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Experimental evidence for dark excitons in monolayer transition metal dichalcogenide crystals XIAOXIAO ZHANG, YUMENG YOU, Columbia University, FRANK ZHAO, Harvard University, TONY HEINZ, Columbia University — Transition metal dichalcogenides in the family of MoS_2, $MoSe_2$, WS_2, and WSe_2 have been identified as direct-gap semiconductors in the limit of monolayer thickness. In addition to the optically bright states associated with dipole-allowed excitonic transitions between these bands, it is predicted that excitonic states will form that are optically dark either because of momentum or spin selection rules. In this paper, we report studies of the temperature dependence of the bright exciton population using photoluminescence and time-resolved photoluminescence spectroscopy. The experimental results indicate the presence of dark states lying below the optically bright states in some members of this family of materials. These states, unlike the usual bright states, are not be constrained by rapid radiative decay and offer new avenues for control of the valley and spin degrees of freedom.

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