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Chiral Symmetry Breaking from Center Vortices

in coop. with M. Faber, U. M. Heller and T. Schweigler

arXiv: 1212.3737 & 1304.1277

Center Vortices

➜ *'t Hooft 1979, Nielsen, Ambjorn, Olesen, Cornwall, 1979 Mack, 1980; Feynman, 1981*

- QCD vacuum is a condensate of closed magnetic flux-lines, they have topology of tubes (3D) or surfaces (4D),
- magnetic flux corresponds to the center of the group,
- Vortex model may explain ...
  - **Confinement** $\rightarrow$ piercing of Wilson loop $\equiv$ crossing of static electric flux tube and moving closed magnetic flux
  - **Topological charge**: intersection points, writhing points and color structure

    ➜ *Engelhardt, Reinhardt (2000), Jordan, R.H., Faber, Heller (2007)*
  - **Spontaneous chiral symmetry breaking**: also center-projected configurations show χSB

➜ *R.H., Faber, Greensite, Heller, Olejnik (2008)*

Chiral Symmetry Breaking

- Instanton Liquid Model:
  - action minima localized in space-time
  - carry $Q = \pm 1$ and attract zero modes according to Atiyah-Singer index theorem
  - overlapping would-be zero modes lead to near-zero modes
  - chiral symmetry breaking via Banks-Casher relation

➜ *Diakonov, Petrov (1984)*

- spherical vortices behave like instantons

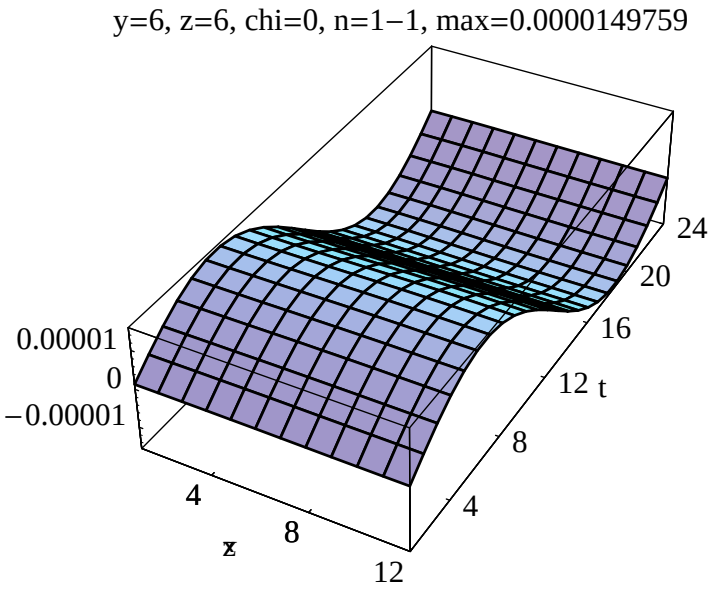
➜ *Schweigler, R.H., Faber, Heller (2012)*

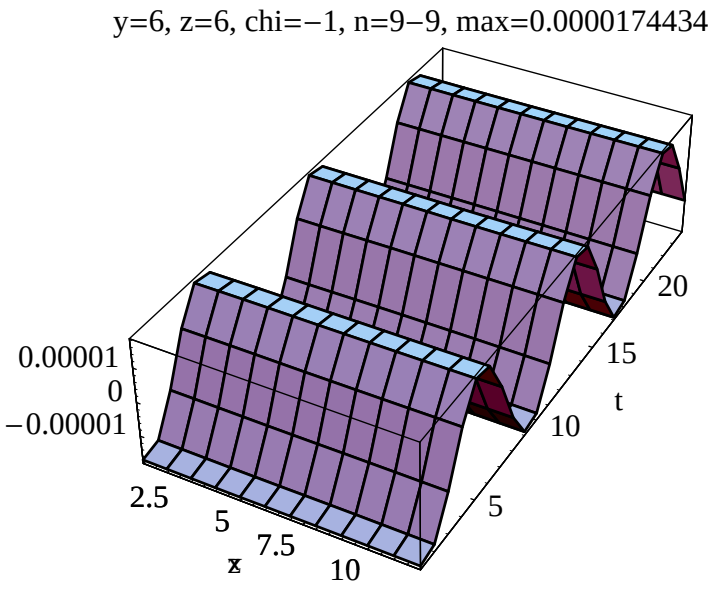
- also intersection points give chiral condensate

➜ *R.H., Faber, Heller, Schweigler (2013)*

Free Dirac Eigenmodes

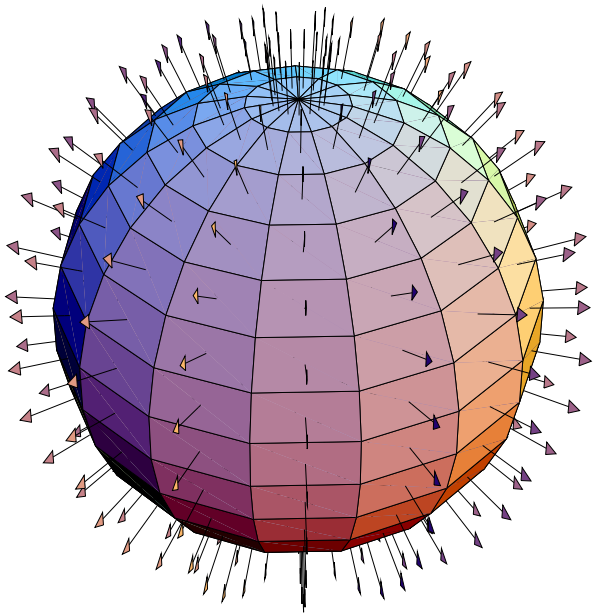
Overlap fermions on trivial gauge configurations:

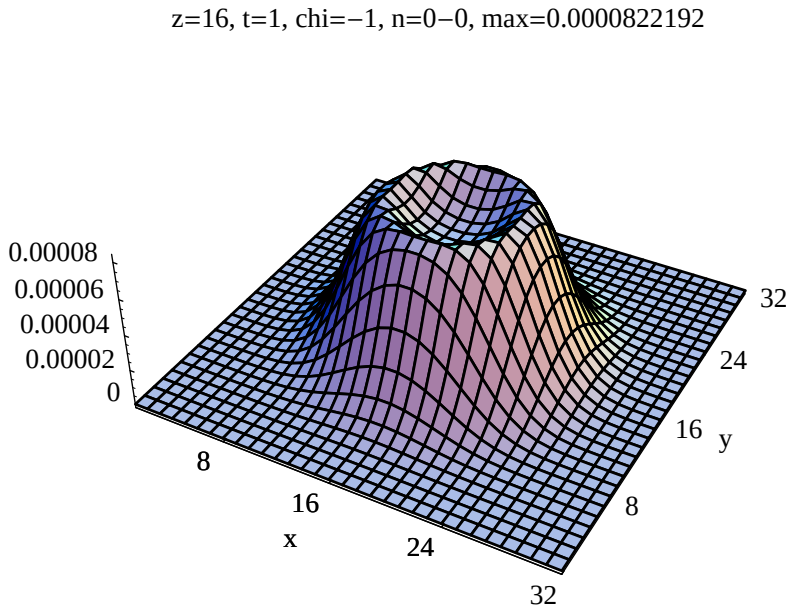




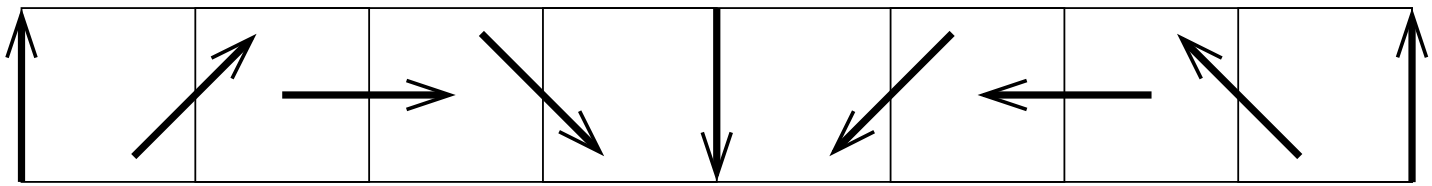
$$\rho_5 = \psi^\dagger_\pm \gamma_5 \psi_\pm = \frac{1}{2}(\chi^\dagger_R \chi_R - \chi^\dagger_L \chi_L) = \rho_+ - \rho_-$$

Thick Spherical SU(2)-Vortices

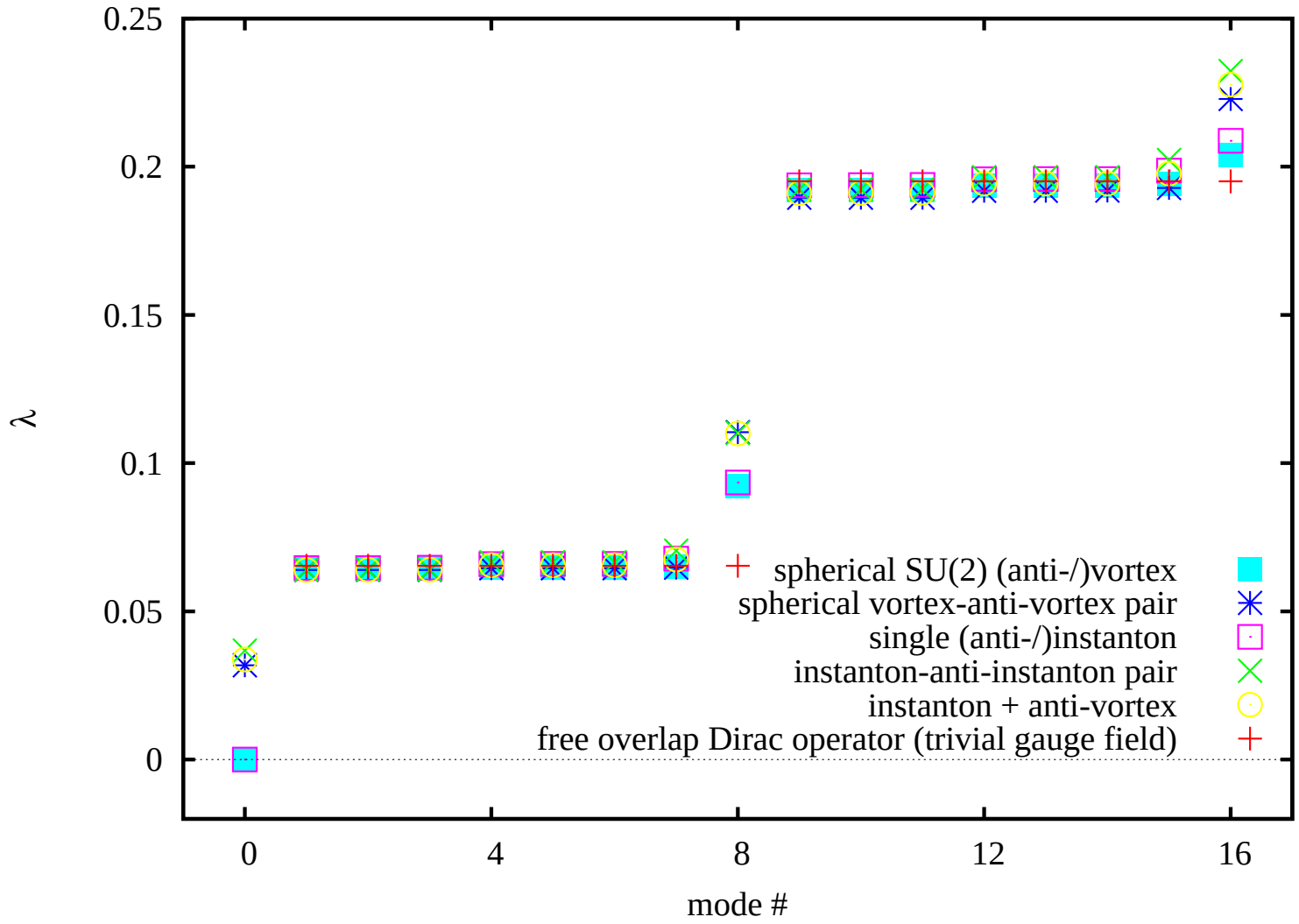




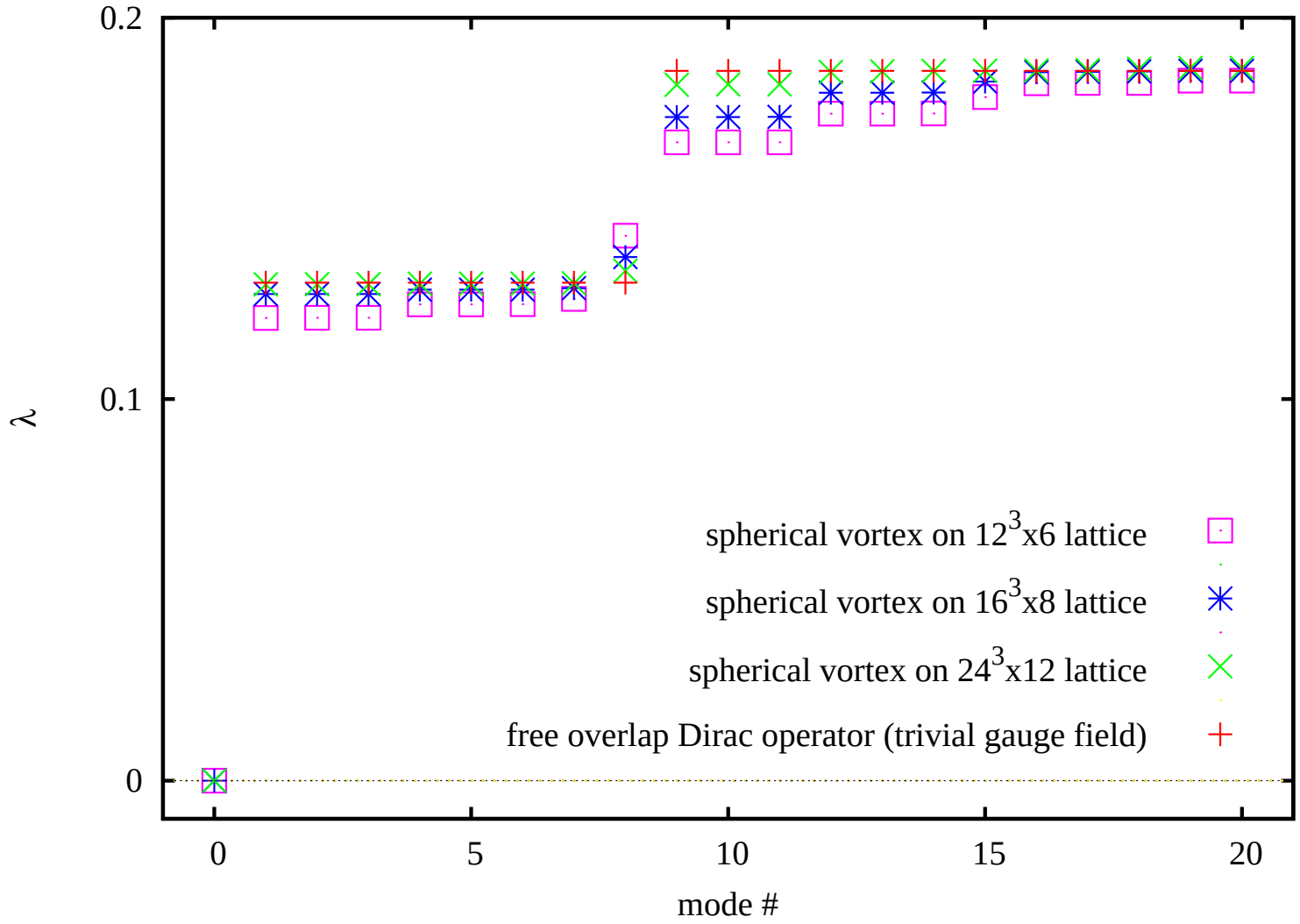
$$U_\mu(\vec{r}) = \begin{cases} \exp\{i\alpha(r)\frac{\vec{r}}{r}\vec{\sigma}\}, & t = 1, \mu = 4 \\ 1 & \text{else} \end{cases}$$



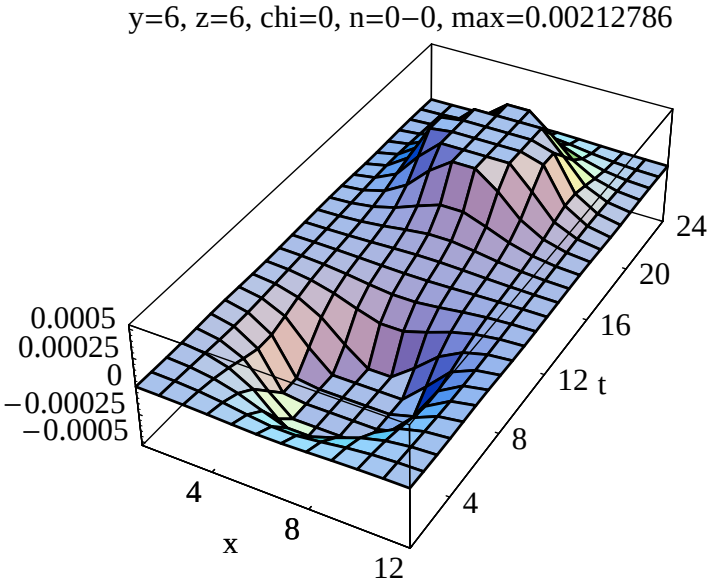
Overlap Eigenmodes

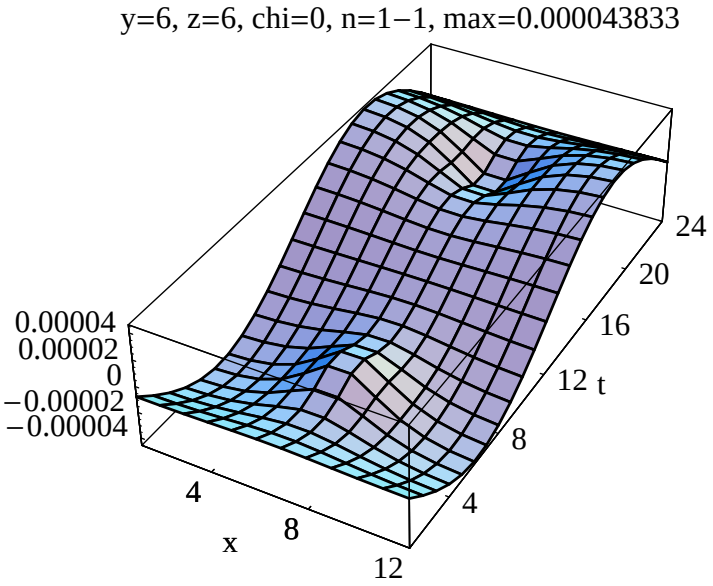


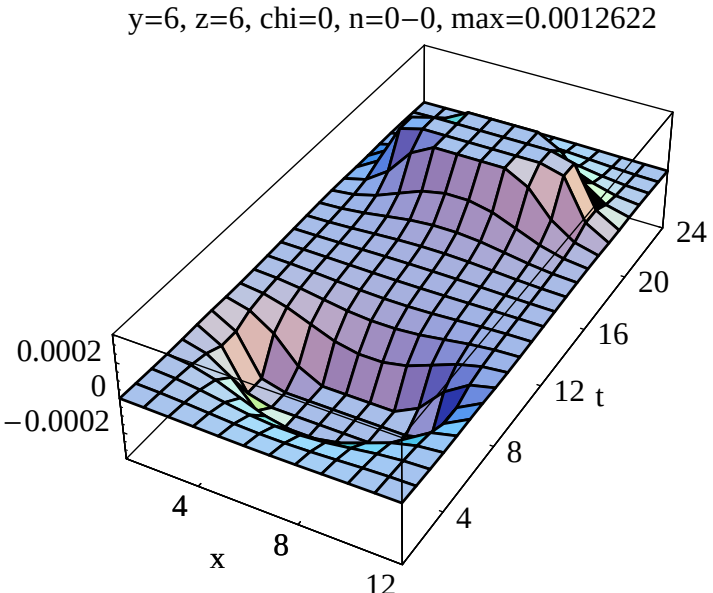
Finite Size Effect

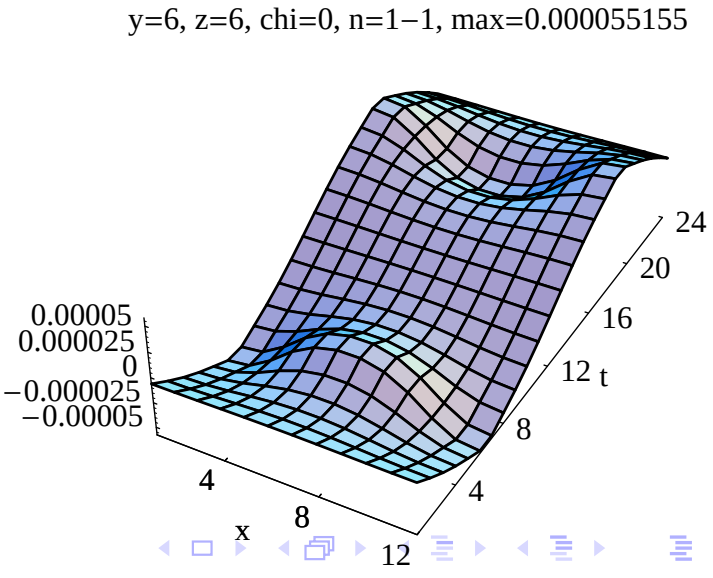


Chiral Densities

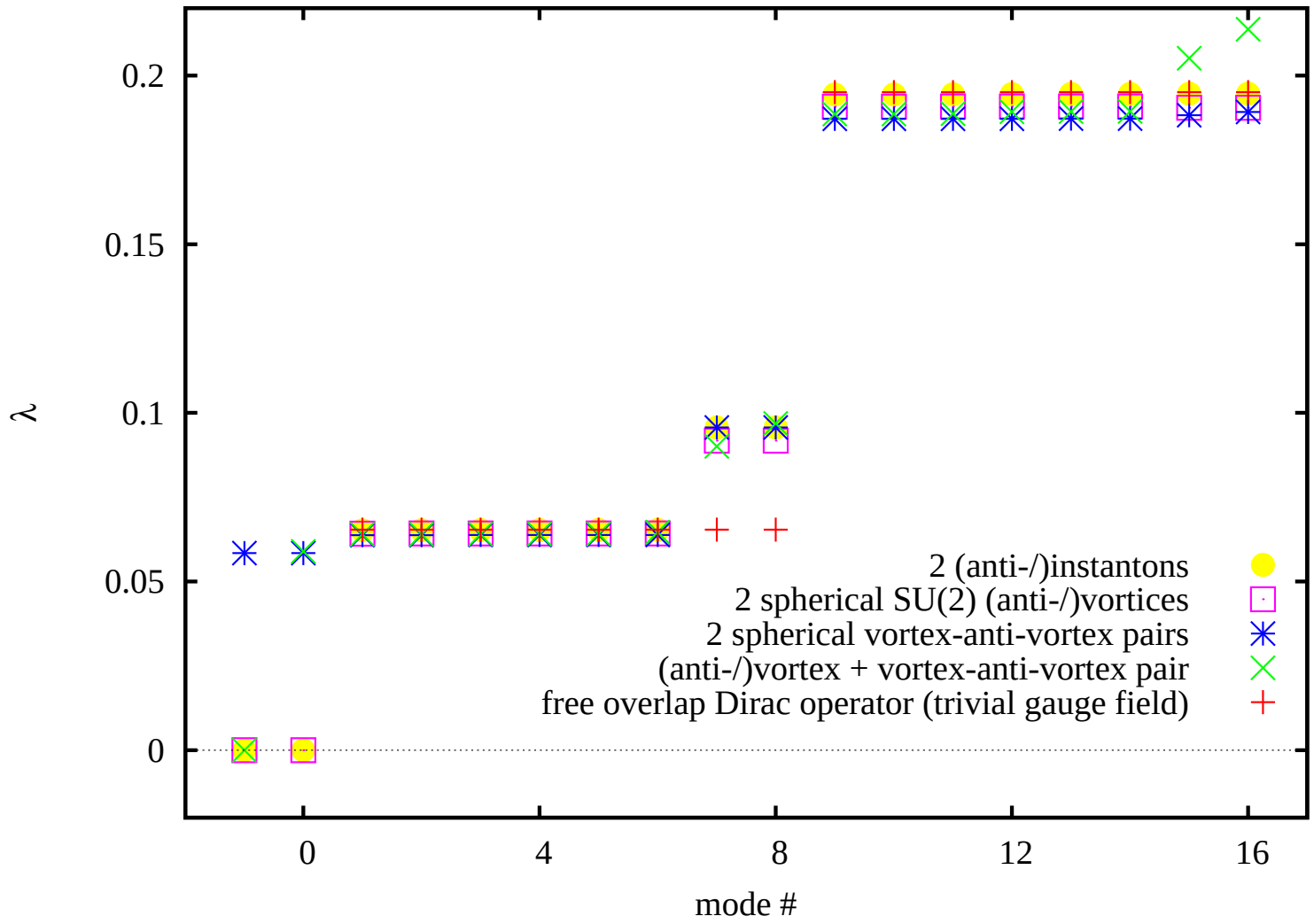




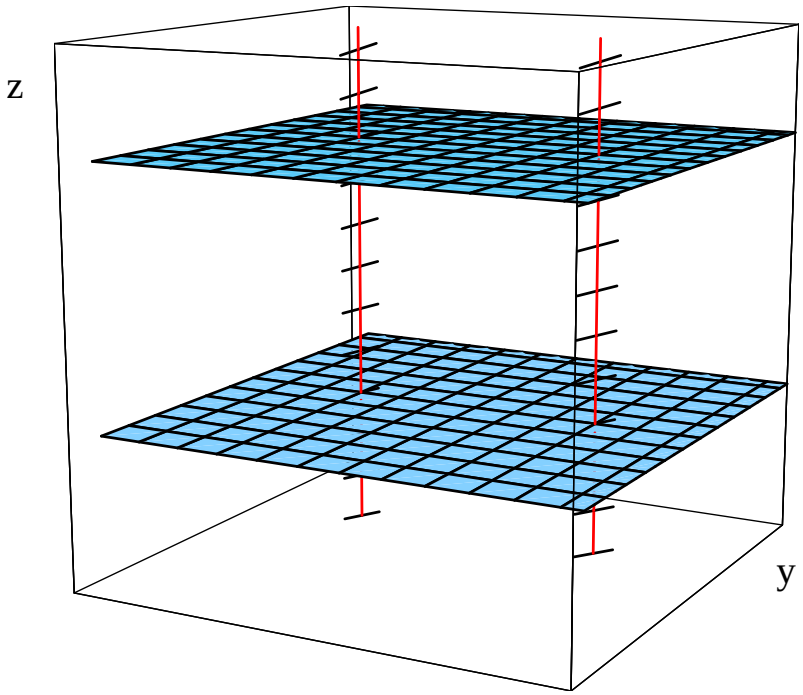


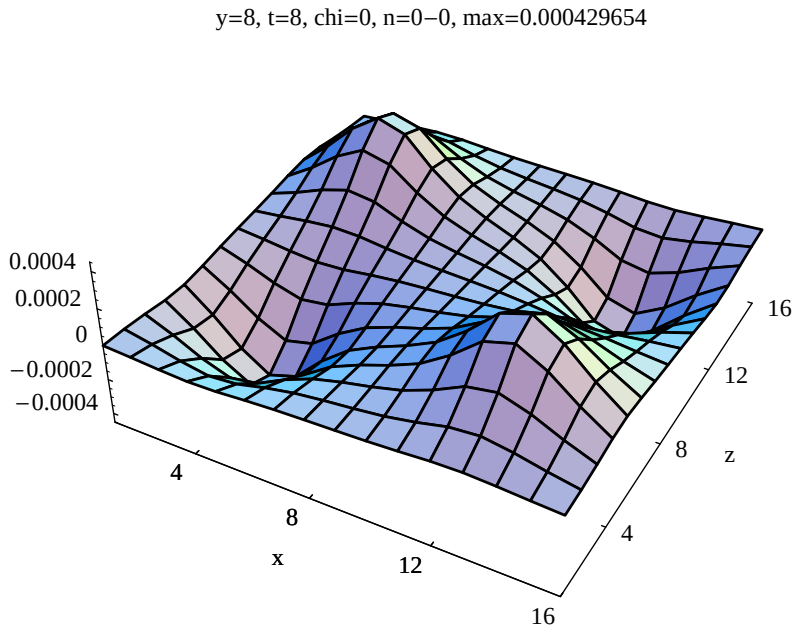


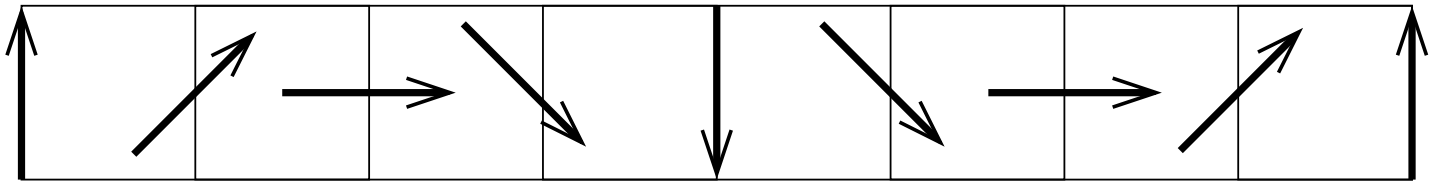
Overlap Eigenmodes



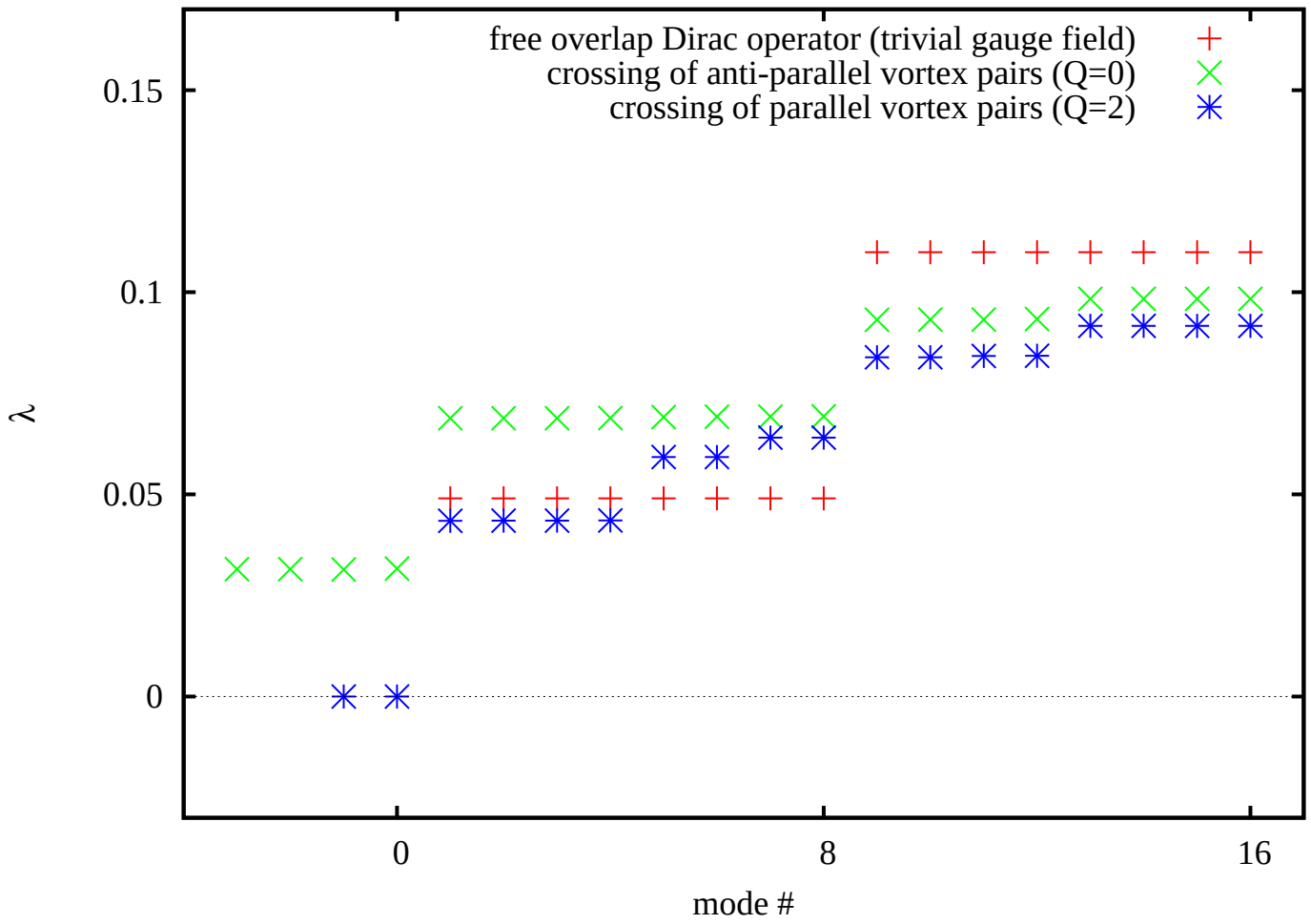
Thick, Planar SU(2)-vortices



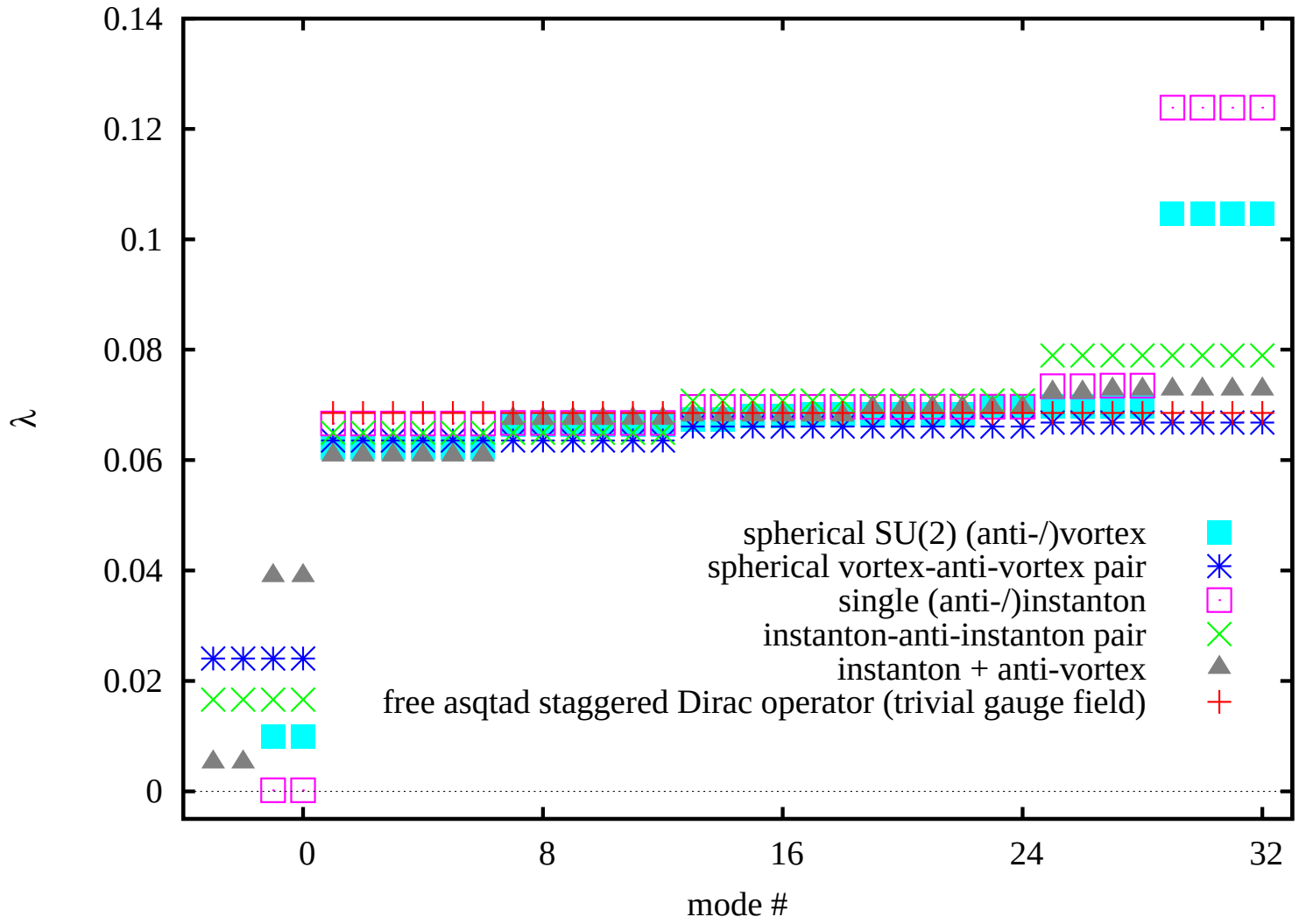




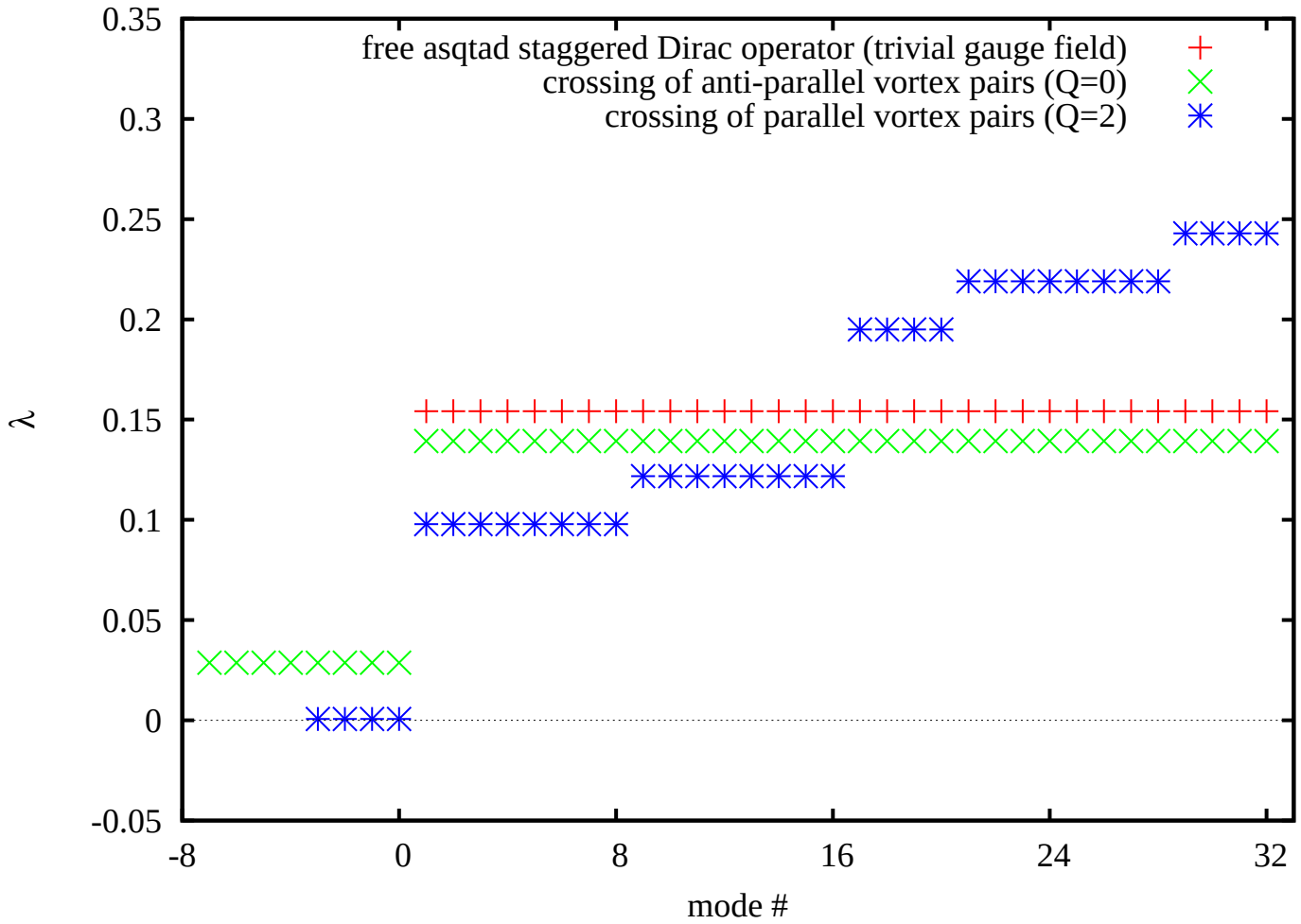
Overlap modes for plane vortices



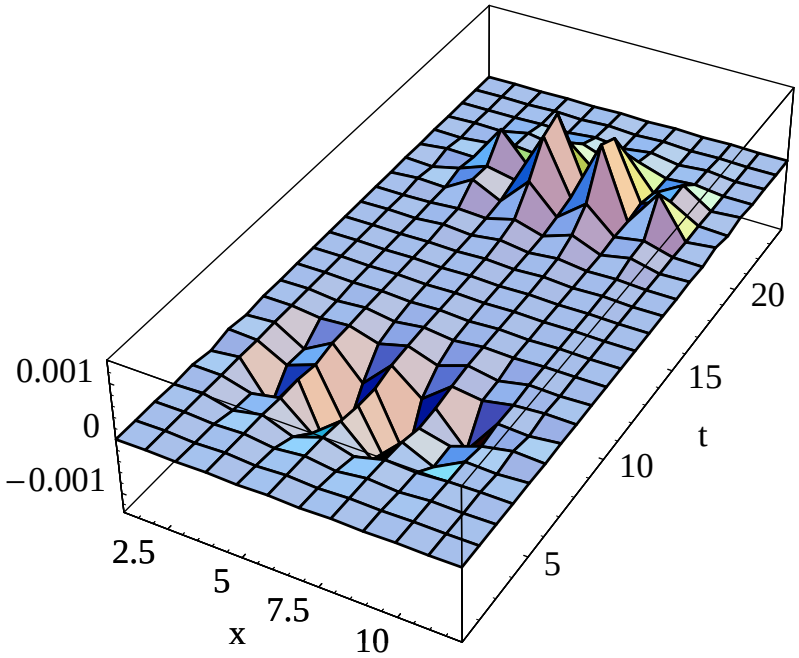
Asqtad Modes for Spherical Vortices

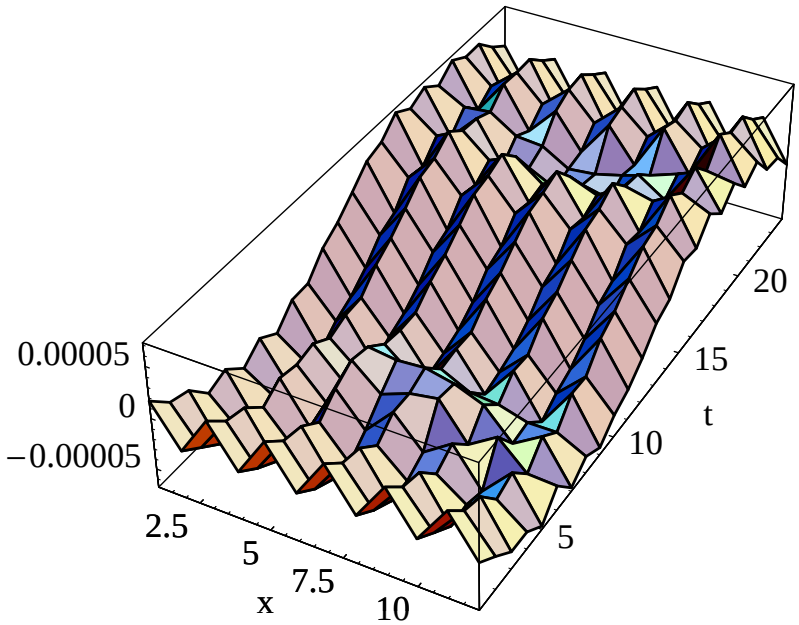


Asqtad Modes for Plane Vortices

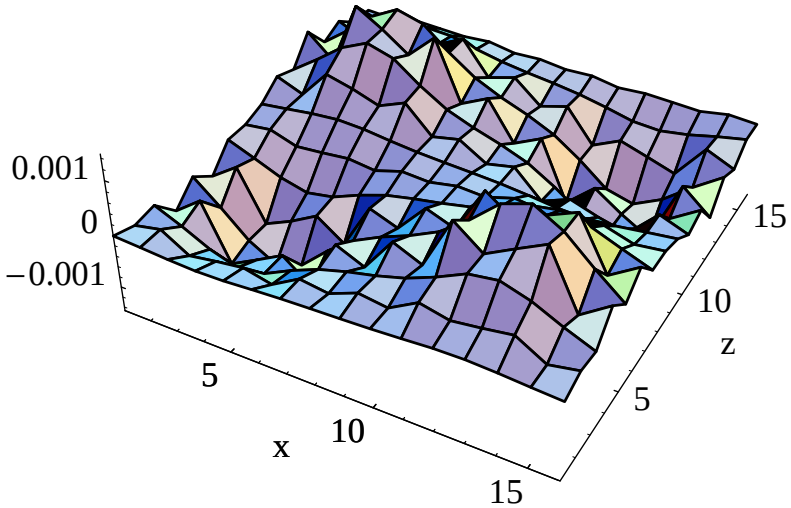


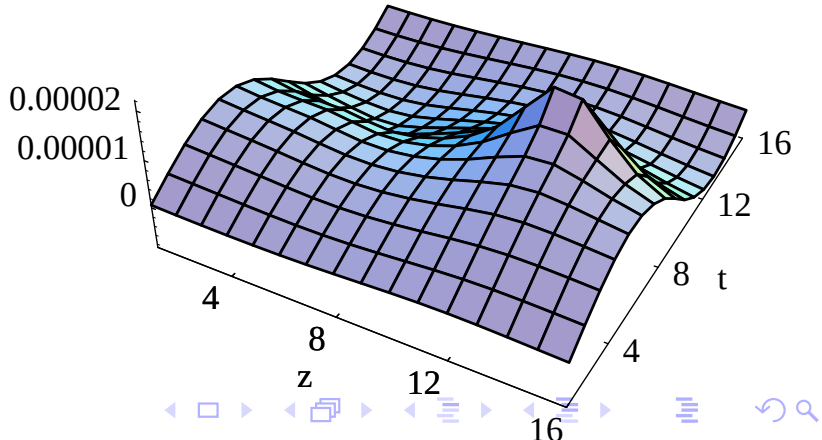
Chiral Densities of Asqtad Modes





x=8, y=8, chi=0, n=1−1, max=0.0000213867





Chiral Symmetry Breaking from Center Vortices

- easy identification of near-zero modes for classical configs
- similar fermion modes for instantons and spherical vortices
- instanton liquid model can be applied to spherical vortices
- also vortex intersections contribute to chiral condensate
- not an exclusive picture of chiral symmetry breaking
- any source of topological charge can contribute (monopoles, instantons, merons, bions, calorons,...)
- random interactions of quarks with the vortex background
- confining interaction by itself could break chiral symmetry

Thank you for your attention!

Questions?