DECONFINEMENT PATTERNS

1. Introduction
2. Critical Behaviour of Ising Model
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4. Onset of Deconfinement
5. Summary

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Hit '99
1. Introduction

Lattice QCD:

Energy density increases rapidly at some $T$

Decoherence?  

Phase transition or cross-over?  Latent heat?

$SU(N)$: order parameter $L \sim e^{-V_0(N)/T}$

~ global $Z_N$ symmetry of $L$

obeyed: confinement  
spontaneous broken: decoherence

$\exists T_c$, critical exponents
universality class of $Z_N$ spin systems

Full QCD:  $m_q < 0$ breaks $Z_N$ explicitly, but effect remains small, even for $m_q \to 0$

$M_q = 0$: chiral symmetry, order parameter, exists in between?
2. Critical Behaviour of Ising Model

$H=0$ implies two equivalent ways to specify critical behaviour:

- Spontaneous magnetisation $m(T)$
  - Order/disorder, spont. $Z_2$ breaking
  - Expts $m \sim (T_c - T)^{\beta}$, $\chi \sim |T - T_c|^{-\gamma}$

- Percolation of site/bond clusters ($d=2$)
  - Percolation strength $P(T)$
  - $P(T) \sim (T_c - T)^{\beta_P}$, cluster size $S(T) \sim |T_c - T|^{-\gamma_P}$
    - for $\nu_B = 1 - e^{-2J/kT}$: $T_P = T_c$ \(\beta_P = \beta, \gamma_P = \gamma\)
    - CK

- Fusion of clusters $\leftrightarrow$ spont. magnetisation

$H \neq 0$

- $Z_2$ explicitly broken, $Z(T)$ non-singular, LY
  - No more magnetisation transition

- Percolation remains as critical phenomenon
\[ m(T) \]

percolation  
no percolation

\[ K \]

\[ H = 0 \]

\[ T_c \]

\[ T \]

\[ H \neq 0 \]

3 critical behaviours at \( T_n, H_n \) with exponents:

\[ P(T) \sim (T_c - T)^{\beta_n}, \quad \Delta(T) \sim |T_c - T|^{\delta_n}. \]

For \( H = \infty \), pure bond percolation.

**Ising percolation phase diagram**

- no "cross-over", genuine phase transition
- not obtained from Ising partition function \( Z_\lambda(T) \)

Imagine metallic bonds: \( T_c \sim \) onset of magnetisation

\( T_n \sim \) onset of conductivity
3. Polyakov Loop Percolation

SU(2) gauge theory in 2+1 dimensions study "islands" of like-sign Polyakov loops, bound weights $p_b^i = 1 - e^{-vL_i}$.

Lattices $N^2_\sigma \times N_\tau$, $N_\tau = 2$

$N_\sigma = 64, 96, 128, 160$

for $N_\tau = 2$, $x = \beta^{N_\tau}$ OK

apply finite size scaling, get:

\[
T_p = T_c; \quad (\beta/v)_p = (\beta/v)_{\text{Ising}}
\]

\[
(\gamma/v)_p = (\gamma/v)_{\text{Ising}}
\]

...here Polyakov loop percolation = deconfinement

much work in progress:

- $N_\tau > 2$
- $d = 3$
- SU(3)
- add dynamical quarks, get QCD Vaidya line: et quasi-deconf. ?
- chiral transition?
S. Fortunato et al. (Poster)
4. Onset of Deconfinement

Percolation phenomenology:

- quark core of hadrons, constituent quarks, strings, ...
- of "effective spherical" size $V_0$

- percolation of spheres $V_0 \approx$ deconfinement
- critical density $n_c \equiv n_c / V_0 = 0.33 / V_0$

- percolation config.: how much empty space?

- $V_{vou} / V = 1 - e^{-n_c} = 0.28$

$\Rightarrow 72\%$ empty at $T_c$

- $E_{gap} \approx 4 E_c$
  - percolating cluster; 3 smaller clusters...

- $n_c$ grows monotonically

- $V_{vou} / V$ grows "singularly"

- $\Rightarrow \sim$ percolation transition

- qualitative onset: at $T_c$, first percol. cluster;
  from $T = T_c$ to $T \approx 1.2 T_c$, cluster fusion
D. Gandolfo

\( D=3 \) - coupure par un plan \( x=x_0 \) - 2000 disques - densité critique
$E/T^4$

- percol. cluster covers $\sim$ all
growth of percol. cluster by fusion

$\rightarrow$ percolating cluster first appears

- $E(T_c) \ll E_{SB}$ for $d \geq 3$
  since at $T_c$ percolat. cluster covers $< 25\%$ of space

- check: for $d = 2$, percol. cluster covers $65\%$ of space at $T_c$;
  study in lattice QCD!
5. Summary

- critical behaviour in Ising model equivalently
  - spontaneous $\mathbb{Z}_2$ symmetry breaking or
  - percolation of site/bond clusters.

- Polyakov loop percolation $\sim$ deconfinement
  in SU(2) gauge theory ($d=2, N_c=2, \ldots$)

- Polyakov loop percolation $\rightarrow$ critical
  behaviour also in full QCD (Kertész line); is it deconfinement also there?

- percolation phenomenology $\rightarrow$ onset of
  deconfinement as cluster fusion.

Well defined program to study deconfinement!