ISIS neutron and muon source: an insight inside the materials.

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Observatorio de El roque de los Muchachos, November 2019

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Acknowledgments

- Dr. Sabrina Gaertner (space ice)

- Dr. Adrian Hillier (muons and Isis facts)

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Non-flammable, flat(-ish) material

Flammable material

From primitive technology
https://www.youtube.com/watch?v=uHN60owoFoE

"Vieja friendo huevos." Diego Velázquez
https://commons.wikimedia.org/w/index.php?curid=19980800

Flexible, strong and light

Material with low specific heat

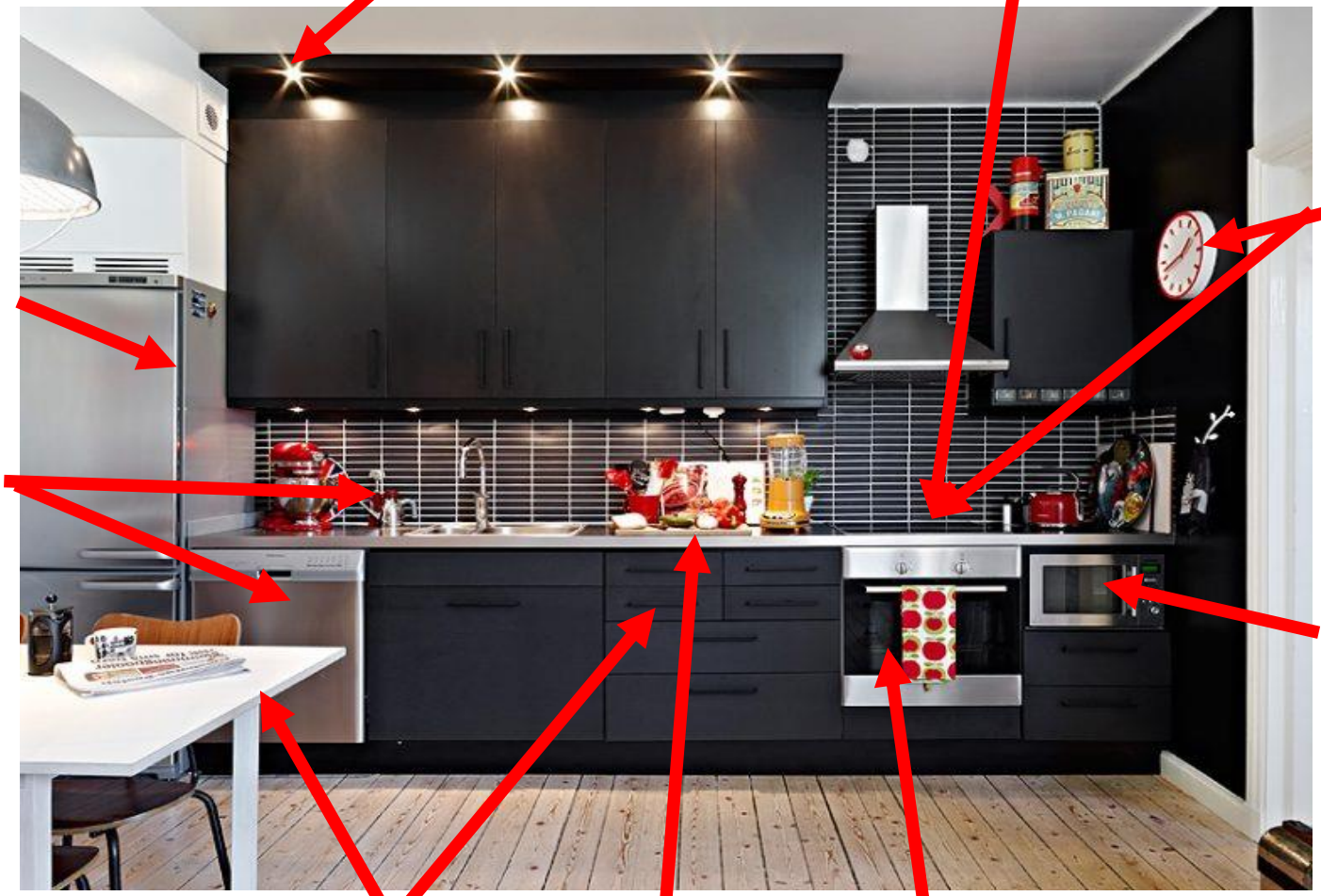
Oil allows temperature control

Confined heat source

Waterproof and concave

Sharp, hard and strong

Dull and robust


Semiconductors LED
High performing glasses
Piezoelectrics
Magnets
Micelles
Magnetron + Faraday cage
Composites
High melting point materials
Antibacterial surface

Physics Nobel prices on materials

- 2016 Topological materials
- 2014 Blue LED
- 2010 Graphene
- 2009 Optical fibres and CCD
- 2007 Giant Magneto Resistance
- 2003 Superfluidity and superconductivity
- 2001 Bose Einstein Condensate
- 2000 Semiconductor heterstructures and integrated circuit

Hubbard Theory Consortium

SEPnet ACM

SEPnet & Hubbard Theory Consortium, Department of Physics,
Royal Holloway, University of London

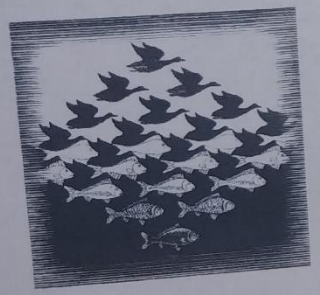
ROYAL HOLLOWAY UNIVERSITY

Symmetry

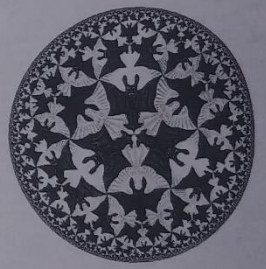
Coherence

Concepts in
Many Body Physics

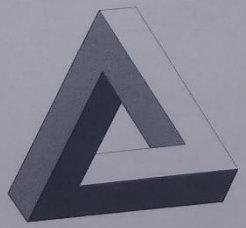
Emergence



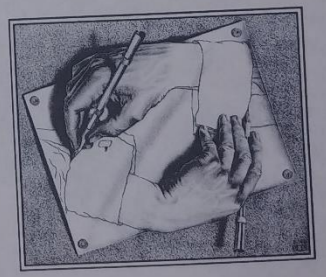
Geometry



Topology



Correlation



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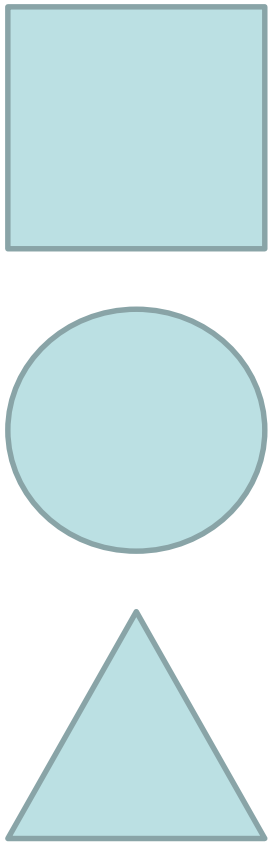
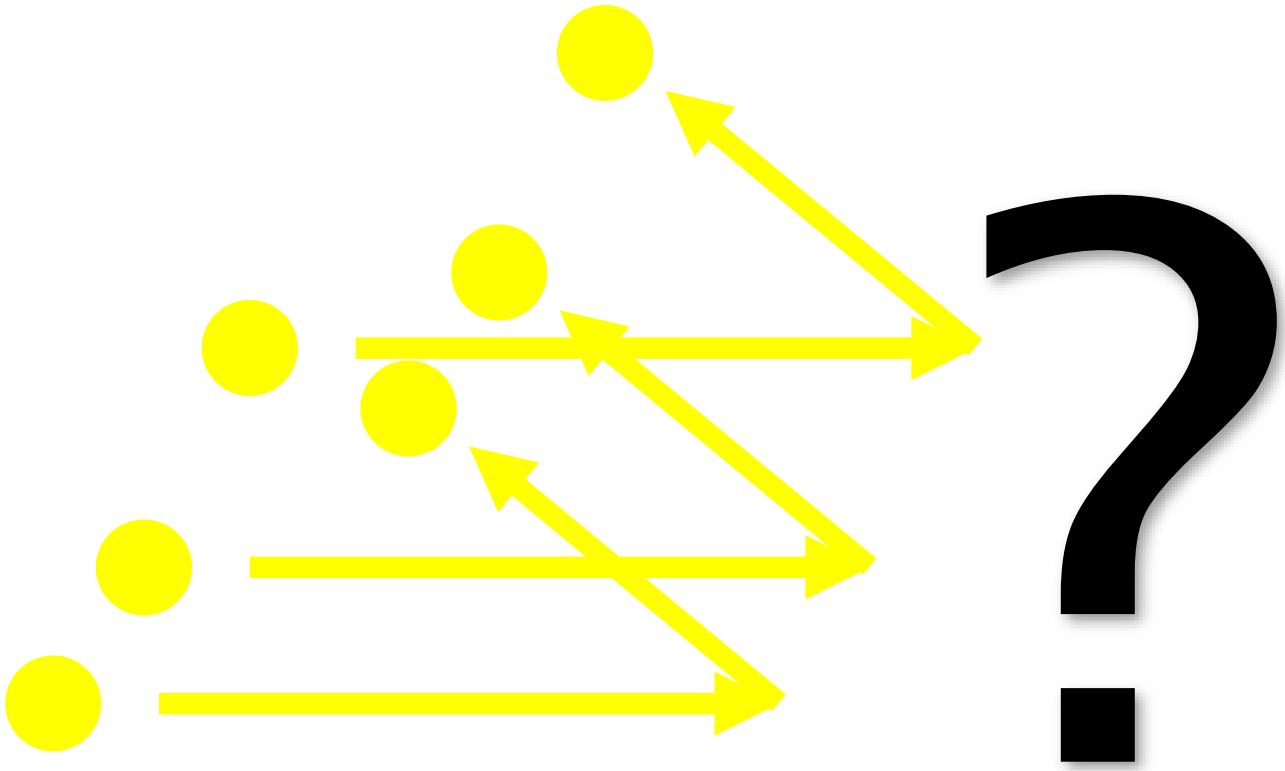
?





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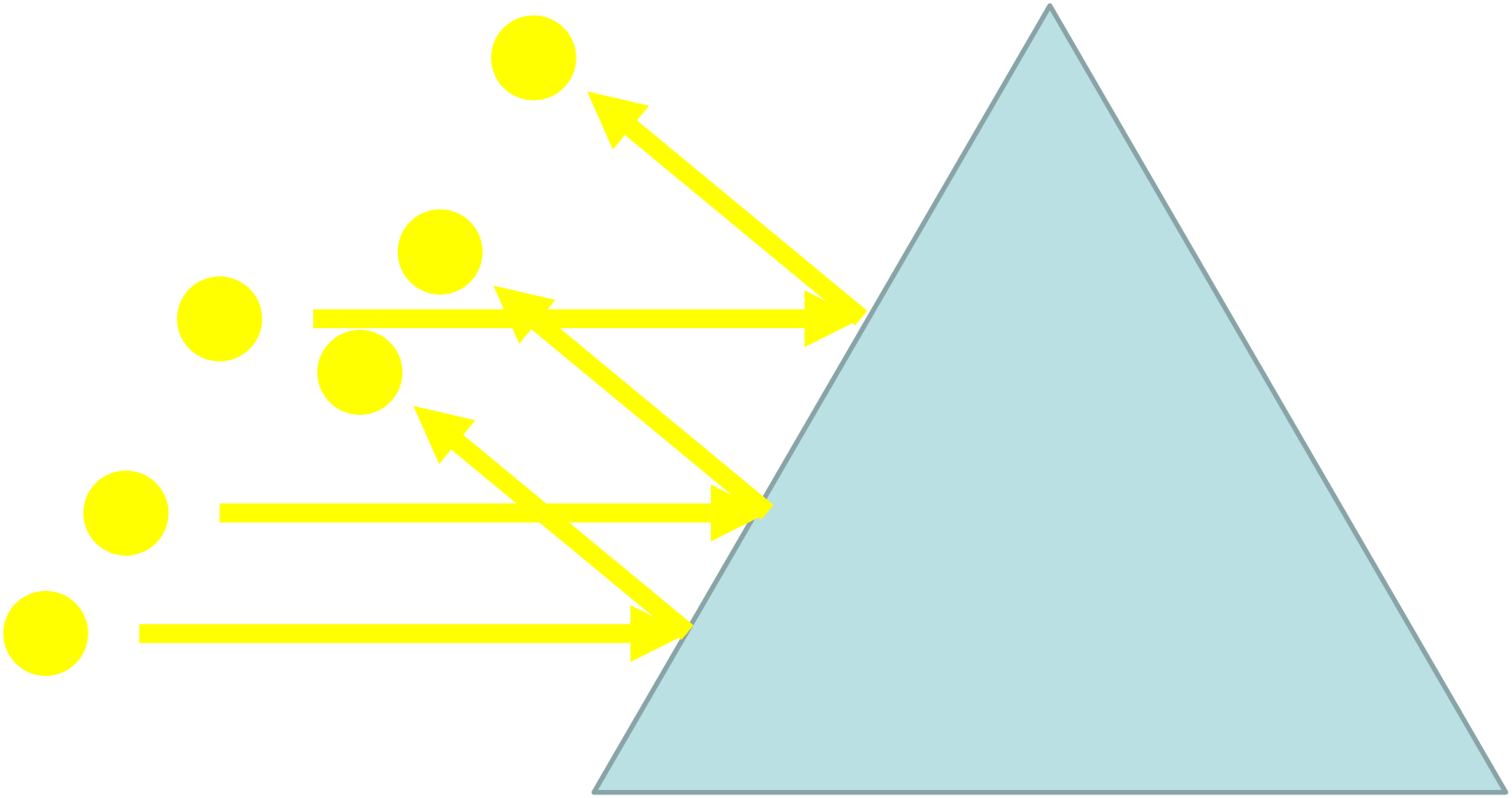
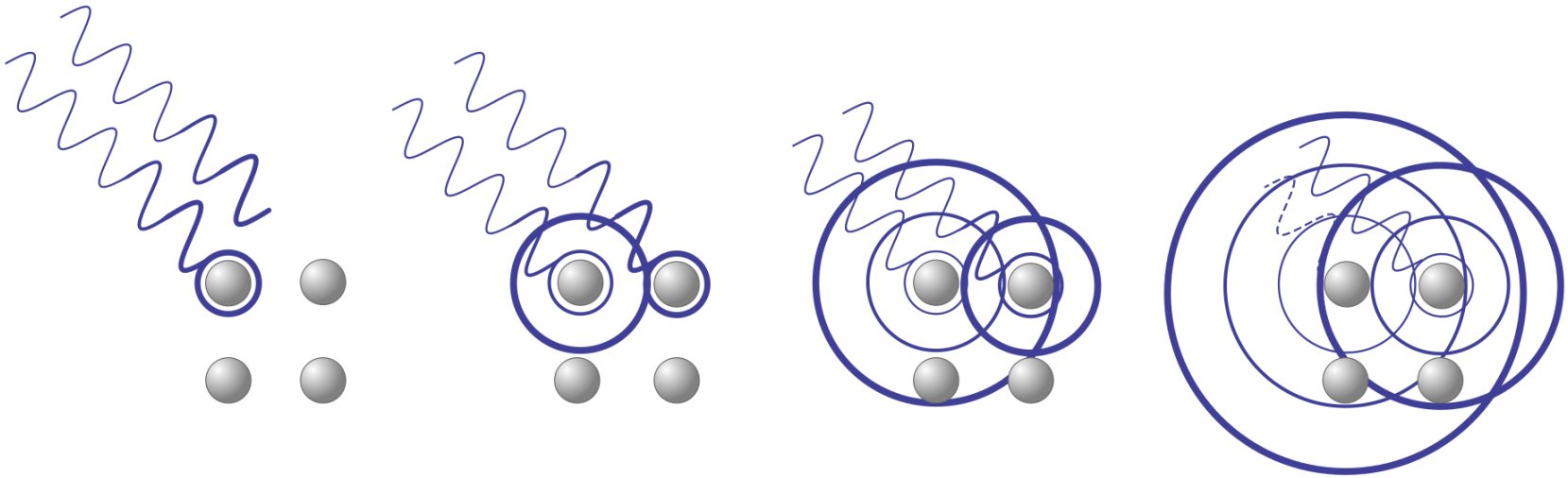


Understanding the science

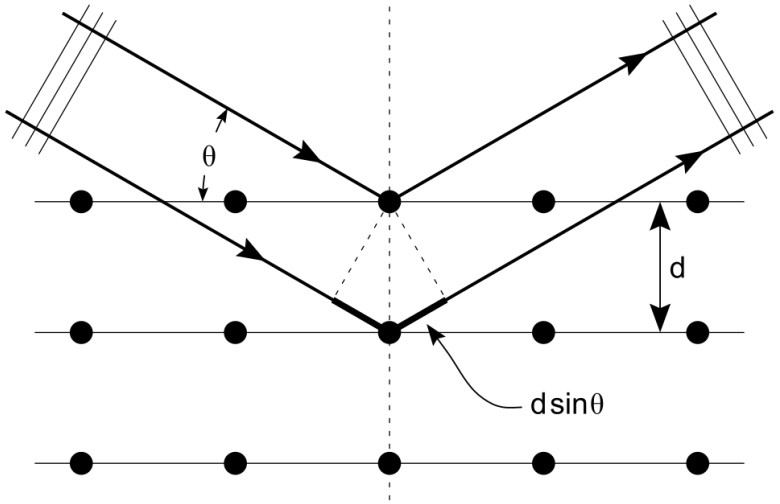
- Where the atoms are?

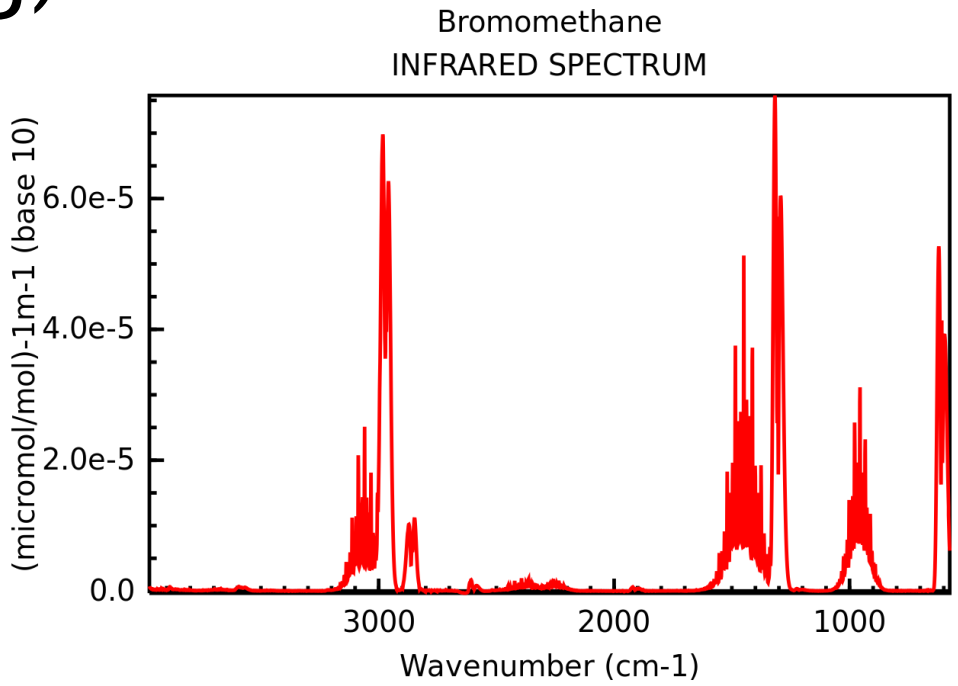


- What the atoms do?

Scattering!

- Where the atoms are? Diffraction (elastic scattering)





NIST Chemistry WebBook (http://webbook.nist.gov/chemistry)

- What the atoms do? Spectroscopy (inelastic scattering)

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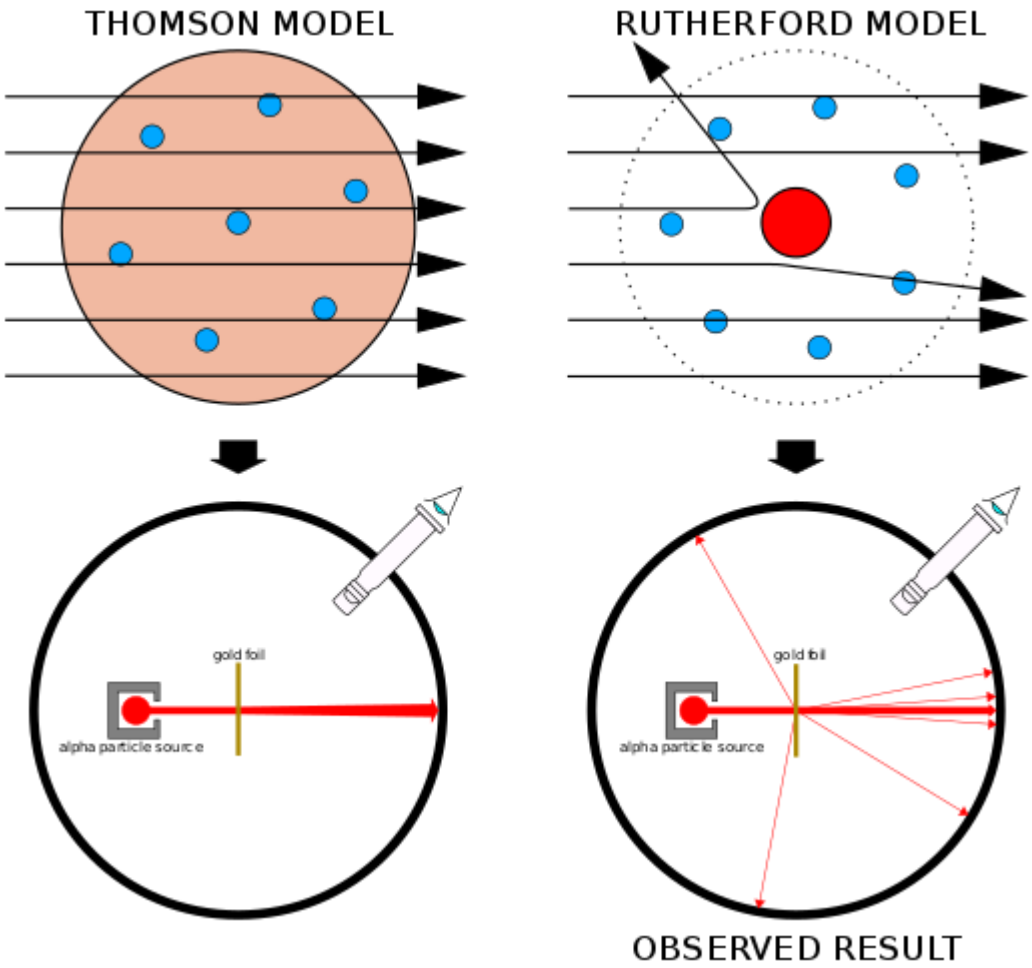
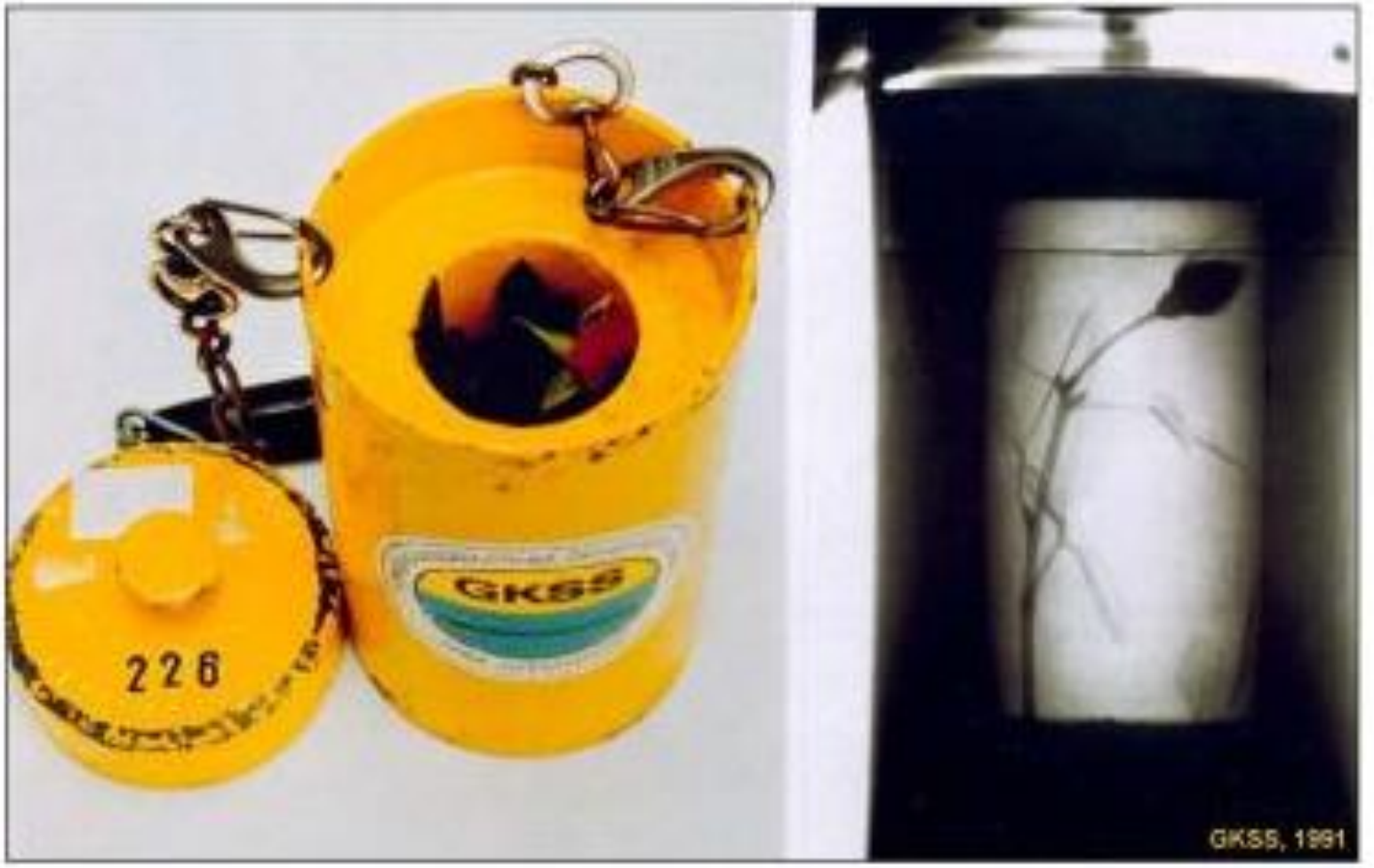
Scattering

- Balls
- Alpha particles (Rutherford)
- Electromagnetic radiation (X-rays, UV,IR…)
- Electrons (TEM, e^- diffraction)
- Neutrons (ISIS, ILL, NIST, etc.)
- Muons (ISIS, PSI, etc.)
- Everything!



By Kurzon - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=32215297

Why neutrons?

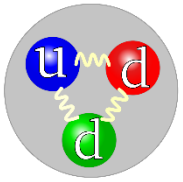


Why neutrons?

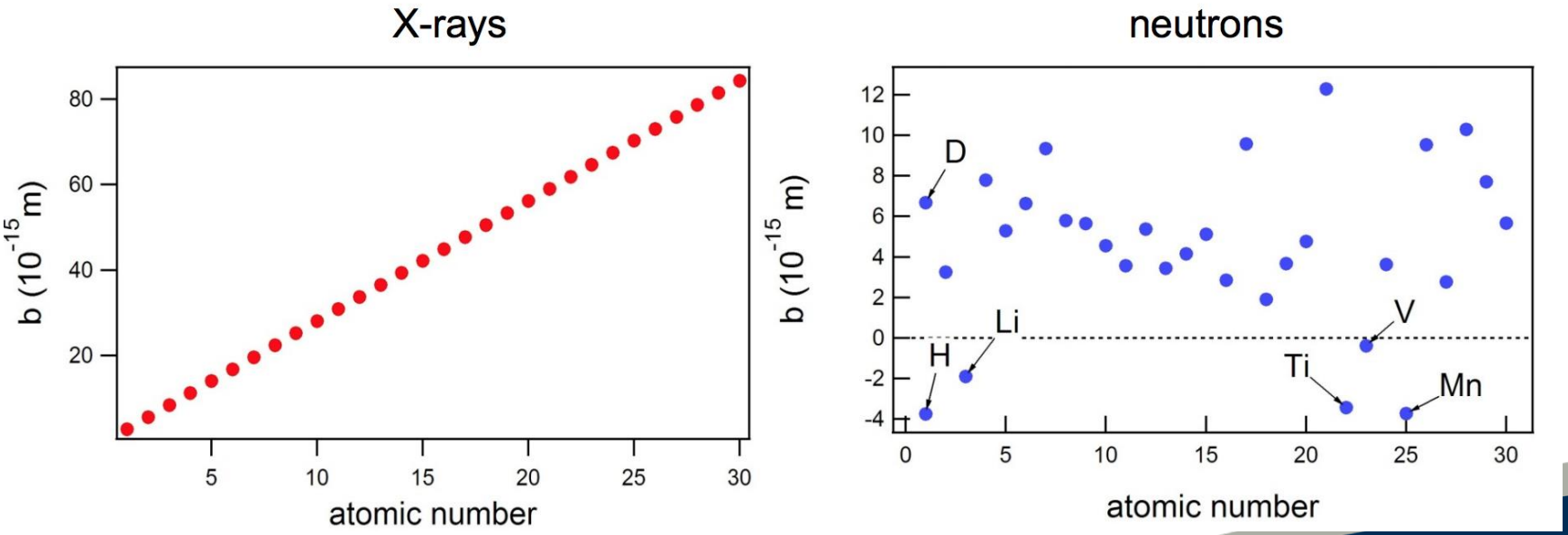
https://www.youtube.com/watch?v=VESMU7JfVHU&feature=youtu.be

A. Kaestner *et al.*, *PSI*

Why neutrons?



- Charge ~0 e ($<2\times10^{-22}$ e)
- Magnetic moment: $\mu_N = 9.66\times10^{-27}$ JT^{-1} (spin = ½)



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^{235}U fission (ILL, LLB, FMR II)

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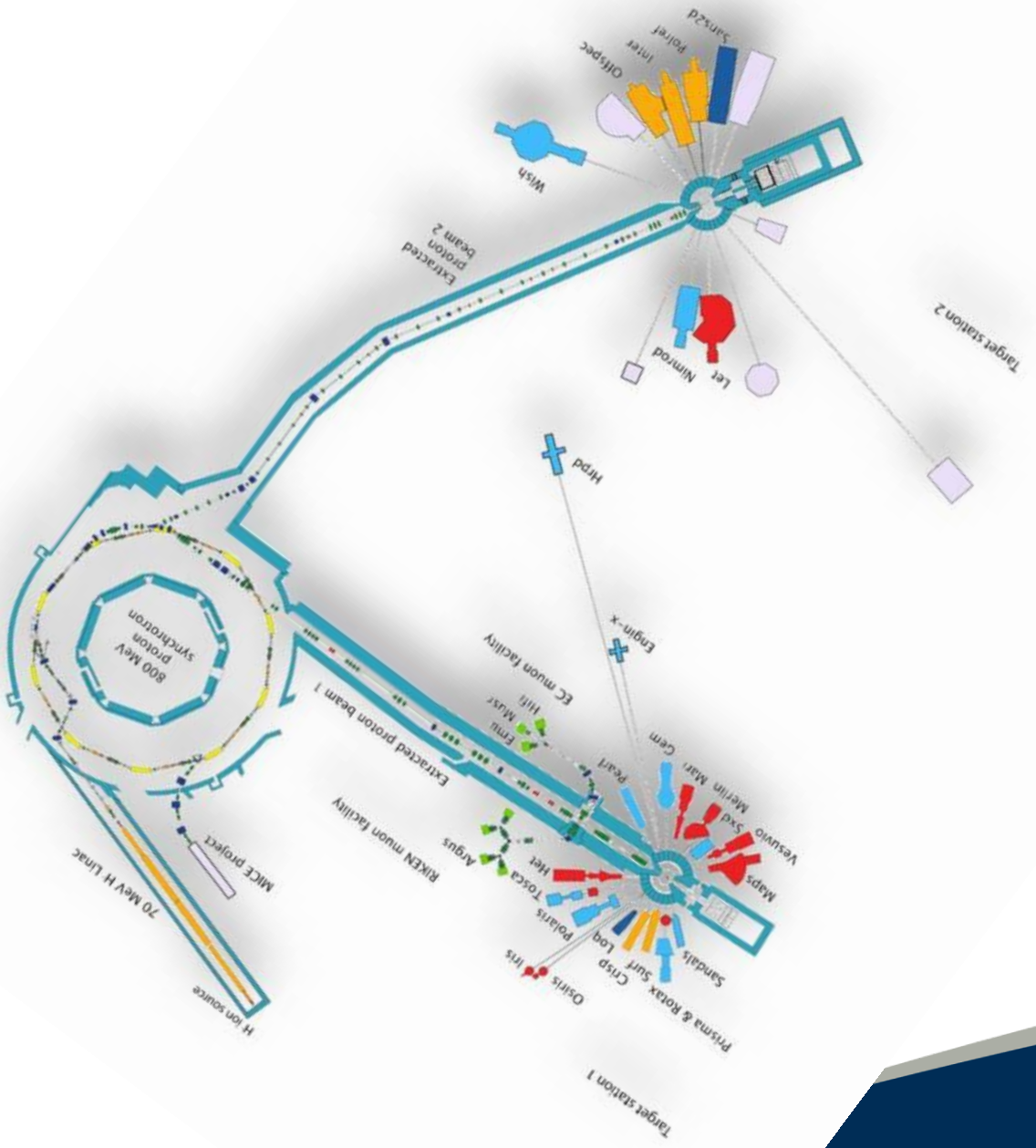
Spallation (SNS, ISIS, ESS)



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Spallation neutron source

800 MeV proton beam

Neutrons produced for 25 instruments

7 muon experimental areas

2000 users/yr

~800 experiments/yr

~500 publications/yr

Free for UK users

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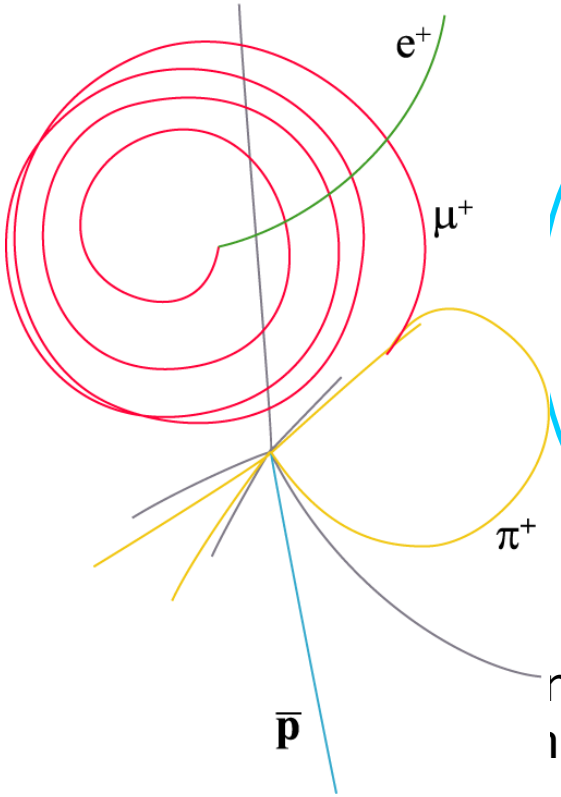
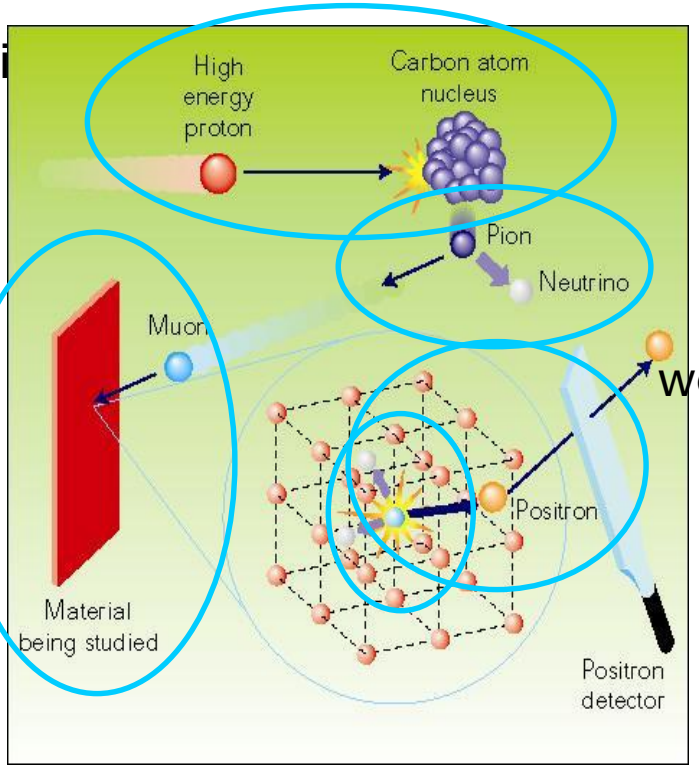
Muons

High energy protons (800 MeV at ISIS) collide with carbon nuclei producing pions





$\pi^+ \rightarrow \mu^+ + \nu_\mu$

4 MeV muons are 100% spin polarised

Decay, lifetime 2.2μs

$\mu^+ \rightarrow e^+ + \nu_e + \nu_\mu$

we detect decay positrons

The positrons are preferentially emitted in muon spin direction

n distribution to infer the muons' polarisation after
n about the muons' local environment or the muon behaviour itself.

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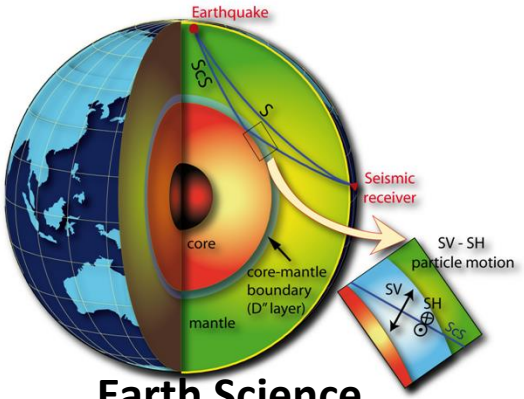
Achievements of neutron scattering
– the evolution and diversification of neutron scattering over the past 40 years

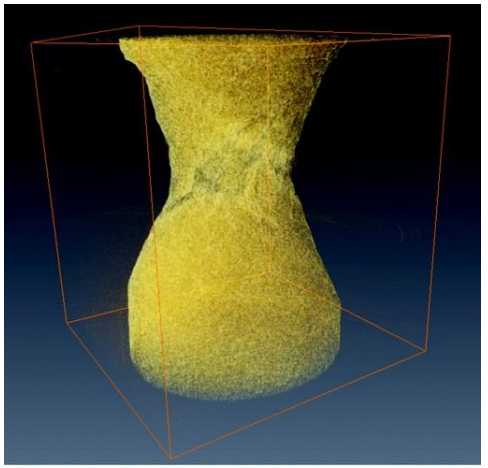


Earth Science

Studying ferropericlase helps understanding of earthquakes

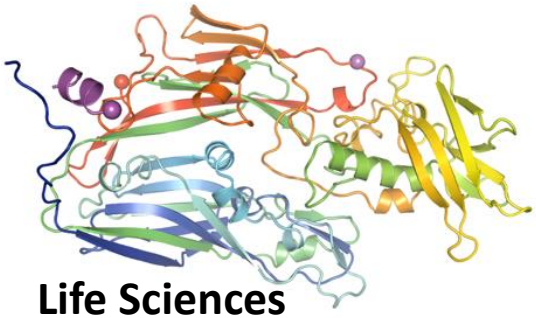
Cultural Heritage

understanding molecular processes of preservation of polychrome carved wood



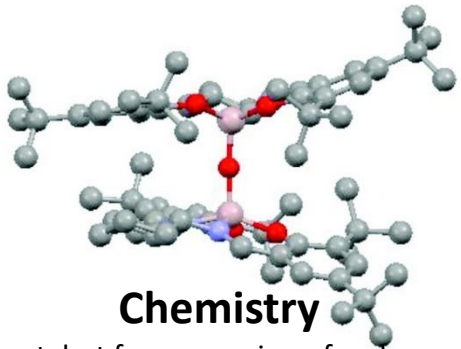
Engineering

3-D high speed tomography



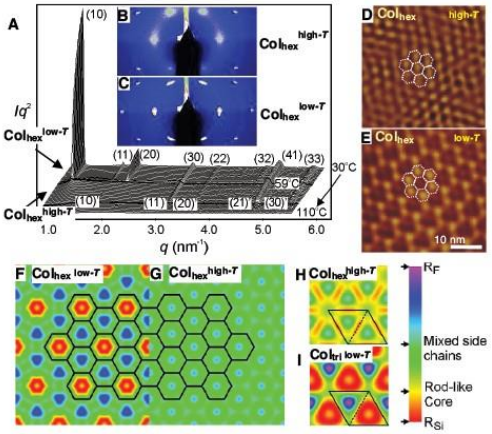
Life Sciences

Structure and history of viruses



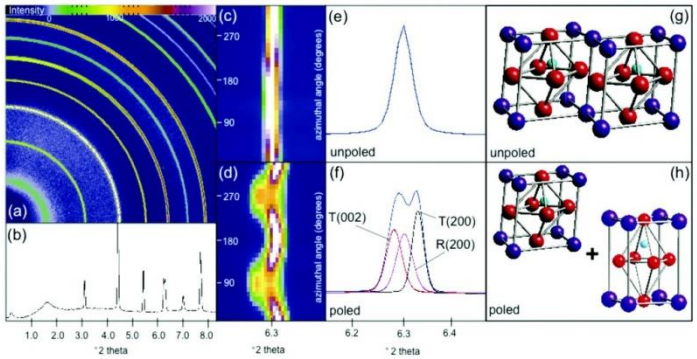
Chemistry

catalyst for conversion of carbon dioxide to cyclic carbonates



Physics and Materials Science

Magnetic contrast imaging for FeRh films



Environmental Science

Electric-field-induced phase transformations in lead-free piezoelectric ceramics

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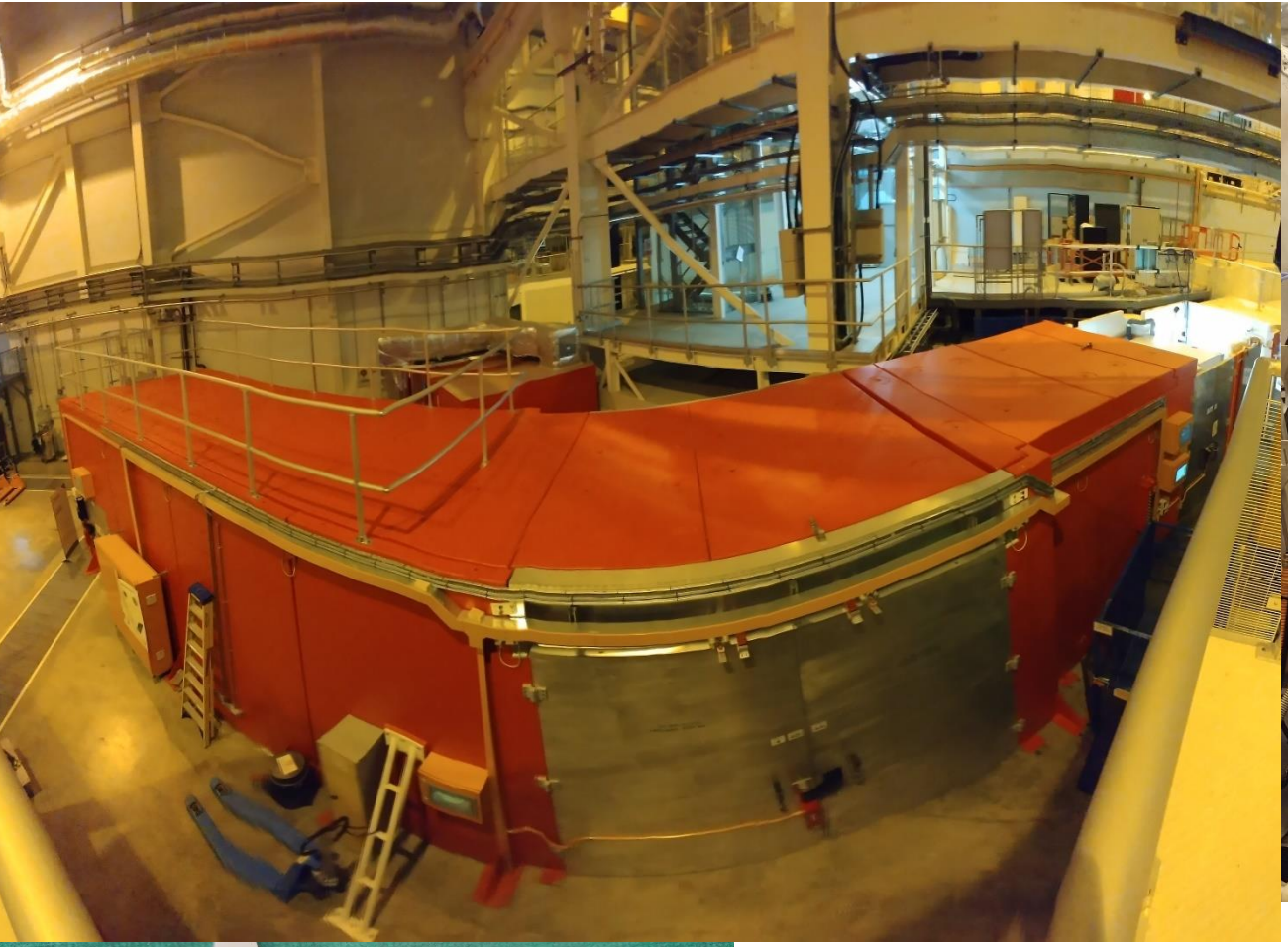

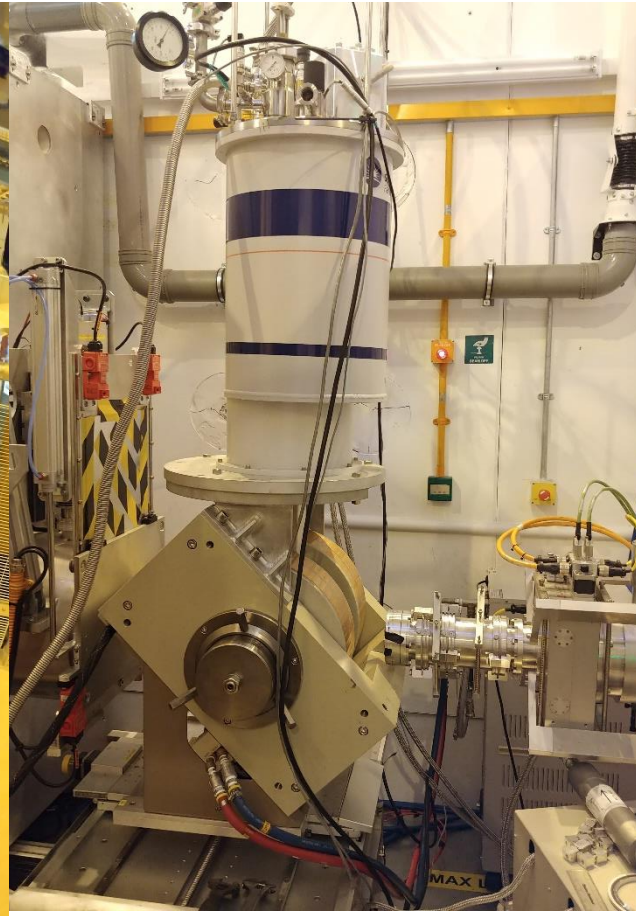

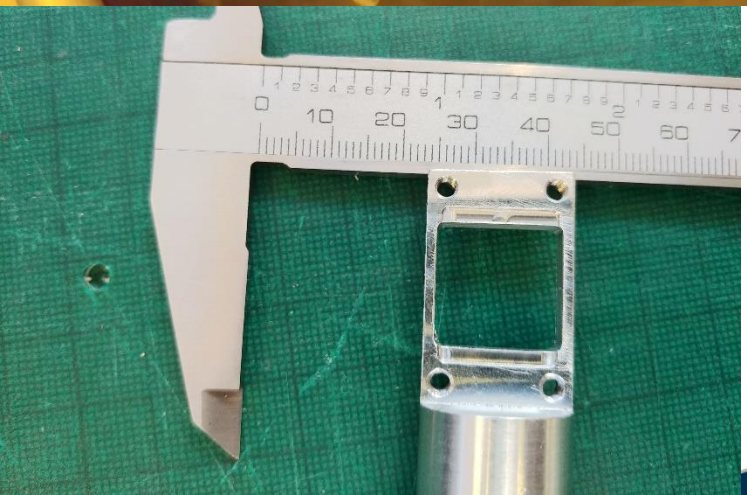

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Case of study: neutrons for Astrochemistry

What do Å - nm scale structures tell us about planet formation?

Sabrina Gaertner

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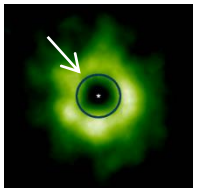
Acknowledgements

Jürgen Blum
Bastian Gundlach
Judy Ratte

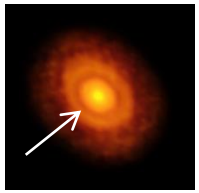
Daniel Bowron
Tom Headen
Tristan Youngs

Helen Fraser

Ice in Planetessimal Formation

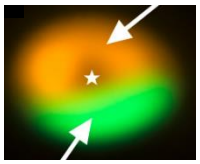


Qi *et al*
Science 2013

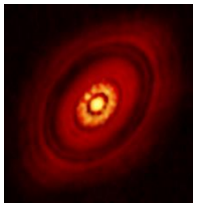


Cieza *et al*
Nature 2016

Snow Lines in Disks

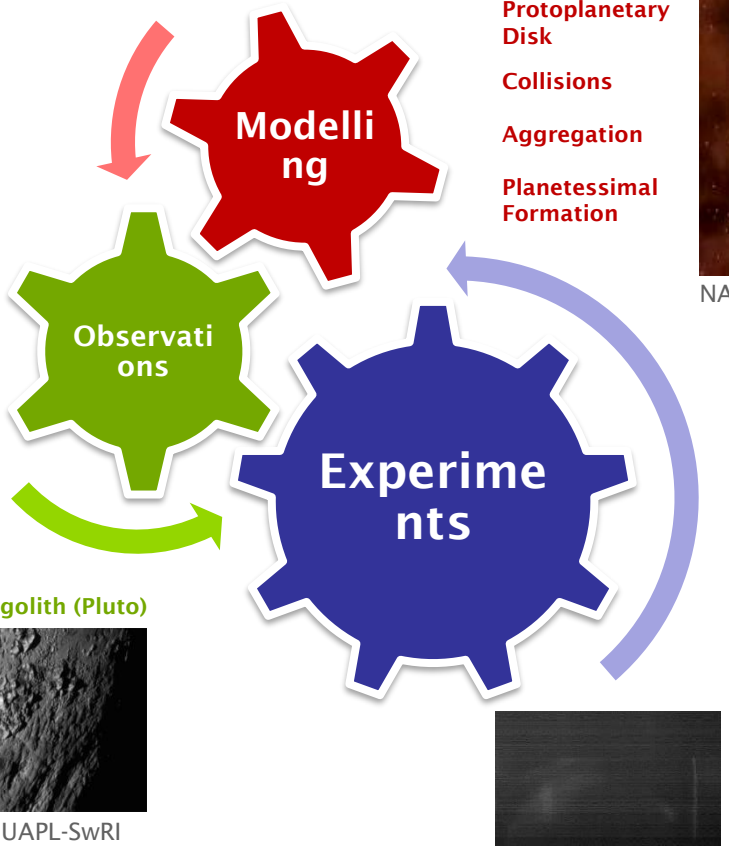


van der Marel *et al*
Science 2013



Carrasco-Gonzalez *et al* ApJ Lett 2016

Protoplanetary Disks

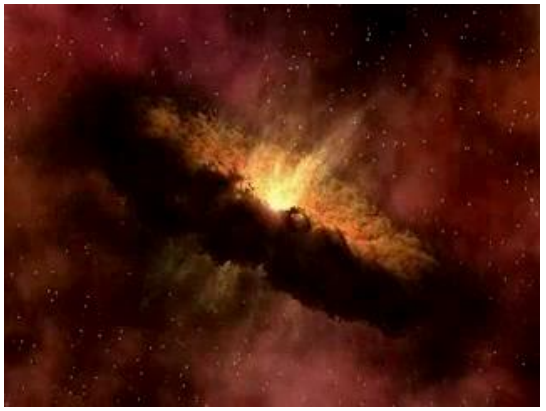


Protoplanetary Disk

Collisions

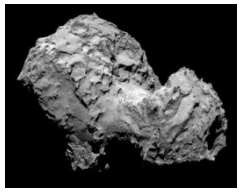
Aggregation

Planetessimal Formation



NASA/JPL-Caltech/R. Hurt (SSC)000

Comets: low-density, fluffy grains



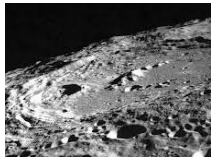
ESA/Rosetta/MPS

Icy regolith (Pluto)

NASA-JHUAPL-SwRI

Bouncing

Erosion



Sticking

Mass Transfer

Fragmentation

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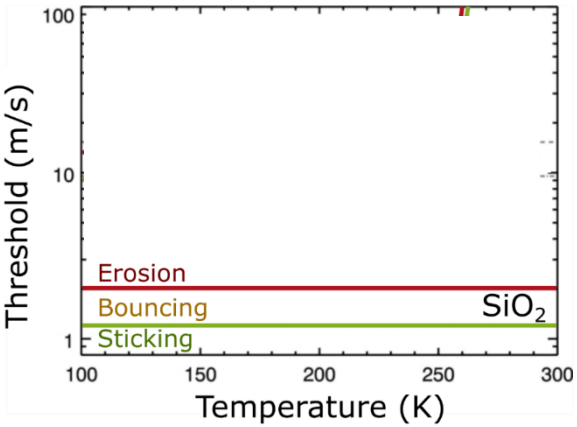
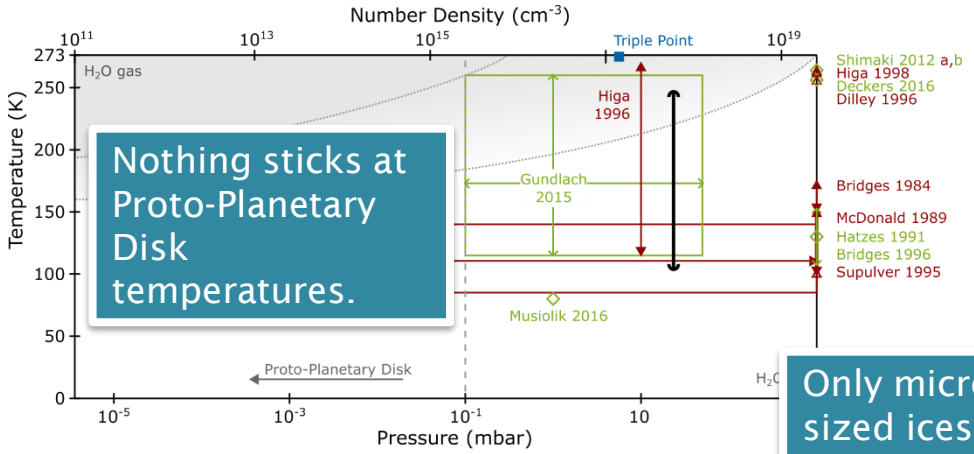
Does Ice in Collisions Stick?



Ice is stickier than dust.

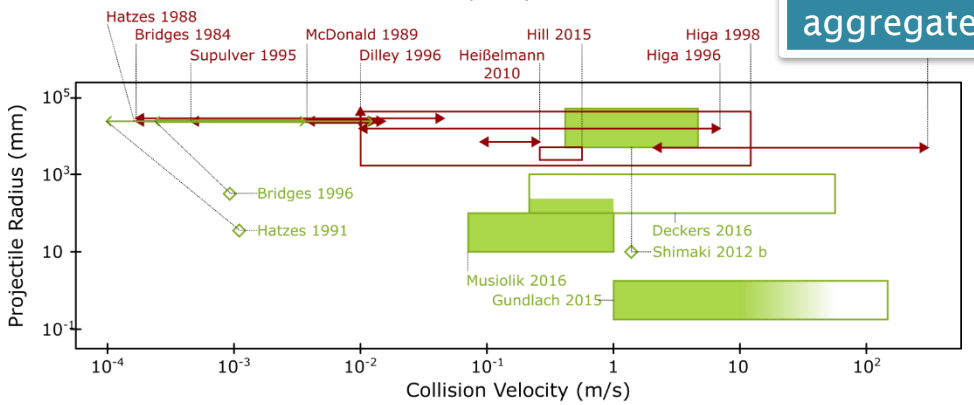
Warm ice is stickier than cold ice.

Gundlach & Blum
ApJ 2015



Nothing sticks at Proto-Planetary Disk temperatures.

Only micrometer-sized ices or aggregates stick.



Gärtner *et al*
ApJ 2017

What is the structure of the collided ices?

NIMROD
ISIS TS2

Spray water into LN2

Transfer ice into sample cell

Be ready at beamline …

… quickly & smoothly …

… transfer sample to beam

30 mbar
100 – 250 K

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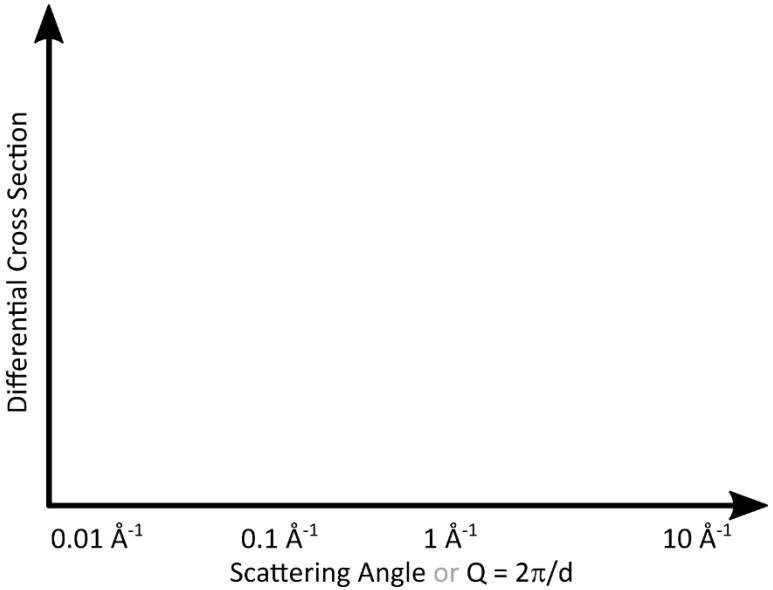
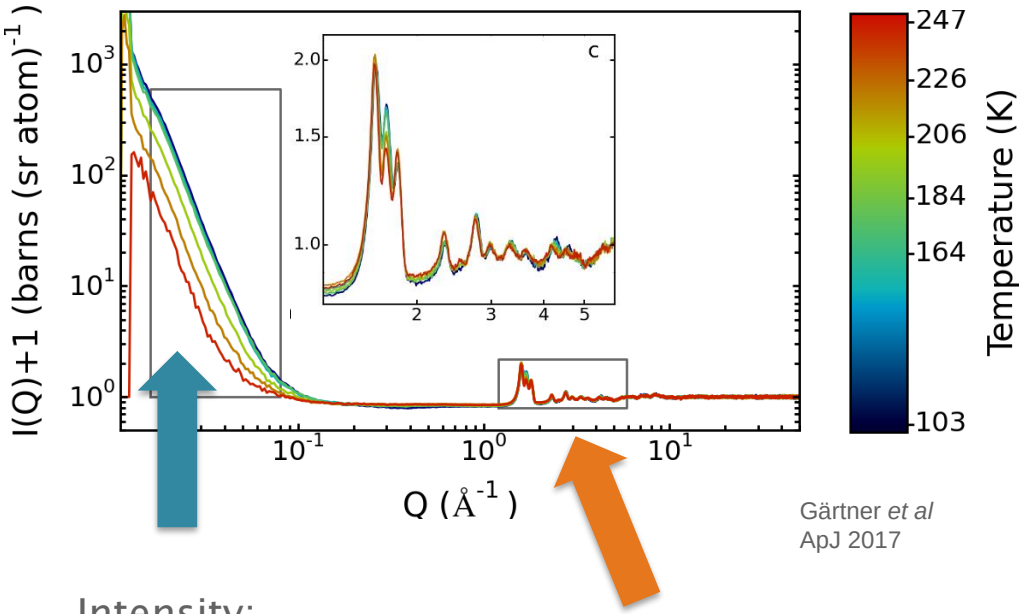
Neutron Diffraction





Gärtner *et al*
ApJ 2017

Intensity:
Specific Surface Area

Slope:
Diffuse Interface

Peaks:
Crystalline
(Stacking Disordered)

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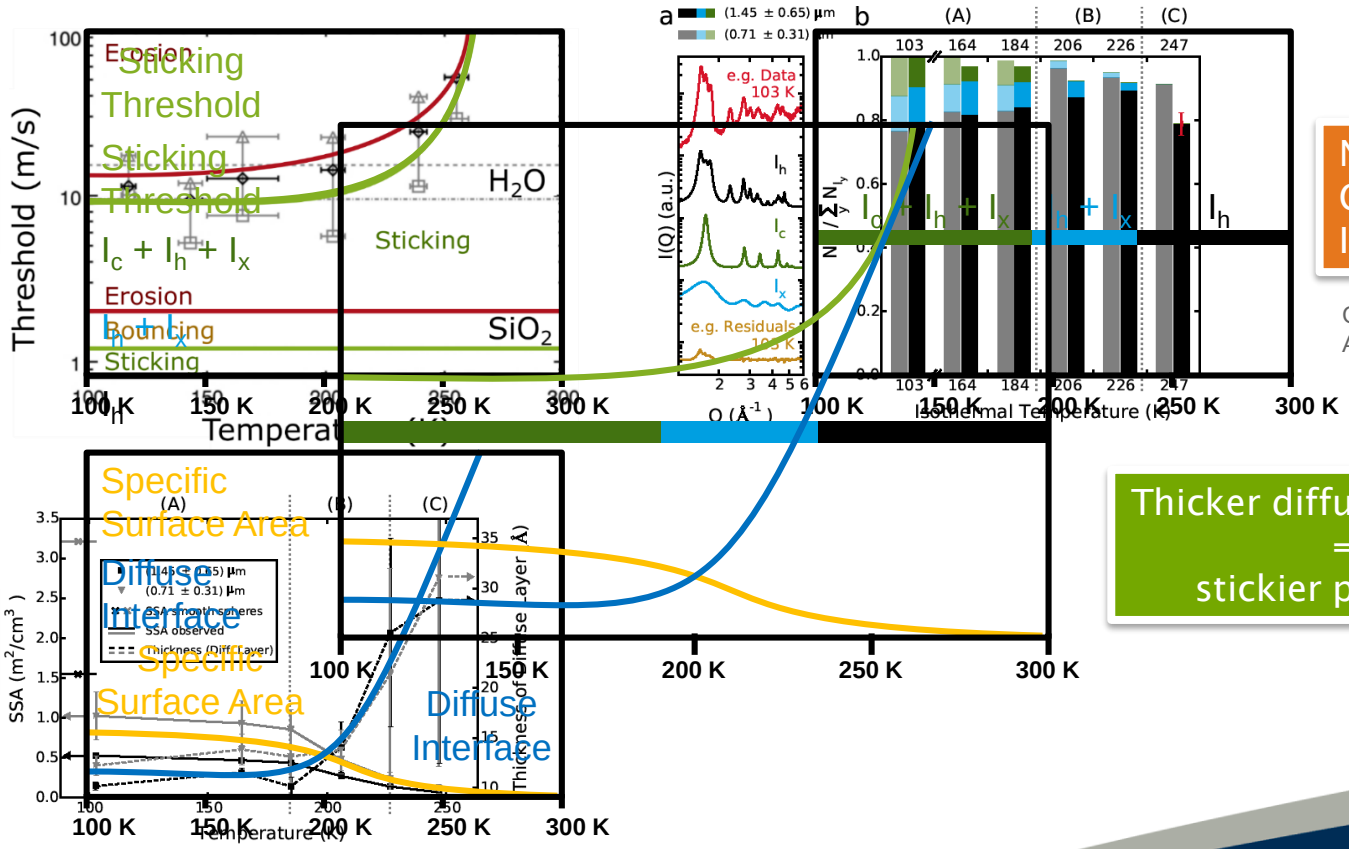
Results

Collision Experiments

Gundlach & Blum
ApJ 2015

Neutrons: Surface

Gärtner *et al*
ApJ 2017



Neutrons: Crystalline Ice Phase

Gärtner *et al*
ApJ 2017

Thicker diffuse interface = stickier particles!

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Thank you very much for your attention!