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KRYO 2015 oral presentation. Not submitted for publication.

Escape and retrapping experiments with Josephson j junctions

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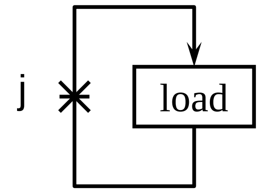
29.09.2015 Burg Warberg, Germany

j Josephson junction



degenerate ground state phase - j or +j

d-wave GB JJs (intrinsic j JJ)

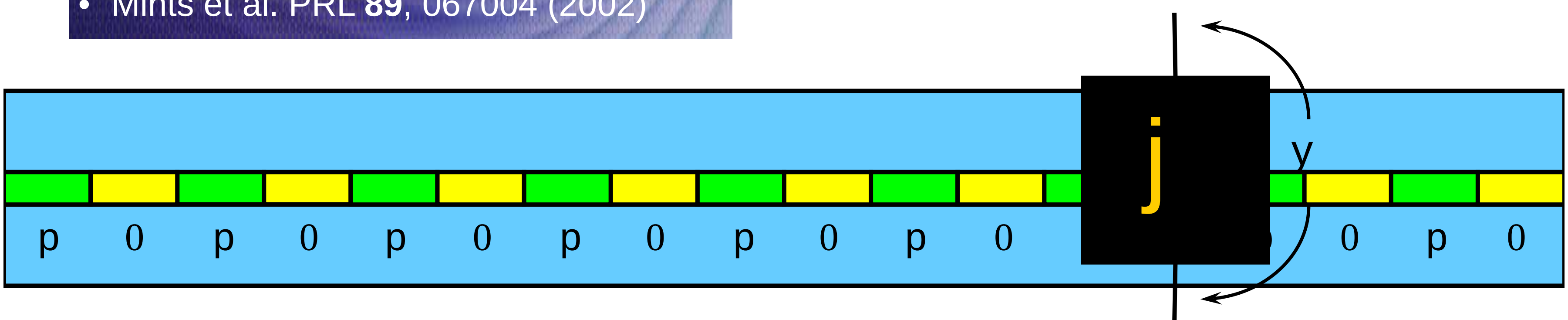
- Tanaka et al. PRB **56**, 892 (1997)
- Testa et al. APL **85**, 1202 (2004)
- Il'ichev et al. PRL **86**, 5369 (2001)

d-wave GB JJs (faceting j JJ)

Splintered vortices due to GB faceting:
- R. Mints et al. PRB **57**, R3221 (1998);
- Mints et al. PRL **89**, 067004 (2002)

j JJ engineered from 0-p JJ:

R. Mints et al. PRB **57**, R3221 (1998);
A. Buzdin et al. PRB **67**, R220504 (2003).

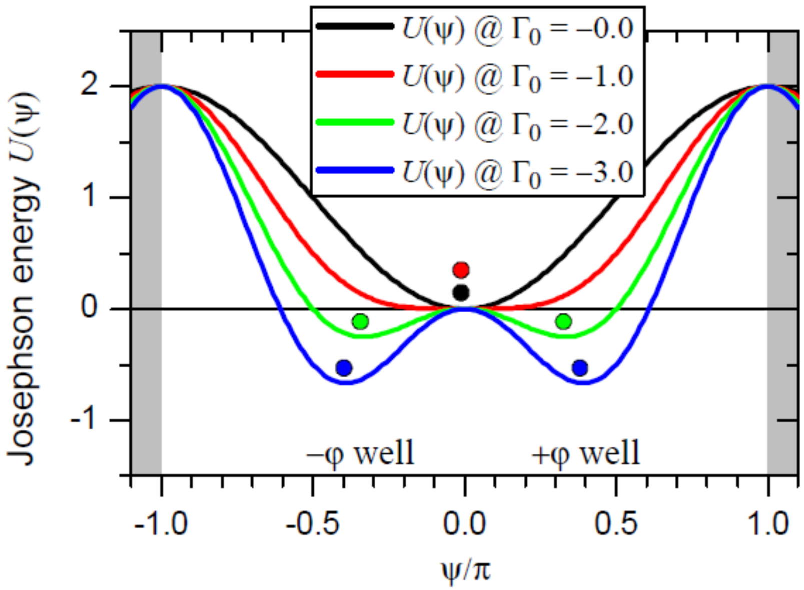


& Proposal: E. Goldobin et al., PRL **107**, 227001 (2011)
& http://www.pro-physik.de/details/news/3790631/Supraleiter_als_Phasenbatterie.htm

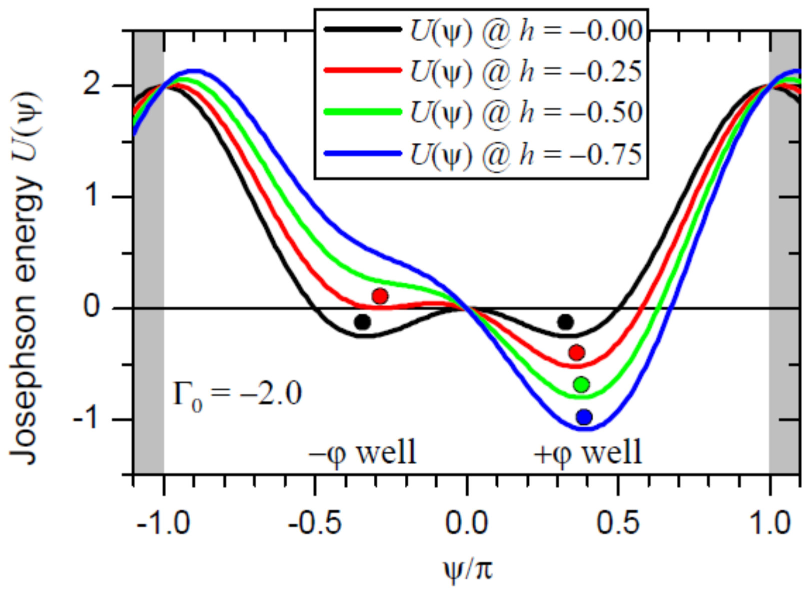
j Josephson junction

$$U_J(\psi) = 1 - \cos(\psi) + \frac{\Gamma_0}{4}[1 - \cos(2\psi)] + \Gamma_h h \sin(\psi),$$

$$\varphi = \arccos(-1/\Gamma_0)$$



Bistable/two-level system

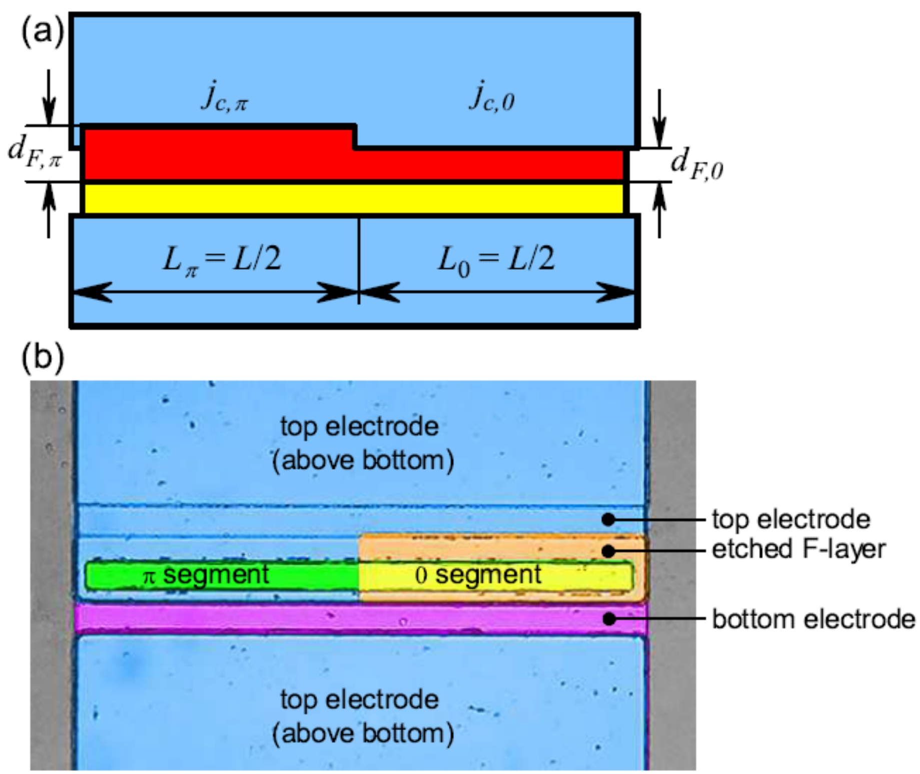


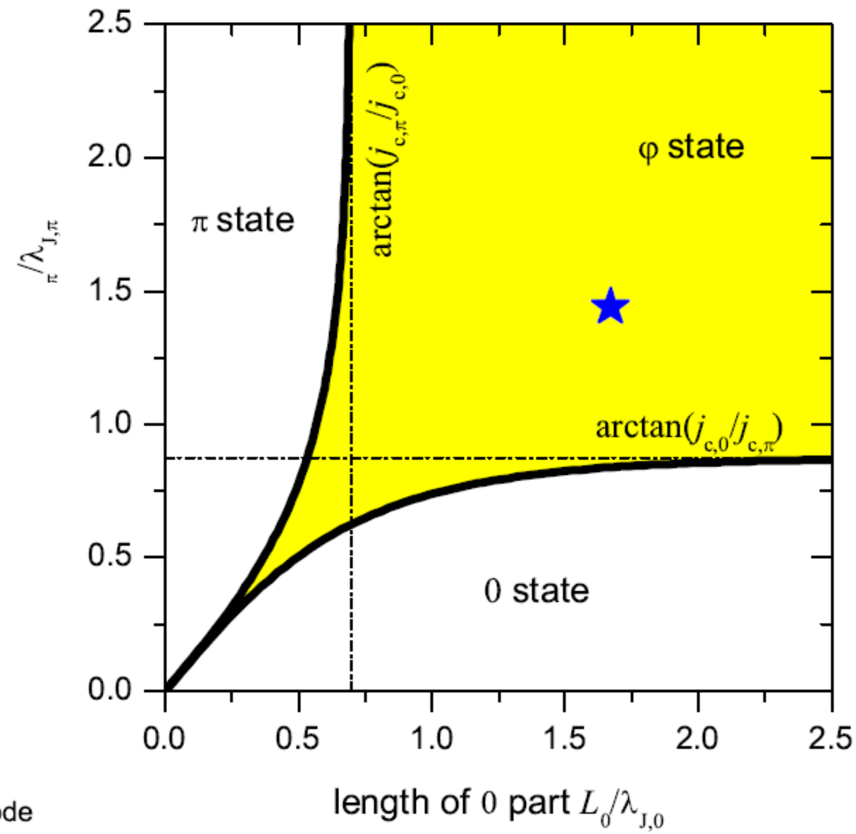
Ratchets & co.

& Proposal: E. Goldobin et al., PRL **107**, 227001 (2011)
& Experiment: H. Sickinger et al., PRL **109**, 107002 (2012)
& http://www.pro-physik.de/details/news/3790631/Supraleiter_als_Phasenbatterie.htm

Experiment: samples

SIFS 0-p Josephson junction:
L = 100+100 mm,
j_{c0}=67.8A/cm^2, j_{cp}=47.4A/cm^2,
L_0 ~ 1.73 l$_{J,0}$, L_p ~ 1.45 l$_{J,p}$, @300mK





@ T = 2.35 K

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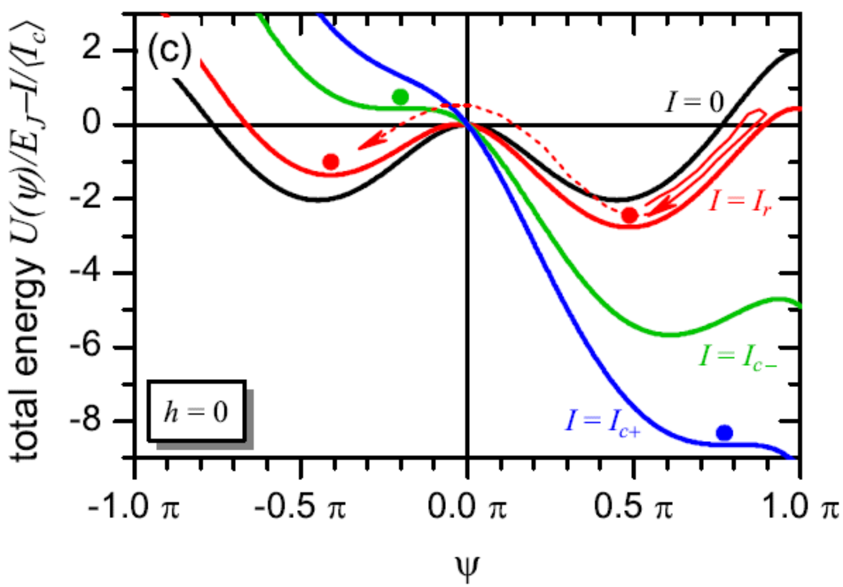
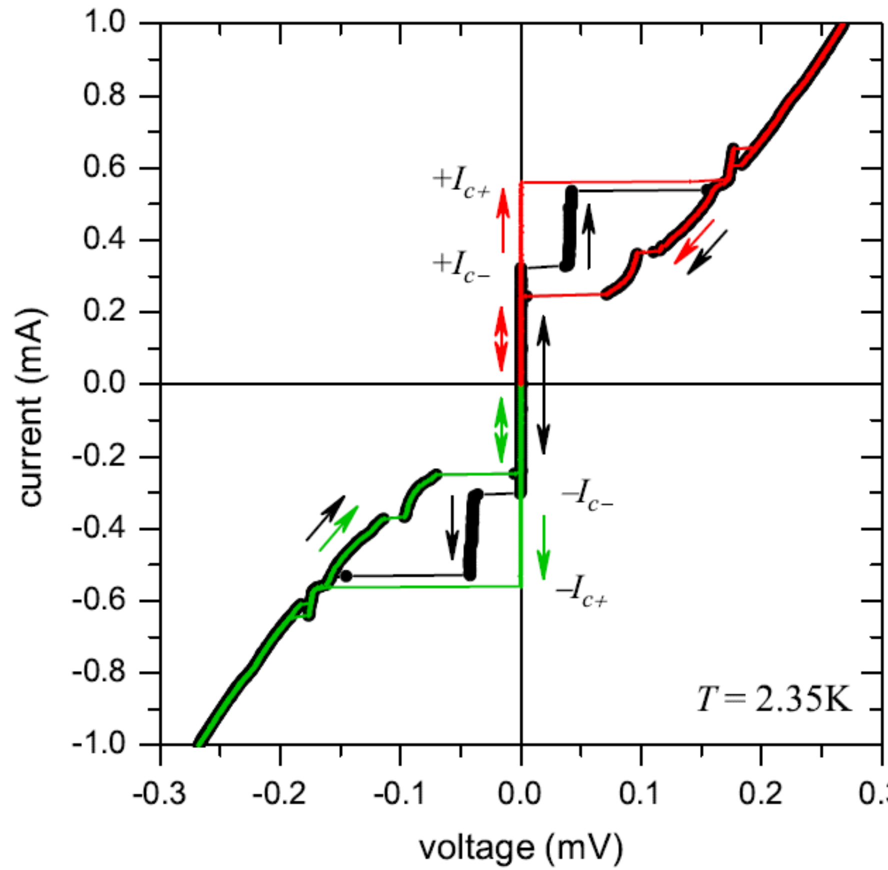
IVC: two critical currents

Observation of I_{c+} and I_{c-}

- I_{c+} is always observed
- I_{c-} only @ 0.3 K < T < 3.5 K (low damping a)
- immediate retrapping in the +j well (high damping a)





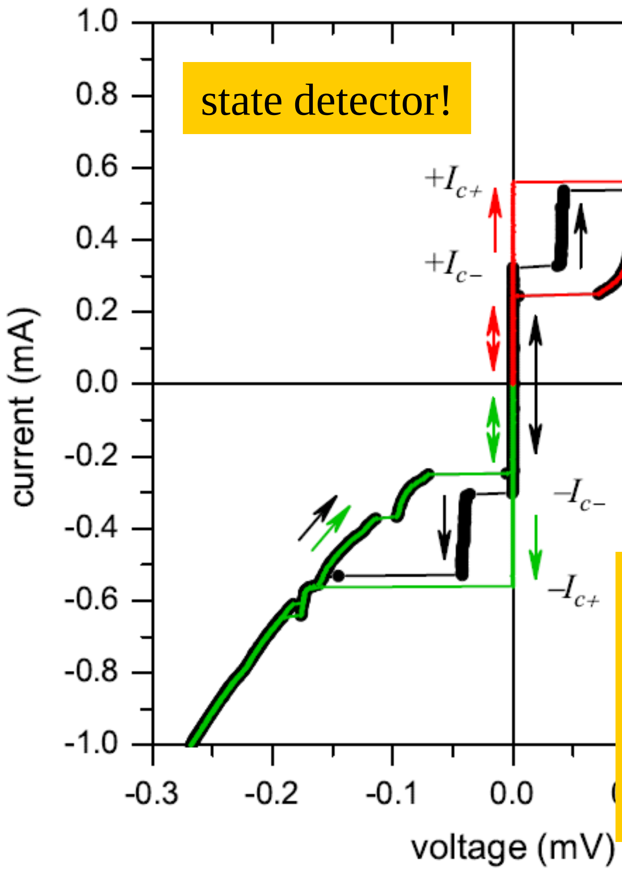
state detector!

& H. Sickinger et al., PRL **109**, 107002 (2012)

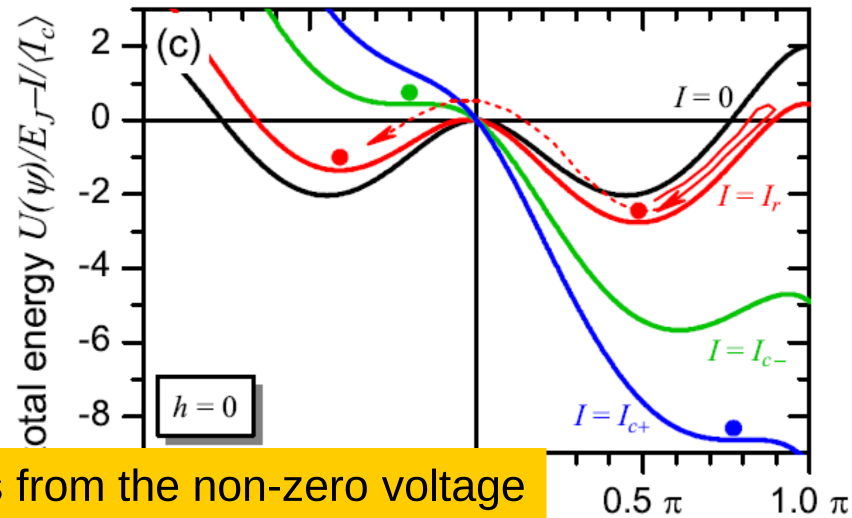
Phase retrapping in j JJ

IVC and phase retrapping

I--*V* characteristic



$$U(\psi) = U_J(\psi) - \gamma\psi,$$

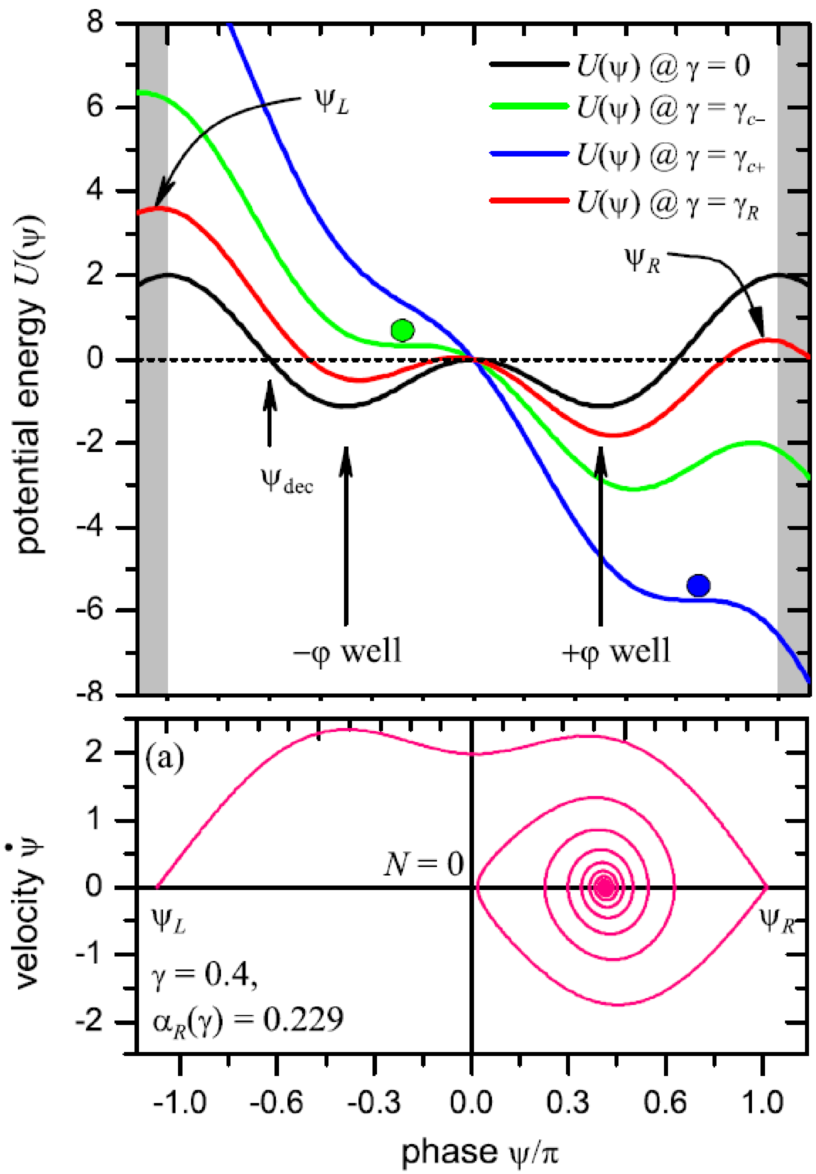


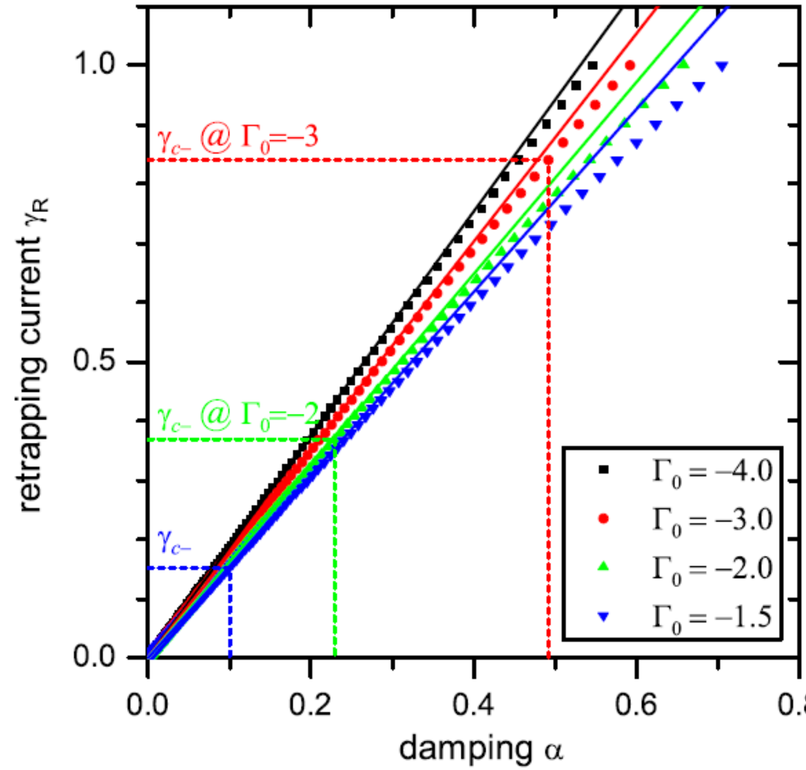
If j -JJ returns from the non-zero voltage state (sliding phase) to zero voltage state

in which well is the phase trapped?

$$\ddot{\psi} + \frac{\partial U_J}{\partial \psi} = \gamma - \alpha\dot{\psi},$$

Phase Retrapping

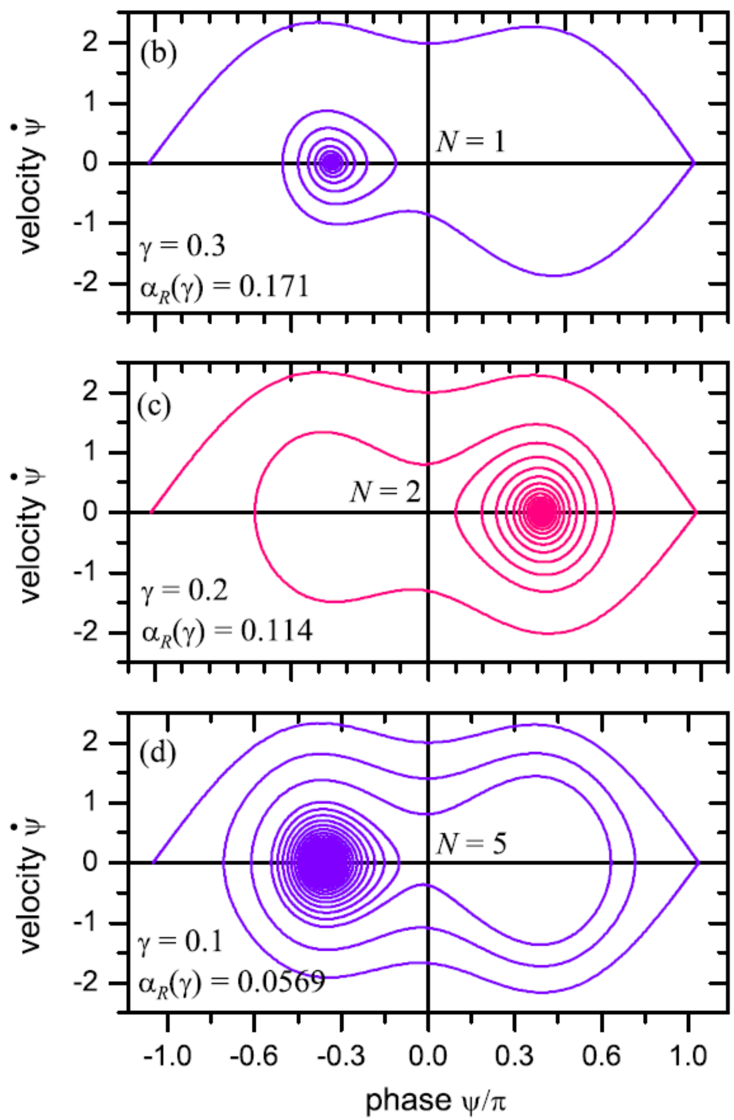


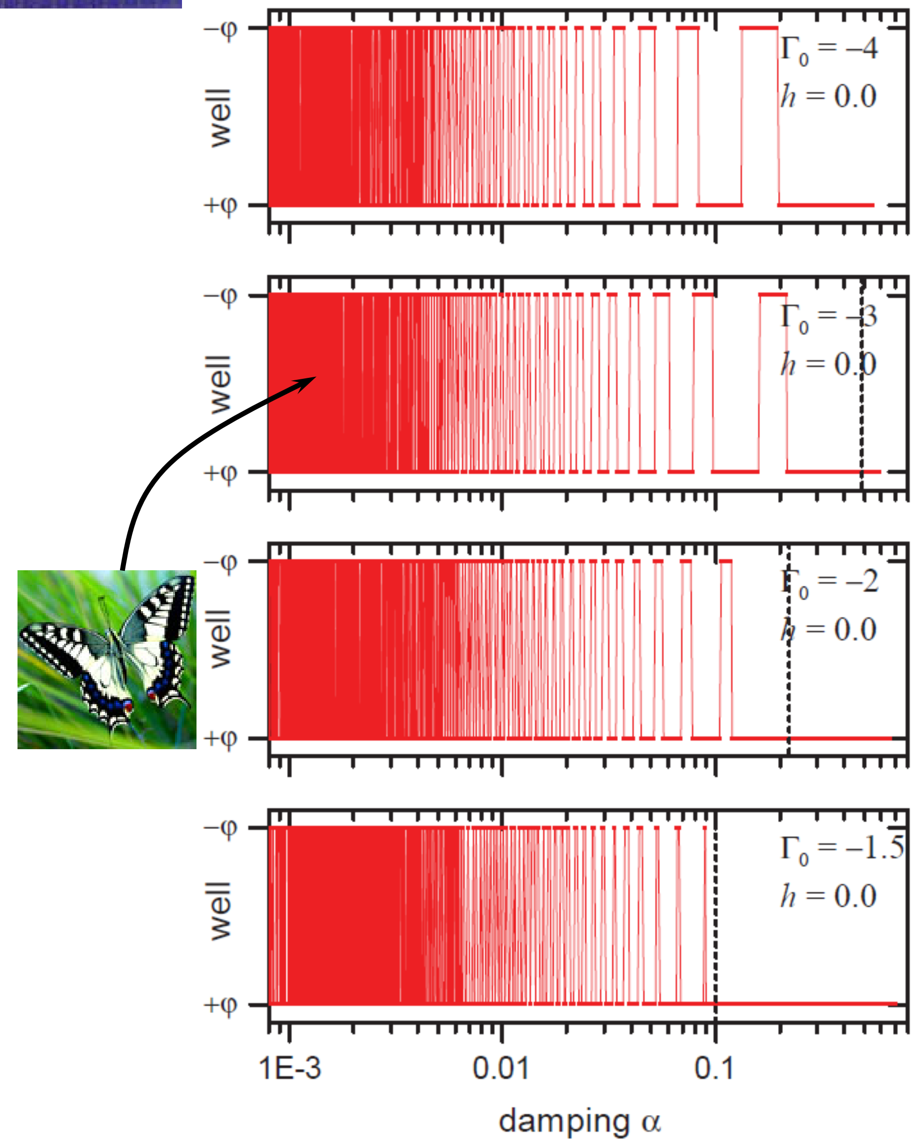


Perturbation theory (a<<1, g<<1):

$$\gamma_R(\alpha) = \frac{I(\Gamma_0)}{2\pi}\alpha.$$

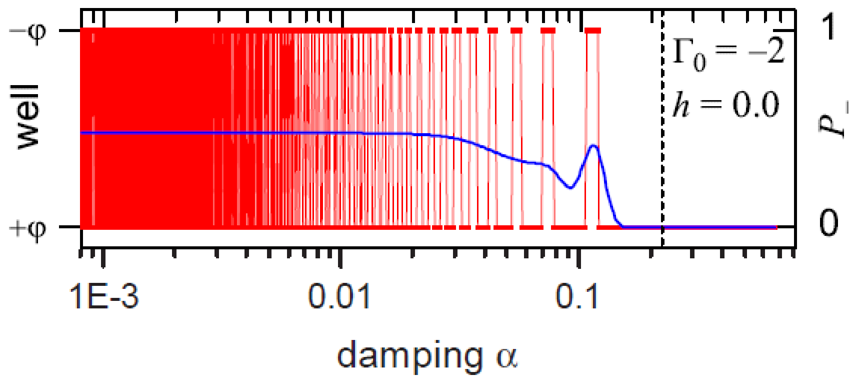
Butterfly effect



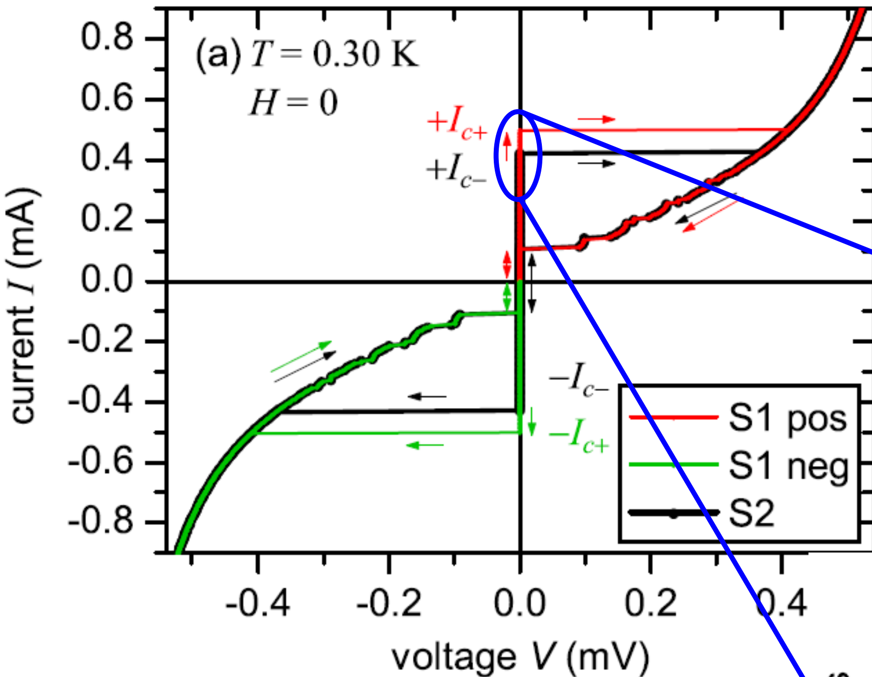


Presence of noise

Simple model: low frequency Gaussian noise



Experiment: Retrapping+Escape



Nb-AlO-CuNi-Nb j JJ:
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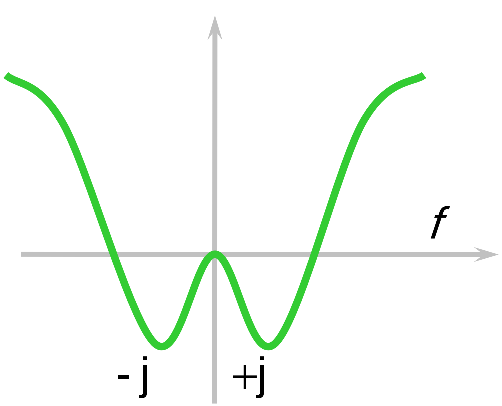
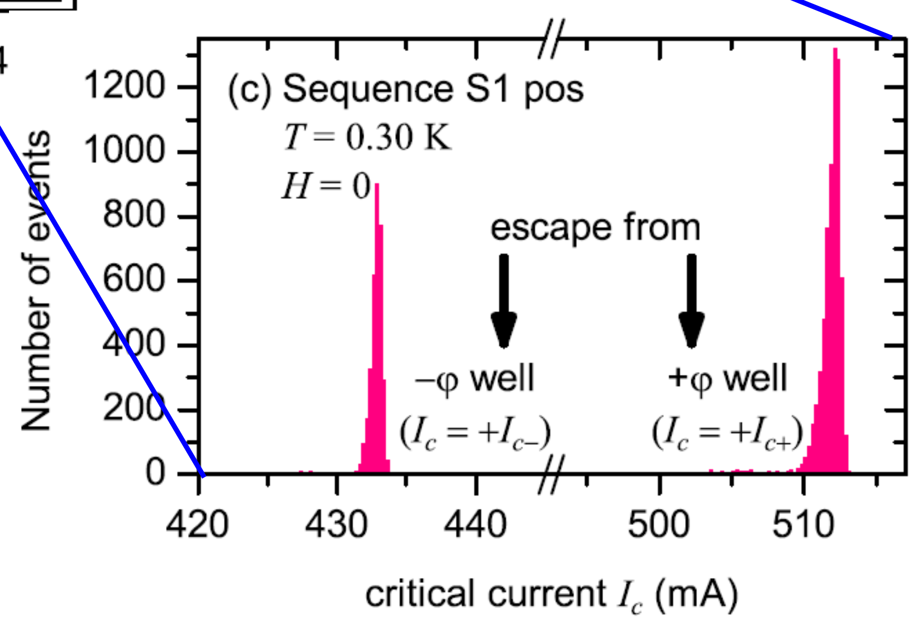
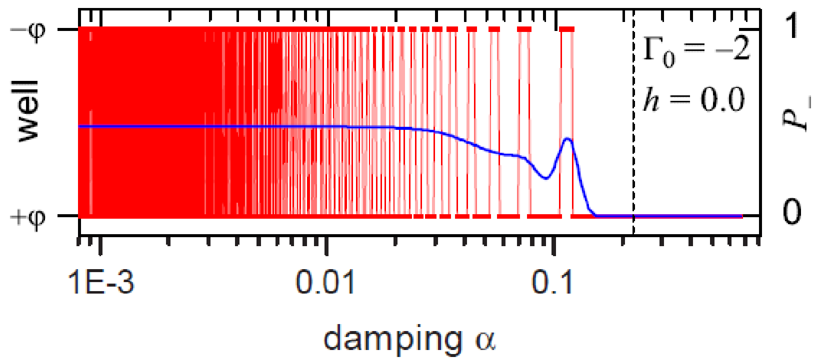
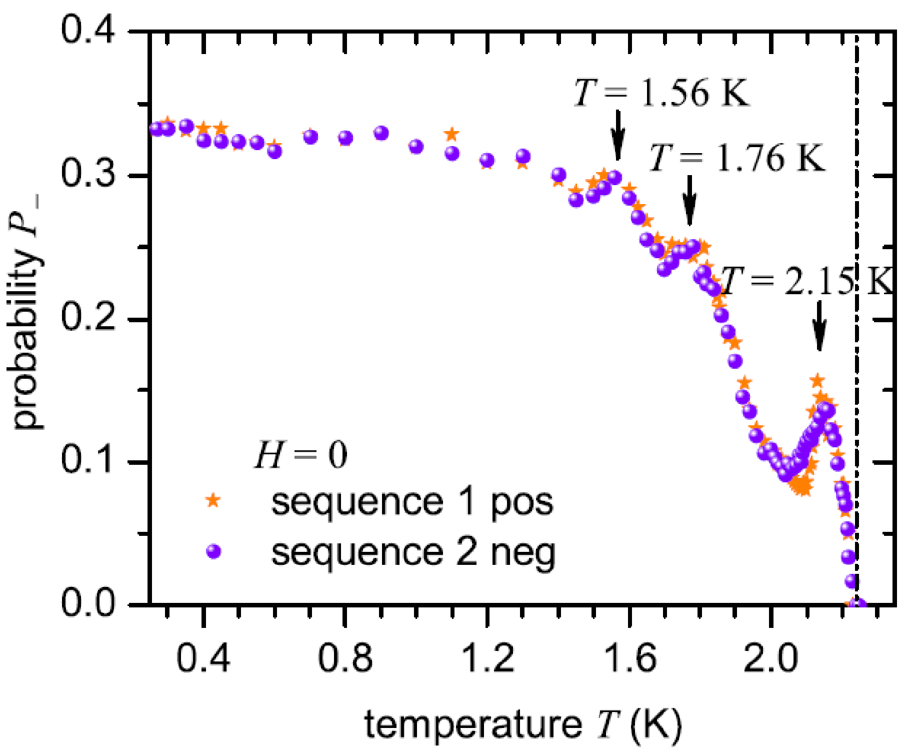
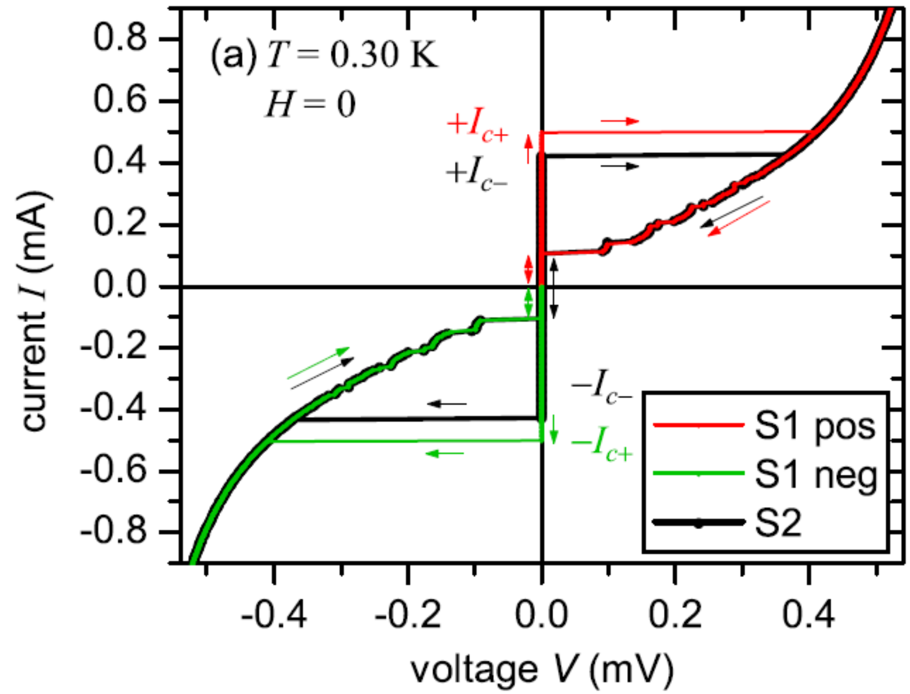




Retrapping statistics vs. T



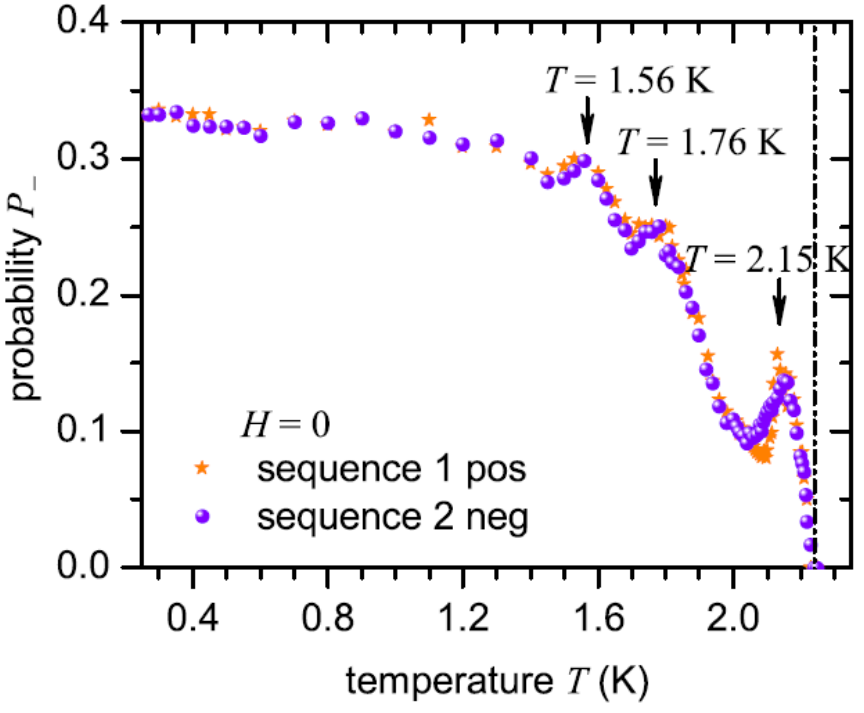


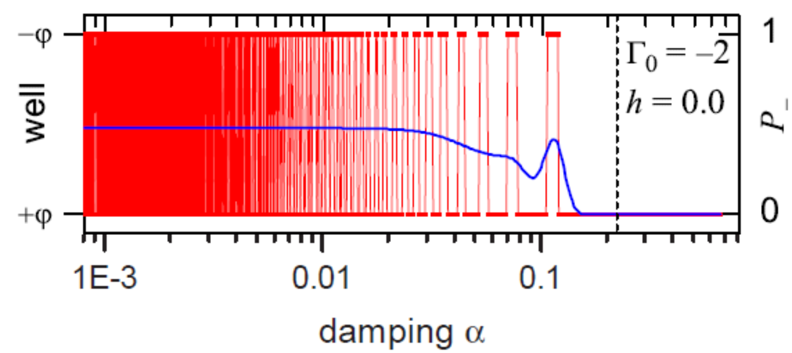


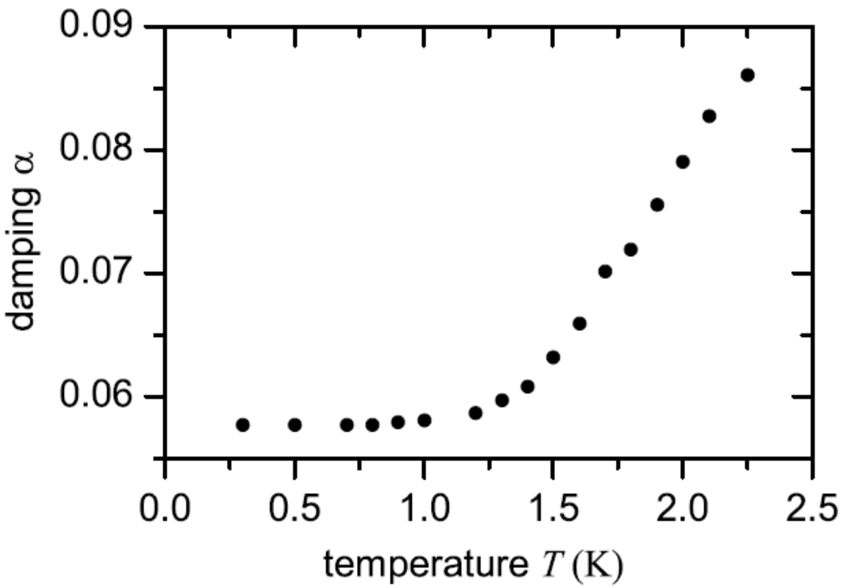
Why saturation of P_- is not at 50%?

- Asymmetric double well potential
- Saturation of damping a(T)
- other nontrivial effects

Retrapping statistics vs. T







Summary

Summary:

- Introduction to j -JJs and their main properties
- Phase retrapping experiments:
  - Onset of the butterfly effect
  - Saturation at 33% instead of 50%
    (due to saturation of the damping)

Outlook:

- **repeat the experiment with a low damping system (e.g. SIS JJ) to reach lower damping i.e. go deeper into the butterfly-effect region.**