SKYRMIONS
A MODEL FOR NUCLEAR PHYSICS

MAREIKE HABERICHTER

UNIVERSITY OF CAMBRIDGE

University of Kent

QUESTION

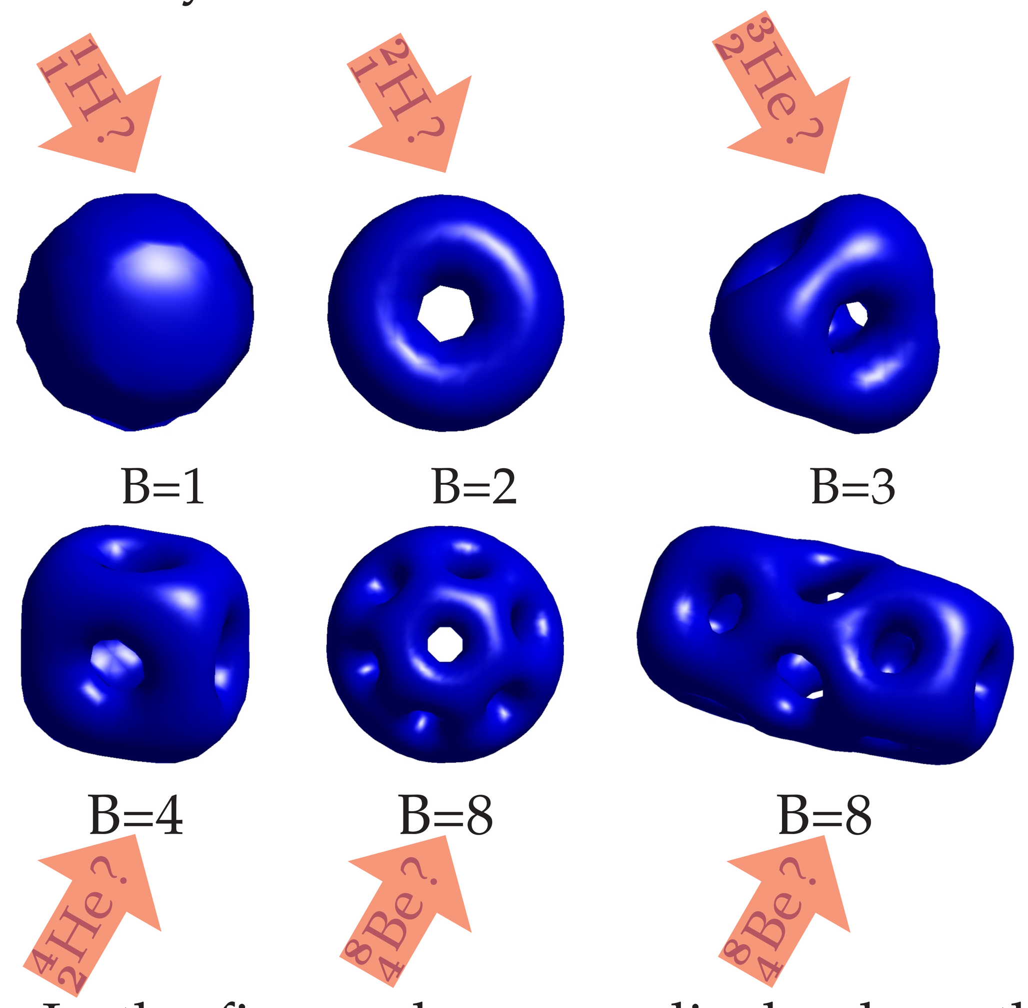
Nuclear physicists explore the properties and structure of nuclei – the matter found at the core of atoms. Atoms are particles that make up every object in everyday life and are held together by enormous amounts of energy. Surprisingly, it is still poorly understood

(a) **how** nuclei are formed from individual protons and neutrons?

(b) **how** we can derive nuclear properties directly from their constituents?

SKYRMIONS

The Skyrme theory is a nuclear physics model that can give us more insight into the building blocks of atomic nuclei. In the Skyrme model protons, neutrons and atomic nuclei are modelled as extended objects, so-called Skyrmions.



In the figure above we display how the energy of various types of Skyrmions is distributed in space. Each Skyrmion can be labelled by an integer B. The number B cannot be changed by deforming the Skyrmion. B is identified with the mass number (the total number of protons and neutrons in an atomic nucleus).

METHOD

We calculate Skyrmions by solving complicated equations on the COSMOS supercomputer at DAMTP, University of Cambridge.

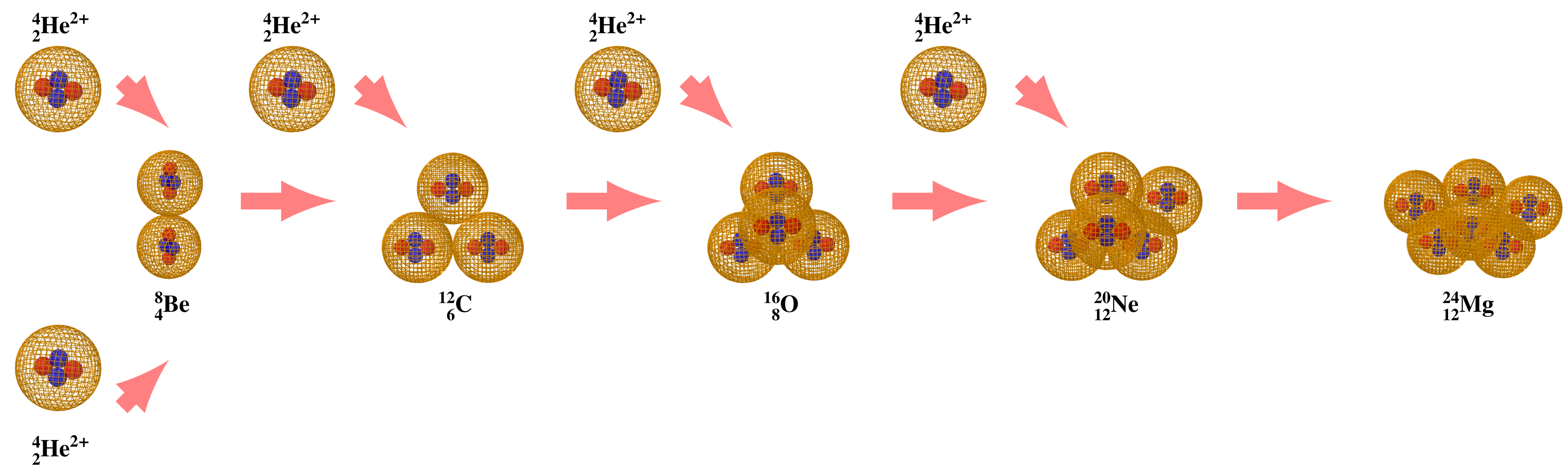
REFERENCES

[1] D. T. Feist, P. H. C. Lau, N. S. Manton, Skyrmions up to Baryon number 108, *Phys. Rev. D 87, 085034, (2013).*

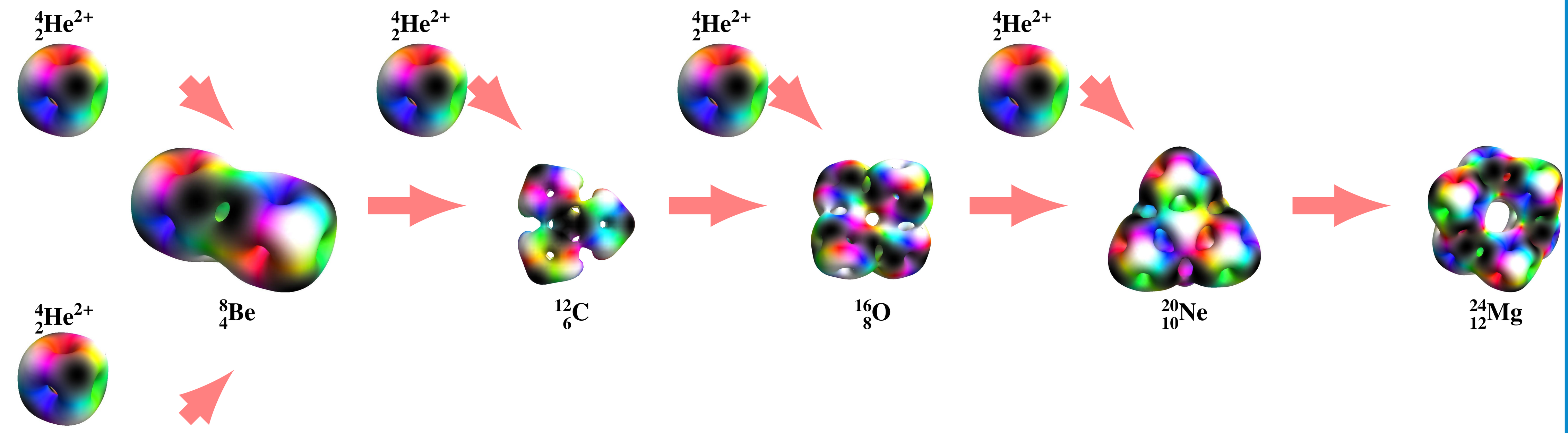
[2] R. A. Battye, M. Haberichter and S. Krusch, Classically Isospinning Skyrmion Solutions, *Phys. Rev. D 90, 125035, (2014).*

SKYRMIONS & ALPHA PARTICLE MODEL

The alpha particle model considers nuclei to consist of alpha particles – two protons and two neutrons bound together into a particle identical to a helium nucleus. Nuclei that comprise equal and even numbers of protons and neutrons are well described by this model. We display schematically in the figure below how several light nuclei (beryllium, carbon, oxygen, neon, magnesium) can be thought of being composed of alpha particles.

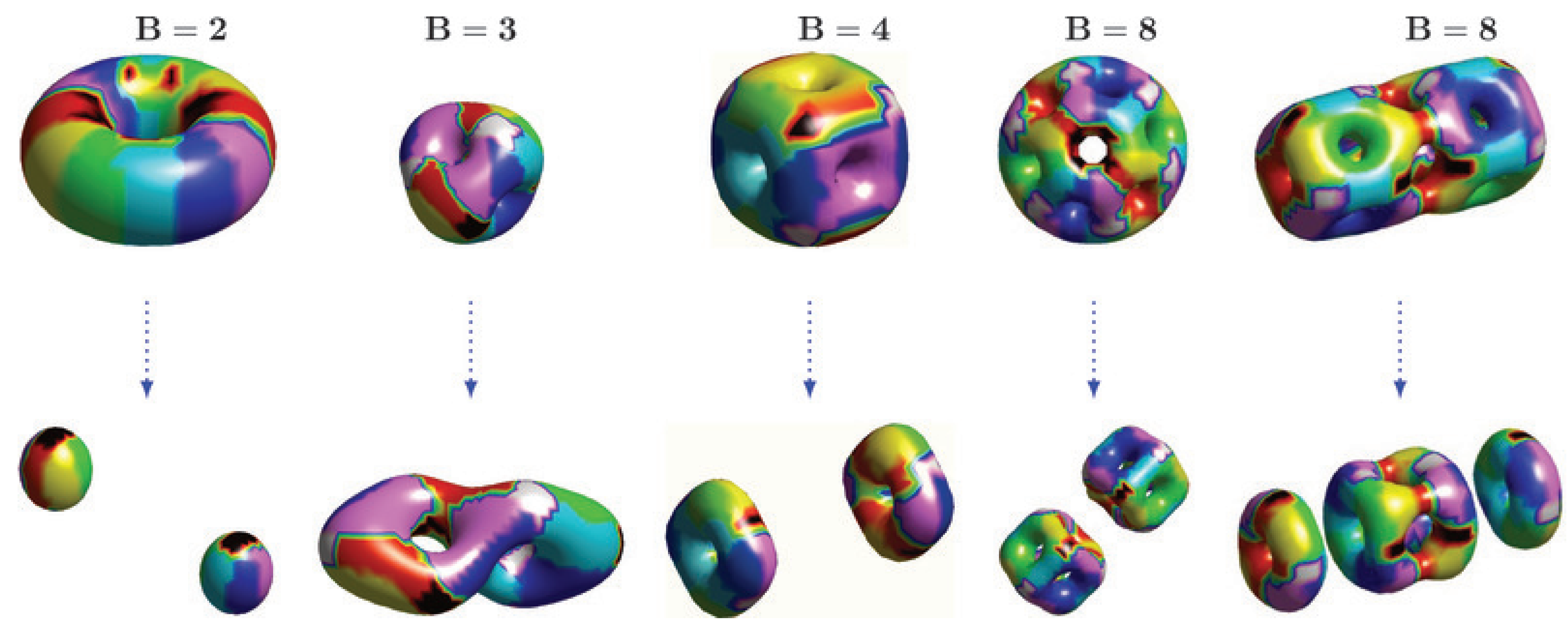


This experimentally observed alpha clustering in light nuclei can also be modelled and understood within the Skyrme theory. In the Skyrme theory the $B = 4$ cubic Skyrmion takes the role of the alpha particle. Nuclei with mass number a multiple of four can be interpreted as an arrangement of Skyrmion cubes, see figure below.



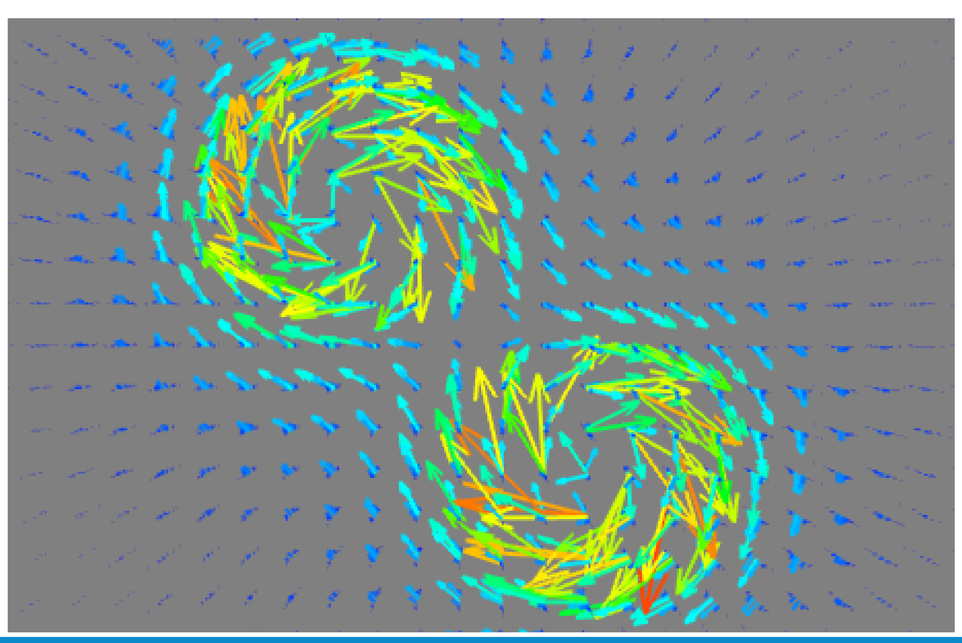
SKYRMIONS & ANGULAR MOMENTUM

Since nuclei have spin angular momentum, just as electrons do, we need Skyrmions to spin when we want to describe nuclei as Skyrmions. Energies and allowed spin values of nuclei have so far almost exclusively been calculated by assuming that Skyrmions do not deform as they spin. We compute in the figure below how Skyrmions of various mass numbers B (see first row in figure) change their shape when spinning (see second row in figure). Colours show the field structure.



We have explored whether taking into account these deformations improves the agreement of the Skyrme theory with experimental nuclear physics data.

SKYRMIONS & ELECTROMAGNETISM



We can also interpret electromagnetic properties of atomic nuclei within the Skyrme theory. As an example, in the figure on the left we visualize the electromagnetic currents for a B = 2 Skyrmion spinning at a certain rotation frequency ω. These types of currents give rise to magnetic moments which can be compared with experimental nuclear magnetic moments.