

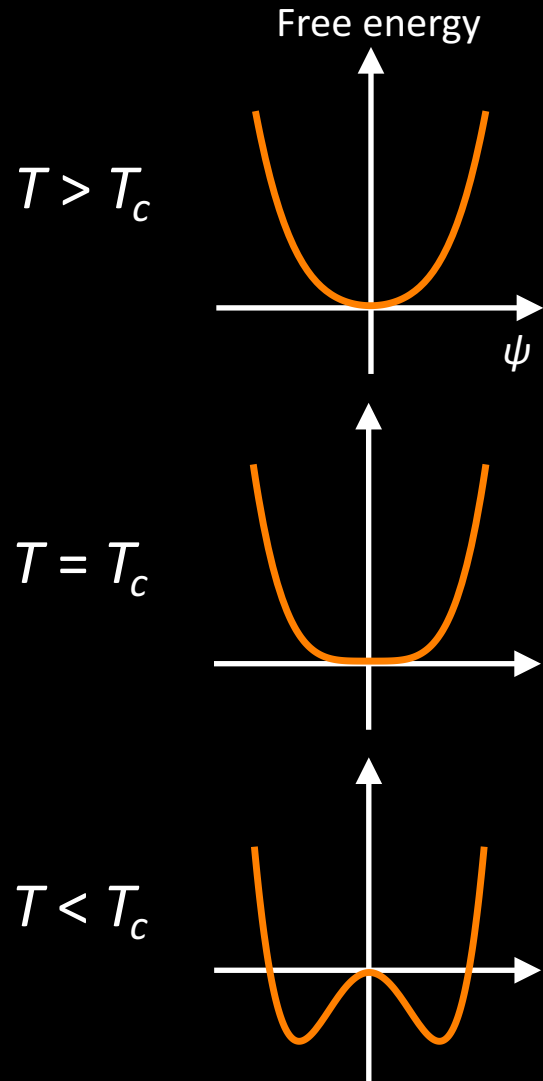
Dynamical slowing down in nonequilibrium phase transitions

Alfred Zong

GEDIK GROUP



In physics...



“As the correlation length diverges, the regions of the system, which represent **fluctuations** about the equilibrium state, get larger and larger; correspondingly, they take longer and longer to relax by whatever is the equilibration mechanism (often diffusion).”

– Nigel Goldenfeld, *Lectures on Phase Transitions and the Renormalization Group*

$$\tau \sim \xi(T)^z \quad \leftarrow \text{Dynamic critical exponent}$$

Time-dependent Ginzburg-Landau equation:

$$\frac{\partial \psi(\mathbf{r})}{\partial t} = -\Gamma \frac{\delta F}{\delta \psi(\mathbf{r})} + \zeta(\mathbf{r}, t)$$

Fluctuations \swarrow

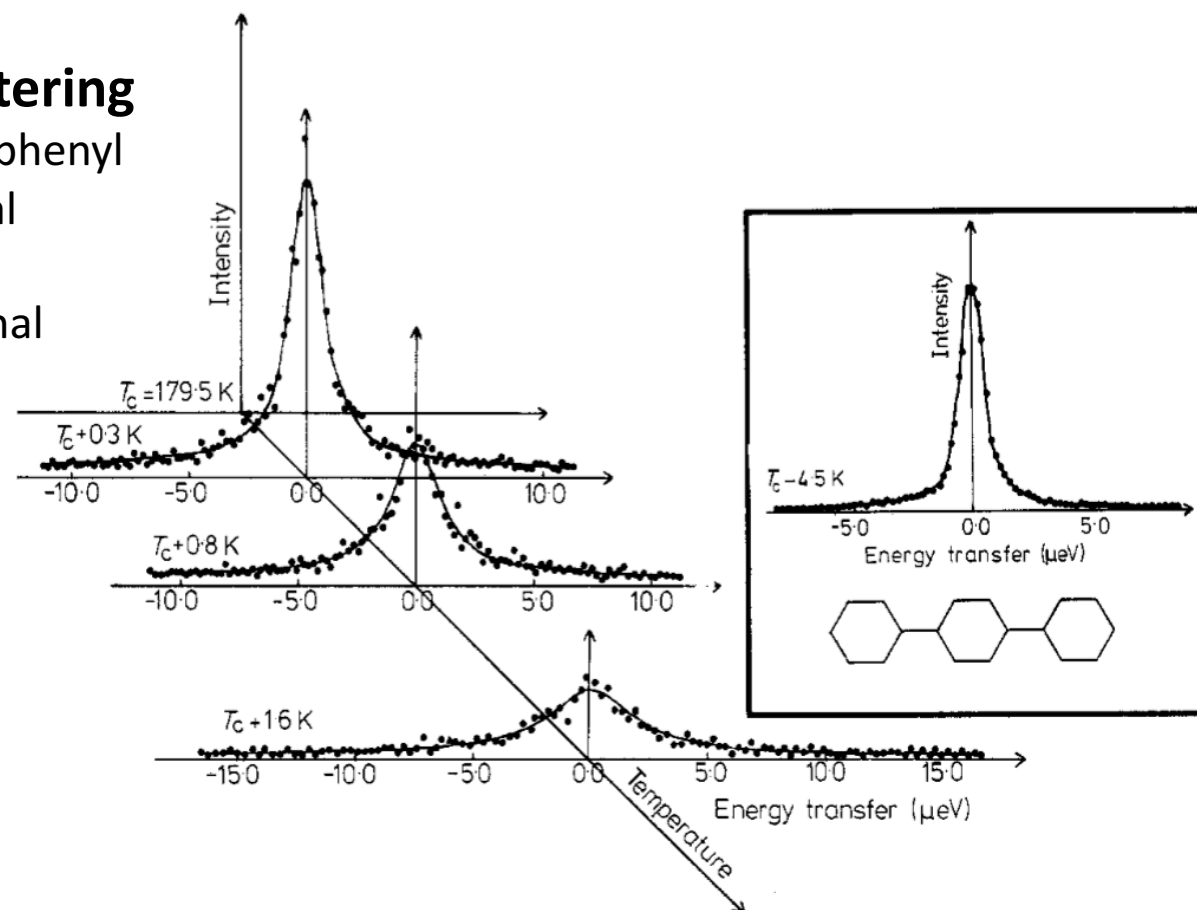
Critical slowing down in equilibrium phase transition

Frequency

Time

Critical quasi-elastic scattering

- Neutron scattering on p-terphenyl
- Antiferrodistorsive structural transition at $T_c = 179.5$ K
- Slowing down of orientational fluctuation



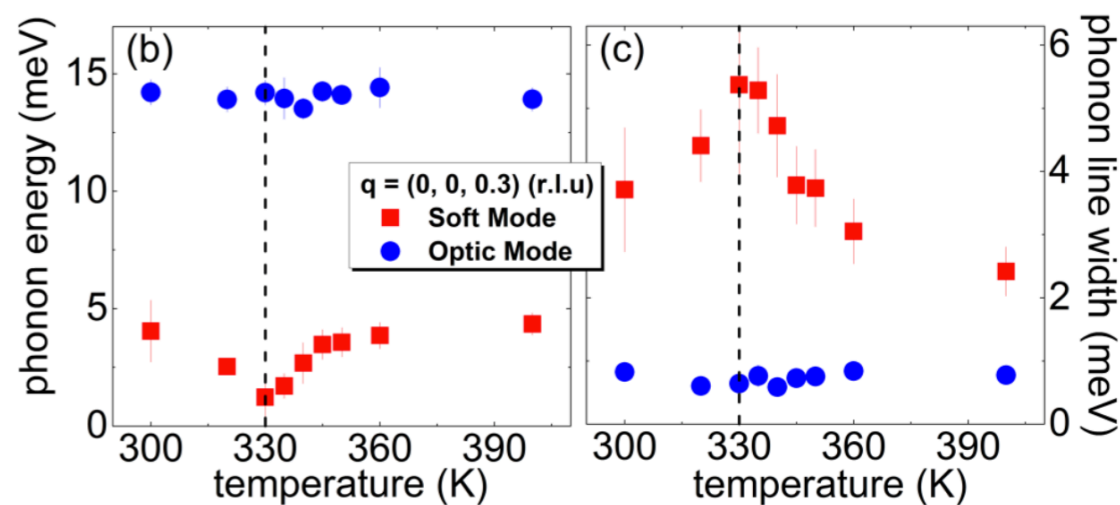
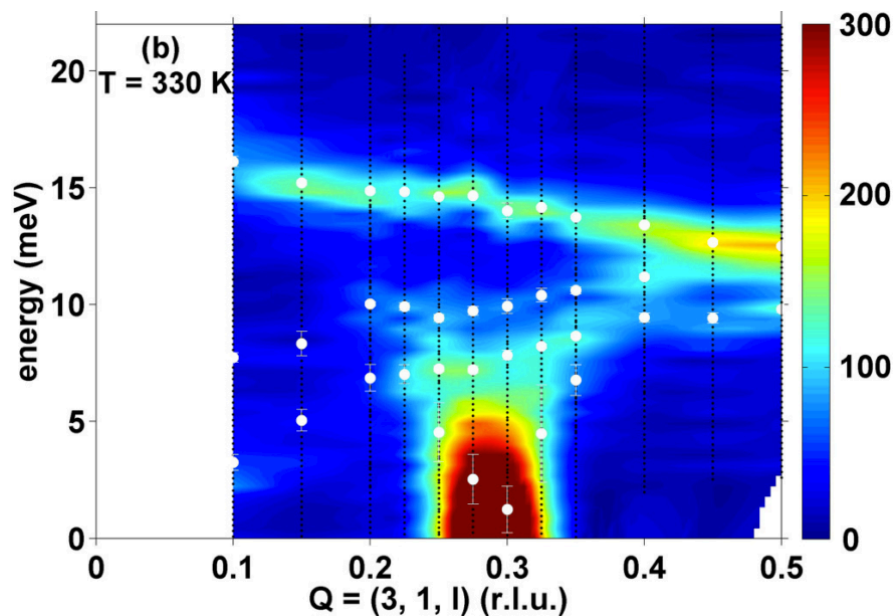
Critical slowing down in equilibrium phase transition

Frequency

Time

Softening of collective mode

- Kohn anomaly in TbTe_3 , $T_{\text{CDW}} = 330$ K

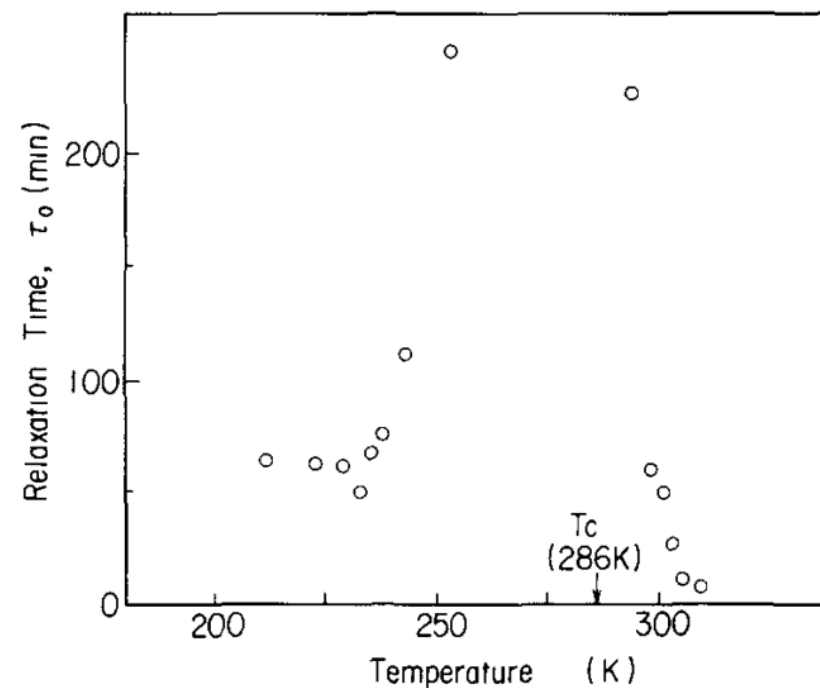
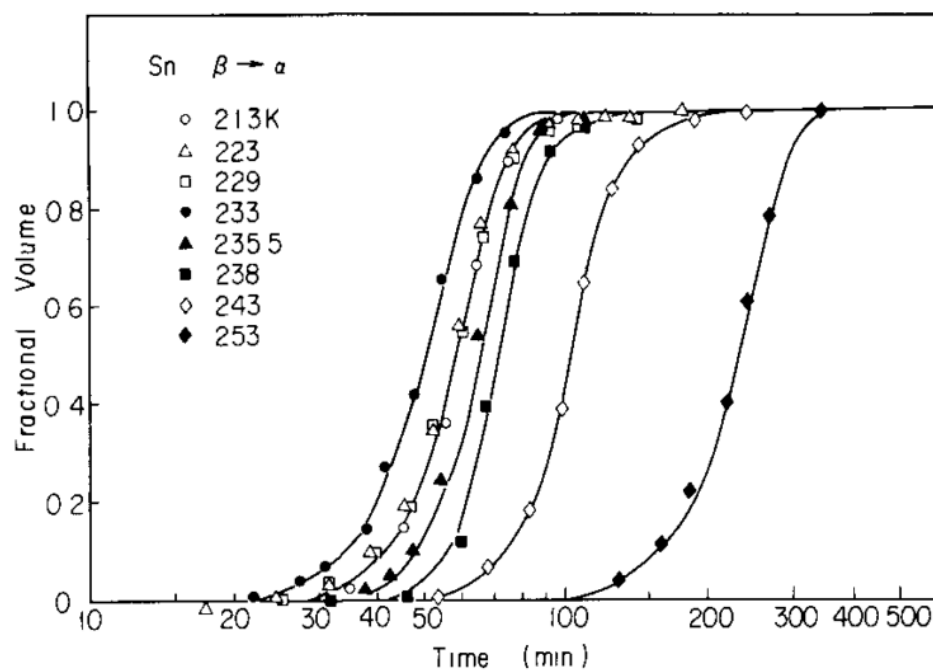


Critical slowing down in equilibrium phase transition

Frequency

Time

- First-order structural transition in Sn: $T_{\beta-\alpha} = 260$ K

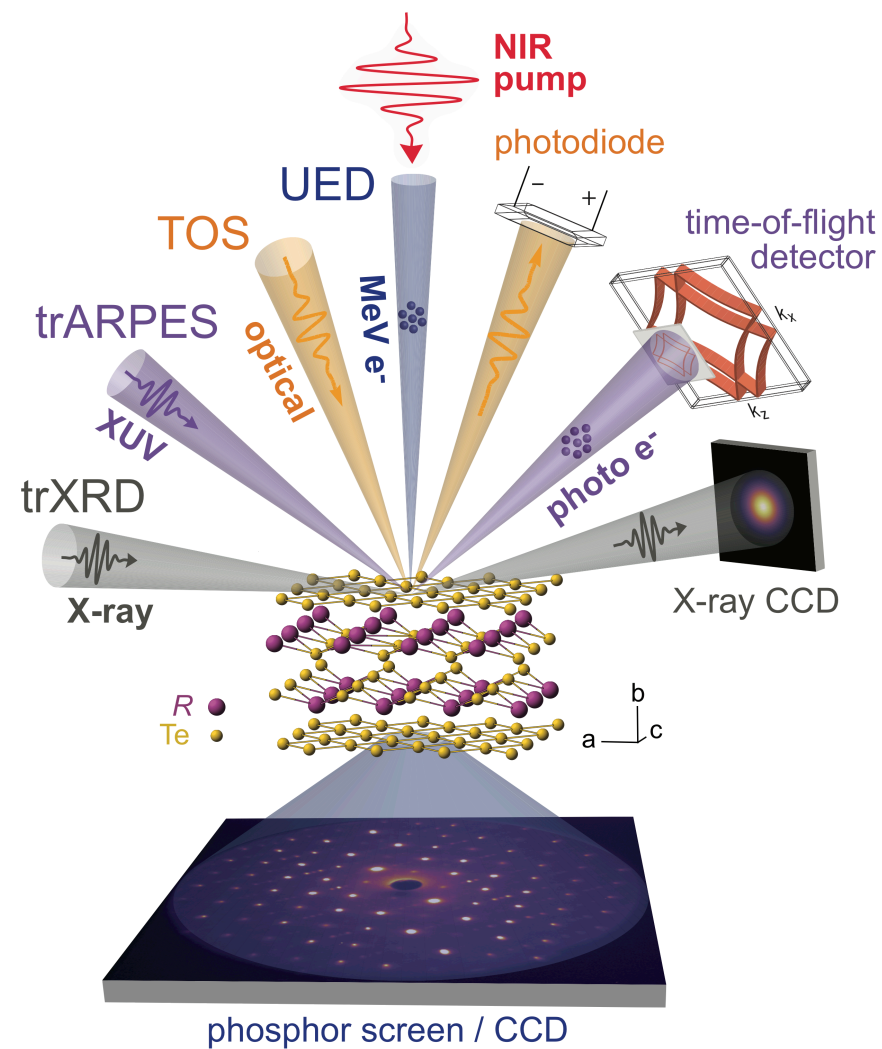
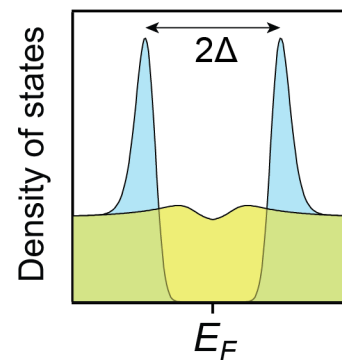
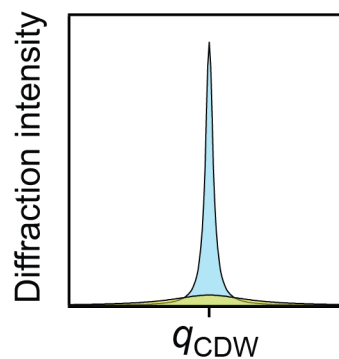
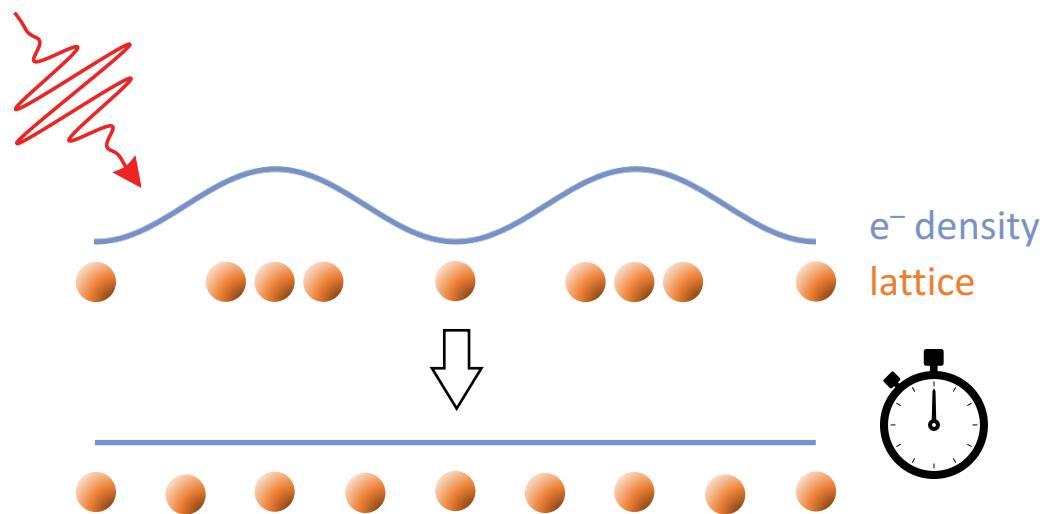


the path ahead

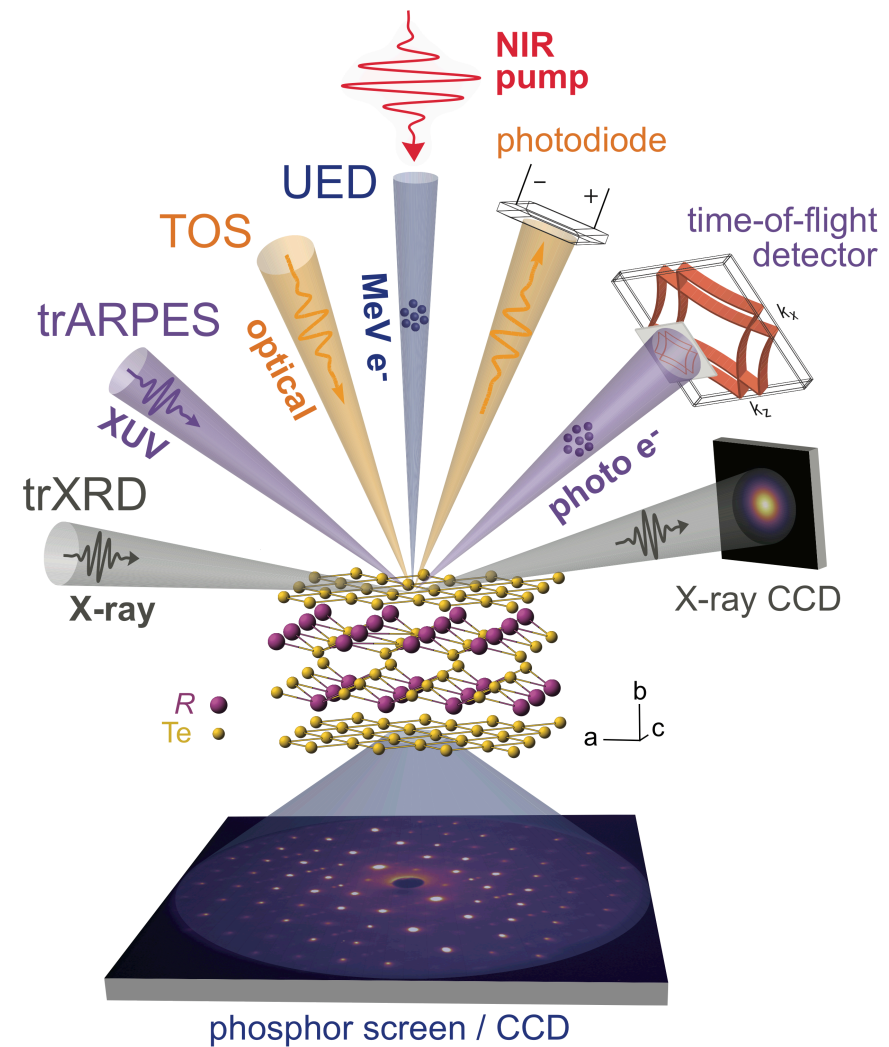
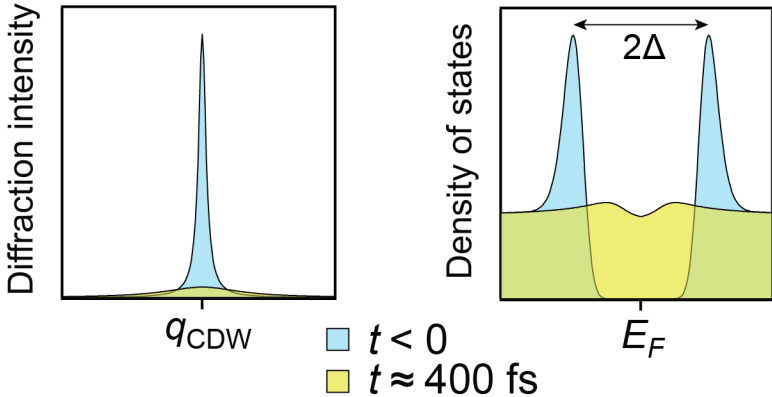
Equilibrium  Nonequilibrium

- Signatures of dynamical **slow**ing down in the ultra**fast** melting of a charge density wave
- Slowing down in other nonequilibrium regimes

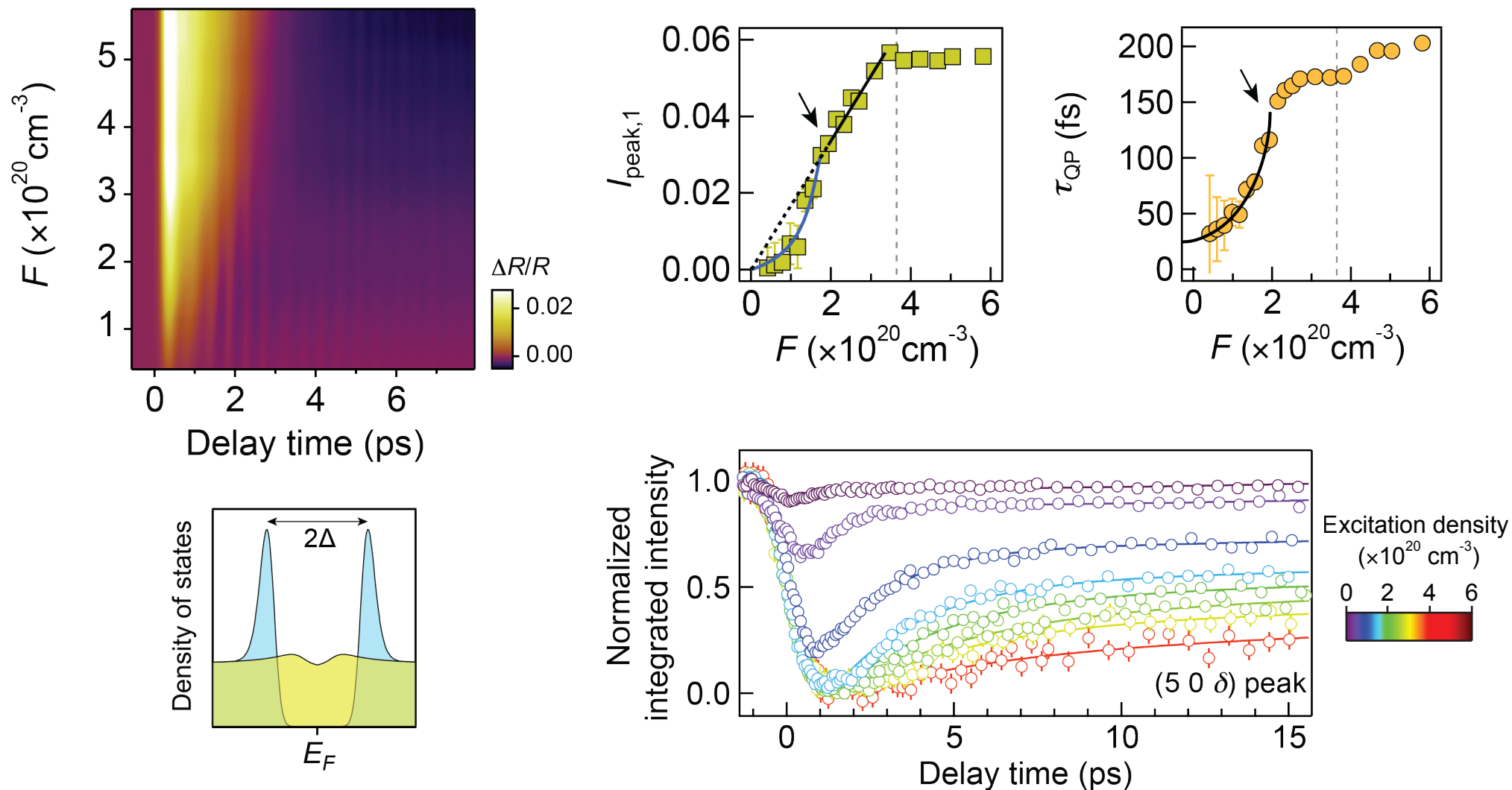
Photo-induced melting of CDW in LaTe_3



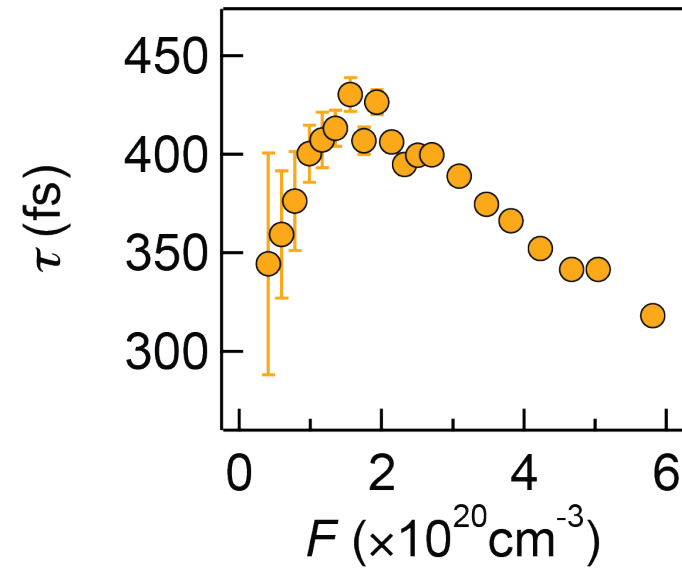
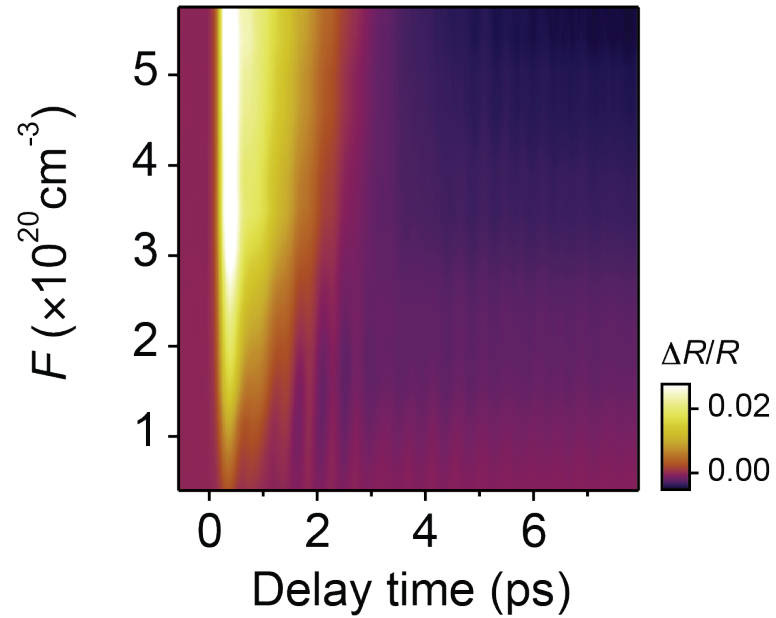
Downloaded from <http://ajph.org/> on November 10, 2014



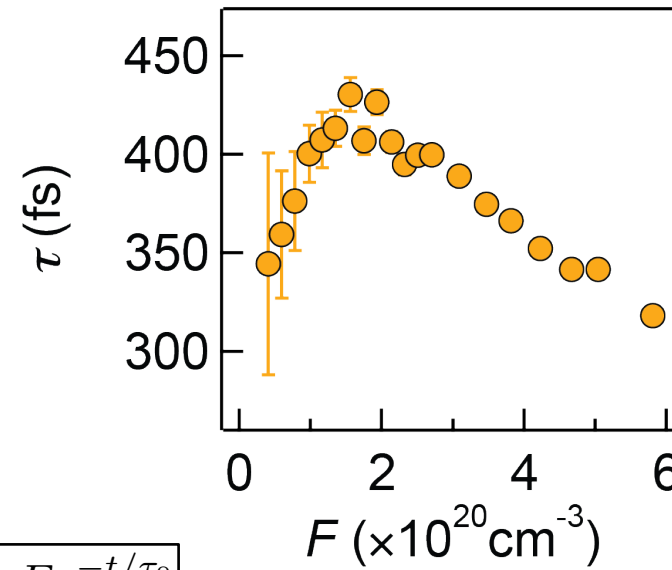
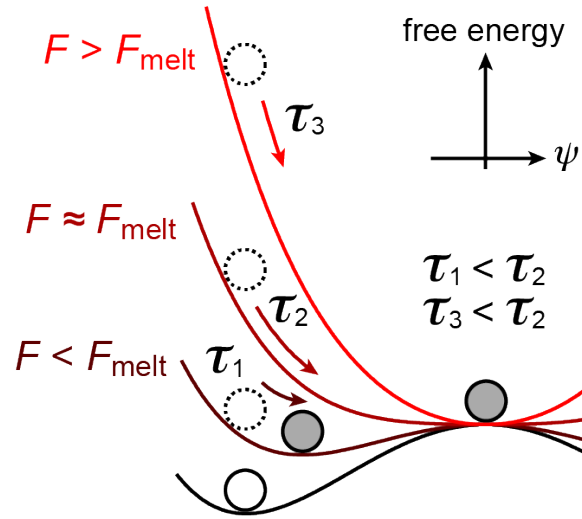
Threshold excitation density



Slowing down at the threshold



Slowing down at the threshold

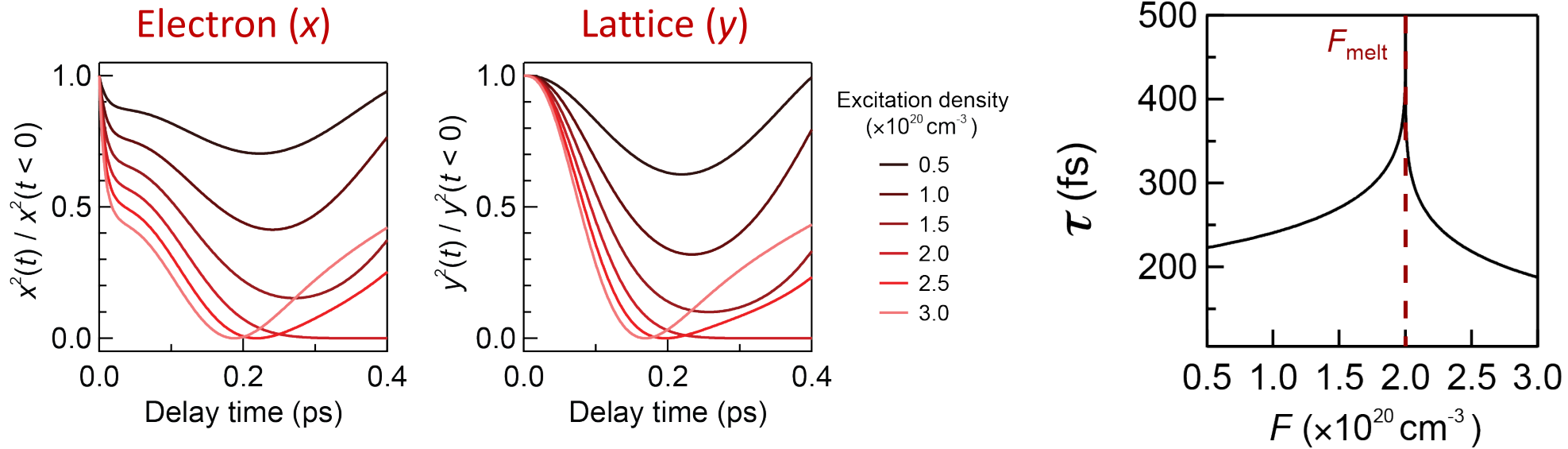


$$\alpha(t) = \alpha_0 - \Theta(t)\kappa F e^{-t/\tau_0}$$

Electron (x): $\tau_e \frac{dx}{dt} - \alpha(t)x + x^3 + \zeta_0(x - y) = 0$

Lattice (y): $\frac{1}{\omega_0^2} \frac{d^2 y}{dt^2} + (y - x) = 0$

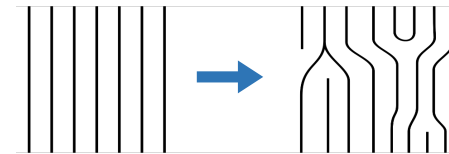
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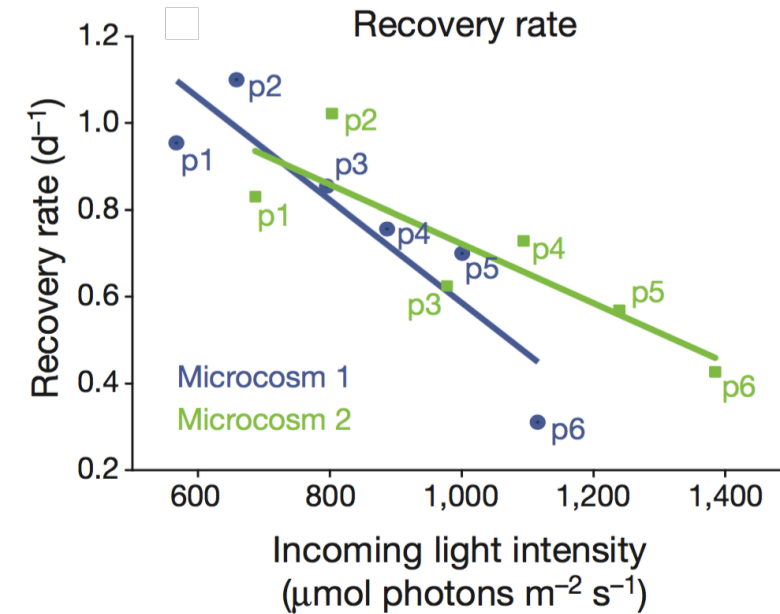
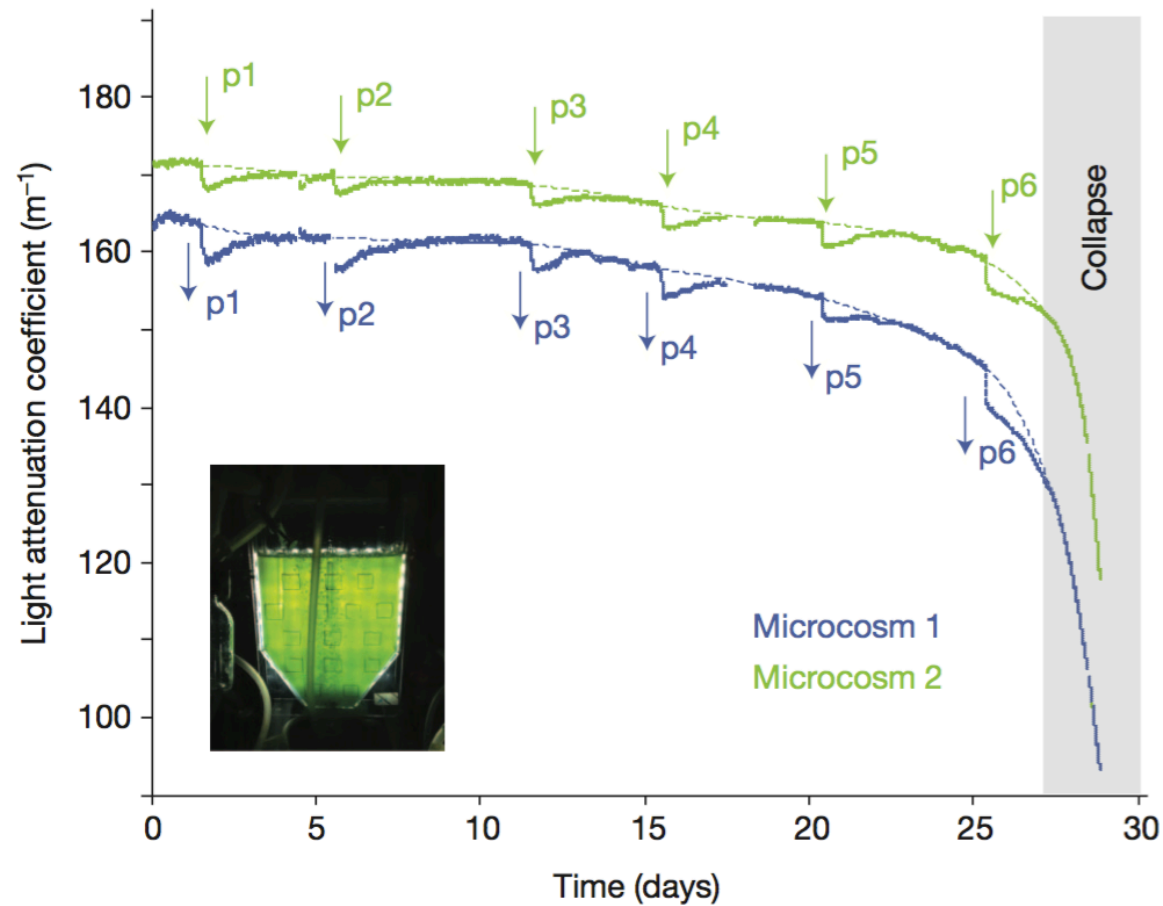
Equilibrium



Nonequilibrium

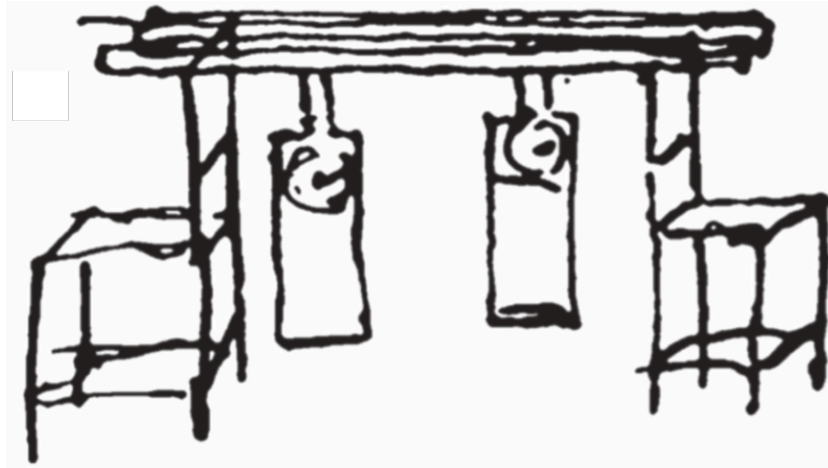
- Signatures of dynamical slowing down in the ultrafast melting of a charge density wave
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In living systems...

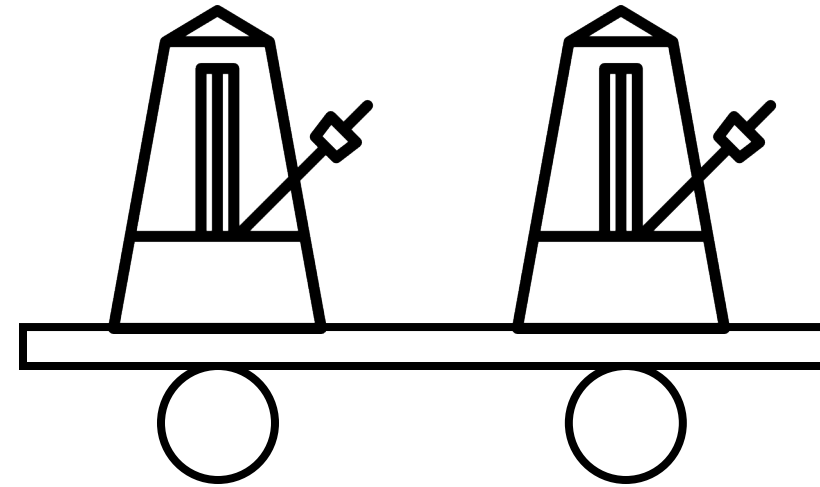


Veraart *et al.*, *Nature* **481**, 357 (2012)

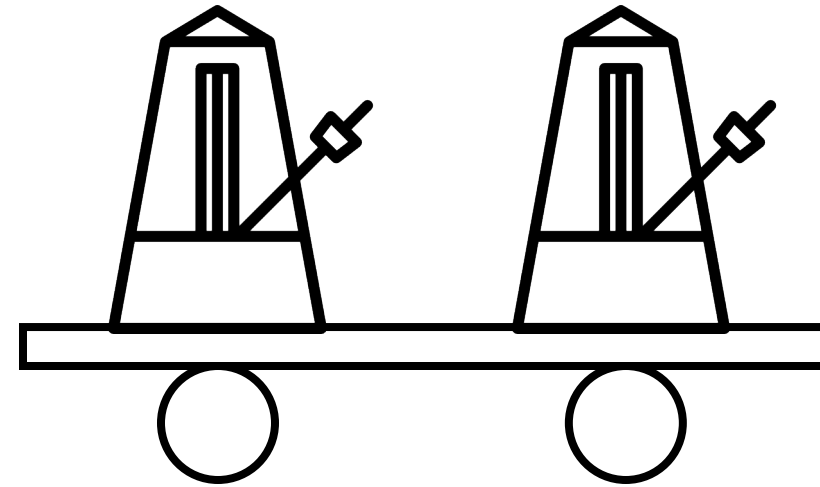
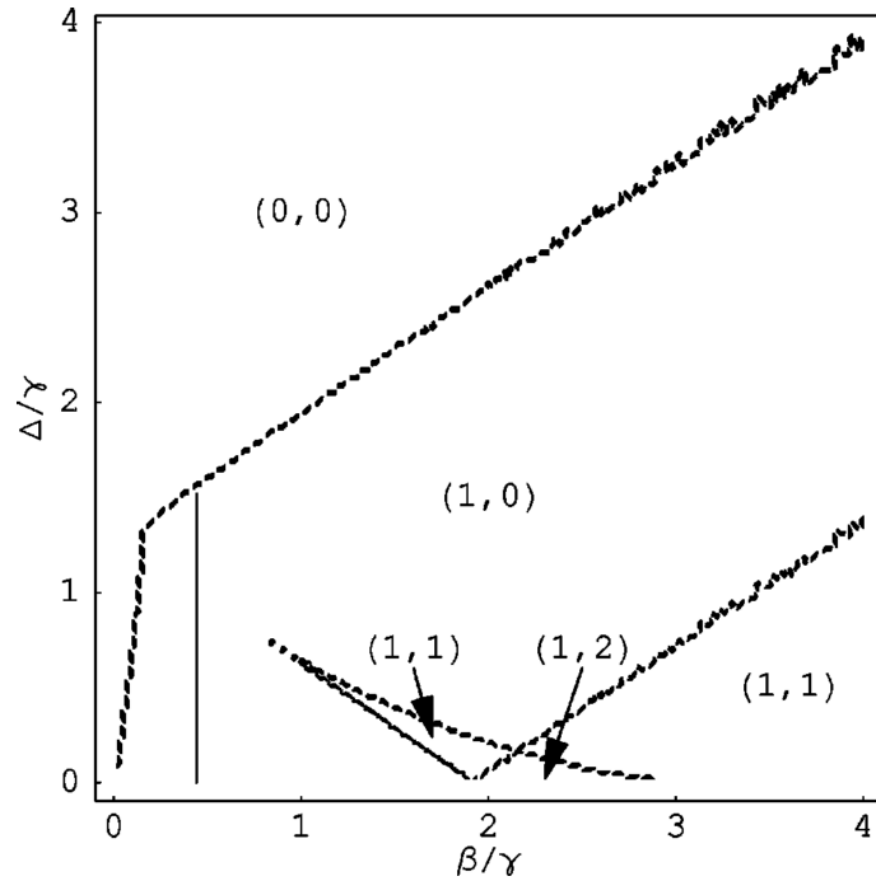
A simpler interacting dynamical system



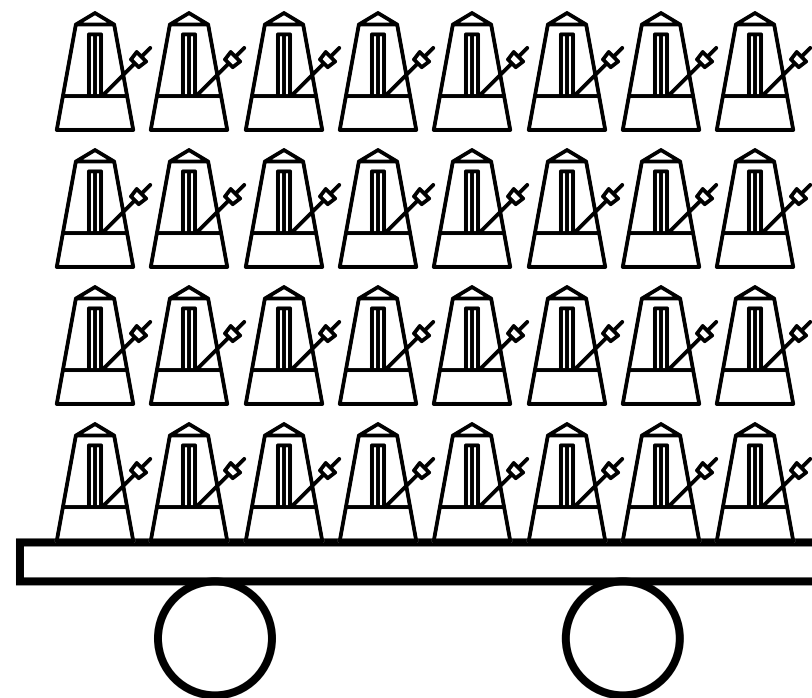
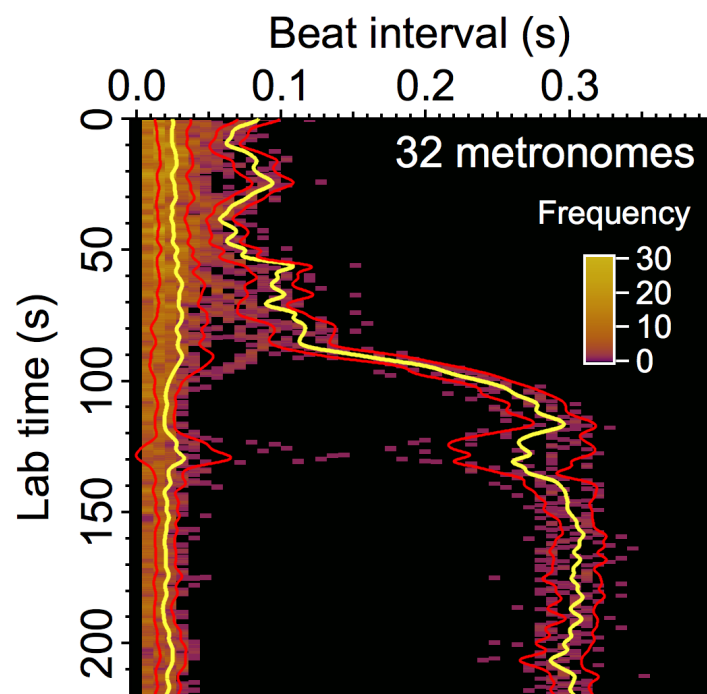
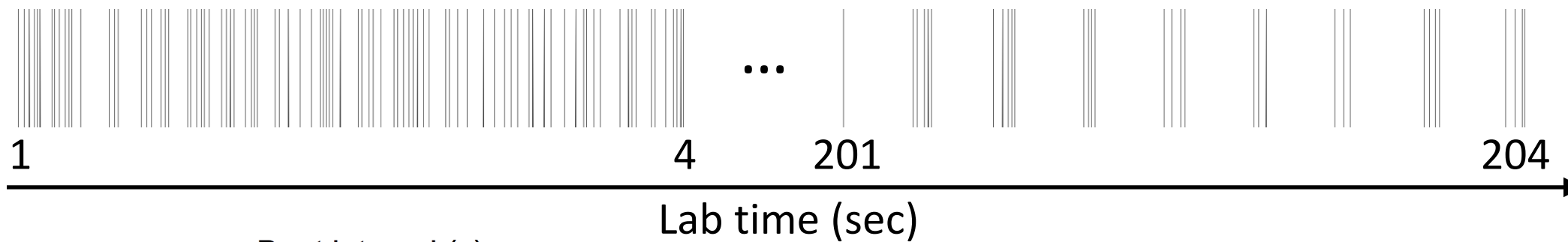
Huygens (1665): “an odd kind of sympathy”



Phase diagram of metronome synchronization



Measuring the synchronization timescale

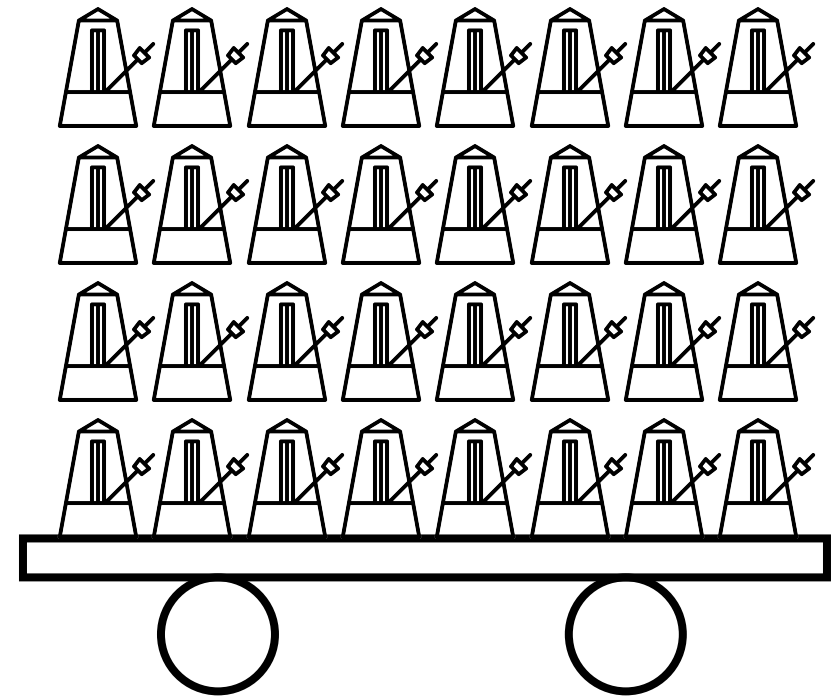
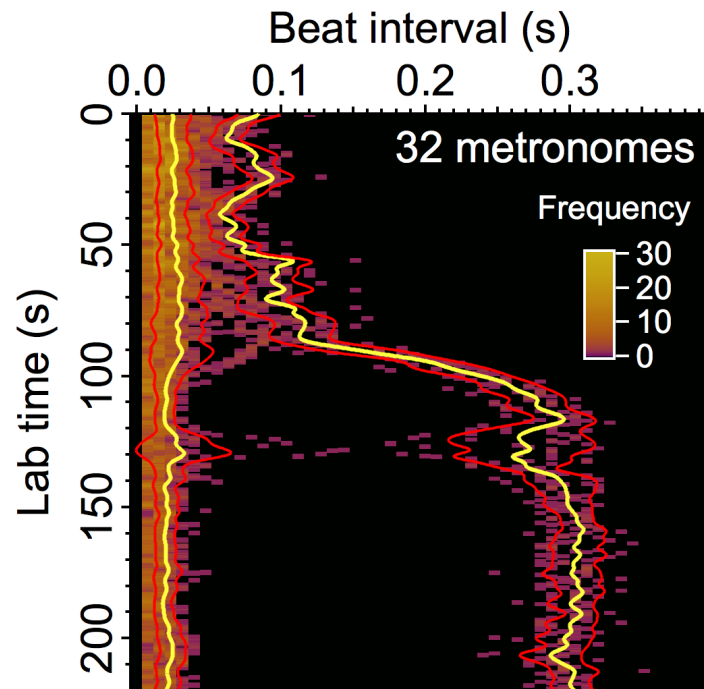


Critical behavior near the phase boundary

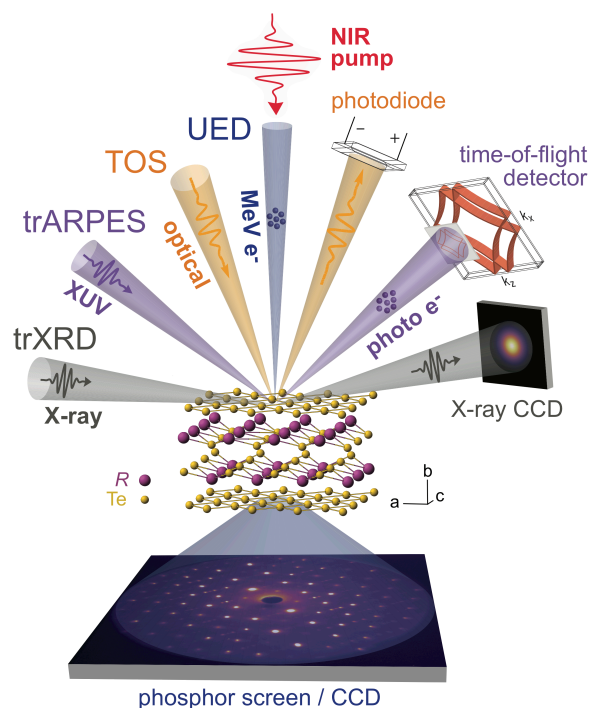


- Time to synchronize the system diverges as a power law?
- The recovery time diverges after perturbing a single metronome in the synchronized state?
- Softening of a collective mode, if there is any?

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summary



- Universality of **slowing** down near a phase transition – even in the highly nonequilibrium and ultra**fast** regime
 - A similar framework of **time-dependent Landau formalism** may help understand other aspects of photo-induced phase transitions
- For driven interacting dynamical systems, it may be interesting to study a “simpler” mechanical analogue – **metronome synchronization**

Acknowledgements



This Condensed Life

A Blog About Condensed Matter Physics that Trespasses on Topical Tangents

<https://thiscondensedlife.wordpress.com/2018/08/19/critical-slowness-down/>

- **Transient optical spectroscopy:** Emre Ergeçen and Mehmet Yilmaz
- **Ultrafast electron diffraction:** Timm Rohwer, I-Cheng Tung, Haidan Wen, and the SLAC UED team (Xiaozhe Shen, Jie Yang, Renkai Li, Suji Park, Matthias Hoffmann, Benjamin Ofori-Okai, Michael Kozina, and Xijie Wang)
- **Sample preparation:** Ya-Qing Bie and Pablo Jarillo-Herrero
- **Sample growth and characterization:** Joshua Straquadine, Philip Walmsley, and Ian Fisher
- **Theory:** Pavel Dolgirev, Alexander Rozhkov, and Boris Fine

