Novel critical behavior in binary-production, reaction-diffusion systems

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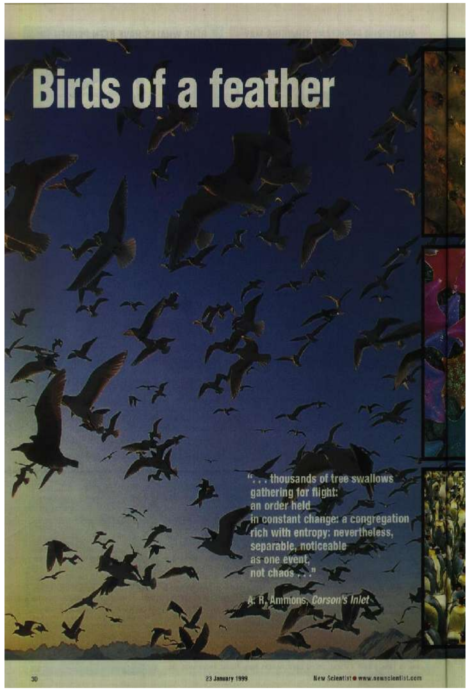
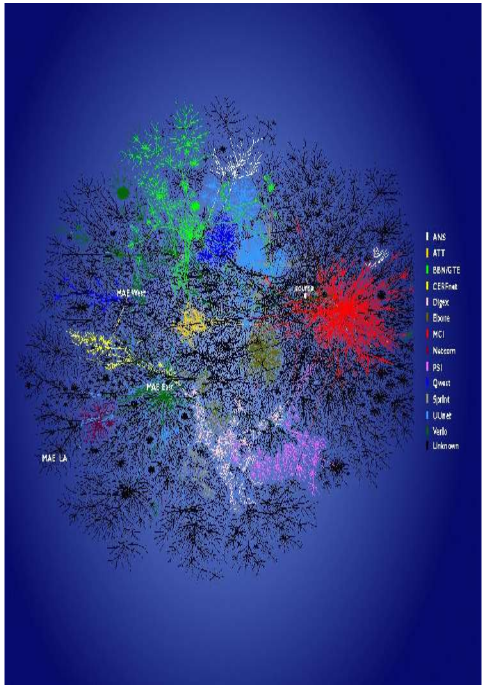
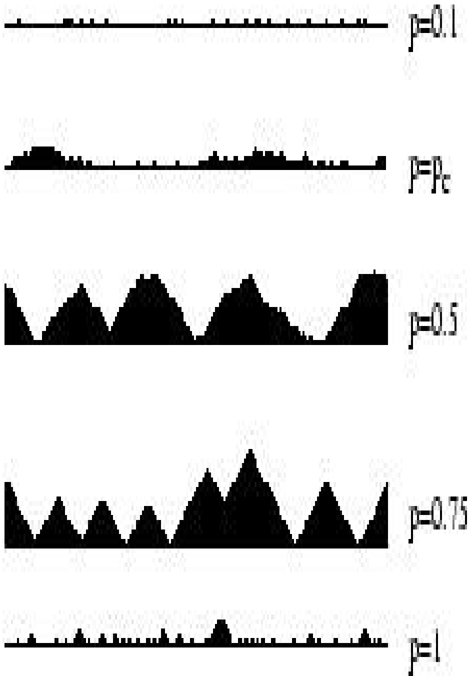
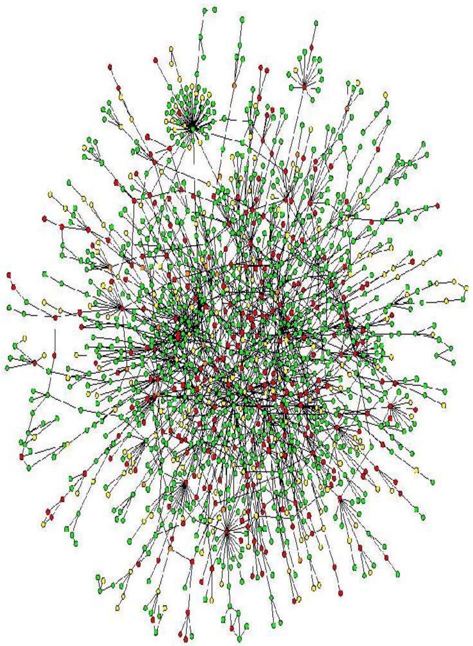
Short overview of nonequilibium critical classes.
Simulation results for a two dimensional, binary production reaction-diffusion model.
Computational realization on Hungarian grid network

Universality in complex systems







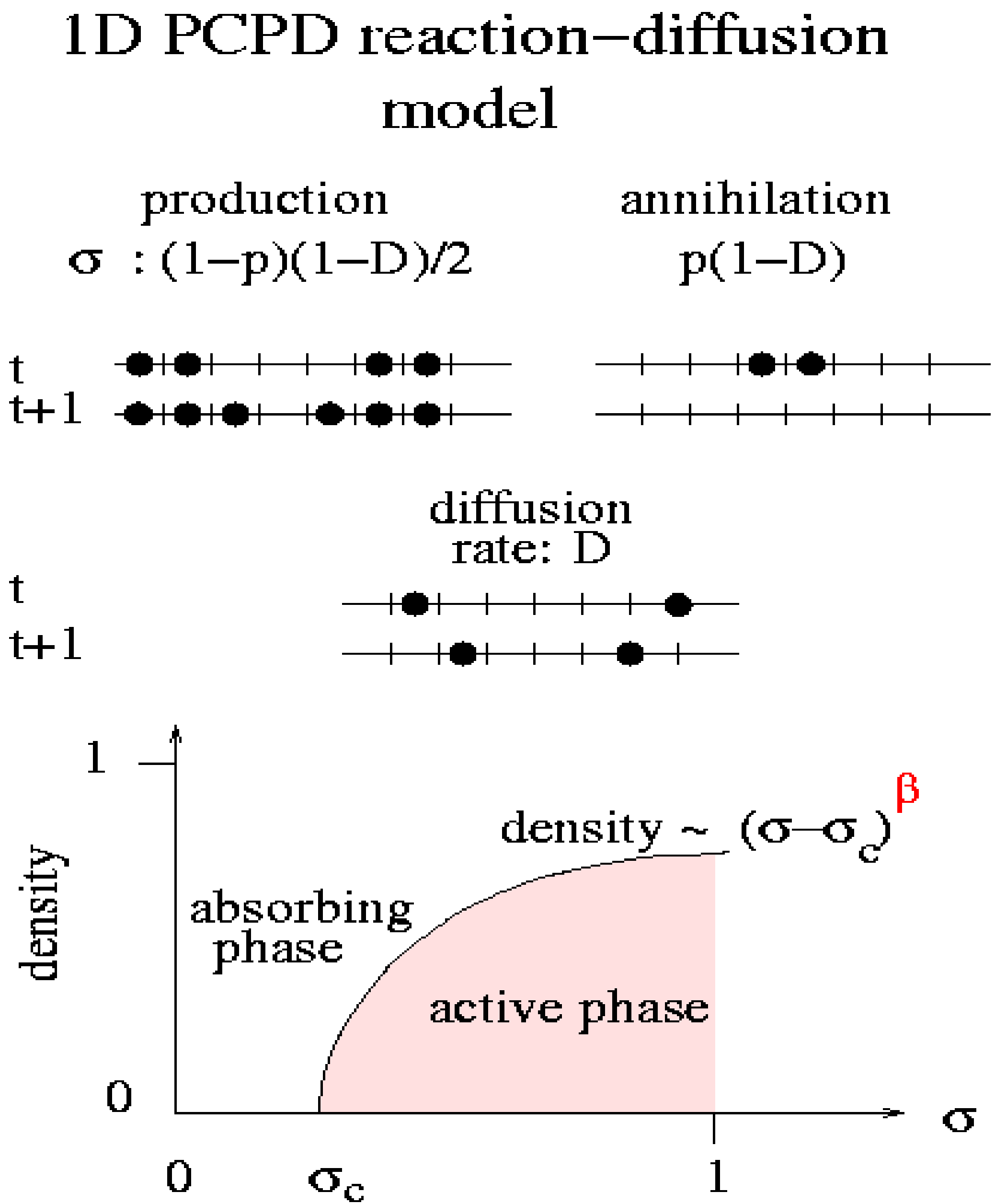


- Among complex, interacting systems built up from: particles, galaxies, animals, cars, money, web nodes ... etc. power-laws, fractals are common -> ***Universality classes*** appear determined solely by the collective behavior of parts.
- Example at critical phase transitions, where the correlation length diverges.
- In equilibrium systems these classes are well understood: standard classes; role of symmetries, dimensions, boundary conds. are discovered)
- We hope to extend this scenario for nonequilibrium systems.

Overview of dynamical universality classes
G. Ó.: cond-mat/0205644

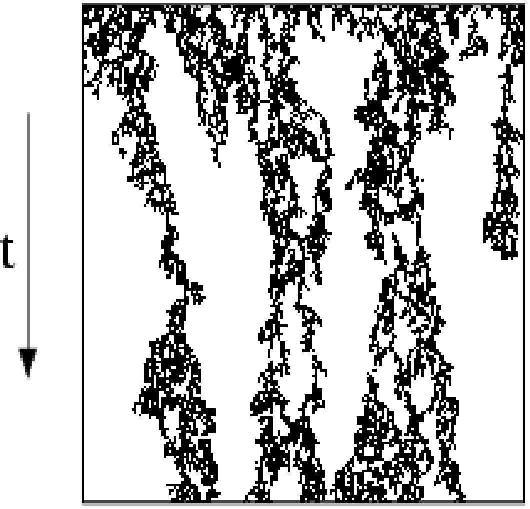
- Extension of static equilibrium classes (Ising, Potts, O(N)...) with different dynamics : Glauber, Kawasaki ...
- Mixture of the above dynamics to create out of equilibrium systems
- Genuine nonequilibrium classes appear by phase transitions to absorbing state, example in reaction-diffusion systems :
  a) Directed percolation class : *A->2A, 2A->A, A->0, time reversal*
  b) Dynamical percolation: *As a) with long time memory*
  c) Voter model class: *Diffusion and annihilation at surfaces*
  d) Branching with kA->0 (k>2) classes (mostly mean-field like)
  d) Parity conserving class: *A->3A, 2A->0*
- Multi-component reaction-diffusion model classes:
  e) DP with coupled diffusive or non-diffusive random walk
  f) The same as e) with global particle conservation...

The binary production PCPD model

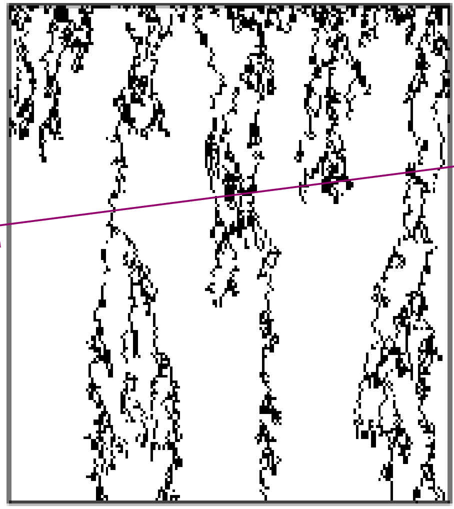


- Two absorbing states **without symmetry,** one of them is diffusive. Carlon, Henkel, Schollwock (PRE 2001).
- Bosonic field theory ('97) failed to describe critical behavior. In the bosonic model diverging active phase.
- Fermionic model shows different critical behavior but field theory is too hard. Numerical methods show new exponents.
  No extra symmetries or conservation laws found to explain.

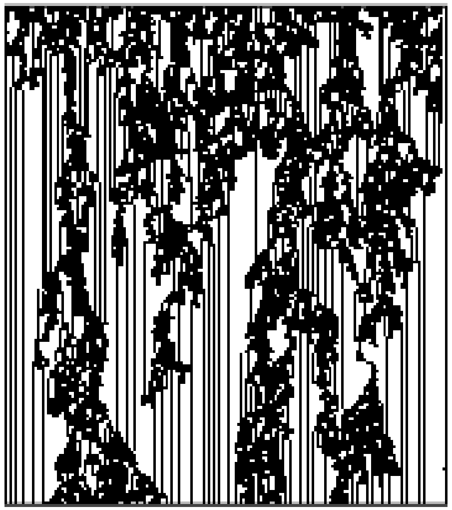
Space-time evolution of universal nonequilibrium spreading models with absorbing states



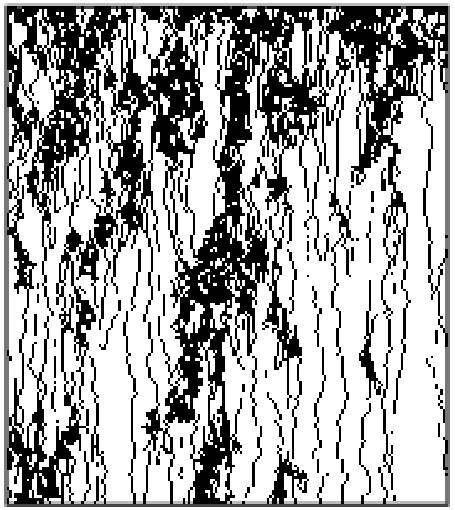
DP



BAW2



PCP



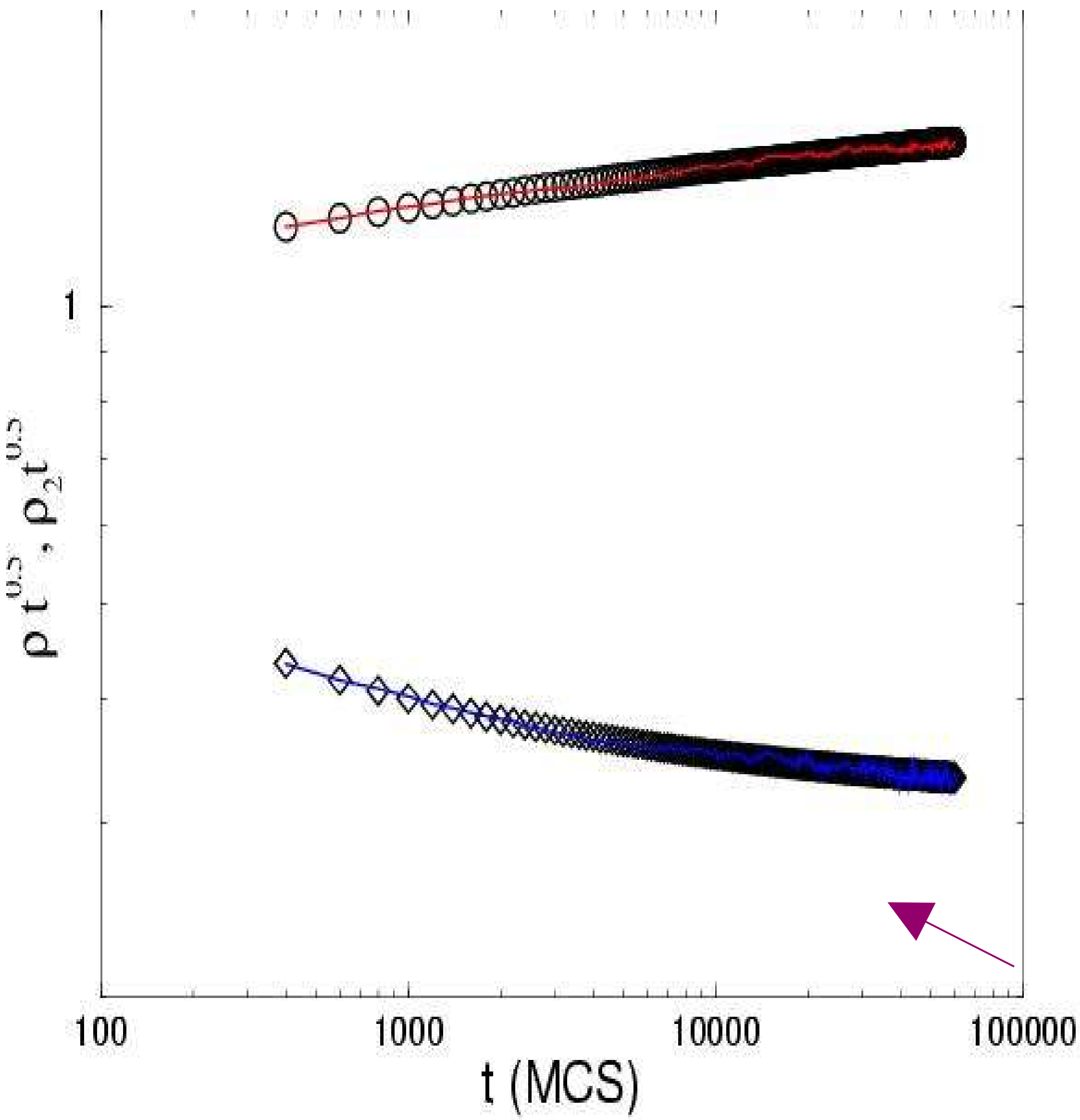
PCPD

- **Unary** production spreading without and with *parity conservation*:
  A -> (m+1)A, 2A -> 0

- **Binary** production spreading coupled to slave modes without and with *diffusion*:

  2A -> (m+2)A, 2A -> 0
  Reactive and diffusive sectors, changing exponents by varying the diffusion rate: *G.Ódor, Phys. Rev. E 62 (2000) R3027.*   **Two class ?**

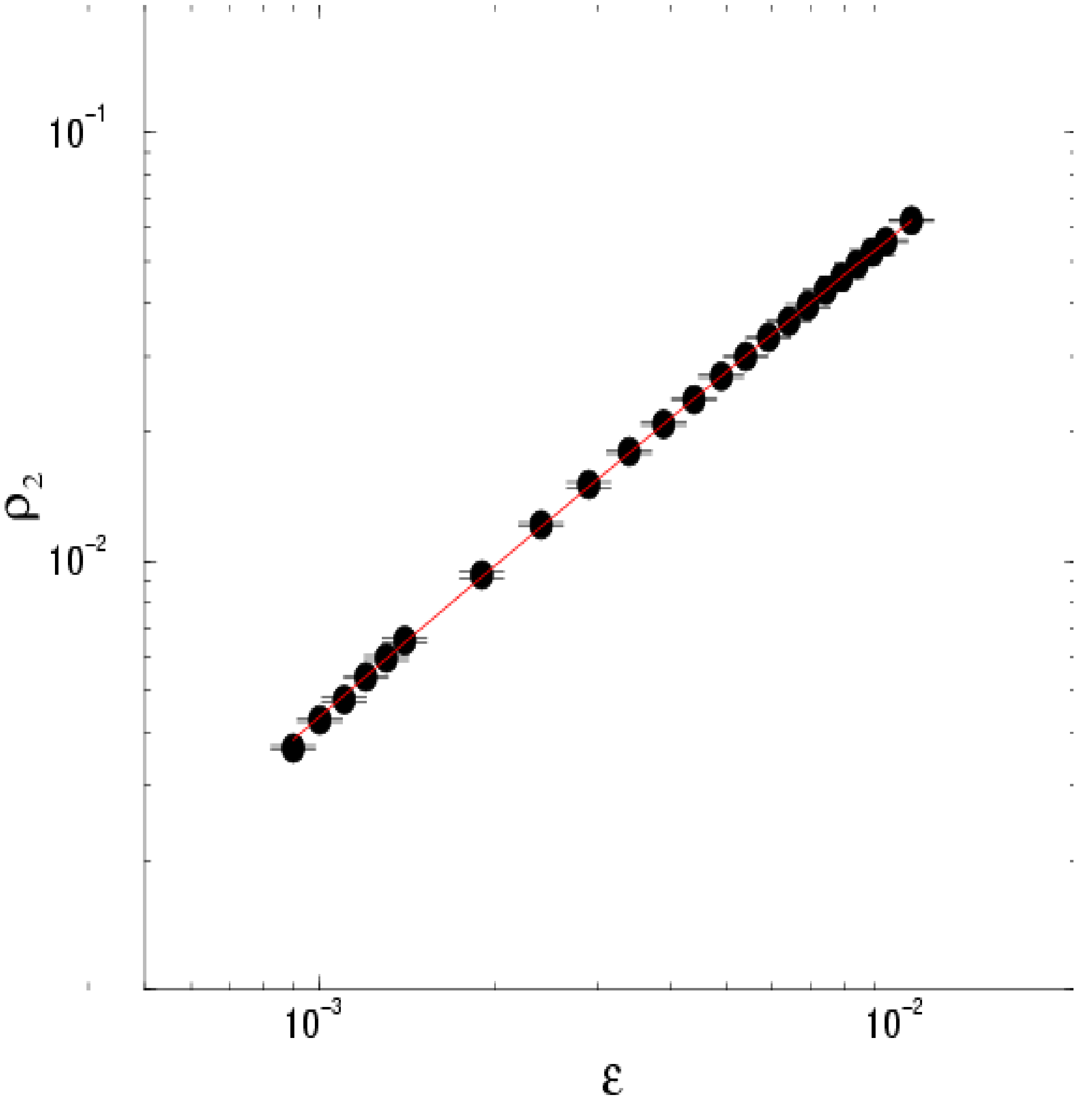
2D binary spreading



- Fermionic RG predicts d_c=1, bosonic: d_c=2.
- G.Ódor, M.A.Santos, M.C. Marques: *Phys. Rev. E 65 (2002) 056113.*
  2A -> 4A, 2A -> 0, 0A <-> A0

  Density decay simulations in L = 200-2000 systems:
  ρ, ρ_2 scales the same way except in the inactive phase.
  Mean-field scaling: $\rho \propto \rho_2 \propto t^{-0.5}$
  with logarithmic corrections is supported.

2D binary spreading results



- Steady state behavior: Mean-field scaling with logarithmic correction.

	D=0.2	D=0.5	D=0.8
p_c	0.4124(1)	0.4394(1)	0.4751(1)
α	0.507(10)	0.496(6)	0.497(10)
α_2	0.501(10)	0.501(5)	0.484(15)
β	1.07(10)	1.01(10)	1.07(10)
β_2	1.03(8)	0.96(5)	0.95(5)

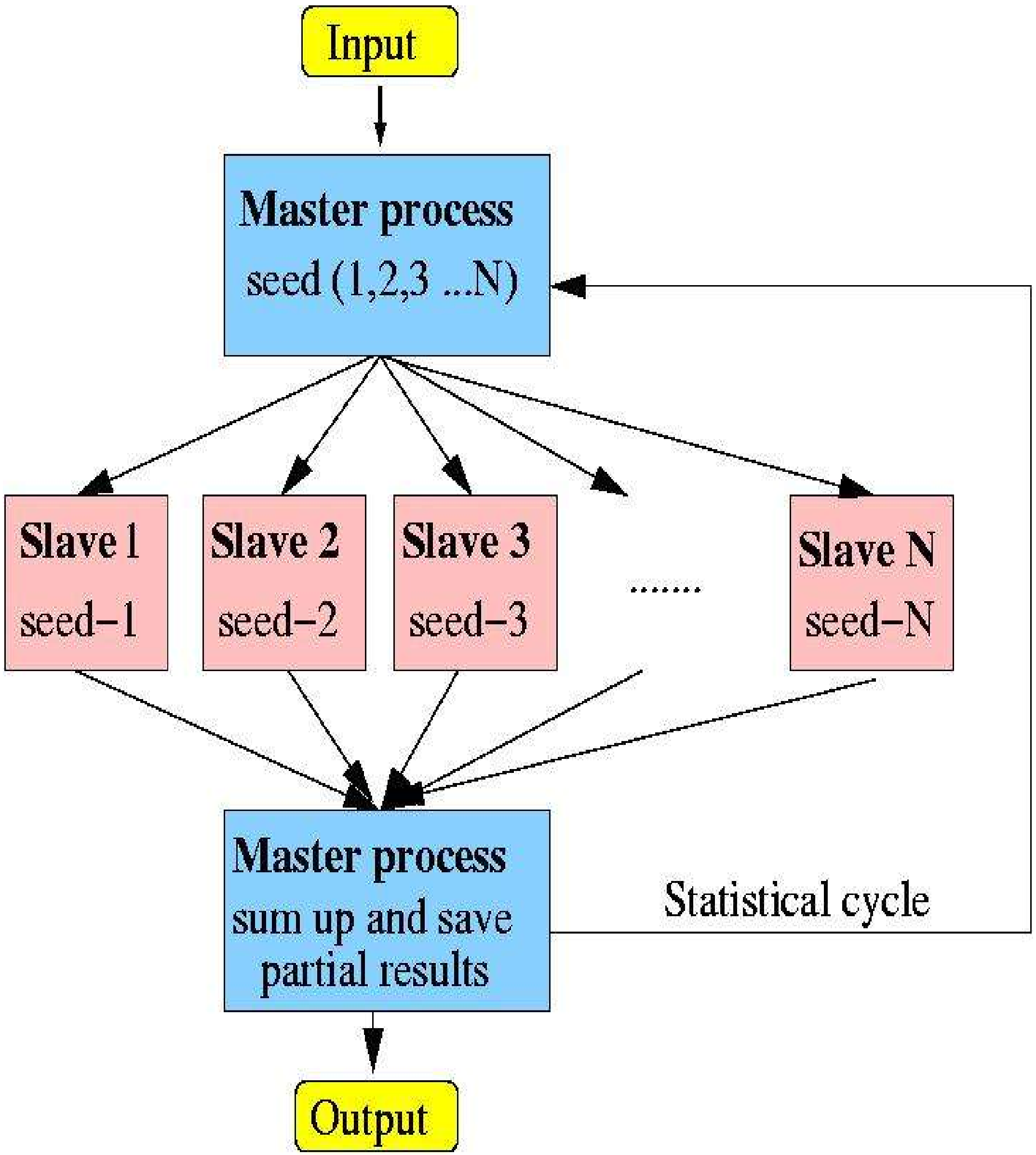
d_c =2 upper critical dimension is supported.

- In the inactive phase: $\rho(t) \propto (\ln(t)/t)$

Open problems

- Field theoretical understanding
- Lack of symmetries and conservation laws
- Insensitivity to conservation laws ?
- In 1d two classes or non-universal scaling ?
- More complex: nA -> (n+m) A type reaction -diffusion models with n > 2 show similar new universal behavior in low dimensions ...

Parallel algorithm realizations



- Master-worker setup, Single Program Multiple Data (SPMD) algorithm.
- The slave processes are completely identical and sequential. Minimal communication losses, easy program development
- Portable MPI programs run on SUN E10000, and PC clusters connected by GRID.