Localization and topology in high temperature QCD

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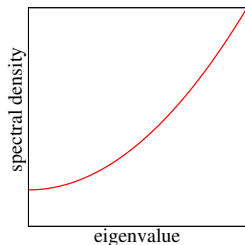
with

Réka Á. Vig

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Lattice 2018, July 24, 2018

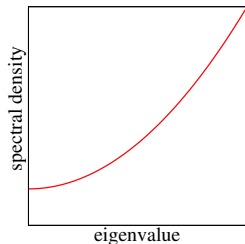# Above T_c low Dirac eigenmodes are localized

Below T_c

- Chiral symmetry broken
- All eigenmodes delocalized

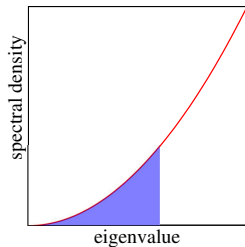# Above T_c low Dirac eigenmodes are localized

Below T_c

- Chiral symmetry broken
- All eigenmodes delocalized

Above T_c

- Chiral symmetry restored
- Lowest eigenmodes localized

Low Dirac modes are related to topology

- Instanton $\longrightarrow$ quark zero mode

- Instanton + antiinstanton $\longrightarrow$ two cmplx conj. modes

- QCD at $T < T_c$: $\quad r_I \approx d_{IA}$ instanton liquid

- Zero-mode zone $\longrightarrow$ finite density of modes at 0 (SχSB)

Above T_c dilute instanton gas

- Instanton density falls sharply with increasing T

- Zero modes exponentially localized

- $r_I, r_A \ll d_{IA} \Rightarrow |\lambda_{IA}|$ small

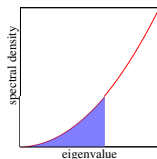- Can the zero-mode zone explain localized modes?
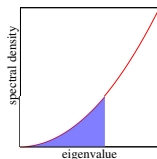
  Is this the ZMZ?

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- Can the zero-mode zone explain localized modes?

  Is this the ZMZ?

- How to count modes in the zero-mode zone?

Above T_c the ZMZ separates from bulk spectrum

Overlap spectral density

- quenched

- $N_t = 6, \quad T = 1.06 \, T_c$

- zero modes removed

- $r_I, r_A \ll d_{IA} \;\Rightarrow\; |\lambda_{IA}|$ small

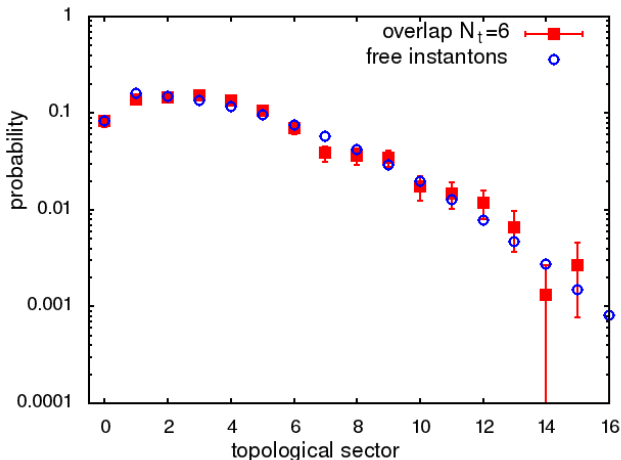- Already seen by Edwards, Heller, Kiskis, Narayanan, PRD (1999)
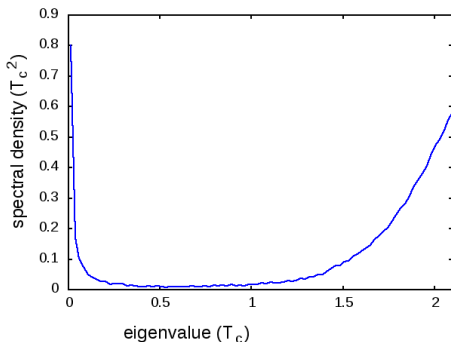
- Is this really the full ZMZ?

- Count topological charge: $\langle Q^2 \rangle \;\longrightarrow\;$ density of top. obj.-s (Assume non-interacting gas.)
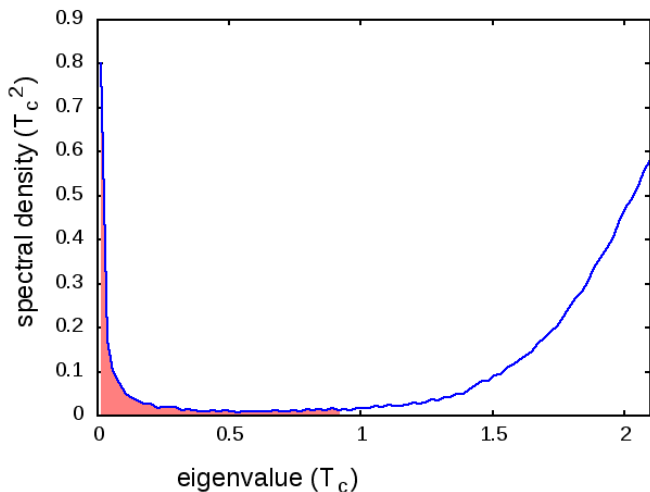
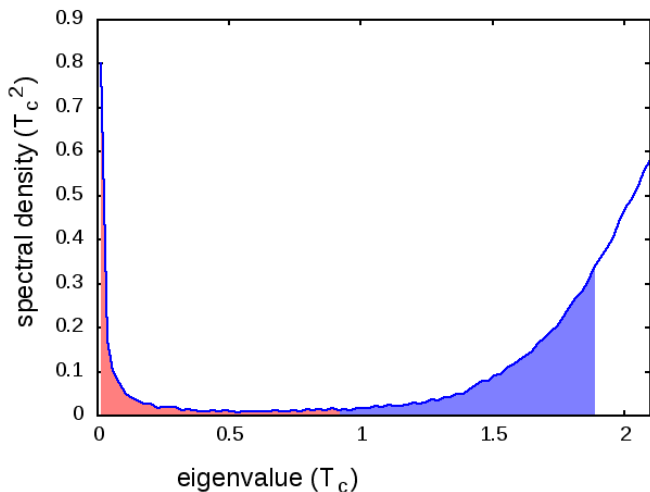Simulation data compared with non-interacting instanton gas with the same topological susceptibility

Peak at zero in the density is the ZMZ
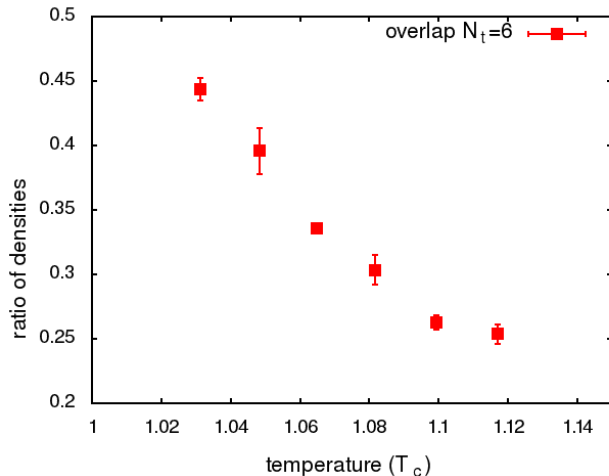
The zero-mode zone in the overlap spectrum

Localization extends beyond the ZMZ

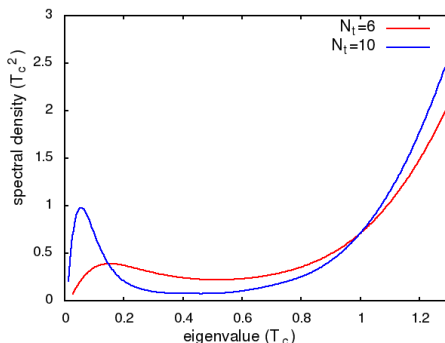The ZMZ and localized part in the overlap spectral density

Fraction of localized modes contained in the ZMZ

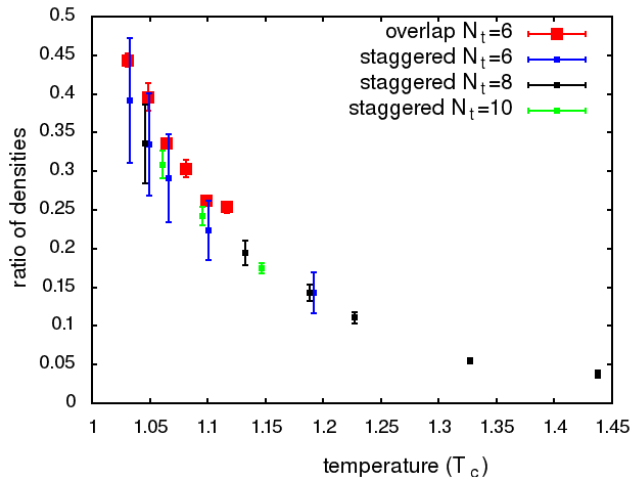# Staggered ZMZ also separates from bulk sectrum

Staggered spectral density

- staggered + 2 stout

- $N_t = 6, 10$ $T = 1.06 T_c$

- zero modes included

- Zero-mode zone can be identified

- Finer lattice $\longrightarrow$ better precision

Fraction of localized modes contained in the ZMZ

Conclusions and outlook

- "Good" chiral action $\longrightarrow$ ZMZ separates from bulk spectrum (staggered + 2 stout $N_t = 6$ already good).

- Zero-mode zone consists of localized modes.

- Only a small fraction of localized modes are in the ZMZ (falls sharply with icreasing T).

- Quark modes related to topology cannot explain localization.

- Dynamical quarks? (See talk by Holicki, Friday).

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- interesting structure in locality properties of lowest modes.
  $\longrightarrow$ maybe connected to chiral polarization?
  (see Alexandru and Horvath Lattice 2014)

Participation ratio for different volumes

fraction of volume occupied by eigenmode
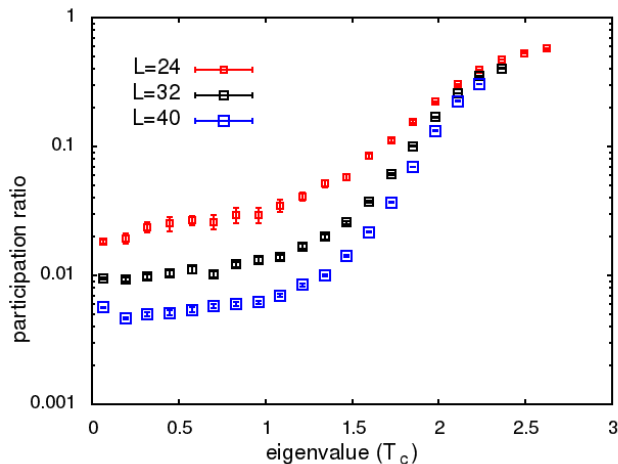
Participation ratio for different volumes

Lowest part of the spectrum