



Universiteit  
Leiden  
The Netherlands

## **Disorder and interactions in high-temperature superconductors**

Sulangi, M.A.

### **Citation**

Sulangi, M. A. (2018, July 5). *Disorder and interactions in high-temperature superconductors*. *Casimir PhD Series*. Retrieved from <https://hdl.handle.net/1887/63332>

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/1887/63332>

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

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/63332> holds various files of this Leiden University dissertation.

**Author:** Sulangi, M.A.

**Title:** Disorder and interactions in high-temperature superconductors

**Issue Date:** 2018-07-05

---

## ACKNOWLEDGEMENTS

---

Here I would like to thank everyone I've encountered who in one way or another has enabled me to enjoy life in the past several years as a theoretical physicist.

First, I thank Jan Zaanen for being a wonderful supervisor, and for being singularly responsible for my worldview as a theoretical physicist. In the years I've spent working with him I learned much about condensed matter physics from him, and his endless reserves of knowledge about the vast universe of theories and experiments on the cuprates (among other materials) helped convince me that the down-and-dirty world of high- $T_c$  superconductivity and strongly correlated electrons was where the most interesting questions in physics were. From Jan I also learned to be intellectually fearless and independent—he impressed upon me the need to find my own direction as a scientist and not to simply follow the herd, advice that I've adopted as a life mantra of sorts.

Milan Allan has been a wonderful collaborator and sounding board for many of my ideas, and has been remarkably patient with me in going over some real-life subtleties of experiments that would likely have flown over the heads of theorists like me. I can't thank him enough for giving me a dose of "reality"—nothing really matches the thrill of doing theory that one can actually see in experiments close by!

A considerable part of what I know about condensed matter physics and quantum field theory was a direct result of my interactions, whether in-class or informal, with a terrific set of physicists I've been very lucky

## ACKNOWLEDGEMENTS

to have known in my first few years as a graduate student—Peter Armitage, Hans Hilgenkamp, Predrag Nikolic, Tjerk Oosterkamp, Koenraad Schalm, and Oleg Tchernyshyov—and for that I am truly grateful. Discussions with Lewis Bawden, Seamus Davis, Mark Golden, Marc-Henri Julien, and Steven Kivelson proved invaluable in shaping the content of the papers forming this thesis.

I wouldn't have made it this far if it weren't for two physicists in particular who have been profoundly formative in my early training as a physicist and who have, unfortunately, passed on. Germelino Abito introduced me to condensed matter theory early in my undergrad years in Ateneo, and my experience working with him would later prove to be truly invaluable as I moved up to graduate school—I can't thank him enough for affording me a considerable amount of intellectual freedom in my research, which no doubt readied me for the rigors of life yet to come. Zlatko Tesanovic taught me graduate quantum mechanics and took me in as a Ph.D. student in his group at Johns Hopkins, a stint that ended with his sudden and tragic passing; from my interactions with him as a beginning graduate student I became acquainted with the very high standards of theoretical physics he operated by. It makes for an interesting coincidence that this thesis revolves around topics they specialized in (disorder for Germelino, high- $T_c$  superconductivity for Zlatko), and I hope that they would've at the very least found what I wrote here interesting.

I am grateful to the secretaries at the Instituut-Lorentz for all they've done for me and my colleagues. To Marianne van Dun, Manon van Ette, Trudy Geurds, and Fran Ouwerkerk, thank you for all your help, advice, conversations, and good humor, all of which were instrumental in making my life as a Ph.D. student easier and more productive.

I owe a lot to my friends who've made graduate school an enjoyable experience. To all the members of Jan and Koenraad's group I over-

lapped with—Andrey Bagrov, Floris Balm, Bartosz Benenowski, Josko de Boer, Richard Davison, Philippe Sabella-Garnier, Mikhail Goykhman, Saso Grozdanov, Olfa Jaibi, Nikolaos Kaplis, Alexander Krikun, Ke Liu, Balazs Meszena, Jaakko Nissinen, Nick Poovuttikul, Louk Rademaker, Aurelio Romero Bermudez, Petter Saterskog, Vincenzo Scopelitti, and Robert-Jan Slager—thank you for all the wide-ranging discussions and the countless dinners and drinks we’ve had together that have helped make academic life less dreary. I owe a lot in particular to Robert-Jan for being a fantastically helpful academic sibling, to Louk for guiding me upon arriving in Leiden, to Jaakko for sharing his insights and perspectives on matters both physics- and non-physics-related, to Floris and Josko for help in translating part of this thesis into Dutch, and, last but not least, to Nick for the interminable conversations about life and physics (inevitable if you’ve been housemates with this guy for four years). Back at Hopkins, my fellow grad students in condensed matter theory—Damien Benveniste, Wes Fuhrman, Anirban Ghosh, Jian Kang, Imam Makhfudz, James Murray, and Yuan Wan—were generous with their time and helped me find my direction as a beginning graduate student. My experimentalist buddies at Hopkins—Nick Laurita, JT Mlack, and Mike Valentine—were fantastic comrades, and I thank them for all the fun and not-so-fun times spent inside and outside Bloomberg, for the infrequent but memorable reunions, and for the impromptu lessons in experimental methods. Finally I should mention my many friends outside physics whose presence—whether constant or intermittent—has enriched my life in one way or another. Jed Alegado, Toni Ang, Anj Aquino, Herdeline Ardona, Virgil Banta, Euben Concepcion, Uzein Corcuera, Icai Enriquez, Jay-El Esguerra, Paul Francisco, Srikar Ganti, JP Garcia, Mark Hernandez, Guy Hotson, Ehsan Jahangiri, Jeanette Kindipan-Dulawan, Lean Lava, Lex Maglunob, Mitch Sayoc, Joanna San Pedro, Cheska Siongco,

## ACKNOWLEDGEMENTS

Jerome Unidad, Paul Villa, and Paulo Zaragoza, thank you guys for the travels, reunions, basketball games, brunches, dinners, cookouts, etc.—you know where you fit in this scheme!—that have made graduate school life as fun as it could be.

Finally, my stint in graduate school would not have been possible had it not been for the persistent love, support, and encouragement from my family. My parents have been tremendously supportive of my career choices and have been constantly patient and understanding. I am very happy to know that they'll always support me, even if they live halfway across the world from me (literally). My sister Thea and I are pretty much on the same wavelength nearly all the time, despite working in vastly different fields, and I am grateful for her advice and support.

---

## LIST OF PUBLICATIONS

---

- M. A. Sulangi and Q. M. Sugon Jr., "The effect of the geometric potential and an external magnetic field on a charged particle on a helicoid," arXiv:1211.5699 (2012).
- M. A. Sulangi, M. P. Allan, and J. Zaanen, "Revisiting quasiparticle scattering interference in high-temperature superconductors: The problem of narrow peaks," *Phys. Rev. B* **96**, 134507 (2017). **(Chapter 3.)**
- M. A. Sulangi and J. Zaanen, "Quasiparticle density of states, localization, and distributed disorder in the cuprate superconductors," *Phys. Rev. B* **97**, 144512 (2018). **(Chapter 4.)**
- M. A. Sulangi and J. Zaanen, "Self-energies and quasiparticle scattering interference," to be submitted. **(Chapter 5.)**
- M. A. Sulangi and J. Zaanen, "Superconducting phase fluctuations and gap-filling phenomenology in the underdoped cuprates," in preparation.





---

## CURRICULUM VITAE

---

I was born on September 5, 1989 in Manila, Philippines. I spent my childhood in Bataan and Aklan before moving back to Manila to study at Ateneo de Manila University, from which I graduated with a B.S. in Physics, *cum laude*, in 2011. As an undergraduate I did thesis research on the quantum mechanics of charged particles on curved surfaces under the supervision of Germelino Abito and Quirino Sugon, for which I received the Bank of the Philippine Islands-Department of Science and Technology Science Award in 2011. In addition to physics and mathematics coursework, I spent time as a member of the editorial staff of *Heights*, Ateneo's literary journal, and I was lucky to be a part of the Silliman National Writers Workshop in 2011 as a fellow for non-fiction.

After finishing my undergraduate studies, I moved to Baltimore, Maryland to begin graduate school at Johns Hopkins University. I joined Zlatko Tesanovic's research group, having decided to focus on condensed matter theory as a Ph.D. student, but that stint was unfortunately cut short by Zlatko's sudden and tragic passing in 2012. After receiving my M.A. in Physics and Astronomy from Johns Hopkins, I decided to move to Leiden, Netherlands in 2013 to start anew my Ph.D. work, this time in Jan Zaanen's group at Leiden University. I spent the vast majority of my time at Leiden working on high- $T_c$  superconductivity, with much of that research work covered in this very thesis.

Throughout my time in graduate school I have attended several conferences, workshops, and summer schools in various countries—the

## CURRICULUM VITAE

Netherlands, Poland, Spain, France, and the United States—and have presented my work a number of times. I have also served as a teaching assistant at Johns Hopkins, where I led discussion sessions for general physics and taught laboratory classes, and at Leiden, where I was a grader for the graduate-level condensed matter theory class.