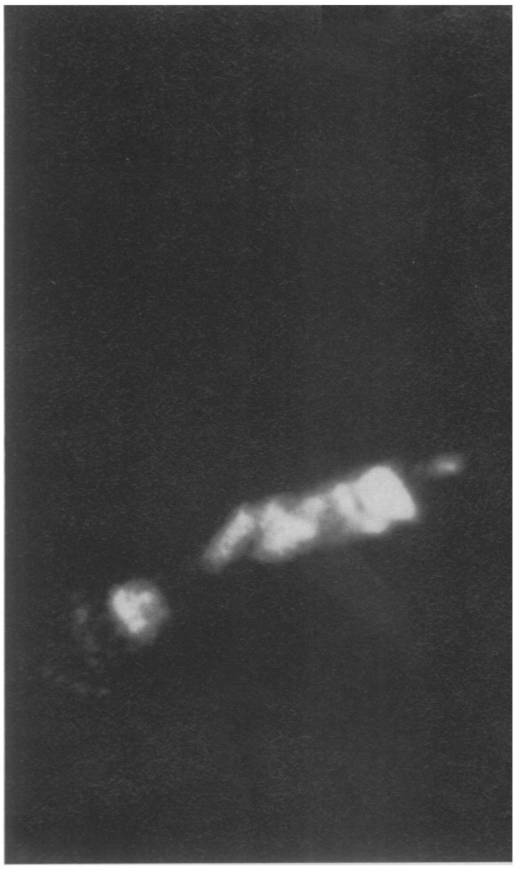
New Challenge to the BIG BANG?

By RON COWEN



Most cosmologists subscribe to the idea that a single giant explosion gave birth to the cosmos. And even though not everyone agrees with the Big Bang theory (SN: 4/13/91, p.232), a plethora of new observational evidence has clearly limited the number of competing theories. So why would anyone begin work on yet another theory to challenge this popular model?

Call them diehards or consider them researchers who believe they have come up with a more compelling version of how the universe evolved. But a group of veteran cosmologists who have long questioned the tenets of the Big Bang say they couldn't have developed their theory at a more appropriate time. They argue that it fits a wealth of recent observations obtained with the Cosmic Background Explorer (COBE) satellite (SN: 1/16/93, p.43) and can explain certain phenomena that the Big Bang can't.

Geoffrey Burbidge of the University of California, San Diego, Jayant V. Narlikar of the Inter-University Center for Astronomy and Astrophysics in Pune, India, and Fred Hoyle, now retired from the University of Cambridge in England, presented their theory in the June 20 Astrophysical Journal. They plan to report further details in several physics and astronomy journals during the next year.

In their model, unlike the Big Bang, the universe wasn't created at one instant in time. Instead, the cosmos has no defined beginning and could be thousands of times older than the 15 to 20 billion years indicated by most Big Bang models. Rather than postulating a single explosion, the astronomers envision a series of localized "minibangs," some larger than others, which occur at sporadic intervals throughout the history of the cosmos. These mini explosions, spaced millions to billions of years apart, disturb and continually reshape the universe.

Burbidge and his colleagues assert that their theory, known as quasi-steady state cosmology (QSSC), exactly predicts the temperature of the cosmic microwave background radiation, a feat that the Big Bang model can't as yet accomplish.

The researchers also report that their model can account for the cosmic abundance of hydrogen, helium, and deuterium. And unlike a favored version of the Big Bang, QSSC can explain the amount of primordial deuterium without having to invoke the notion of dark matter – hypothetical material that doesn't emit light and is thought to consist of exotic particles rather than ordinary protons and neutrons. The cosmologists also claim that their minibang theory can explain the abundance of other light elements, including lithium, beryllium, and boron.

But physicist David N. Schramm of the University of Chicago insists the Big Bang theory has no rival when it comes to explaining fundamental aspects of the universe. He counts three pieces of evidence that have convinced many scientists of the theory's validity: the expansion of the universe, the existence and character of the microwave background, and the abundance of primordial hydrogen and several other light elements. All three pieces of evidence, he and a multitude of others maintain, can best be explained by the Big Bang.

Schramm notes that the expansion of the universe is a natural outcome of Einstein's theory of gravitation. The microwave background seems to represent the cooled relic radiation left over from a hot explosion, and its predicted smoothness has now been verified to high precision by COBE. And astronomers can account for the abundance of the light elements if the early universe was both hot and dense – a nuclear furnace capable of fusing hydrogen atoms into helium.

Schramm asserts that several of the assumptions in QSSC appear ad hoc and some are flawed. "They have so many parameters that they tweak and play around with that they can fit anything, but it's not a real fit," he says. Schramm charges, for example, that the team's method for explaining the primordial abundance of light elements does not properly account for interactions among the entire family of elementary particles discovered since the 1960s. Thus, the team's results, he asserts, constitute "not a *pre*diction, but a *post*diction."

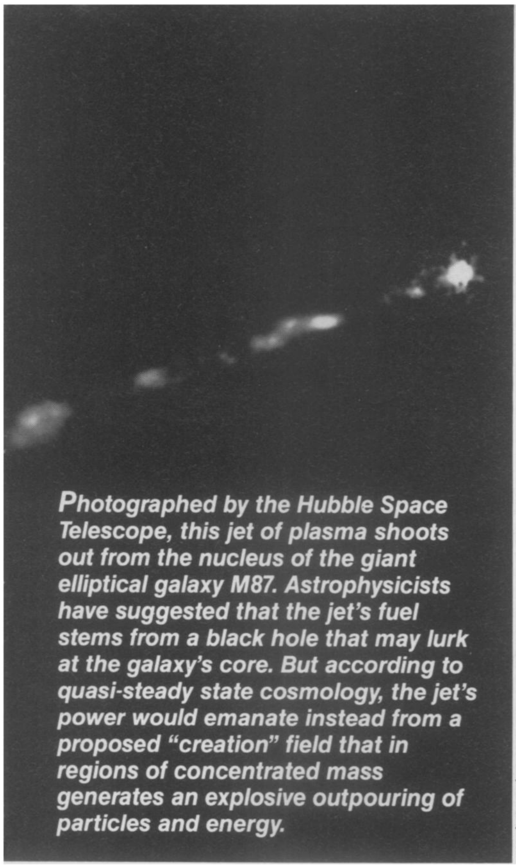
Cosmologist P.J.E. Peebles of Princeton University generally concurs. The model, he says, is "set up by hand to get what they want."

Burbidge counters that QSSC does not rely on any more parameters than those of other cosmologies. "You have to remember, when you're talking with cosmologists, we all have very strongly held beliefs," he says.

In contrast to most other cosmologies, notes Burbidge, QSSC links the evolution of the universe with the violent activity observed at the heart of many galaxies. Indeed, it was this association, he says, that first attracted him to the model.

The link comes about because QSSC modifies Einstein's equations of general relativity to include the existence of a "creation" field, which acts to spontaneously create particles and radiation. A predecessor of QSSC, the steady-state theory of the universe, also invoked the existence of a creation field. Hoyle and two former colleagues at Cambridge, Hermann Bondi and Thomas Gold, proposed that model in 1948.

In this older theory, the creation field



Photographed by the Hubble Space Telescope, this jet of plasma shoots out from the nucleus of the giant elliptical galaxy M87. Astrophysicists have suggested that the jet's fuel stems from a black hole that may lurk at the galaxy's core. But according to quasi-steady state cosmology, the jet's power would emanate instead from a proposed "creation" field that in regions of concentrated mass generates an explosive outpouring of particles and energy.

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✯ Debating an ✯ alternative ✯ model for the ✯ creation ✯ of the ✯ universe

spread out uniformly, continuously filling the entire universe with new particles and radiation as it increased in volume. Thus, the cosmos would always look the same. In contrast, the creation field in QSSC exists only with adequate strength in regions of high mass density, such as in a large cluster of galaxies or at the dense core of an individual galaxy. Confining the field in this way allows an evolving universe – a significant departure from the old steady-state model, notes Peebles.

The explosive outpouring of particles and radiation produced by the creation field could well account for the jets of radiation and other violent emissions spewed from the center of some galaxies, Burbidge says. He notes that astronomers are often forced to explain such violence by assuming that black holes lie hidden at the hearts of these galaxies. In that scenario, as matter falls onto a galactic black hole, the material releases huge amounts of energy that the galaxy then spews out. But QSSC simply does not require black holes, he says.

Schramm, however, notes that black holes emerge as a natural consequence of Einstein's relativistic theory of gravitation and that their existence needn't be avoided. Moreover, he sees no physical basis for the proposed creation field. "I guess it [comes down] to philosophy, but for most people in physics and astronomy, you don't invent a new law of physics to explain observational phenomena until you're forced to."

Even without the presence of a black hole, according to Peebles, "gravity is plenty capable of doing violent things [at the center of galaxies]. That also, of course, suggests very strongly that you don't need this magical creation of matter to account for it."

But Burbidge argues that the creation field, a critical component of QSSC, has as much validity as exotic entities proposed by other cosmologists. In a large, very dense cluster of matter, the field can create such an intense outpouring of energy that it induces a sizable minibang, he says. Burbidge, Hoyle, and Narlikar propose that these minibangs, or creation events, happen throughout the life of the universe.

In particular, they suggest that the cosmos cycles between phases in which the creation field alternately strengthens or weakens. During a denser phase, when the creation field is strongest, the minibangs are either more intense or more frequent, accelerating the expansion of the universe. But as the universe expands, it grows less dense, weakening the creation field.

The weak field triggers fewer explosions, eventually putting the brakes on the expanding universe. But as this slowdown continues, the density of the cosmos begins to increase, causing the creation field to regain strength and trigger more explosions. And as more explosions occur, the cycle repeats.

Overall, the researchers propose, the universe has already undergone near-steady expansion for some 1 trillion years. Superimposed on this overall expansion, however, are the relatively short-term fluctuations, some of them 40 billion years in duration, in which the creation field is weaker and the cosmic growth rate slower. Burbidge, Hoyle, and Narlikar suggest that the cosmos is now about midway through one of the short-term slowdowns.

Because the QSSC model indicates a very ancient universe, it's easy to envision the accumulation of an enormous amount of matter that no longer emits light, says Burbidge. This "dark matter," however, would consist of ordinary material – the countless number of dead stars and galaxies that have burned out over the lifetime of the universe.

But what about the microwave background? How could a series of distinct minibangs ever produce the smooth distribution of radiation typically associated with the aftermath of a single giant explosion? Burbidge and his co-workers rely on a proposed supply of needle-shaped particles of iron dust. The violent death of a massive star in a supernova explosion is known to produce iron and might produce such particles, he says.

According to the researchers, the needle-shaped particles would efficiently absorb and reradiate the light emitted during a minibang. And in re-emitting that light, the dust would produce a uniform distribution of radiation matching that of the observed microwave background, the team calculates.

To account for the visibility of microwave radiation originating from the distant past, most of the light-obscuring particles of iron dust could not have formed any more recently than 10 billion years ago, Schramm says. (Dust that formed later would make the universe appear much more opaque at microwave wavelengths than it actually does, he notes.) Schramm asserts that this scenario, in which the universe appears transparent in more recent times but more opaque in the distant past, looks suspiciously like that of a universe born from a single high-density explosion billions of years ago – the Big Bang. "Their model is starting to lose its difference [from the Big Bang model]," he charges.

It remains to be seen what kind of observations could provide a definitive test of QSSC. Narlikar suggests that a planned search for gravity waves using laser interferometers might detect gravitational radiation produced by a minibang. But the minibang would have to have triggered an asymmetric – rather than spherical – explosion, and it would need to have other properties that distinguished it from other sources of gravity waves, such as supernova explosions or rotating neutron stars.

"If we can't find the signature of our 'black box' that differs from the signature of the conventional black box, then there is going to be a real problem," says Burbidge. "It then gets back to a matter of taste, and taste is not science."

"At present, almost everybody believes in the conventional wisdom [of the Big Bang]. But nobody has [yet] played a game like ours." ❑