Non-equilibrium dynamics in « electron glasses »: indications of a universal temperature dependence

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+

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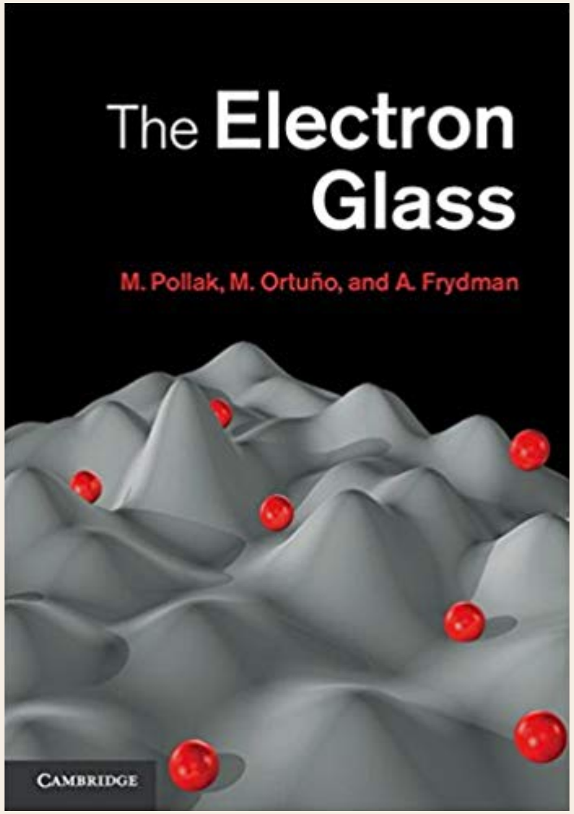
A. Frydman, Tal Havdala *(Bar Ilan)*

M. F. Orihuela, M. Ortuno, A. M. Somoza, J. Colchero, and E. Palacios-Lidon *(Murcia)*

What is an electron glass ?



- **structure** : disordered landscape → disordered electronic arrangement (Efros-Schklovskii …)

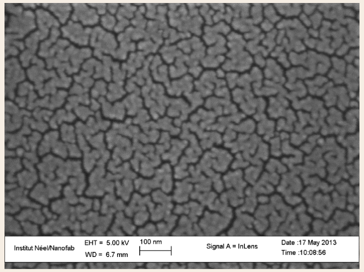
- **dynamics** : slow relaxation, ageing, (thermo-)dynamical glass transition ?

How does it compare to other glasses (structural, spin …) ?

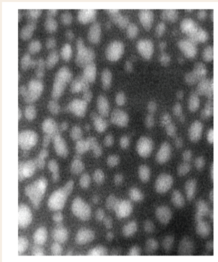
The « electron glass zoo »

Metals

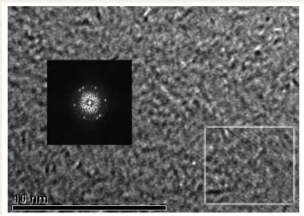
Discontinuous metals
Au, Ag, Ni, Al
(Adkins 1984, Frydman et al.)



Granular Al
(Grenet & Delahaye)



Ultra thin continuous(?) metals
Pb, Bi, (granular ?)-Be
(Goldman et al., Ovadyahu et al.)



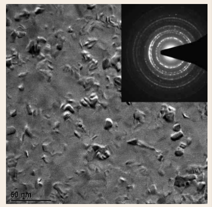
Oxydes

Amorphous or Microcrystalline
In_2O_{3-x} , Tl_20_{3-x}
(Ovadyahu et al.)

Metal-SC alloys

Amorphous NbSi
(Delahaye et al.)

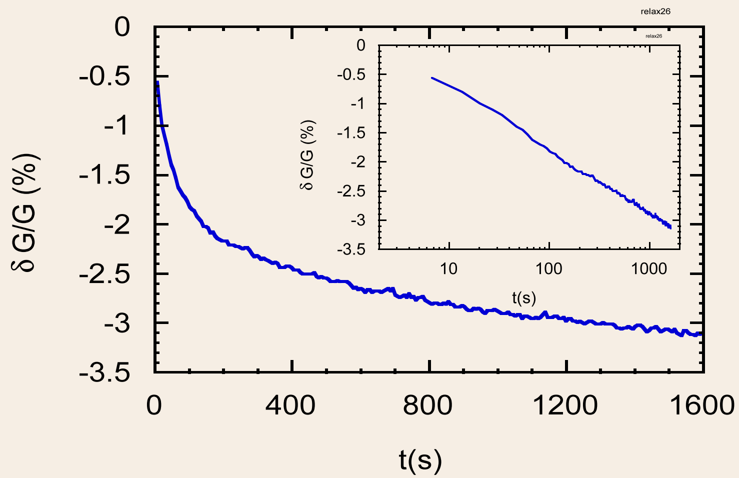
Microcrystalline (Sb,Bi)GeTe
(Ovadyahu)



Manifestations of glassiness

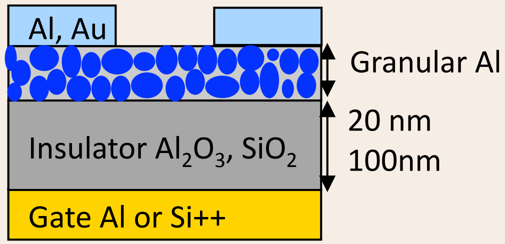
Systems are never in equilibrium:

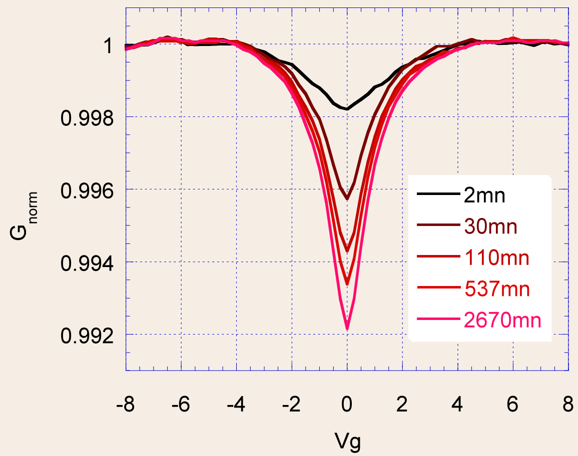
Ex: *G* relaxation after a cool down

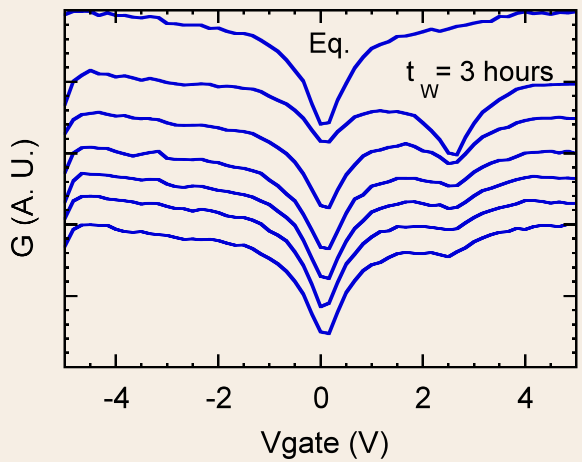


Playing with a gate:

The memory dip

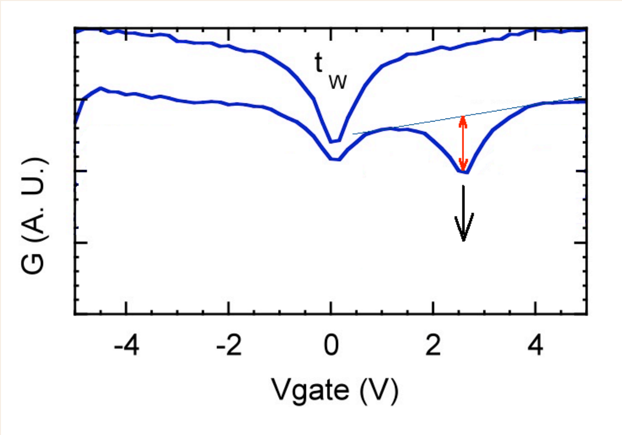


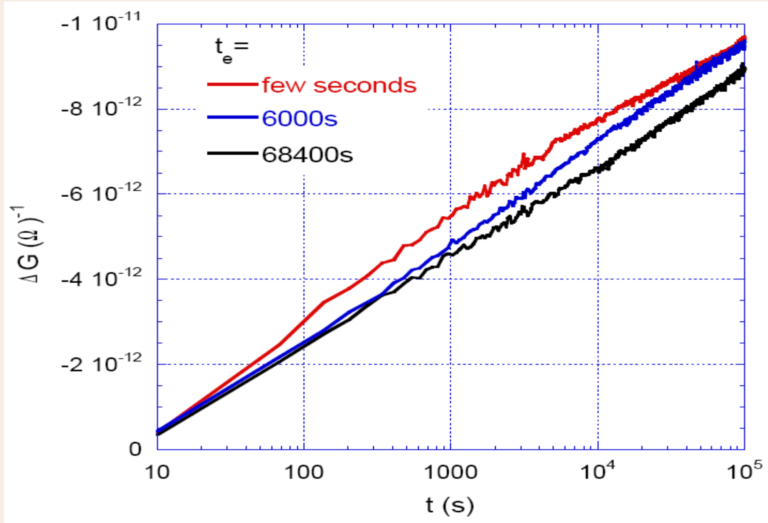


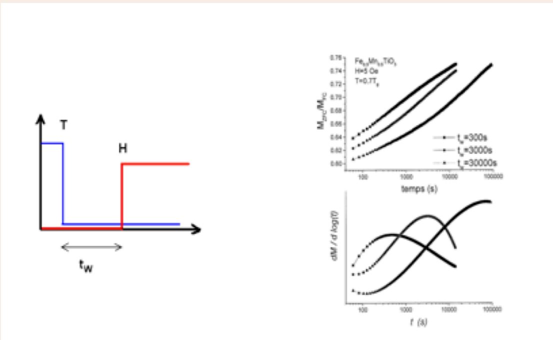


T. Grenet, J. Delahaye et al., Eur. Phys. J. B 56, 183–197 (2007)

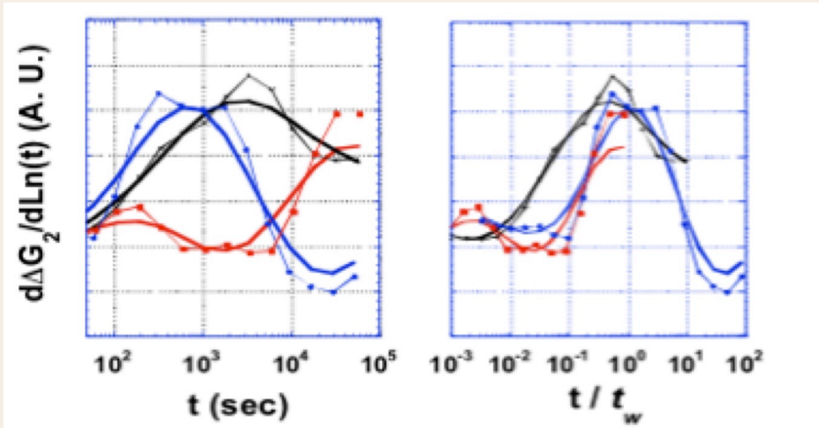
Ageing







Spin glasses



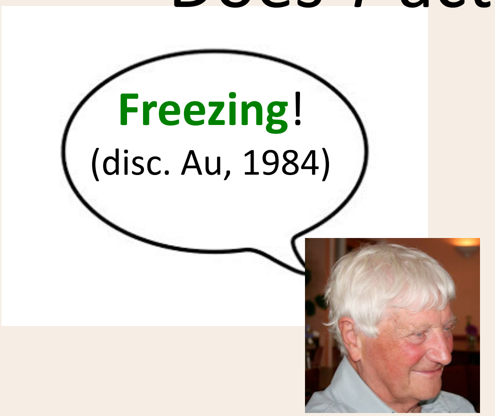
Effective relaxation time distribution
scales with system's age (*time since cooldown*)

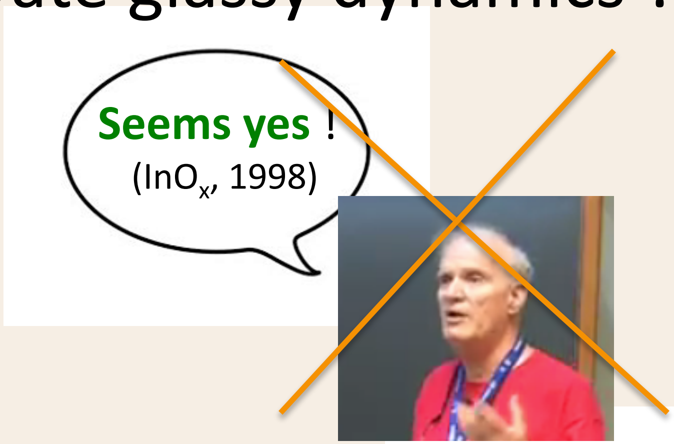
Grenet & Delahaye, Eur. Phys. J. B 76, 229–236 (2010)

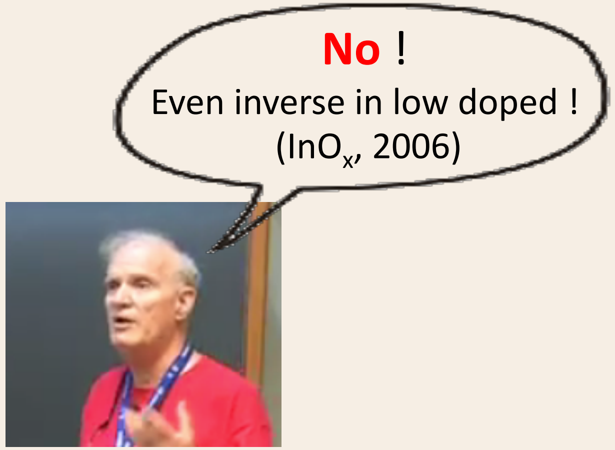
Effect of temperature ?

T_g ?

Does *T* activate glassy dynamics ?

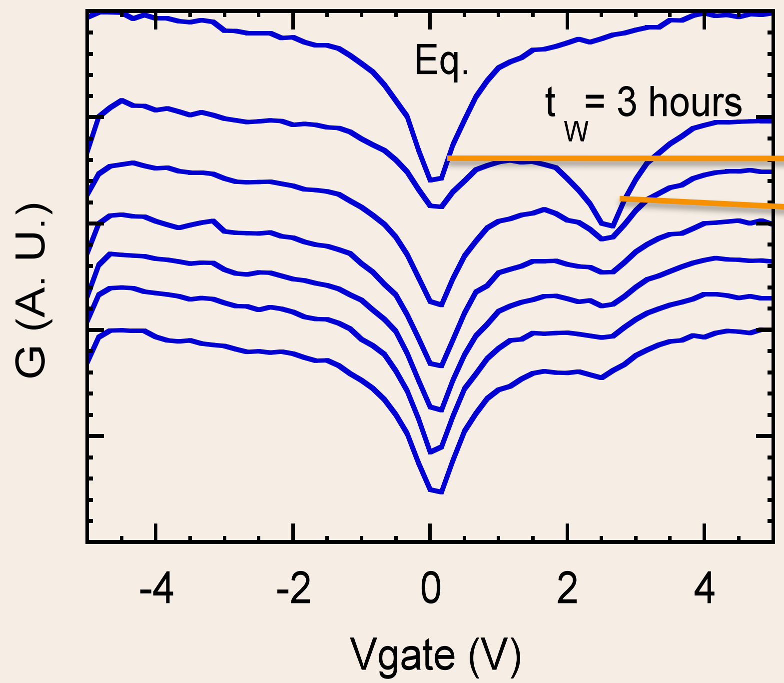


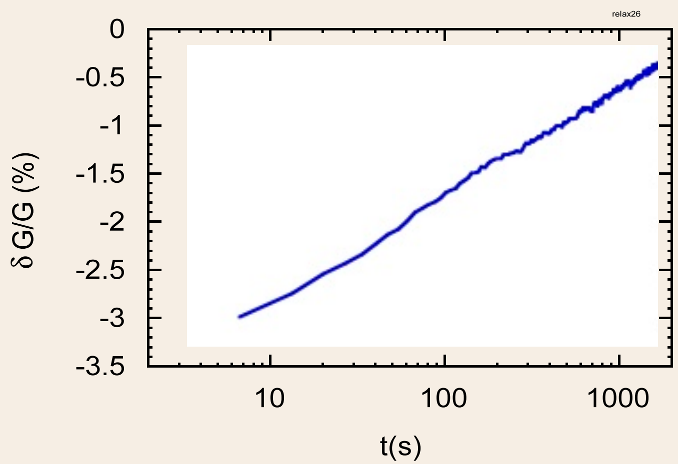




How to study the effect of *T* ?

Measure memory dip growth at various *T* ?





Non saturating Ln*t* relaxation …

- no characteristic time
- don't know how to compare slopes at ≠ T

→ No way !

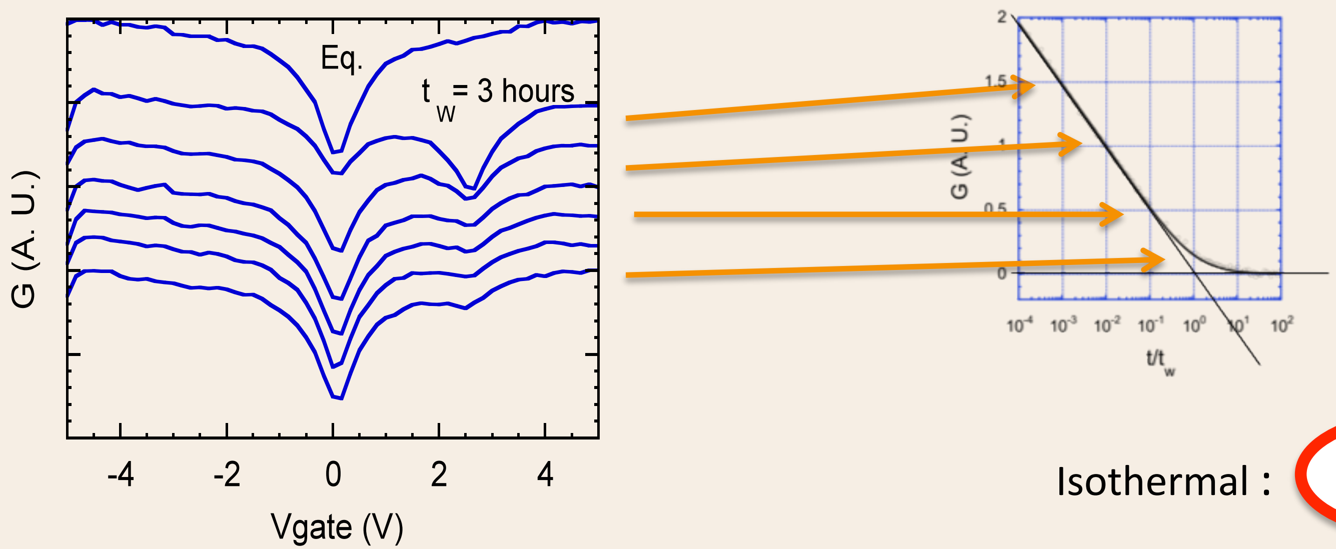
How to study the effect of T ?

Two temperatures protocol :

- « write » a memory dip at T_1 for t_w

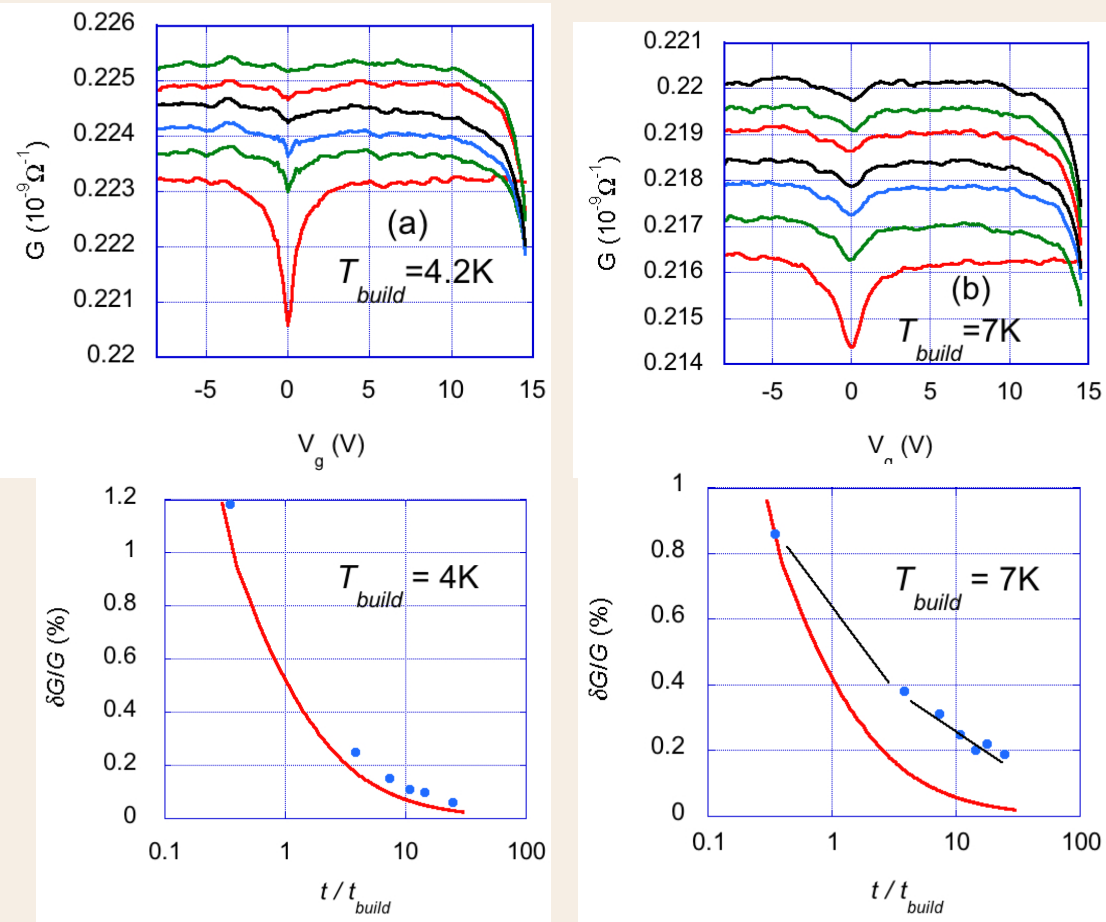
- erase it at $T_2 \neq T_1$

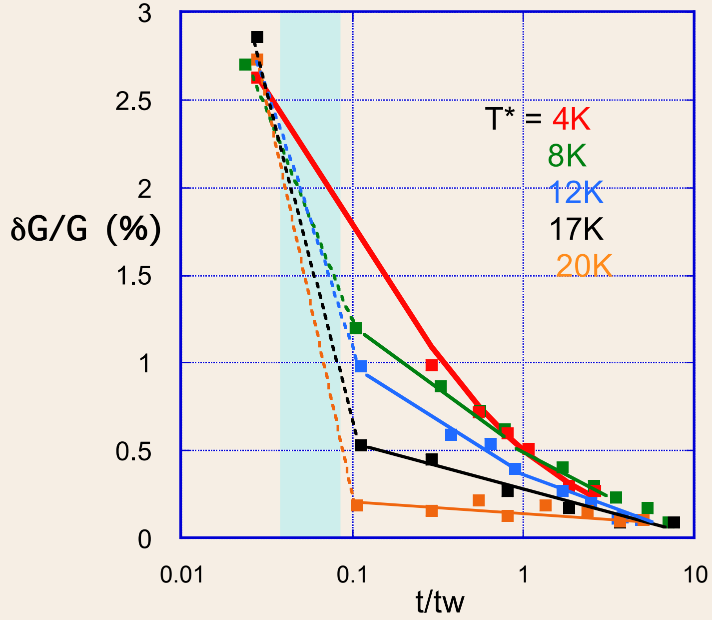
- Compare erasure kinetics to the isothermal case



Isothermal : $Ln(1+t_w/t)$

Gran-Al : dynamics is activated !





Erasure slows down upon *T* decrease & accelerates during higher *T* excursion

T. Grenet and J. Delahaye, Phys. Condens. Matter **29** (2017) 455602

Effect of temperature ?

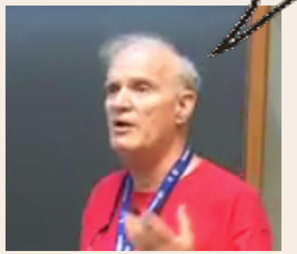
T_g ?

Does *T* activate glassy dynamics ?

Freezing!
(disc. Au, 1984)

Seems yes !
(InO_x, 1998)

No !
Even inverse in low doped !
(InO_x, 2006)



No !
(gran Al, 2007)

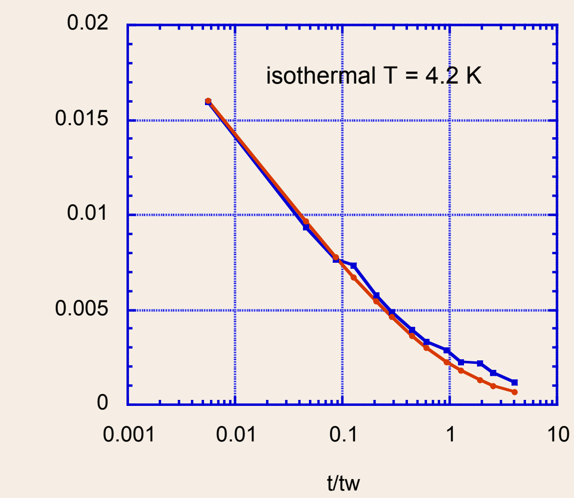
Yes !
(gran Al, 2017)

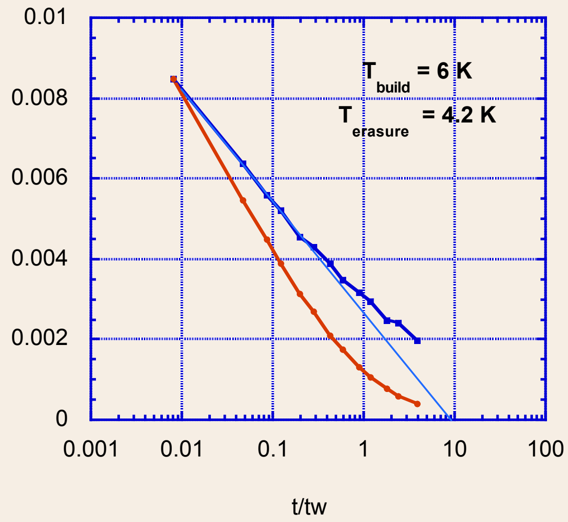
Yes !
(disc. Metals, 2012)

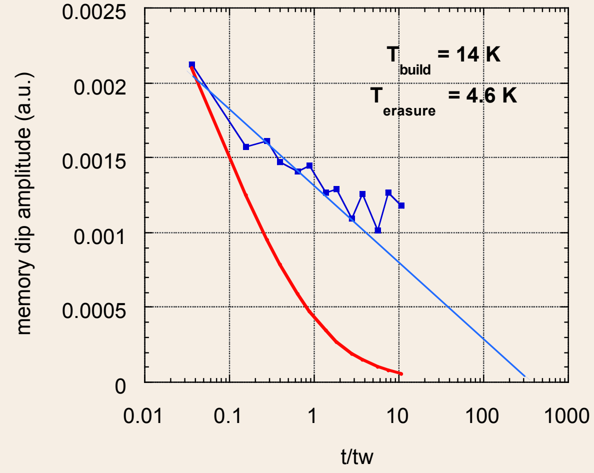
Yes !
(a-NbSi, 2014)

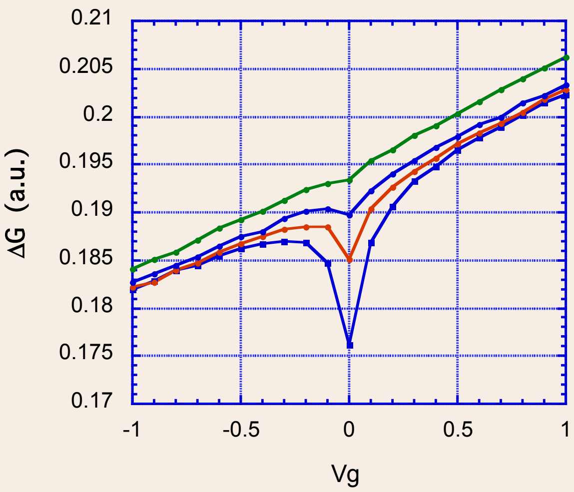
InO_x : dynamics is activated as well !

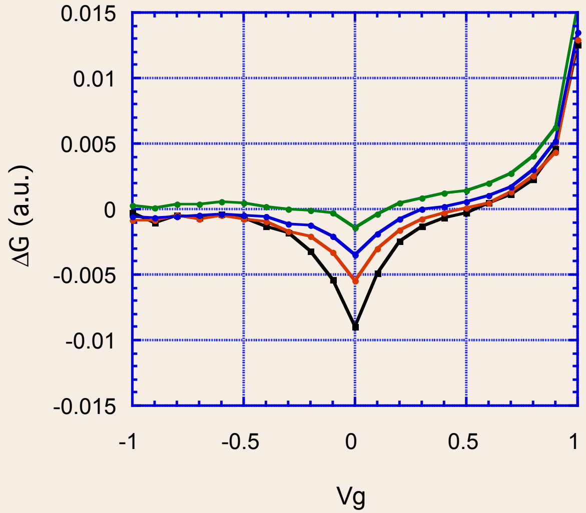
a-InO_x, *R*(4K)=*15 Gohms*

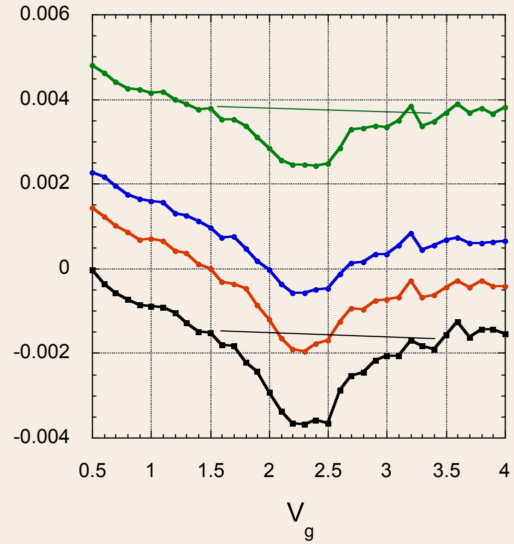












In all cases investigated, dynamics is activated

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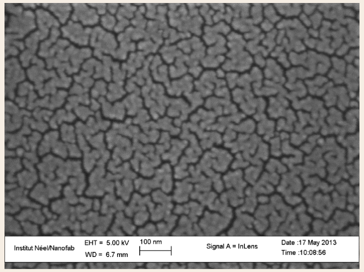
Au, Ag, Ni, Al
(Adkins 1984, Frydman et al.)



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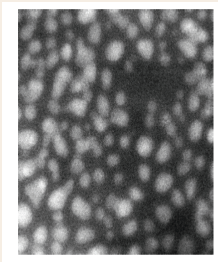

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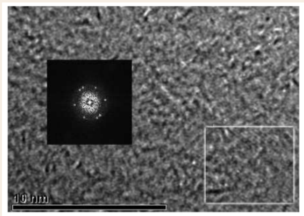

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In_2O_{3-x}, Tl_2O_{3-x}
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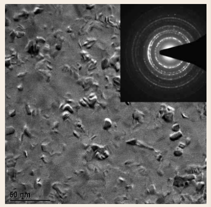
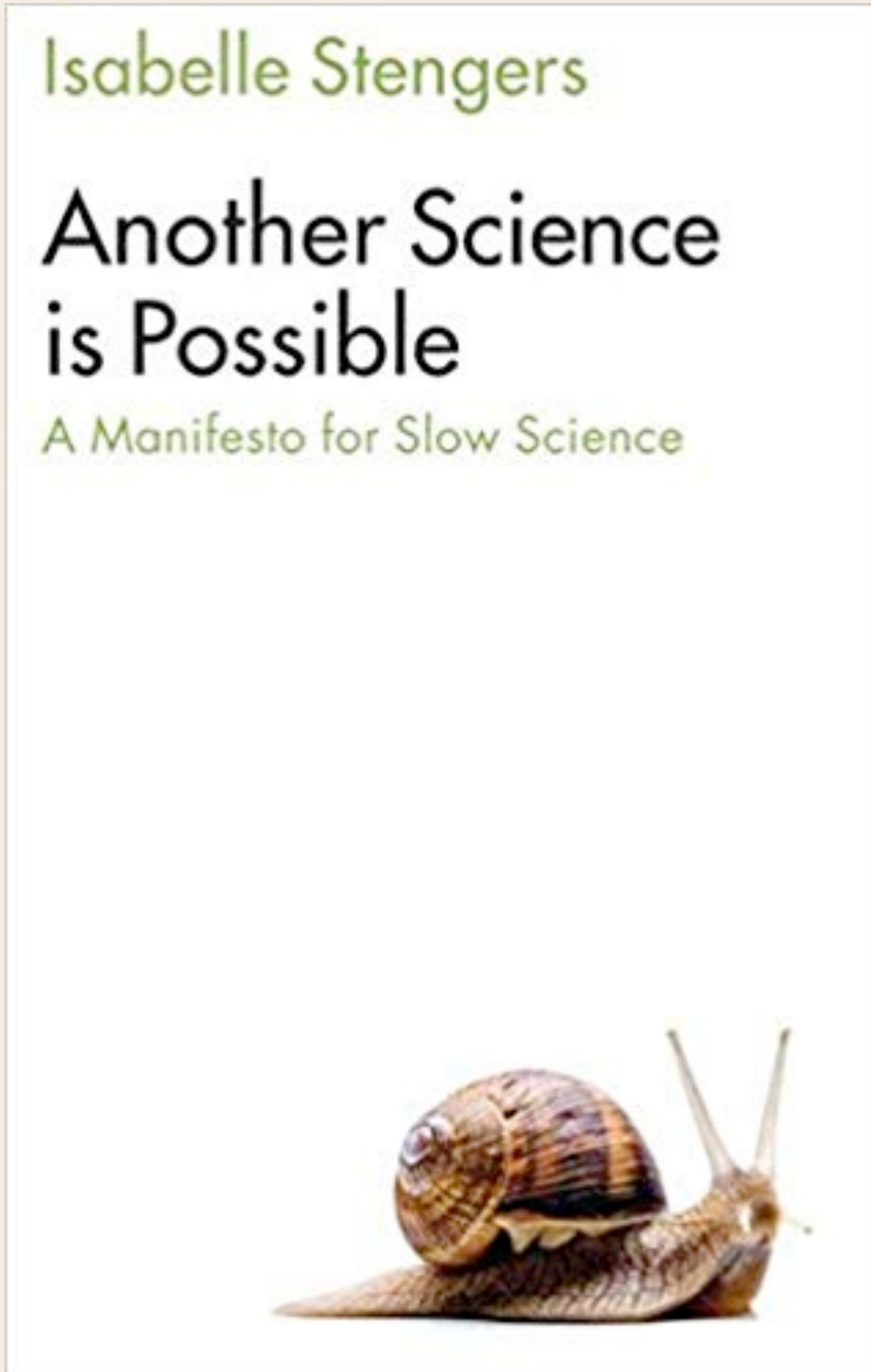
Metal-SC alloys

Amorphous NbSi
(Delahaye et al.)

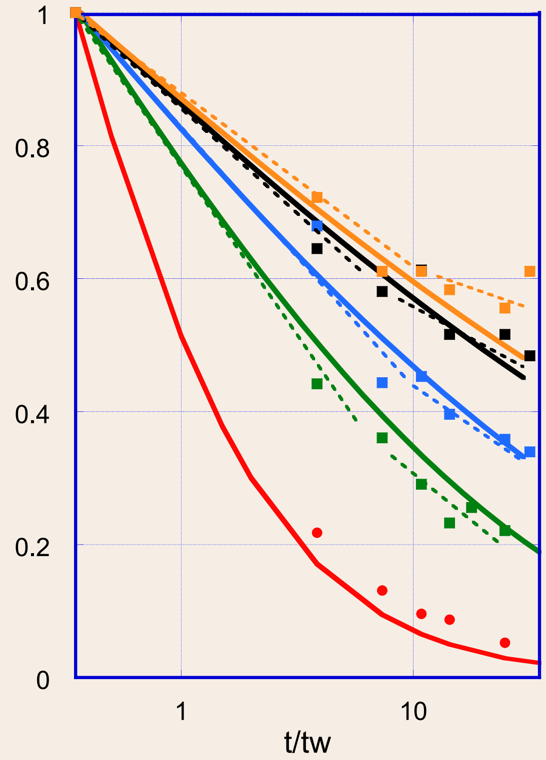
Microcrystalline (Sb,Bi)GeTe
(Ovadyahu)




Isabelle Stengers
Another Science is Possible
A Manifesto for Slow Science

Activation energies ?

Ex: gran-Al



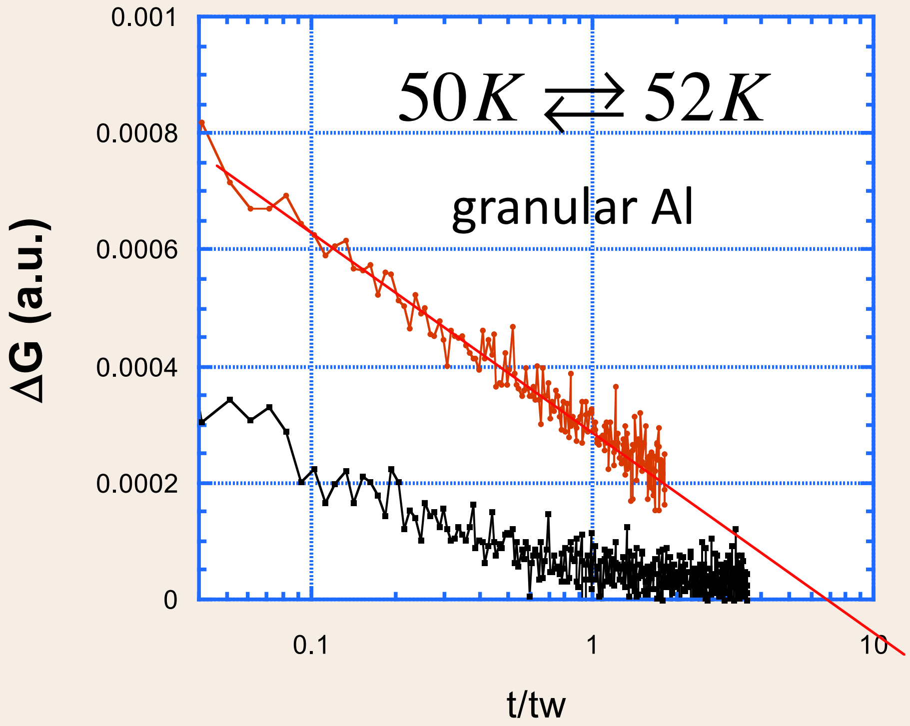
T_{build} = 29K
20K
10K
7K
4.2K

($T_{erasure}$=4.2K)

BUT …

Fit assuming all relaxation times are activated (Arrhenius)

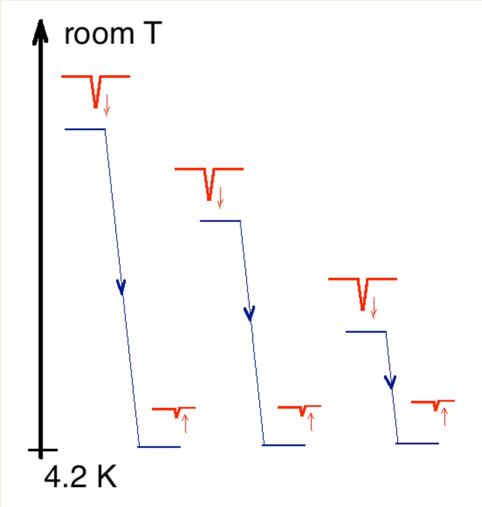
→ E_a = 30 K

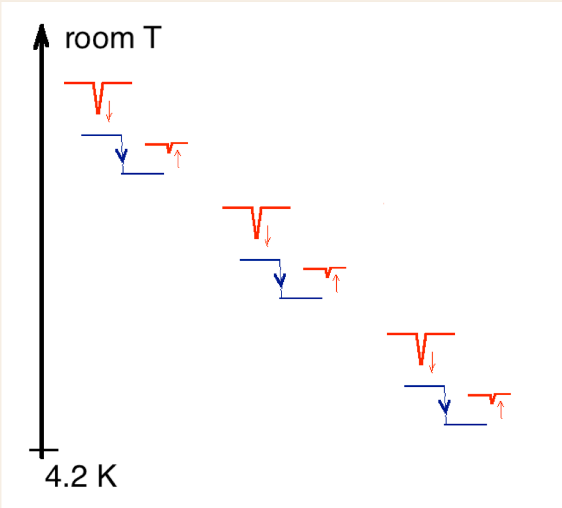


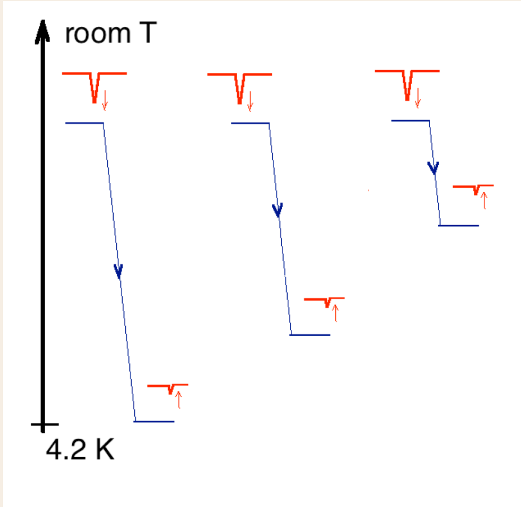
$$E_a \geq 2500K!$$

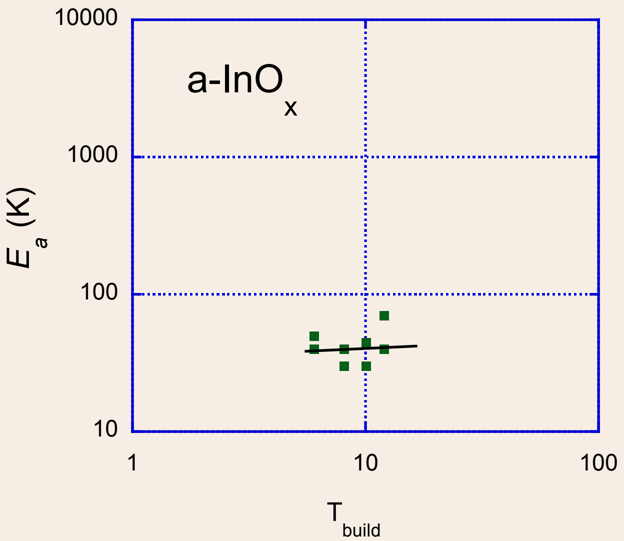
… & the same thing in a-InO_x

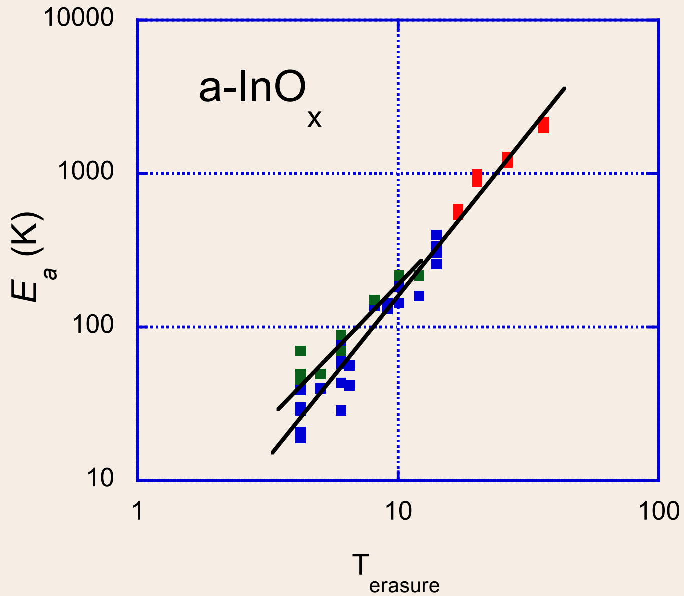
Activation energies ?











Arrhenius behaviour
($E_a \approx$ 40K)

Highly non-Arrhenius
E_a = f(T)

Summary

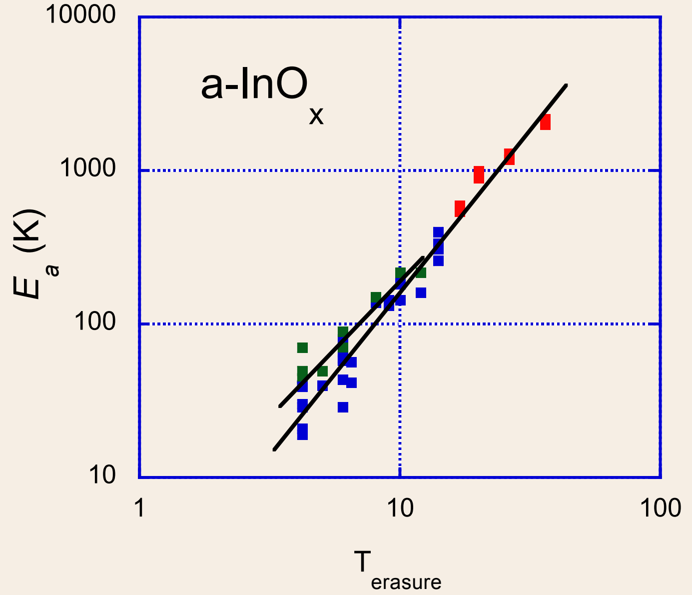
- all systems studied show « activation » of glassy dynamics

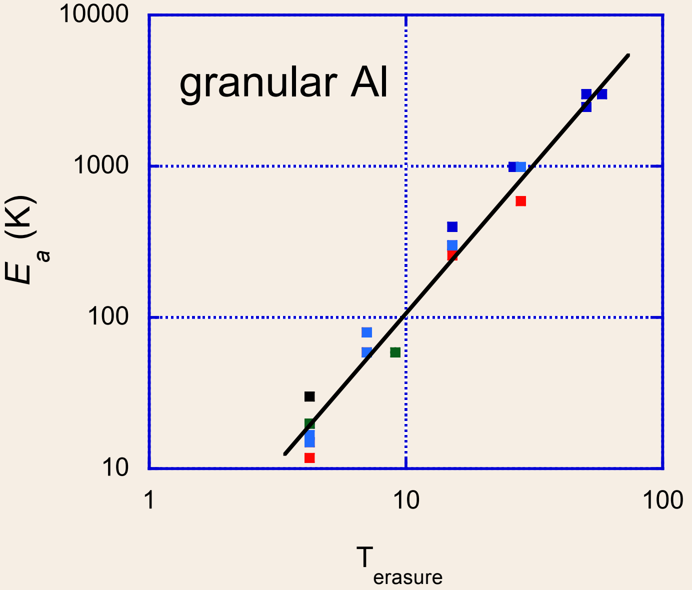
- a-InO_x and gran-Al are strikingly similar

- not arrhenius, E_a is a function of T_{build} and $T_{erasure}$

- <u>approx</u>: E_a is independent of T_{build} and $E_a \propto {T_{erase}}^2$

- unique curve for samples with different resistances





Ideas ?

-E_a depends on T_{erase} but not of T_{build} :

→ because free energy landscape changes with T ?

- $E_a \propto T_{erase}^{\ 2}$, varies faster than T (paradoxical !) :

→because activated + non activated (tunnel) relaxation channels in parallel ?

→Theorists are welcome !