Temperature-induced DNA density transition in phage lambda capsid revealed with contrast matching SANS

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1. Abstract

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Structural details of a genome packaged in a viral capsid are essential for understanding the mechanisms of viral genome packaging and release during the infectious cycle. Furthermore, the structural arrangement of a viral genome in a capsid controls its release dynamics during infection, which critically affects viral replication. We previously found, using atomic force microscopy (AFM) and isothermal titration calorimetry (ITC), a temperature-induced, solid-like to fluid-like mechanical transition of packaged lambda-genome that leads to rapid DNA ejection. However, an understanding of the structural origin of this transition behavior was lacking. In this work, we use small-angle neutron scattering (SANS) to reveal the scattering form factor of dsDNA packaged in phage lambda capsid by contrast matching the scattering signal from the icosahedral viral capsid with deuterated buffer. We used small-angle X-ray scattering (SAXS) and cryo electron microscopy reconstructions to determine the initial structural input parameters for intracapsid DNA, which allows accurate modeling of our SANS data. As result, we show a temperature-dependent density transition of intracapsid DNA occurring between two coexisting phases – a hexagonally ordered high-density DNA phase in the capsid periphery and a low-density, less ordered DNA phase in the core. As the temperature is increased from 20°C to 40°C, we found that core-DNA density increases by ~5 fold, triggering a density transition in the core-DNA close to the physiological temperature of infection (~37°C). This data explains the mechanism that facilitates DNA ejection from phage into a host bacterial cell, causing infection, and reconciles earlier findings of mechanical DNA transition in phage.