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CHAOS BEYOND THE ONSET IN AC-DRIVEN PHASE SLIP CENTERS

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Chaos beyond the onset for the generalized time-dependent Ginzgurg-Landau equations exhibits generic behavior. We present qualitative and quantitative evidence of a multifractal phase transition and of a symmetry-increasing bifurcation. We also discuss the underlying mechanisms of these phenomena.

The different routes to chaos received a great deal of attention in recent years; in contrast much less is known about dynamical systems beyond the onset of chaos. There is an increasing theoretical effort in this direction and recent experiments confirmed some universal features beyond the onset of chaos (1).

In this paper we explore the supercritical regime in ac-driven phase slip centers (2). We show that this system exhibits a couple of interesting phenomena characteristic of discrete maps: multifractal phase transitions (4) and a symmetry restoring bifurcation (6).

The ac-driven phase slip centers are solutions of the generalized time-dependent Ginzburg-Landau equations which describes a thin and long current carrying filament. For dirty superconductors in the local equilibrium regime, these equations are given by (2),

$$u\left(1+\gamma^2|\psi|^2\right)^{-1/2}\left[\partial_t + i\mu + \frac{1}{2}\gamma^2\partial_t|\psi|^2\right]\psi = \partial_x^2\psi + \left(1-|\psi|^2\right)\psi \qquad (1)$$

$$j = \psi^*\partial_x\psi - \partial_x\mu \qquad (2)$$

$$j = j_{ac}\cos(\omega t) \qquad (3)$$

where $\Psi(x,t)$ is the complex order parameter, j is the current density, $\mu(x,t)$ is the chemical potential, $\gamma(T)$ is a measure of the damping of the system, $\xi(T)$ is the coherence depth and u is a dimensionless parameter which arises from the microscopic theory. Variables are renormalized in the usual fashion (2). In this paper parameter values are $u=5.79$, $\omega=0.2$ and $\gamma=10$. We employ periodic boundary conditions.

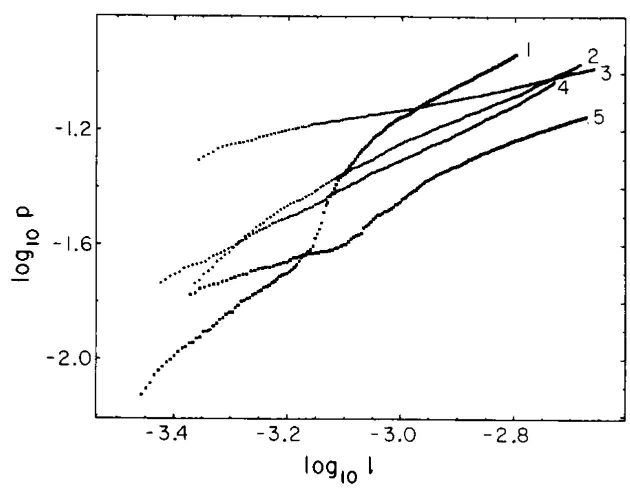

FIGURE 1

The ac-driven phase slip centers present the period doubling route to chaos as the amplitude of the driving force is decreased (2).

As will be reported elsewhere, at the onset of chaos ($j_{ac}=0.474892$) the system is ruled by an strange attractor which exhibits an universal multifractal spectrum $f(\alpha)$ and as j_{ac} is decreased higher dimensional effects appear: an internal crisis sequence removes a supercritical behavior like the one characteristic of the logistic map, giving rise to an attractor more likely to the Hénon attractor ($j_{ac}=0.47455$).

Figure 1 and the corresponding Table I presents the local scaling of the probability measure for a representative group of points of the attractor at $j_{ac}=0.47455$. This calculation allows us a quantitative understanding of the scaling structure ($p \approx l^{-\alpha}$) of the attractor, in particular allows us to detect points with abnormally high local density (curves 3 and 5 at Figure 1).

Curve	Slopes	
	Bottom	Top
1	1.468961	1.070476
2	1.796748	0.831836
3	0.322568	0.464425
4	0.986235	
5	0.569997	0.808245

TABLE I

These points are generated by tangencies between the stable and the unstable manifolds of unstable periodic orbits (3).

Curves 1, 2 and 4 shows local values of α bigger or equal than one which arise from hyperbolic parts of the attractor (3,4).

The simultaneous presence of regions of the attractor with two different local scalings (hyperbolic and non-hyperbolic) causes a first-order-multifractal phase transition (3,5).

Figure 2 shows a strobed plot $\mu(x=0,t)$ vs. $\mu(x=0,t+\delta t)$ for $j_{ac}=0.4715$. This plot reveals an attractor which has in average the following symmetry of the equations (1), (2) and (3),

$$t \to t + nT/2, \quad \psi \to \psi^*, \quad \mu \to -\mu \qquad (4)$$

here $T=2\pi/\omega$ is the period. This symmetry of the solution was lost slightly before the beggining of the period doubling cascade (symmetry breaking bifurcation) (2).

The attractors related through (4) are called conjugated attractors. Which attractor settles in depends on the initial conditions. At a value of amplitude of the driving force $j_{ac} \approx 0.47358$ a symmetry increasing bifurcation occurs (6). The signature is the presence of only odd multiples of ω in the power spectrum of $\mu(x=0,t)$. The symmetry increasing bifurcation occurs when the stable and the unstable manifold of the periodic solution with symmetry (4) touch in tangency (7). This last solution exists before the symmetry breaking bifurcation.

We have shown that a rather complex system exhibits a quite generic behavior beyond the onset of chaos, previously reported for low dimensional maps.

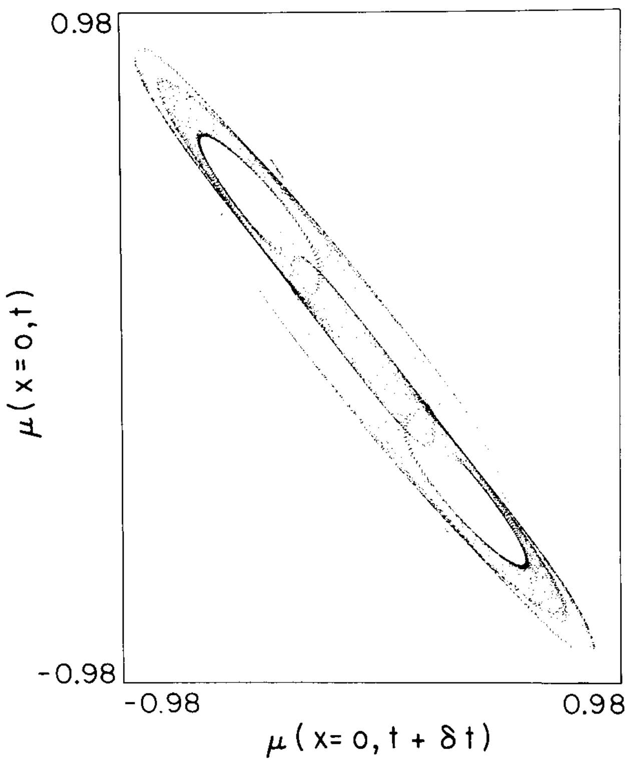

FIGURE 2

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REFERENCES

(1) G. H. Gunaratne, P. S. Linsay and M. J. Vinson, Phys. Rev. Lett. 63 (1989) 1.
(2) R. Rangel and L. Kramer, J. Low Temp. Phys. 74 (1989) 163.
(3) E. Ott, C. Grebogi and J. A. Yorke, Phys. Lett. A 135 (1989) 343.
(4) M. H. Jensen, Phys. Rev. Lett. 60 (1988) 1680.
(5) D. Katzen and I. Procaccia, Phys. Rev. Lett. 58 (1987) 1169.
(6) P. Chossat and P. Golubitsky, Physica D 32 (1988) 423.
(7) Y. Yamaguchi, Phys. Lett. A 135 (1989) 259.