Balancing a Career in Physics and Family

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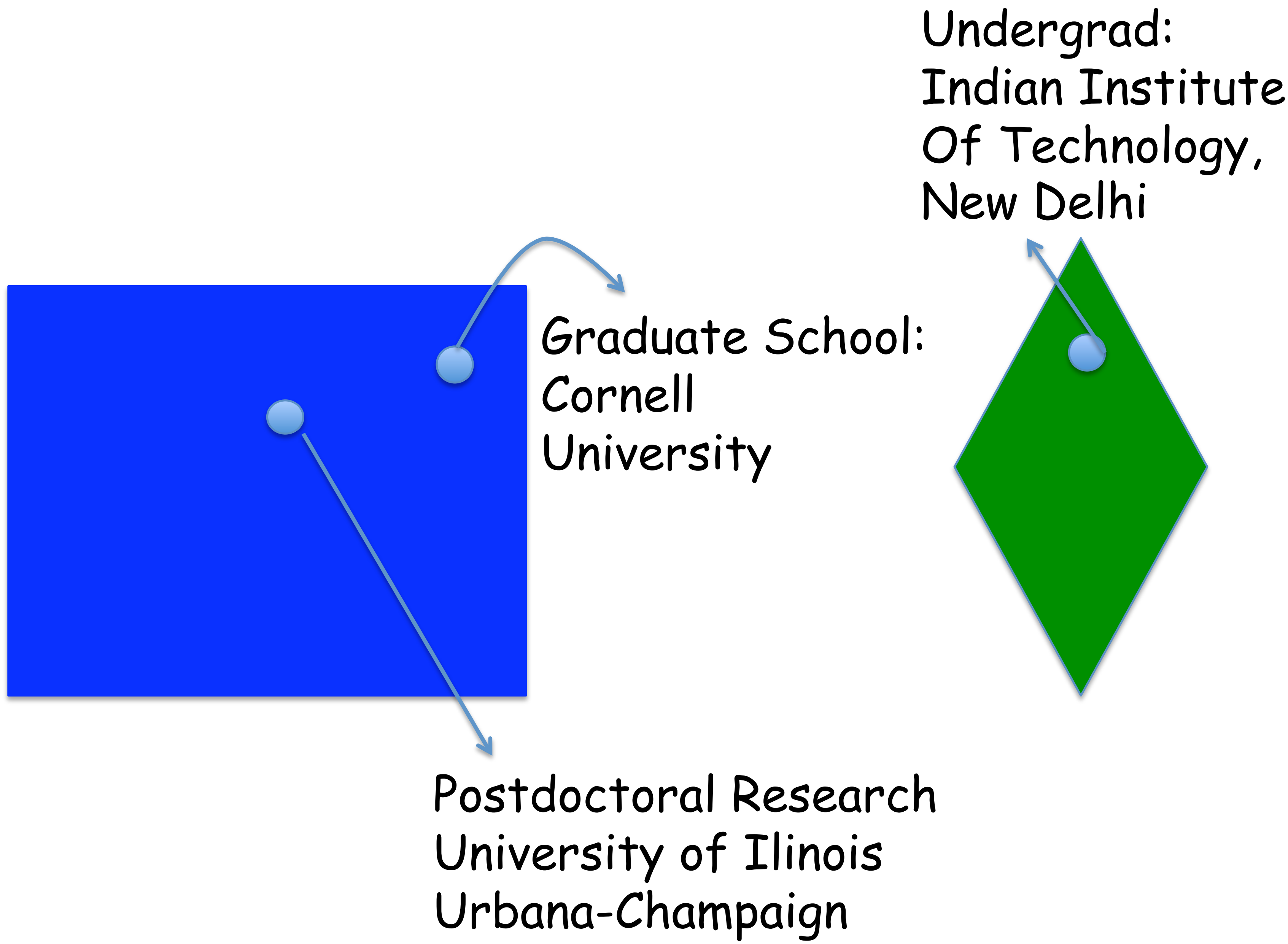
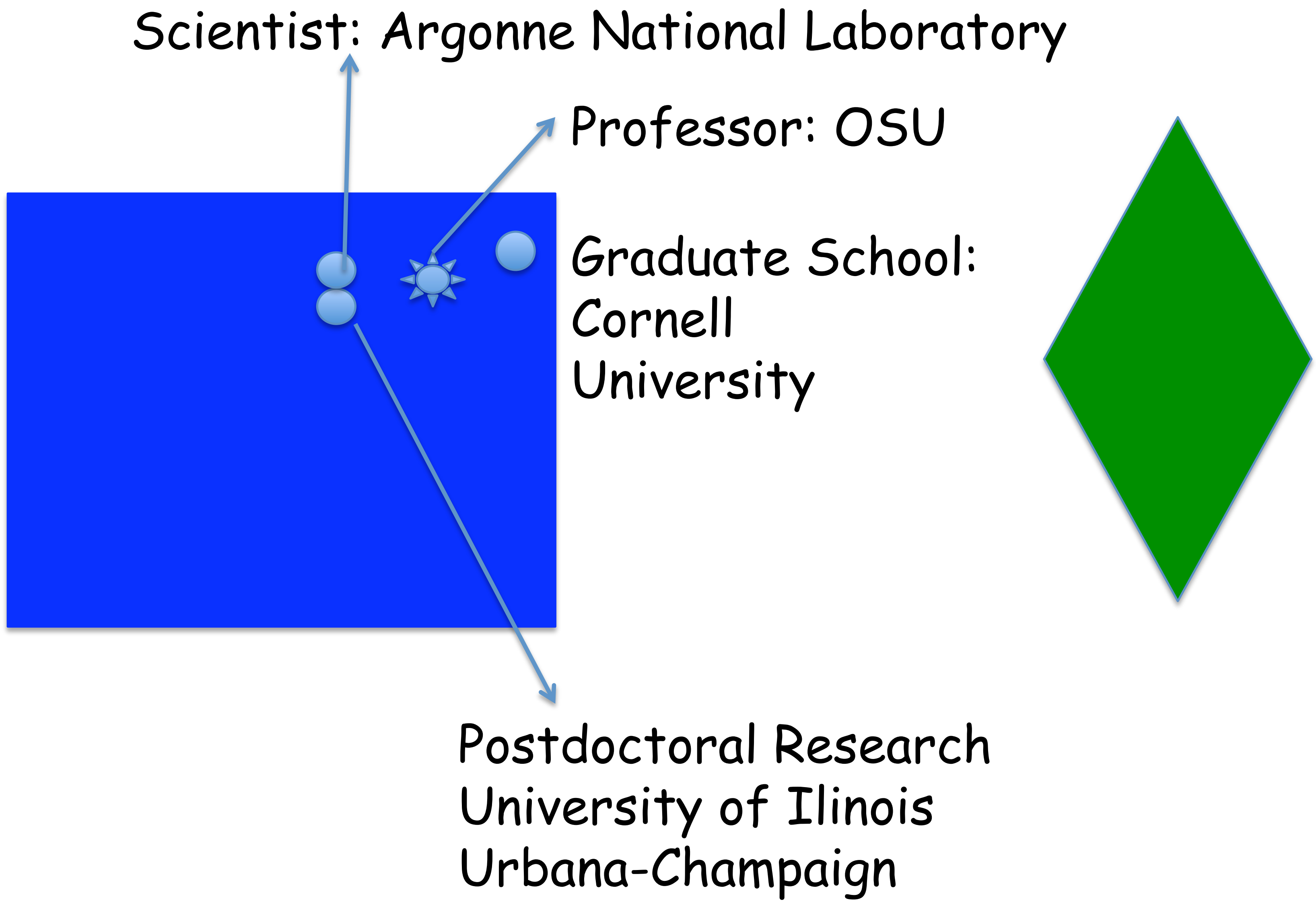
My Research

Condensed Matter Physics

- Quantum Materials
- Ultracold Atoms


Undergrad:
Indian Institute
Of Technology,
New Delhi
Graduate School:
Cornell
University
Postdoctoral Research
University of Ilinois
Urbana-Champaign


Scientist: Argonne National Laboratory
Professor: OSU
Graduate School: Cornell University
Postdoctoral Research University of Ilinois Urbana-Champaign

School:

Experiments in biology (first dissection set when I was in 9th grade)

Biology fascinating but too much to memorize

Chemistry experiments in garage

Interest in physics started later in school in about 11th grade

Attracted by

- Simplicity of concepts
- Universality
- Power of theory

....to calculate the trajectory of a space shuttle to the moon
………………and to be able to bring astronauts back!
Apollo 13!

LESSON 1:

Look for new challenges

Transition from small town to big city

Exciting

Scary

Learning to survive on one's own

First shock: first semester in college
C in physics and C in math

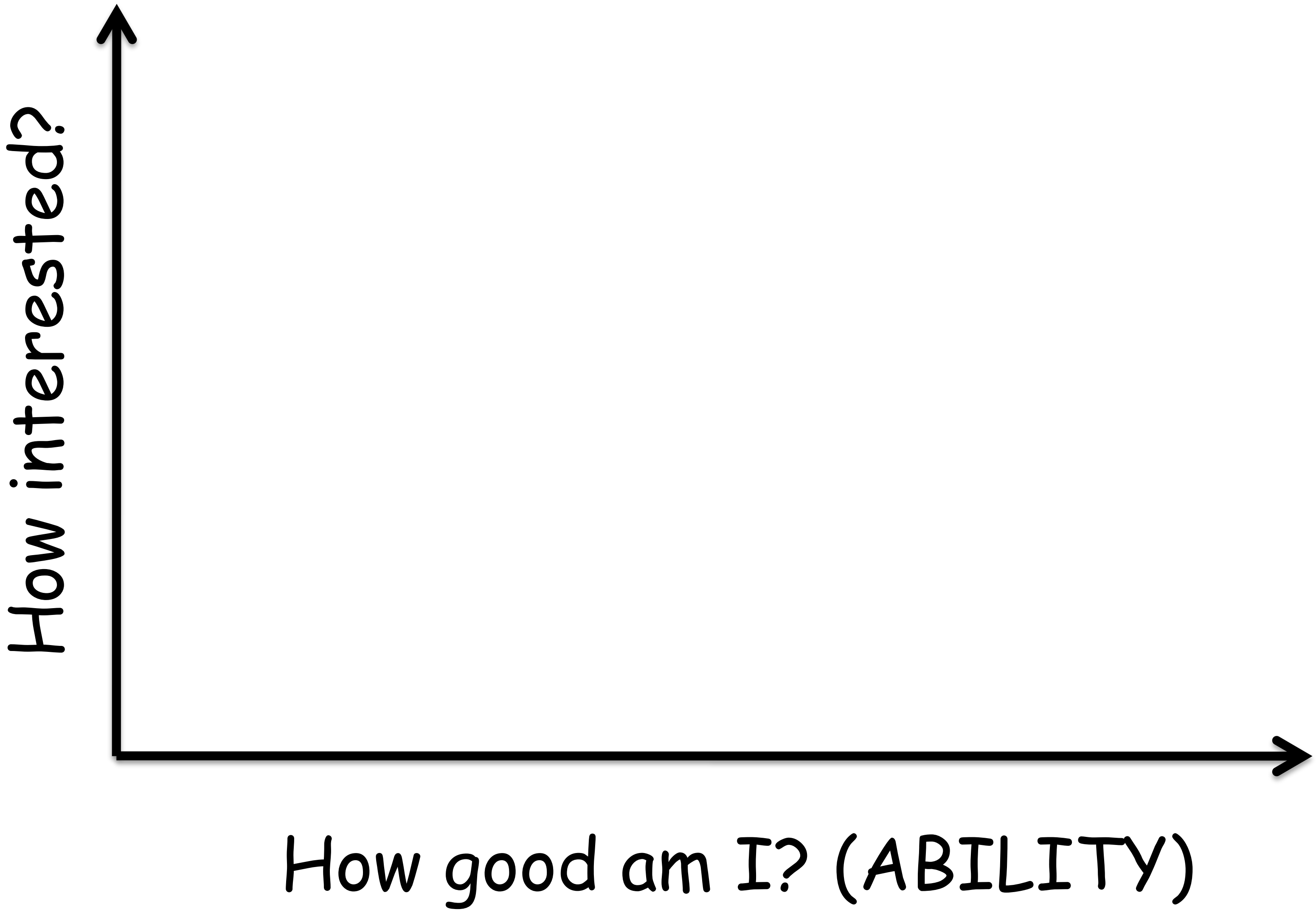
Much soul searching
....when you are being tested....
possibility of taking a new path

- Do I really like physics?
  Feynman Lectures convinced me
- Make a strategy-
- Identify the problem
- Ask for help

First shock: first semester in college
C in physics and C in math

Lesson 2:
Do not necessarily take the soft way out....

How to pick a career?



How to pick a career?

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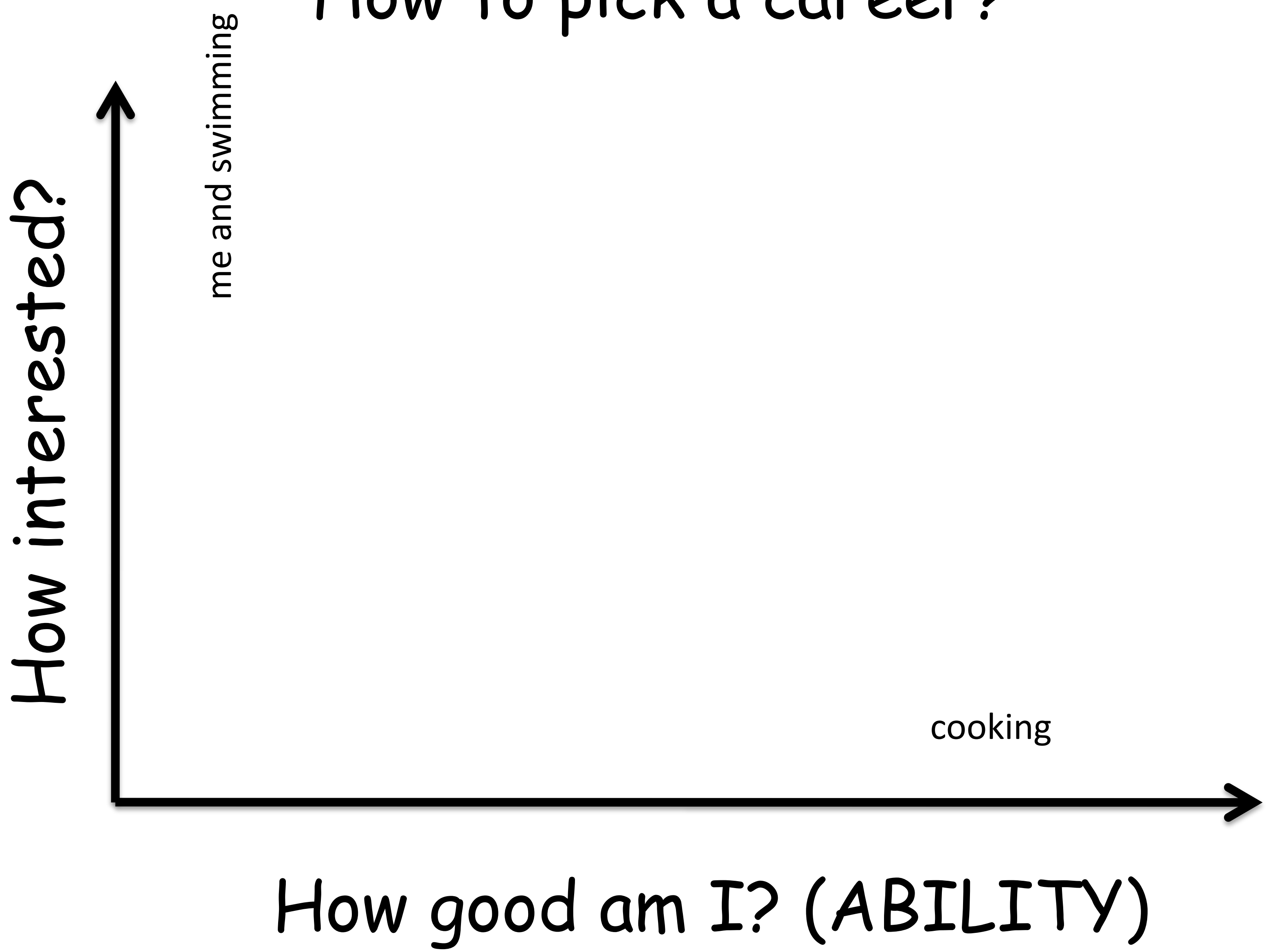
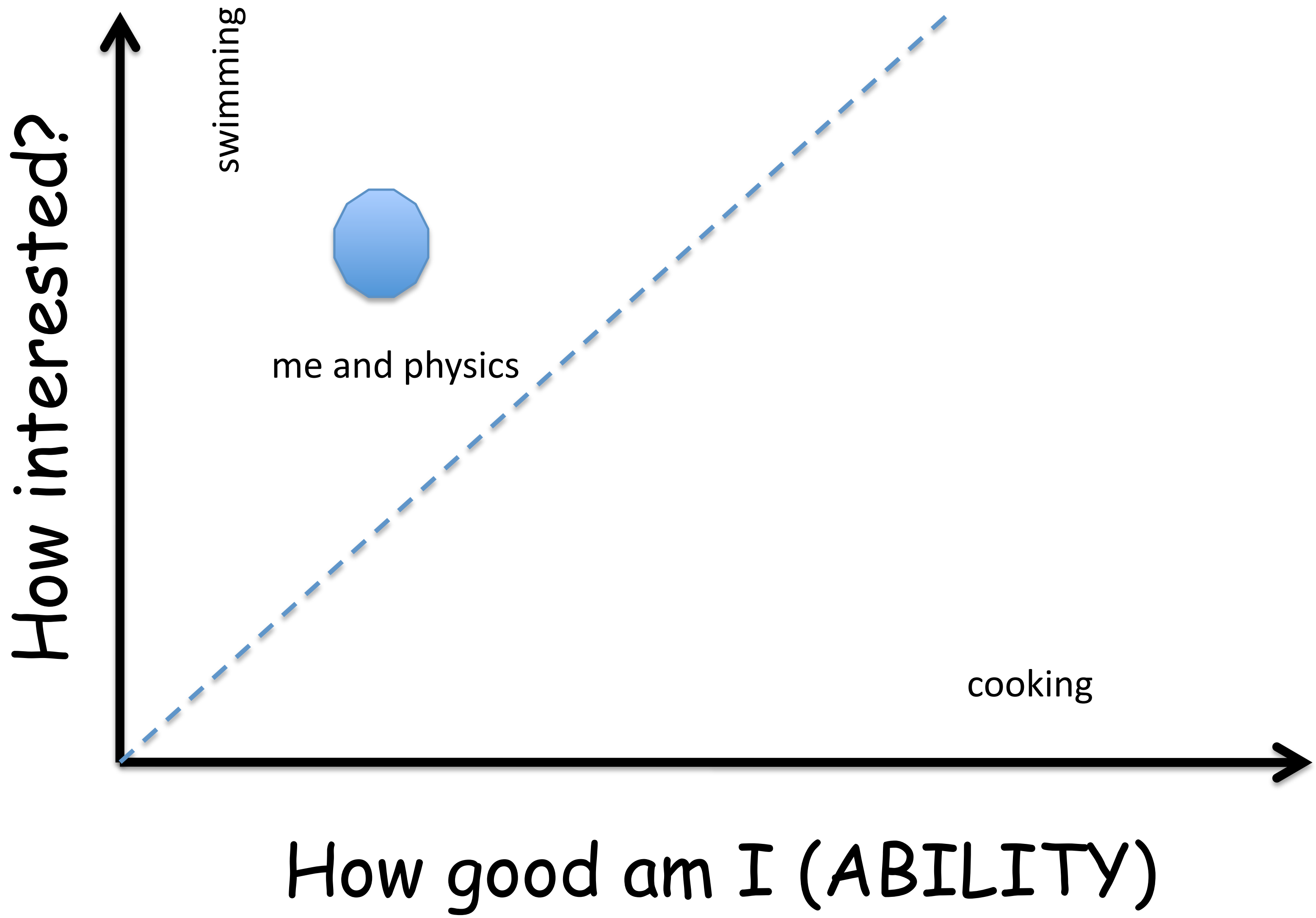
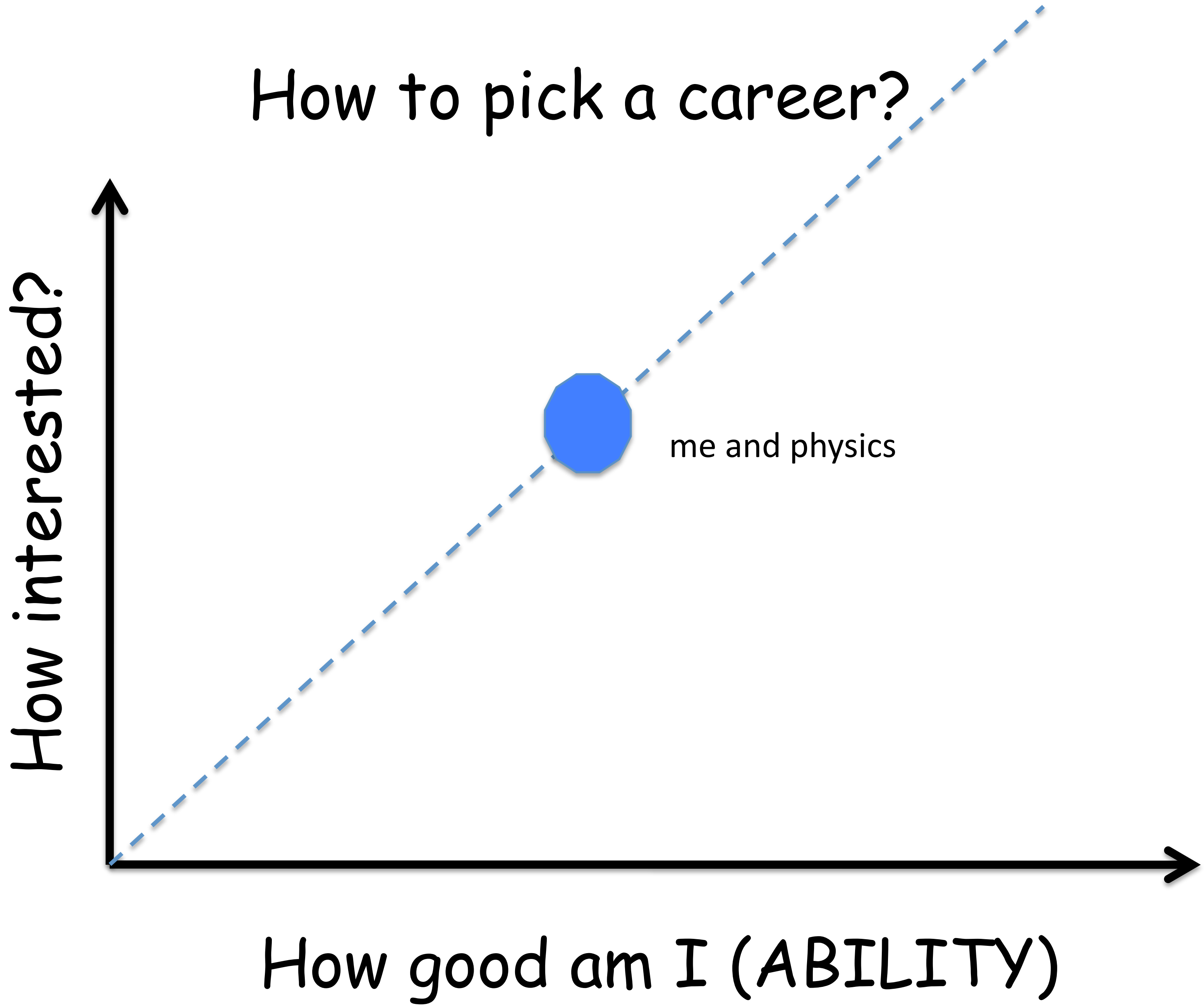
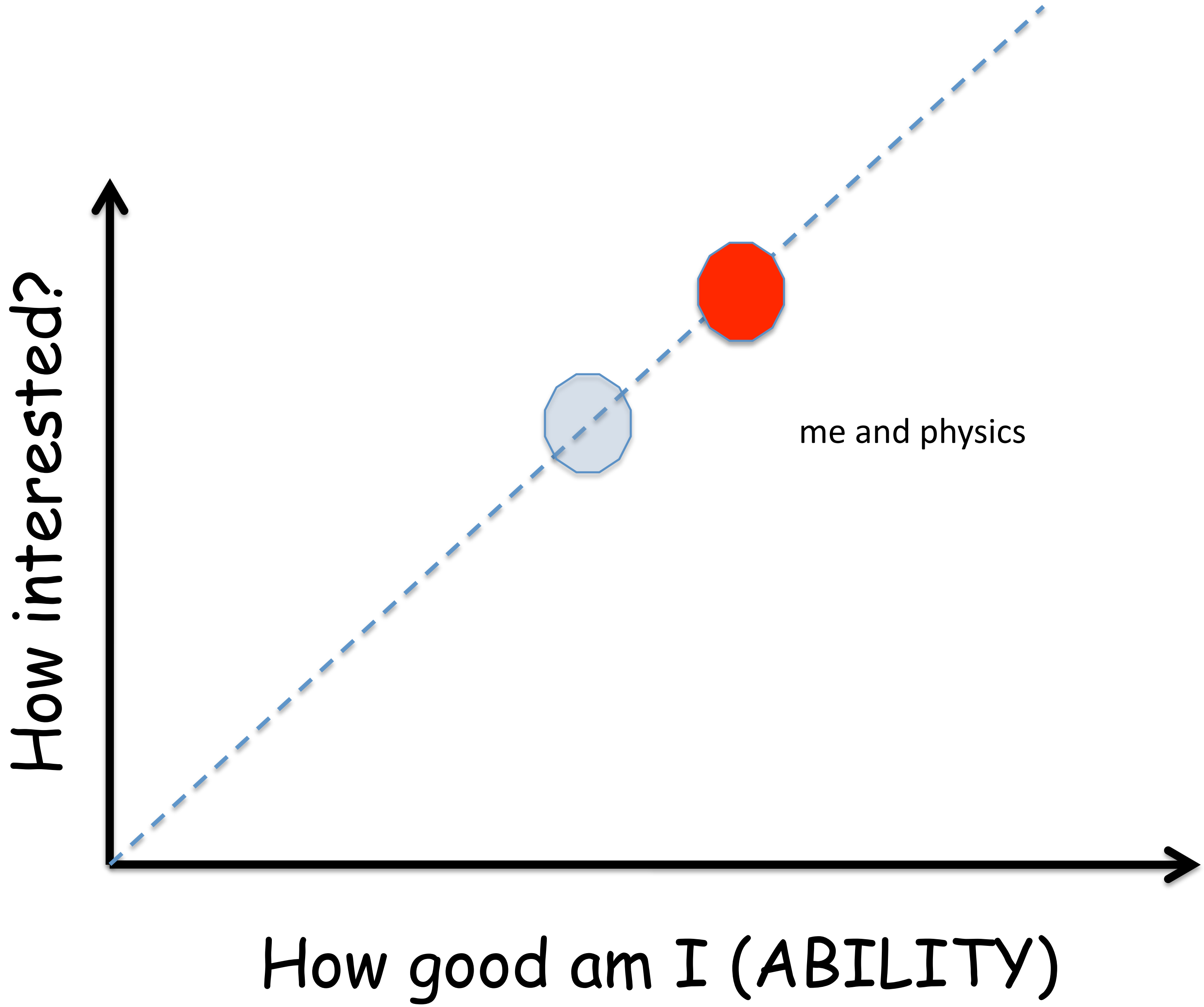


How to pick a career?



How to pick a career?




How interested?
me and physics
How good am I (ABILITY)

My Research

Condensed Matter Physics

- **physics of the very small:**

  High energy physics & String theory

- **physics of the very large:**

  Astrophysics & Cosmology

- **physics of the very complex:**

  Condensed matter physics

Condensed Matter Physics

Complex behaviour of systems of many interacting particles

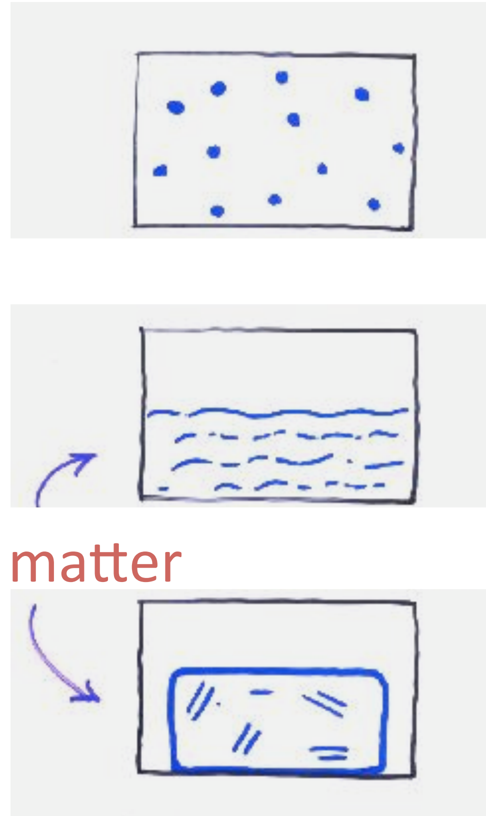
Most Amazing: the complexity can often be understood as arising from simple local interactions

"Emergent properties"

The collective behaviour of a system is qualitatively different from that of its constituents

Emergent Properties

Phases and
Phase transitions



gas

liquid

condensed matter

solid

- **Rigidity**

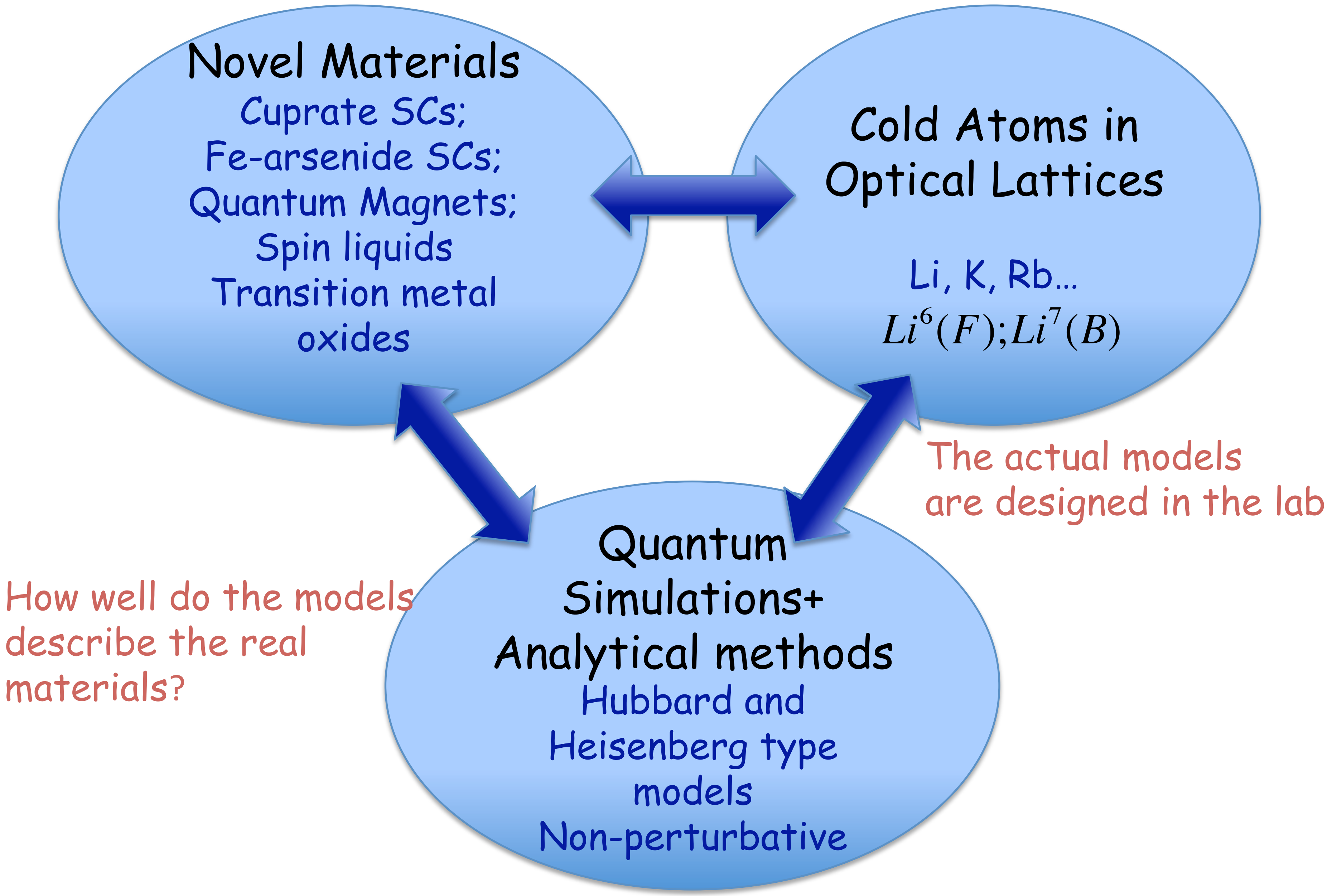
- **Metallic behaviour**
- **Magnetism**
- **Superconductivity**

....

Many examples of emergent properties in biology!

Life....

Strongly Interacting Systems



Measuring Temperature

KELVIN CELSIUS FARENHEIT

$$C + 273 = K$$

Absolute Zero →

Low Temperatures

233K	(-40 C= -40 F)	
195K	(-78 C)	dry ice forms
77K	(-196 C)	Nitrogen liquefies
66K	(-207 C)	Nitrogen freezes
50K	(-223 C)	Surface temperature on Pluto
20K	(-253 C)	Hydrogen liquefies
14K	(-259 C)	Hydrogen solidifies
4.2K	(-268.8 C)	Helium Liquefies
3 K	(-270 C)	Interstellar space
0 K		ABSOLUTE ZERO

Ultracold Atoms

Quantum Materials

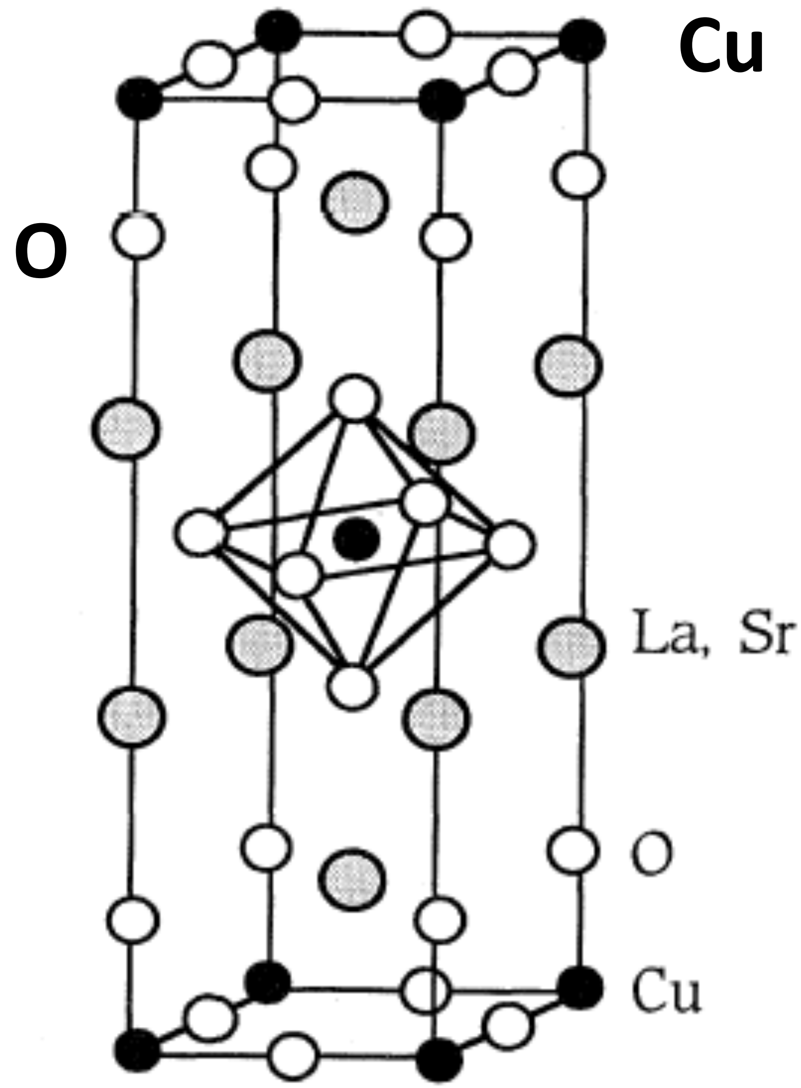


FIG. 1. Crystal structure of $La_{2-x}Sr_xCuO_4$ (**T** phase). Taken from Almasan and Maple (1991).

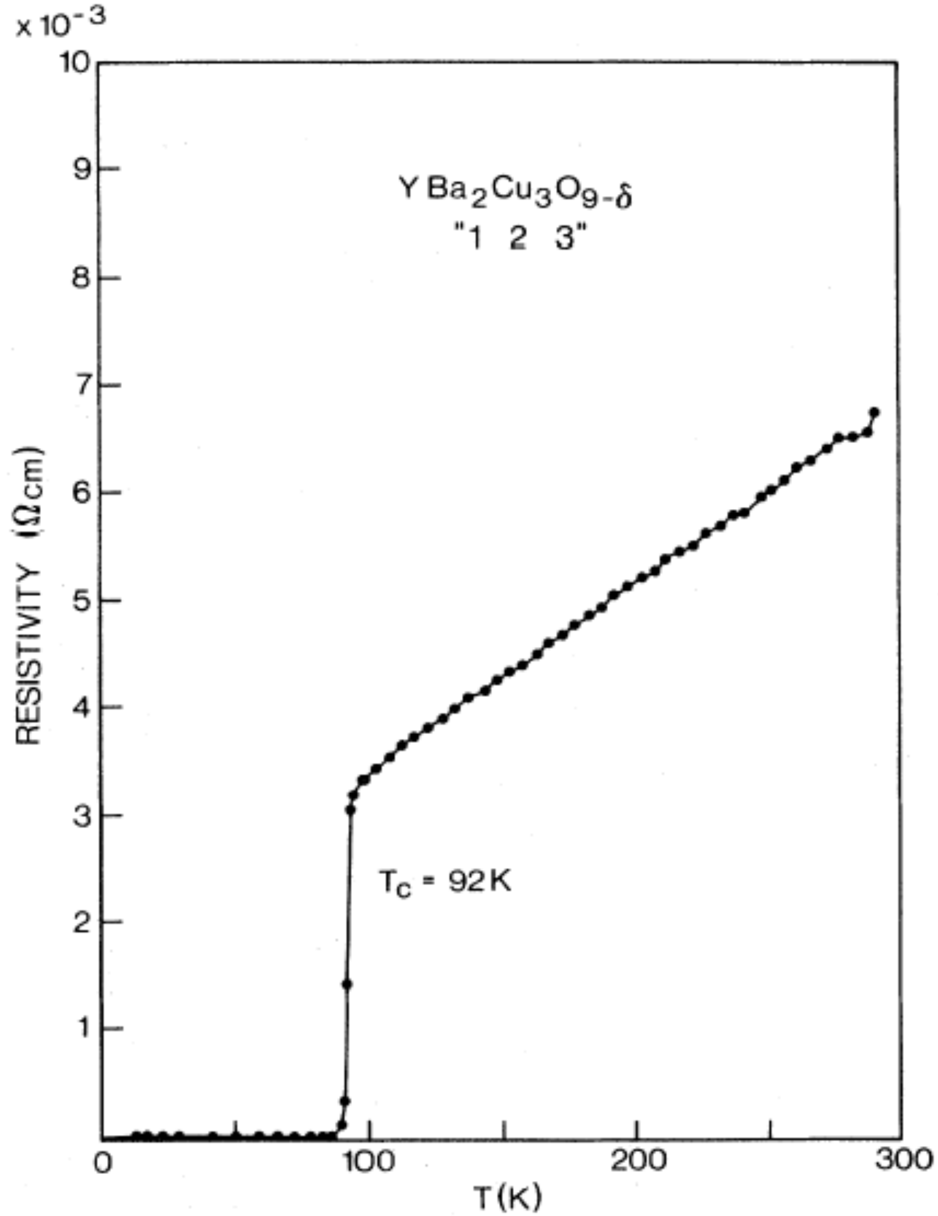


FIG. 14. Resistivity of a single-phase $YBa_2Cu_3O_7$ sample as a function of temperature.

Ultra cold Atoms

Temperature and average speeds:

* Hot atoms move fast
  Room temp 300 K
  Atoms move at 400 m/s
  ** comparable to a Jet plane!**

* Cold atoms are slow
  At 1 nano K (1 billionth of a Kelvin)
  atoms move very slowly ~1 cm/s
  Slower than a snail...

* Absolute Zero
  at T = 0 K, all motion ceases
  (except for some weird "quantum effects")

Matter is a Wave!

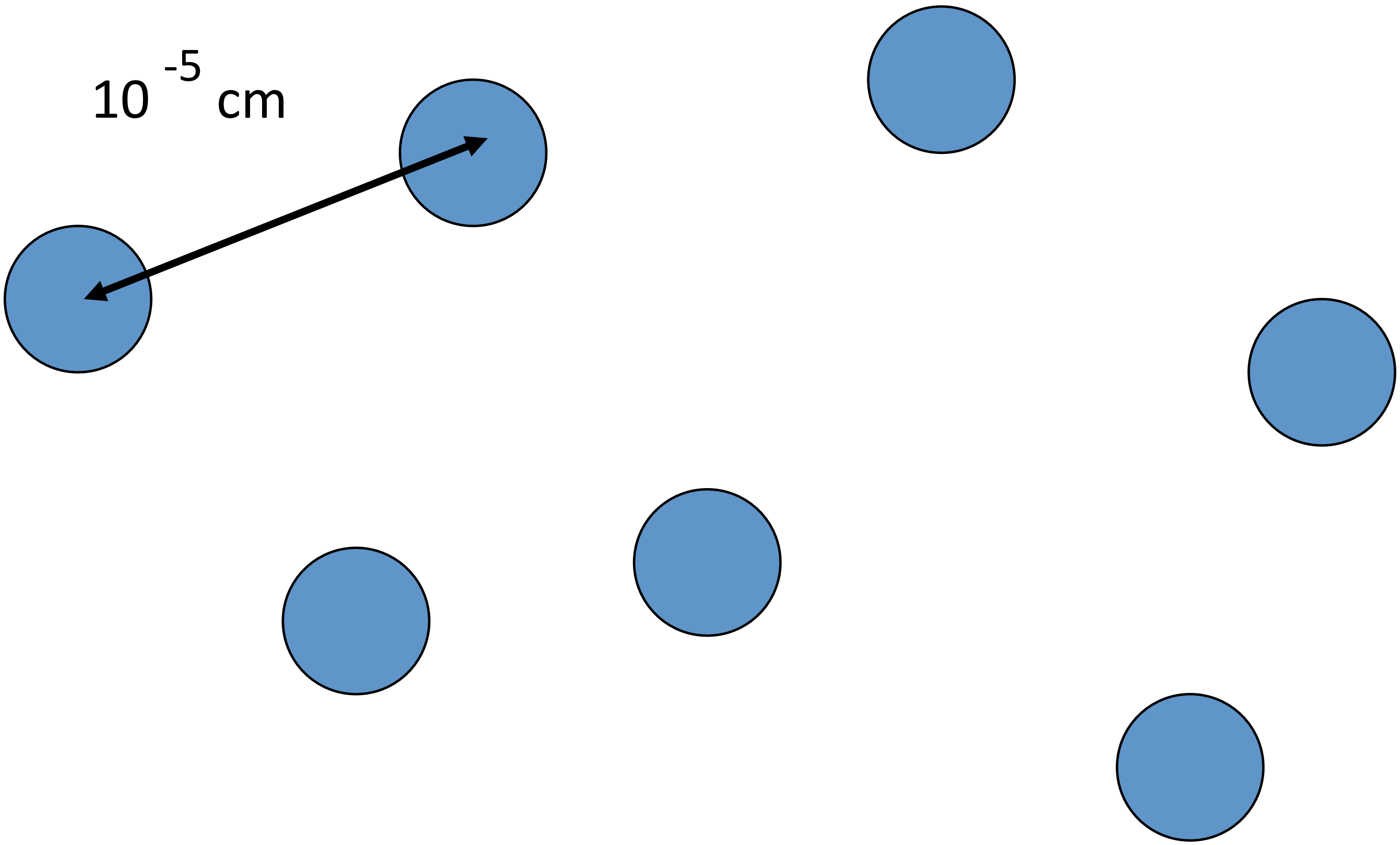
Louis-Victor de Broglie

$$\lambda = \frac{h}{p} = \frac{h}{m \cdot v}$$

Erwin Schrödinger

$$i\hbar \frac{\partial}{\partial t} \Psi = H \Psi$$

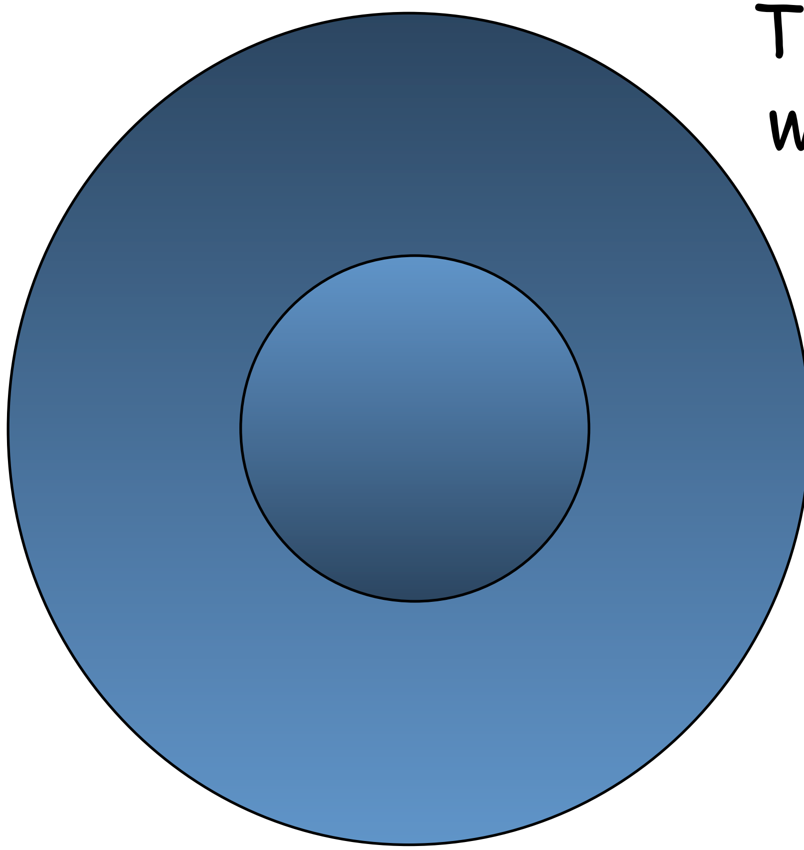
Very Low Density Atomic Gas



Gas of Lithium, or Sodium, or Potassium or Rubidium atoms

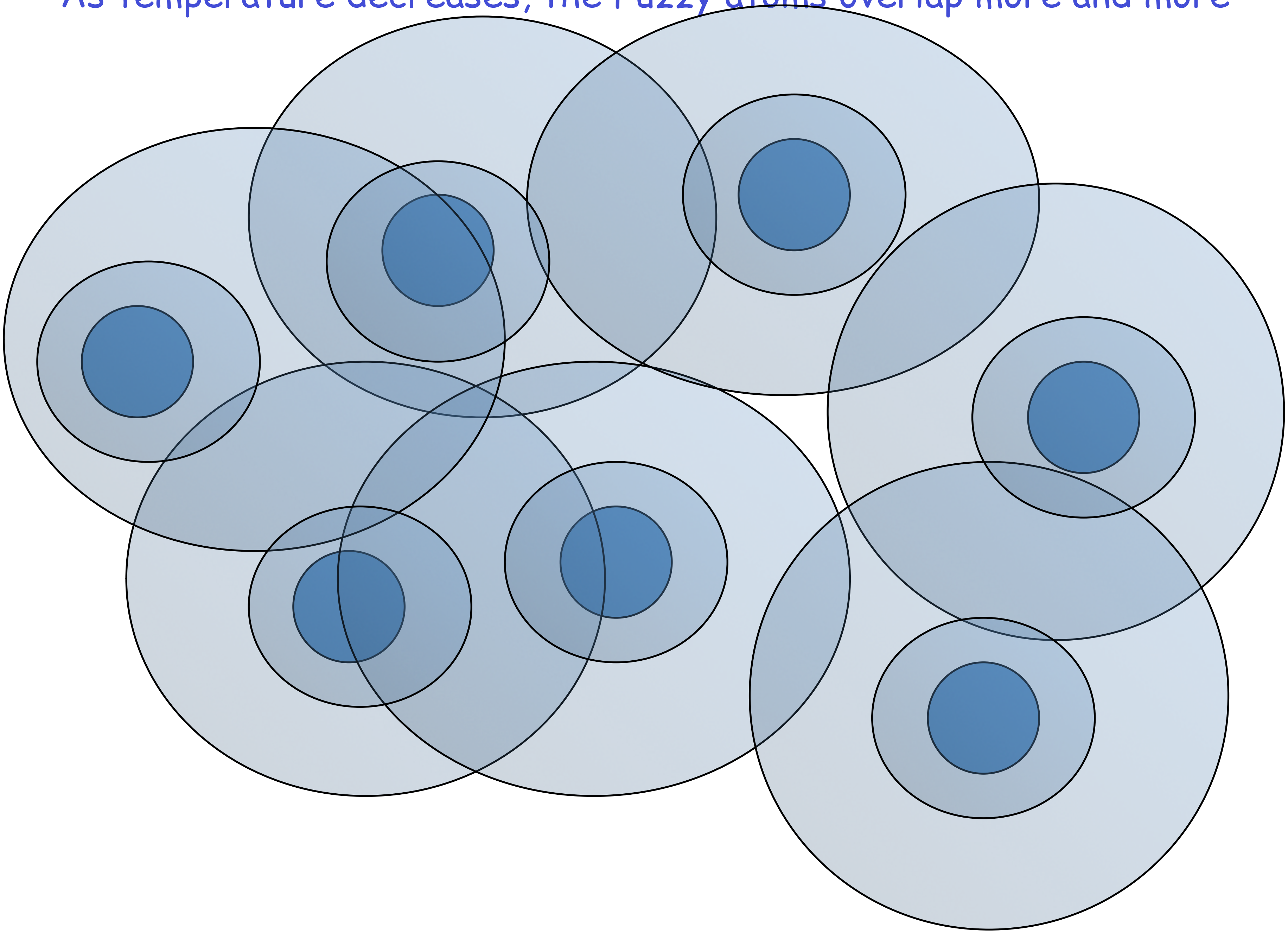
Fuzzy atom

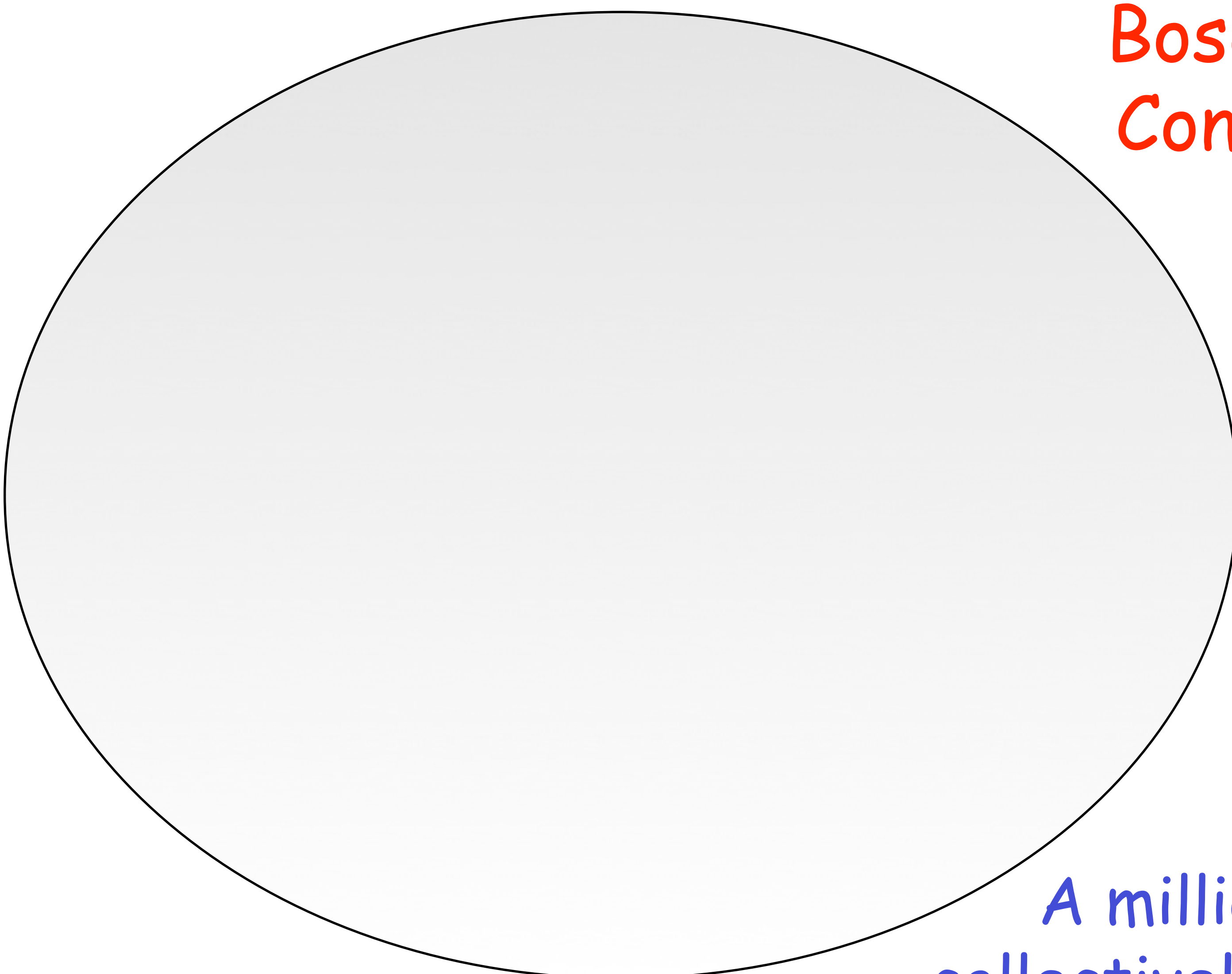
The region over which the atom can be found increases



Fuzziness increases as you cool further

As temperature decreases, the Fuzzy atoms overlap more and more





Bose-Einstein Condensation

A million bosons collectively behave like one "giant atom" which is stationary

How can we cool atoms down to less than 1 micro K (one millionth of a Kelvin)?

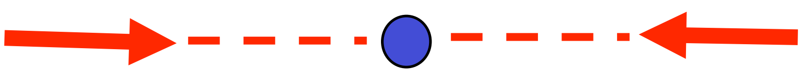
Step # 1:

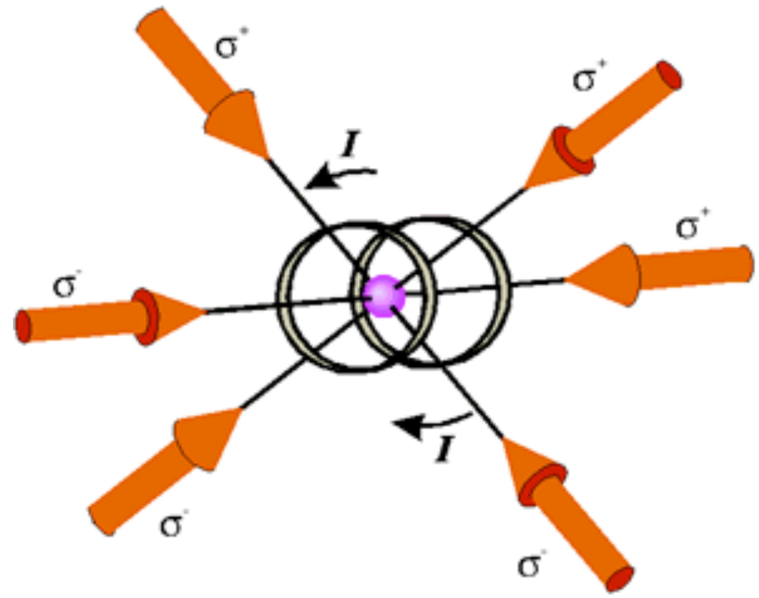
Laser cooling & trapping

Step #2:

Evaporative Cooling

(1) Laser Cooling





Cooling =
Slowing Down
Atoms!

Cool a billion atoms
from 300 K down to
one thousandth K (1 milli K)

(1) Evaporative Cooling

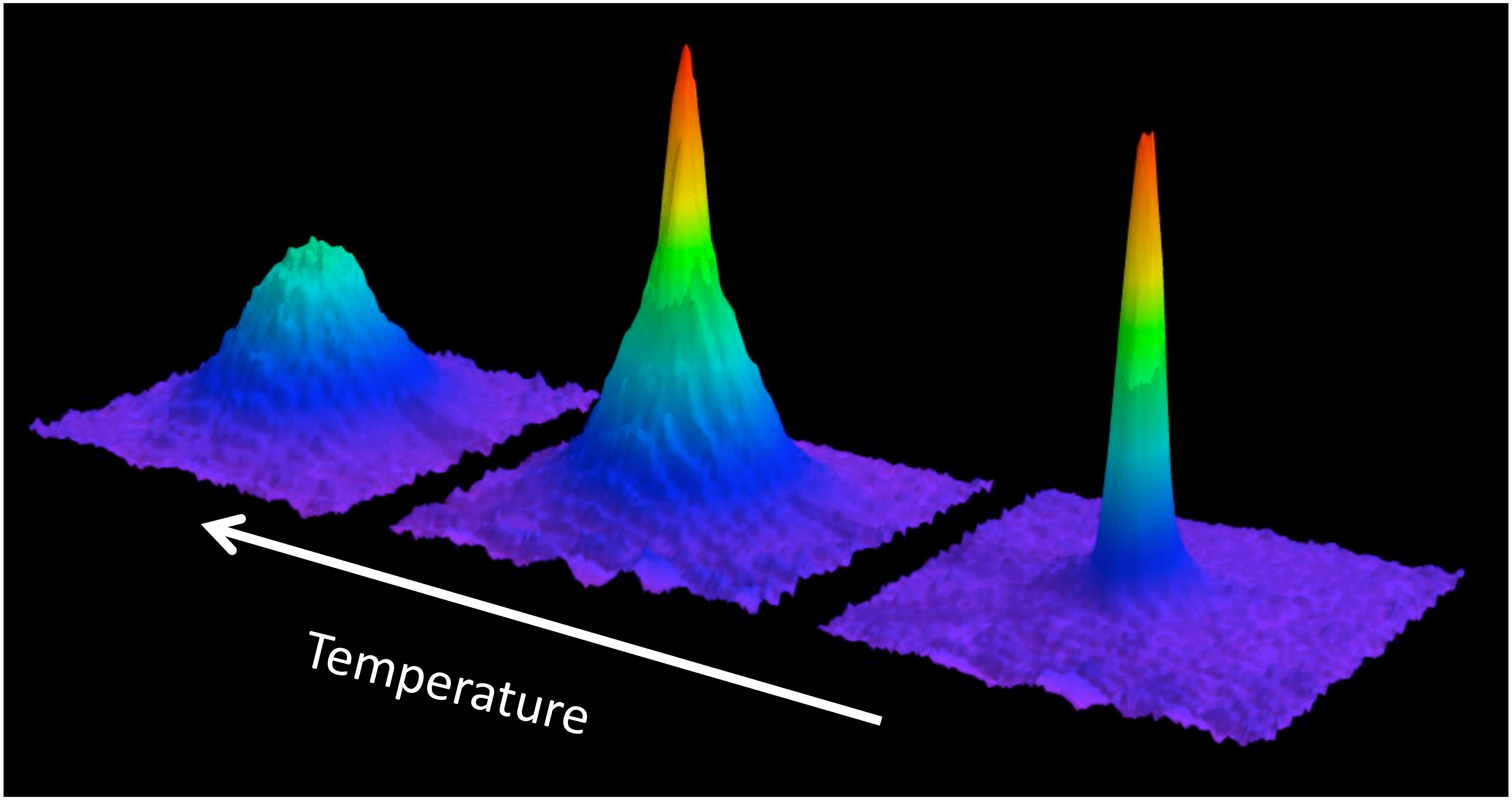
Let the hot atoms escape by "evaporation"
Only the cold ones remain

Cool from 1/1000 K
Down to one
millionth K
(1 micro K)

→ A million atoms

What do you expect to see at ultra cold temperatures?

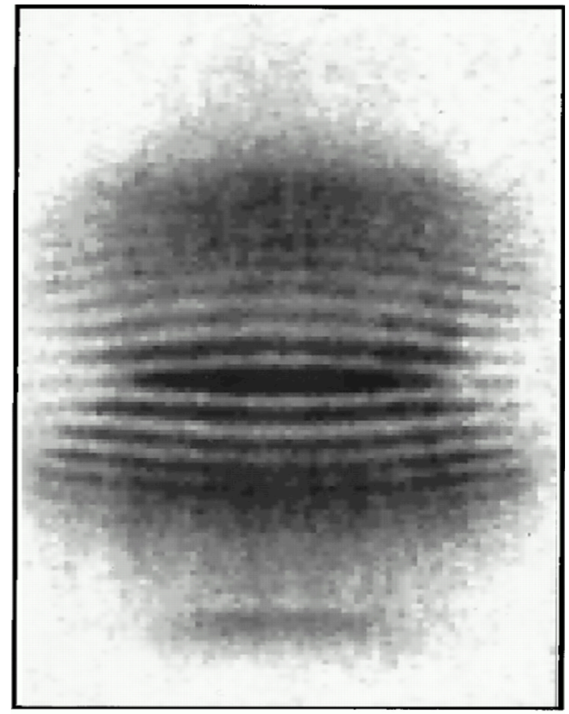
Velocity distribution of atoms



Temperature calculated by fitting to the profile in the wings coming from thermal atoms

INTERFERENCE PATTERN OF TWO EXPANDING CONDENSATES

$$\lambda = \frac{ht}{md}$$



t=delay between switching off the trap and observation~40 ms
d=separation between the two pointlike condensates~96 μm

λ~15 μm (size of condensate much larger than λ)

Condensates have a high degree of spatial coherence

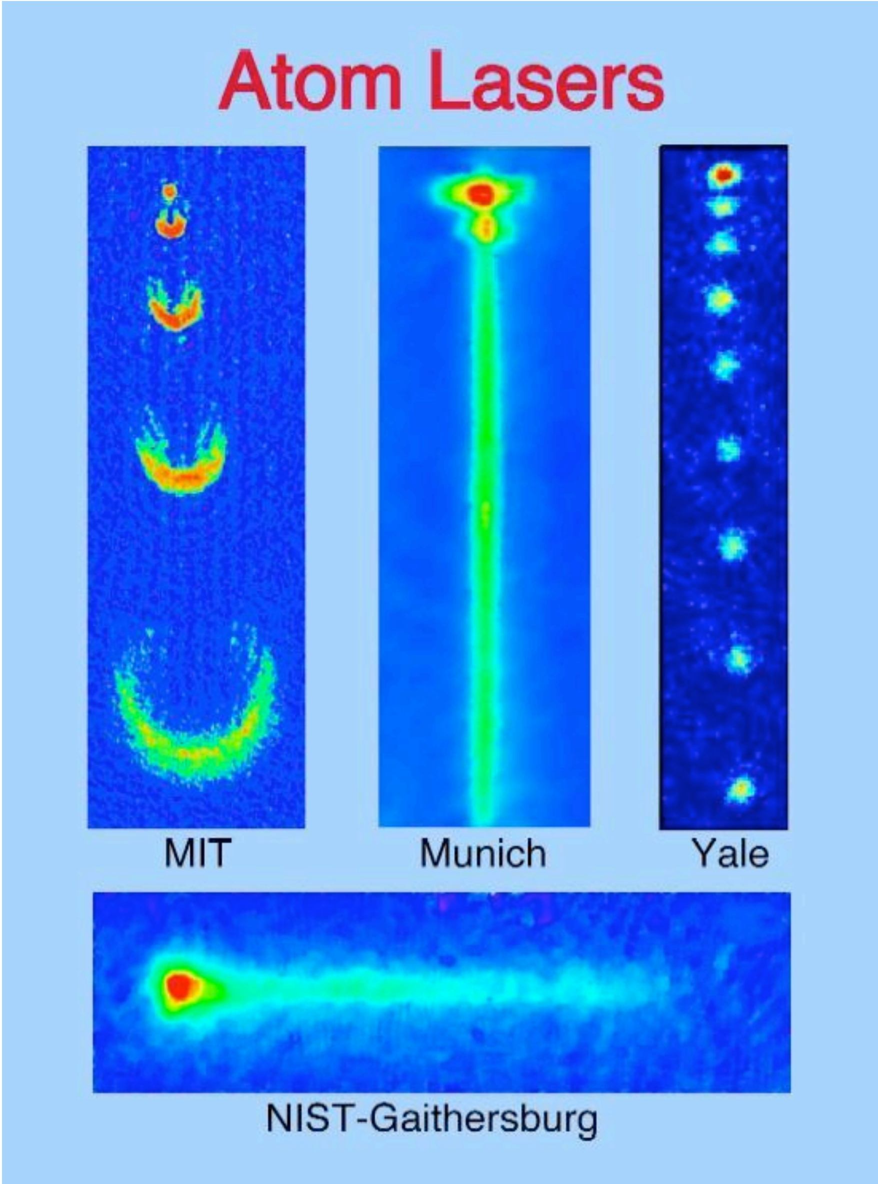
Andrews et al
Science 275, 637 (1997)

- New insights into the quantum properties of matter

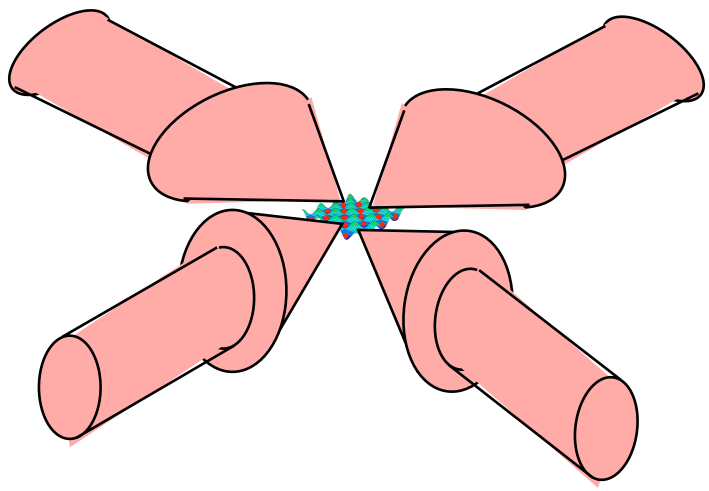
- First Atom Lasers

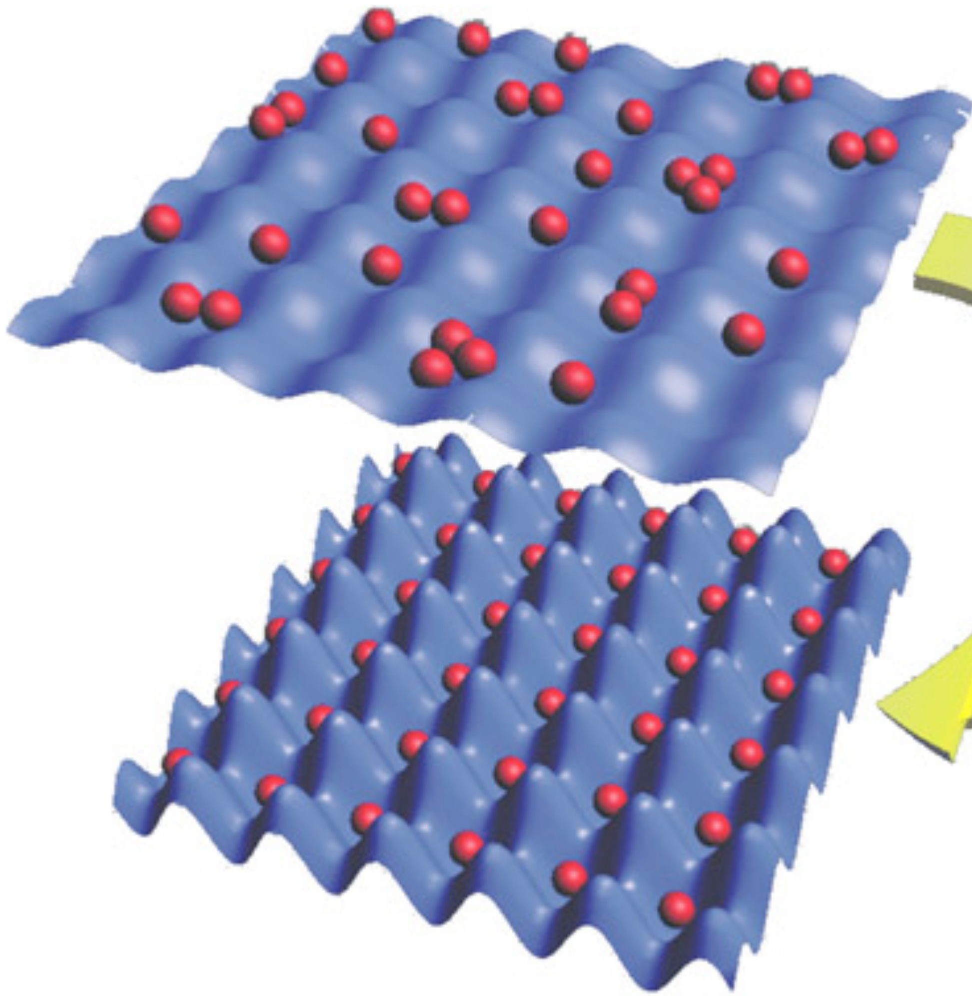
- Atom chips & nanotechnology

- improvements in Atomic Clocks



OPTICAL LATTICES





Challenges in grad school and later:

Aggressive attitude:

- They don't mean it; don't take it personally; use it to your advantage!

- Counter it by doing your homework, prepare well

- Control the things you can control: your own research; Work hard and intelligently

Balancing Family and Career:

Career: Make sure you are really passionate about it
…that it really matters to you
……that you are doing this for yourself

2 daughters:
Undergrad
10^{th} grade

Balancing Family and Career:

- Supportive husband
- Be flexible
- Prioritize , Organize, Simplify
- Network (both professionally and with friends)
- Face challenges thoughtfully

Research opportunities at the undergrad level

Reading Course

Research in the Summer

Research during the year

Can get paid for it!!

Research at the undergrad level can lead to
real papers and talks in conferences

We are the result of the choices we make

The end