EGU General Assembly 2022

Contribution of thermal weakening in frictional rupture dynamics

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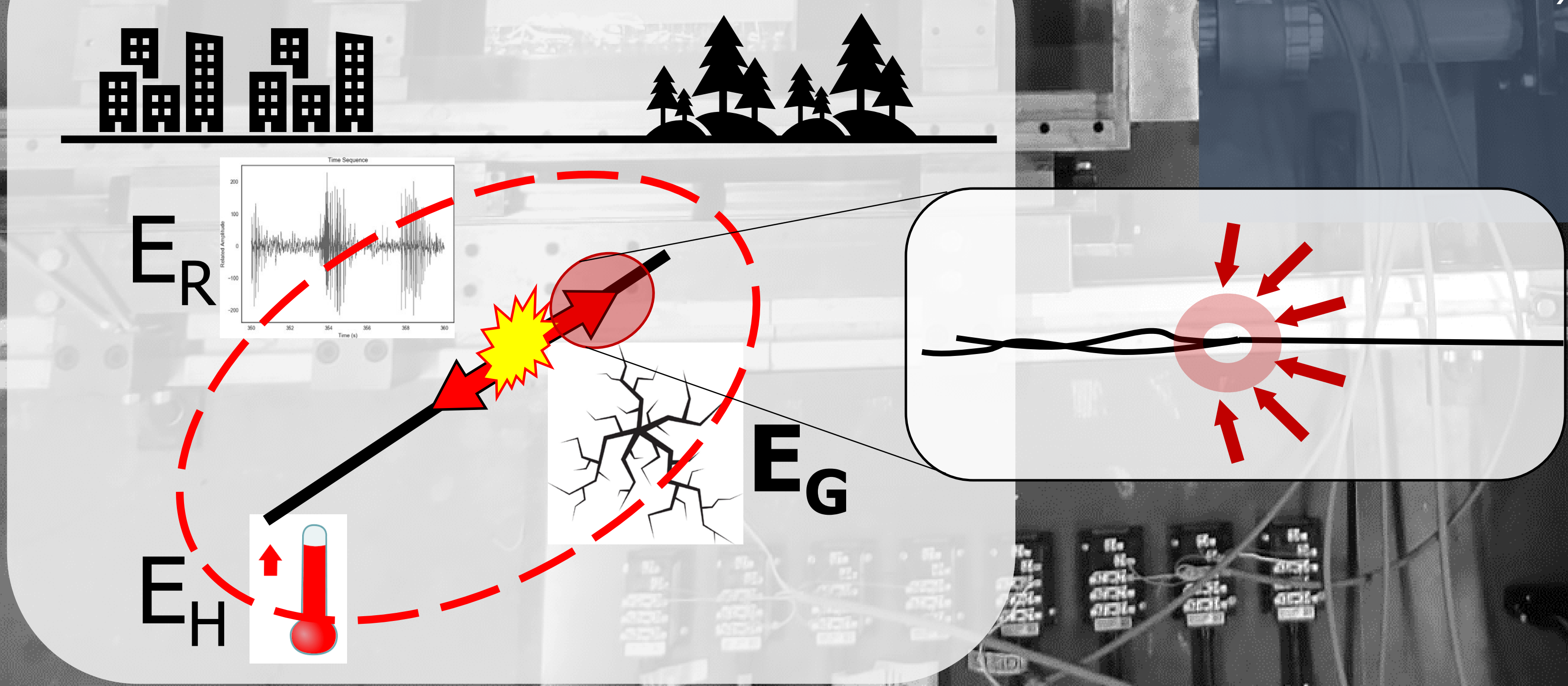
Earthquakes Energy Budget:



Earthquakes breakdown work

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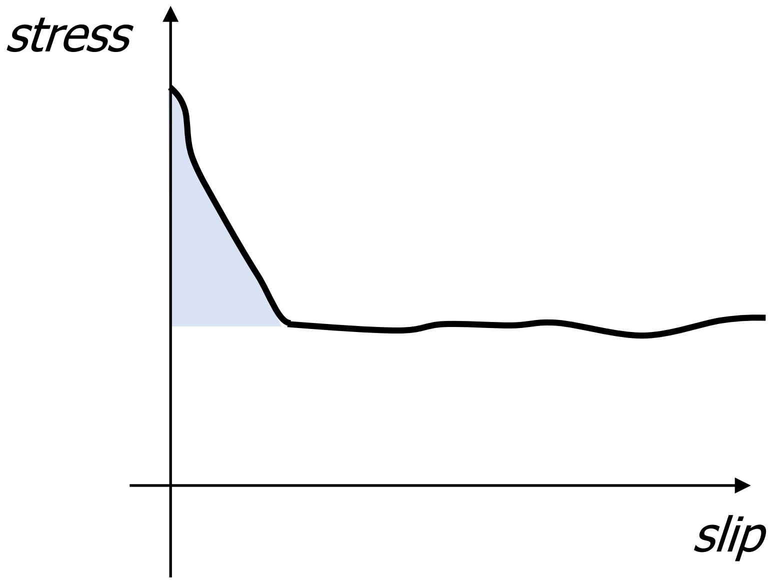

Breakdown work:

$$W_{bd} = \int_0^{D_{fin}} (\tau - \tau(D))\, dD$$

including dissipative processes

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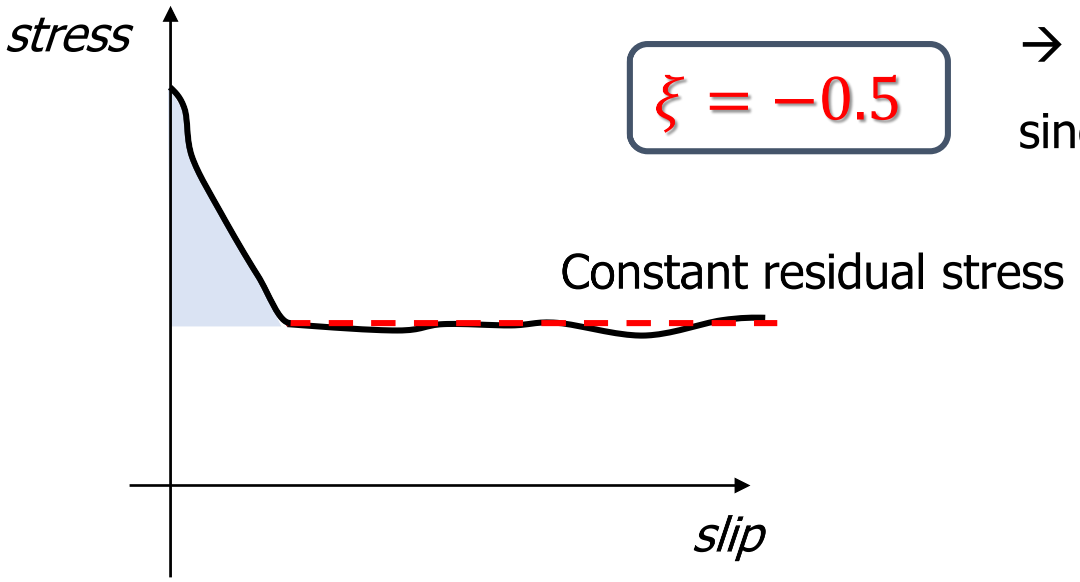

Earthquakes often described as ***ordinary* cracks.**

→ Stress and displacement field controlled by square root singularity (Linear Elastic Fracture Mechanics)

Showed by laboratory earthquakes in analog materials and rocks.

Svetlizky and Fineberg, 2014
Kammer et al., 2019

Breakdown work:

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including dissipative processes

Earthquakes breakdown work

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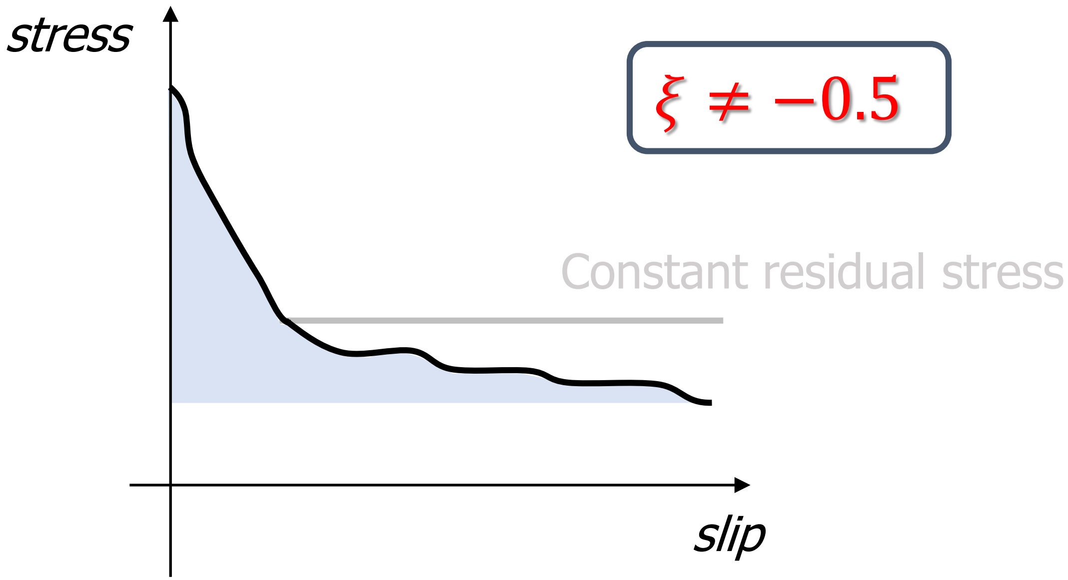

$\xi \neq -0.5$

Frictional weakening talking place behind the rupture tip can modify the singularity order (Unconventional singularity)

Viesca and Garagash, 2015
Brantut and Viesca, 2017
Brener and Bouchbinder, 2021

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Brener and Bouchbinder, 2021

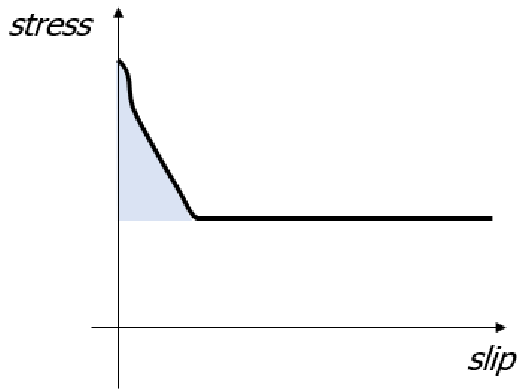
Describes the slip dependence of W_{bd} as:

$$\boldsymbol{W_{bd}} \sim \left[\boldsymbol{K}^{(\xi)}\right]^2 \boldsymbol{r^{1+2\xi}} / \boldsymbol{\mu}$$

For $\boxed{\xi = -0.5}$ (*square root singularity*)

$$r^{1+2\xi} = 1$$

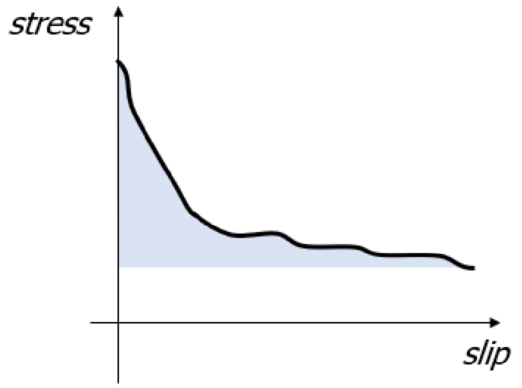
W_{bd} slip independent



For $\boxed{\xi \neq -0.5}$

$$r^{1+2\xi} \neq 1$$

W_{bd} slip dependent



Experimental setup

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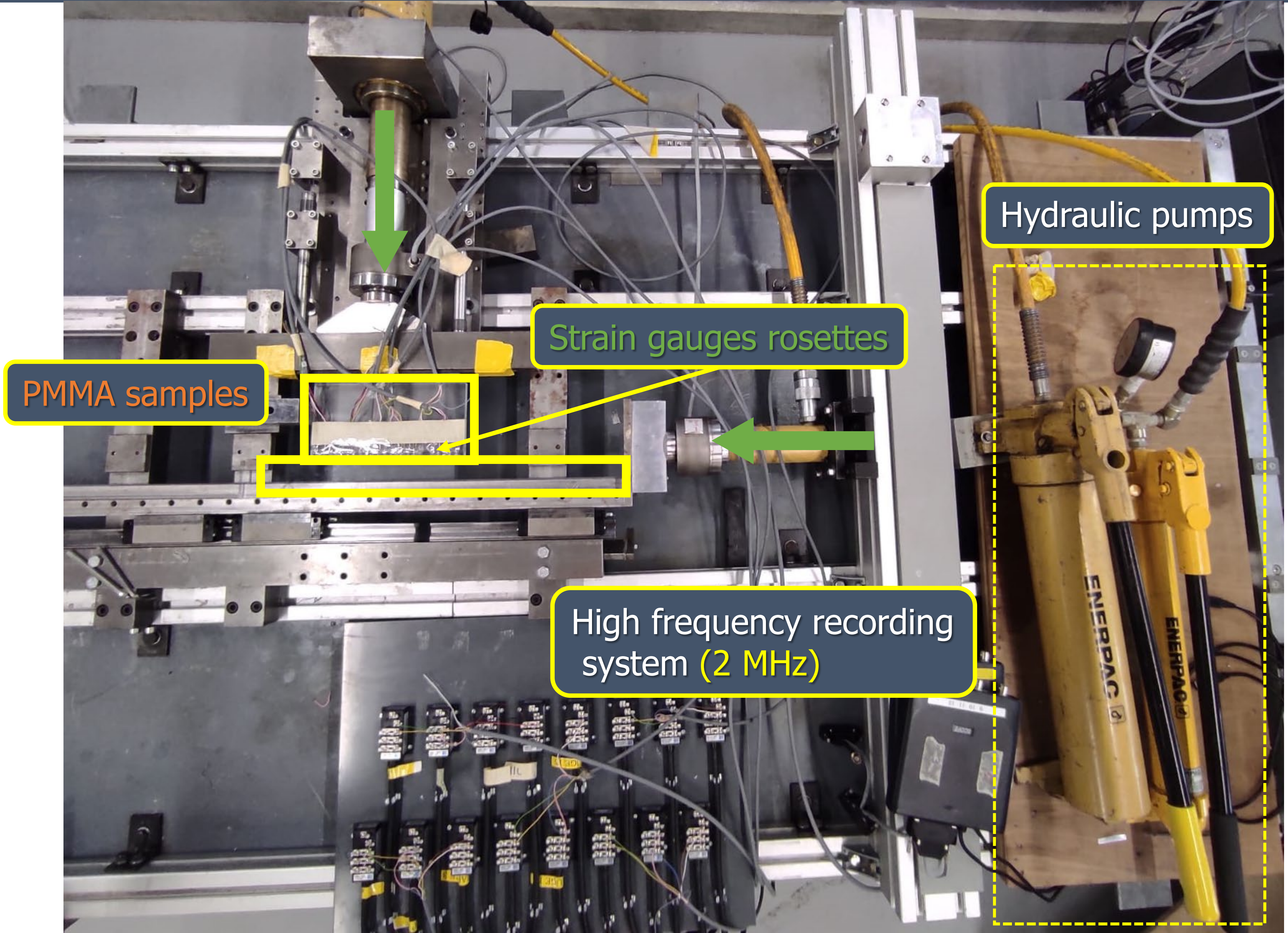

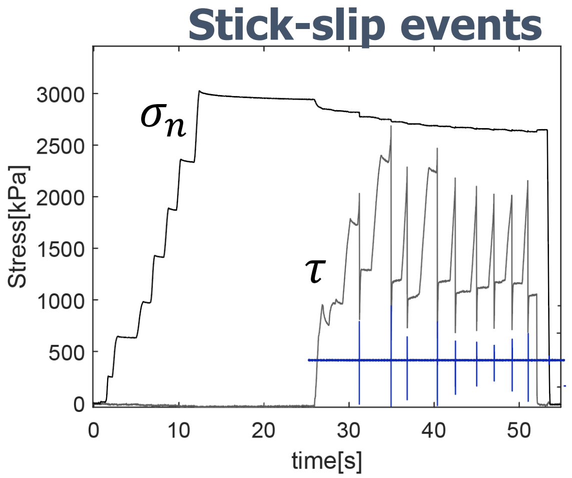

Results. Slip-dependent Breakdown work

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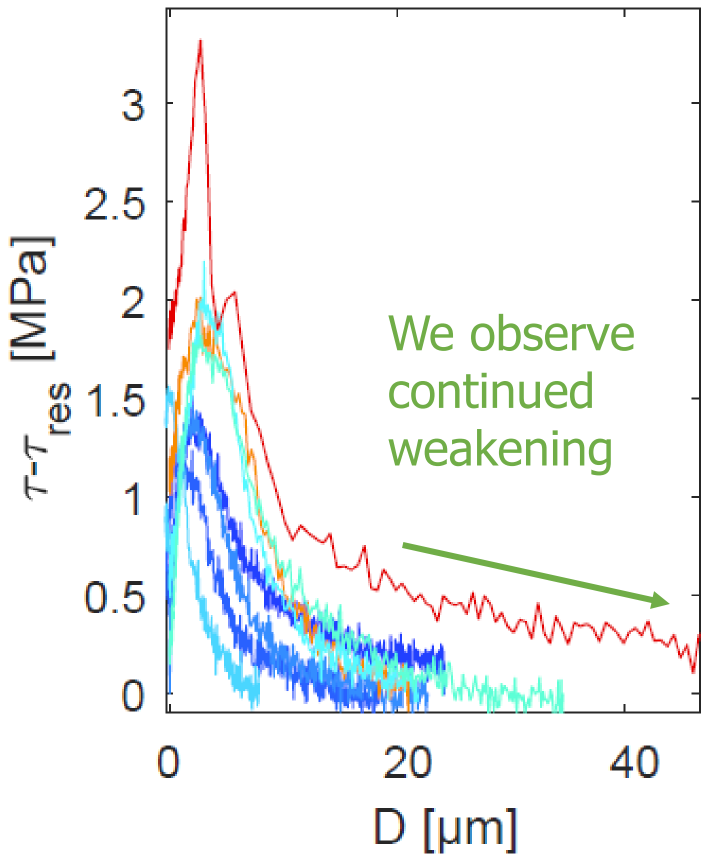

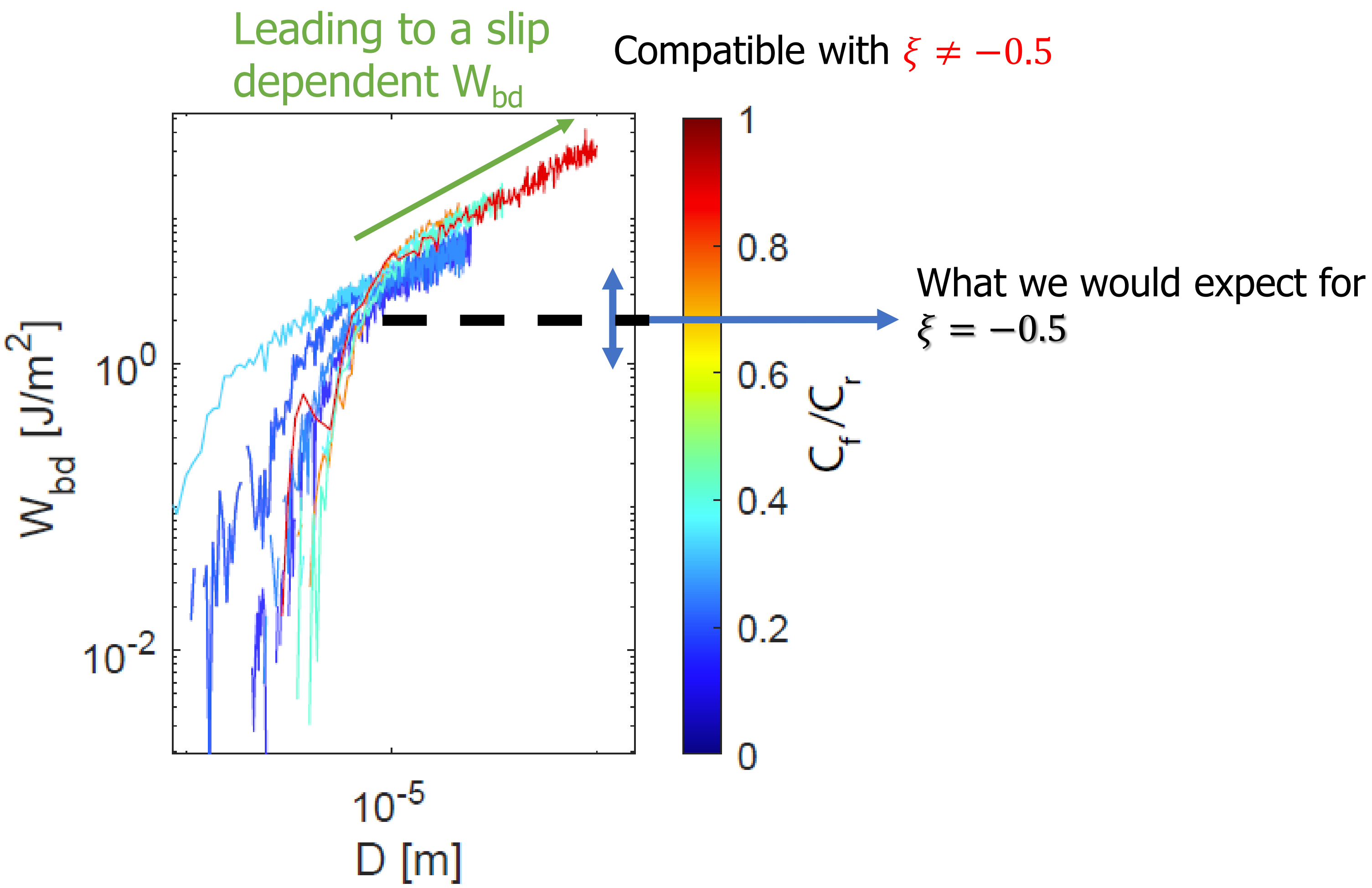

$$W_{bd} = \int_0^D (\tau - \tau(D))\, dD$$

Results. Slip and stress controlled by $\xi \neq -0.5$

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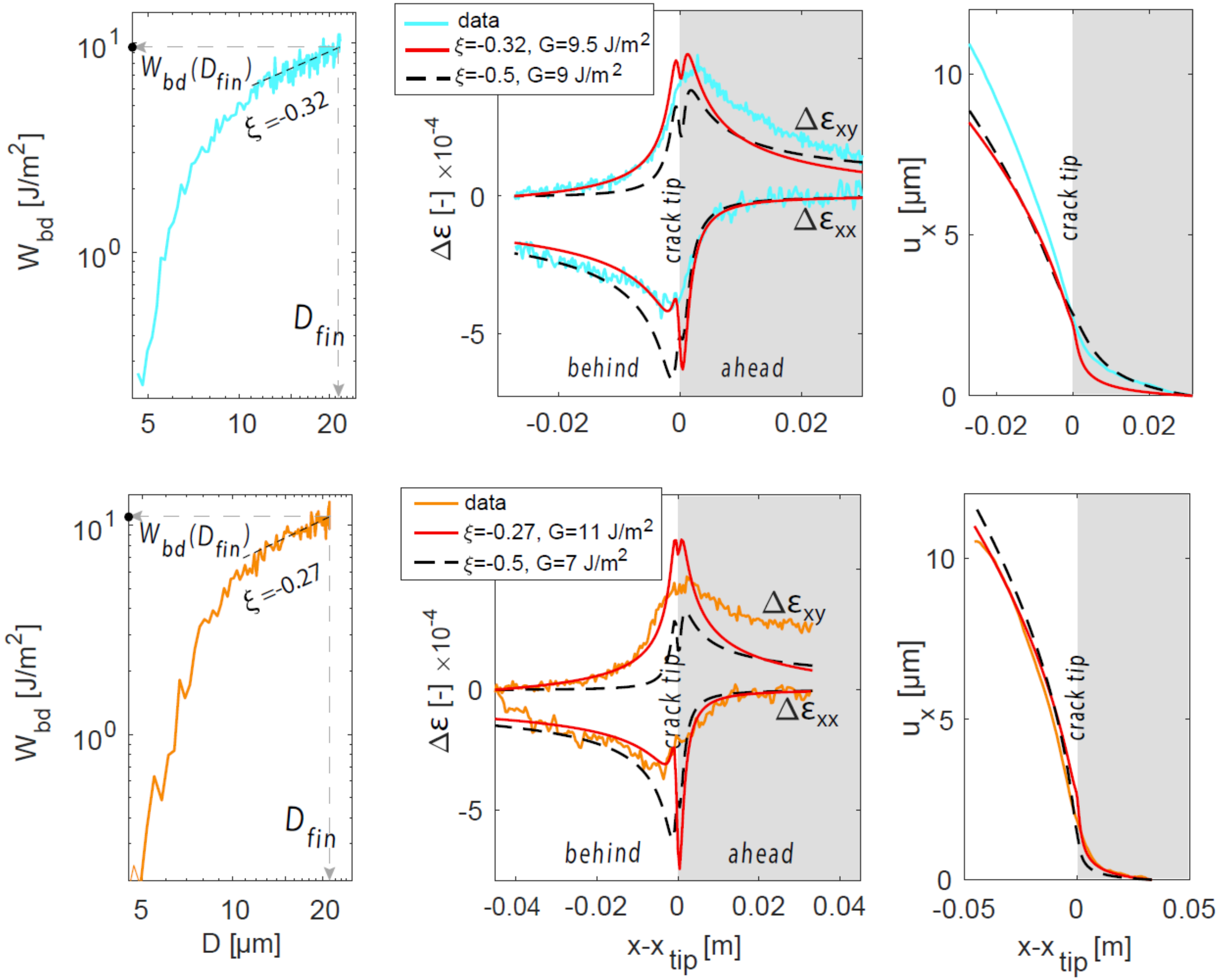

Brener and Bouchbinder, 2021

$$u_x(r,\theta) = \frac{2K_{II}^{(\xi)}}{\mu\sqrt{2\pi}\,R(C_f)}\left[2\alpha_s r_d^{\xi+1}\sin\left((\xi+1)\theta_d\right) - \alpha_s(1+\alpha_s^2)\,r_s^{\xi+1}\sin\left((\xi+1)\theta_s\right)\right]$$

$$\tau(r,\theta) = \frac{2(\xi+1)K_{II}^{(\xi)}}{\sqrt{2\pi}\,R(C_f)}\left[4\alpha_s\alpha_d\,r_d^{\xi}\cos(\xi\theta_d) - (1+\alpha_s^2)^2\,r_s^{\xi}\cos(\xi\theta_s)\right]$$

with $K_{II}^{(\xi)} = \sqrt{\dfrac{E\,W_{bd}(D_{fin})}{(1-\nu^2)\,f_{II}(C_f)\,r^{1+2\xi}}}$

Un unconventional order singularity $\xi \neq -0.5$ can better describe both stress and displacement evolution than classical LEFM for our experiments

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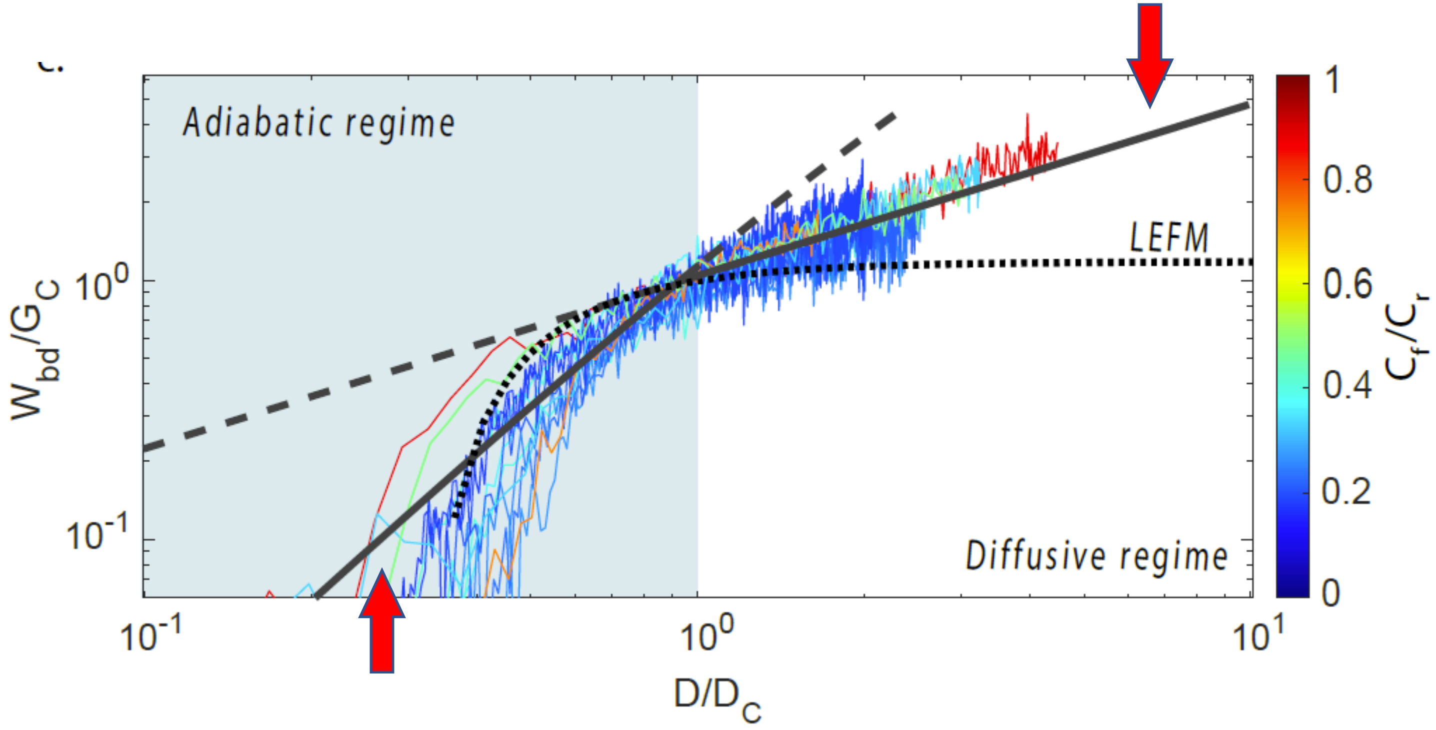
Results. Cause of unconventional singularity

WHY?

The activation of thermal weakening mechanisms can modify the stress evolution behind the crack tip, inducing a slip-dependent Wbd

Viesca and Garagash, 2015

Brantut and Viesca, 2017



→ **FLASH HEATING** investigated as possible candidate

(already observed by *Rubino et al., 2017)*

Asymptotic solutions for FLASH HEATING (*Brantut and Viesca, 2017*) well describe the observed slip-dependence of W_{bd}

Conclusions

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- We observed continued weakening in laboratory frictional ruptures leading to slip dependent breakdown work.
- We showed how frictional ruptures can be described by unconventional singularity order ($\xi \neq -0.5$).
- This is possibible due to activation of frictional weakening (flash heating) behind the crack tip.