



Universiteit
Leiden
The Netherlands

Transport coefficients and low energy excitations of a strongly interacting holographic fluid

Poovuttikul, N.

Citation

Poovuttikul, N. (2017, November 16). *Transport coefficients and low energy excitations of a strongly interacting holographic fluid*. *Casimir PhD Series*. Retrieved from <https://hdl.handle.net/1887/57561>

Version: Not Applicable (or Unknown)

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/57561>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/57561> holds various files of this Leiden University dissertation

Author: Poovuttikul, N.

Title: Transport coefficients and low energy excitations of a strongly interacting holographic fluid

Date: 2017-11-16

Transport coefficients and low energy excitations of a strongly interacting holographic fluid

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus Prof. Mr. C. J. J. M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op dinsdag 16 November 2017
te klokke 10:00 uur

DOOR

Napat Poovuttikul

geboren te Bangkok (Thailand) in 1990

Promotiecommissie

Promotor: Prof. dr. J. Zaanen
Overige leden: dr. K. Landsteiner (IFT-UAM/CSIS, Spain)
dr. A. Parnachev (Trinity College Dublin, Ireland)
Prof. dr. S. Vandoren (IFT, Utrecht University)
Prof. dr. E. R. Eliel
Prof. dr. K. E. Schalm
Prof. dr. V. Vitelli

Casimir PhD series 2017-35

ISBN 978-90-8593-319-9

The work describe in this thesis has been carried out at the Lorentz Institute, Leiden University. The author was supported by Development and Promotion of Science and Technology (DPST) Scholarship from the Thai government.

The cover shows the private and public transport phenomena of electricity, heat, humans and other pollutants. Incidentally, this photo was taken at Wong-sawang junction (close to the author's house in Bangkok), infamous for its traffic congestion, a few seconds before a waterfall-like fluid (a.k.a. a tropical rain) starts to pour down and almost destroys the author's camera.

Contents

1	Introduction	1
1.1	Preface : What is QFT?	1
1.2	Gauge/gravity duality and effective theory	4
1.3	This thesis : A hunt for universality beyond standard hydrodynamics	9
2	Lightning review of hydrodynamics and gauge/gravity duality	12
2.1	Global symmetry, conserved current and background fields	13
2.1.1	Charge neutral relativistic fluid	15
2.1.2	Breaking translational symmetry	20
2.1.3	Introducing anomalous $U(1)$ current	22
2.1.4	Generalised global symmetry	24
2.2	2-point correlation functions and Kubo formulae	28
2.3	Bottom-up approach to holographic duality	30
2.3.1	Capturing global symmetry	31
2.3.2	Holographic thermal 1-point and 2-point function	35
2.3.3	Holographic RG flow	36
2.3.4	The “membrane paradigm”	38
2.3.5	Higher derivative holography	40
3	Shear viscosity in holography and effective theory of transport without translational symmetry	42

3.1	Motivation	42
3.2	Effective theory for systems with broken translational symmetry	46
3.2.1	Constructing the constitutive relation	47
3.2.2	Kubo's formula for η^*	52
3.3	Holographic computation	54
3.3.1	Action and Thermodynamics	55
3.3.2	Coherent regime and constitutive relation from fluid/- gravity correspondence	57
3.3.3	Fluctuations and violation of the viscosity bound at lead- ing order	59
3.3.4	Numerical results and beyond the leading order	62
3.4	Discussions and outlook	64
3.5	Appendices	67
3.5.1	Scalars, vectors and tensors from basic structures	67
4	Universality of anomalous conductivities in theories with higher- derivative holographic duals	69
4.1	More background materials and motivations	69
4.2	The holographic setup	78
4.3	Proof of universality	83
4.3.1	Anomalous conductivities and the membrane paradigm	84
4.3.2	Universality	88
4.4	Examples and counter-examples	93
4.4.1	Einstein-Maxwell-dilaton theory at finite temperature	94
4.4.2	Four-derivative Einstein-Maxwell theory	95
4.4.3	Theories without horizons and theories with scaling ge- ometries at zero temperature	97
4.4.4	Bulk theories with massive vector fields	100
4.5	Discussion	101
4.6	Appendices	103
4.6.1	Anomaly polynomials and the replacement rule	103

5	Magnetohydrodynamic waves in a strongly interacting holographic plasma	104
5.1	Introduction	104
5.2	Matter coupled to electromagnetic interactions	110
5.2.1	Quantum electrodynamics	110
5.2.2	Strongly interacting holographic matter coupled to dynamical electromagnetism	112
5.3	Holographic analysis: equation of state and transport coefficients	118
5.3.1	Holographic action and the magnetic brane	119
5.3.2	Holographic renormalisation and the bulk/boundary dictionary	121
5.3.3	Equation of state	127
5.3.4	Transport coefficients	131
5.4	Magnetohydrodynamic waves in a strongly coupled plasma . .	137
5.4.1	Speeds and attenuations of MHD waves	143
5.4.2	MHD modes on a complex frequency plane	146
5.4.3	Electric charge dependence	148
5.5	Discussion	152
5.6	Appendices	155
5.6.1	Kubo formulae for first-order transport coefficients . . .	155
5.7	Further details regarding the derivation of the transport coefficients	157
5.8	Dispersion relations of magnetosonic waves	163
6	Conclusion and outlook	167
	Samenvatting	173
	Bibliography	175
	Curriculum Vitæ	200
	List of Publications	202

Acknowledgement

203