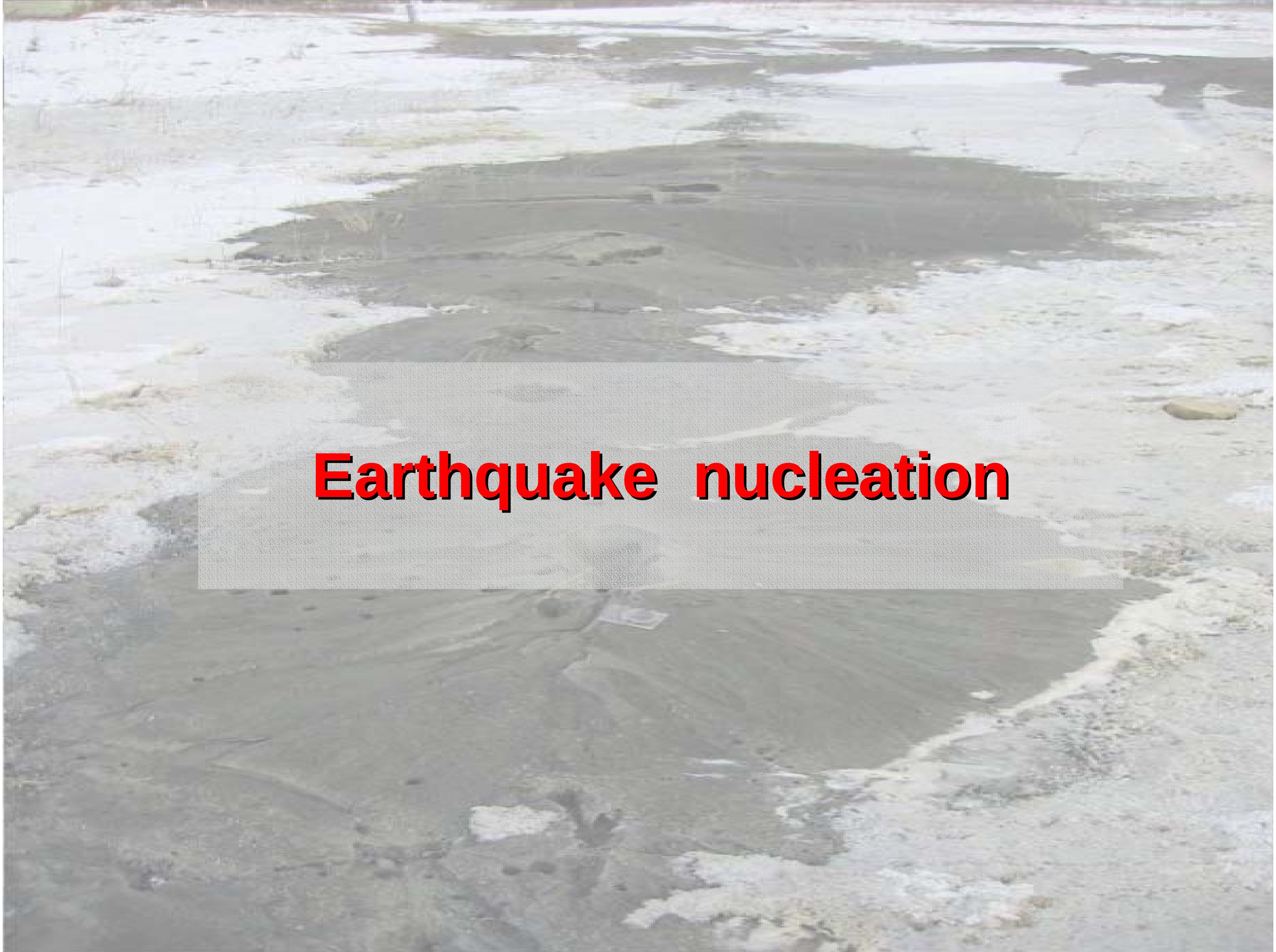


# Earthquake nucleation

# Nucleation Models

## 1. SELF – SIMILAR MODEL

- Allways fully dynamic process
- Slip velocity linearly increases with time
- Waves emission since initial stages of nucleation

## 2. CASCADE MODEL

- Small events with mutual triggering accumulate up to a big event
- Only the final stage is fully dynamic with waves emission

## 3. PRE – SLIP MODEL

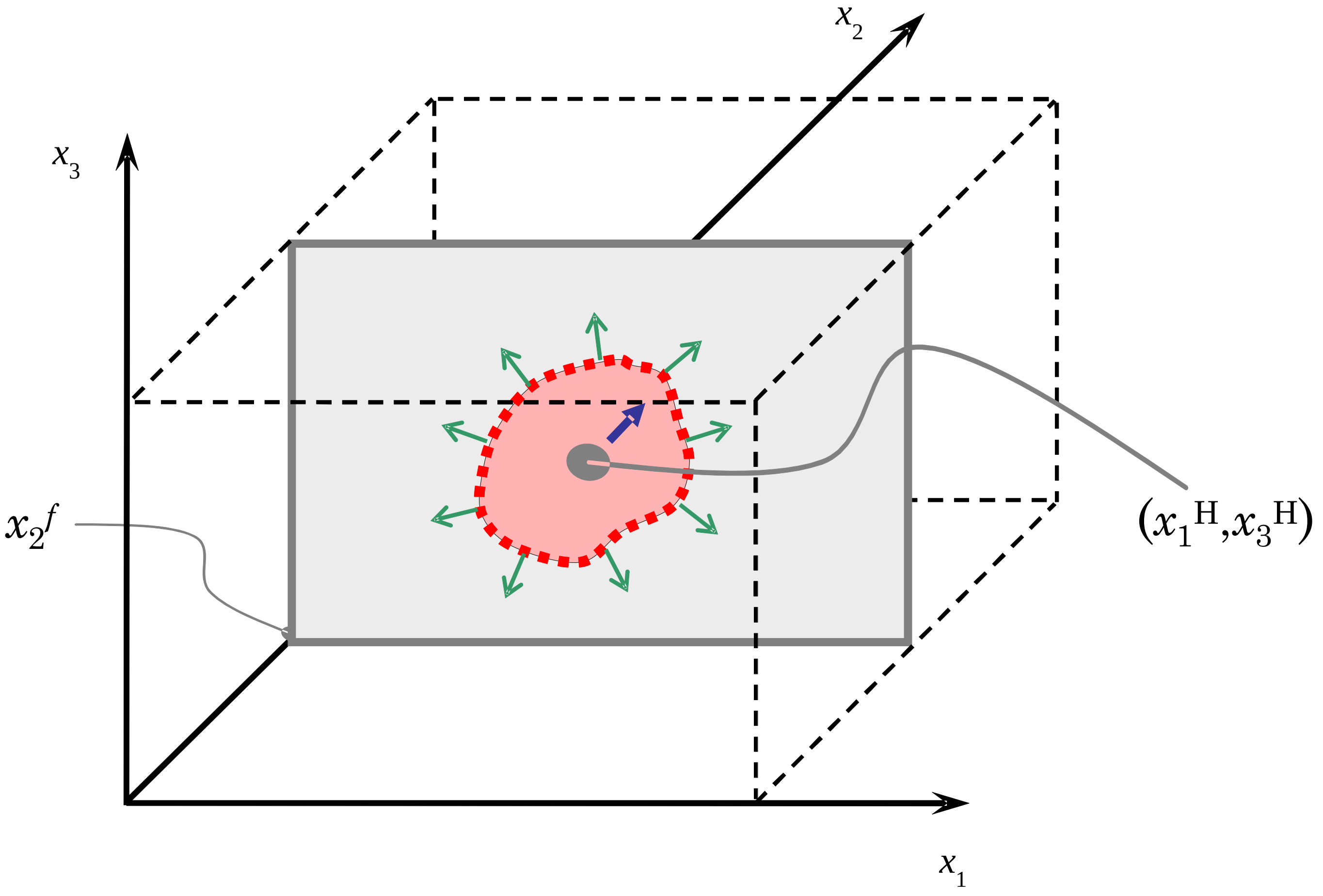
- Initially an asismic process increases the total crached area
- When a critical dimension is reached the process is spontaneous
- Dieterich and Andrews models

# How to simulate the earthquake nucleation?

## 1. SLIP – WEAKENING CONSTITUTIVE EQUATION

- Linear SW is unable to model the nucleation stage and therefore rupture initiation has to be prescribed ( i. e. imposed )
- Different nucleation strategy have to be compared in order to see what are the effects of the initialization parameters on the following rupture propagation
- In order to correctly represent a physical process nucleation strategies have to be equivalent results
- The Ohnaka' s SW contain the slip – hardening phase and is able to account for nucleation

# Notations and symbols



→ *Local crack enlargement*

➡ $T(x_1,x_3,0)$

# Time - weakening

`inuclstrat = 1`

$$\tau = \begin{cases} \left[ \mu_u - (\,\mu_u - \mu_f\,)\,\dfrac{\left(t - t_{force}\right)}{t_0} \right] \sigma_n{}^{eff} & ,t - t_{force} < t_0 \\ \mu_f \sigma_n{}^{eff} & ,t - t_{force} \geq t_0 \end{cases}$$

$t_{force}$ = $t_{force}(\xi)$ is the forced rupture onset time in every fault point $\xi$ = $(x_1,x_3)$:

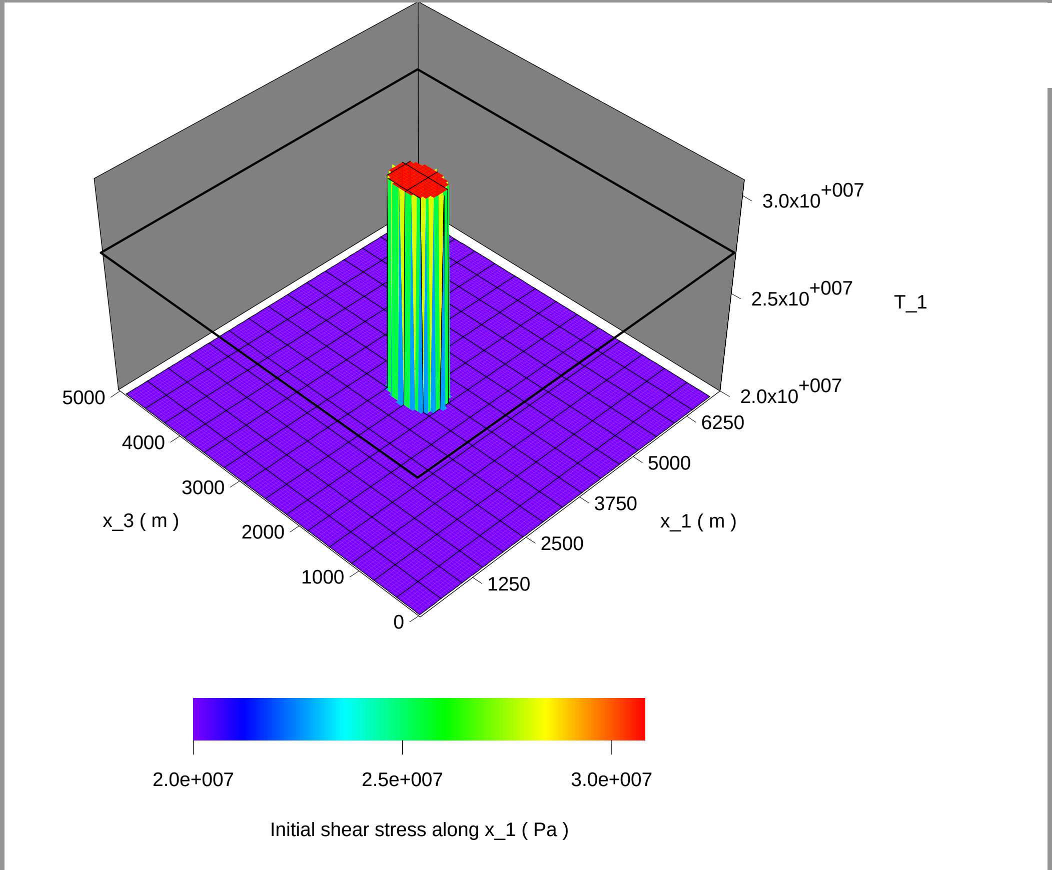
$$t_{force}\left(x_1, x_3\right) = \frac{\sqrt{\left(x - x_1{}^{\mathrm{H}}\right)^2 - \left(x - x_3{}^{\mathrm{H}}\right)^2}}{v_{force}}$$

$t_0$ is the characteristic time – weakening duration.

*Andrews ( 1985 )*, *Bizzarri et al. ( 2001 )* and other following Bizzarri’ s papers

# Pre - stress asperity

`inuclstrat = 2`



*i_nucl* is the asperity radius. In general, arbitrary distribution of $T(x_1,x_3,0)$ is read from input files.

*Bizzarri and Cocco ( 2005c, 2005d )* and other following Bizzarri' s papers

# Slip velocity perturbation

`inuclstrat = 3`

$$V\begin{Bmatrix}1\\2\\3\end{Bmatrix}(x_1,x_2,x_3,0)=\frac{1}{2}\,\mathrm{sign}\left(x_2-x_2{}^{f}\right)v_{init}\begin{Bmatrix}\cos\varphi\\0\\\sin\varphi\end{Bmatrix}\,\mathrm{e}^{\frac{\left(x_1-x_1{}^{\mathrm{H}}\right)^2}{\left(x_1-x_1{}^{\mathrm{H}}\right)^2-\left(i_{nucl}\,\Delta x_1\right)^2}}\;\mathrm{e}^{\frac{\left(x_3-x_3{}^{\mathrm{H}}\right)^2}{\left(x_3-x_3{}^{\mathrm{H}}\right)^2-\left(j_{nucl}\,\Delta x_3\right)^2}}\;\mathrm{e}^{-\frac{\left(x_2-x_2{}^{f}\right)^2}{\left(r_{nucl}\right)^2}}$$

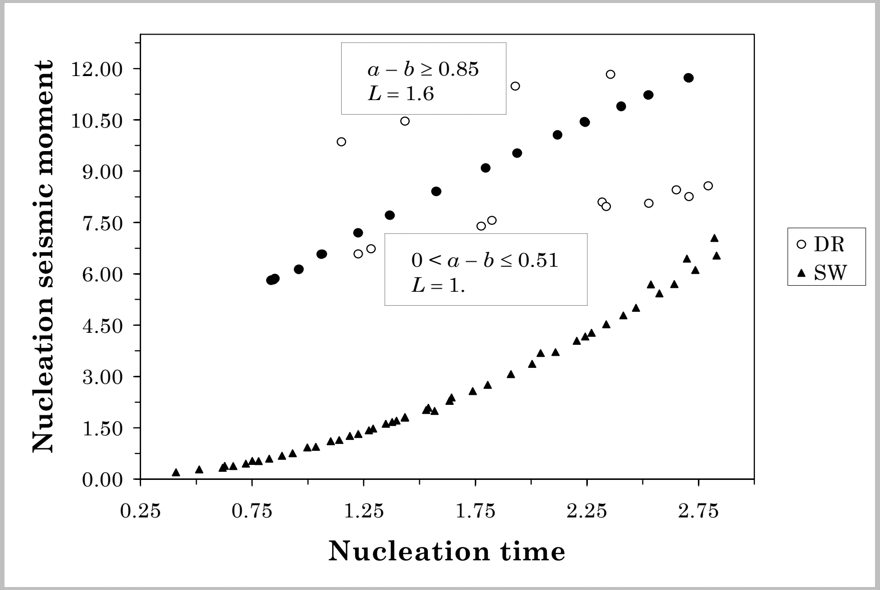
$$\mathrm{H}\left(\left(i_{nucl}\,\Delta x_1\right)^2-\left(x_1-x_1{}^{\mathrm{H}}\right)^2\right)\mathrm{H}\left(\left(j_{nucl}\,\Delta x_3\right)^2-\left(x_3-x_3{}^{\mathrm{H}}\right)^2\right)$$

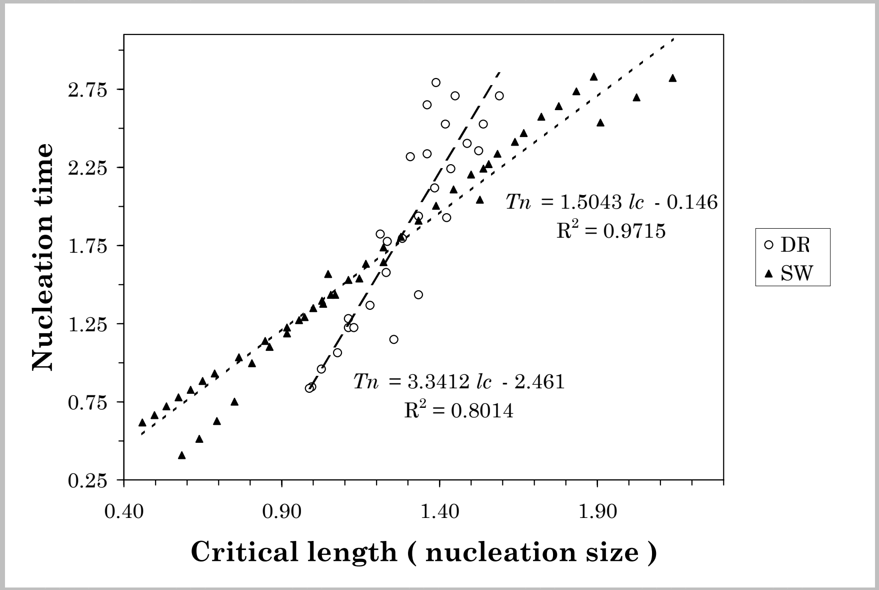
$\varphi$ is the rake angle, measured from $x_1$ in anti – hourly sense; $\varphi = 0$ represents a left – lateral strike slip fault

With opportune corrections and modifications of *Ionescu and Campillo ( 1999 )* and *Badea et al. ( 2004 )*

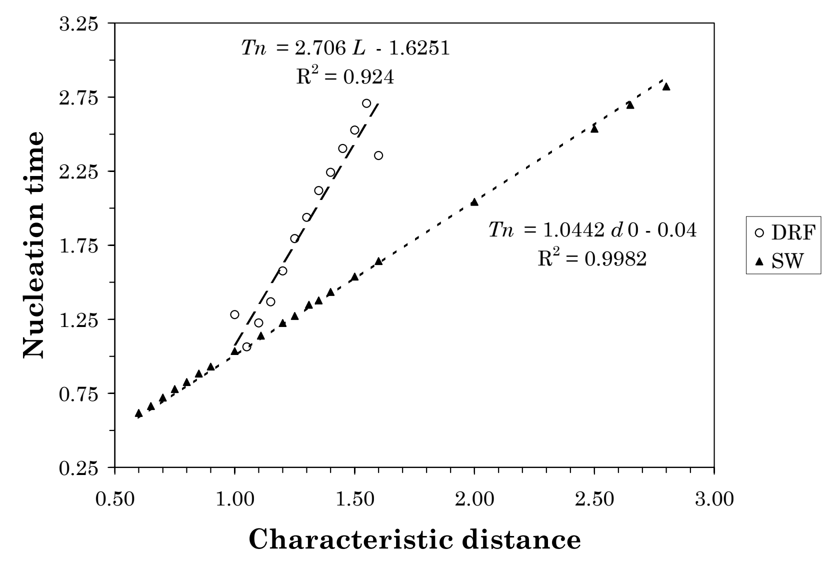
$v_{init}$ is the maximum imposed fault slip velocity; $i_{nucl}$ and $j_{nucl}$ deterimine the extension of the nucleation patch and $r_{nucl}$ is a sensitivity factor

# Some correlations during nucleation





$T_n$ is the time necessary for the rupture tip to reach a distance along $x_1$ equal to the critical half–length $L_c^{(II)}$



## 2. RATE AND STATE CONSTITUTIVE EQUATIONS

- Rate – and state – dependent friction laws are able to describe the nucleation stage
- The spontaneous rupture nucleation is modeled through the evolution of the state variable
- The earthquake initiation is promoted in a nucleation path assuming a different distribution of the contact time of the micro – asperities

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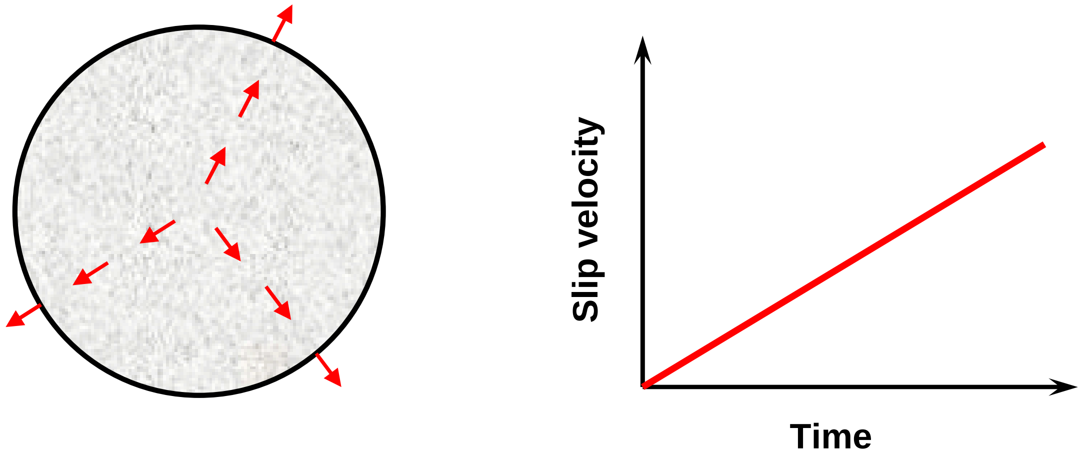
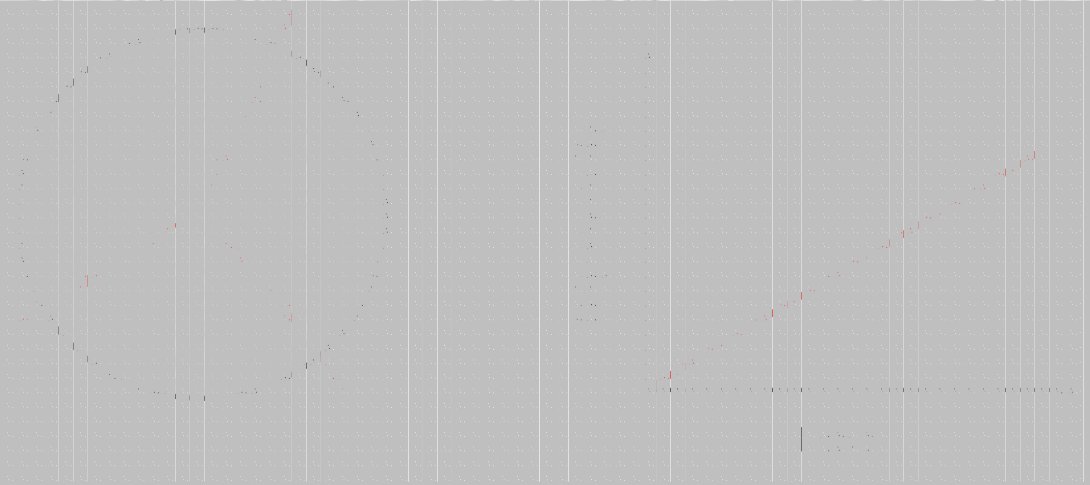
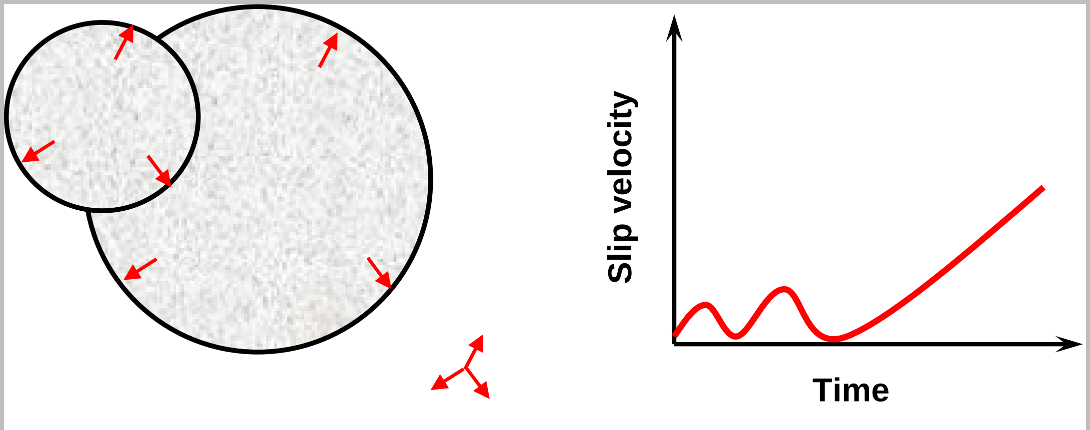
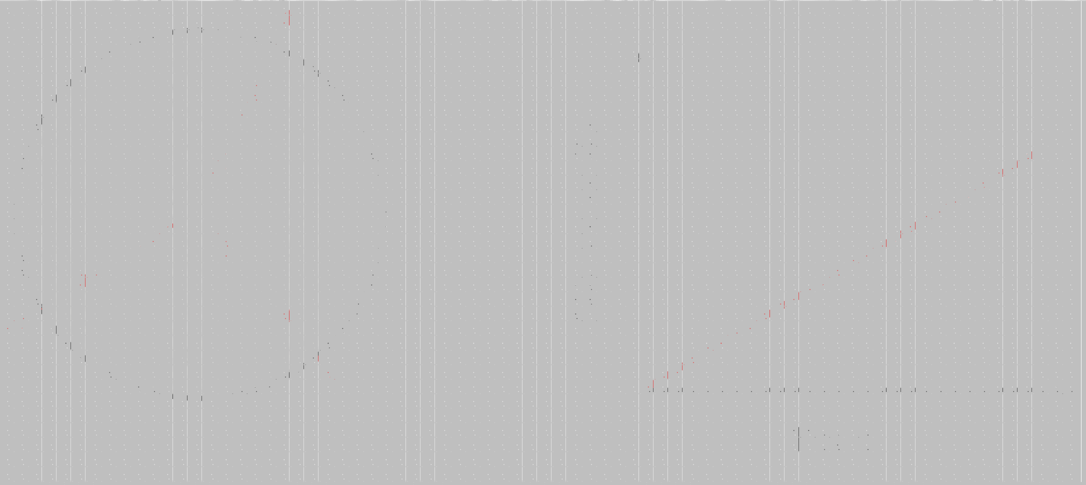
# Support Slides:
# Parameters, Notes, etc.

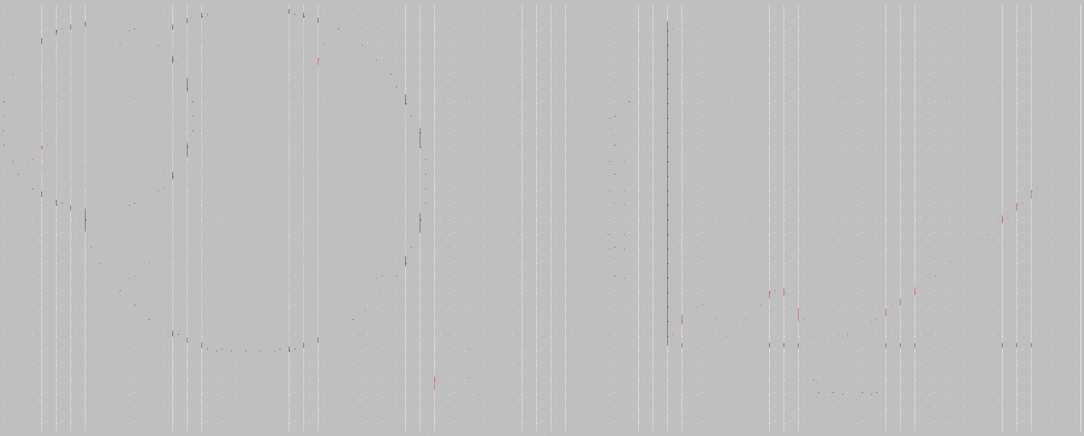
*To not be displayed directly. Referenced above.*

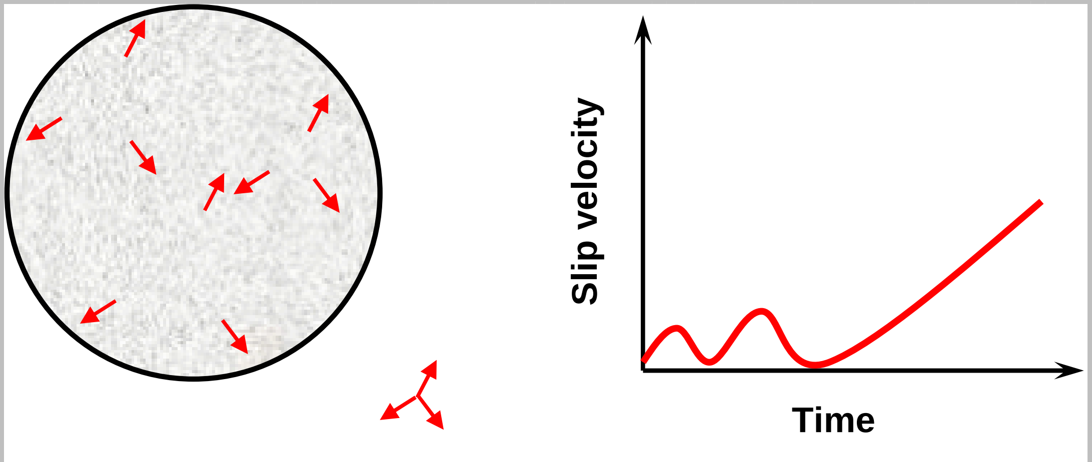

Slip velocity
Time




Slip velocity
Time






Slip velocity
Time