Richard Seto
September 29, 2003

The Physics Department

A Vision for the 21st Century

UNIVERSITY OF CALIFORNIA, RIVERSIDE
COLLEGE OF NATURAL & AGRICULTURAL SCIENCES
CNAS

UNIVERSITY of CALIFORNIA Riverside

What I want to cover

- Remarks about the Physics (Department)
  - Actually its about the unity of physics (science)
- Future of the “Particle” Physics side of the department
  - Will speak only generally
  - specifics will take time
- Harry will talk about the “condensed matter side”

Across the Boundaries of Disciplines

- We are gaining an unprecedented ability to answer the **"why"** of things in a fundamental way and to make quantitative calculations and predictions about things we never dreamed of
  - Techniques first used by physicists (mathematicians?-Field theory/Lagrangians)
    - Atomic
    - Particle
    - Condensed matter
    - Similar techniques beginning too be used to understand e.g. biological systems (DNA)

Across the boundaries (cont)

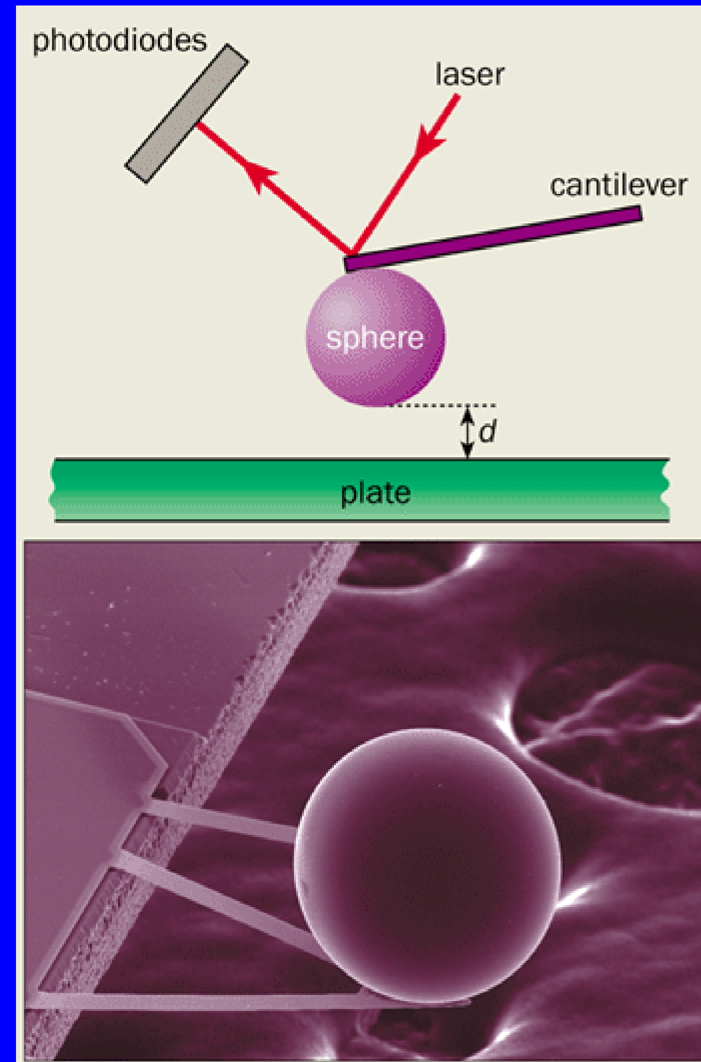
- Complexity (emergent phenomena)
  - Even the simplest of systems (e.g. the vacuum, or the proton) has shown itself to be a “complex” system
  - Complex systems are not interesting in of itself
  - What makes them interesting is “understanding”
- Powerful arguments
  - Symmetries
  - Rigorous arguments about the best way of describing phenomena at a particular scale (renormalization group)

An example: the vacuum

- Vacuum ~ nothing?? – NO
  – Seething with activity
    - Fluctuating fields
    - Condensates
    - Dark energy?
  – more like a material: a complex system
  – Idea stems from both the condensed matter and particle physics communities
  – Crosses boundaries between fields: energy scales

UCR Vacuum Apparatus I: in Prof Mohideen's Lab

- Prof. Umar Mohiddeen et al
- Studying the force of the **electromagnetic** component of the vacuum – the "Casmir effect"
- Energy scale ~eV

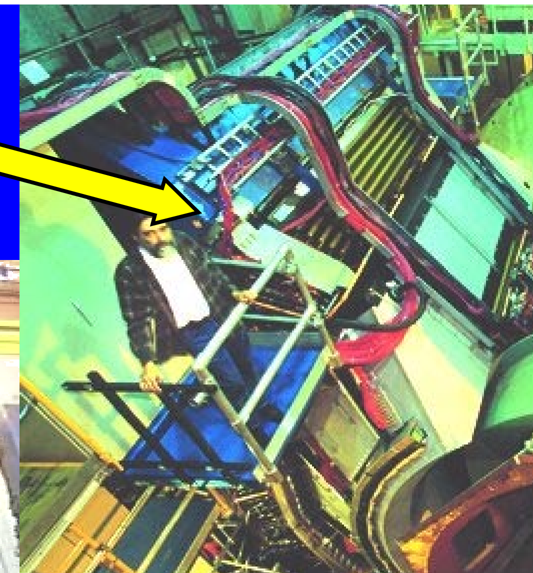


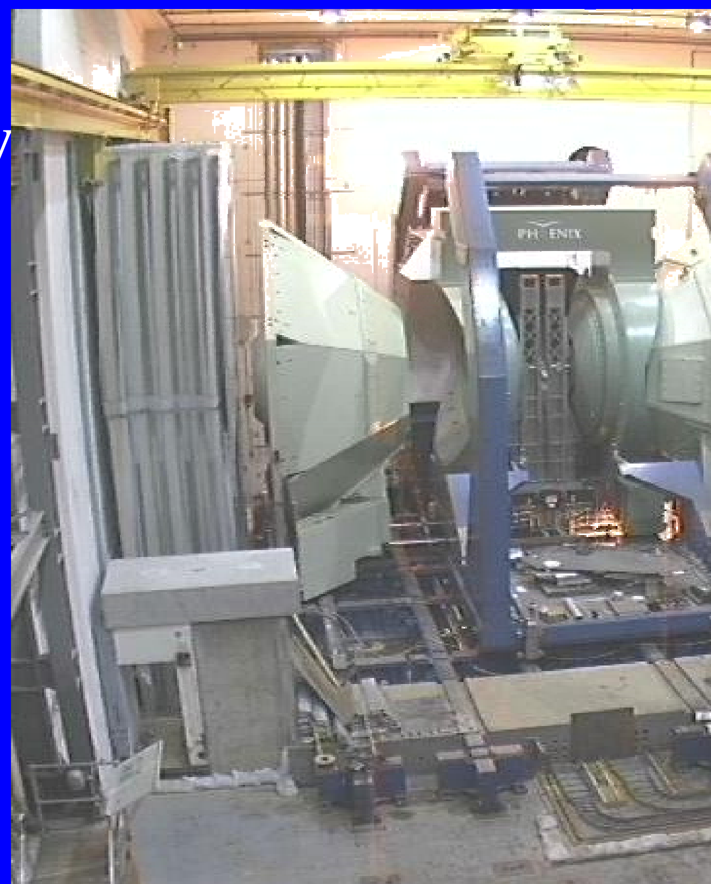
UCR Vacuum Apparatus II:
PHENIX @ RHIC

- Profs. Barish, Seto
- Studying the **QCD** component of the vacuum in Relativistic Heavy Ion Collisions
- measure effect of vacuum on mass directly
- $\sim 10^9$ eV

$$$ courtesy of CNAS Deans!

Top view – close up

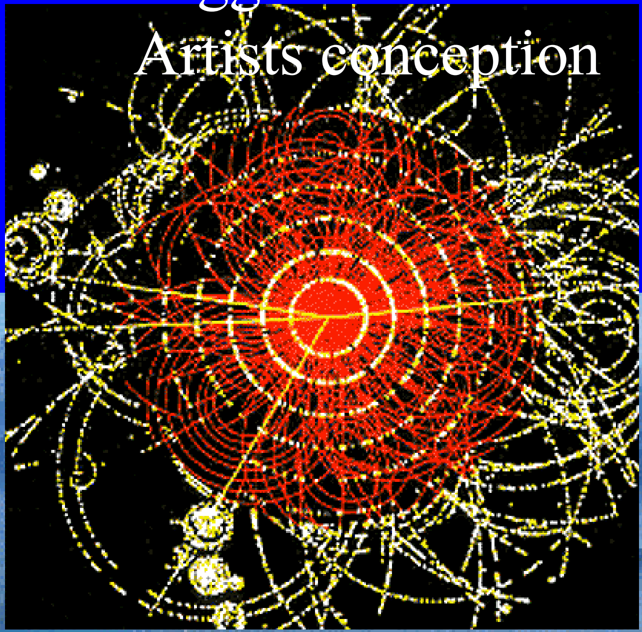




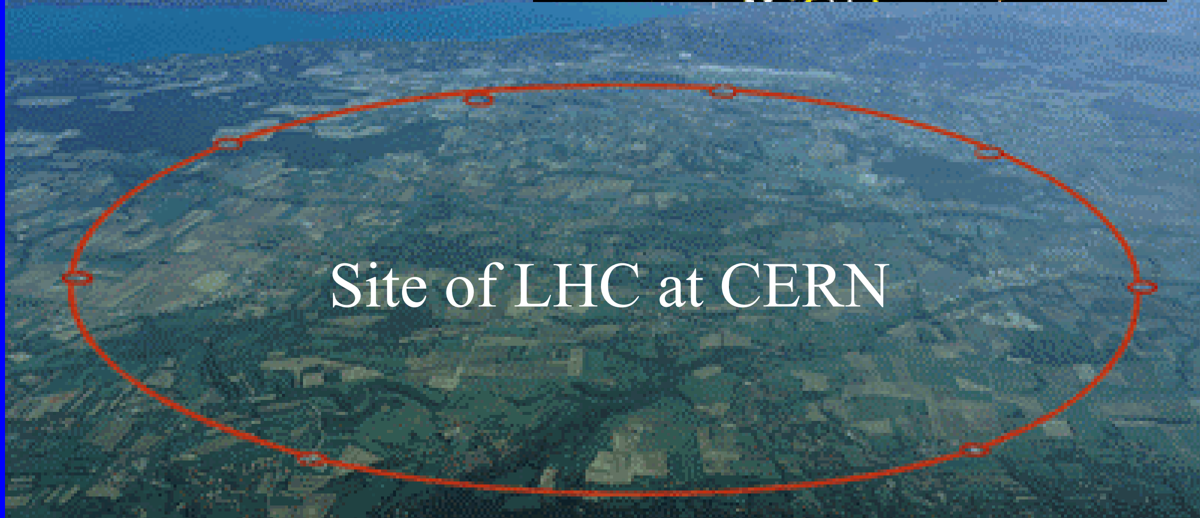
UCR Vacuum Apparatus III: CMS @ LHC and D0@FNAL

- Profs. CMS: Clare, Gary, Hanson, Shen; D0: Ellison, Wimpenny

Higgs event: Artists conception

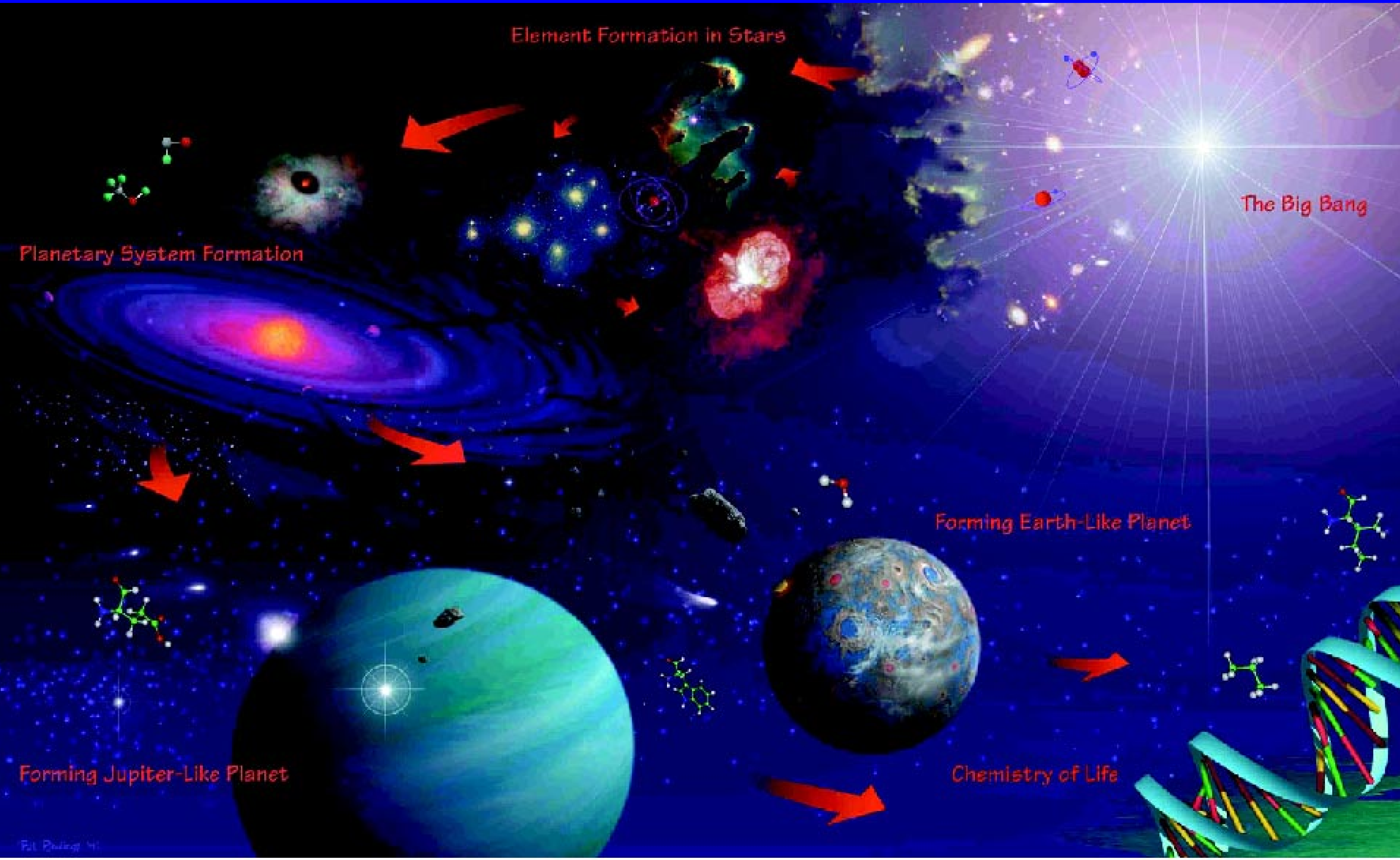


- Studying the **Electro-Weak** component of the vacuum : pp collisions
- Find the Higgs "condensate"
- $\sim 10^{12}$eV

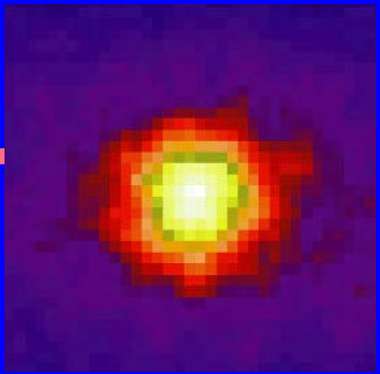


Site of LHC at CERN

UCR Vacuum apparatus IV: The Ultimate experiment



Were are we going?



Sun: neutrinos

- Enormous advances made
  - In understanding: (as I mentioned)
    - Experiment/theory: “standard model”
  - technology
    - Tools – accelerators, detectors, satellites, telescopes
    - Computing advances – both speed and storage capacity
      - Allowed us to work with vast amount of data

➔Opportunities:

- ask some audacious questions (and hope for answers) e.g.
  - What is matter?
    - Why do things weigh what they do?
  - What is time and space
    - How many dimensions are there (why do we only see 3?)
  - How did the universe begin – Why did it begin?

To answer such questions…

- Leads us inevitably to cross traditional boundaries

Physics

Math

Quantum gravity

The questions (e.g.)

–What is matter?

–What is time and space?

–How and why did the universe begin?

Engineering Computing

Faster chips
Grid computing

Astronomy

Dark matter/energy

interdisciplinary collaborations: a comment

- Grow where we are strong
  - The large experimental collaborations already are interdisciplinary
    - Physicists, Engineers, computer scientists, (even MBA's!)
      - New and faster chips
      - New paradigms of computing (WWW ,Teraflops QCD, the grid, data mining etc)
- We should consider collaborations at UCR – but they should add to our ability to answer the questions which are at the heart of who we are.
  - They should not depend on technique, money, or popularity
  - They should be driven by the science – by the "WHY's"

Conclude

- Grow where we are strong and nurture those collaborative efforts we have
  - Make sure experimentalists have good theoretical support and vice-versa
- Use our strength to move into new areas to allow us to formulate and answer the "Why" questions

➔ inevitably leads us to cross disciplinary boundaries (thanks for the push!)

- Task for us in the coming weeks/months

Spin-off's

"Medical advances may seem like wizardry. But pull back the curtain, and sitting at the lever is a high-energy physicist, a combinational chemist or an engineer. Magnetic resonance imaging is an excellent example. Perhaps the last century's greatest advance in diagnosis, MRI is the product of atomic, nuclear and high-energy physics, quantum chemistry, computer science, cryogenics, solid state physics and applied medicine."

Harold Varmus

– President-Sloan Kettering and Director of NIH '93-'99
– The Washington Post; October 4, 2000
– from an argument to increase the funding for the DOE Office of Science and NSF

Extra slides

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- Desire to understand quantitatively the why's of the most fundamental things about our universe
  - Why is there a universe?
  - Why are there
    - Things?
  - Why are there 3+1 dimensions?
  - Why do things weigh what they do?

- In the first half of the 20th century the twin revolutions of quantum theory and relativity dramatically changed scientists' perspective on the physical world.
- Building on this base, over the last half of the 20th century physicists developed and tested a new quantum theory of matter (now called the Standard Model) and extended and tested the theory of classical space-time (general relativity and big bang cosmology). These successes present extraordinary new opportunities for physics in the new century.
- Questions of unprecedented depth and scope about the ultimate laws governing physical reality, and about the origin and content of the physical

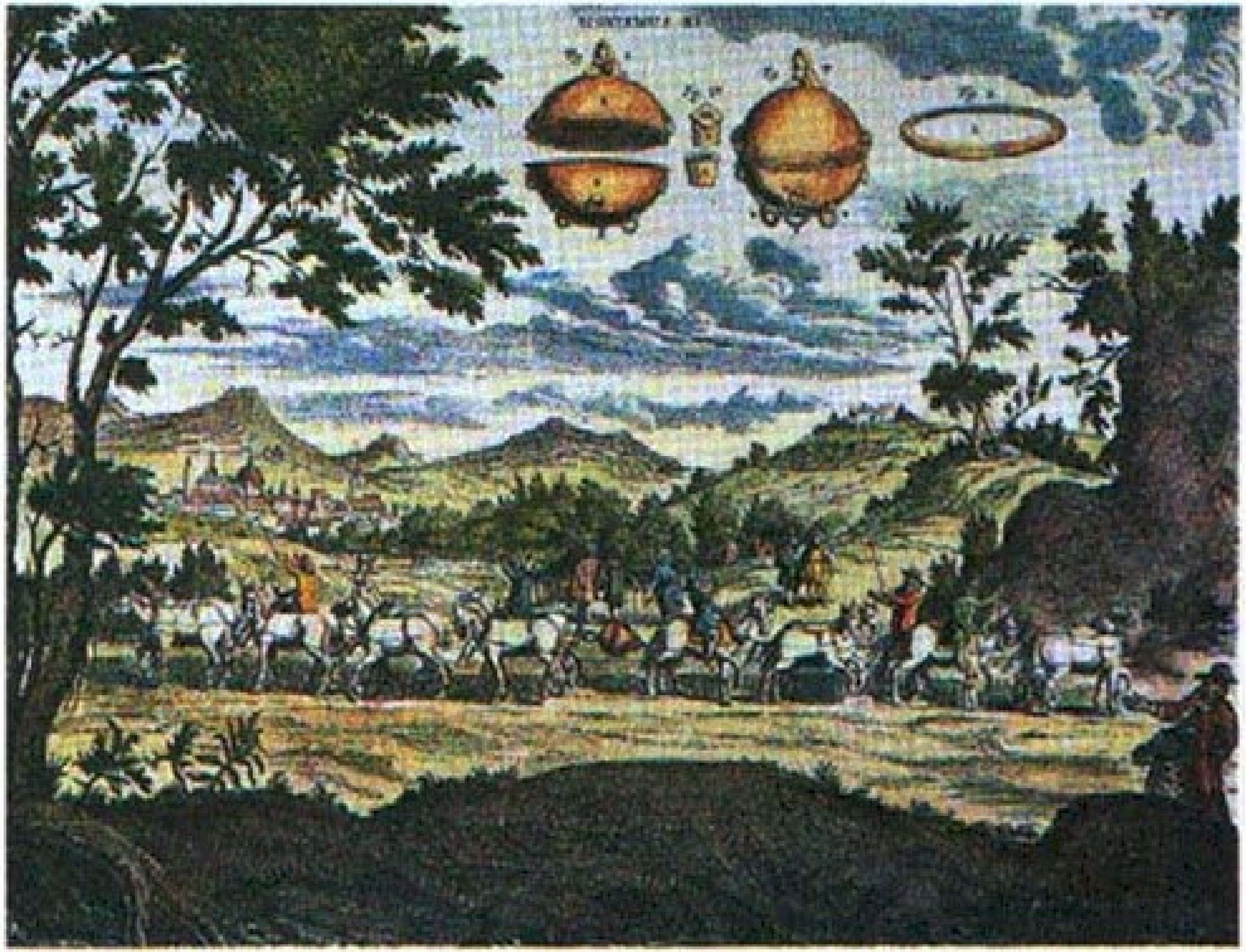
Outline

- Unprecedented ability to answer the "why" of things in a fundamental way and to make quantitative calculations and predictions about things we never dreamed of
  - Mathematical techniques
    - used by physicists (Lagrangian)
      - first by the particle physicists
      - Particle
      - Atomic
      - Condensed matter
    - Powerful arguments (renormalization group theory) so one can rigorously prove the applicability of a theory in a particular energy regime

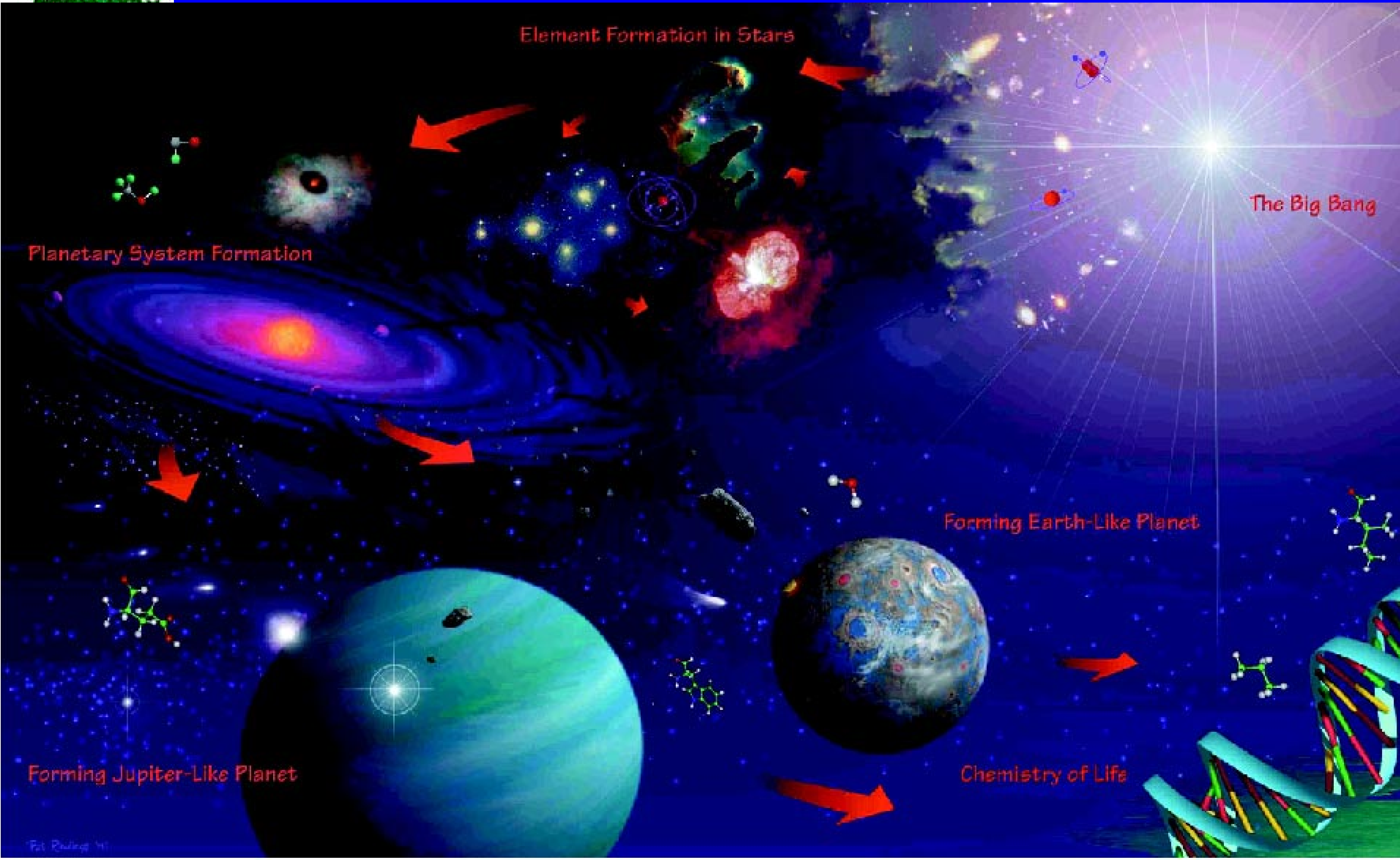
- Crosses artificial boundaries between fields
- What drives us is not the particular discipline but the questions.

Magdeburg Hemispheres

The Magdeburg Hemispheres



In the 17th century, Otto von Guerrike, Lord Mayor of Magdeburg,
demonstrated the force of atmospheric pressure, 1kg/sqcm, on



Element Formation in Stars
The Big Bang
Planetary System Formation
Forming Earth-Like Planet
Forming Jupiter-Like Planet
Chemistry of Life

- This is a special moment. If we can take advantage of the opportunities
- that exist, we stand to make truly fundamental advances in our understand-ing
- of how the universe began as well as of the basic nature of matter,
- space, and time.

- These advances owe much to new technology. Optical astronomy has witnessed a million fold gain in sensitivity since 1900, and a hundredfold gain since 1970. Gains in the ability to view the subatomic world of elementary particles through new accelerators and detectors have been similarly impressive. The exponential growth in computing speed and in information storage capability has helped to translate these detector advances into science breakthroughs. Technology has extended researchers' vision across the entire electromagnetic spectrum, giving them eyes on the universe from radio waves to gamma rays, and new forms of "vision" using neutrinos and gravitational waves may reveal more cosmic surprises. Entirely new detectors never dreamed of before are making possible the search for new kinds of particles.