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THE EPOCHS OF BULGE AND DISK FORMATION

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Abstract

To understand the evolution of galaxies, particularly in the early stages, it is fundamental to investigate the different components of a galaxy and the interactions between them. The number of components and, even more important, the number of processes that account for mass, momentum and energy transfer between the components make it impossible to describe galactic evolution with simple analytical models. Especially in the case of rotating galaxies, a two-dimensional hydrodynamical treatment is necessary.

We calculate the evolution of rotating galaxies using a 2-D hydrodynamical code with five components, i.e., low-mass (LMS), intermediate-mass (IMS) and high-mass stars (HMS), a warm cloudy component with embedded cold clumps (CM) and a hot intercloud medium (ICM). The following interactions are taken into account: condensation, evaporation, cooling and heating of the gas, cloud collisions with dissipation, star formation and stellar mass loss (SN I, SN II and planetary nebulae).

Starting with a rigidly rotating protogalactic cloud of $1.5 \cdot 10^{11}$ $M_{\odot}$, which is close to virial equilibrium, the system begins to collapse slowly. Due to the collapse, the density of the CM and, therefore, the star-formation rate (SFR) in the central region of the galaxy increases. In contrast to the cloudy medium, which is gravitationally accelerated towards the center of the galaxy, the hot metal-enriched gas (IMC), ejected by the first SN II, streams out of the central galactic region due to pressure support. In the outer regions, preferably

in the equatorial plane, the metal-rich gas condenses onto the clouds and raises the metallicity of the CM.

After $1.6 \cdot 10^9$ years the metallicity of the cloudy medium in the bulge reaches solar values. If we compare the observed metallicity distributions of stars in the bulge (e.g., Grenon 1990) with the results of our chemo-dynamical models, we find them in good agreement.

From the numerical calculations we find that the galactic disk begins to form after two Gyrs. Up to that time the outflowing gas, together with the star formation, has enriched the CM in the galactic plane to a metallicity of $2 \cdot 10^{-3}$. Our results imply that nearly all stars formed in the galactic disk are metal enriched. This could serve as an explanation for the G-dwarf problem (Pagel & Patchett 1975).

References

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