

# Charge-controlled biexcitons in monolayer WSe<sub>2</sub>

**Alejandro R-P. Montblanch<sup>1</sup>**

Matteo Barbone<sup>1,2</sup>, Dhiren M. Kara<sup>1</sup>, Carmen Palacios-Berraquero<sup>1</sup>, Alisson R. Cadore<sup>2</sup>, Domenico De Fazio<sup>2</sup>, Benjamin Pingault<sup>1</sup>, Elaheh Mostaani<sup>2</sup>, Han Li<sup>3</sup>, Bin Chen<sup>3</sup>, Kenji Watanabe<sup>4</sup>, Takashi Taniguchi<sup>4</sup>, Sefaattin Tongay<sup>3</sup>, Gang Wang<sup>2</sup>, Andrea C. Ferrari<sup>2</sup>, Mete Atatüre<sup>1</sup>

<sup>1</sup>*Cavendish Laboratory, University of Cambridge, JJ Thomson Ave., Cambridge CB3 0HE, UK*

<sup>2</sup>*Cambridge Graphene Centre, University of Cambridge, Cambridge CB3 0FA, UK*

<sup>3</sup>*School for Engineering of Matter, Transport and Energy, Arizona State University, Tempe, AZ 85287, USA*

<sup>4</sup>*Advanced Materials Laboratory, National Institute for Materials Science, Tsukuba, Ibaraki 305-0034, Japan*

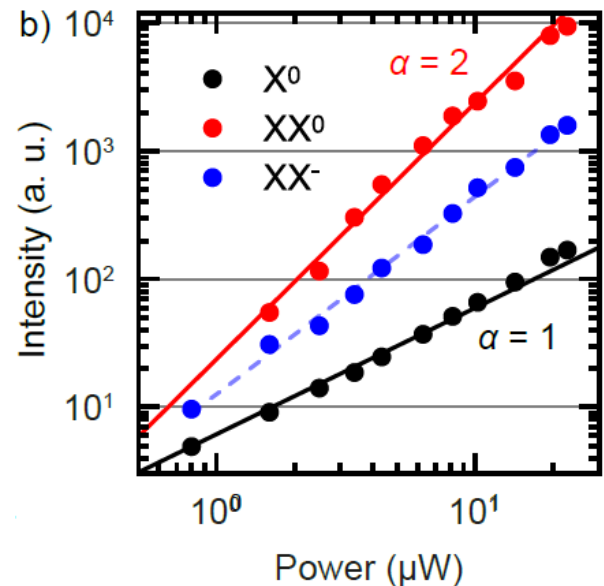
[ar820@cam.ac.uk](mailto:ar820@cam.ac.uk)

In atomically thin transition metal dichalcogenides (TMDs) Coulomb-mediated many-body interactions result in a variety of free and localized complexes, such as excitons and trions. Biexcitons, a two-exciton molecule<sup>1</sup>, hold great interest for applications such as sources of entangled photons<sup>2</sup>. Signatures of free biexcitons have been reported in TMDs<sup>3</sup>, but the inhomogeneously broadened linewidths in the photoluminescence (PL) spectra combined with the lack of electric and magnetic control have so far prevented their manipulation. Here we report direct experimental evidence of two fundamental biexciton complexes in monolayer WSe<sub>2</sub> (1L-WSe<sub>2</sub>): the neutral biexciton and the five-particle negatively charged biexciton, Fig. 1. We identify and controllably access these via a combination of polarization resolved, gate-controlled (see Fig. 2) and magnetic-field dependent PL measurements. We identify the fine-structure of the neutral biexciton and clarify the internal structure of both complexes. Our results prove the existence and unveil the nature of multi-exciton complexes in TMDs.

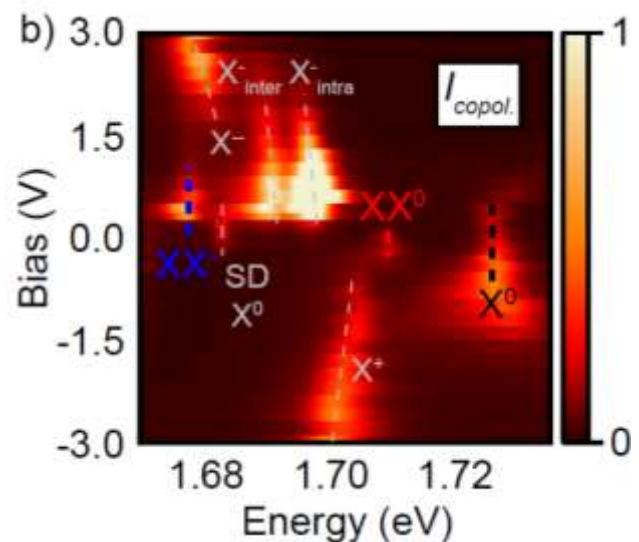
## References

- [1] Kim, J. C., Wake, D. R. & Wolfe, J. P. *Phys. Rev. B* **50**, 15099 (1994)
- [2] Li, X. *et al. Science* **301**, 809 (2003).
- [3] You, Y. *et al. Nat. Phys.* **11**, 477 (2015).

## Figures



**Figure 1:** Power dependence of selected PL peaks in 1L-WSe<sub>2</sub>. A superlinear behaviour indicates the biexcitonic nature of XX<sup>0</sup> and XX<sup>-</sup> as opposed to X<sup>0</sup>.



**Figure 2:** PL intensity as a function of gate bias across 1L-WSe<sub>2</sub>. Dashed lines are a guide the eye.