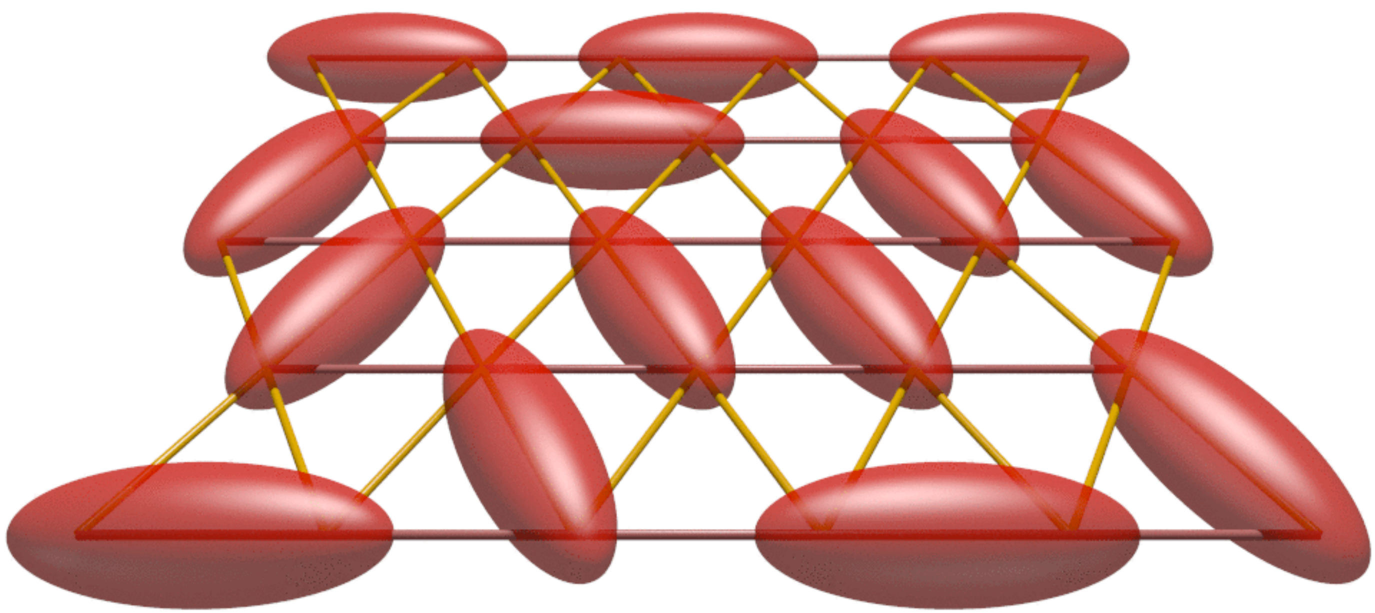
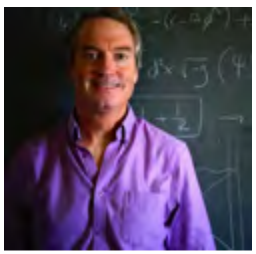
Leon Balents, KITP Yzurdiaga Chair Inauguration Nov 28, 2017

Magical magnetism and strange stuff



Thanks also to

The KITP faculty and staff, and our strong community supporters

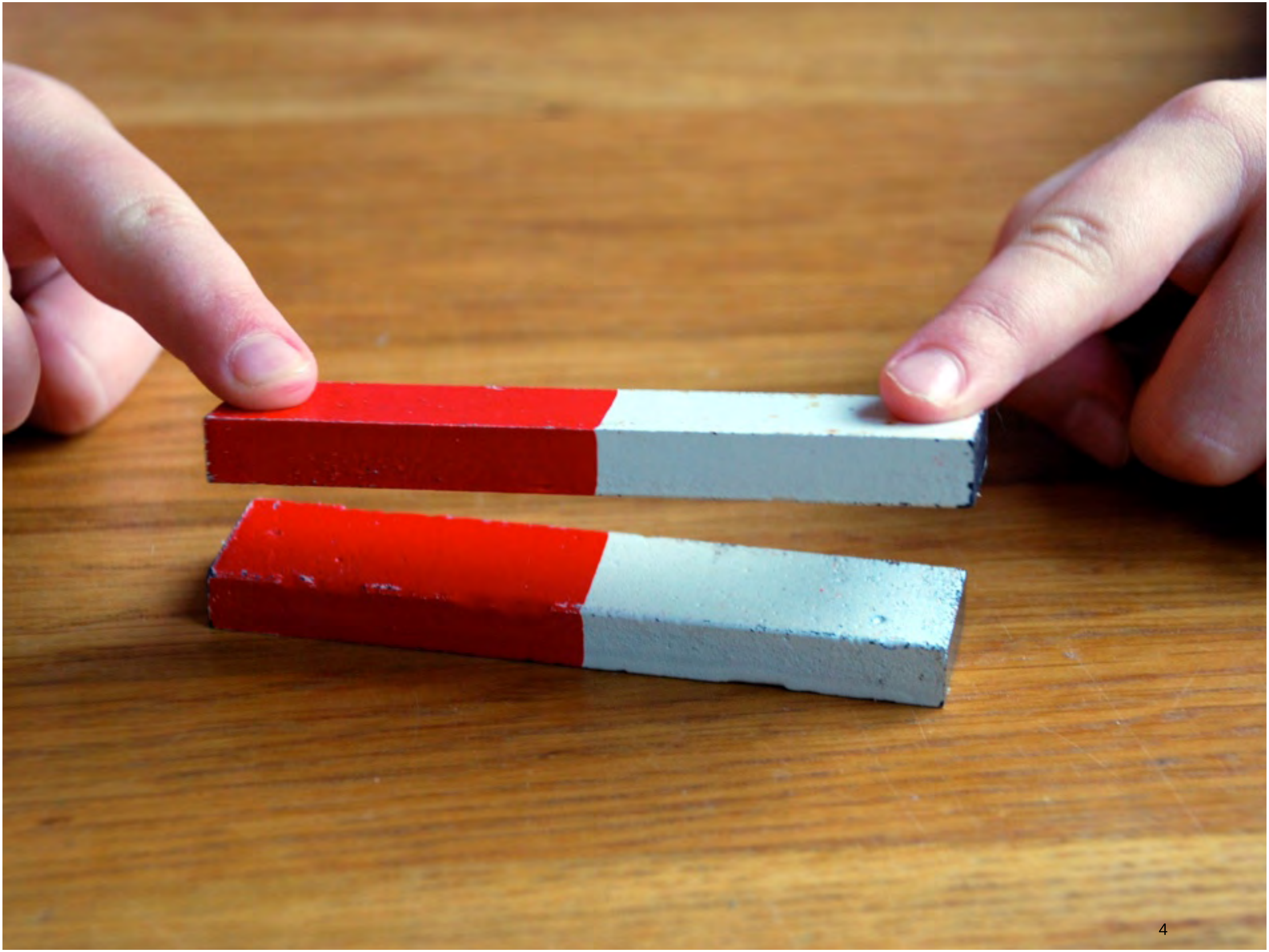


Joe Polchinski

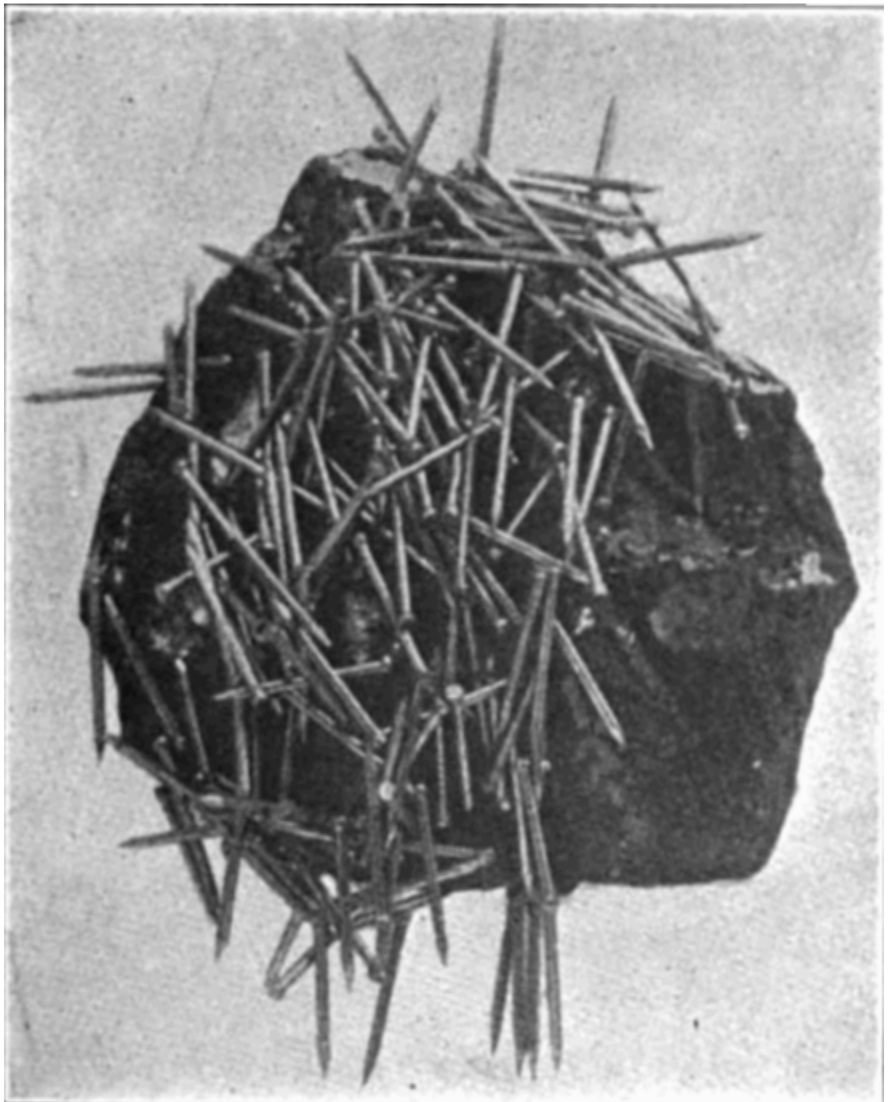
My friends and colleagues in the UCSB Physics and Materials departments

Many many past and present students, postdocs, and faculty visitors

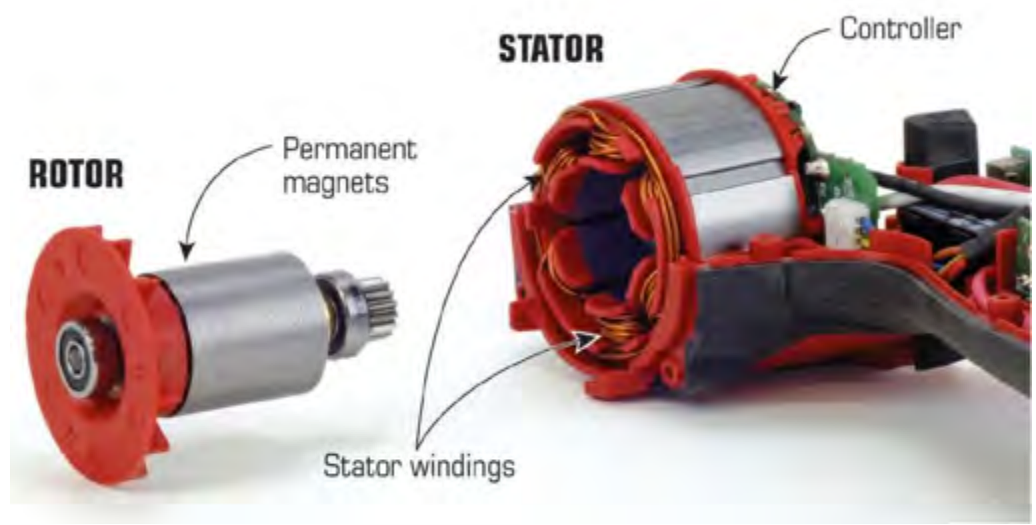
research support from the NSF, DOE, ARO, and the Moore Foundation



sinan, ~ 200BC




DEWALT
20V MAX XR
XR
11 • 13 • 15

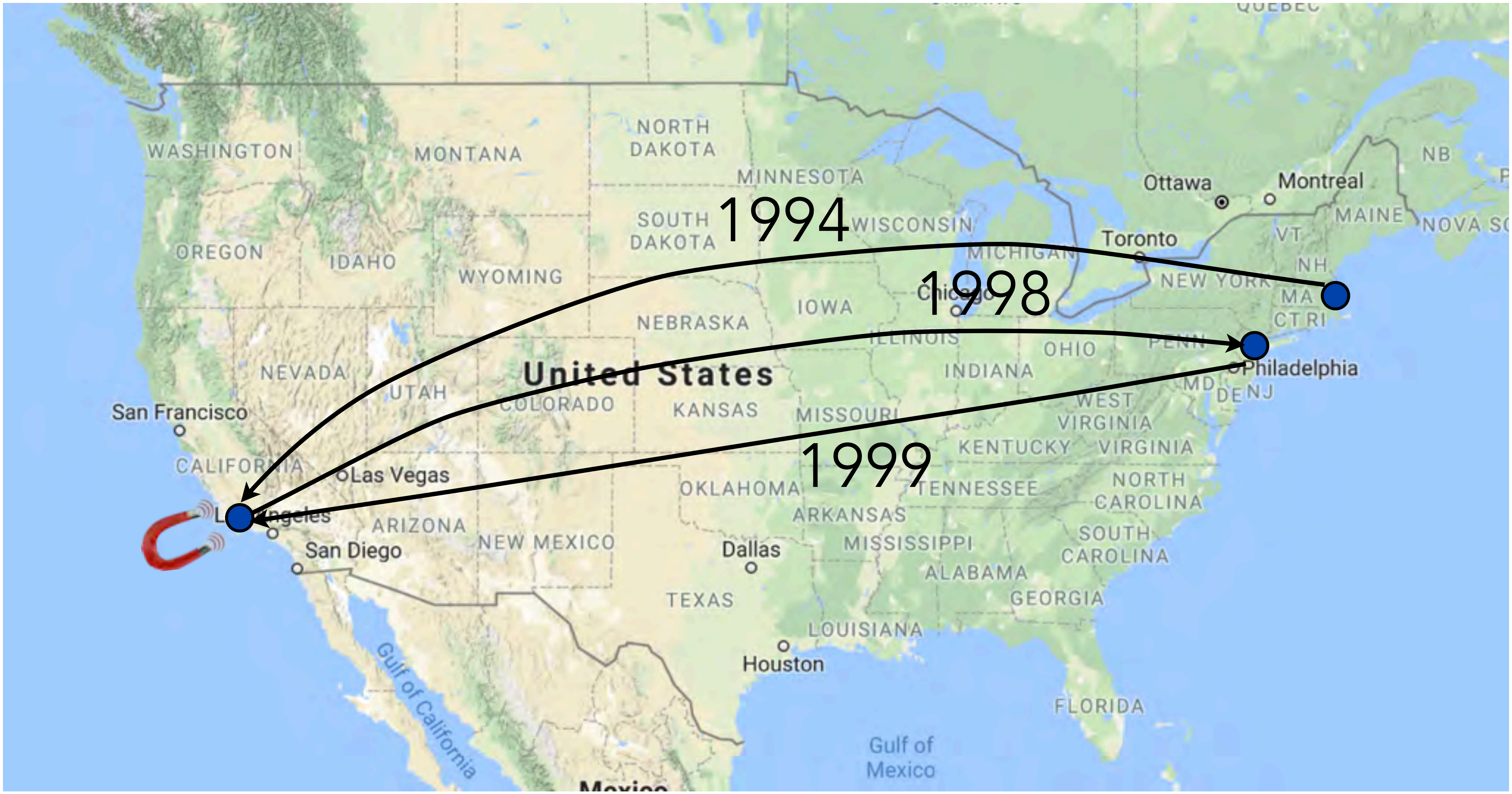

STATOR
Controller
ROTOR
Permanent
magnets
Stator windings


These ancient magnets were found as naturally occurring rocks called
"lodestones", which are made of the mineral magnetite


SONOS
PLAY:3
SONOS
TEARDOWN

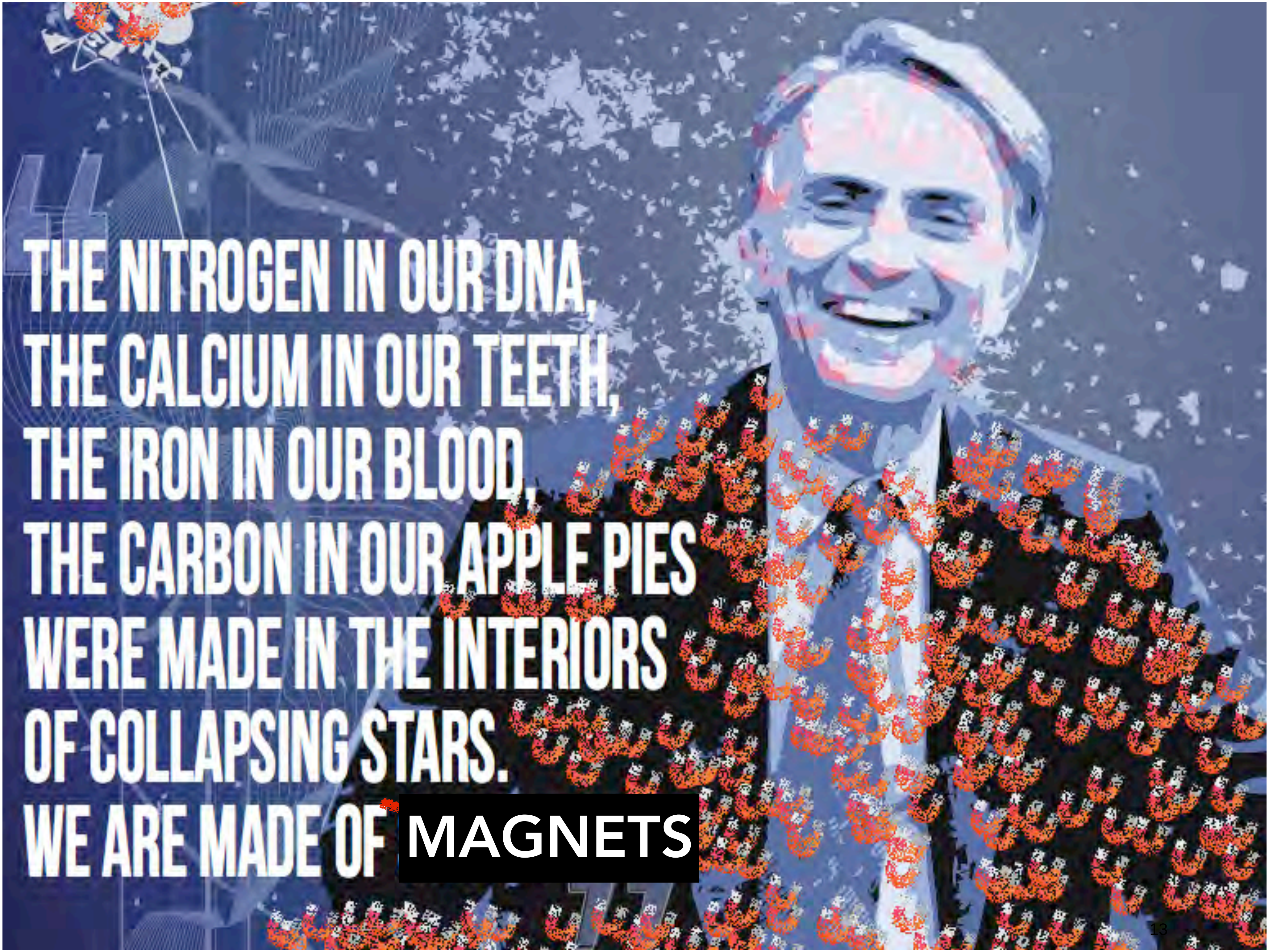

TARE
PCS
UNIT

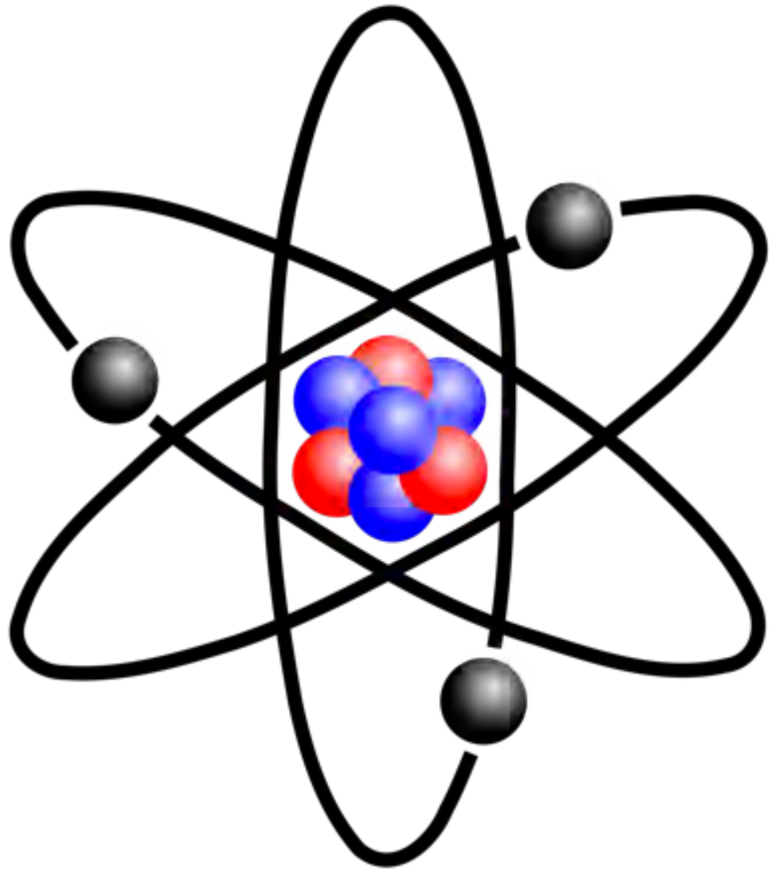

FUN
FRIDGE
MAGNETS
Vat19.com

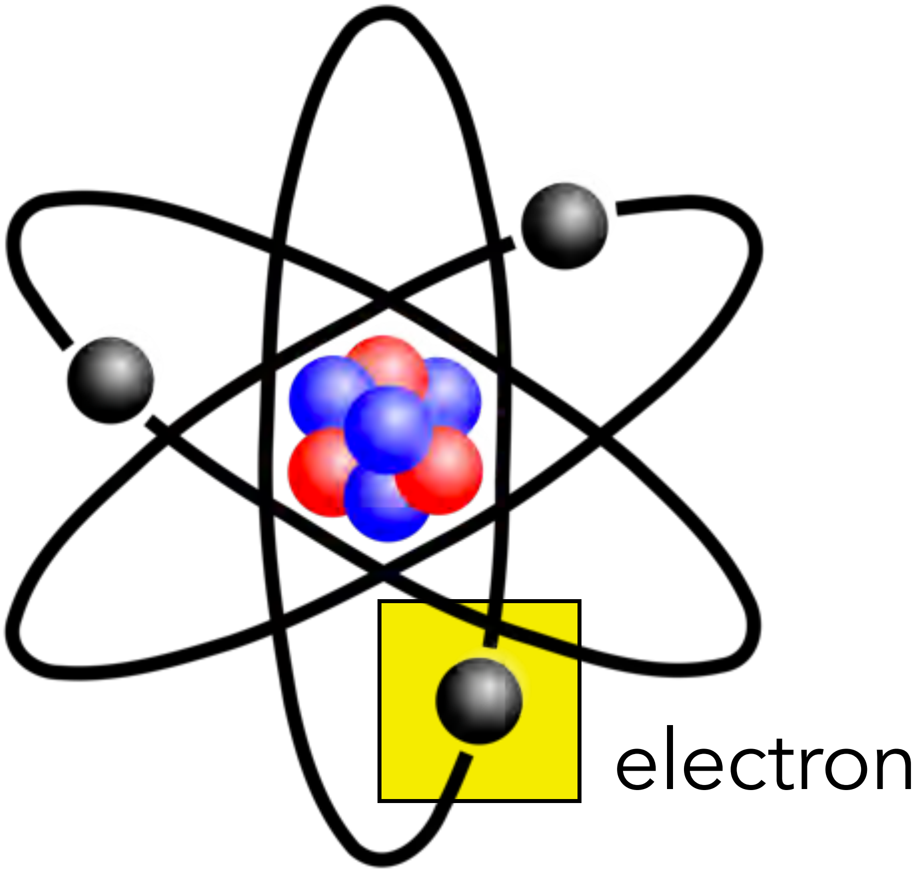


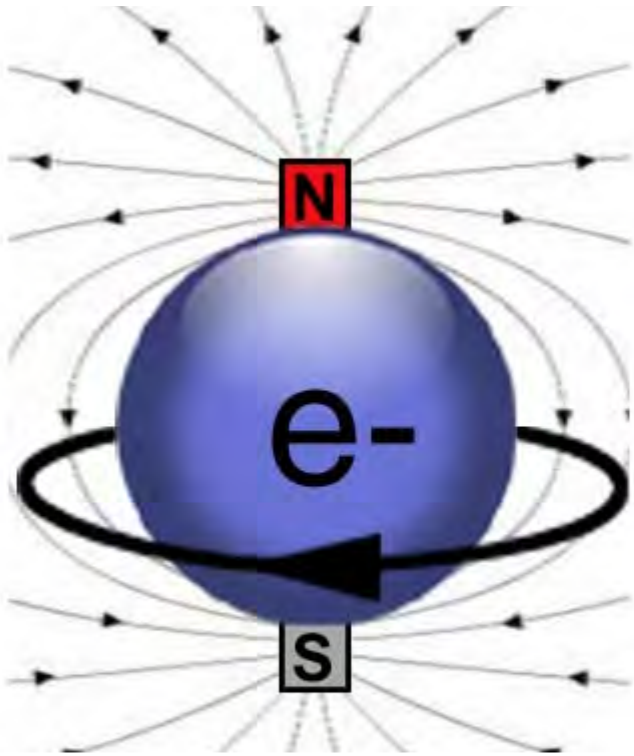
UCSB's powerful attraction


"THE NITROGEN IN OUR DNA,
THE CALCIUM IN OUR TEETH,
THE IRON IN OUR BLOOD,
THE CARBON IN OUR APPLE PIES
WERE MADE IN THE INTERIORS
OF COLLAPSING STARS.
WE ARE MADE OF STARSTUFF."


THE NITROGEN IN OUR DNA,
THE CALCIUM IN OUR TEETH,
THE IRON IN OUR BLOOD,
THE CARBON IN OUR APPLE PIES
WERE MADE IN THE INTERIORS
OF COLLAPSING STARS.
WE ARE MADE OF MAGNETS




electron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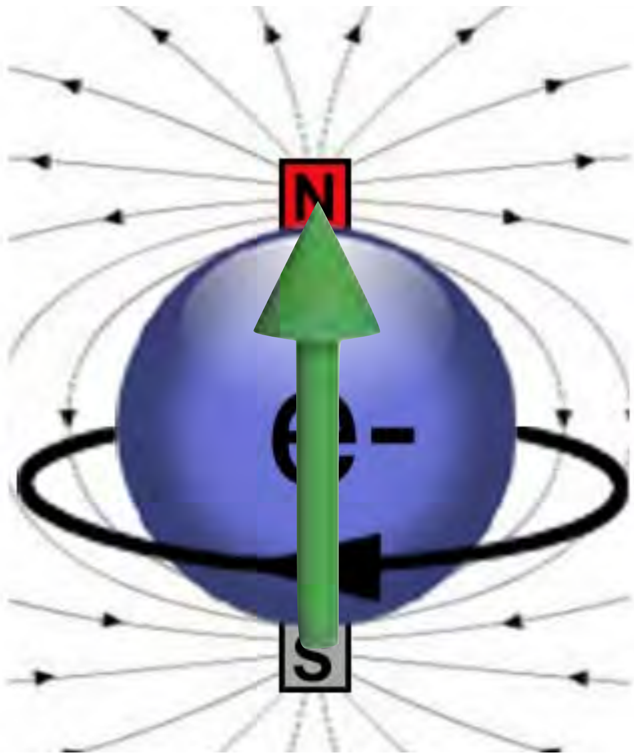
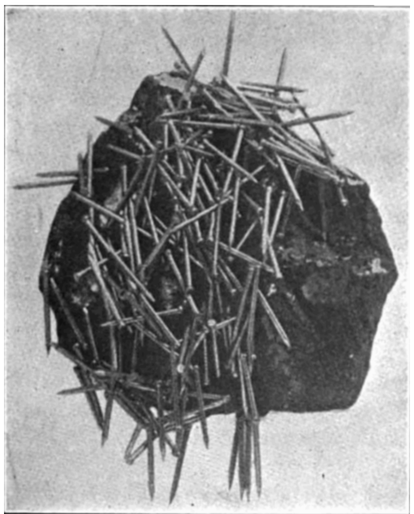
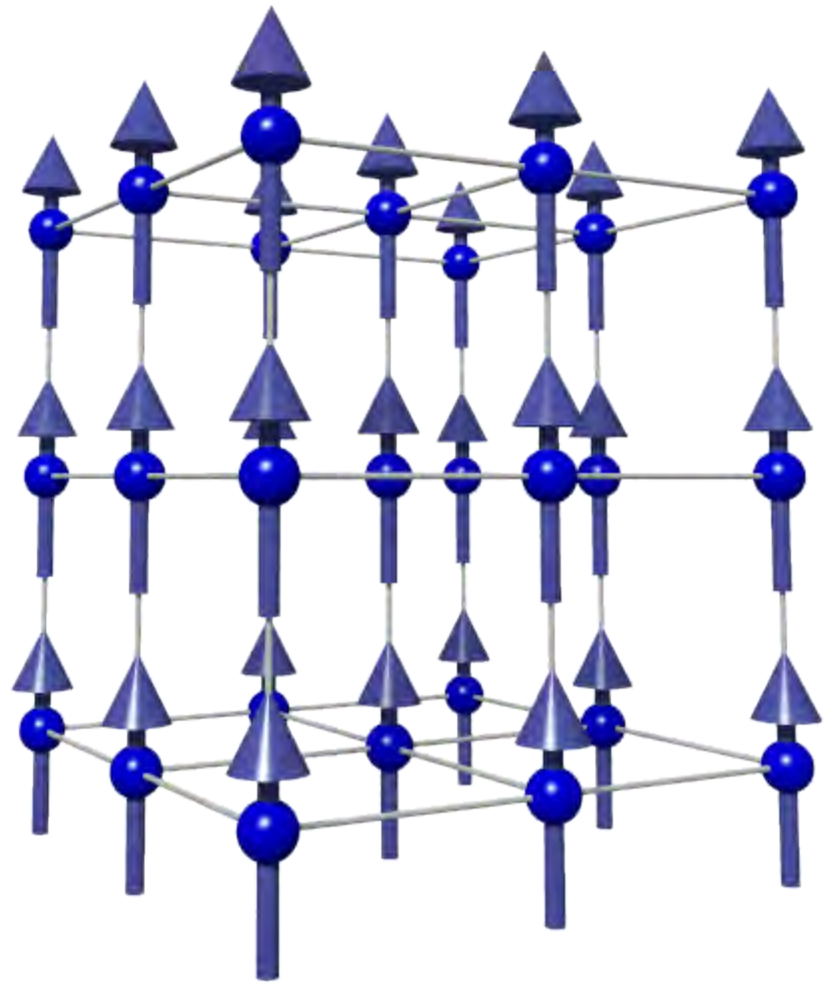
S

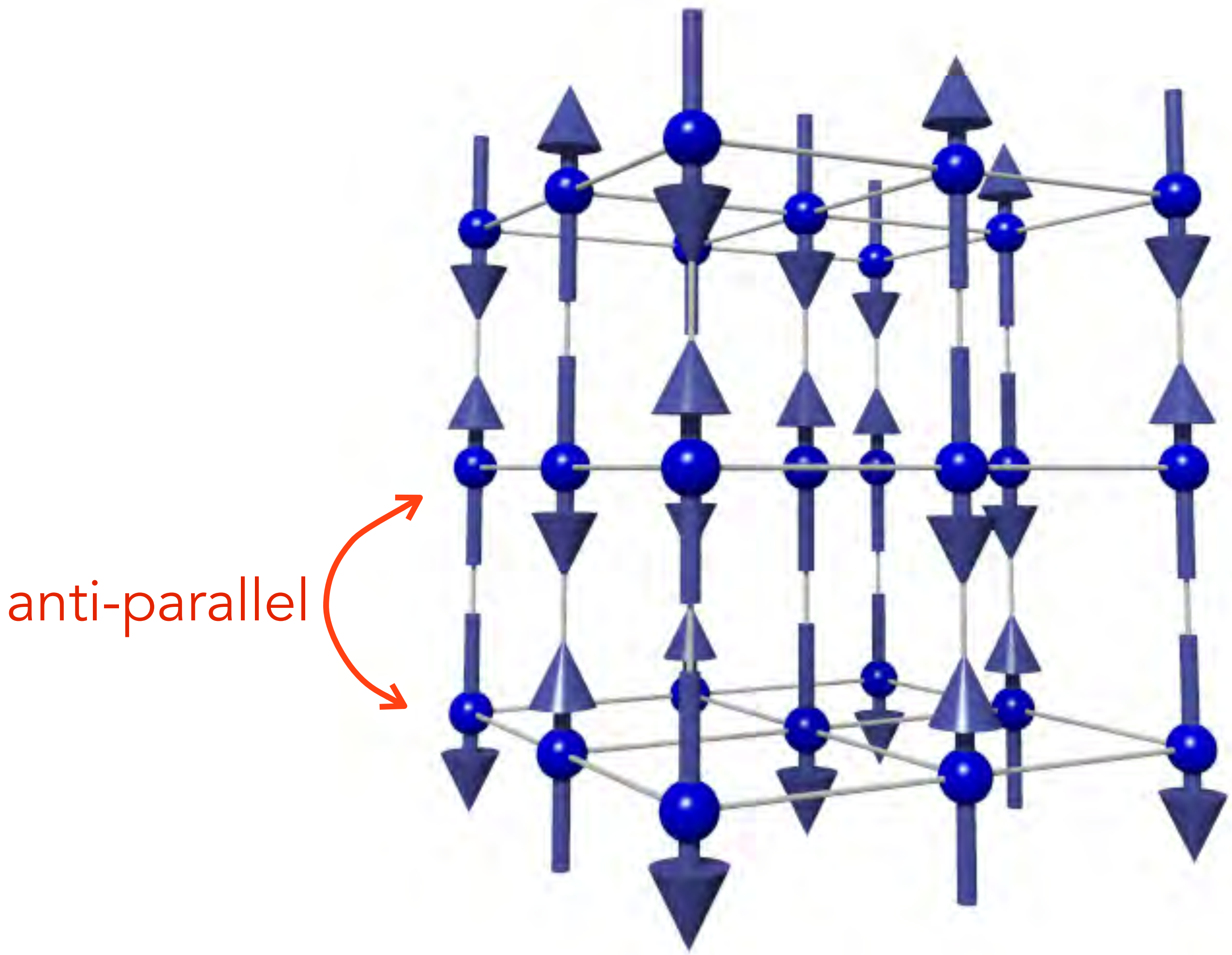


"spin"

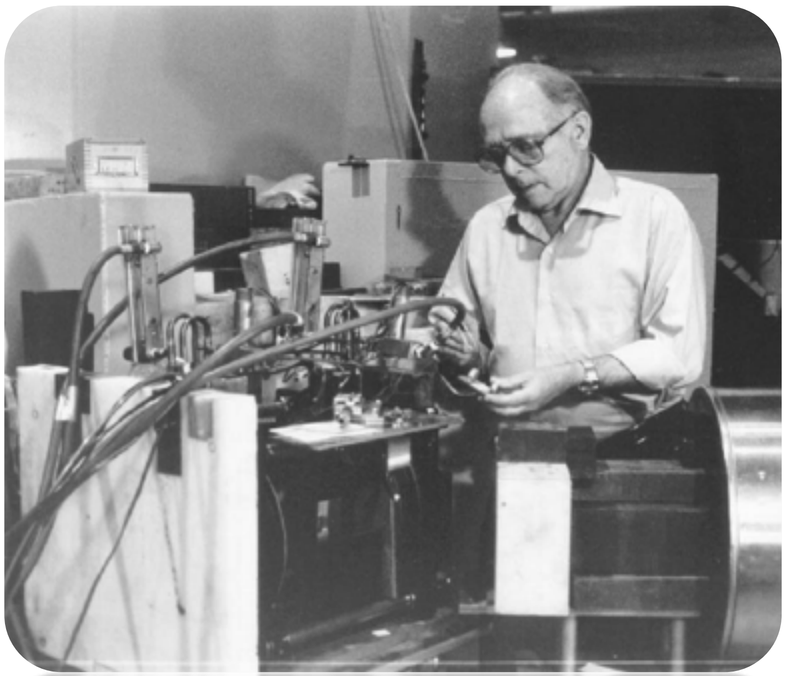




Ferromagnet



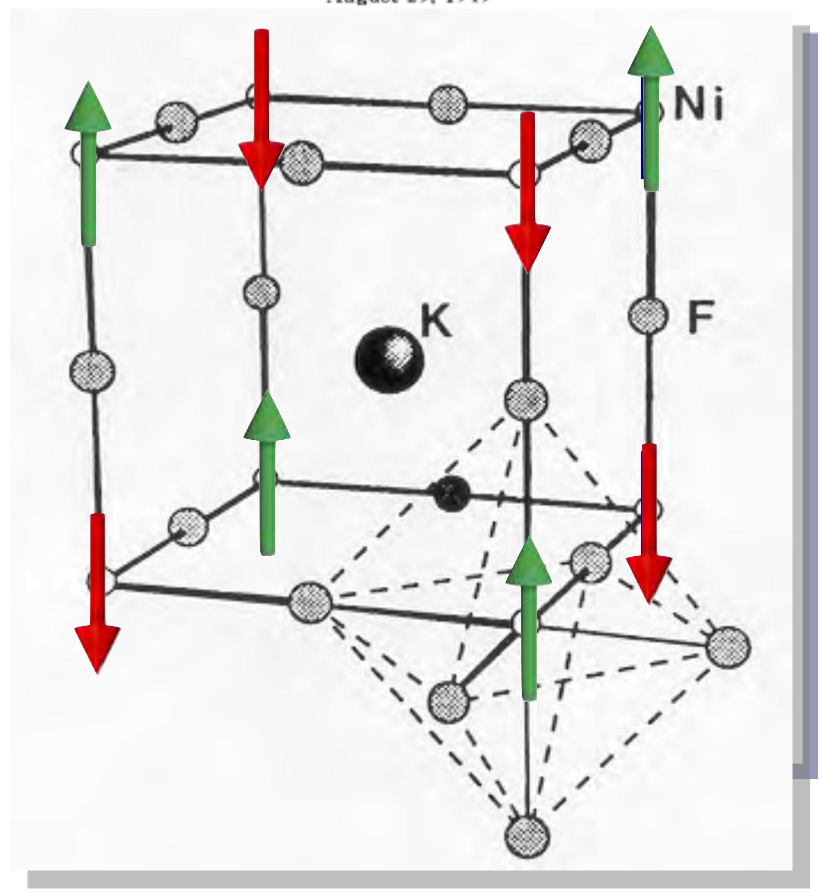
antiferromagnet

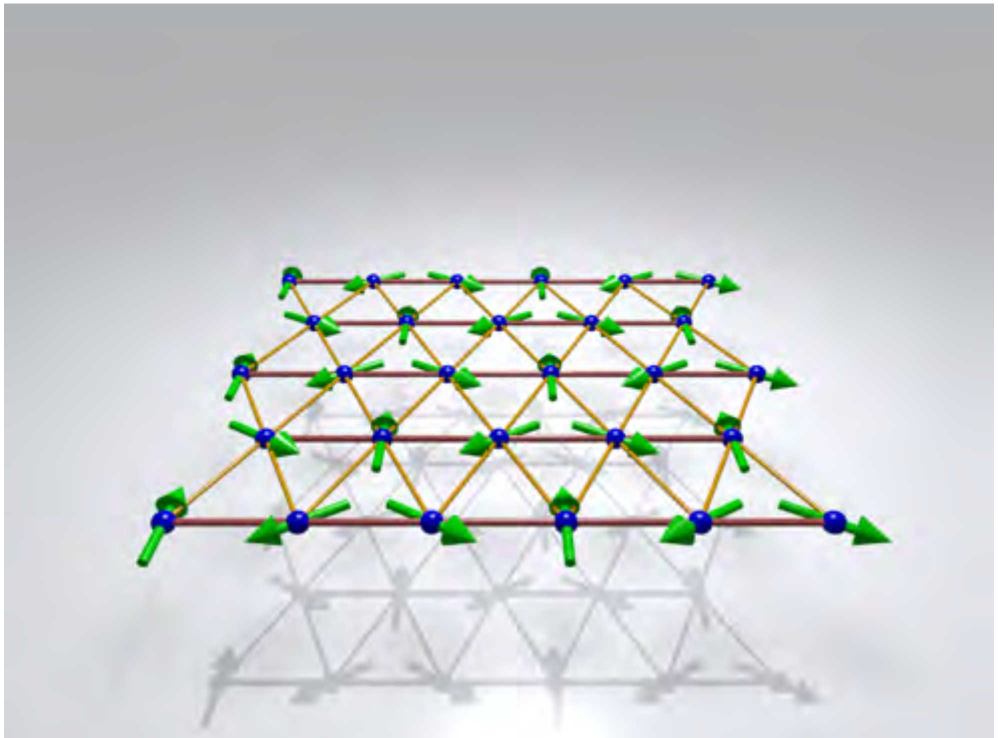


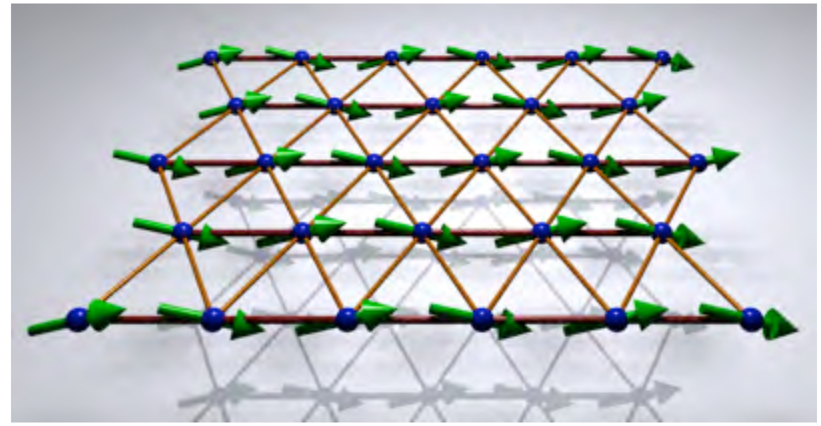
1994 Nobel prize

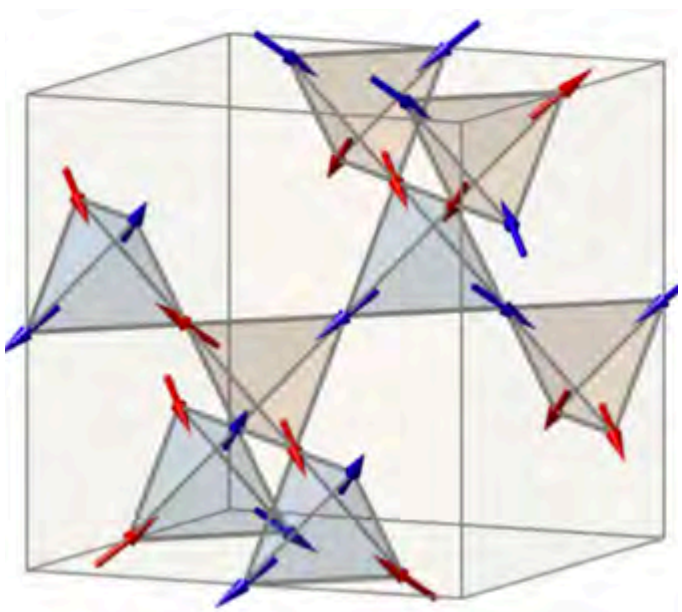
Detection of Antiferromagnetism by Neutron Diffraction*

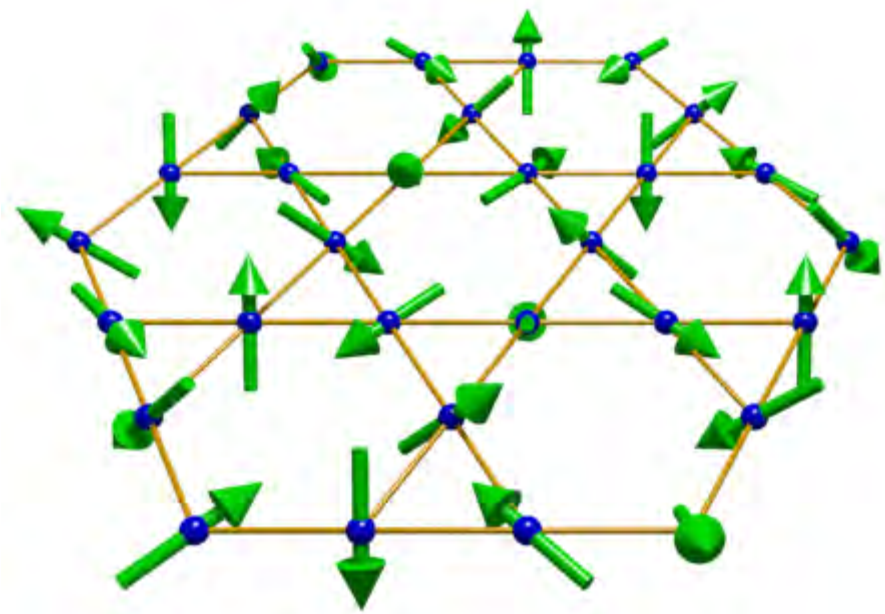
C. G. SHULL
Oak Ridge National Laboratory, Oak Ridge, Tennessee
AND
J. SAMUEL SMART
Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland
August 29, 1949

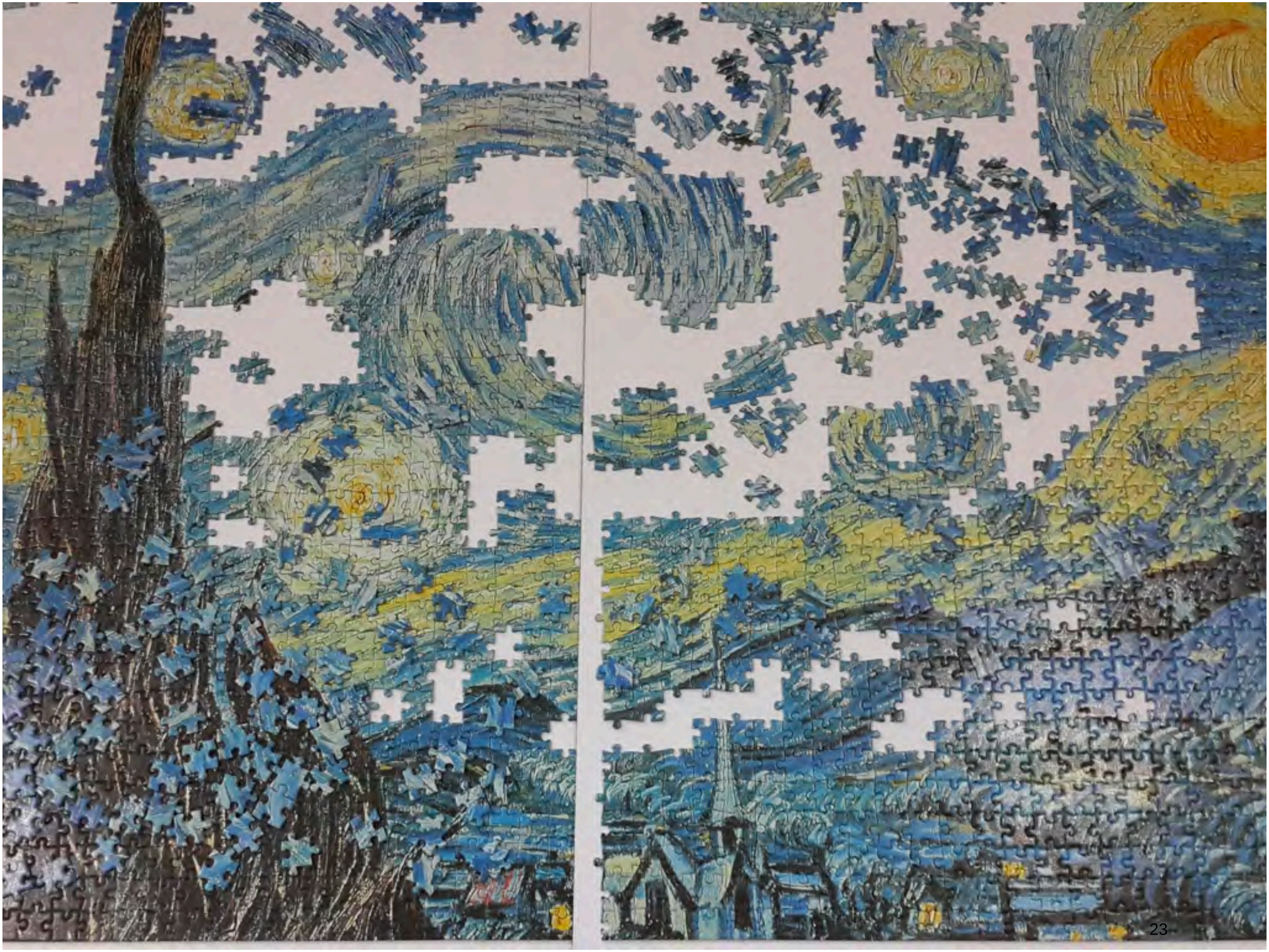








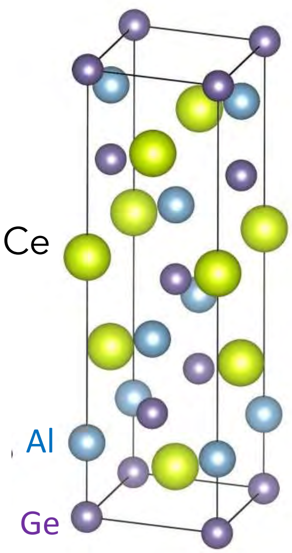


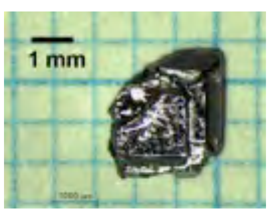


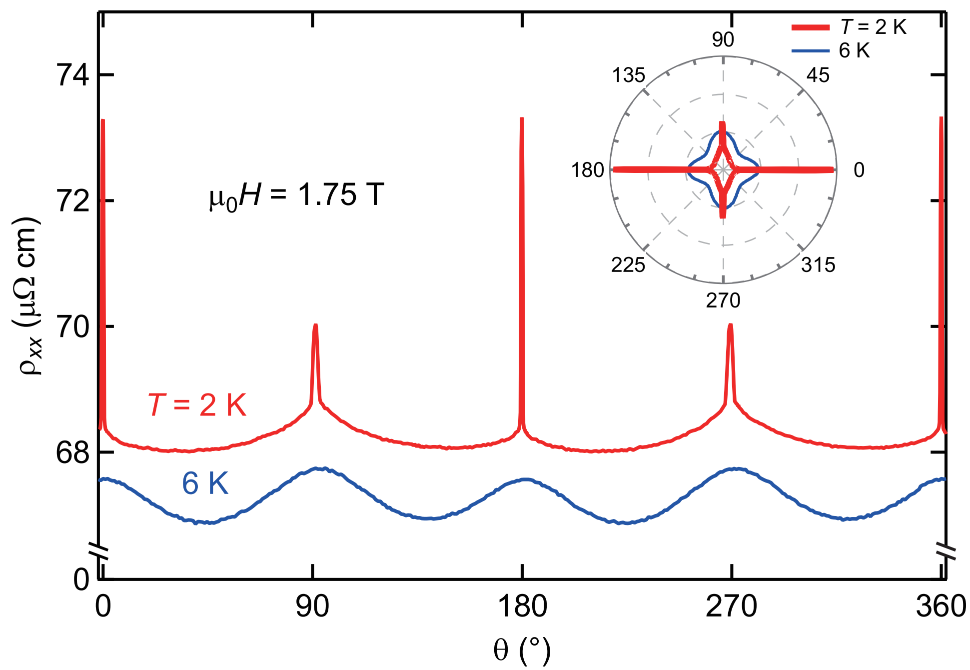
Lucile Savary

Joe Checkelsky

Takehito Suzuki





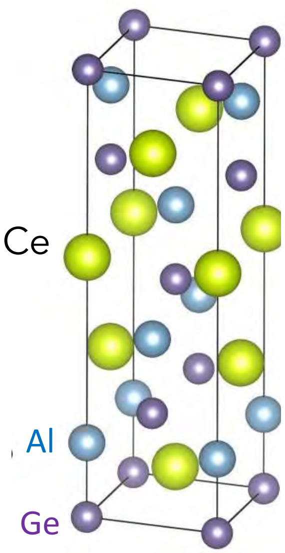


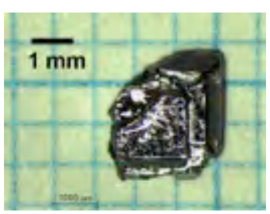
Lucile Savary

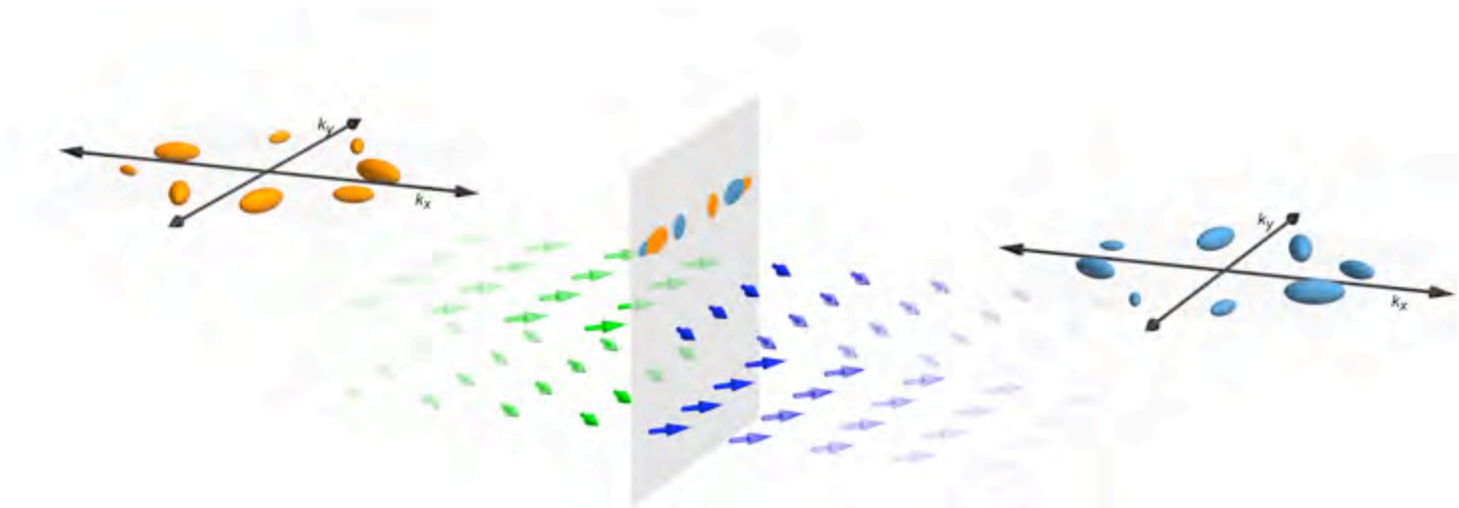
Joe Checkelsky

Takehito Suzuki

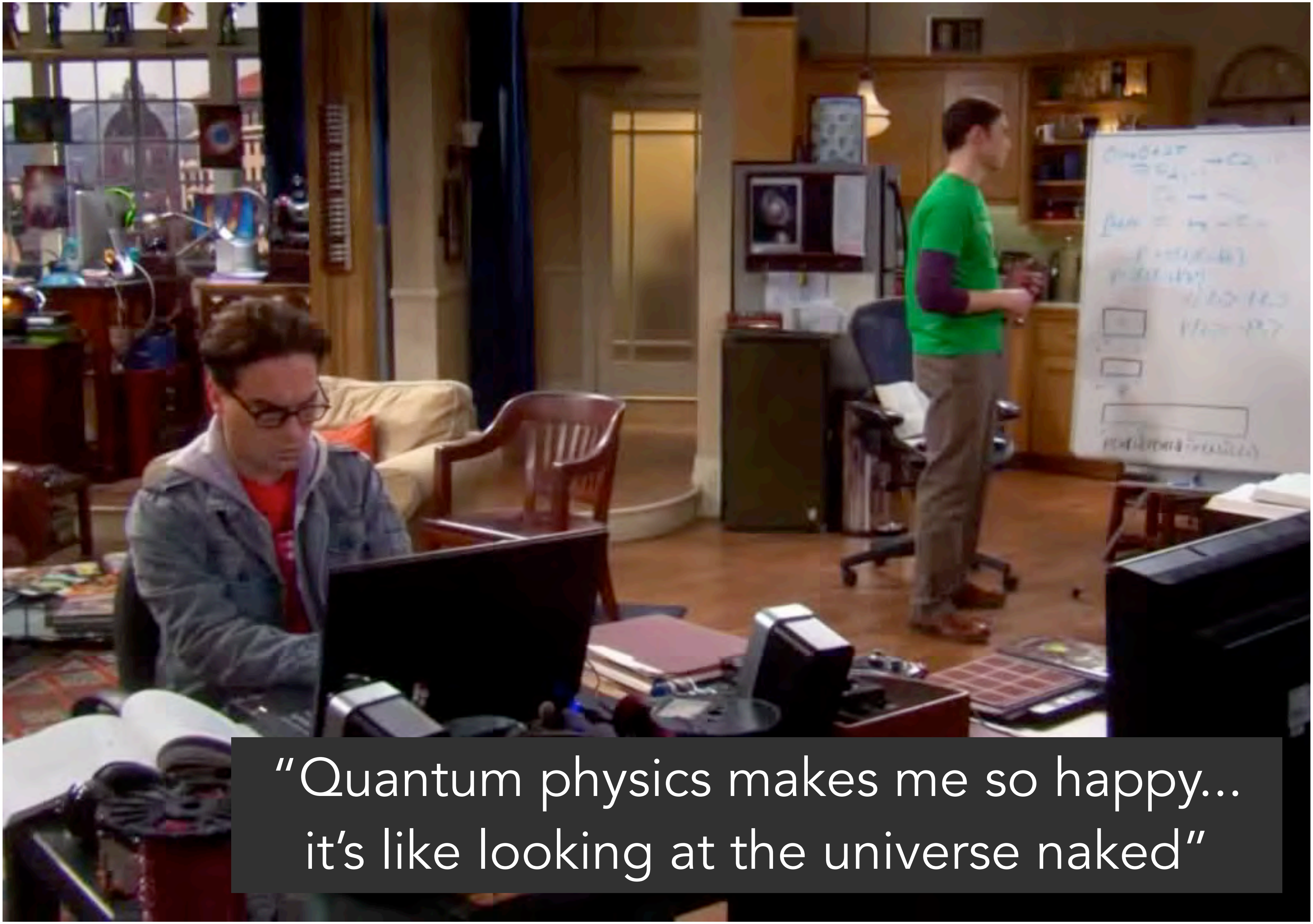
Jianpeng Liu







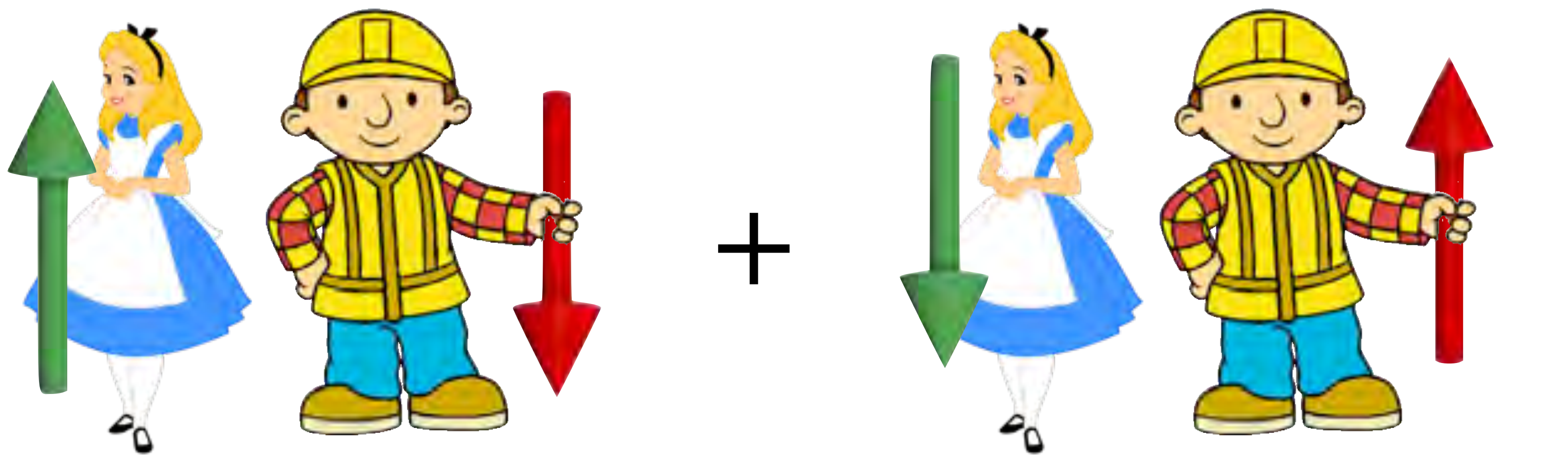
"domain wall"


“Quantum physics makes me so happy…
it’s like looking at the universe naked”

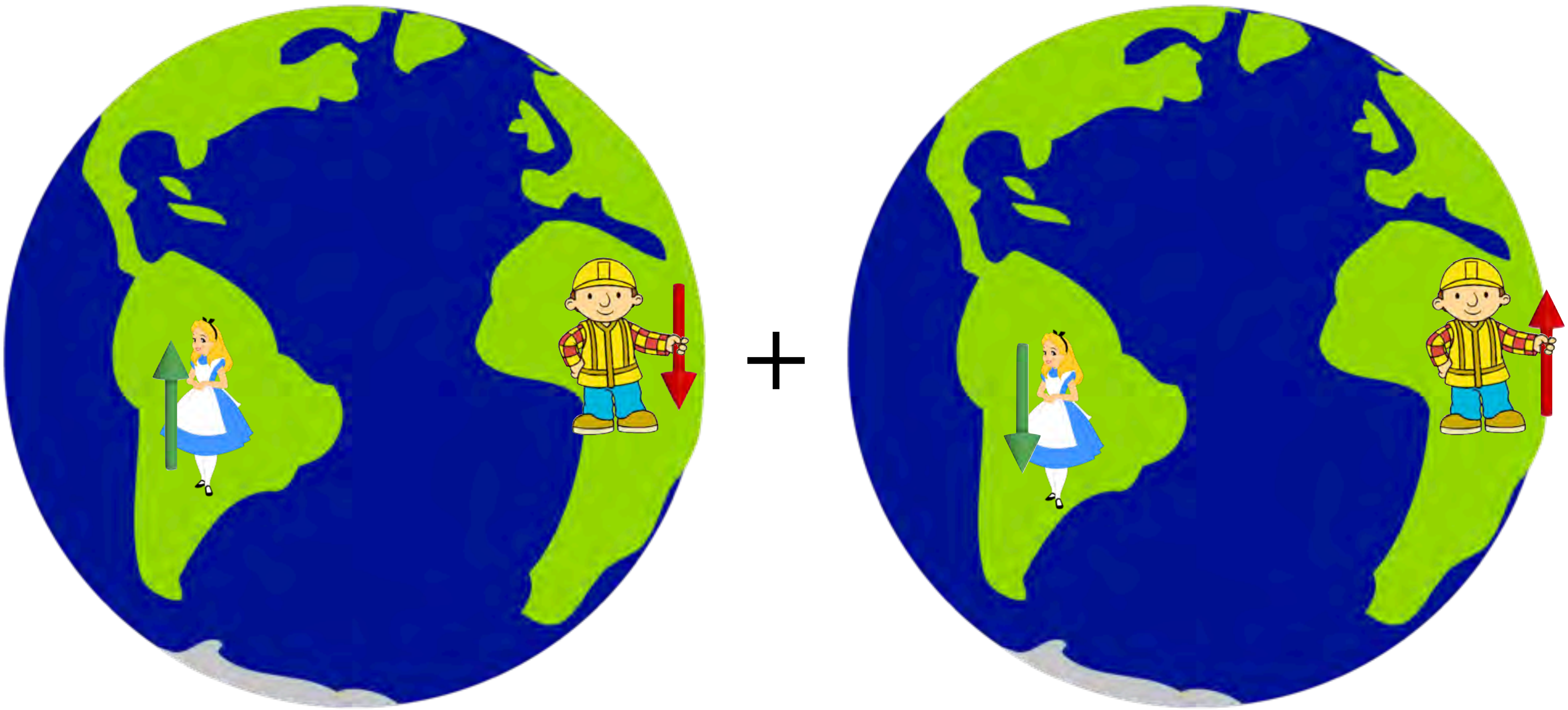
Entanglement

Entanglement

Entanglement

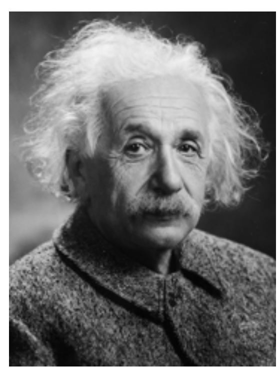


Entanglement

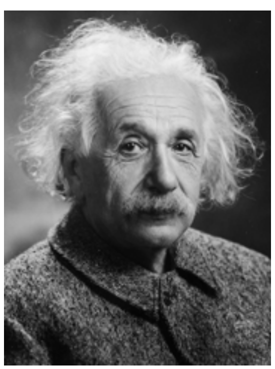


Einstein-Podolsky-Rosen Pair

+

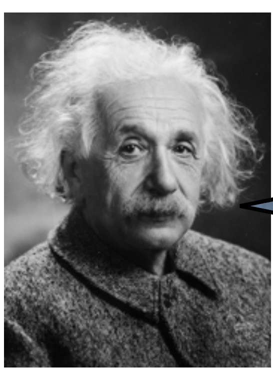


Einstein-Podolsky-Rosen Pair

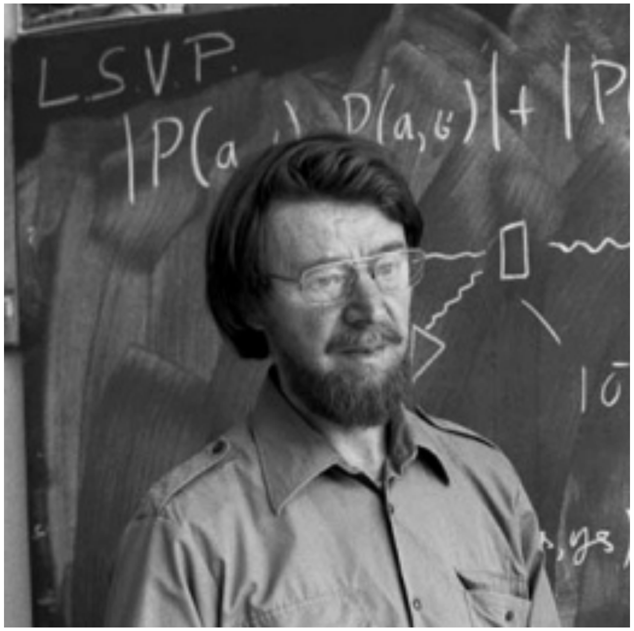


"quantum non-locality"

Einstein-Podolsky-Rosen Pair

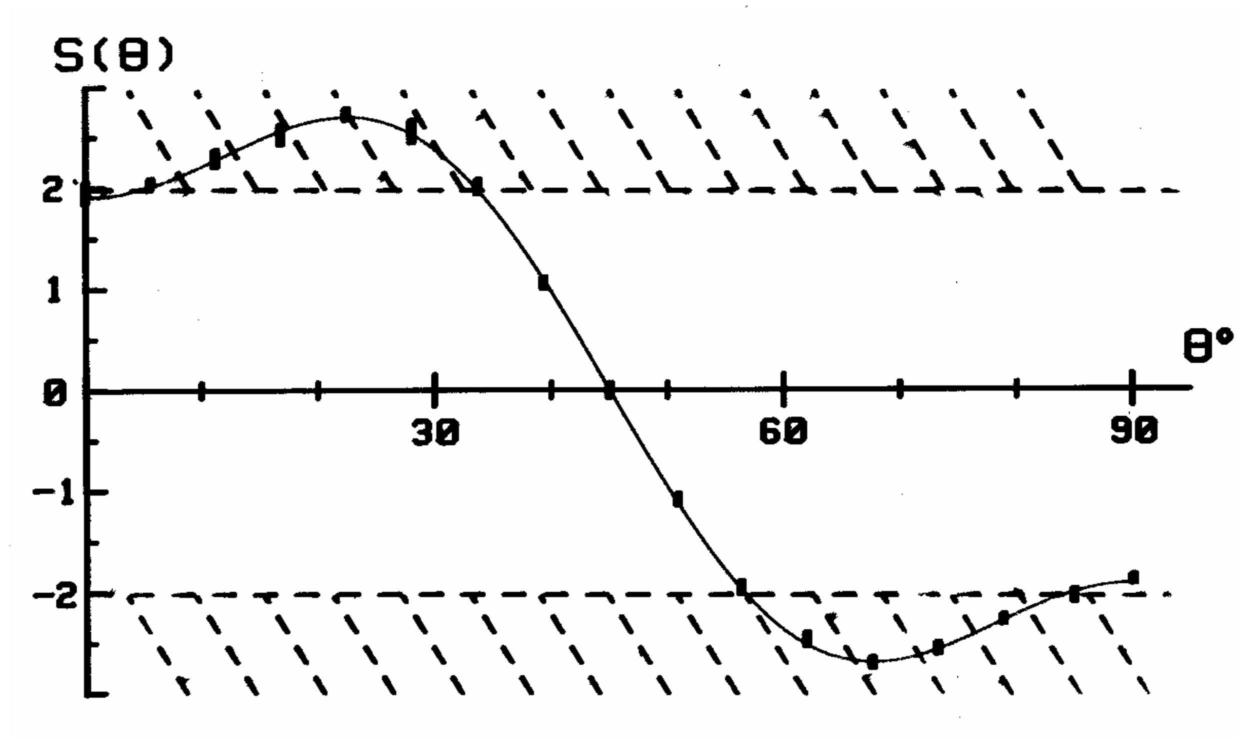


spukhafte Fernwirkung!



John Bell

Alain Aspect



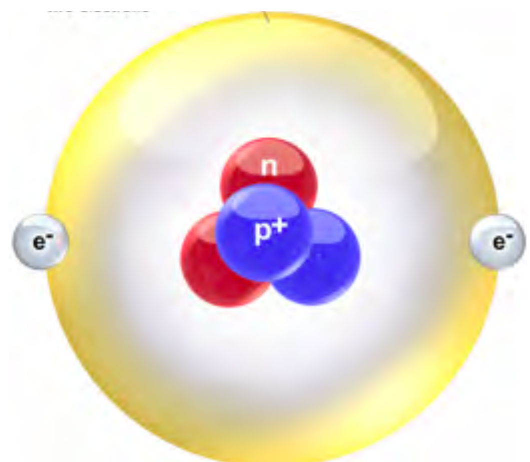
no local realism

id Quantique
A Quantum Leap for Cryptography

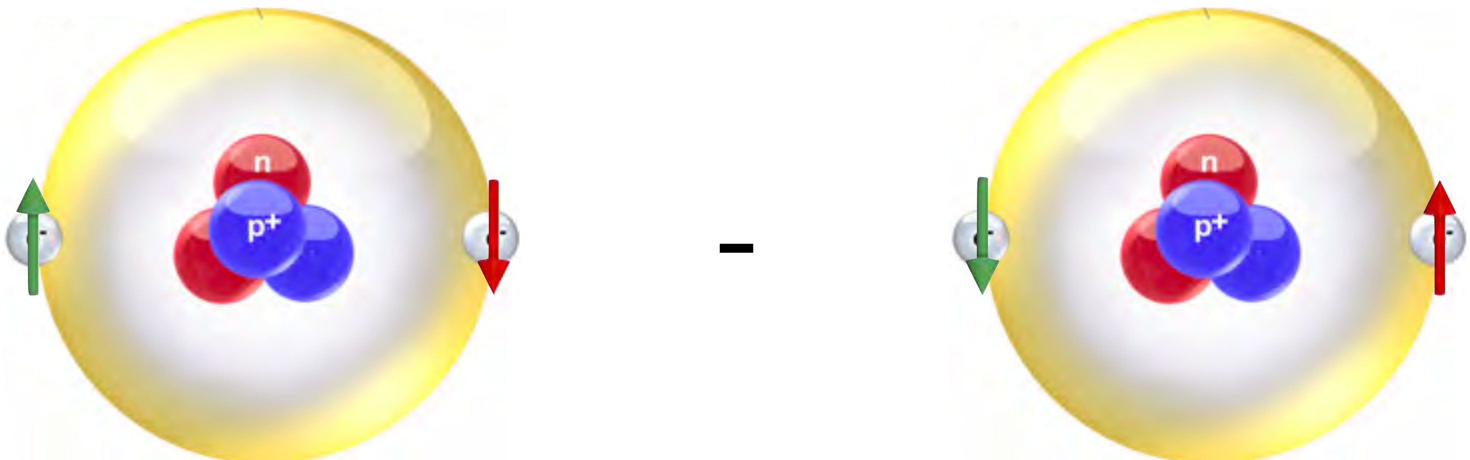
MagiQ

Quintessence labs

SeQureNet
A Quantum Key to Network Security



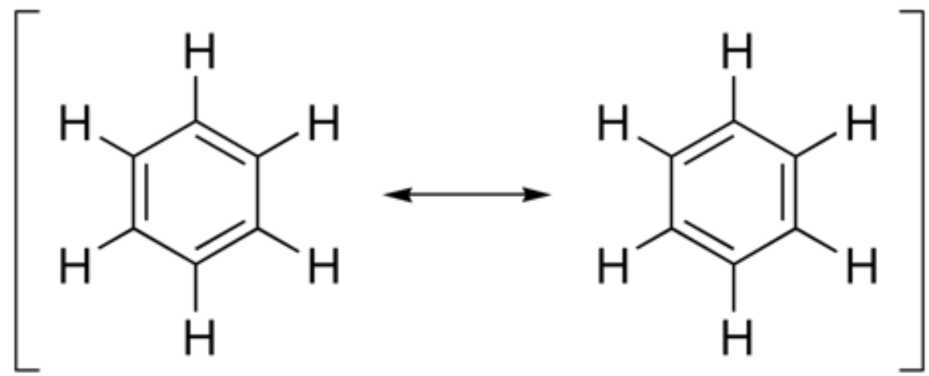
Helium



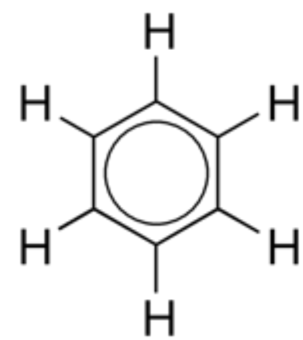
Helium

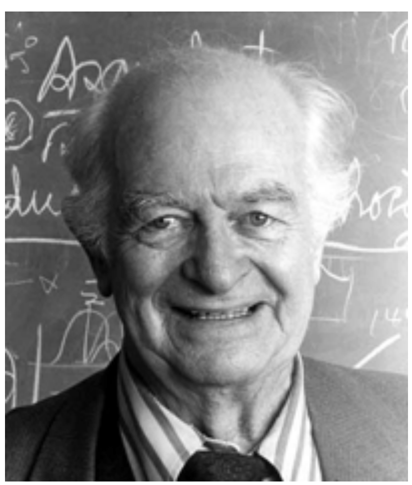
Resonance

benzene



C_6H_6

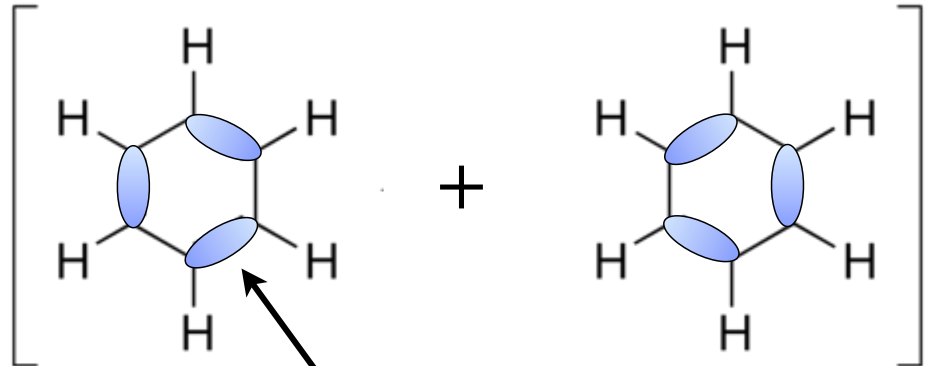




Linus Pauling ~ 1930

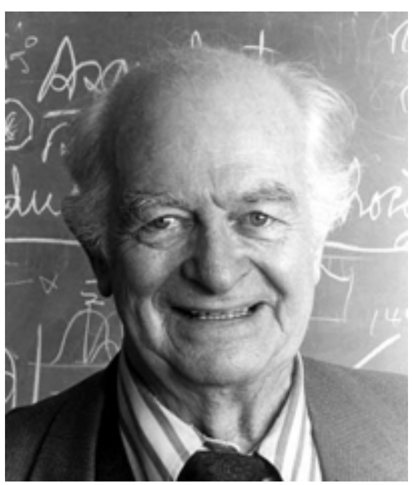
Resonance

benzene



C_6H_6

chemical bond = EPR pair!



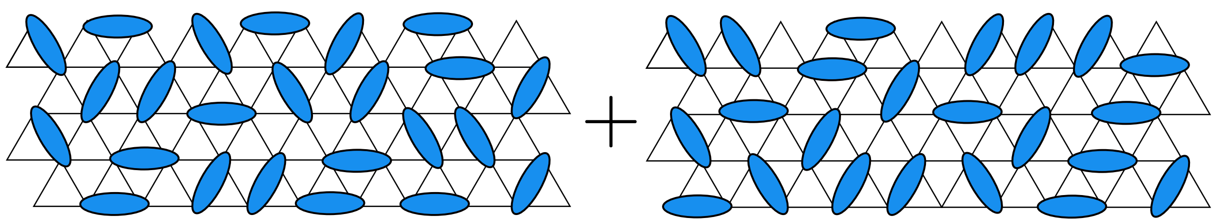
Linus Pauling ~ 1930

Strange Stuff

Phil Anderson, 1973

a "quantum liquid" of spins

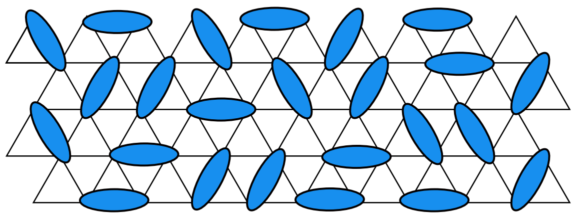
$$\Psi = \quad + \quad + \ldots$$



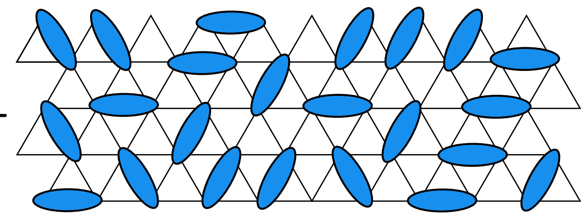
Resonating **V**alence **B**ond state

Quantum spin liquid

$\Psi =$



$+$



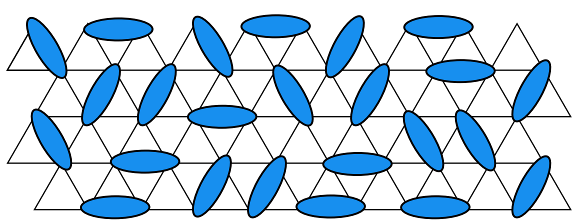
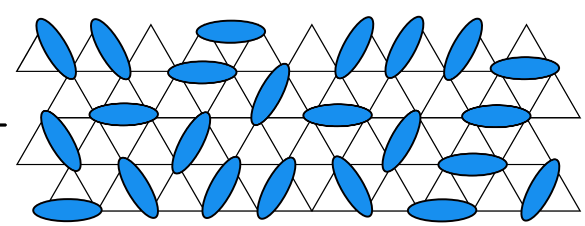
$+\ldots$

For ~500 spins, there are more components than there are atoms in the visible universe!

“Schrödinger cat”

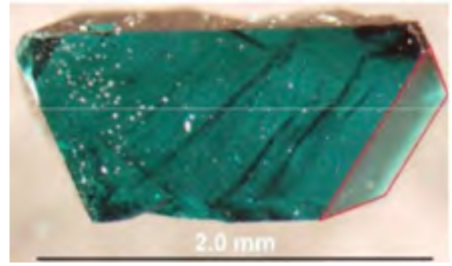
$+$

vs

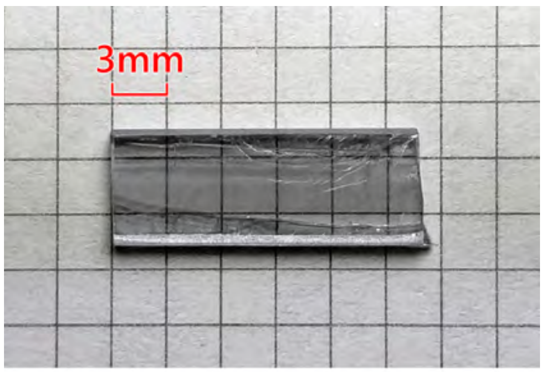
$\Psi =$  $+$  $+ \ldots$

“Schrödinger kitten”

Strange stuff

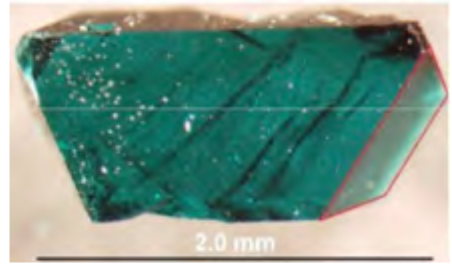


herbertsmithite, a natural mineral discovered in Chile

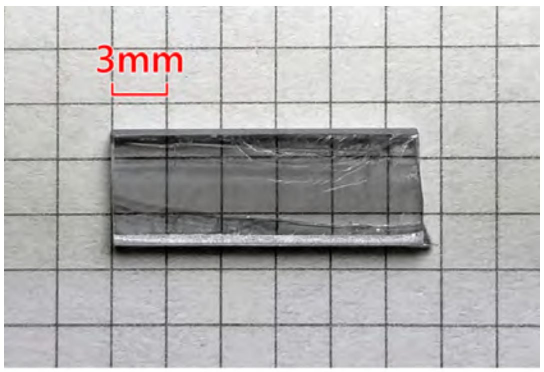


$YbMgGaO_4$, synthesized 2015

Bi_2Se_3, a semiconductor used as a thermoelectric



herbertsmithite, a natural mineral discovered in Chile



$YbMgGaO_4$, synthesized 2015

Quantum-ness is not obvious!!

Bi_2Se_3, a semiconductor used as a thermoelectric

Strange stuff

$\Rightarrow$

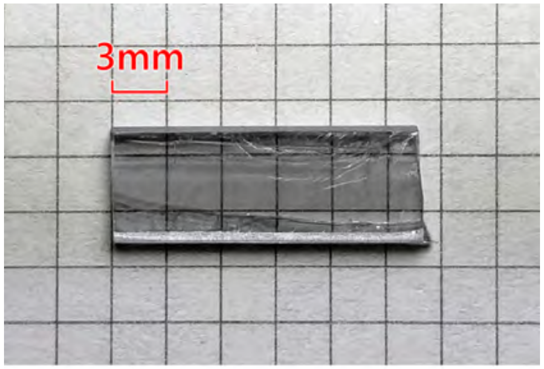
Peculiar particles

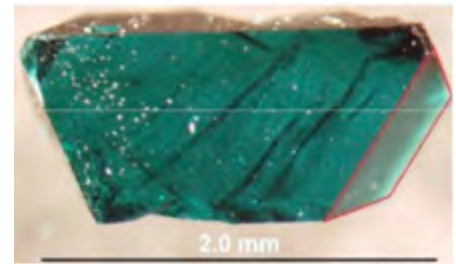
Strange
stuff

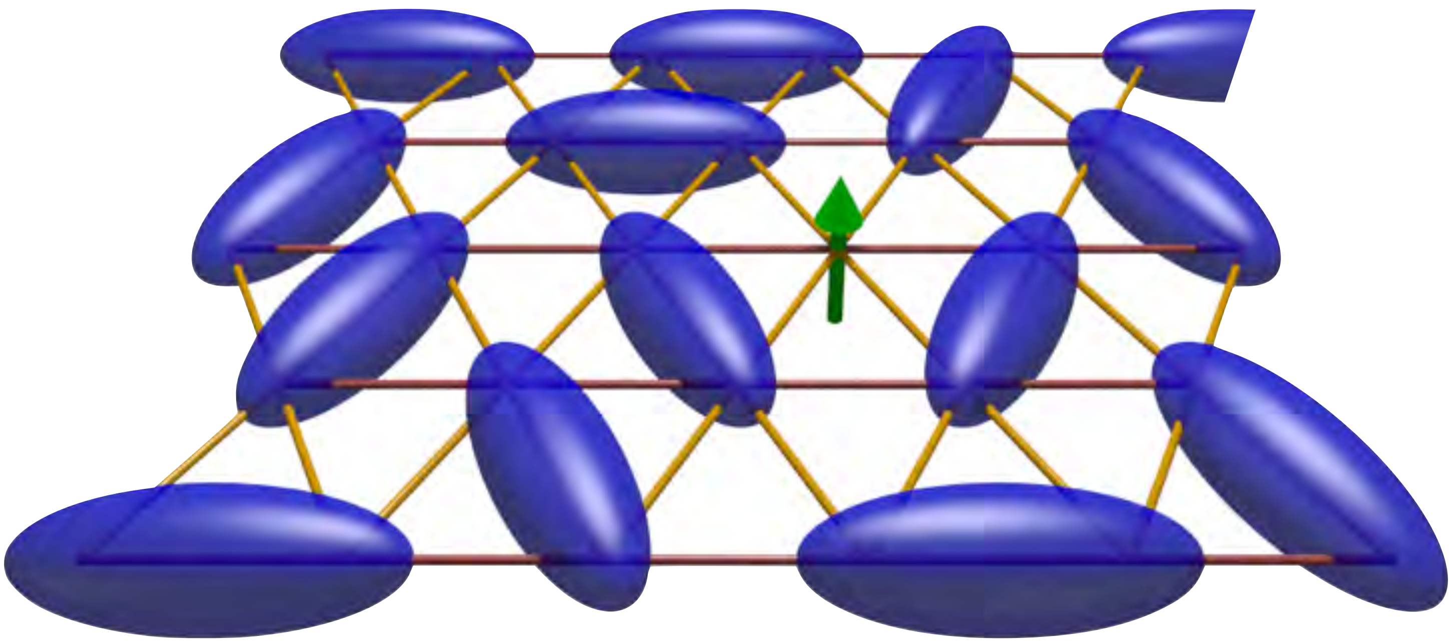
Peculiar
particles

"quasi-particles"

Spin Liquid

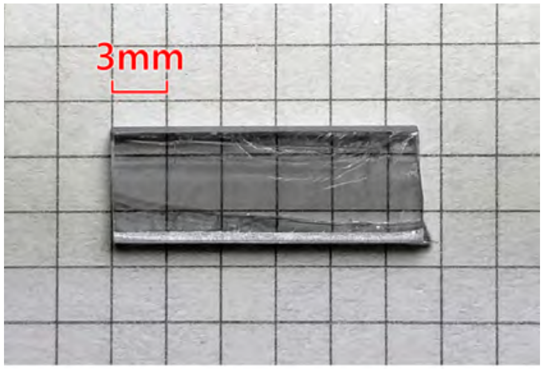


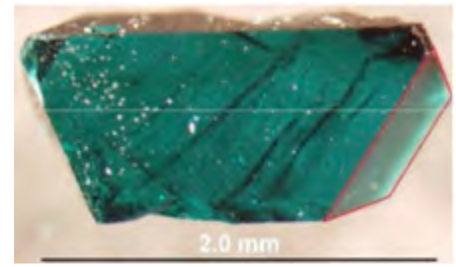


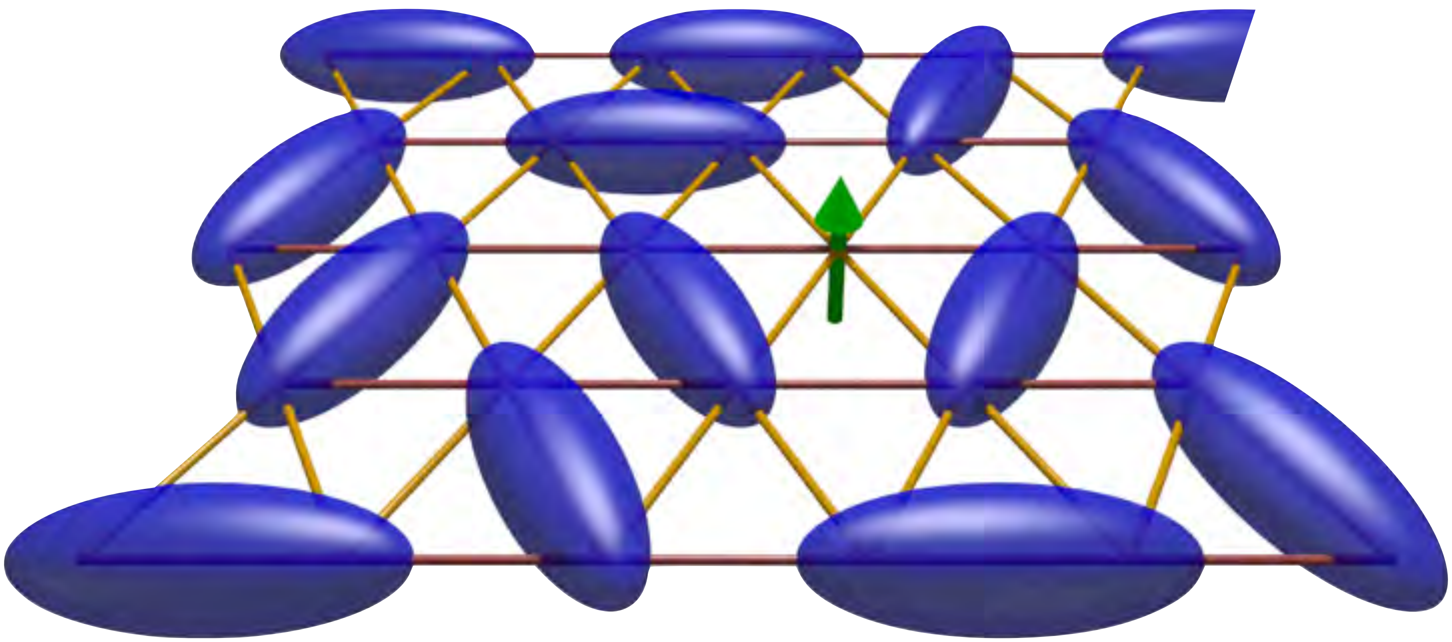


"spinon"

Spin Liquid







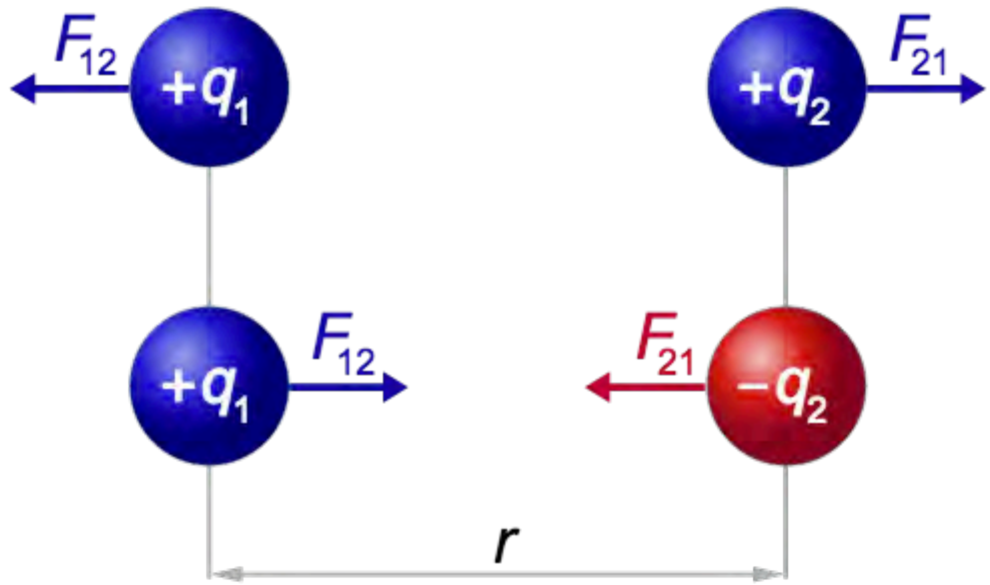
"spinon"

Fundamental applications?
Can elementary particles and forces of our world emerge from entanglement?

Coulomb, 1785

DES recherches qui précèdent, il réſultera :

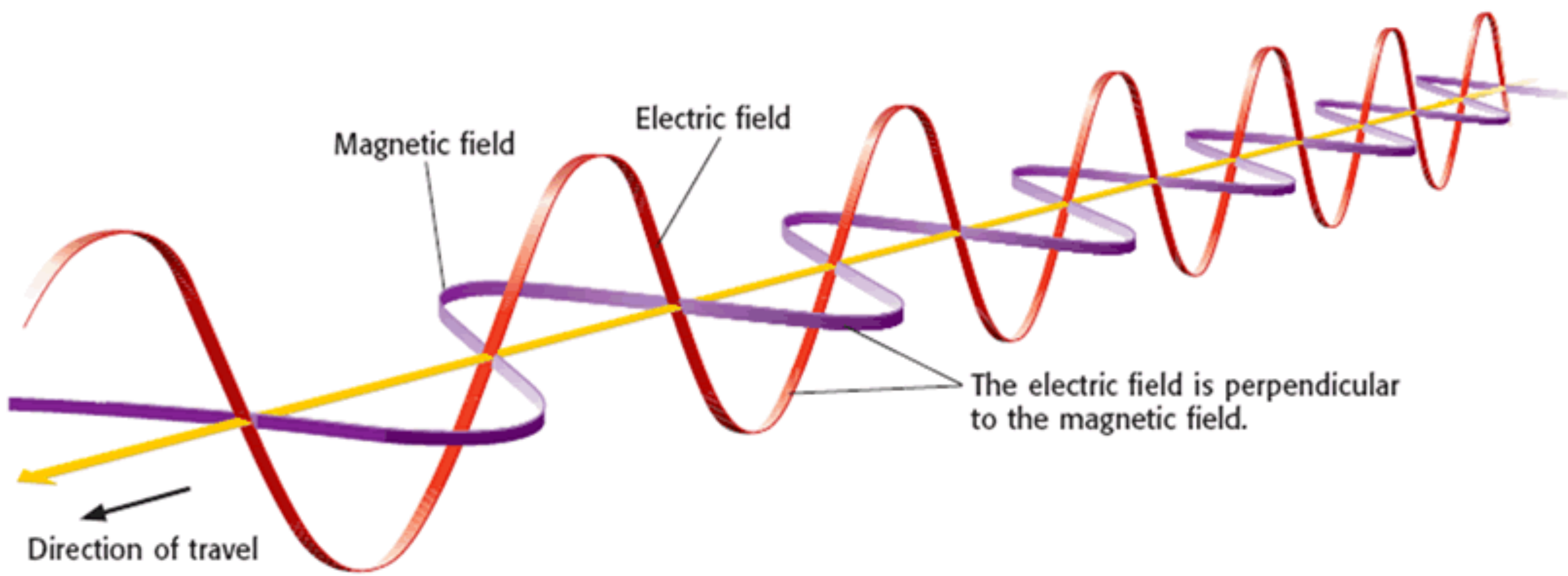
1.° Que l'action, ſoit répulſive, ſoit attractive de deux globes électriſés, & par conſéquent de deux molécules électriques, eſt en raiſon compoſée des denſités du fluide électrique des deux molécules électriſées, & inverſe du carré des diſtances.



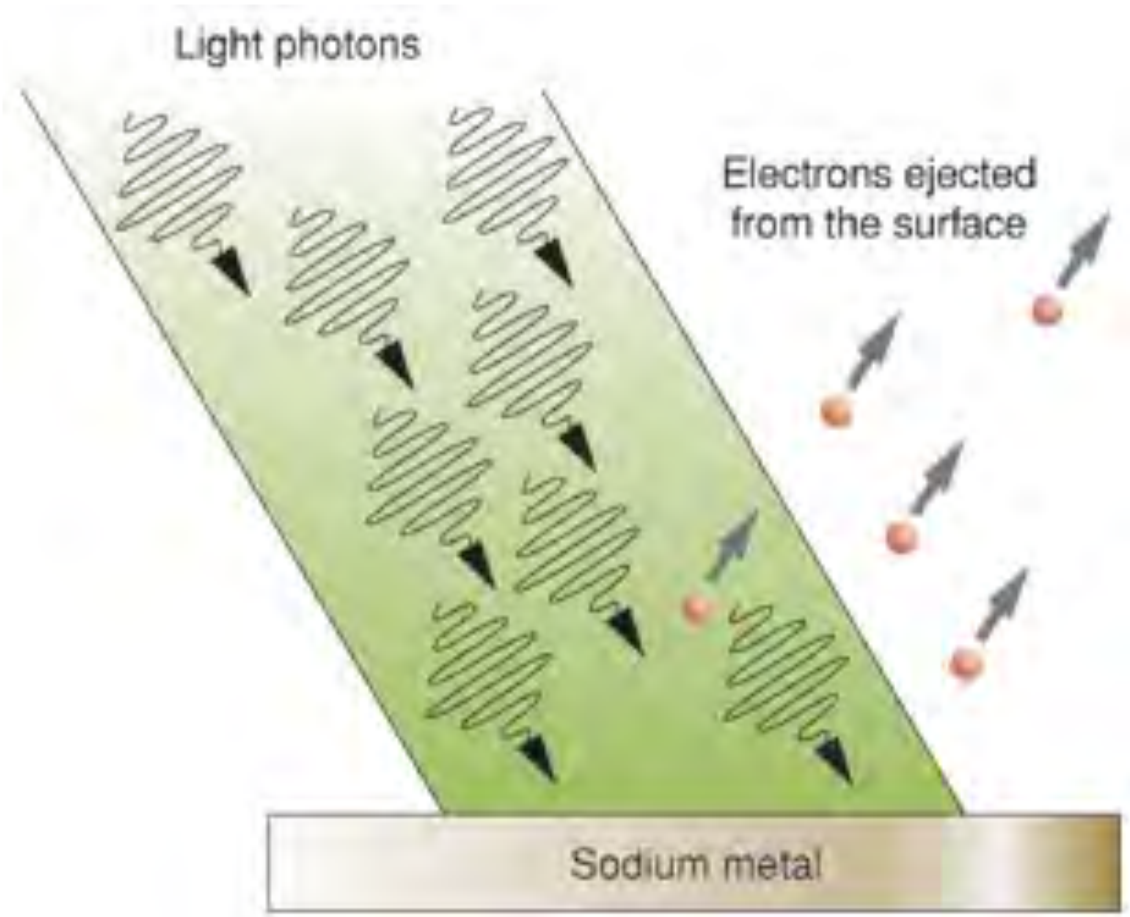
$$F_{12} = F_{21} = k\,\frac{q_1\,q_2}{r^2}$$

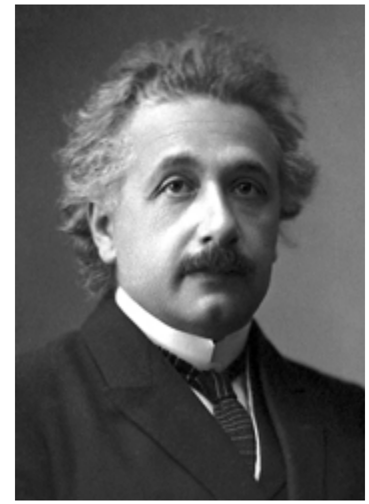
Electromagnetism

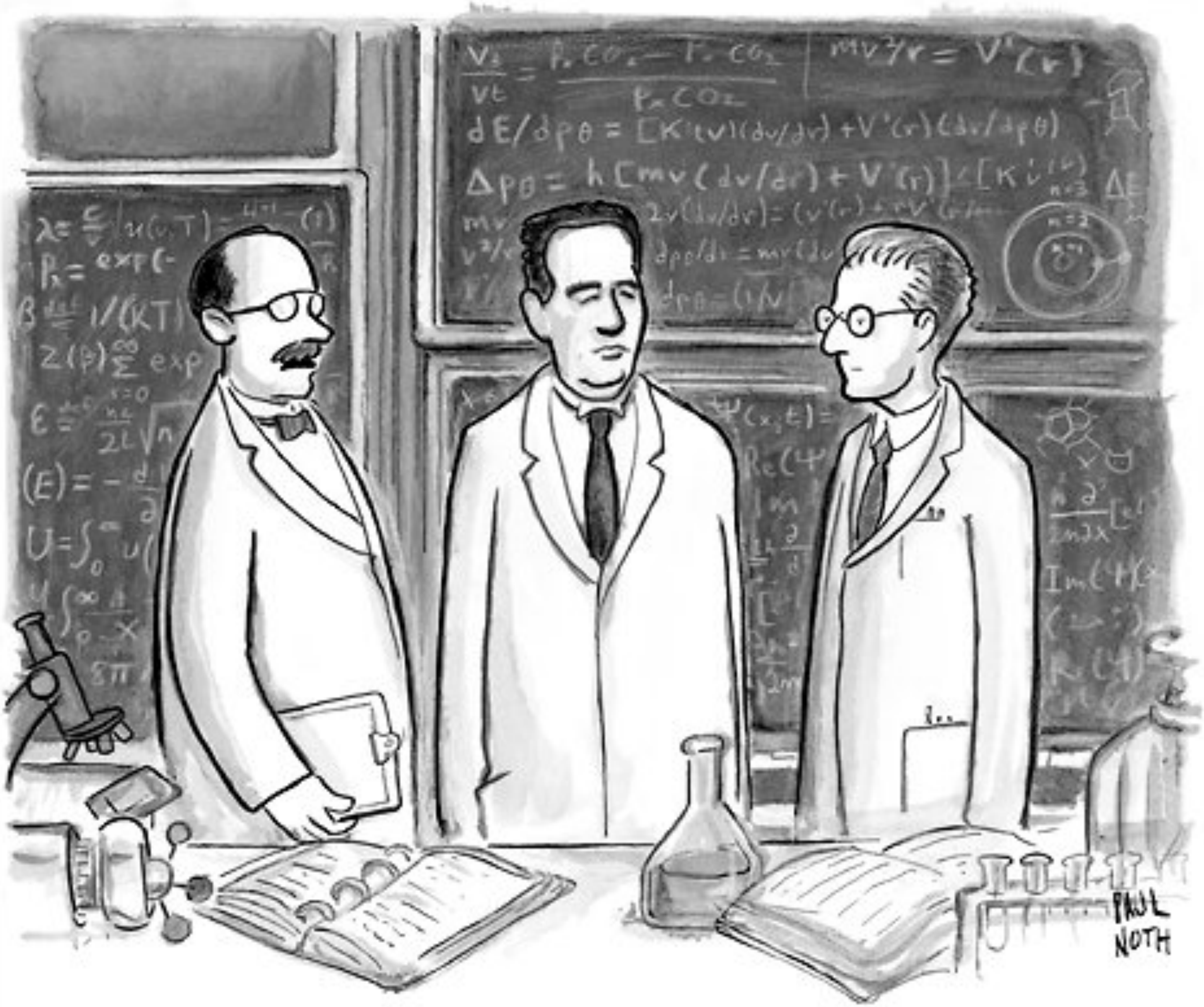
James Clerk Maxwell



Photoelectric effect

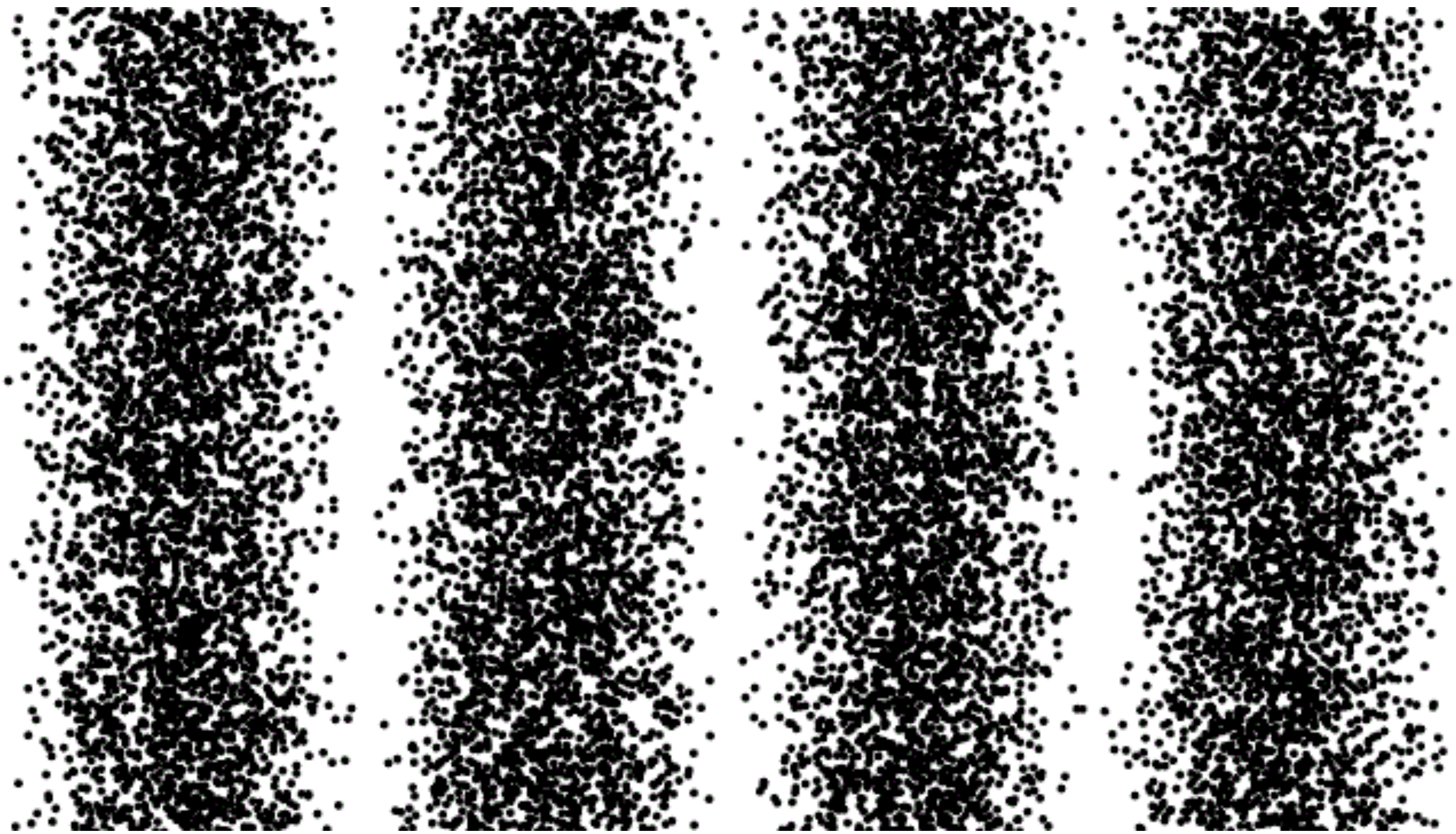






"We've agreed to count it as both a wave and a particle for tax purposes."

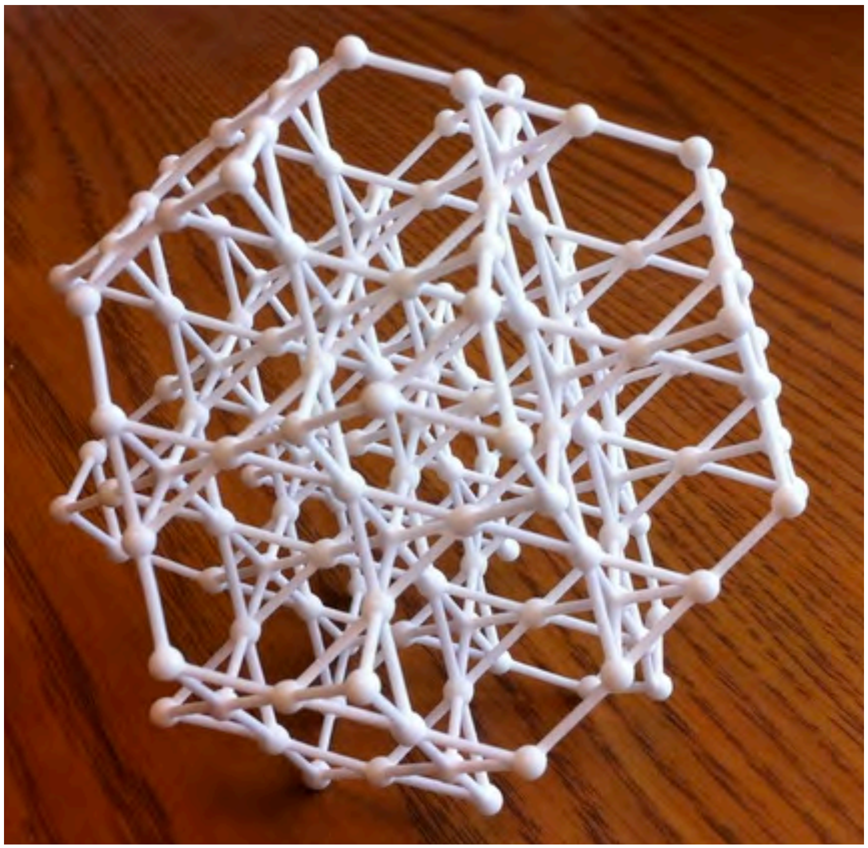
Particle-wave duality

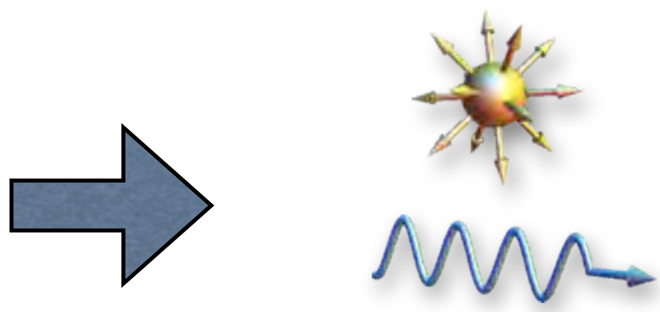


But where does electromagnetism come from?

Mike Hermele

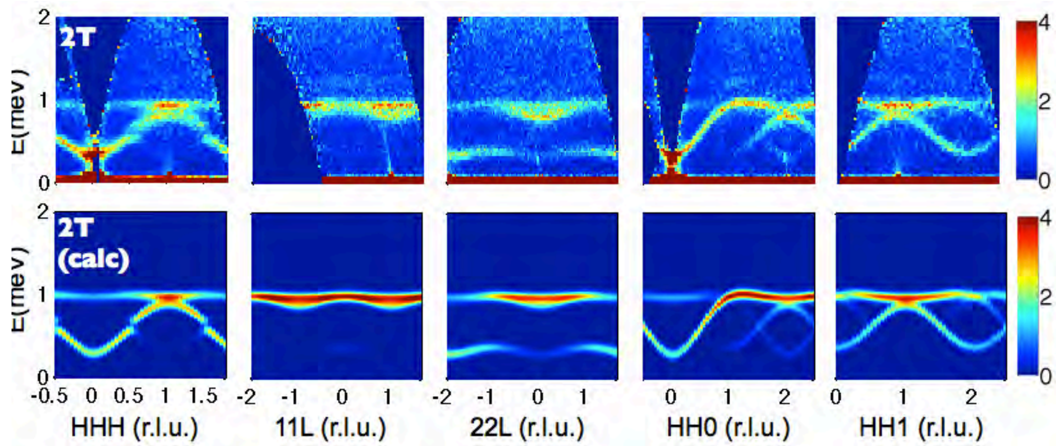
Matthew Fisher



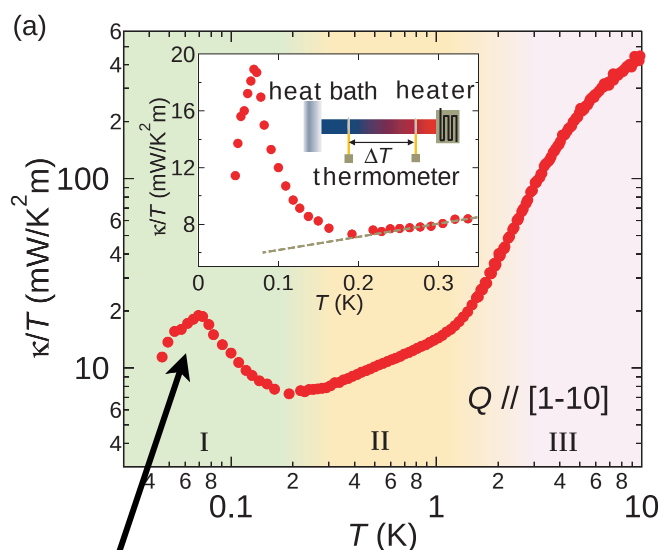


Lucile Savary

SungBin Lee



$Yb_2Ti_2O_7$



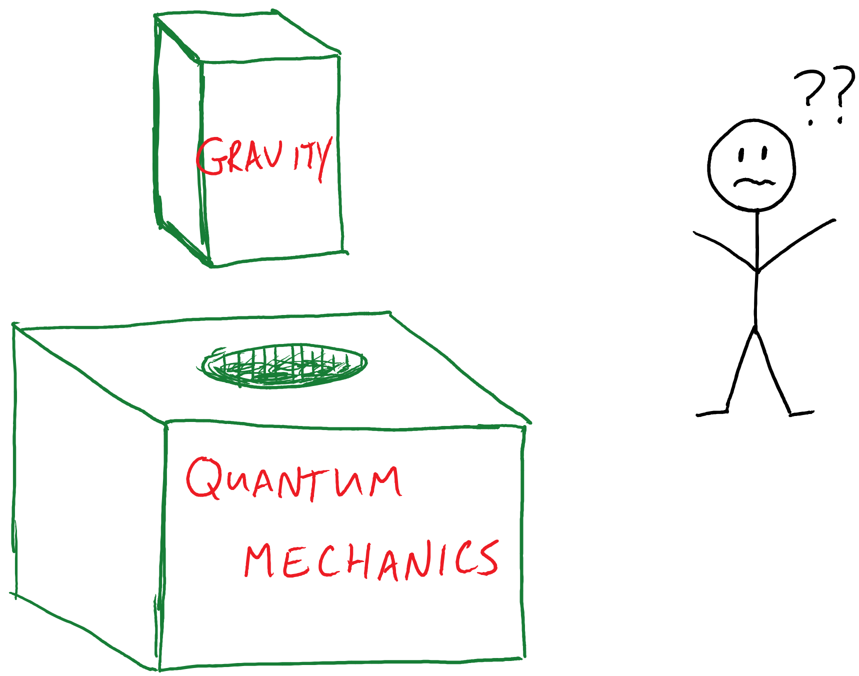
photon?

Y. Matsuda group, unpublished

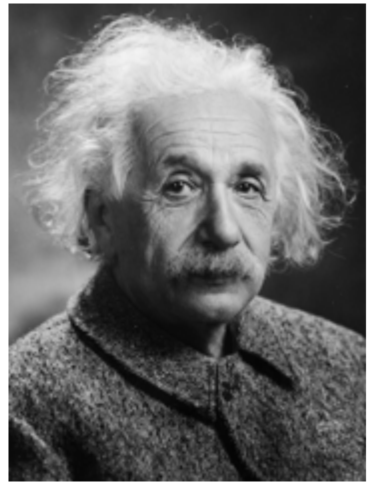
Gravity

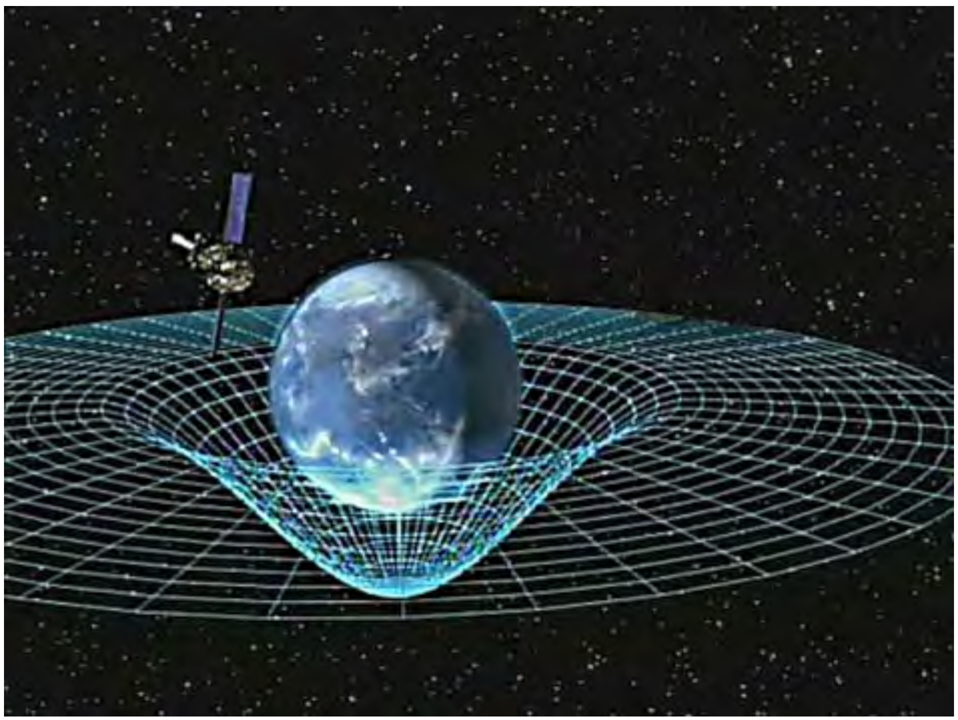
Mark Van Raamsdonk, UBC

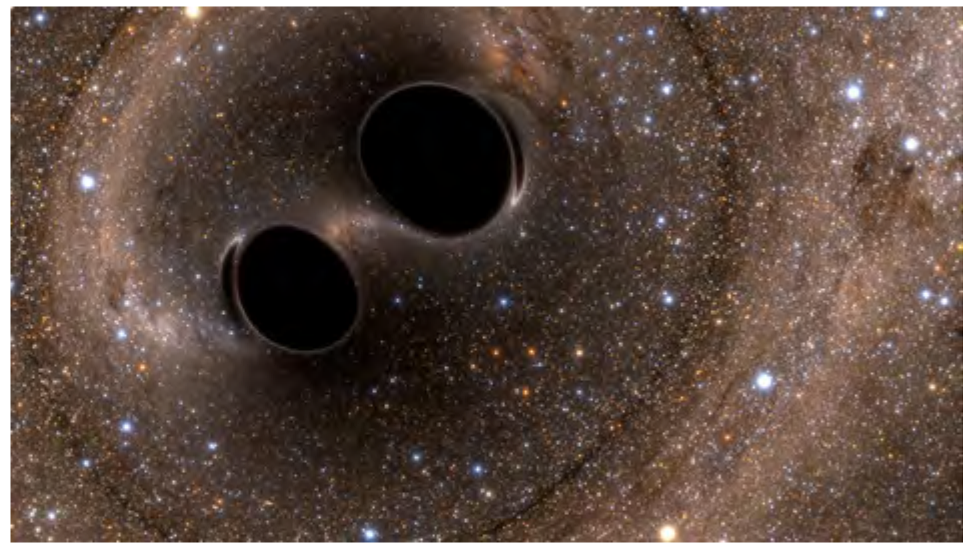
KITP, April 2015



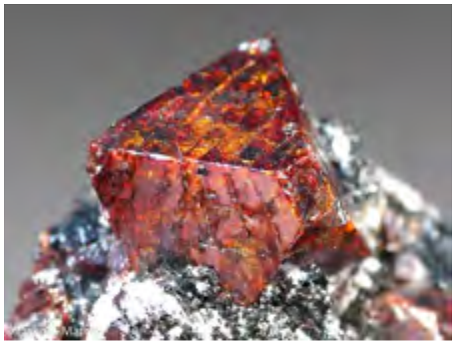
There is no theory of quantum gravity







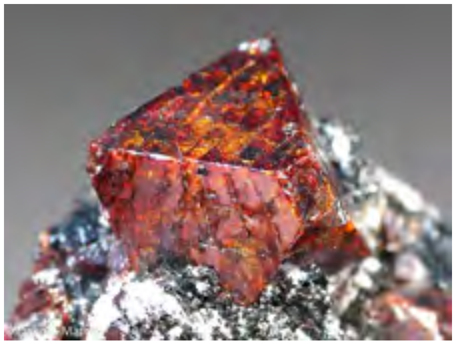
explaining gravity is explaining the emergence of space-time itself



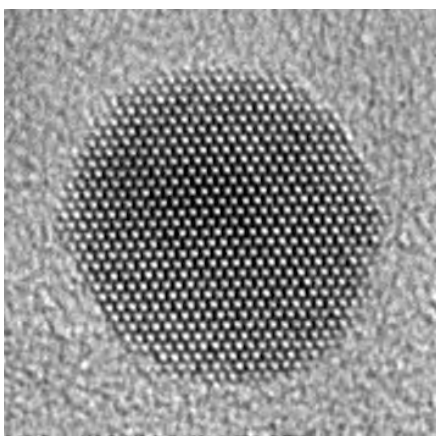
electromagnetism

???

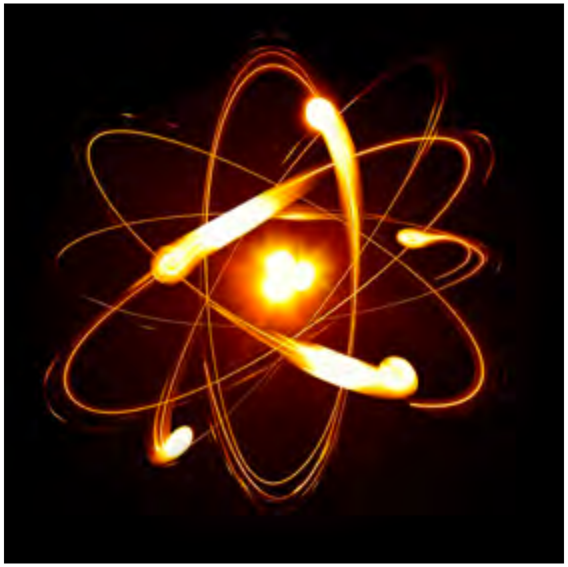
gravity?



electromagnetism

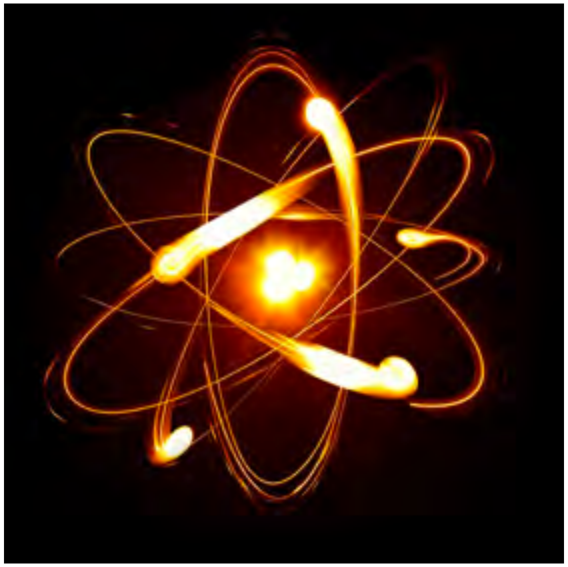


gravity?



Electrons

Black holes



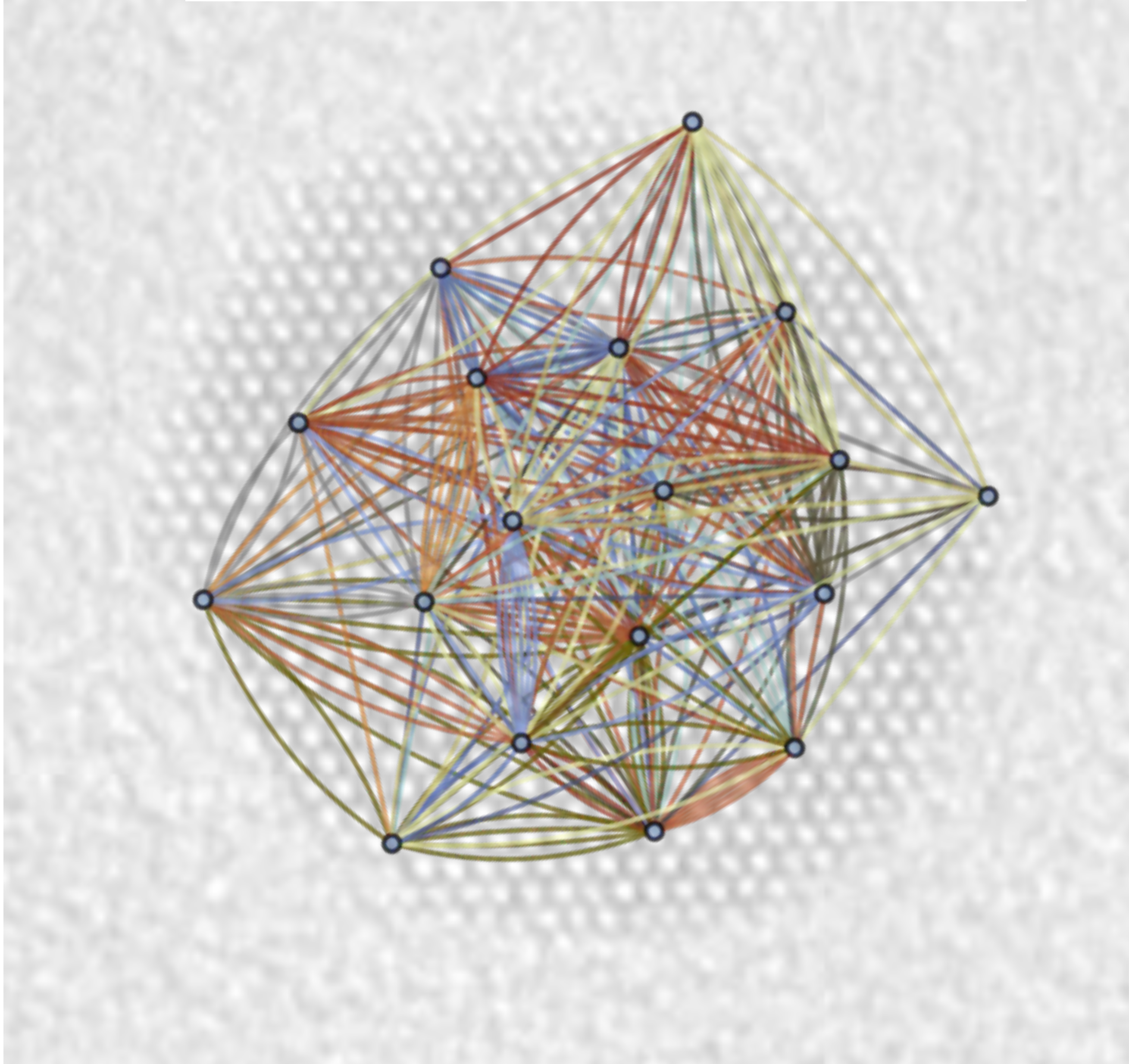
Electrons

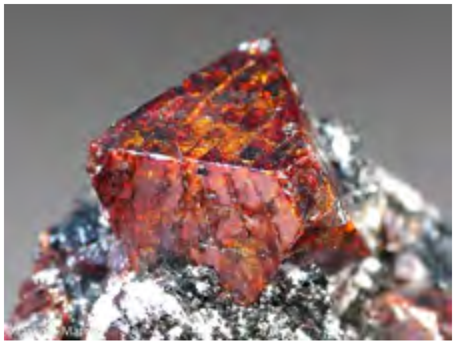
.0000000000000000000000000000009kg

Black holes

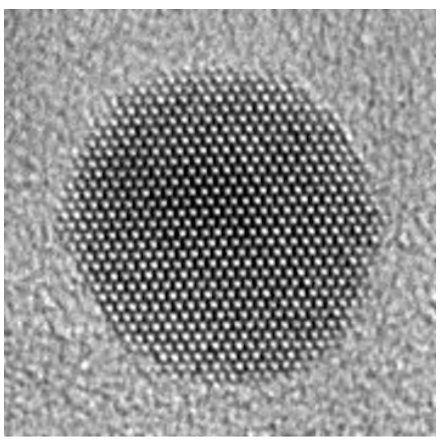
60000000000000000000000000000000kg

Sachdev-Ye-Kitaev Model



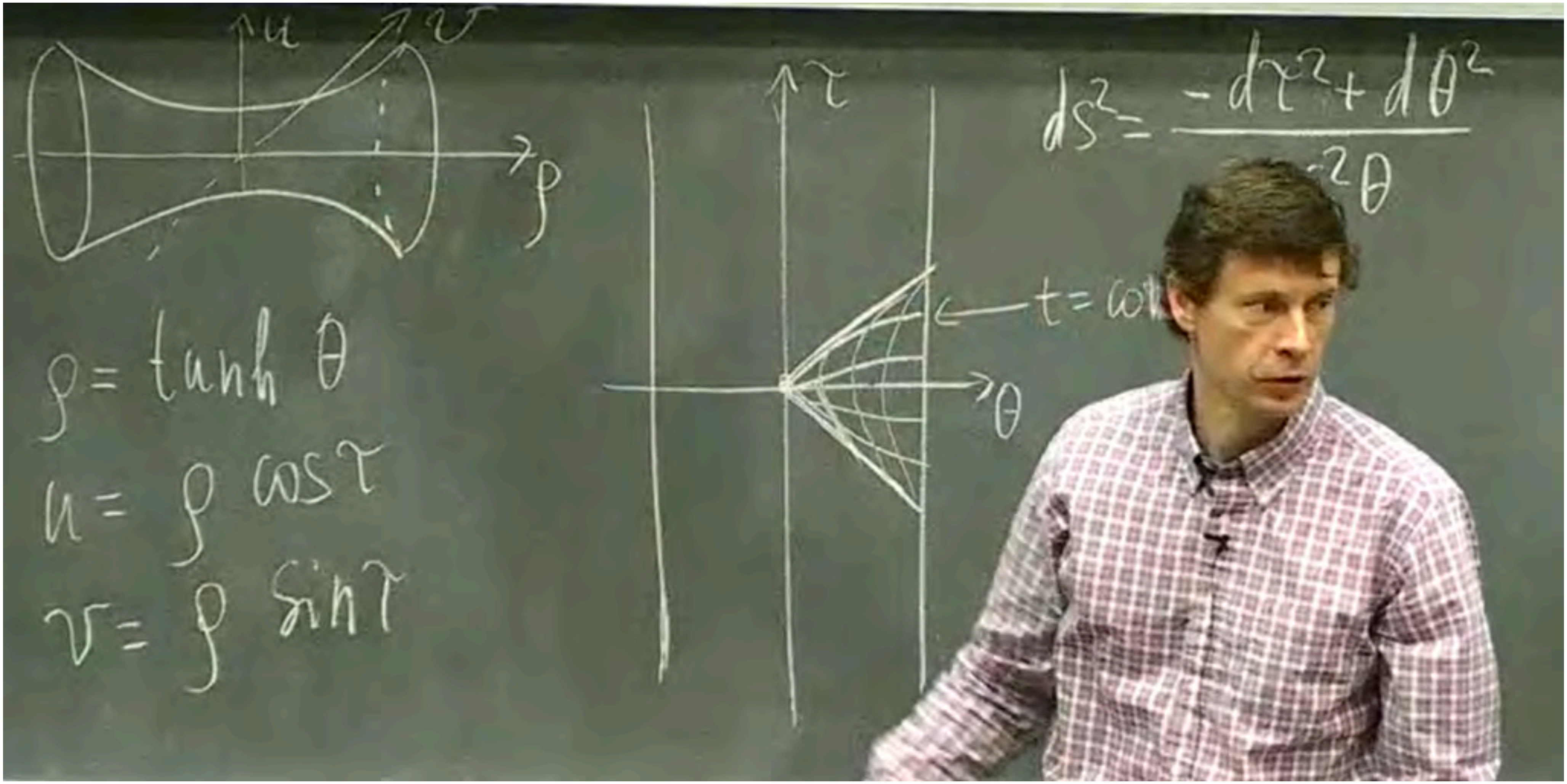


electromagnetism

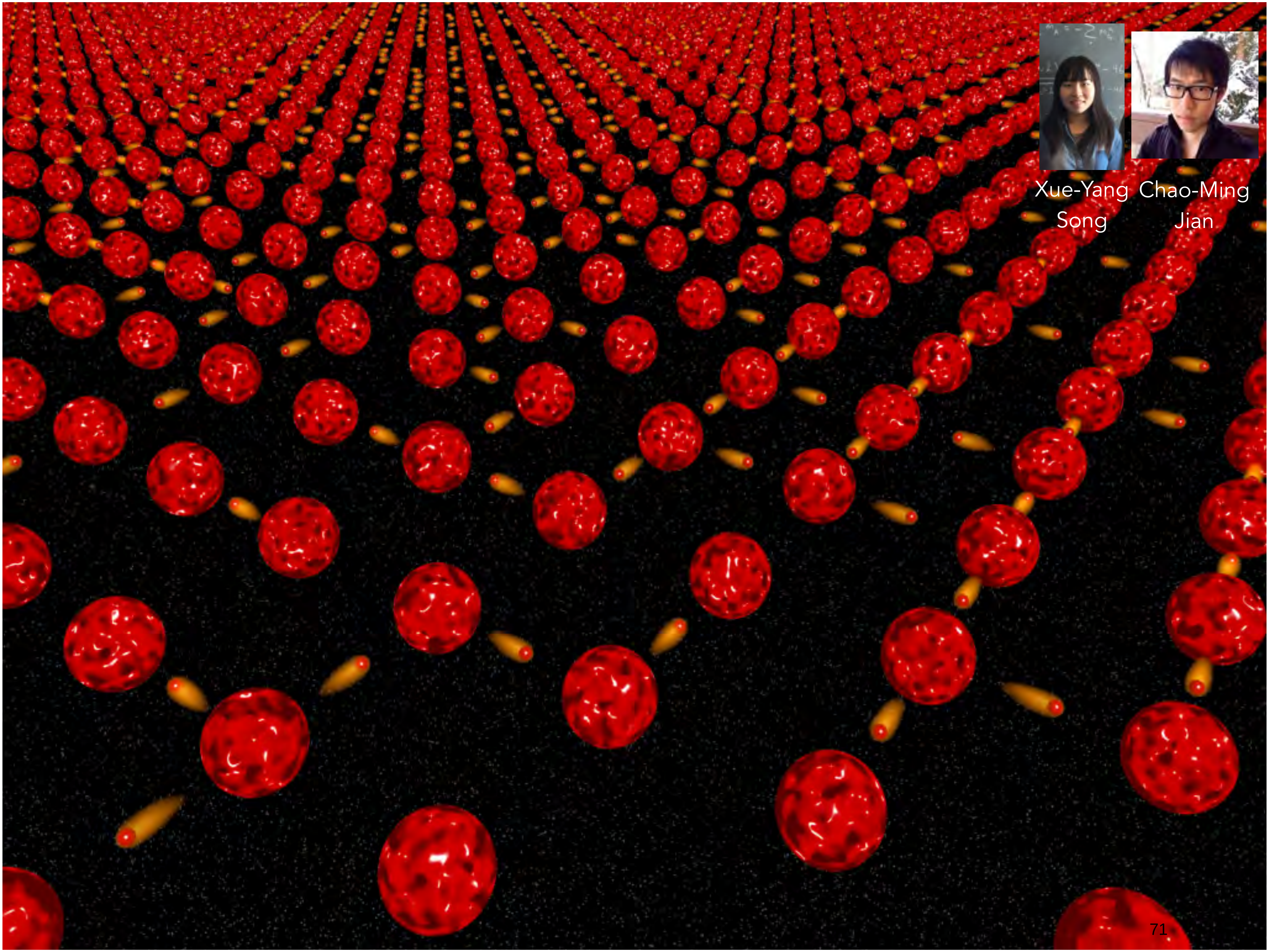


1+1-dimensional gravity in anti-de Sitter space

KITP online



April 2015


Xue-Yang Song
Chao-Ming Jian


m c j
thank you
gettyimages
Tom And Steve
f a i r s