Acceptance speech

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Allan MacDonald, awardee in the Basic Sciences category (18th edition)

Distinguished members of the BBVA Foundation, members of the committee, colleagues, friends, ladies and gentlemen: I am deeply honored to accept this Frontiers of Knowledge Award, which recognizes both the theory side of quantum materials – where I come in – and the experimental side represented by Pablo Jarillo-Herrero. Theoretical ideas are refined by experiments, which sometimes prove that the theorist was, against all odds, not completely wrong. We theorists would make no progress without our experimental colleagues. In this case, Pablo and his students turned an idea on paper – the moiré materials concept – into a new category of materials that is now regularly realized in laboratories around the world. The two of us represent a larger community of talented experimental and theoretical scientists who have over the past decade developed moiré materials into an exciting thread in quantum materials physics.

The story begins with graphene, a single sheet of carbon atoms arranged in a simple, elegant honeycomb pattern. Graphene was already famous for its remarkable properties. Then came a simple question: what happens if you place two sheets of graphene, or other similar materials, on top of one another and twist, just a little? A new, larger pattern appears – a moiré pattern. Moiré patterns can arise from fabrics, screens, or overlapping grids, and in ordinary life can be a visual annoyance. In physics, they can also be a gift, by creating a new landscape for electrons. Like people, electrons behave differently depending on the landscape they find themselves in.

At certain twist angles – now known as "magic angles" – electrons slow down and interact much more strongly with one another. Physicists do not use the word "magic" very often, except perhaps when an experiment agrees with a calculation. But the name has stuck, and it is not entirely undeserved. Simply by controlling twists, we can make bilayers behave in profoundly different ways: insulating, conducting, superconducting, magnetic, and something in ways we didn't previously have a name for. We do this not by changing carbon into some rare element. We just change the spatial arrangement of the same

atoms – the geometry – and this is enough to allow electrons to find a new script. Sometimes the difference between ordinary and extraordinary is not what something is made of, but how it is put together. Nature is richer in organization than in ingredients.

The larger significance of moiré materials is that they give materials science a new form of control. For centuries, materials discovery has often meant searching the natural world, synthesizing compounds, and hoping to find useful properties. That work remains essential. But moiré materials provide a wicked new trick: we can design quantum behavior by stacking, twisting, and tuning layers that are only atoms thick. This strategy may help us understand some of the deepest problems in quantum materials physics, and perhaps lead to better electronics, more efficient energy technologies, or new platforms for quantum information.

But we should be honest: fundamental research does not travel in a straight line from discovery to application. It is more like hiking in the mountains. You climb one ridge because you are curious what can be seen from the top. Only later do you realize that the view has revealed a valley, a river, and possibly a road no one knew existed. That is why awards like this one are important. They affirm the value of basic questions, even when the practical destination is not yet visible. Humanity benefits from knowledge not only when it produces immediate tools, but also when it enlarges our imagination of what is possible.

Science is sometimes described through individual names, but the work is always collective. Ideas are always sharpened in conversation, corrected by criticism, and energized by students. I am personally indebted to my collaborators, students, and postdocs – especially Rafi Bistritzer and Fengcheng Wu, who developed key moiré materials ideas with me. I share this award with them. I am grateful to my family, who have long tolerated my tendency to distraction when I get lost thinking about those invisible, stubborn electrons that are always whirling around in my mind. I am also grateful to the University of Texas at Austin, and to the Richardson and Simons Foundations, and others who have supported my work.

To young scientists, I would say: do not be afraid of simple questions. “What happens if we twist it?” is not, on the face of it, a grand philosophical inquiry. But simple questions, pursued seriously, can open unexpected doors. Questions that do not have obvious answers are always good questions.

Thank you again to the BBVA Foundation for this extraordinary honor. I accept it with humility, gratitude, and excitement for what comes next – because the frontier of knowledge is like the end of the rainbow: every time we think we have reached it, we discover it lies further ahead.