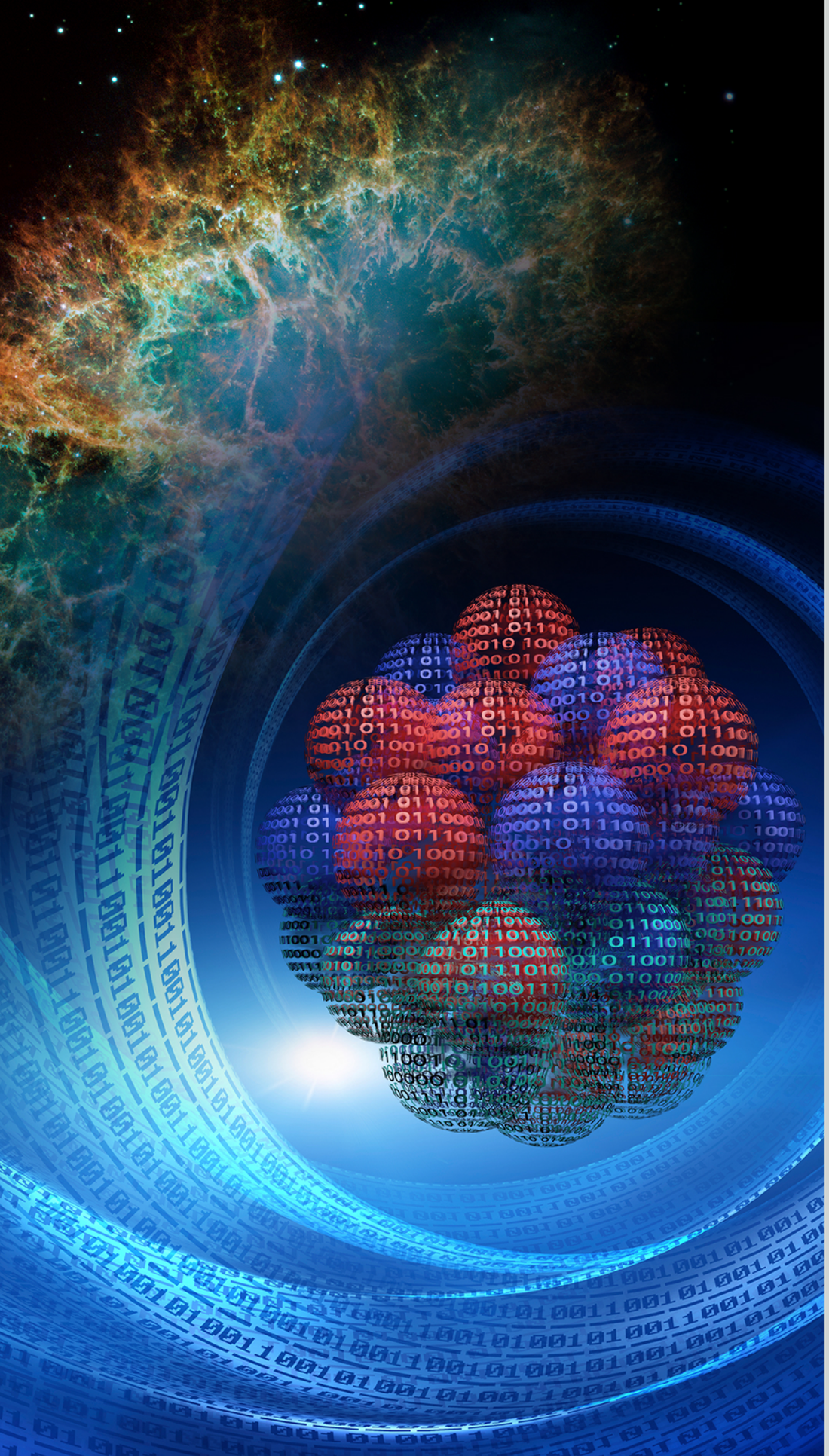


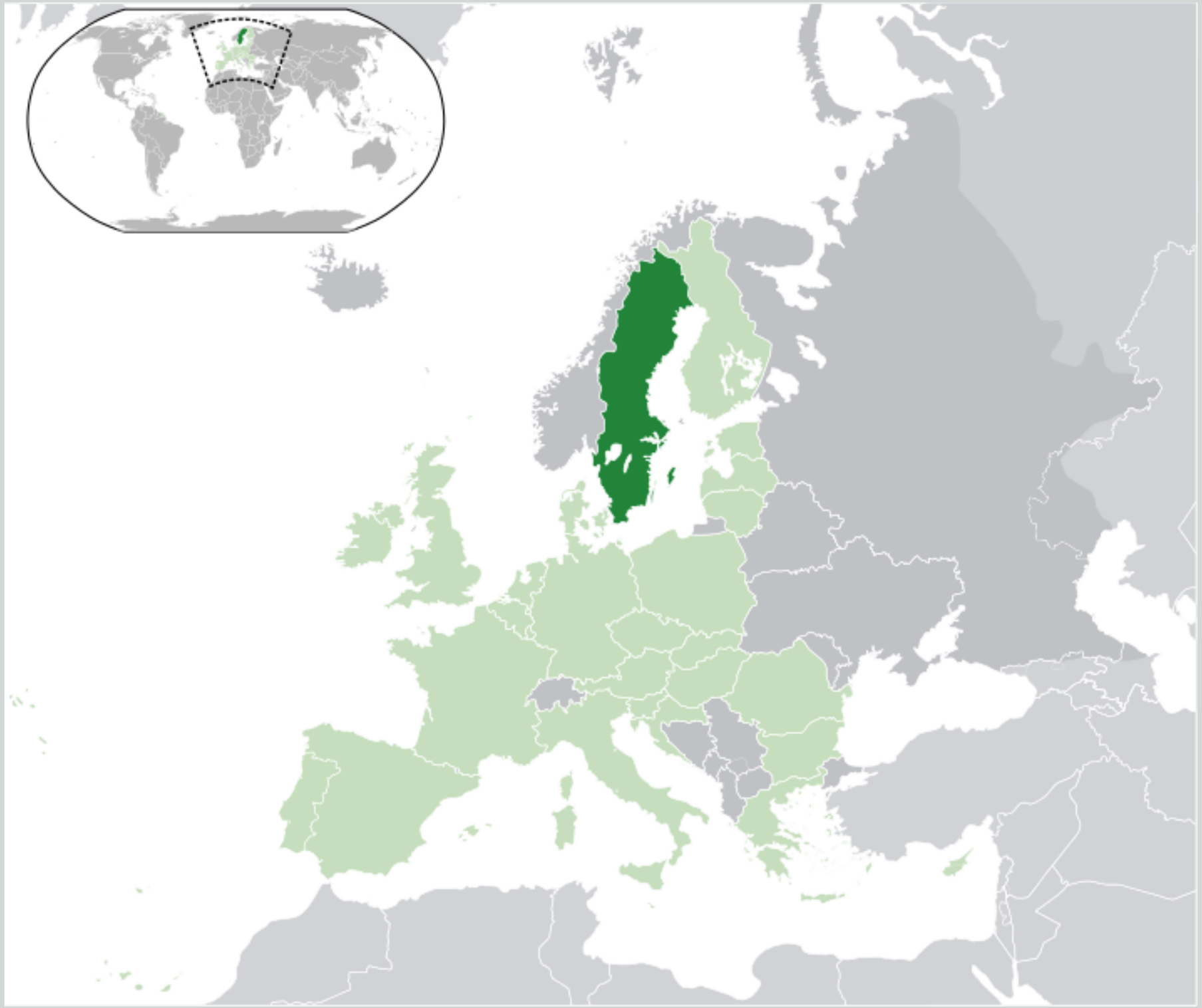
EUROSCHOOL ON EXOTIC BEAMS

Christian Forssén,
Department of Physics, Chalmers

NUCLEAR THEORY AND PREDICTIVE POWER

LECTURE 1

SWEDEN



SWEDEN — FROM NORTH TO SOUTH

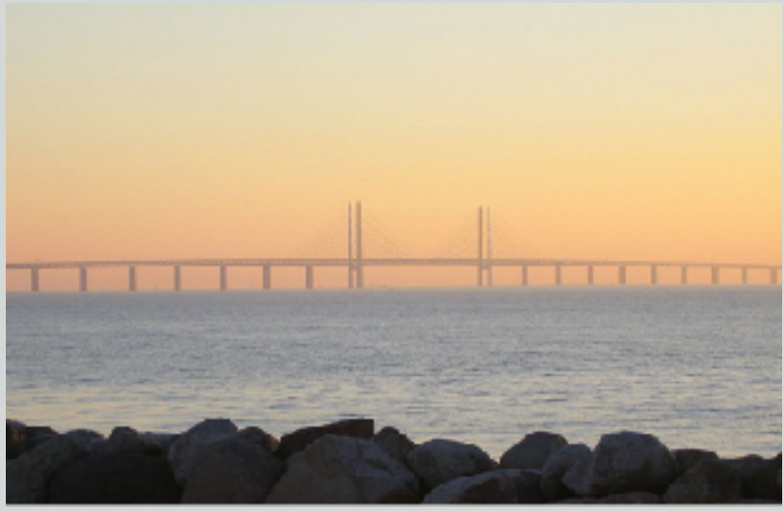
Stora Sjöfallet

West coast

East coast

Midsommar

Öresund bridge



FAUNA

Swedish moose

Swedish lynx

Swedish pig

Swedish lawn after visit of Swedish pigs

Swedish herring

Swedish mosquito

DRUNK FAUNA

Drunken moose ends up stuck in Swedish apple tree

By **Per Nyberg**, CNN

September 9, 2011 -- Updated 0108 GMT (0908 HKT)

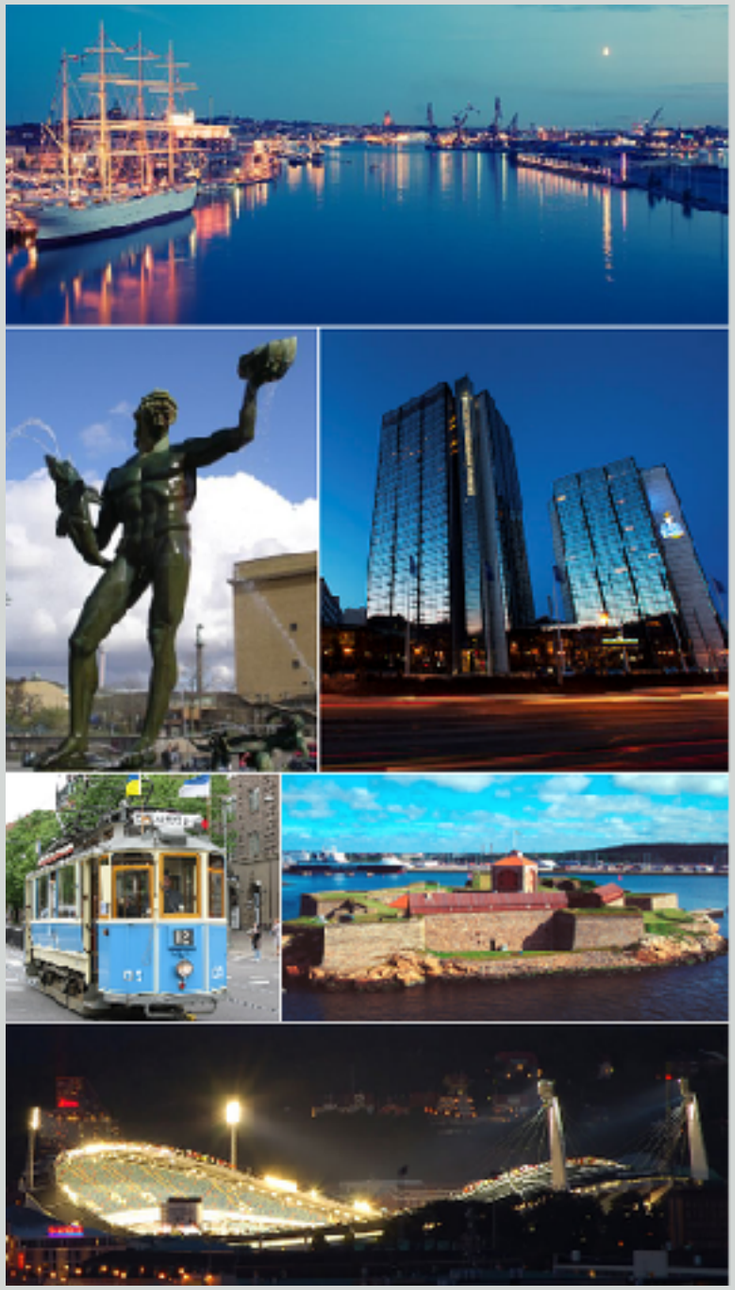
A moose got stuck in a tree after eating fermented apples in Saro, Sweden, Wednesday night.

STORY HIGHLIGHTS

- "I saw something really big up in a tree," Per Johansson says, "and it was a moose"

(CNN) -- It was a dark, windy and rainy night when Per Johansson returned from work to his home in Saro just south of Gothenburg, Sweden.

CHALMERS UNIVERSITY OF TECHNOLOGY



Gothenburg, Sweden
pop. ~600,000

Chalmers

students ~11,000
phd students ~1,200
faculty ~1,800

Theoretical Subatomic Physics @ Chalmers

- From QCD to nuclear interactions
- Nuclear structure
- Few-body physics
- Effective field theory
- Astroparticle physics, dark matter phenomenology
- Physics beyond the standard model

LECTURE PLAN

- **Lecture 1: Learning from data and predictive power**
  - Theoretical models and predictability
  - Learning from data / Bayesian statistics
- **Lecture 2: From nucleons to nuclei**
  - Strong QCD
  - Effective theories / Chiral Effective (Field) Theory
  - *NN* scattering
  - *Ab initio* nuclear theory

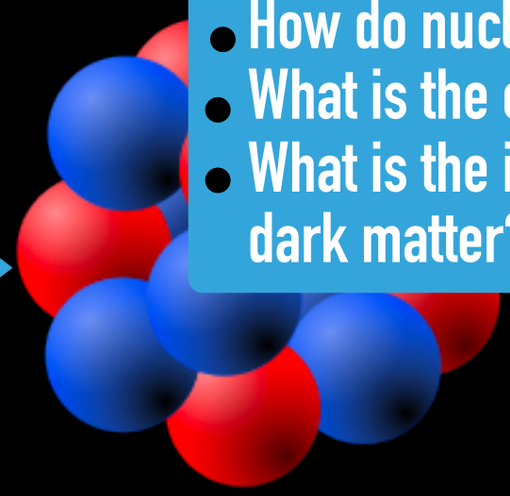
PROFOUND INTERSECTIONS

- Can we solve QCD to describe hadronic structures and interactions?
- Can we employ the separation of scales to build successful effective field theories?
- What is the new standard model of particle physics?

subfemto...

femtophysics

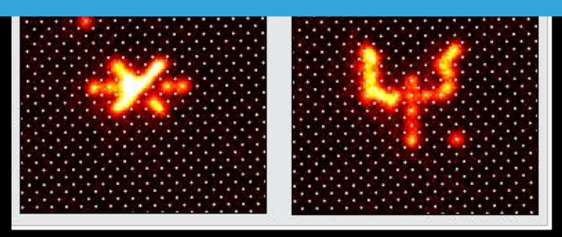
- What controls nuclear saturation?
- What are the properties of nuclei with extreme neutron/proton ratios?
- Can we predict useful cross sections that cannot be measured?
- Can nuclei provide precision tests of fundamental symmetries?



- How do nuclei shape the physical universe?
- What is the origin of the elements?
- What is the interaction between baryonic and dark matter?

ARTICLES

giga...



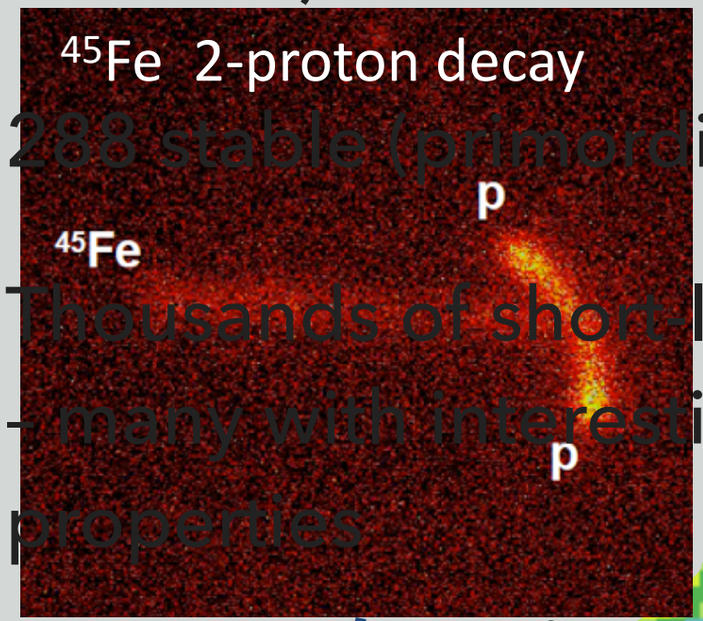
QUANTUM MANY-BODY PHYSICS

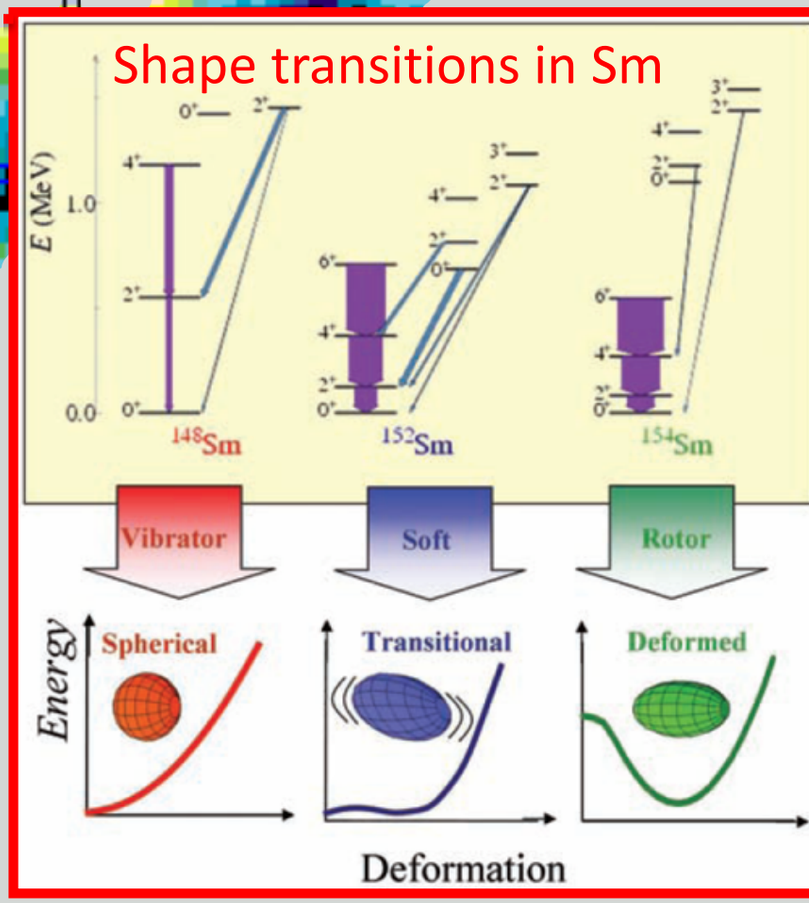
PHYSICS OF NUCLEI

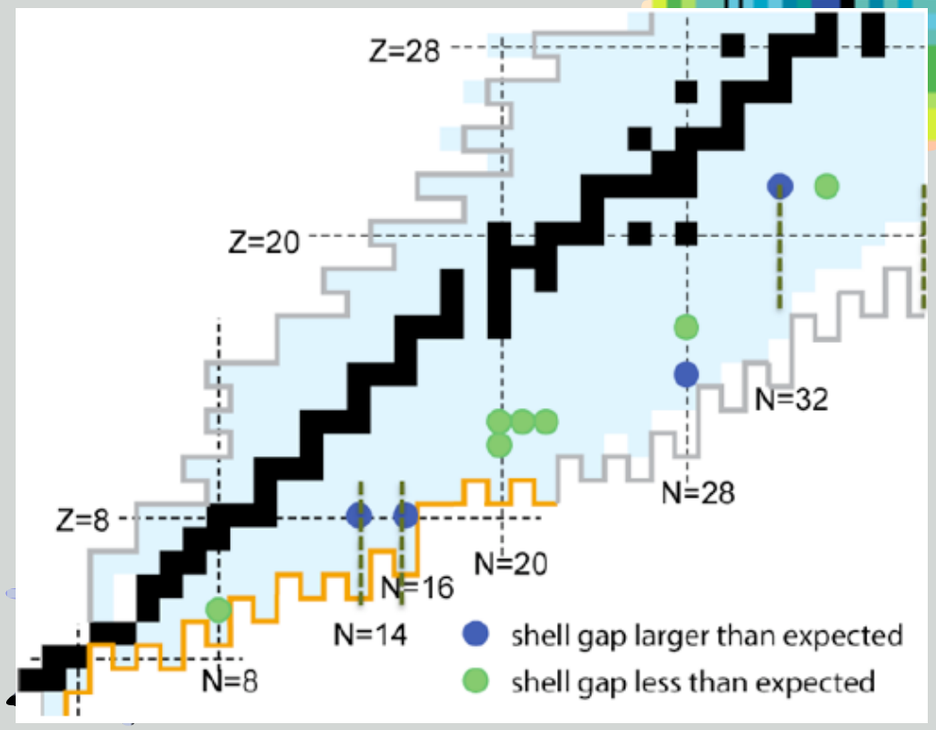
- How do collective phenomena emerge from simple constituents?
- How can complex systems display astonishing simplicities?
- What are unique properties of open quantum systems?

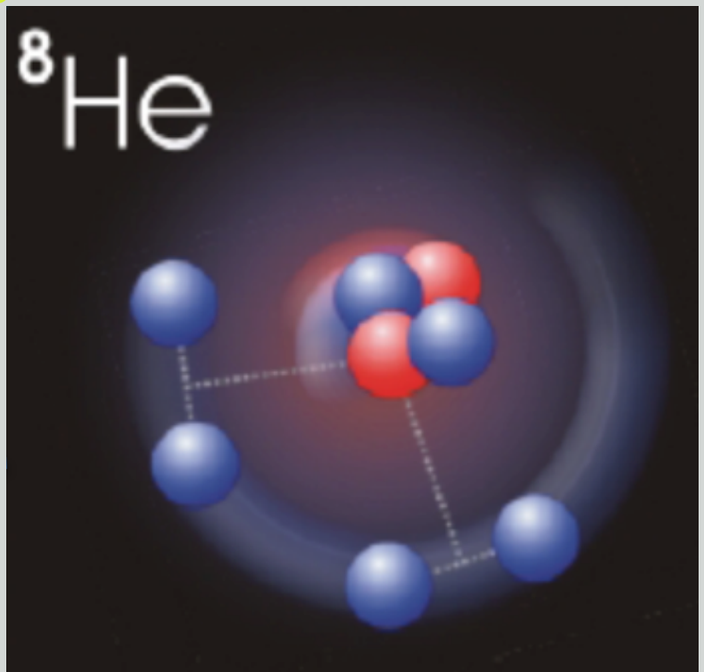
HYSICS AND COSMOLOGY

- 118 chemical elements (94 naturally found on Earth)
- 288 stable (primordial) isotopes
- Thousands of short-lived isotopes – many with interesting properties









b.socratiive.com (room: CFORSSEN)

What should be the goal for our theoretical understanding of atomic nuclei?

A. To find a "standard model" of nuclear physics that both explains and predicts all properties of atomic nuclei from fundamental principles.

B. Same as A, but let us not be greedy. We should aim to reproduce gross properties, but not necessarily fine details.

C. Developing a number of different nuclear models that explains observed nuclear properties in a specific region of the nuclear chart.

D. Same as C, but aiming for predictive power.

E. I don't really care. I just need a theory curve with my experimental data to satisfy the referee and publish my paper.

> The first, the basic approach, is to study the elementary particles, their properties and mutual interaction. Thus one hopes to obtain knowledge of the nuclear forces.

M. Goeppert-Mayer (Nobel Lecture)

[...]
If the forces are known, one should, in principle, be able to calculate deductively the properties of individual nuclei. Only after this has been accomplished can one say that one completely understands nuclear structure.

M. Goeppert-Mayer (Nobel Lecture)

> [...]
> The other approach is that of the experimentalist and consists in obtaining by direct experimentation as many data as possible for individual nuclei. One hopes in this way to find regularities and correlations which give a clue to the structure of the nucleus .

M. Goeppert-Mayer (Nobel Lecture)

[...]
The shell model, although proposed by theoreticians, really corresponds to the experimentalist's approach.

M. Goeppert-Mayer (Nobel Lecture)

CLASSIFICATION OF THEORIES

Classification of theories (from Kitaigorodskii):

- A third rate theory explains after the facts (postdictive)
- A second rate theory forbids
- A first rate theory predicts (predictive)

All three categories are needed!

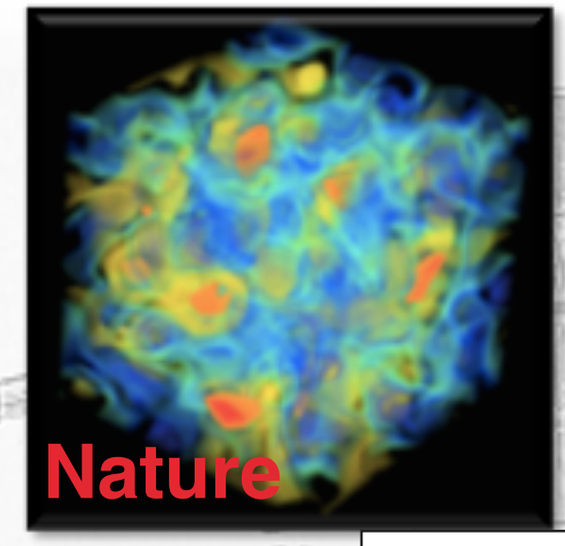
What property is absolutely critical for achieving predictive power?

THEORETICAL ERRORS

What kinds of theoretical errors
can one encounter?

- Statistical errors
  - Model parameter uncertainties
  - Monte Carlo method statistics
- Systematical errors
  - Method uncertainties (convergence)
  - Model uncertainties (missing physics)
  - Unknown physics

THE SCIENTIFIC METHOD



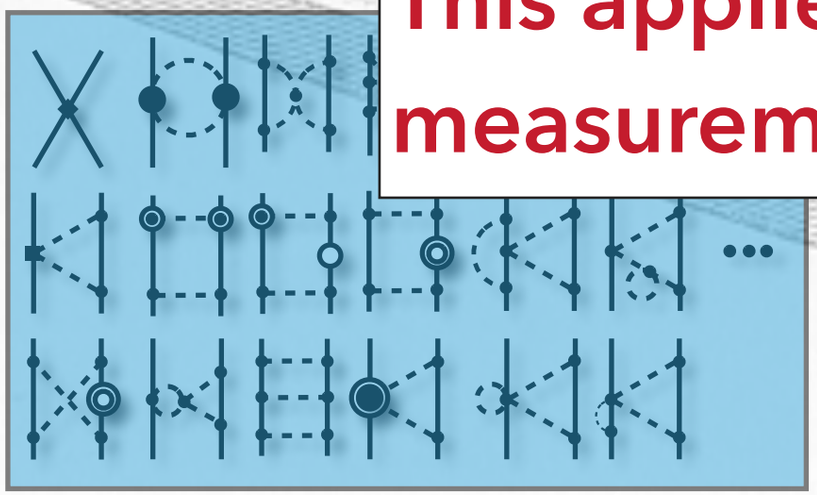
Nature

Manifests itself in

Reactions

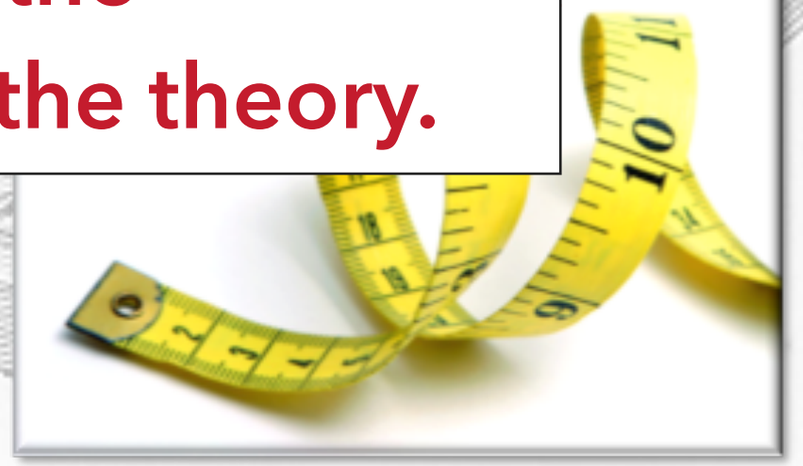
accessible to

The quantification of uncertainties is absolutely critical for progress. This applies BOTH to the measurement and to the theory.



Theories

inspire



“UNCERTAINTY IS AN UNCOMFORTABLE POSITION. BUT CERTAINTY IS AN ABSURD ONE.”

Voltaire

USEFUL THEORIES

- It makes no sense to improve a model below model's resolution
- Statistical tools can be used to both improve and eliminate a model

Next: *"Learning from data"*

See: https://github.com/cforssen/Euroschool2018_Forssen.git