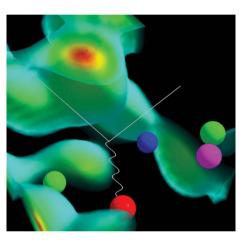


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PC30121: Introduction to Nuclear and Particle Physics





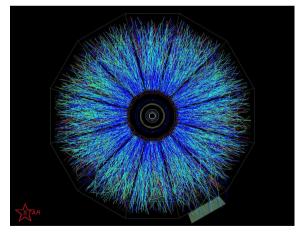












Prof Sean J Freeman (Nuclei) and Prof Fred K Loebinger (Particles)



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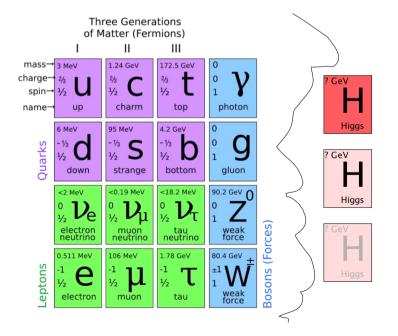
Simplicity AND Complexity

PARTICLE PHYSICS

Quarks, leptons and gauge bosons are (currently) the most fundamental constituents.

Basic interactions.

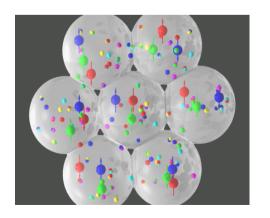
"Theories of everything"?



NUCLEAR PHYSICS

Hadrons and nuclei are simplest *complex* systems built from *fundamental* constituents.

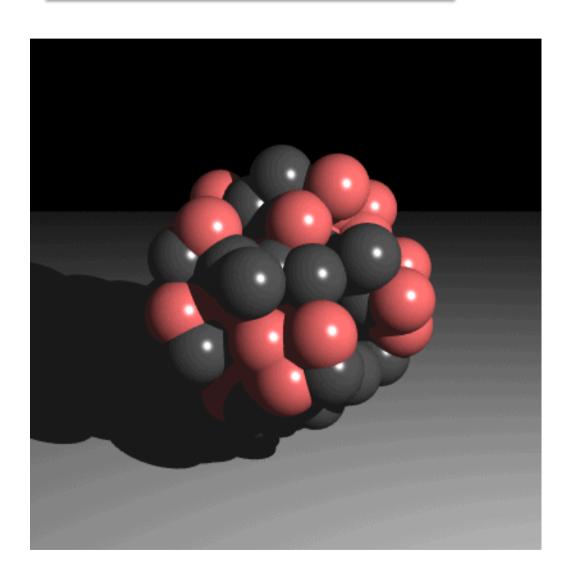
Emergence of new physics in complex systems from correlations between constituents: collectivity, super fluidity...





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A nucleus?





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Concepts so far...

binding energy
mass-energy equivalence
definitions of atomic and nuclear mass
atomic mass scale
mass excess and defect
Q values



Quick Tour of the Hydrogen Isotopes

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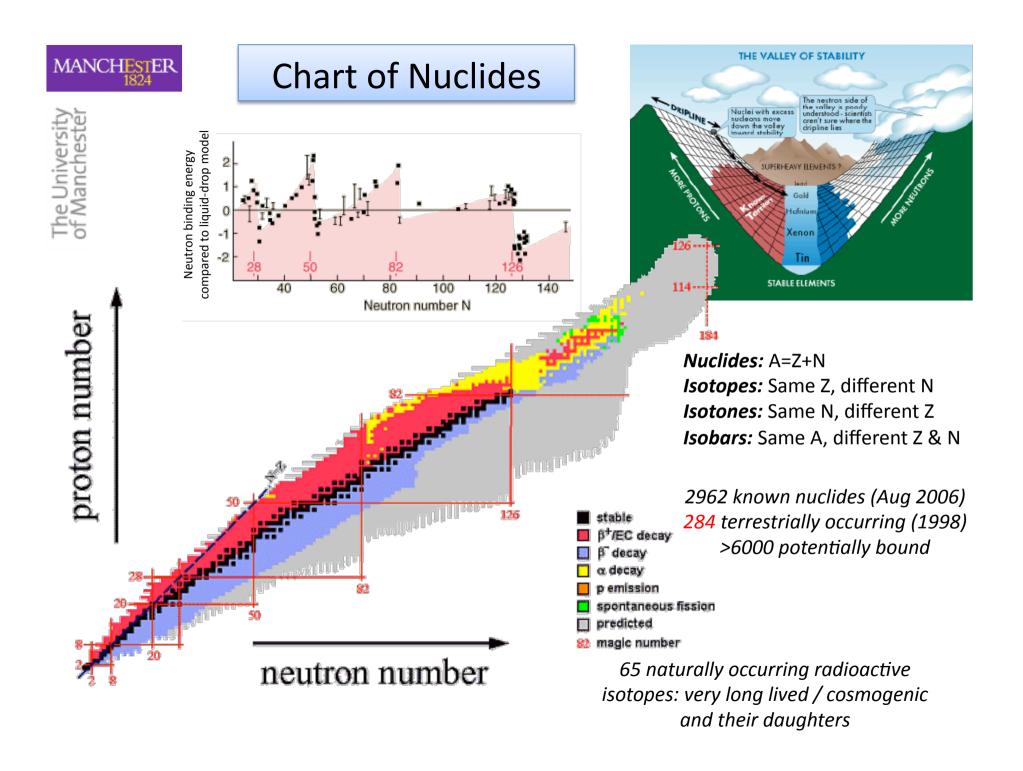
Hydrogen, 1_1H_0 or p: 99.985% of the Universe! Stable...mean life $\tau > 1.6 \times 10^{25}$ yr

Deuterium, deutron, diplon.... ${}_{1}^{2}H_{1}$ or d. Stable and 0.016% of all hydrogen atoms.

Tritium, triton... 3_1H_1 or t. Unstable, but naturally occurring.

Hydrogen isotopes out to ⁷H have been artificially manufactured in nuclear reactions. All unstable with short lifetimes.

							5E-22 s	~1E-20 s
				9	18.9984032		p1.4	p.51
					Fluorine			
					∂a ~9.4 mb, 21 mb		15.0180	16.01147
10 ²⁵ yr				O 15.9994	O12 ~ 1E-21 s	O13 (3/-) 8.6 ms	O14 70.60 s β+ 1.81, γ 2312.59,	O15 1/2 2.037 m β+ 1.72
TO AL			8	Oxygen		(p) 1.45,···	y 2312.59,···	ε ω
			on our	∂a .28 mb, .4 mb	12.03440	E 17.77	E 5.1430	E 2.754
		_	N 14.0067		N11 1/+ 1E-21 s	N12 1+ 11.00 ms β+ 16.3,···	N13 1/- 9,97 m β+ 1.190	N14 99.632 o _y .080, .036
or d.		/	Nitrogen			γ 4439,··· (3α) .192,···		σ _p 1.83, .85
O1 O 1.			σ ₈ ~1.89, .87	00 (2/-)	11.0268	E 17.338	E 2.2204	14.003074005 C13 1/
atoms.	6	C 12.0107	2.0E-21 s	C9 (3/-) 127 ms β^+ (p) 9.3, 12.3, (2 α)	C10 19.29 s β +1.87, γ 718.3,	20.36 m β+ .960 ε ω	C12 98.93 ay 3.5 mb, 1.6 mb	1.07 o _y 1.4 mb, 1.6 mt
		Carbon						
		σ ₈ 3.5 mb, 1.6 mb	8.03768	E 16.498	E 3.6478 B9 3/-	E 1,983	12.000000000 B11 3/-	13.003354838 B12
5	B 10.811		B7 (3/-) 3E-22 s	770 ms β+ 14,··· (α) 8.359 (2α) 1.57	8E-19 s p, 2a	19.9* σ _α 384Ε1, 173Ε1	80.1*	20.20 ms β= 13.37,···· γ 4439,···
	Boron			(2a) 1.57	1-11-12	∂p 7 mb ∂t 8 mb	\overline{a}_{y} 5 mb, 2 mb	(a) .2,···
	σa 76E1, ~343		7.0299	E 17.979	9.013329	10.0129370	11.0093055	E 13.369
	Be 9.012182		Be6 5.0E-21 s 2p, α	Be7 3/-	Be8 ~7E-17 s 2a .0461	Be9 3/-	Be10 1.5E6 a β556	Be11 1/ 13.8 s β-11.5, 9.4,···
4	Beryllium σ _a 8 mb, 4 mb		- 0.01070	γ 477.6 σ _p 3.9E4, ~1.8E4 σ _α .14, 0.06 E 0.86182	8.00530509	ay 8 mb, 4 mb	$\frac{\text{no } \gamma}{\partial \gamma} < 1 \text{ mb}$ E .556	y 2124.5, (a) E 11.51
11	og o mo, 4 mo	Li4 2-	6.01973 Li5 3/-	Li6 1+	Li7 3/-	Li8 2+	Li9 3/-	Li10(1-, 2
6.941		8E-23 s	~3E-22 s p. a	7.59*	92.41° σ _y .045, .020	0.840 s β-13 (2α) 1.57	178.3 ms β- 13.5, 11.0,··· (n) .3,···	2E-21 s
Lithium		and the second		∂ _y 39 mb, 17 mb			(2a) .7,	
σ ₈ 71, 32		4.0272	5.0125	6.015122	7.016004	E 16.0045	E 13.606	10.03548
He 4.002602		He3 1/+ 0.000137*	He4 99.999863	He5 7.0E-22 s n, α	He6 807 ms β-3.510 no y (d) νω	He7 (3/) — 3E-21 s	He8 119 ms β-10, γ 980.7 (n) .61-3.0 (t) ω	He9 very short
Helium		σ _D 5.33E3, 2.40E3 σ _y .05 mb	σ _γ 0		(d) νω		(n) .61-3.0 (t) ω	
σ ₈ 7 mb, 3 mb		3.016029310	4.002603250	5.0121	E 3.508	7.02803	E 10.65	9.0438
H 1.00794	H1 1/+ 99.9885	H2 1+ 0.0115*	H3 1/+ 12.32 a β=.018591	H4 2- 8E-23 s	H5 (1/+) very short	H6 (2 -) 3E-22 s 3n ?, 4n ?	6	
Hydrogen	σ _γ .332, .149	σ _γ .52 mb, .23 mb	$\frac{\text{no } \gamma}{\partial \gamma} \le 6 \mu \text{b}$					
σ ₀ .332, .149	1.007825032	2.014101778	E .018591	4.0278	5.035	6.0449		
		n1 1/+ 10.25 m β782			4	and 197		
				111111111111111111111111111111111111111				





Some things to think about

- The University of Manchestel
- how do you know if something is stable or just very long lived?
- there are naturally occurring radioactive nuclei with both long and short half lives; why?
- if the neutron is unstable, why do they exist in nuclei?
- if neutrons were just 800 keV/c² lighter, hydrogen atoms would be unstable and the world would be a dull place.



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Books: Read Them!

Books on Nuclear and Particle Physics:

Nuclear and Particle Physics by R.J. Blin-Stoyle (Chapman Hall 1991)

Nuclear and Particle Physics: An Introduction by Brian R. Martin (Wiley 2009)

Nuclear and Particle Physics by W. S. C. Williams (Cambridge 1991)

Nuclear and Particle Physics by W.E. Burcham and M. Jobes (Prentice Hall 1994)

Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles by Eisberg and Resnick

Particles and Nuclei: An Introduction to the Physical Concepts

by Bogdan Povh, Klaus Rith, and Christoph Scholz (Springer 2008)

...plus many more.

Books on Nuclear Physics and Applications: Nuclear Physics: Principles and Applications by J.S. Lilley (Wiley 2001) Manchester Physics

Books on Nuclear Physics:

Introductory Nuclear Physics by Kenneth S. Krane (Wiley 1987)

An Introduction to Nuclear Physics by W. N. Cottingham and D. A. Greenwood (Cambridge 2001)

Introductory Nuclear Physics by P.E. Hodgson, E. Gadioli, and E. Gadiloi Erba, (Oxford 1997)

The Properties of Nuclei by G. A. Jones (Oxford 1987)

Nuclear Physics in a Nutshell by Carlos A. Bertulani (Princeton 2007)

...plus many more.





Important Ideas from Second-Year Quantum Mechanics

- Schrodinger equation and energy eignvalues/functions.
- Separable solutions in 3D potentials.
- Eigenvalues/functions of orbital angular momentum.
- Pauli principle.
- Parity.
- Potential barriers, steps and wells.
- Intrinsic spin and symmetry.
- Atomic shell structure.

PHYS20101: Introduction to Quantum Mechanics and PHYS20302: From Atoms to Solids

A.C. Phillips Introduction to Quantum Mechanics Wiley
R.M. Eisberg and R. Resnick Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles Wiley

Read the primer on Quantum Mechanics of Potential Wells