

# Handbook of High-Temperature Superconductivity

**Theory and Experiment**

J. Robert Schrieffer

Editor

James S. Brooks

Associate Editor

 Springer

# Contents

<b>Preface</b> .....	v
<b>Acknowledgments</b> .....	ix
<b>List of Contributors</b> .....	xxi
<b>Credit Lines</b> .....	xxiii
<b>1 From Single- to Bipolarons with Jahn–Teller Character and Metallic Cluster-Stripes in Hole-Doped Cuprates</b>	
<i>K. A. Müller</i>	
1.1. The Original Jahn–Teller Polaron Concept and Its Shortcomings .....	1
1.2. Recent Experiments Probing Delocalized Properties .....	2
1.3. Probing of Local Properties .....	4
1.4. The Intersite JT-Bipolaron Concept Derived from EXAFS, EPR, and Neutron Scattering .....	5
1.5. Two-Component Scenario .....	7
1.6. JT-Bipolarons as the Elementary Quasiparticles to Understand the Phase Diagram and Metallic Clusters or Stripes .....	9
1.7. Substantial Oxygen Isotope Effects .....	12
1.8. Concluding Remarks .....	17
Bibliography .....	17
<b>2 Tunneling Measurements of the Cuprate Superconductors</b>	
<i>J. R. Kirtley and F. Tafuri</i>	
2.1. Introduction .....	19
2.2. General Concepts .....	20
2.2.1. Types of Junction Structures .....	20
2.2.2. Generalized Junction Conductance .....	22
2.2.3. The Tunnel and Proximity Effects .....	22
2.2.4. Andreev Reflection and Bound States .....	25
2.2.5. The Josephson Effect: General Features .....	27
Andreev Reflection in SNS Junctions .....	28
2.3. Means of Preparing Tunnel Junctions .....	32
2.3.1. Junctions with Single Crystals .....	32

2.3.2.	Grain Boundary Junctions . . . . .	32
	Bicrystal Junctions . . . . .	32
	Biepitaxial Junctions . . . . .	33
	Step-Edge Junctions . . . . .	34
	Electron Beam Junctions . . . . .	34
2.3.3.	Junctions with Artificial Barriers . . . . .	35
	Noble Metal Barriers . . . . .	35
	Perovskite and Layered Materials Barriers . . . . .	36
2.3.4.	Interface-Engineered Junctions . . . . .	37
2.3.5.	Junctions with HTS Rather than YBCO . . . . .	37
	La <sub>1.85</sub> Sr <sub>0.15</sub> CuO <sub>4</sub> -Based Trilayer with One-Unit-Cell-Thick Barrier . . . . .	37
	Electron Doped HTS . . . . .	38
	Ca and Co Doped YBCO: Insights into the Overdoped Regime . . . . .	38
	Ultra-Thin Films and Superlattices . . . . .	38
	Intrinsic Stacked Junctions . . . . .	38
2.4.	$\pi$ -Rings and $0 - \pi$ -Junctions . . . . .	39
2.5.	Tunneling Spectroscopy . . . . .	44
2.5.1.	Superconducting Gap . . . . .	44
	General Features . . . . .	44
	Temperature Dependence . . . . .	50
	Momentum Dependence . . . . .	53
	Doping Dependence . . . . .	57
	Macroscopic Quantum Effects . . . . .	59
2.5.2.	Pseudogap . . . . .	60
	Temperature Dependence . . . . .	60
	Magnetic Field Dependence . . . . .	62
2.5.3.	Linear Conduction Background . . . . .	64
2.5.4.	Zero-Bias Anomalies . . . . .	65
2.5.5.	Atomically Resolved Conductivity Modulation Effects . . . . .	69
2.5.6.	Strong Coupling Effects . . . . .	72
	Electron-Phonon . . . . .	73
	Electron-Magnon . . . . .	74
2.6.	Conclusions . . . . .	75
	Bibliography . . . . .	75

### 3 Angle-Resolved Photoemission Spectroscopy on Electronic Structure and Electron-Phonon Coupling in Cuprate Superconductors

*X. J. Zhou, T. Cuk, T. Devereaux, N. Nagaosa, and Z. -X. Shen*

3.1.	Introduction . . . . .	87
3.2.	Angle-Resolved Photoemission Spectroscopy . . . . .	88
	3.2.1. Principle . . . . .	88
	3.2.2. Technique . . . . .	90
3.3.	Electronic Structures of High Temperature Superconductors . . . . .	95
	3.3.1. Basic Crystal Structure and Electronic Structure . . . . .	95
	3.3.2. Brief Summary of Some Latest ARPES Results . . . . .	98
3.4.	Electron-Phonon Coupling in High Temperature Superconductors . . . . .	98
	3.4.1. Brief Survey of Electron-Phonon Coupling in High-Temperature Superconductors . . . . .	99

3.4.2.	Electron–Phonon Coupling: Theory . . . . .	102
	General . . . . .	102
	Weak Coupling—Perturbative and Self-Energy Description . . . . .	106
	Strong Coupling—Polaron . . . . .	110
3.4.3.	Band Renormalization and Quasiparticle Lifetime Effects . . . . .	111
	EI–Ph Coupling Along the $(0,0)$ – $(\pi,\pi)$ Nodal Direction . . . . .	111
	Multiple Modes in the Electron Self-Energy . . . . .	116
	EI–Ph Coupling Near the $(\pi,0)$ Antinodal Region . . . . .	118
	Anisotropic EI–Ph Coupling . . . . .	122
3.4.4.	Polaronic Behavior . . . . .	124
	Polaronic Behavior in Parent Compounds . . . . .	124
	Doping Dependence: From $Z\sim 0$ Polaron to Finite $Z$ Quasiparticles . .	128
	Doping Evolution of Fermi Surface: Nodal–Antinodal Dichotomy . .	130
3.4.5.	Electron–Phonon Coupling and High Temperature Superconductivity . . . . .	135
3.5.	Summary . . . . .	137
	Bibliography . . . . .	138

## 4 Microwave Electrodynamics of High Temperature Superconductors

*D. A. Bonn and W. N. Hardy*

4.1.	Introduction . . . . .	145
4.2.	Electrodynamics of Superconductors . . . . .	146
	4.2.1. London Theory . . . . .	146
	4.2.2. Surface Impedance Approximation . . . . .	147
	4.2.3. Non-local Electrodynamics . . . . .	151
	4.2.4. Excitation Spectrum of a d-Wave Superconductor . . . . .	151
	Phenomenological Pairing Model . . . . .	152
	Effect of Impurities . . . . .	154
4.3.	Experimental Techniques . . . . .	156
	4.3.1. Penetration Depth Techniques—Single Crystals . . . . .	158
	Excluded Volume Techniques . . . . .	158
	Far Infrared Reflectivity: $ R e^{i\theta}$ . . . . .	159
	Measurement of Internal Field Distribution in Mixed State . . . . .	160
	Zero-Field Gadolinium ESR . . . . .	161
	4.3.2. Penetration Depth Techniques—Thin Films . . . . .	161
	Low Frequency Mutual Inductance Techniques . . . . .	161
	Thin Film Resonator Techniques . . . . .	161
	Millimetre Wave Transmission . . . . .	162
	Far-Infrared Reflection . . . . .	162
	Slow Muon Beam Method . . . . .	162
	4.3.3. Penetration Depth Techniques—Powders . . . . .	162
4.4.	Measurement of Surface Resistance $R_s$ . . . . .	163
	4.4.1. Single Crystals . . . . .	163
	Cavity Perturbation . . . . .	163
	Broadband Bolometric Spectroscopy . . . . .	165
	Thin Film Methods . . . . .	165

4.5.	Penetration Depth	166
4.5.1.	Complementary Roles of $\lambda$ and $R_s$	166
4.5.2.	$\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$	167
4.5.3.	Penetration Depth Anisotropy in $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$	170
4.5.4.	Oxygen Doping Effects	171
4.5.5.	Other Materials	174
	$\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$	174
	$\text{Tl}_2\text{Ba}_2\text{CaCu}_2\text{O}_8$	174
	$\text{Tl}_2\text{Ba}_2\text{CuO}_{6+\delta}$	174
	$\text{La}_{1-x}\text{Sr}_x\text{CuO}_4$	175
	$\text{HgBa}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+\delta}$	175
	Electron Doped Thin Films and Single Crystals	175
4.5.6.	$\hat{c}$ -Axis Penetration Depth	177
4.6.	Surface Resistance	179
4.6.1.	$\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ $\hat{ab}$ -Plane	180
4.6.2.	Disorder and Quasiparticle Damping	185
4.6.3.	Other Materials— $ab$ -Plane	187
4.6.4.	Low Temperature Limit	193
4.6.5.	Anisotropy	200
4.7.	Fluctuations	202
	Bibliography	209

## 5 Magnetic Resonance Studies of High Temperature Superconductors

*Charles P. Slichter*

5.1.	Introduction	215
5.2.	Basic NMR Theory and Experiment	216
5.2.1.	The Resonance Spectrum	216
5.2.2.	Exciting a Resonance	217
5.2.3.	Spin–Lattice Relaxation	219
5.2.4.	Double Resonance	220
5.2.5.	NMR in Superconductors	221
5.3.	NMR in Normal State Metals	221
5.4.	NMR in Conventional BCS Superconductors	223
5.5.	The Cuprate Spin Hamiltonian	224
5.6.	YBCO above $T_C$	226
5.6.1.	One or Two Components?	226
5.6.2.	The Spin Pseudogap	227
5.6.3.	The Spin–Lattice Relaxation Time	227
5.6.4.	Transverse Relaxation and $T_{2G}$	232
5.6.5.	Scaling Relationships	234
5.7.	YBCO Below $T_C$ : NMR Evidence About the Pairing State	236
5.7.1.	The Knight Shift	236
5.7.2.	Spin–Lattice Relaxation	239
5.8.	LSCO	240
5.8.1.	The Spectrum	240
5.8.2.	One or Two Components	243
5.8.3.	The Incommensurate State	244
5.8.4.	Spatial Modulation	245

5.8.5.	The High Temperature Properties .....	248
5.8.6.	The Low Temperature Properties: Wipeout .....	248
5.9.	Brief Review of EPR .....	252
	Bibliography .....	254

## 6 Neutron Scattering Studies of Antiferromagnetic Correlations in Cuprates

*John M. Tranquada*

6.1.	Introduction .....	257
6.2.	Magnetic Excitations in Hole-Doped Superconductors .....	259
6.2.1.	Dispersion .....	259
6.2.2.	Spin Gap and "Resonance" Peak .....	262
6.2.3.	Discussion .....	263
6.3.	Antiferromagnetism in the Parent Insulators .....	264
6.3.1.	Antiferromagnetic Order .....	264
6.3.2.	Spin Waves .....	267
6.3.3.	Spin Dynamics at $T > T_N$ .....	271
6.4.	Destruction of Antiferromagnetic Order by Hole Doping .....	272
6.5.	Stripe Order and Other Competing States .....	274
6.5.1.	Charge and Spin Stripe Order in Nickelates .....	274
6.5.2.	Stripes in Cuprates .....	276
6.5.3.	Spin-Density-Wave Order in Chromium .....	279
6.5.4.	Other Proposed Types of Competing Order .....	280
6.6.	Variation of Magnetic Correlations with Doping and Temperature in Cuprates .....	280
6.6.1.	Magnetic Incommensurability vs. Hole Doping .....	280
6.6.2.	Doping Dependence of Energy Scales .....	282
6.6.3.	Temperature-Dependent Effects .....	283
6.7.	Effects of Perturbations on Magnetic Correlations .....	284
6.7.1.	Magnetic Field .....	284
6.7.2.	Zn Substitution .....	286
6.7.3.	Li-Doping .....	286
6.8.	Electron-Doped Cuprates .....	286
6.9.	Discussion .....	288
6.9.1.	Summary of Experimental Trends in Hole-Doped Cuprates .....	288
6.9.2.	Theoretical Interpretations .....	289
	Bibliography .....	290

## 7 Optical Conductivity and Spatial Inhomogeneity in Cuprate Superconductors

*J. Orenstein*

7.1.	Introduction .....	299
7.1.1.	Optical Conductivity of Superconductors .....	299
7.1.2.	Optical Conductivity and the Cuprates .....	300
7.2.	Low Frequency Optical Conductivity in the Cuprates .....	301
7.2.1.	YBCO Single Crystals: Success of the Two-Fluid Model .....	301
7.2.2.	The BSCCO System: Failure of the Two-Fluid Description .....	303
7.2.3.	Additional Examples .....	307

7.3.	Optical Conductivity vs. Hole Concentration in BSCCO .....	309
7.3.1.	Systematics of the Conductivity Anomaly .....	309
7.3.2.	Quantitative Modeling of $\sigma(\omega, T)$ .....	312
7.4.	Collective Mode Contribution to Optical Conductivity .....	314
7.4.1.	Origin of the Collective Contribution .....	314
7.4.2.	Optical Conductivity in the Presence of Inhomogeneity .....	316
7.4.3.	Extended Two-Fluid Model .....	316
7.4.4.	Comparison of Model and Experiment .....	320
7.5.	Summary and Outlook .....	321
7.5.1.	Summary .....	321
7.5.2.	Outlook and Directions of Future Research .....	321
	Bibliography .....	323

## 8 What $T_c$ can Teach About Superconductivity

*T. H. Geballe and G. Koster*

8.1.	Introduction .....	325
8.2.	Cuprate Superconductivity .....	326
8.2.1.	Pairing and $T_c$ s in the Cuprates .....	327
	The Cu Ion .....	327
8.3.	Interactions Beyond the $\text{CuO}_2$ Layers .....	328
8.3.1.	Pairing Centers in the Charge Reservoir Layer Cuprates .....	329
8.3.2.	Negative-U Center Electronic Pairing in a Model System .....	330
8.3.3.	The Chain-Layer Cuprates .....	334
8.3.4.	Other Chain Layer Compounds .....	338
8.4.	Superconductivity Originating in the $\text{CuO}_2$ Layers .....	339
8.5.	Summary .....	341
	Bibliography .....	341

## 9 High- $T_c$ Superconductors: Thermodynamic Properties

*R. A. Fisher, J. E. Gordon, and N. E. Phillips*

9.1.	Introduction .....	345
9.1.1.	Scope and Organization of the Review .....	345
9.1.2.	Cuprate Superconductors: Occurrence; Structures; Nomenclature; Phase Diagram; Characteristic Parameters .....	346
9.1.3.	Magnetic Properties; Critical-Field Measurements .....	349
9.1.4.	Specific-Heat Measurements .....	350
	Specific Heat: Component Contributions; Field and Temperature Dependences; Nomenclature .....	350
	Specific Heat: Experimental Techniques .....	352
	Specific Heat: Problems and Uncertainties in Analysis of Data .....	353
9.2.	Low-Temperature Specific Heat .....	353
9.2.1.	Zero-Field "Linear" Term .....	354
9.2.2.	Evidence for Line Nodes in the Energy Gap .....	357
9.3.	Chemical Substitutions .....	360
9.3.1.	Rare-Earth Substitutions on the Y and La Sites .....	361
9.3.2.	General Effects of Substitutions on the Cu Sites .....	362
9.3.3.	Effects of Zn Substitution on the Cu Sites .....	364

9.4. Stripes ..... 367

9.5. Specific-Heat Anomaly at  $T_c$ : Fluctuations; BCS Transition, BEC ..... 372

    9.5.1. Gaussian and Critical Fluctuations: ..... 372

        Fluctuations: Optimally-Doped Samples in Zero Field ..... 373

        Fluctuations: Optimally Doped Samples in Field ..... 375

        Fluctuations: Under- and Over-Doped Samples ..... 376

    9.5.2. BCS to BEC ..... 376

9.6. Vortex-Lattice Melting ..... 380

    9.6.1. Introduction; Early Measurements on YBCO ..... 380

    9.6.2. Other Measurements on YBCO ..... 381

    9.6.3. Measurements on Other HTS ..... 386

9.7. Calorimetric Evidence for the Pseudogap ..... 386

    9.7.1. Determination of the Electron Specific Heat of  $\text{YBa}_2\text{Cu}_3\text{O}_{6.97}$  ..... 387

    9.7.2. Use of the Differential Method to Obtain the Conduction-Electron Specific Heat of  $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ —A Simplified Discussion ..... 388

    9.7.3. Other Specific-Heat Results and Their Interpretation ..... 390

Bibliography ..... 390

**10 Normal State Transport Properties**

*N. E. Hussey*

10.1. Introduction ..... 399

10.2. Evolution of the In-Plane Resistivity with Doping ..... 400

    10.2.1. Introduction ..... 400

    10.2.2. Optimally Doped Cuprates ..... 401

    10.2.3. Underdoped Cuprates ..... 404

    10.2.4. Overdoped Cuprates ..... 406

10.3. The Out-of-Plane Transport ..... 406

    10.3.1. Introduction ..... 406

    10.3.2. Optimal Doped Cuprates ..... 407

    10.3.3. Underdoped Cuprates ..... 408

    10.3.4. Overdoped Cuprates ..... 409

10.4. The Anomalous Hall Coefficient and Violation of Kohler's Rule ..... 410

    10.4.1. Introduction ..... 410

    10.4.2. Magnitude of  $R_H$  ..... 410

    10.4.3. The Inverse Hall Angle  $\cot \vartheta_H(T)$  ..... 411

    10.4.4. Theoretical Modeling of  $\rho_{ab}T$  and  $R_H(T)$  in Cuprates ..... 412

    10.4.5. In-Plane Magnetoresistance ..... 414

10.5. Impurity Studies ..... 416

10.6. Thermal Transport ..... 417

    10.6.1. Introduction ..... 417

    10.6.2. Thermoelectric Power ..... 418

    10.6.3. Thermal Conductivity ..... 418

    10.6.4. Nernst–Ettinghausen Effect ..... 419

10.7. Discussion and Summary ..... 419

Bibliography ..... 422



## 11 High-Pressure Effects

*J. S. Schilling*

11.1.	Introduction .....	427
11.2.	Elemental Superconductors .....	430
	11.2.1. Simple Metals .....	430
	Nonalkali Metals .....	430
	Alkali Metals .....	433
	11.2.2. Transition Metals .....	436
11.3.	Binary Superconductors .....	437
	11.3.1. A-15 Compounds .....	437
	11.3.2. A Special Case: MgB <sub>2</sub> .....	438
	11.3.3. Doped Fullerenes A <sub>3</sub> C <sub>60</sub> .....	439
11.4.	Multiatom Superconductors: High- <i>T<sub>c</sub></i> Oxides .....	442
	11.4.1. Nonhydrostatic Pressure Media .....	446
	11.4.2. Structural Phase Transitions .....	446
	11.4.3. Oxygen Ordering Effects .....	447
	11.4.4. Intrinsic Pressure Dependence <i>T<sub>c</sub><sup>intr</sup>(P)</i> .....	451
	11.4.5. Uniaxial Pressure Results .....	453
11.5.	Conclusions and Outlook .....	455
	Bibliography .....	457

## 12 Superconductivity in Organic Conductors

*J. S. Brooks*

12.1.	Introduction .....	463
12.2.	Organic Building Blocks and Electronic Structure .....	464
12.3.	“Conventional” Properties of Organic Superconductors .....	466
12.4.	The “Standard Model” for Metallic, Insulating, and Antiferromagnetic Ground States .....	475
	12.4.1. Band Filling and Its Consequences .....	475
	12.4.2. Can Superconductivity Emerge From the “Standard Model”? .....	479
	12.4.3. But What if it is Really Just Phonons? .....	481
12.5.	“Unconventional” Properties of Organic Superconductors .....	481
	12.5.1. Q1D Materials and p-Wave Pairing .....	481
	12.5.2. Q2D Materials and d-Wave Pairing .....	482
	12.5.3. Magnetic Field Induced Superconductivity and Possible FFLO States .....	483
12.6.	Comparison of High <i>T<sub>c</sub></i> Superconductors with Organic Conductors .....	486
12.7.	Summary and Future Prospects .....	488
	Bibliography .....	490

## 13 Numerical Studies of the 2D Hubbard Model

*D. J. Scalapino*

13.1.	Introduction .....	495
13.2.	Numerical Techniques .....	496
	13.2.1. Determinantal Quantum Monte Carlo .....	497
	13.2.2. The Dynamic Cluster Approximation .....	499
	13.2.3. The Density Matrix Renormalization Group .....	501

13.3.	Properties of the 2D Hubbard Model . . . . .	503
13.3.1.	The Antiferromagnetic Phase . . . . .	504
13.3.2.	$d_{x^2-y^2}$ Pairing . . . . .	506
13.3.3.	Stripes . . . . .	510
13.3.4.	The Pseudogap . . . . .	512
13.4.	The Structure of the Effective Pairing Interaction . . . . .	516
13.5.	Conclusions . . . . .	522
	Bibliography . . . . .	524

**14  $t$ - $J$  Model and the Gauge Theory Description of Underdoped Cuprates**

*Patrick A. Lee*

14.1.	Introduction . . . . .	527
14.2.	Basic Electronic Structure of the Cuprates . . . . .	528
14.3.	Phenomenology of the Underdoped Cuprates . . . . .	531
14.4.	Introduction to RVB and a Simple Explanation of the Pseudogap . . . . .	534
14.5.	Slave-Boson Formulation of $t$ - $J$ Model and Mean Field Theory . . . . .	536
14.6.	$U(1)$ Gauge Theory of the URVB State . . . . .	541
14.7.	$SU(2)$ Slave-Boson Theory of Doped Mott Insulators . . . . .	546
14.7.1.	$SU(2)$ Slave-Boson Mean-Field Theory at Finite Doping . . . . .	547
14.7.2.	Effect of Gauge Fluctuations: Enhanced $(\pi, \pi)$ spin Fluctuations in Pseudogap Phase . . . . .	550
14.7.3.	$\sigma$ -Model Effective Theory and New Collective Modes in the Superconducting State . . . . .	551
14.7.4.	Vortex Structure . . . . .	554
14.7.5.	Phase Diagram . . . . .	555
14.8.	Spin Liquids, Deconfinement, and the Emergence of Gauge Fields and Fractionalized Particles . . . . .	557
14.9.	Application of Gauge Theory to the High $T_c$ Superconductivity Problem . . . . .	559
14.9.1.	Spin Liquid, Quantum Critical Point, and the Pseudogap . . . . .	560
14.9.2.	Signature of the Spin Liquid . . . . .	562
14.10.	Summary and Outlook . . . . .	563
	Bibliography . . . . .	565

**15 How Optimal Inhomogeneity Produces High Temperature Superconductivity**

*Steven A. Kivelson and Eduardo Fradkin*

15.1.	Why High Temperature Superconductivity is Difficult . . . . .	570
15.2.	Dynamic Inhomogeneity-Induced Pairing Mechanism of HTC . . . . .	572
15.2.1.	Pairing in Hubbard Clusters . . . . .	573
15.2.2.	Spin-Gap Proximity Effect . . . . .	574
15.3.	Superconductivity in a Striped Hubbard Model: A Case Study . . . . .	576
15.3.1.	Zeroth-Order Solution: Isolated two-Leg Ladders . . . . .	578
15.3.2.	Weak Inter-Ladder Interactions . . . . .	579
15.3.3.	Renormalization-Group Analysis and Inter-Ladder Mean Field Theory . . . . .	580
15.3.4.	The $x \rightarrow 0$ Limit . . . . .	581
15.3.5.	Relation to Superconductivity in the Cuprates . . . . .	582

15.4.	Why There is Mesoscale Structure in Doped Mott Insulators .....	582
15.5.	Weak Coupling Vs. Strong Coupling Perspectives .....	584
15.6.	What is so Special About the Cuprates? .....	585
	15.6.1. Is Charge Order, Or Fluctuating Charge Order, Ubiquitous? .....	585
	15.6.2. Does the “Stuff” Between the Cu–O Planes Matter? .....	586
	15.6.3. What About Phonons? .....	588
	15.6.4. What About Magnetism? .....	588
	15.6.5. Must We Consider Cu–O Chemistry and the Three-Band Model? ....	589
	15.6.6. Is d-Wave Crucial? .....	589
	15.6.7. Is Electron Fractionalization Relevant? .....	590
15.7.	Coda: High Temperature Superconductivity is Delicate But Robust .....	590
	Bibliography .....	592

## 16 Superconducting States on the Border of Itinerant Electron Magnetism

*Emma Pugh, Siddharth Saxena, and Gilbert Lonzarich*

16.1.	Introduction .....	597
16.2.	Uncharted Territory: The New Frontier .....	597
16.3.	Logarithmic Fermi Liquid .....	598
16.4.	The Puzzle of MnSi .....	599
16.5.	Superconductivity on the Border of Magnetism .....	600
16.6.	Three Dimensional vs. Quasi-Two-Dimensional Structures .....	600
16.7.	Density Mediated Superconductivity .....	601
16.8.	The Search for Superconductivity on the Border of Itinerant Ferromagnetism	602
16.9.	Why Don't All Nearly Magnetic Materials Show Superconductivity? .....	605
16.10.	From Weak to Strong Coupling .....	607
16.11.	Superconductivity Without Inversion Symmetry .....	608
16.12.	Quantum Tuning .....	608
16.13.	Concluding Remarks .....	611
	Bibliography .....	611

<b>Index</b> .....	615
--------------------	-----