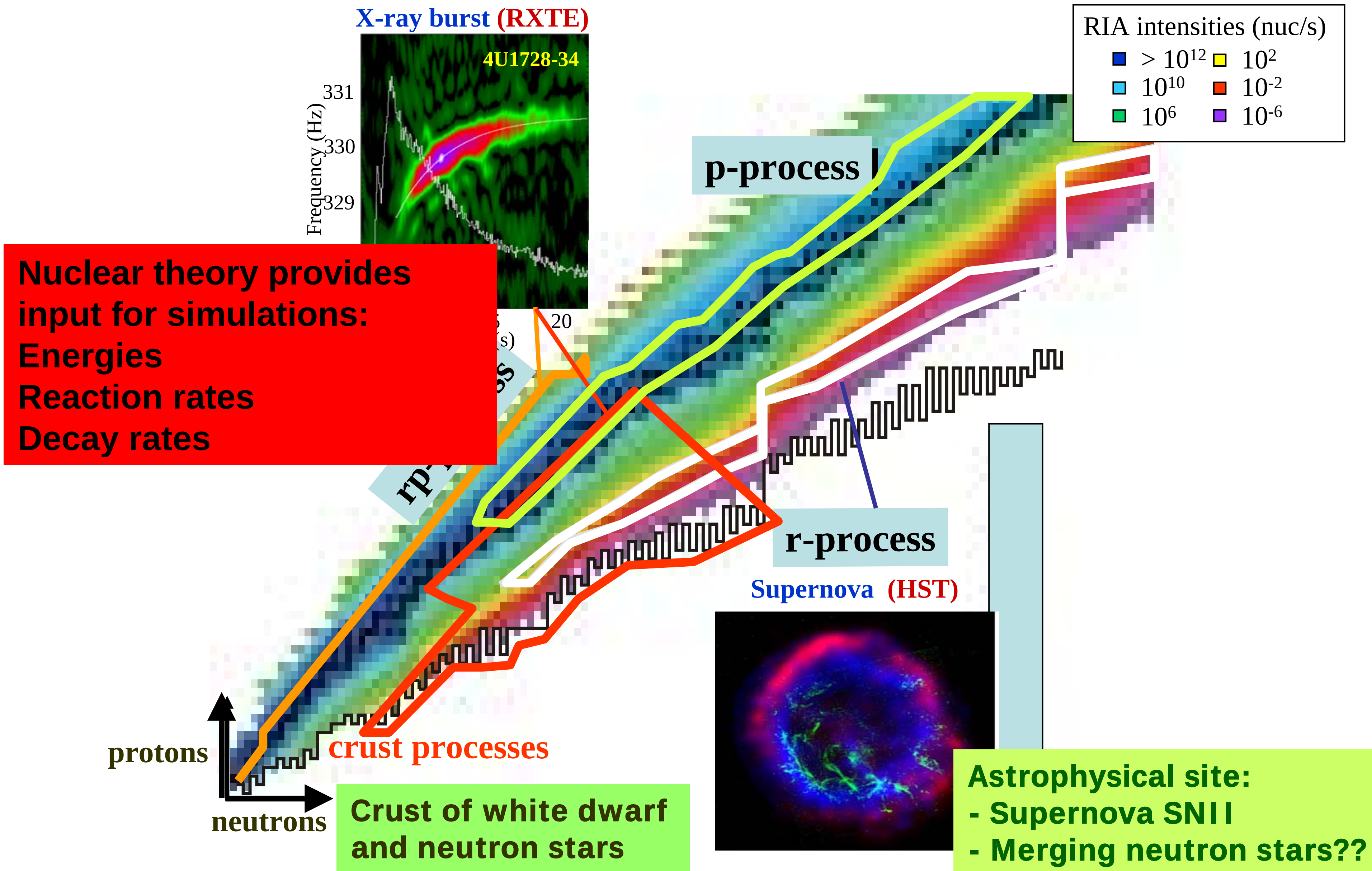
Many body Theory of small Systems

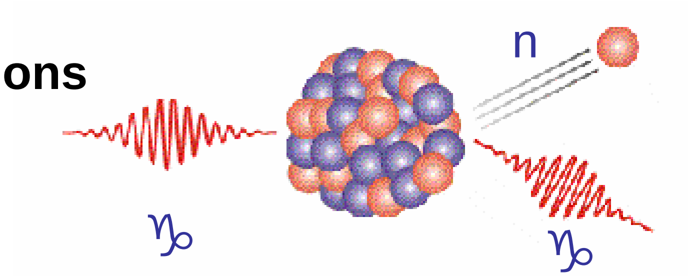
Prof. Stefan Frauendorf

2 graduate students

Origin of the Elements, Nuclear Microphysics of the Universe



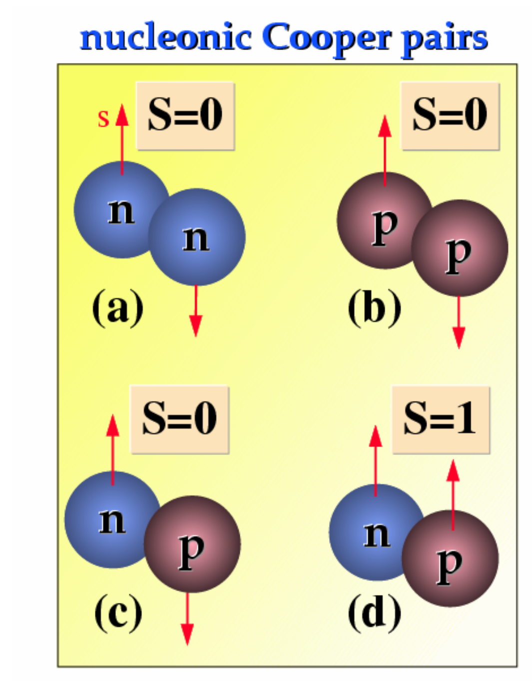
Structure of very proton- and neutron-rich nuclei



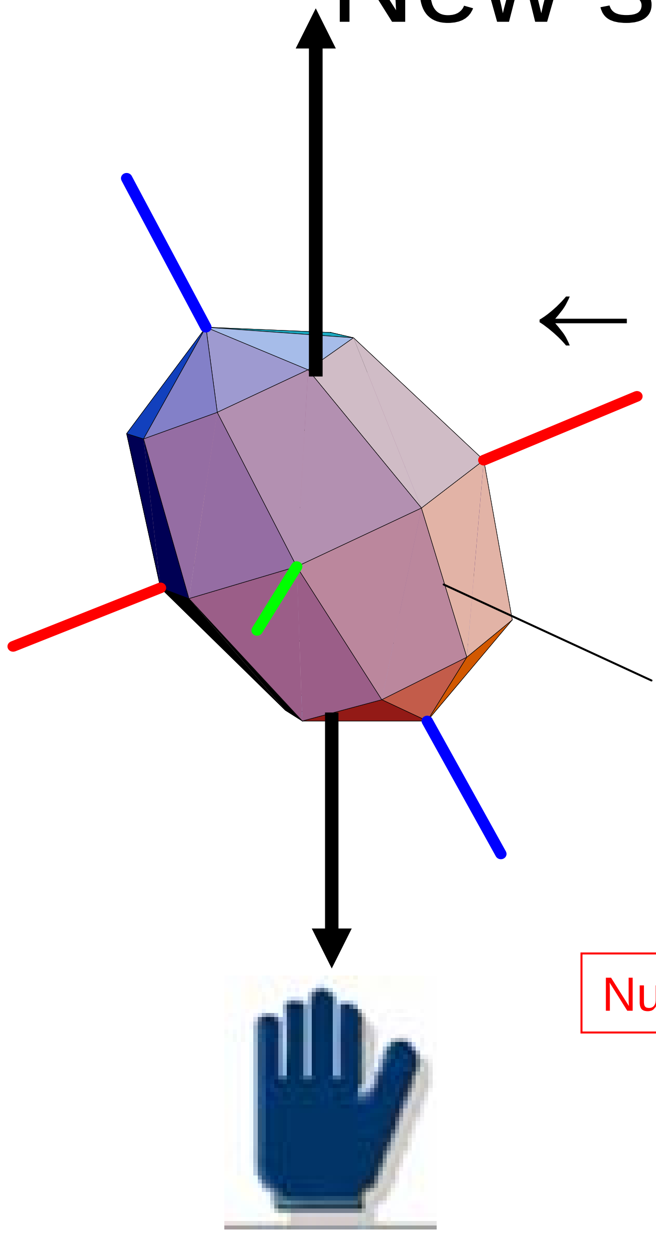
♑📫absorptions cross sections for stellar reactions
SF+1 Graduate in collaboration with
M. Wiescher's group and FZ Dresden

G. Rusev et al., Phys. Rev. Lett. **95**, 062501 (2005)
S. Zhang et al., Phys. Rev. Lett. , subm.

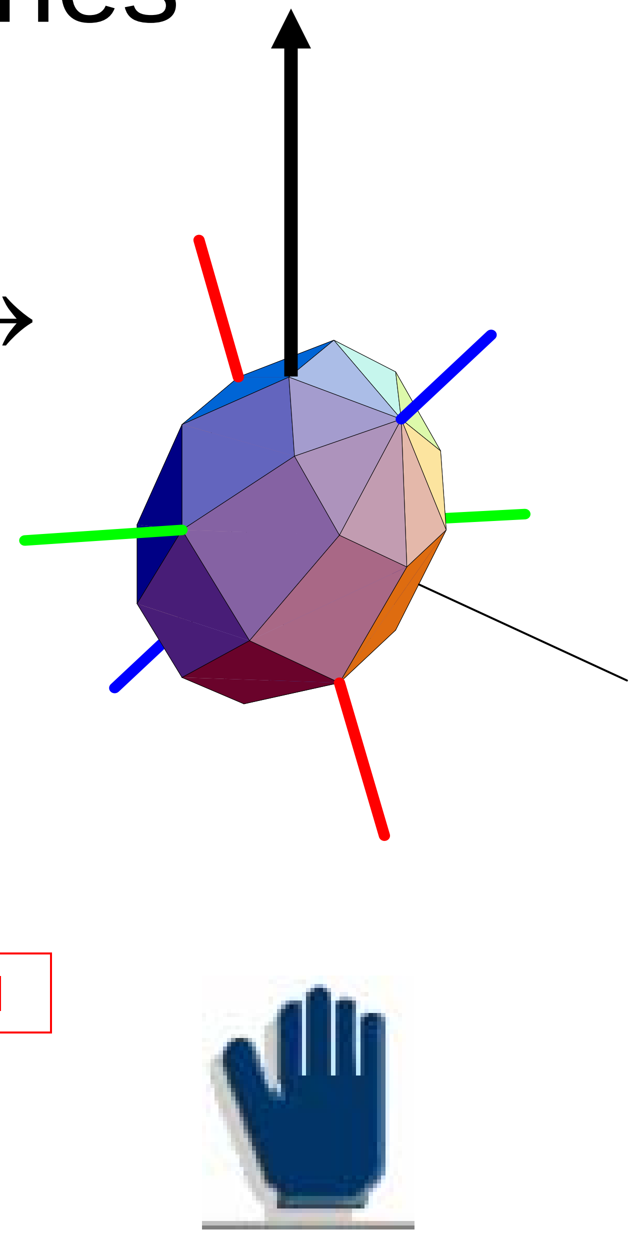
Proton – neutron pairing and isospin symmetry
SF + 1 Graduate



New symmetries



$$\leftarrow \mathrm{TR}_y(\pi) \rightarrow$$



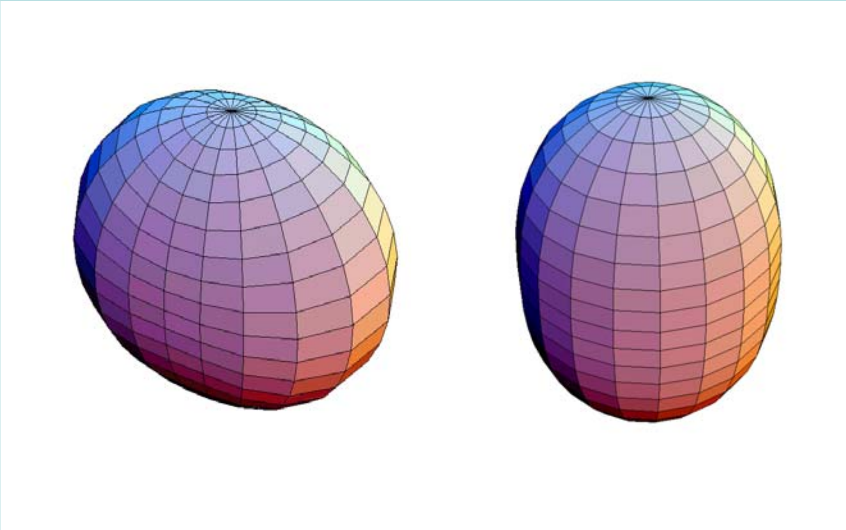
Nuclei can be chiral

New large project with Prof. Caprio and Prof. Zelevinsky (MSU)

Microscopic foundation of large amplitude collective motion by Generalized Density Matrix Theory

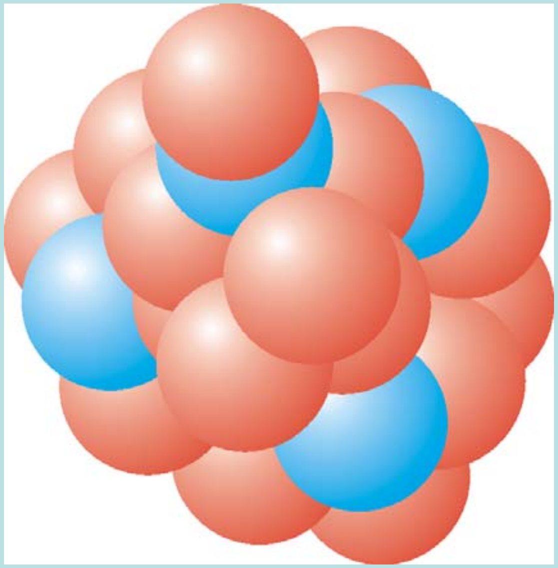
MC+1 PostDoc+SF+1 Graduate
in collaboration with MSU and FZ Dresden

Calculate how such motion
Self-organizes from
the quantal orbital motion of
protons and neutrons.



Mesoscopic systems:
Small is different- large as well

Bulk matter



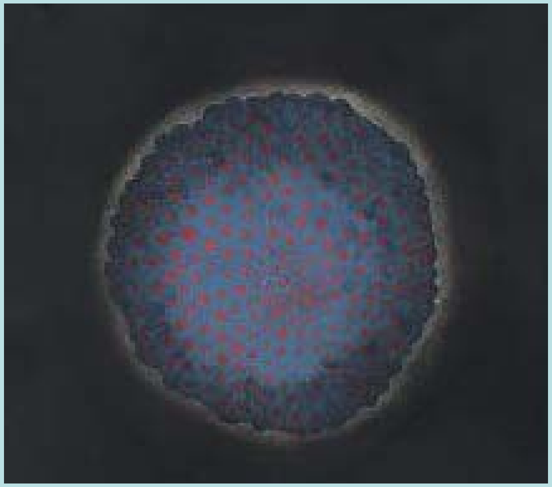
Few particle systems

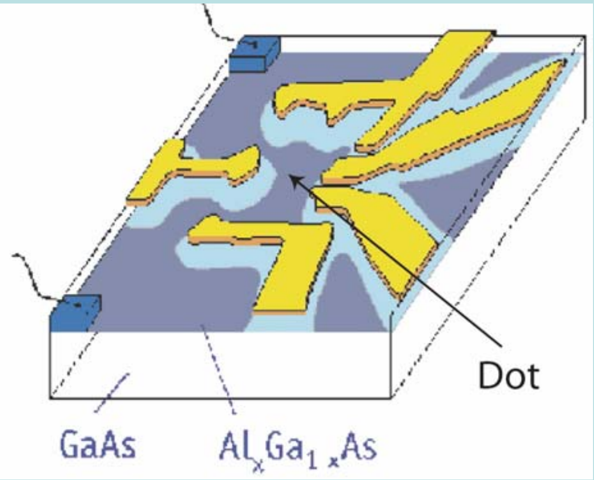
Quantum effects become dominant with decreasing particle number.

Collective phenomena emerge with increasing particle number.

Nobel prize winner Laughlin in his book A Different Universe:

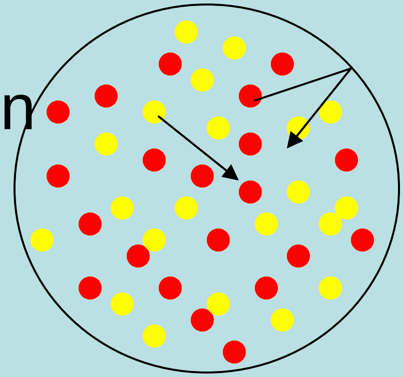
Emergence is identified as something universal that becomes increasingly exact in the limit of large sample sizes, hence the idea of emerging.



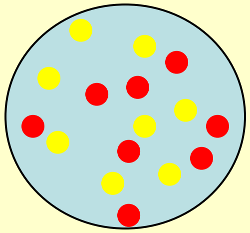


Nucleus Metalcluster Quantumdot

Small (mesoskopische) systems show universal phenomena, because they contain Fermions (protons, neutrons, electrons), which move freely inside.

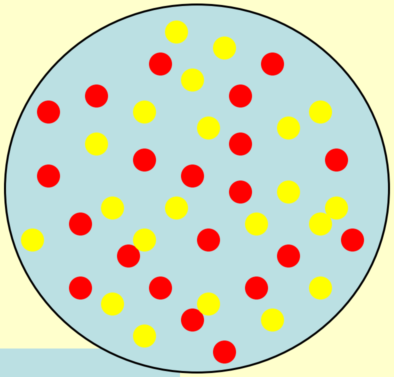


Mesoscopic systems

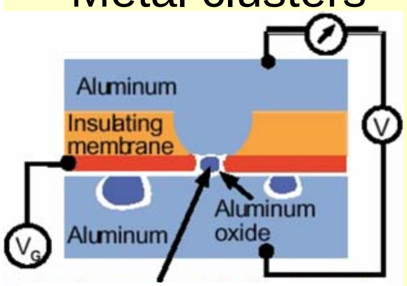


N

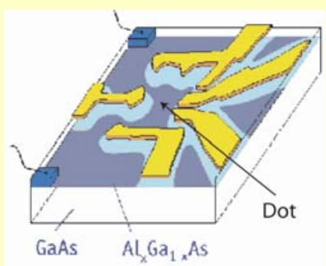
complexity



Nuclei
He-droplets
Metal clusters



Nano particles



Quantum dots

E

Emergent phenomena:

-Liquid-gas surface, droplet features
-superconductivity / superfluidity
-thermal phase transitions
-shell structure, quantal shapes (liquid)
-spatial orientation, rotational bands
-rotational/magnetic response
-quantum phase transitions

How?

macroscopic

Quantum chaos:

When should H to be considered random?
Prediction for quantum states vs. level statistics (GOE, P),
transition statistics (PT), conductance fluctuations
When can one use thermodynamical concepts ?
Which ensemble? (micro c. , canonical, grand c.)

Universality of phenomena at different scales

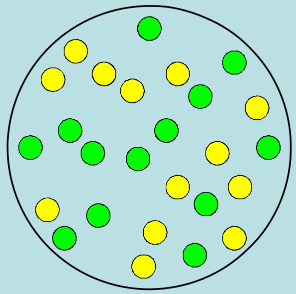
energy
size

Nuclei

Protons

Neutrons

strong
interaction



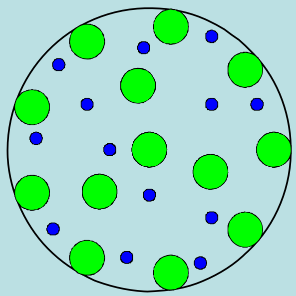
10^{6} eV
10^{-15} m

Metal - Clusters

Metal Ions

Conduction Electrons

electromagnetic
interaction
(metallic bonds)

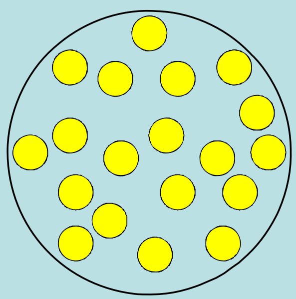


1 eV
10^{-10} m

He_3 - Clusters

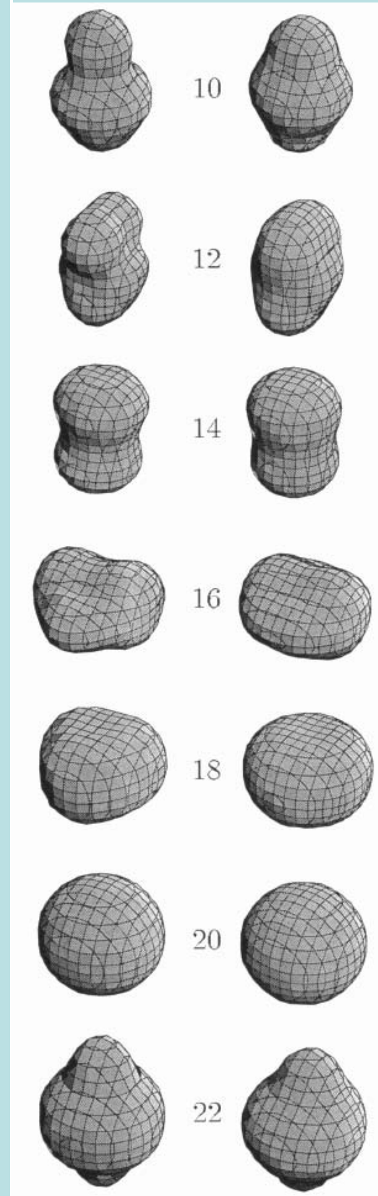
Atoms

electromagnetic
interaction
(van der Waals bonds)



10^{-4} eV
10^{-10} m

cluster nucleus



Getting the gist of it

Experiment – lot of work

Summer support available

Theory – lot of fun

Calculations – the price for the fun

Very useful skills – think of later