THICK DISCS AND THE FORMATION OF DISC GALAXIES

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The formation of disc galaxies is generally believed to involve the dissipative collapse of primordial gas clouds, moving in the potentials of dark, self-gravitating massive halos. Until now, most theories have considered only spherically symmetric collapse, with the luminous disc being formed out of a plane of cold gas which is in centrifugal equilibrium. However, it is unlikely that the halo potential will in fact be spherical.

We have investigated the fate of gas collapsing in the potential of an oblate halo, obtaining analytic results for various density profiles, as a function of halo axial ratio. For all but the most nearly spherical halos, analysis of the dynamical timescales in the vertical and radial directions (governed by the dark matter) indicate that the gas will be shock heated, and able to cool and form stars before angular momentum is important in the collapse. Thus the resultant stellar disc will be formed out of centrifugal equilibrium. The subsequent relaxation processes lead to a hot, pressure supported system with exponential light profiles in the outer regions. These are identified with the thick discs seen in external edge-on disc galaxies. The inner, denser regions will have suffered a higher rate of dissipation leading to a stellar distribution which is more centrally concentrated, and here rotation will be more important: the bulge.

The thin disc forms from the gas lost by stellar evolution in the thick disc and accretion of primordial gas from the outer regions of the halo which can cool only by this later time. The halo potential is now steady and this gas settles to form a cold thin disc that relaxes dissipatively into centrifugal equilibrium. The resultant disc follows the exponential profile of the thick disc.

The important model parameters are the axial ratio of the halo potential, and the slope and central value of the halo density profile. These govern the collapse dynamics, i.e. timescales, collapse factors in the radial direction and the temperature of the shocked gas.

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If the cooling is by Compton scattering off background photons it is governed purely by the redshift Z_f assumed for galaxy formation. However, for this to be the dominant cooling mechanism, $Z_f \gtrsim 15$. Bremsstrahlung and line radiation are more important at later epochs, i.e. for larger masses, which for most reasonable power spectra of primordial fluctuations collapse later. The cooling times for these processes are determined by the temperature and density of the shocked gas itself. This last density depends in turn on the halo density profile and the fraction of the total halo mass which is initially gaseous, as opposed to in some dark form. A further model dependent parameter of relevance here is the enhancement of gas density due to the collapse itself. It should be noted that λ_H, the dimensionless angular momentum parameter for the halo, is not an important quantity in this theory.

The assumption of suitable scaling laws to describe, for example, the dependence of the power spectrum of primordial density fluctuations, and that of the fraction of matter in gaseous form, on total mass, together with the derived behaviour of the model parameters allow in principle a comparison of the theory predictions with the observations of other galaxies. It is unfortunate that there is not an overwhelming body of relevant observational data which is self consistent, but we can say that our models are in agreement with such seemingly fundamental observations as the Tully Fisher relation.

The observational situation concerning our own Galaxy is somewhat more clear cut. Our model predicts a distinct dichotomy between the thick and thin discs, both in kinematics and chemistry: since the thick disc relaxes after forming stars we expect there to be no metallicity gradient, whereas the thin disc forms once relaxation processes have been completed. We also prefer a rapid formation for the thick disc and a much longer formation time for the thin disc. These predictions are indeed upheld by the observations, if we identify the high-velocity stars of the solar neighbourhood as the thick disc population, and use an updated metallicity calibration for the RRlyrae stars.

A full description of the model is in Jones & Wyse (1982) to appear in Astronomy and Astrophysics.