Differenciating Canted Phases from Phase Separation regions in Doped Manganites with Spin Waves

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Outline

I. Continuum Double Exchange Model
II. Spin Waves in Magnetic ordered configurations
III. Canted Phases vs. Phase Separation

Effective Potential for homogeneous configurations is obtained after integrating out the fermions in the path integral

$$V_{eff} = J_{AF} M^2 \left[2y^2 - 1 - A \left((y_0+y)^{5/2} + (y_0-y)^{5/2} \right) \right]$$

$$A = \frac{z^{3/2}}{15\pi^2} \frac{t}{J_{AF} M^2 a^3}$$

$y = \cos\frac{\theta}{2} \longrightarrow$ Canting angle

$y_0 \longrightarrow$ Chemical Potential measure

Doping is conjugate of chemical potential

$$x = -a^3 \frac{\partial V_{eff}}{\partial \mu} = -\frac{a^3}{t} \frac{\partial V_{eff}}{\partial y_0}$$

$$x = -a^3 \frac{\partial V_{eff}}{\partial \mu} = -\frac{a^3}{t} \frac{\partial V_{eff}}{\partial \varphi_0}$$

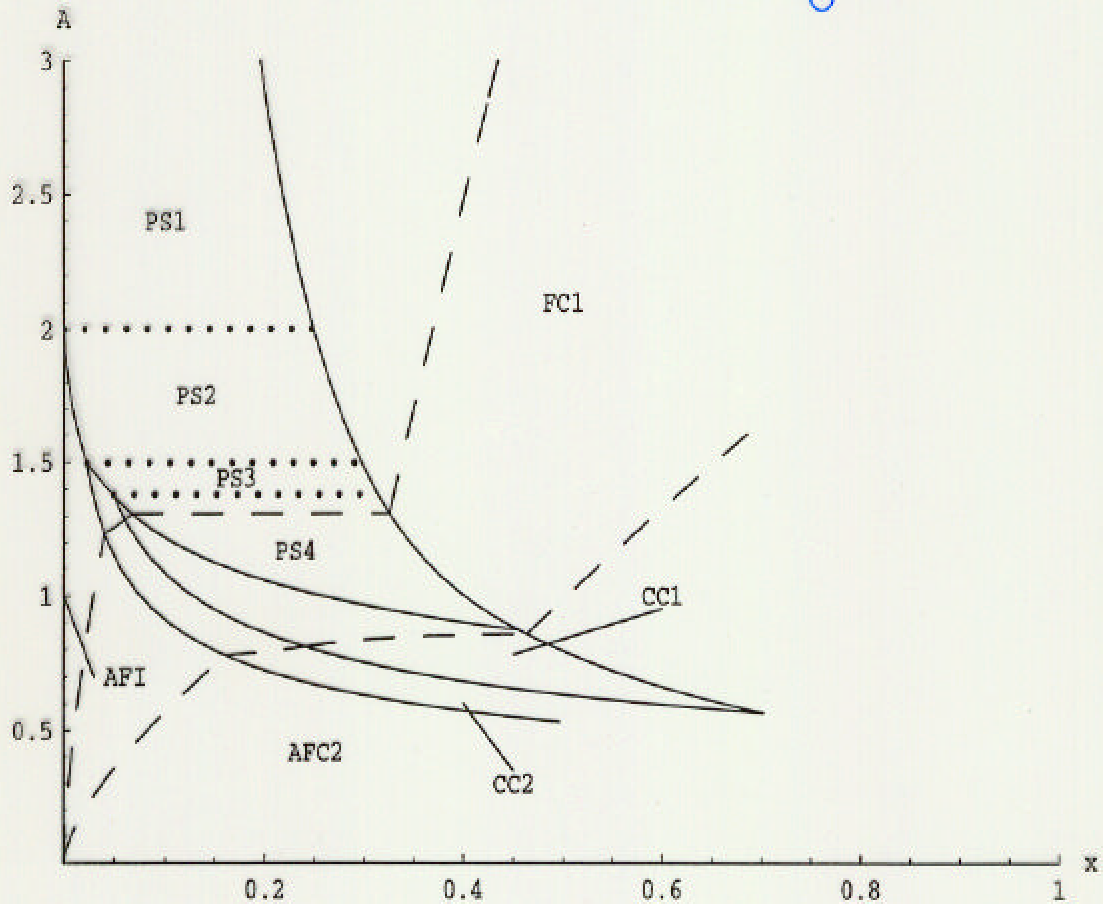


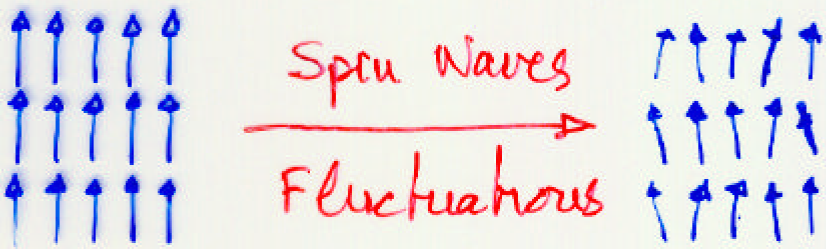
Figure 2: Phase diagram in the (x, A) plane. PSi $(i = 1, 2, 3, 4)$ indicates the new regions where the phases at their boundary may coexist. The $x = 0$ axis corresponds to the AFI phase. The two dashed lines are the boundaries for the reliability of our model for $z|J_H|M/2(J_{AF}a^3M^2) \sim 50$ and $z|J_H|M/2(J_{AF}a^3M^2) \sim 200$ respectively. Only the part of the phase diagram to the left of the corresponding dashed line is trustworthy in each case.

$$\frac{t}{J_{AF}a^3M^2} \sim 10\text{-}20 \Longrightarrow \boxed{A \sim 1\text{-}2}$$

II. Spin Waves in Magnetically Ordered conf.

Magnetic Order $\Longrightarrow$ Spontaneous Symmetry Breaking

Spontaneous Symmetry Breaking $\Longrightarrow$ Goldstone Modes (Spin Waves)



$$\Psi_0 = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \longrightarrow \Psi(x) = U(x)\,\Psi_0$$

$$U(x) = e^{i(\pi^1(x) S^1 + \pi^2(x) S^2)}$$

Spin Waves Fields

Symmetry principles allow us to write general effective lagrangians (model independent)

• Ferromagnetic Configuration $(SU(2) \to U(1))$

$$\mathcal{L} = \pi^- i \partial_t \pi^+ - \frac{1}{2m'} \partial_i \pi^- \partial_i \pi^+$$

Schrödinger eq.: Quadratic dispersion

• Antiferromagnetic Configuration $(SU(2) \to U(1))$

$$\mathcal{L} = \partial_t \pi^- \partial_t \pi^+ - v^2 \partial_i \pi^- \partial_i \pi^+$$

Wave equation: Linear dispersion

• Canted Configuration $(SU(2) \to 1)$

$$\mathcal{L} = \pi^- i \partial_t \pi^+ - \frac{1}{2m'} \partial_i \pi^- \partial_i \pi^+ + \\ + \frac{1}{2} \partial_t \pi^3 \partial_t \pi^3 - \frac{v^2}{2} \partial_i \pi^3 \partial_i \pi^3$$

$\pi^+(x) \to$ Quadratic dispersion

$\pi^3(x) \to$ Linear dispersion.

Dispersion relations in Manganites

In the CDEM there are two sources of spin waves terms in the lagrangian

1) Heissenberg term
2) interaction electron-spin wave

→ After integrating out the electrons in the path integral, a dependence on the doping raises

Different interaction for every configuration (F, AF, C)

⇓

Different dependence of the dispersion relations on the doping

IV. Canted Phases vs. Phase Separation

Phase Separation Region guess:

- Two macroscopic F and AF domains
- The interphase does not modifies qualitatively the properties

PS: One F and two AF branches
C: One F and one AF branches

PS: Splitting of the AF branches by a magnetic field
C: No modification of the AF branch by a magnetic field.

Different behaviour of the mass and velocity with the doping

PS: Figure A = 2,20
C: Figure A = 0,80

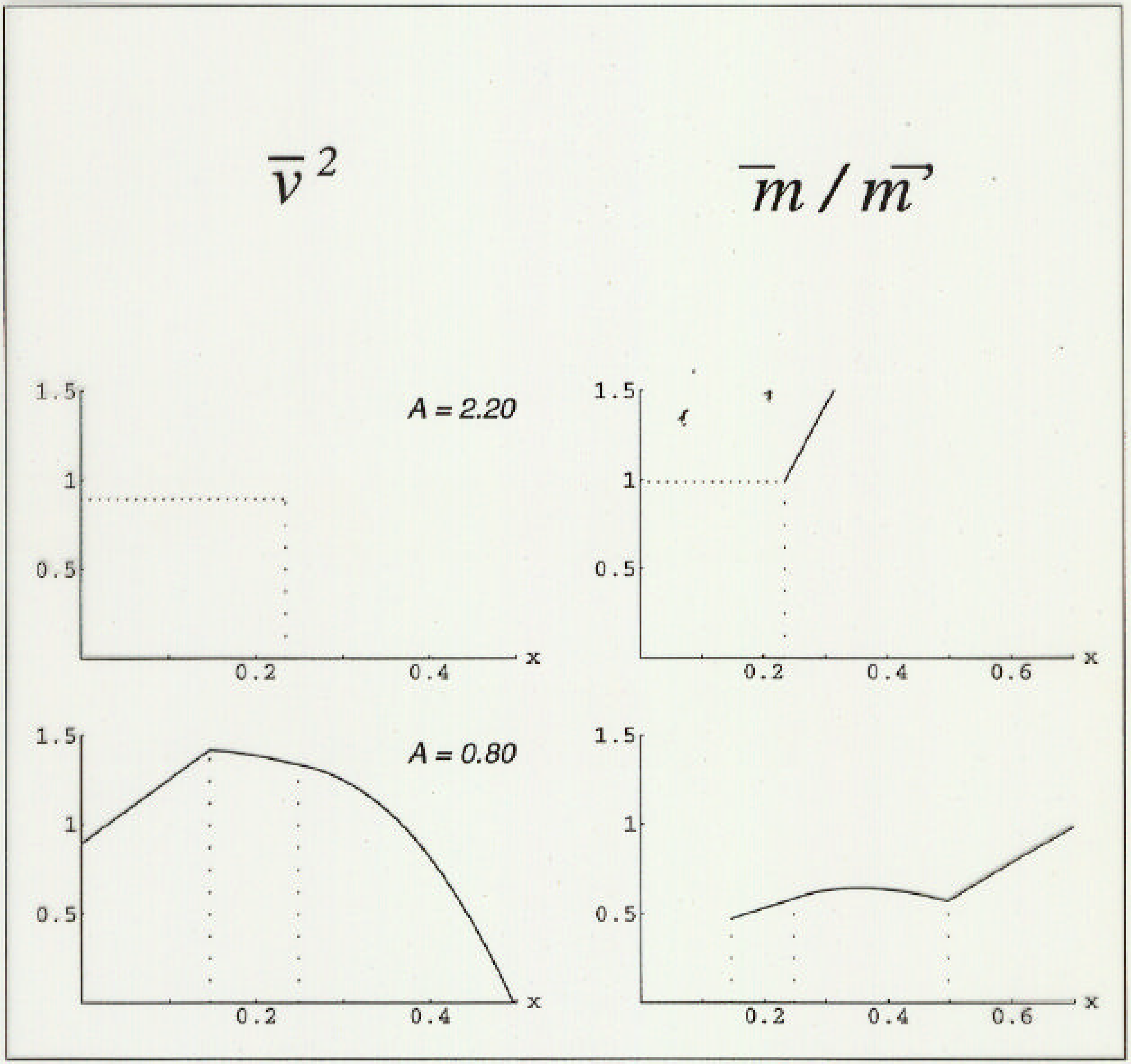


Figure 1: The dependence of the velocities and the masses on the doping for the $F - AF$ phase separation region and the canted phase. $\bar{v}^2 = (15\pi^2 A)2mzv^2/6z^{3/2}(J_{AF}a^3M^2)$ and $\bar{m}/\bar{m}' = (15\pi^2 A)m/z^{3/2}m'$. The horizontal dotted lines correspond to the phase separation regions, and the vertical dotted lines correspond to the phase transitions.

Conclussions

- A simple continuum model describes the low energy and long distance properties for manganites systems

- Phase Diagram: AF, F, Canted and Phase Sep.

- The effective lag. for spin waves on the low energy and momentum presents:
  - F: One quadratic branch
  - AF: Two linear branches
  - C: One quadratic and one lineal.

- We presented the the spin waves dispersion relations in the manganites (dependence on the doping)

- Three distinctive characteristic of the spin waves differenciate the canted phases from the phase separation regions.