Introductory remarks

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THE ROYAL SOCIETY

Introductory remarks

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In his contribution to the proceedings of IAU Symposium no. 79, held in Tallin in 1977, the Russian physicist Ya. B. Zeldovich made his now famous remark: 'Extrapolating from Krakov through Tallinn, to the next symposium somewhere in the early eighties one can be pretty sure that the question of the formation of galaxies and clusters will be solved in the next few years' (Longair & Einasto 1978).

Such optimism was not new to the subject. Already in 1755, the German thinker Immanuel Kant had provided another famous quotation in his *Universal natural history and theory of the heavens*: 'If in the immeasurable space in which all the suns of the Milky Way have formed themselves, we assume a point around which, through some cause or other, the first formation of nature out of chaos began, there the largest mass and a body of extraordinary attraction will have arisen which has thereby become capable of compelling all the systems in the process of being formed within an enormous sphere around it, to fall towards itself as their centre, and to build up a system around it on the great scale. ... Observation puts this conjecture almost beyond doubt' (Kant 1969).

Over the past few years there has been a growing suspicion that Zeldovich's prediction was correct. It seems possible that the basic material content of the Universe, the physics which set the initial conditions for structure formation, and the processes responsible for transforming these initial conditions into galaxies were all correctly identified in the early eighties. To convince ourselves of this, however, requires observational proof, for although it is quite clear that Kant jumped the gun in claiming an understanding of structure formation, his basic methodology—the principle that observation is the ultimate arbitrator—remains the guiding principle. It was to assess how close we really are to validating Zeldovich's prophecy that we proposed to The Royal Society a Discussion Meeting on 'The formation of galaxies'. The meeting took place just over 10 years after another meeting on the same topic was held at the University of Durham under the title of 'The epoch of galaxy formation'. About half of the speakers at The Royal Society meeting also spoke in Durham, yet what they had to say was very different.

At the time of the Durham meeting, the only galaxies known with redshifts greater than a few tenths were giant radio galaxies whose connection to the galaxy population as a whole was poorly understood. Today, the number of galaxies with measured redshifts at $z > 3$ (when the Universe was only *ca.* 10% of its present age) is comparable with the total number of galaxies in the local Universe which had known redshifts in the early 1980s. Several great technological advances such as the Hubble Space Telescope and Keck have ushered in this new era. Data collected with these and other instruments have built up a fairly detailed empirical picture of the evolution of the Universe since about $z \simeq 5$. Thus, we observe the amount of neutral gas in the Universe (the raw material for stars), the star formation rate and the attendant production of metals varying slowly with redshift and appearing to decline at $z \simeq 1-2$ as the gas available for stars is consumed. At $z \simeq 3.5$, there is already a population of star-forming galaxies in place, the 'Lyman-break galaxies', which are strongly clustered and differ markedly from nearby galaxies. This epoch is clearly part of the early phases of galaxy formation, although our knowledge is by no means complete and becomes increasingly fuzzier at larger redshifts. For example, the role of dust in shrouding galaxy formation remains highly uncertain. One major development since the Durham meeting is the view that galaxy formation is a drawn-out, perhaps continuing process, rather than an event which occurred in the distant past.

While observational progress over the past few years has been truly breathtaking, the theoretical framework most commonly used to interpret the data—the cold dark matter theory—has changed little. The most notable shake-up since this model was first explored in the early 1980s has been the measurement of (perhaps) more reliable values for the fundamental cosmological parameters: the mean cosmic density parameter, Ω, the cosmological constant, Λ, and Hubble's constant, H_0. The best current estimates, $\Omega \simeq 0.3$, $\Lambda/3H_0^2 \simeq 0.7$, and $H_0 \simeq 65\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ are different from those typically adopted by theorists a decade ago ($\Omega = 1$, $\Lambda = 0$, $H_0 = 50\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$). Some significant progress has been made in recent years in our ability to predict observables from the theory. These advances have come from computer simulations, from analytical work and from detailed phenomenological modelling of the formation of individual galaxies. These developments have led to an appealing explanation for the physical properties of intergalactic gas at high redshift (observed in absorption against background quasars) and to specific predictions for the evolution and clustering of galaxies. The resulting unified framework links the fluctuations observed in the cosmic microwave background, the intergalactic medium and the Lyman-break population at high redshift, and the morphological, structural and clustering properties of nearby 'normal' galaxies. Although some of the successes of the current paradigm are impressive, it is worth recalling that its most basic tenet—that the dark matter consists of cold, collisionless particles—remains unproven.

In surveying the current state of knowledge, there is every reason to feel that genuine progress towards unravelling the origin of galaxies is being made and that Zeldovich's prophecy may be proved right. Nevertheless, it may be wise not to forget the words of Thomas Wright of Durham, a precursor of Kant, who in his *Original theory or new hypothesis of the Universe*, published in 1750, wrote: 'Which of these (hypotheses) is most probable I shall leave undetermined, and must acknowledge at the same time my notions here are so imperfect I hardly dare conjecture' (Wright 1971).

We thank The Royal Society for sponsoring what turned out to be a very well attended and hugely stimulating meeting. With the impressively efficient support of Catherine Devereux's team at The Royal Society and Dorothy Almond at the University of Durham, the organization of the meeting was a pleasure rather than a chore. Finally, we thank the editorial coordinator of these proceedings, Cathy Brennan, whose tactful cajoling succeeded in extracting manuscripts from even the most reticent of contributors.

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