Touching Horizons with lasers at SIBOR

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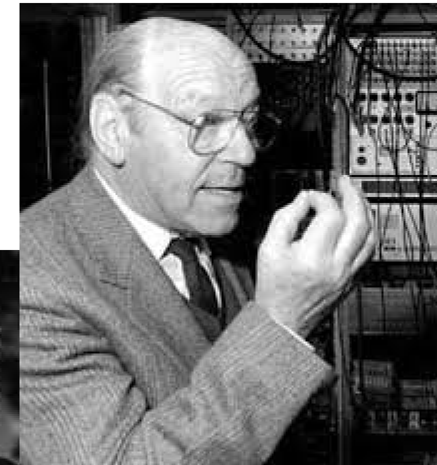
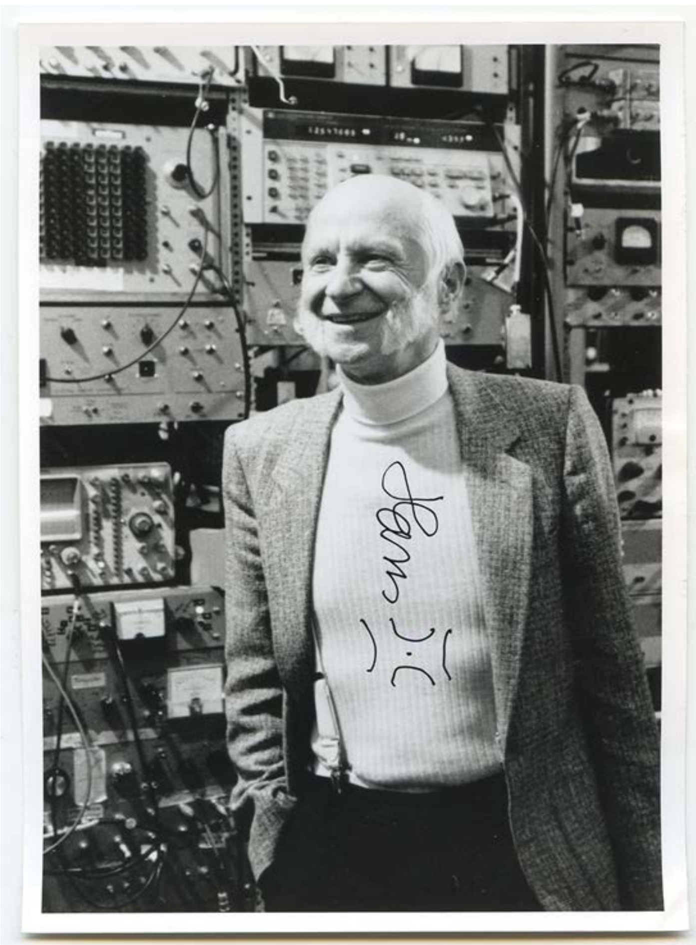
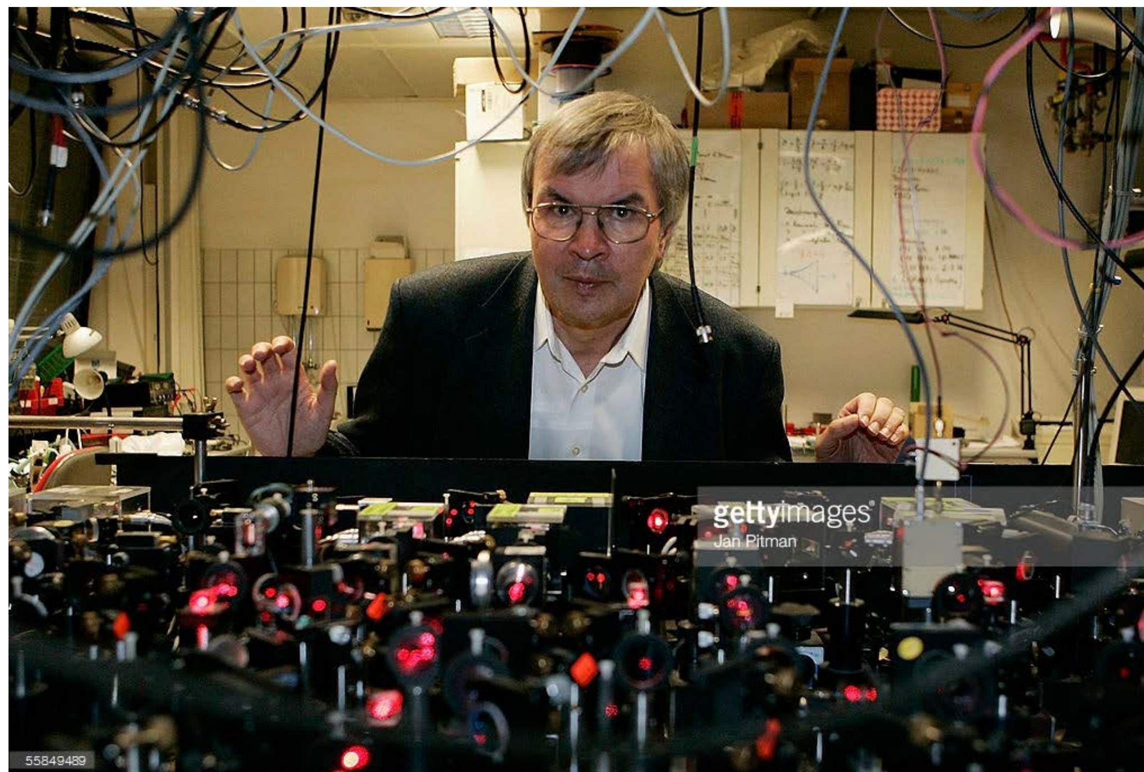
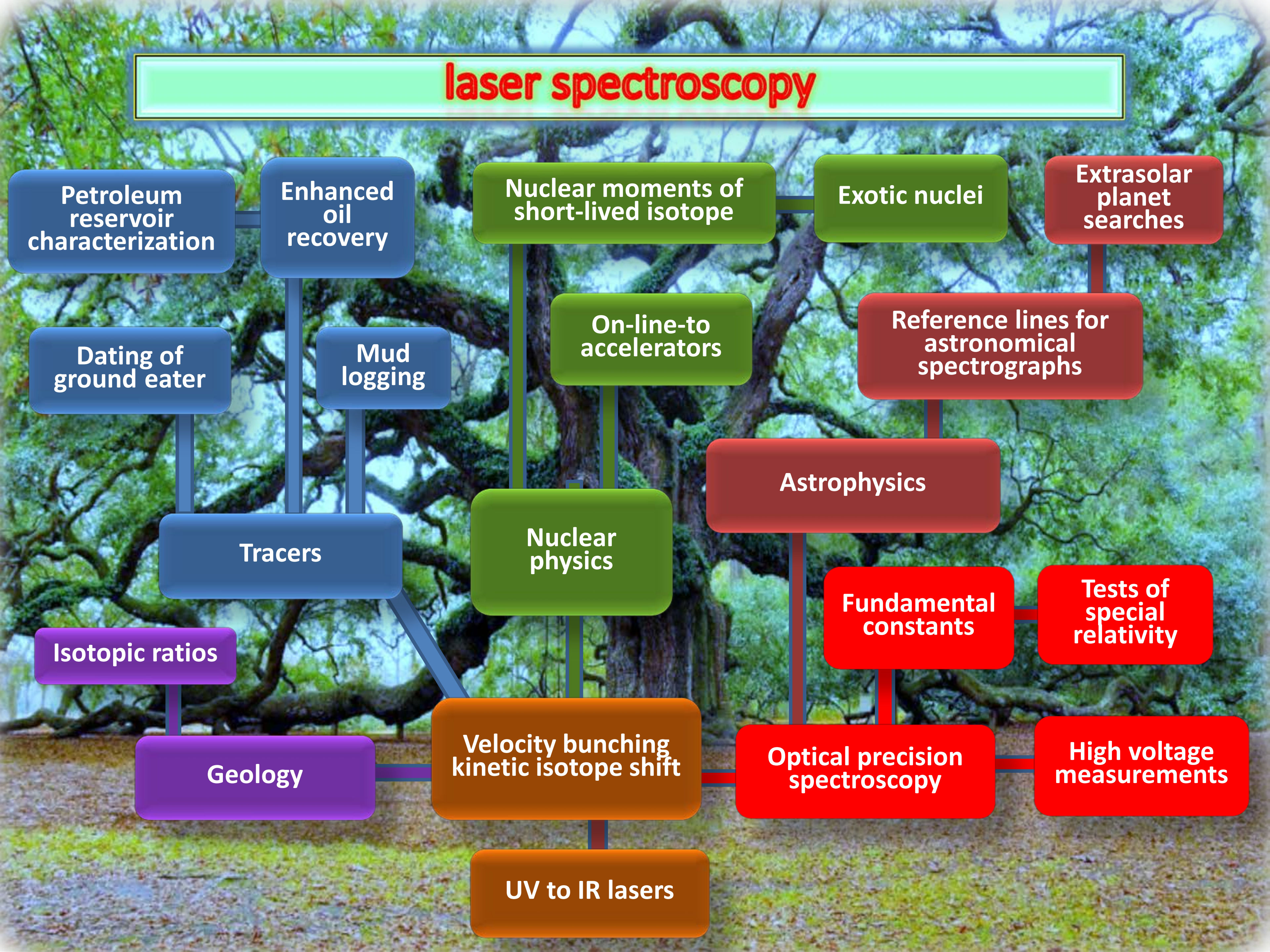
My Teachers

Hans Kopfermann
Hans Jensen (Nobel prize 1963)
Wolfgang Paul (Nobel prize 1989)
Hans Dehmelt(Nobel prize 1989)
Ted Haensch(Nobel prize 2005)



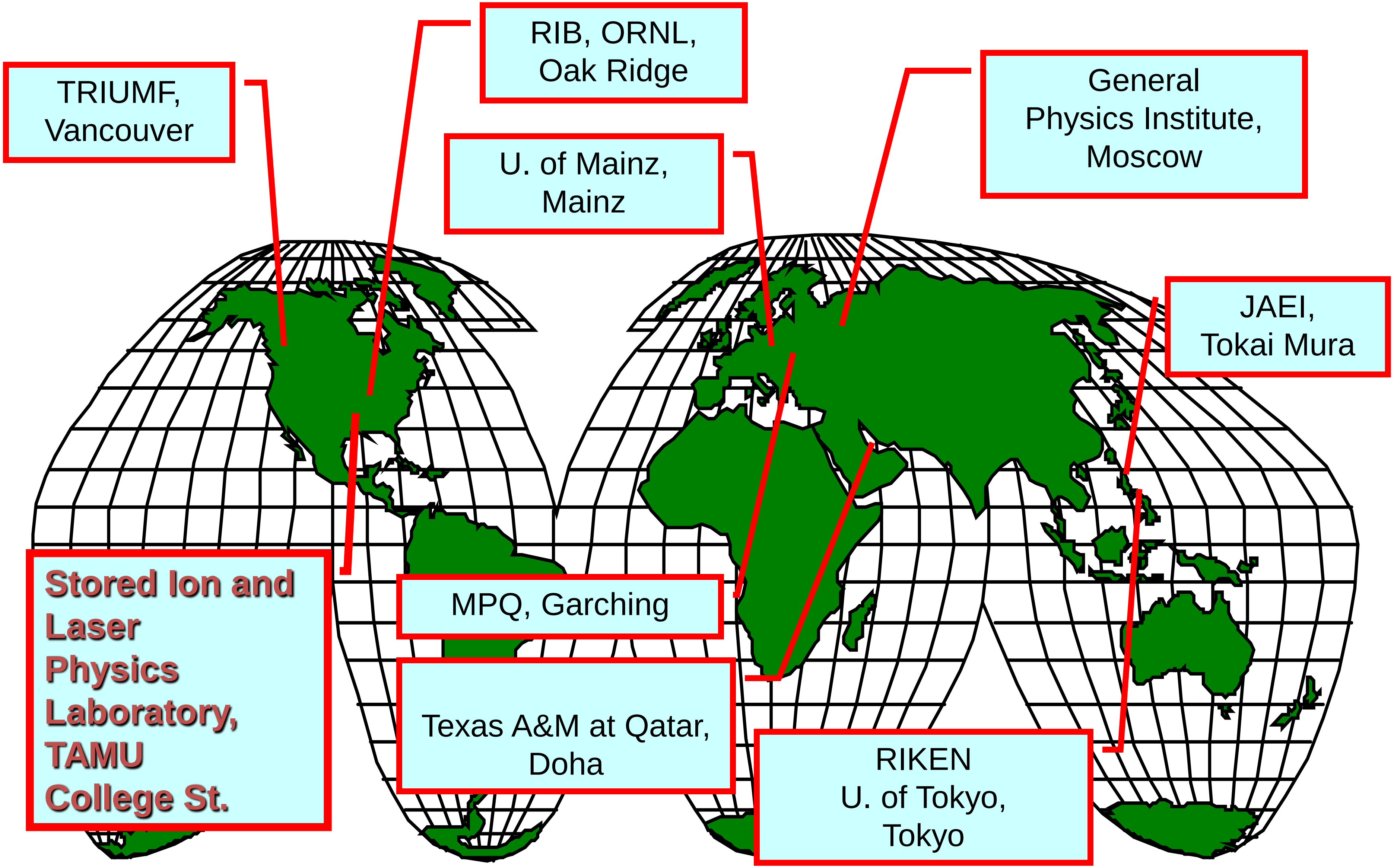






laser spectroscopy
Petroleum reservoir characterization
Enhanced oil recovery
Nuclear moments of short-lived isotope
Exotic nuclei
Extrasolar planet searches
Dating of ground eater
Mud logging
On-line-to accelerators
Reference lines for astronomical spectrographs
Astrophysics
Tracers
Nuclear physics
Fundamental constants
Tests of special relativity
Isotopic ratios
Geology
Velocity bunching kinetic isotope shift
Optical precision spectroscopy
High voltage measurements
UV to IR lasers

World collaborations



Outline

- SIBOR = **S**tored **I**on **B**io**O**ptical **R**esearch
- The International Year of Light 2015
- Atoms, the Periodic Table, and Molecules
- LASER = **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation
- Touching Horizons
  - In Atomic and Molecular Physics
  - In Nuclear Physics
  - In Astro Physics
  - In Environmental Physics
  - In the Biosciences
- Movie of Ion Trapping
  - Movie of Myosin walking on Tubulin

The International Year of Light

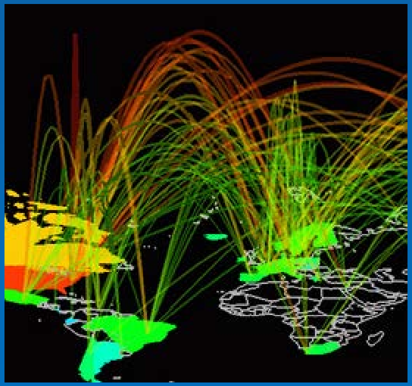
and Light-based Technologies

2015

INTERNATIONAL
YEAR OF LIGHT
2015

Health

Communications



Economy

Environment

Social

Opportunity for the future

The Proclamation of an International Year of Light is a tremendous opportunity to coordinate international activities and promote new initiatives to support the revolutionary potential of light technologies

How?

Clear themes, cross-cutting activities, communication with the public, such as Saturday Physics at TAMU

2015 celebrates major anniversaries

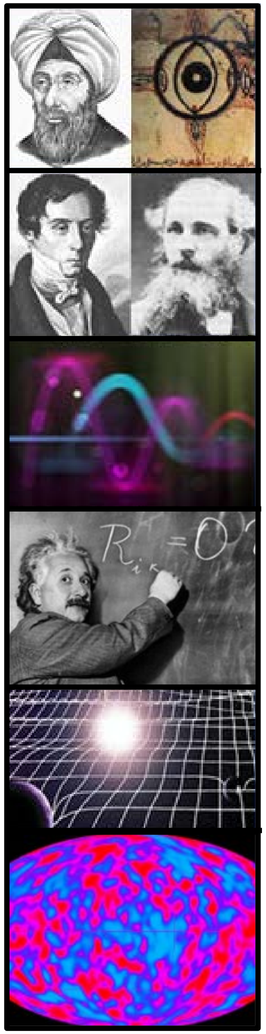
1015 Ibn Al Haythem *Book of Optics*

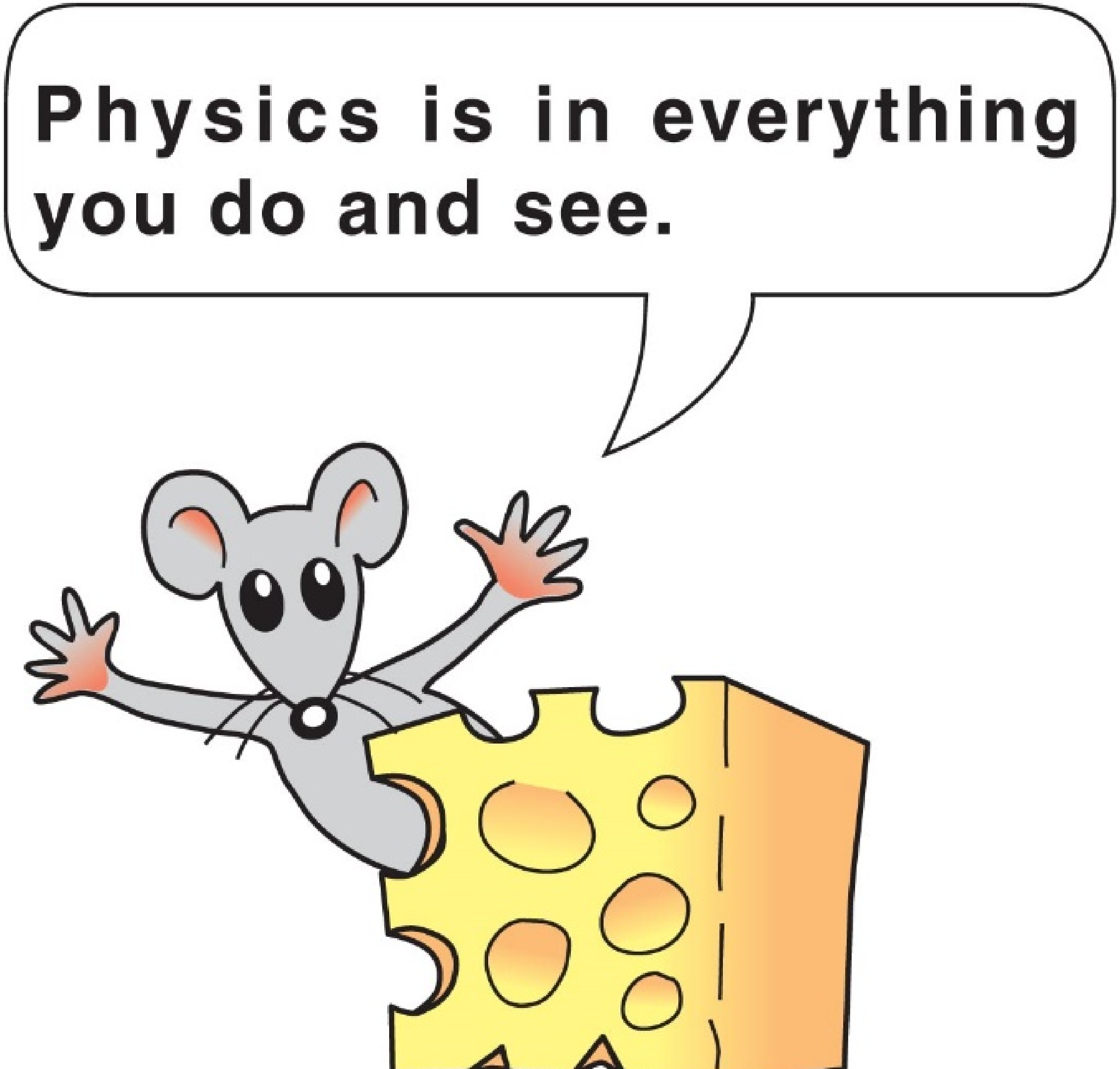
1815 Fresnel and the wave nature of light

1865 Maxwell and electromagnetic waves

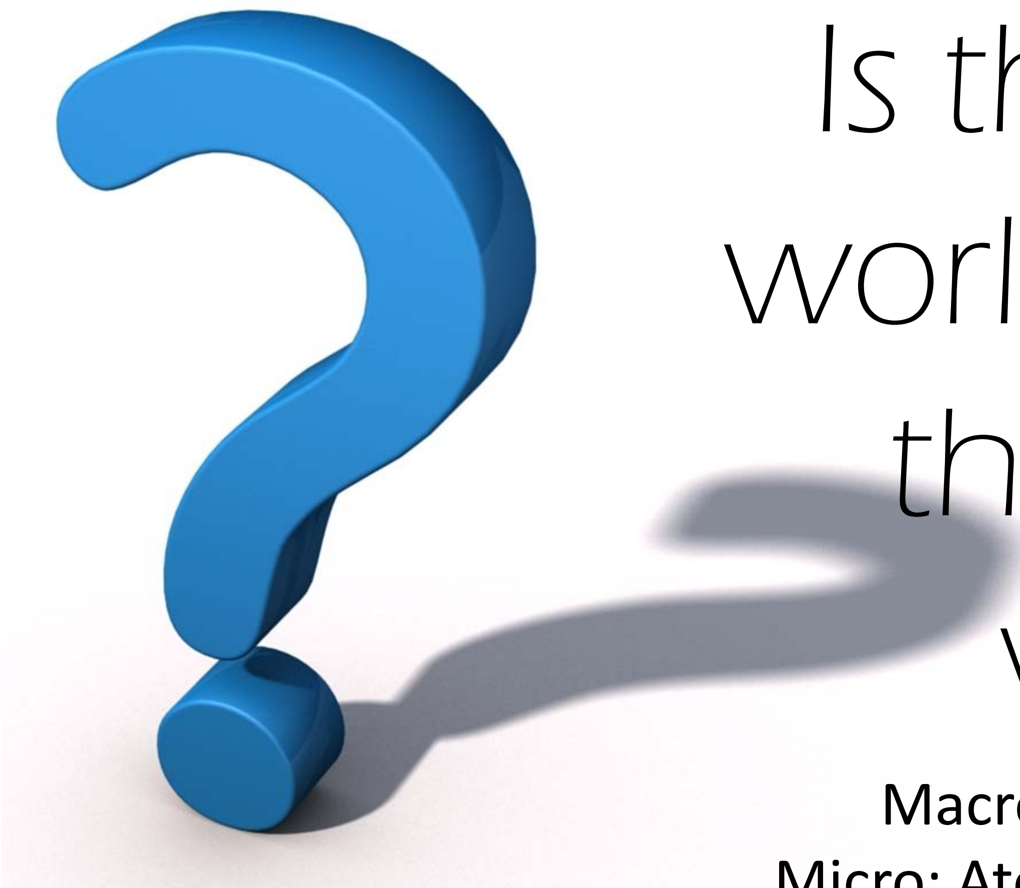
1915 General relativity – light in space and time

1965 Cosmic microwave background, Charles Kao and optical fibre technology




Physics is in everything you do and see.

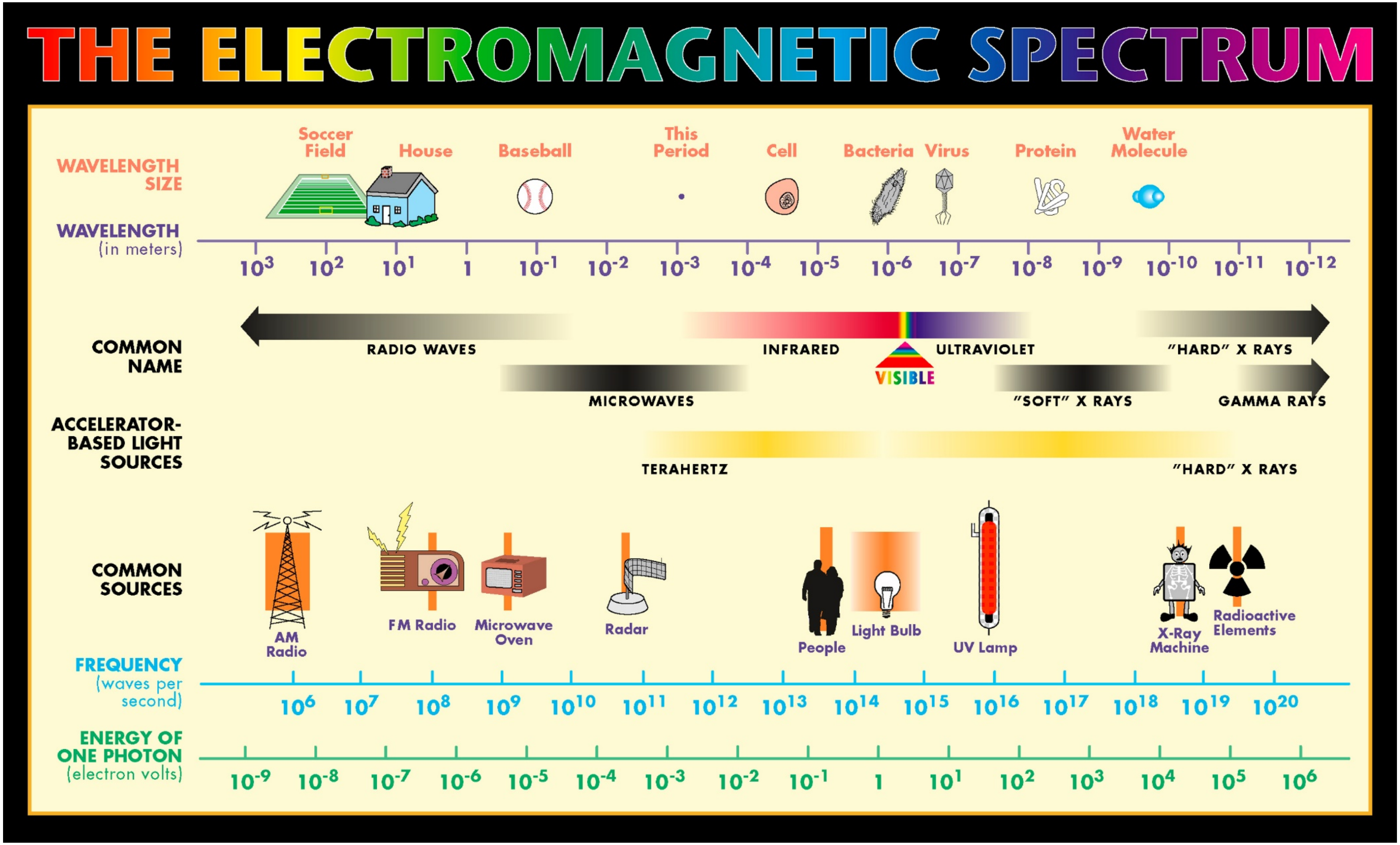
Atoms, the Periodic Table, and Molecules



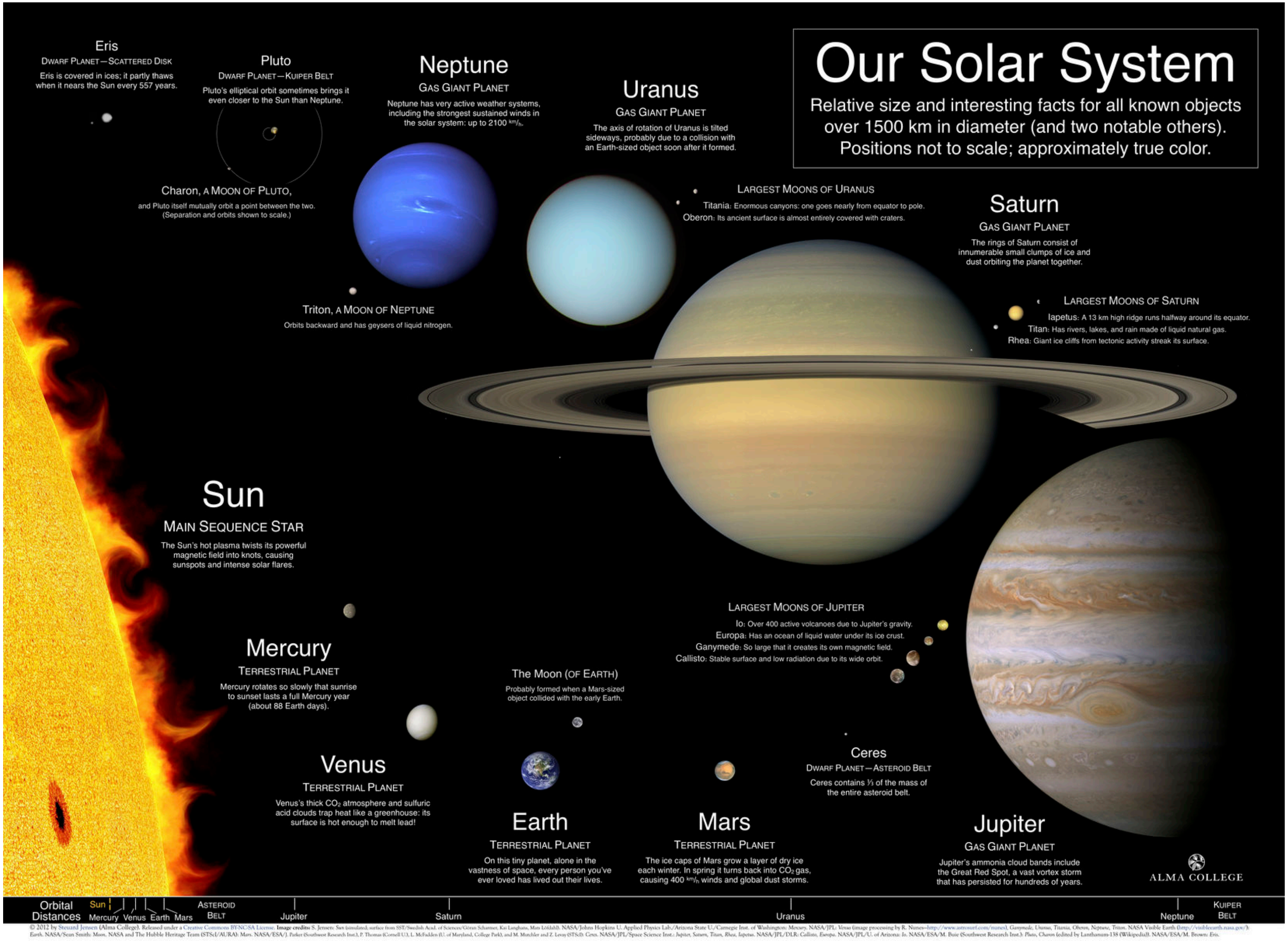
Is the micro world similar to the macro world?

Macro: Solar System

Micro: Atoms and Molecules


THE ELECTROMAGNETIC SPECTRUM
WAVELENGTH SIZE
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
WAVELENGTH (in meters)
10^3 10^2 10^1 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}
COMMON NAME
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
ACCELERATOR-BASED LIGHT SOURCES
TERAHERTZ
"HARD" X RAYS
COMMON SOURCES
AM Radio
FM Radio
Microwave Oven
Radar
People
Light Bulb
UV Lamp
X-Ray Machine
Radioactive Elements
FREQUENCY (waves per second)
10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20}
ENERGY OF ONE PHOTON (electron volts)
10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10^1 10^2 10^3 10^4 10^5 10^6

Solar System



http://www.slimy.com/~steuard/teaching/solarsystem/

4.4: The Bohr Model of the Hydrogen Atom

Bohr's dramatic general assumptions:

A. "Stationary" states or orbits must exist in atoms, i.e., orbiting electrons *do not radiate* energy in these orbits. These orbits or stationary states are of a fixed definite energy E.

B. The emission or absorption of electromagnetic radiation can occur only in conjunction with a transition between two stationary states. The frequency, f, of this radiation is proportional to the *difference* in energy of the two stationary states:

C. $$E = E_1 - E_2 = hf$$

where h is Planck's Constant

D. Classical laws of physics do not apply to transitions between stationary states.

A. The mean kinetic energy of the electron-nucleus system is $K = nhf_{orb}/2$, where f_{orb} is the frequency of rotation. This is equivalent to the angular momentum of a stationary state to be an integral multiple of $h/2\pi$

$$L = mvr = nh/2\pi$$

Bohr Radius

- The diameter of the hydrogen atom for stationary states is

$$r_n = \frac{4\pi\varepsilon_0 n^2 \hbar^2}{me^2} \equiv n^2 a_0$$

Where the **Bohr radius** is given by

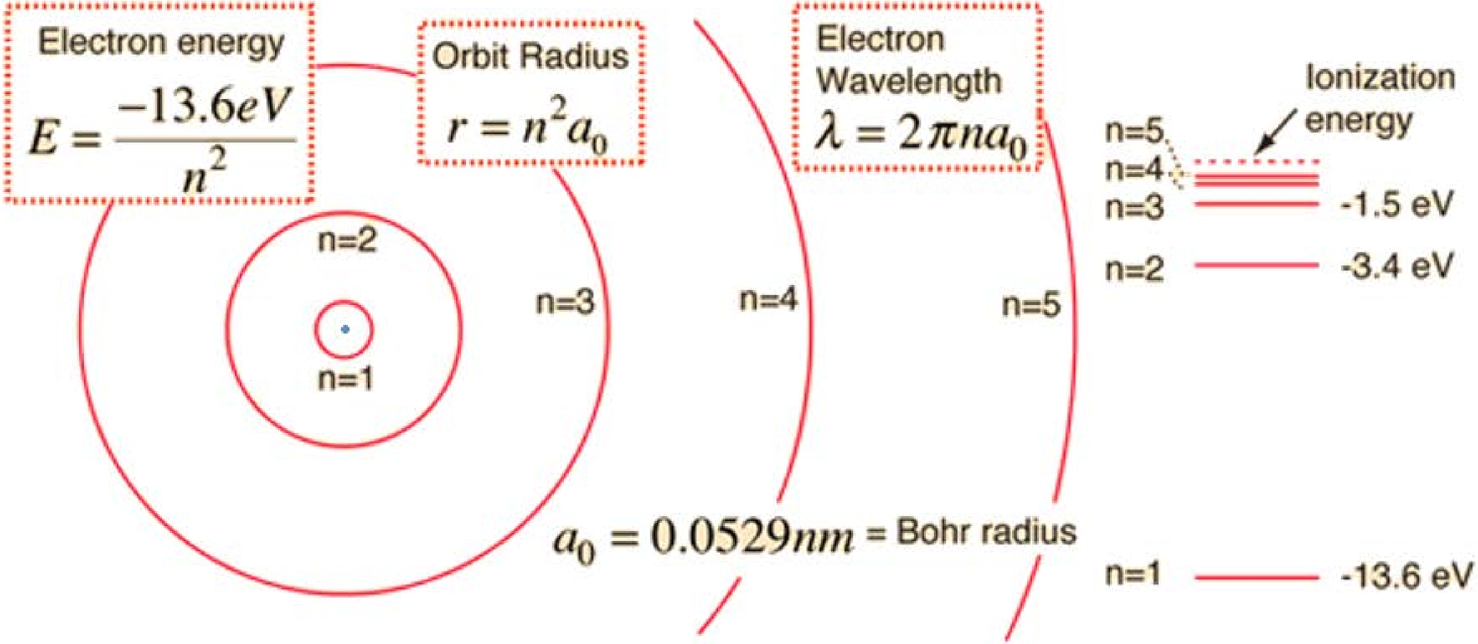
$$a_0 = \frac{4\pi\varepsilon_0 \hbar^2}{me^2} = \frac{(1.055\times10^{-34}\ \mathrm{J\cdot s})^2}{} \left(8.99\times10^{9}\,\frac{\mathrm{N\cdot m^2}}{\mathrm{C^2}}\right)(9.11\times10^{-31}\ \mathrm{kg})(1.6\times10^{-16}\ \mathrm{C})^2 = 0.53\times10^{-10}\ \mathrm{m}$$

- The smallest diameter of the hydrogen atom is

$$2r_1 = 2a_0 \approx 10^{-10}\mathrm{m}$$

- n = 1 gives its lowest energy state (called the "ground" state)

Hydrogen atom

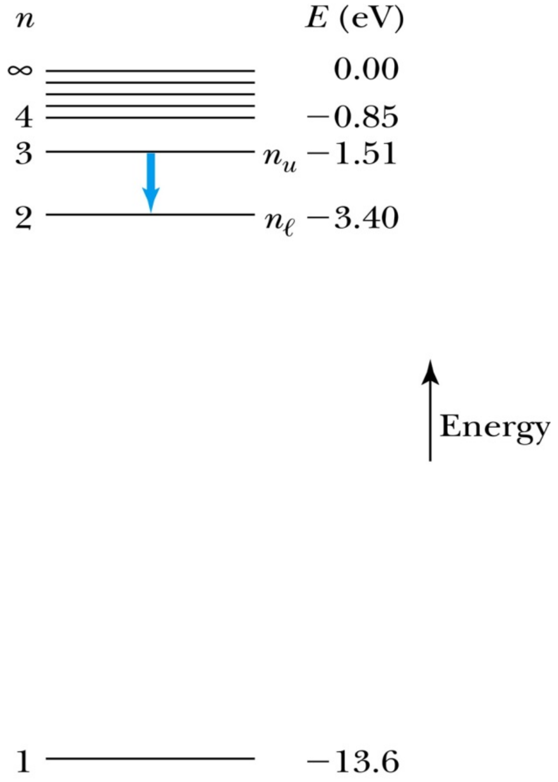


The Hydrogen Atom

- The energies of the stationary states

$$E_n = -\frac{e^2}{8\pi\varepsilon_0 r_n} = -\frac{e^2}{8\pi\varepsilon_0 a_0 n^2} \equiv -\frac{E_0}{n^2}$$

where E_0 = 13.6 eV



- Emission of light occurs when the atom is in an excited state and decays to a lower energy state ($n_u \rightarrow n_\ell$).

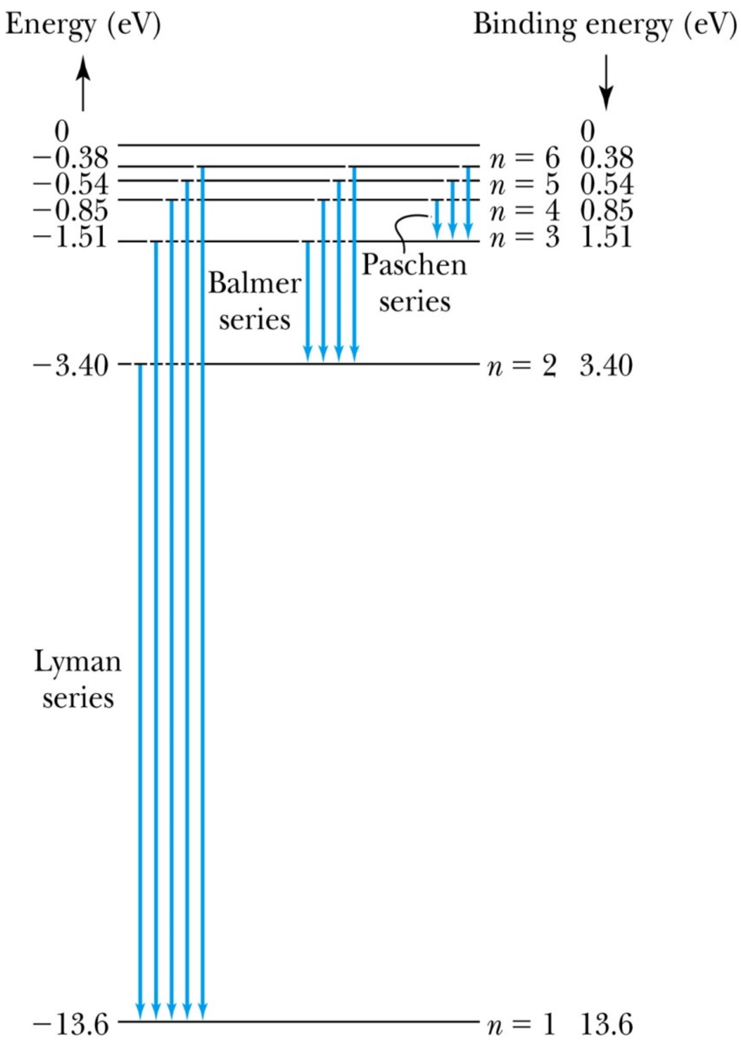
$$hf = E_u - E_\ell$$

where *f* is the frequency of a photon.

$$\frac{1}{\lambda} = \frac{f}{c} = \frac{E_u - E_\ell}{hc} = R_\infty \left(\frac{1}{n_\ell^{\ 2}} - \frac{1}{n_u^{\ 2}} \right)$$

R_∞ is the **Rydberg constant**.

Transitions in the Hydrogen Atom

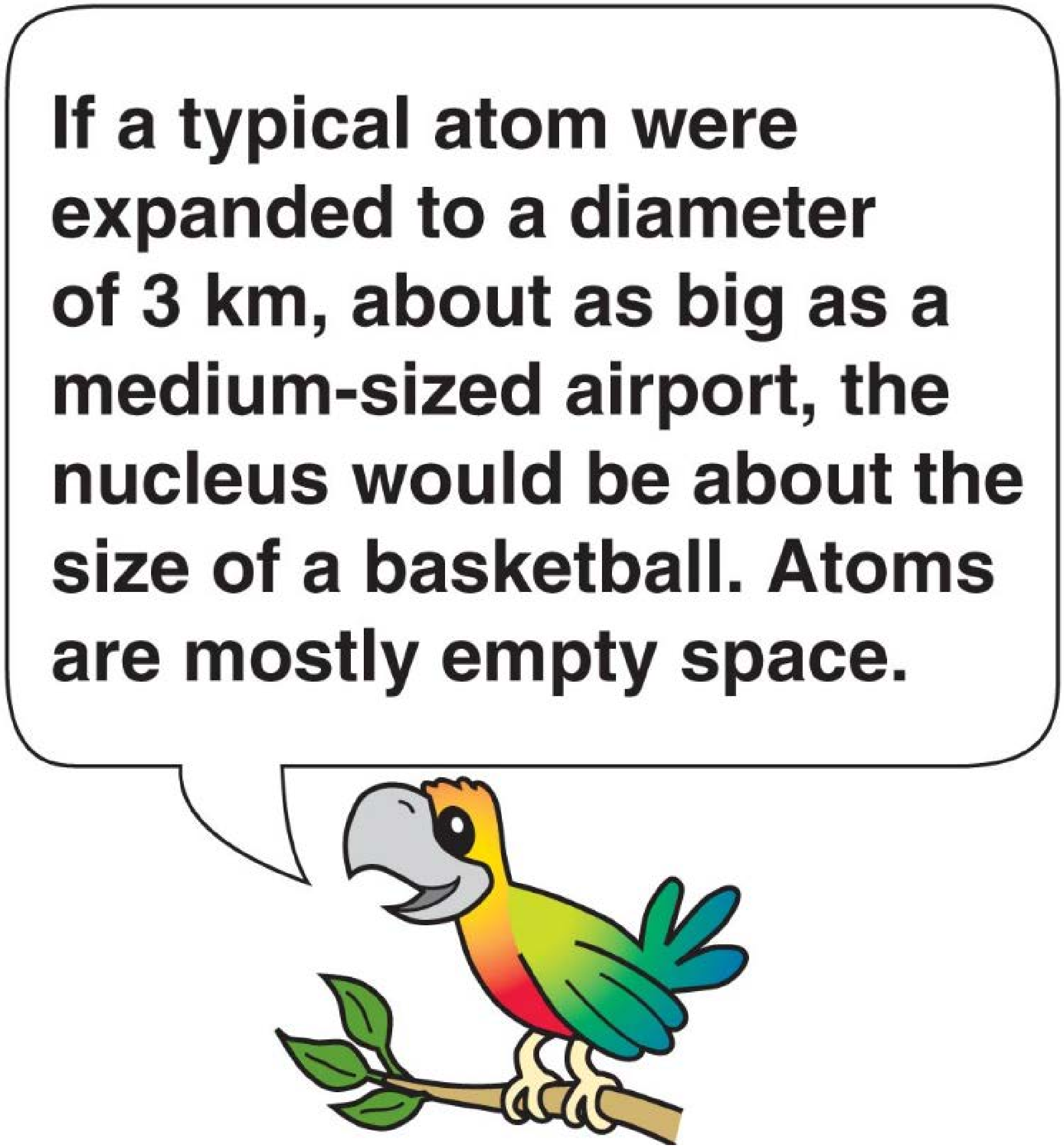


Lyman series

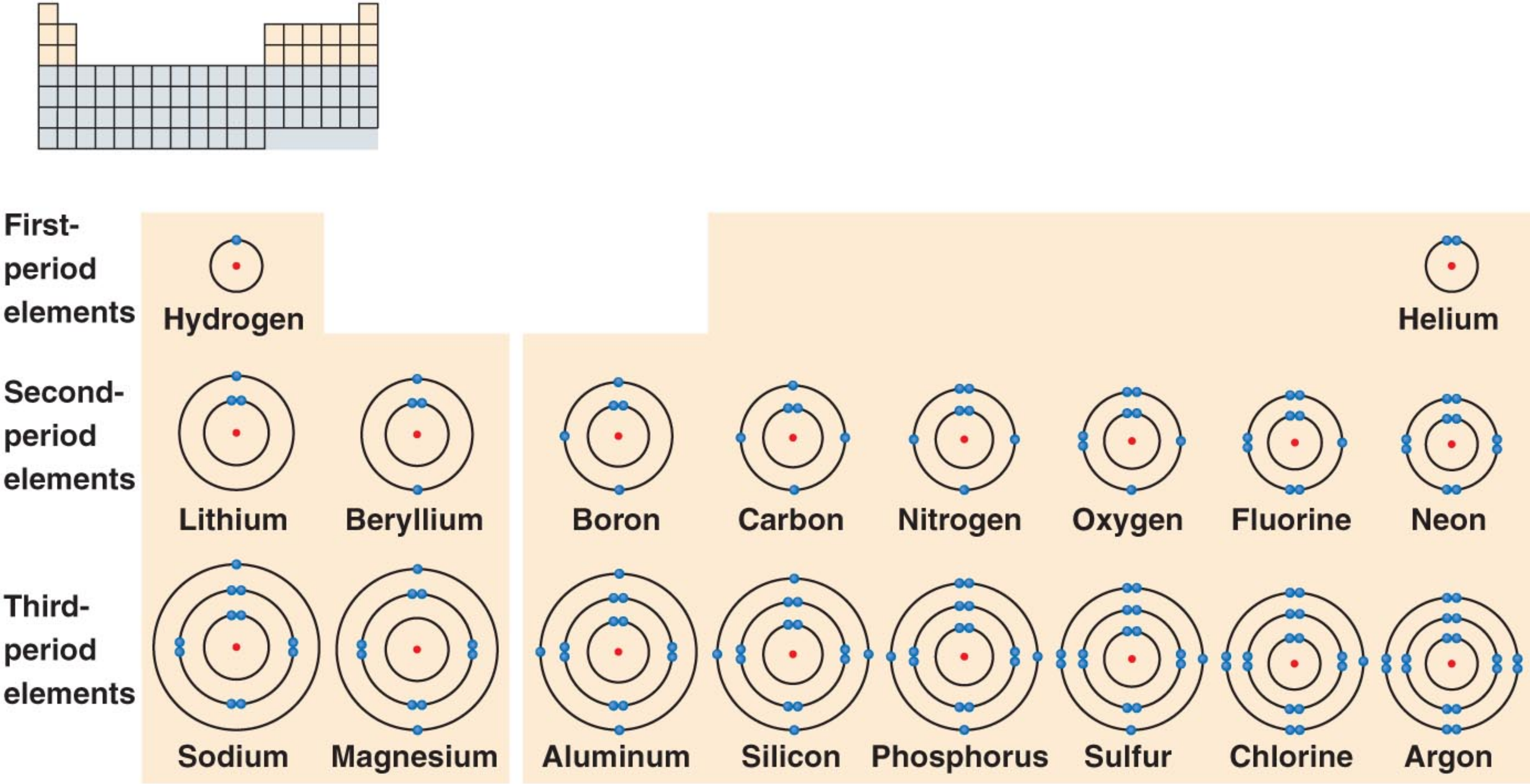
The atom will remain in the excited state for a short time before emitting a photon and returning to a lower stationary state. All hydrogen atoms exist in *n* = 1 (invisible).

Balmer series

When sunlight passes through the atmosphere, hydrogen atoms in water vapor absorb the wavelengths (visible).


If a typical atom were expanded to a diameter of 3 km, about as big as a medium-sized airport, the nucleus would be about the size of a basketball. Atoms are mostly empty space.

Successive filling of the electron shells in the periodic table



The Periodic Table

Periodic Table of Elements

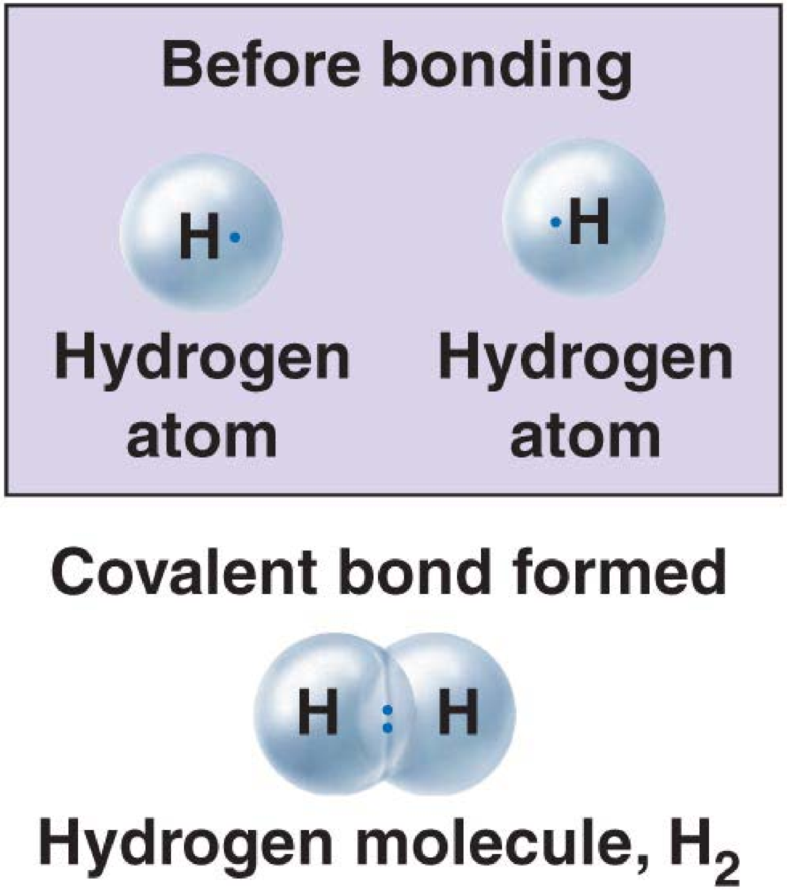
Closed shells | Alkalis (Group 1) | Alkaline earths (Group 2) | Transition elements (Groups 3–12) | Halogens (Group 17) | Rare gases (Group 18)

Closed shells	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1 **H** $1s$																	2 **He** $1s^2$
$1s^2$	3 **Li** $2s^1$	4 **Be** $2s^2$											5 **B** $2s^2 2p^1$	6 **C** $2s^2 2p^2$	7 **N** $2s^2 2p^3$	8 **O** $2s^2 2p^4$	9 **F** $2s^2 2p^5$	10 **Ne** $2s^2 2p^6$
$2s^2 2p^6$	11 **Na** $3s^1$	12 **Mg** $3s^2$											13 **Al** $3s^2 3p^1$	14 **Si** $3s^2 3p^2$	15 **P** $3s^2 3p^3$	16 **S** $3s^2 3p^4$	17 **Cl** $3s^2 3p^5$	18 **Ar** $3s^2 3p^6$
$3s^2 3p^6$	19 **K** $4s^1$	20 **Ca** $4s^2$	21 **Sc** $3d^1 4s^2$	22 **Ti** $3d^2 4s^2$	23 **V** $3d^3 4s^2$	24 **Cr** $3d^5 4s^1$	25 **Mn** $3d^5 4s^2$	26 **Fe** $3d^6 4s^2$	27 **Co** $3d^7 4s^2$	28 **Ni** $3d^8 4s^2$	29 **Cu** $3d^{10} 4s^1$	30 **Zn** $3d^{10} 4s^2$	31 **Ga** $3d^{10} 4s^2 4p^1$	32 **Ge** $3d^{10} 4s^2 4p^2$	33 **As** $3d^{10} 4s^2 4p^3$	34 **Se** $3d^{10} 4s^2 4p^4$	35 **Br** $3d^{10} 4s^2 4p^5$	36 **Kr** $3d^{10} 4s^2 4p^6$
$3d^{10} 4s^2 4p^6$	37 **Rb** $5s^1$	38 **Sr** $5s^2$	39 **Y** $4d^1 5s^2$	40 **Zr** $4d^2 5s^2$	41 **Nb** $4d^4 5s^1$	42 **Mo** $4d^5 5s^1$	43 **Tc** $4d^6 5s^1$	44 **Ru** $4d^7 5s^1$	45 **Rh** $4d^8 5s^1$	46 **Pd** $4d^{10}$	47 **Ag** $4d^{10} 5s^1$	48 **Cd** $4d^{10} 5s^2$	49 **In** $4d^{10} 5s^2 5p^1$	50 **Sn** $4d^{10} 5s^2 5p^2$	51 **Sb** $4d^{10} 5s^2 5p^3$	52 **Te** $4d^{10} 5s^2 5p^4$	53 **I** $4d^{10} 5s^2 5p^5$	54 **Xe** $4d^{10} 5s^2 5p^6$
$4d^{10} 5s^2 5p^6$	55 **Cs** $6s^1$	56 **Ba** $6s^2$	57 **La** $5d^1 6s^2$	72 **Hf** $4f^{14} 5d^2 6s^2$	73 **Ta** $4f^{14} 5d^3 6s^2$	74 **W** $4f^{14} 5d^4 6s^2$	75 **Re** $4f^{14} 5d^5 6s^2$	76 **Os** $4f^{14} 5d^6 6s^2$	77 **Ir** $4f^{14} 5d^9$	78 **Pt** $4f^{14} 5d^9 6s^1$	79 **Au** $4f^{14} 5d^{10} 6s^1$	80 **Hg** $4f^{14} 5d^{10} 6s^2$	81 **Tl** $4f^{14} 5d^{10} 6s^2 6p^1$	82 **Pb** $4f^{14} 5d^{10} 6s^2 6p^2$	83 **Bi** $4f^{14} 5d^{10} 6s^2 6p^3$	84 **Po** $4f^{14} 5d^{10} 6s^2 6p^4$	85 **At** $4f^{14} 5d^{10} 6s^2 6p^5$	86 **Rn** $4f^{14} 5d^{10} 6s^2 6p^6$
$4f^{14} 5d^{10} 6s^2 6p^6$	87 **Fr** $7s^1$	88 **Ra** $7s^2$	89 **Ac** $6d^1 7s^2$	104 **Rf** $5f^{14} 6d^2 7s^2$	105 **Db** $5f^{14} 6d^3 7s^2$	106 **Sg** $5f^{14} 6d^4 7s^2$	107 **Bh** $5f^{14} 6d^5 7s^2$	108 **Hs** $5f^{14} 6d^6 7s^2$	109 **Mt** $5f^{14} 6d^7 7s^2$	110 **Ds** $5f^{14} 6d^9 7s^1$	111 **Rg** $5f^{14} 6d^{10} 7s^1$	112 **Cn** $5f^{14} 6d^{10} 7s^2$						

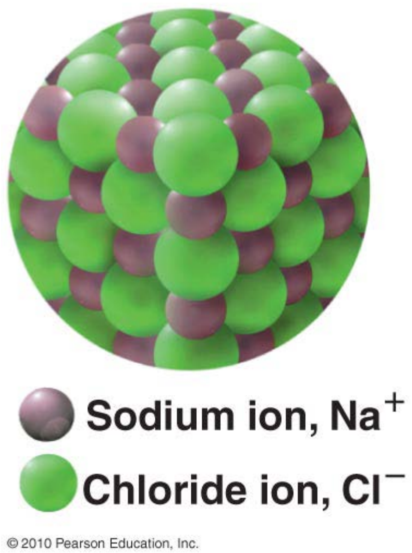
Lanthanides	58 **Ce** $4f^2 6s^2$	59 **Pr** $4f^3 6s^2$	60 **Nd** $4f^4 6s^2$	61 **Pm** $4f^5 6s^2$	62 **Sm** $4f^6 6s^2$	63 **Eu** $4f^7 6s^2$	64 **Gd** $4f^7 6s^2 5d^1$	65 **Tb** $4f^9 6s^2$	66 **Dy** $4f^{10} 6s^2$	67 **Ho** $4f^{11} 6s^2$	68 **Er** $4f^{12} 6s^2$	69 **Tm** $4f^{13} 6s^2$	70 **Yb** $4f^{14} 6s^2$	71 **Lu** $4f^{14} 5d^1 6s^2$
Actinides	90 **Th** $6d^2 7s^2$	91 **Pa** $5f^2 6d^1 7s^2$	92 **U** $5f^3 6d^1 7s^2$	93 **Np** $5f^4 6d^1 7s^2$	94 **Pu** $5f^6 7s^2$	95 **Am** $5f^7 7s^2$	96 **Cm** $5f^7 6d^1 7s^2$	97 **Bk** $5f^8 6d^1 7s^2$	98 **Cf** $5f^{10} 7s^2$	99 **Es** $5f^{11} 7s^2$	100 **Fm** $5f^{12} 7s^2$	101 **Md** $5f^{13} 7s^2$	102 **No** $5f^{14} 7s^2$	103 **Lr** $5f^{14} 6d^1 7s^2$

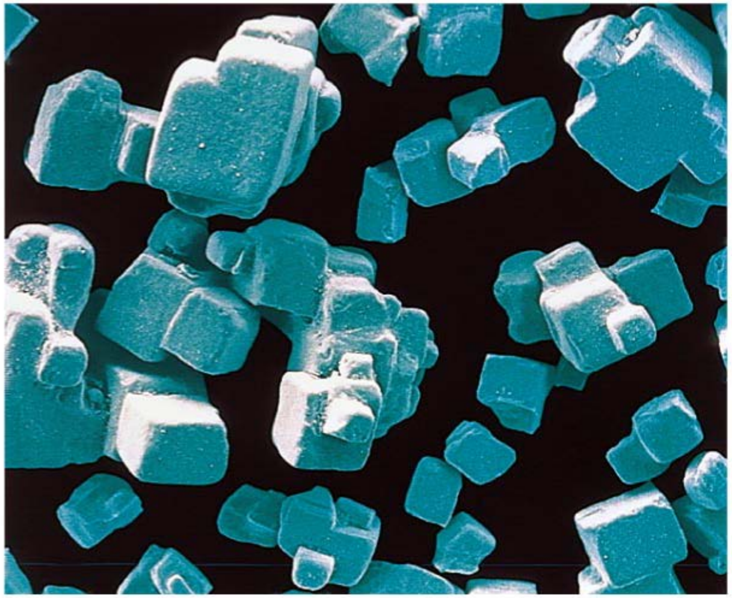
Simplest molecule

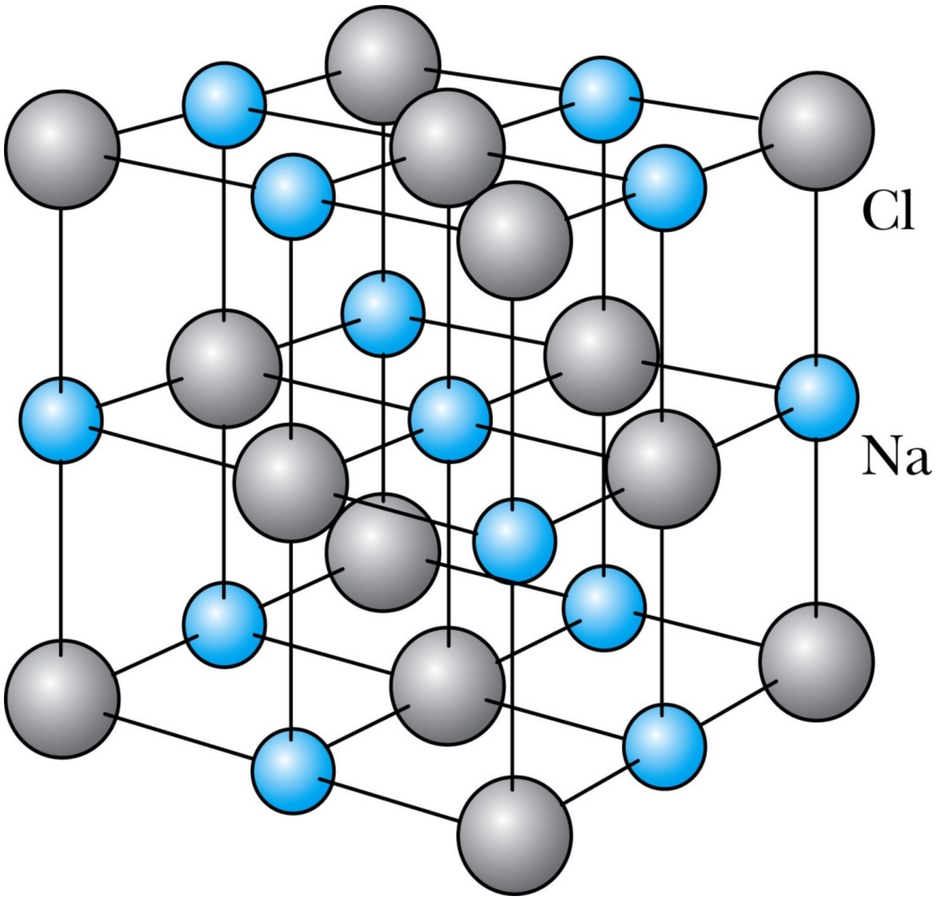
- Covalent Bond-
  - A chemical bond formed by the sharing of one or more electrons between atoms



A solid Sodium chloride = salt





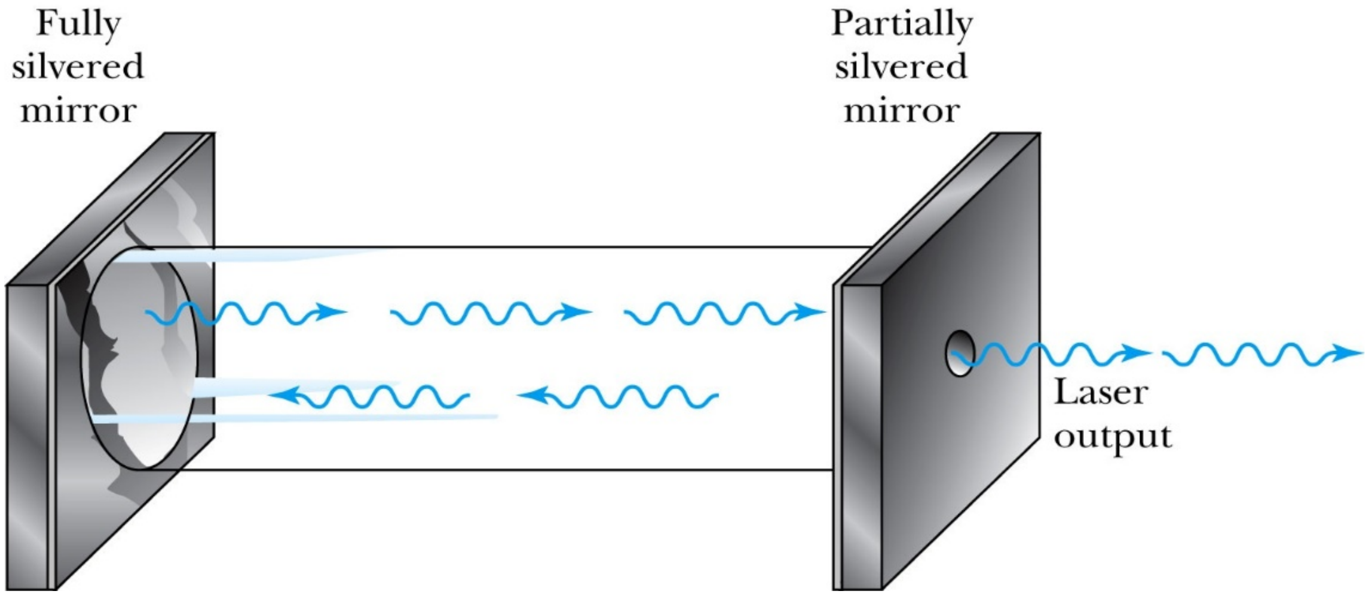


Laser

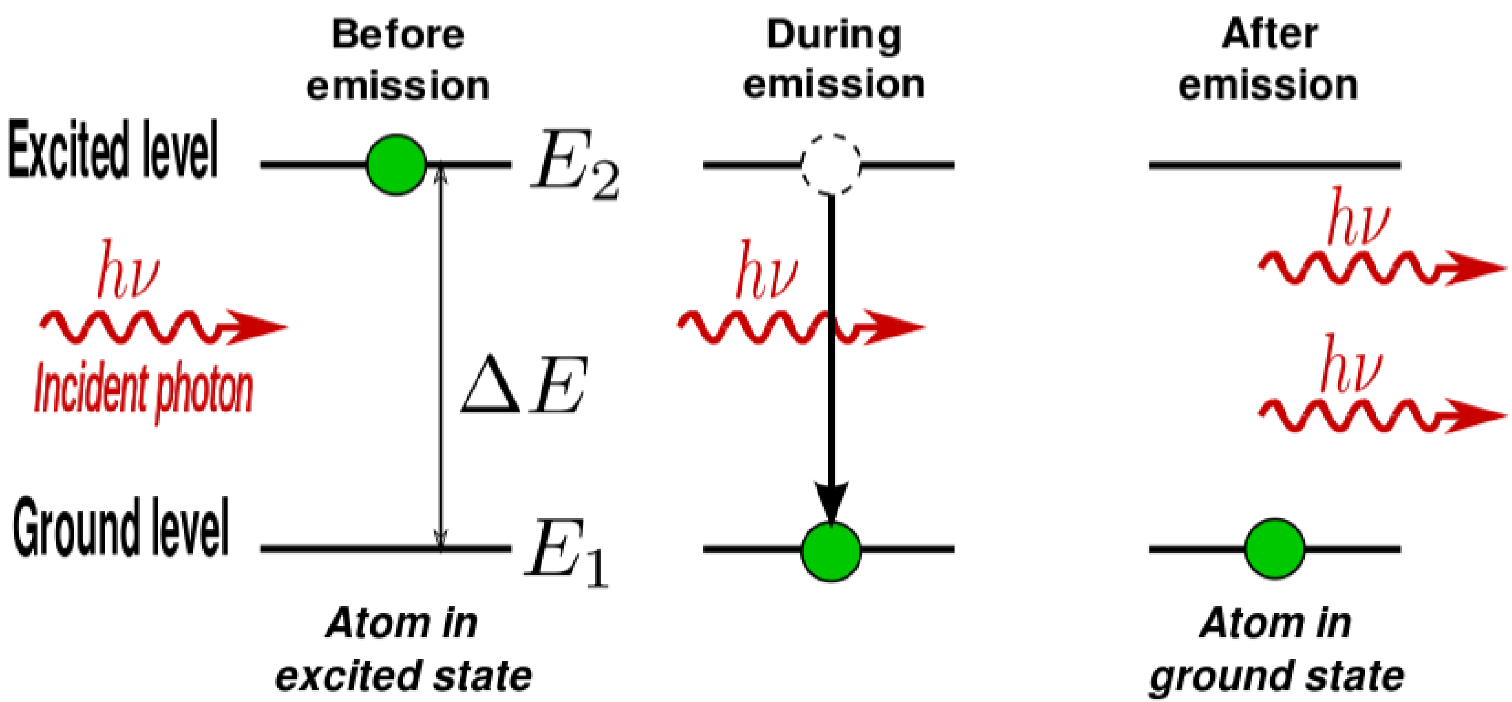
Laser:

- An acronym for "light amplification by the stimulated emission of radiation"

- The first working laser by Theodore H. Maiman in 1960



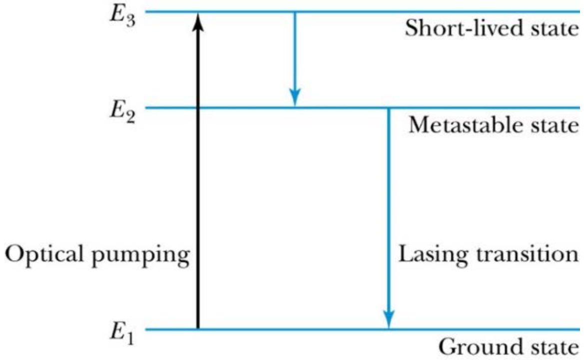
Stimulated Emission



$$E_2 - E_1 = \Delta E = h\nu$$

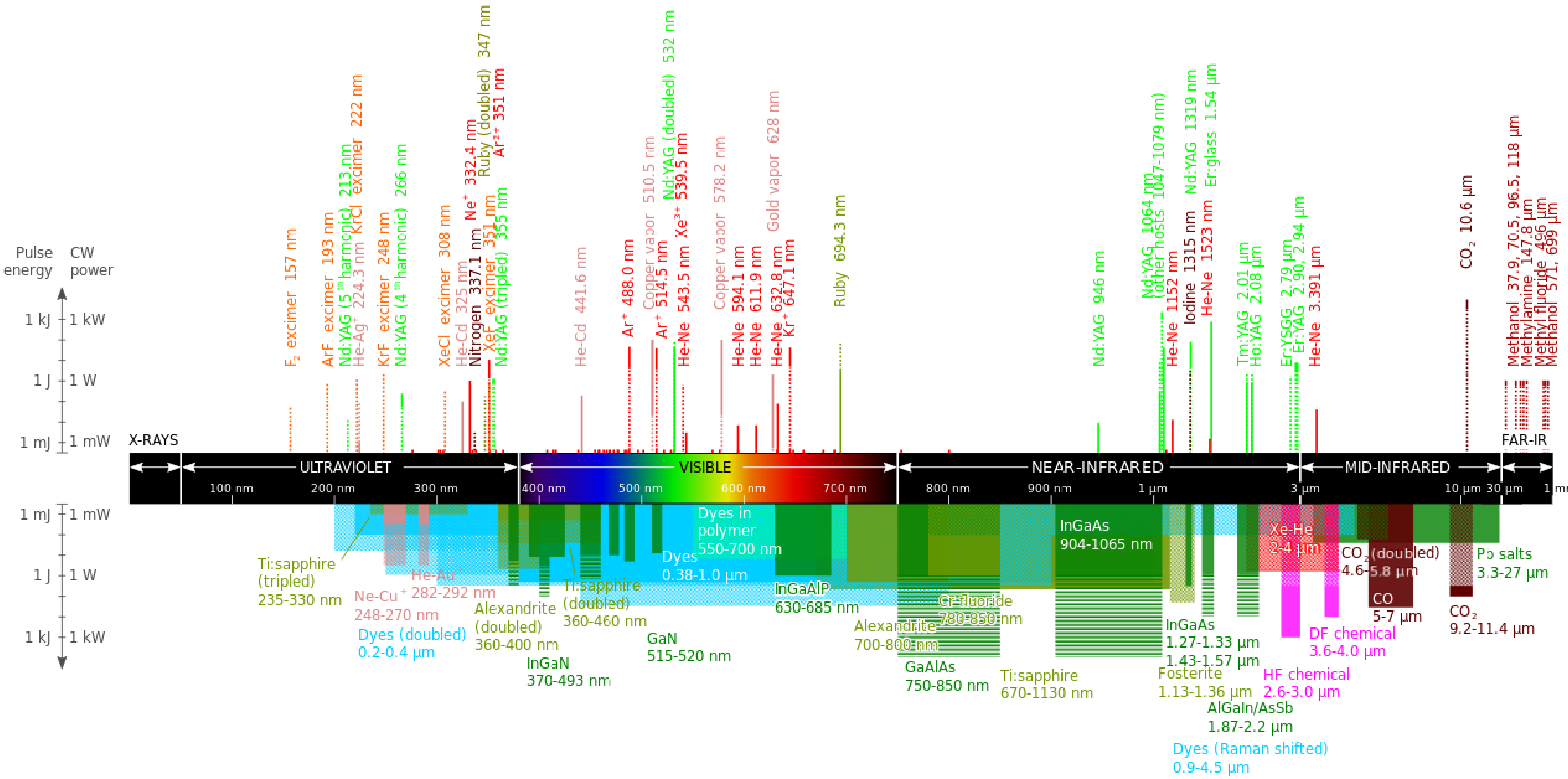
Stimulated emission and lasers

- **Three-level system**



1) Atoms in the ground state are *pumped* to a higher state by some external energy.
2) The atom decays quickly to E_2.
   The transition from E_2 to E_1 is forbidden by a $\Delta\ell = \pm 1$ selection rule.
   E_2 is said to be *metastable*.
3) *Population inversion*: more atoms are in the metastable than in the ground state

Figure 10-13 p350



Pulse energy
CW power
1 kJ
1 kW
1 J
1 W
1 mJ
1 mW
X-RAYS
ULTRAVIOLET
VISIBLE
NEAR-INFRARED
MID-INFRARED
FAR-IR
100 nm
200 nm
300 nm
400 nm
500 nm
600 nm
700 nm
800 nm
900 nm
1 µm
3 µm
10 µm
30 µm
1 mm
F2 excimer 157 nm
ArF excimer 193 nm
Nd:YAG (5th harmonic) 213 nm
KrCl excimer 222 nm
He-Ag+ 224.3 nm
KrF excimer 248 nm
Nd:YAG (4th harmonic) 266 nm
XeCl excimer 308 nm
He-Cd 325 nm
Ne+ 332.4 nm
Nitrogen 337.1 nm
Ruby (doubled) 347 nm
XeF excimer 351 nm
Ar2+ 351 nm
Nd:YAG (tripled) 355 nm
He-Cd 441.6 nm
Ar+ 488.0 nm
Copper vapor 510.5 nm
Ar+ 514.5 nm
Nd:YAG (doubled) 532 nm
Xe3+ 539.5 nm
He-Ne 543.5 nm
Copper vapor 578.2 nm
He-Ne 594.1 nm
He-Ne 611.9 nm
Gold vapor 628 nm
He-Ne 632.8 nm
Kr+ 647.1 nm
Ruby 694.3 nm
Nd:YAG 946 nm
Nd:YAG 1064 nm (other hosts 1047-1079 nm)
He-Ne 1152 nm
Iodine 1315 nm
Nd:YAG 1319 nm
He-Ne 1523 nm
Er:glass 1.54 µm
Tm:YAG 2.01 µm
Ho:YAG 2.08 µm
Er:YSGG 2.79 µm
Er:YAG 2.90, 2.94 µm
He-Ne 3.391 µm
CO2 10.6 µm
Methanol 37.9, 70.5, 96.5, 118 µm
Methylamine 147.8 µm
Methyl fluoride 496 µm
Methanol 571, 699 µm
Ti:sapphire (tripled) 235-330 nm
Ne-Cu+ 248-270 nm
He-Au+ 282-292 nm
Dyes (doubled) 0.2-0.4 µm
Alexandrite (doubled) 360-400 nm
InGaN 370-493 nm
Ti:sapphire (doubled) 360-460 nm
GaN 515-520 nm
Dyes in polymer 550-700 nm
Dyes 0.38-1.0 µm
InGaAlP 630-685 nm
Alexandrite 700-800 nm
Cr:fluoride 780-850 nm
GaAlAs 750-850 nm
Ti:sapphire 670-1130 nm
InGaAs 904-1065 nm
InGaAs 1.27-1.33 µm 1.43-1.57 µm
Fosterite 1.13-1.36 µm
AlGaIn/AsSb 1.87-2.2 µm
Dyes (Raman shifted) 0.9-4.5 µm
Xe-He 2-4 µm
HF chemical 2.6-3.0 µm
DF chemical 3.6-4.0 µm
CO2 (doubled) 4.6-5.8 µm
CO 5-7 µm
CO2 9.2-11.4 µm
Pb salts 3.3-27 µm

TOUCHING HORIZONS

In Atomic and Molecular Physics

Seeing is believing,
but can we see an
atom?

Values of the Fundamental Constants http://physics.nist.gov/cuu/Constants/

c = 299,792,458 m·s^{-1}

$\hbar$ = 1.054571596(82) × 10^{-34} J·s

G = 6.673(10) × 10^{-11} m^3·kg^{-1}·s^{-2}

m_e = 9.10938188(72) × 10^{-31} kg

m_p = 1.67262158(13) × 10^{-27} kg

m_n = 1.67492716(13) × 10^{-27} kg

e = 1.602176462(63) × 10^{-19} C

Dimensionless ratios characterize the strength of an interaction

$$\alpha_{EM} \equiv \frac{q^2}{\hbar c} \sim 1/137.03599976(50)$$

$$\alpha_W \equiv \frac{G_F m_P^2 c}{\hbar^3} \sim 1.03 \times 10^{-5}$$

$$\alpha_S(E) \equiv \frac{g_s^2(E)}{\hbar c}$$

$$\alpha_G \equiv \frac{G m_p^2}{\hbar c} \sim 5 \times 10^{-39}$$

$$\mu \equiv \frac{m_e}{m_p} \sim 5.44617 \times 10^{-4}$$

History of Hydrogen Spectroscopy

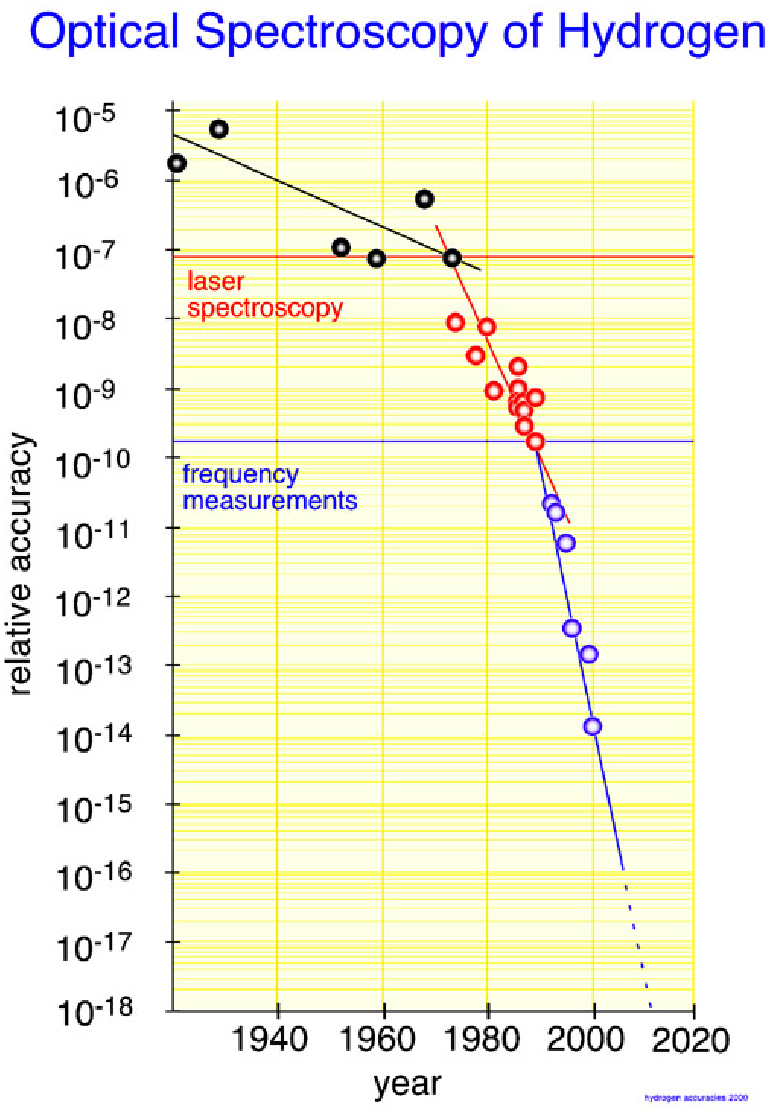
Planetary model
(Bohr)

Quantum mechanics
(Schroedinger)

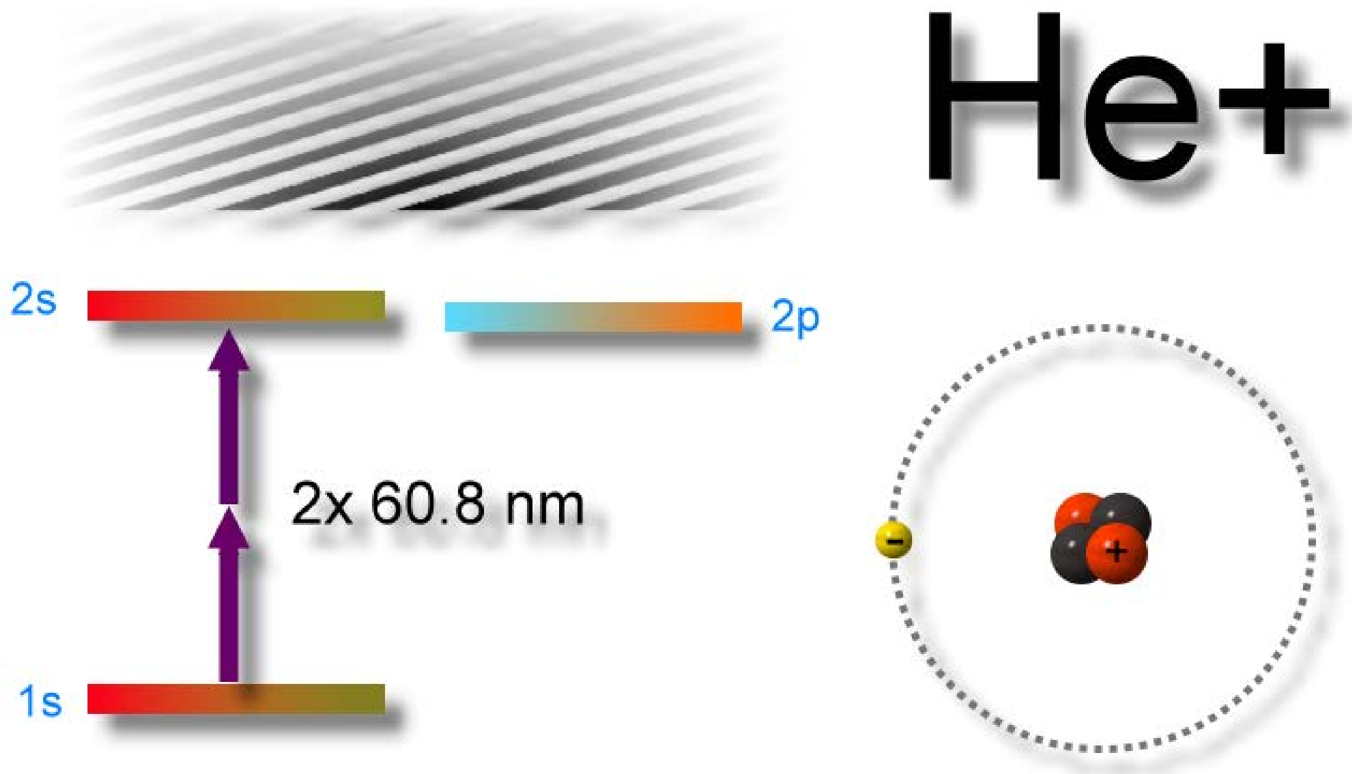
Relativistic quantum mechanics
(Feynman, Schwinger, Tomonaga)

Relativistic quantum field theory
(Lamb)

Standard model
(Glashow, Weinberg, Gell Mann)

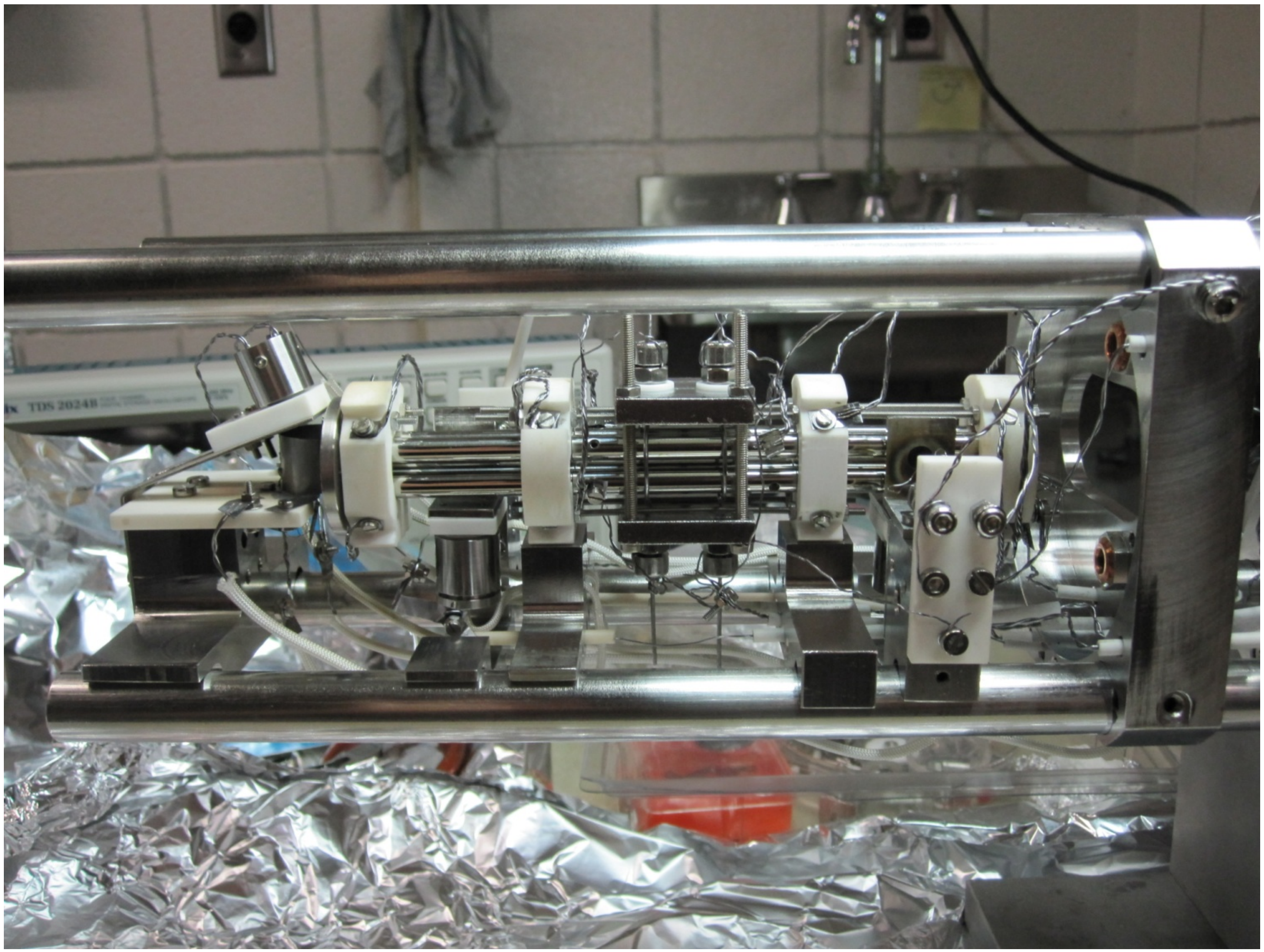


What?

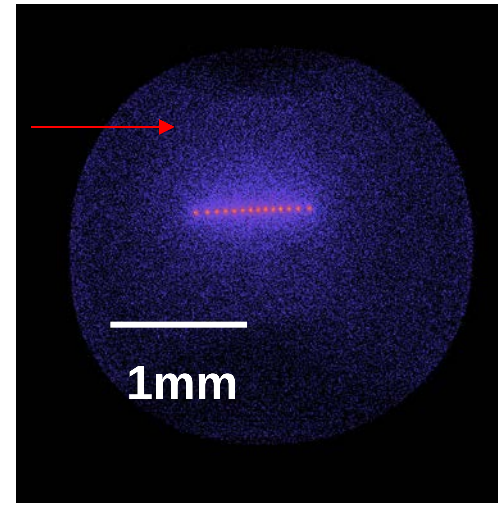


- Perform 2 photon precision spectroscopy on narrow (83Hz) transition in XUV on hydrogen like He+

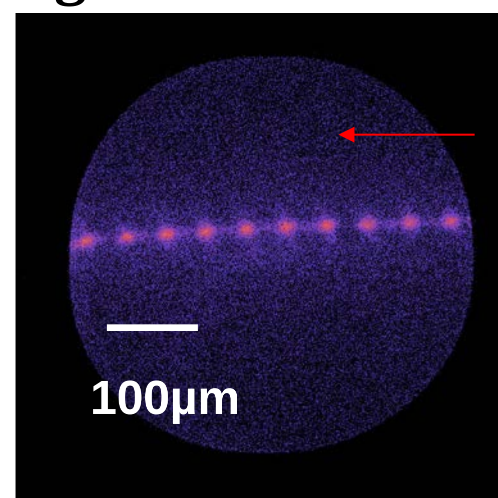
Ion Trap



Magnification ×6



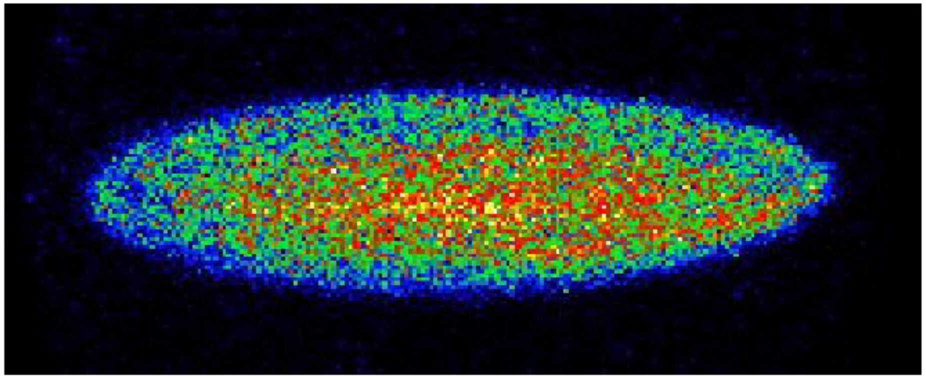
Magnification ×6 ×8

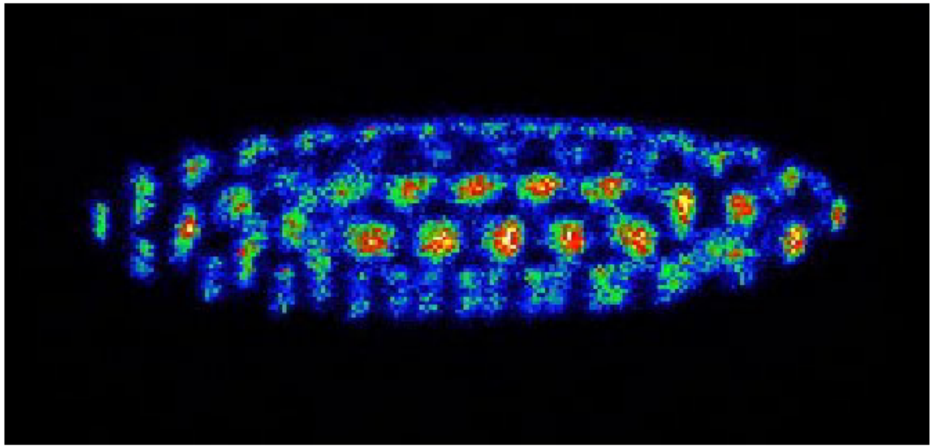


Results: Endcap Trap

Isotope selective Mg loading, imaging with very high time resolution (SPC)

$^{24}Mg^+$ cloud consisting of ~100 ions, cooling laser detuning ~GHz to the red -> no crystallization

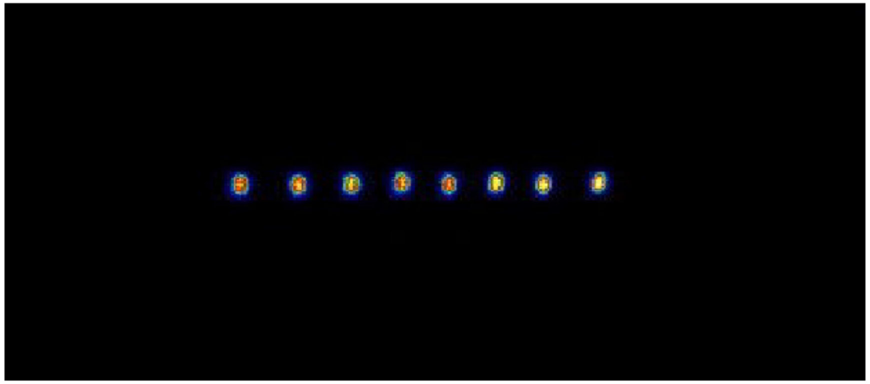


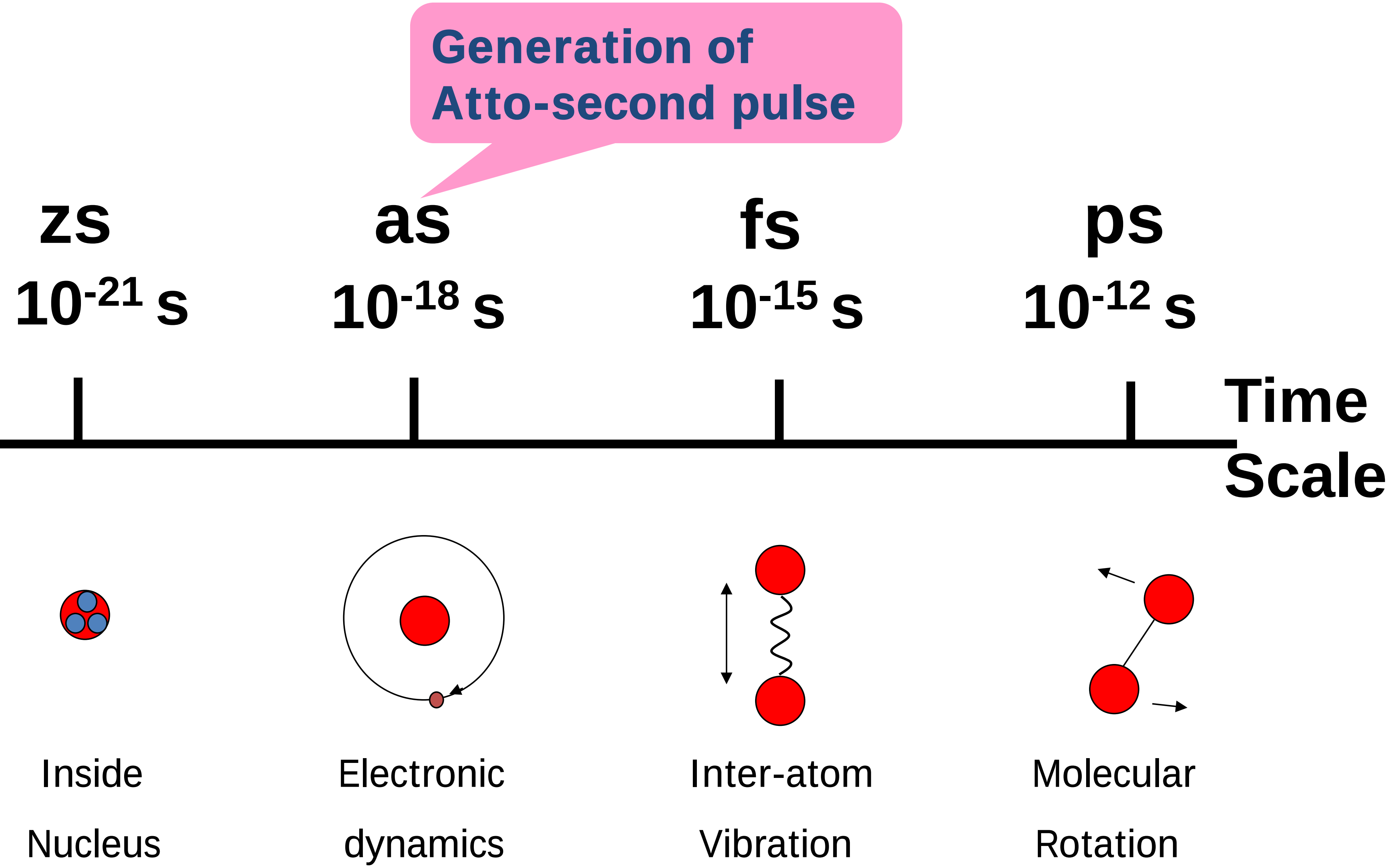


same cloud, cooling laser detuning ~100MHz to red ->crystallized state

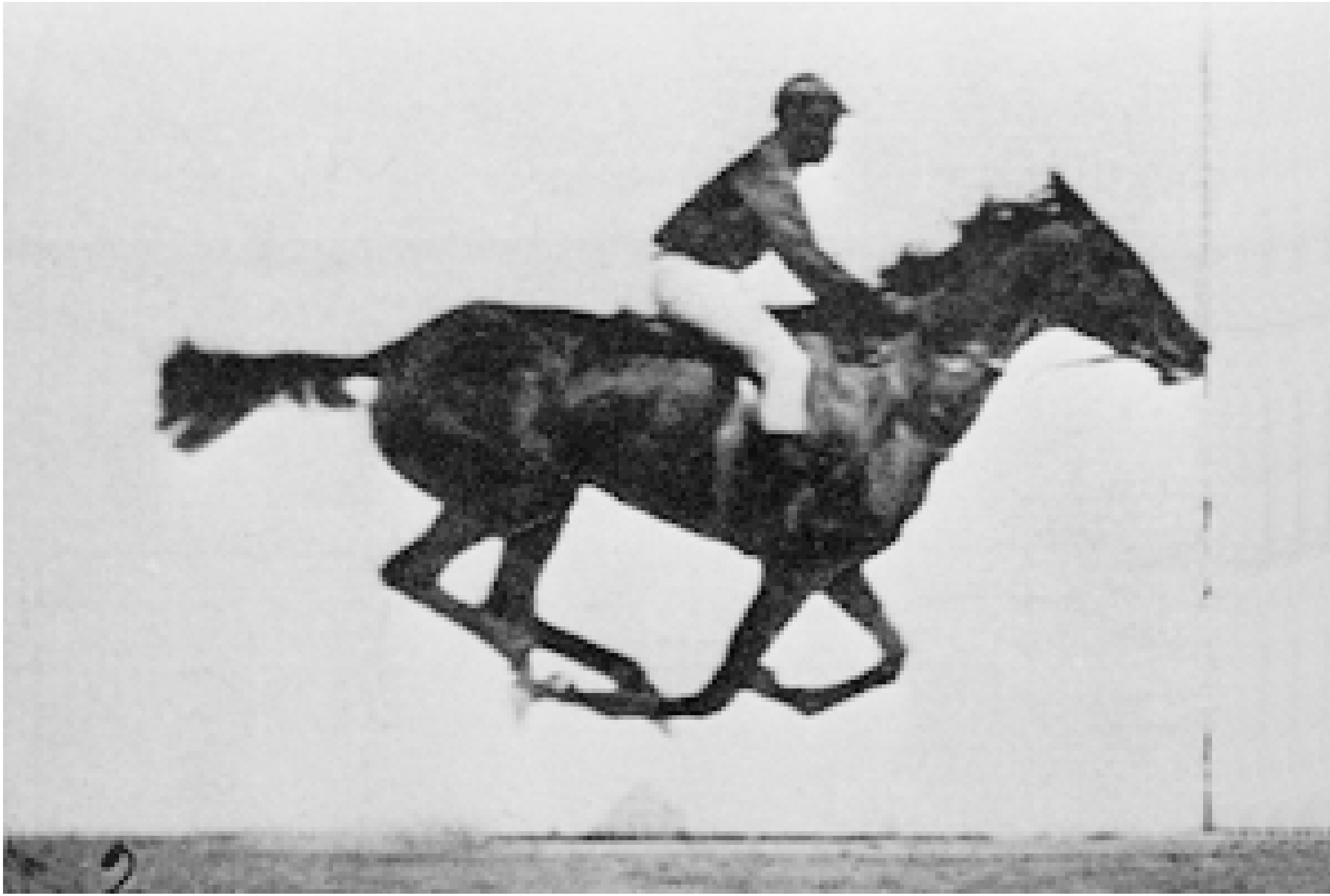
Chain of 8 ions

Resolution of imaging optics ~1μm

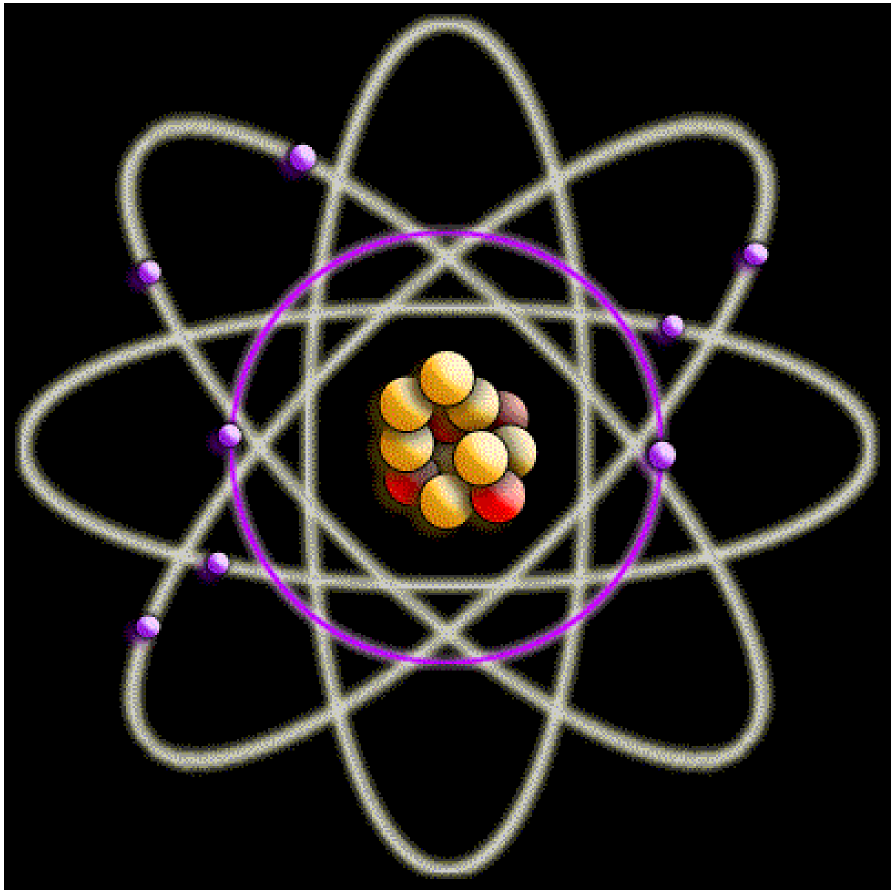



Generation of
Atto-second pulse
zs
10^{-21} s
as
10^{-18} s
fs
10^{-15} s
ps
10^{-12} s
Time
Scale
Inside
Nucleus
Electronic
dynamics
Inter-atom
Vibration
Molecular
Rotation

The Horse in Motion by Muybridge



Time-scale of electrons : attoseconds



Characteristic time scale

Bohr-orbit time in hydrogen:

152 attoseconds

TOUCHING HORIZONS

In Nuclear Physics

Seeing is believing, but can we see a nucleus?

The HFS of the halo nucleus 11Be^{+} by laser microwave spectroscopy of stored ions

1. SLOWRI -- universal slow RI-beam facility
2. **10^{-15} -fold reduction of kinetic energy**
3. Spectroscopy of trapped Be ions and the neutron halo

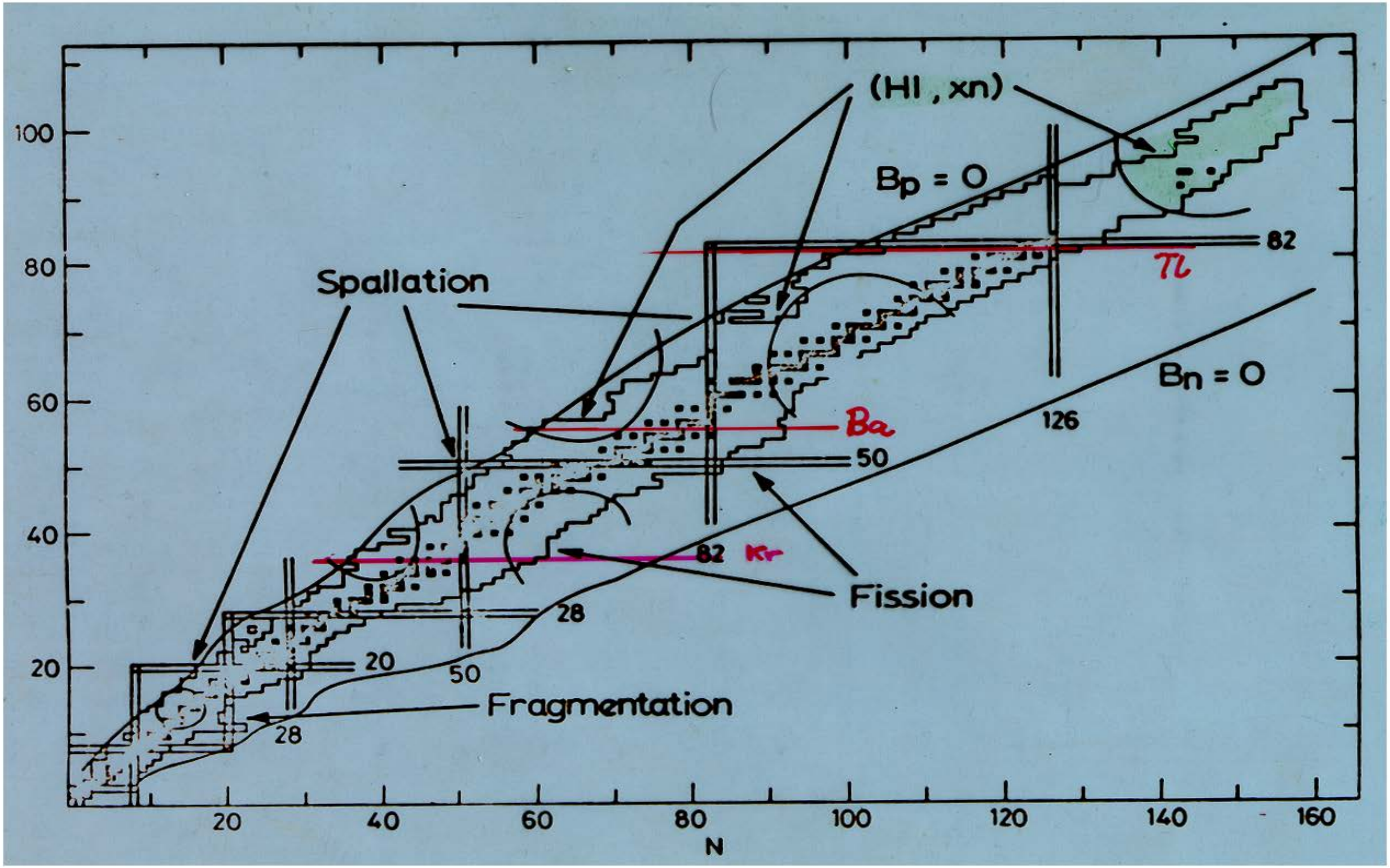
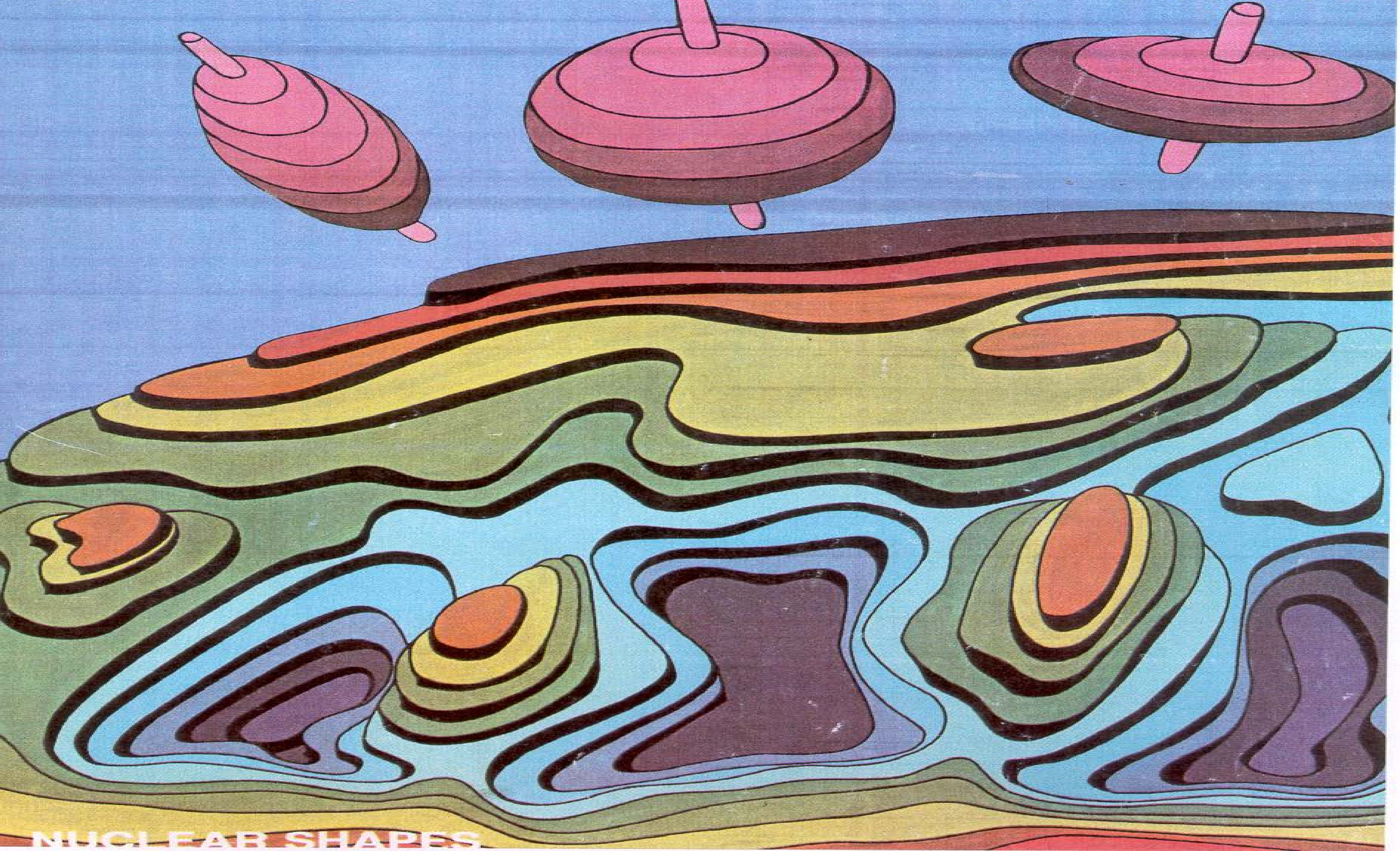


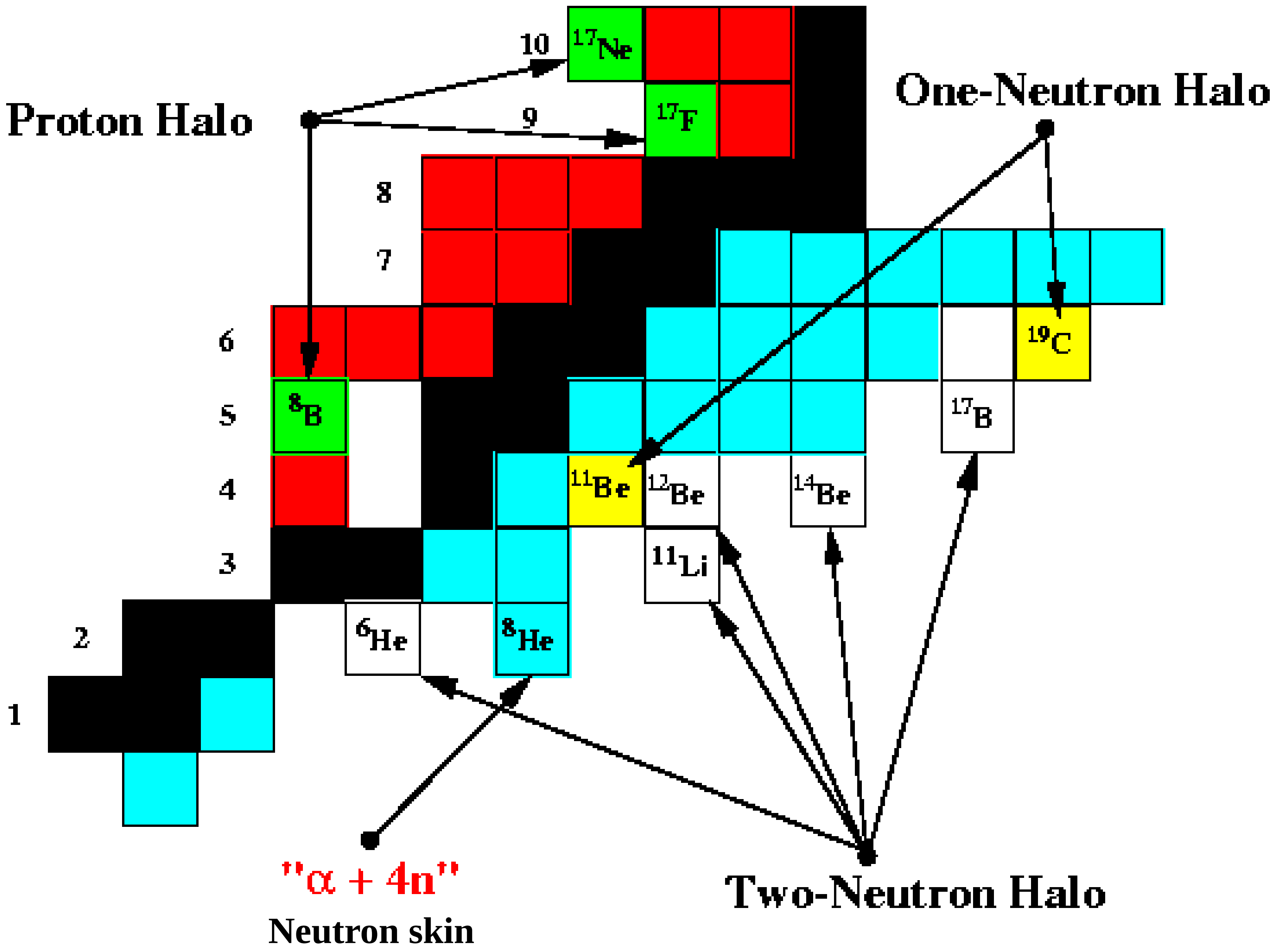
Chart of nuclei

physics today

FEBRUARY 1981



NUCLEAR SHAPES

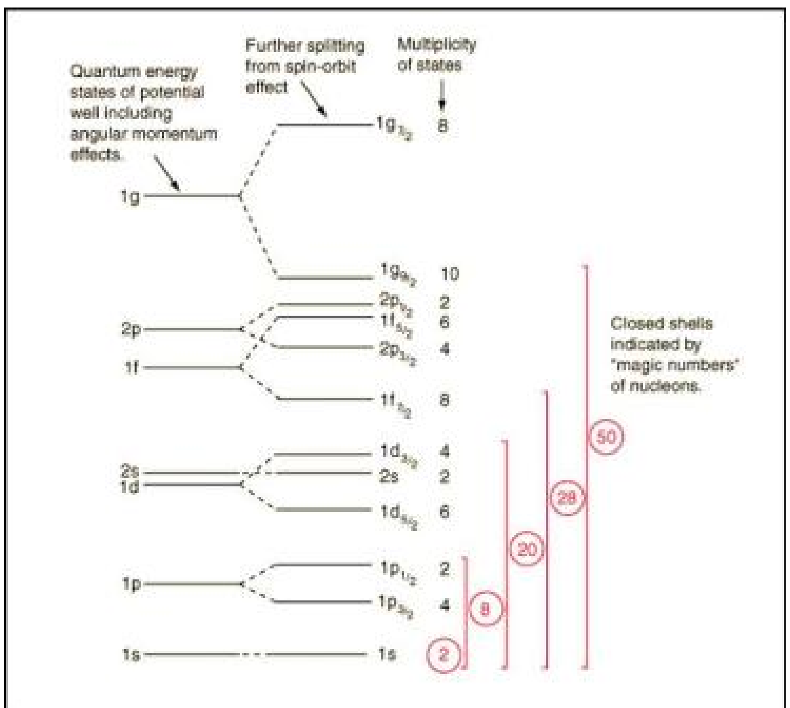


Proton Halo
One-Neutron Halo
Two-Neutron Halo
"α + 4n"
Neutron skin
1
2
3
4
5
6
7
8
9
10
17Ne
17F
8B
19C
11Be
12Be
14Be
17B
11Li
6He
8He

$R = R_0 A^{1/3}$

Shell Structure

Magic Numbers

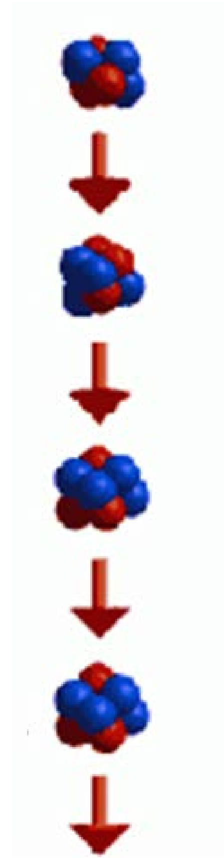


^{7}Be

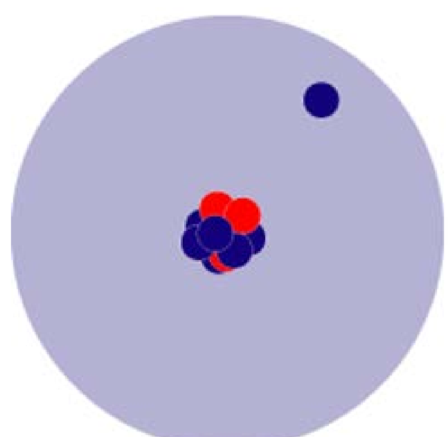
^{8}Be

^{9}Be

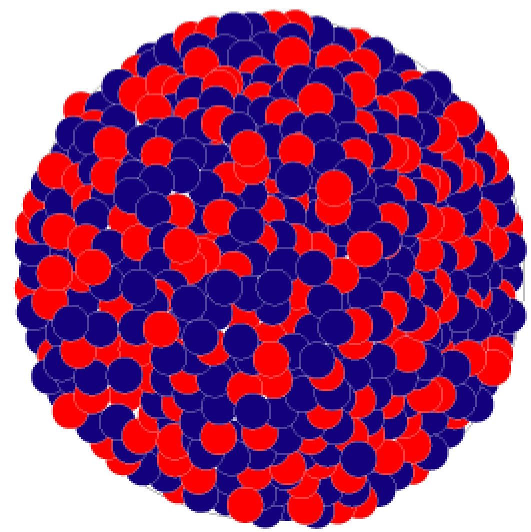
^{10}Be



^{11}Be

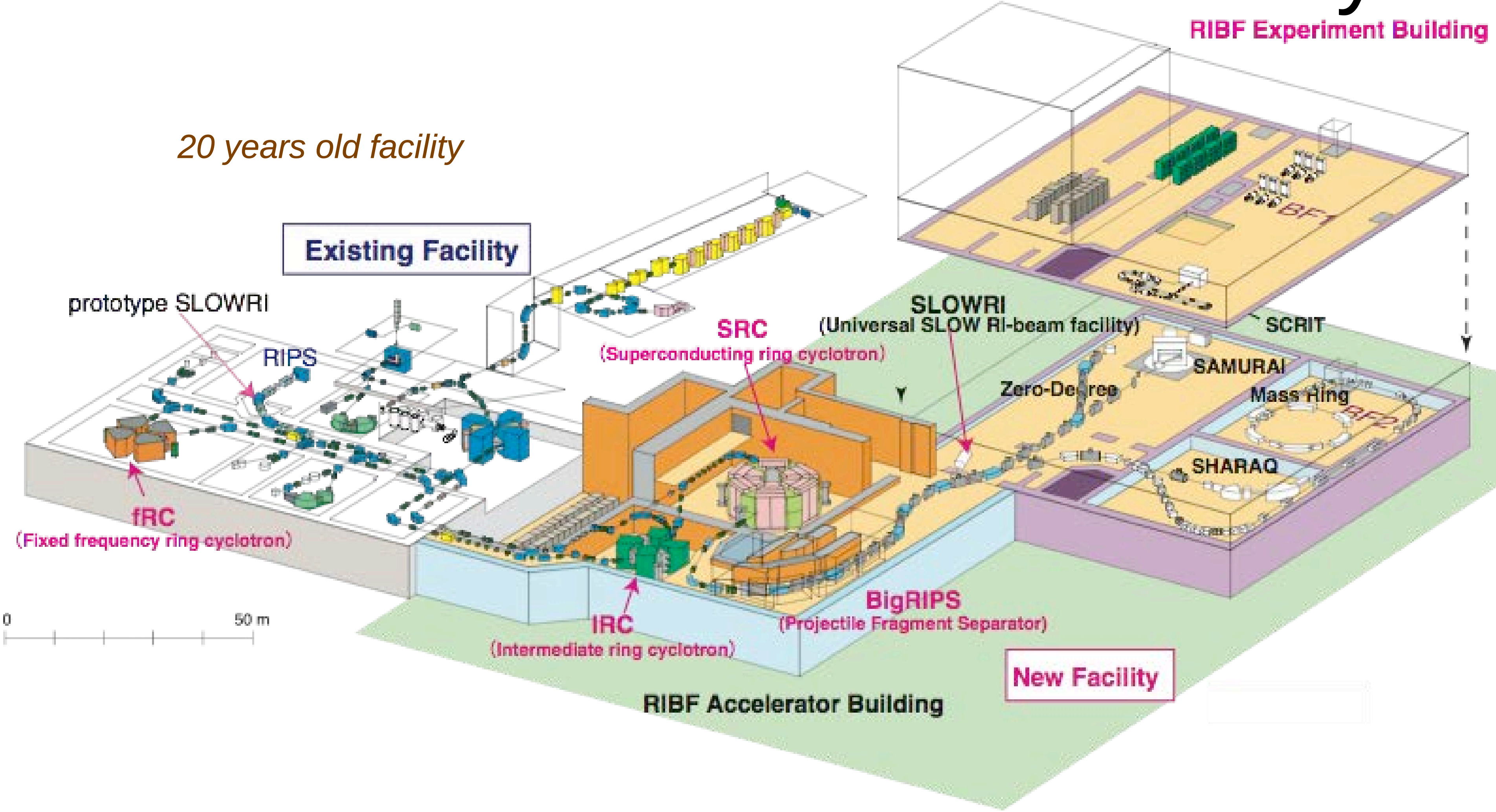


^{208}Pb

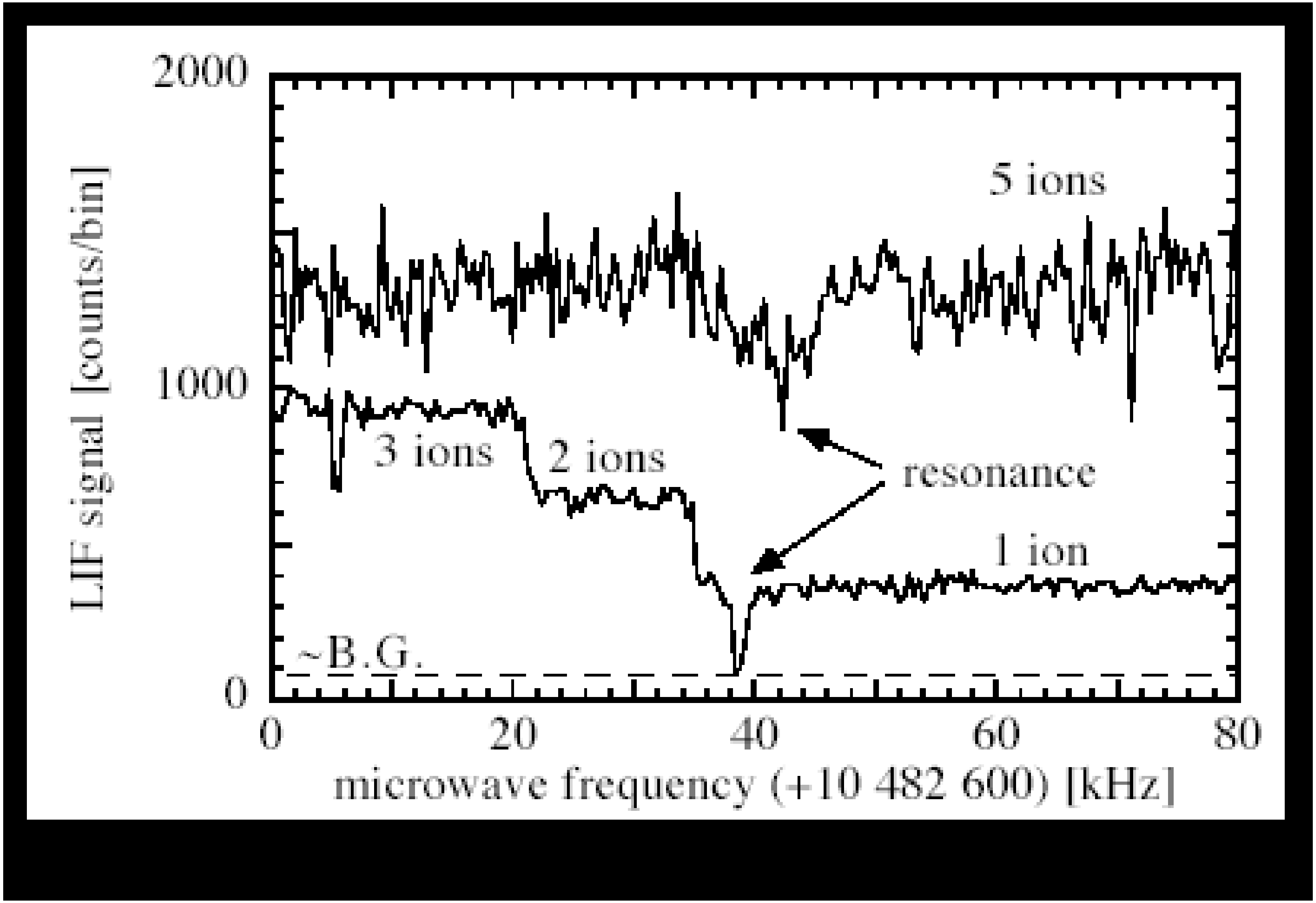


SLOWRI @RIBF
- A universal slow RI beam facility -

20 years old facility



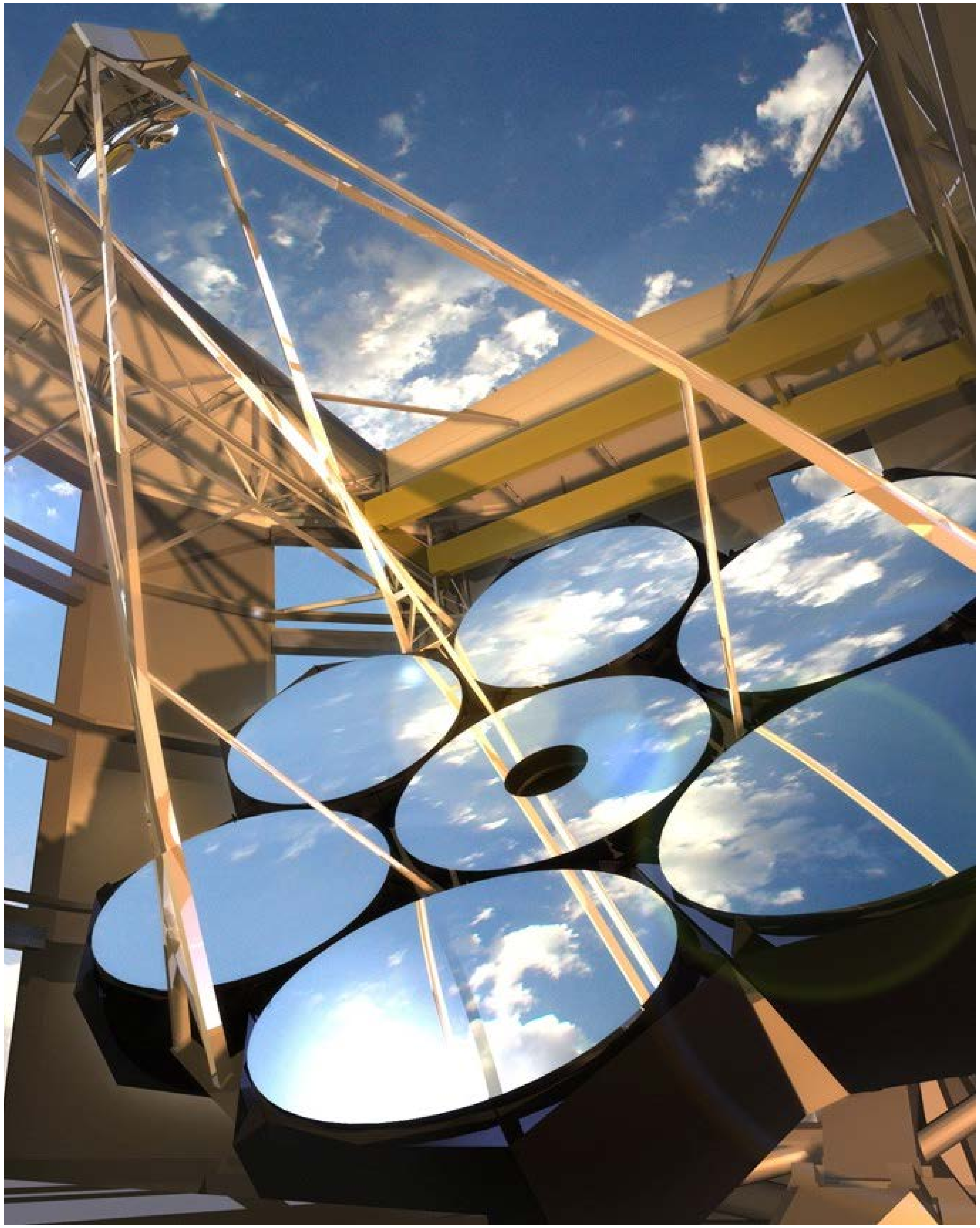
Electron spin-flip microwave spectroscopy of a single ion in a combined trap



TOUCHING HORIZONS

In Astro Physics

Seeing is believing,
but can we see an
Extrasolar Planet?



Frequency Comb Lasers for Astrophysics

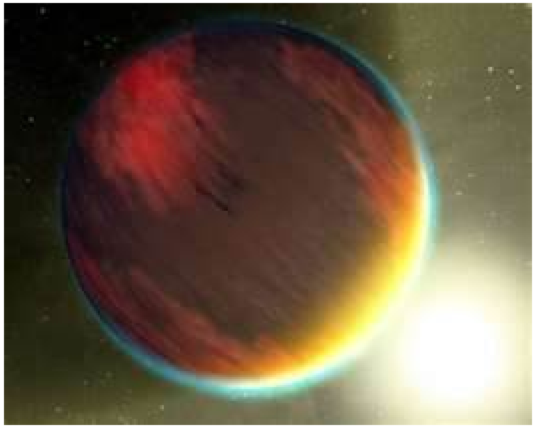
Hans Schuessler

Texas A&M University

Department of Physics and Astronomy

Detecting Extrasolar Planets

- Great effort is made to discover earth-like planets in distant solar systems
- Various techniques to detect Exoplanets via:
  - the additional redshift caused by the star's motion around a common center of gravity
  - the induced change in position of its star
  - the dimming of the star's brightness during the transition of a planet
  - the induced change of a another planet's orbit



Habitable Earth-like exoplanets?

StoRy of GoldiLocks & the 3 bears

Once upon a time, there was a little girl named Goldilocks. She went for a walk in the forest. Pretty soon, she came upon a house. She knocked, and when no one answered, she walked right in…

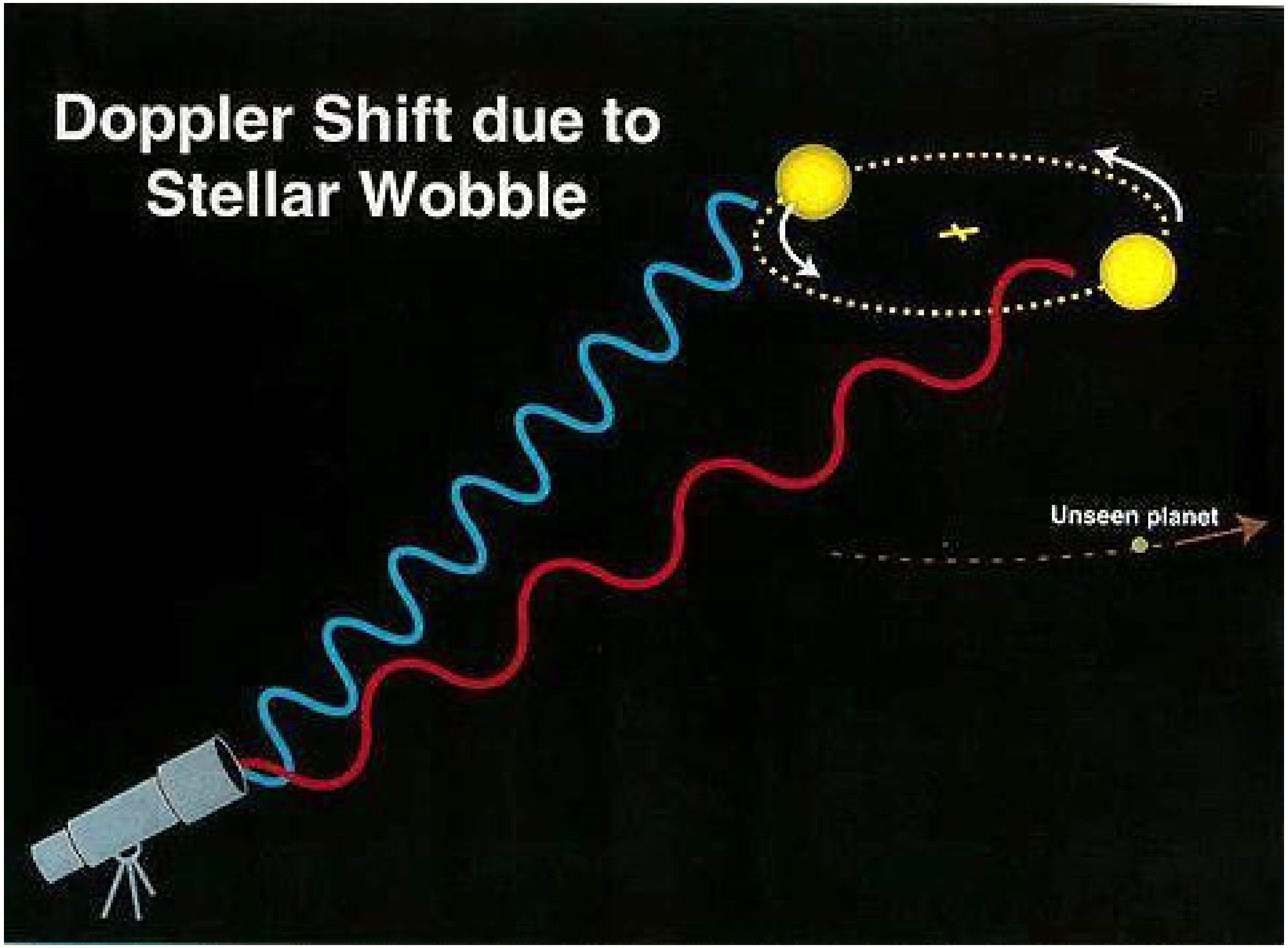
At the table in the kitchen, there were three bowls of porridge.

- "This porridge is **too hot**!"
- "This porridge is **too cold**!"
- "This porridge is **just right**!"

She also tried out each of the three chairs and three beds.

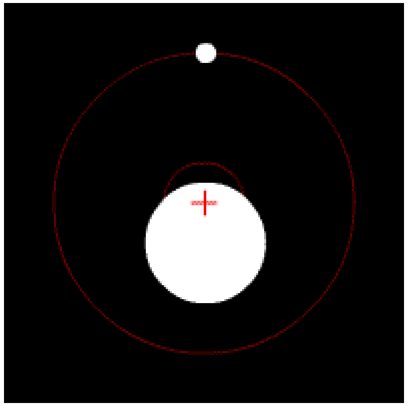
- **Too big**, **Too small**, **Too hard**, **Too soft**, and **Just Right**

RV search for exo - Planets

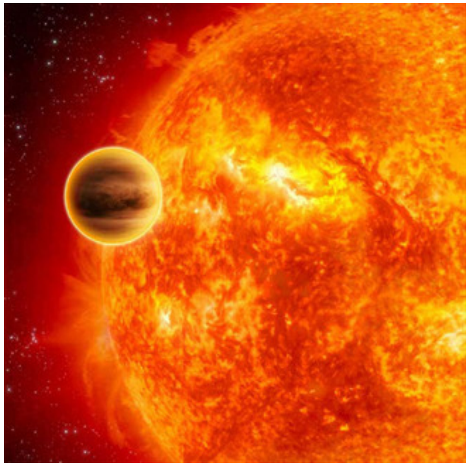


Radial Velocity
Variations induced
by exo-planets

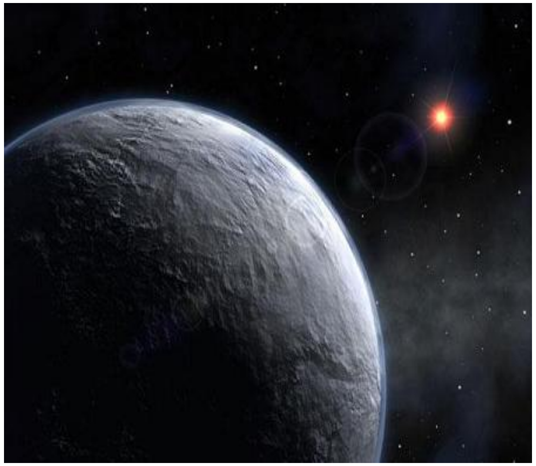
~200 discovered
 in 10 years
with RV technique



Detecting Extra Solar Planets



- As of February 5, 2015 there are 1,813 exoplanets discovered
- smallest planet detected so far: 5-Earth-mass
- corresponding precision: **60 cm/s** required
- precision for an Earth-mass object in an Earth-like orbit around a Sun-like star: **5 cm/s (50 kHz)**
- long term stability **over years**

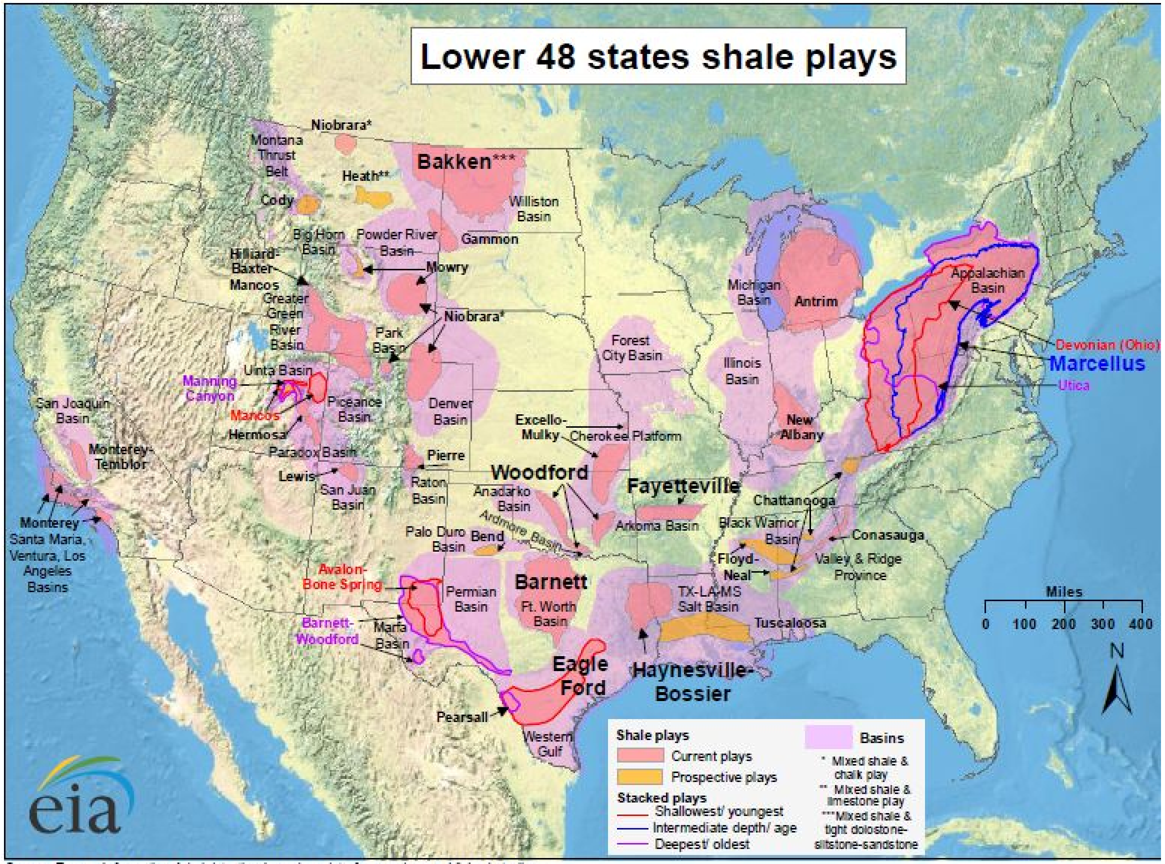


TOUCHING HORIZONS

In Environmental Physics

Seeing is believing, but
can we see Air Pollution?

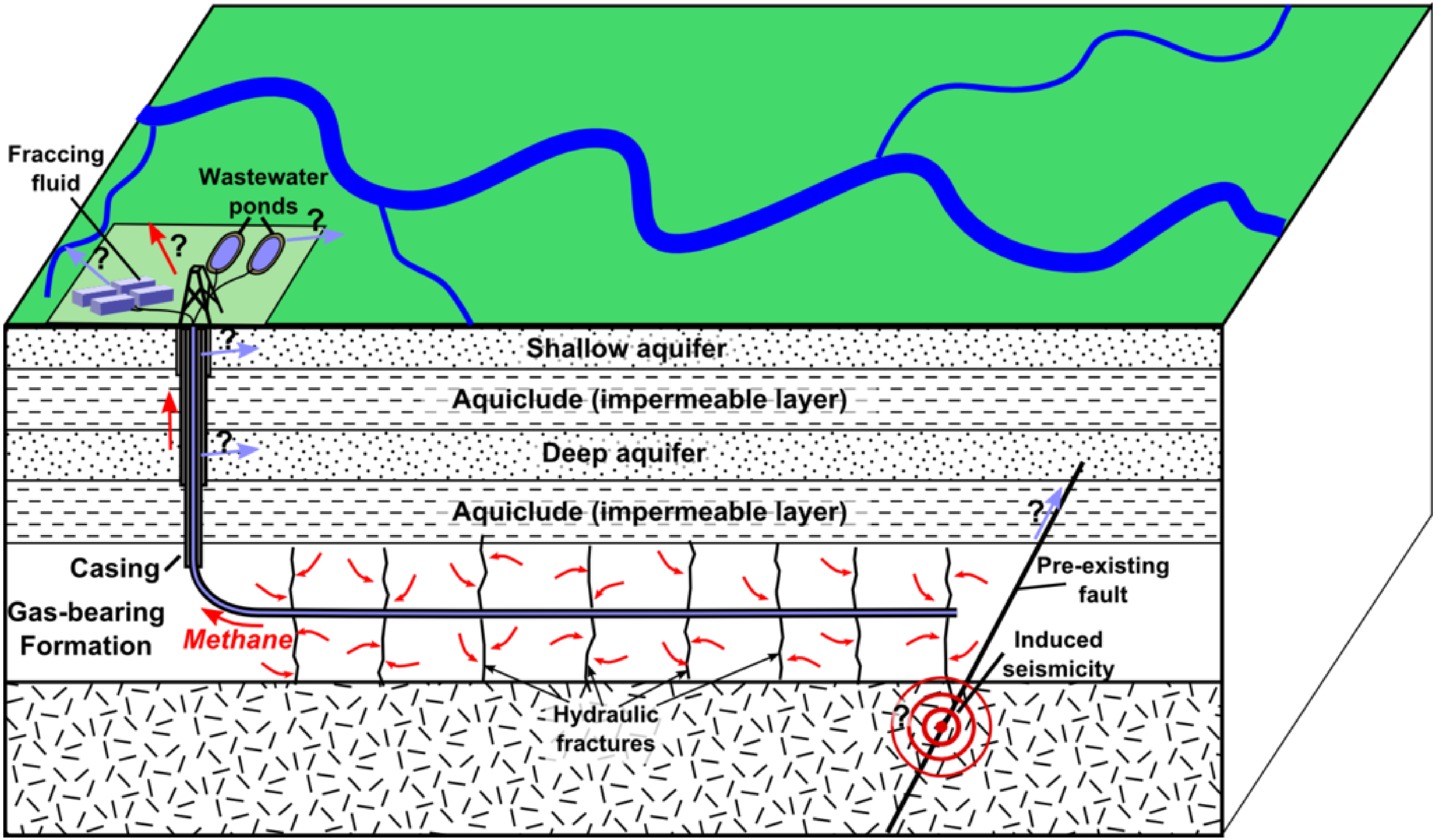
Shale gas basins in the United States



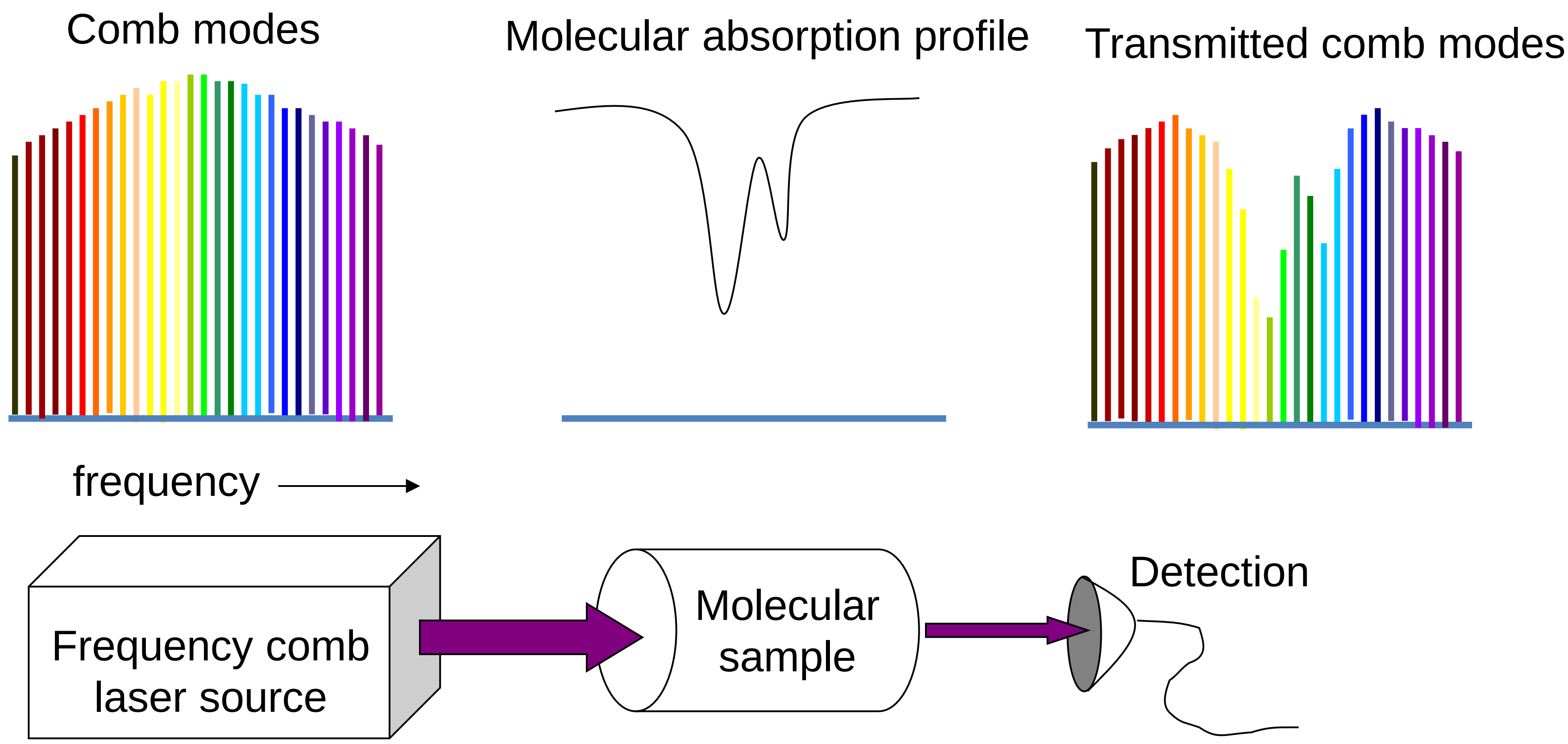
Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

Shale gas formations in North America hold trillions of cubic feet of natural gas. The U.S. has enough reserves of clean natural gas to power our homes and even our vehicles for years to come. The shale basins shown above will be a major source of that natural gas. According to the A.A.P.G. shale gas will account for more than 51% of our gas supply this decade.

Schematic of petroleum reservoir fracking



Frequency comb for gas detection

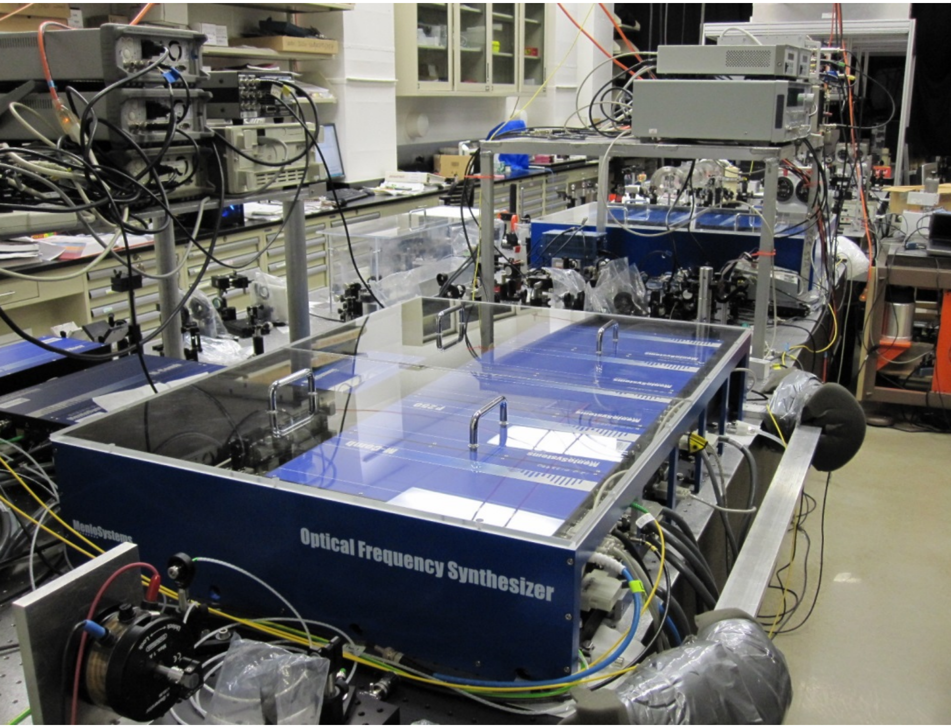


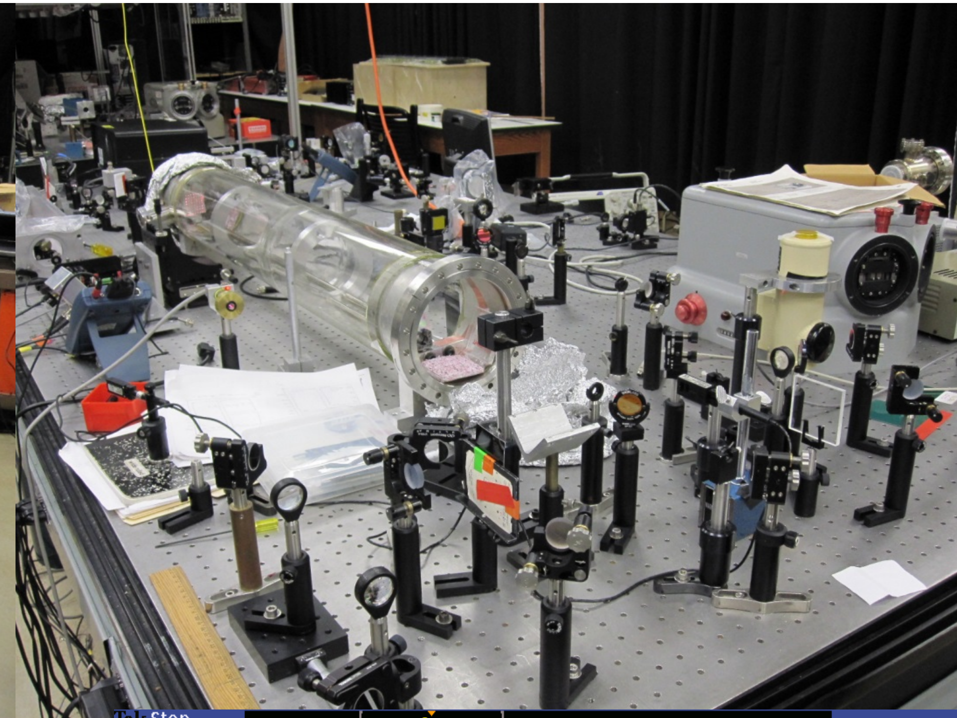
Frequency comb can provide the advantages: - Broad Spectral coverage with high brightness - High frequency precision on each comb tooth

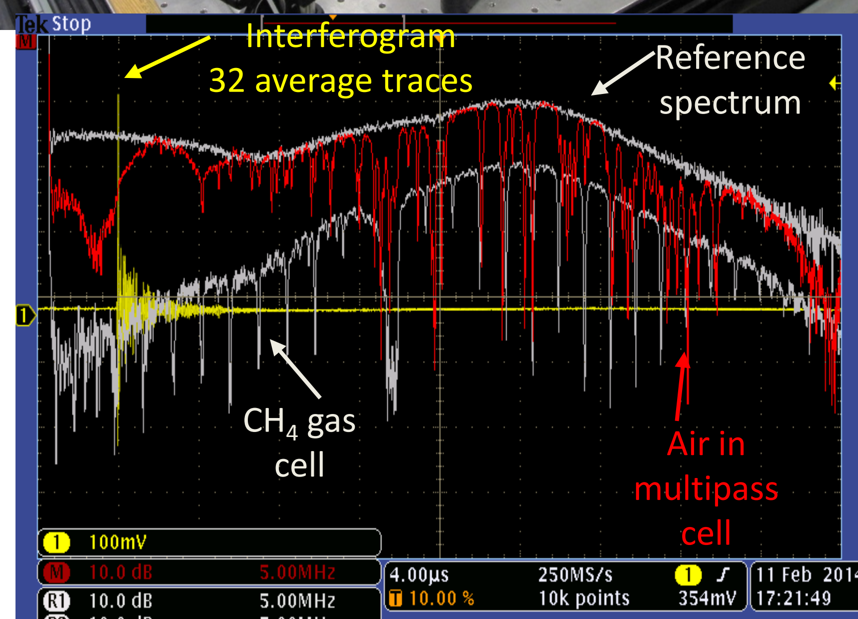
Strong molecular absorptions in mid-infrared (1.5-5 microns) - Requires frequency comb source in mid-IR
- Requires broad detection over large comb range

Courtesy of Scott Diddams

Mid-IR Dual comb spectroscopy with a multipass cell

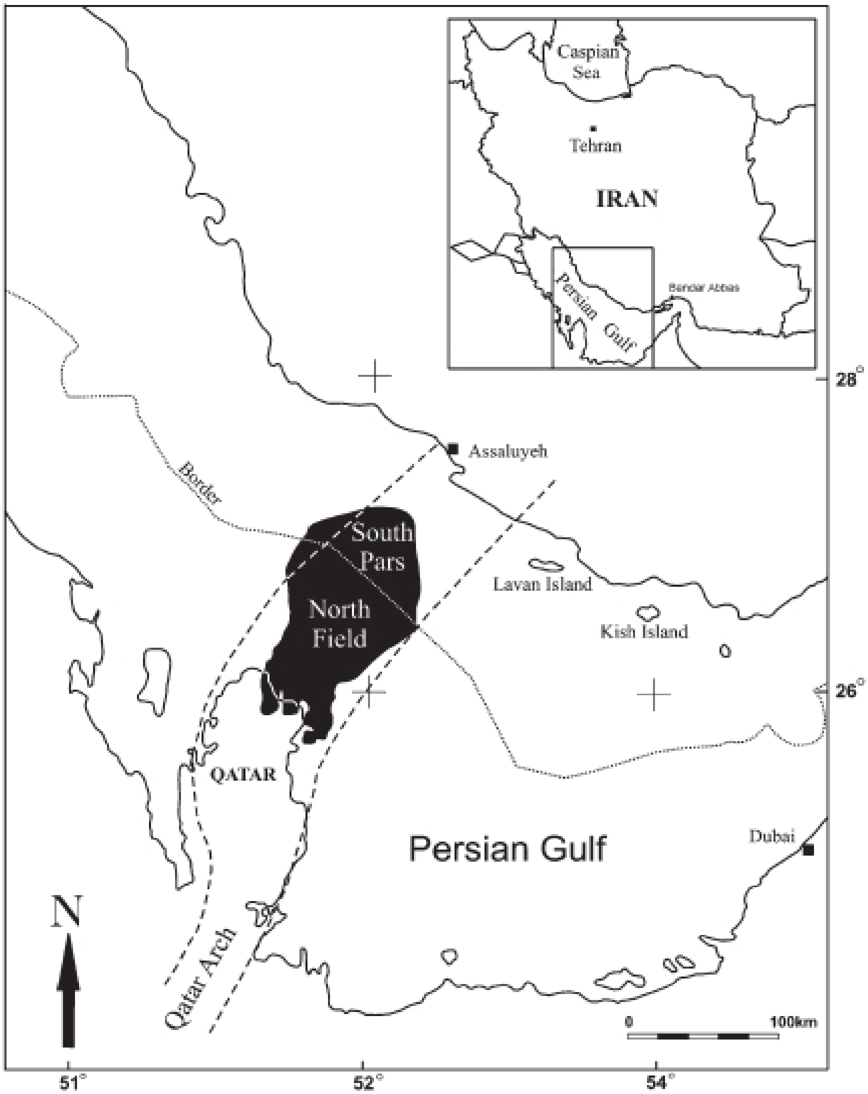


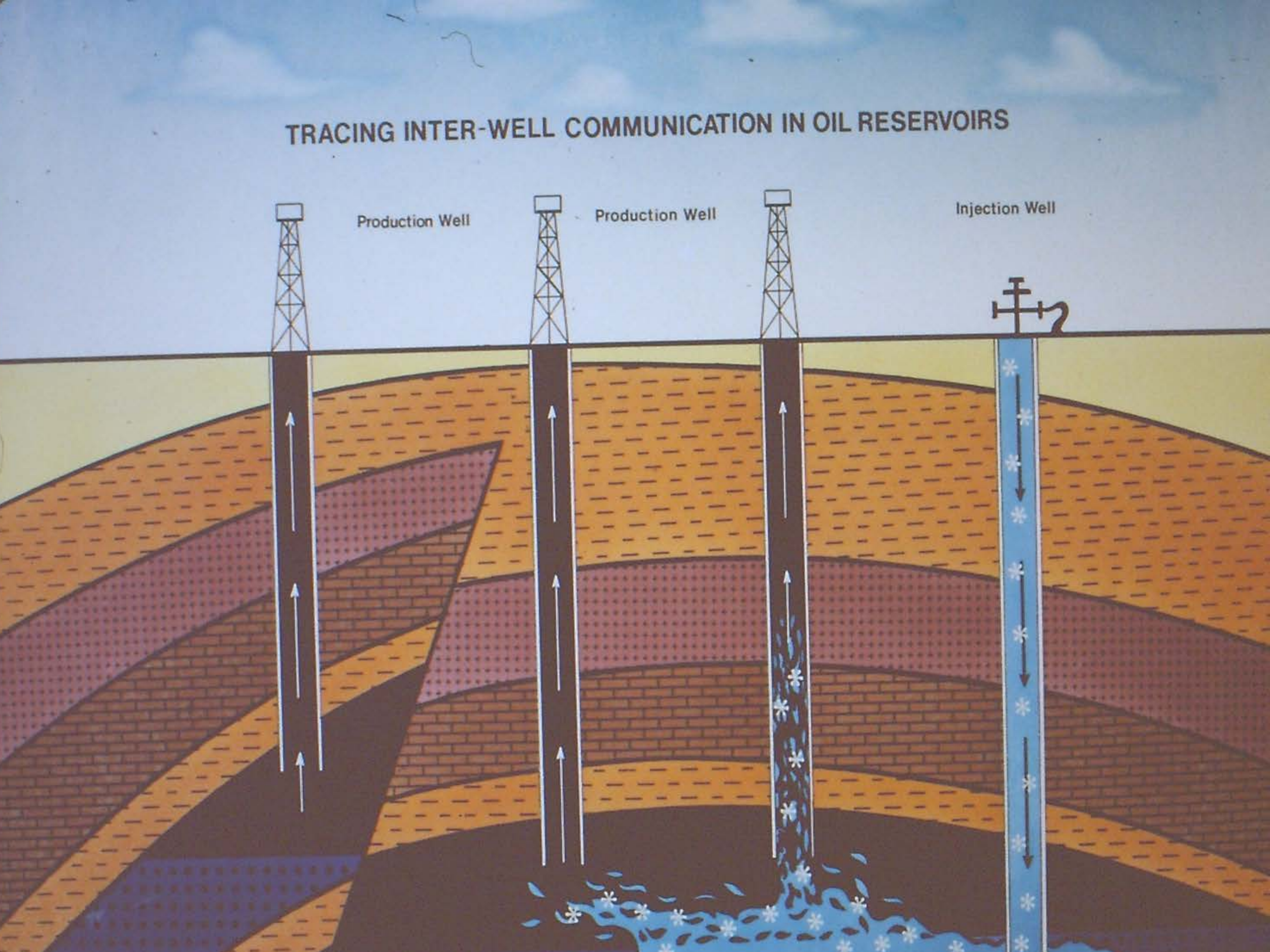




RV Pelican and collection apparatus

Qatari North Field





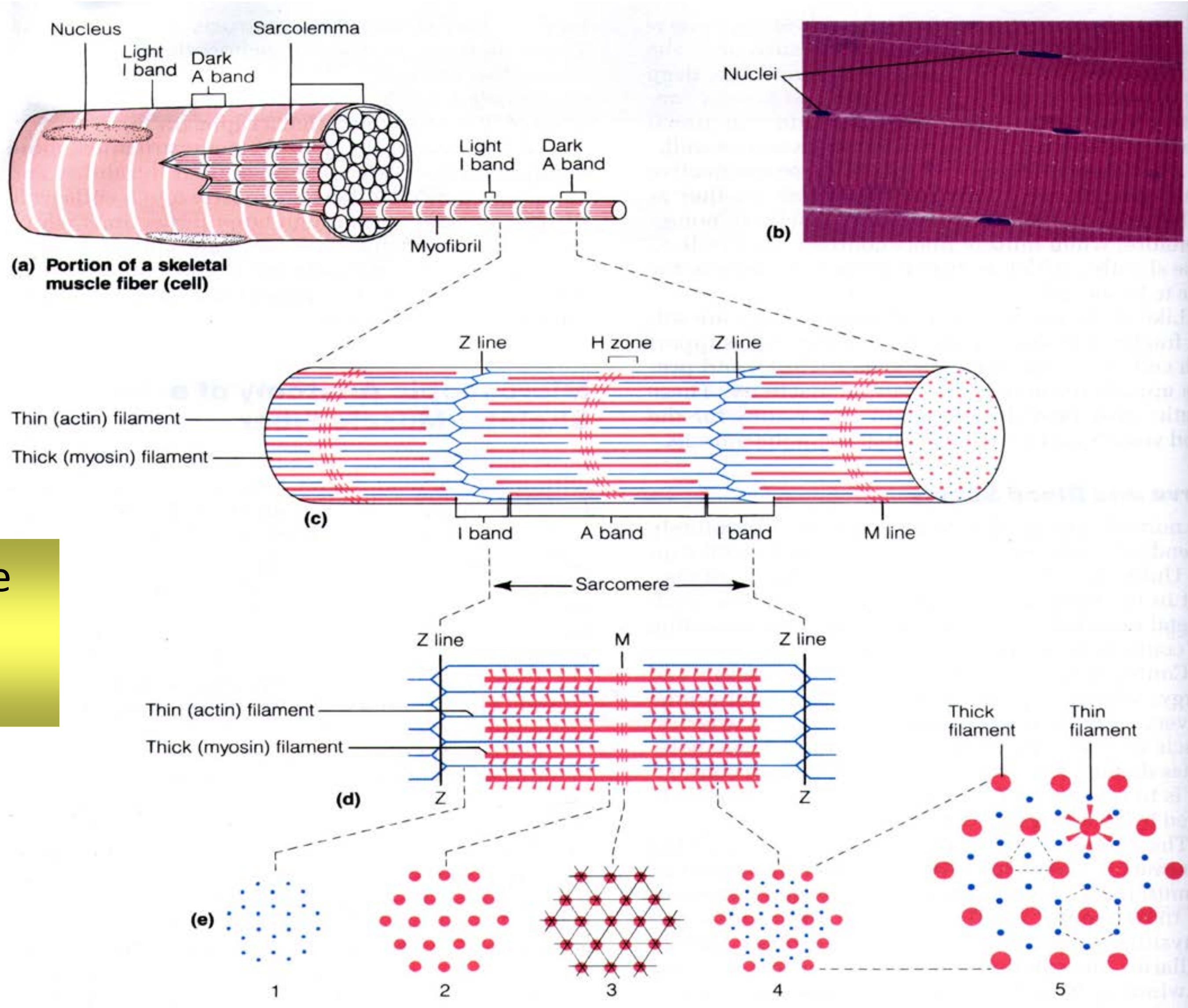
TRACING INTER-WELL COMMUNICATION IN OIL RESERVOIRS
Production Well
Production Well
Injection Well

TOUCHING HORIZONS

In the Biosciences

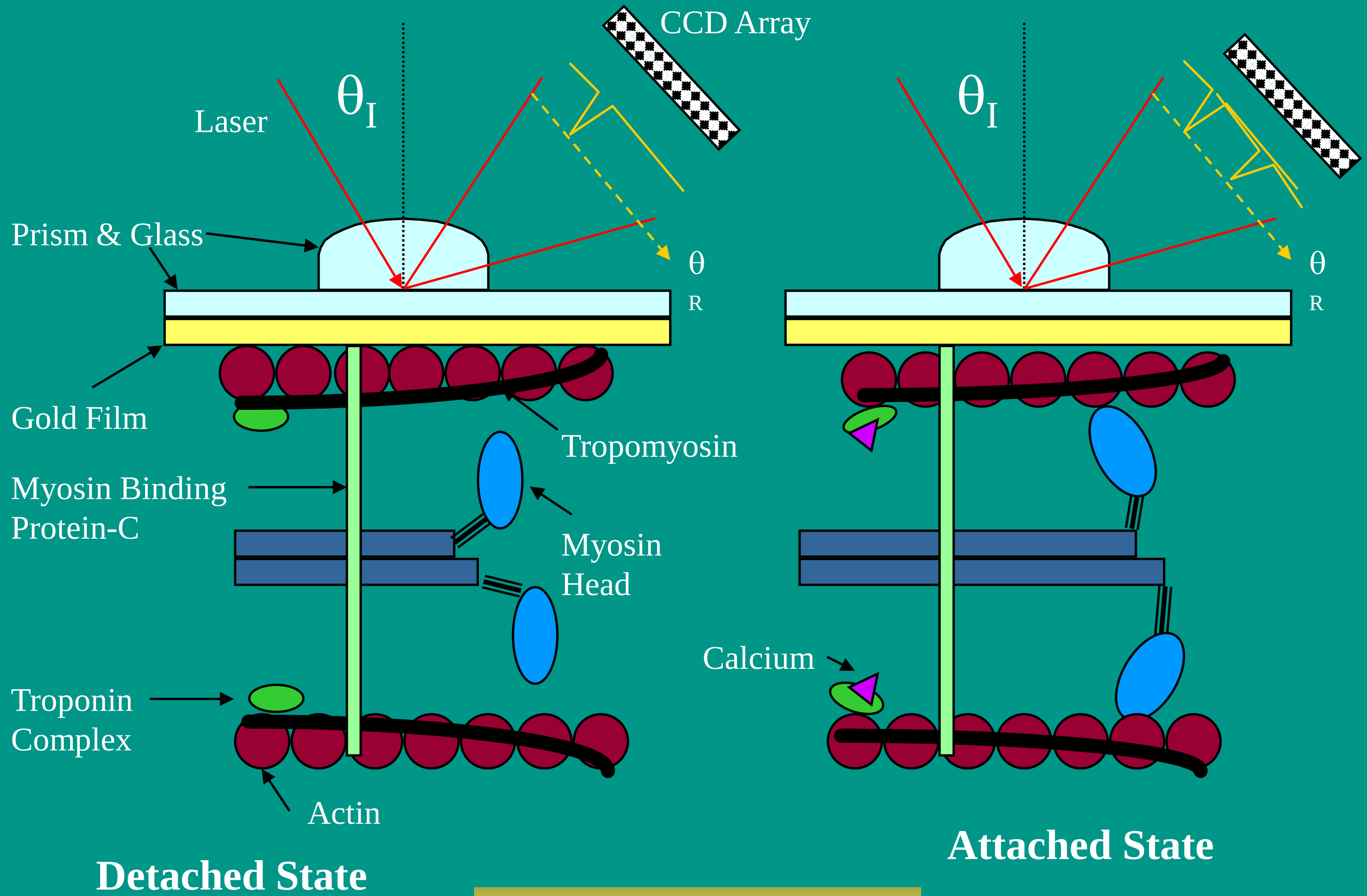
Seeing is believing, but can we see a biomolecule?

Sarcomeres (actin-myosin contractile complexes)



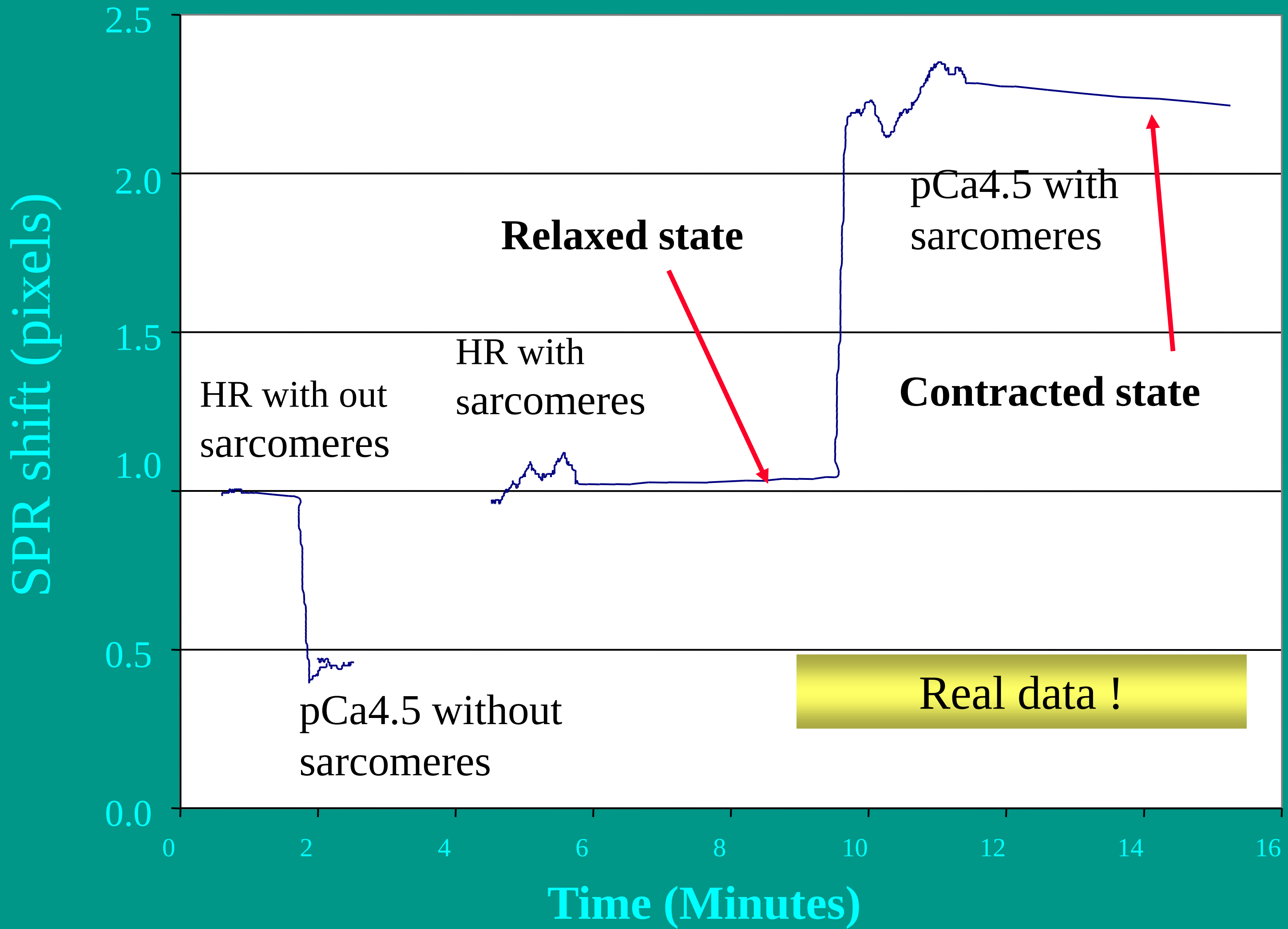
We monitored live sarcomere contraction....

SPR experiment with sarcomeres



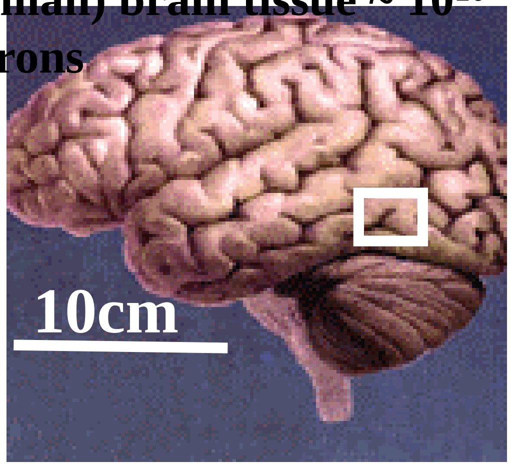
…. in real time

Response of contraction (HR to pCa4.5)



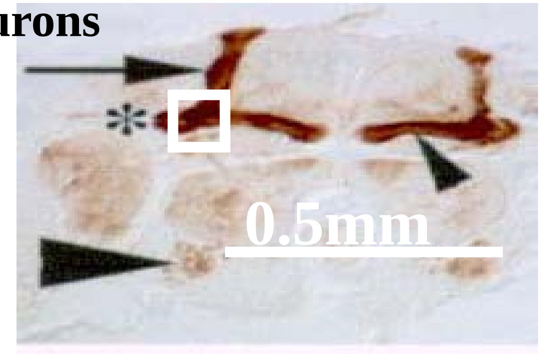
•Background: From the brain to tubulin

(Human) brain tissue ~ 10^{10} neurons



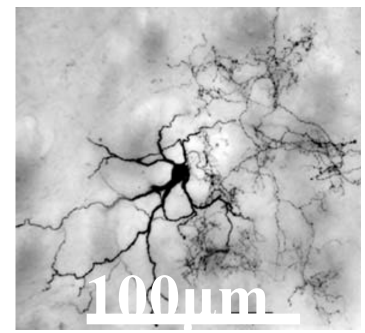
x200

(Drosophila) 2 neural bundles ~ 2x2500 neurons



x5

Neural net ~ 10 neurons st



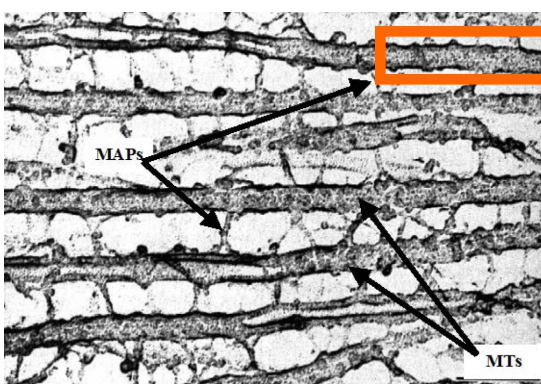
x10

Neural synapse, ~10^4 synapses/cortical ne

x100

Axonal cytoskeleton

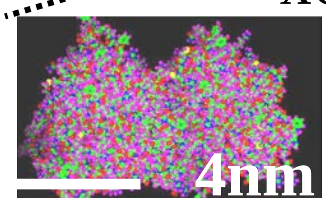
100nm



x4

One Microtubule

x6



One tubulin dimer

Summary and outlook

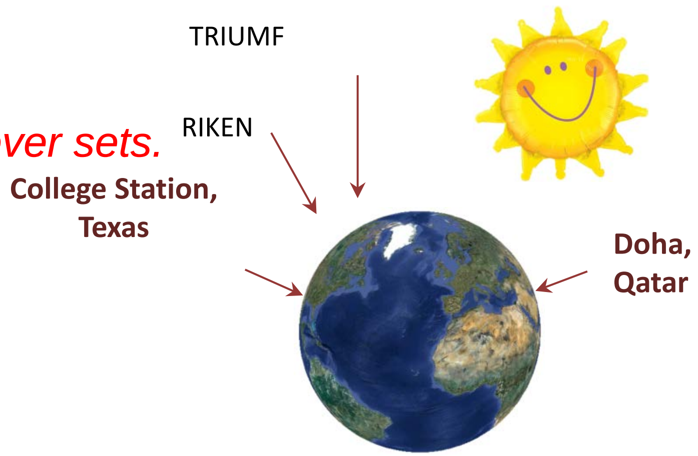
- **Selfie of the SIBOR**
- **We touched horizons in atomic and molecular physics, nuclear physics, astrophysics, environmental physics, and biosciences.**
- **Around the globe**
- **Two short movies of the macro and micro world follow**

私の研究室は太陽が沈まない *On my laboratories, the sun never sets.*

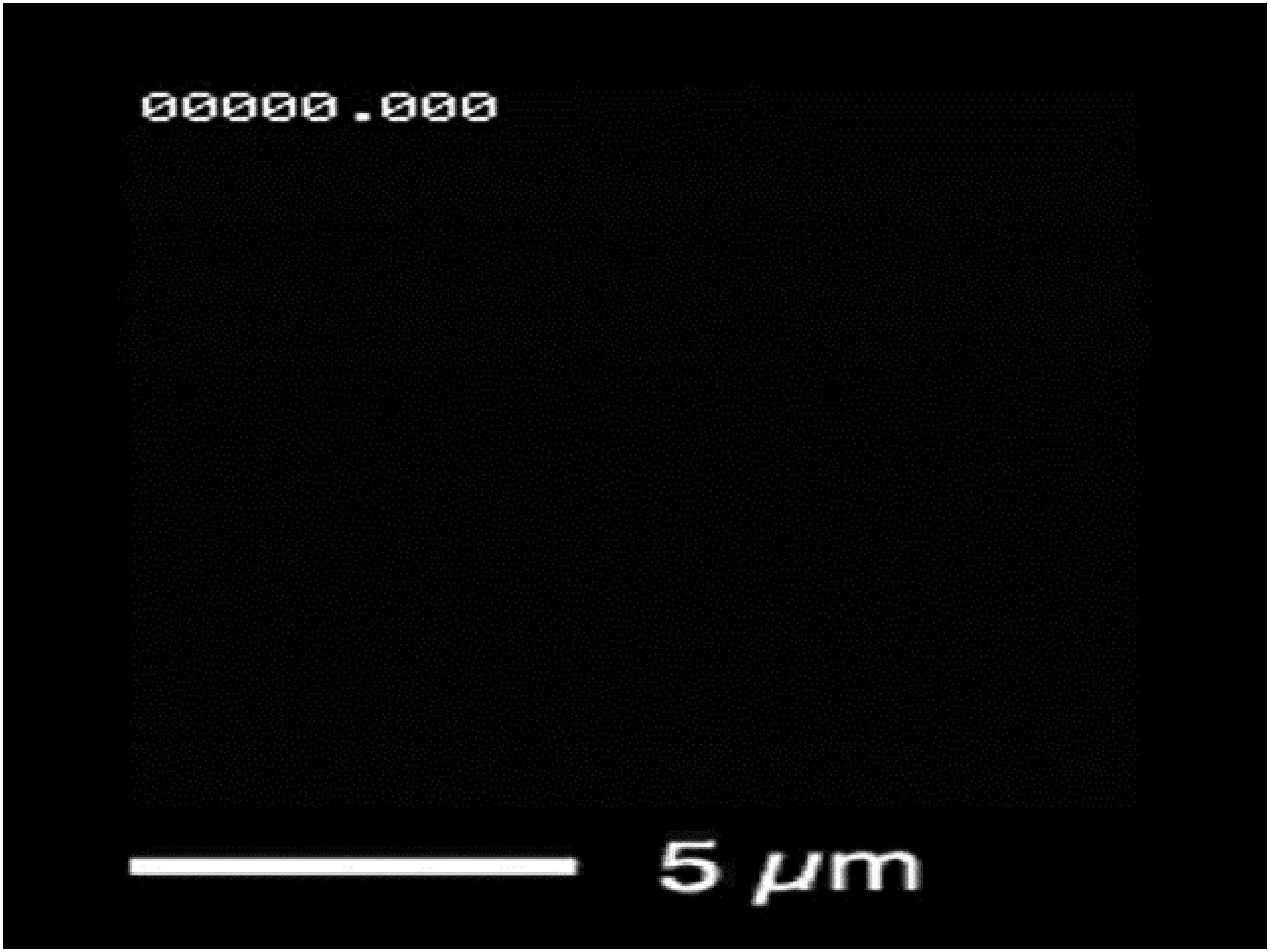
Sur mes laboratoires, le soleil ne se couche jamais.

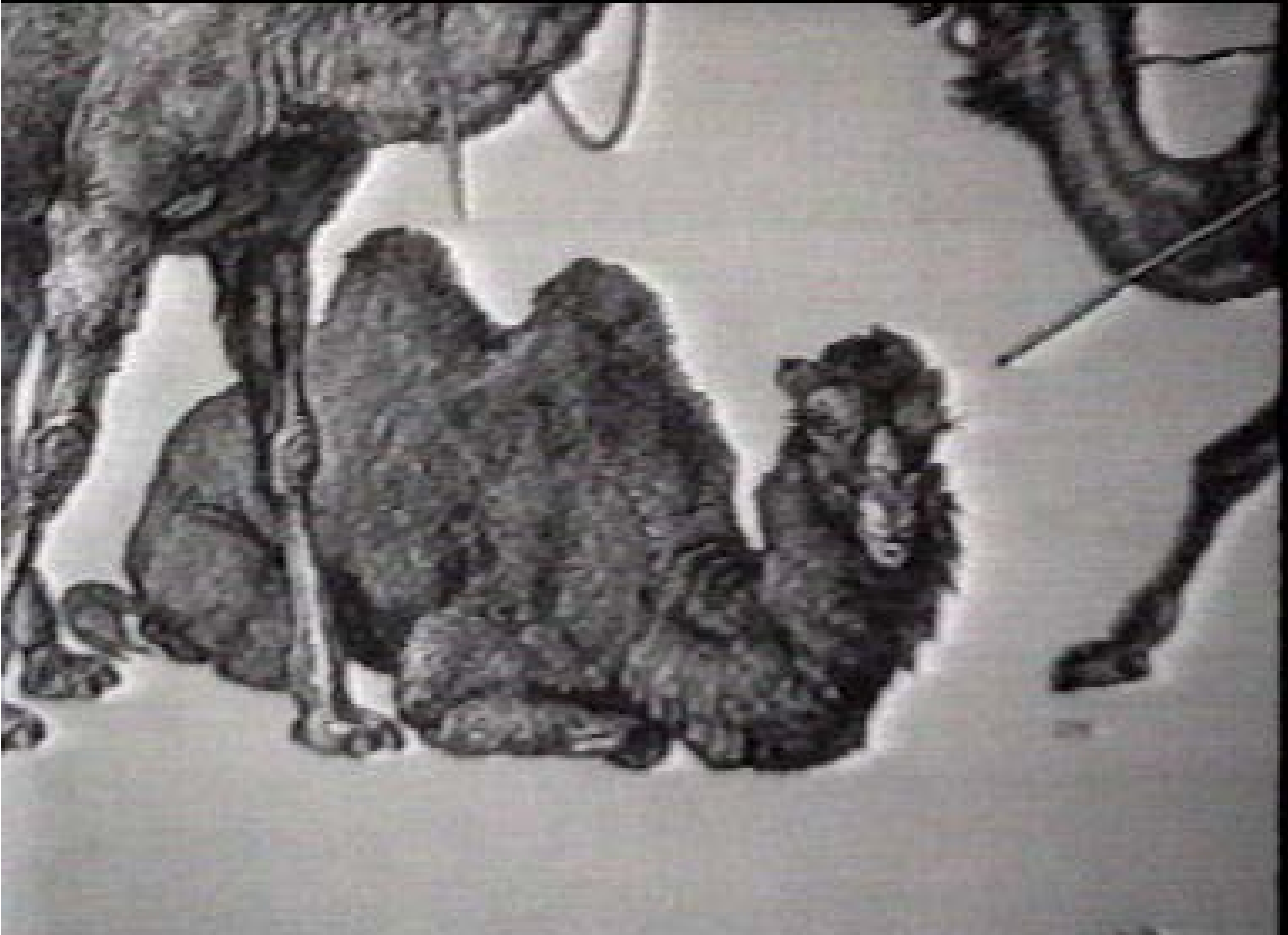
In meinem Labor geht die Sonne nicht unter.

على مختبرات بلدي، لا تغيب عنها الشمس



Cooperative Binding of Myosin to Tubulin

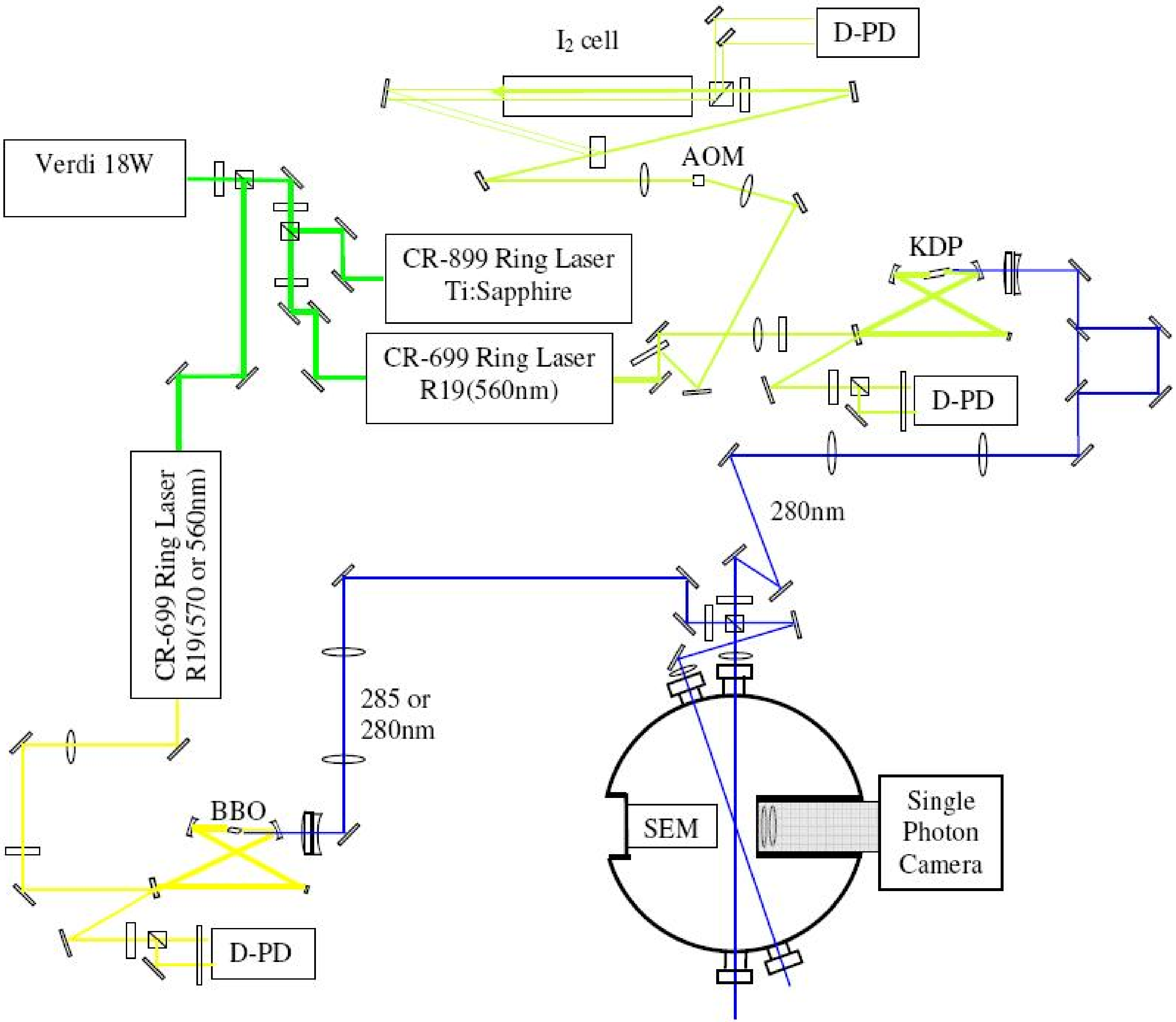




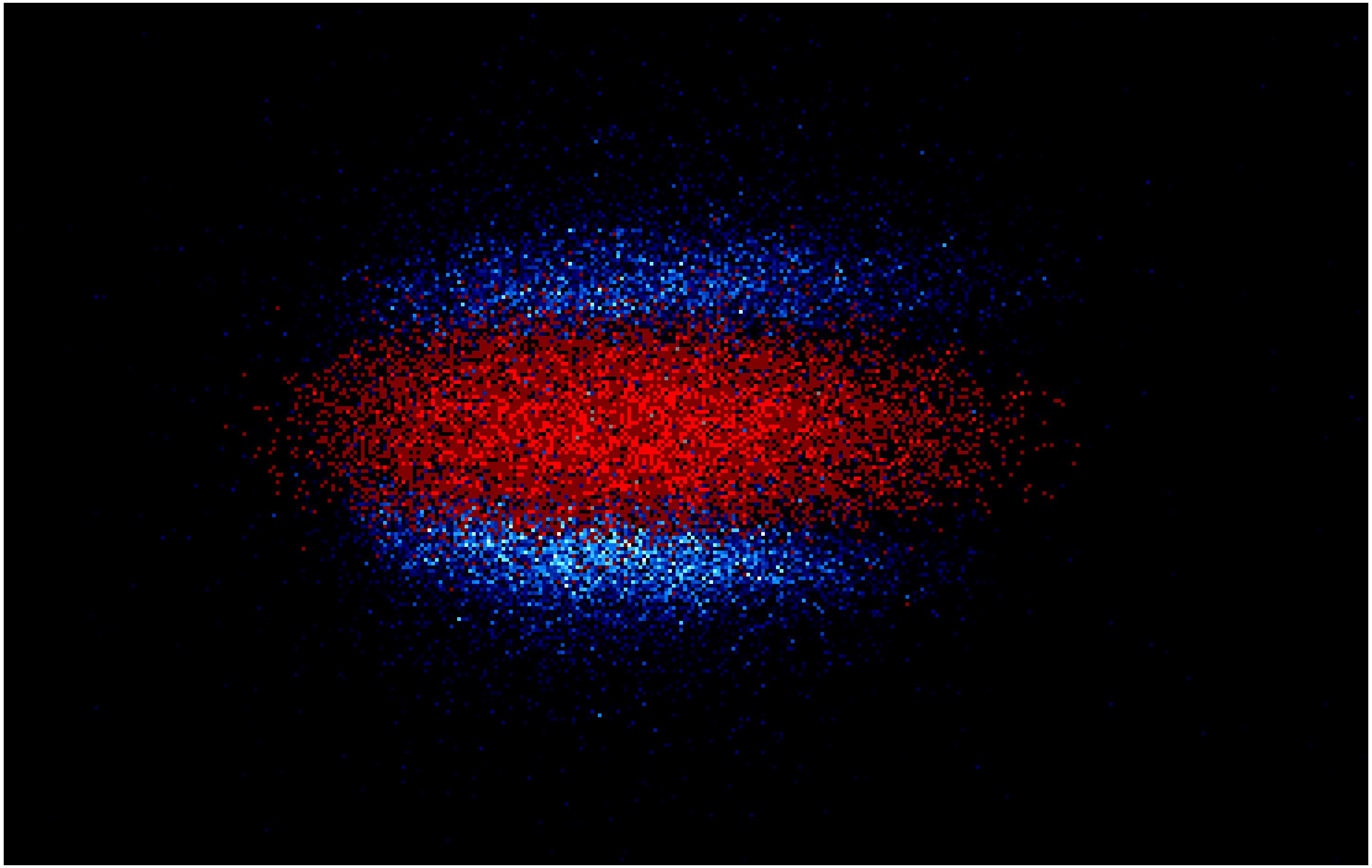
Novel Systems for Precision Spectroscopy

- Helium ion 1s-2s
- HydrogenMolecule Ion and Isotopo-mers(highly excited states at 12eV)
- XUV Frequency Combs
- Detection Schemes

Lab Tour



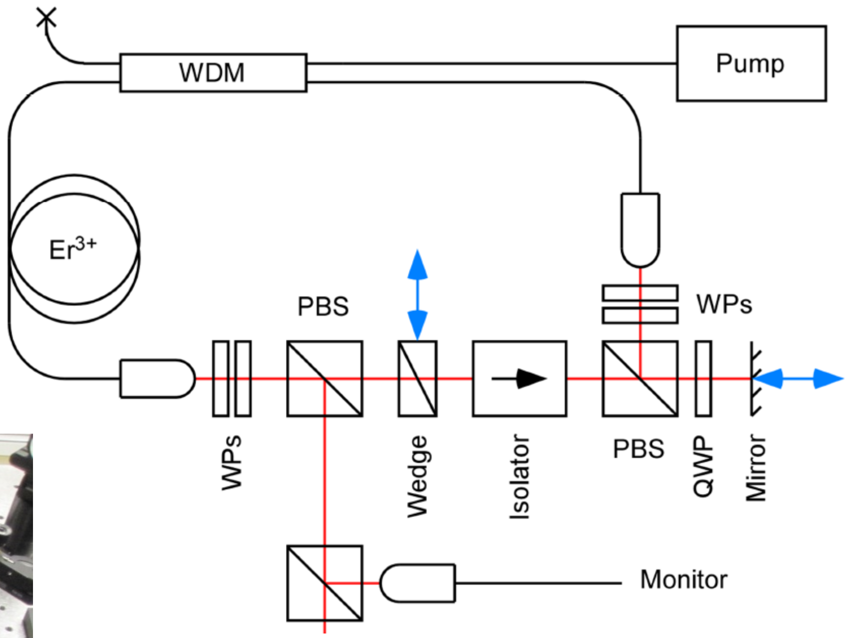
I$_2$ cell
D-PD
Verdi 18W
AOM
CR-899 Ring Laser
Ti:Sapphire
KDP
CR-699 Ring Laser
R19(560nm)
D-PD
CR-699 Ring Laser
R19(570 or 560nm)
280nm
285 or
280nm
BBO
SEM
Single
Photon
Camera
D-PD

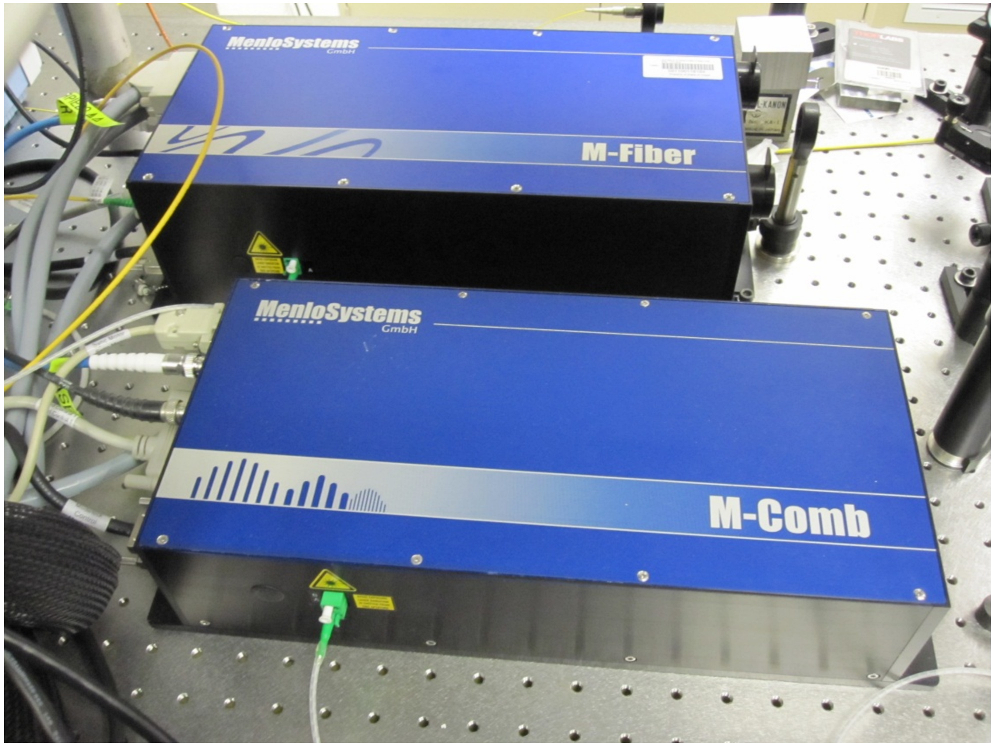


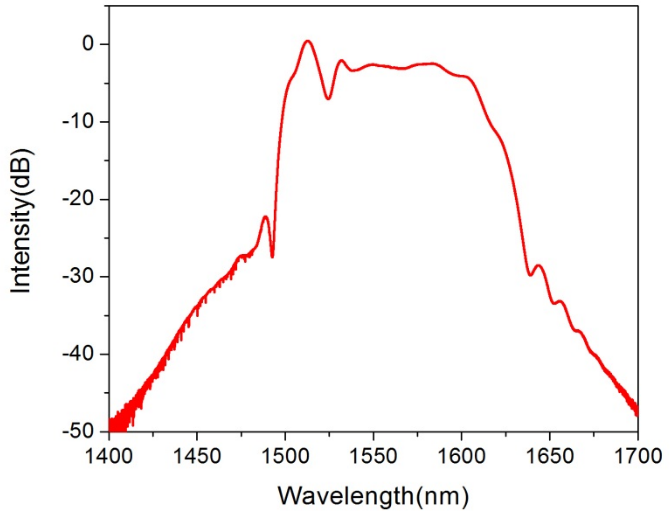
Large $^{24}Mg^{+}$ - $^{26}Mg^{+}$ ion crystal ($N \sim 10^4$)

The Current Er Laser

- Standard Er-Fiber Laser
  - λ_c = 1570 nm (FWHM > 60 nm)
  - f_{rep} = 250 MHz
  - τ < 90 fs
  - P > 400 mW

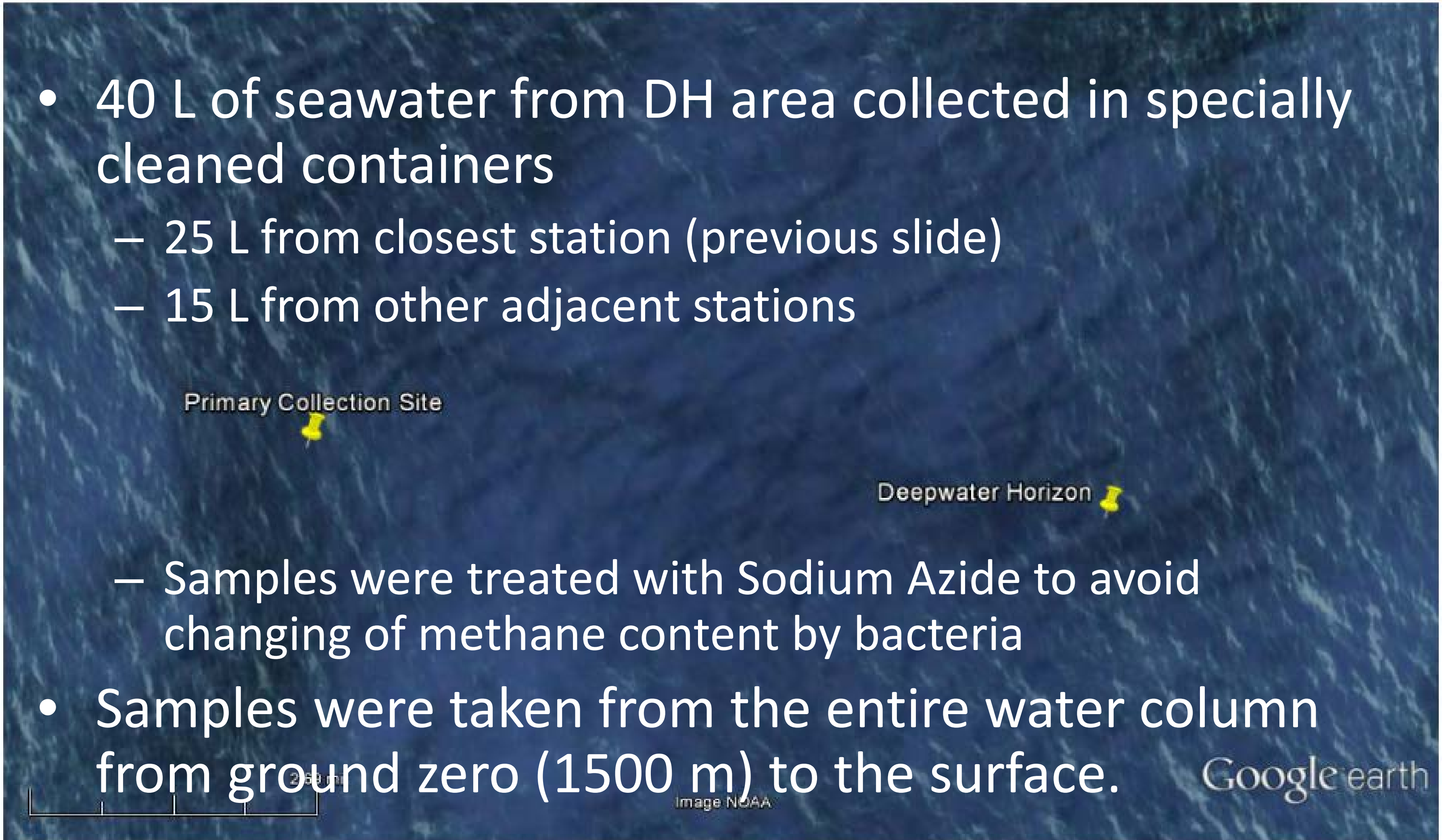






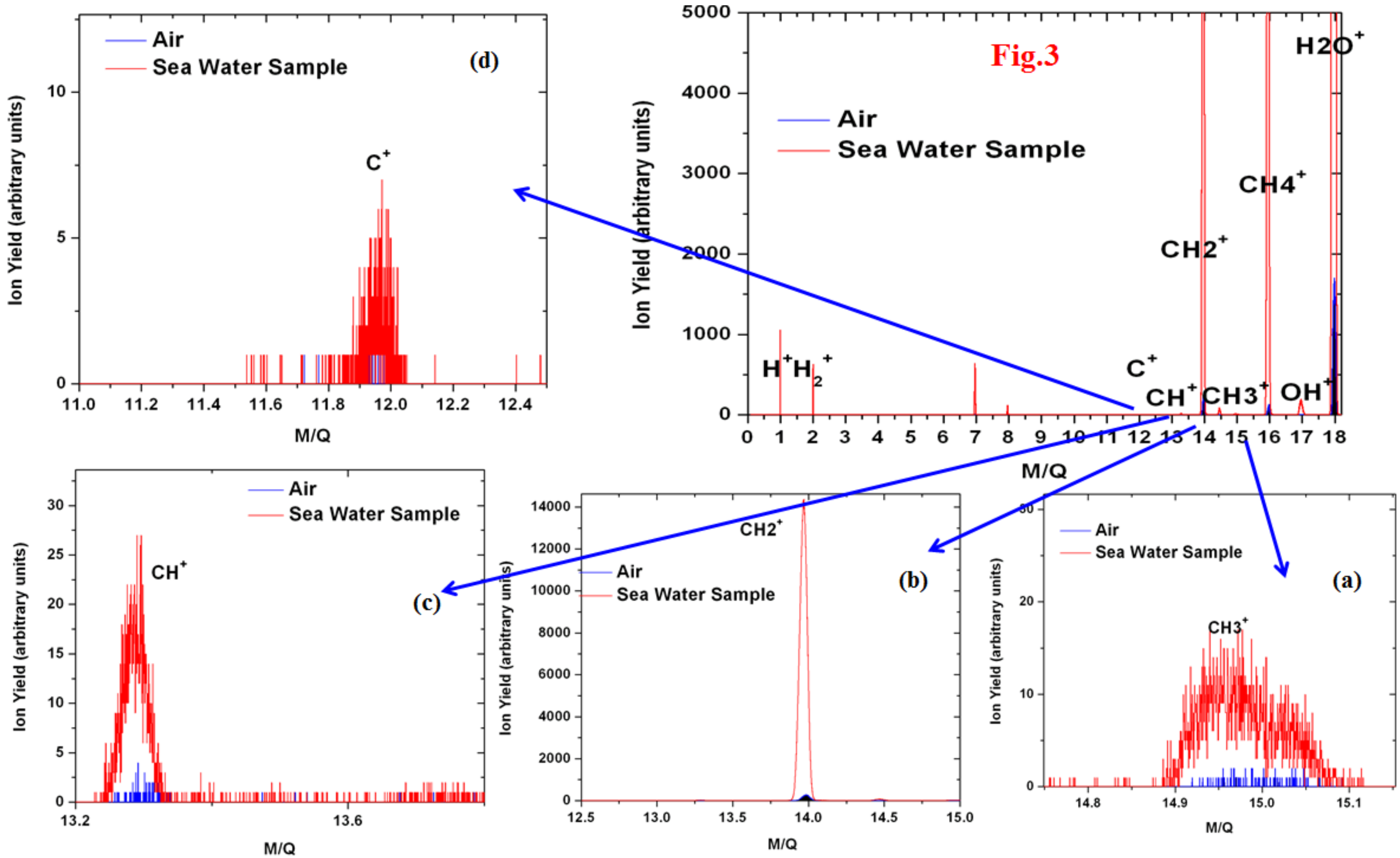
Seawater samples collected in situ 7 miles from DH

- 40 L of seawater from DH area collected in specially cleaned containers
  - 25 L from closest station (previous slide)
  - 15 L from other adjacent stations
  - Samples were treated with Sodium Azide to avoid changing of methane content by bacteria
- Samples were taken from the entire water column from ground zero (1500 m) to the surface.

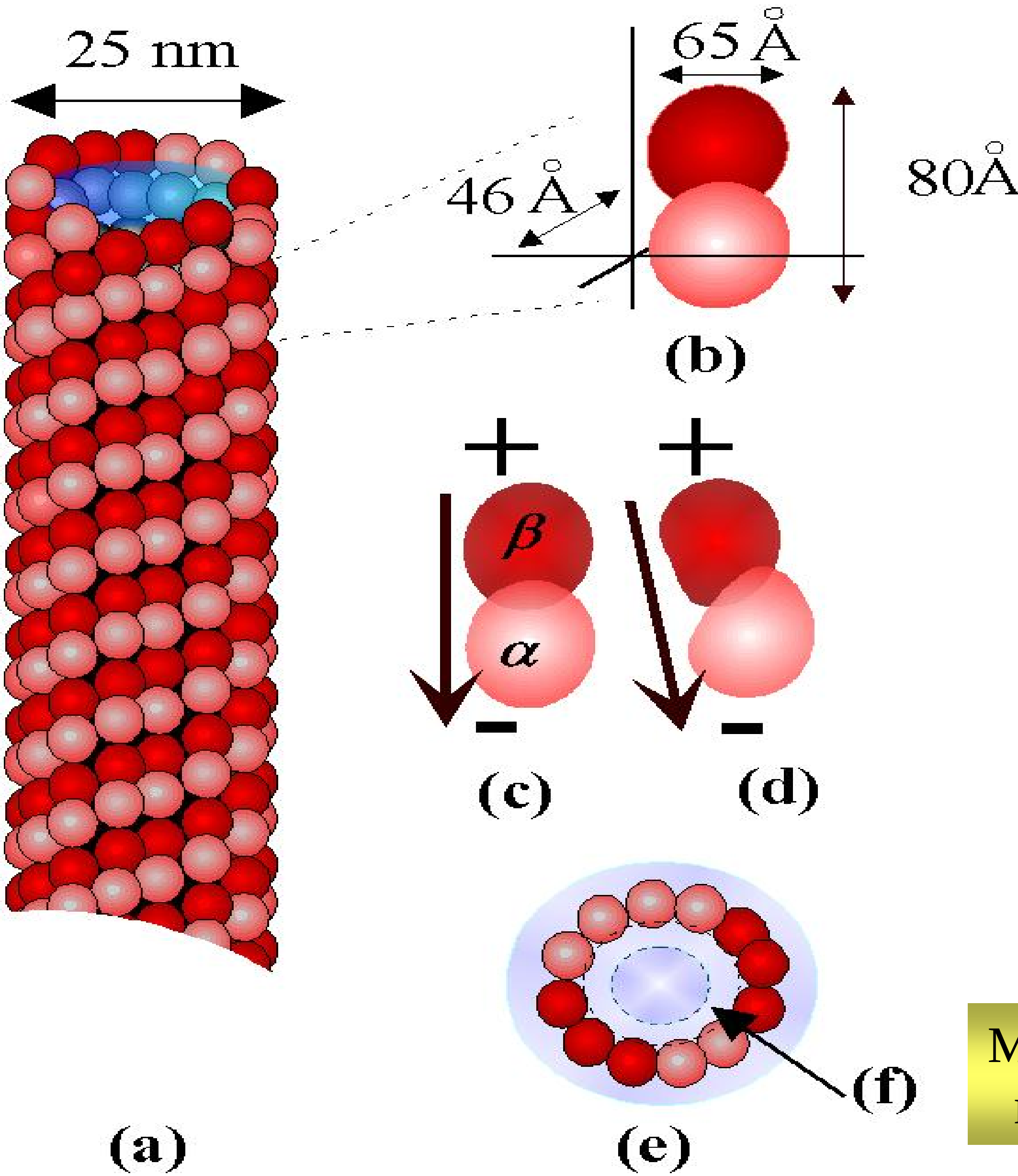


Scale
miles 6
km 10

Fragmentation signatures of methane extracted from a seawater sample near the Horizon well site obtained by TOF laser spectroscopy



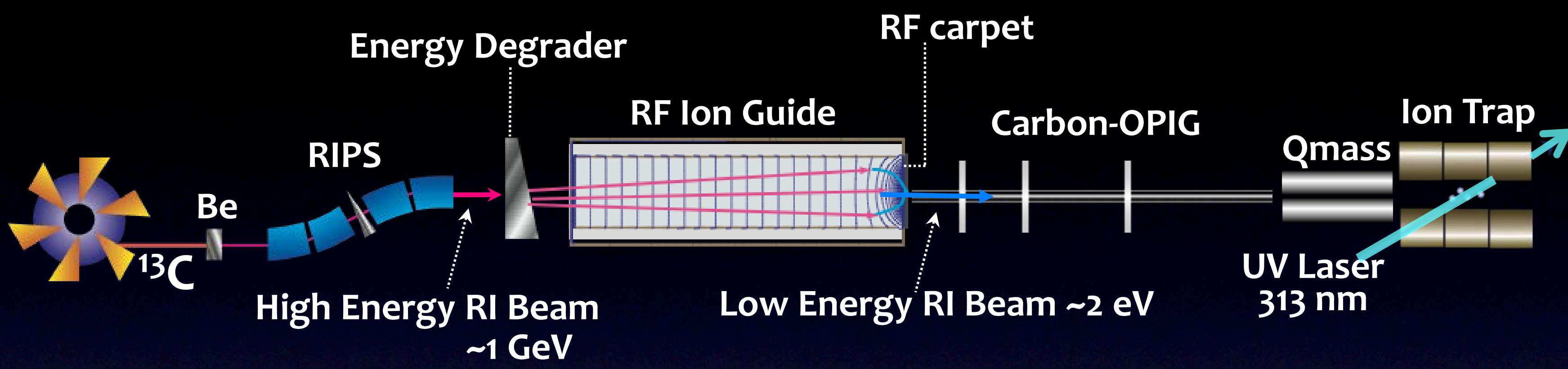
Tubulin and Microtubule structure

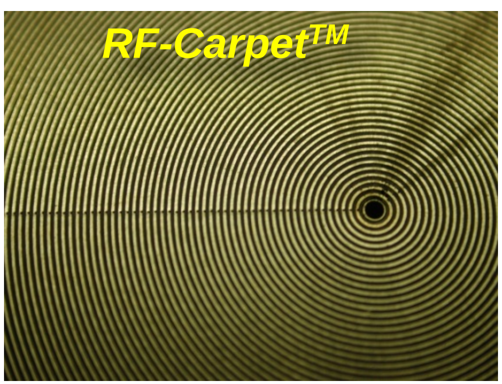


(a): Typical microtubule made of 13 tubulin protofilaments. **(b)**: dimensions of the heterodimer as solved by electron crystallography of zinc-induced sheets note that the MT consists of **(c)**: GTP-tubulin and **(d)**: GDP-tubulin. Arrows indicates electric dipole moment for the two conformations. The percent change in the magnitude of the projection along the MT axis of the dipole moment (Dx) is expected to be readily detectable and roughly equal to 11% { $\Delta Dx = (1-\cos\theta)Dx = 190$ Debye }, where $\theta \sim 27^o$ and Dx ~1700Debye **(e)**: a cross section of the MT showing pitch **(f)** region where theoretical biophysicists have suggested is equivalent to a QED-cavity.

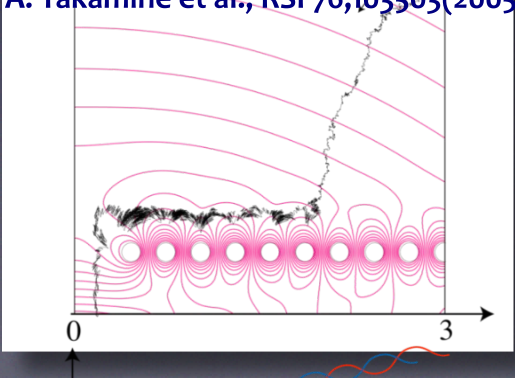
Monitoring actin-myosin similar to monitoring tubulin/microtubules

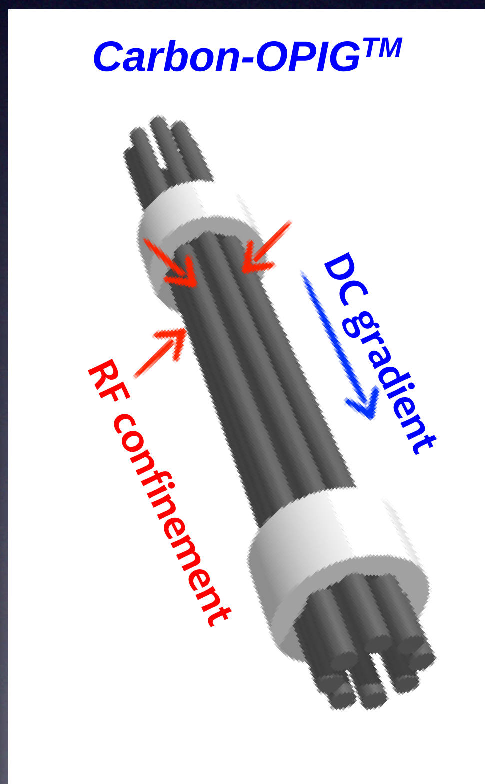
Experimental Setup : SLOWRI prototype @ RIBF, RIKEN



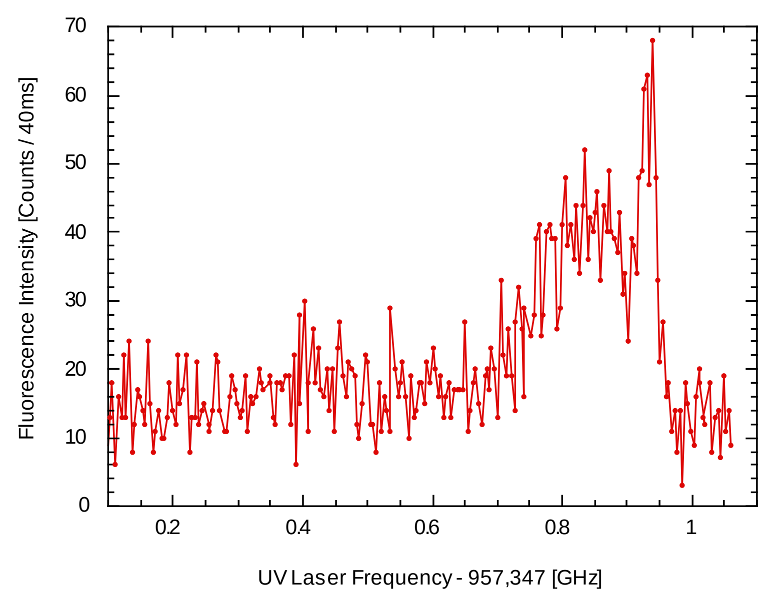


M. Wada et al., NIM B 204,570(2003)
A. Takamine et al., RSI 76,103503(2005)



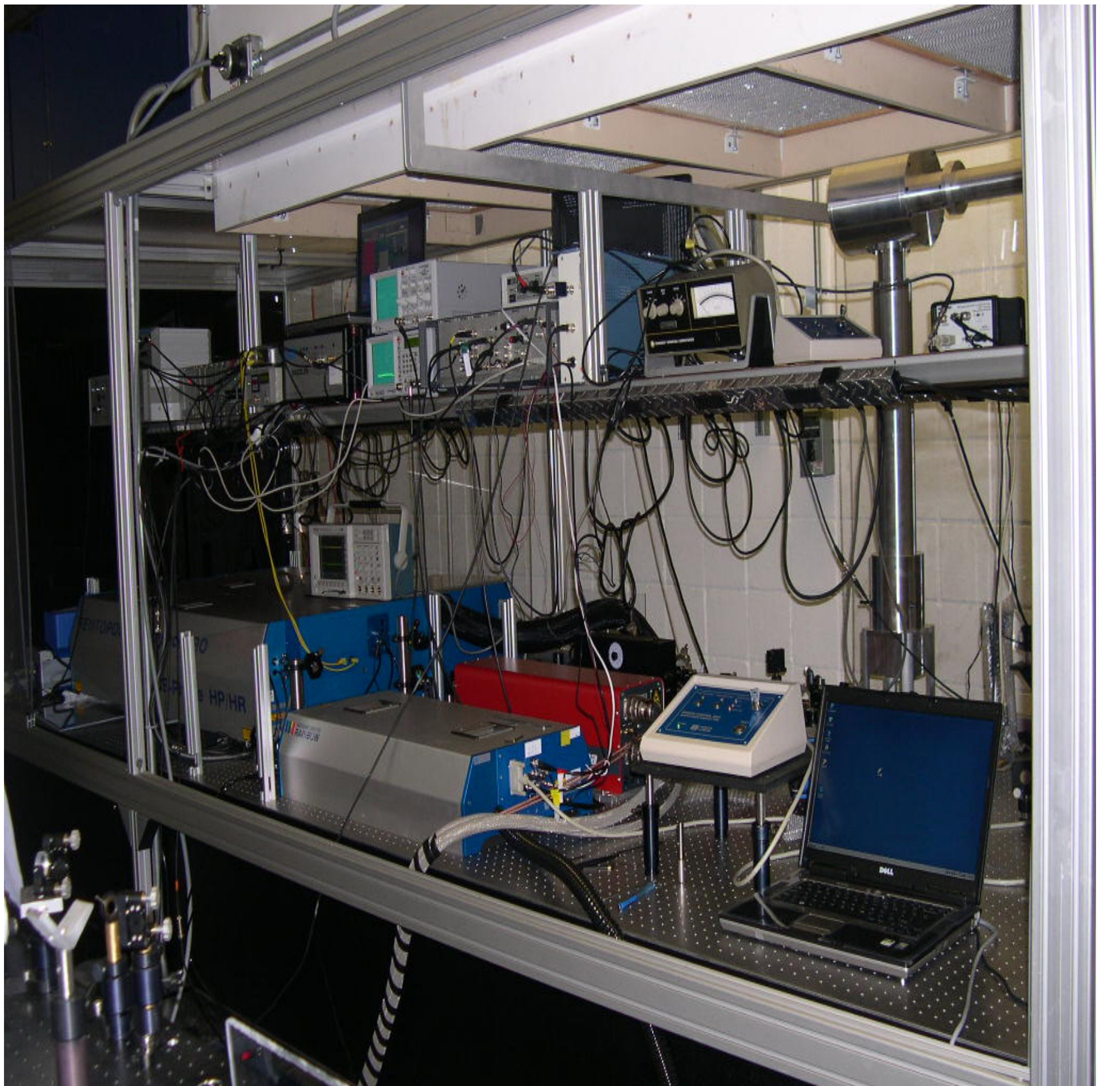


10^{-15} -fold reduction of kinetic energy!



T. Nakamura *et al.*, PRA 74, 052503 (2004)
K. Okada *et al.*, PRL 101, 212502 (2008)

Carrier-Envelope Phase Stabilized Few-Cycle FEMTOLASERS System



Parameters

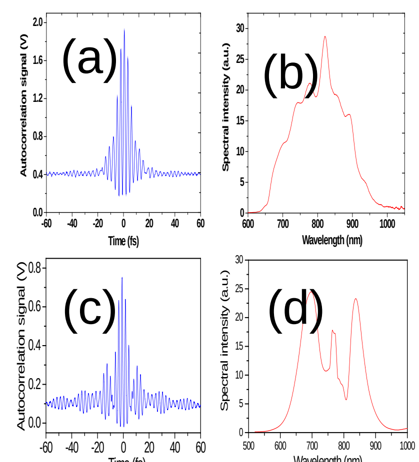
Pulse width = 6.5 fs

Output power = 4.5 W

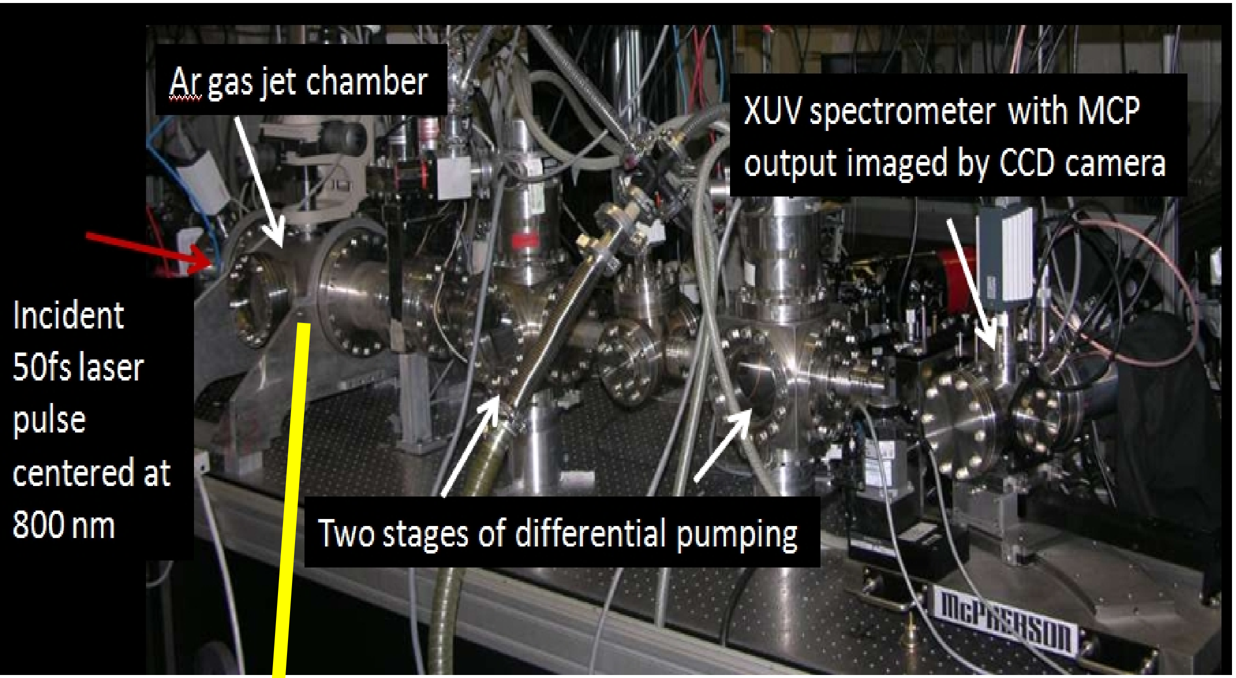
Rep rate = 5 KHz

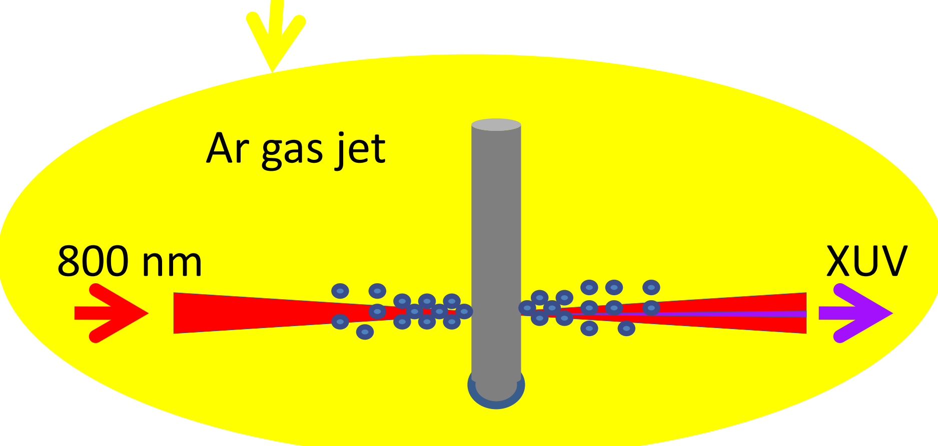
Energy per pulse = 1 mJ

Autocorrelator traces and spectra: oscillator (a), (b) and amplifier (c),(d).



Experimental setup for XUV generation

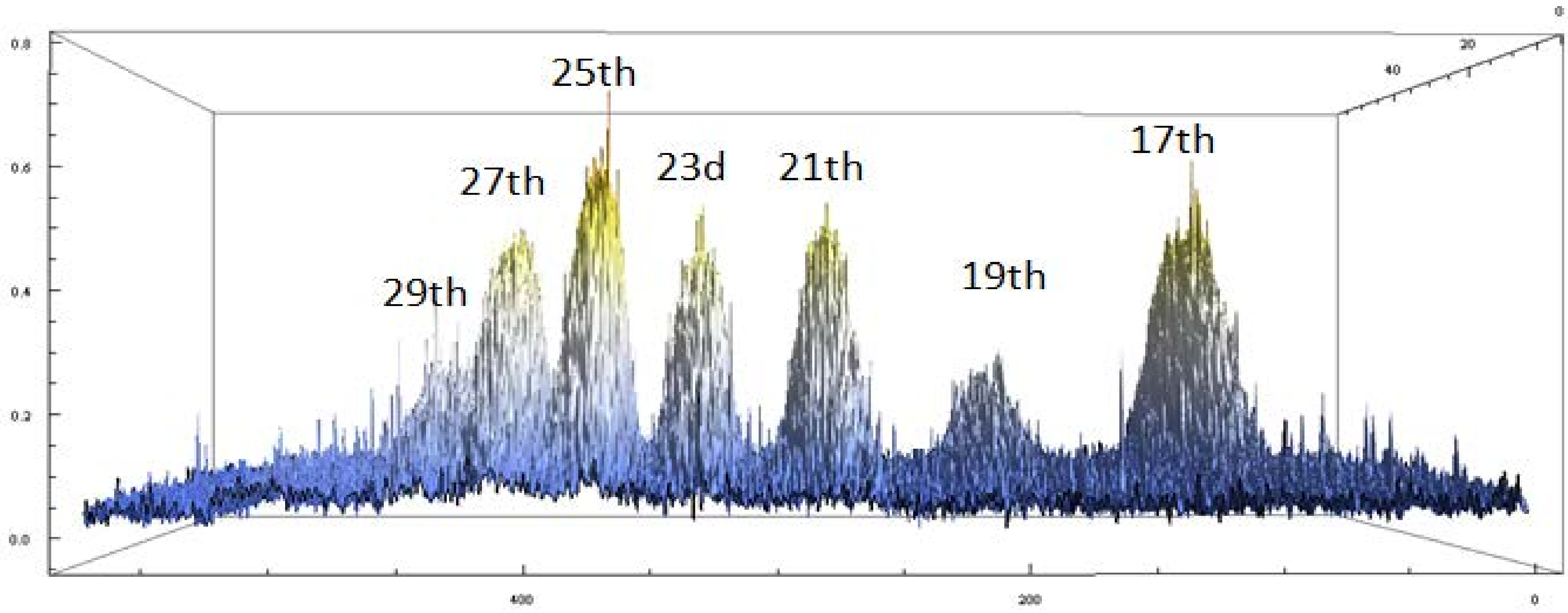




Typical experimental parameters:

- Energy/pulse at the fundamental wavelength from 0.5 mJ to 5mJ.
- Laser intensities from 5×10^{14} to 5×10^{15} W/ cm^2 .
- Repetition rate 1kHz for 0.5 mJ pulses and 10Hz for higher energy.
- Backing pressure for the gas jet: about 5 bar
- Pressure in the gas jet (caculated from the gas flow rate) about 100-mbar.

Intensity distributions of higher order harmonics generated in Ar gas and imaged on the CCD



The generated high harmonics extended to 29th order and were well separated for the used pulse, which contained about 20 periods of the fundamental field.

Drillling Rig Near Wyoming's Wind River Range

Deepwater Horizon well blowout

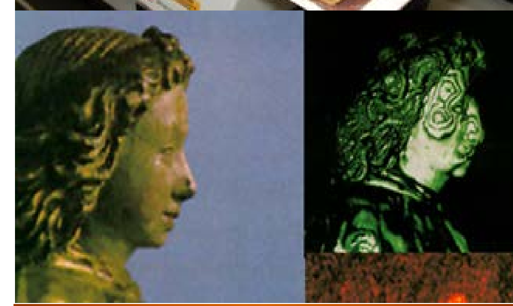
… and more than science

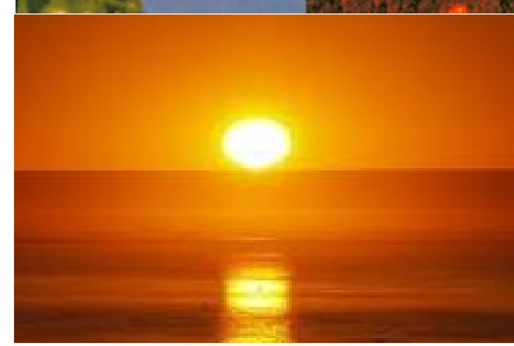
Cultural Heritage

Education for All

Nature

Light and Art





Activities are very broad - science…

Origin of Life

Healthcare

Communications & GPS

Optical Instruments

The Universe

100+ partners from 85 countries

Atomic Radii

Some properties of elements are compared by the **ionization energies of elements** and **atomic radii**: