Astroparticle Physics International Forum (APIF)

Astroparticle Physics (ApP): A European Roadmap

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College de France, Paris

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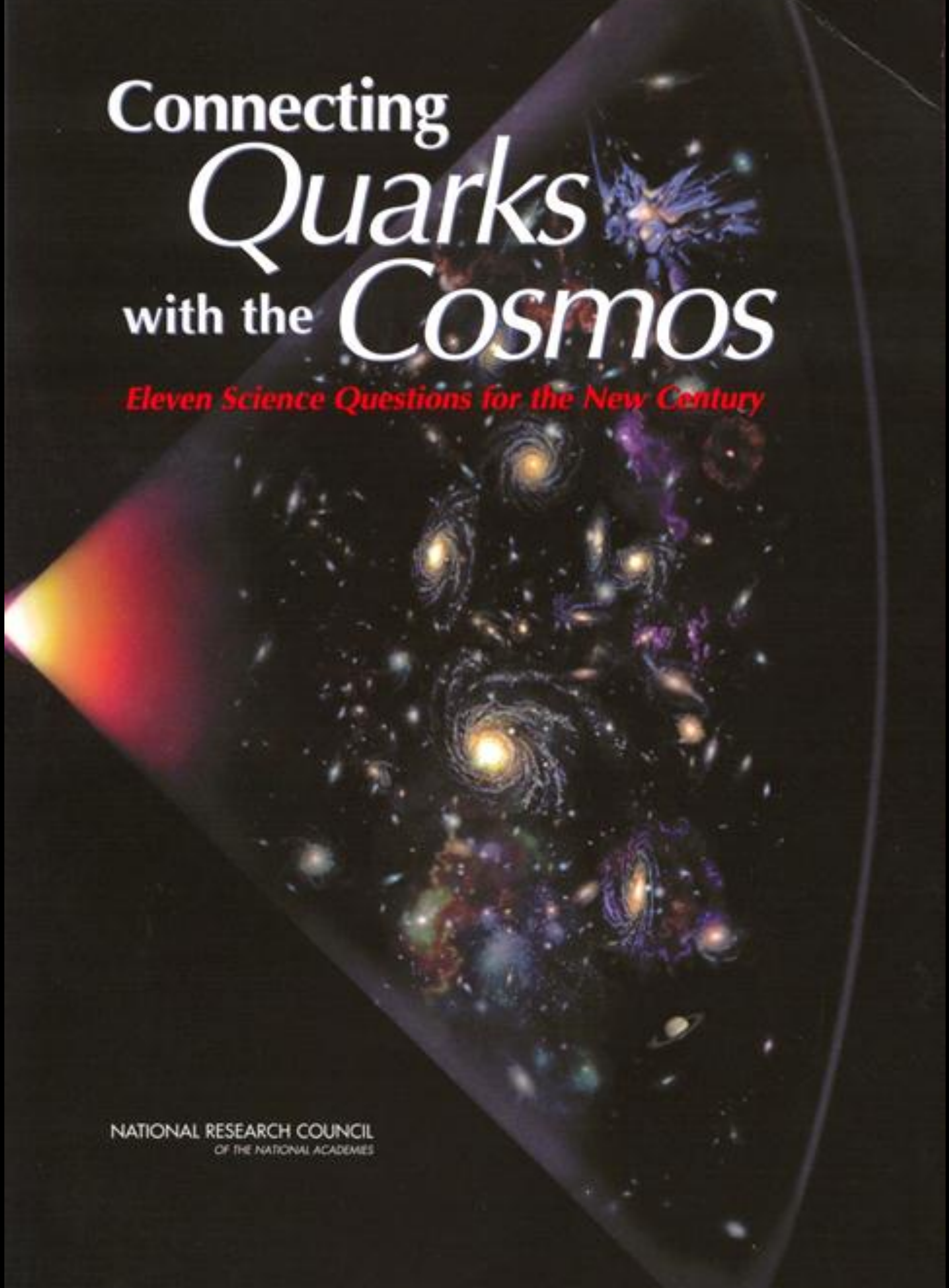
The very small and the very big are connected:
The largest things in the Universe
began from subatomic quantum fluctuations!
WOW!

Deep Connections

- Dark matter
- Dark energy
- Inflation
- Origin of atoms
- Neutrinos shaped the Universe

- New particle of nature
- Energy of the vacuum or breakdown of GR
- Galaxies and LSS from quantum fluctuations
- Particle interactions in the Early Universe
- Window to unification & new physics

2002 US National Academy of Sciences Study



What is dark matter?

What is dark energy?

How did the universe begin?

Was Einstein right about gravity?

How have neutrinos shaped the universe?

What are nature's most energetic particles?

Are protons unstable?

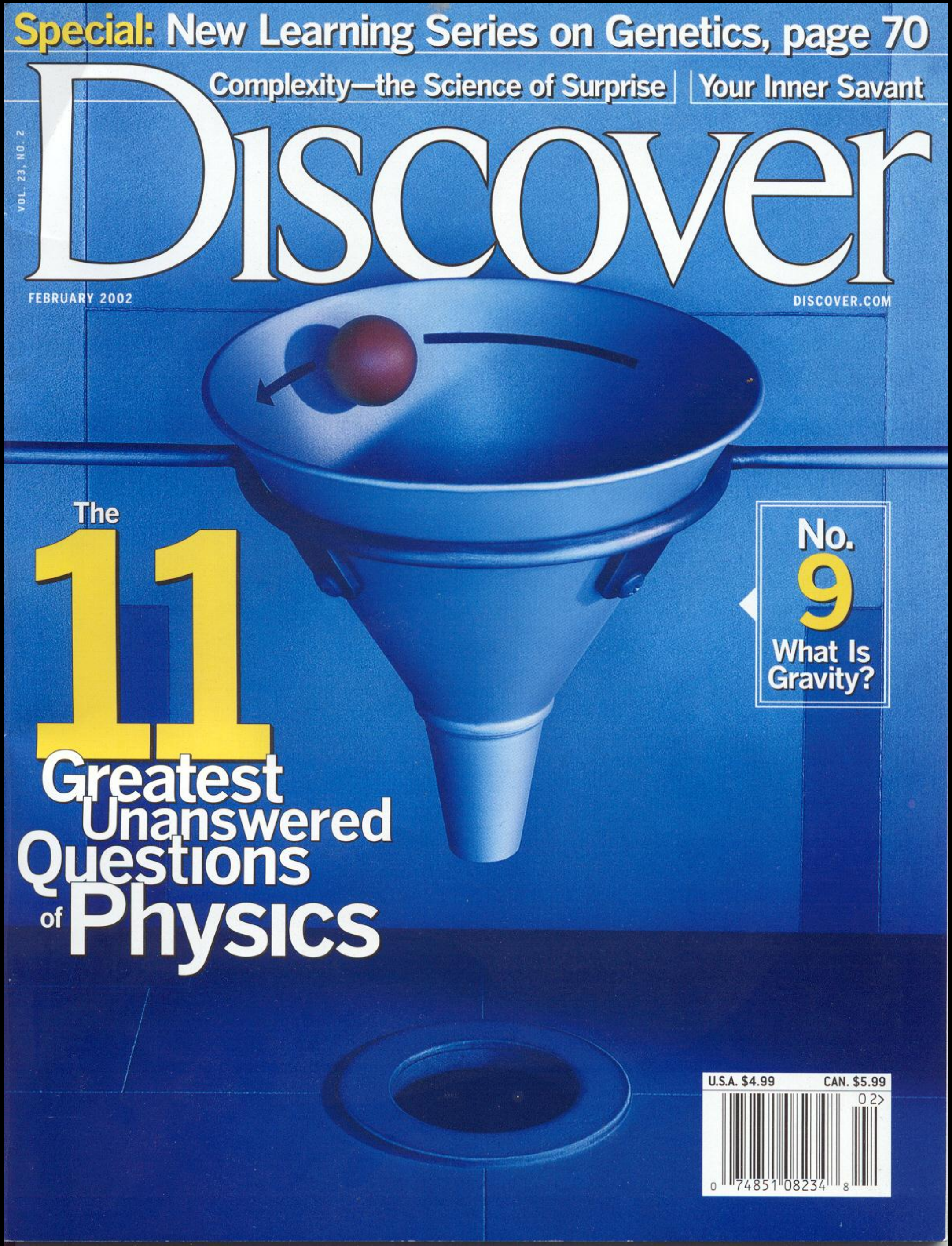
What are the new states of matter?

Are there more space-time dimensions?

How were the elements from Fe to U made?

Is a new theory of light and matter needed?

"The answers to these questions strain the limits of human ingenuity, but the questions themselves are crystalline in their clarity and simplicity."



Astroparticle Physics (ApP)

- Exciting, young, dynamic with high visibility & public appeal
- Enormous range in science scale and techniques
- No universal definition of field (both a bug & a feature!)
- Fundamentally interdisciplinary → cross-program, multi-agency and competes with traditional fields (e.g. in US: DOE ONP, OHEP; NSF PHY, AST, OPP; NASA APD)
- International with strength in many countries
- Rich texture of projects – from technology development and small projects to regional facilities and global projects

→ Coordination, cooperation, and good communications essential to continued progress

ApP Science Topics

- Dark Matter
- Dark Energy
- High-energy messengers (CRs, photons, neutrinos)
- Gravitational waves
- Proton decay
- Neutrino properties (mass and mixing)
- (NOT Cosmic Microwave Background)

Astroparticle Physics International

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Organisation for Economic Co-operation and Development

Global Science Forum

Report of the Working Group on Astroparticle Physics

March 31, 2011

… from the website*

The OECD Astroparticle Physics International Forum (APIF) brings together officials and representatives of funding agencies of countries that make significant investments in astroparticle physics research. It is a venue for information exchange, analysis, and coordination, with special emphasis on strengthening international cooperation, especially for large programmes and infrastructures. APIF members can address issues that are the special responsibility of funding agencies, for example, legal, administrative and managerial arrangements for international projects. They may also consider matters such as access to experimental facilities and data, procurement of essential materials, and optimal use of resources on a global scale. APIF is not a venue for discussing purely scientific matters, and it does not duplicate or replace established national and international processes for planning, prioritisation, funding, assessment or implementation of specific projects or programmes.

*Best access: Google "Astroparticle Physics International Forum OECD"

Current Members

- Argentina
- Belgium
- Canada
- China
- European Commission
- France
- Germany
- India
- Israel
- Italy
- Japan
- Korea
- Netherlands
- Poland
- Spain
- Sweden
- Switzerland
- United Kingdom
- United States
- Stefan Michalowski (GSF)

…. About half of the members are here!

Activities

- Two meetings/year (April & October 2011 in Paris; April 2012 in London)
- Public summary of each meeting (website)
- Some issues on the table
  - How to get expert advice from the science community
  - Organizational structure of large, international projects
  - Status of funding across ApP around the world
  - Coordination of technology development
  - Investment strategies

Personal reflection

We all struggle to find mechanisms to support this exciting, complex and highly visible science − nationally, regionally and globally. APIF hopes to be an important part of the solution.

As always, we are bolstered by extraordinarily exciting science that addresses some of the biggest questions humankind can ask.

CONNECTING QUARKS WITH THE COSMOS:

11 SCIENTIFIC CHALLENGES FOR THE NEW CENTURY

WHAT IS THE DARK MATTER?

Astronomers have shown that the objects in the universe from galaxies a million times smaller than ours to the largest clusters of galaxies are held together by a form of matter that is not what we are made of and that gives off no light. This matter probably consists of one or more as-yet-undiscovered elementary particles, and aggregations of it produce the gravitational pull leading to the formation of galaxies and large-scale structures in the universe. At the same time these particles may be streaming through our Earth-bound laboratories.

WHAT IS THE NATURE OF THE DARK ENERGY?

Recent measurements indicate that the expansion of the universe is speeding up rather than slowing down. This conclusion goes against the fundamental idea that gravity is always attractive. This discovery calls for the presence of a form of energy, dubbed “dark energy,” whose gravity is repulsive and whose nature determines the destiny of our Universe.

HOW DID THE UNIVERSE BEGIN?

There is evidence that during its earliest moments the universe underwent a tremendous burst of additional expansion, known as inflation, so that the largest objects in the universe had their origins in subatomic quantum fuzz. The underlying physical cause of this inflation is a mystery.

DID EINSTEIN HAVE THE LAST WORD ON GRAVITY?

Black holes are ubiquitous in the universe, and their intense gravity can be explored. The effects of strong gravity in the early universe have observable consequences. Einstein's theory should work as well in these situations as it does in the solar system. A complete theory of gravity should incorporate quantum effects —Einstein's theory of gravity does not—or explain why they are not relevant.

WHAT ARE THE MASSES OF THE NEUTRINOS, AND HOW HAVE THEY SHAPED THE EVOLUTION OF THE UNIVERSE?

Cosmology tells us that neutrinos must be abundantly present in the universe today. Physicists have found evidence that they have a small mass, which implies that cosmic neutrinos account for as much mass as dostars. The pattern of neutrino masses can reveal much about how the Nature's forces are unified and how the elements in the periodic table were made.

HOW DO COSMIC ACCELERATORS WORK AND WHAT ARE THEY ACCELERATING?

Physicists have detected an amazing variety of energetic phenomena in the universe, including beams of particles of unexpectedly high energy but of unknown origin. In laboratory accelerators, we can produce beams of energetic particles, but the energy of these cosmic beams far exceeds any energies produced on Earth.

ARE PROTONS UNSTABLE?

The matter of which we are made is the tiny residue of the annihilation of matter and antimatter that emerged from the earliest universe in not-quite-equal amounts. The existence of this tiny imbalance may be tied to a hypothesized instability of protons, the simplest form of matter, and to a slight preference for the formation of matter over antimatter built into the laws of physics.

ARE THERE NEW STATES OF MATTER AT EXCEEDINGLY HIGH DENSITY AND TEMPERATURE?

The theory of how protons and neutrons form the atomic nuclei of the chemical elements is well developed. At higher densities, neutrons and protons may “dissolve” into an undifferentiated “soup” of quarks and gluons, which can be probed in heavy-ion accelerators. Still higher densities and temperature occur and can be probed in neutron stars and the early universe.

ARE THERE ADDITIONAL SPACETIME DIMENSIONS?

In trying to extend Einstein’s theory and to understand the quantum nature of gravity, particle physicists have posited the existence of spacetime dimensions beyond those that we know. Their existence could have implications for the birth and evolution of the universe, could affect the interactions of the fundamental particles, and could alter the force of gravity at short distances.

HOW WERE THE ELEMENTS FROM IRON TO URANIUM MADE?

Scientists’ understanding of the production of elements up to iron in stars and supernovae is fairly complete. The precise origin of the heavier elements from iron to uranium remains a mystery.

IS A NEW THEORY OF MATTER AND LIGHT NEEDED AT THE HIGHEST ENERGIES?

Matter and radiation in the laboratory appear to be extraordinarily well described by the laws of quantum mechanics, electromagnetism and their unification as quantum electrodynamics. The universe presents us with places and objects, such as neutron stars and the sources of gamma ray bursts, where the energies are far more extreme than anything we can reproduce on Earth in order to test these basic theories.