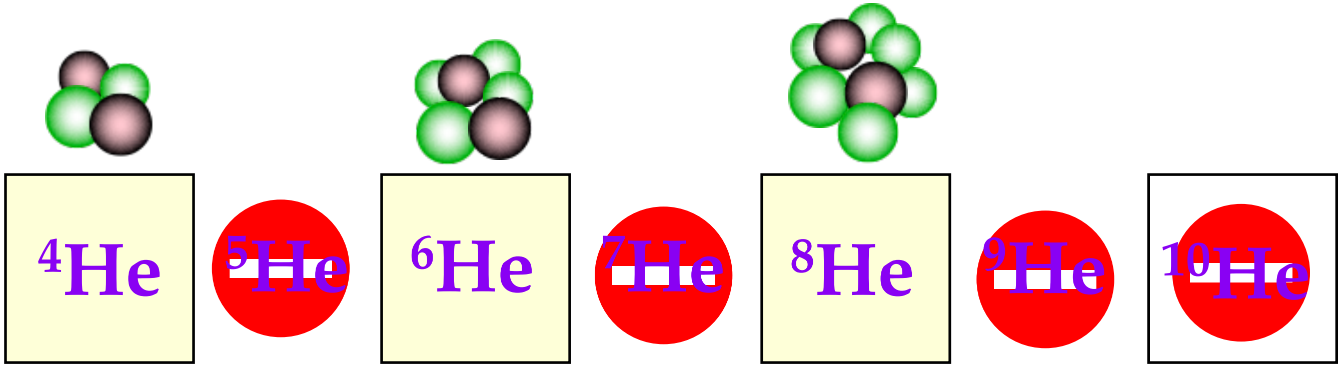
Neutron Drip line nuclei

HUGE

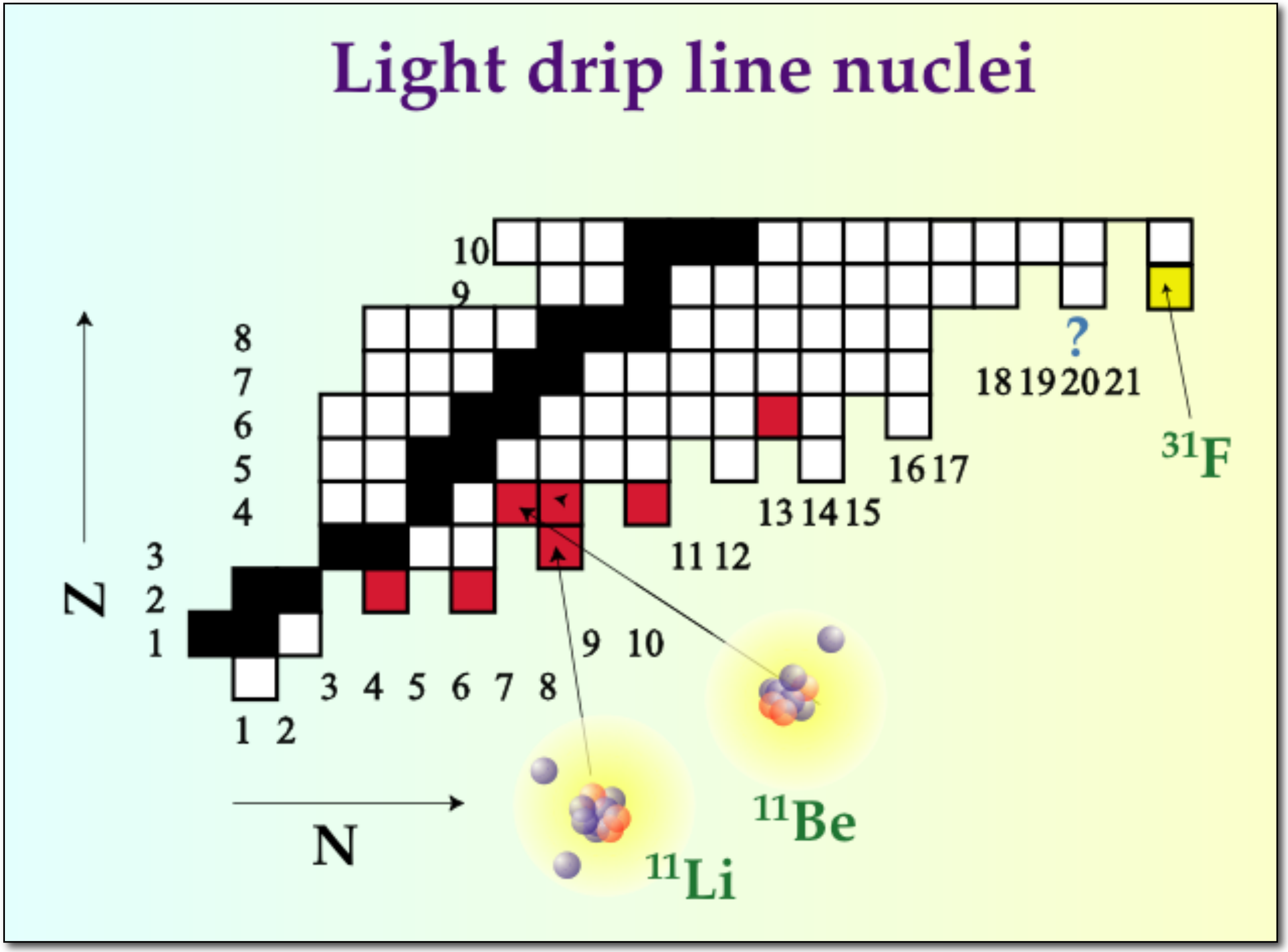
Diffused

PA IR ED



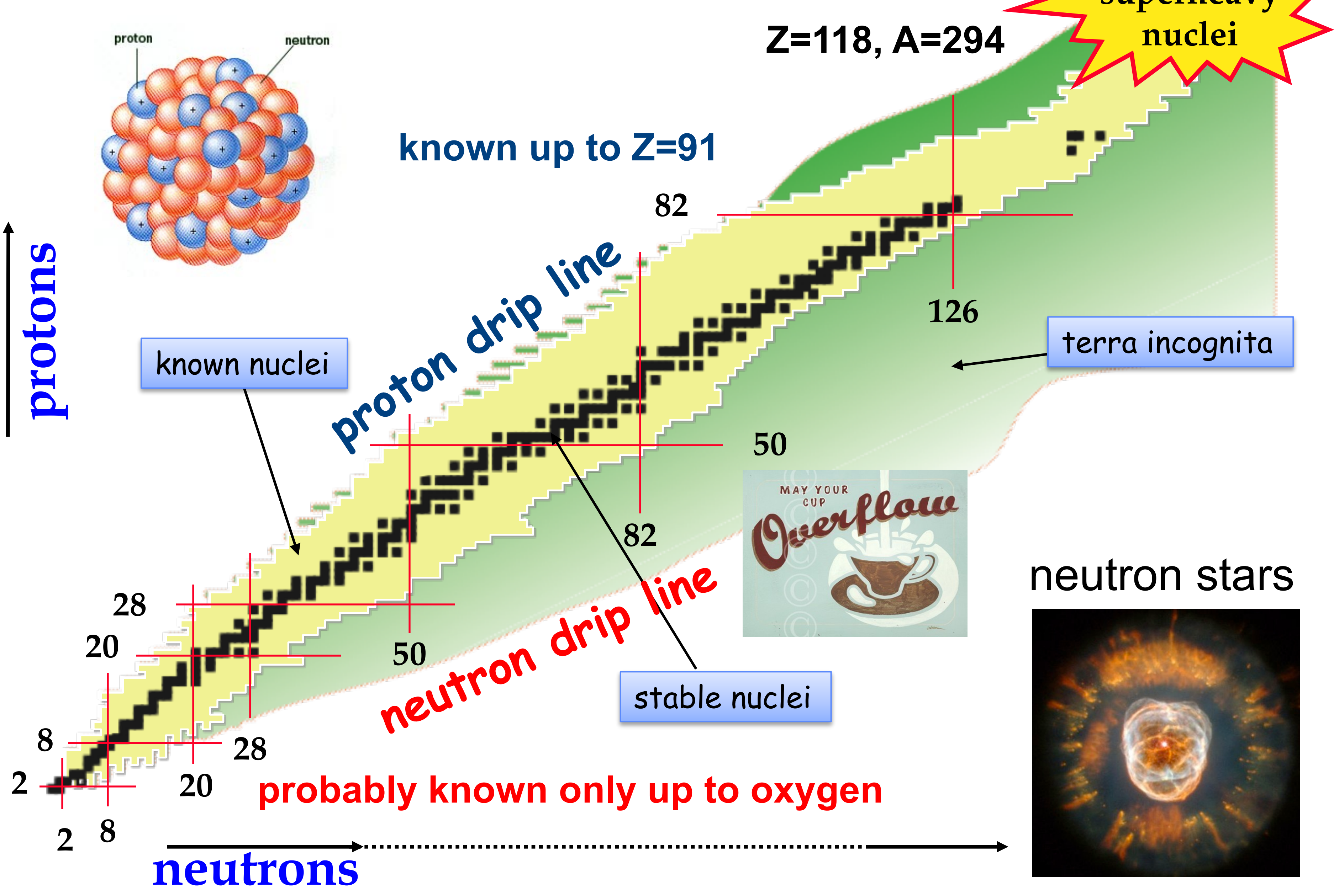
^{4}He ^{5}He ^{6}He ^{7}He ^{8}He ^{9}He ^{10}He

Pairing and binding



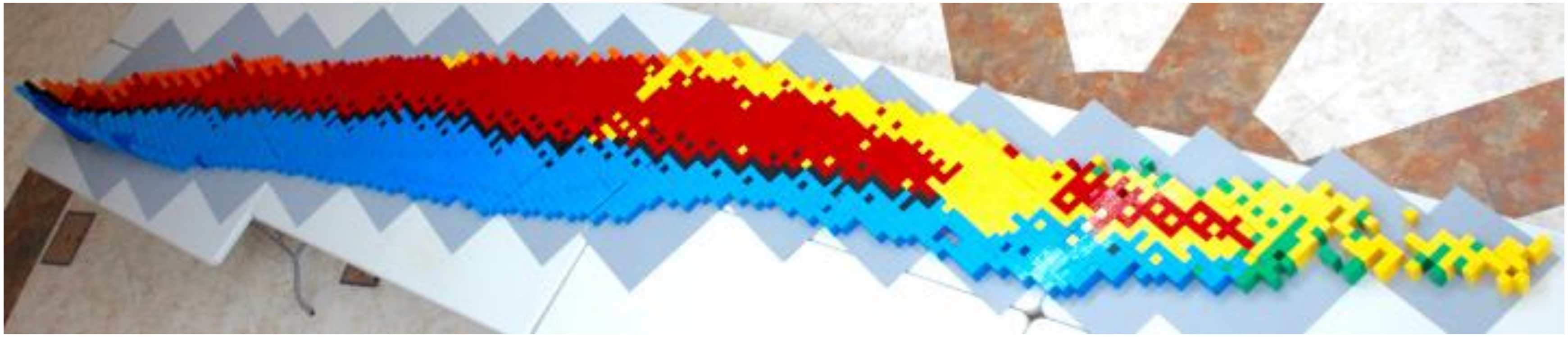
The Grand Nuclear Landscape

(finite nuclei + extended nucleonic matter)



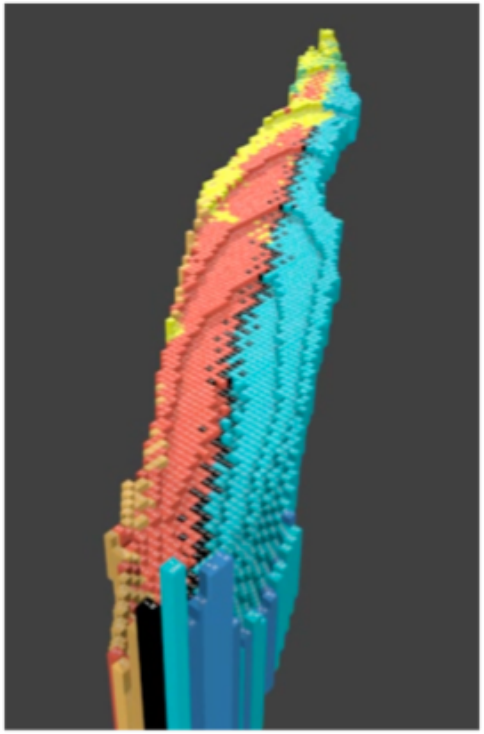
Binding Blocks

http://www.york.ac.uk/physics/public-and-schools/schools/secondary/binding-blocks/



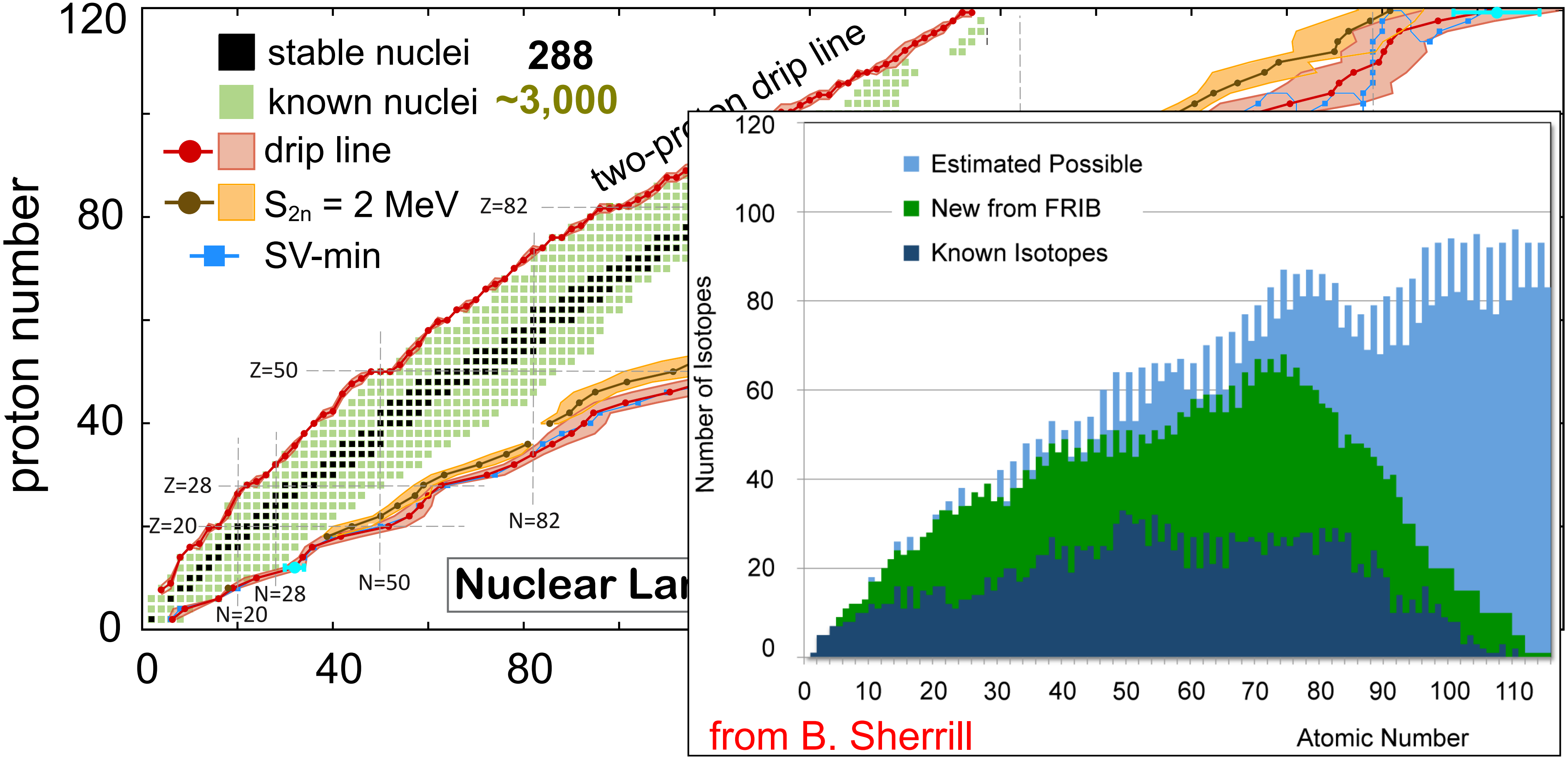
http://www.york.ac.uk/physics/public-and-schools/schools/secondary/binding-blocks/interactive/

https://arxiv.org/abs/1610.02296



http://www.nishina.riken.jp/enjoy/kakuzu/kakuzu_web.pdf

The limits: Skyrme-DFT Benchmark 2012



from B. Sherrill

How many protons and neutrons can be bound in a nucleus?

Literature: 5,000-12,000

Erler et al.
Nature 486, 509 (2012)

Skyrme-DFT: 6,900±500_{syst}

HW:

a) Using http://www.nndc.bnl.gov/chart/ find one- and two-nucleon separation energies of ^{6}He, ^{7}He, ^{8}He, ^{141}Ho, and ^{132}Sn. Discuss the result.

a) Find the relation between the neutron pairing gap and one-neutron separation energies. Using http://www.nndc.bnl.gov/chart/ plot neutron pairing gaps for Hf (Z=72) isotopes as a function of N.

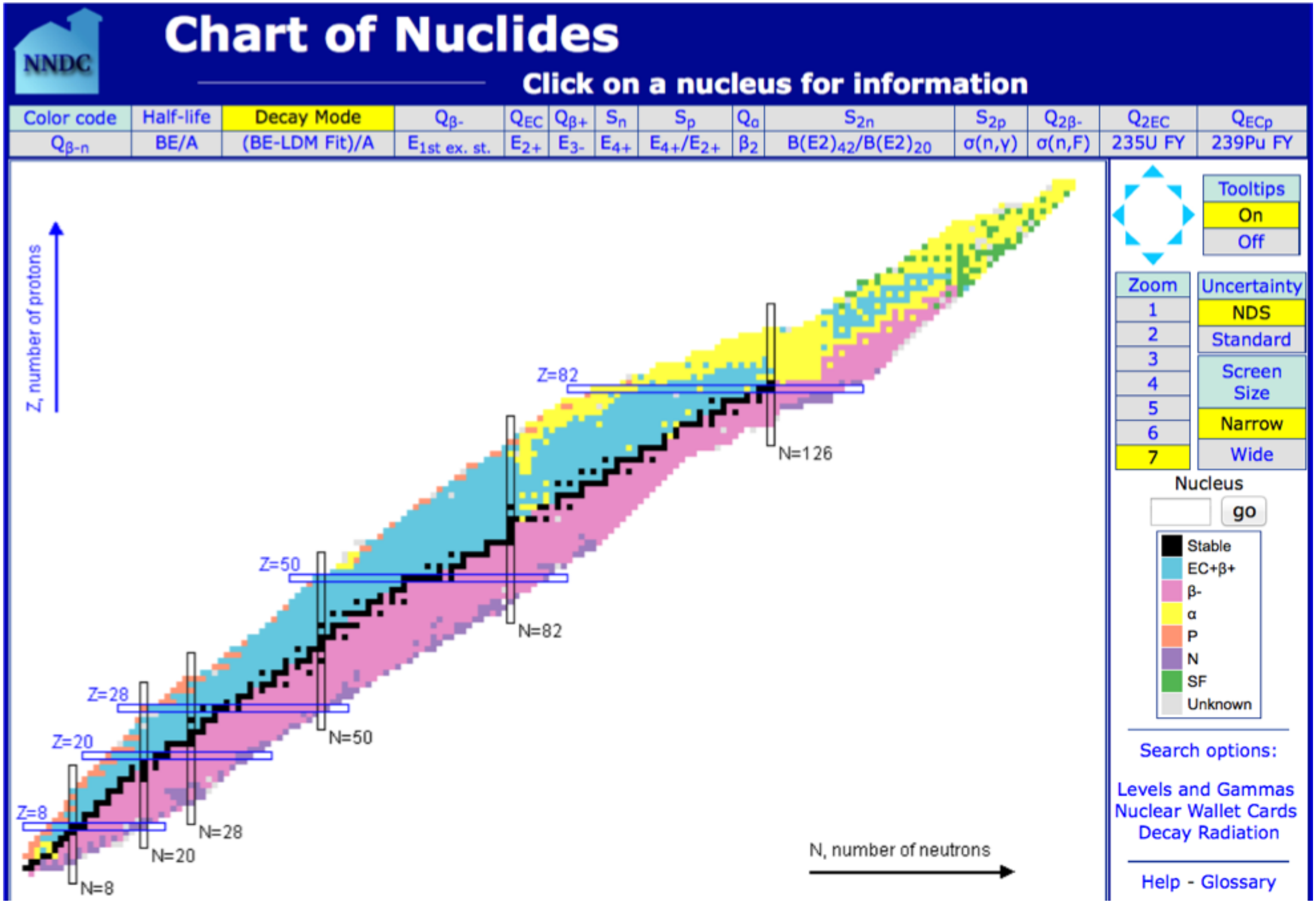
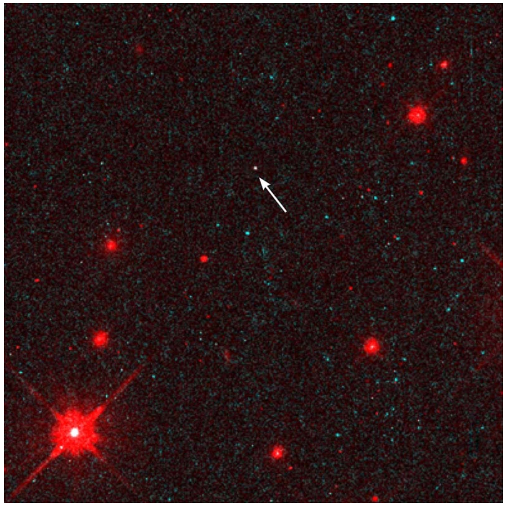


Chart of Nuclides

Click on a nucleus for information

Neutron star, a bold explanation



A lone neutron star, as seen by NASA's Hubble Space Telescope

$$B = a_{vol}A - a_{surf}A^{2/3} - a_{sym}\frac{(N-Z)^2}{A} - a_C\frac{Z^2}{A^{1/3}} - \delta(A) + \frac{3}{5}\frac{G}{r_0 A^{1/3}}M^2$$

Let us consider a giant neutron-rich nucleus. We neglect Coulomb, surface, and pairing energies. Can such an object exist?

$$B = a_{vol}A - a_{sym}A + \frac{3}{5}\frac{G}{r_0 A^{1/3}}(m_n A)^2 = 0$$

limiting condition

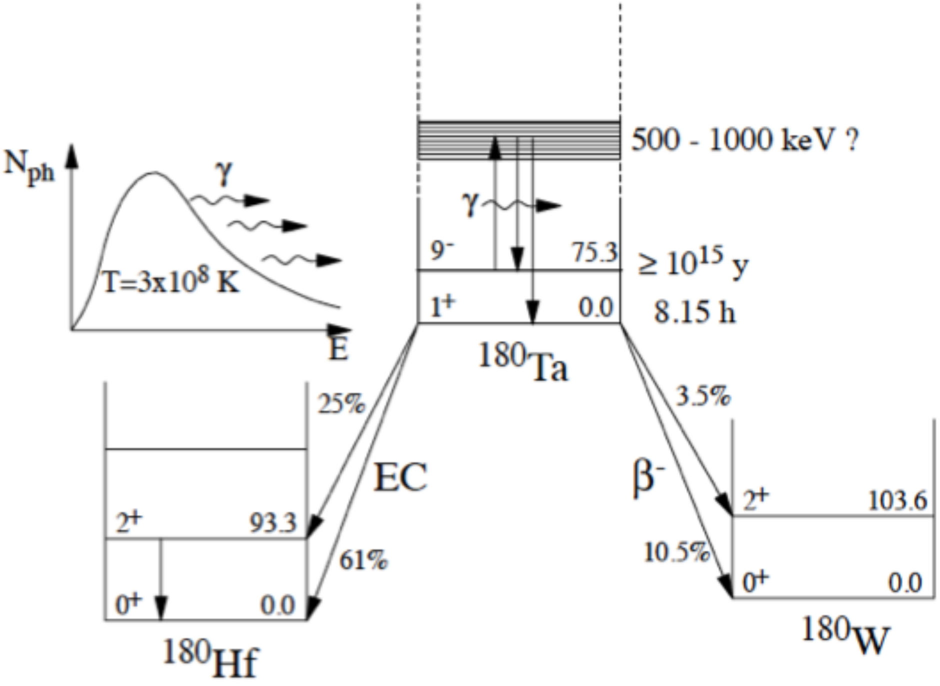
$$\frac{3}{5}\frac{G}{r_0}m_n^2 A^{2/3} = 7.5\,\text{MeV} \Rightarrow A \cong 5\times 10^{55},\ R \cong 4.3\,\text{km},\ M \cong 0.045 M_\odot$$

More precise calculations give M(min) of about 0.1 solar mass ($M_\odot$). Must neutron stars have

$$R \cong 10\,\text{km},\ M \cong 1.4\, M_\odot$$

Nuclear isomers

The most stable nuclear isomer occurring in nature is ^{180m}Ta. Its half-life is at least 10^{15} years, markedly longer than the age of the universe. This remarkable persistence results from the fact that the excitation energy of the isomeric state is low, and both gamma de-excitation to the ^{180}Ta ground state (which itself is radioactive by beta decay, with a half-life of only 8 hours), and direct beta decay to hafnium or tungsten are all suppressed, owing to spin mismatches. The origin of this isomer is mysterious, though it is believed to have been formed in supernovae (as are most other heavy elements). When it relaxes to its ground state, it releases a photon with an energy of 75 keV.




VOLUME 83, NUMBER 25 PHYSICAL REVIEW LETTERS 20 DECEMBER 1999

Photoactivation of ^{180}Ta^m and Its Implications for the Nucleosynthesis of Nature's Rarest Naturally Occurring Isotope

Discovery of a Nuclear Isomer in ^{65}Fe with Penning Trap Mass Spectrometry

http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.100.132501

^{229}Th has a metastable excited state ~7.6 eV above the ground state. Such a low transition energy is typical for electrons in the valence shell of atoms but about four orders of magnitude lower than common nuclear excitation energies.

A number of applications of this unique nuclear system, which is accessible by optical methods, have been proposed. Most promising among them appears a highly precise nuclear clock that outperforms existing atomic timekeepers.

It has also been suggested that the nuclear transition may be extraordinarily sensitive to variation of fundamental constants (particularly the fine structure constant) due to the interplay of the strong and electroweak interactions inside this nucleus.

PRL 118, 042501 (2017): Lifetime Measurement of the ^{229}Th Nuclear Isomer
https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.118.042501

Laser spectroscopic characterization of the nuclear clock isomer ^{229m}Th,
Thielking et al., https://arxiv.org/abs/1709.05325