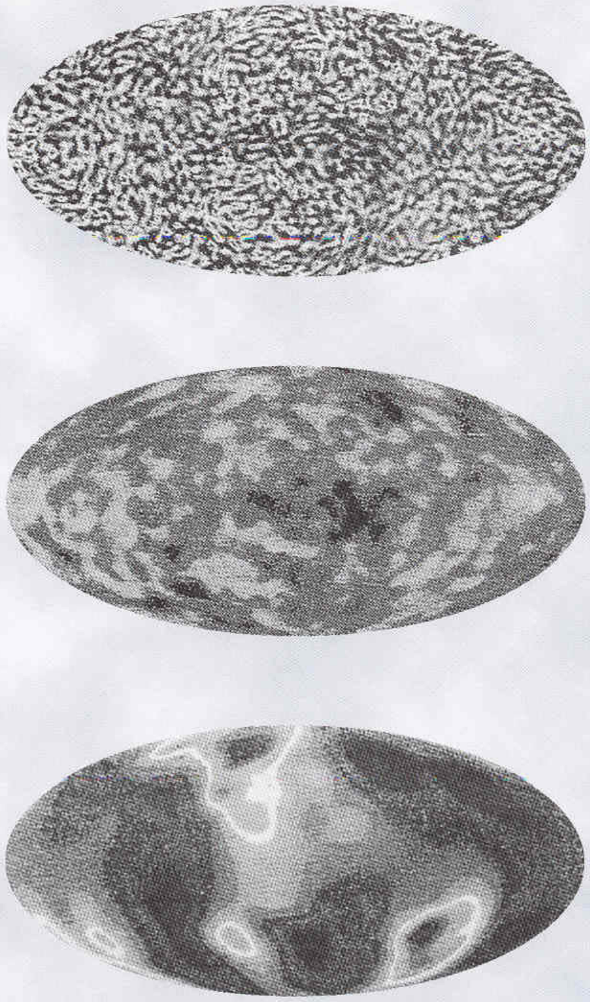
Reconstructing the Initial Large-Scale Structure of the Universe



Modern cosmology postulates that our universe began as an ultra-small, ultra-dense, ultra energetic mass whose explosion, the "Big Bang," eventually spawned the massive structures seen today.

Evidence for this scenario includes the observed red-shifts in the spectra of galaxies, which indicate that they are still racing away from each other at high speeds, and the cosmic microwave background (CMB) radiation from the primeaval fireball, suitably cooled over the eons, which still permeates all space. However, the CMB seems, at first glance, completely homogenous and isotropic, i.e., the same in all directions. How could such a uniform expansion result in the galaxies and galactic clusters - and the even larger "walls" of galactic clusters and intervening "voids" - that characterize the observed large-scale structure of the universe?

This problem is so important that an entire satellite observatory (COBE) was launched just to search for subtle, localized fluctuations in the CMB. These are usually expressed as the temperature of a featureless "black body" that would emit the equivalent microwave spectrum. The observed fluctuations are very small (less than 0.001 K); and they are highly contaminated with random noise and (near the galactic plane) galactic background emission. Nonetheless, their discovery in 1992 has revolutionized efforts to discover the initial conditions from which our universe developed.

Now that the issue of "texture" has been resolved, some scientists have been trying to reconstruct the major specific features of the underlying anisotropies (hot and cold spots) from the sparse and noisy data that are available. These presumably represent the "seeds" from which today's large-scale structure developed. The more common approach applies "unbiased" algorithms (mathematical procedures) that smooth the available density velocity fields without making a priori assumptions. However, the transformation from raw (top figure) to smoothed data (middle figure) is typically insufficient to extract statistically significant spatial features from the noise.

Israel NSF grantee Prof. Yehuda Hoffman and his Hebrew University colleagues have taken a different approach. Using special (Wiener) filtering techniques, they first assume a reasonable, a priori model then solve for some optimal estimator of the "true" sky map. The quality of the data still matters, but noise removal is biased by the model. By choosing a reasonable set of such models and associated parameters, and comparing the different maps obtained, one can identify persistent spatial features at levels 2-3 times above the underlying noise level (bottom figure).

The investigators' discovery of robust, statistically significant (four times standard deviation) hot and cold spots in the COBE map of the universe are significant advances, both in their own right, and as a guide to the ongoing Tenerife experiment. Such experiments will either confirm the Israel NSF investigators' view of the universe or require major changes in the accepted astrophysical theories which underlie the investigators' assumptions.