How the cosmos got its first lumps

Cosmology has a number of fundamental problems. One of the worst is how matter was able to form clumps and aggregations. On every scale of the universe, from protons to galaxy clusters, matter is articulated in organized concentrations, yet the big bang theory of the universe's origin does not account for them. It yields a smooth undifferentiated gruel of matter.

Cosmologists have generally thought — or perhaps feared — that the only way to account for organized concentrations of matter was to muck up the primal simplicity of the big bang by putting in primordial density fluctuations around which later concentrations such as galaxies could condense. Now a theory propounded in the Aug. 5 NATURE by Matt Crawford and David N. Schramm of the University of Chicago shows how to avoid this unsatisfying ad hoc procedure, at least for the earliest articulations of matter.

The theory deals with a time when the universe was three millionths of a second old. At that epoch the cosmos consisted of a smooth homogenous mix of quarks and antiquarks, the structural elements and predecessors of matter, and electromagnetic radiation. It is just the expansion of the universe that causes quarks and antiquarks to clump together to make subatomic particles. No insertion of primal lumps or density fluctuations into the theory is necessary.

This happy state of affairs comes about because of the nature of the force that attracts quarks to one another, which is called for technical reasons the "color force" or chromodynamic force. As experiments with the most recently discovered families of subatomic particles, those designated by the Greek letters psi and upsilon, have shown, the attractive force between quarks gets stronger the farther the quarks are from each other. This is quite a strange property compared to the behavior of well known forces such as electromagnetism or gravity, which all get weaker as the distances between the bodies involved get longer. The color force does the opposite, and that is how physicists explain their inability to find free quarks in the universe of today: To pull a quark out of one of the particles that quarks build means to fight an ever increasing force, an impossible task.

Back before the third microsecond of history, however, the quarks in the universe were too close together to form larger particles. The forces they felt from their nearest neighbors were too weak to bring them together, and the nearest neighbors screened each quark from the possible attraction of more distant ones. As the universe expanded, the distance between nearest-neighbor quarks increased until they felt a force strong enough to impel them together.

Under such an attraction a quark and an antiquark might come together to form one of the class of subatomic particles called mesons, or three quarks might form one of the baryon class (such as a neutron or proton) or three antiquarks an antibaryon. Particle formation is a self-encouraging process up to a point. When nearest neighbors have formed a particle, the particle no longer feels the color force, and so no longer screens the quarks on either side of it from each other. These, being more distant from each other, feel an even stronger attraction, and so hasten to make more particles. The saturation point is reached when the attractive force is so strong that, by the tension it sets up in space, a kind of stored energy effect, it spontaneously creates new quarks and antiquarks in pairs, which then reestablish the screening effect and put a damper on particle formation.

Crawford and Schramm say their theory does not directly lead from particle formation to such things as galaxies and clusters, but further work may show how to get there. However, clumps of mesons and baryons form that are so close together that they immediately become black holes with masses equal to that of Jupiter (up to 10^{30} grams or 10^{24} metric tons). Such black holes could solve two important cosmological puzzles: Does the universe expand forever? And what holds galaxy clusters together?

Galaxies appear to be associated in clusters. If these are not chance associations, but really bound together, there must be a lot of dark matter in them. The visible matter does not produce enough gravity to hold them together. Black holes of this kind are a good candidate. Enough matter in the universe as a whole could provide the gravity to decelerate, stop and reverse the expansion. Evidence is by no means conclusive that this "closed universe" is the actual case, but the option seems most plausible to many cosmologists. Again dark matter is necessary, and again Jupiter-mass black holes seem a good candidate.

—D.E. Thomsen

Doubts surface on Love Canal study

The U.S. Environmental Protection Agency's monitoring study, which led to the announcement that the Love Canal neighborhood in Niagara Falls, N.Y., is as habitable as other areas of the city (SN: 7/24/82, p. 52), may be flawed, a congressional subcommittee was told last week. Ellen K. Silbergeld, a scientist with the Environmental Defense Fund, raised the issue at a hearing of the House subcommittee on Commerce, Transportation and Tourism. Other testimony revealed difficulties in judging the quality of the data collected and the validity of the scientific procedures used.

Silbergeld argued that the Love Canal study was not designed to answer the questions of habitability and safety. "In the absence of information on health effects, only questions of relative habitability can legitimately be addressed by this report," she said. Even this could not be done because too few control sites for comparison were sampled, and as many as 90 percent of the samples analyzed showed no detectable chemical compounds present, Silbergeld said. The analytical methods may have been applied too carelessly or were not sensitive enough to detect very low but possibly still-dangerous levels of chemicals.

Raymond G. Kammer, deputy director of the National Bureau of Standards, testified that based on an EPA draft report review, released in May, "the EPA had not, at that time, incorporated estimates of precision, accuracy and limits of detection into its validated data base, thus making difficult, if not impossible, any further interpretation of the data by scientists other than those intimately familiar with the details of the study." Kammer also said that NBS could not, under any circumstances, "certify" the monitoring data and could not comment on the significance of the EPA report's deficiencies to the conclusions. He said NBS did not review the final version of the Love Canal study to see if the deficiencies had been corrected.

Of greatest concern to Department of Health and Human Services scientists, who had to make the habitability judgment, was the question of minimum detection levels. Edward N. Brandt Jr., HHS assistant secretary for health, said at the hearing, "We asked EPA to assure us that the organic toxicants of interest, which were reported to be nondetectable, were indeed not present in levels greater than the parts-per-billion range." NBS was also willing to say that EPA's approach for determining method detection limits was reasonable provided certain conditions were met. With those assurances, the HHS scientists affirmed that the levels reported in the area outside the canal itself and the surrounding two rings of houses were not significantly different from comparison neighborhoods and presented minimal health risk. "Our habitability conclusion was based on the assumption that the EPA data were valid," Brandt said.

Courtney M. Riordan, acting assistant administrator of EPA's Office for Research and Development, admitted that a study as large and accelerated as the Love Canal monitoring effort encountered problems, but said, "The simple fact is that the pattern of results of the monitoring and subsurface investigations are so consistent as to minimize the potential impact that these problems might have had on the overall findings and conclusions of the study."

—I. Peterson