Superconducting states in the orbital-paramagnetic pair-breaking regime

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IVW-10, Tata Institute, Mumbay, January 9-14, 2005

How stable is the FFLO state ?

Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state requires `complete` absence of orbital pair-breaking effects.

In reality, the theoretical limit of purely paramagnetic pair-breaking cannot be realized.

How stable is the FFLO state ?

The FFLO state will be disturbed by the following (orbital) effects:

- Coupling between adjacent conducting planes
- Finite thickness of conducting planes
- Applied field not exactly parallel to conducting planes
  This is the topic of my talk

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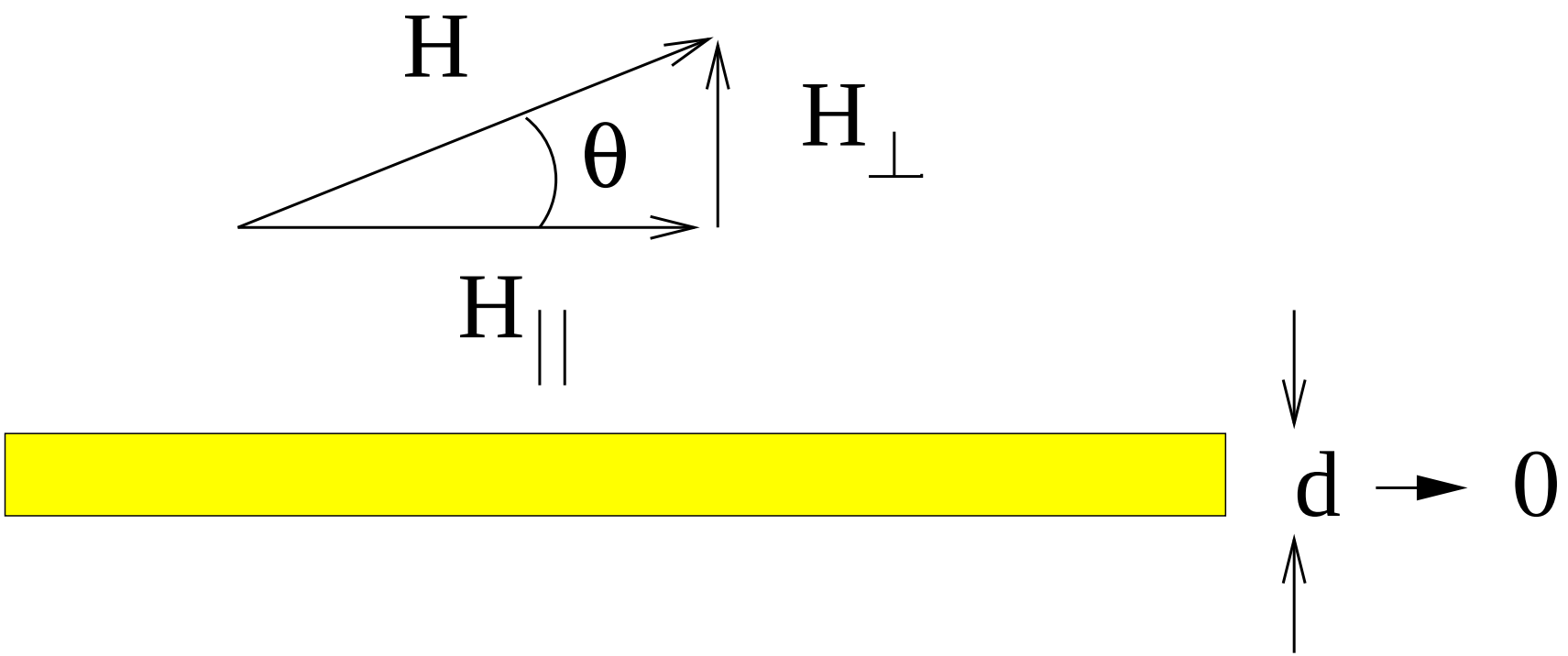
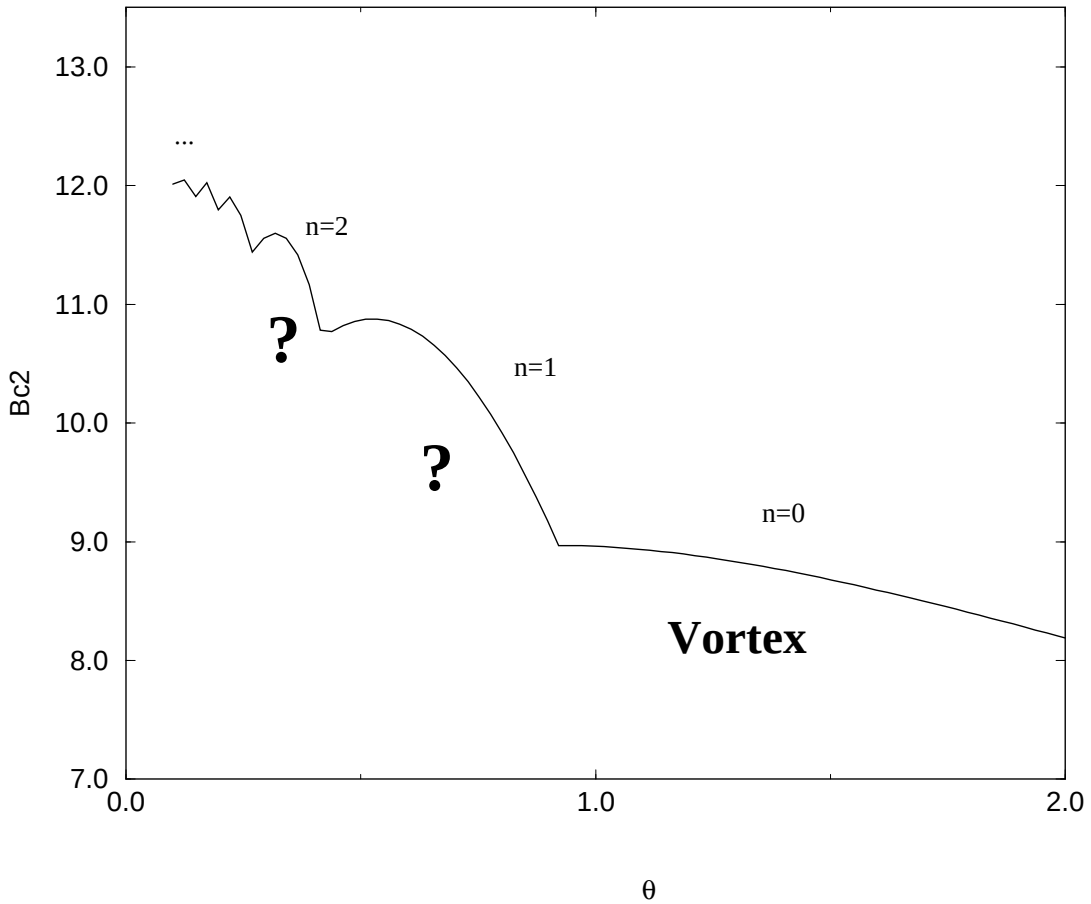
The problem to be studied.



The upper critical field B_{c2}.



Bulaevskii 1974, Shimahara and Rainer 1997

Calculation

- Using the quasiclassical equations with Zeeman coupling.
- These equations are solved near the upper critical field, the results hold for arbitrary T.
- A superconductor in the clean limit is considered.
- A superconductor with isotropic gap and circular Fermi surface is considered

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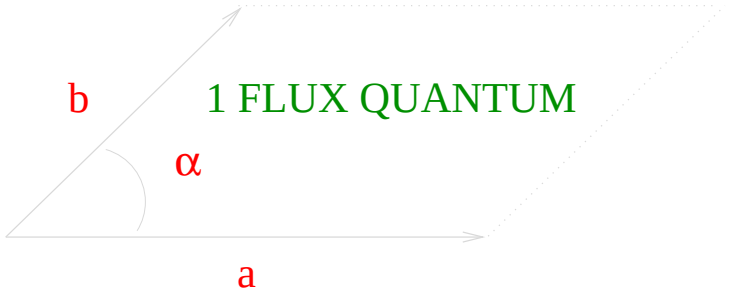
Calculation

- The Free energy is calculated taking terms of fourth order in the order parameter magnitude and infinite order in the order parameter gradient into account.
- The unit cell is assumed to carry a single flux quantum - otherwise no restriction (no Ansatz) on the shape of the unit cell.



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U. Klein, Phys.Rev. B69, 134518, (2004)

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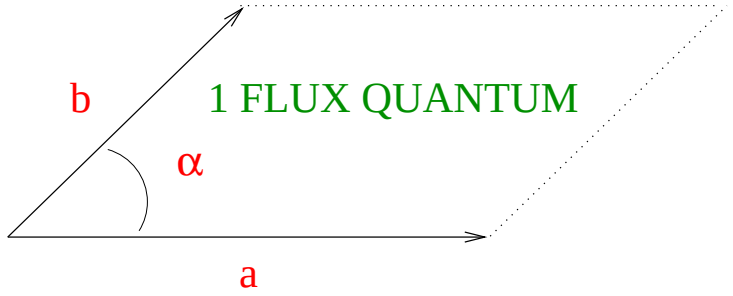

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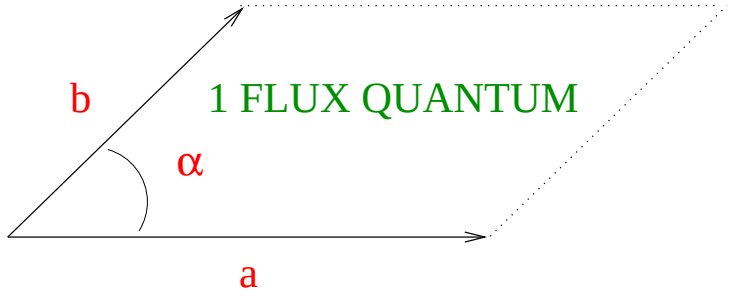

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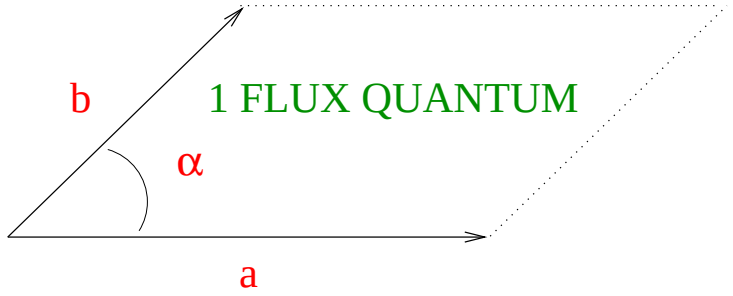

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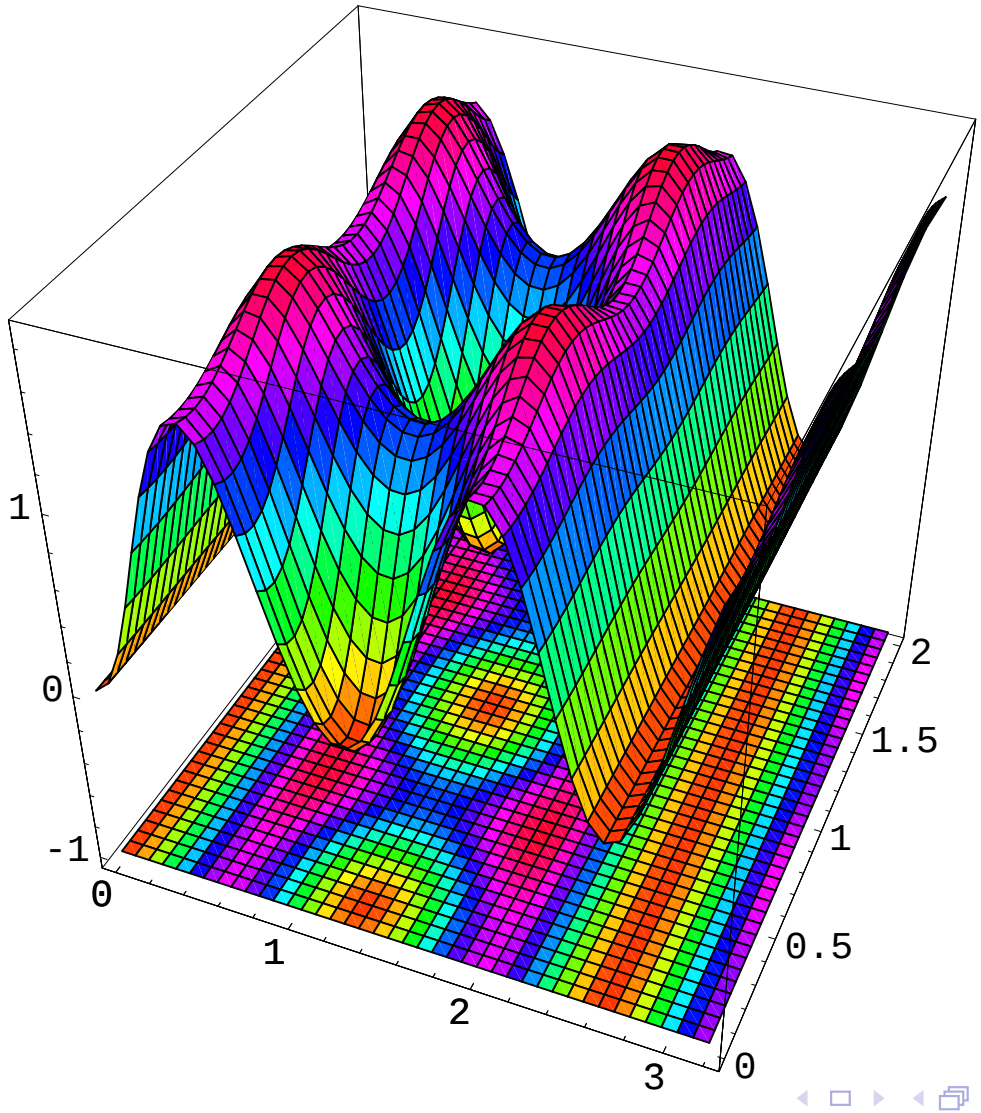
The paramagnetic vortex structure at n=1, ($\theta = 1.2$)

$|\psi|^2$ as a function of x, y



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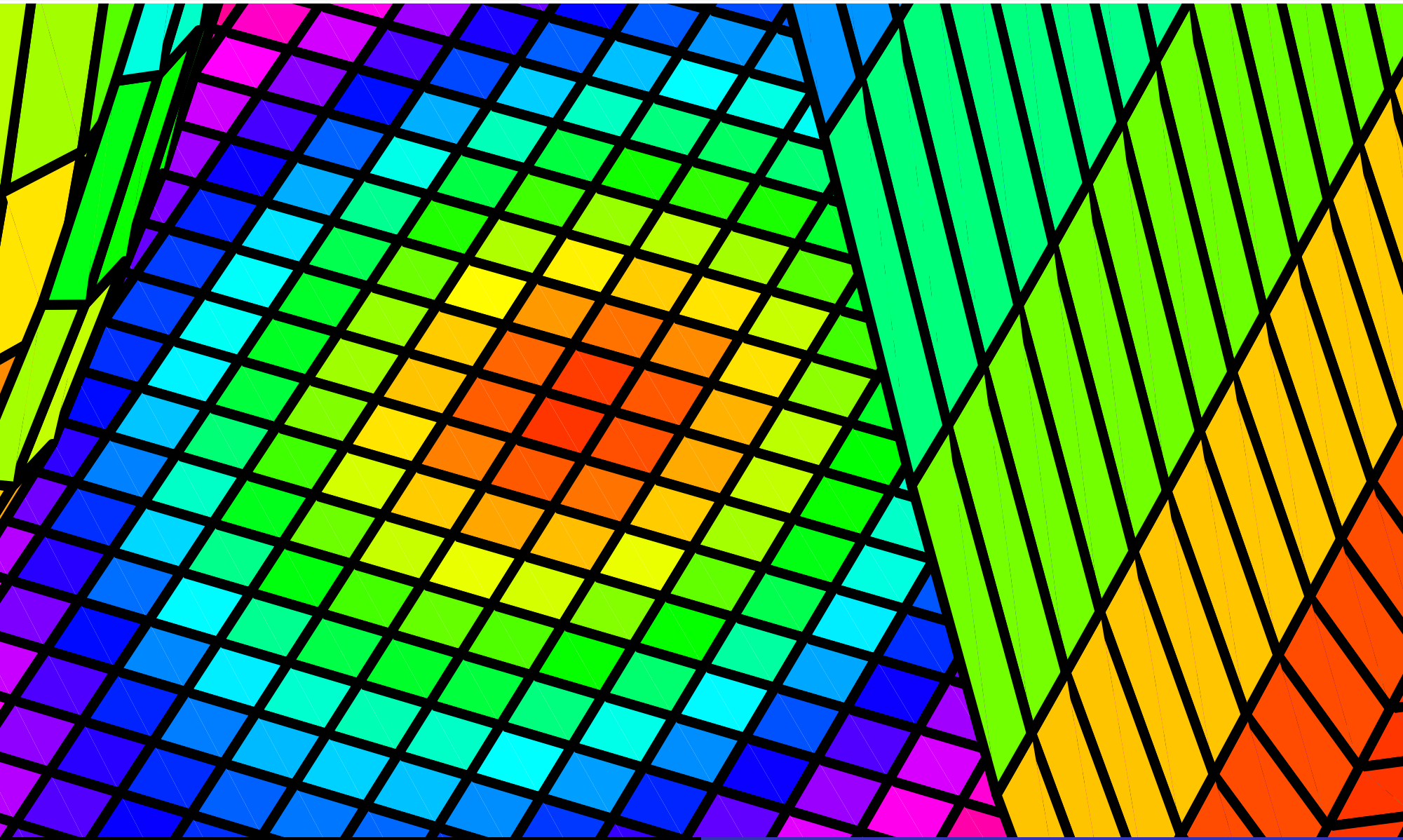

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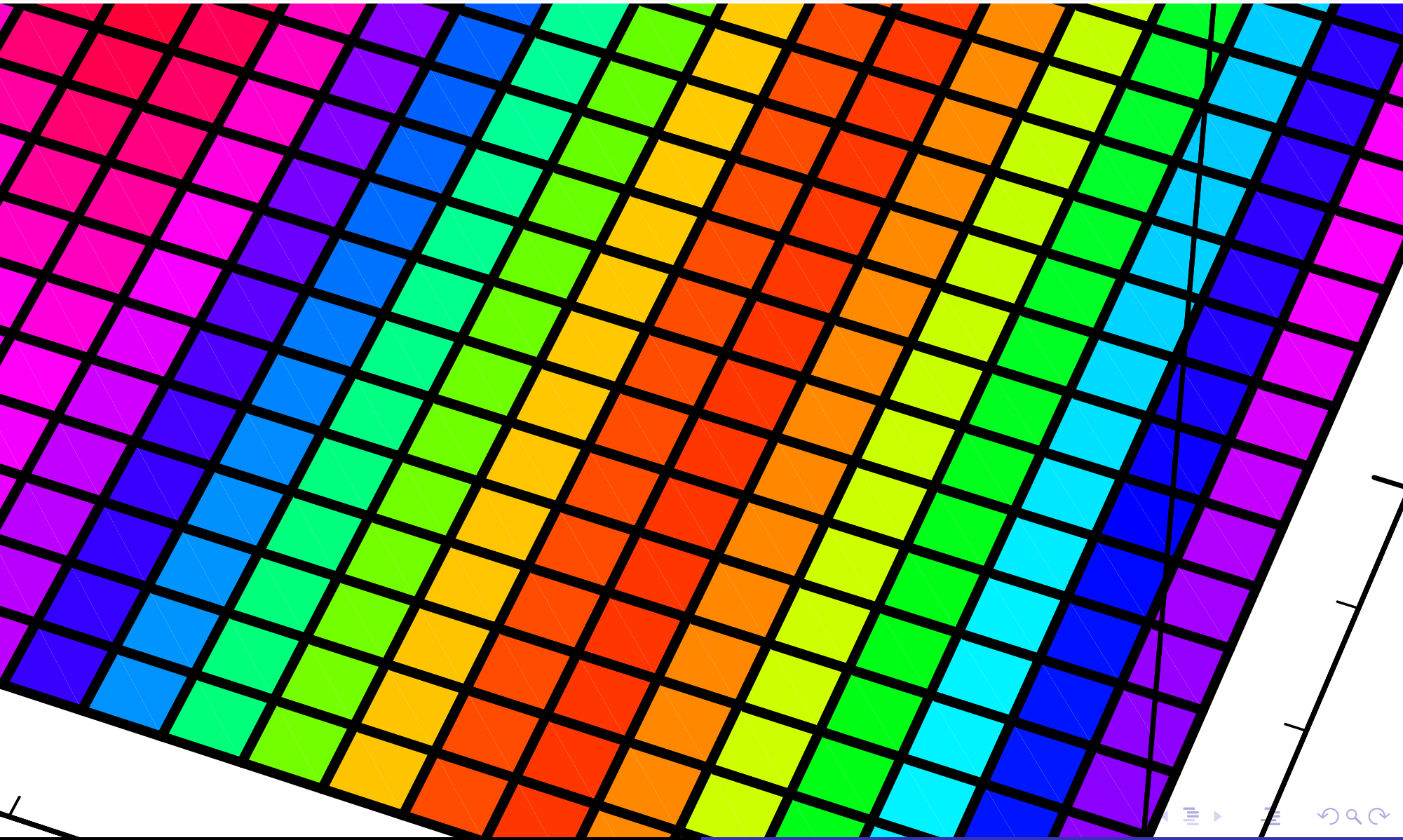

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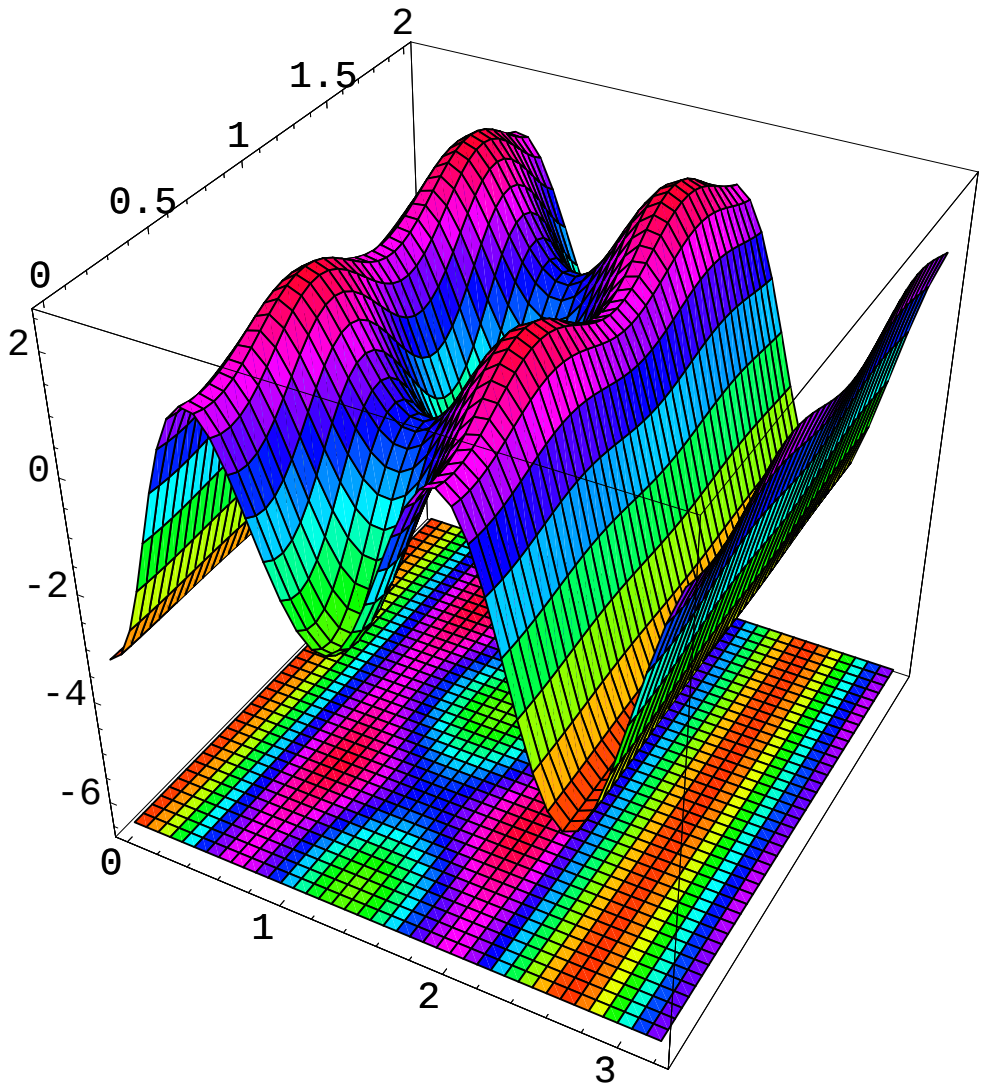
$B_{1||}$ as a function of x, y



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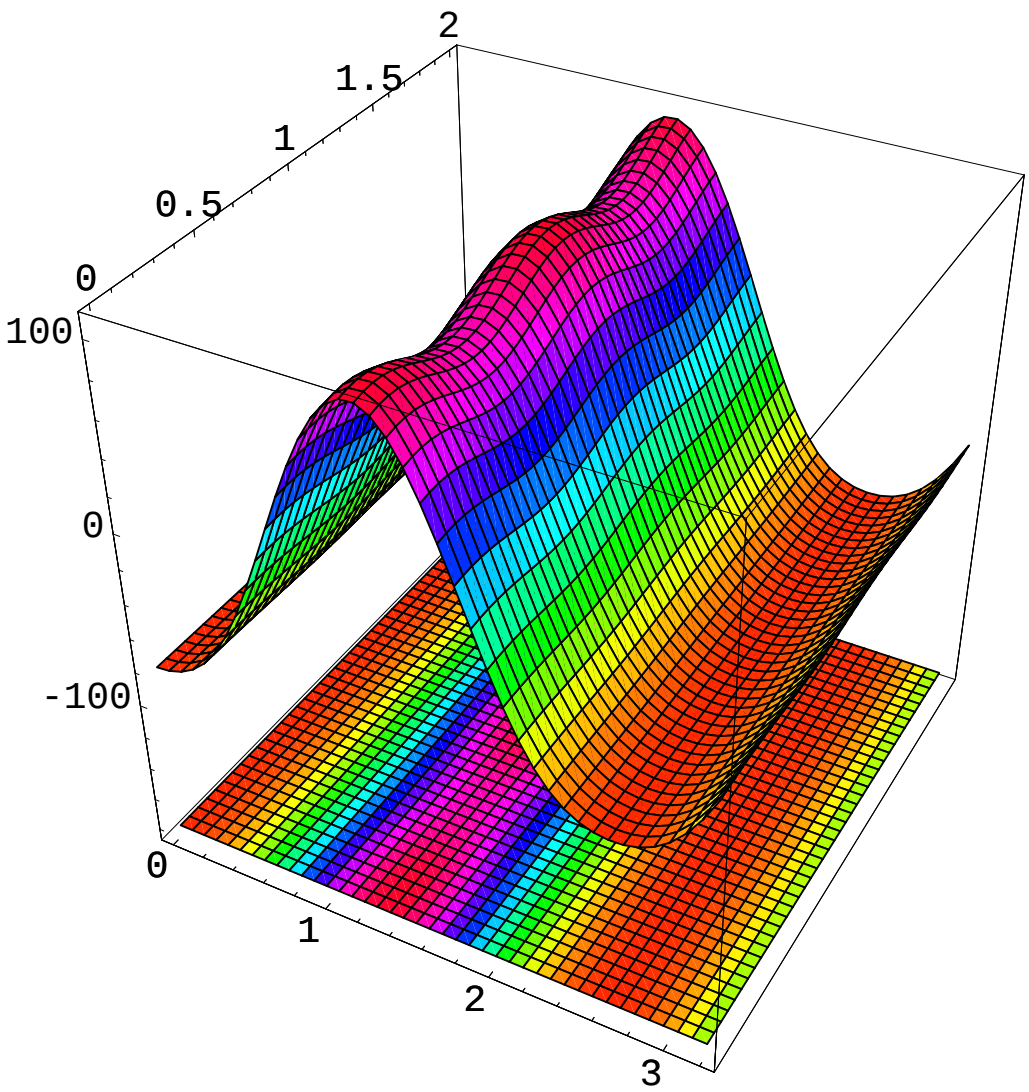
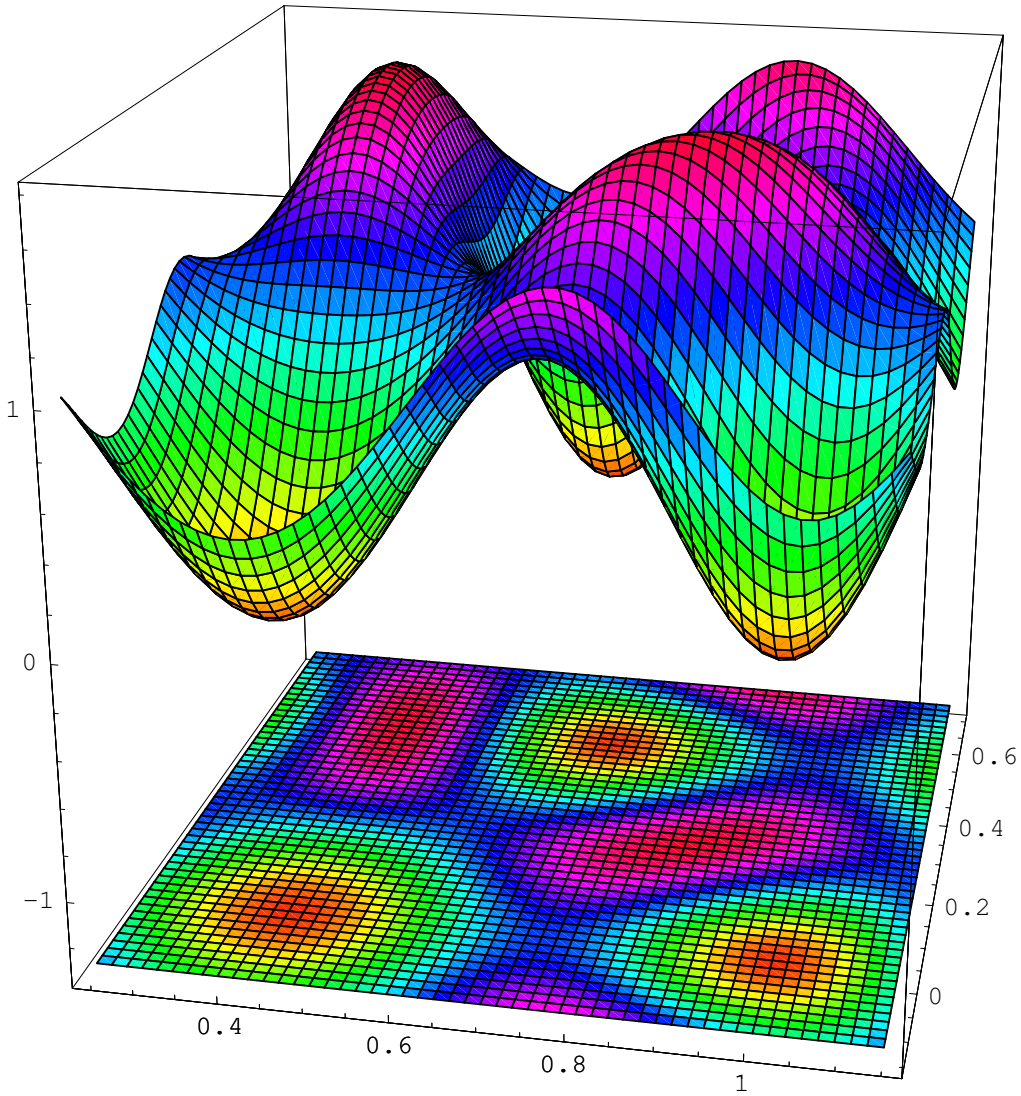
$B_{1\perp}$ as a function of x, y



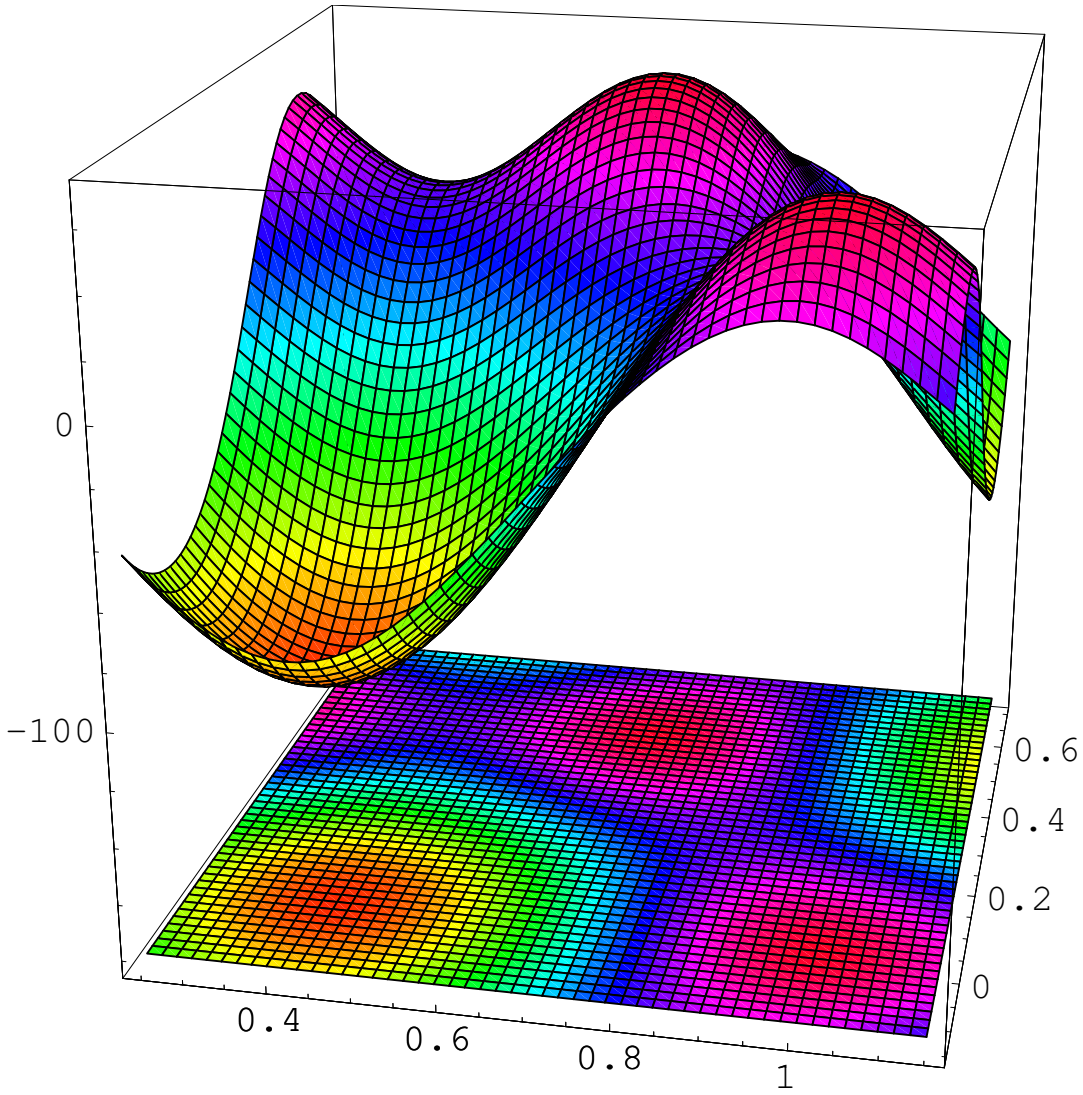
Paramagnetic vortex structure at n=2

$|\psi|^2$ as a function of x, y



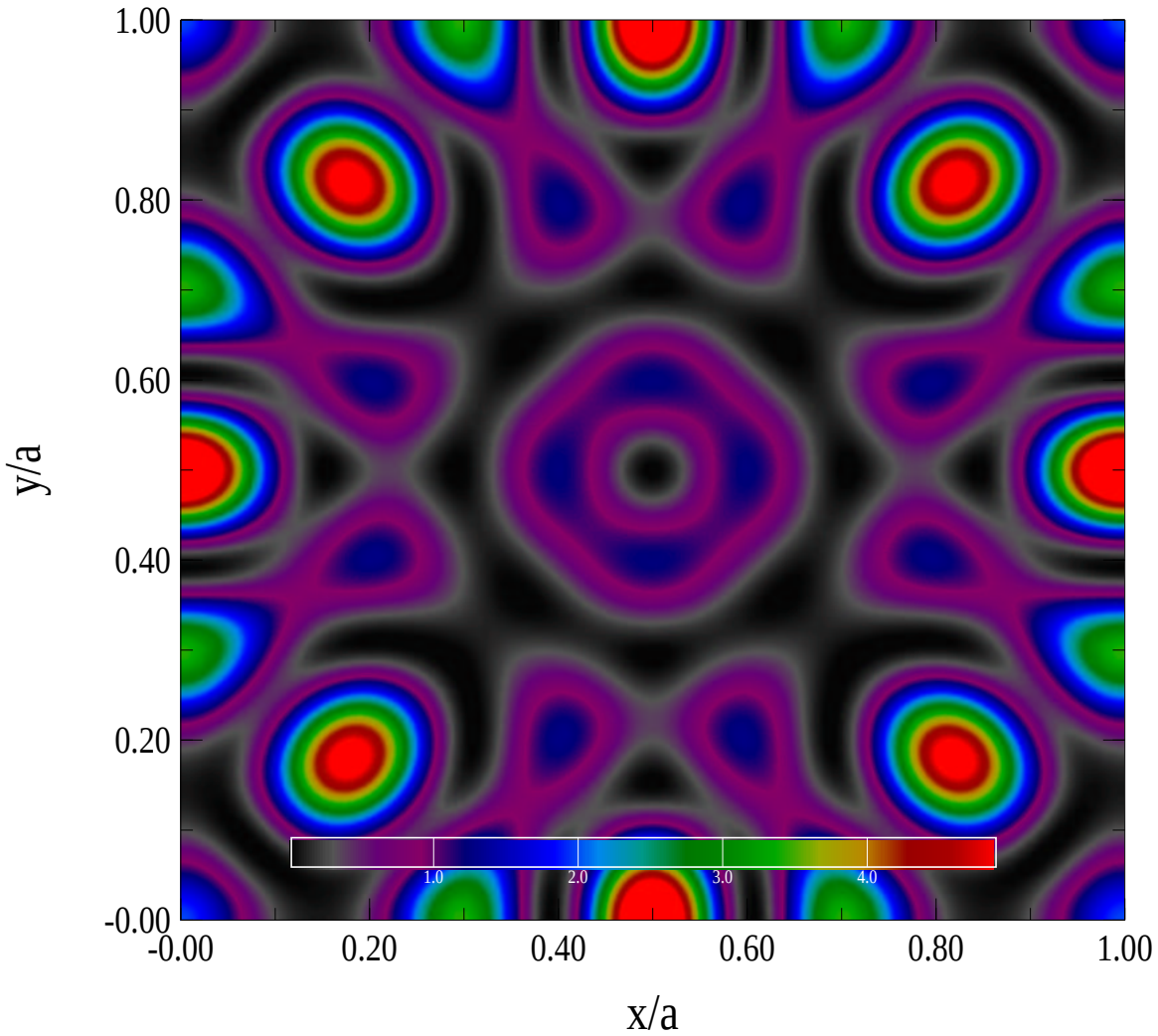
Paramagnetic vortex structure at n=2

$B_{1\perp}$ as a function of x, y: Antivortices



Paramagnetic vortex structure at n=28

$|\psi|^2$ as a function of x, y



Summary

- A large number of interesting structures with really unusual features exists in this mixed pair-breaking regime.
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