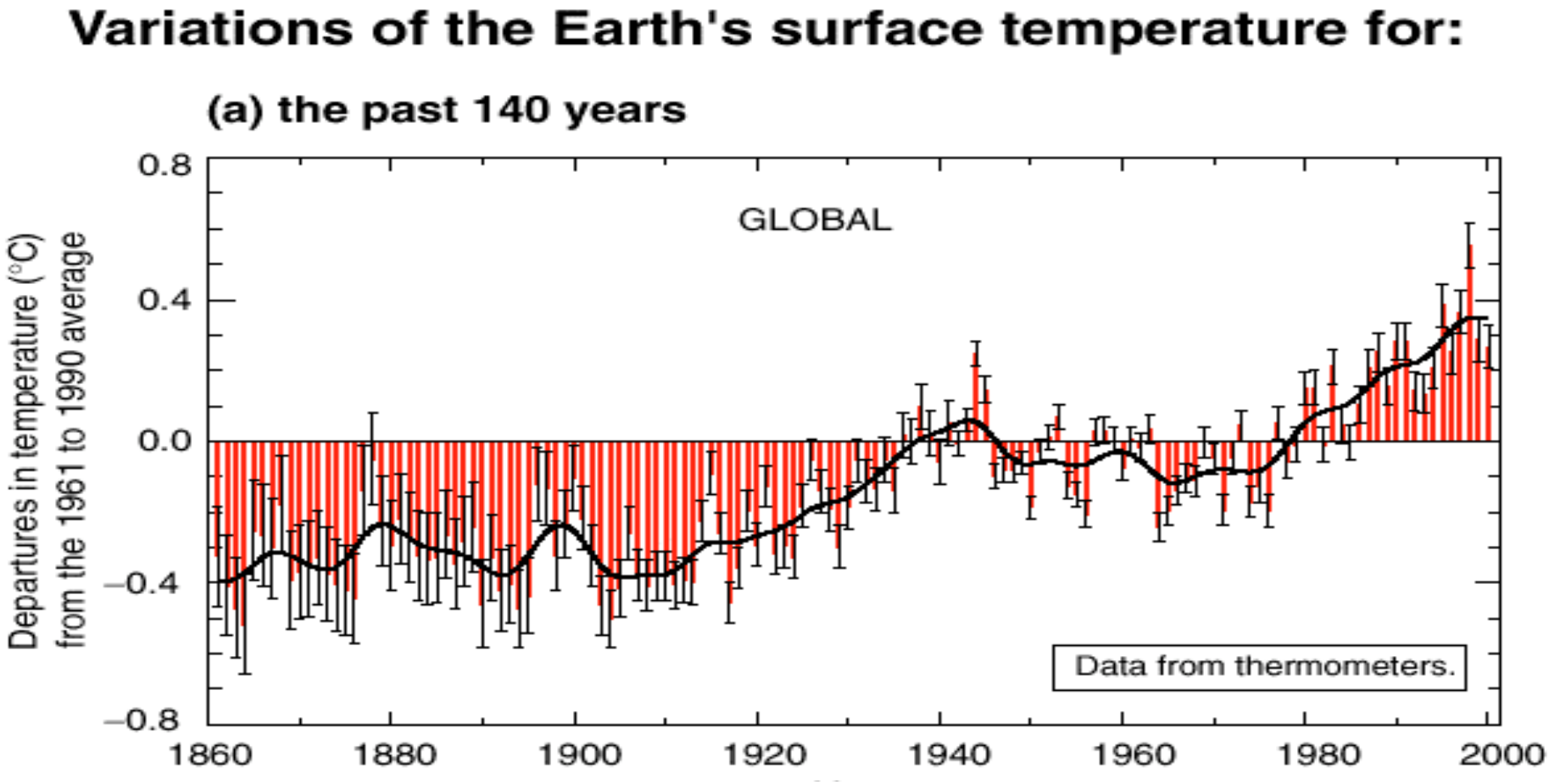
Global Warming, the energy crisis and what we can do about it

Nano*High Talk
29 October, 2005

What I got the Nobel Prize for

- The possibility (likelihood) of climate change and its consequences

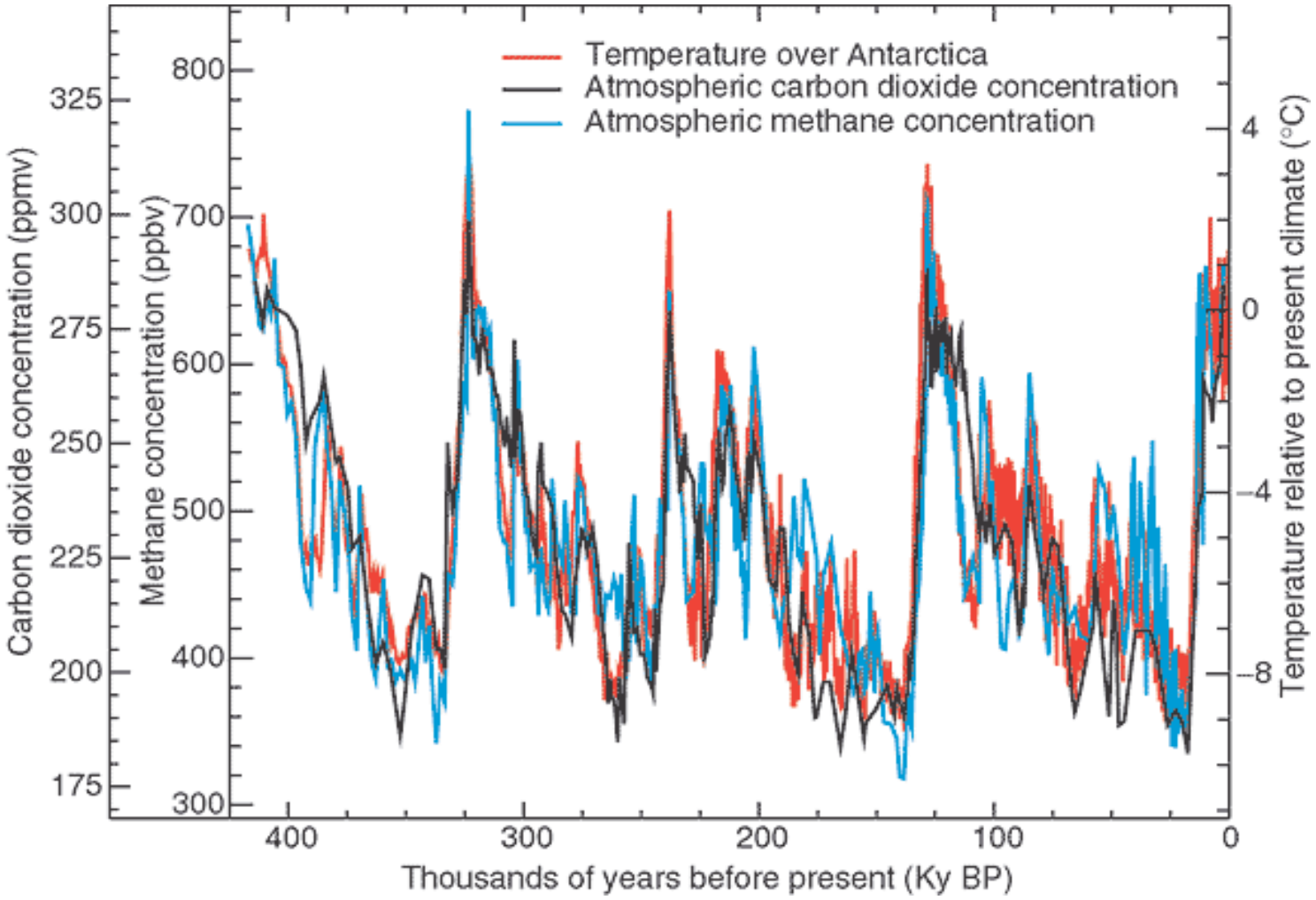
- Possible solutions

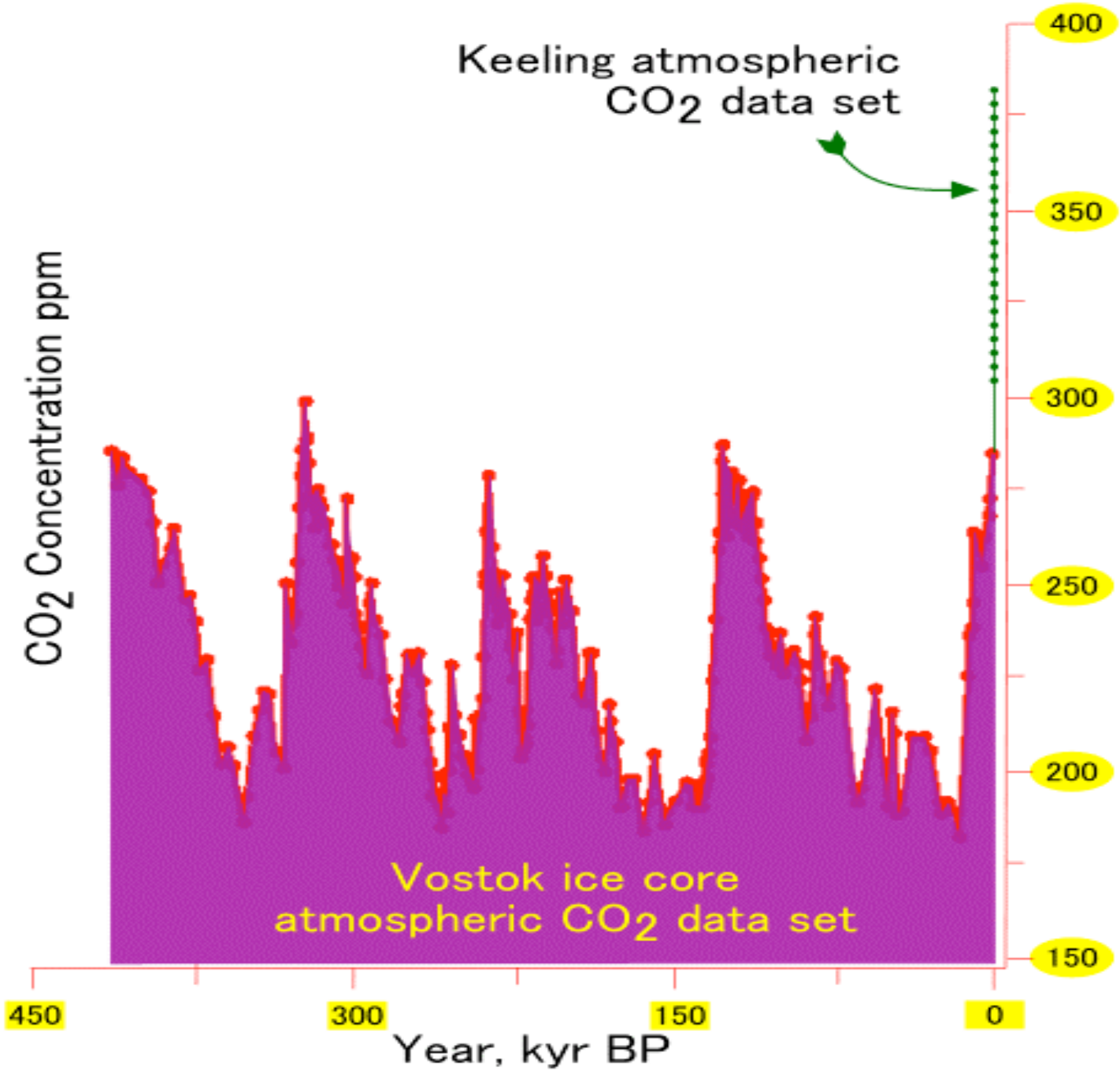


140 years is nothing by geological time scales!

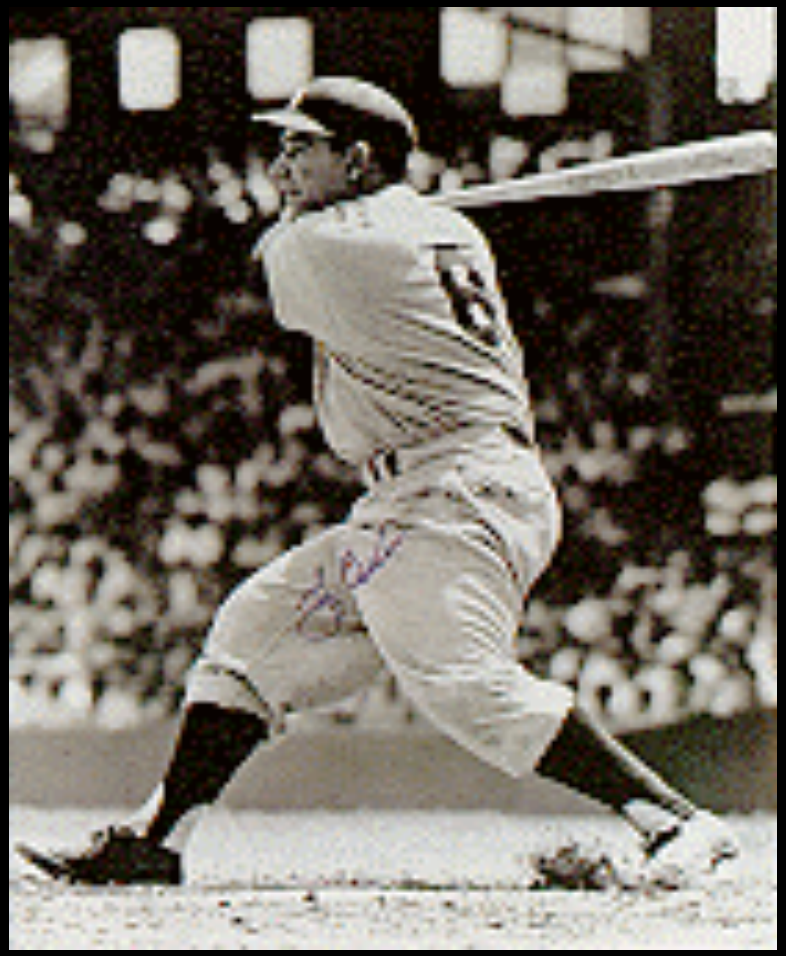
Temperature over the last 420,000 years

Source: Working Group I of the Intergovernmental Panel on Climate Change



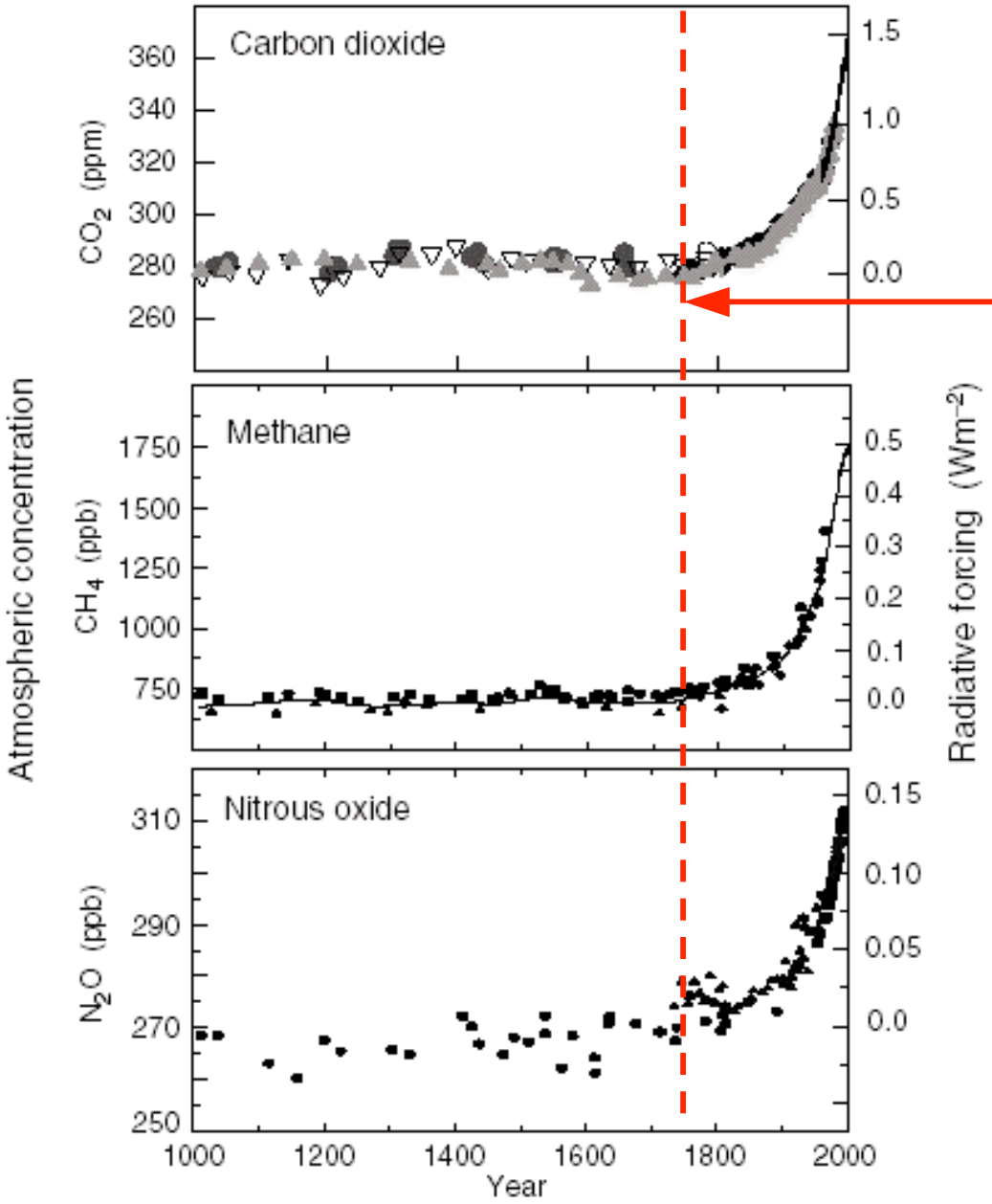

Keeling atmospheric
CO2 data set
CO2 Concentration ppm
400
350
300
250
200
150
Vostok ice core
atmospheric CO2 data set
450
300
150
0
Year, kyr BP

Can we predict climate change due to increased greenhouse gases?



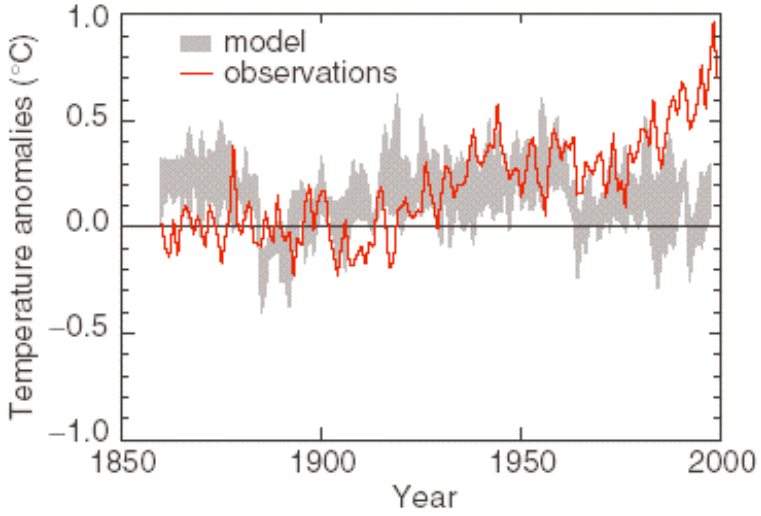
"Predictions are hard to make,
especially about the future."

Concentration of Greenhouse gases

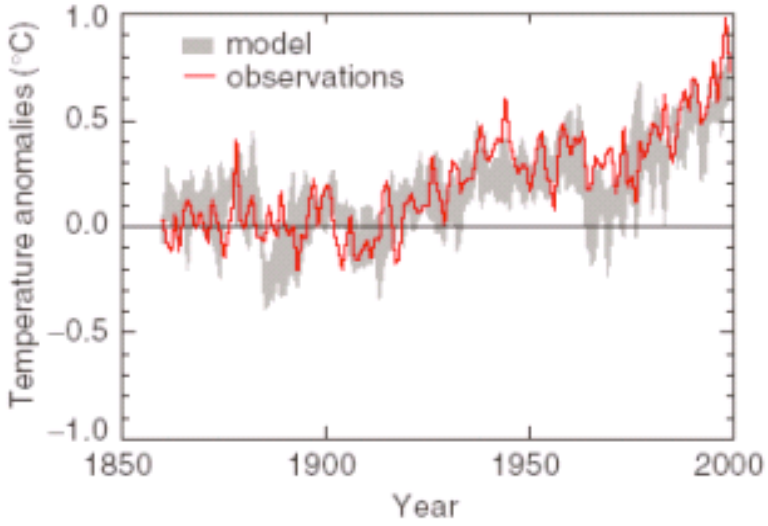


1750, the beginning of the industrial revolution

Can we predict the past?

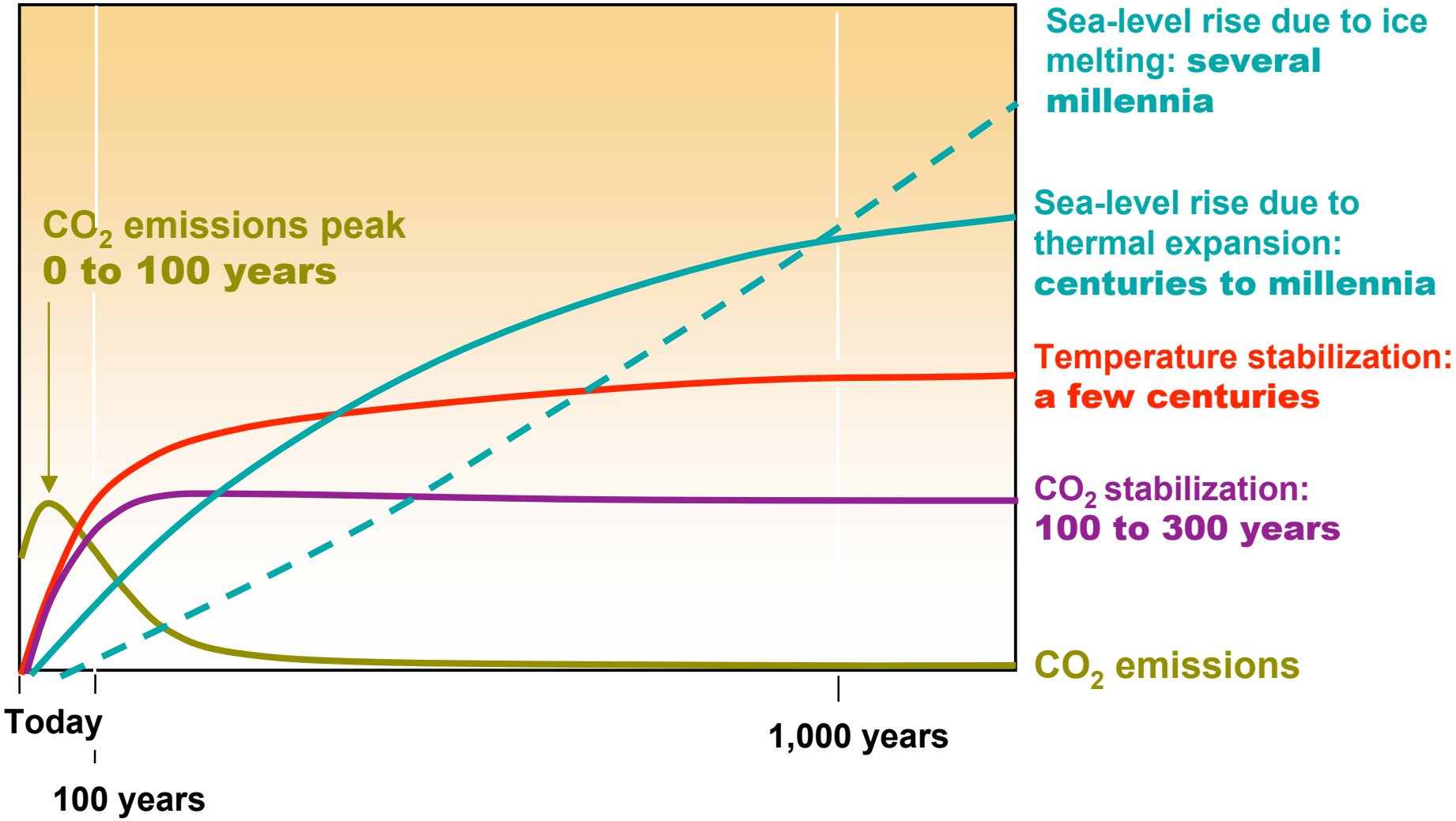


Climate change due to natural causes (solar variations, volcanoes, etc.)

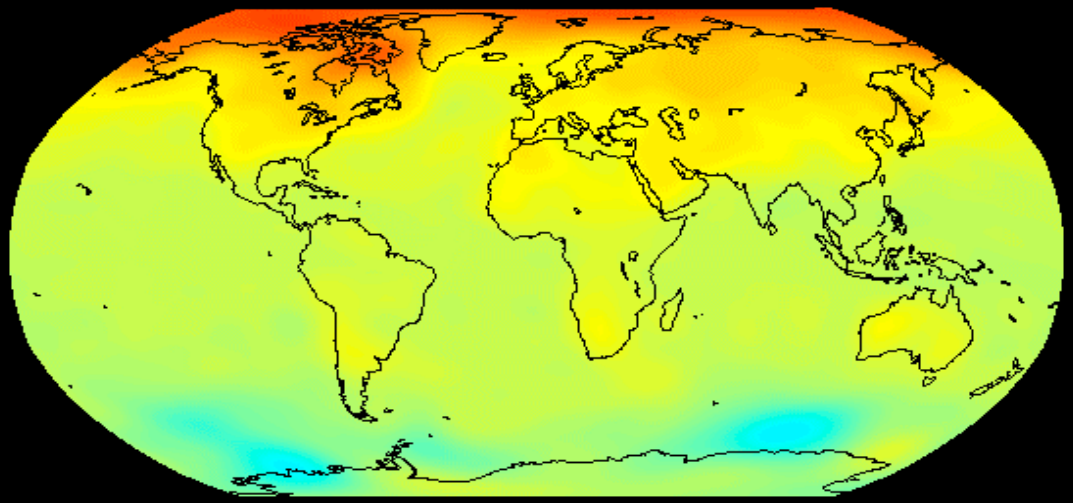


Climate change due to natural causes and human generated greenhouse gases

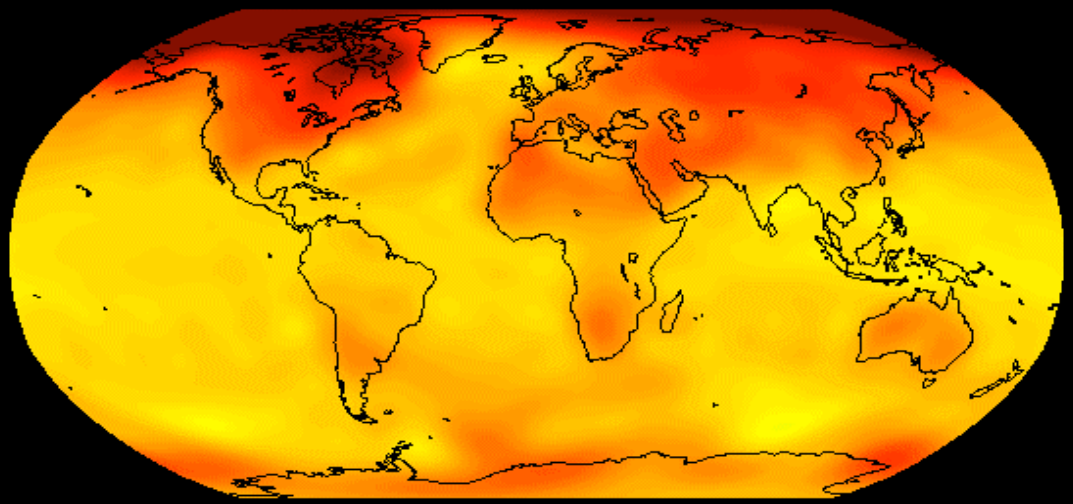
CO_2 Concentration, Temperature, and Sea Level Continue to Rise Long after Emissions are Reduced



2 x CO_2



4 x CO_2



Computer simulations by the Princeton Geophysical Fluid Dynamics Lab for CO2 increases above pre-industrial revolution levels:

2x CO_2 : 5 – 8° F

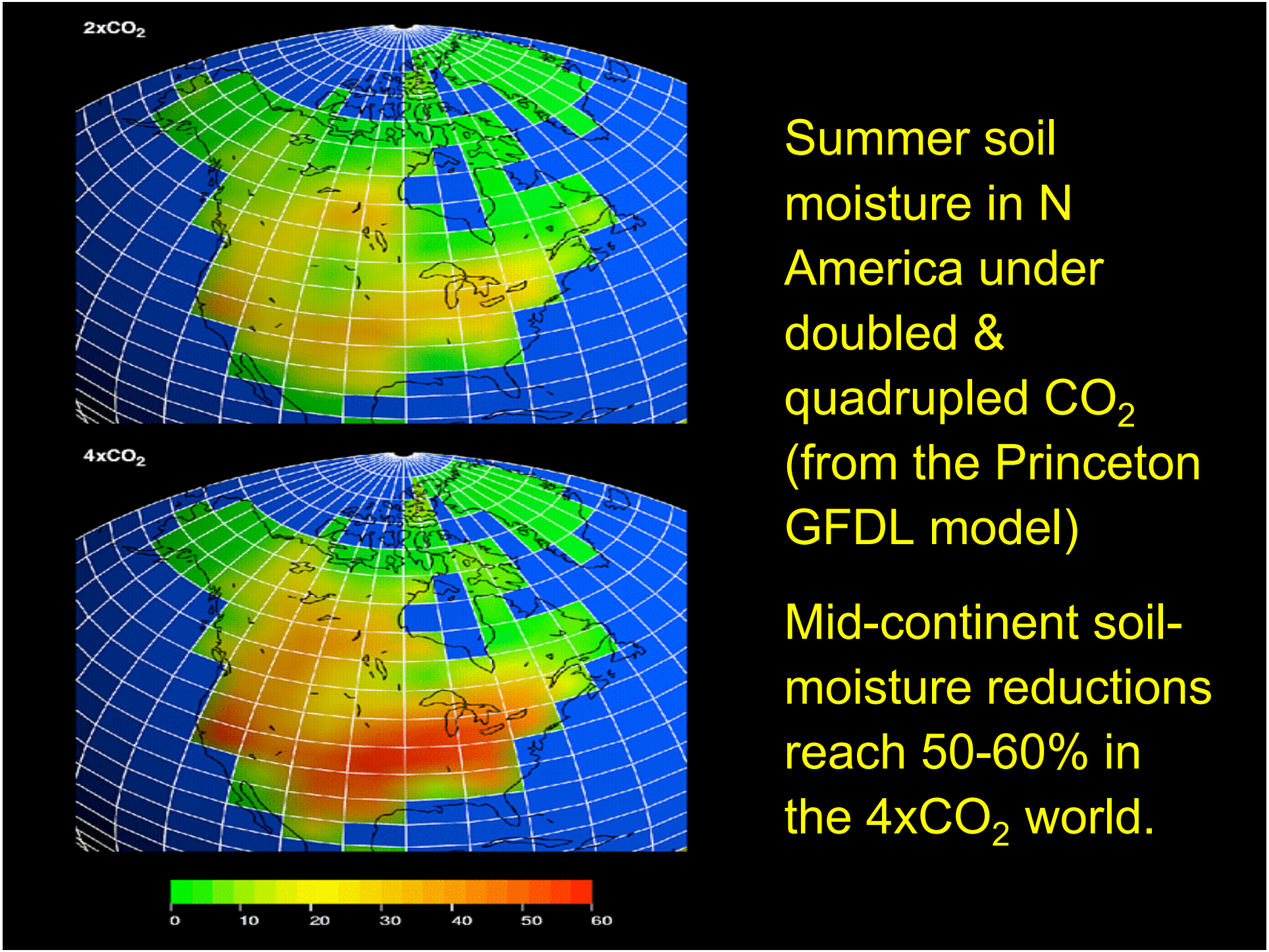
4x CO_2 : 15-25° F

Pre-industrial:

~275 ppm

Today:

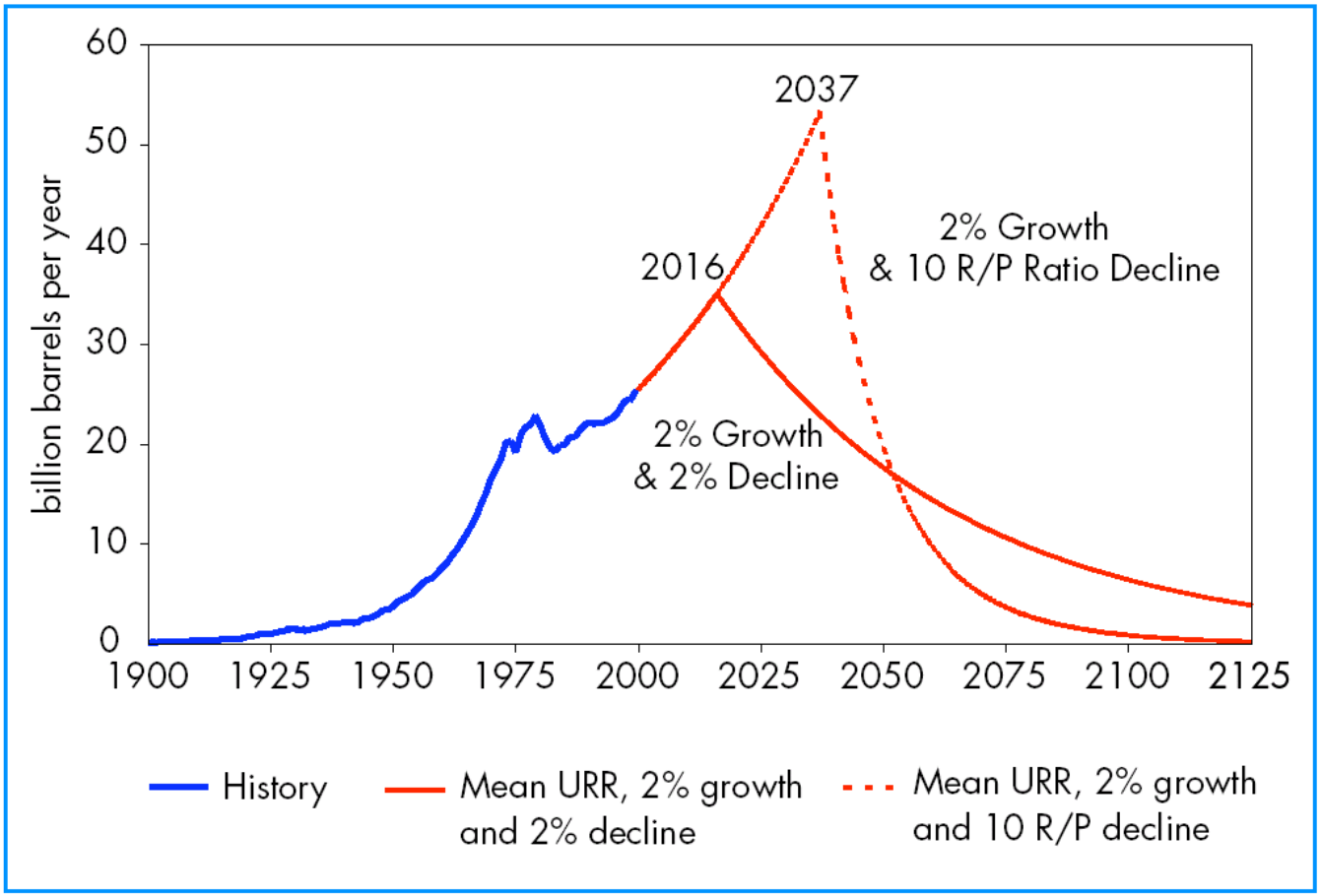
~380 ppm



Summer soil moisture in N America under doubled & quadrupled CO_2 (from the Princeton GFDL model)

Mid-continent soil-moisture reductions reach 50-60% in the 4xCO_2 world.

US Geological Survey and Department of Energy estimates of ***total*** discovered ***and*** undiscovered global reserves



Source: *World Energy Outlook, 2001* by the International Energy Agency, a body of the Organization for Economic Co-operation and Development (OECD)

International Energy Agency (IEA)
Carbon Emission forecast

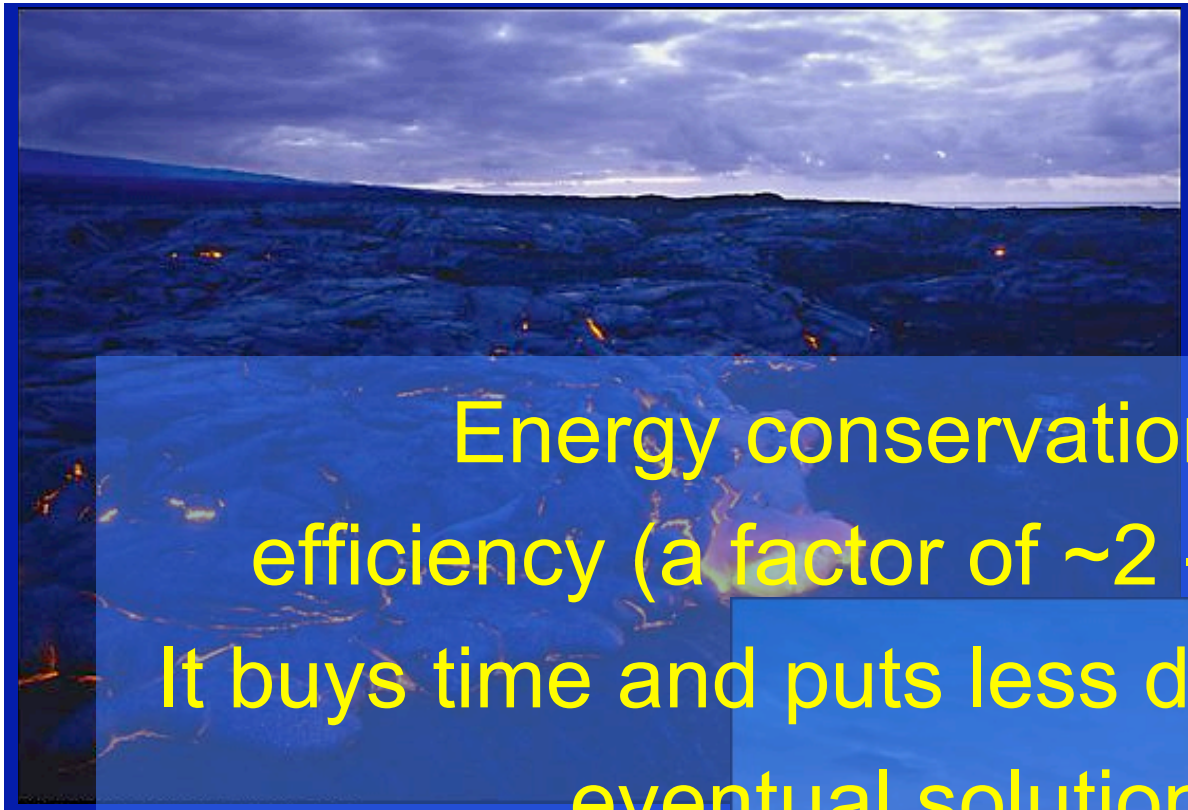
Between 2003-2030:

New Coal Plants = 1.4 TW

New Natural Gas Plants = 1.9 TW

The projected carbon emission in the next 30 years we will add 3x more CO_2 emission than the previous 250 years!

Energy from tar sands and shale oil will be as bad for CO_2 emissions as coal .



Energy conservation and efficiency (a factor of ~2 - 5) is vital.

It buys time and puts less demand on the eventual solutions.

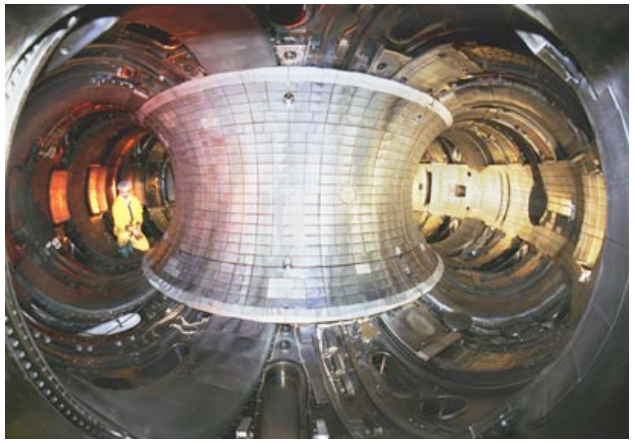
The problem still remains: how can we reduce CO2 emissions?

- The possibility (likelihood) of global warming and its consequences

- Possible solutions

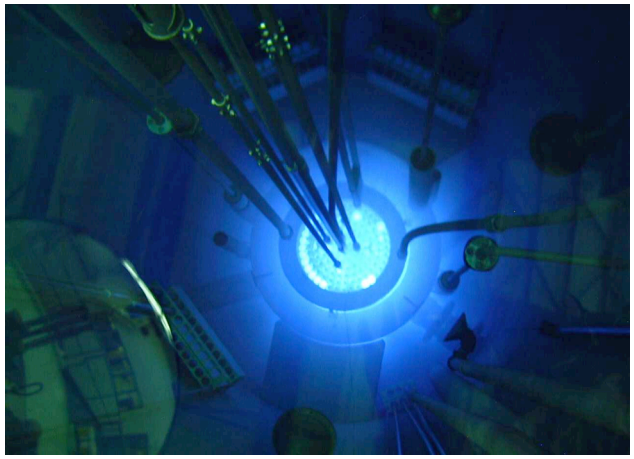
Potential Sources of Energy when Fossil Fuels Run Out

Nuclear Fusion



Magnetic plasma confinement or inertial fusion. At least 40 - 50 years in the future

Nuclear Fission



Waste and Nuclear Proliferation

3 TW = One new GW reactor every week for the next 50 years)

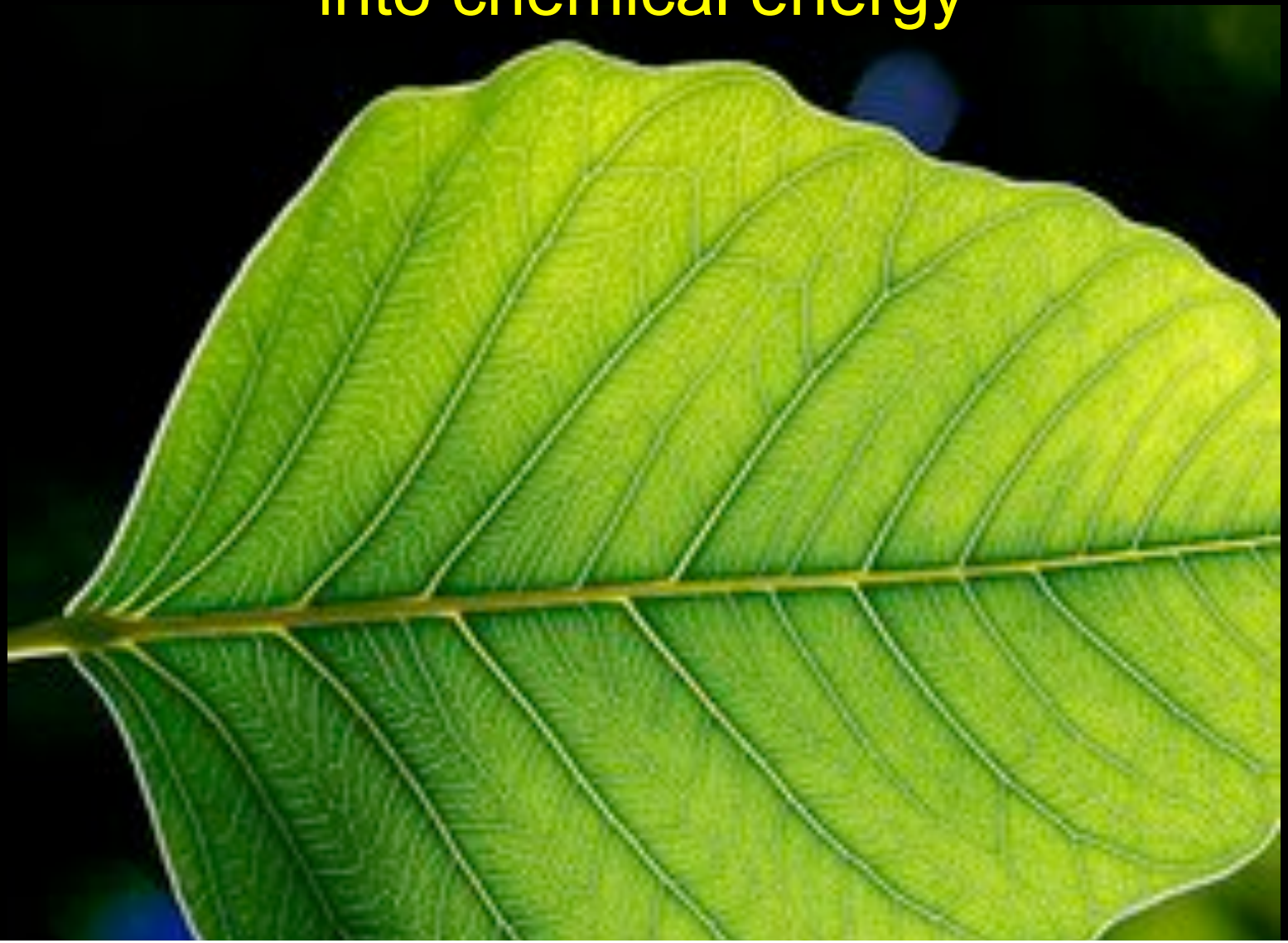
Solar Energy

large scale storage of electricity is an unsolved problem

Photo-voltaic cells

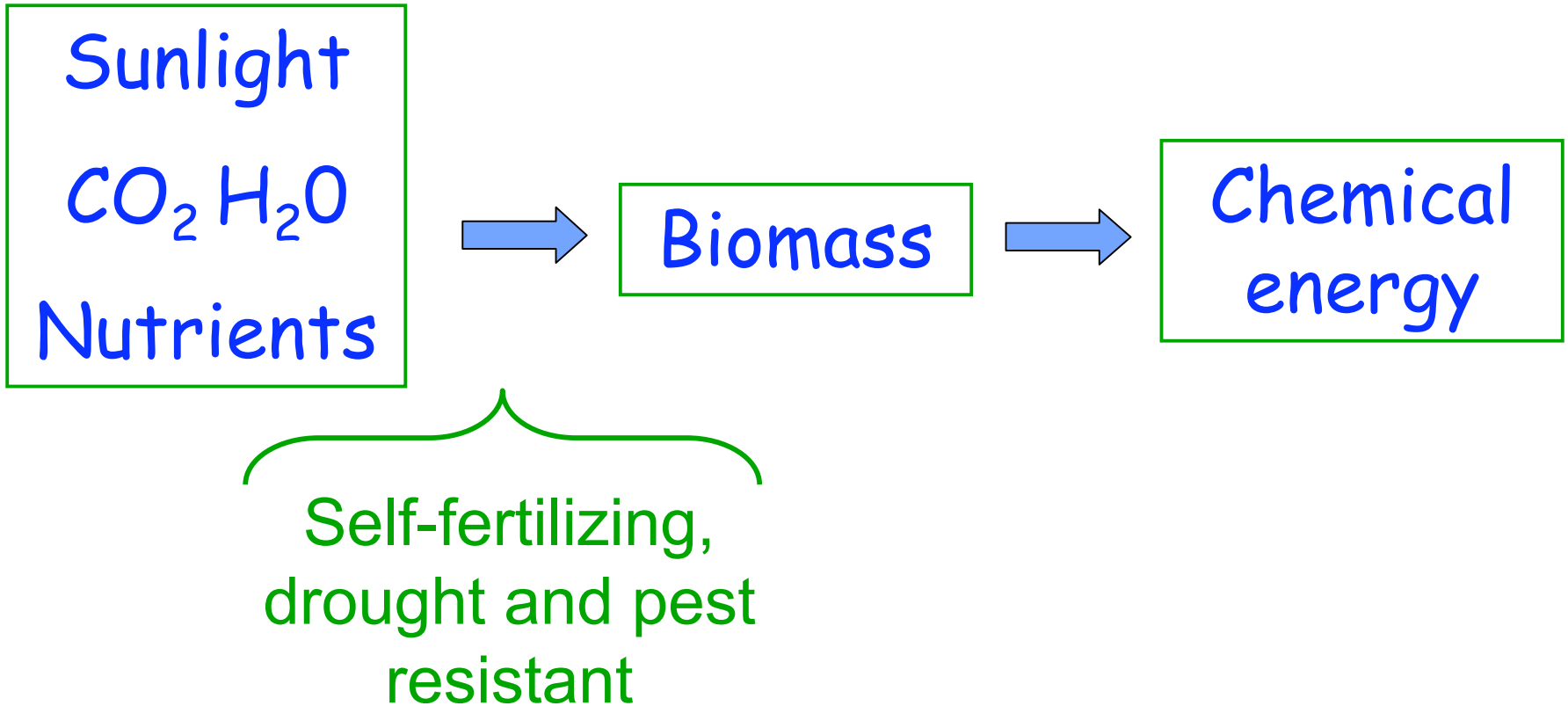
Wind

Photosynthesis: Nature has found a way to convert sunlight, CO_2, water and nutrients into chemical energy



The majority of a plant is structural material

Cellulose	40-60% Percent Dry Weight
Hemicellulose	20-40%
Lignin	10-25%

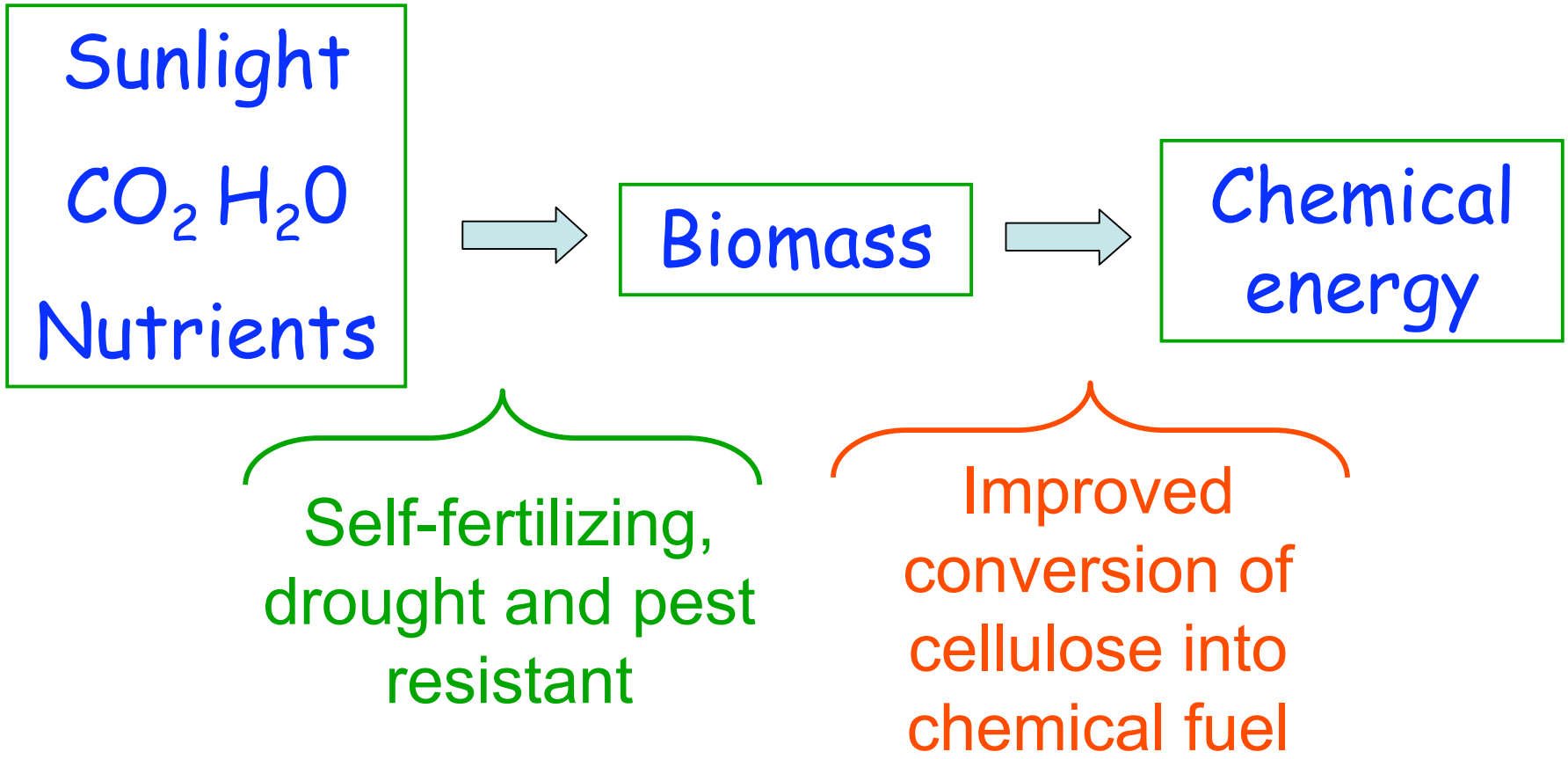


Corn

Switchgrass

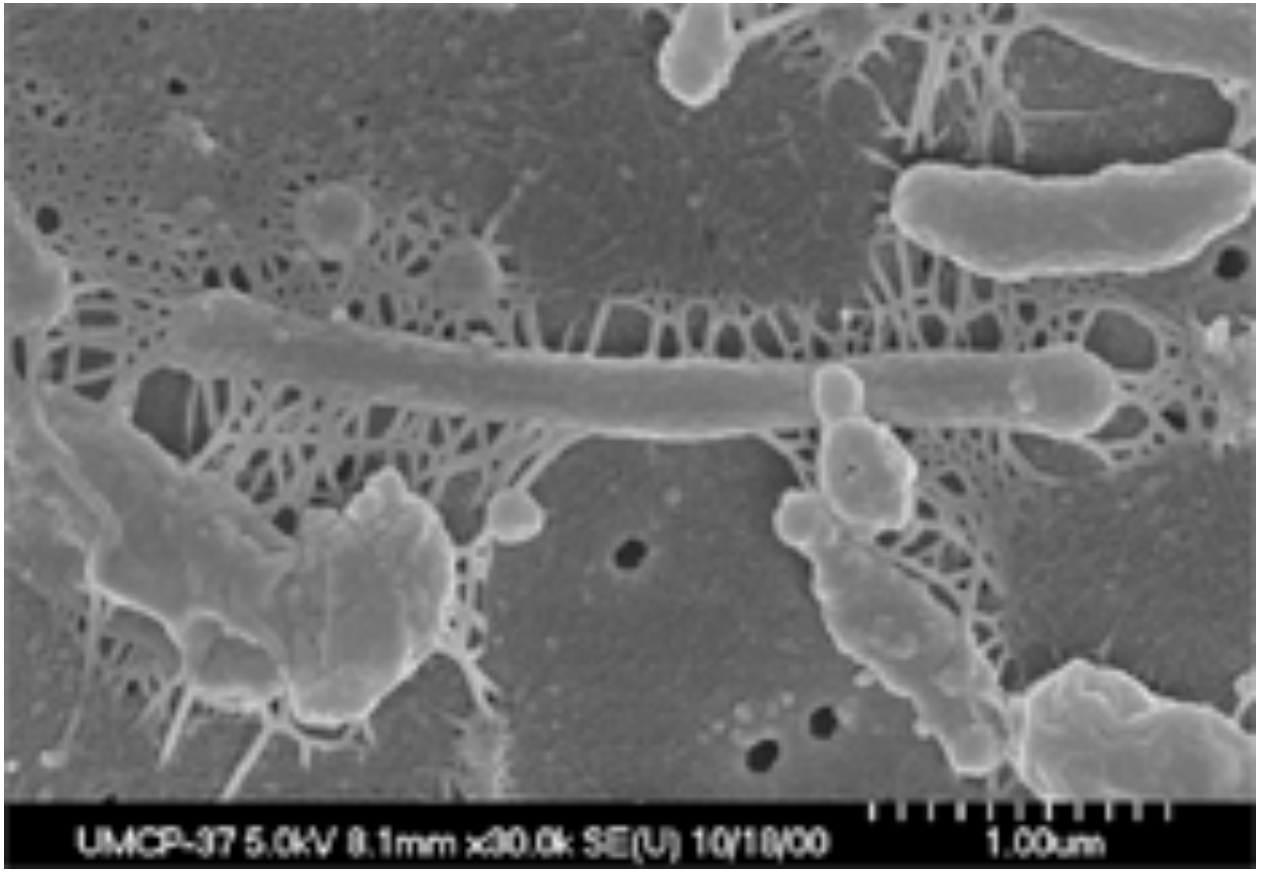
The majority of a plant is structural material

Cellulose	40-60% Percent Dry Weight
Hemicellulose	20-40%
Lignin	10-25%



Microbulbifer degradans

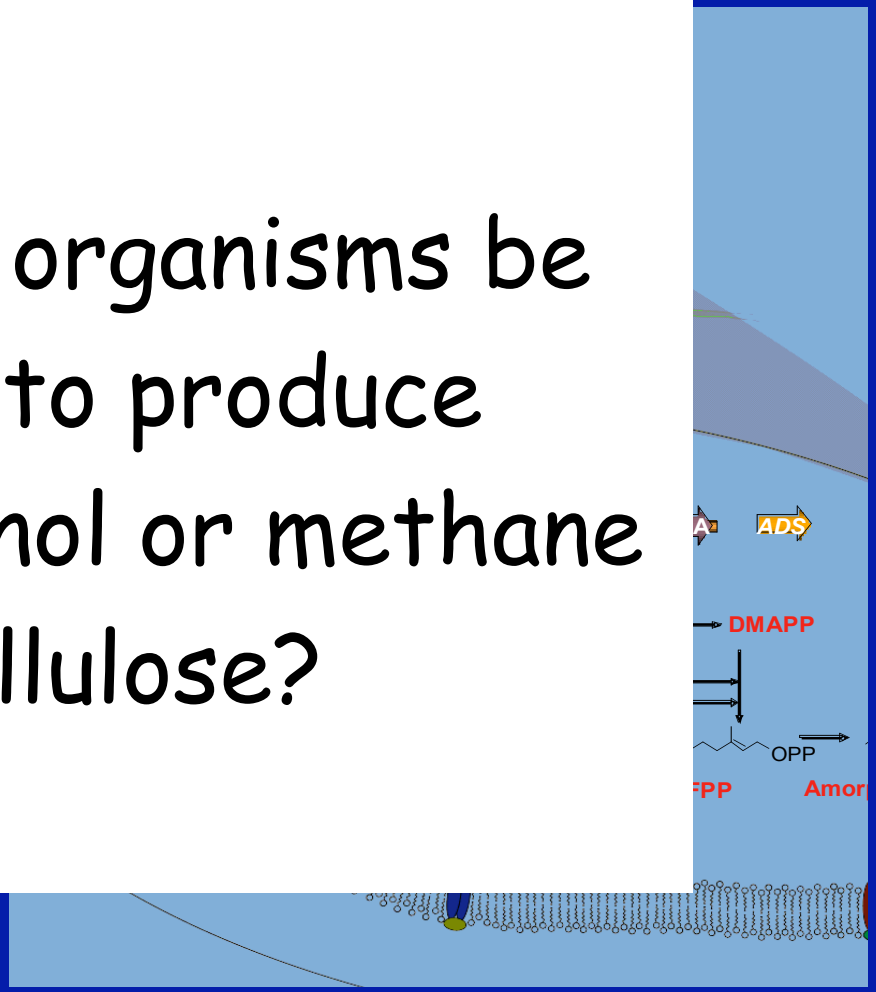
A group of microorganisms that degrades of a significant portion of the 50+ billion tons of cellulose



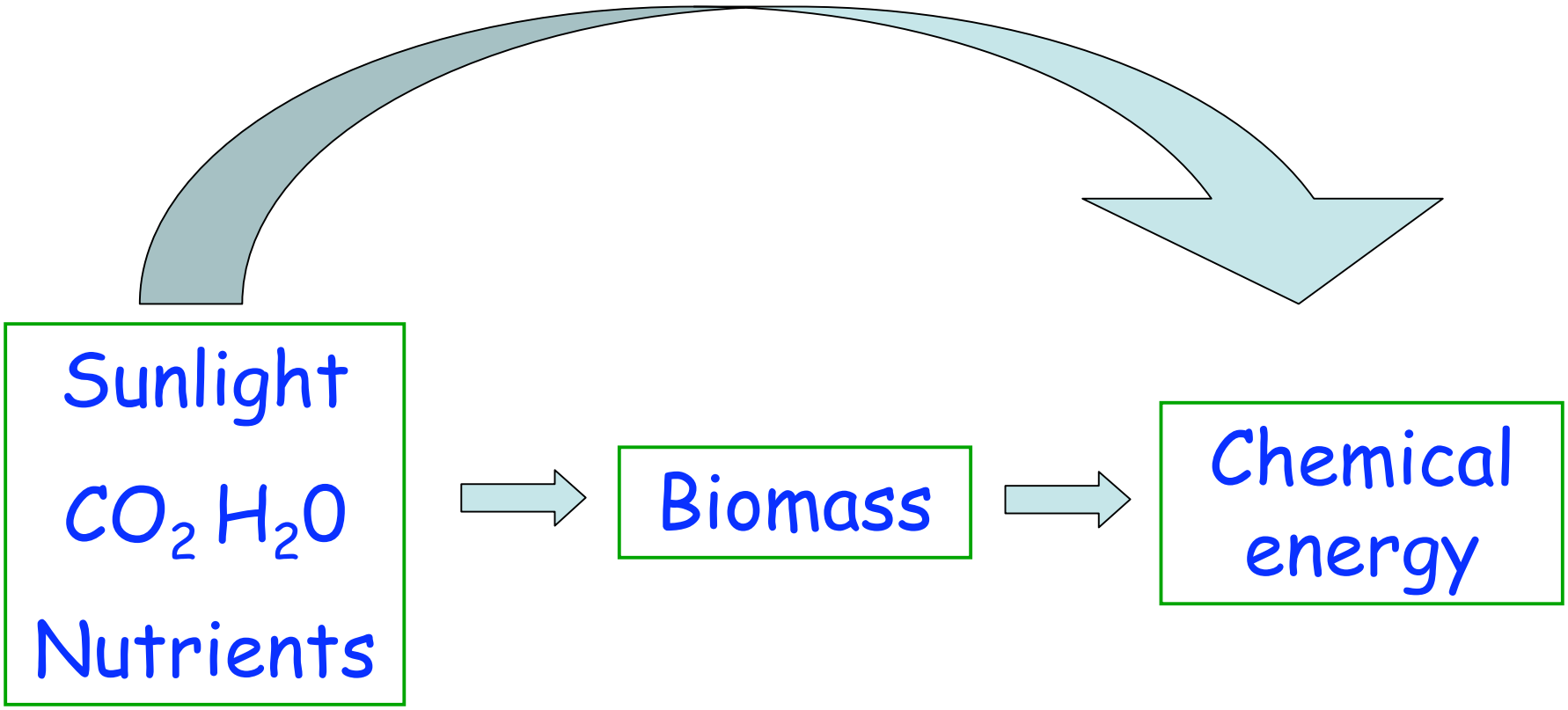
Synthetic Biology:

Production of artemisinin in bacteria Jay Keasling

Can synthetic organisms be engineered to produce ethanol, methanol or methane from cellulose?



Can we modify existing organisms or design new ones to directly produce energy?



A diversified portfolio of investments is needed

A solution may lie at the interface of biology
and
the physical sciences at the nano-scale

National and International Concerns

1) National security which is intimately tied to energy security

2) Economic prosperity

3) The environment

Sustainable, CO_2 neutral energy

Lawrence Berkeley National Laboratory

3,800 employees, ~$500 M budget

10 Nobel Prize winners were/are employees of LBNL, and another "on the way"

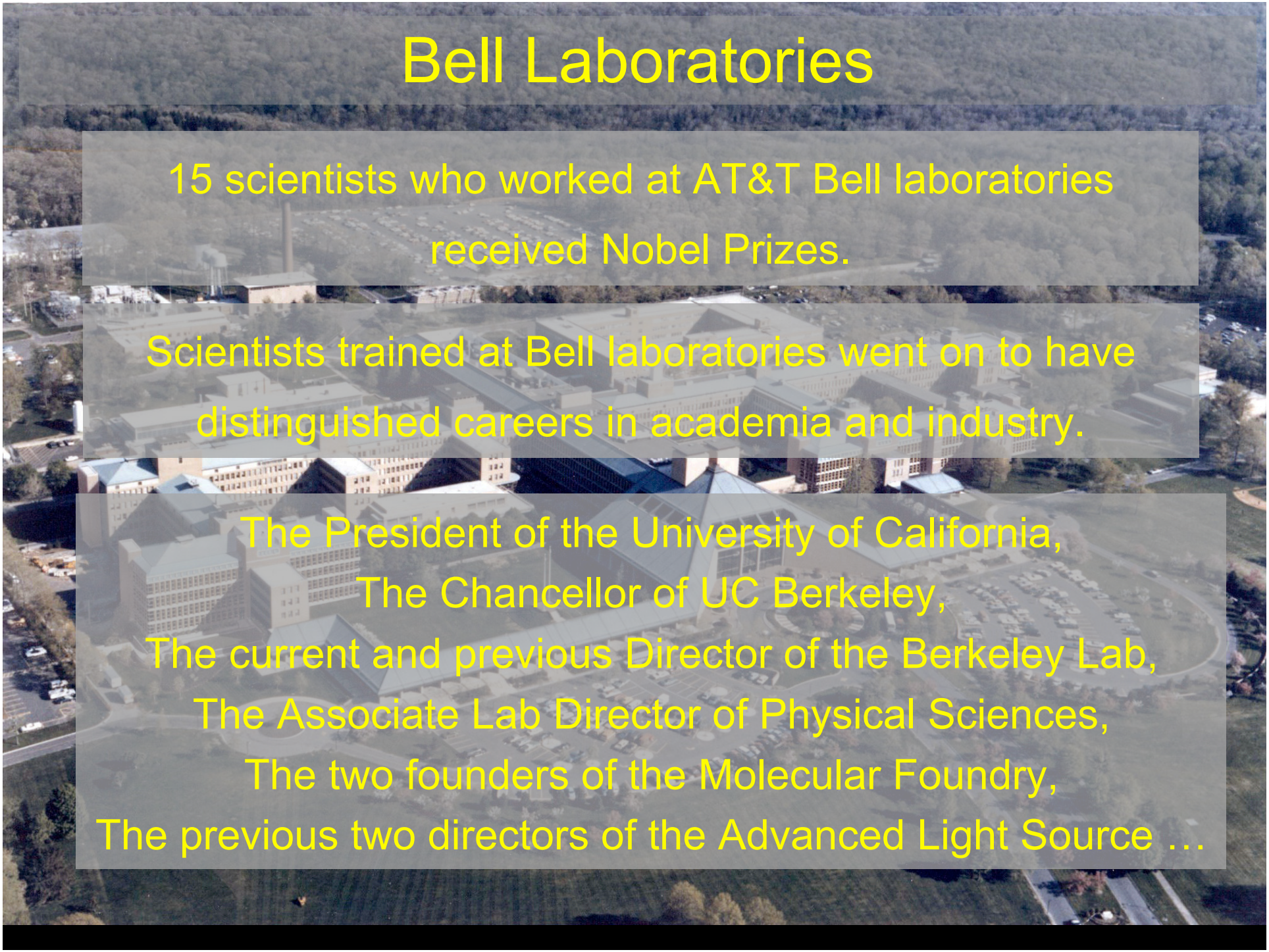
Berkeley Lab
200-acre site

Today:

59 employees in the National Academy of Sciences,
18 in the National Academy of Engineering,
2 in the Institute of Medicine,
7 MacArthur Fellows,

UC Berkeley
Campus

…

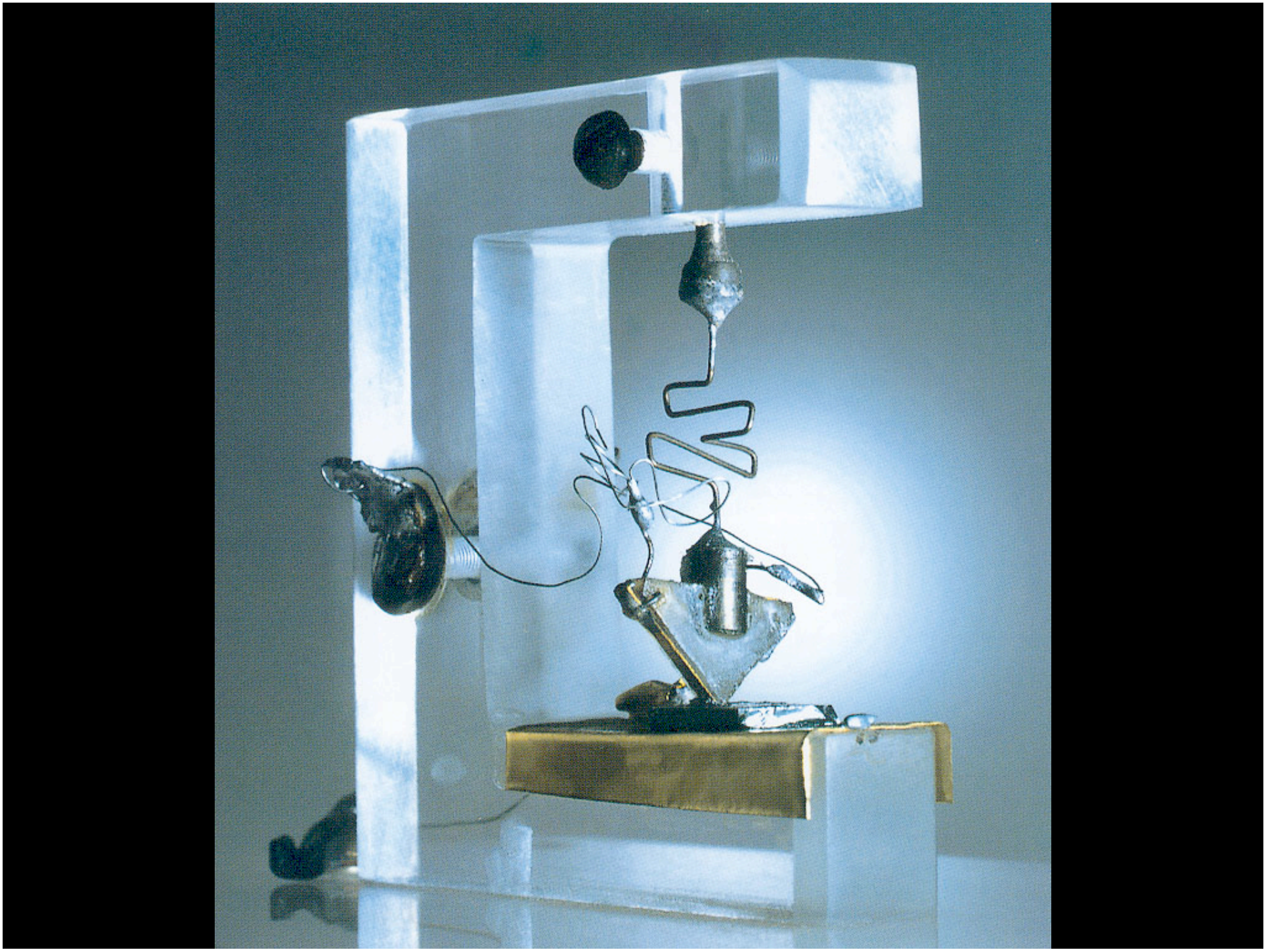


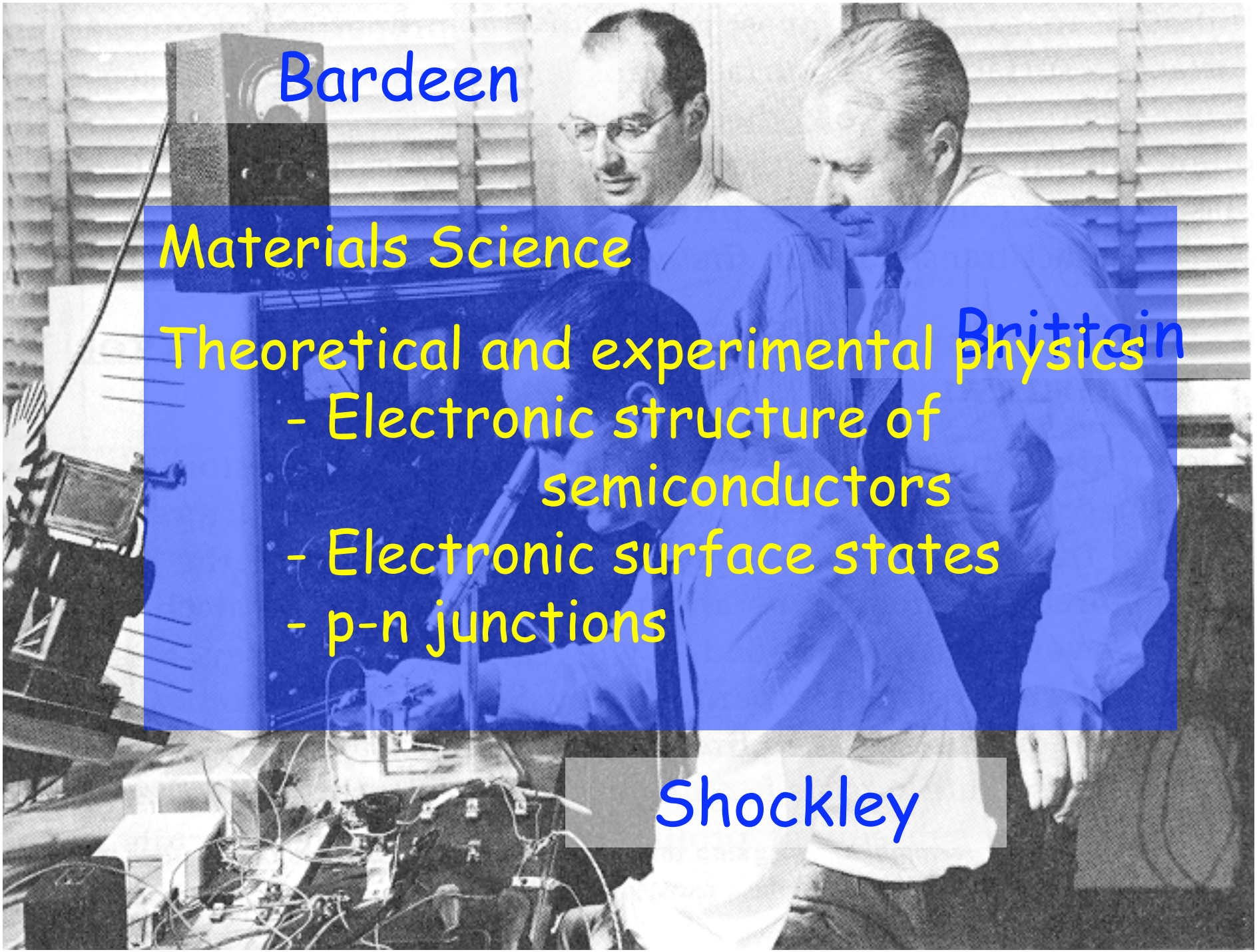
Bell Laboratories

15 scientists who worked at AT&T Bell laboratories received Nobel Prizes.

Scientists trained at Bell laboratories went on to have distinguished careers in academia and industry.

The President of the University of California,
The Chancellor of UC Berkeley,
The current and previous Director of the Berkeley Lab,
The Associate Lab Director of Physical Sciences,
The two founders of the Molecular Foundry,
The previous two directors of the Advanced Light Source …

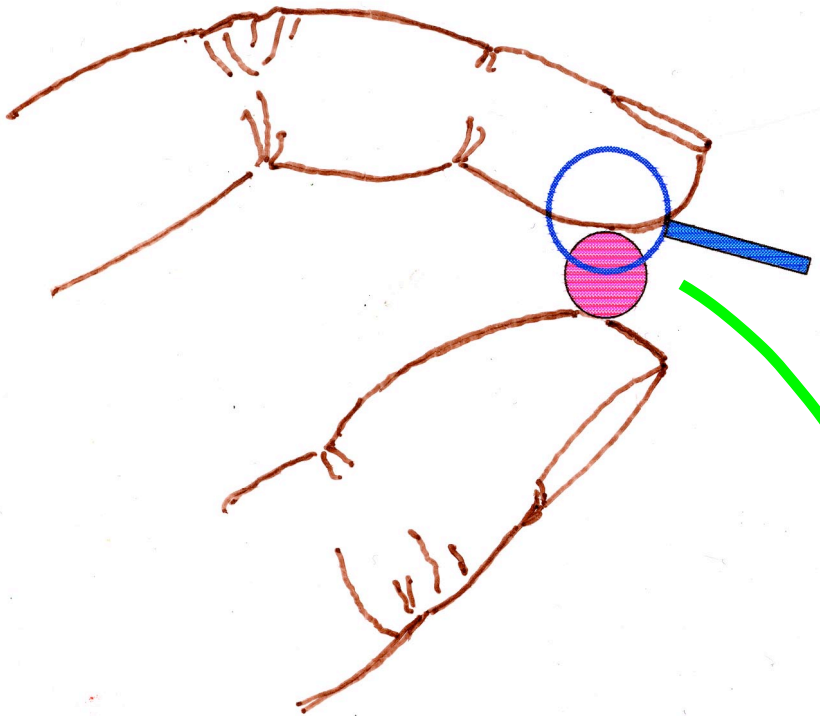


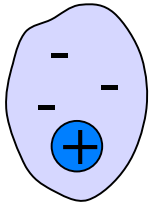

Bardeen
Materials Science
Theoretical and experimental physics
- Electronic structure of semiconductors
- Electronic surface states
- p-n junctions
Brittain
Shockley


Meanwhile, the polar ice
caps continue to melt.

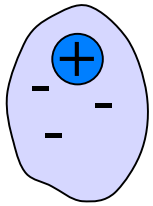
Holding on to atoms and molecules with laser light

Can we hold onto particles with a magic wand?

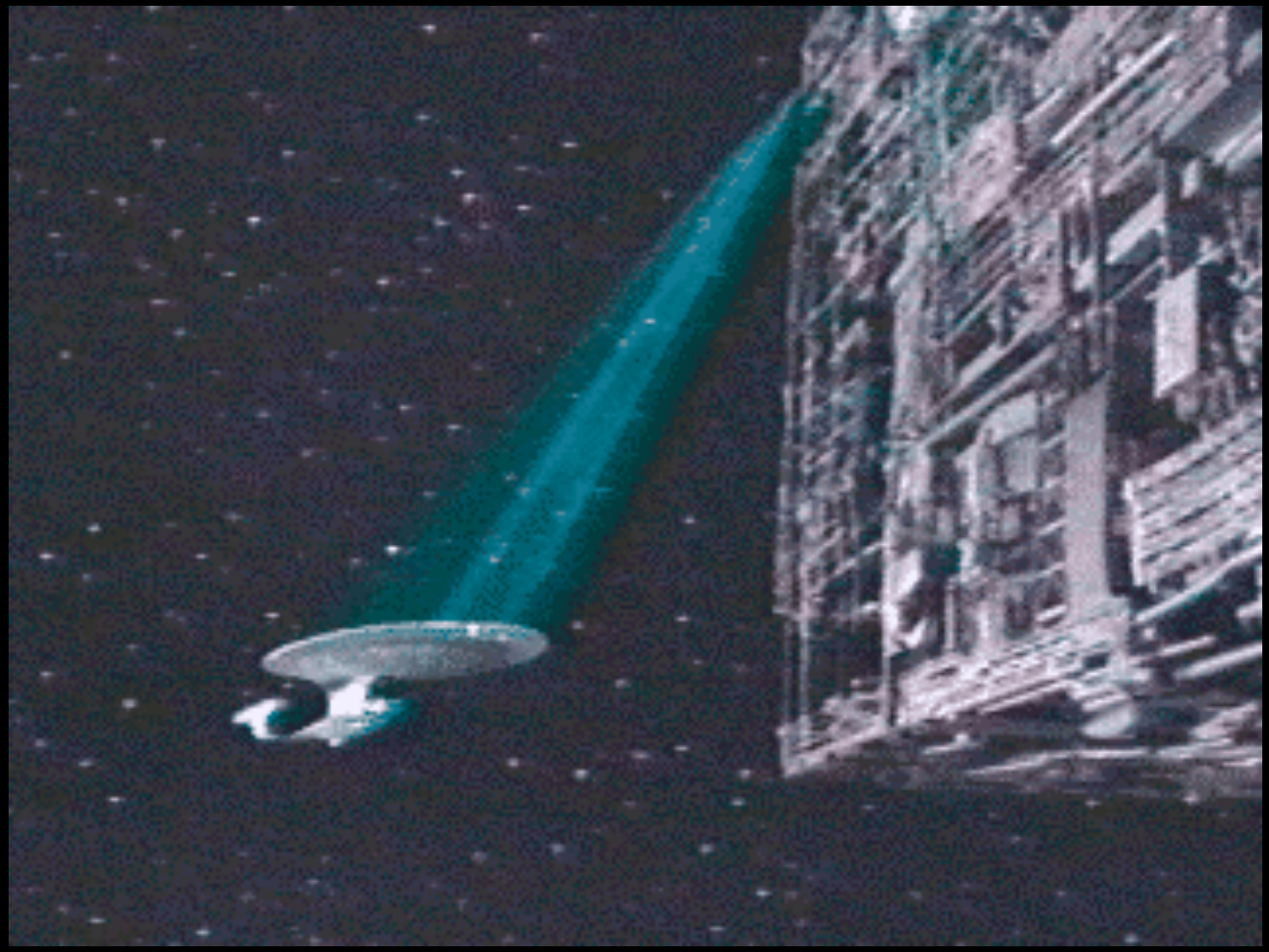




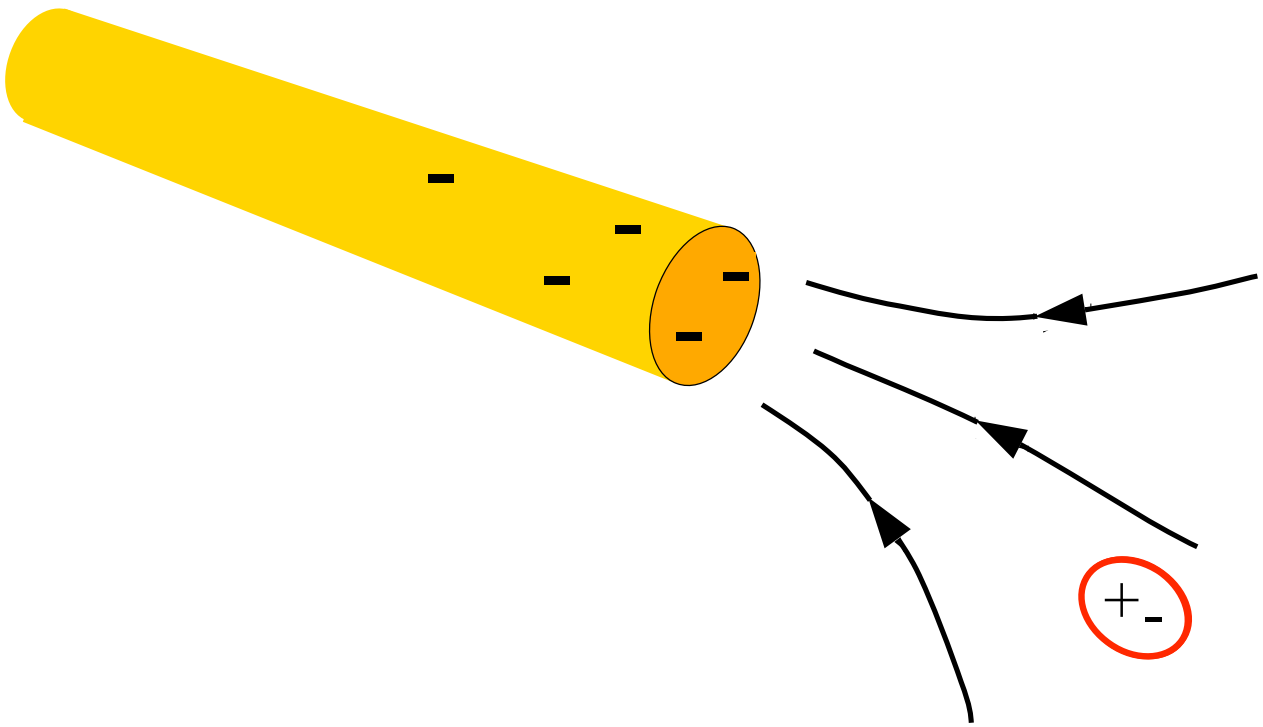
Atom on finger



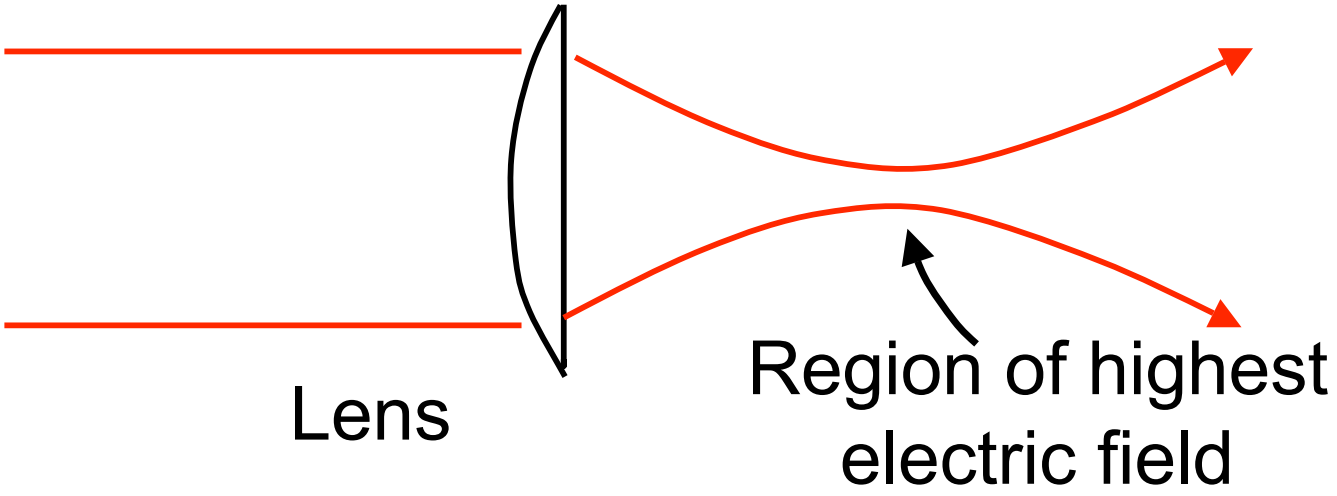
Atom on object



A lesson in static electricity

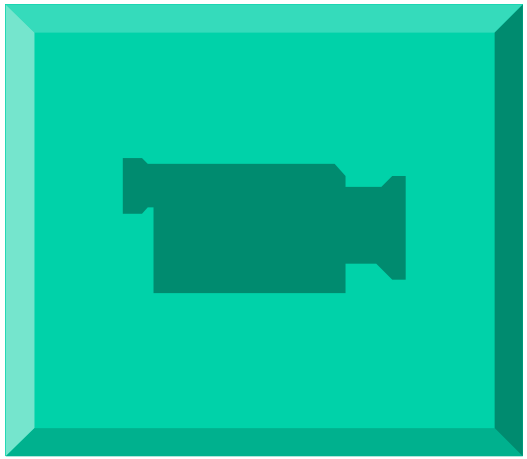


The particle is attracted to where the electric field is strongest

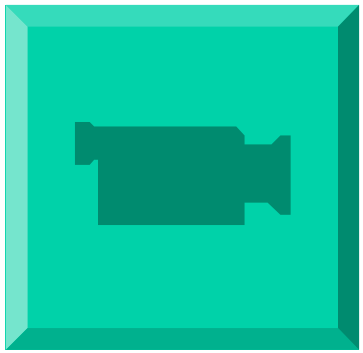


… but order to hold onto atoms, they have to be moving *very* slowly.

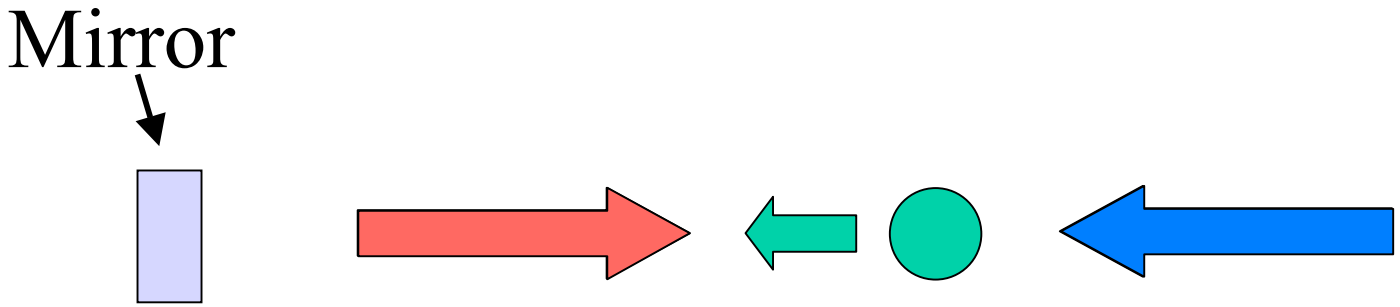
Temperature and Absolute Zero



Laser light can be used to cool atoms!

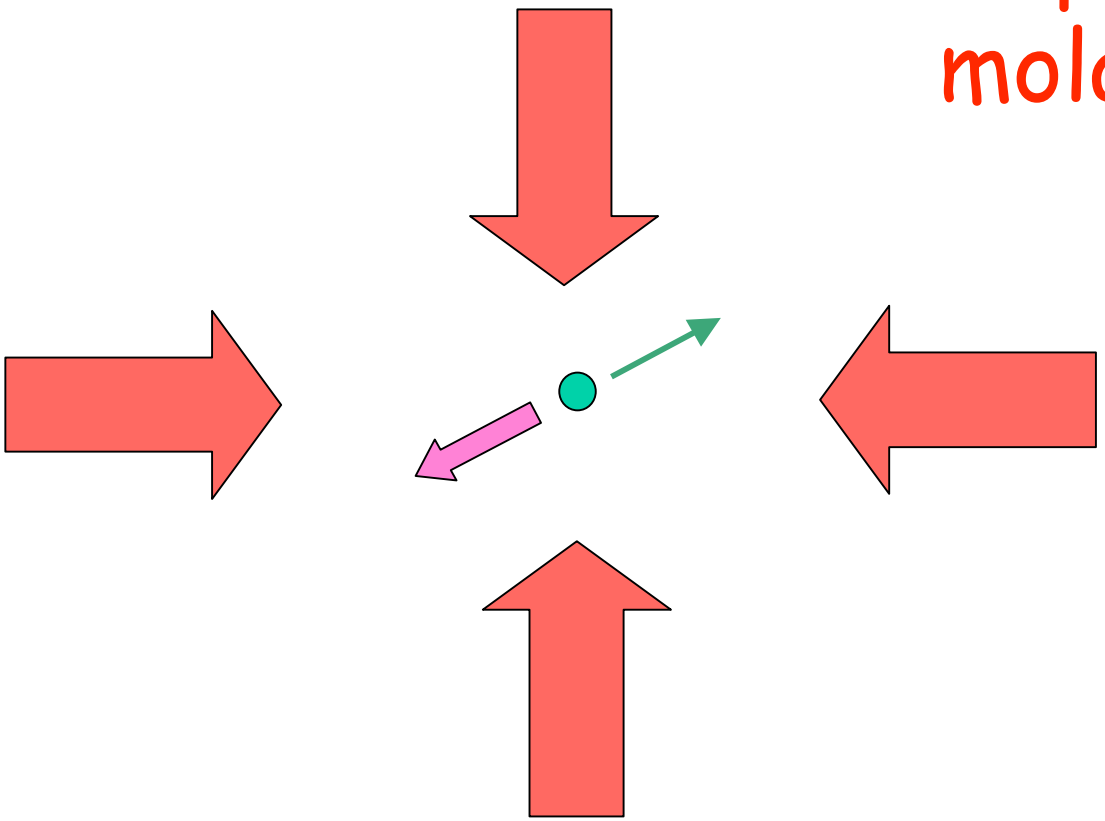


Cooling using the Doppler effect



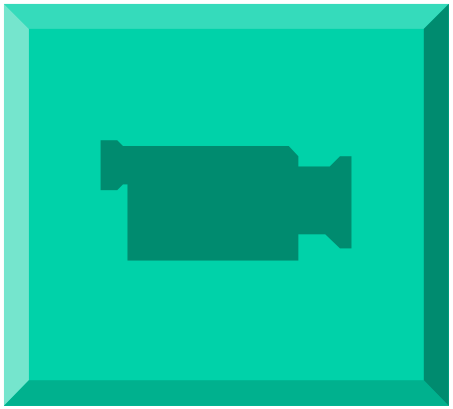
If the atom wants to scatter more blue light than red light, it will slow down no matter which way it is going.

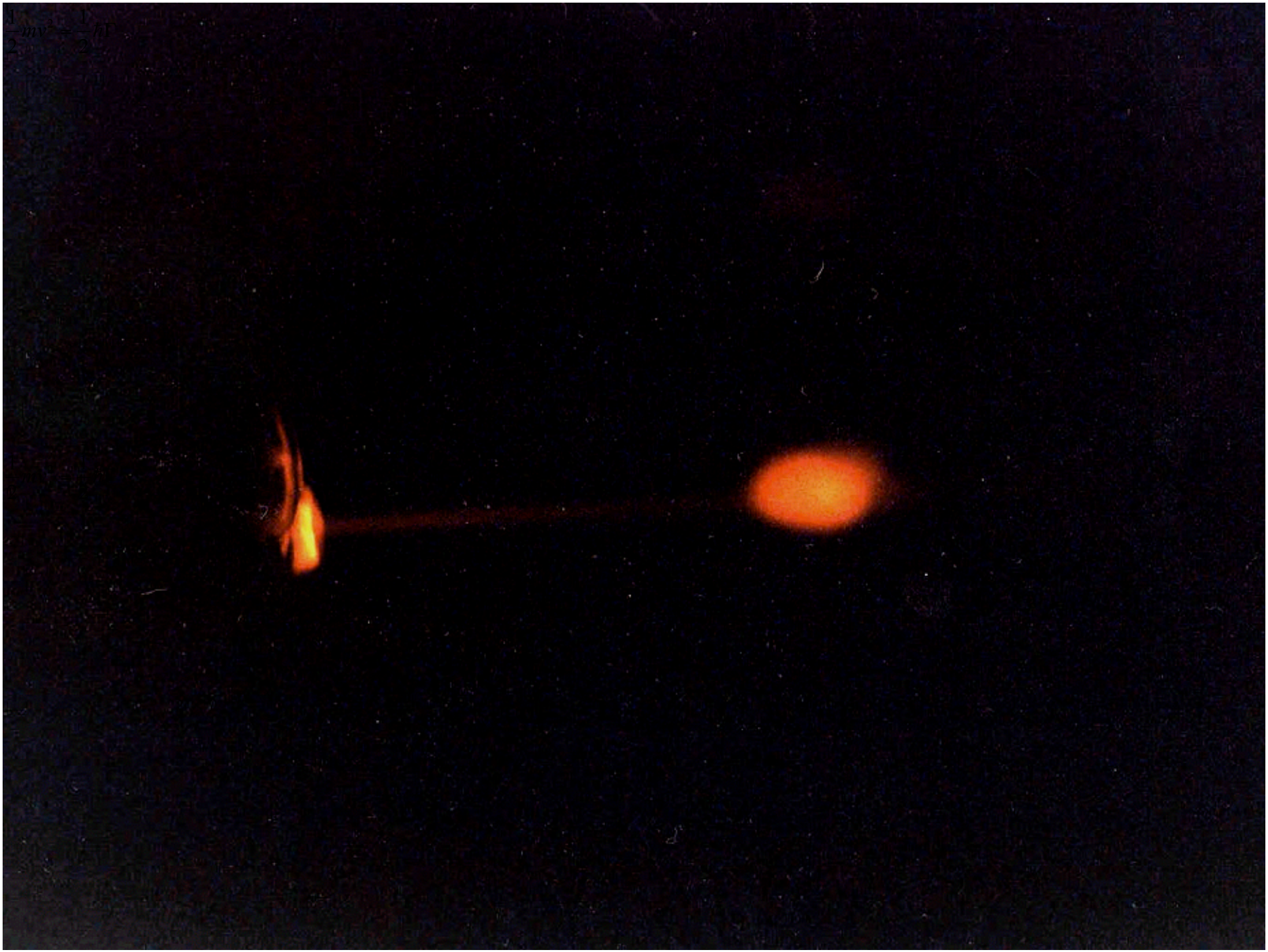
"Optical molasses"



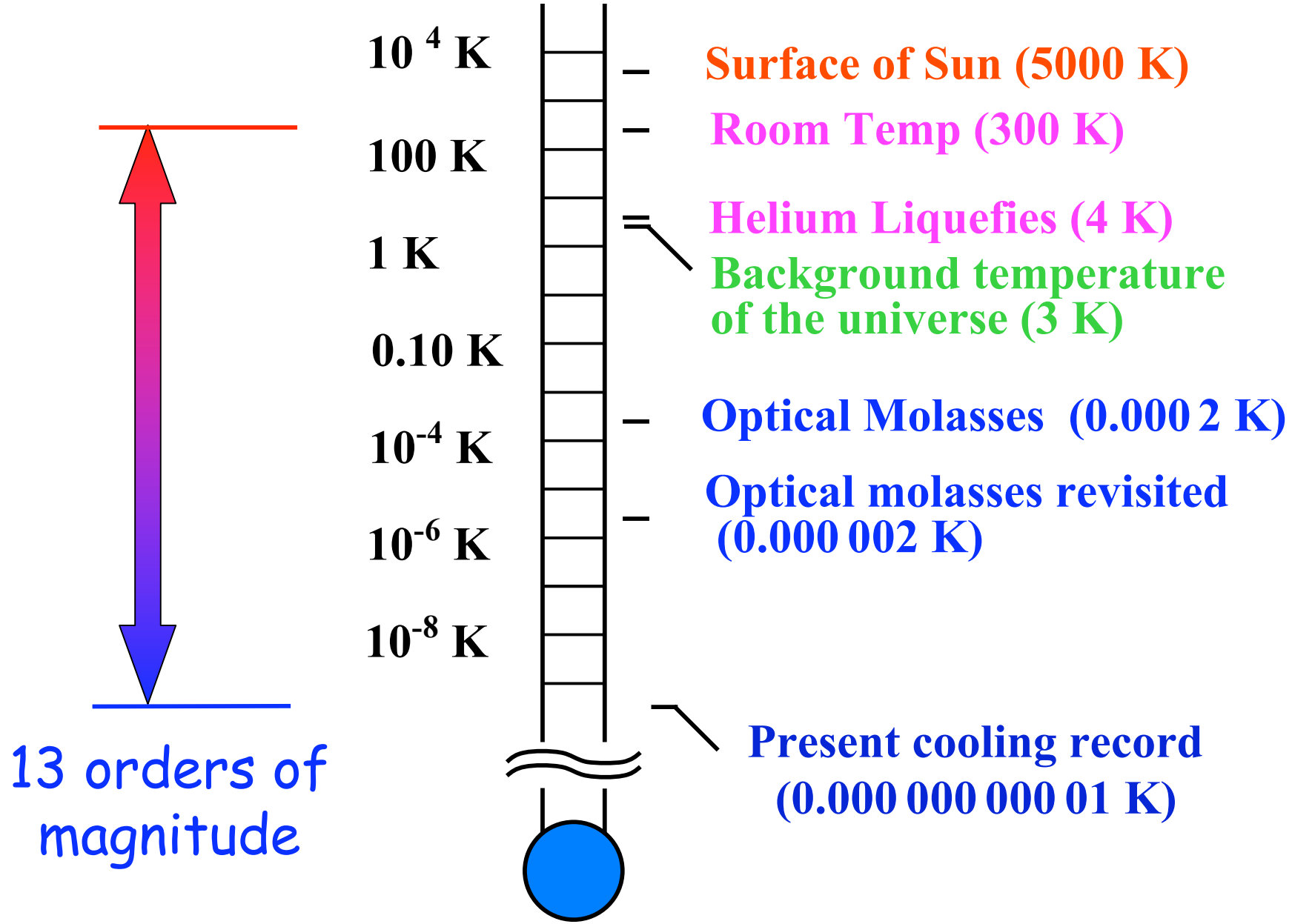
Force is *opposite* the motion

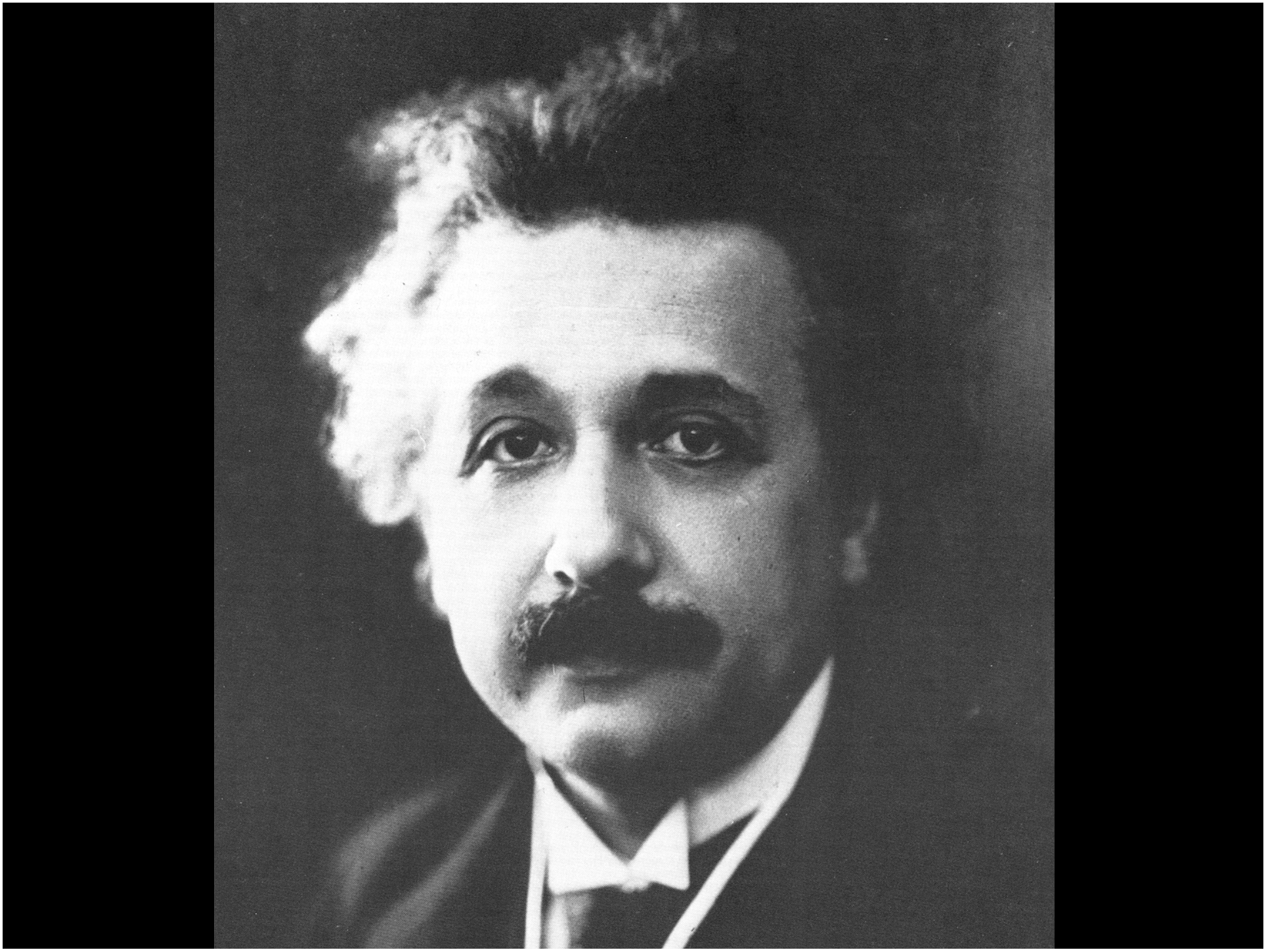
Optical molasses



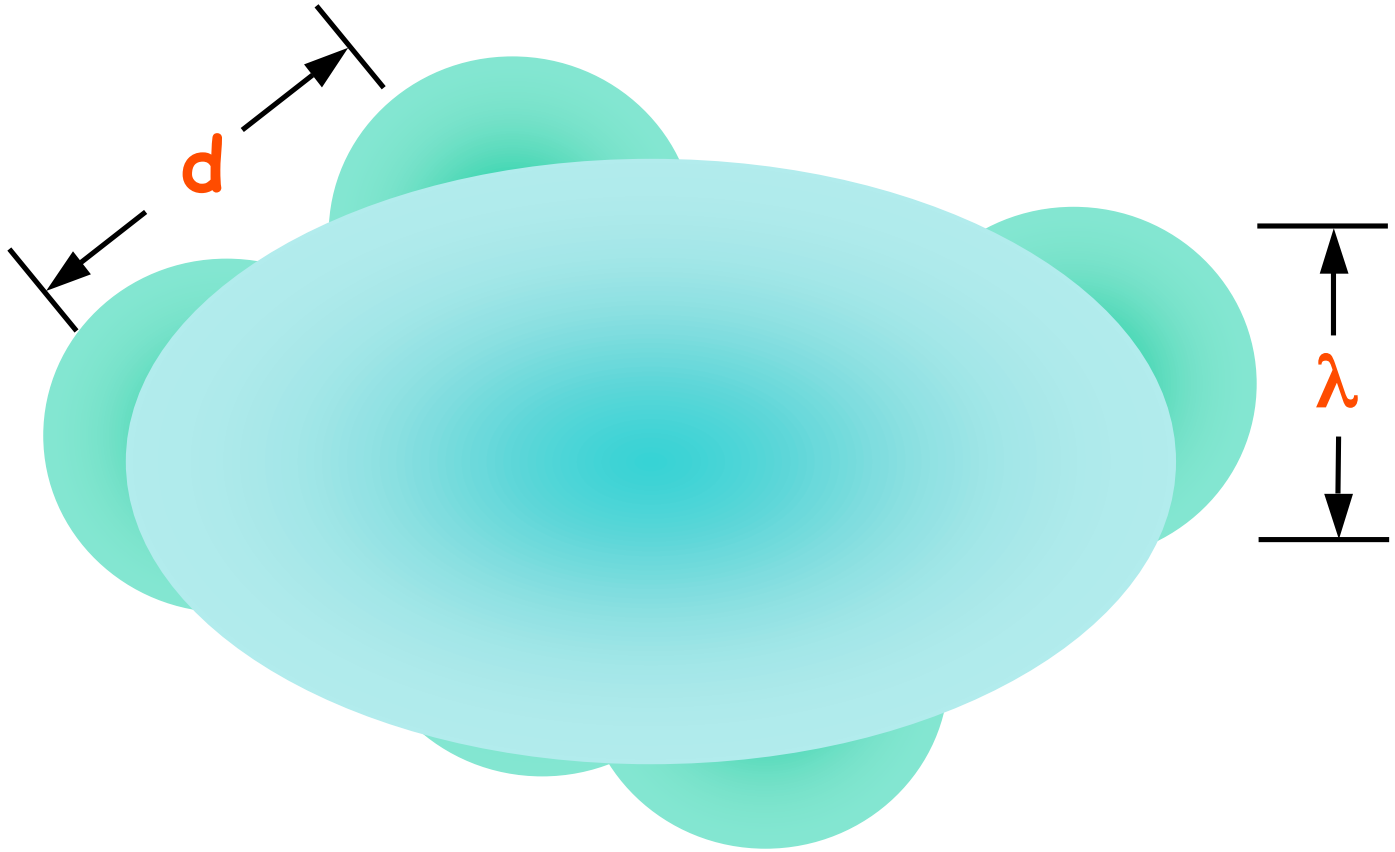

$\frac{1}{2}mv^2 = \frac{1}{2}fl$

Laser Cooling Lows

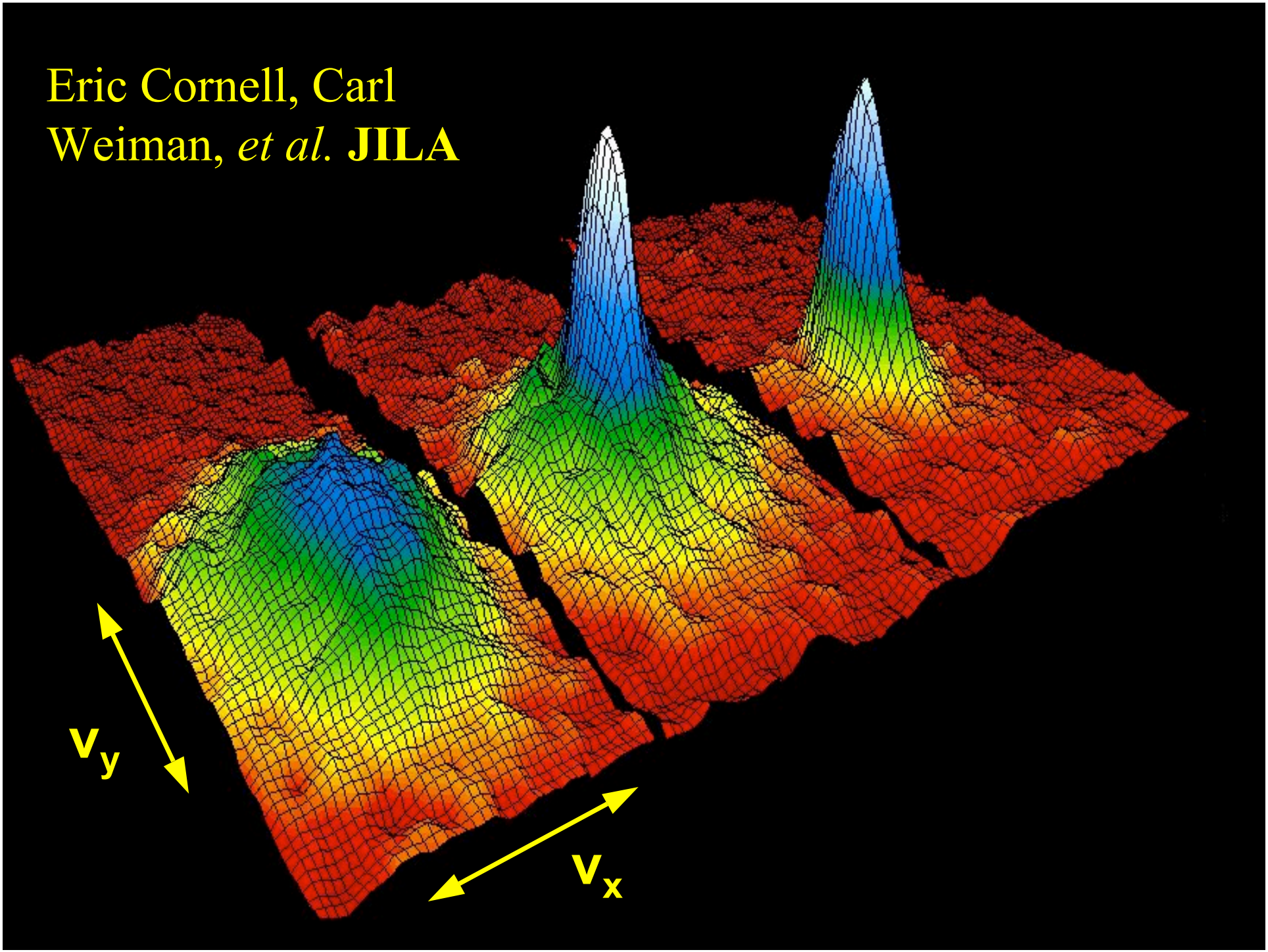




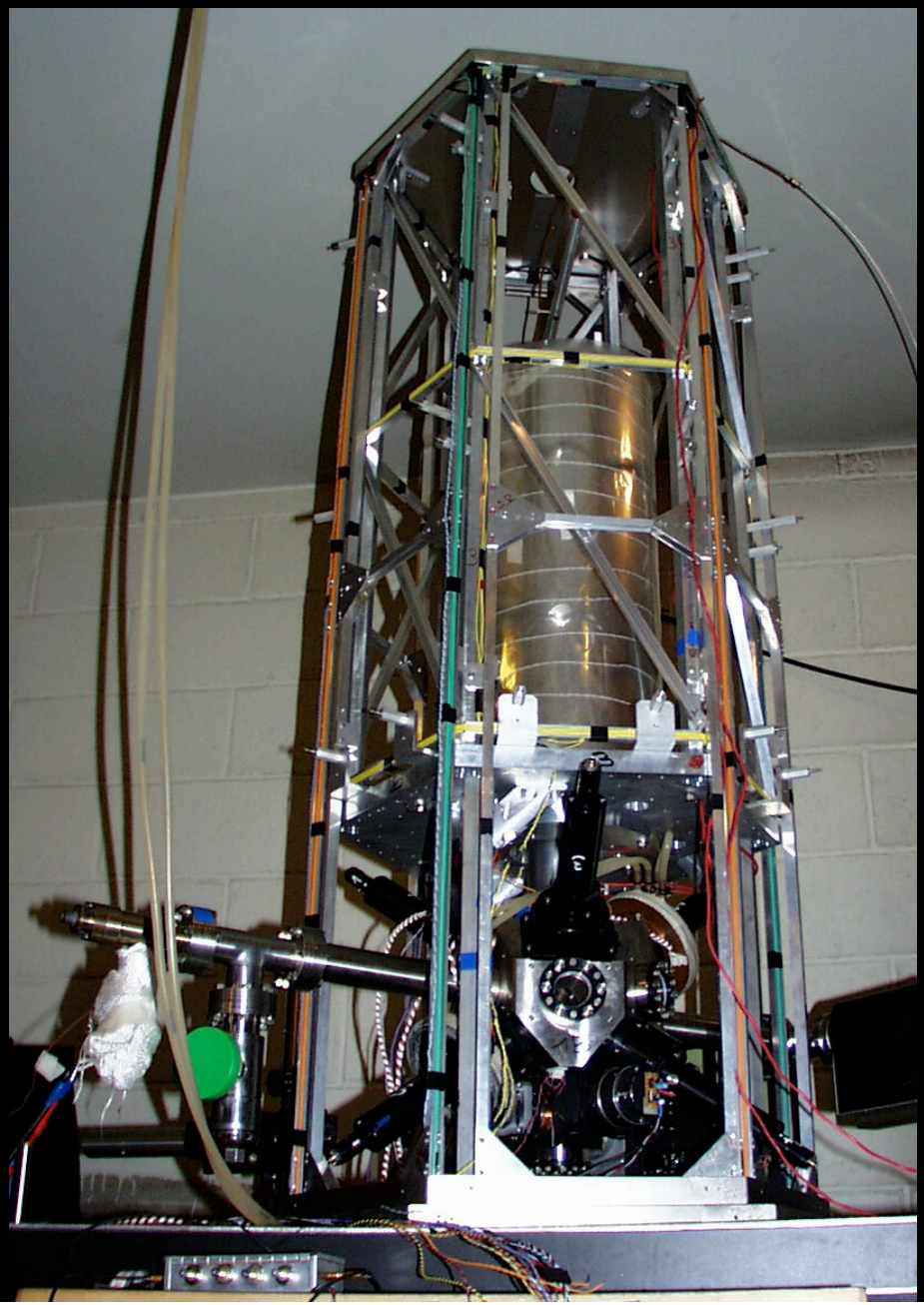
When atoms move slowly, they become big-fuzz balls



Einstein's prediction: When λ > d, the atoms will condense into a *single* gigantic wave


Eric Cornell, Carl
Weiman, *et al.* **JILA**
v_y
v_x

Rubidium atomic fountain

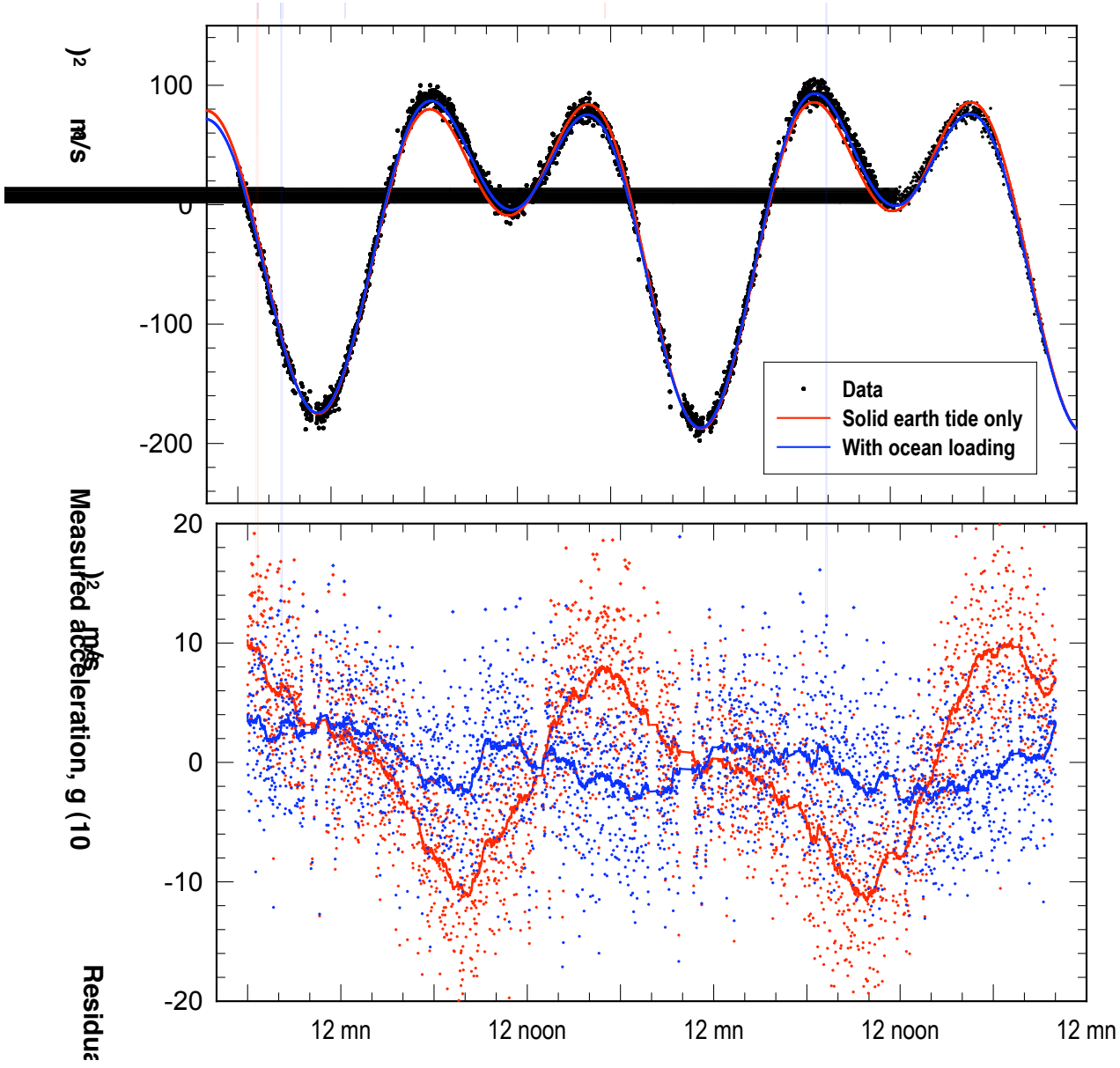


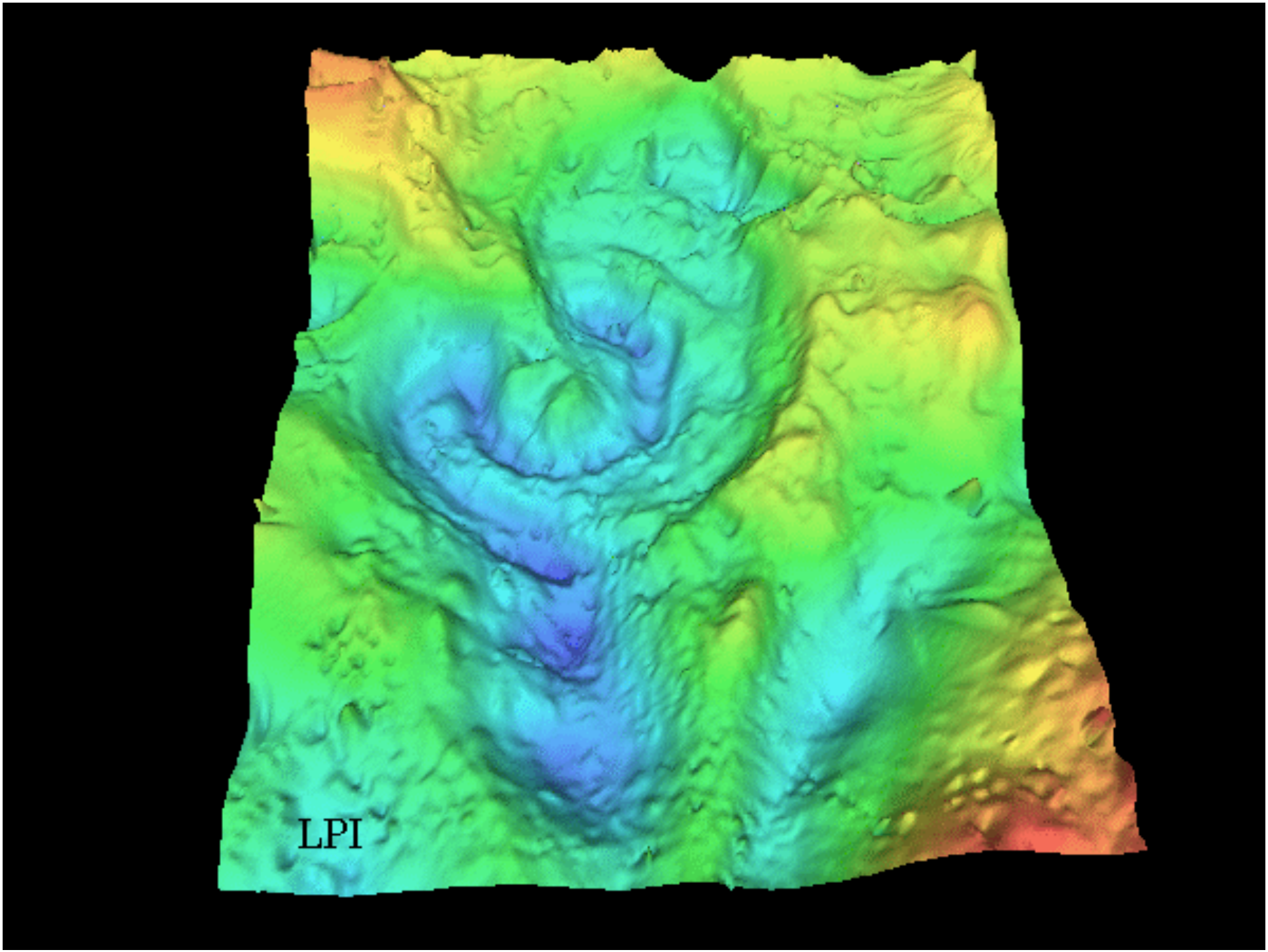
Time can now be measured to an accuracy of one part in 10^{15}

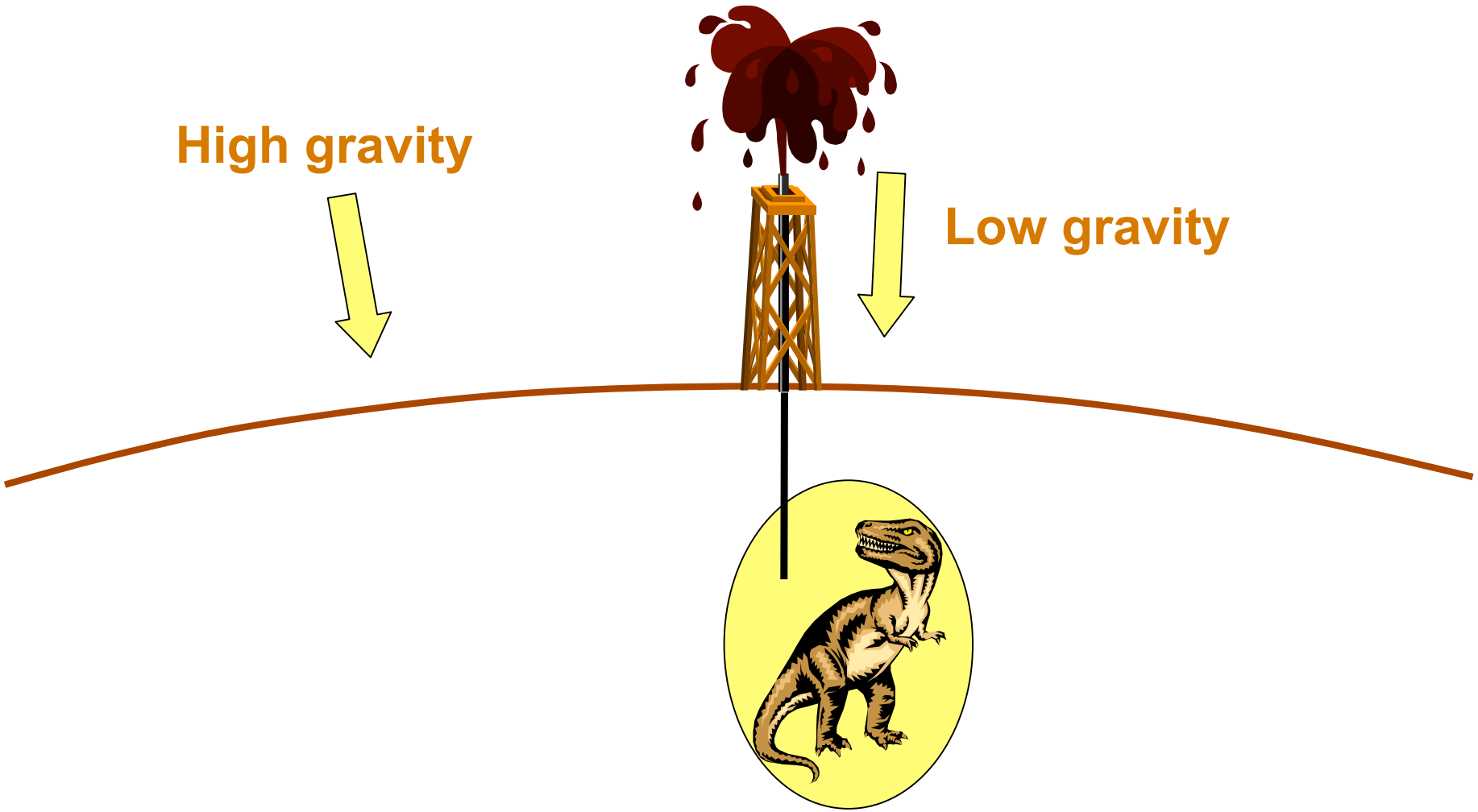
Over the life to the Universe, we will know what time it is to 7 minutes.

- The most precise measurements in science are frequency measurements.
- The meter, the ohm, the volt are defined in terms of time.
- The Global Positioning Satellite (GPS) system is based on atomic clocks.

Measurement of gravity compared to Earth tide models

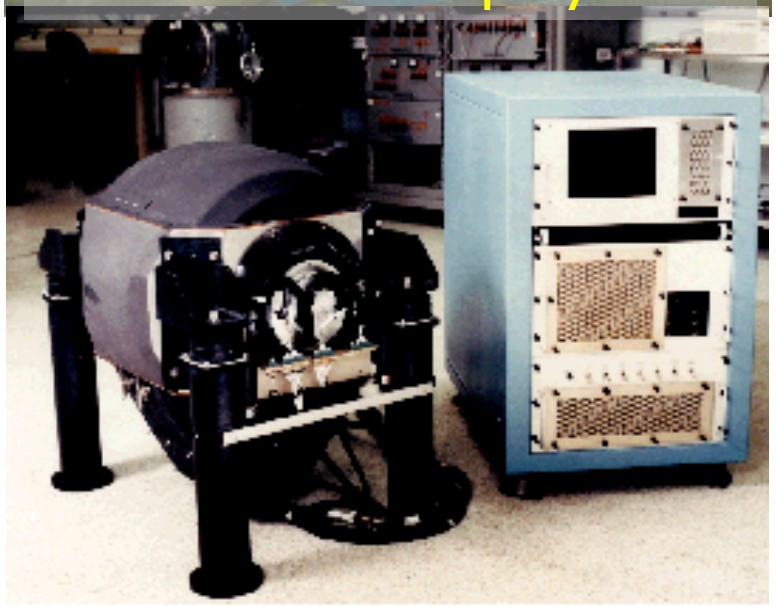



LPI


High gravity
Low gravity

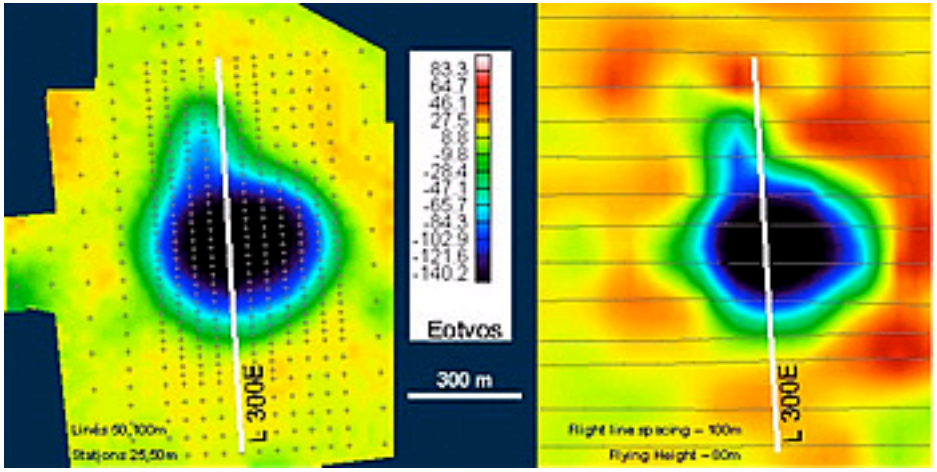
Airborne Gravity Gradiometer

Existing technology

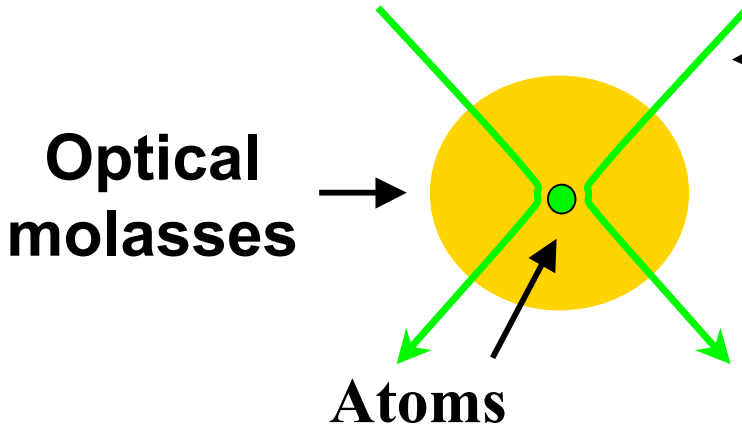


Kimberlite diamond shaft

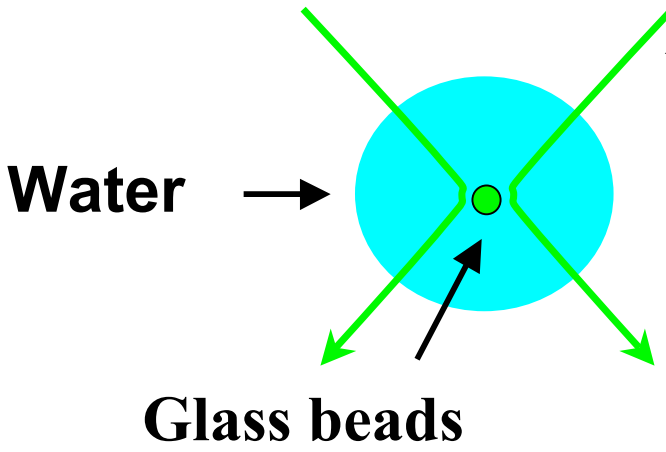
Land: 3 wks. Air: 3 min.



Optical Trapping in a Focused Laser Beam



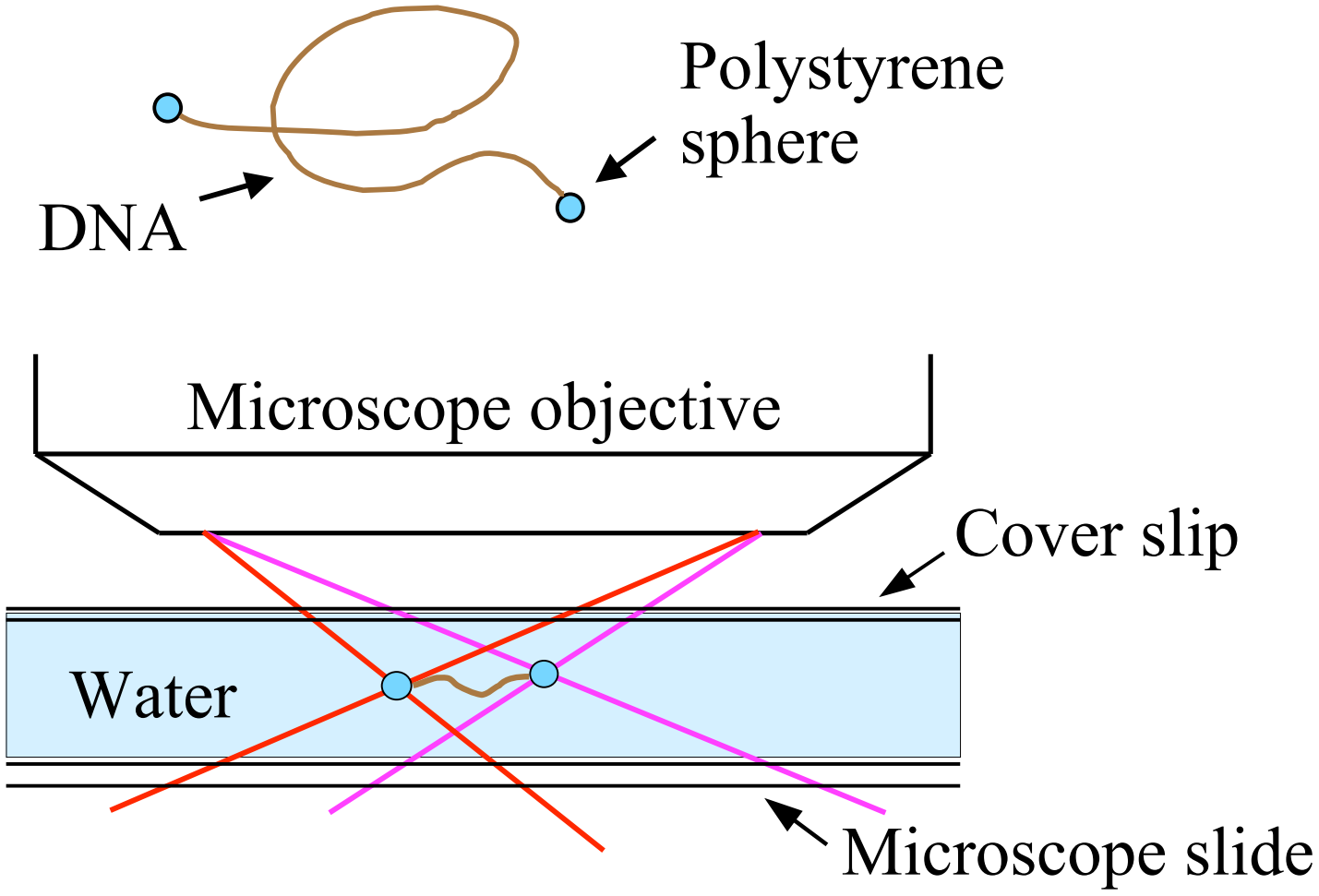
Chu, Bjorkholm, Cable and Ashkin (1986)



Ashkin, Diezic, Bjorkholm and Chu (1986)

Laser Manipulation of DNA

S. Chu, Science **253**, 861 (1991)




08:44:51 92

By looking at Bio-molecules, one at a time, we found that

identical molecules, placed in identical external conditions act as individuals!

"Molecular individualism"

Standard reactions to a scientific discovery

Its wrong.

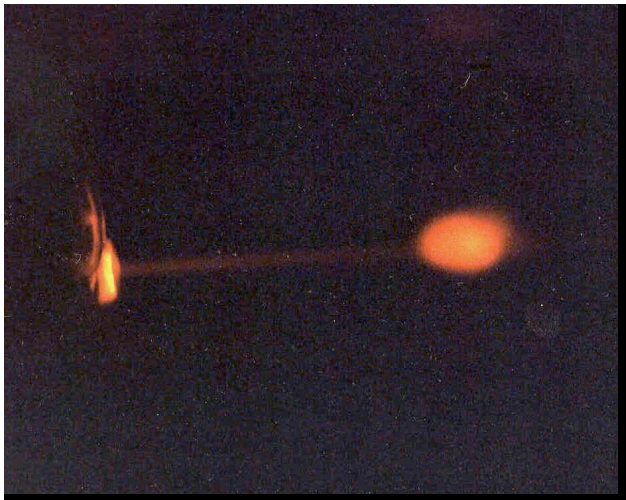
Its trivial.

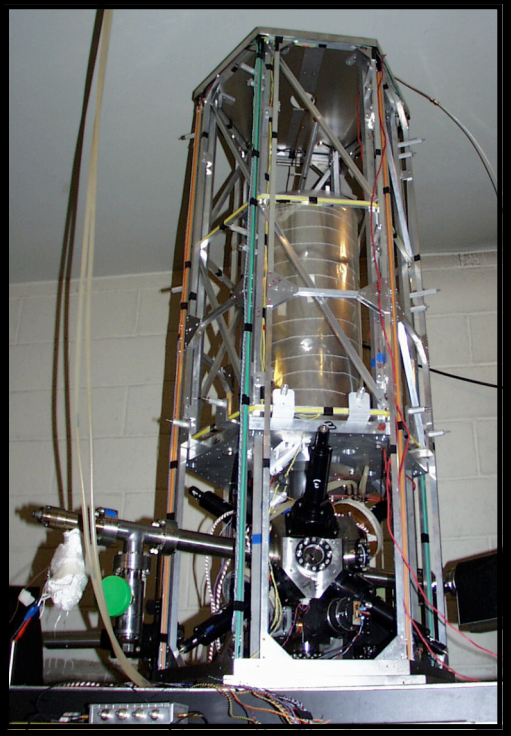
You were not the first to discover it!

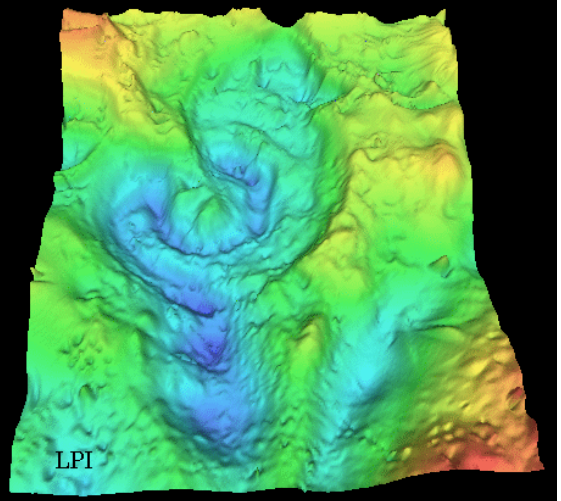
What about biology?

Most of what we know about in chemistry and biology has been determined by bulk studies …

… could we have missed something?



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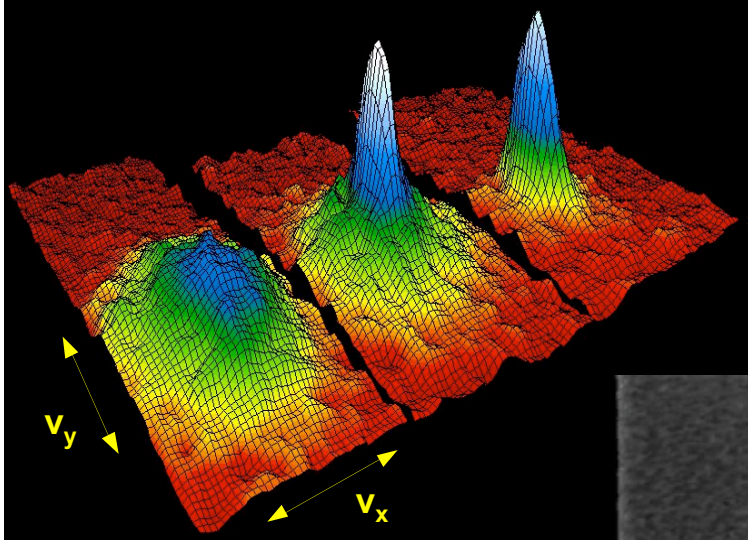
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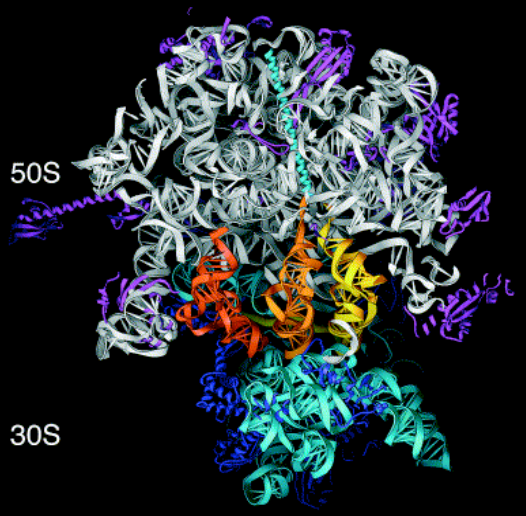
50S
30S

When my colleagues and I first began our work, we never foresaw the wealth of applications that would follow in just a few years….Instead of working with a clear vision of the future, I followed my nose, head close to the ground where the scent is strongest…

The knowledge we acquire in science is additive. At its core is our ability to build on the knowledge of others. As scientists, we hope that others take note of what we have done, and use our work to go in directions we never imagined. In this way, we continue to add to our collective scientific legacy…."

me, Nobel Lecture, 1997