

Anomalous Transport Noise in YBCO.

Prof. Dale Van Harlingen (UIUC)

Prof. Michael Weissman (UIUC)

Tony Bonetti (took early data)

David S. Caplan (kept it going despite odds)

Prof. Tom Lemberger and Mike Hinton (some very nice samples OSU)

Prof. Hans Hilgenkamp (new oriented samples U of Twente)

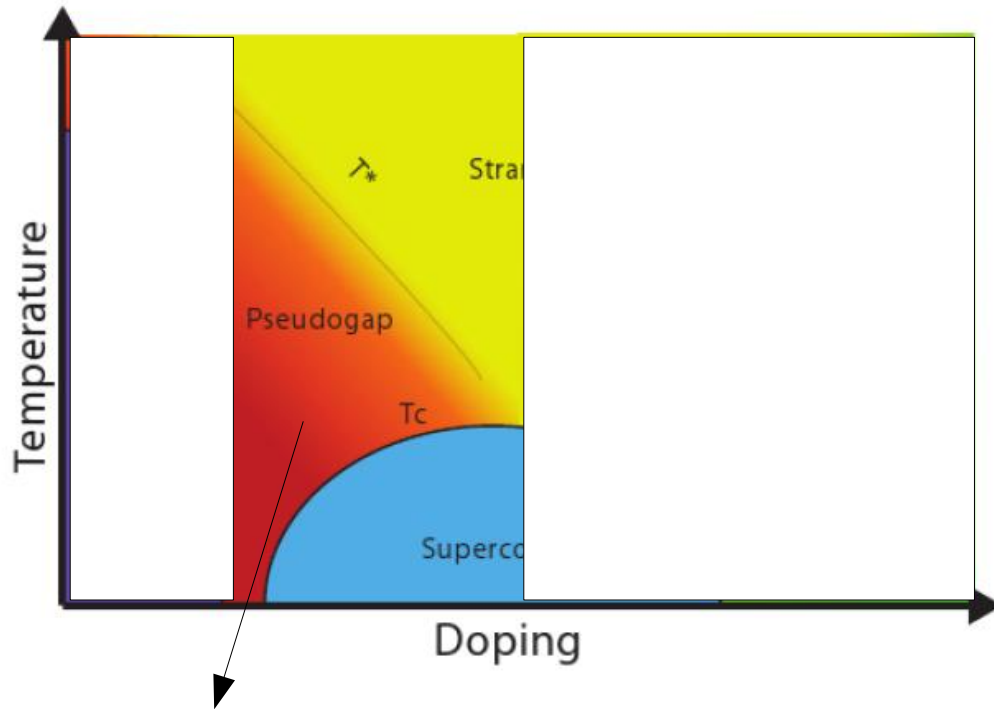
Prof. Eduardo Fradkin (theoretical guidance UIUC)

Vladimir Orlyanchik

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Motivation

The Generic Phase Diagram

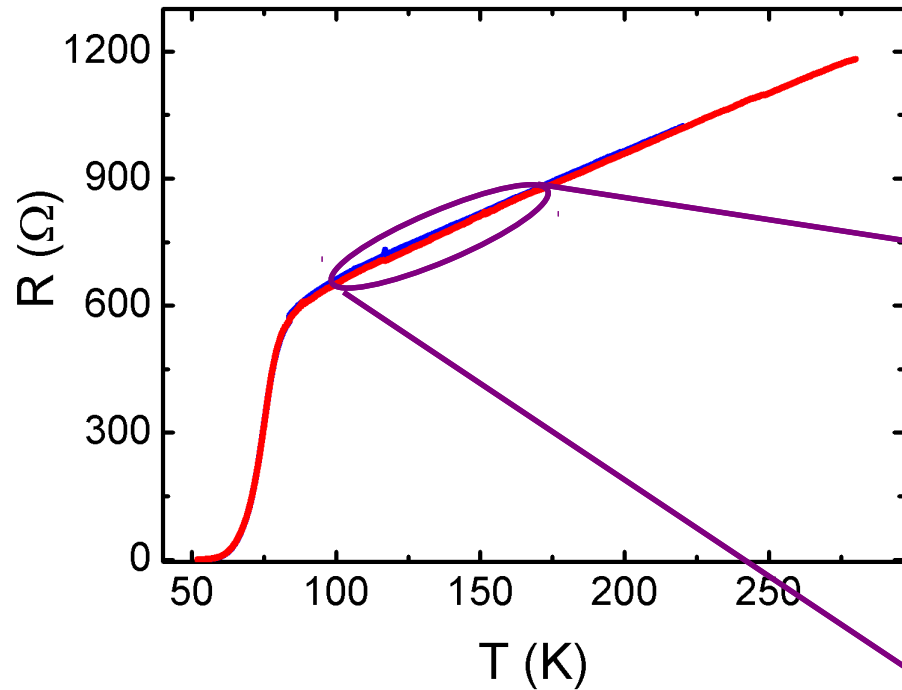


- Very Low doping:
AF, Mott insulator
- **Low to optimal doping:**
d-wave SC, and PG state above T_c .
- Highly overdoped:
no SC, behaves like a normal metal.

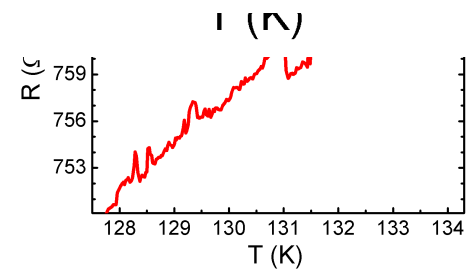
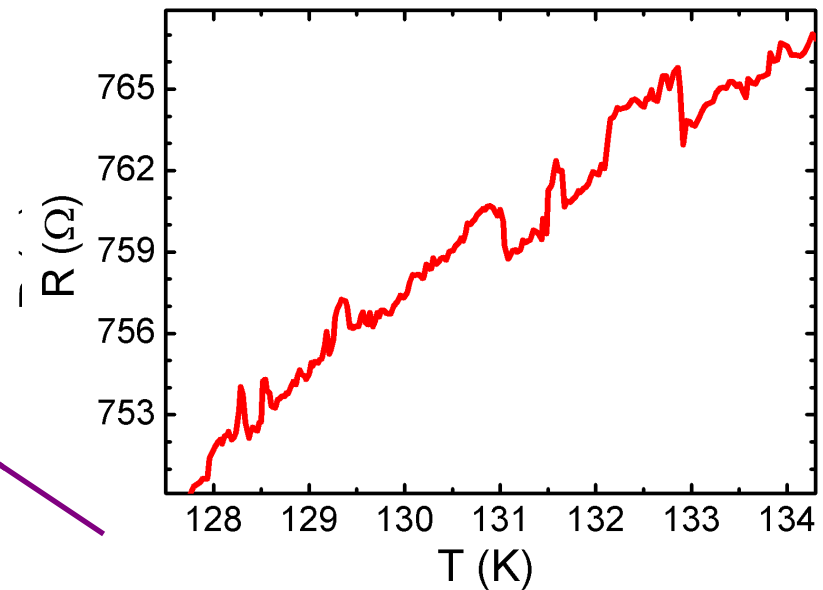
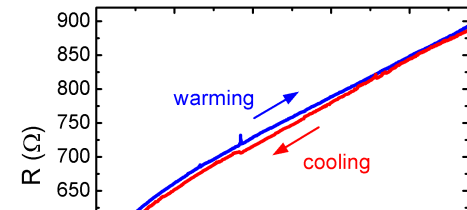
- Some AF neutron correlations
- T-dependent resistive anisotropy in untwinned YBCO
- Messy inhomogeneous STM pictures

Stripes?

Experimental Motivation



J. A. Bonetti, D. S. Caplan, D. J. Van Harlingen, and M. B. Weissman, Phys. Rev. Lett. **93**, 087002 (2004).



Samples and Noise measurement setup

$\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ $\text{Y}_{1-x}\text{Ca}_x\text{Ba}_2\text{Cu}_3\text{O}_{7-\delta}$

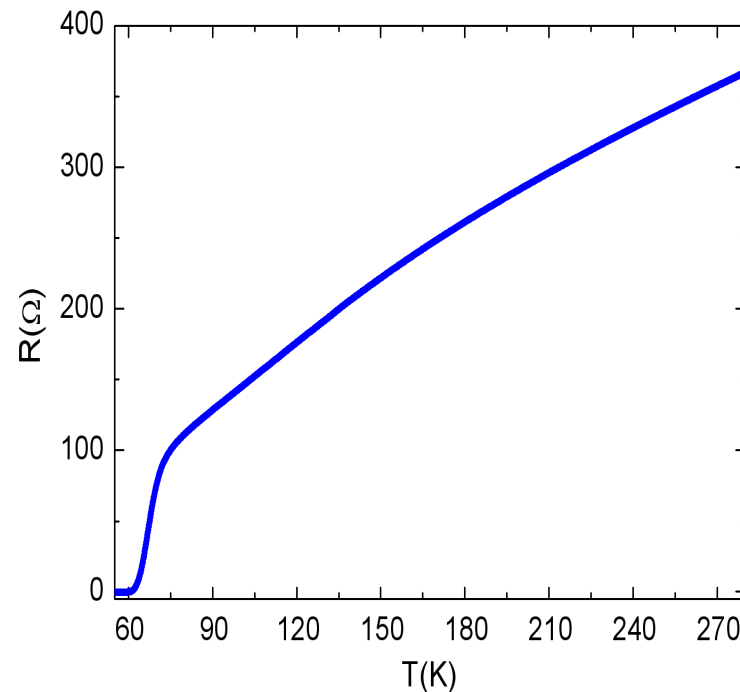
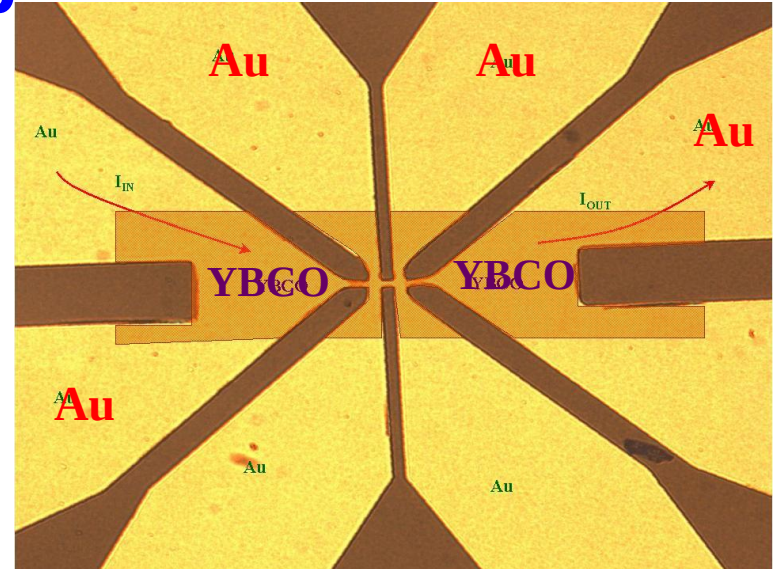
Highly twinned films, grown by PLD

Doping: $0.3 < \delta < 0.65$ or $85\text{K} > T_c > 30\text{K}$

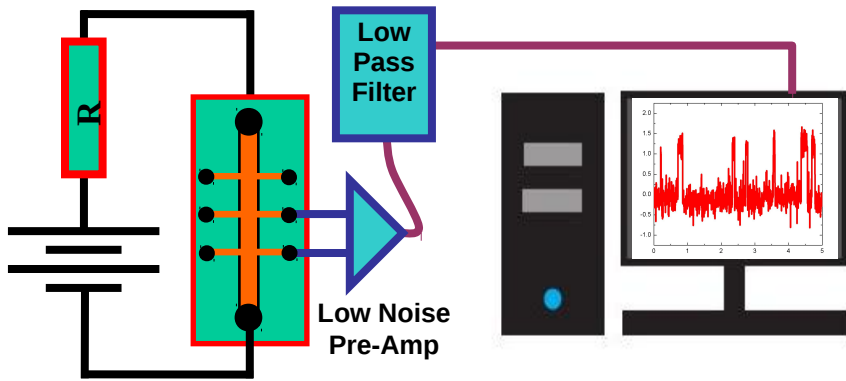
Thickness ~ 30-100nm

Length ~ $15\mu\text{m}$ Width ~ $2\text{-}5\mu\text{m}$

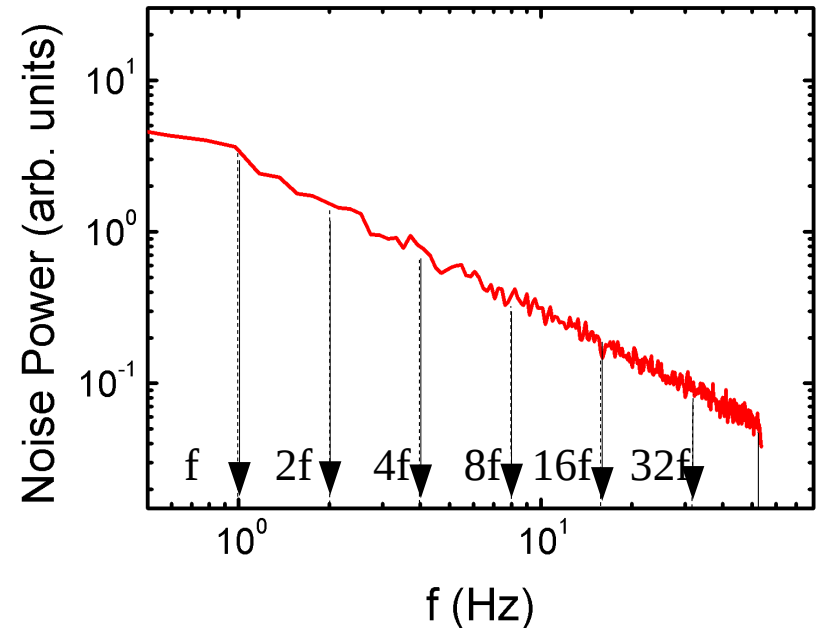
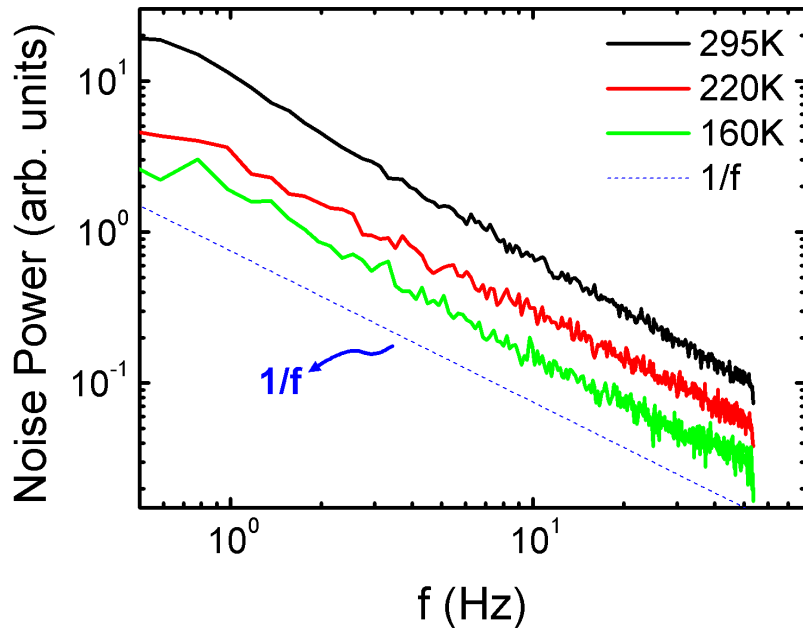
Measurement T range $100\text{K} < T < 300\text{K}$



Samples and Noise measurement setup



- Frequency window ~ 1 -200 Hz
- Linear current response
- Spectrum (above background)
roughly of form $1/f^\alpha$, $0.9 < \alpha < 1.2$

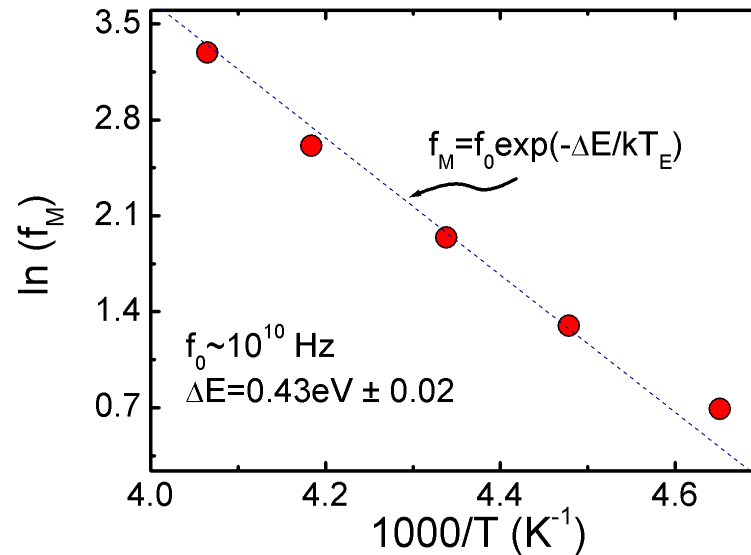
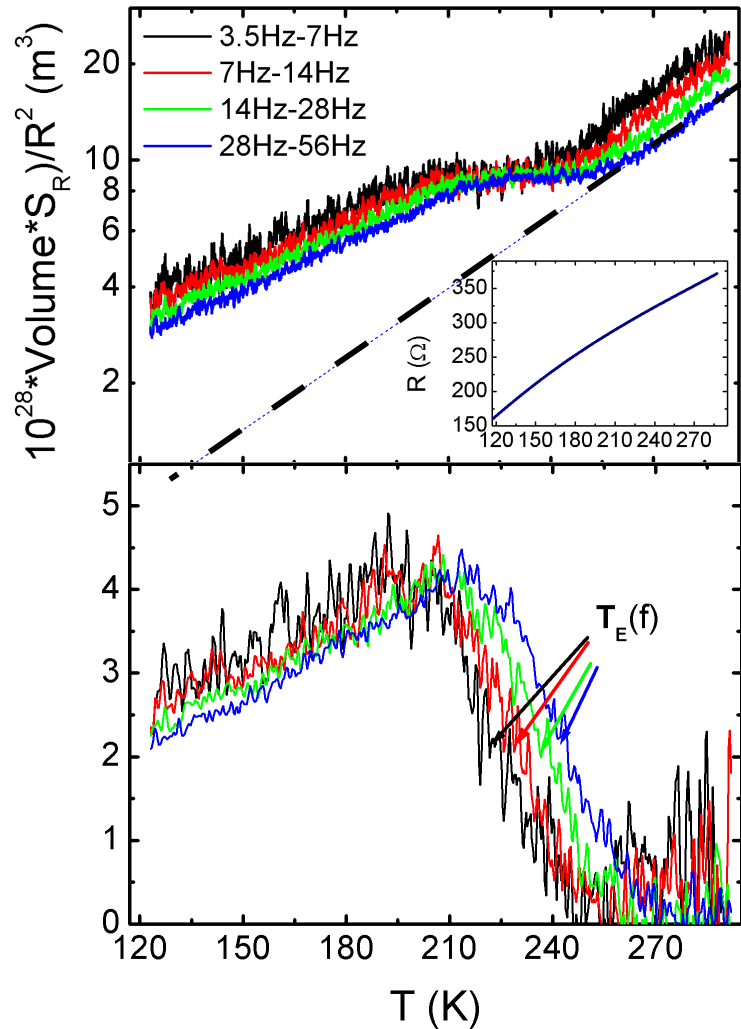


Octave summing

Noise measurements - Arrhenius behavior

Recipe

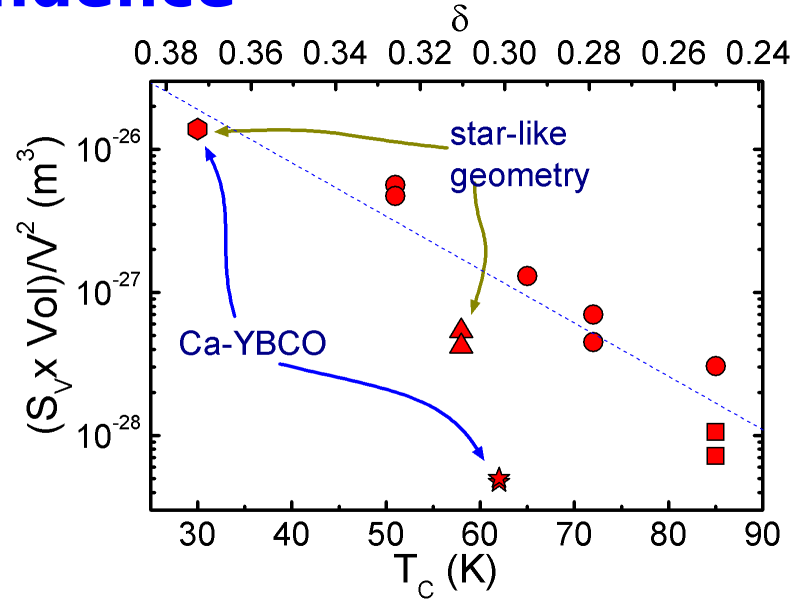
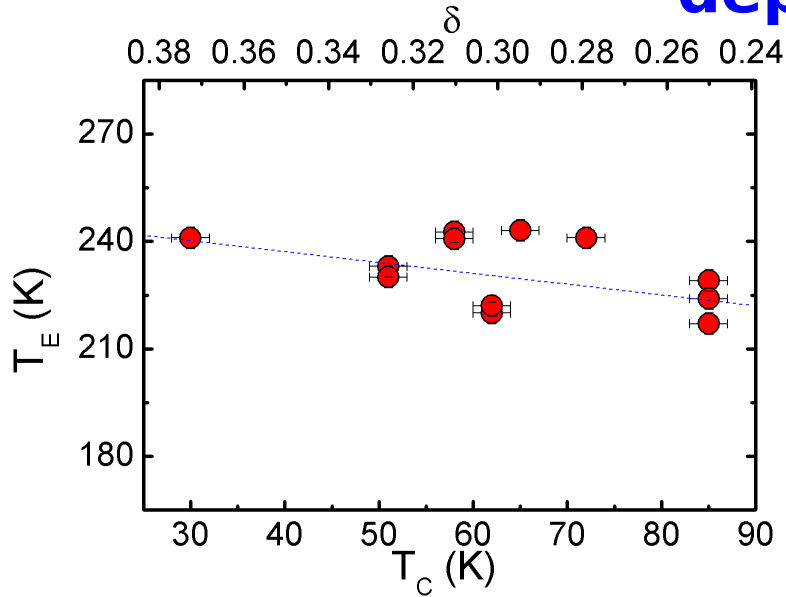
- Subtract extrapolated **higher temperature noise**
- Look at remainder



$T_E(f)$ shows ordinary activated dependence of frequency on T , unlike any glass or phase transition

Is it just a boring feature in a distribution?

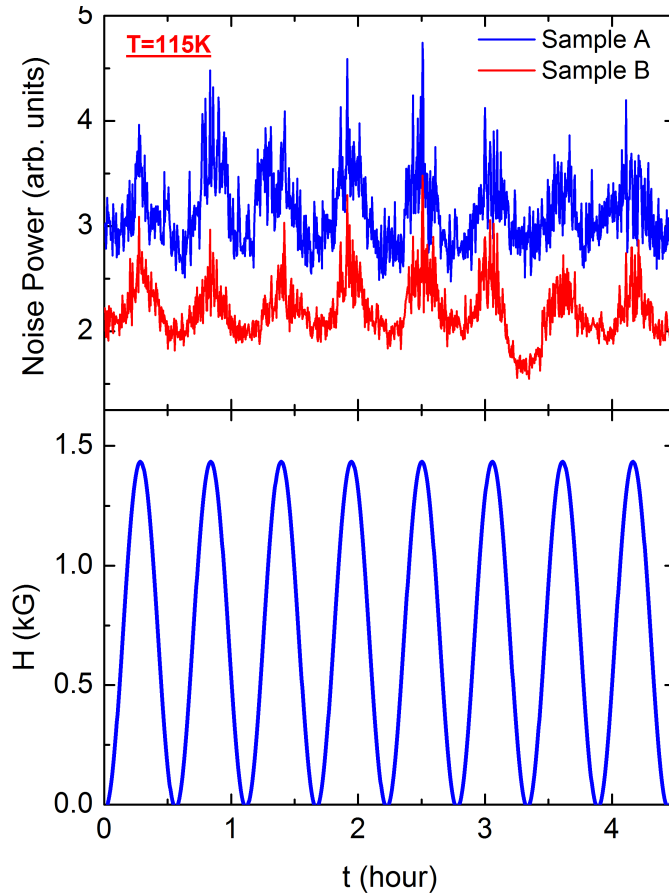
Noise measurements - doping dependence



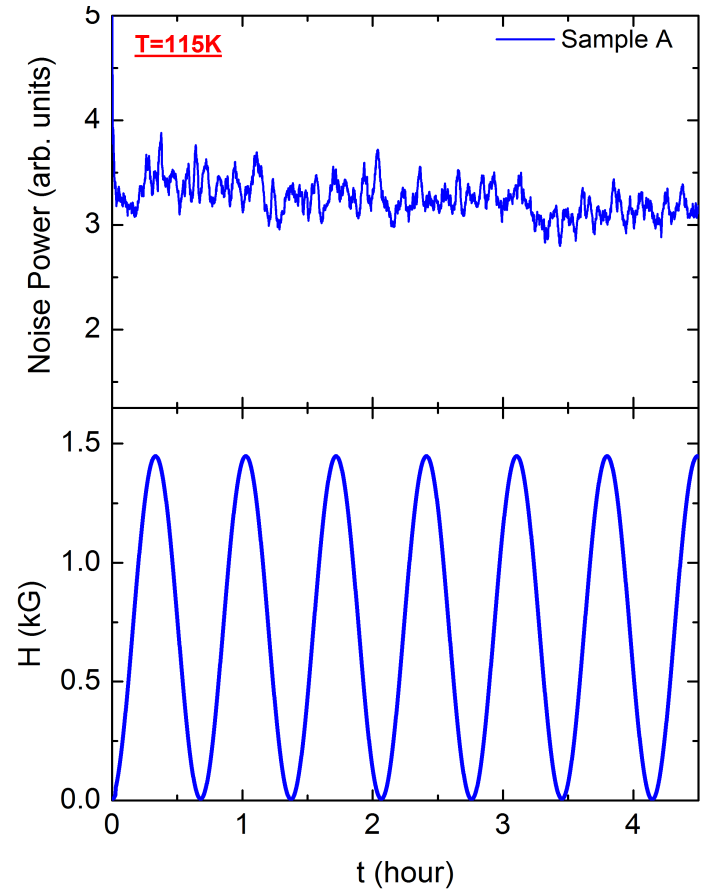
- T_e exhibits almost **NO** doping dependence!!!
- **Not** related to T^*
- **Not** a phase transition
- **Not** a sharp crossover
- **Excess noise** amplitude **is sharply** doping dependent

Noise measurements - low field dependence

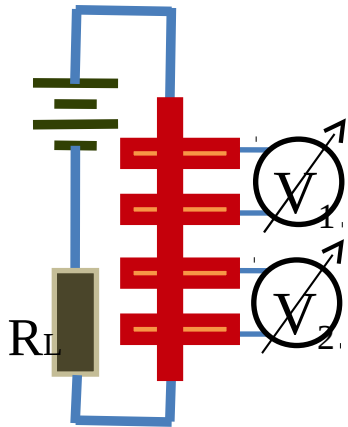
In-Plane



Out-of-Plane

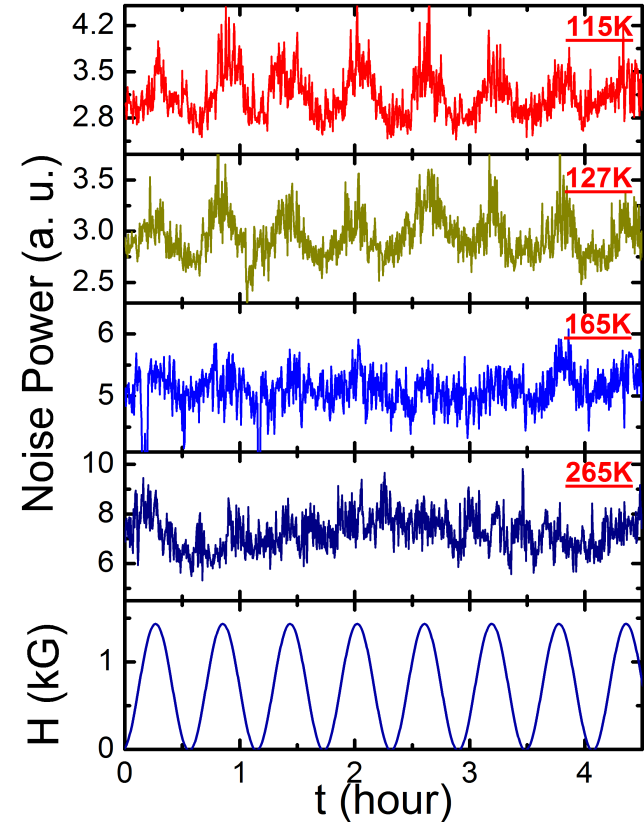
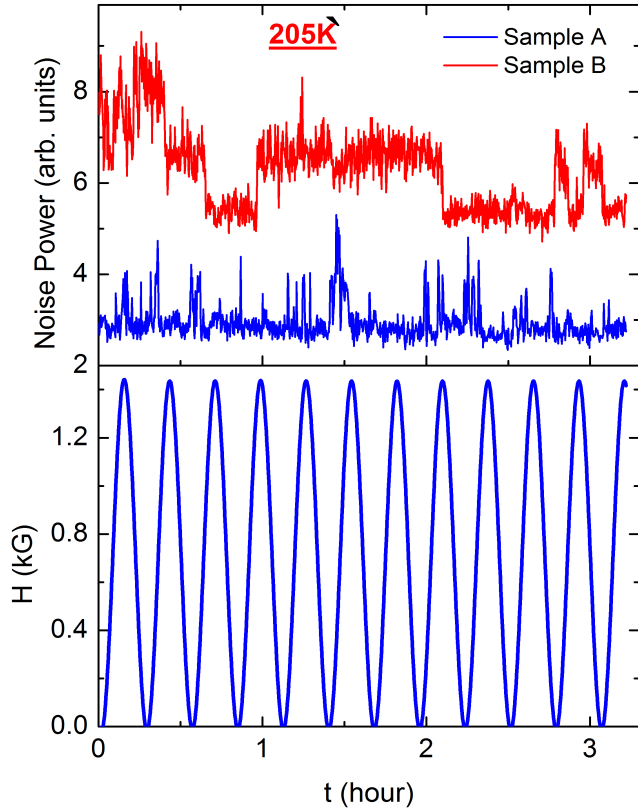


T-dependence?



Noise measurements - low field dependence

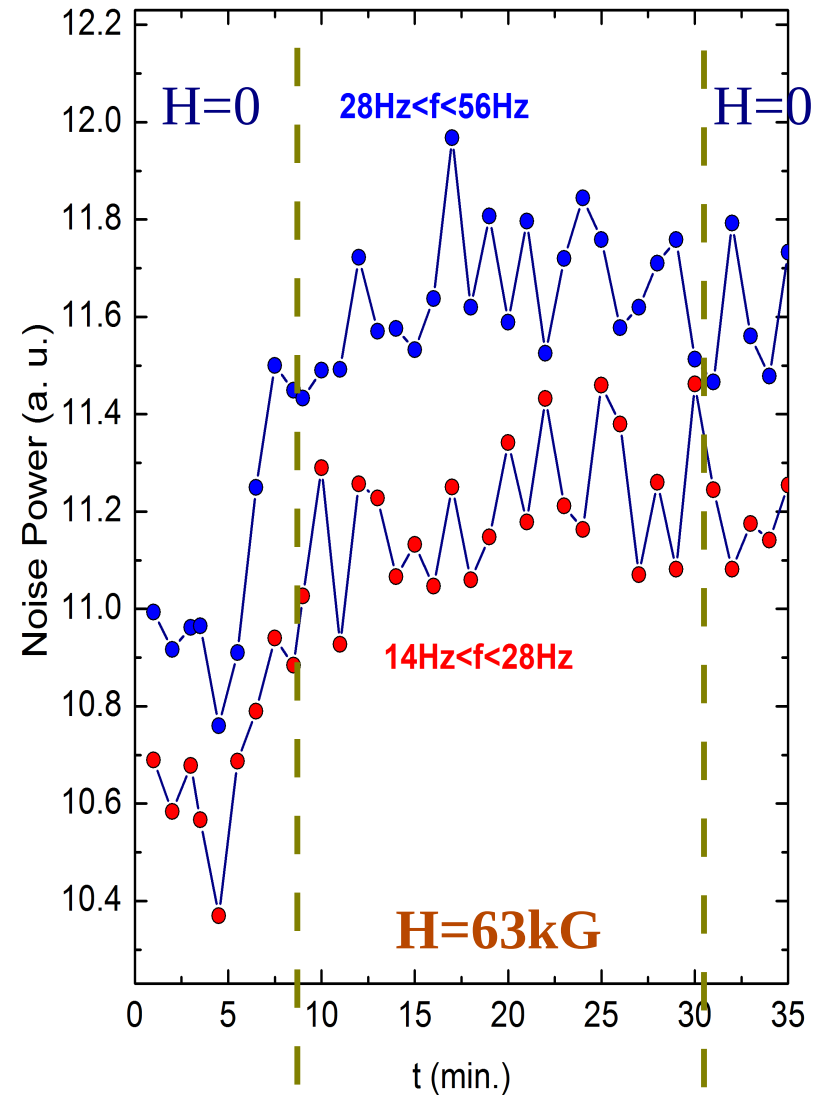
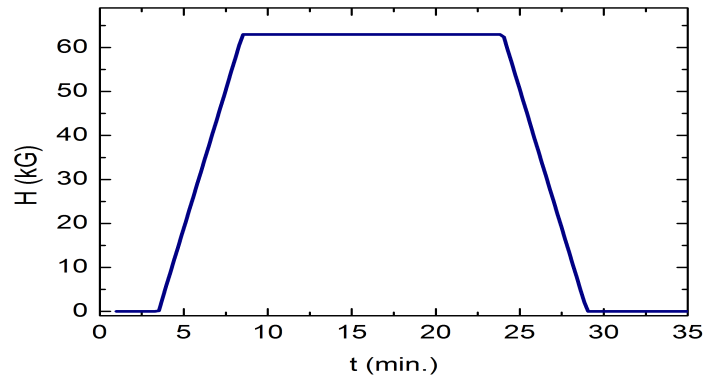
Becomes more irregular at higher T



H dependence gone above ~ 245K !!!

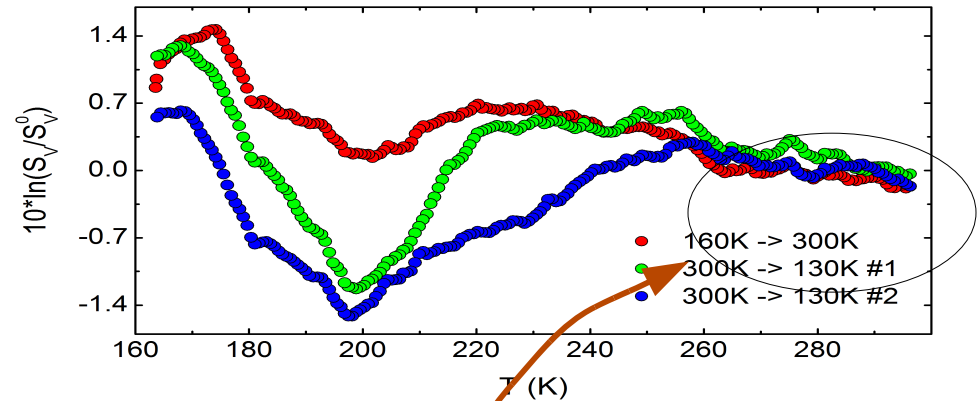
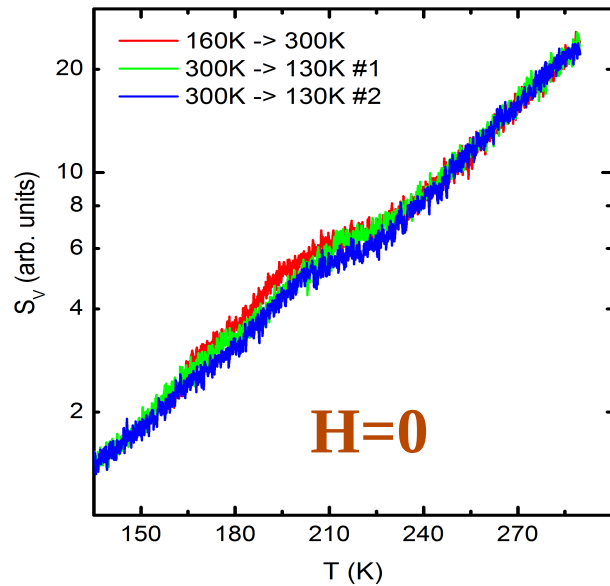
Noise measurements - high field dependence

- i. Measure noise without field
- ii. Apply 6.3 Tesla out-of-plane
- iii. Remove field



Distinct magnetic noise hysteresis

Noise measurements - Relaxation of magnetic effects

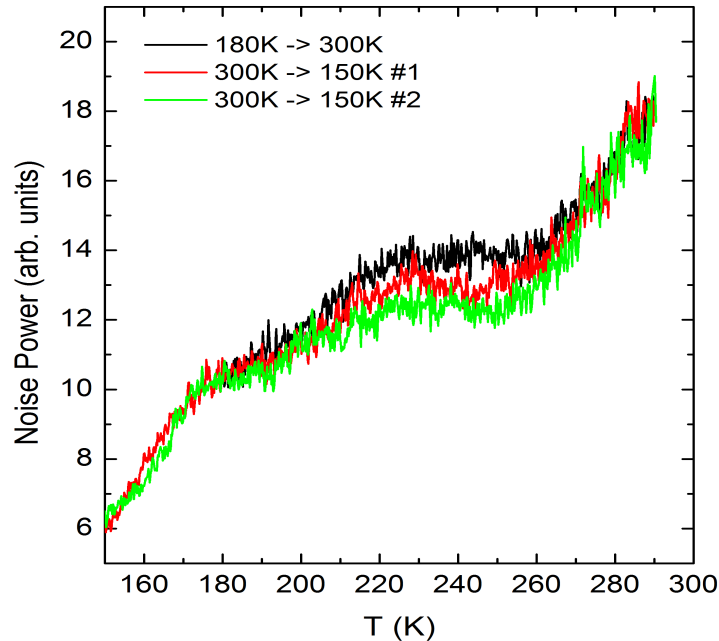


- Long time sweeps, $dT/dt=0.3\text{K/min}$
- Up to room temperature and down to 130K
- Total time > 18 hours

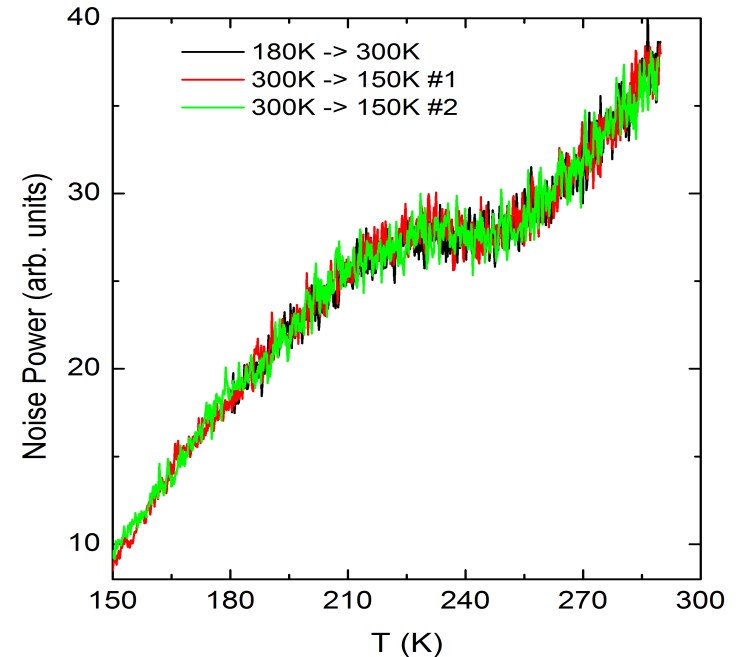
Effects **ONLY** below
~250K

Noise measurements - No cheating

Out-of-Plane

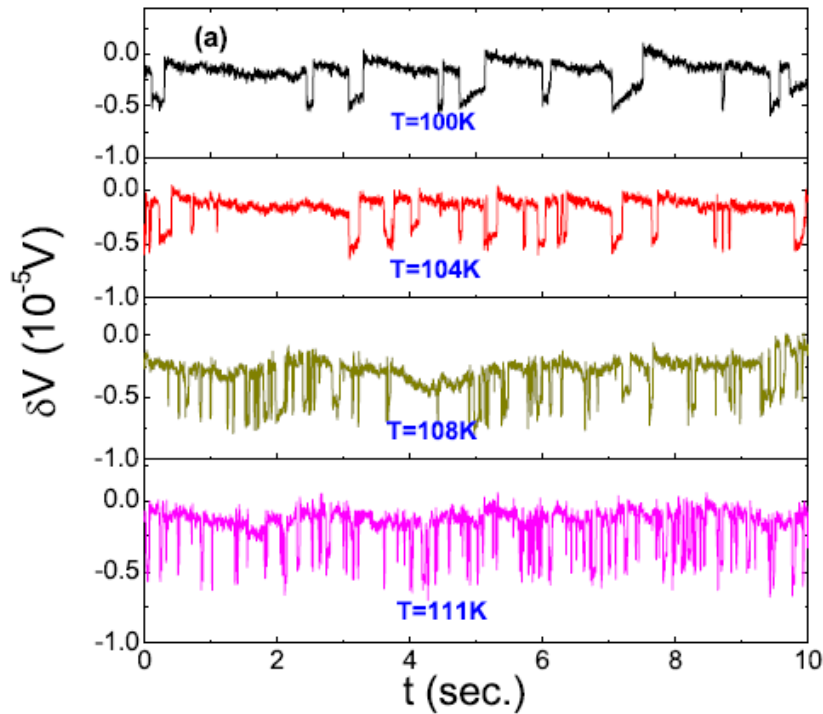


In-Plane



Similar to Kerr effect magnetic memory Jing Xia et al. PRL **100**, 127002 (2008) (Kapitulnik group)

Noise measurements - time domain



$\delta R/R \sim 10^{-5} \gg \gg$ Point-like defect $\delta R/R \sim 10^{-8}$

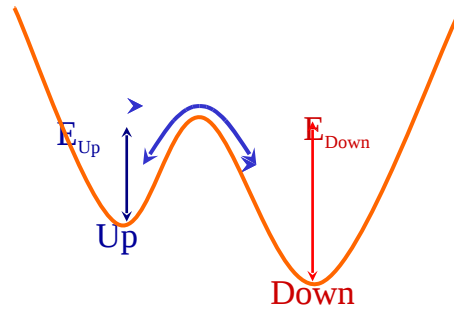
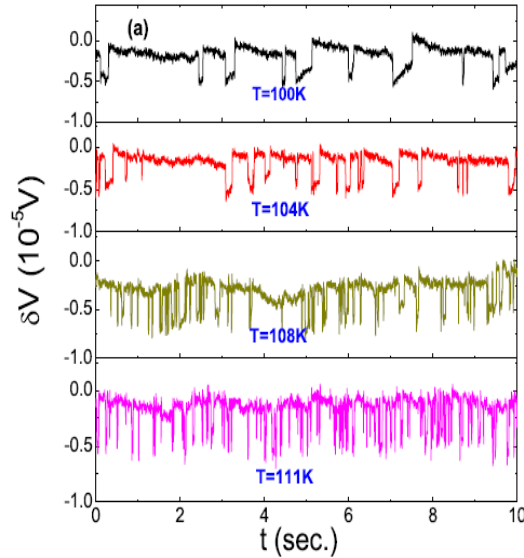
Large coherently
fluctuating
regions

Strongly
inhomogeneous
conduction

seen in almost every sample only at $T < \sim 180K$

Noise measurements - time

domain Some Thermodynamics



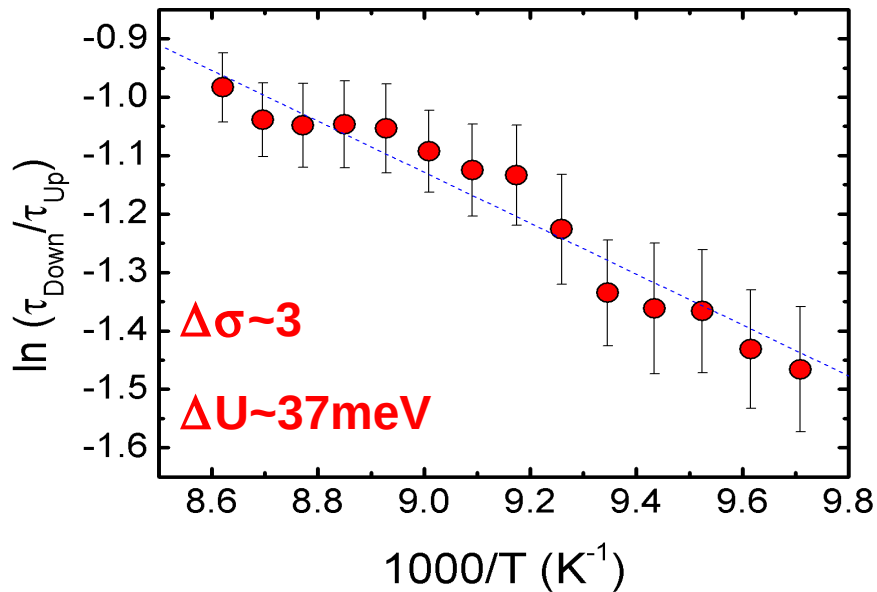
$$r \equiv \frac{\text{time}_{\uparrow}}{\text{time}_{\downarrow}} = \exp \left[\frac{\Delta F}{k_B T} \right]$$

$$\Delta F = k_B T \ln(r)$$

$$\Delta \sigma = - \frac{1}{k_B} \left(\frac{d\Delta F}{dT} \right)_H$$

$$\Delta U = \Delta F + T\Delta \sigma$$

$$0 < |\Delta \sigma| < 10 \quad \Delta U \neq 0$$



- Large coherently fluctuating regions or strongly inhomogeneous conduction **stripes???**
- Scalar quantities (U, S) change **Not pure rotations**
- *Small* changes in scalars suggest **almost rotations not fluctuations between distinct phases**

Making sense out of noise - A dilemma

- Arrhenius characteristics;
- Onset T not very sensitive to doping;

Boring feature in the distribution of fluctuators energies

- Amplitude increases with lowering T_c
- Magnetic sensitivity (memory, Aging, etc.)
- Single fluctuators ($0 < |\Delta\sigma| < 10$, $\Delta E \neq 0$)
- Changes in noise pattern only below $\sim 250K$
- Not pure rotations ($\Delta\sigma \neq 0$ and $\Delta E \neq 0$)

Disordered collective state with electronic correlations and intrinsic magnetic sensitivity

What it might be:

Above 250K - noise of a pattern partially averaged over some unquenched disorder, mobile for our (f, T).

Below 250K

(A) a defect (antiferromagnetic surface layer) with activation energy of $\sim 0.4\text{eV}$ slows considerably down. This defect pins otherwise fast fluctuating stripes making them “visible” for the frequency range used in our measurements.

(B) stripes are slowed down intrinsically by “sticking” to defects and forming a collective state with “sticking” energy of $\sim 0.4\text{eV}$.

In any case (either **(A)** or **(B)**) stripes seem to form mayonnaise like “order” rather than clean nematic.