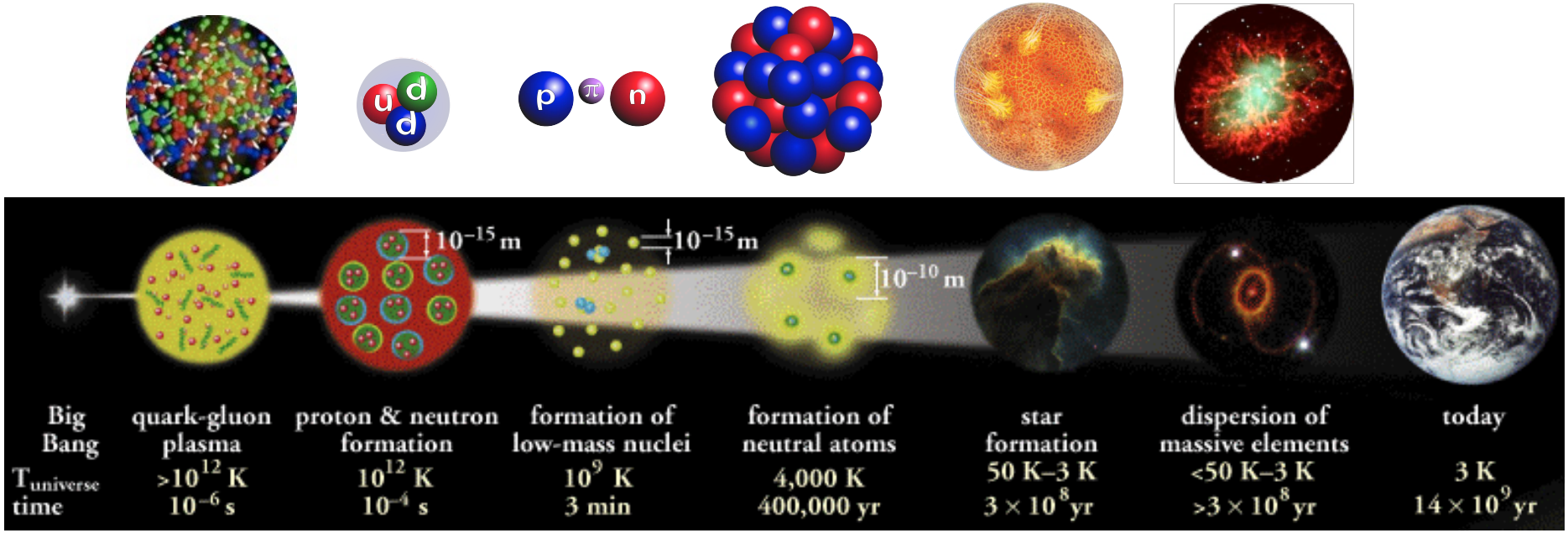
Nuclear Physics in the Universe:

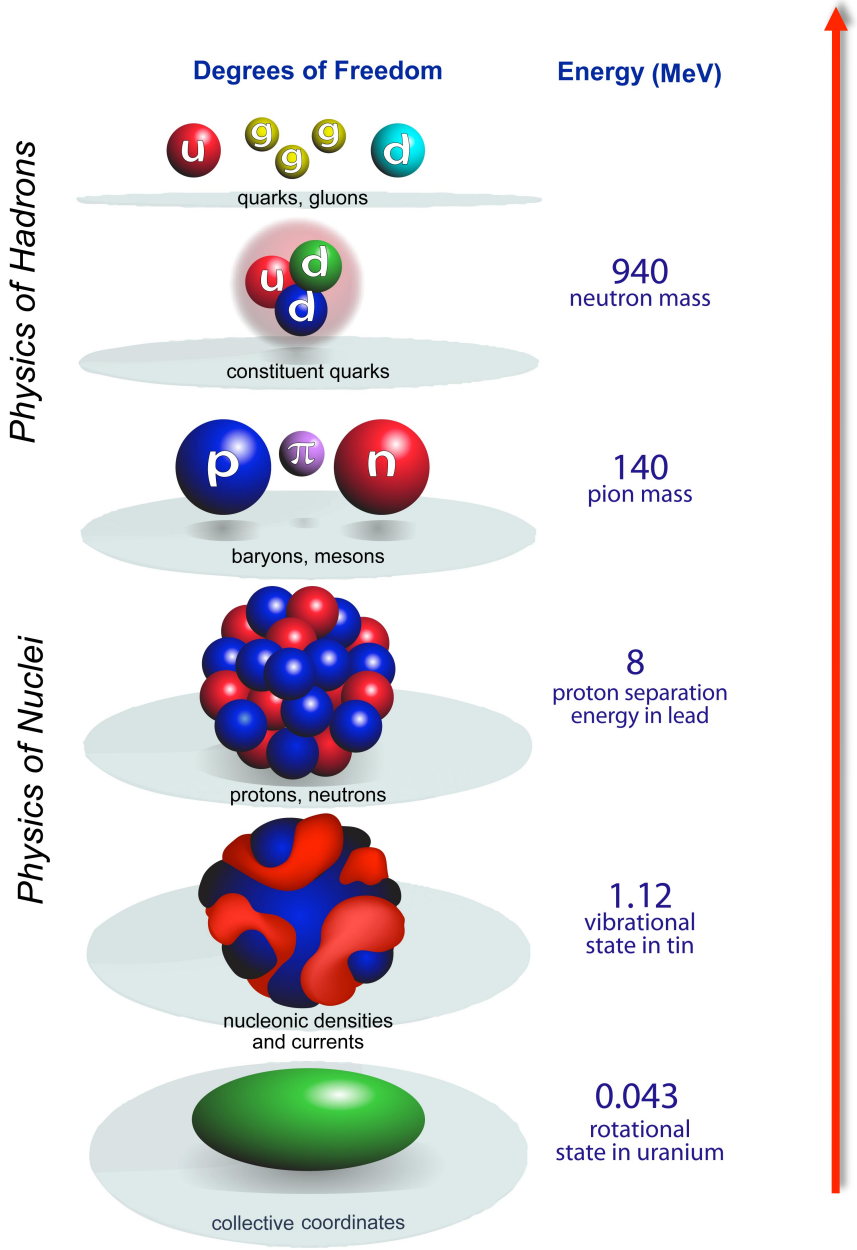
The Big Bang timeline, from inflation to quark soup to the birth of the light nuclei to the formation of atoms and gravitationally bound structures.



http://www.lbl.gov/abc/wallchart/

Image: Particle Data Group/Lawrence Berkeley National Laboratory

Nuclear degrees of freedom



Resolution

Hot and dense quark-gluon matter

Hadron structure

Hadron-Nuclear interface

Nuclear structure
Nuclear reactions

Nuclear astrophysics
New standard model

Applications of nuclear science

The scientific agenda (questions that drive the field)

PERSPECTIVES ON THE STRUCTURE OF ATOMIC NUCLEI

- What are the limits of nuclear existence and how do nuclei at those limits live and die?
- What do regular patterns in the behavior of nuclei divulge about the nature of nuclear forces and the mechanism of nuclear binding?
- What is the nature of extended nucleonic matter? What are its phases?
- How can nuclear structure and reactions be described in a unified way?
- How can the symbiosis of nuclear physics and other subfields be exploited to advance understanding of all many-body systems?

NUCLEAR ASTROPHYSICS

- How old is the universe?
- How did the elements come into existence?
- What makes stars explode as supernovae, novae, or X-ray bursts?
- What is the nature of neutron stars?
- What can neutrinos tell us about stars?

EXPLORING QUARK-GLUON PLASMA

- What are properties of near-perfect liquid QGP
- What is the origin of confinement?
- What are the properties of the QCD vacuum? What is the origin of chiral symmetry breaking?
- What are the experimental signatures for a transition to new phases in relativistic heavy-ion collisions?
- What are the implications for the analogous epoch in the Big Bang?

THE STRONG FORCE AND THE INTERNAL STRUCTURE OF NEUTRONS AND PROTONS

- What are the internal structural properties of protons and neutrons and how do those properties arise from the motions and properties of their constituents?
- How do those properties change when protons and neutrons are combined into complex nuclei?
- Can QCD describe the full spectrum of hadrons in both their ground and excited states?
- How do the nucleonic models emerge from QCD?

FUNDAMENTAL SYMMETRIES

- What is the nature of the neutrinos, what are their masses, and how have they shaped the evolution of the cosmos?
- Why is there now more visible matter than antimatter in the universe?
- What are the unseen forces that were present in the dawn of the universe but disappeared from view as it evolved? Once very hot and very homogeneous, the universe now displays a preferred “handedness” and so the existence of lost forces.
- What are the low-energy manifestations of physics beyond the Standard Model? How can precision experiments in nuclear physics reveal them?