Inelastic neutron scattering of in van der Waals honeycomb magnets

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A diverse range of exotic properties have recently been observed on two-dimensional honeycomb magnets such as massless and massive Dirac magnons, Kitaev quantum spin liquids and majorana excitations, coherent Zhang-Rice many-body excitons, spin supersolid and giant magnetocaloric effect, etc. Underlying and subsequently responsible for such interesting physics are the interplays between structural and magnetic symmetries. The unit cell of honeycomb lattice consists of two sublattices that are connected to each other by inversion symmetric nearest neighbor bonds, which collectively form three-fold rotational symmetric networks. In contrast, each sublattice is connected via the next neighbor bonds which lack the inversion symmetry. In this talk, we will present the recent experimental works on spin and lattice excitations of two honeycomb magnets, ferromagnetic $CrGeTe_3$ and zigzag antiferromagnetic $FePSe_3$, where intricate interplays between the two symmetries determine the spin dynamics on the honeycomb lattice [1,2].

The magnon band structure of $CrGeTe_3$ hosts gapped Dirac magnons suggesting it is a topological magnon insulator similar to CrI_3. On the contrary, its in-plane magnons exhibit anisotropic broadening even at T = 2 K indicating that its two dimensional magnetism is subject to instability due to quantum fluctuations in the form of acoustic phonons. The structural space group of $FePSe_3$ is $R\overline{3}$ which is identical to that of $CrGeTe_3$ preserving the C_3 symmetry of the honeycomb lattice. Nevertheless, its magnetic ordering is the zigzag-type with $\boldsymbol{k}_{\mathrm{AF}} = (1/2, 0, 1/2)$ which is essentially of C_1 symmetry. Its spin excitation spectra across the Neel temperature suggests that its first-order antiferromagnetic ordering is driven by the $C_3 - C_1$ symmetry breaking. We also find that the nearest neighbor bonds possess strong biquadratic exchange.

[1] L. Chen *et al.*, Nature Commun. 13:4037 (2022).
[2] L. Chen *et al.*, npj Quan. Mater. 9:40 (2024).