at the edge of the nuclear landscape, where isotopes are always fleeting and most commonly found within exploding stars. Nevertheless, if we are to understand how the universe is put together, we must understand exotic isotopes such as oxygen-23. A research team from ORNL, the University of Tennessee and the University of Oslo recently contributed to this understanding with intense calculations of the oxygen-23 nucleus performed on ORNL's Jaguar supercomputer. In doing so the researchers also demonstrated that supercomputer simulation has become an indispensable tool for scientific discovery, on par with physical experiment.

The isotope that makes up nearly 100 percent of naturally occurring oxygen is oxygen-16, whose nucleus has eight positively charged protons and eight uncharged neutrons. It doesn't decay and is especially important to sustaining life, both as the stuff that keeps us breathing and as the heavier of water's two elements. When you step on a scale, oxygen-16 is nearly two-thirds of the weight that stares back up at you. Whereas oxygen-23 contain eight protons and 15 neutrons, does decay very quickly. It has a half-life of 82 milliseconds, meaning that if you have 10,000 atoms now you will be down to two or three within a second. Its neighbor, oxygen- 24, is believed to be the heaviest an oxygen isotope can get; beyond it lies the so-called neutron drip line, where neutrons will no longer attach to a nucleus. While they may be rare, these and other exotic isotopes are important, at least in part because they challenge current theories of how a nucleus and therefore the universe is constructed (http://www.ornl.gov /info/ornlreview/v45_3_12/article11.shtml).

## Magic isotopes

This model does well describing stable isotopes, but it becomes problematic as you move toward unstable, exotic nuclei. For instance, the model would suggest that oxygen-28, with eight protons and 20 neutrons, is magic, yet no such isotope has been observed and researchers believe oxygen-24 is the heaviest possible oxygen isotope. In fact, a recent paper from Hagen and colleagues in the journal Physical Review Letters supports the contention that oxygen-24 itself is magic, although existing theory would say otherwise. By exploring exceptions to the shell model as it has been understood, researchers seek a deeper understanding of all nuclei, stable and unstable alike. "The idea is that these naïve shell model pictures of the nucleus do not hold when you go to the very extreme of the nuclear chart," Hagen noted, "where you have very neutron rich or unstable or fragile systems."

Enter oxygen-23. The oxygen nucleus reaches a relatively stable subshell with 14 neutrons at oxygen-22. The twenty-third neutron is essentially left over. Experimental data from a decade ago suggested that the twenty-third neutron did not even touch the others, but rather hovered over the nucleus as a halo.

## Conclusion

The above conclusion grew from observation that the nucleus had an especially large cross section; in other words, it was very wide.Oxygen-23 is a very neutron-rich nucleus, which until very recently could not be accurately analyzed microscopically with existing supercomputers. Hagen noted that the calculations necessary to handle 23 strongly interacting particles were very complex and required a system of Jaguar's power.

Comparraatvie study of In the study of $^{8}B$ and $^{6}He$, total cross sections for proton-halo ($^{8}B$) and neutron-halo ($^{6}He$) systems has been pointed out. Static and dynamic halo effects are elucidated by comparing data for a neutron-halo nucleus and its core. A halo may be not only difficult to acquire in terms of virtue, but also tough to calculate in terms of physics. A halo nucleus differs from the more traditional nuclei because it has one or more nucleons (protons or neutrons) that are only weakly bound to the nuclear core. Consequently, they drift far away from it, forming, in effect, a halo. These nuclei are difficult to study because their lives are both short (often lasting only milliseconds) and fragile. Halo nuclei appear at the limits of nuclear existence, very near the drip line. the events in experimental techniques have probed extreme types of nuclear structures not previously known, termed 'exotic nuclei'. Amongst such structures are the 'halo' nuclei and occur all over the periodic table, ranging from light to heavy nuclei.

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