The researchers used nematode biomass and the accumulation rate of ostracodes as proxies for ecosystem functions (e.g., productivity in an ecosystem). They compared the taxonomic and functional diversity of nematodes and ostracodes with these proxies of ecosystem functioning to investigate BEF relationships over decadal to millennial time scales and found generally positive, long-term relationships between biodiversity and ecosystem functioning, consistent with studies of BEF relationships based on present-day spatial analyses and short-term manipulative experiments. However, the deep-sea BEF relationships over longer time scales are much noisier than those inferred by modern observational studies. These relatively noisy BEF relationships suggest that environmental changes over decadal to millennial time scales may affect biodiversity and biomass independently, and these effects may be much stronger than the impacts of biodiversity on ecosystem functioning. This study suggests that abiotic factors are more important than biotic factors in shaping the patterns of biodiversity and ecosystem functions at macroevolutionary time scales because the changes observed over the decadal to millennial time scales investigated in this study are much shorter than the approximate lifespan of a species (1–2 million years). This work also implies that climate change may affect both diversity and ecosystem functioning over long time scales in the deep sea.

Reference

Moriaki Yasuhara, Hideyuki Doi, Chih-Lin Wei, Roberto Danovaro, and Sarah E. Myhre (2016). Biodiversity–ecosystem functioning relationships in long-term time series and palaeoecological records: deep sea as a test bed. *Philosophical Transactions of the Royal Society B: Biological Sciences, 371*(1694), 20150282. DOI:10.1098/rstb.2015.0282

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Quantum topological Hall effect in noncoplanar antiferromagnetic oxides

The integer quantum Hall (IQH) effect, first discovered in 1980 by von Klitzing [1] (a 1985 Nobel Laureate), is one of the most fascinating discoveries in physics. When a strong perpendicular magnetic field is applied to a two-dimensional (2D) electron gas (EG) at low temperatures, the Hall conductance is precisely quantized due to Landau-level quantization, and its values are an integer (NC) multiple of the fundamental conductance quantum (e^2/h). In 1982, Thouless (a 2016 Nobel Laureate) demonstrated that this quantization is directly connected to the topological property of the 2D bulk insulating states, characterized by a topological invariant called the Chern number (NC) [2]. Intriguingly, the conductance quantum number (NC) is exactly equal to the number (NC) of dissipationless chiral edge states in the 2DEG plane [Figure 1(a)]. The topological interpretation of the IQH effect implies that the effect can also occur in other time-reversal symmetry broken systems with a topologically non-trivial band structure in the absence of the external magnetic field, such as ferromagnetic topological insulators, leading to the so-called quantum anomalous Hall (QAH) effect [Figure 1(b)], as first proposed for a honeycomb lattice model in 1988 by Haldane [3] (2016 Nobel Laureate).

Due to its intriguing nontrivial topological properties and the potential application of its dissipationless edge states for designing low-power consumption electronics and spintronics, extensive studies have been performed to search for real materials to host the QAH effect. Indeed, this extensive effort culminated in the experimental observation of the QAH effect in Cr-doped $(Bi,Sb)_2Te_3$ ferromagnetic topological insulator films in 2013 by Xue and coworkers [4]. Nevertheless, the QAH phase appeared at extremely low temperatures (less than 30 mK) due to the small band gap, weak magnetic coupling and low carrier mobility. These factors hinder further exploration of the exotic properties of the QAH phase and its applications.

The problems with weak magnetic coupling and small band gap could be overcome by adopting 4*d* and 5*d* transition metal atoms, which simultaneously have more extended *d*-orbitals and stronger relativistic spin-orbit coupling (SOC). Therefore, through *ab initio* density functional calculations, we have recently conducted a systematic search for high-temperature QAH phases in 4*d* and 5*d* transition metal oxides. Indeed, we discovered that layered rhodium oxide $K_{1/2}RhO_2$ in the noncoplanar antiferromagnetic state is a QAH insulator with a large band gap of ~0.2 eV and a Néel temperature of a few tens of Kelvins [5] [Figure 2]. Furthermore, this QAH phase is found to be unconventional because it occurs in the antiferromagnetic state without the need for net magnetization and SOC. The quantum topological Hall effect caused by the nontrivial topology of the noncoplanar antiferromagnetic structure in the system is rather exotic [Figure 2(a)]. These findings thus show that 4*d* and 5*d* metal oxides are promising materials for exploring exotic quantum phases and for realizing advanced technological applications such as low-power consumption nanoelectronics and oxide spintronics.

References

1. K. V. Klitzing, G. Dorda, and M. Pepper (1980). New method for high-accuracy determination of the fine-structure constant based on quantized Hall resistance. *Physical Review Letters, 45*(6), 494-497. DOI:10.1103/PhysRevLett.45.494.
2. D. J. Thouless, M. Kohmoto, M. P. Nightingale, and M. den Nijs (1982). Quantized Hall conductance in a two-dimensional periodic potential. *Physical Review Letters, 49*(6), 405-408. DOI:10.1103/PhysRevLett.49.405.
3. F. D. M. Haldane (1988). Model for a quantum Hall effect without Landau levels: Condensed-matter realization of the 'parity anomaly'. *Physical Review Letters, 61*(18), 2015-2018. DOI:10.1103/PhysRevLett.61.2015.
4. Cui-Zu Chang, Jinsong Zhang, Xiao Feng, Jie Shen, Zuocheng Zhang, Minghua Guo, Kang Li, Yunbo Ou, Pang Wei, Li-Li Wang, Zhong-Qing Ji, Yang Feng, Shuaihua Ji, Xi Chen, Jinfeng Jia, Xi Dai, Zhong Fang, Shou-Cheng Zhang, Ke He, Yayu Wang, Li Lu, Xu-Cun Ma, Qi-Kun Xue (2013). Experimental observation of the quantum anomalous Hall effect in a magnetic topological insulator. *Science, 340*(6129), 167-170. DOI:10.1126/science.1234414.
5. Jian Zhou, Qi-Feng Liang, Hongming Weng, Y. B. Chen, Shu-Hua Yao, Yan-Feng Chen, Jinming Dong, and Guang-Yu Guo (2016). Predicted quantum topological Hall effect and noncoplanar antiferromagnetism in $K_{0.5}RhO_2$. *Physical Review Letters, 116*(25), 256601. DOI:10.1103/PhysRevLett.116.256601

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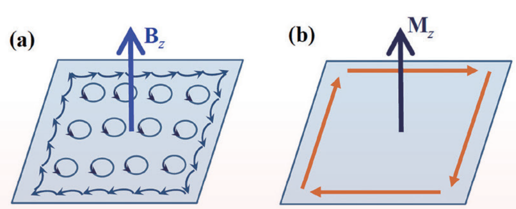

Figure 1. Schematic diagrams of chiral conductive edge states in (a) the integer quantum Hall effect and (b) the quantum anomalous Hall effect. Note that the bulk regions are nonconductive due to either (a) Landau level quantization by the strong magnetic field (Bz) or (b) ferromagnetism (Mz) plus the relativistic spin-orbit coupling gap.

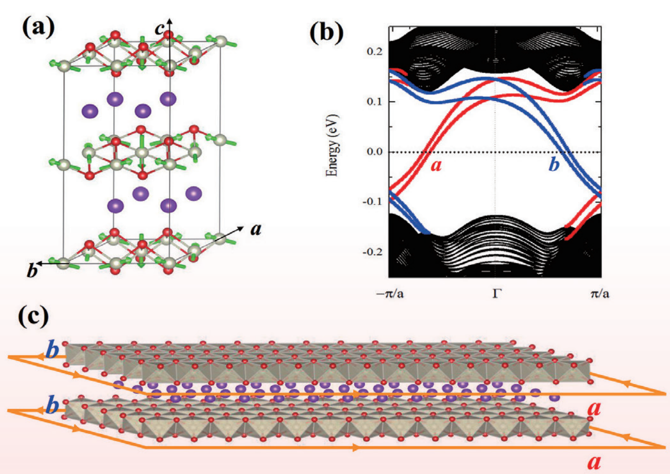

Figure 2. Layered $K_{1/2}RhO_2$. (a) Crystalline and antiferromagnetic structure. (b) Edge band diagram. The gapless chiral edge states are denoted by red and blue lines, and black lines represent the insulating bulk band structure. (c) Illustration of the chiral edge states (orange lines) labelled *a* and *b* in (b).