Incompressibility of fractional quantum Hall states

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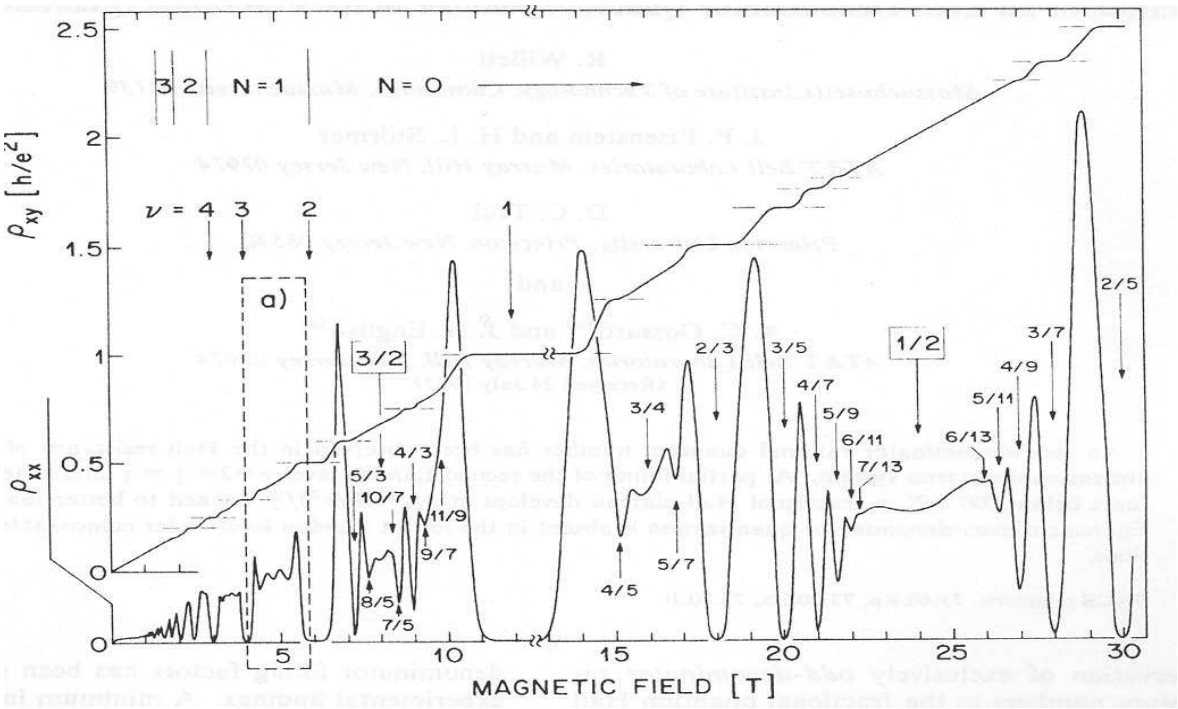
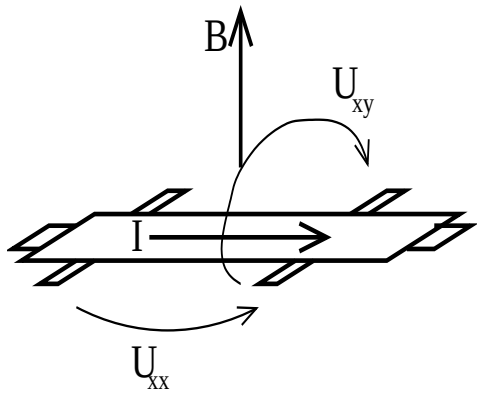
Fractional quantum Hall effect



Willett *et al.*, PRL **59**, 1776



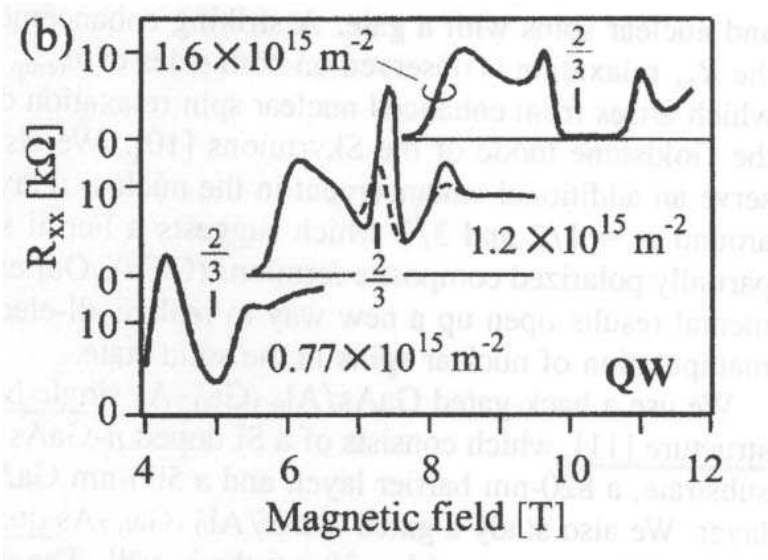
$R_{xx} \to 0 \quad \Rightarrow$ incompr. GS

Incompressible state? What does it mean in terms of response to

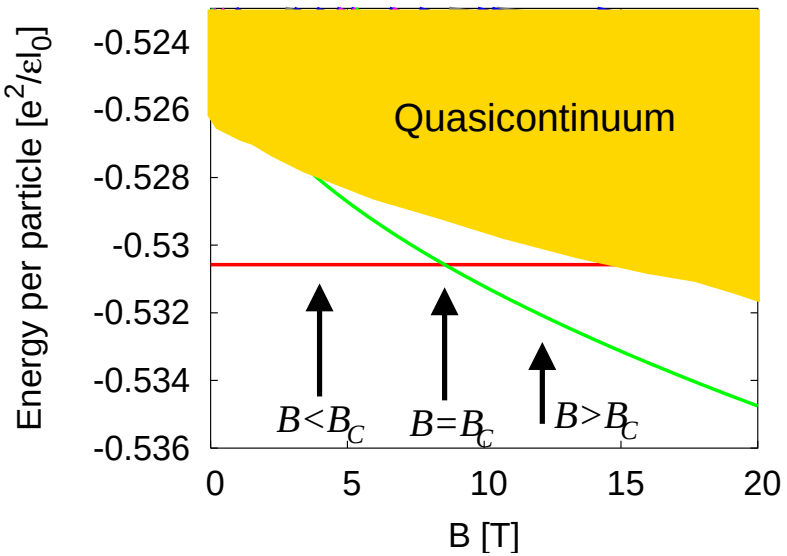
- a non-magnetic impurity
- a magnetic impurity

Filling factor 2/3: two incompressible ground states

Longitudinal magnetoresistance [1]



Exact diagonalization (ED) spectrum, $\nu = \frac{2}{3}$

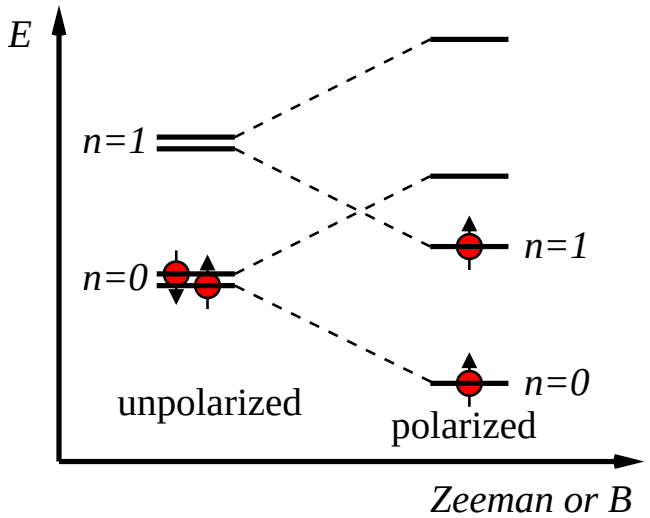


Two competing ground states:

- polarized ($\uparrow\uparrow$)
- singlet ($\uparrow\downarrow$)

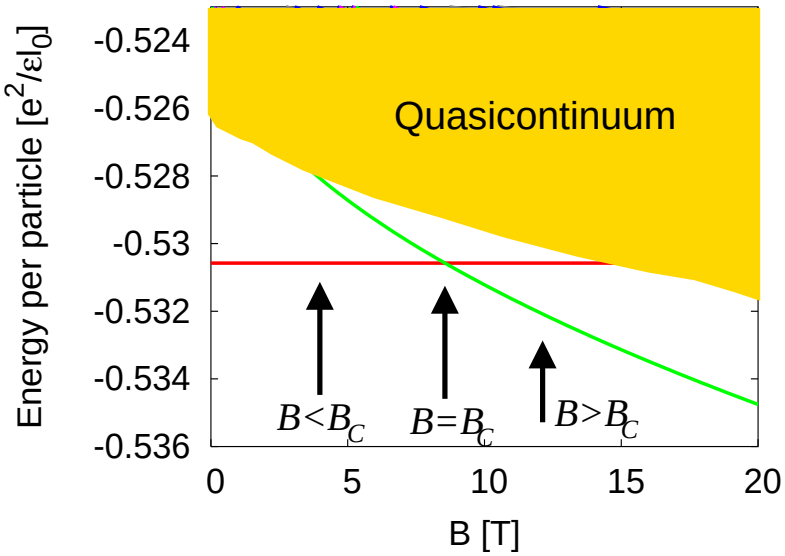
[1] Hashimoto et al., *Phys. Rev. Lett.*, **88**, 176601 (2002)

Composite fermion picture, $\nu_{CF} = 2$



- $B \to \infty$: $(n = 0, \uparrow)$, $(n = 1, \uparrow)$ $\Rightarrow$
- $B \to 0$: $(n = 0, \uparrow)$, $(n = 0, \downarrow)$ $\Rightarrow$

Exact diagonalization spectrum, $\nu = \frac{2}{3}$

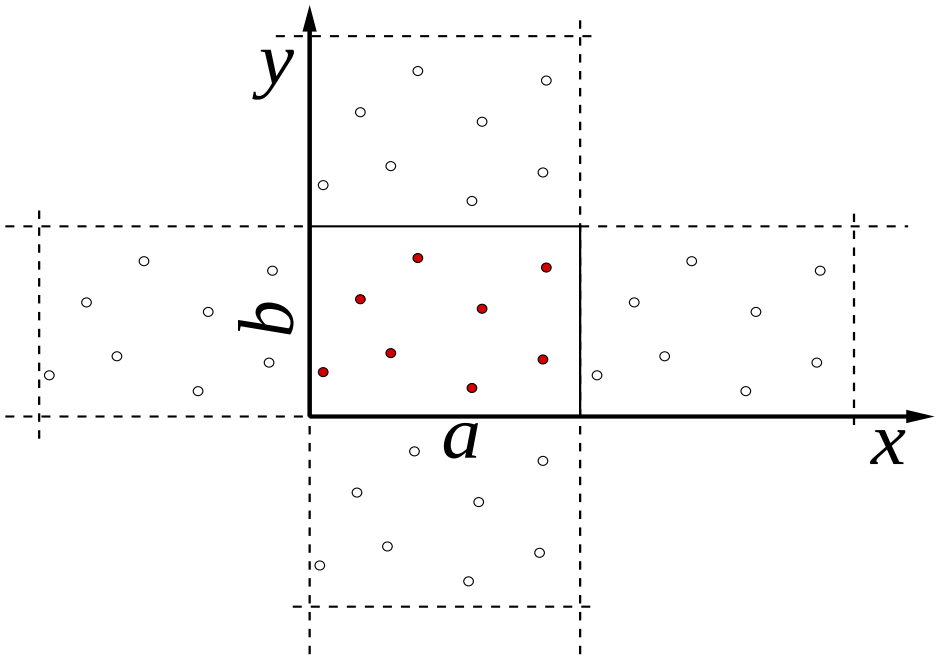


- polarized ($\uparrow\uparrow$)
- singlet ($\uparrow\downarrow$)

Model

- rectangle + periodic boundary conditions with $N \approx 10$ electrons
- lowest Landau level
- exact diagonalization

Yoshioka, PRB **29**, 6833 (1984)
Zhang, Chakraborty, PRB **30**, 7320 (1984)



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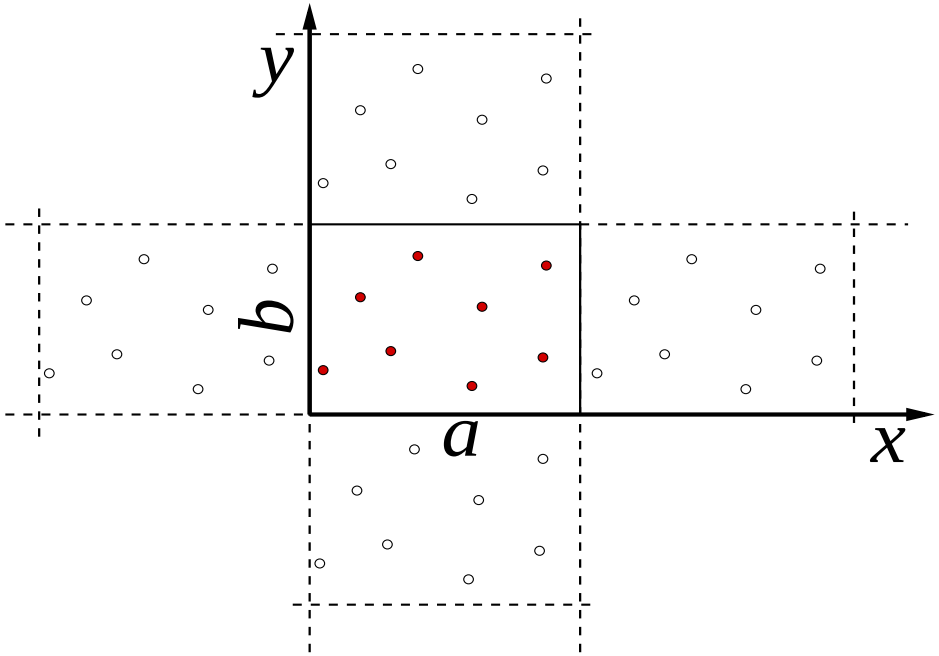
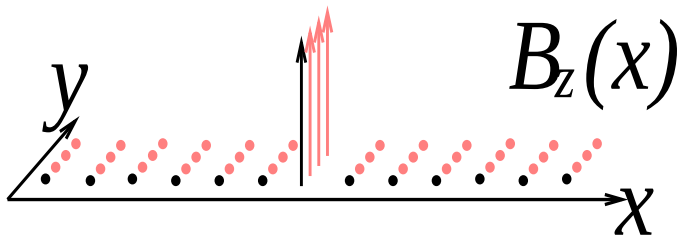
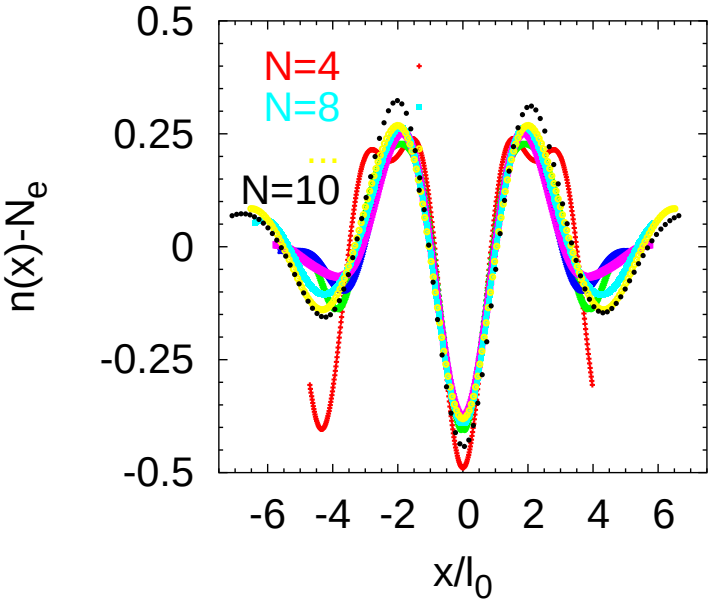


$$H = \frac{e^2}{4\pi\varepsilon} \sum_{i<j} \frac{1}{|r_i - r_j|} + g\mu_B \sum_i B_z(x_i)\sigma_i^z$$



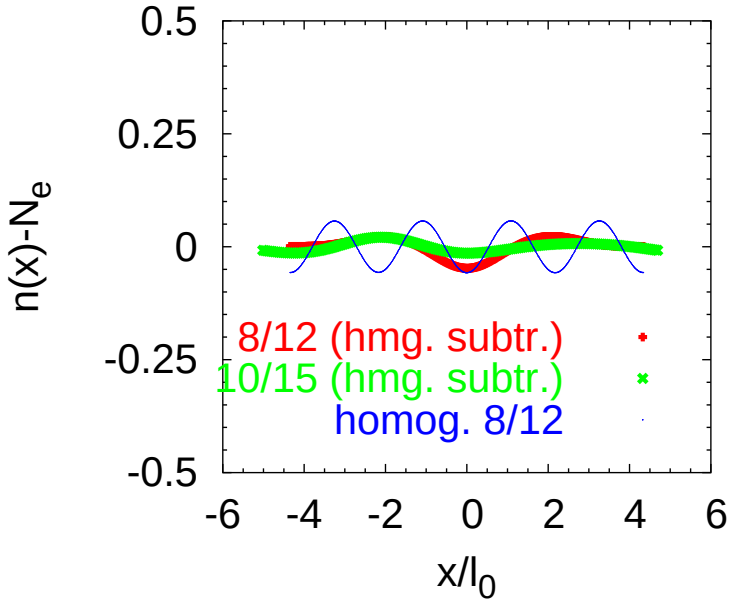
- magnetic impurity (spatially varying Zeeman)
- $\sigma_i^z \rightarrow 1$: non-magnetic impurity

Non-magnetic impurity ($\nu = \frac{2}{3}$, ground states)



The polarized state

- strong response
- intrinsic length scale (first max.)
- 'incompressible' on length scales $> 10\ell_0$

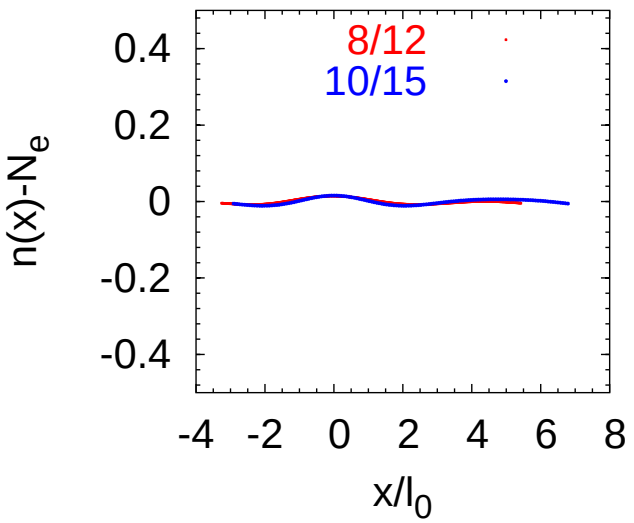


The singlet state

- weak response

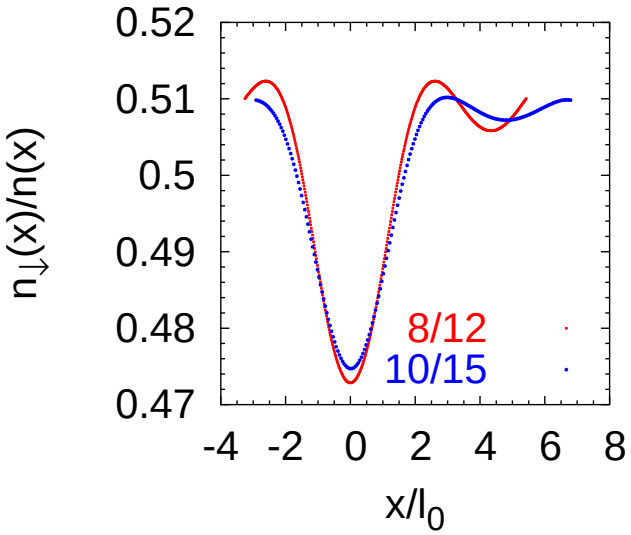
Magnetic impurity ($\nu = \frac{2}{3}$, singlet ground state)

Density



- weak response again

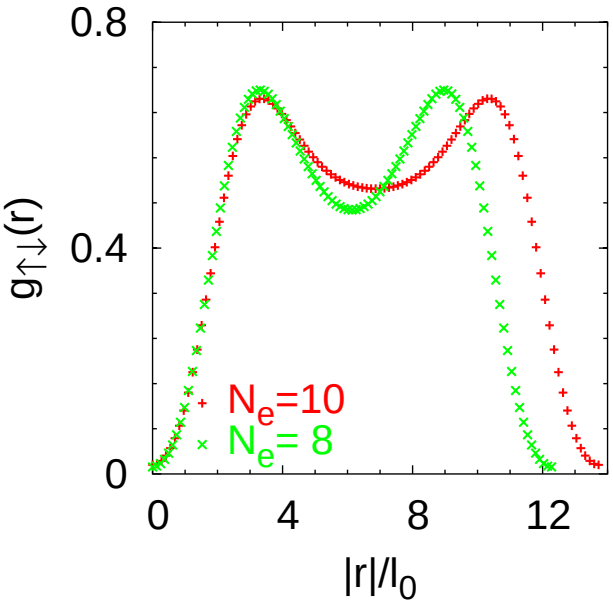
Polarization

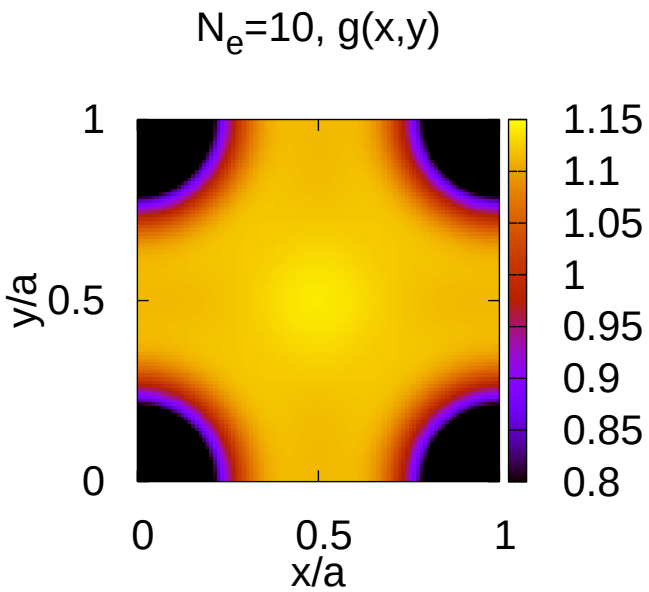


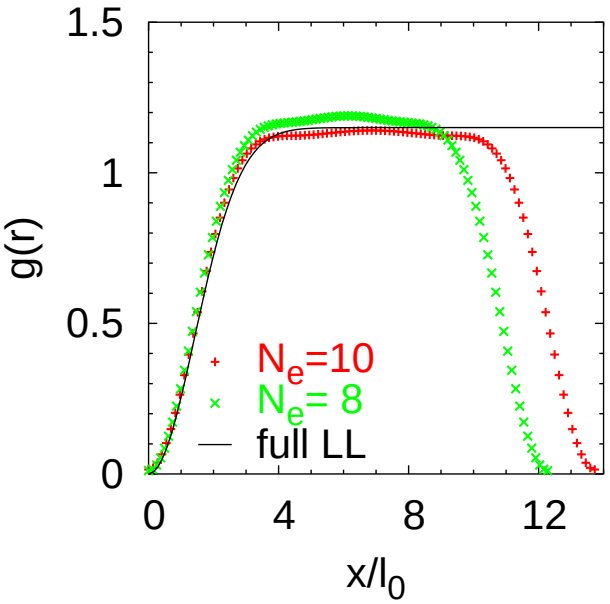
- easily polarizable
- 'compressible'
- no intrinsic length scale

The singlet ground state: inner structure

Density–density correlation functions $g(r) = \langle \delta(r_i - r_j - r) \rangle$







$g_{\uparrow\downarrow}(r)$ correlation
- $\uparrow$- $\downarrow$ pairing

Spin–unresolved correlation
- $\nu = 1$ incompressible liquid of $\uparrow$- $\downarrow$ pairs

Conclusions

- $\nu = 2/3$ fractional quantum Hall states studied by exact diagonalization
- spin–singlet and spin–polarized ground states

- response to non-mag. impurity: $S = 0$ GS much more rigid
- magnetic impurity: $S = 0$ GS easily polarizable
- $S = 0$ GS: $\nu = 1$ liquid of $\uparrow - \downarrow$ pairs?