

Charge density oscillations around the DNA double helix

Tuesday, 22 September 2026 17:00 (5 minutes)

The DNA macromolecule has nanometer dimensions, a double helix structure consisting of chemically bonded atoms, and a large negative charge. Being in an aqueous environment or inside cells, the DNA macromolecule interacts mainly through electrostatic forces, hydrogen bonds, hydration and biochemical bonding, including medium ions, so the environment strongly influences DNA conformation, stability and biological functions. Positively charged ions, named counterions, in the aqueous medium around the DNA macromolecule, play an important role as a screening cloud. Their motion is typically considered as strongly damped, in particular due to medium viscosity and collisions, and therefore, counterion distribution is usually calculated in the electrostatic approximation. However, some studies demonstrate the possibility of high translational mobility of counterions in the screening cloud and their high-frequency movements inside the hydrated shells. Thus, a counterion evolution around the DNA double helix remains an important problem.

We considered kinetic equations in the collisionless approximation and the DNA macromolecule approximation as a charged cylinder with a weak and moderate electric field to describe the counterion distribution evolution in the electric field of the DNA macromolecule. Using such approximations, the dispersion equations for counterion oscillatory dynamics with an infinite number of oscillatory branches are obtained. It is demonstrated that each of such branches is purely real if it is far from other branches, while the intersection with other branches leads to instability. The upper bound of the instability coefficient of the mode, which appears at the branch intersection point, is estimated.

The author thanks to COSY COST Action CA21101; National Research Foundation of Ukraine (project № 2025.07/0355).

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Session Classification: Poster Session

Track Classification: STATISTICAL PHYSICS AND SOFT MATTER