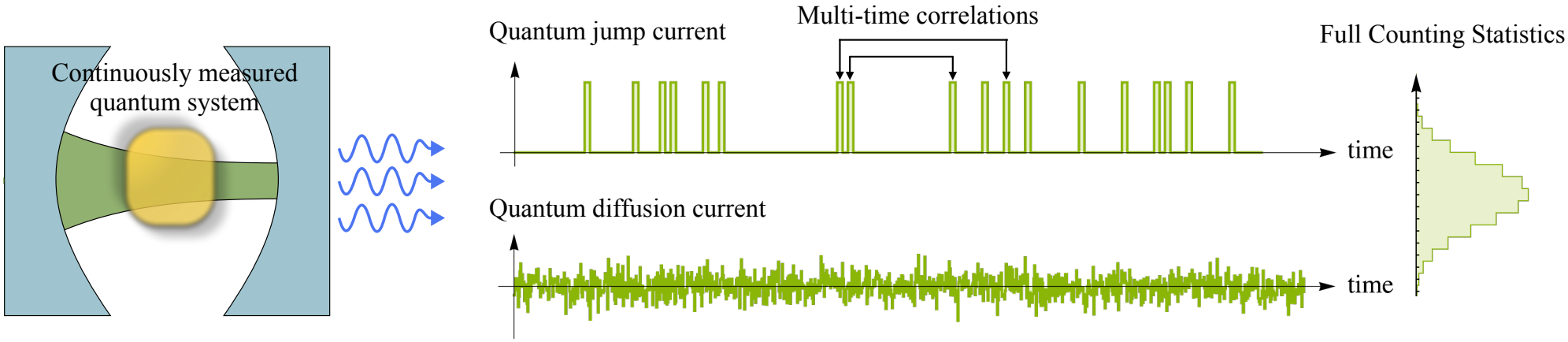

Diverging current fluctuations in critical Kerr resonators

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03/07/2023 - APS March Meeting 2023 - Las Vegas

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Current fluctuations - Full Counting Statistics

- Two-time correlation function:

$$F(\tau) := \left\langle I(t)I(t+\tau)\right\rangle - J^2$$
$$= J\ \delta(\tau) + J^2\left[g^{(2)}(\tau) - 1\right]$$

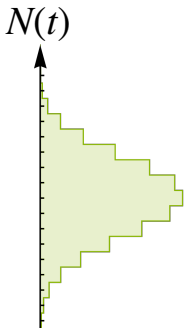
$g^{(2)}$ = Glauber's 2nd order coherence function

- Power spectrum:

$$S(\omega) = \int_{-\infty}^{\infty} e^{-i\omega\tau} F(\tau) d\tau$$

- Zero-frequency component of the power spectrum := "noise":

$$D = S(0) = \lim_{t\to\infty} \frac{d}{dt} \mathrm{Var}\left(N(t)\right)$$

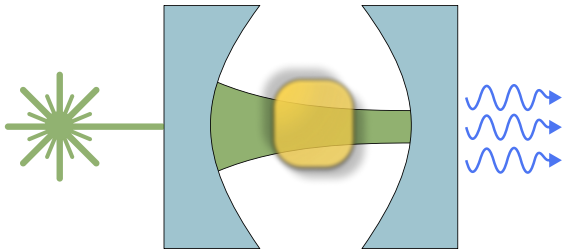


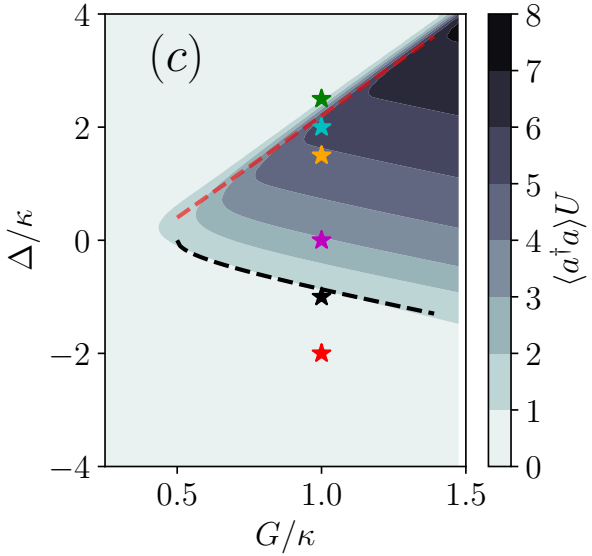
Parametric Kerr model

- Non-linear quantum harmonic oscillator:

$$\frac{d\rho}{dt} = -i[H(t), \rho] + \kappa\left[a\rho a^\dagger - \frac{1}{2}\{a^\dagger a, \rho\}\right]$$

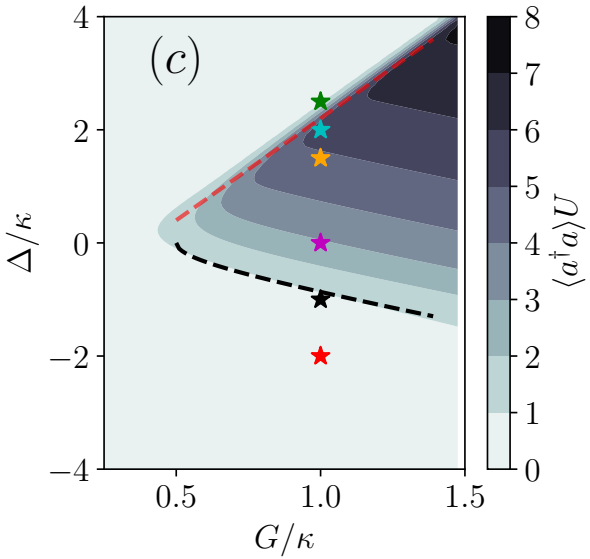
$$H = -\Delta a^\dagger a + \frac{U}{2} a^\dagger a^\dagger a a + \frac{G}{2}(a^{\dagger 2} + a^2)$$





- a = annihilation operator
  photon operator for an optical cavity
- $\Delta = \omega_p - \omega_c$ = detuning
- U = Kerr non-linearity.
  (requires a non-linear crystal inside the cavity)
- G = 2-photon pump
  (input laser produces photons in pairs)
- κ = loss rate
  rate at which photons leak out of the cavity

Becomes critical when $U \to 0$



- 2 phase transitions, continuous and discontinuous
- Proper criticality occurs in the limit $U \to 0$ (“thermodynamic limit”)

Wigner function

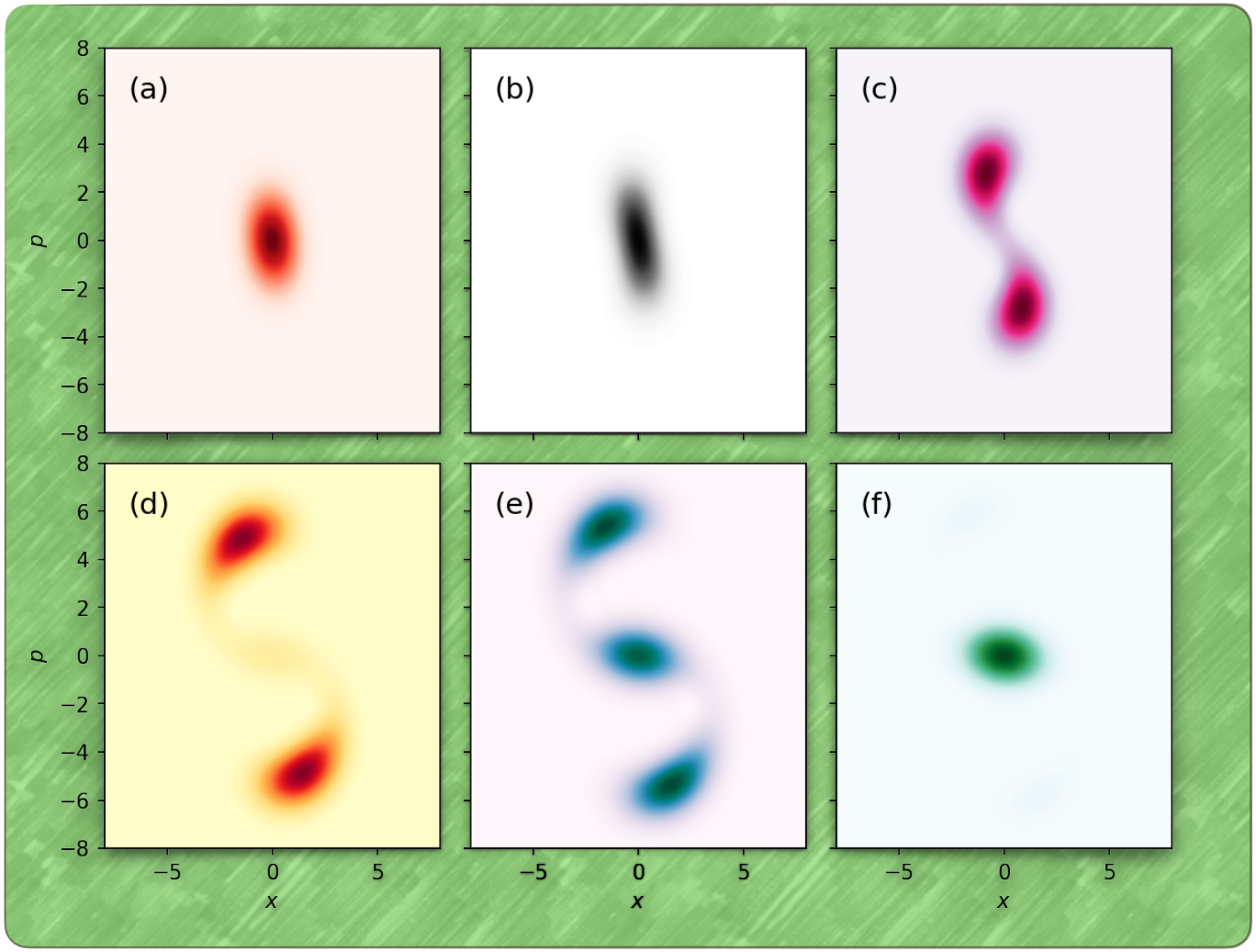
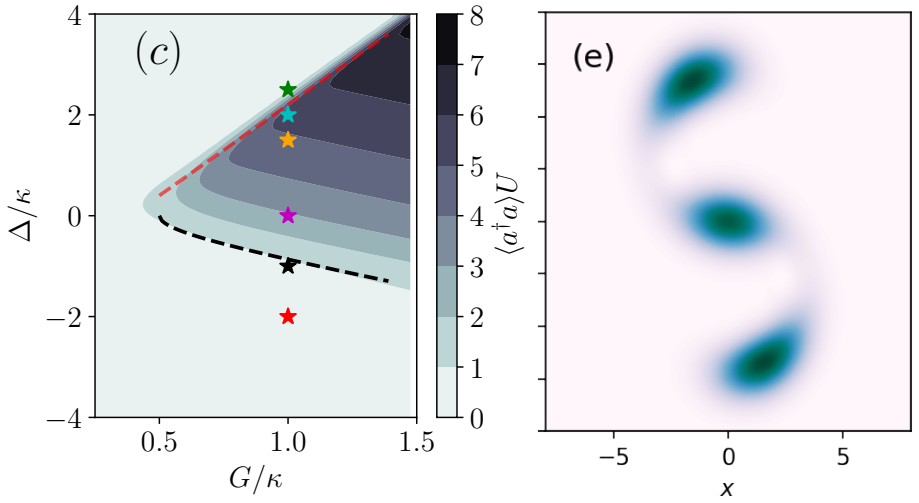
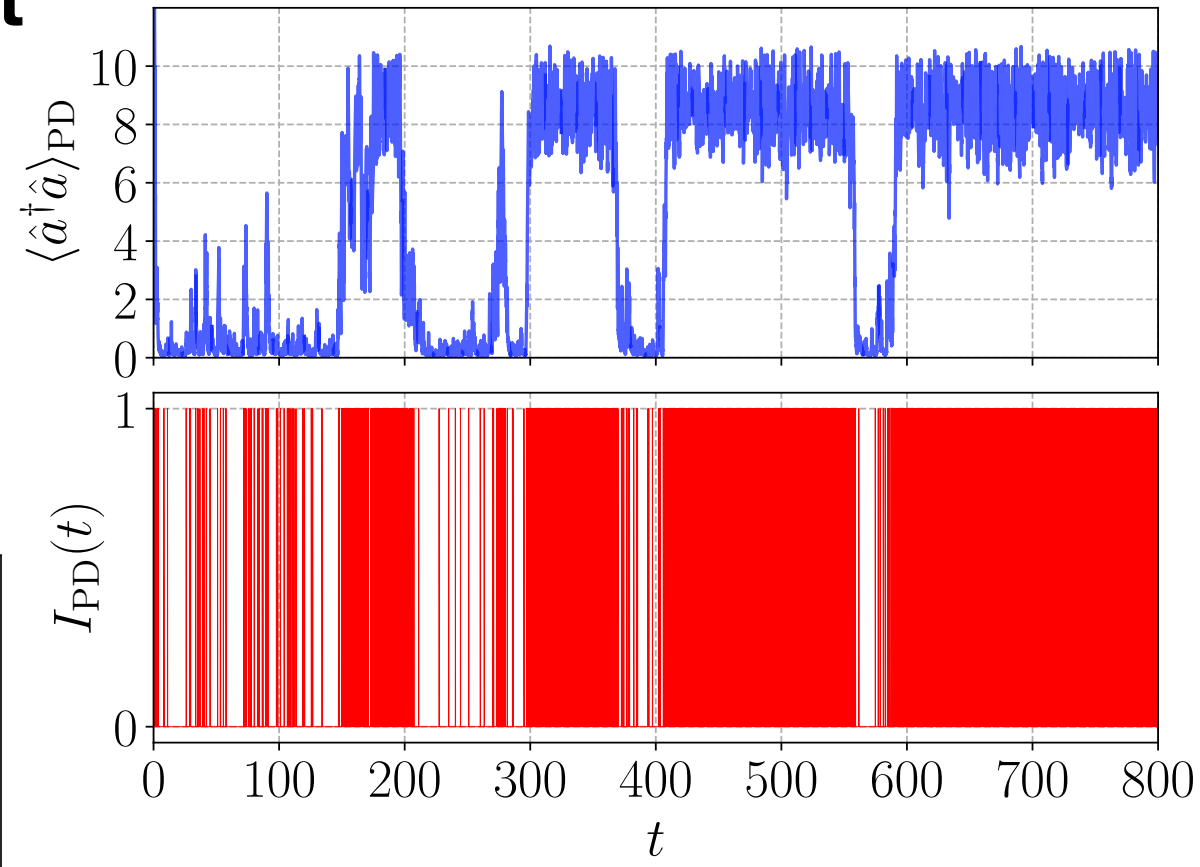


Photo-detection current

- @ discontinuous transition: on/off (telegraph) behavior of the current.
- Photo-detection cannot resolve upper vs. lower blobs.



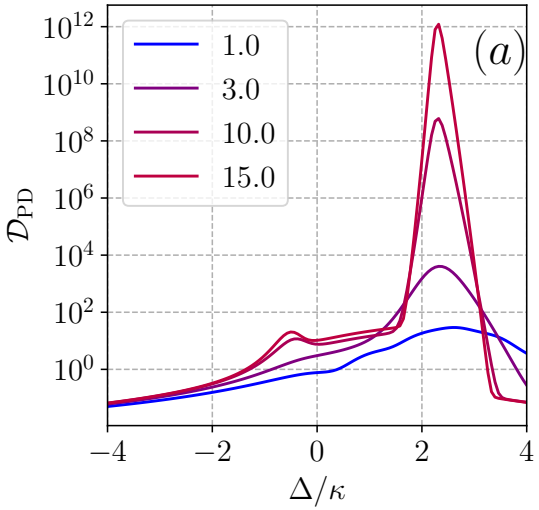


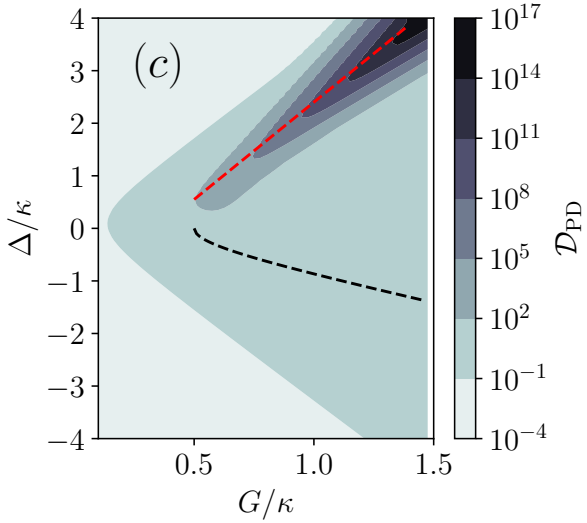
$J = \langle I \rangle$ = photon current = clicks/second

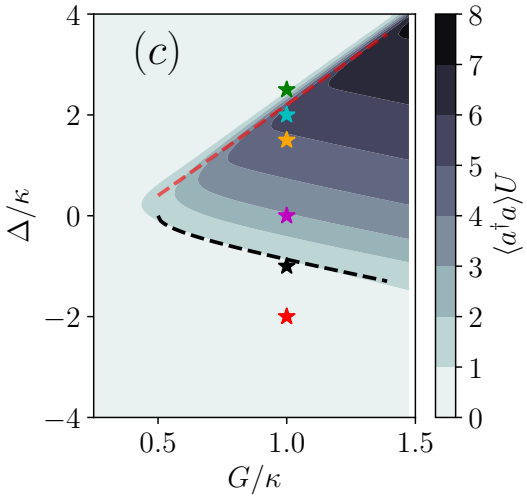
Exponential divergence of the noise

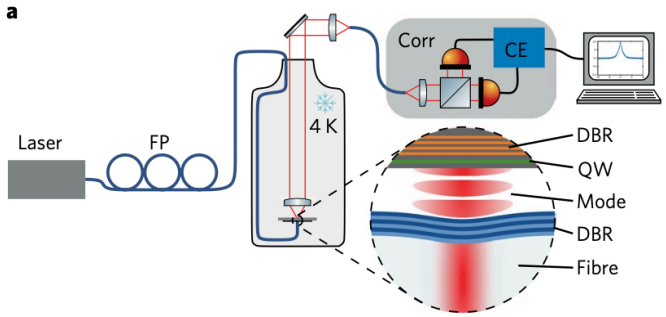
- "Thermodynamic limit:" $U \to 0$
- In the discontinuous transition ($\Delta > 0$)

$$D \sim e^{1/U}$$





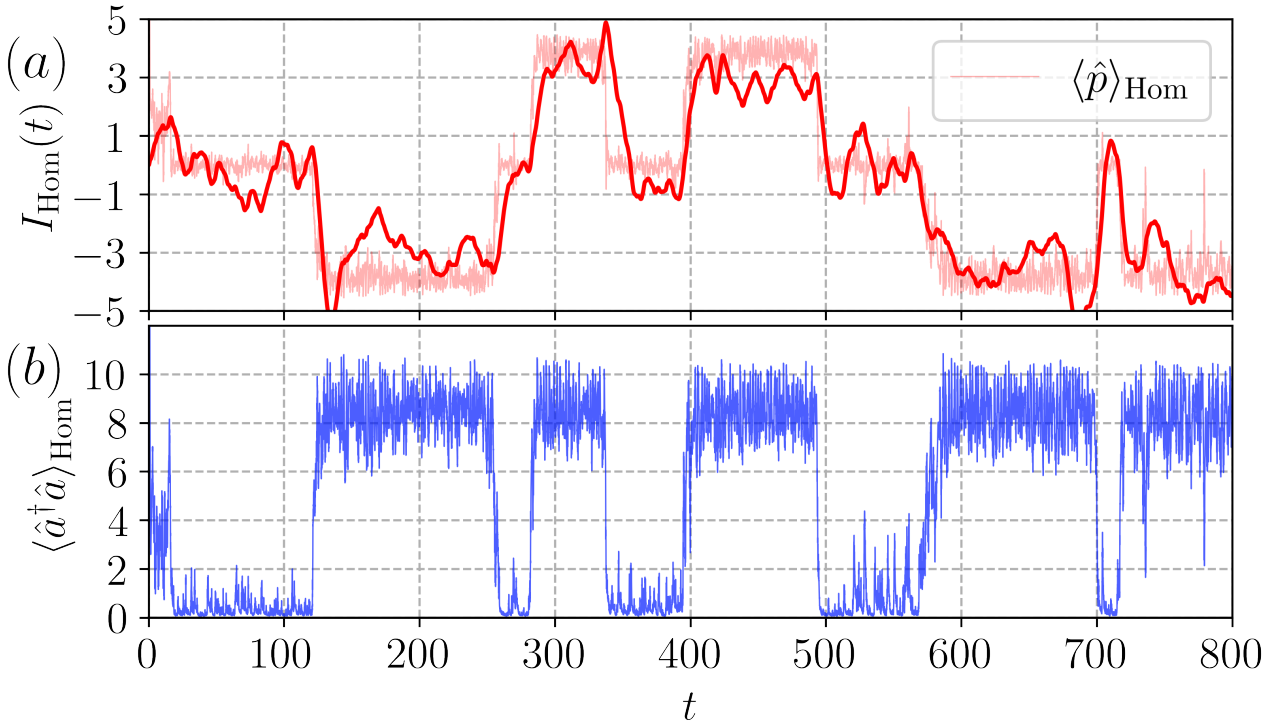


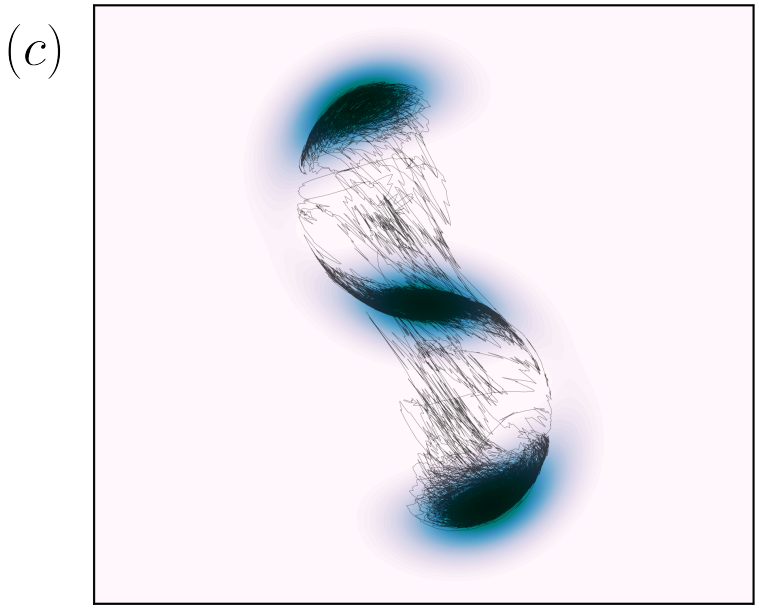


T. Fink, *et. al.*, *Nature Physics,* **14**, 365 (2018)

Homodyne current

- Observable is now $p = i(a^\dagger - a)$.
- The homodyne current switches between 3 values (+,0,-).
- Captures the tunneling between the 3 blobs.



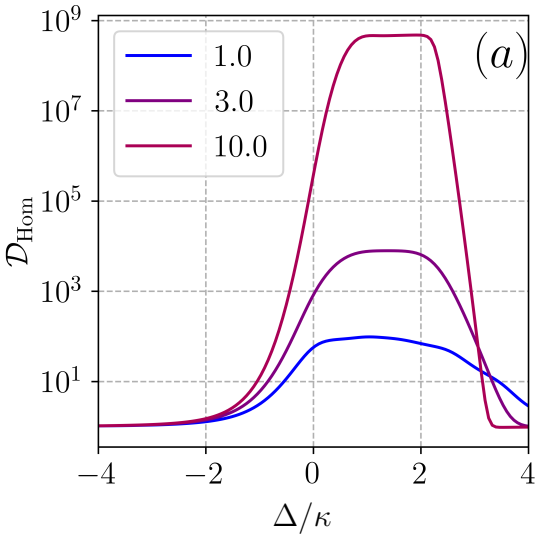


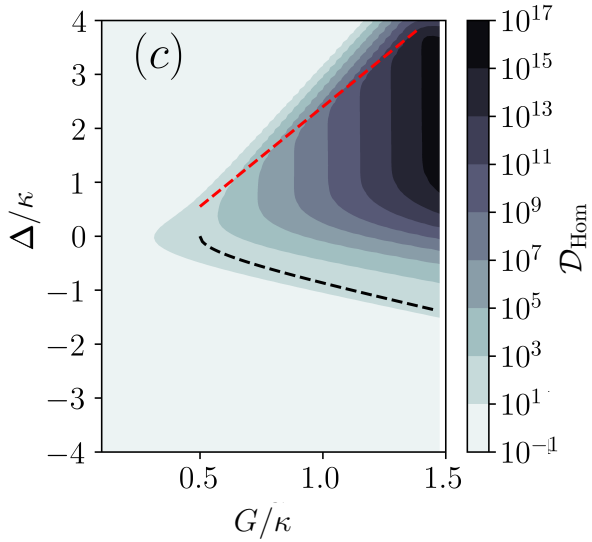
Divergence of the noise in the homodyne case

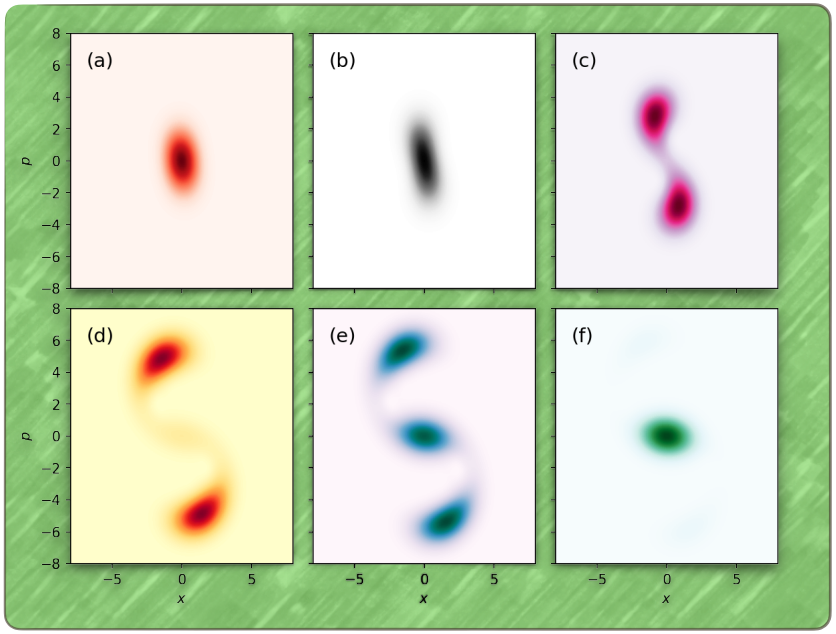
- Homodyne current noise diverges exponentially in a much broader region.

$$D \sim e^{1/U}$$

- Reflects sensitivity to all 3 blobs.





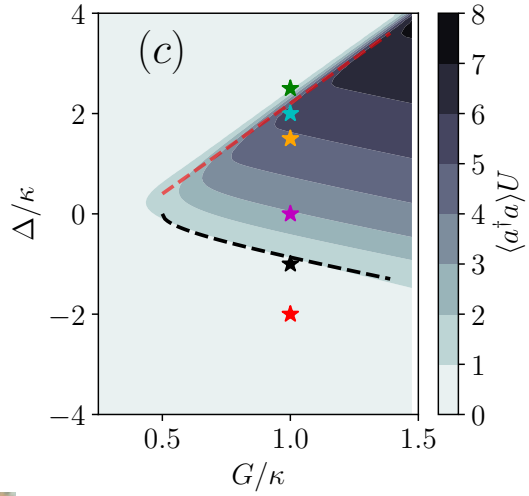


First study of Full Counting Statistics of the homodyne current

Summary

M. Kewming, M. Mitchison & GTL,
“**Diverging current fluctuations in critical Kerr resonators**”,
Phys. Rev. A **106**, 033707 (2022)

GTL, M. Kewming, M. Mitchison, P. Potts,
“**Current fluctuations in open quantum systems: Bridging the gap between quantum continuous measurements and full counting statistics.**”
Tutorial, in preparation

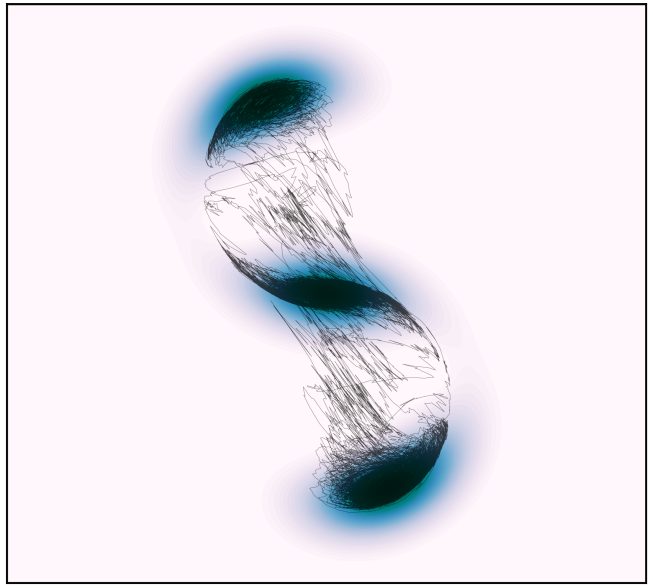


Z02:9 - Friday


Patrick Potts


Michael Kewming


Mark Mitchison



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