Dislocation Avalanches
from Strain Rate Controlled Loading:
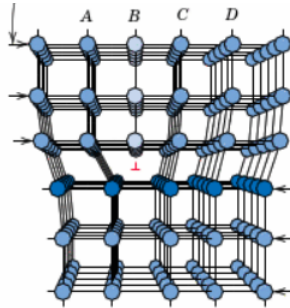
A Discrete Dislocation Dynamics Study

David Kurunczi-Papp and Lasse Laurson

david.kurunczi-papp@tuni.fi

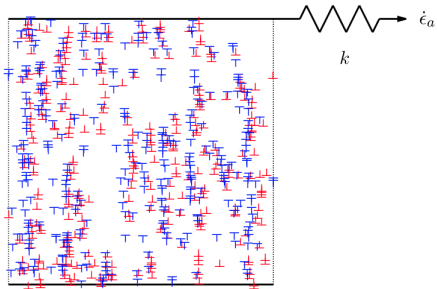Avalanche 2022, Debrecen, Hungary
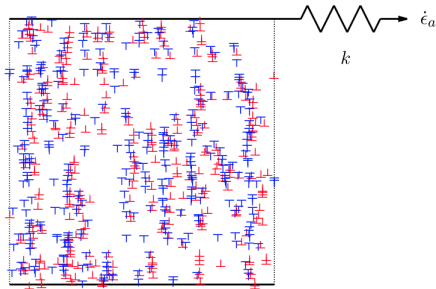31.08.2022

Motivation

Motivation

William D. Callister and David G. Rethwisch: Materials Science and Engineering

2D Discrete Dislocation Dynamics

D. Kurunczi-Papp and L. Laurson, PRE **104**, 025008 (2021)
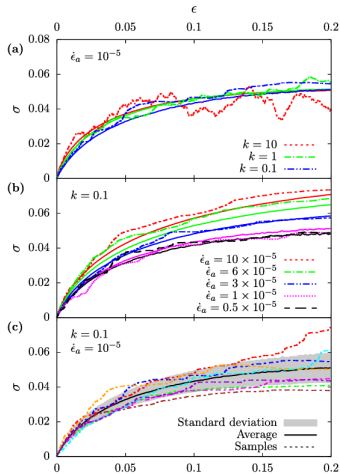
2D Discrete Dislocation Dynamics

$$\frac{\dot{x}_i}{Mb} = s_i b \left[\sum_{j \neq i} s_j \sigma_{\mathrm{d}}(\mathbf{r}_i - \mathbf{r}_j) + \sigma \right],$$
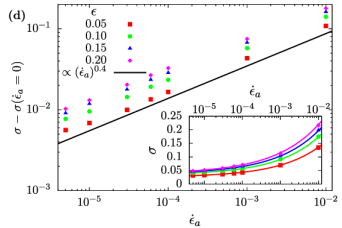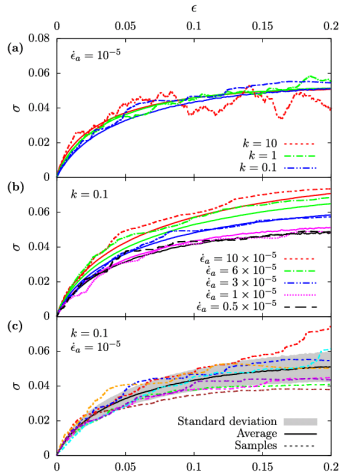
$$\sigma_{\mathrm{d}}(\mathbf{r}) = Db \frac{x(x^2 - y^2)}{(x^2 + y^2)^2}$$

$$\sigma(t) = k \left[\dot{\epsilon}_a t - \epsilon(t) \right]$$

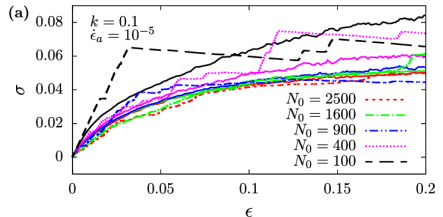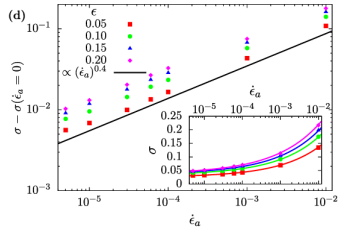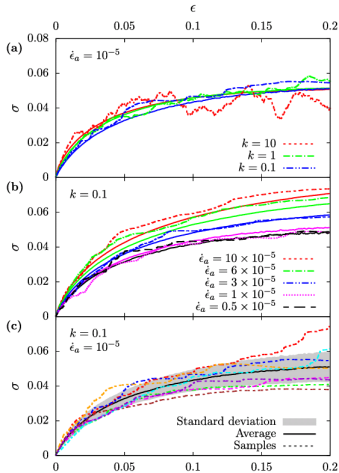D. Kuruncziki-Papp and L. Laurson, PRE **104**, 025008 (2021)

Stress-strain curves

Stress-strain curves

Stress-strain curves

D. Kurunczi-Papp and L. Laurson, PRE **104**, 025008 (2021)

Stress drop magnitude distributions

$$P_{\text{INT}}(\Delta\sigma) \propto (\Delta\sigma)^{-\tau_\sigma} \exp\left(-\frac{\Delta\sigma}{\Delta\sigma_0}\right)$$
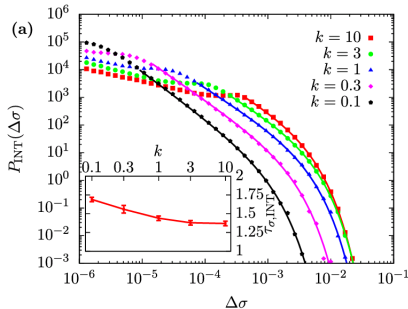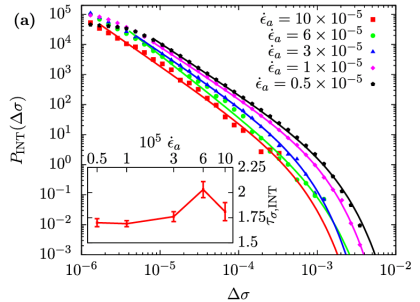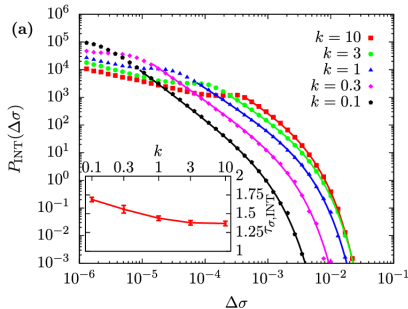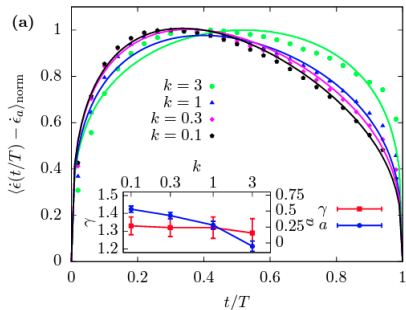
Stress drop magnitude distributions

$$P_{\text{INT}}(\Delta\sigma) \propto (\Delta\sigma)^{-\tau_\sigma} \exp\left(-\frac{\Delta\sigma}{\Delta\sigma_0}\right)$$
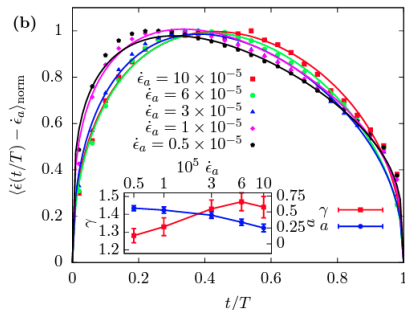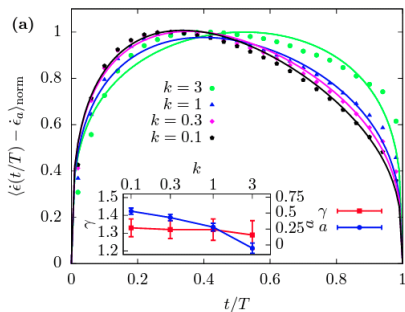
Average avalanche shapes

$$\left\langle \dot{\epsilon}\left(\frac{t}{T}\right) - \dot{\epsilon}_a \right\rangle \propto T^{\gamma-1} \left[\frac{t}{T}\left(1 - \frac{t}{T}\right)\right]^{\gamma-1} \left[1 - a\left(\frac{t}{T} - \frac{1}{2}\right)\right]$$

D. Kurunczi-Papp and L. Laurson, PRE **104**, 025008 (2021)

Average avalanche shapes

$$\left\langle \dot{\epsilon}\left(\frac{t}{T}\right) - \dot{\epsilon}_a \right\rangle \propto T^{\gamma-1} \left[\frac{t}{T}\left(1 - \frac{t}{T}\right) \right]^{\gamma-1} \left[1 - a\left(\frac{t}{T} - \frac{1}{2}\right) \right]$$
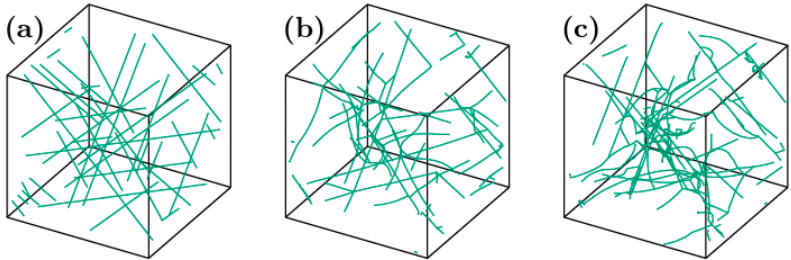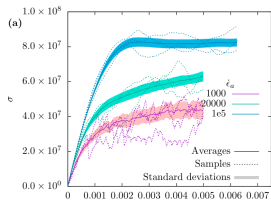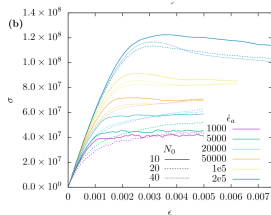
D. Kurunczi-Papp and L. Laurson, PRE **104**, 025008 (2021)

3D Discrete Dislocation Dynamics

Stress-strain curves

Stress-strain curves

Stress-strain curves

Stress drop magnitude distributions

$$P_{\text{INT}}(\Delta\sigma) \propto (\Delta\sigma)^{-\tau_\sigma} \exp\left(\frac{\Delta\sigma}{\Delta\sigma_0}\right)$$

Average avalanche shapes

$$\langle \dot{\sigma}\left(\frac{t}{T}\right)\rangle \propto T^{\gamma-1}\left[\frac{t}{T}\left(1-\frac{t}{T}\right)\right]^{\gamma-1}\left[1-a\left(\frac{t}{T}-\frac{1}{2}\right)\right]$$
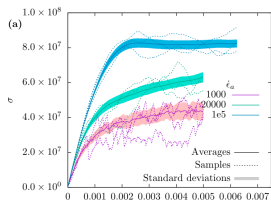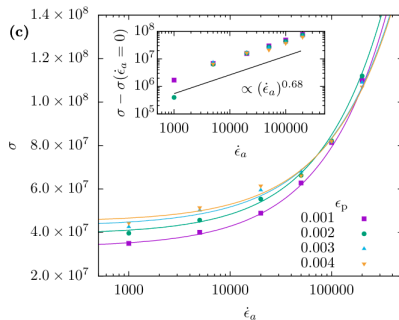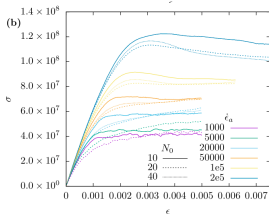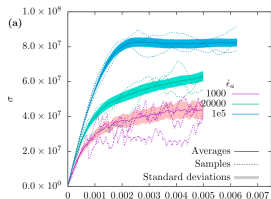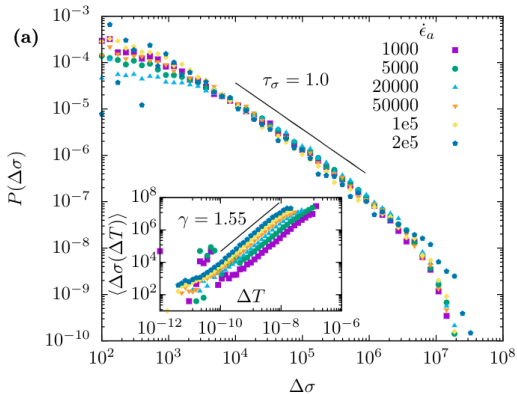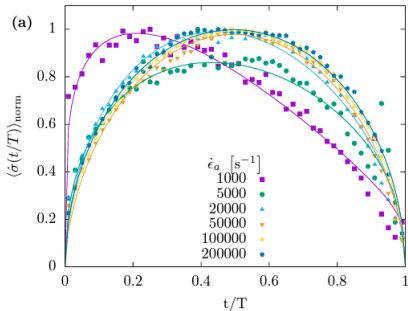

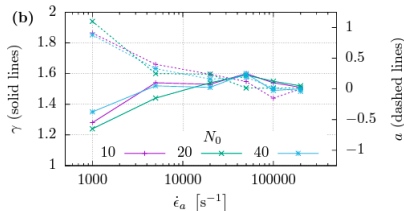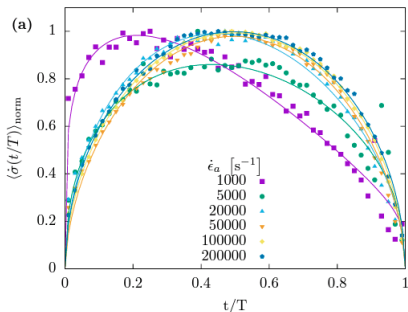D. Kurunczi-Papp and L. Laurson, arXiv:2207.07439

Average avalanche shapes

$$\langle \dot{\sigma} \left(\frac{t}{T} \right) \rangle \propto T^{\gamma - 1} \left[\frac{t}{T} \left(1 - \frac{t}{T} \right) \right]^{\gamma - 1} \left[1 - a \left(\frac{t}{T} - \frac{1}{2} \right) \right]$$

D. Kurunczi-Papp and L. Laurson, arXiv:2207.07439

Summary and conclusions

▶ Study the statistical properties of strain rate controlled loading of both 2D and 3D discrete dislocation simulations.

▶ Size- and rate dependence of the stress-strain curves

▶ In 2D the avalanche sizes are distributed by rate-dependent power laws, while in 3D the universal power law $\tau \approx 1.0$ is observed

▶ Rate dependent avalanche shapes with left asymmetries

▶ Several universality classes present in crystal plasticity

Thank you for Your attention!