

# APPLICATIONS OF AdS/CFT TO NON-RELATIVISTIC SYSTEMS

*A thesis submitted for the degree of  
DOCTOR OF PHILOSOPHY (Science)*

*in*

Physics (Theoretical)

by

PARIJAT DEY

*Department of Physics*

UNIVERSITY OF CALCUTTA

2014

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Some preliminaries of string theory . . . . .	2
1.2	D-branes . . . . .	4
1.3	Dualities in string theory . . . . .	5
1.4	AdS/CFT duality . . . . .	7
1.5	Non-relativistic gauge/gravity duality . . . . .	10
1.6	Outline of the thesis . . . . .	14
<b>2</b>	<b>Hyperscaling violating Lifshitz space-times from intersecting branes in string/M theory</b>	<b>16</b>
2.1	F-D $p$ and the Lifshitz-like space-time . . . . .	18
2.1.1	Construction of F-D $p$ solutions . . . . .	18
2.1.2	RG flow & phase structure of F-D $p$ : case by case study . . . . .	24
2.1.3	A delocalized F-D1 and Lifshitz space-time . . . . .	32
2.2	Intersecting D-branes and Lifshitz-like space-time . . . . .	34
2.2.1	Construction of intersecting D-branes . . . . .	34
2.2.2	RG flow and phase structures . . . . .	36
2.2.3	D $p$ -D( $p+2$ ), D2-D2', D3-D3', D4-D4' and Lifshitz-like metrics . . . . .	38
2.3	NS5-D $p$ states and Lifshitz-like metric . . . . .	47
2.3.1	Construction of NS5-D $p$ states . . . . .	47
2.3.2	RG flows and phase structures of NS5-D $p$ solutions . . . . .	49
<b>3</b>	<b>Holographic entanglement entropy of the near horizon 1/4 BPS F-D<math>p</math> bound states</b>	<b>54</b>
3.1	Holographic Entanglement Entropy of F-D $p$ bound states . . . . .	56
3.2	Holographic Entanglement Entropy at finite temperature . . . . .	62

<b>4 Schrödinger/Lifshitz dual space-times without or with hyperscaling violation</b>	<b>67</b>
4.1 From AdS to Schrödinger/Lifshitz dual space-times . . . . .	69
4.2 Schrödinger/Lifshitz from single brane solutions . . . . .	73
4.2.1 M2-brane . . . . .	73
4.2.2 M5-brane . . . . .	76
4.2.3 D(p+1)-branes . . . . .	78
4.3 Schrödinger/Lifshitz from intersecting solutions . . . . .	84
4.3.1 M2 $\perp$ M5 solution . . . . .	84
4.3.2 More Lifshitz-like space-times . . . . .	87
4.3.3 M5 $\perp$ M5 $\perp$ M5 solution . . . . .	89
4.3.4 D1 $\perp$ D5 solution . . . . .	92
4.3.5 D2 $\perp$ D4 solution . . . . .	93
4.3.6 F $\perp$ NS5 solution: an exception . . . . .	94
<b>5 Strange metals with hyperscaling violation from holography</b>	<b>96</b>
5.1 The holographic model . . . . .	98
5.2 Probe thermodynamics . . . . .	99
5.3 Holographic Zero sound . . . . .	102
5.4 AC conductivity . . . . .	110
<b>6 Conclusion</b>	<b>112</b>
<b>Bibliography</b>	<b>116</b>