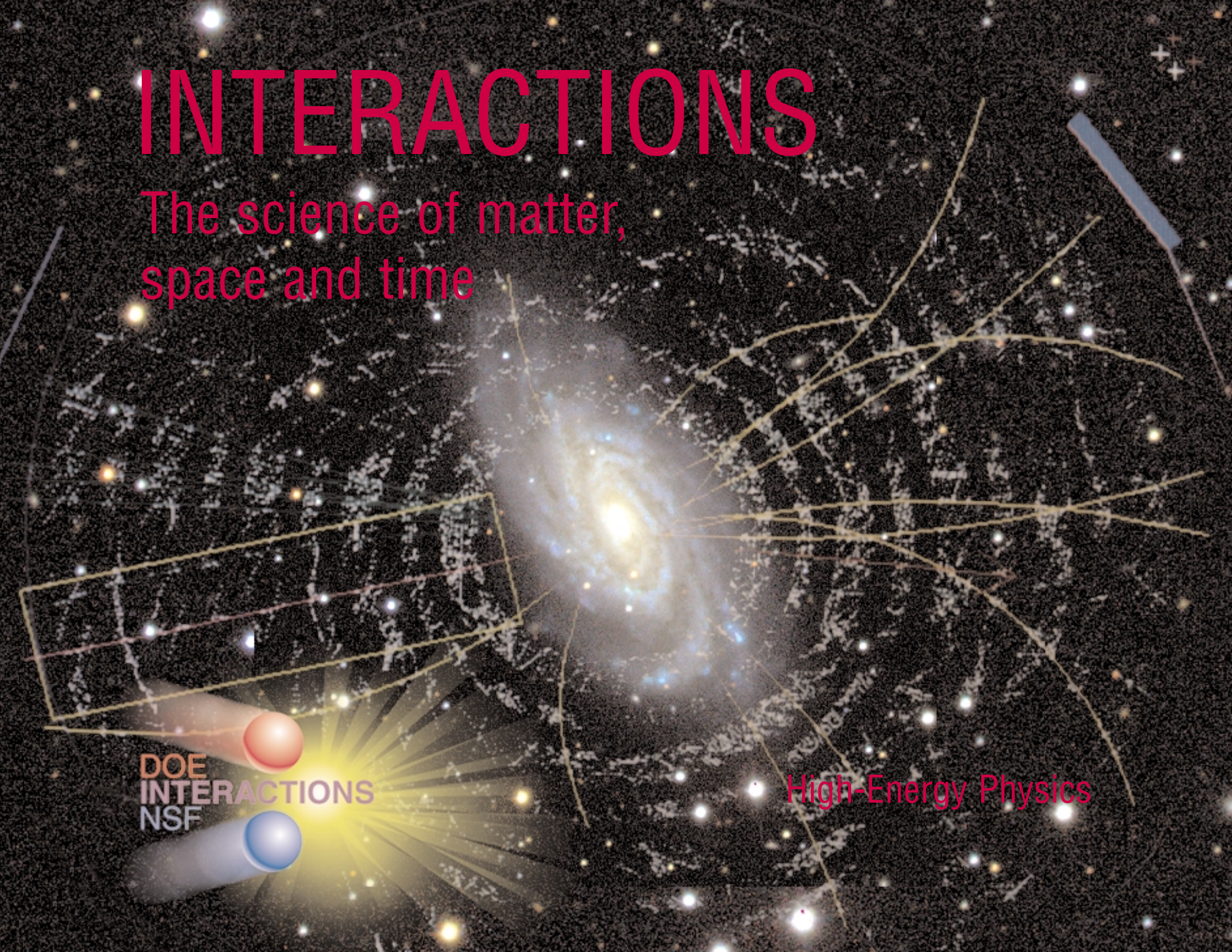
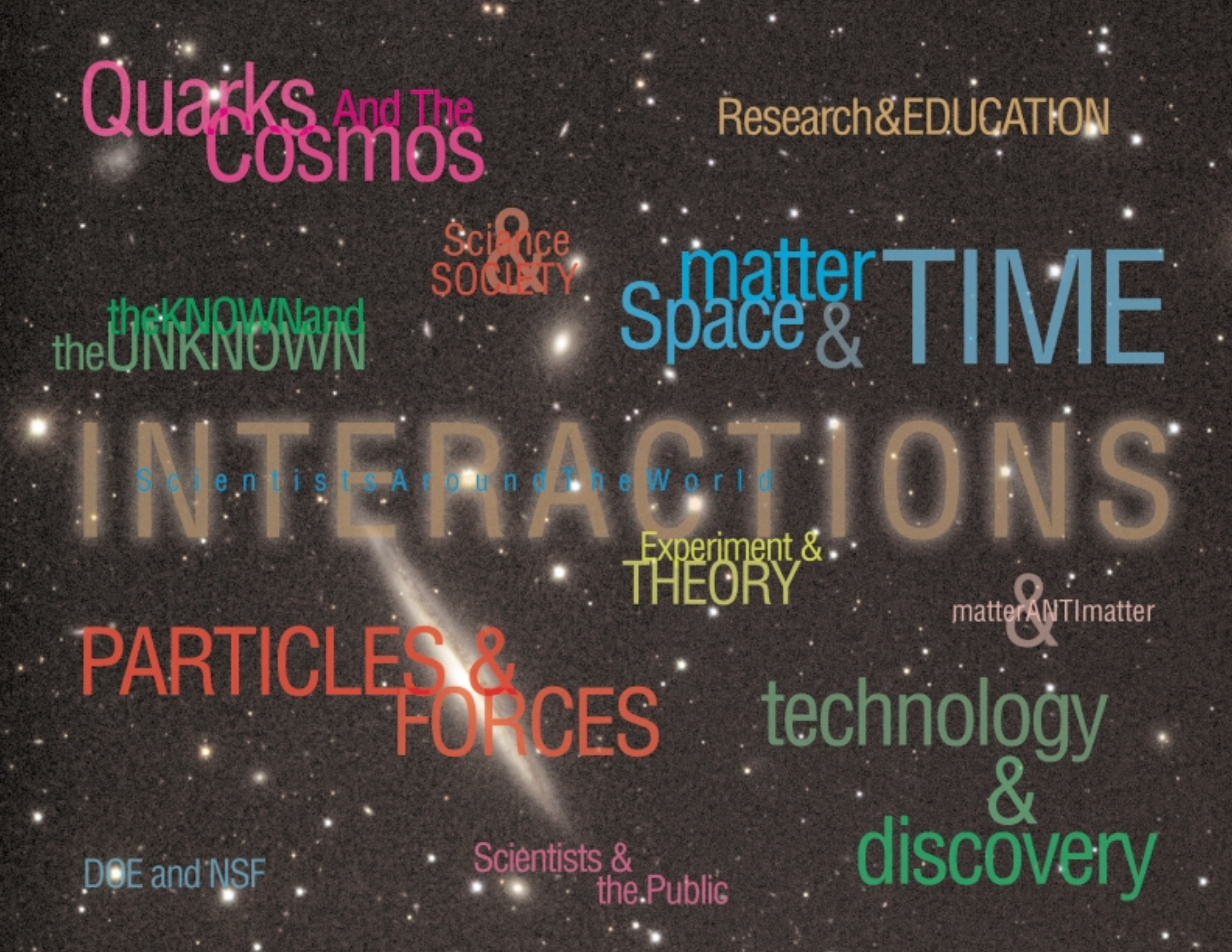
INTERACTIONS

The science of matter, space and time



High-Energy Physics


Quarks And The Cosmos
Research&EDUCATION
Science & SOCIETY
matter Space & TIME
the KNOWN and the UNKNOWN
INTERACTIONS
Scientists Around The World
Experiment & THEORY
matter ANTImatter &
PARTICLES & FORCES
technology & discovery
DOE and NSF
Scientists & the Public

High Energy Physics is the Science of Interactions

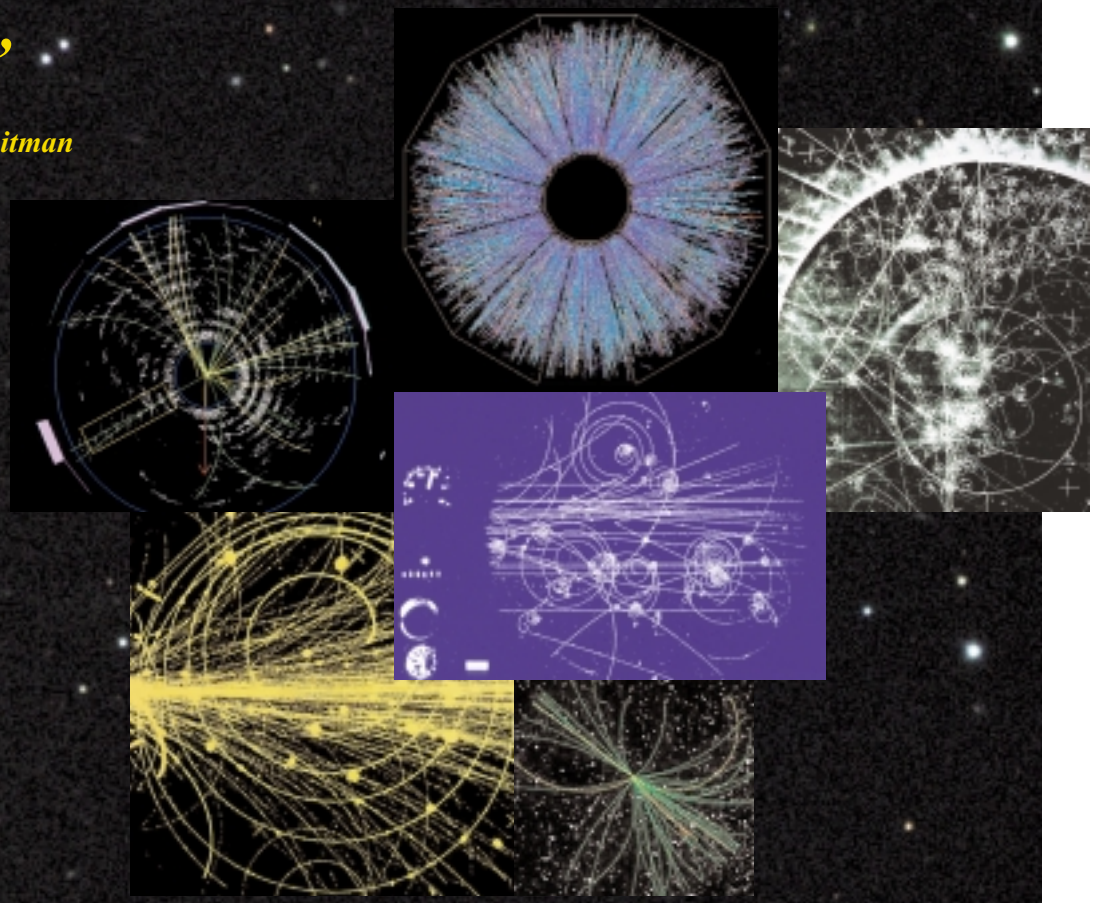
- "Since we (and everything in the universe) are made mostly of empty space, and even particles of matter are just vibrating chunks of energy, what is it that makes us essentially *us*? It's all about relationships—the way the particles and forces interact. It's all of a piece, a tapestry of relationships woven in space and time."

  —K.C. Cole, science writer, Los Angeles Times

The deepest secrets of the universe

"Every cubic inch of space is a miracle."

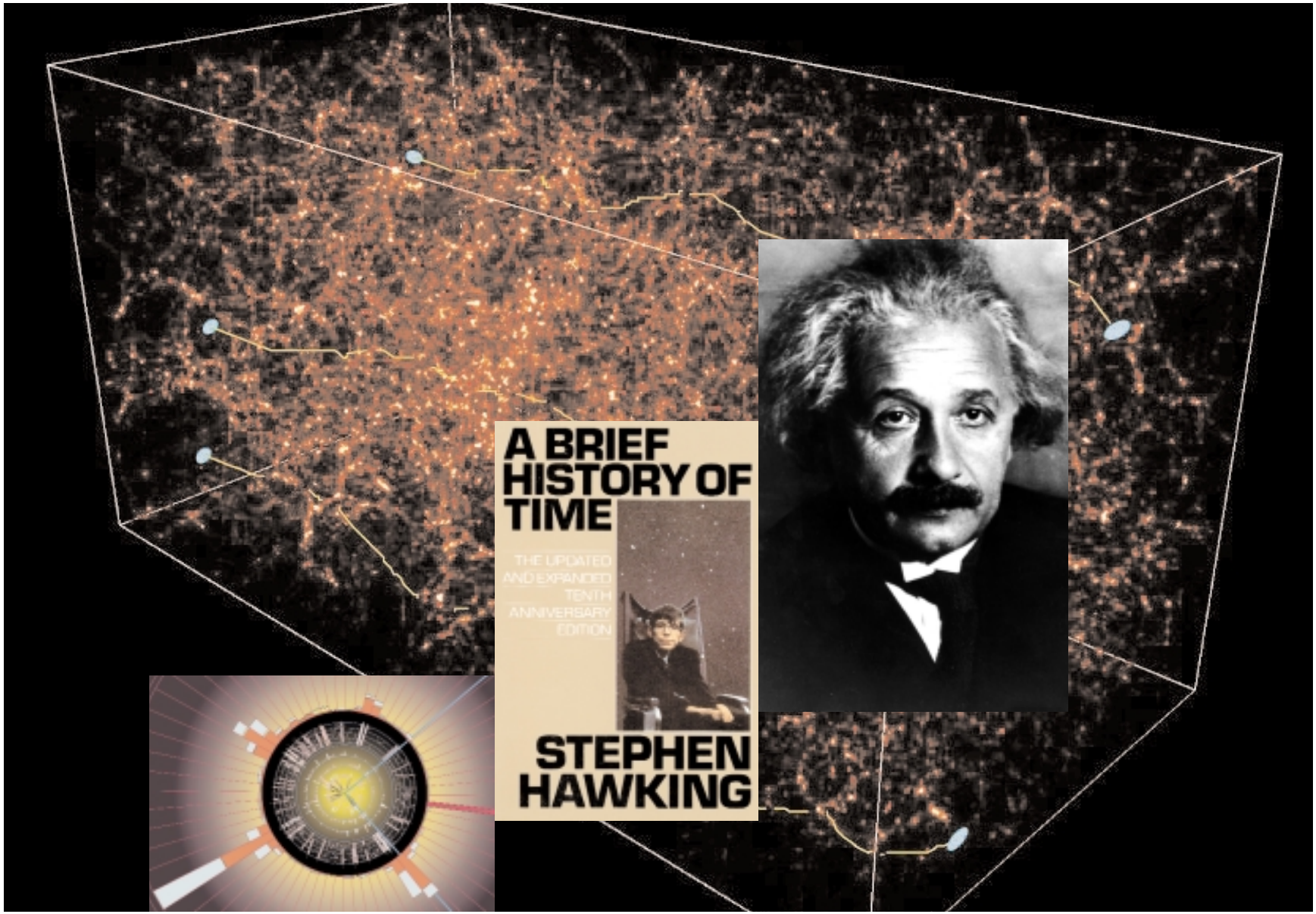
—Walt Whitman



INTERACTIONS: Unlocking the deepest secrets of the universe

- What is the universe made of ?
- How does it work?
- Where did it come from?

Matter, space and time



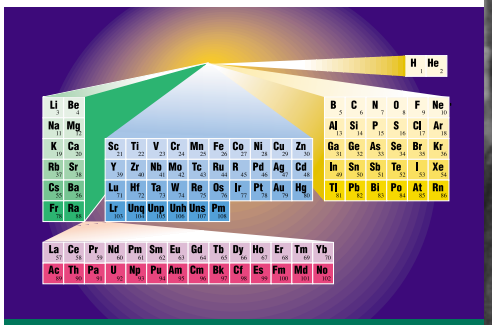
INTERACTIONS
The science of matter, space and time

- To unveil MATTER's ultimate building blocks
- To find the hidden dimensions of SPACE
- To discover what points the arrow of TIME

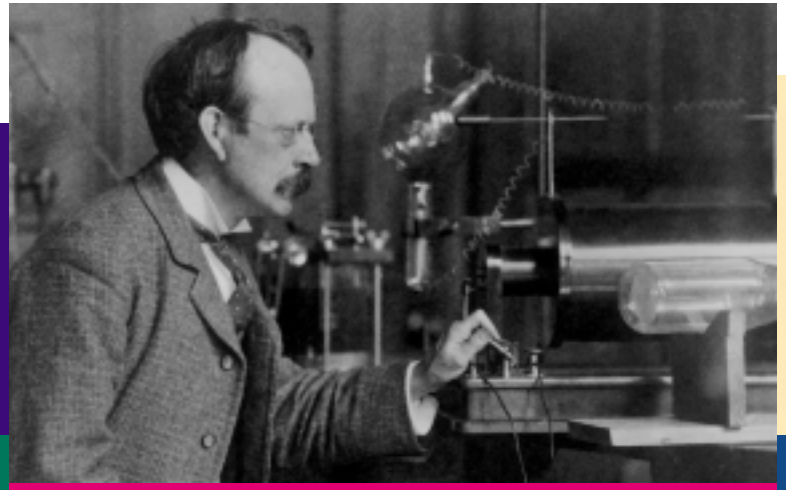
➢ *Fulfilling Einstein's dream of unified forces and energy*

➢ *Revealing the power source for the Big Bang*

A Century of Discovery

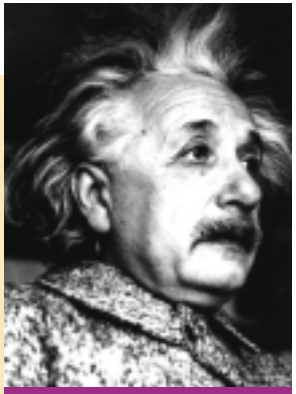


1. By the end of the 1800s, the periodic table arranged the elements of matter into a pattern ordered by atomic weight.



2. In 1897, J.J. Thomson found the first subatomic particle, the electron.

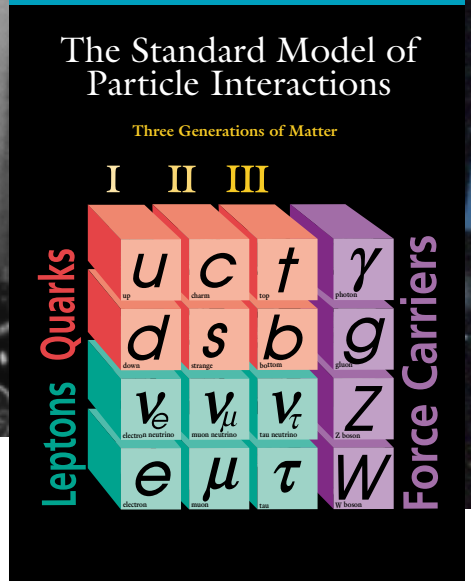
3. In 1908, Ernest Rutherford's scattering experiment revealed the nucleus.



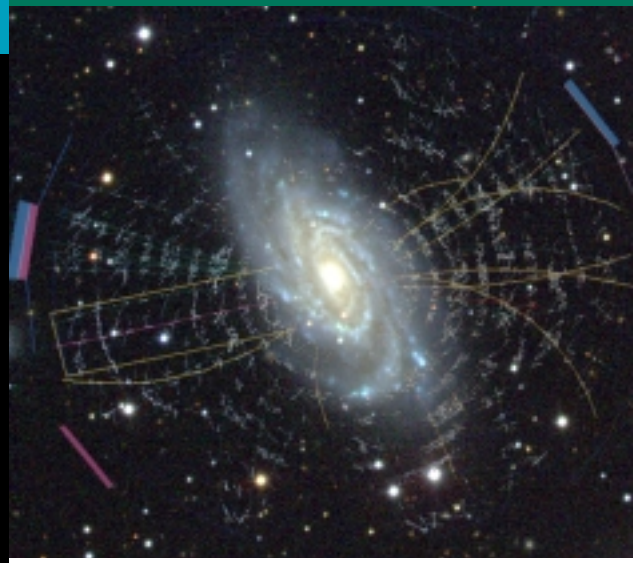
4. Einstein's theory of special relativity showed that space and time can change in different reference frames. $E=mc^2$

5. Quantum mechanics: Particles can behave like waves, energy can exist in quanta, and particles behave by probability, not certainty. Quantum pioneers Werner Heisenberg and Niels Bohr.

6. The fundamental particles of matter are leptons and quarks. Everything we see in nature can be understood as the interplay of the particles and forces of the Standard Model.



7. The physics of the ultimately small is deeply connected to the physics of the ultimately large; matter-antimatter, the early universe, dark matter, the expanding universe.



A Century of Discovery

Discoveries of the 20th century revolutionized our understanding of matter, space and time.

- Atoms
- Protons
- Quantum Mechanics
- Special Relativity
- Quarks and Leptons
- The Standard Model
- The Cosmic Connection
- Dark Matter
- The Expanding Universe

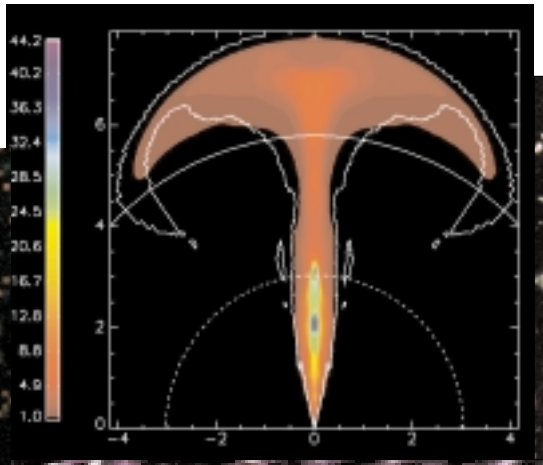
Recent discoveries

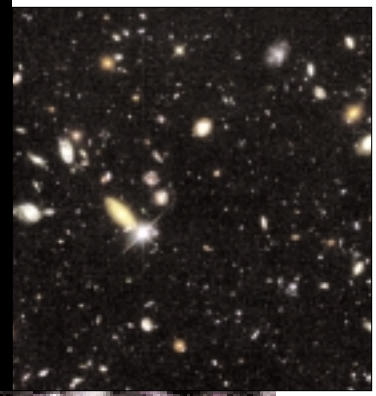
Recent discoveries point to a new world

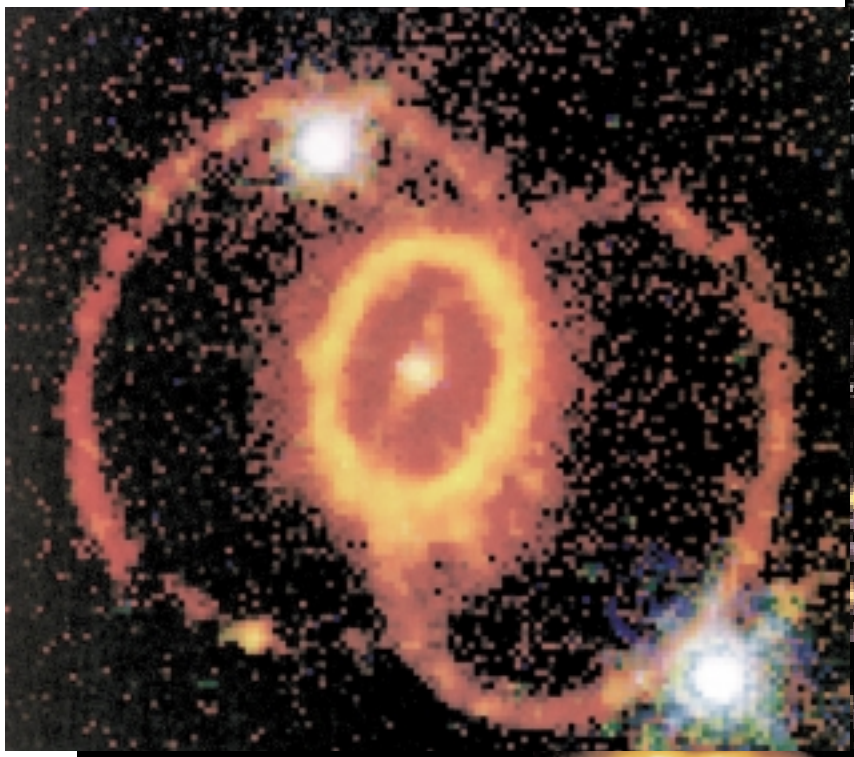
- Mysterious dark particles bind the universe together. An unknown force drives it apart.
- An unseen sector casts its shadow on recent experiments.
- Theoretical breakthroughs point to hidden dimensions, unified forces and parallel universes.

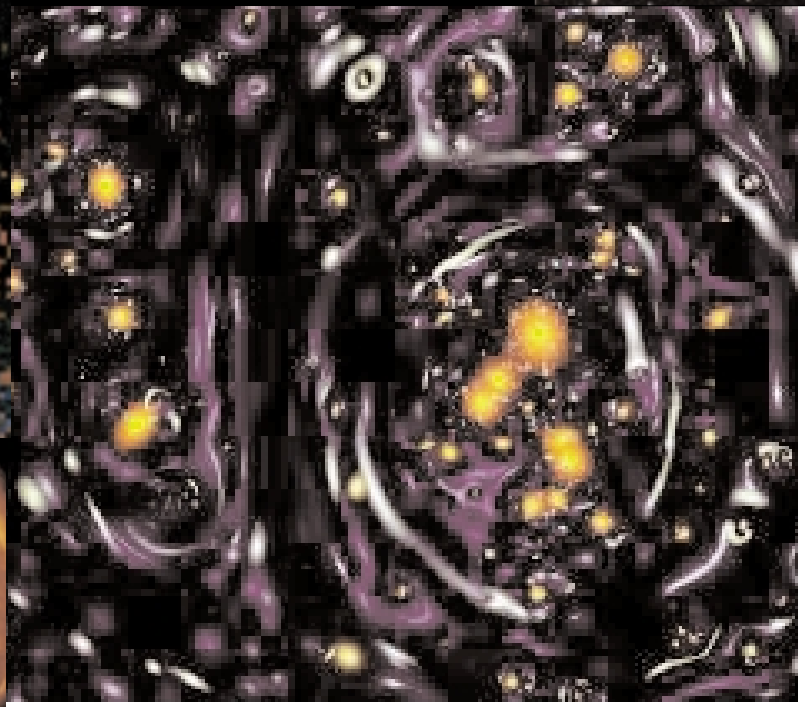
➢ *Technology breakthroughs—superconductivity, nanotechnology, lasers, information technology—promise the means to explore this new world.*

Dark particles, dark forces

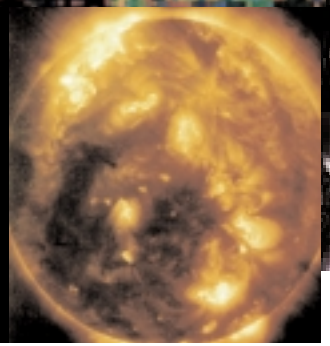








Galaxies are rushing away from each other, carried along by the expanding universe, much faster than the speed of light. There is no speed limit on the universe.



Dark particles, dark forces

- Most of the universe's matter is dark, unknown—and not made of atoms.
- A mysterious dark force permeates space and drives the universe apart.
- Where is the antimatter in our universe? No antigalaxies, no antistars, no antiplanets…

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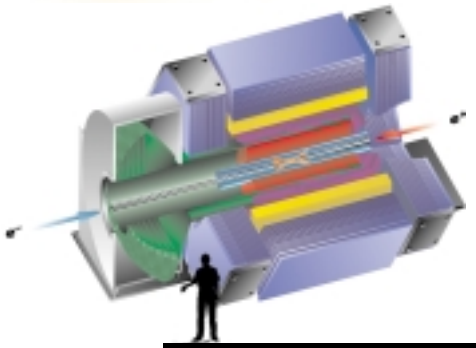
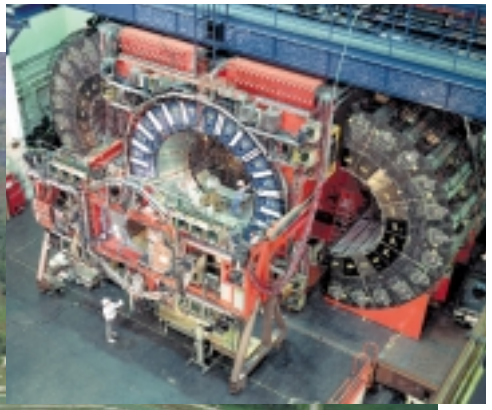
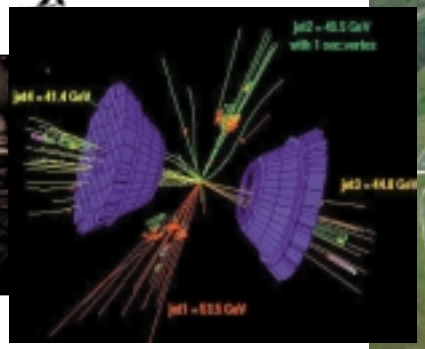
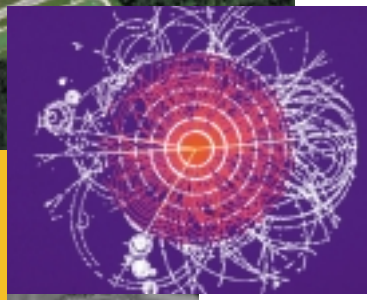
Shadows of a new world









Will the Higgs boson explain why the heaviest known particle, the top quark, is 350,000 times heavier than the electron?

The shadows of a new world — just beyond reach

- Quantum effects tell us that the Higgs boson should appear in the next round of experiments.
- Evidence that neutrinos change their identities suggests new interactions and that neutrinos are part of dark matter.
- Experiments studying the mysterious differences between matter and antimatter probe the arrow of time.

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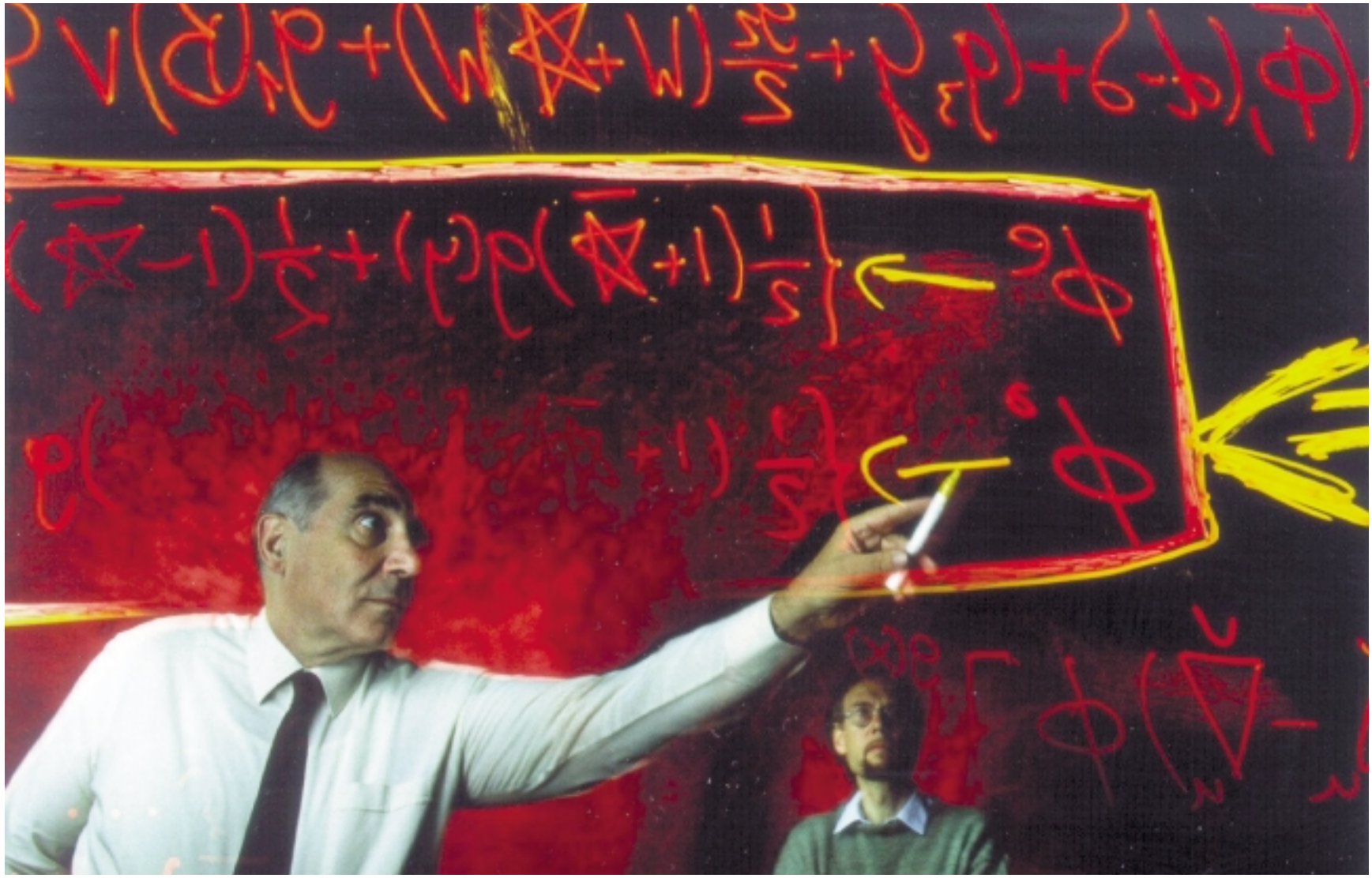
Theoretical breakthroughs



Theoretical breakthroughs

Powerful ideas (supersymmetry, superstrings …) point to

- new particles
- new forces
- hidden dimensions of space

We can explore this new world by experiment.

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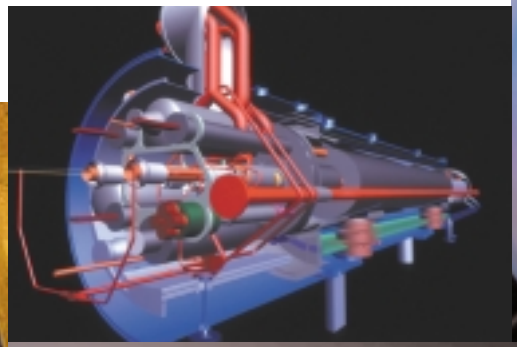
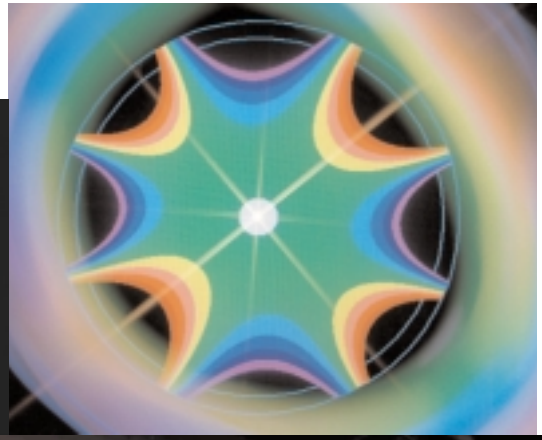
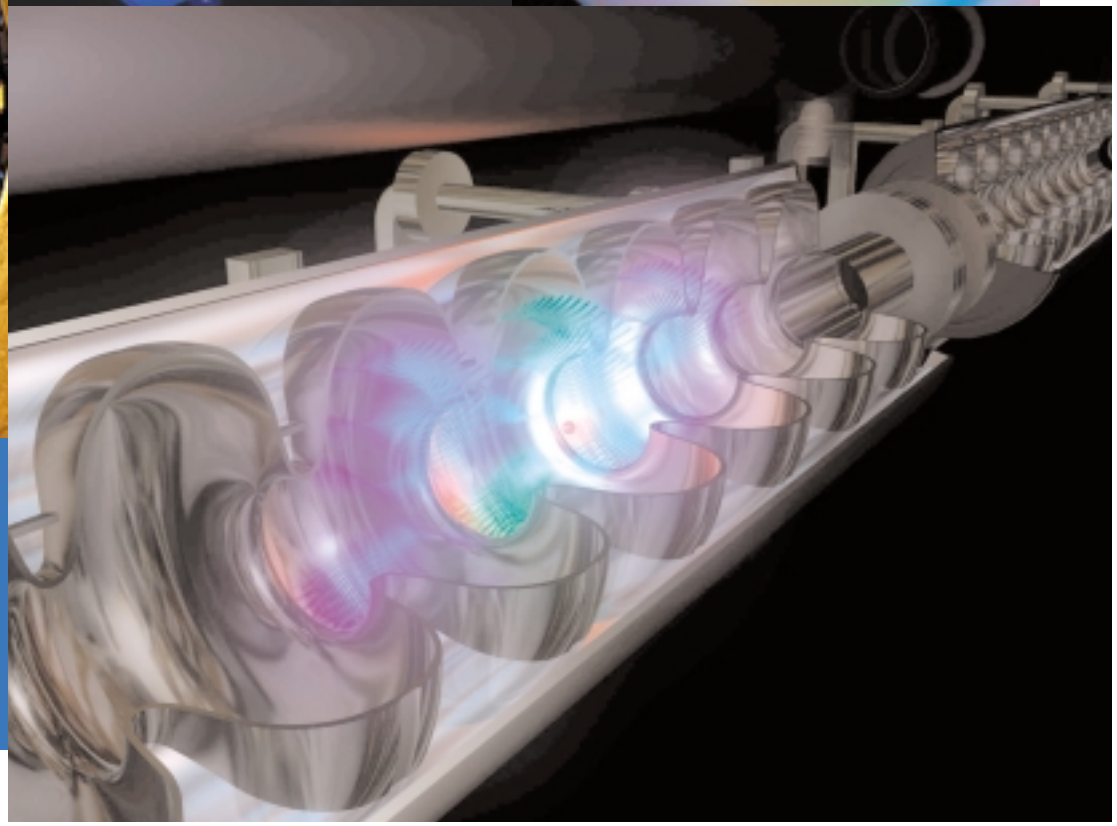
Technology breakthroughs







High-energy particle beams reveal the smallest objects human beings have ever seen—a billion times smaller than the most powerful microscope can see.

Technology breakthroughs to explore the new world

- Superconducting magnets
- Nanometer beams
- Laser instrumentation
- Information technology

21st century

"One has to have the imagination to think of something that has never been seen before, never been heard of before."

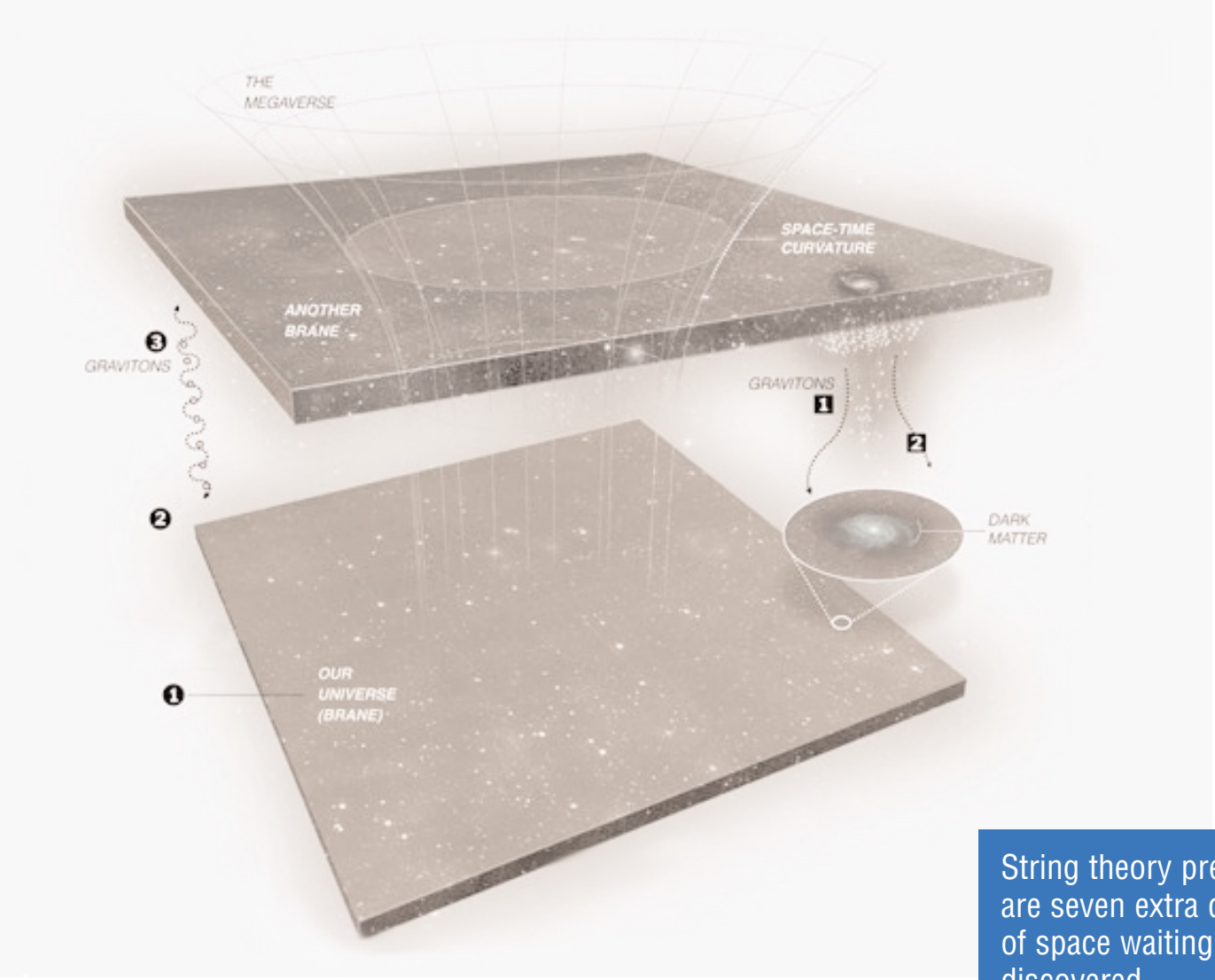
—Richard P. Feynman

According to superstring theory, all particles and forces can be explained as different notes plucked on tiny loops of vibrating strings.

INTERACTIONS
Toward a new understanding of matter, space and time in the 21st century

- Expose the hidden dimensions of space
- Unify quantum physics and gravity
- Reveal the true nature of quarks and leptons
- Connect to the cosmos

Hidden dimensions



"The imagination is one of the forces of nature."

—Wallace Stevens

String theory predicts there are seven extra dimensions of space waiting to be discovered.

Expose the hidden dimensions of space

Theories predict a world of new dimensions.

- Supersymmetry predicts quantum dimensions connecting forces and matter.
- Unification of gravity with the other forces requires dimensions beyond the three that we know.
- Could there be extra time dimensions?
- Are we part of a multidimensional megaverse?

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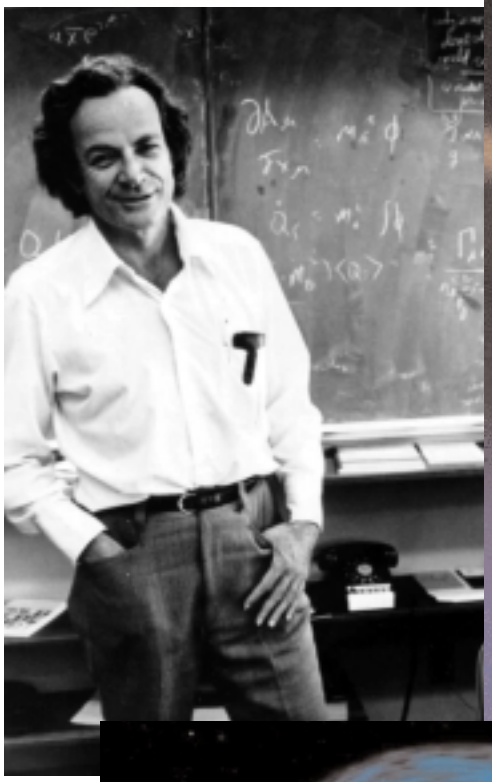
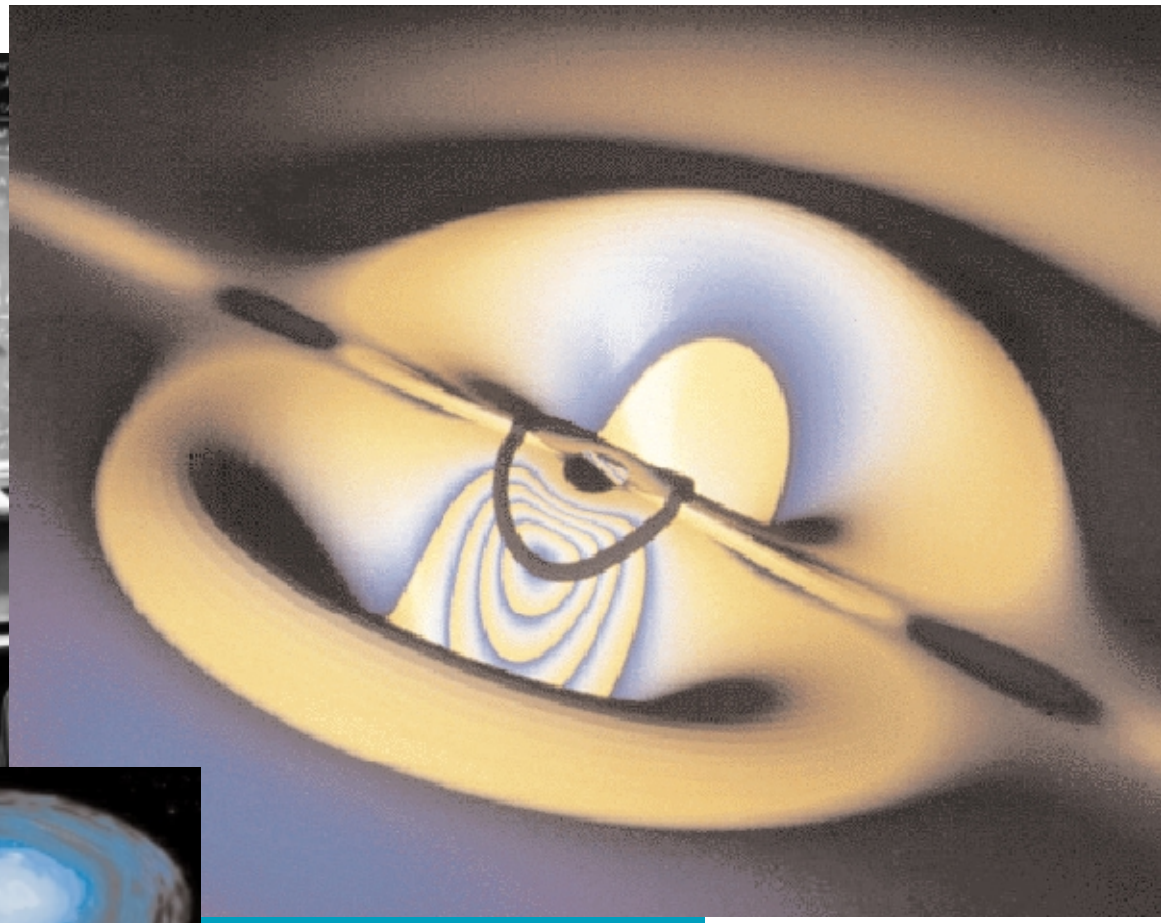
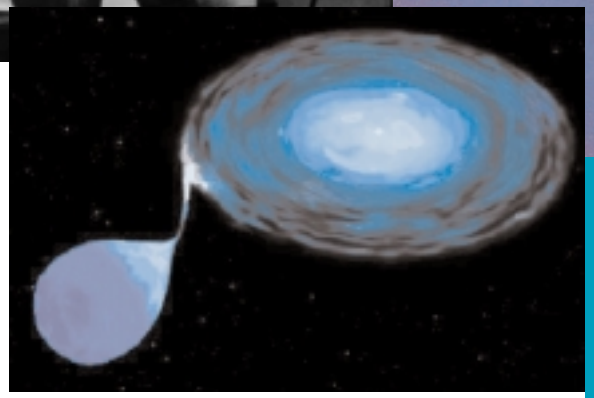
Quantum physics and gravity







Quantum computing holds the promise of breaking Moore's law—with calculations faster than the speed of light. (No kidding!)

Unify quantum physics and gravity

- Discover the energy realm of unification:
  Do all forces become one?
- Test the stability of matter: Are protons forever?
- Grapple with the nature of gravity:
  How are space and time quantized?
- Explore the new world of String Theory:
  Are we notes plucked on tiny loops of string?

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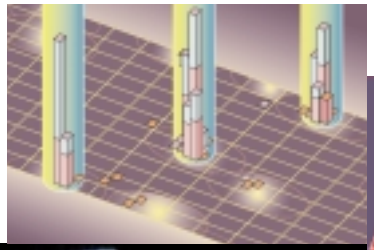
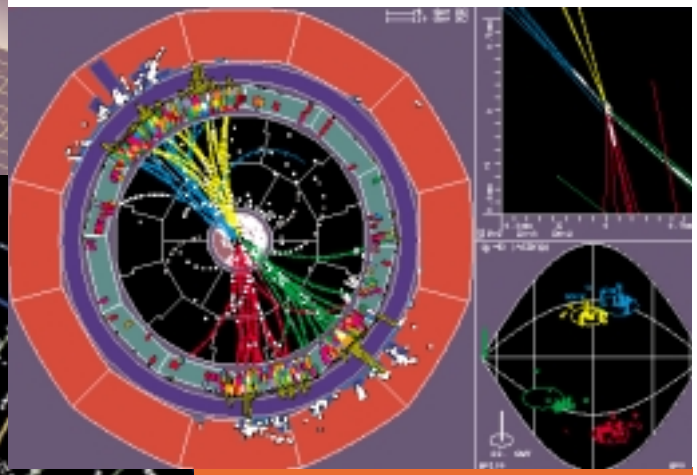
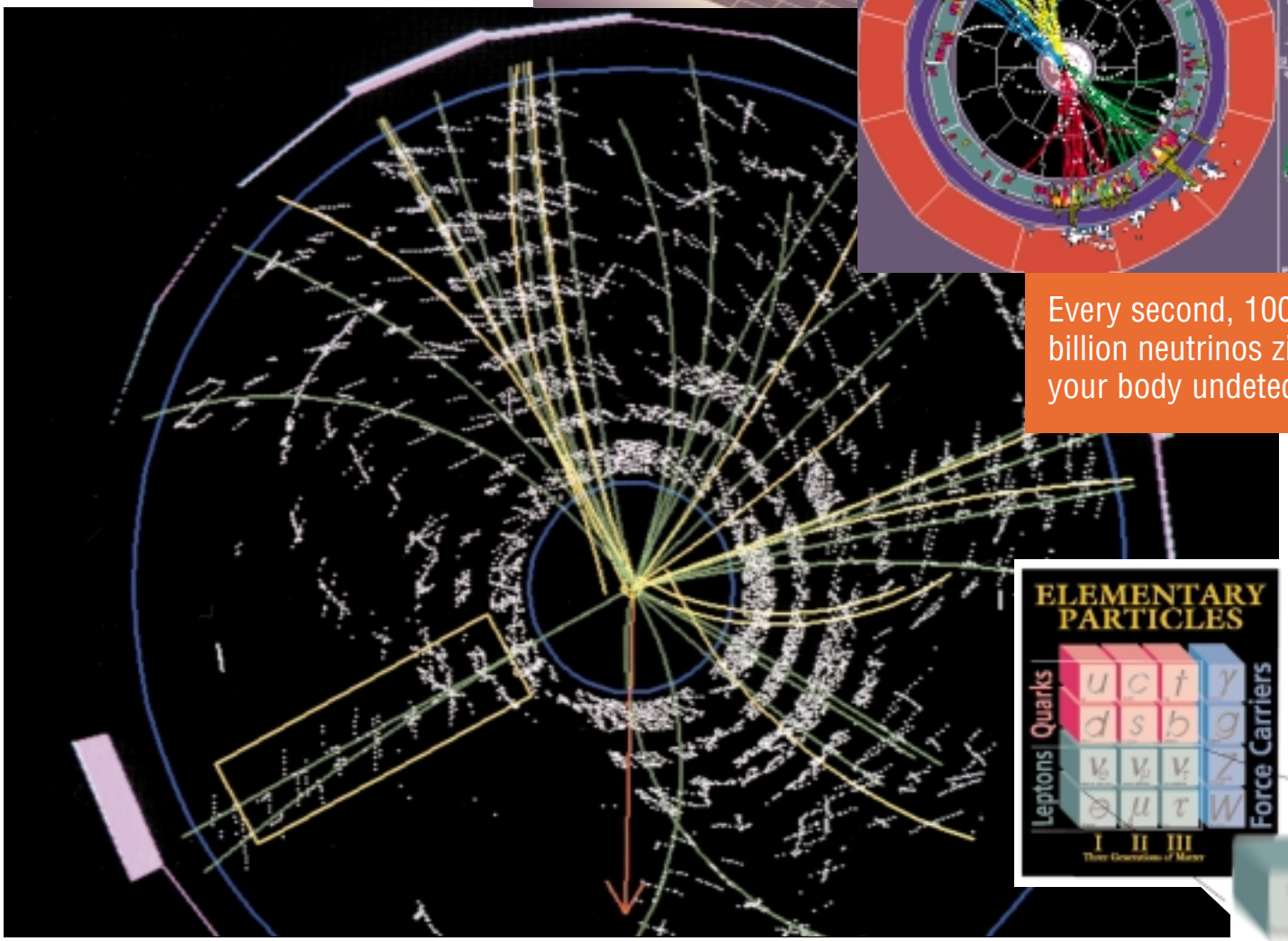
True nature of quarks and leptons







Every second, 100 million billion neutrinos zip through your body undetected.

Understand the true nature of quarks and leptons

- Uncover the wellspring of mass:
  Why don't all the particles weigh the same?
- Discover supersymmetry: Do quarks and leptons have counterparts in the shadow world?
- Reveal the secrets of neutrino metamorphosis:
  Why can't neutrinos decide who they are?
- Understand the absence of antimatter:
  Why is there any matter at all?

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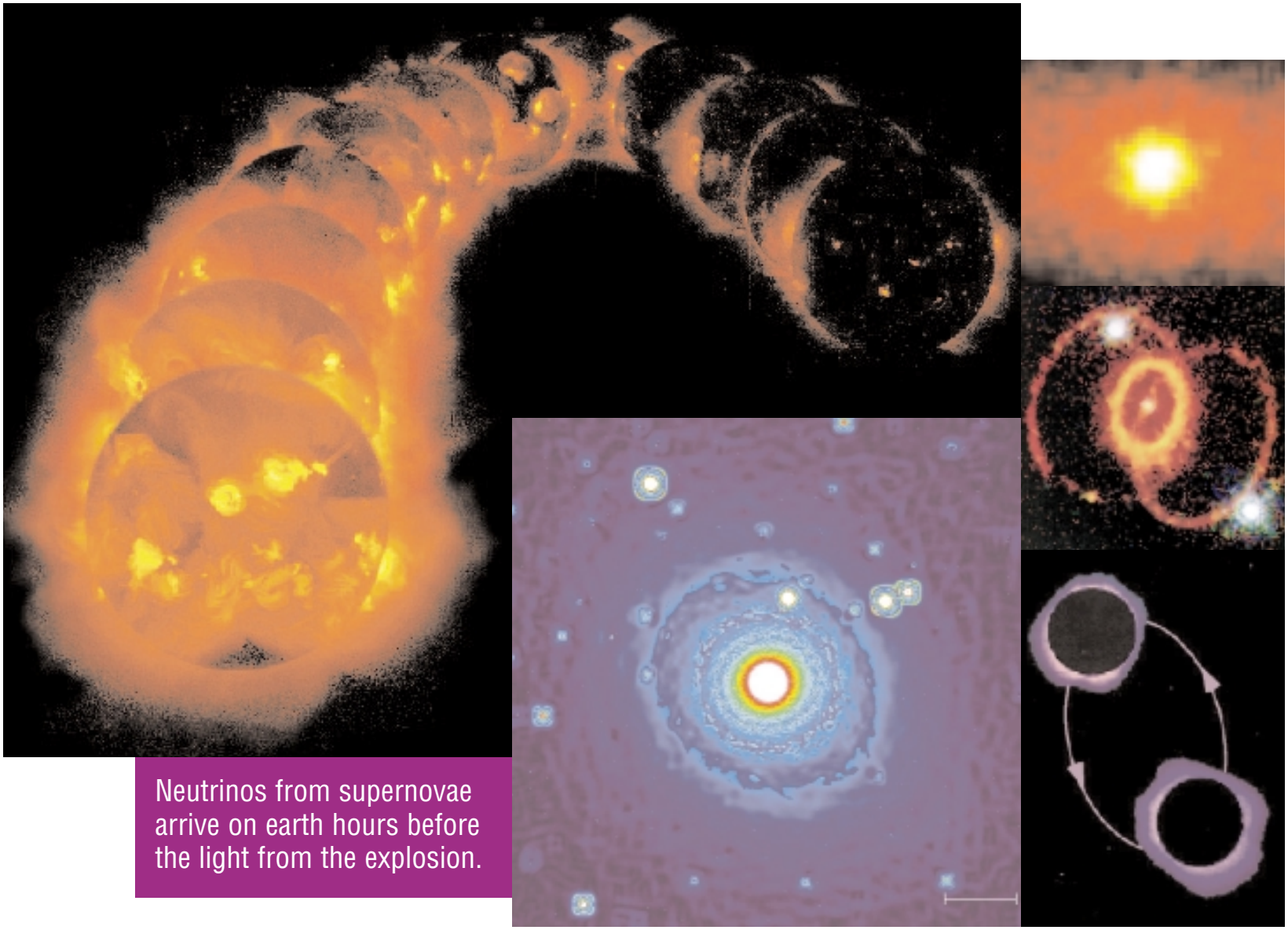
Cosmic connection

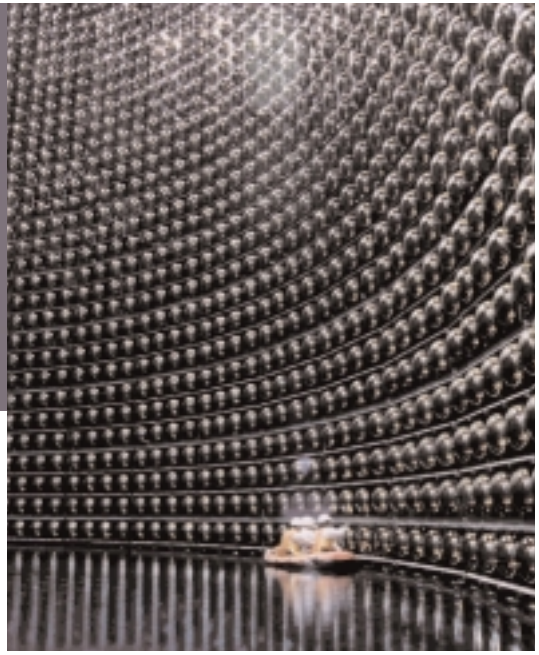


Neutrinos from supernovae arrive on earth hours before the light from the explosion.

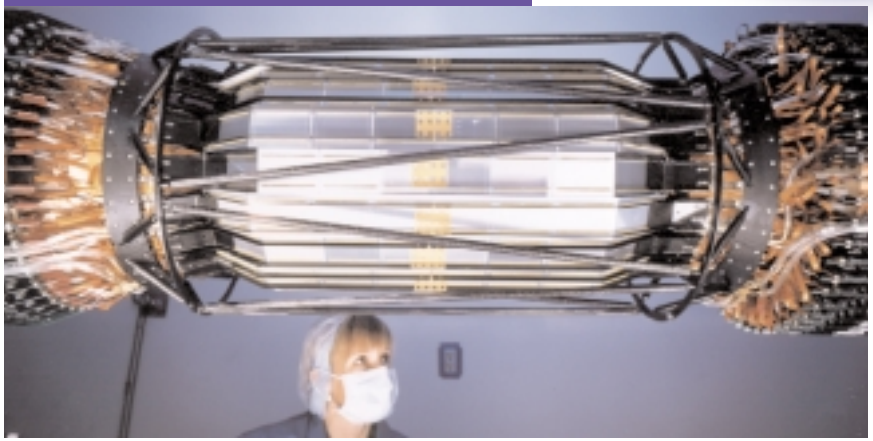
Connect to the cosmos

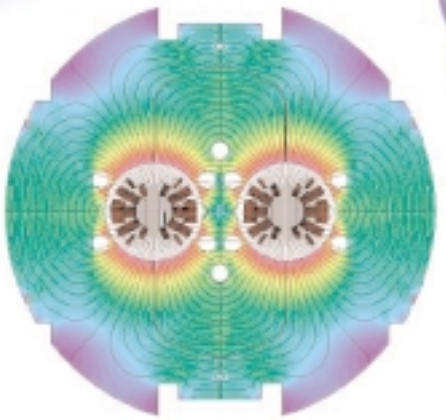
- Create dark matter in the laboratory, and detect its presence in the universe.
- Discover the origin of the mysterious dark energy that accelerates the expansion of the universe.
- Explore the universe with elementary particles.
- Connect the beginning of the universe to fundamental physics.

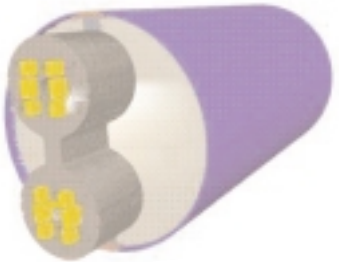
Bold ideas, innovative tools

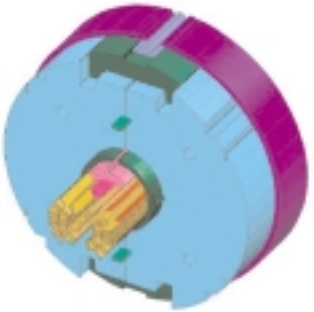


Fermilab's accelerators produce one nanogram of antimatter per year—the world's largest supply.









INTERACTIONS: A new world revealed by bold ideas and innovative tools

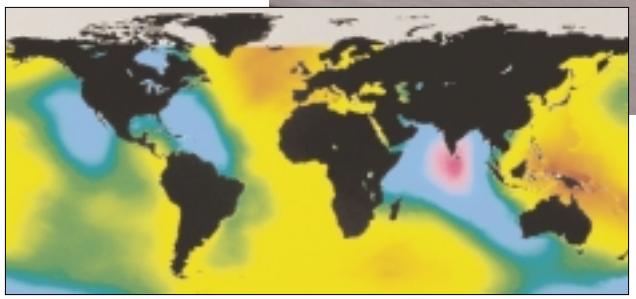
- The discoveries of the 21st century will require a new generation of accelerators and detectors.
- R&D will lead to new and cheaper tools.
- Developing technology for a frontier facility takes sustained effort over many years.

The discoveries of tomorrow require investment in R&D today.

Plans for the future

"Don't be afraid to take a big step if one is indicated. You can't cross a chasm in a series of small jumps."

—David Lloyd George

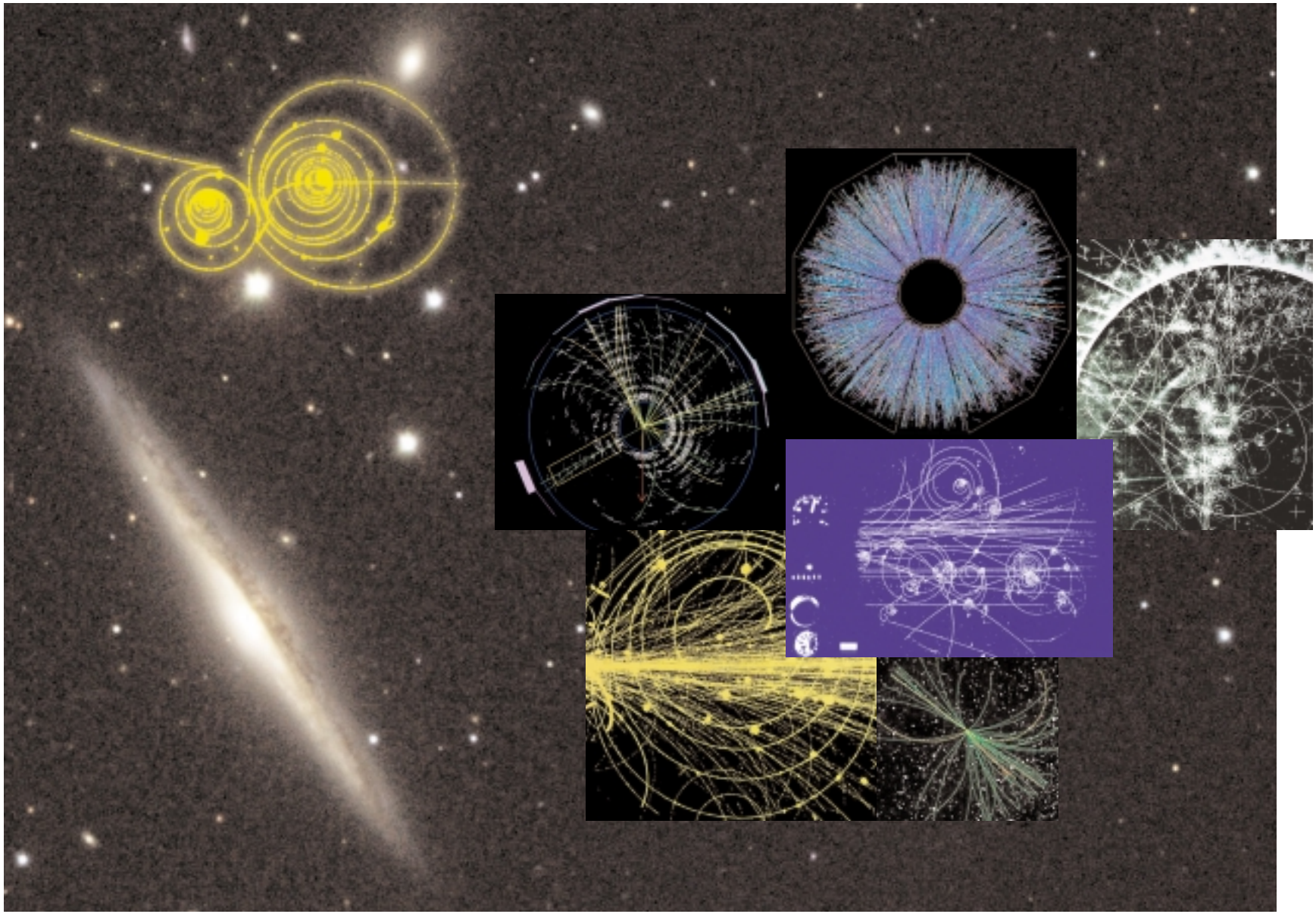


INTERACTIONS
The Community plans for the future

The High Energy Physics Advisory Panel and community summer studies provide a continuing planning process

- 1998: The Decadal NRC Study and HEPAP Subpanel recommended a new U.S. facility at the energy frontier and R&D to lead us to the new frontier.
- 2000: HEPAP White Paper places U.S. program in a world context of future frontier facilities.
- 2001: Snowmass meeting of the APS
- 2001: DOE/NSF HEPAP subpanel

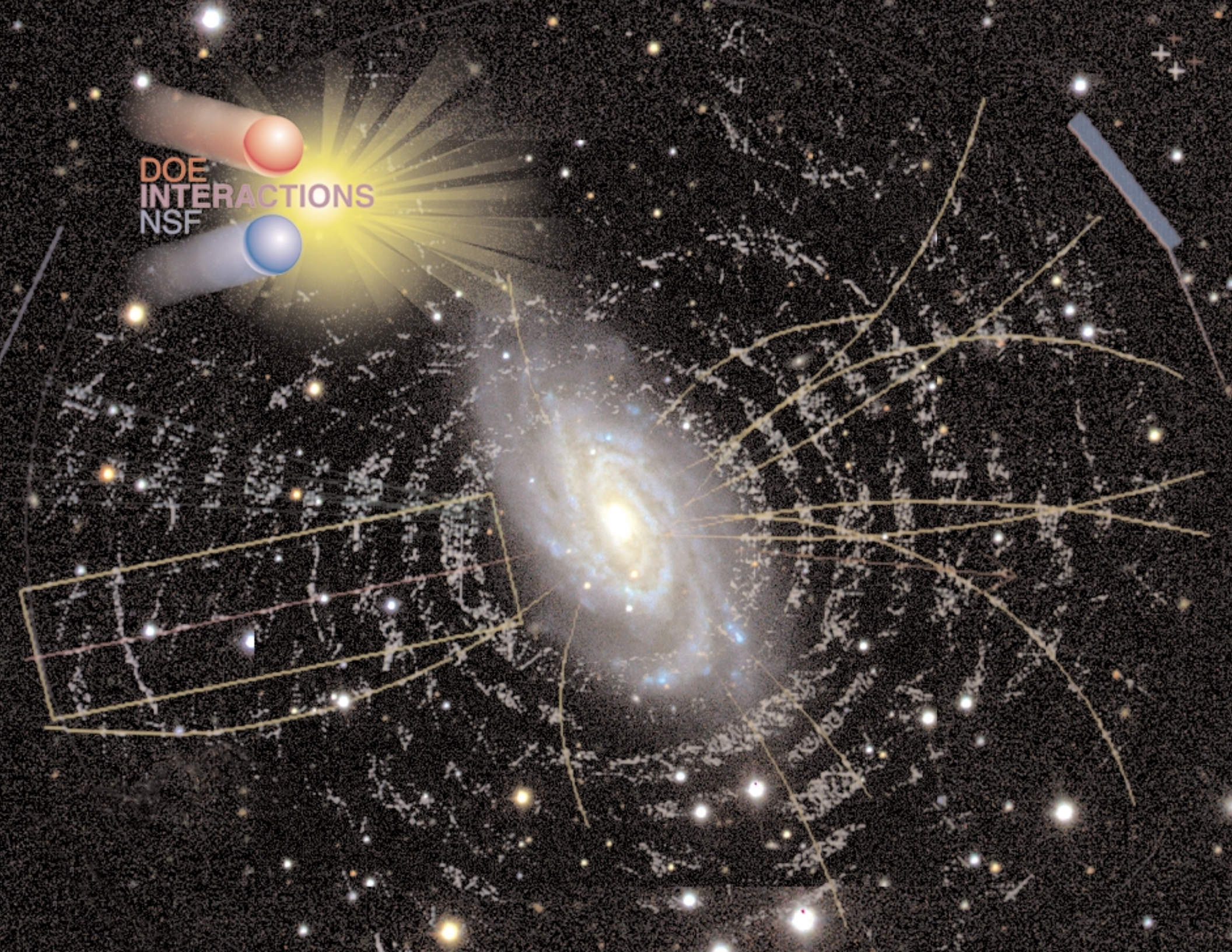
Secrets of matter, space and time



INTERACTIONS will unlock the deepest secrets of matter, space and time

- Unify the extraordinary discoveries that revolutionized the 20th century.
- Develop technologies and make discoveries that will revolutionize the 21st century.

Take strong U.S. leadership into a dynamic global era of discovery.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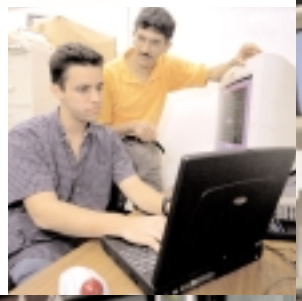
INTERACTIONS

The science of matter, space and time

PEOPLE

Today's students, tomorrow's leaders



Three-quarters of the graduate students trained in high-energy physics find careers far beyond academic science—in business, industry, finance, information technology and government.

INTERACTIONS
Preparing tomorrow's leaders in science, technology and society

- Students learn science by taking an active part in frontier research.
- University particle-physics research requires national and international laboratories.
- The university-national laboratory partnership puts students at the forefront of particle-physics research.

Today's students are tomorrow's leaders.

The People's Universe

In 1991, SLAC opened the first World Wide Web site in the United States.

INTERACTIONS: It's your universe too!

- The fundamental questions of the universe are not just for physicists.
- The public will share the excitement of discovery.
- Through the World Wide Web, every schoolchild will be able to see high-energy particle collisions as they happen—once only possible for a few scientists.

DOE INTERACTIONS NSF

Physics without borders

The DZero collaboration at Fermilab includes scientists who speak 47 languages.

INTERACTIONS
Physics without borders

- Particle physics is a high-energy collaboration of scientists worldwide.
- Building frontier facilities of the future challenges us to find new models of international partnership.