New correlated quasiparticles in an atomically-thin semiconductor

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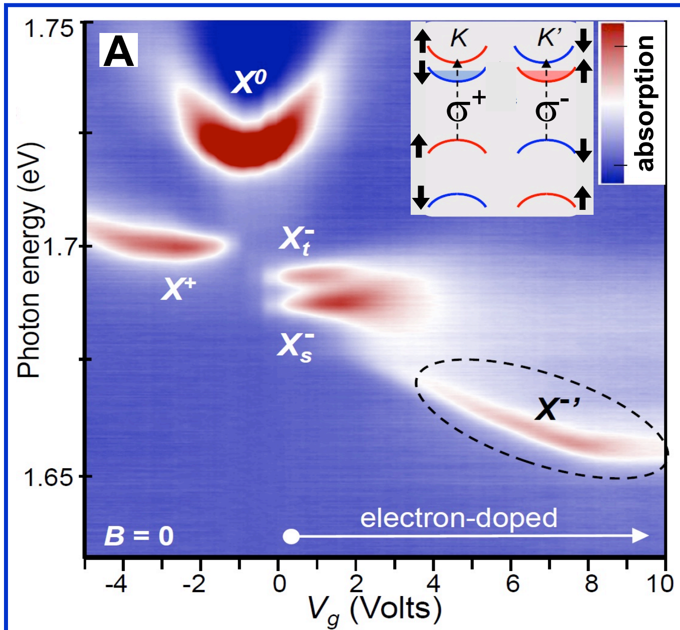
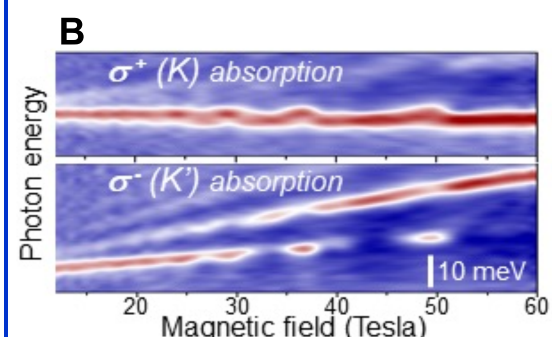
In atomically-thin semiconductors such as monolayer MoS_2 or WSe_2, many-body correlations can manifest in optical spectra when electron-hole pairs (excitons) are photoexcited into a Fermi sea of mobile electrons. At low background electron densities, the formation of negatively charged excitons (X^-) is well documented. However, *in WSe_2 monolayers, it has been known since 2013 that an additional strong absorption resonance, often called $X^{-\prime}$, emerges at high electron density. Its origin has remained elusive to date*.

Here, researchers use magnetic fields to 60T to investigate the $X^{-\prime}$ state via polarized absorption spectroscopy of gated WSe_2 monolayers. Field-induced filling and emptying of the upper electron levels in the *K'* valley (see Figure) causes repeated quenching of the corresponding σ^- polarized optical absorption. Surprisingly, these quenchings are accompanied by absorption changes to higher energy levels in both *K* and *K'* valleys, which are **unoccupied**. *These results cannot be reconciled within any single-particle picture, and demonstrate that $X^{-\prime}$ is a many-body state with inter-valley correlations.*

*These high-magnetic field results evidence new classes of correlated many-body quasiparticles that can emerge when an "impurity" (here, the exciton) is coupled to not just one, but **multiple** reservoirs of electrons, each having **distinguishable** spin and valley quantum numbers.* This work may have implications for other multi-valley materials, including silicon.



A: Optical absorption of monolayer WSe_2, showing neutral excitons (X^0) at zero doping, charged excitons (X^-) at low electron doping, and the mysterious $X^{-\prime}$ state at high doping.



B: In large fields, σ^+ circularly-polarized absorption to the unoccupied *K* valley is modulated when electrons fill/empty the opposite *K'* valley. The mysterious $X^{-\prime}$ is therefore a many-body state, comprising a spin-up exciton in *K* coupled to multiple (up to three) different electron reservoirs, each with distinguishable spin and valley quantum numbers.

Facilities used: 65 T pulsed magnets at the Pulsed Field Facility.

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