

Preliminaries

<http://people.nsl.msu.edu/~witek/Classes/PHY802/NuclPhys802-2017.html>

Instructor: Witold Nazarewicz and guest stars

TA: Mara Grinder (grinderm@msu.edu)

Recommended textbooks:

- *Nuclear Physics: Exploring the Heart of Matter* (2013)
<http://www.nap.edu/catalog/13438/nuclear-physics-exploring-the-heart-of-matter>
- *2015 NSAC Long Range Plan: Reaching for the Horizon*
http://science.energy.gov/~media/np/nsac/pdf/2015LRP/2015_LRPNS_091815.pdf

Requirements/grading criteria:

- Attendance and participation [40%]
- Answers to the problems [35%]
- Final presentation [25%; May 2, 2016] (PHY 802) or essay (PHY 492; tier II writing requirement) – based on 1-2 selected nuclear physics papers from Physical Review Letters, Science, or Nature. Consult <http://physics.aps.org/browse/>



You will have one week to send your answers to Mara by 10am on Wednesday

FINAL EXAM: [PHY 802 presentations 2016](#) [PHY 492 Sample Essay](#)

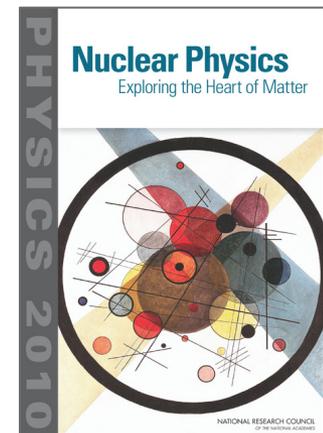
May 2, 2017, 7:45-9:45am, 1415 BPS

Focus:

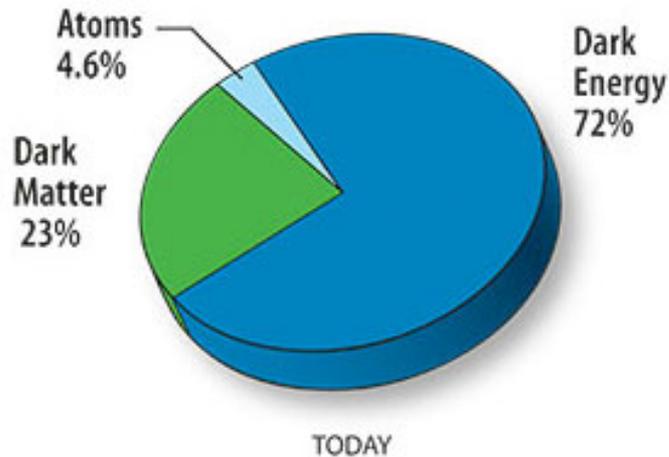
- Broadening and deepening students' knowledge and understanding
- Critical thinking; connecting the dots
- Limited technical knowledge

“All the matter that makes up all the living organisms and ecosystems, planets and stars, throughout every galaxy in the universe, is made of atoms, and 99.9% of the mass of all the atoms in the (visible) universe comes from the nuclei at their centers which are over 10,000 times smaller in diameter than the atoms themselves”

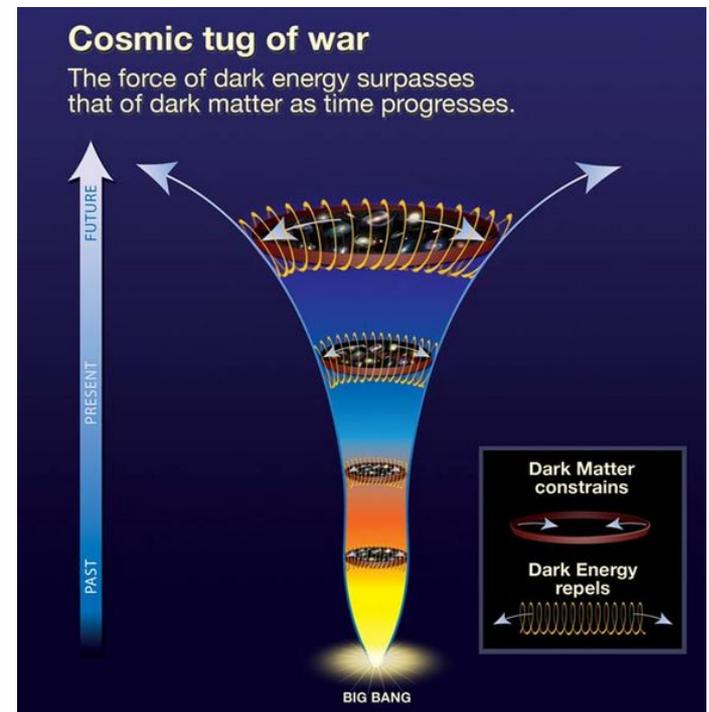
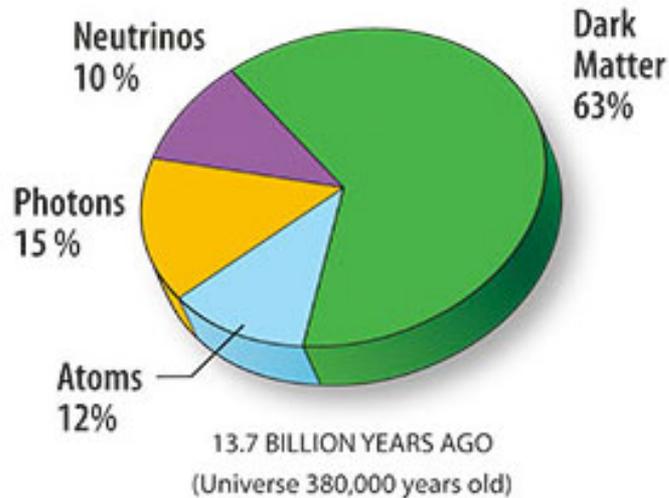
NRC Decadal Study Report



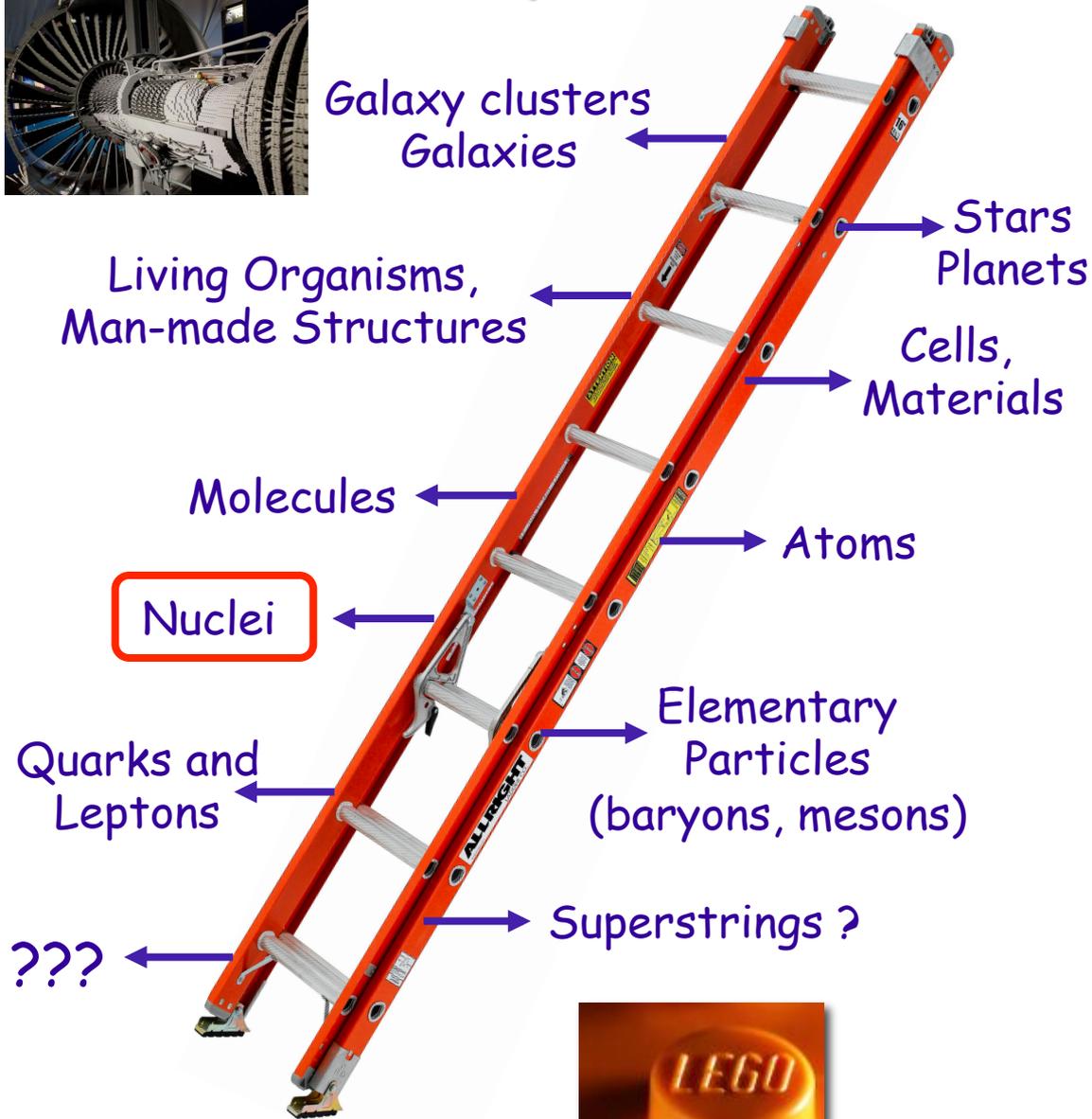
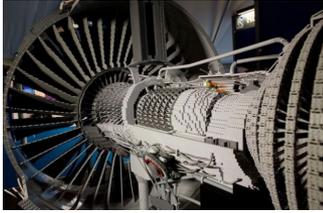
But...



Dark matter and dark energy together make up some 96% of the universe



The Quantum Ladder



macroscopic



subatomic



reduction



complexity

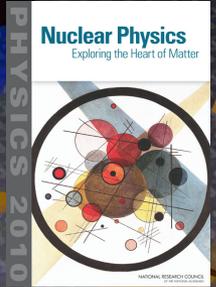
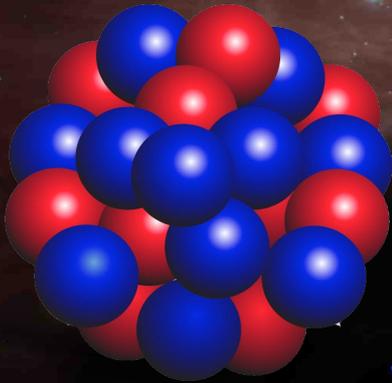
The Scale of the Universe

<http://scaleofuniverse.com>

<http://htwins.net/scale2/>

The Nuclear Landscape and the Big Questions

- Where do nuclei and elements come from?
- How are nuclei made and organized?
- What are practical and scientific uses of nuclei?



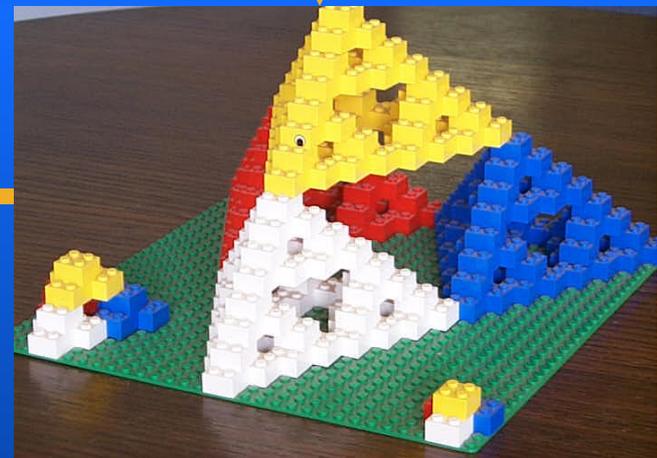
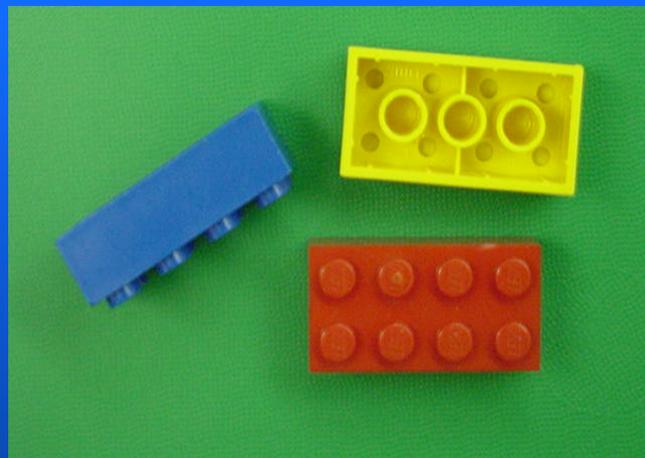
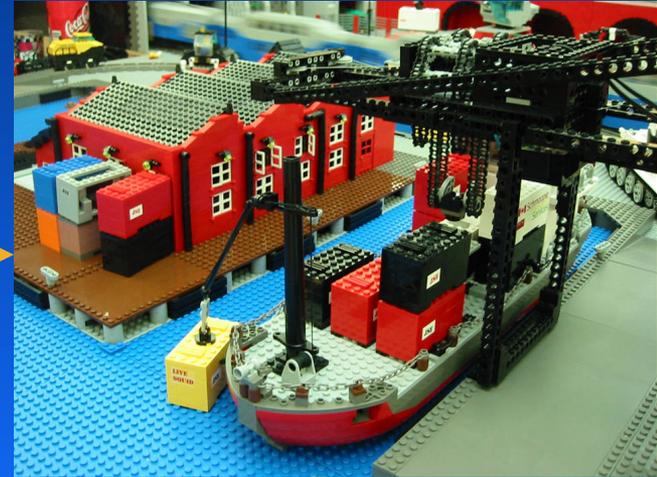
TIMESCALE

→ from QCD transition (color singlets formed; 10 ms after Big Bang) till today (13.8 billion years later)

DISTANCE SCALE

→ from 10^{-15} m (proton's radius) to ~12 km (neutron star radius)

The Lego Block Approach



Reduce the complex forms and materials to one (or a few) fundamental building blocks

Emergent Behavior

The phenomenon of emergent order refers to this kind of organization, with the higher levels displaying new properties not evident at the lower levels. Unique properties of organized matter arise from how the parts are arranged and interact, properties that cannot be fully explained by breaking that order down into its component parts. You can't even describe the higher levels in terms of lower-level language.

Emergence in physics and mathematics is often used in a slightly different sense than biological systems. In physics, going from the micro to the macro doesn't necessarily result in great organization, but it does introduce new properties, often ushering in a new structure with it... Almost anything can be more than the sum of its parts!

Examples:

friction, pressure, flow,
superfluidity, ferromagnetism

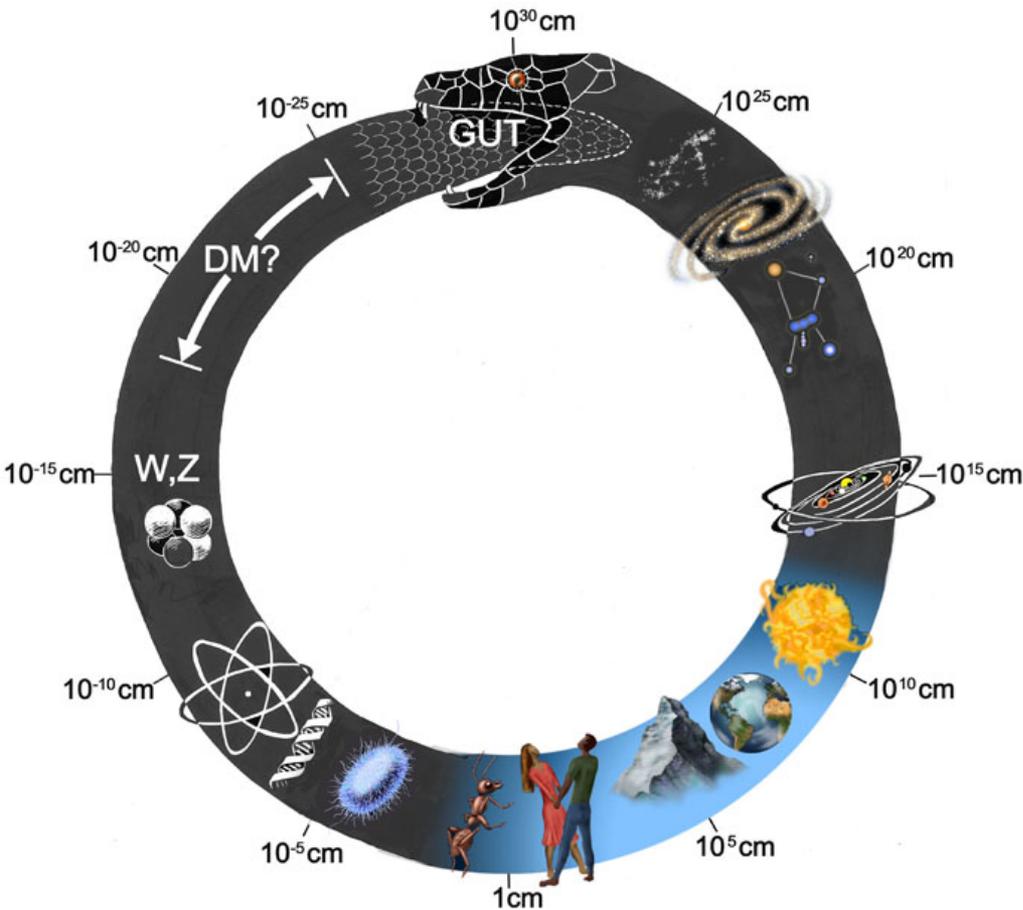


Möbius strip: a surface with only one side and only one boundary component. (Try to cut it along the center line!)



Think of examples of emergent phenomena in subatomic physics

A unifying view



The Cosmic Uroboros

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- Sheldon Glashow originally suggested this symbol, with the swallowing of the tail expressing his hope for a unification of the theories governing the largest and smallest scales
- Sixty orders of magnitude separate the very smallest from the very largest.
- The Cosmic Uroboros represents the universe as a continuity of vastly different size scales, of which the largest and smallest may be linked by gravity.
- There are connections between large and small: electromagnetic forces are most important from the scale of atoms to that of mountains; strong and weak forces govern both atomic nuclei and stars; cosmic inflation may have created the large-scale of the universe out of quantum-scale fluctuations.
- Few realize that the universe exists on all scales, everywhere, all the time. This is a truly extravagant thought.

The View from the Center of the Universe (2006)

http://physics.ucsc.edu/cosmo/primack_abrams/COSMO.HTM