EVIDENCE FOR THE GRAVITATIONAL INSTABILITY PICTURE IN A DENSE UNIVERSE

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The statistical nature of the galaxy distribution is in a sense remarkably simple. The two-point correlation function $\xi(r)$, which measures the count of galaxies at separation r in excess of that expected for a random distribution, varies as $\xi \propto r^{-1.8}$ for $\xi > 1 (r \lesssim 15$ Mpc). At larger separations ξ apparently decreases more rapidly. The power law behavior is observed in different galaxy catalogs of varying depth and positions in the sky. What is the explanation of this universal behavior of $\xi(r)$, and what do correlation functions tell us about the initial conditions at the recombination epoch and/or the value of Ω?

A power law shape for $\xi(r)$ is a natural expectation of gravitational instability in a Universe with no fixed scales. There exists a similarity solution of the BBGKY hierarchy equations describing the time evolution of $\xi(r)$ in the limit of: 1) an Einstein-de Sitter cosmology (Ω=1); 2) a power law initial spectrum of small perturbations; 3) absence of non-gravitational forces; 4) no effects caused by the discreteness of the particles. If boundary conditions are chosen to match the growth rate of linear perturbations on large scales, and to form stable (non-collapsing) clusters on small scales, then the observed slope of 1.8 is expected for a white noise initial spectrum.

A detailed calculation based on an observed model of the three point correlation function has been performed by Davis & Peebles (1977) and compares favorably to the available data, suggesting $\Omega \gtrsim .3$. Analysis of galaxy catalogs complete with redshift for each member will yield consistency checks on our model. A study of the Shapley-Ames catalog (Davis, Geller, and Huchra, 1977) again suggests rather high values of Ω, but this sample is too biased by the Virgo supercluster to be a fair test.

Davis, M., and Peebles, P.J.E., Ap.J. Supp., 34, 4
Davis, M., Geller, M.J., and Huchra, J., 1977, Preprint

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DISCUSSION

Zeldovich: I would like to understand in simple physical terms the influence of Ω. If you change Ω, small perturbations grow at the same rate but they do so at a different epoch. Bound systems, once they have formed are independent of Ω. This is where the difference in the shapes of the correlation functions comes from.

Davis: This is correct.

Turner: Those of us (Drs Aarseth, Gott, and myself) who have been analyzing the N-body simulations of galaxy clustering do not feel that the discrepancy between the calculated BBGKY $\xi(r)$ and the measured N-body $\xi(r)$ is necessarily due to the introduction of a mean initial interparticle separation in the simulations. Indeed, it seems implausible that the presence of this characteristic scale of which there is no sign in the N-body $\xi(r)$ could cause a (BBGKY predicted) break in the $\xi(r)$ power law to disappear and leave a pure power law with no preferred scales. We feel that there is some evidence that $\xi(r)$ is determined by relaxation processes and is relatively independent of Ω and the initial conditions.

Davis: Indeed, relaxation may occur, but it is caused by the discreteness of particles in the N-body calculation and cannot be included within a similar solution. The relationship between the spectral index and the slope γ follows from the BBGKY equations in the similar solution with no approximations, if boundary conditions on small scales are chosen to ensure that virialized clusters are stable against collapse.

In addition the predicted break in $\xi(r)$ occurs on scale lengths unattainable in the N-body simulations.

Silk: Is it fair to say that your conclusion of $\Omega = 0.3$ is dominated by Local Supercluster galaxies, and that the "background" value of Ω could therefore be somewhat lower?

Davis: We evaluated Ω separately in the northern and southern galactic hemispheres. In the south, where it was argued earlier in this meeting that the sample of galaxies to m = 13 is a fair sample of the Universe, we found $\Omega = 0.26$ from the cosmic virial theorem. In the north, even excluding the Virgo cluster, we found 0.46 which is probably not representative.

Tinsley: Can anyone explain why the cosmic virial theorem results in values of Ω three times that found from the analyses of groups and knowledge of the mean luminosity density?

Davis: There is a trend towards larger values of M/L as one proceeds to larger and larger scales and these cosmic virial theorem estimates refer to the largest possible scales.

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Gott: As I said in my talk I would correct Davis' value of $\Omega = 0.3$ downward by a factor of 3/2 to give $\Omega = 0.2$. This is because statistical virial theorem methods always weight large clusters with large velocity dispersions more heavily. Davis' estimate is also larger than some previous ones because Davis, Geller and Huchra found an amplitude of the covariance function that is lower than previous estimates.

Davis: The downward correction of 3/2 is model dependent on the N-body simulations. According to model dependent theory of the BBGKY equations my estimate of Ω should be increased by a factor of as much as 1.4. I have chosen a middle ground and have made no further model dependent corrections.

Fessenko: How do you account for the influence of observational selection due to the irregular absorption of light in our Galaxy?

Davis: We restricted our sample to galactic latitudes greater than 40° where the effects of absorption can be neglected.

Ostriker: How do you find a break on a characteristic scale in the covariance function in a closed Universe?

Davis: The break corresponds to the scale on which the perturbations become non-linear. The division between the linear and non-linear regimes is determined by the amplitude of the initial perturbation spectrum.

Tammann: There must be an observational error of the velocities $\sigma(v)$ which makes your result insignificant. For what value $\sigma(v)$ does this become true?

Davis: If the RMS velocity error of a single galaxy $\sigma(v)$ were ~ 225 km s^{-1}, our data would be consistent with no peculiar motions.

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