粉体の破砕と粒径分布関数

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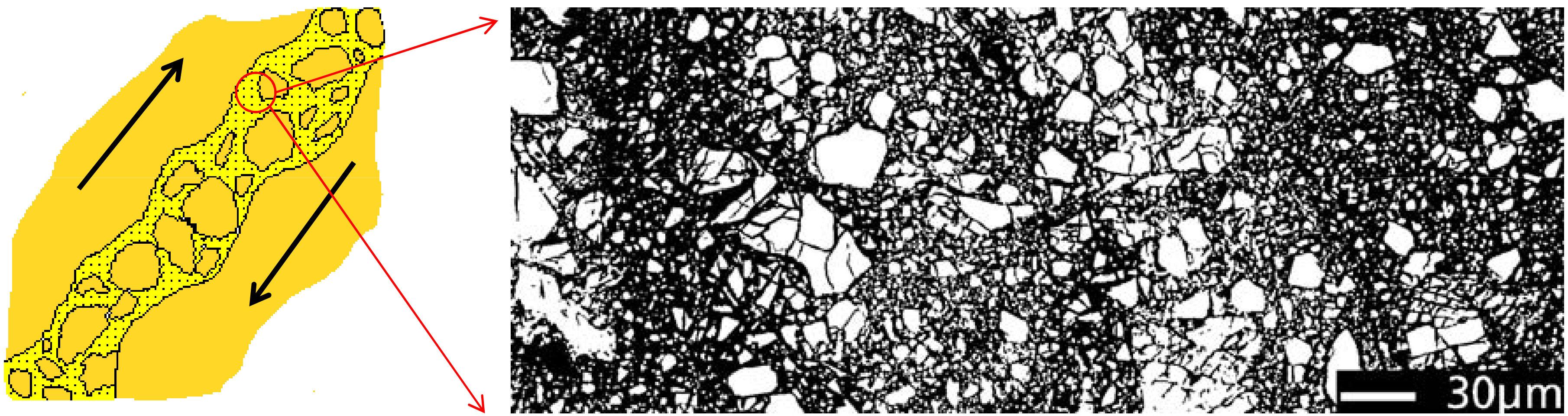
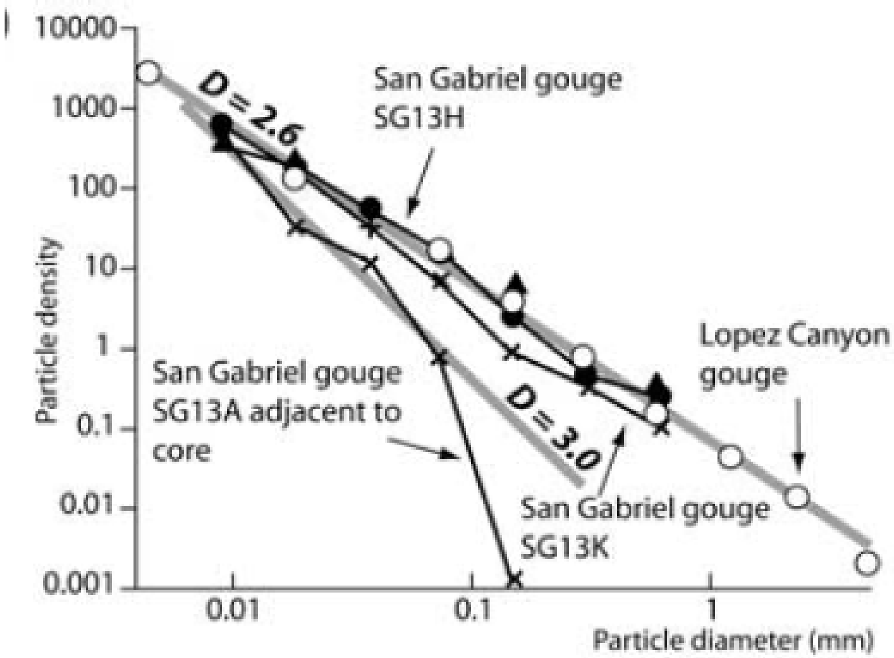


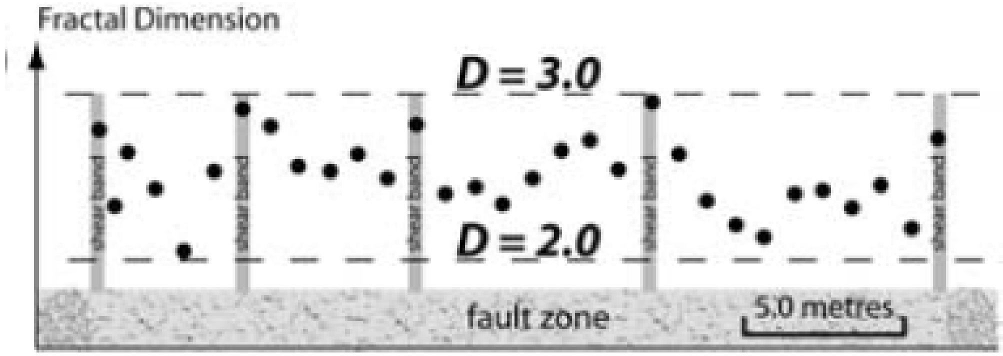
Heilbronner & Keulen 2006

- ➢断層破砕物＝大きさ分布はベキ的
- ➢ 指数はひずみ量に伴い増大

particle-size distribution = power law



(Chester et al. 1993)



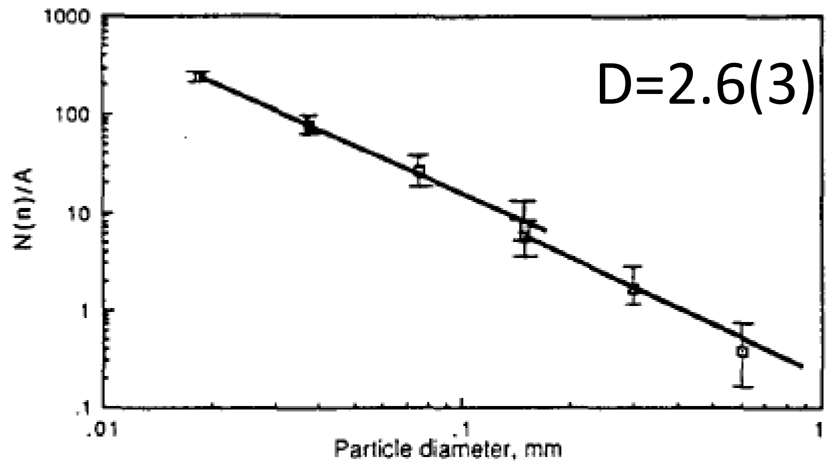
- Exponent D = 2.0 – 3.0
- depends on the strain?

Sammis1987, Blenkinsop 1991, Storti et al. 2003

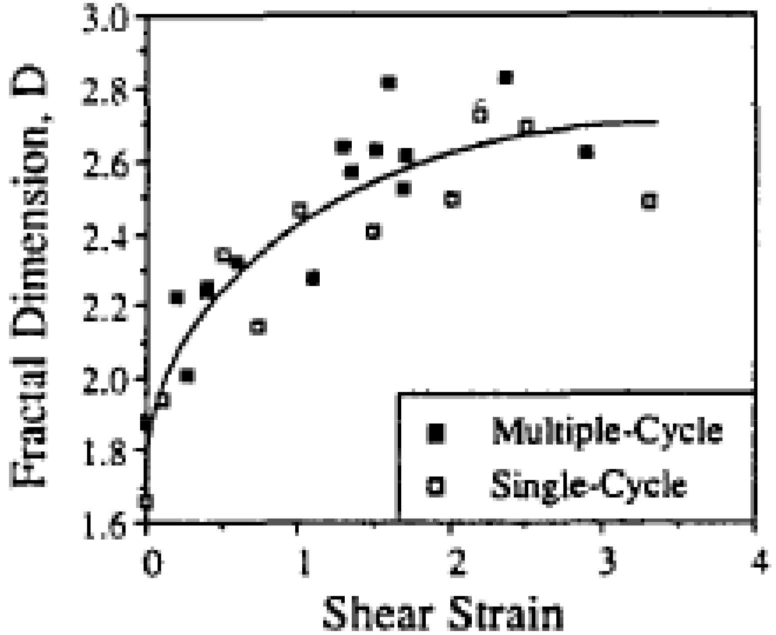
NOTE: exponent different from impact fragmentation
(e.g. D=1.3-1.6)

laboratory experiments

experiments on wear and comminution of rock



Biegel, Sammis, Dieterich 1989



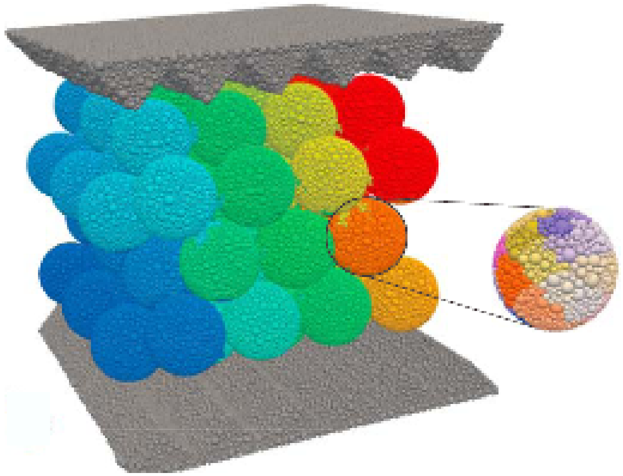
Marone & Scholz 1989

D = 1.9 - 2.9

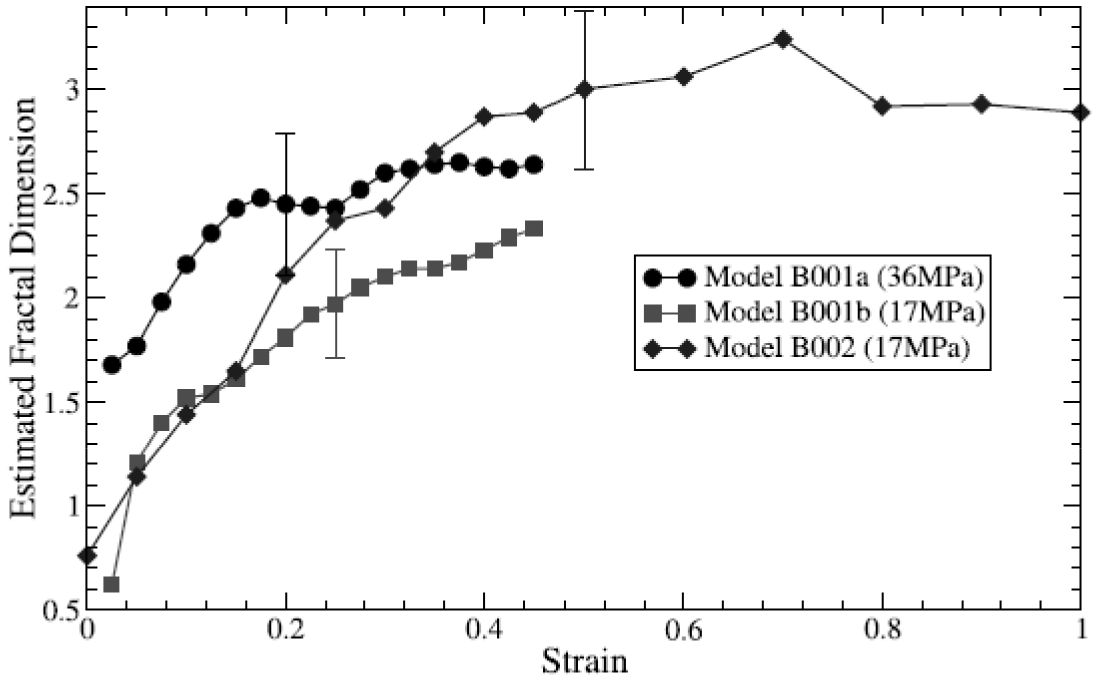
also Marone & Scholz 1989, An & Sammis 1994, Stuniz et al. 2009, etc.

exponent “D” depends on the strain

numerical experiment



Abe & Mair 2005

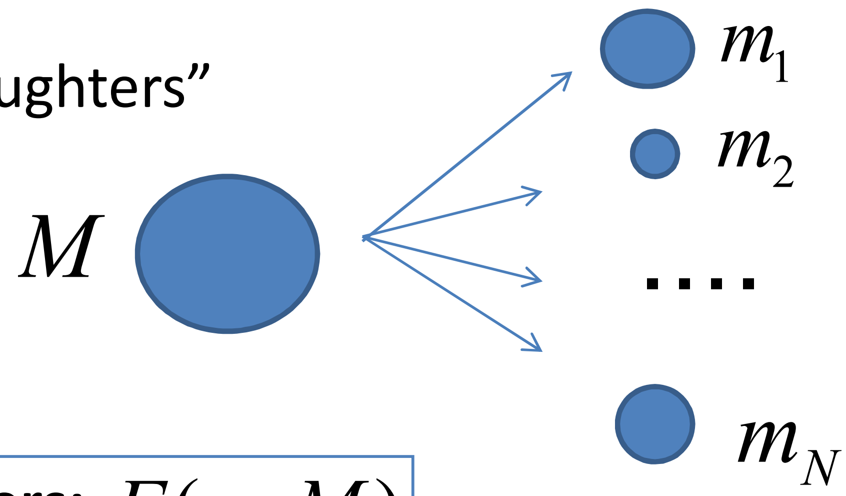


- ➢exponent “D” depends on the strain
- ➢ “D” approaches 3?

model: elementary process

<u>an elementary process</u>

a grain is broken up into "daughters"

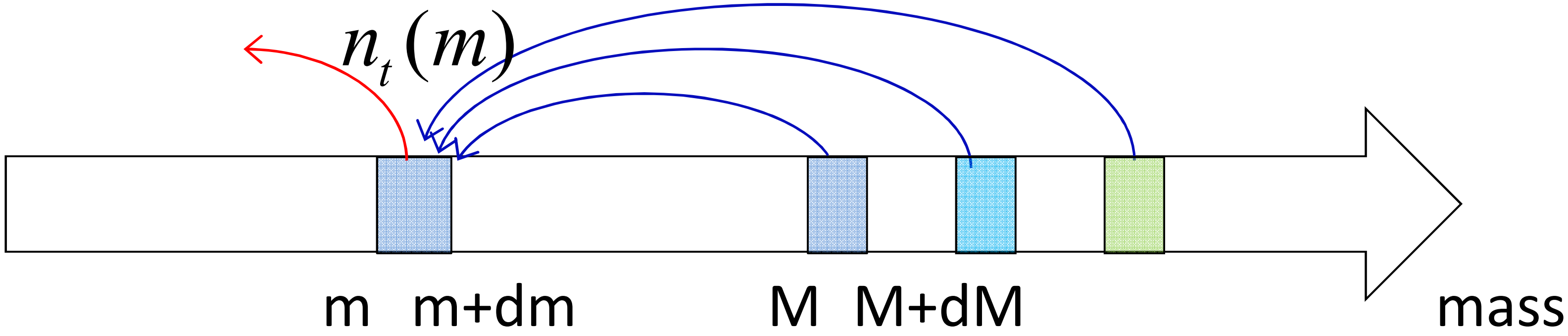


1. mass distribution of daughters: $F(m, M)$

- mass conservation: $\int_0^M dm F(m, M) m = M$

2. k(M): frequency of fracture ("reaction" rate)

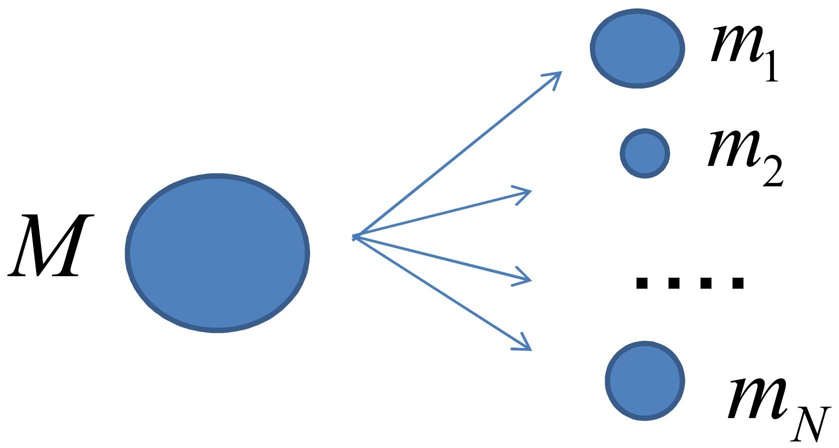
time evolution of particle-size distribution



$$\dot{n}_t(m) = \int_m^{M_0} dM k(M) n_t(M) F(m,M) - k(m) n_t(m)$$

trivial steady state $n_{ss}(m) = \delta(m_{\min})$

scale-free assumption



if $M \to \lambda M$

then $m_i \to \lambda m_i$

$$F(m,M) = M^{-1} f\left(\frac{m}{M}\right)$$

$$\dot{n}_t(m) = \int_0^1 dx\, x^{-1} k\left(\frac{m}{x}\right) n\left(\frac{m}{x}\right) f(x) - k(m) n(m)$$

$$x \equiv m / M$$

simplified equation

nontrivial steady state

$$\int_0^1 dx x^{-1} k\left(\frac{m}{x}\right) n\left(\frac{m}{x}\right) f(x) - k(m)n(m) = 0$$

$\longrightarrow$ $$n_{ss}(m) \propto m^{-2} k^{-1}(m)$$

irrespective of f(x) !

k(m): *"fracture frequency"*

if uniform probability (k(m) = const.)

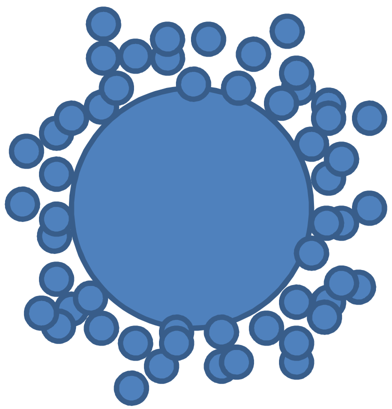
$\longrightarrow$ $$n_{ss}(m) \propto m^{-2}$$ D=6 too large!

(mass) ∝ (size)^3

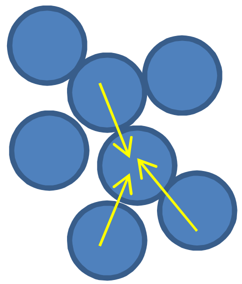
more plausible estimate of k(m) ?

k(m) depends on the configuration

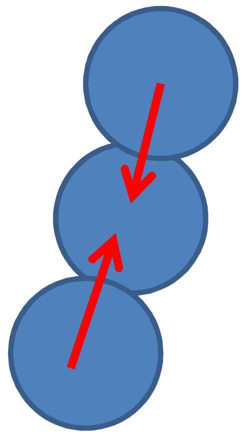
large differential stress → fracture



hydrostatic



large differential stress

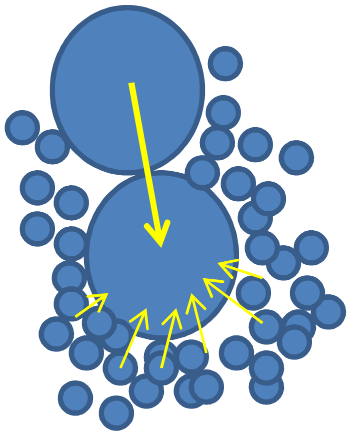


<u>experimental observation</u>

most grains undergo tensile fracture under uniaxial compression

(e.g. Marone & Scholz 1989)

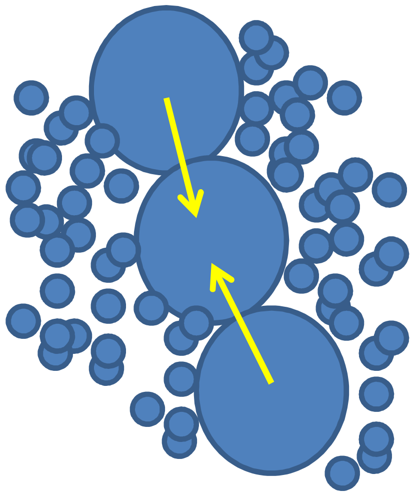
probability of having similar-sized neighbors



one similar-sized neighbor

$$k(m) \propto \frac{n(m)}{N_{tot}}$$

(population)



two similar-sized neighbors

$$\left(\frac{n(m)}{N_{tot}}\right)^2 \ll \frac{n(m)}{N_{tot}}$$

negligible

exponent of steady-state solution

$$\left.\begin{aligned} n_{ss}(m) &\propto m^{-2}k^{-1}(m) \\ k(m) &\propto \frac{n(m)}{N_{tot}} \end{aligned}\right\} \longrightarrow \quad n_{ss}(m) \propto m^{-1}$$

PSD exponent

(mass) ∝ (size)^3

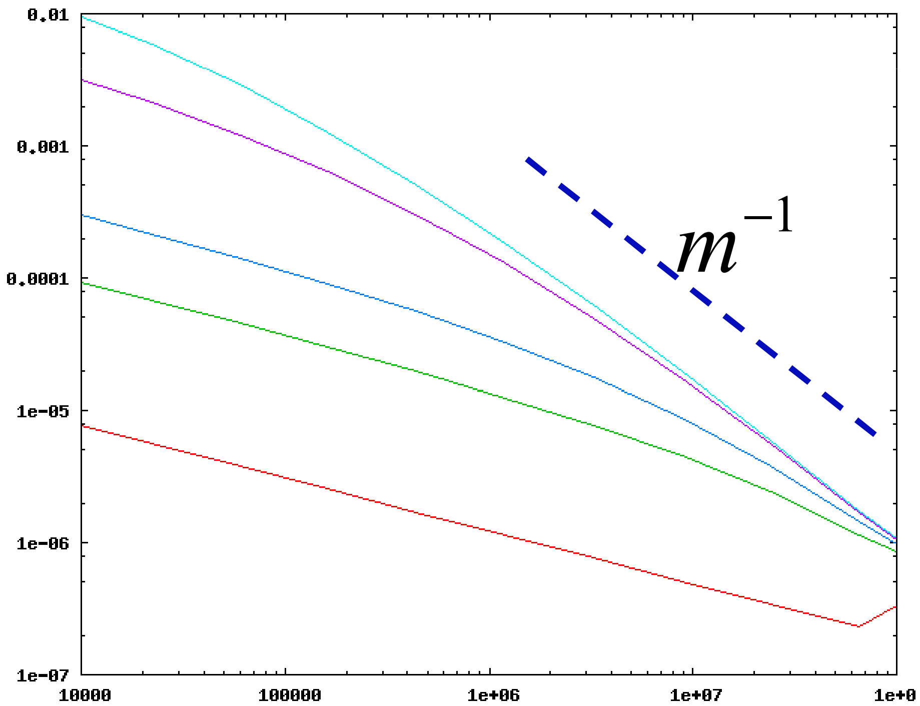
D=3

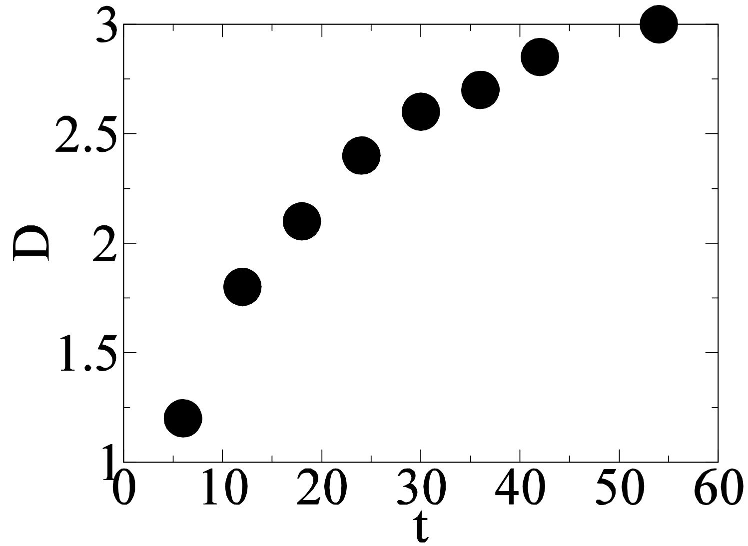
obtain exponent "D=3"

transient behavior

$$\tau \dot{n}_t(m) = \int_m^{M_0} dM k(M) n^2{}_t(M) M^{-1} f\left(\frac{m}{M}\right) - n^2{}_t(m)$$

a model: $f(x) = const.$ $n_0(m) = const.$





explain experiments and field observations