Valleytronic four- and five-particle bound states in monolayer WSe_2

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As hosts for tightly-bound electron-hole pairs carrying quantized angular momentum, atomically-thin direct-gap semiconductors of transition metal dichalcogenides provide an appealing platform for optically addressing the valley degree of freedom. In ultra-high quality WSe_2 monolayers, the photoluminescence (PL) emission peaks are sharp and can arise from excited exciton states at high energies and multi-particle bound states at low energies. We observe PL of the 1s, 2s, 3s and 4s Rydberg series [1]. Interestingly the 2s exciton exhibits much better valley polarization and coherence than the 1s exciton [2]. We also observe PL emission from correlated quantum states involving four and five particles [3]. Through a set of control experiments including charge doping, thermal activation, and magnetic-field tuning, we determine that the biexciton consists of a bright exciton and a dark exciton, while the exciton-trion is composed of a bright trion and a dark exciton, and that both of them are intervalley entities. Such unique spin-valley configuration gives rise to emissions with large, negative valley polarizations in contrast to that of the well-known two-particle excitons. Our experimental results provide new opportunities for building valleytronic quantum devices harnessing a variety of excitations in the system.

References

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Figures

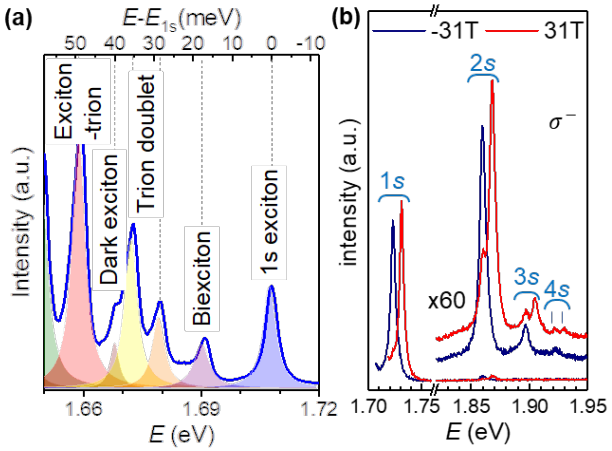

Figure 1: PL emission features from high-quality monolayer WSe_2. (**a**) Low energy (as compared to the 1s exciton) peaks due to two-particle dark exciton, three-particle trion, four-particle biexciton and five-particle exciton-trion. (**b**) High energy features due to radiative recombination of the Rydberg 1s, 2s, 3s and 4s series in a strong magnetic field.