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ELECTRON-PHONON DECOUPLING NEAR THE SUPERCONDUCTOR- INSULATOR TRANSITION

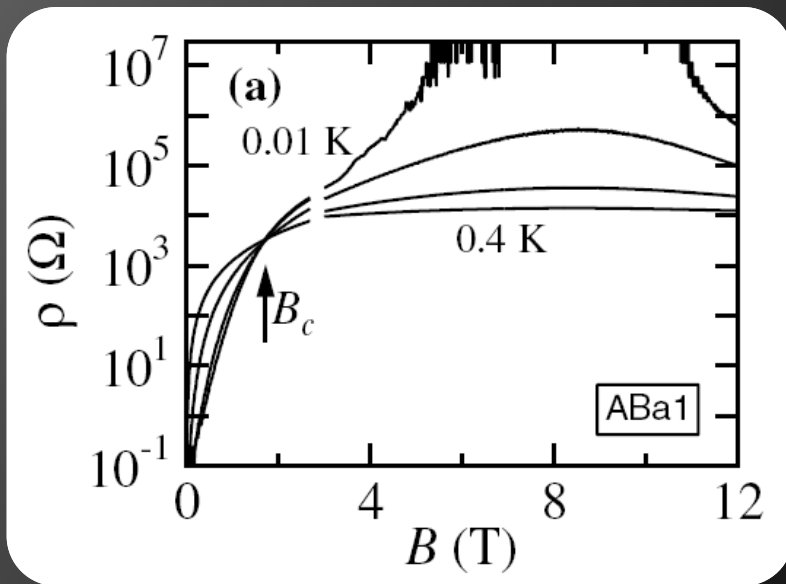
SCQP 2009
Israel Institute of Technology
Haifa, Israel



Dan Shahar (WIS)
Benjamin Sacepe (WIS, Geneva)
M.O. (WIS)

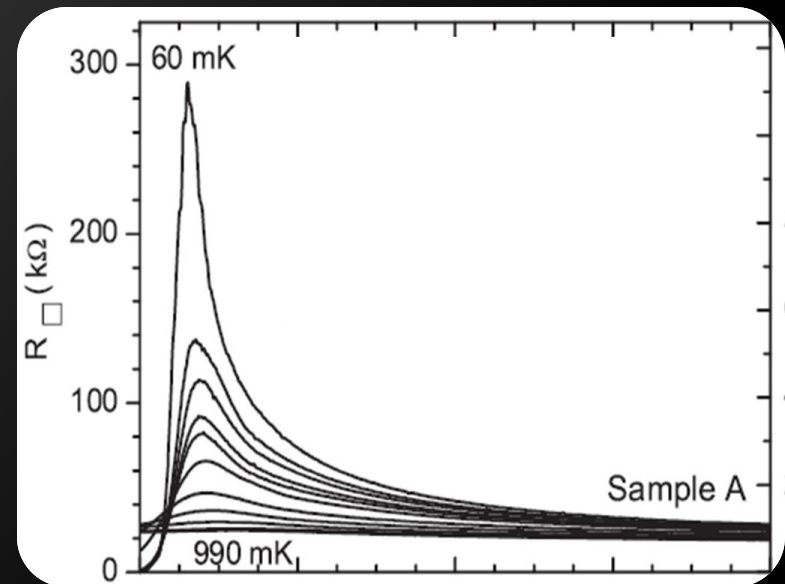
Magnetic field-tuned SIT

$\alpha\text{-InO}_x$



G. Sambandamurthy, L.W. Engel, A. Johansson, E. Peled, D. Shahar
PRL 94, 017003 (2005)

TiN

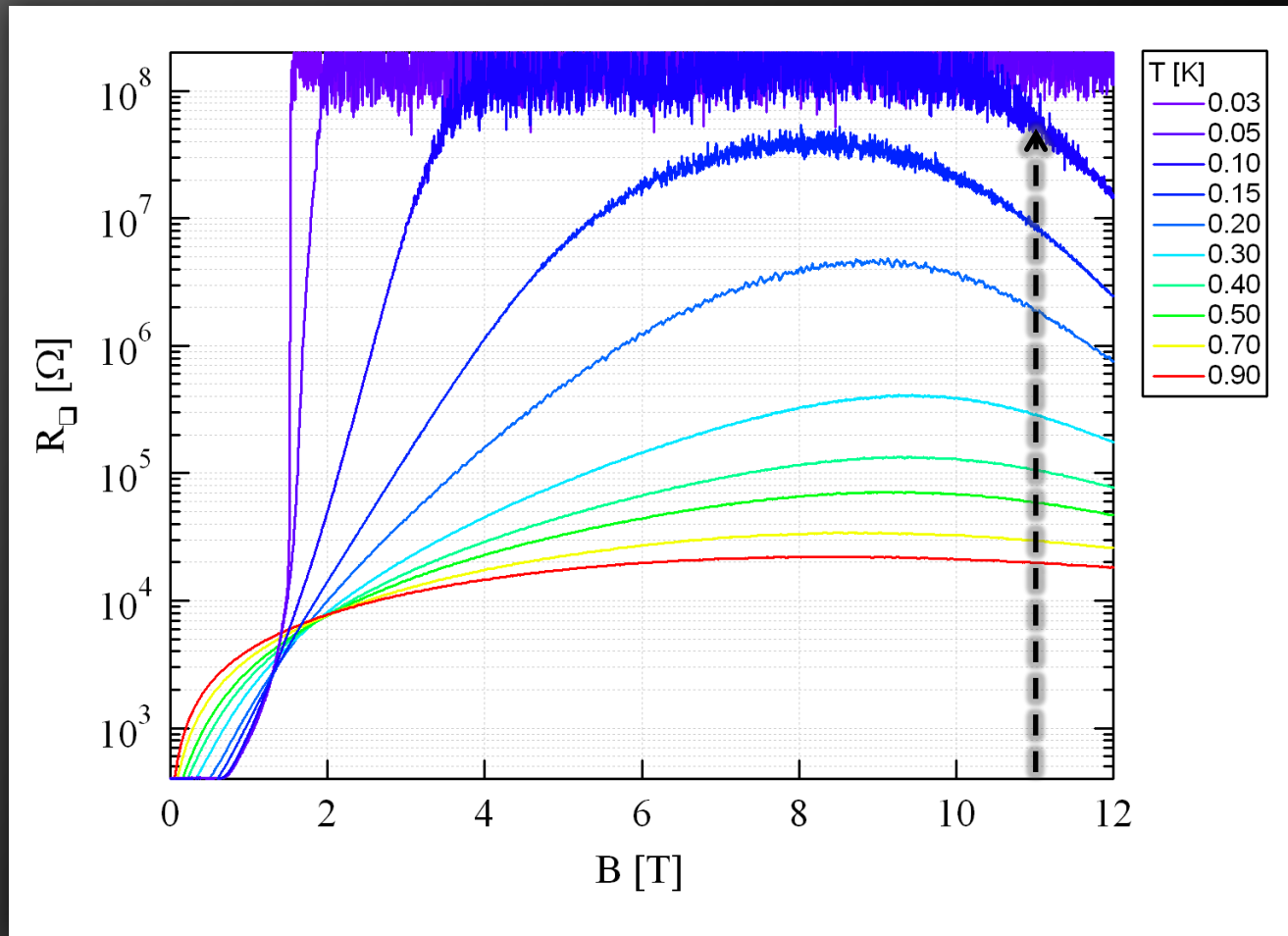


T. Baturina, C. Strunk, M. Baklanov, A. Satta
PRL 98, 127003 (2007)

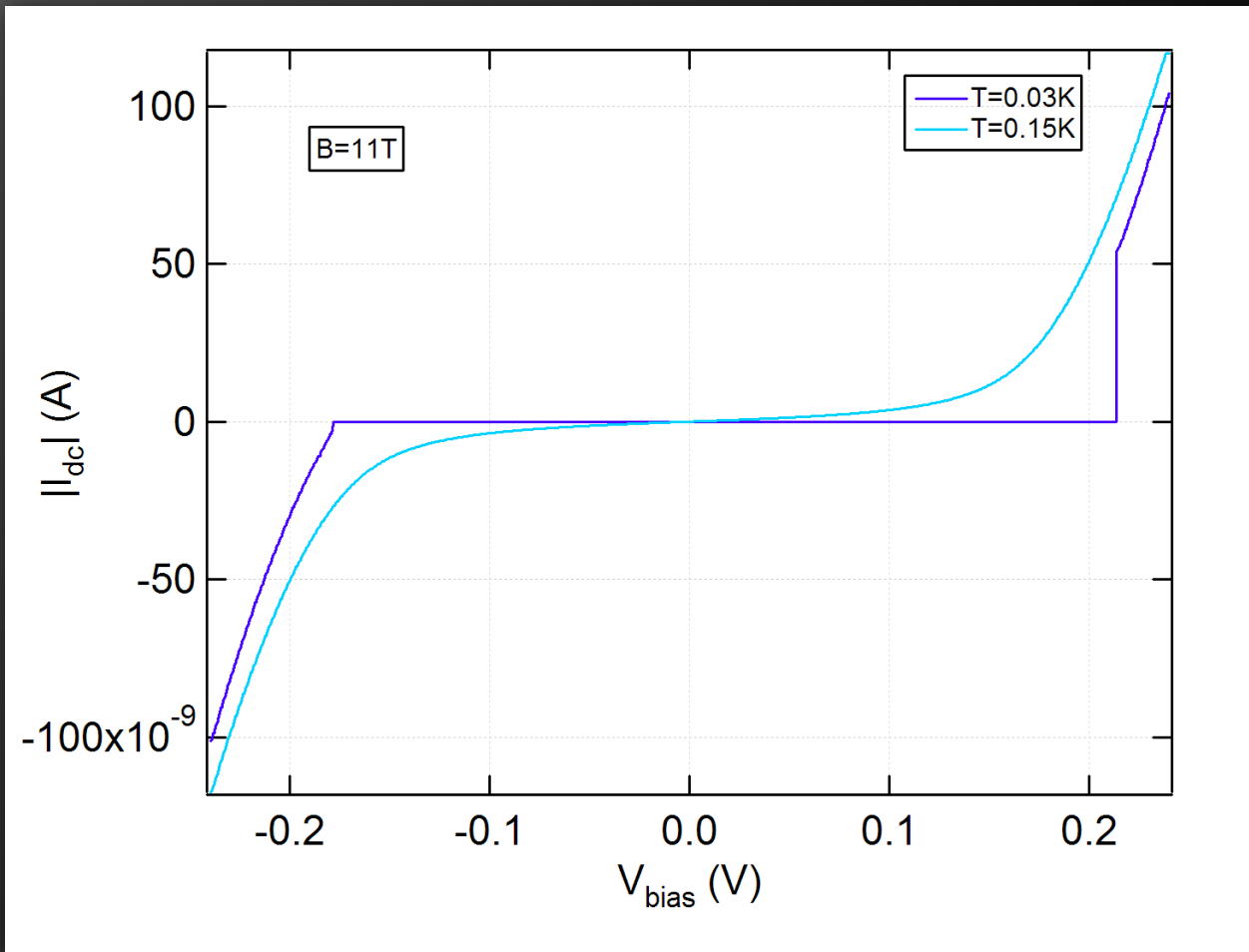
Amorphous indium oxide

- ⦿ Homogenously disordered amorphous film
- ⦿ Superconductor-insulator transition can be driven by
 - Film thickness / disorder
 - Magnetic field
- ⦿ For this talk
 - 30nm thickness, mm-scale lateral dimensions
 - Indium contacts (negligible contact resistance)
 - Deposited on SiO_2
 - T_c is approximately 1K

B-driven SIT: α -InO_x film

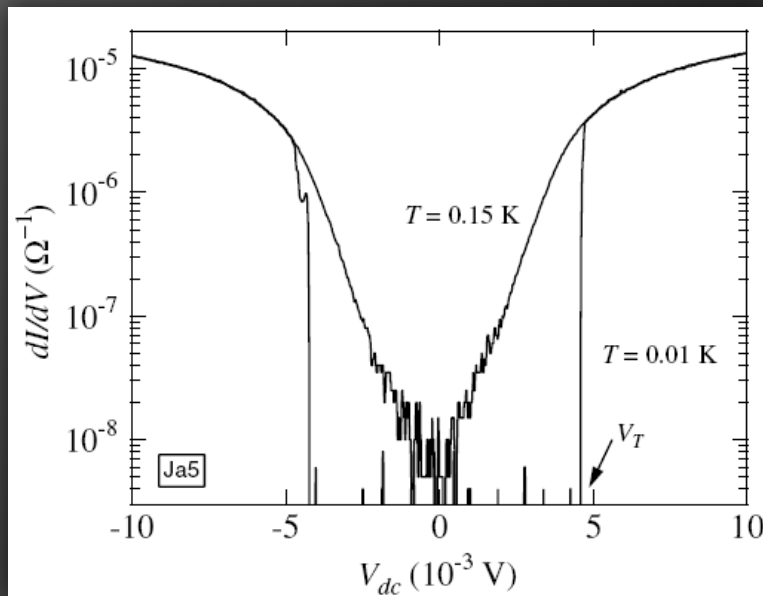


I-V (B=11T insulator)



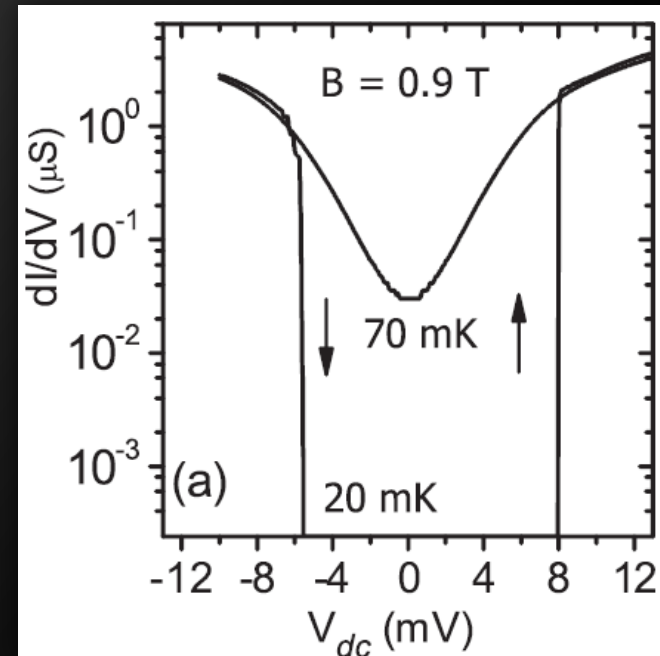
“Critical voltage” only at very low T

Field-tuned insulating state $\alpha\text{-InO}_x$



PRL **94**, 017003 (2005)

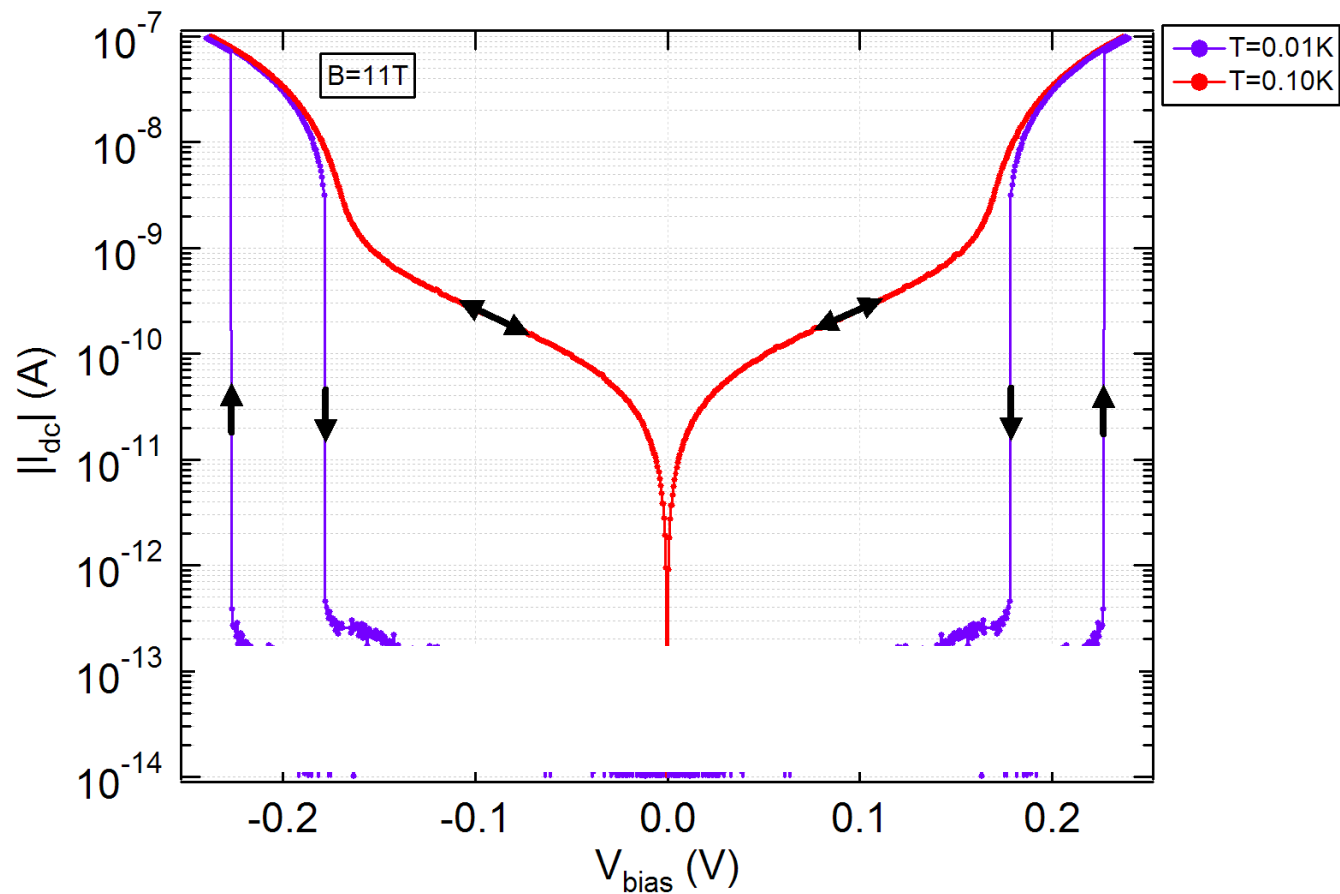
Disorder-tuned insulating state TiN



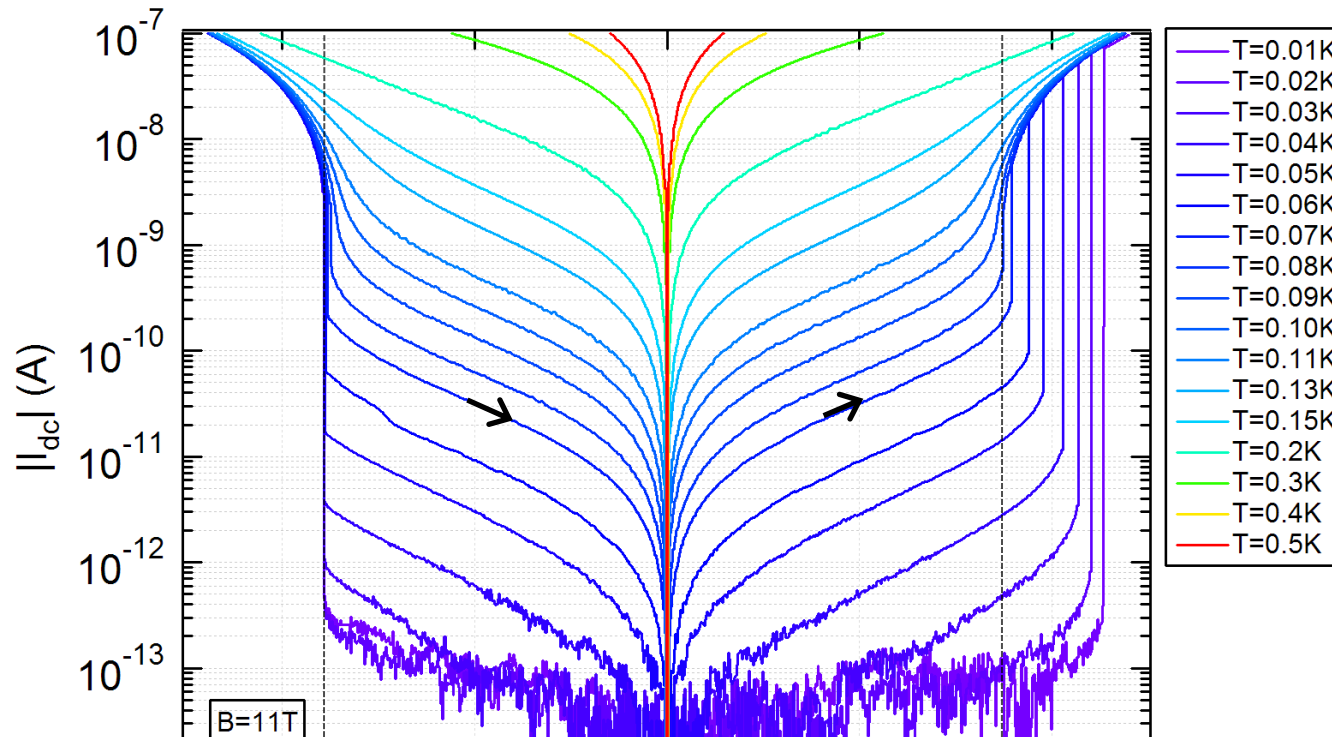
PRL **99**, 257003 (2007)

Something dramatic occurs around $T^* \sim 0.1$ K, at finite bias
Collective coulomb gap? “Superinsulator”?

Voltage threshold \Leftrightarrow Hysteresis



Temperature dependence

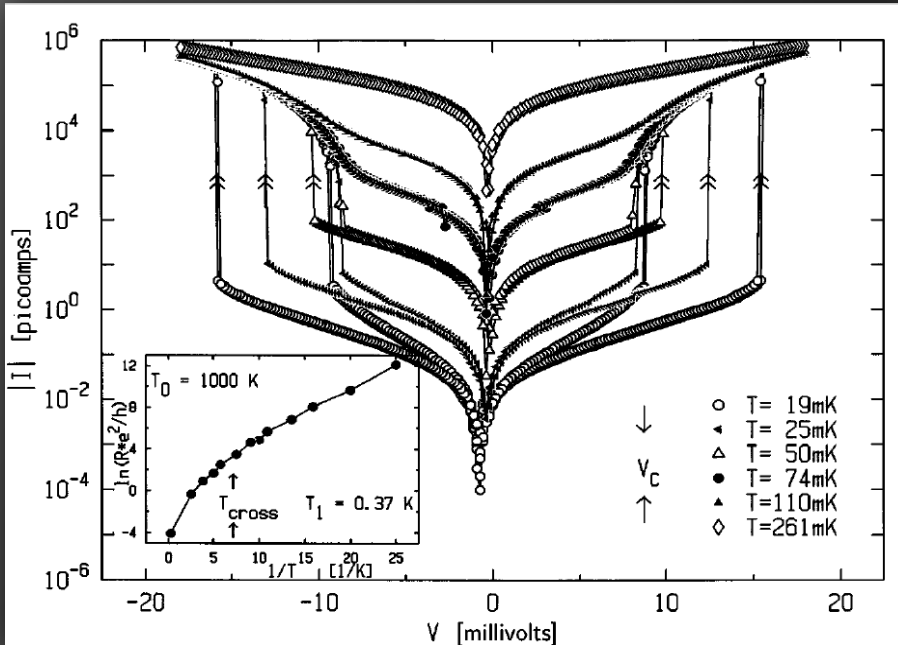


⇒ I-V is linear at low voltage, regardless of T

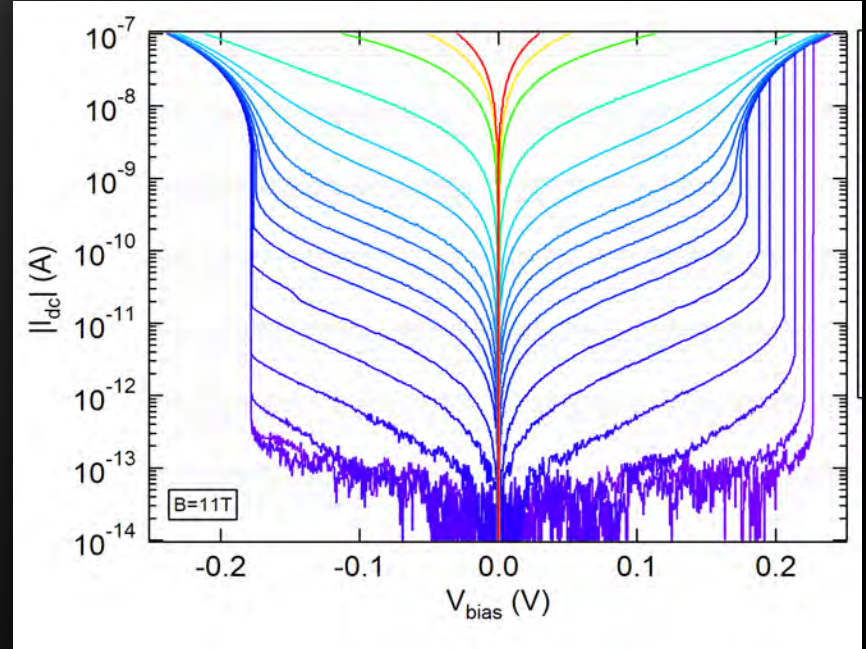
⇒ Presence of current jump does not change low bias IV form

A striking similarity

Amorphous Y_xSi_{1-x}



Amorphous InO_x



Depinning transition in Mott-Anderson insulators

F. Ladieu, M. Sanquer, and J. P. Bouchaud
PRB 53 (3) p973, 1996

Role of
superconductivity?

Electron overheating

PRL 102, 176803 (2009)

PHYSICAL REVIEW LETTERS

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1 MAY 2009



Jumps in Current-Voltage Characteristics in Disordered Films

Boris L. Altshuler,^{1,2} Vladimir E. Kravtsov,³ Igor V. Lerner,⁴ and Igor L. Aleiner¹

- ⊙ Interactions: e-e strong, e-ph weak.
- ⊙ Under finite joule heating $T_{el} > T_{ph}$
- ⊙ Intrinsic $I - V$ is linear: nonlinearities are due to heating only
- ⊙ $R(T)$ is steep, such as $R \sim R_0 \exp[T_1/T]$

Thermal bistability

PRL 102, 176803 (2009)

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Boris L. Altshuler,^{1,2} Vladimir E. Kravtsov,³ Igor V. Lerner,⁴ and Igor L. Aleiner¹

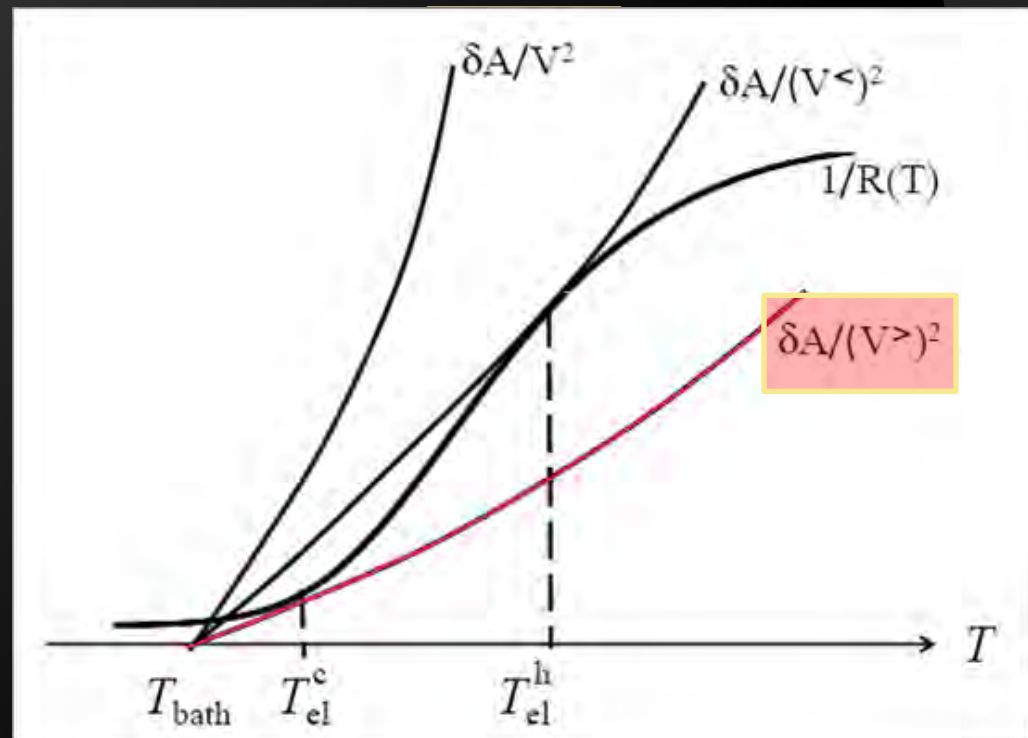
Insulating behaviour

$$R(T) = R_0 \exp\left(\frac{\Delta}{T_0}\right)$$

Heat balance equation

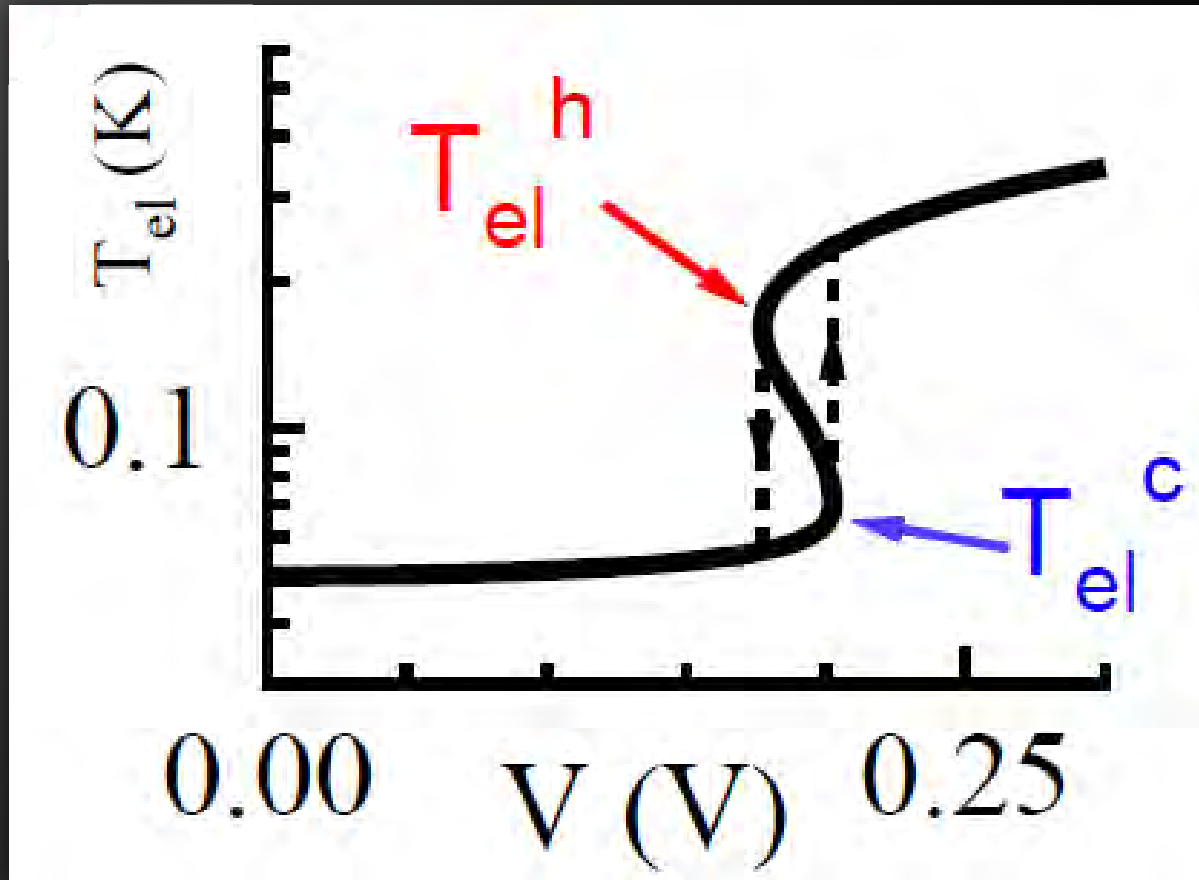
$$\frac{V^2}{R(T_{el})} = c(T_{el}^6 - T_{ph}^6) = \delta A$$

$$c = \Gamma\Omega$$

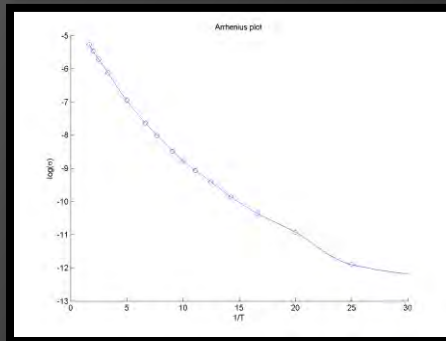
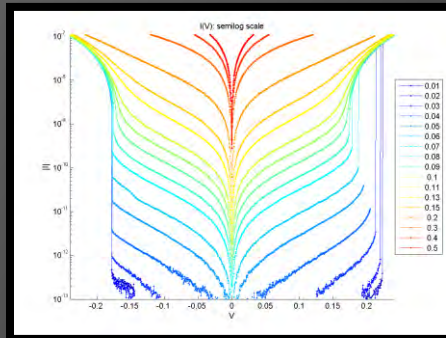


Numerical solution

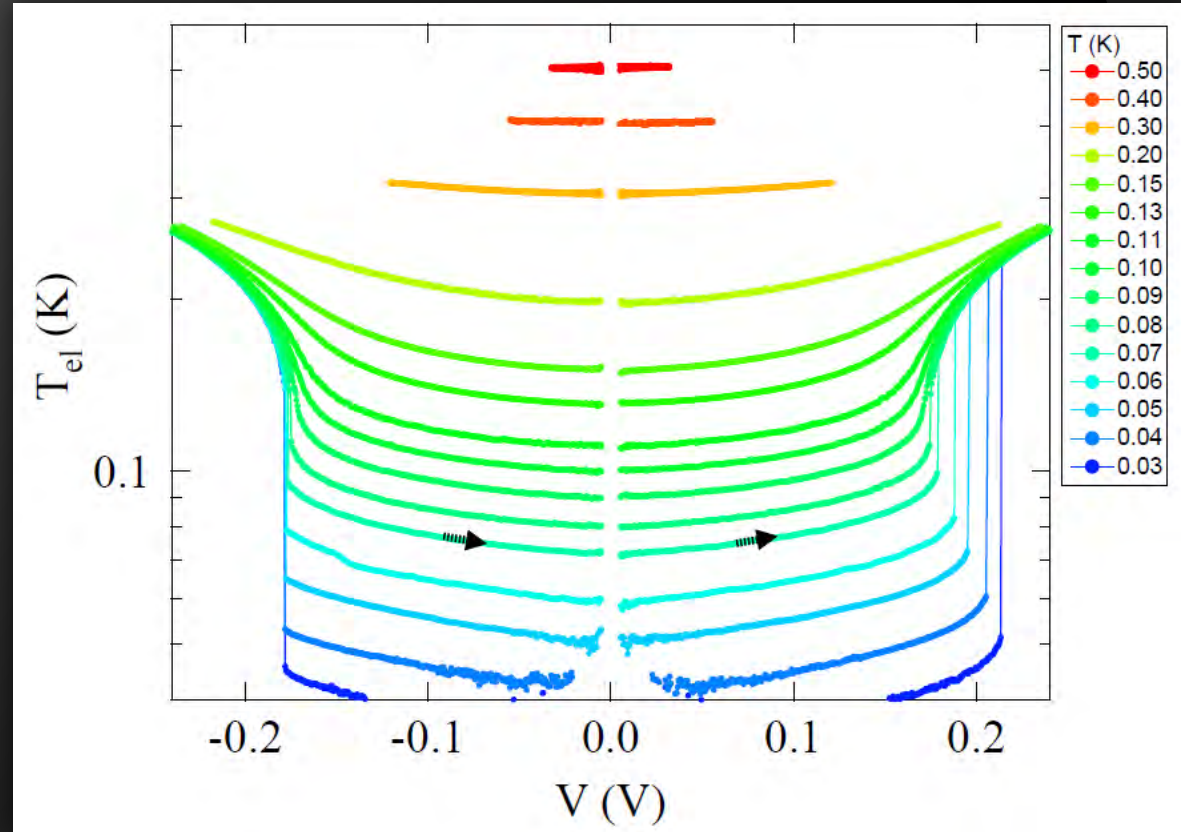
$$\frac{V^2}{R(T_{el})} = c(T_{el}^6 - T_{ph}^6) = \delta A$$



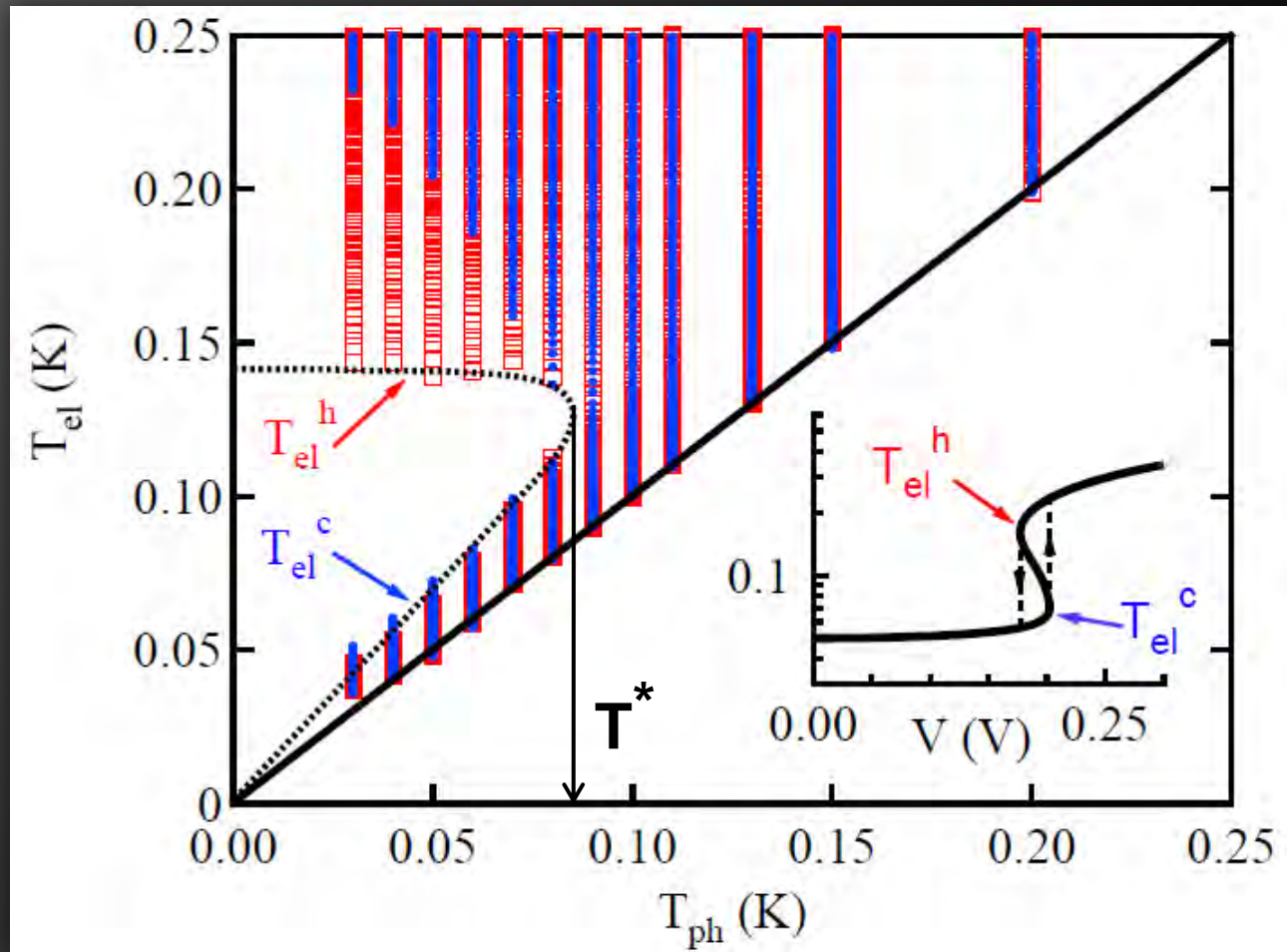
Electronic temperature



$$T_{el} = T_{el}(V / I)$$

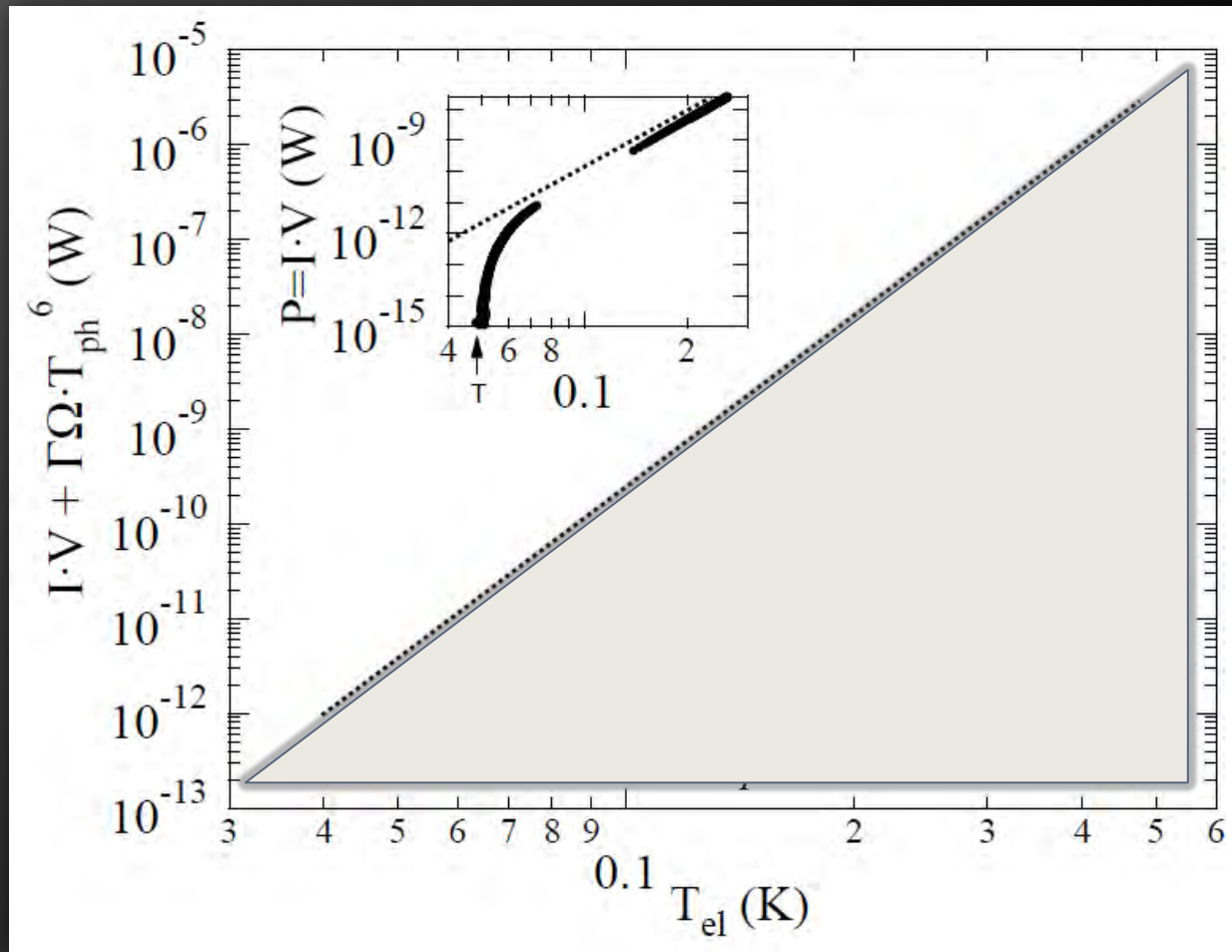


Thermal bistability



Heat balance eq.

$$\frac{V^2}{R(T_{el})} = c(T_{el}^6 - T_{ph}^6) = \delta A$$



Summary

PRL 102, 176802 (2009)

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Electron-Phonon Decoupling in Disordered Insulators

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(Received 28 January 2009; published 28 April 2009)

- ⊙ I – V characteristic
 - Remains linear at low bias
 - Nonlinear at higher bias with hysteretic jumps at ultralow T
- ⊙ Electron overheating scenario
 - Explains the bistability and hysteresis in I – V
 - Heat balance equation consistent with entire I – V data set
- ⊙ Open questions
 - Electron overheating is incompatible with conventional phonon-assisted transport
 - How does the el-ph coupling change, approaching the superconductor?