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Interactive Comment

Interactive comment on "The validity of the kinetic collection equation revisited" *by* L. Alfonso et al.

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Reply to Reviewers

First, we would like to thank the anonymous referees for their comments, that will improve the quality of our paper. The revised version will include several of their suggestions.

Anonymous referee # 1

General comments:

a) Applications of the results to droplet collisions in clouds:

Of course, we agree with the referee that simulations with monodisperse initial distributions with the mentioned above kernels, are not realistic in the cloud physics context, but they are the only way to check the accuracy of the statistic proposed (the maximum

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Discussion Paper

of the ratio of the standard deviation for the largest droplet mass over all the realizations to the averaged value calculated from the Monte Carlo).

Traditionally, to test the accuracy of the approximations methods developed for the solution of the KCE (Kovetz and Olund (1969), Bleck (1970), Berry and Reinhardt (1974), Tzivion et al. (1987), and Bott (1998), they are usually applied to simple coalescence processes with well-known analytical solutions (sum, constant and product kernel with monodisperse or bidisperse initial conditions), as we did in our work.

The idea is to apply this criterium to solutions of the KCE with polydisperse initial conditions calculated using the gravitational kernel, or kernels modified by turbulence or electrical processes.

But to rigorously validate the statistic proposed by Inaba (1999), a detailed comparison with analytical solutions of the KCE is necessary. Unfortunately, there is no analytical solutions for the KCE with gravitational kernel. Then, we need to use reliable numerical algorithms for the handling of the coalescence process in real cloud conditions. A possible solution is to integrate the KCE (following Valioulis and List, 1984) by using the Gear´s (1971) modification of Adam´s multistep variable-order predictor-corrector method, that gave them very good results in the investigation of the stochastic completeness of the KCE.

Another problem with numerical approximations in that they could be no reliable when simulations with the hydrodynamic kernel are performed. For example, Scott and Levin (1975) show that the results of the method of Kovetz and Olund (1969) and the integration scheme of Berry and Reinhardt (1974) both agree with analytical solutions of a simple coalescence process, but their results differ from one another when realistic coalescence kinetics are investigated.

Finally, one important question is the behavior of the numerical approximations after the breakdown time.

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b) Choice of the cloud volume:

Actually, the KCE remains valid before droplets grow to the mass comparable to the total mass of the system. Then, when one or a relatively smaller fraction of the droplets grow prominently, this process cannot be described by the KCE because it stands on the assumption that there exists sufficiently large number of droplets in each relevant mass range (this growing bodies in the large end of the distribution are called runaway planets by the astronomers).

In our simulations, we choose a small volume of $1cm^3$. Thus, one single particle forms, but for a 10^6 times larger volume ($1m^3$), after some time, a fraction of the 10^8 droplets in the initial distribution are growing faster than the rest (these droplets form the gel part), and become detached from the smooth distribution. These are the runaway droplets.

To further study this trend we can perform Monte Carlo simulations for different initial volumes and calculate the maximum of the statistic in order to estimate the validity time for each case.

Simulation were performed for two cloud volumes ($1cm^3$ and $100cm^3$), and initial monodisperse distribution of $(100,10000)$ droplets of $14\mu m$ in radius (droplet mass 1.1494×10^{-8}g). In the simulations was used the product kernel. The maximum of was obtained at the same time in the two simulations, a fact that confirms that the validity time is the same in all the situations analyzed.

Then, our results do not depend on the cloud volume. For larger cloud volumes the KCE is no longer valid after the formation of relatively large droplets that grow faster than the rest.

c) Break up of droplets:

Despite the differences in the initial number of droplets and cloud volumes, the largest droplets (runaway droplets) have a similar size (between $40 - 50\mu m$ in radius) .The collisional and spontaneous breakup mechanisms will act for larger sizes.

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d) Relevance for different branches of Physics:

A frequently-encountered process in many fields of science is the random coalescence of small bodies into larger ones, conserving total mass. Astrophysical examples include the coalescence of planetesimals into planets (Safronov 1969) and of stars into black holes (Lee 1987; Quinlan and Shapiro 1990), but the largest application area is Physical Chemistry (aerosols, polymerization, phase separation in mixtures).

In astrophysics, the non-conservation of mass after the breakdown of the KCE is usually interpreted to mean that a runaway planet has formed, also known as a gel because of applications in physical chemistry.

In the revised version, these questions will be commented more carefully in the discussion part of the paper.

References:

Berry, E., 1967: Cloud droplet growth by collection. J.Atmos. Sci. 24, 688-701.

Berry E.X., Reinhardt, R.L., 1974. An analysis of cloud drop growth by collection. Part I. Double distributions. J. Atmos. Sci. 31, 1814-1824.

Bleck, R., 1970: A fast, approximative method for integrating the stochastic coalescence equation. J. Geophys. Res. 75, 5165-5171.

Bott, A., 1998. A flux method for the numerical solution of the stochastic collection equation: extension to two dimensional particle distributions. J. Atmos. Sci. 57,284-294.

Gear, C.W., 1971: Numerical Initial Value Problems in Ordinary Differential Equations. Prentice-Hall,Inc., 253 pp.

Inaba, S., Tanaka, H., Ohtsuki, K., and Nakazawa, K.: High-accuracy statistical simulation of planetary accretion: I. Test of the accuracy by comparison with the solution to the stochastic coagulation equation, Earth Planet Space, 51, 205-217, 1999.

Kovetz, A., Olund, B., 1969. The effect of coalescence and condensation on rain formation in a cloud of finite vertical extent. J. Atmos. Sci. 26, 1060 -1065.

Lee, H. M. 1987. Dynamical Effects of Successive Mergers on the Evolution of Spherical Stellar Systems. Astrophys. J. 319, 801.

Quinlan, G. D., and Shapiro, S. L. 1990. Dynamical Evolution of Dense Star Clusters in Galactic Nuclei. Astrophys. J. 356, 483-500.

Safronov, V. S. 1969. Evolution of the Protoplanetary Cloud and Formation of the Earth and the Planets. Nauka, Moscow. Transl. Israel Program for Scientific Translations,v. 206, NASA Technical Translations NASA-TT F-677 (1972).

Scott, W.D. and Levin, Z., 1975. A comparison of formulations of stochastic collection. J. Atmos. Sci.,32: 843-847.

Tzivion, S., Feingold, G. and Levin, Z., 1987. An efficient numerical solution to the stochastic collection equation. J. Atmos. Sci., 44: 3139-3149.

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