VALLEY ZEEMAN EFFECT AND EXCITON DIAMAGNETIC SHIFTS IN MONOLAYER WS_2 AND MOS_2 TO 65 TESLA

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Monolayer transition-metal dichalcogenides (TMDs) are a recently discovered class of semiconductors that feature direct bandgaps at the extreme points (K/K' valley) of their hexagonal Brillouin zone. Strong spin-orbit coupling, time-reversal symmetry and broken inversion symmetry couple spin and valley degrees of freedom , leading to valley-specific optical selection rules: right/left circularly polarized light couples to exciton transitions in the K/K' valley [1]. This allows an interesting opportunity to explore valley physics with circularly polarized light. As K and K' valleys are related by time reversal symmetry, they have equal but opposite magnetic moments ($\boldsymbol{\mu}_K^{c,v} = -\boldsymbol{\mu}_{K'}^{c,v}$) such that a splitting between valley-specific transitions can be expected in applied magnetic fields. This is called the "valley Zeeman effect".

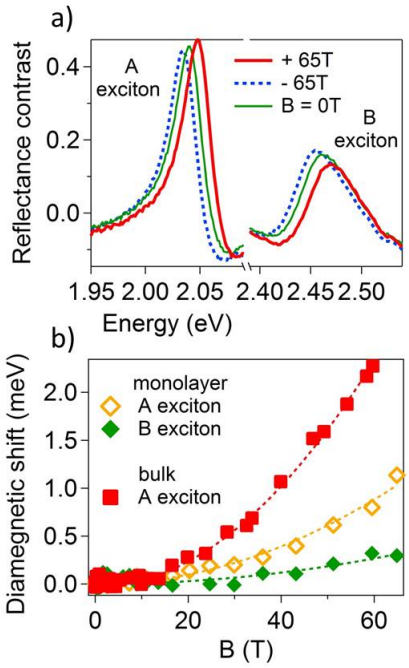

Figure 1: a) Valley Zeeman splitting and b) diamagnetic shift of the monolayer WS_2 A and B exciton as well as bulk A exciton .

Here we measure the valley Zeeman effect in monolayer WS_2 and MoS_2 using optical reflection spectroscopy in high magnetic fields up to 65T (Fig. 1a) [2]. We compare our results to recent low field reports on transition-metal diselenides. Further, we report on the first observation of exciton diamagnetic shift for monolayer WS_2 (Fig. 1b.). The diamagnetic shift is an experimental measure of the exciton wavefunction extent. Knowing the size of the exciton is of interest because the 2D character of these materials results in unconventional screening effects, which causes strong Coulomb interactions (large exciton binding energy) between the oppositely charged particles that comprise the exciton. We model our results in the framework of 2D Coulomb interactions and discuss our findings in light of the diamagnetic shift obtained on bulk crystals.

[1] see, *e.g.,* X. Xu, W.Yao, D. Xiao, T.F. Heinz, Nature Physics **10**, 343 (2014)
[2] A.V. Stier *et al.*, submitted. (2015)

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