OBSERVATIONAL LIMITS ON NEUTRAL HYDROGEN IN PRIMORDIAL PROTOCLUSTERS

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After recombination in the early Universe, gas will pass through a neutral phase on its way to condensation into galaxies and stars. Radio emission in the reshifted 21 cm line of neutral hydrogen can be used to detect condensations in the early Universe. Sunyaev and Zeldovich (1972,1975) have suggested that primordial protoclusters may be predominantly neutral at z = 3 to 10 and may have neutral hydrogen masses $\sim 10^{14}$ $M_{\odot}$. Two observational approaches have been made to the search for this emission.

The first was to choose a direction in which intergalactic gas is known to lie and to make a deep search for redshifted hydrogen in an associated protocluster. Such a feature is the low excitation gaseous cloud seen at z = 2.3099 in the absorption spectrum of the radio-quiet quasar PHL 957. Observations have been made of the redshifted hydrogen line radio emission at 429.123 MHz. If this cloud were of the Sunyaev and Zeldovich type then its neutral hydrogen mass would be less than 3×10^{13} $M_{\odot}$ (Davies, Booth and Pedlar 1977).

The alternative approach is to use a frequency in the range of emission expected and search a number of regions of the sky for the characteristic 1000 km s^{-1} wide emission spectrum of a protocluster. Observations of this type have been made at 328 MHz (z = 3.33) and 240 MHz (z = 4.92) in 20 fields at each frequency (Davies, Pedlar and Mirabel 1977). The upper limits set by these observations show that the neutral hydrogen masses are $< 10^{15}$ $M_{\odot}$ and that the number of protoclusters in the early Universe is $< 5 \times 10^{5}$; the time spent by such protoclusters in the neutral form is assumed to be 10 percent of their age. These results present significant limits on the properties of the neutral gas in the early Universe.

REFERENCES

Davies, R.D., Booth, R.S. and Pedlar, A., 1977. Mon. Not. R. astr. Soc., in press.

M. S. Longair and J. Einasto (eds.), The Large Scale Structure of the Universe, 447–448.

Davies, R.D., Pedlar, A. and Mirabel, F., 1977. Mon. Not. R. astr. Soc., in press.
Sunyaev, R.A. and Zeldovich, Ya. B., 1972. Astr. Astrophys., 20, 189; 1975. Mon. Not. R. astr. Soc., 171, 375.

DISCUSSION

Sunyaev: This is a very important observation, because this is a possible way to observe protoclusters of galaxies at the stage when there were no galaxies and there was only gas. The mass of cold gas may be 10 to 100 times greater than today, because the gas was not condensed into stars at that time. I want to mention that the limits obtained by Dr Davies and his colleagues are very useful and give an upper limit on the lifetime of a protocluster at this stage. They are also important when we choose the epoch of cluster formation. I must mention also that in the open Universe ($\Omega << 1$) it is much more difficult to find these objects because their angular dimensions are smaller. Therefore the restrictions on M, V and Δt depend strongly on the accepted value of Ω. We are very grateful to Dr Davies for obtaining data so important for our theory.

There is an interesting possibility of finding the redshifts of distant radio sources at radio wavelengths. If there are protoclusters or galaxies or clouds of cold matter on the line of sight between the source and the observer, absorption radiolines might appear in the radio spectrum. They must be redshifted. For example, the detection of an absorption line in the metre waveband might be interpreted as a strongly redshifted 21(1+z) cm line. In this case we can measure the redshift of absorbing matter and find a lower limit to the redshift of the source. It is important that there are no well-known radio lines in the metre waveband.

It is possible also to predict other strong absorption lines in the spectra of distant radio sources. Among these are λ 2.6 mm CO line (redshifted to the 1 cm band) and λ 6 cm line of formaldehyde (redshifted to the decimetre waveband).

ORIENTATION OF SPIRAL GALAXIES AS A TEST OF THEORIES OF GALAXY FORMATION

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The cosmological turbulence theory and the theory of adiabatic fluctuations predict different orientations of galaxies in clusters and superclusters. The first theory favours the alignment of the planes of galaxies with the supergalactic plane, whereas the planes of spiral galaxies formed according to the second theory are perpendicular to the plane of a supergalaxy.

We compared these alternative predictions with the observed distri-