What did we find?

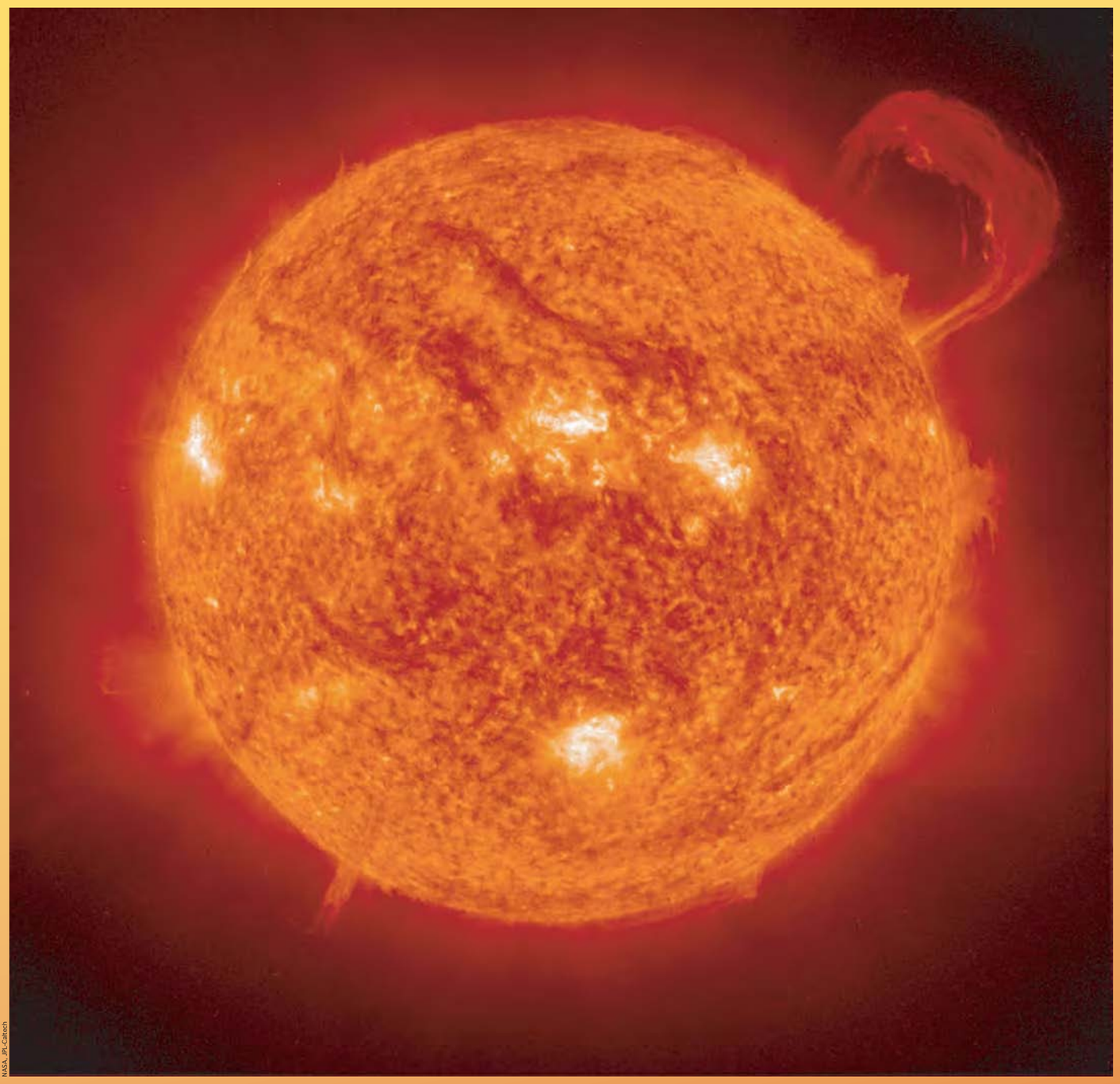
The Breakdown

Gotcha!

SNO counted the same total number of solar neutrinos reaching Earth as predicted, confirming that the nuclear fusion model for the Sun is accurate.

But only one-third of the solar neutrinos captured by SNO were electron-neutrinos. We know the Sun only produces this variety. This means that two-thirds of the neutrinos must have changed flavour en route.

As for those missing solar neutrinos: Davis's 1968 equipment could only detect electron-neutrinos. No wonder he missed the other two-thirds!



NASA, JPL-Caltech

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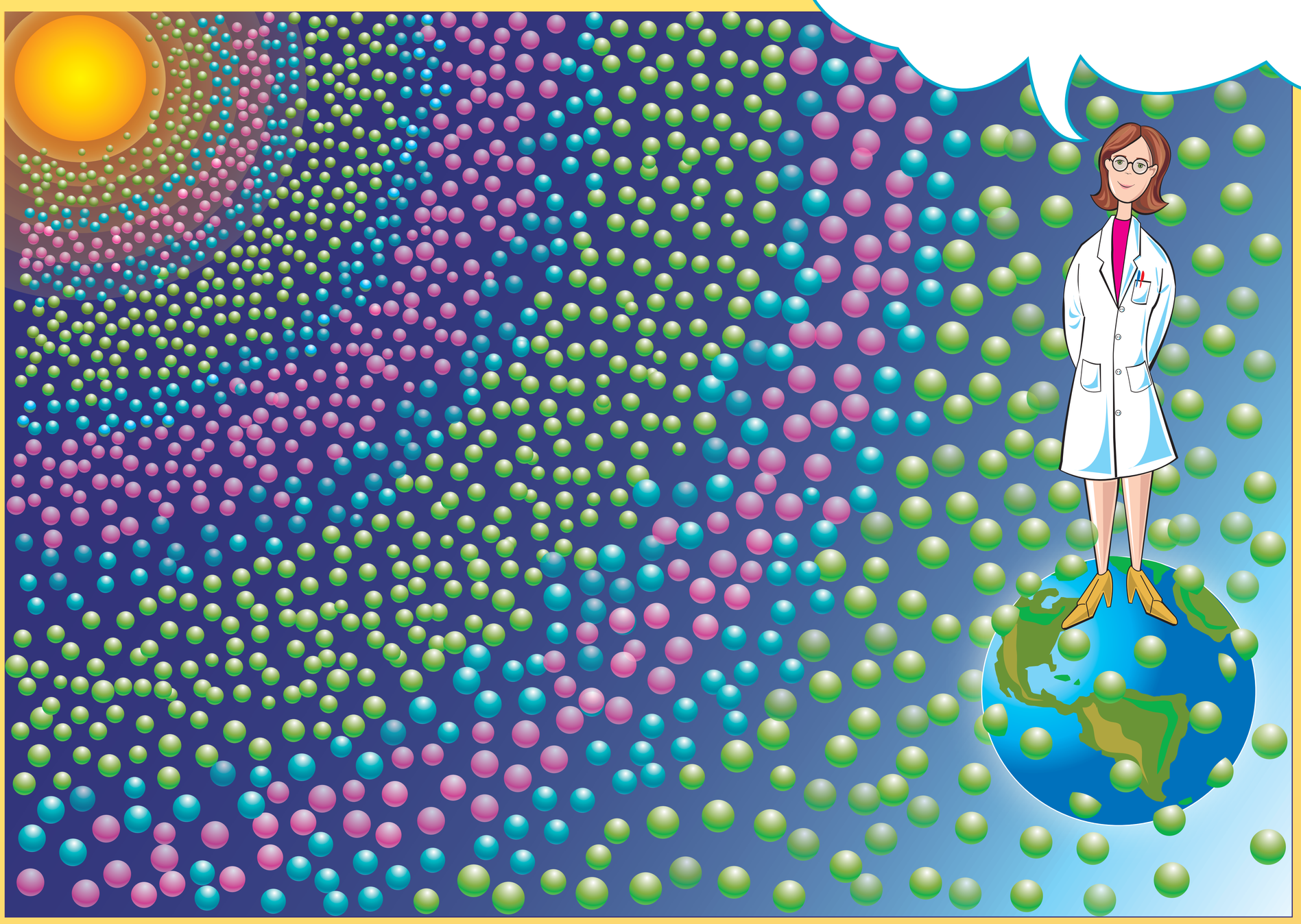
Success!



Based on results gathered since 1968, scientists detected only one-third of the number of neutrinos they expected to find.

By 2002, however, they were able to measure all three flavours of this elusive particle, thanks to SNO. This time, they found 5.1 million high energy neutrinos per square centimetre every second, which is what the theory originally told them to expect.

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What Does It Mean?

The Neutrino Contribution

Long before SNO, it was known that the mass of a neutrino must be extremely small. Many physicists thought that they had zero mass. However, it turns out that for neutrinos to change flavour, they must have at least a little mass.

That mass is tiny—far less than the mass of an electron. But neutrinos are so numerous that the total mass of all of the neutrinos in the Universe is about as much as the mass of all the visible stars combined!

NASA, ESA and the Space Sciences Institute

This Hubble ultra-deep-field photo is studded with distant stars and galaxies.

SNO

Many of the SNO collaborators met in February 2004 to discuss the results and progress of the SNO experiments.

The following Institutions are currently participating in SNO:

Queen's University (Ontario, Canada)
Carleton University (Ontario, Canada)
University of Guelph (Ontario, Canada)
Laurentian University (Ontario, Canada)
University of British Columbia (Canada)
University of Pennsylvania (USA)
Los Alamos National Laboratory (New Mexico, USA)
Lawrence Berkeley National Laboratory (California, USA)
University of Washington (USA)
Oxford University (UK)
Brookhaven National Laboratory (New York, USA)
University of Texas at Austin (USA)

Major funding, material or facilities support for SNO has been provided by:

Canadian Foundation for Innovation
National Research Council of Canada
Atomic Energy of Canada
Inco Limited

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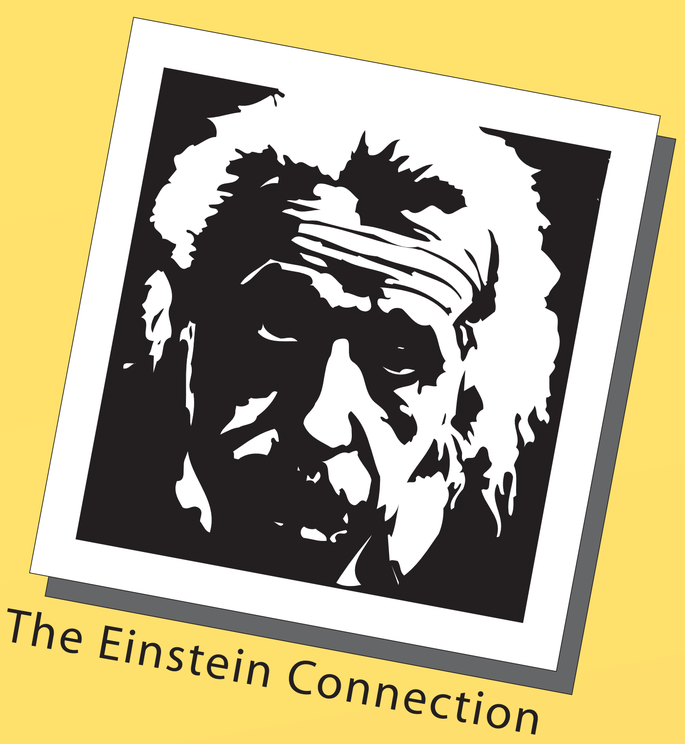
Neutrinos and the Cosmos

Einstein's General Relativity

By 1916, Einstein had extended his theory of relativity and demonstrated that gravity is just the warping of space and time by a massive object.

The equations of general relativity underlie modern cosmology. Later theories, building on these mathematical equations, tell us that the Universe began with a Big Bang, and that it continues to expand.

Einstein would have been interested in the SNO results. The mass of neutrinos has an influence on whether the Universe will expand forever, or eventually collapse in a big crunch.



The Einstein Connection

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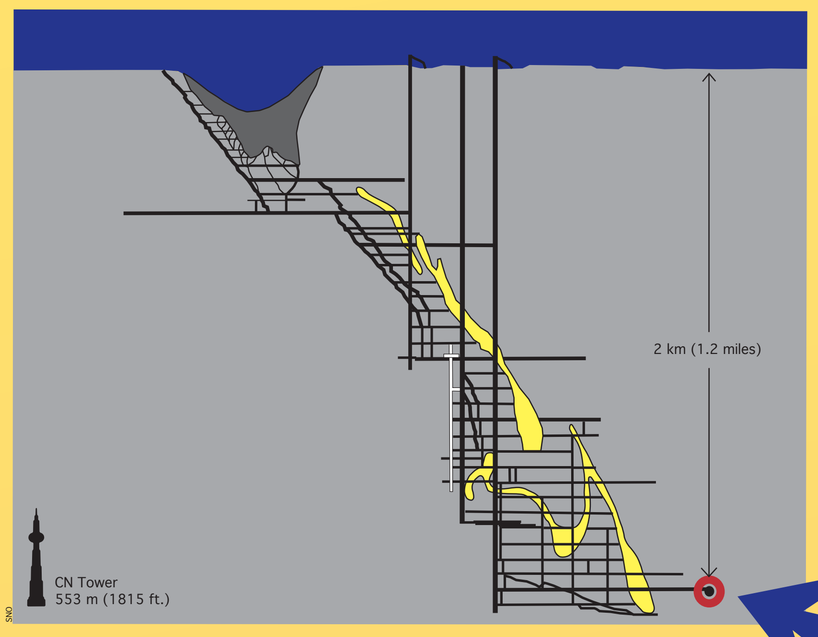
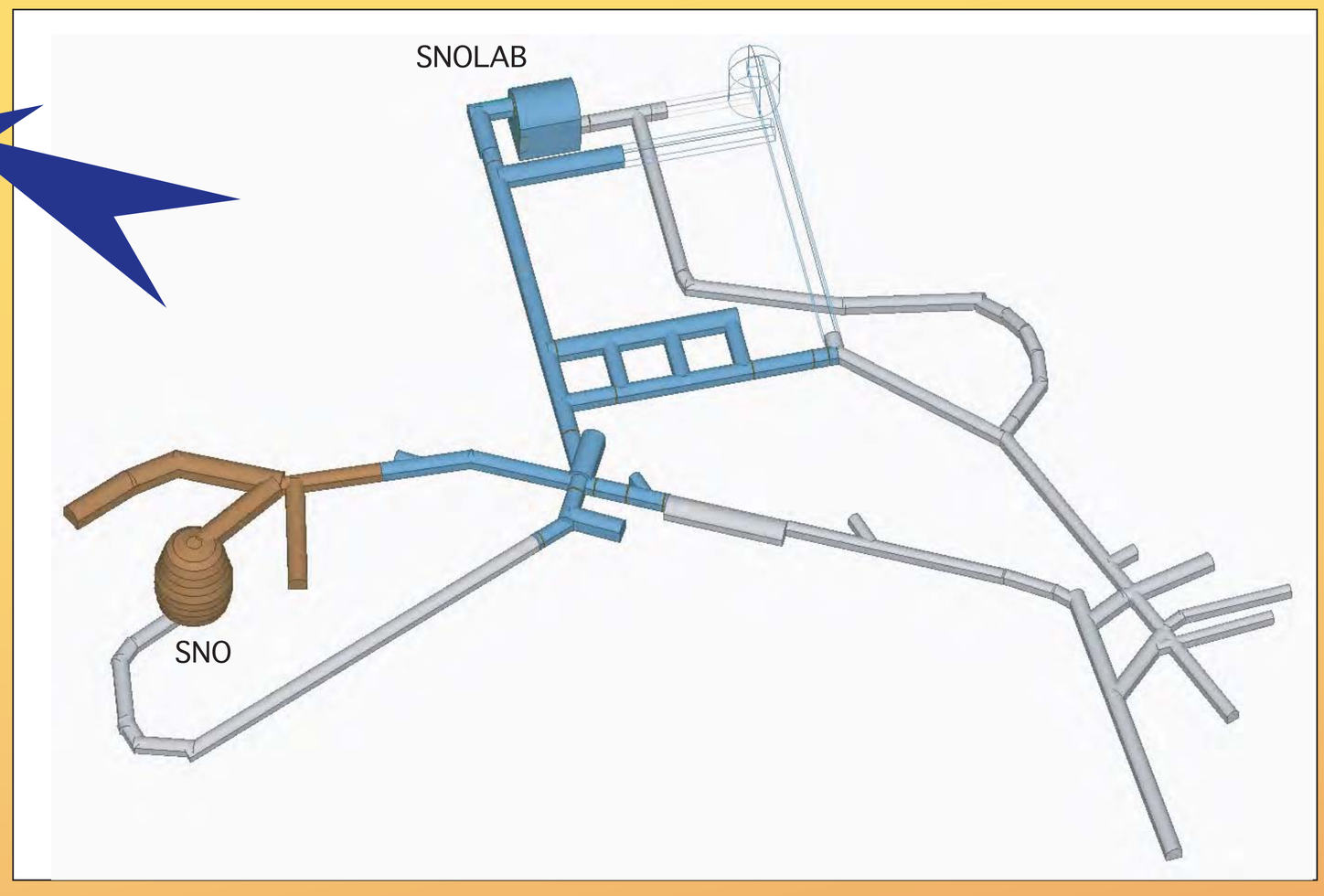
Where do we go from here?

SNOLAB will be the new permanent facility in Canada for ultra-clean, low background radiation experiments. Collaborators from around the world now clamour for a place at SNOLAB, deep in the Sudbury mine.





Deep in the Creighton mine, SNOLAB, which includes the SNO chamber, is scheduled to open in 2007.

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No Sunset for SNO

The Search for Dark Matter

Galaxies, made of stars, dust and gas, spin rapidly. But when astronomers add up all the mass that they can see, plus the neutrino mass, it still isn't enough to keep the galaxies from flying apart. Either Einstein's theory of gravity is wrong, or there is still some hidden matter.

That hidden matter has become known as Dark Matter. An experiment called PICASSO will search for Dark Matter in the new SNOLAB.

NASA, ESA and the Space Science Institute

Even with all the visible mass held by the billions and billions of galaxies we can see, plus the mass of the neutrinos confirmed by SNO, we can only account for less than 20% of the mass of the Universe.

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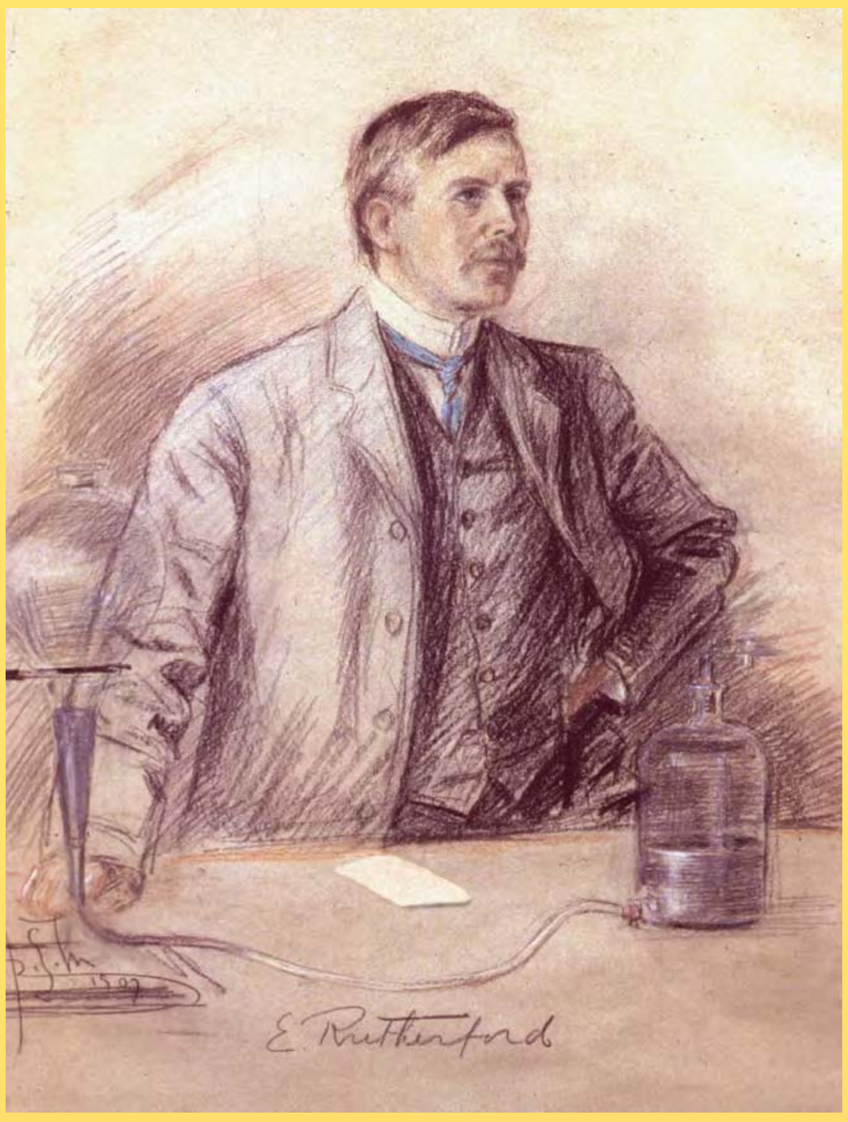
Exploration and Discovery

Why Does It Matter?



Portrait of Ernest Rutherford by R. G. Matthews 1907; courtesy of the Rutherford Museum, McGill University

In 1898 New Zealand–born **Ernest Rutherford** accepted a posting as Professor of Experimental Physics at McGill University in Montreal, Quebec, Canada.

For over 100 years—since Rutherford first studied radioactive decay at McGill University—particle physicists have been solving fundamental mysteries in Canada.

Innovations such as radiation therapy to treat cancer, and even the World Wide Web, have trickled down to everyday life from these scientists' discoveries. But that isn't why they do it.

Scientists, like kids, are driven to explore by their curiosity. Ultimately, the greatest impact may not be a material benefit, just a deeper appreciation for the wonder of our existence.

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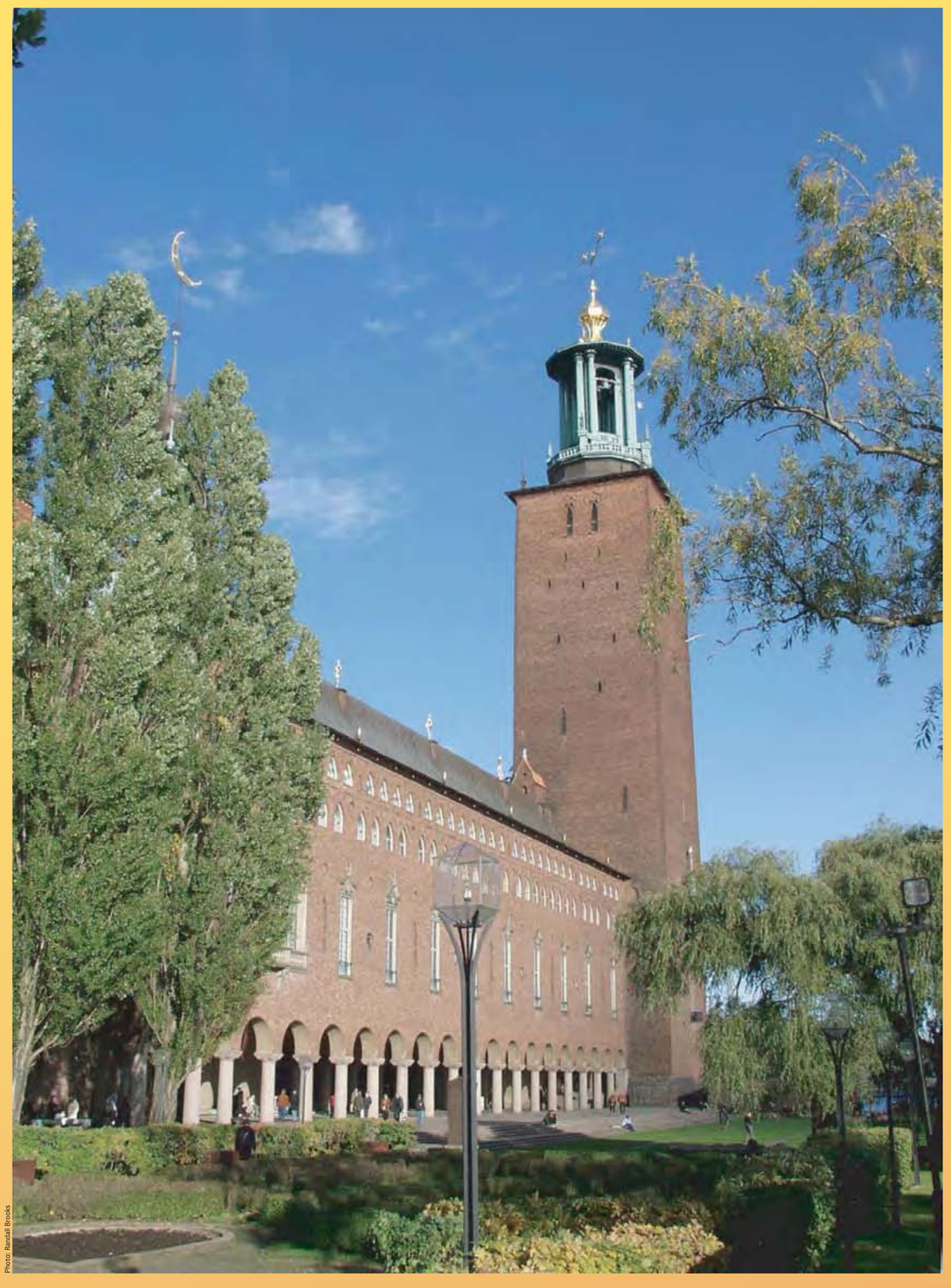
A Prizewinning Recipe

Canada on the World Stage

SNO solved a problem that had been troubling researchers for over thirty years.

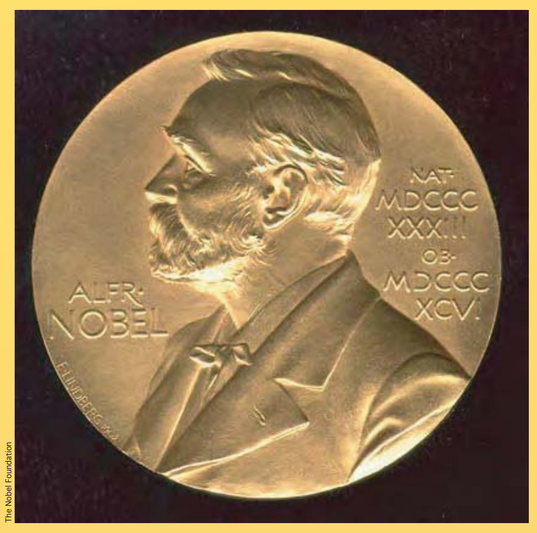
The papers describing SNO results are among the most often cited in all of physics. The work was named the top physics story of 2002 by the American Institute of Physics and the American Association for the Advancement of Science.

SNO results and the results from other neutrino experiments such as Super-Kamiokande in Japan are shaking up the scientific world. Do you think these discoveries are worthy of a Nobel Prize?



Photos: Randall Brooks

Stockholm City Hall



The Nobel Foundation

Selected Honours to Members of the Sudbury Neutrino Collaboration

CANADA

Alain Bellerive, Carleton University
Canada Research Chair, 2001

Walter Davidson, National Research Council Canada
Fellow, Royal Society of Canada, 2003

George Ewan, Queen's University
D.Sc, honoris causa, University of Guelph, 2001
D.Sc, honoris causa, Laurentian University, 2002

Arthur McDonald, Queen's University (SNO Project Manager)
LL.D., honoris causa, Dalhousie University, 1997
Fellow, Royal Society of Canada, 1997
Killam Research Fellowship, 1998
LL.D., honoris causa, University College of Cape Breton, 1999
D.Sc., honoris causa, Royal Military College, 2001
Queen's University Research Chair, 2002
T.W. Bonner Prize in Nuclear Physics from the American Physical Society, 2003
Canadian Association of Physicists Medal for Lifetime Achievement in Physics, 2003
Natural Sciences and Engineering Research Council of Canada Award of Excellence, 2003
Gerhard Herzberg Canada Gold Medal for Science and Engineering, 2003
U.K.–Canada Rutherford Lecturer for the Royal Society, 2003
Bruno Pontecorvo Prize, 2005

Tony Noble, Queen's University (SNO Institute Director)
Canada Research Chair, 2002

Scott Oser, University of British Columbia
Canada Research Chair, 2003

David Sinclair, Carleton University (SNO Deputy Director until 2002, SNOLAB Director)
Davidson Dunton Research Lecturer, 2002
Carleton Research Achievement Award, 2002
Fellow, Royal Society of Canada, 2003

Sudbury Neutrino Observatory
Ontario Association of Certified Engineering Technicians and Technologists Award for Outstanding Technical Achievement in Engineering and Project Management, 1995

UNITED STATES

Mark Boulay, Los Alamos National Laboratory
Los Alamos National Laboratory Distinguished Post Doctoral Fellow Award, 2004

Richard L. Hahn, Brookhaven National Laboratory
American Chemical Society National Award in Nuclear Chemistry, 2000
Brookhaven National Laboratory Research & Development Award, 1997

Karsten Heeger, University of Washington
American Physical Society Nuclear Physics Dissertation Award, 2003
Case Western Reserve University Michelson Postdoctoral Lectureship, 2004

Andrew Hime, Los Alamos National Laboratory
Fellow, American Physical Society, 2004

Josh Klein, University of Texas
Sambamurti Prize Lectureship, Brookhaven National Laboratory, 2004
Outstanding Junior Investigator Award, U.S. Department of Energy, 2004

Kevin Lesko, Lawrence Berkeley National Laboratory
Fellow, American Physical Society, 2000

Hamish Robertson, University of Washington
T.W. Bonner Prize in Nuclear Physics from the American Physical Society, 1997
Fellow, American Academy of Arts and Sciences, 2003

UNITED KINGDOM

David Wark, Rutherford Appleton Laboratory and Oxford University
Rutherford Prize, 2004

Regalis Societas Canadensis

Diploma Aggregationis

David Sinclair

Ontario Association of Certified Engineering Technicians and Technologists

presented this award to

Sudbury Neutrino Observatory

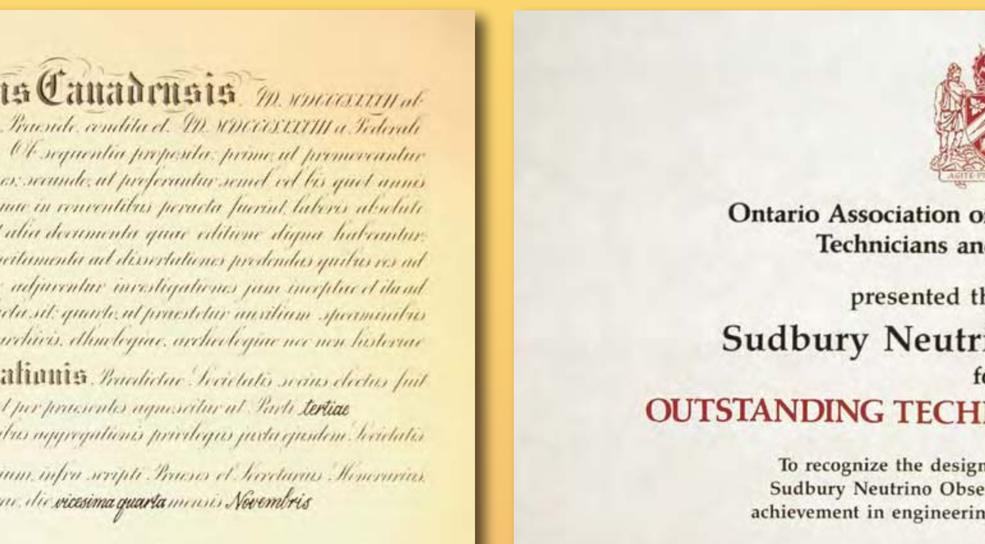
for

OUTSTANDING TECHNICAL ACHIEVEMENT

To recognize the design and construction of the Sudbury Neutrino Observatory as an outstanding achievement in engineering and project management.

March 29, 1995

President



Regalis Societas Canadensis

Diploma Aggregationis

Dr. Walter F. Davidson

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