The particles number inside a bounded area of a vessel for a mixture of two gases

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We consider a mixture of two gases in a vessel. The one of them is an ideal gas with point particles, the other is a gas consisting of solid balls of the same volume. A part of the vessel with gases is separated by a wall with an opening. The dynamics of the number of each type of particles in this selected region are random process and can be described by two corresponding stochastic differential equations with pulse noises. Each positive pulse corresponds to an incoming particle, and a negative pulse corresponds to an outgoing particle. For the balls, the Poisson sequence of gauss-shaped pulses is used in the model. The width of the pulses corresponds to the time of passage of this particle through the opening. For the point particles, this pulse noise is a random δ-pulse train depending on the movement of the large particles, since they can close the the passage for a while and change the volume free for the point particles to move inside and outside the selected area. The statistical properties of these pulse processes depend on the selected and total volumes, the size of the opening, the temperature, the masses of the balls and point particles, the number of particles in and outside the region, the volume of the balls. The general dynamics of the probability density function and its stationary form can only be obtained numerically. Meanwhile, an analytical solution is possible under some conditions.

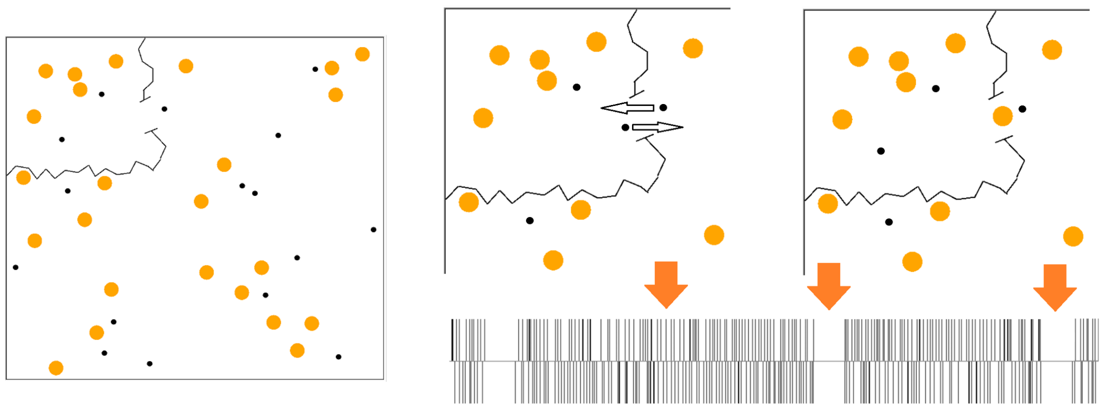

Figure 1: The mixture of an ideal gas with point particles and a gas of hard balls and two regimes of open and closed gate

We suggest that the solid balls number in the selected region does not depend on the point gas and is described by a stationary distribution. These particles have a size close to the size of the opening. We take into account the correlation properties of the point particles dynamics, since the gates close as a result of the movement of a large particle throw it. In this approximation, the pulse noise can be described as a renewal process. The distances between neighboring pulses are called the waiting times and the probability density function of them fully characterizes the process. To take into account the periods of closed gate, we use the distribution with a locally thickened tail. This probability density function consists of two parts exponential and gaussian with corresponding weight numbers. The larger weight number corresponds to an exponential distribution and describes the incoming and outgoing point particles in the absence of large particles as obstacles in the gate. The second part, the tail, corresponds to relatively large values of waiting times until the big particle opens the gate again. We obtain a kind of intermittency with switching two regimes: (1) the point particles motion through the gate and fluctuating number of them in the area; and (2) the dead-time regime without any changes of the particle number. For such distributions the characteristic function, Laplace transform, high-order moments, and cumulants exist and can be expressed in special functions. This distribution describes two time-scales processes.

The methods of analytical study of these processes are based on characteristic functions and Laplace transforms. The direct application of Central Limit Theorem is also considered. For numerical simulations the Mersenne twister is used as pseudorandom number generator. The results of numerical simulations are in good agreement with the analytical results.