Learning from Insulators: New Trends in the Study of Conduction Properties of Metals

Final Report for Lorentz Centre

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1 Description and aims

The idea behind the workshop was to reinvigorate interest in the mathematics of transport properties of conductors. While this is an old topic, in recent decades the focus of most mathematical physics sub-communities lied with insulators and topological insulators. Many of the methods initially developed for (topological) insulators can be applied to conductors: new rigorous semiclassical methods yield semiclassical equations of motion with subleading corrections that hitherto have not yet been studied. Advances in dynamical systems and symplectic geometry could help understanding the role of such corrections. Furthermore, functional analytic and operator-algebraic approaches seem necessary if one wants to includes effects of disorder and electron-electron interactions.

Consequently, the main aim of the workshop was to bring in the same room people with diverse scientific backgrounds and who have not met before, and to have the workshop act as an incubator for new collaborations. Specifically, organizers and participants included experts from symplectic geometry, dynamical systems, semiclassics, functional analysis, spectral theory, random operators, and non-commutative geometry.

The idea of being in the same room was a key part of the workshop concept and, thus, the outbreak of the COVID-19 pandemic proved particularly challenging. This required us to completely revisit the whole concept twice, first to fit into an hybrid scheme and finally in an online-only one. In the final plan, mini courses were taken out of the live program and uploaded in advance for the participants's benefit, and the number and lengths of contributed talks were cut in half. This freed a lot of time that we have then allotted for discussions. Further, to allow people from Asia to the Americas to attend, the program was split into a Core program suitable for live participation from all time zones and an Encore program, that allowed participants to at least participate in the morning or evening program according to their time zones. Topical days were kept as much as possible; exceptions were necessary to accommodate scheduling constraints.

Overall, there were 43 participants and 4 organizers with very diverse backgrounds:

- 5 participants were female (about 13 %), 38 male.
- 5 talks were given by female speakers (about 29 %), 12 talks by male speakers
- 25 % were in the early part of their careers, 39 % in the middle and the remaining 35 % were senior researchers.
- Participants hailed from Asia (China, Japan), Russia, Europe, and the Americas (USA, Chile, Canada).

2 Experience with online-only workshop during Covid-19 pandemic

Travel restrictions made it impossible to have a large enough in-person component and the workshop was ultimately held online-only. In collaboration with the Lorentz Center, the program was redesigned to accommodate 12 hours's worth of time zones. The organizers would like to thank the Lorentz Center for their

input and support, which was crucial to react to changing circumstances on the fly, and their insistence on having sufficient opportunity for discussions.

In hindsight, the redesigned program worked remarkably well when compared with other online-only programs and received extremely positive feedback from many of the participants. In the end, the four mini courses were made available offline in advance to the participants and the workshop had only 2 Core talks and 2 Encore talks per day. The talks were also shortened significantly, because in the experience of the organizers the listeners's attention spans tend to be smaller for online events. This allowed us to dedicate a large amount of time to questions, discussions and breaks. In the end, most talks were recorded and have been published on Youtube (with the speakers's and participants's permissions).

The discussion sessions, informal and not recorded to allow people to talk freely, proved surprisingly popular and saw a much larger participation than what our previous experiences would have suggested. Notes were taken by the organizers to structure the thoughts and a 5–10-minute recap was given at the beginning of every Core session to keep participants from all time zones updated.

For the mini courses one lecturer submitted written lecture notes and the other three opted for "classroom-style" video lectures with handwritten boards rather than slides. The recorded mini courses were of varying lengths, ranging from 90 minutes to 12 hours; they have since been accessed surprisingly often as can be gleaned from e. g. their view counts on Youtube. In all cases this provided high quality pedagogical material to ease into the workshop topics and also received praise from many participants.

We expect that some of the lessons learned will also be incorporated in "traditional" conferences that will be held in the future. To mention but two, allowing people to participate remotely in workshops and conferences will be the default going forward. And organizers should allocate sufficient time to discussions at the expense of talks.

The streamlined program, shortened talks and generous breaks were very positively received by the participants. For example, it allowed participants outside of Europe to meet their parenting obligations. The main complaint we received has been, not surprisingly, that participants would have greatly preferred an in-person event. A few participants also had difficulties with Microsoft Teams, despite good support from the Lorentz Center.

3 Scientific outcomes

Overall, the workshop proved very successful from a scientific vantage point. It definitely succeeded in getting people to meet (virtually) and get them to see connections between their fields and others they were previously not aware of. The balance of speakers in terms of topics was spot-on, and the talks — as evidenced by the lively discussions — well-received.

There were also a few concrete outcomes:

- The bulk of the talks is available on Youtube.
- The notes for the discussions, which will be polished and extended in the upcoming weeks, are publicly available.
- A special issue of the Journal of Mathematical Physics will document the state-of-the-art. It is open to submissions from all participants, and we have specifically asked all speakers to contribute.
- On the last day there were informal inquiries about a follow-up workshop, preferably held in-person to further this line of investigation.
- There were a few concrete discussions about specific scientific works and new collaborations.

All in all, the material gathered during the workshop will provide a good resource for (young) researchers to get an overview of the subject and the current state-of-the-art, in order to be able to start working on it.