contents 2002

the once and future COSMOS

SCIENTIFIC AMERICAN

Volume 12 Number 2

INTRODUCTION

2 Making Sense of Modern Cosmology

by P. James E. Peebles
Confused about all the theories? Good.

EVOLUTION

4 The First Stars in the Universe

by Richard B. Larson and Volker Bromm Exceptionally massive and bright, the earliest stars changed the course of cosmic history.

12 The Life Cycle of Galaxies

by Guinevere Kauffmann and Frank van den Bosch Astronomers are on the verge of explaining the bewildering variety of galaxies.

EXPANSION

22 Surveying Spacetime with Supernovae

by Craig J. Hogan, Robert P. Kirshner and Nicholas B. Suntzeff

Exploding stars seen across immense distances show that the cosmic expansion may be accelerating—a sign that an exotic form of energy could be driving the universe apart.

30 Cosmological Antigravity

by Lawrence M. Krauss

The long-derided cosmological constant a contrivance of Albert Einstein's—may explain changes in the expansion rate of the universe.

40 The Quintessential Universe

by Jeremiah P. Ostriker and Paul J. Steinhardt
The universe has recently been commandeered by
an invisible energy field, which is causing its expansion
to accelerate outward.

50 The Fate of Life in the Universe

by Lawrence M. Krauss and Glenn D. Starkman
Billions of years ago the universe was too hot for life to
exist. Countless aeons from now, it will become so cold
and empty that life, no matter how ingenious, will perish.

Cone Nebula, captured in April 2002 by the Hubble Space Telescope



STRUCTURE

58 Is Space Finite? by Jean-Pierre Luminet, Glenn D. Starkman and Jeffrey R. Weeks

Conventional wisdom says the universe is infinite. But it could be finite, merely giving the illusion of infinity. Upcoming measurements may finally resolve the issue.

66 The Universe's Unseen Dimensions

by Nima Arkani-Hamed, Savas Dimopoulos and Georgi Dvali

The visible universe could lie on a membrane floating in a higher-dimensional space. The extra dimensions would help unify the forces of nature and could hold parallel universes.

"Infinity box" creates the effect with mirrors, page 58

DESTINY

74 A Cosmic Cartographer

by Charles L. Bennett, Gary F. Hinshaw and Lyman Page The Microwave Anisotropy Probe will provide a much sharper picture of the early universe.

76 Echoes from the Big Bang

by Robert R. Caldwell and Marc Kamionkowski

Scientists may soon glimpse the universe's beginnings by studying subtle fluctuations in the cosmic microwave background.

82 Exploring Our Universe and Others

by Martin Rees

In this century cosmologists will unravel the mystery of our universe's birth—and perhaps prove the existence of other universes as well.

88 Ripples in Spacetime

by W. Wayt Gibbs

LIGO, a controversial observatory for detecting gravitational waves, is coming online after eight years and \$365 million.

98 Plan B for the Cosmos

by João Magueijo

If the new cosmology fails, what's the backup plan?

Cover illustration by Edwin Faughn; NASA/Associated Press (opposite page); Bryan Christie Design (left and above)

Scientific American Special (ISSN 1048-0943), Volume 12, Number 2, 2002, published by Scientific American, Inc., 415 Madison Avenue, New York, NY 10017-1111. Copyright © 2002 by Scientific American, Inc. All rights reserved. No part of this issue may be reproduced by any mechanical, photographic or electronic process, or in the form of a phonographic recording, nor may it be stored in a retrieval system, transmitted or otherwise copied for public or private use without written permission of the publisher. Canadian BN No. 127387652RT; OST No. 01015332537. To purchase additional quantities: 1 to 9 copies: U.S. \$5.95 each plus \$2.00 per copy for postage and handling (outside U.S. \$5.00 P&H). Send payment to Scientific American, Dept. COSM, 415 Madison Avenue, New York, NY 10017-1111. Inquiries: Fax 212-355-0408 or telephone 212-451-8890. Printed in U.S.A.