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Merger Driven Explosive Evolution of Distant Galaxies (Minor Mergers)

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Abstract—We derived solutions for the Smoluchowski kinetic equation for the mass function of galaxies, which describes mergers in differential approximation, where mergers with low-mass galaxies are the dominant factor. The evolution of the initial distribution is analyzed as well as the influence of the source represented by galaxies (halos) that disengage from the global cosmological expansion. It is shown that the evolution of the slope of the power-law portion of the luminosity function at a constant mass-to-luminosity ratio observed in the Ultradeep Hubble Field can be described as a result of explosive evolution driven by galaxy mergers. In this case the exponent depends exclusively on the uniformity degree of merger probability as a function of mass.

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1. INTRODUCTION

In its generally adopted form the hierarchical clustering model yields self-similar solutions [1–3]. At the same time, investigations of distant galaxies reveal markedly non-self-similar behavior, which shows up, among other things, in the redshift dependence of the slope α of the power-law portion of the Schechter luminosity function (LF) [4–6]

$$\phi(L) = \phi_* L^{\alpha} \exp\left(-L/L_*\right). \qquad (1)$$

(Here we do not discuss the parameters ϕ_* and L_* of the Schechter function.)[1]

We show that the observed evolution of the LF slope (Section 2), understood as the slope of the mass function (MF) of galaxies, can be described as a result of *explosive evolution* driven by galaxy mergers. Currently, mergers are believed to be the factor responsible for the evolution of types and masses of galaxies [7] (see also the discussion and references in the reviews [8–10]). Although the actual situation is more complex (see the recent reviews by Ellis and Silk [11] and Silk and Mamon [12]), we show that the observed parameters of the MF can be explained satisfactorily in terms of our hypothesis.

We derive solutions for the Smoluchowski kinetic equation (KE) that describes merger-driven explosive evolution of the mass function of galaxies [13, 14] in differential approximation [13], where mergers of massive galaxies with low-mass galaxies (minor mergers) play the main part (Sections 3 and 4). Note that the slope α of the MF of massive galaxies, which is proportional to the Schechter exponent M^{α}, can be written exclusively in terms of the uniformity degree u of the merger probability as a function of mass (Sections 5 and 6). This property, in principle, makes it possible to determine the probability of mergers as a function of mass including that of the dark matter, based on observational data. In this paper we use the well-known dependences of the probabilities of galaxy mergers on their mass to show that the observed evolution can be explained in terms of natural assumptions about merger mechanisms in different epochs (Sections 5 and 6).

Explosive evolution occurs if the exponent $u > 1$, which is evidently true for galaxy mergers. In the case of explosive evolution of an initial MF of sufficiently general form (i.e., decreasing faster than the square of the mass) a power-law asymptotic develops with the exponent $\alpha = -u$; in the case of predominant influence of a mass-localized source the exponent is equal to $\alpha = -(u+1)/2$ (Section 6). Galaxies that disengage from cosmological expansion play the role of the source. At large redshifts $z = 6$–8 the exponent u is determined by mergers of low-mass galaxies and is close to $u = 2$. At small z, where more massive galaxies merge, gravitational focusing has to be taken into account [15] (see also Appendix 4). At

[1] At large masses the MF is not exponential, but decreases in accordance with a square-root law (Section 7), which is due to the adopted model of source localization in the kinetic equation.