From fireball to galaxies: Making late waves

How a universe that started out as a hot, dense fireball developed an intricate structure consisting of galaxies, clusters of galaxies, voids and other large-scale features is one of the major conundrums in cosmology today. Theorists believe that at some point after the Big Bang, fluctuations in the smooth flow of matter and energy served as seeds for galaxy formation. The question is when and how those fluctuations occurred. A new theory postulates that these fluctuations happened much later than suggested by previous models.

All models for generating fluctuations on a cosmological scale require a phase transition – a change in the fabric of space itself to produce lumps and ripples in the distribution of matter. Such density fluctuations eventually yield the galaxies and galaxy clusters now observed.

David N. Schramm of the University of Chicago and his collaborators suggest that such a phase transition occurred a million or so years after the Big Bang rather than during the first nanosecond of the universe's life. "Before, people always thought phase transitions had to be early, and then they were stuck with a particular mode of thought," Schramm says. "Allowing the phase transition to be late opens up all sorts of new possibilities." He and his colleagues describe their theory in the April COMMENTS ON NUCLEAR AND PARTICLE PHYSICS.

When water freezes to form an ice cube, different parts often freeze at slightly different rates. These separately formed regions of ice don't quite mesh to create a perfect crystal. Consequently, an ice cube often shows internal imperfections, usually seen as fractured lines and planes. Similarly, a phase transition on a cosmological scale would produce "topological" defects in the vacuum of space. The universe's lumpiness would arise much in the same way frosty white planes appear within ice cubes.

Schramm and his colleagues base their arguments for a late phase transition on the possibility that neutrinos – subatomic particles normally thought to have no mass at all – may actually have a tiny mass. That mass would manifest itself about a million years after the Big Bang. Such a neutrino mass, about one fifty-billionth that of an electron, would also help account for why the sun produces fewer neutrinos than expected according to conventional theories (SN: 4/30/88, p.277).

The idea of a late phase transition is appealing because such a change occurs after electrons combine with protons to produce hydrogen atoms and the amount of energy in the form of electromagnetic radiation, or photons, stabilizes. This means a late phase transition has practically no effect on the microwave background radiation, which pervades the universe and appears uniform in every direction. Theories in which phase transitions happen earlier have a great deal of difficulty explaining how fluctuations can grow to become seeds for galaxy formation without distorting the microwave background radiation to a greater extent than observed.

"In our model, we avoid making fluctuations in the background radiation while still making fluctuations that would produce galaxies," Schramm says. "The seeds of galaxy formation are created at the time the galaxies need them, not before."

Measurements of any slight distortions in the microwave background radiation would provide one of the best tests of the new model, Schramm says. The less distortion observers detect, the more promising a late-phase-transition model looks.

Computer simulations also provide a useful check on the model. Recently, David N. Spergel of Princeton (N.J.) University and William H. Press of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., investigated one particularly simple case to see if a late phase transition involving neutrinos would evolve into the kind of structures observed in the universe.

"In its simplest form, it doesn't look too promising," Spergel says. "However, many other variations are possible. A lot of work needs to be done to explore the model and see if it provides a viable alternative for galaxy formation."

Furthermore, a neutrino phase transition isn't the only possibility. "Once we recognized that this particular transition could do it, we realized that particle physics offers other possibilities for a late phase transition," Schramm says. "We need to look at other kinds of particle models . . . that can yield the same kind of effect."

"Maybe something crazy is needed," says Princeton astrophysicist P. James E. Peebles. "None of the standard models for formation of galaxies and clusters of galaxies fits very well with all of the data. That could be because we're missing some elementary point in the way we approach the data, or it could be we're missing something big, like a late-time phase transition. I certainly wouldn't dismiss [that possibility], because we're getting a little desperate." *– I. Peterson*

Global smog: Newest greenhouse projection

Most forecasts of "greenhouse" climate changes focus on higher average land-surface temperatures and sea-level rises – changes that could blight crops and inundate coastal communities. But farmers and beachfront dwellers aren't the only individuals likely to suffer directly from greenhouse effects, scientists reported last week. New studies suggest a greenhouse warming could greatly exacerbate air pollution – especially smog-ozone levels – throughout the world.

At NASA's Goddard Institute for Space Studies in New York City, David Rind and his co-workers have begun tweaking the institute's computer model of climate to explore weather-related changes that might result from a doubling in atmospheric levels of carbon dioxide, the primary greenhouse gas. In general, the model anticipates a growing sluggishness in weather systems, Rind told a Washington, D.C., conference on climate and air quality sponsored by the Environmental Protection Agency and American Gas Association.

As climate warms, temperatures climb faster at high latitudes (nearer the poles) than at low latitudes (nearer the equator), Rind says. Because latitudinal temperature gradients drive the circulation of air masses around the globe, diminishing the gradient can be expected to reduce the energy driving weather systems.

His model indicates a carbon dioxide doubling would in general slow surface winds, reduce winter and spring storms outside the tropics, reduce the intensity of storms that do occur and slow the eastward transport of pressure systems and air masses across the globe's midlatitudes. A shift to fewer and weaker storms, combined with sluggish movement of air masses, suggests dirty air masses could be left hovering over industrial centers longer than they are today, he says.

Moreover, "with a warmer climate, there's more evaporation of moisture into the air," Rind says. His model predicts that a doubling of carbon dioxide could increase humidity "on the order of 30 to 40 percent." At the same time, there's likely to be more vertical exchange of air – a convective mixing of high- and low-altitude air masses. "Our model also seems to imply that there will be a greater transport of ozone from the stratosphere [upper atmosphere] into the troposphere [lower atmosphere extending down to land]." The obvious implication, Rind says, is that urban smog-ozone levels may be enhanced by ozone generated in the stratosphere.

Greenhouse changes will also affect the chemistry of pollutants in the air at Earth's surface. An urban-smog model being developed at Systems Applications Inc. in San Rafael, Calif., indicates "air will become more reactive in the future," reports C. Shepherd Burton, the company's senior vice president. In a warmer environment, reactions between sunlight and air pollutants will occur more rapidly. This suggests that smog and other reactive by-products of such processes will form closer to their sources – primarily in the centers of cities and industrial areas, where population densities tend to be highest. As a result, Burton says, "we would expect that attaining the federal ozone standard could become more difficult."

However, his computer model shows, this smog equation could change with a dramatic reduction in ozone precursors such as hydrocarbons and nitrogen oxides. The atmosphere's increased reactivity could alter the ozone precursors before they have time to generate much ozone. In that case, if one were to consider smog-ozone only, "it might look like climate change didn't end up hurting us at all," Burton says. However, he notes, the reaction products generated in place of ozone are oxidants – such as peroxides and nitrogen compounds – "whose health effects may be as bad as ozone's."

Greenhouse smog increases probably will not be restricted to urban areas, according to new computer analyses by Anne M. Thompson, a chemist at NASA's Goddard Space Flight Center in Greenbelt, Md. Using current global emission rates for methane and carbon monoxide, two important greenhouse gases, she calculates that by the year 2030, total atmospheric ozone levels in the low and middle latitudes could increase about 10 percent globally, with levels highest at Earth's surface. Her data show that smog-ozone in distant suburbs and outlying areas could increase 20 to 25 percent. Even at sea, she says, ozone levels might increase 5 to 10 percent.

The ground-level ozone increases predicted by these studies justify expanding federal funding for air-quality monitoring and ozone mitigation, says John Topping, president of the Washington, D.C.-based Climate Institute. Moreover, he argues, when Clean Air Act amendments are drafted this year, they should permit the Environmental Protection Agency administrator to evaluate air-pollution-control strategies in light of their possible impact on larger environmental problems, such as greenhouse warming and stratospheric-ozone depletion.

Topping recalls being hampered by such restraints when he was staff director of EPA's office of air and radiation. He says there was a time, for instance, when regulations forced him to approve state requests to substitute chlorofluorocarbons (CFCs) for volatile and chemically reactive solvents, such as perchloroethylene, because the reactive solvents directly contributed to urban air pollution and CFCs would not. Such requests struck him as ironic, he says, because at the time he was also initiating the CFC risk assessments that ultimately led to the Montreal Protocol, a treaty aimed at banning most CFC use. *– J. Raloff*

Modern humans take a spin back in time

Scientists using a recently developed dating technique say anatomically modern humans apparently inhabited an Israeli cave known as Skhul about 100,000 years ago. Their conclusion, described in the April 27 NATURE, is consistent with reports that early modern humans were living at the nearby Qafzeh cave more than 90,000 years ago (SN: 2/27/88, p.138).

Nonetheless, the accumulating evidence for an early human presence in the Near East, more than twice as long ago as had been previously assumed, does not quell an ongoing dispute over the evolution of modern *Homo sapiens*. Some investigators say anatomically modern humans originated in Africa and spread throughout the world, replacing groups such as the Neanderthals, while others contend there was at least some interbreeding between early modern humans and Neanderthals.

Researchers had roughly dated Skhul at about 40,000 years old by comparing stone tools and the remains of animals and humans at the site with those from nearby caves.

The new age for Skhul was obtained by Christopher B. Stringer of the British Museum in London and his colleagues. They analyzed two teeth from an ancestral form of the cow or ox excavated more than 50 years ago and housed in a British Museum collection. The teeth came from sediment containing the remains of at least 10 early modern humans. Stringer's group calculated the age estimate through electron spin resonance (ESR) dating, a technique used with several archaeological samples over the last decade.

ESR measures the density of trapped electrons that gather in bone and other organic material as a result of environmental radiation after the material is buried. The technique gauges a specimen's natural radioactivity as well as sources of the radiation, such as uranium and thorium. Natural electron density is then compared with that produced by standardized doses of high-energy radiation. From this, researchers can calculate the specimen's annual radiation dose and an estimated age.

Assuming the uranium in the animal teeth was absorbed soon after burial, the researchers place Skhul's minimum age at approximately 81,000 years. A better estimate, based on the assumption that the uranium was taken up more gradually, is around 101,000 years, they contend.

These dates are nearly the same as those previously obtained at Qafzeh with ESR and another technique, thermoluminescence dating.

Anatomically modern humans appear to have inhabited the Near East about 50,000 years before entering Europe, the investigators maintain. But modern humans' relationship, if any, to early Neanderthals who lived near Skhul and Qafzeh remains unknown, Stringer and his co-workers assert. To solve that puzzle, researchers need better dates for the Neanderthal sites, which themselves have yielded some important remains (SN: 4/15/89, p.229).

Early modern humans at Skhul and Qafzeh may have briefly inhabited the area as they migrated from Africa to Asia and much later to Europe, the scientists suggest. On the other hand, modern humans and Neanderthals may have alternated or overlapped in their occupation of the Near East for 60,000 years. *– B. Bower*

Bush picks science adviser

President Bush last week nominated nuclear physicist D. Allan Bromley of Yale University as his science adviser, an appointment that also would make Bromley head of the White House Office of Science and Technology Policy.

Bromley carried out pioneering studies on the structure and dynamics of nuclei and is considered the father of modern heavy-ion science. He has been a leading science spokesman as president of both the American Association for the Advancement of Science (AAAS) and the International Union of Pure and Applied Physics.

"I think it's an outstanding choice," says Richard S. Nicholson, the new executive officer of the AAAS in Washington, D.C. "He's highly accomplished both as a scientist and in science policy [and] will have the respect of everybody."

"He's a good, solid mainstream adviser in an administration that is trying to be middle of the road," says Philip Speser, president of Foresight Science and Technology Inc., a research firm in Washington, D.C. Bush has elevated the science advisory post to the same level as the national security adviser. This means the science adviser will report directly to the President, Bromley says.

The science adviser should interject science and technology into areas that may relate only indirectly to science, such as international relations, Bromley says. "Science and technology sometimes provide an opportunity to build communication channels [between nations] . . . because scientists really do share a common language," he says.

Bromley's appointment requires Senate confirmation, but a vote on his nomination probably won't occur until at least the end of May, says an aide to the Committee on Commerce, Science and Transportation. *– I. Wickelgren*

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