

So What Does An Atom Look Like?

So What Does An Atom Look Like?



Dr Steve Barrett 26 June 2008

2 Introduction

So What Does an Atom ...

- ~~A Sense of Scale~~
Metres → Nanometres
- A Sense of Symmetry
Underlying Structure
- The Quantum World
Seeing Atoms
- ~~And Beyond...~~
What is Even Smaller?

Snowflakes



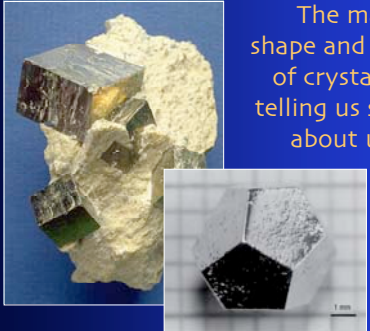
4 Structure Within

So What Does an Atom ...



5 Structure Within

So What Does an Atom ...



The macroscopic shape and symmetry of crystals must be telling us something about underlying structure

6 Atoms

So What Does an Atom ...


1600	1700	1800	1900
Democritus	Boyle	Dalton	Maxwell
	Newton		
		Lavoisier	Avogadro
			Boltzmann

So What Does An Atom Look Like?

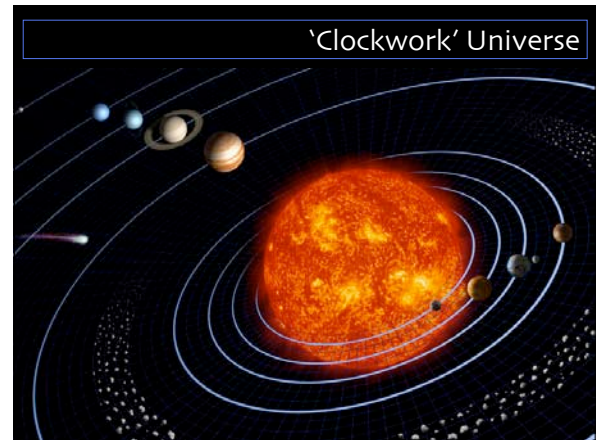
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Newton

So What Does an Atom...





Laws of Motion
Law of Gravity
Nature of Light
"Classical Mechanics"



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Particles and Waves









So What Does an Atom...

1800	1850	1900
		
Young		Thomson
^ Light (Waves)		^ Electrons (Particles)

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Atoms To Quantum Mechanics

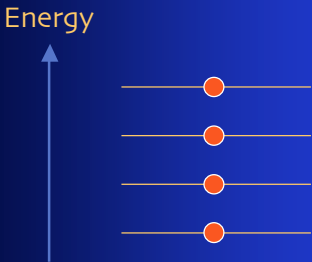
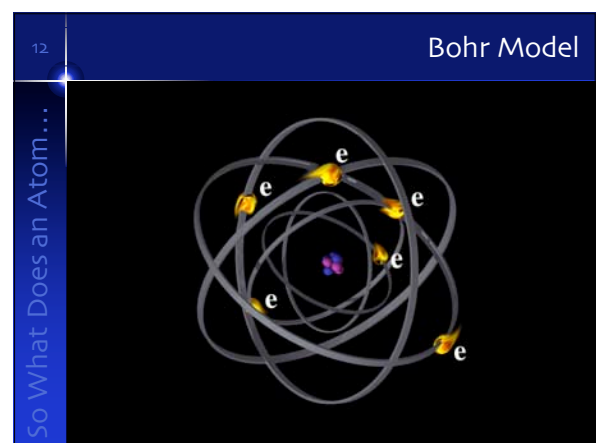
So What Does an Atom...

1900	1910	1920	1930
Becquerel	Rutherford	deBroglie	Heisenberg
			
	Einstein	Bohr	Schrödinger
			
Planck	Einstein	Bohr	Schrödinger
^ Radio-activity	^ Light (Particles)	^ Atoms	^ Atomic Nucleus
		^ Probability	^ Electrons (Waves)
			^ QM

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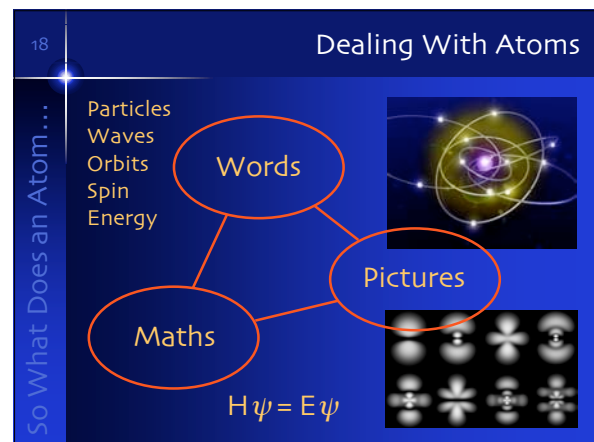
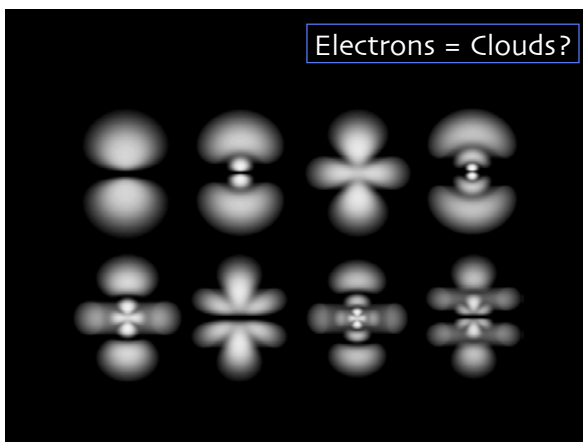
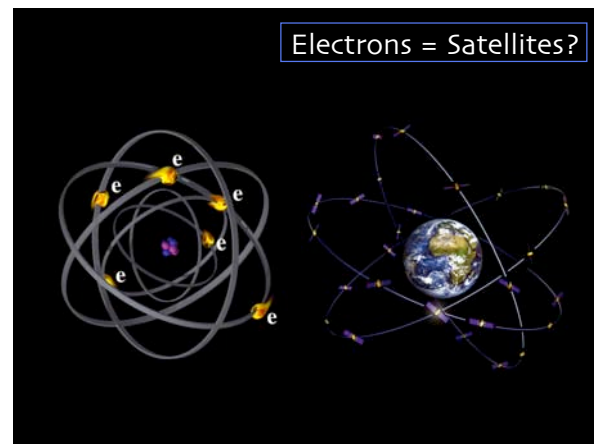
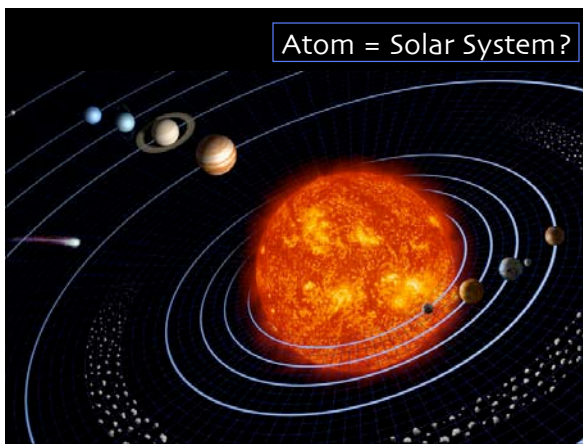
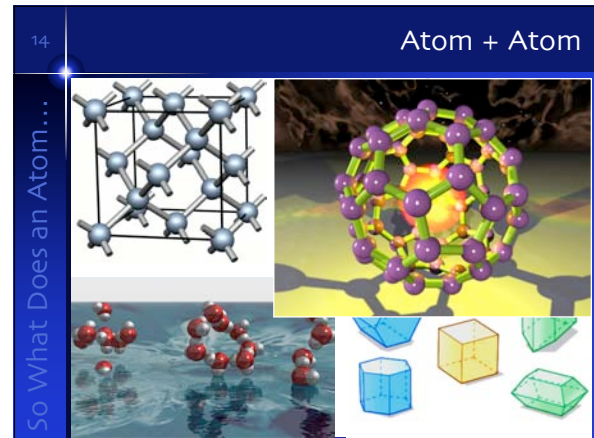
Quantised States

So What Does an Atom...

So What Does An Atom Look Like?

PERIODIC TABLE of the ELEMENTS




So What Does An Atom Look Like?

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Heisenberg

So What Does an Atom...



"We wish to talk about the structure of atoms. But we cannot talk about atoms in ordinary language"

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Dealing With Atoms

So What Does an Atom...

Would it be better to use words that don't carry any 'baggage', or preconceptions?

Rather than say...

"The electrons orbit and spin in the atom"


Would it be better to say...

"The slithy toves did gyre and gimbal in the wabe"

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Bohr

So What Does an Atom...

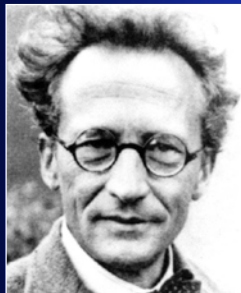


"Everything we call real is made of things that cannot be regarded as real"

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Schrödinger

So What Does an Atom...

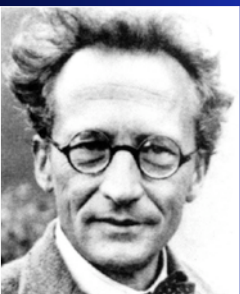


"Atomic physics has shown that atoms have no meaning, but can only be understood in experimental measurement"

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Schrödinger

So What Does an Atom...



"I don't like it, and I'm sorry I ever had anything to do with it"

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QM vs Common Sense

So What Does an Atom...

Atoms (indeed, all particles) are unpredictable
We can know **only the probability** of an atom having a particular position, speed, energy, ...

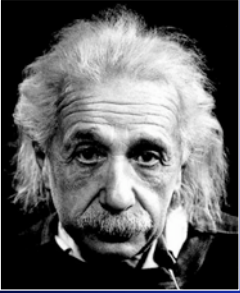
Atoms do not have a finite size
Electron 'in' an atom could be **anywhere**

Atoms can be in two states at the same time
Electron 'spin' can be **simultaneously** clockwise and anticlockwise

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25 Einstein


So What Does an Atom...



"Common sense is the collection of prejudices acquired by age eighteen"

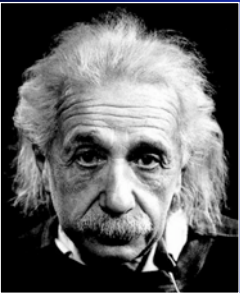
26 Heads or Tails?

So What Does an Atom...



27 Einstein

So What Does an Atom...



"God does not play dice"

"God is subtle but he is not malicious"

28 Three Aspects of QM

So What Does an Atom...

- Order matters
- ~~Schrödinger's Cat~~
- Using QM to see atoms

29 Order Matters

So What Does an Atom...

In algebra

$$A \times B = B \times A$$

In Quantum Mechanics

$$A \times B \neq B \times A$$

So what?

30 If Order Matters

So What Does an Atom...



Top pair: carnivores
Bottom pair: veggies

Left pair: 4 legs
Right pair: wings

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If Order Matters

So What Does an Atom...



Pick 2 out of the 4
For instance, pick the **veggie** animals
From these, pick again
For instance, pick the **4-legged** animals
You're left with waterbuck **and** lion!

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If Order Matters

So What Does an Atom...

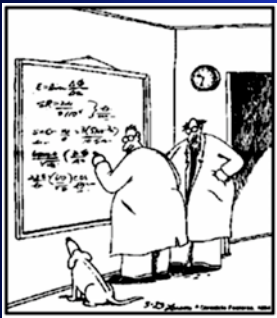


If we had picked in a different order...
First pick the **4-legged** animals
Then from these pick the **veggie** animals
You're left with waterbuck **and** roller!

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QM and Dogs

So What Does an Atom...

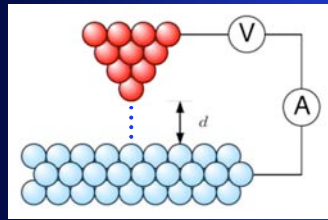


"Ohhh, look at that... dogs are so cute when they try to comprehend quantum mechanics"

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Scanning Tunnelling Microscope

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Sharp tip

Sample

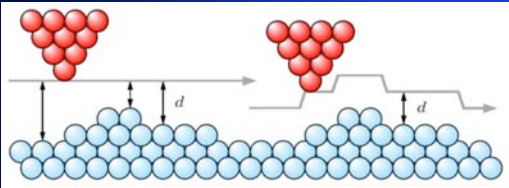
Current flows

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STM

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Move tip across sample...




...measuring current at each point

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Surface Science

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The STM is sealed inside an ultra-high vacuum vessel (10^{-13} atms) to keep it and the sample surface clean.

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