

# Study of the Effective Interaction and Superfluidity in Two-Dimensional Liquid <sup>3</sup>He

### Hideaki KOBAYASHI

A dissertation submitted to the Doctoral Program in Physics, the University of Tsukuba in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Science)

October, 2000

| 寄  | 贈  |
|----|----|
| 1  | 平成 |
| 林英 | 作  |
| R  | 月月 |
| 氏  | 日  |

**01**30**1**694

### Acknowledgments

I would like to express my sincere thanks to Prof. Dai. S. Hirashima, who introduced me to this field of research, for his guidance, valuable discussions, critical reading of the manuscript, and his continual encouragements. I would also like to thank Prof. K. Miyake for his useful comments. Many stimulating conversations with the members of the research group at the University of Tsukuba are much acknowledged.

The computation in this work has been done using the facilities of the Super-computer Center, Institute for Solid State Physics, University of Tokyo, and the facilities of the Information Center, University of Tsukuba.

# List of papers submitted for the requirement of the degree

- 1. "Correlation Effects on the Spin Susceptibility in Two Dimensional Fermion Systems", D. S. Hirashima and H. Takahashi: J. Phys. Soc. Jpn. 67 (1998) 3816-3824.
- 2. "Susceptibility and Effective Interaction in the Dilute Two Dimensional Hubbard Model", H. Takahashi: J. Phys. Soc. Jpn. 68 (1999) 194-203.
- 3. "Effective Interaction and Superfluidity in Two-dimensional Liquid <sup>3</sup>He", H. Takahashi and D. S. Hirashima: J. Low. Temp. Phys. **121** (2000), in press.

## Contents

| 1 | Ger   | neral I         | ntroduction | 1  |  |  |  |  |
|---|---|-----------------|-------------|----|--|--|--|--|
|   | 1.1   | Introd          | luction     | 1  |  |  |  |  |
|   | 1.2   |                 | _           | 3  |  |  |  |  |
|   | 1.3   |                 |             | 8  |  |  |  |  |
| 2 | <b>R</b> -1                                       | R-matrix Theory |             |    |  |  |  |  |
|   | 2.1   | Form            | ılation     | 14 |  |  |  |  |
|   |   | 2.1.1           |             | 14 |  |  |  |  |
|   |   | 2.1.2           |             | 16 |  |  |  |  |
|   |   | 2.1.3           |             | 20 |  |  |  |  |
|   | 2.2   | Result          |             | 27 |  |  |  |  |
|   |   | 2.2.1           |             | 27 |  |  |  |  |
|   |   | 2.2.2           |             | 29 |  |  |  |  |
|   | 2.3   | Summ            |             | 30 |  |  |  |  |
|   | 2.A   |                 |             |    |  |  |  |  |
|   |   |                 |             | 35 |  |  |  |  |
| 3 | Spin-Fluctuation-Mediated Effective Interaction 4 |                 |             |    |  |  |  |  |
|   | 3.1   |                 |             |    |  |  |  |  |
|   |   | 3.1.1           |             | 42 |  |  |  |  |
|   |   | 3.1.2           |             | 43 |  |  |  |  |
|   |   | 3.1.3           |             | 44 |  |  |  |  |
|   |   | 3.1.4           |             | 48 |  |  |  |  |
|   | 3.2   |                 |             | 50 |  |  |  |  |
|   | 0.2   | 3.2.1           |             | 50 |  |  |  |  |
|   |   | 3.2.2           |             | 52 |  |  |  |  |
|   |   | 3.2.3           | <b>.</b>    | 54 |  |  |  |  |
|   |   | 3.2.4           |             | 55 |  |  |  |  |
|   |   | 325             | V 1         | 57 |  |  |  |  |

| 4 | Con | cluding Remarks   | 81 |
|---|-----|---|----|
|   | 3.E | ations  |    |
|   | 3.D | Effective interaction mediated by spin fluctuations and charge fluctu-  |    |
|   | 3.C | Effect of the vertex corrections  | 73 |
|   | 3.B | Aslamasov-Larkin diagrams in the irreducible four-point vertex function | 70 |
|   | 3.A | The quantum Monte Carlo method in the 2D Hubbard model                  | 66 |
|   | 3.3 | Summary and discussion  | 64 |