Introduction:
In material science and metallurgy creep is a special type of plastic deformations of solid matter. In general it is a slow process driven by the thermally activated movement of dislocations (dislocation creep), vacancies (vacancy creep) or diffusion (Nabarro-Herring creep). The applied stresses are below the yield stress resulting in atomic movements that are crystallographically organized. The applied temperatures are usually above T_m, where T_m is the melting temperature. The time evolution of the deformation (strain ε) is often described with the empirical formula ε = ε_0 + δ ln(1 + t/φ), where ε_0 is the immediate strain, δ and φ are creep coefficients [1]. After a short transient phase this describes a steady-state creep, where the rate δφ is determined by the balance of work hardening and thermal softening. Under such circumstances the steady state creep is fairly well represented by the Weeraman-Dorn equation:
\[
\dot{\varepsilon} = C \varepsilon^m (\Delta_{\text{dis}}/E)^n
\]
where C is the stress in the system, n and m are adjustable parameters with 2 ≤ n ≤ 10 (from experiments), ε_0 and E are the creep activation and the thermal energies, respectively. Simplified theoretical models reduced to thermal activation of independent dislocation glide movements predict an exponent m = 1 [1]. This phenomenological theory was derived mostly for tension strain, but can be applied for shear (along the y-axis) as well with the substitution ε → γ, where γ = δxy/δy and \( \dot{\gamma} = \partial \varepsilon/\partial t \). In case of the most common dislocation creep the deformation is realized by the creation and glide movement of edge dislocations with Burgers vectors \( \mathbf{b} \), resulting in shear rates \( \dot{\gamma} = \mathbf{b} \mathbf{v} \) where \( \mathbf{b} \) is the dislocation density and \( \mathbf{v} \) is the average dislocation velocity. The dislocation density is expected to depend on the shear stress as \( \mathbf{v} \sim \sigma^n \). Simple theoretical argumentation and tensile experiments on single and polycrystalline copper predict an exponent n = 2 [2].

Experiments:
We have carried out two independent dusty plasma experiments on single layer crystalline dusty plasma systems aiming the investigation of the microscopic details of the shearing creep deformation. The first experiment was performed in the Hypervelocity Impacts and Dusty Plasmas Lab (HIDPL) of the Center for Astrophysics, Space Physics, and Engineering Research (CASPER) at Baylor University, Waco, Texas, while the second was carried out in the Institute for Solid State Physics and Optics, part of the Wigner Research Centre, Budapest, Hungary (referred to as “TEX” and “BUD” in the following). Details of the dusty plasma apparatus and data processing techniques can be found in earlier publications [3,4]. In both cases the dust layer was illuminated by an extended, spatially linearly modulated laser sheet introducing an external force \( F_\text{ext} = F(x,y) \) on every particle:

\[ F(x,y) = \begin{cases} \varepsilon_0 & \text{if } y < 0 \\ -\varepsilon_0 & \text{if } y > 0 \end{cases} \]

Data processing steps were as (illustrated in the center panel): particle tracking, structural analysis (pair correlation, Delaunay triangulation, bond-order and orientational parameter determination), transverse velocity distribution measurement. To avoid boundary effects (TEX) and to benefit from the inhomogeneous shear (BUD) regions of interest were assigned in the field of view of the camera, as shown in the first row of the central panel.

Most relevant and motivating earlier experiments were [5-9].

References: