Freely and openly

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In the autumn of 1990, I took a month off between the end of my postdoc at the Institute of Space and Astronautical Science in Sagamihara, Japan, and the start of my next job at NASA's Goddard Space Flight Center in Greenbelt, Maryland. During that sojourn I visited the Institute of Astronomy at Cambridge University, where I had done my PhD.

Among the new people I met there was Ian Stevens, who coincidentally had just finished a postdoc at Goddard. I no longer remember the circumstances of our encounter. Most likely it was during the 11:00am coffee break, when almost all of the institute's members gather in the library to converse over freshly brewed coffee. However, I can't forget the outcome. Stevens and I decided to work together. Our paper, "An x-ray excited wind in Centaurus X-3," appeared just over two years later.[1]

Collaboration pervades scientific research. Of the 150 or so news stories I've written for PHYSICS TODAY's Search and Discovery department, just one was about a paper by a single author, Rodney Baxter ("Order parameter of the chiral Potts model succumbs at last to exact solution," November 2005, page 19). Sometimes the work I reported on resulted from a collaboration among the members of a single group. Other times it resulted from a collaboration between groups.

One of my favorite examples of intergroup collaboration is the first observation of the quantum spin Hall effect (QSHE) in a heterostructure made of a layer of mercury telluride of just the right thickness sandwiched between layers of mercury cadmium telluride (see PHYSICS TODAY, January 2008, page 19).

The intricate setting has an interesting back story. Condensed-matter theorists began investigating the QSHE in the early 2000s. It arises when an insulator's band structure includes two spin-polarized edge states. Because of the states' topology, the corresponding edge currents flow without dissipation. The QSHE is not only interesting; it also has potential applications. The effect proved difficult to measure. It was too puny in the first prospective material, graphene. A proposal to realize it in a mechanically strained semiconductor was experimentally infeasible.

A hint of a way forward arrived when one of the theorists who elucidated the QSHE, Shoucheng Zhang of Stanford University, met one of the experimenters who eventually observed it, Laurens Molenkamp of the University of Würzburg, at a conference in South Korea. Molenkamp told Zhang about the narrow-bandgap semiconductor, HgTe. Spin-orbit coupling is so strong in HgTe that it splits the valence band and raises the higher of the split bands above what would otherwise be the conduction band. Could band inversion be a way to create the QSHE? the experimenter asked the theorist. When they met again a year later in Singapore, they agreed to collaborate.

A crucial step was taken from a general search for the QSHE in HgTe to a specific one in a heterostructure of HgCdTe/HgTe/HgCdTe when Molenkamp gave Zhang an electronic copy of the doctoral thesis of Alexander Pfeuffer-Jeschke. In 2000 Pfeuffer-Jeschke had calculated the threshold thickness below which the bandgap of the HgTe layer becomes zero and then becomes positive under the increasingly strong influence of the HgCdTe layers. He wrote his thesis in German, a language that Zhang had acquired as an undergraduate at the Free University of Berlin. Zhang read the thesis on the flight back from Singapore.

The story of the discovery of the QSHE is not only one of collaboration. It's also one of the free movement of people and ideas between countries. Molenkamp works in Germany and is from the Netherlands. The experiment that he and his collaborators carried out was sketched out in a *Science* paper[2] written by Zhang and two of his then students, B. Andrei Bernevig, who is from Romania, and Taylor Hughes, who is from the US. Zhang grew up in Shanghai.

I asked Molenkamp to fact-check the first draft of this editorial. His emailed reply closed with the observation that physics has been an international undertaking for a century. "There is just a rather limited number of professionals in the field," he wrote. "And you really only get things done when you exchange ideas. Freely and openly. And respecting scientific discourse."

References

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2. B. A. Bernevig, T. L. Hughes, S.-C. Zhang, *Science* **314**, 1757 (2006).

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