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

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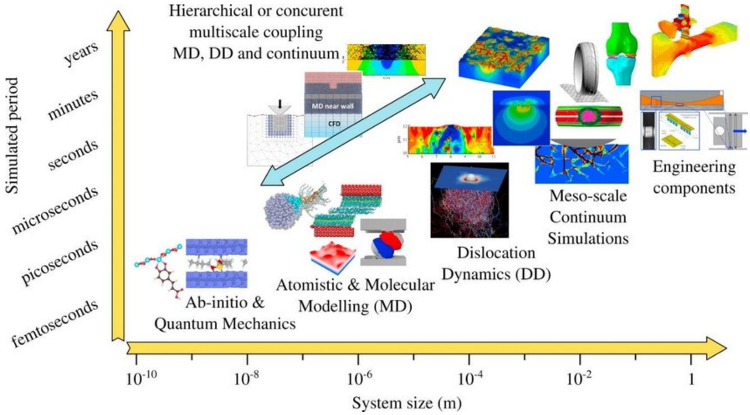
"Interaction, Disorder, Elasticity"
workshop at Les Houches
April 3-7, 2023

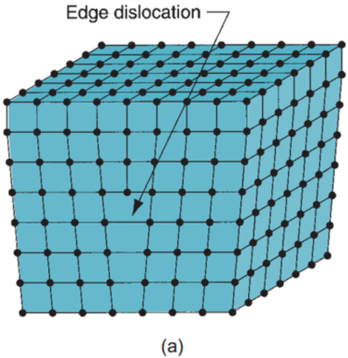
Plastic deformation

Scales



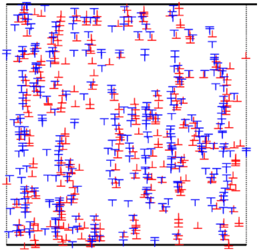
Goel et al., Materials Today Chemistry **18** (2020)

Dislocations



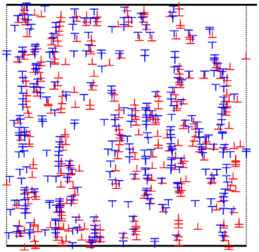
Anderson, Hirth, and Lothe, **Theory of Dislocations** (2017)

2D Discrete Dislocation Dynamics



Ispánovity et al., Phys. Rev. Lett. **112**, 235501 (2014)

2D Discrete Dislocation Dynamics



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

$$\sigma_{\mathrm{d}}(\mathbf{r}) = Db \frac{x(x^2 - y^2)}{(x^2 + y^2)^2}$$

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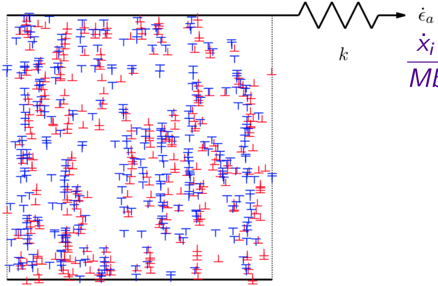
Strain controlled loading



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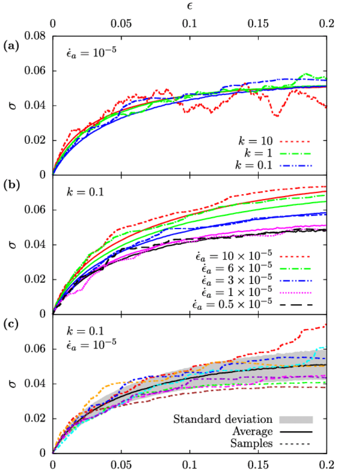
$$\sigma(t) = k \left[\dot{\epsilon}_a t - \epsilon(t) \right]$$

Ispánovity et al., Phys. Rev. Lett. **112**, 235501 (2014)

Stress-strain curves



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

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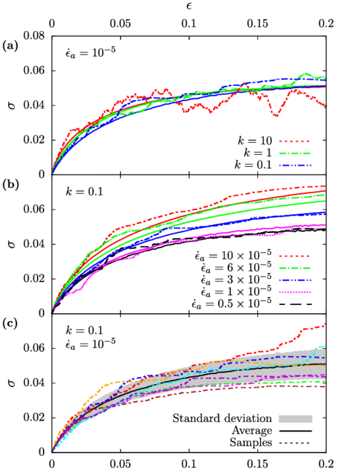

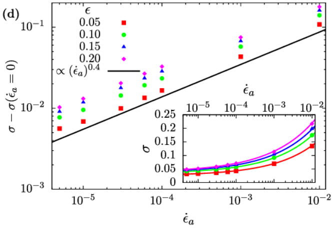

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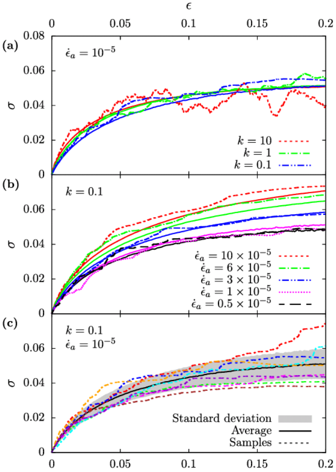
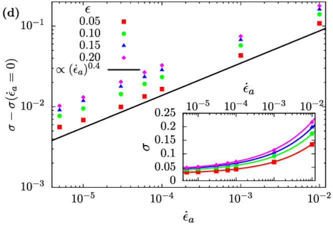
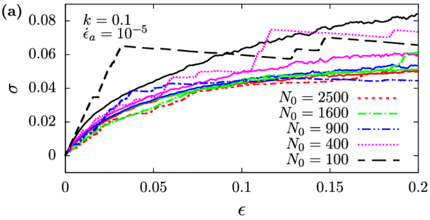


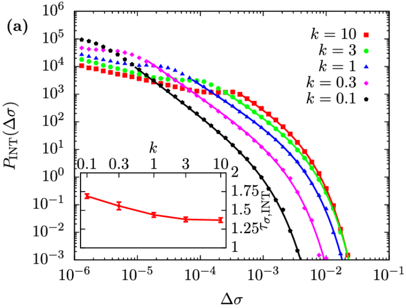




Kurunczi-Papp and Laurson, PRE **104**, 025008 (2021)

Stress drop magnitude distributions

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



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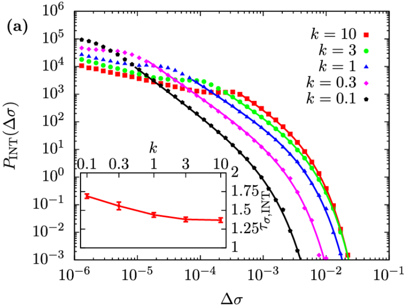
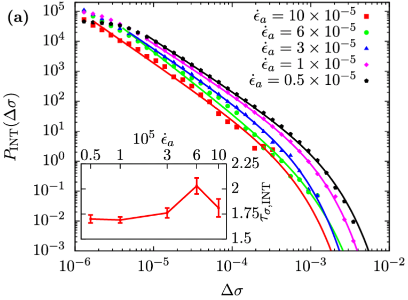
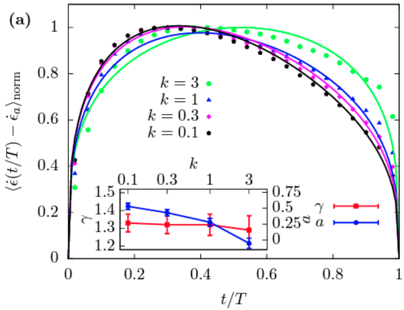




Kurunczi-Papp and Laurson, PRE **104**, 025008 (2021)

Average avalanche shapes

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



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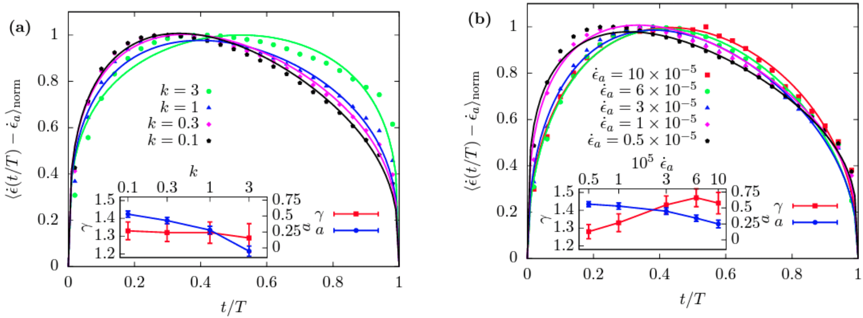

Kurunczi-Papp and Laurson, PRE **104**, 025008 (2021)

3D Discrete Dislocation Dynamics

- Dislocation lines
- Mixed character
- Material specific mobility

Arsenlis et al., Model. Sim. Mater. Scie. Eng. **15**, 553 (2007)

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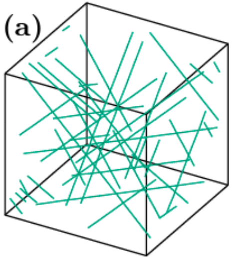
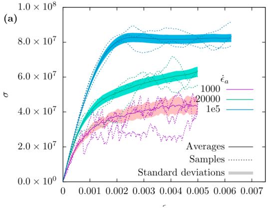


Kurunczi-Papp and Laurson, Phys. Rev. Materials **7**, 013605 (2023)

Stress-strain curves



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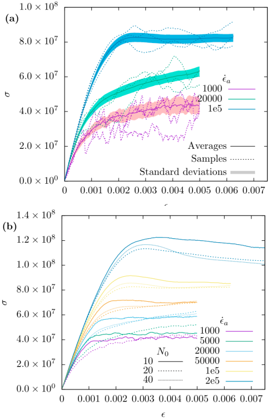

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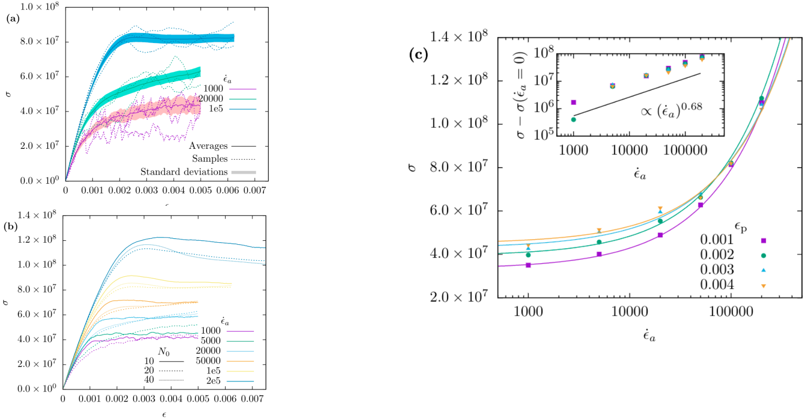

Kurunczi-Papp and Laurson, Phys. Rev. Materials **7**, 013605 (2023)

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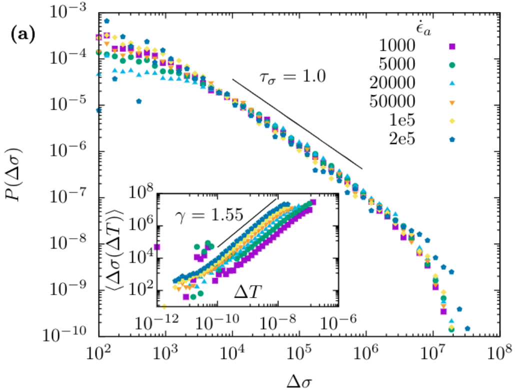

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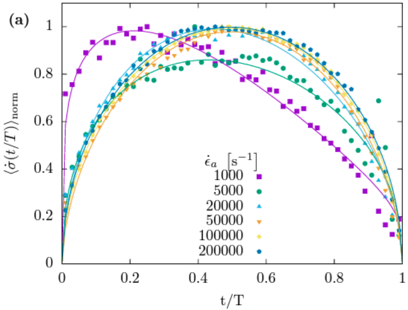

Kurunczi-Papp and Laurson, Phys. Rev. Materials **7**, 013605 (2023)

Tampere University

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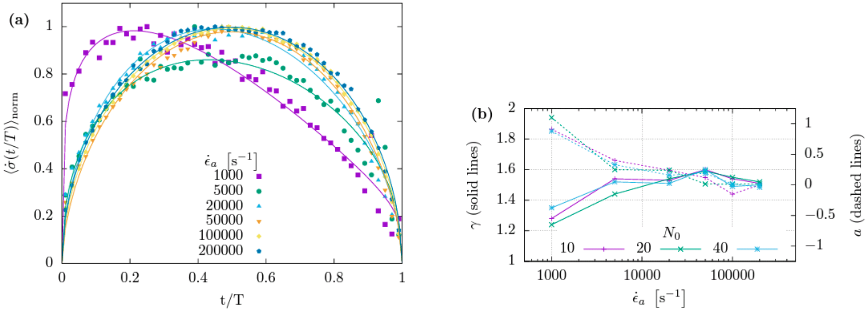
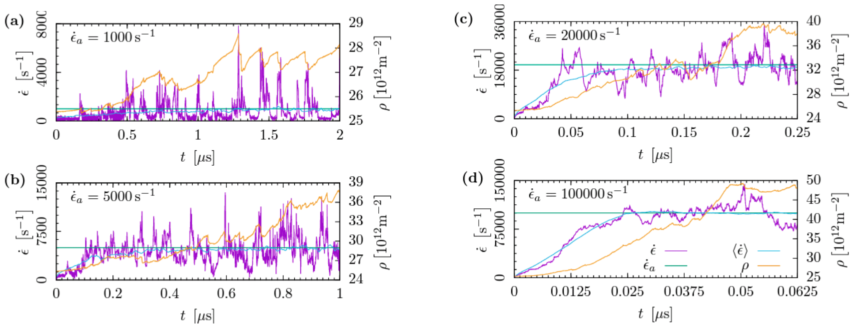


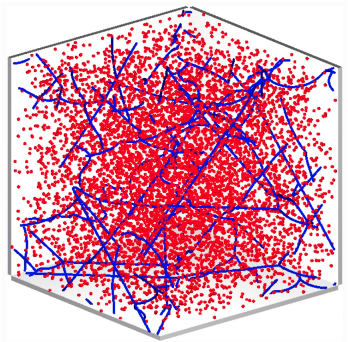
Kurunczi-Papp and Laurson, Phys. Rev. Materials **7**, 013605 (2023)

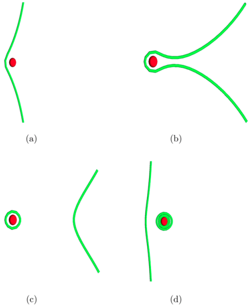
Asymmetry explained



Kurunczi-Papp and Laurson, Phys. Rev. Materials **7**, 013605 (2023)

Precipitates





Lehtinen et al., PRE **93**, 013309 (2016)

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!