The Origin and Evolution of Galaxies

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Sixteen scientific contributions, an inaugural lecture, and an editor's epilog make up this volume, which closes with a general subject index. The subject matter encompasses practically all the topics in current theories for the origin of galaxies, from the emergence of large-scale structure in the universe to the formation of the pioneer (pregalactic?) generation of stars.

N. Dallaporta (Padua) introduces the proceedings of outlining the strategic problems that face observational and theoretical cosmology and theories of galaxy evolution. Most of the ensuing papers similarly are in the format of survey lectures, and there is very little overlap among them. M. A. H. MacCallum's lecture (Queen Mary College, London), "Relativistic cosmology for astrophysicists," offers an introduction to the range of problems involved in anisotropic and inhomogeneous model universes. The reasons for using nonstandard models are explained; these models are classified and their basic equations given. Special attention is paid to the task of defining the horizon in the different models and to the big bang singularity

Joan Centrella (University of Texas) describes the formation and techniques of numerical methods in general relativity theory. Taking the conventional Friedmann–Robertson–Walker models as examples, the author shows how such methods can be used to construct inhomogeneous cosmological models on a computer.

The influence upon cosmology of new ideas in quantum field theory is the topic of J. N. Fry (Chicago). Calling his lecture "Grand unification and cosmology," Fry considers some astronomical implications of the recent theory of electroweak interactions. Examples include the development of matter–antimatter asymmetry in an initially symmetric universe and the possibility of a de Sitter phase of exponential growth in the scale factor of the expanding universe, which might perhaps explain why the universe is nearly flat (density parameter $\Omega \approx 1$) and globally homogeneous. Discussed in this same lecture are the cosmological-constant problem in the theory of spontaneous symmetry breaking; the possible existence of novel structures–domain walls, strings, magnetic monopoles; and the nature and origin of fluctuations that might have been present when the universe began to expand. Fry devotes a separate section to the inflationary-universe model.

In the next chapter C. J. Hogan (Chicago) examines several approaches toward explaining the entropy and structure of the universe we observe. A detailed analysis is given for the phase transitions in matter at the start its evolution: string formation at the unification epoch ($t \sim 10^{-20}$ sec), bubble formation in vacuum phase transitions, and the shattering of the pion condensate at the epoch of nuclear density ($t \sim 10^{-5}$ sec) in a "cold" universe. This last process is capable of creating pregalactic star populations in a natural way without requiring any arbitrary initial fluctuations, but it has the drawback of abandoning the elegant theory of big bang nucleosynthesis. These theories can be tested by measuring fluctuations in the microwave background temperature. The same problem is discussed more fully by R. B. Partridge (Haverford College) and P. J. E. Peebles (Princeton). Partridge emphasizes the dynamics of the cosmic background radiation and the information gained by observing it, while Peebles discusses chiefly the results obtained from analysis of the space distribution of galaxies.

In a paper entitled "Adiabatic vs. isothermal: two pictures of galaxy origin," S. A. Bonometto (Padua) compares the two currently popular theories for the large-scale structure in the universe, based on different assumptions about the initial fluctuations. In view of recent progress with massive neutrinos, grand unification theory, and so on, further development of both these concepts may be expected. Bonometto does not show a definite preference for either one, but merely points out that the comparatively late events in the universe–those partially supported by the observations, such as the microwave background anisotropy and the galaxy correlation function–tend to favor the isothermal (or entropic) theory, while the adiabatic theory looks better from the standpoint of producing the primeval fluctuations.

Some developments in large-scale structure theory based on the adiabatic scenario are set forth by S. F. Shandarin (Keldysh Institute, Moscow). Three-dimensional numerical simulations of irregularities evolving by the adiabatic theory have shown that even in the case of collisionless matter (neutrinos), elongated but mutually bound structures analogous to superclusters of galaxies will form in space; the spatial correlation function of the model is in good accord with the observations.

Papers by Janet E. Jones (Paris) and B. J. Carr (Cambridge University) deal with the pregalactic generation of stars. As yet undiscovered, this generation has already taken its place in a sequence: along with stars being formed in our own era (population I) and those formed during or soon after the collapse of the Galaxy (population II), one can now envisage pregalactic stars formed prior to collapse (population III) and "primordial" stars (population IV) created by nucleosynthesis in the primeval hydrogen–helium gas of the universe. These hypothetical population III and IV stars might help to explain the entropy observed in the universe, its large-scale structure and chemical composition, and the missing mass in galaxy halos and clusters of galaxies.

C. Chiosi (Padua) and Bernard J. T. Jones (Cambridge University) review current ideas about the distribution of chemical elements in stars and in the interstellar medium. To compare the theoretical models against the observations, they make use not only of abundance data for solar-neighborhood stars but also of results for external galaxies. The recent findings of correlations between the mass,

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radius, and chemical composition of galaxies suggests that their chemical evolution cannot be understood without allowing for exchange of matter with the intergalactic medium.

A lecture by Simon D. M. White (Berkeley) takes up the dynamical evolution of galaxies and galaxy clusters. Analytic and numerical results are presented which simulate the interaction of galaxies with one another and with the cluster field. White considers in detail the possibility of merger between dwarf galaxies in light of theories for the formation of large stellar systems. In a short paper J. Sellwood (Cambridge University) turns to the dynamics of spiral galaxies. The author is perplexed by the fact that despite the serious instability inherent in disks of stars, there are relatively few barred galaxies in nature. In describing his study of galaxy evolution on cosmological time scales, R. Ellis (University of Durham) reports obsergations of very faint and distant galaxies, while J. V. Wall (Royal Greenwich Observatory) tells of radio-galaxy and quasar counts. Although one can trace the evolution in the number, or luminosity, of quasars without much difficulty, it is not yet feasible to follow that of normal galaxies. Resolution of this problem will have to await big new telescopes.

In the concluding lecture, "Clusters of galaxies," Piotr Flin (Cracow) recounts the history of cluster description and classification, and describes studies of how the vai ious types of member galaxies are distributed within clusters. The properties of the galaxies depend, as Flin has shown, on the properties of the parent cluster; for example, in some clusters the galaxy axes show a decidedly nonrandom orientation.

The closing remarks by one of the editors, Bernard Jones, are headed: "Do we understand how galaxies formed?" Let us leave it to the readers of Soviet Astronomy to answer this question for themselves. These proceedings of the Erice School will enable astronomers of widely differing profiles to learn about the achievements as well as the problems that today face cosmology and theories of galaxy formation. Individual chapters will be helpful to graduate students embarking upon their own studies of those particular topics.

This book is available in the Shternberg Astronomical Institute library.

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Translated by R. B. Rodman