

Disorder-Driven Enhancement of Coulomb Repulsion Governs the Superconducting Dome in Ionic-Liquid-Gated Quasi-2D Materials

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The superconducting dome in the T_c versus doping phase diagram, found in cuprates, nickelates, twisted bilayer graphene, and transition metal dichalcogenides, is often considered a signature of unconventional pairing. Identifying the underlying mechanisms of any of these phase diagrams and developing a reliable theoretical understanding of it remains a critical challenge. Here we demonstrate that, in ionic-liquid-gated quasi-2D materials, the disordered ionic potential from the frozen ionic liquid drives the system close to Anderson transition. In this regime, quenched charge fluctuations and reduced screening markedly enhance repulsive Coulomb interactions, suppressing T_c and naturally leading to the formation of a superconducting dome. By integrating a many-body approach including disorder with first-principles calculations, we obtain the phase diagrams and tunneling spectra of gated few-layer transition metal dichalcogenides in robust quantitative agreement with experiments. Our findings establish that disorder-driven enhancement of Coulomb repulsion is a fundamental feature of ionic-liquid-gated quasi-2D materials at high bias.

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Ionic-liquid-based electric double-layer field effect transistors constitute a unique platform to achieve high doping in low dimensional semiconductors and insulators: the charged ions in the electrolyte form an electric double layer at the interface with the semiconductor, inducing charge accumulation in the latter [1]. A gate-induced superconductivity dome has been shown to occur in cuprates [2,3], twisted bilayer graphene [4], and gated few-layer transition metal dichalcogenides (TMD) where superconductivity was first reported in molybdenum disulfide (MoS_2) by Ye *et al.* in 2012 [5] and soon after by other groups in other TMDs [6–10].

In all these materials, the superconducting dome feature is unexplained, qualitatively and quantitatively. In most of the cases, this is due to the difficulties in determining the pairing mechanism. Gated (electron-doped) few layers TMDs are an exception as there is evidence that superconductivity is mediated by phonons [11–14]; however, the most accurate calculations predict a linear growth of T_c with voltage and neither a saturation nor a superconducting dome [13]. Some theoretical works attributed the saturation of T_c at high voltage to a charge density wave (CDW) [11,12,15]. However, this has been recently disproved theoretically [13] and such a transition has never been

detected in gated experiments, while in theoretical calculations the CDW arises artificially from three approximations: (i) the inappropriate modeling of field effect doping by employing a uniform charged background, (ii) the neglect of anharmonic effects, (iii) and the assumption that the sample thickness is irrelevant. These approximations result in excessively low phonon frequencies, unrealistically high electron-phonon coupling, wrong thickness dependence [16], and incorrect electronic band structure. For example, in Ref. [15], these approximations have led to a factor of 3 overestimation in T_c at electron doping $n_e = 2.2 \times 10^{-14} \text{ e}^-/\text{cm}^2$ and a T_c versus doping diagram in quantitative disagreement with experiments (see also Fig. S8 in Supplemental Material [17]), with superconductivity occurring no earlier than at $n_e = 1.5 \times 10^{-14} \text{ e}^-/\text{cm}^2$ and only in proximity of the artificial CDW due to the aforementioned modeling problems; conversely, in experiments, it occurs at $n_e \approx 0.5 \times 10^{-14} \text{ e}^-/\text{cm}^2$.

All previous theoretical calculations neglected an essential point, namely the crucial role of disorder. When the flake is gated at temperatures where the electrolyte (typically, DEME-TFSI in experiments on TMDs) remains in the liquid state, an electric double layer forms, characterized by the accumulation of positively charged molecules [DEME⁺, N,N-diethyl-N-methyl-N-(2-methoxyethyl) ammonium] at the surface of the gated material. As the temperature is lowered, the electrolyte freezes in a disordered ionic configuration [38,39], and charged impurities occur on the surface of the sample in contact with the electrolyte [7]. The higher the voltage, the larger the

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impurity concentration. There are four key experimental findings confirming that the disorder induced by the electrolyte has substantial effects on the superconducting properties of gated TMDs. First, tunneling spectra show an extreme variability of the superconducting gap size if measurements are taken in different parts of the sample [see inset of Fig. 3(c) in Ref. [8]]. Second, tunneling spectra show a yet unexplained V-shaped feature with kinks [8], which cannot be reconciled with a phonon-mediated superconductor with *s*-wave pairing in the clean limit [13]. Third, in a single layer WS₂, a full superconducting dome as a function of doping is measured, flanked by insulating states on both the underdoped and overdoped sides [7]. The high-doping insulating state does not occur at any fractional filling, and it is, thus, unrelated to any band-insulating or Mott-insulating state; rather, it is strongly reminiscent of an Anderson localization. Fourth, the region of the dome where T_c decreases corresponds to a strong reduction of the measured low-temperature Hall mobility [5,7,40], suggestive of a competition between superconductivity and disorder. These experimental findings point toward a superconducting state where strong disorder plays an increasingly important role as the voltage is increased.

The effect of disorder in low dimensional superconductors mainly follows in two regimes. If the elastic scattering introduced by disorder is larger than the superconducting gap, but the impurity concentration is not high enough to push the system close to an Anderson localization, then T_c is weakly affected by disorder. This regime corresponds to the limit in which $k_F l \gg 1$, k_F is the Fermi momentum and l is the mean free path. Under these conditions, within the BCS theory [41], the pairing does not occur between states having opposite electron momenta, but between a disordered state and its time reversed state [42]. This regime has been thoroughly investigated by Gor'kov in Ref. [43], where it was demonstrated that the density of states is affected at order $(k_F l)^{-1}$. Charge fluctuations are not quenched, and screening is practically unaffected. The Coulomb vertex is almost unchanged, and the repulsion between electrons is essentially the same as in the clean limit.

The situation changes qualitatively when the disorder becomes sufficiently strong that $(k_F l)^{-1} \approx 1$ and the system approaches Anderson localization, while still remaining noninsulating. In the quasi-two-dimensional case represented by few-layer-thick samples, this regime can be approached easily as localization can occur at relatively low values of impurity concentration [44]. The charge fluctuations are strongly quenched, and the kinetic energy is strongly reduced. As a consequence, Coulomb repulsion and screening are strongly influenced, and quantum fluctuations become crucial [45–48]. In this scenario, corrections to the superconducting gap equation of the order of the product $(\epsilon_F \tau_0)^{-1}$ become important, with ϵ_F being the Fermi energy and τ_0 the average scattering time. This effect

determines the suppression of superconducting critical temperature for thin metallic films [49] in combination with the observation of exponentially increasing resistivity. Theoretical analysis pointing out the combined role of disorder and dimensionality has been given in many theoretical works for thick flakes [50] and in the two-dimensional limit [46,47,51,52]. These remarkable theoretical developments rest mainly on the BCS model in the presence of disorder and Coulomb repulsion. They have never been coupled to the high accuracy of first-principles calculations to describe the superconducting phase in the presence of disorder in quasi-two-dimensional systems.

In this Letter, we substantiate the idea that disorder plays a critical role for T_c suppression in gated systems at high voltage. By extending previous many-body approaches [46,47,51,52], we develop a first-principles framework to evaluate superconducting properties in the presence of strong disorder occurring in proximity of an Anderson transition. We demonstrate that this approach quantitatively describes the superconducting dome in single-side gated few-layer MoS₂ and the smaller T_c saturation at high voltage in few-layer MoSe₂. Finally, we explain the V-shaped form, the anomalous kinks, and temperature dependence of the tunneling spectra reaching an unprecedented agreement with experimental data. The present results establish that disorder-driven enhancement of Coulomb repulsion is a universal feature of ionic liquid-gated quasi-2D materials at high bias.

The effect of strong disorder on T_c is described by including the perturbative corrections to the pair propagator, following the approach presented in Ref. [46] for 2D systems and discussed in [47,52,53] (see also Supplemental Material, Sec. S3 [17]). By considering the multivalley nature of our system with almost perfect parabolic valleys, we find the following self-consistent equation for T_c [46]:

$$\ln(T_c/T_{c0}) = \left[-\frac{[g_1 N(0) - 3\lambda]}{4\pi\epsilon_F\tau_0} \left(\ln \frac{1}{T_c\tau_0} \right)^2 - \frac{[g_1 N(0) + \lambda]}{6\pi\epsilon_F\tau_0} \left(\ln \frac{1}{T_c\tau_0} \right)^3 \right], \quad (1)$$

where $N(0)$ is the density of states per spin, τ_0 is the average scattering time, ϵ_F is the Fermi energy in the presence of disorder, g_1 is a constant that accounts for electron-electron interaction ($g_1 N(0) \approx (g_v/2)$, where g_v is the valley degeneracy [47]), and $\lambda = g'N(0)$ is the electron-phonon coupling parameter (see also Supplemental Material [17], Sec. 3), while T_{c0} is the superconducting critical temperature in the absence of disorder. As the scattering time τ_0 decreases, the right-hand side of Eq. (1) becomes larger, causing a suppression of T_c .

The scientific novelty of the present work lies in the fact that we couple the many-body disorder framework to high-accuracy first-principles calculations in the realistic field effect geometry for the first time, providing parameter-free

predictions of λ , ε_F , and T_{c0} as a function of doping. Second, the scattering time τ_0 , representing the only quantity in Eq. (1) that requires an explicit treatment of disorder, is computed from a Wannier tight binding model with a physically motivated electrostatic model for the frozen ionic impurities, rather than being treated as a phenomenological input. Third, we derive the extension of the formalism to the multivalley case relevant for MoS₂ and MoSe₂ (see Supplemental Material [17], Secs. S3 and S4). Finally, the same framework, with the same assumptions and without any material-specific tuning, simultaneously reproduces the full superconducting dome in MoS₂ and the absence of T_c saturation in MoSe₂ up to the measured doping range.

More detailed insights on the behavior of the superconducting critical temperature T_c emerging from the self-consistent solution of Eq. (1) as a function of the Fermi energy ε_F and τ_0 are given in Supplemental Material [17], Sec. S5. We stress that this expansion is rigorously justified in the perturbative disorder regime, dictated by the dimensionless parameter $(\varepsilon_F \tau_0)^{-1}$ and by logarithmic T_c renormalization. When the system approaches the Anderson transition more closely, the perturbative expansion breaks down, and a renormalization group treatment would be required to describe the crossover into the Anderson insulating phase [47].

The corrections to T_c in the rhs of Eq. (1) can be schematically separated in two types: the term

$$R_{HF}(T)/N(0) = -\frac{[g_1 N(0) - 3\lambda]}{4\pi\varepsilon_F \tau_0} \left(\ln \frac{1}{T\tau_0} \right)^2 \quad (2)$$

includes Hartree-Fock-type corrections $\propto \ln(1/T)^2$, while

$$R_v(T)/N(0) = -\frac{[g_1 N(0) + \lambda]}{6\pi\varepsilon_F \tau_0} \left(\ln \frac{1}{T\tau_0} \right)^3 \quad (3)$$

originates from vertex corrections $\propto \ln(1/T)^3$ and constitutes the dominant correction term to the lowest order. The quantities λ , ε_F , and T_{c0} can all be obtained through first-principles calculations in the clean limit. Here, we are employing data from our previous work [13], where we have shown that calculations accounting for the sample thickness, anharmonicity, and the effective field effect geometry lead to values of λ that are in excellent agreement with experiments. The clean limit results for T_{c0} for the case of single gated MoSe₂ and MoS₂ bilayers, the minimal thickness representative of thicker flakes where superconductivity has been detected (see Ref. [13]), are compared with experimental data in Fig. 1. As shown in Fig. 1, the clean limit correctly reproduces the superconducting onset, but T_{c0} increases without saturating and no superconducting dome occurs.

The scattering time τ_0 is the only quantity in Eq. (1) that cannot be directly estimated from calculations on periodic

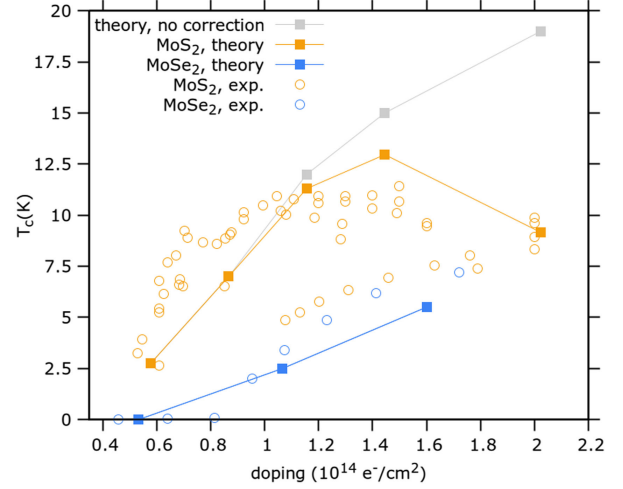


FIG. 1. Predicted superconducting critical temperature T_c as a function of doping with disorder + interaction corrections for single-side gated MoS₂ (orange filled squares) and MoSe₂ (blue filled squares). The gray curve represents the predicted critical temperatures for MoS₂ in the absence of disorder, while for MoSe₂ the correction is negligible. The empty circles represent experimental T_c values from Refs. [5,8–10,40,54].

systems, as it requires the inclusion of disorder. In order to evaluate the average scattering time, we introduce a tight binding model based on maximally localized Wannier functions (MLWFs) [55] with the following form in second quantization:

$$H_{TB} = H_{sp} + H_{imp} = \sum_{\mathbf{R}_i \mathbf{R}_j} \sum_{lm} H_{lm}(\mathbf{R}_i - \mathbf{R}_j) d_{\mathbf{R}_i,l}^\dagger d_{\mathbf{R}_j,m} + \sum_{\mathbf{R}_i,l} U_l(\mathbf{R}_i) d_{\mathbf{R}_i,l}^\dagger d_{\mathbf{R}_i,l}, \quad (4)$$

where $d_{\mathbf{R}_i,l}$ and $d_{\mathbf{R}_i,l}^\dagger$ destroys or creates an electron in the Wannier function l of the supercell $\mathbf{R}_i$. The single particle Hamiltonian H_{sp} is obtained by using MLWF and PythTB [56], retaining all hopping terms larger than 2 meV (details are given in Supplemental Material [17], Secs. S1 and S8). The diagonalization of H_{sp} leads to an electronic structure practically indistinguishable from the first-principles one in the energy region relevant for superconductivity. The term H_{imp} accounts for the interaction with charged impurities formed by freezing the electrolyte [7], and it is assumed to be diagonal in the Wannier function basis. For large values of U_l , the model leads to an Anderson localization. The values of $U_l(\mathbf{R}_i)$ are obtained by assuming a certain density of disordered point charges generating a potential $\phi(\mathbf{r})$ on each cell of the tight binding model. The potential $\phi(\mathbf{r})$ is calculated explicitly Supplemental Material [17], Sec. S2 and includes both the bare potential of the external disordered charges as well as the screening effect due to the induced charge at the Thomas-Fermi level. We, thus,

define the on-site term U_l on the site l as the spatial average around each Wannier center,

$$U_l(\mathbf{R}) = e \int d\mathbf{r} \phi(\mathbf{r}) |w_{l,\mathbf{R}}(\mathbf{r})|^2, \quad (5)$$

where $w_{l,\mathbf{R}}(\mathbf{r})$ is the l th Wannier function in the cell indicated by the lattice vector $\mathbf{R}$.

The physics governing the formation of the electric double layer at the interface is inherently complex [57]. To make the problem tractable, we adopt a simplified model in which the potential $\phi(\mathbf{r})$ is computed by assuming a fixed vertical separation between the positively charged ionic impurities and the TMD layer. A lower bound to the vertical separation d between the nitrogen center (approximating the charge centroid) of the DEME⁺ cation and the topmost chalcogen layer (S or Se) can be realistically estimated based on the steric limit of the DEME⁺ molecular geometry. We assume the cation orients its smallest substituent, the methyl group ($-\text{CH}_3$), toward the interface to minimize electrostatic energy. The distance is, thus, approximated as the sum of the van der Waals radius of the surface chalcogen ($r_s \approx 1.8$ Å; $r_{\text{Se}} \approx 1.9$ Å), the N–C bond length ($d_{\text{N-C}} \approx 1.47$ Å), and the hydrogen van der Waals radius (≈ 1.2 Å), which defines the steric contact distance; the tetrahedral C–H geometry reduces the vertical bond projection but does not alter the hard-sphere limit. This yields a charge-to-surface distance of $d \approx 4.6$ – 4.8 Å, a realistic value when compared to the Stern layer thickness in ionic-liquid-gated 2D materials [58]. We shall adopt a slightly larger value of $d \approx 5$ Å for MoS₂ and $d \approx 5.1$ Å for MoSe₂. We make the simplest possible assumption for the impurity concentration dependence on doping, i.e., that the impurity concentration n_{imp} is approximately equal to the doping concentration n_{el} induced by the gate potential V ; namely, we assume

$$n_{\text{imp}}(V) = n_{el}(V), \quad (6)$$

which is justified if crowding effects are neglected [57]. With these choices, we obtain scattering time τ_0 values that are compatible with the ones measured in Ref. [40] at large doping for single-side gated MoS₂. With these assumptions, we diagonalize the Hamiltonian, obtain eigenvalues and eigenvectors, and calculate the sheet resistivity $R_{\square} = \lim_{\omega \rightarrow 0} \{1/[\sigma(\omega)d]\}$, where $d \approx 6$ Å is the electron gas' thickness and the conductivity $\sigma(\omega)$ is calculated employing the Kubo formula [59] as the in-plane average:

$$\sigma(\omega) = \left\langle -\frac{2\pi}{\Omega} \sum_{nn'} |\langle n | j_x | n' \rangle|^2 (f_n - f_{n'}) \delta(\hbar\omega - \varepsilon_{n'} + \varepsilon_n) \right\rangle, \quad (7)$$

where Ω is the supercell volume, f_n is the occupation of the eigenstate $|n\rangle$, and x is a generic in-plane direction. The α

TABLE I. Model-derived parameters entering the self-consistent formula for T_c and the equation of the superconducting gap in the presence of disorder.

System	n_e/cell	$R_{\square}^0(\Omega)$	$\varepsilon_F^{\text{avg}}(\text{eV})$	τ_0 (fs)	$R_{HF+v}(T_c)/N(0)$
Bilayer	0.1	52.49	0.05	169.85	−0.064
Bilayer	0.125	82.49	0.06	108.08	−0.135
Bilayer	0.175	139.71	0.08	50.56	−0.733

Cartesian components of electric current density operator are obtained as

$$j_{\alpha} = -\frac{ei}{\hbar} \sum_{lm} H_{lm}(\mathbf{R}_i - \mathbf{R}_j)(\mathbf{R}_i - \mathbf{R}_j)_{\alpha} d_{\mathbf{R}_i,l}^{\dagger} d_{\mathbf{R}_j,m}.$$

In practical calculations, a finite broadening η is added to calculate the Dirac δ function, and τ_0 can be obtained by performing two different calculations at the same η , one in the presence of disorder (giving $R_{\square}^{\eta}$) and one in the absence of disorder (giving $R_{\square}^{\eta=0}$). The scattering time in the absence of η is then obtained as $\tau_0 = (2/\eta)(R_{\square}^{\eta}/R_{\square}^{\eta=0} - 1)^{-1}$ (see Supplemental Material [17], Sec. S1). The obtained two-dimensional conductivity σ for a MoS₂ gated bilayer as a function of impurity concentration is reported in Supplemental Material [17], Sec. S1. As expected, disorder strongly suppresses the Drude peak, in agreement with mobility measurements [5,7,40]. The calculated τ_0 , Fermi level ε_F , and sheet resistivity $R_{\square}$ for a gated MoS₂ bilayer are reported in Table I.

The self-consistent solution of Eq. (1) is displayed in Fig. 1 for gated MoS₂ and MoSe₂ bilayers. A superconducting dome appears in bilayer MoS₂ in qualitative and quantitative agreement with experiments. At a carrier concentration of $n_e = 2 \times 10^{14} \text{ e}^{-}/\text{cm}^2$, the T_{c0} suppression due to disorder is approximately 300%. Remarkably, even using the same disorder parameters, a negligible suppression of the critical temperature in the case of a gated MoSe₂ bilayer is observed, at least up to $1.69 \text{ e}^{-} \times 10^{14} \text{ e}^{-}/\text{cm}^2$ [6], as shown in Fig. 1. The reason is that the minimum at K is never occupied in this case [13], generating a higher Fermi energy in the Q valley (a higher carrier velocity at comparable doping) and, thus, making the disorder T_c renormalization less relevant. This is investigated in more detail in Supplemental Material [17], Sec. S5, where we discuss the behavior of T_c as a function of τ_0 and ε_F for a 2D homogeneous electron gas.

Following our analysis, the superconducting dome in gated TMDs is due to two competing effects. The onset of the superconducting dome is determined by the occupation of the Q valleys switching on the electron-phonon interaction that grows proportionally to the Fermi level. The saturation of T_c and the consequent occurrence of a superconducting dome at high voltage is determined by the disorder increasing at higher voltages. We speculate that

disorder will saturate at even larger doping values due to crowding effects [57], leading to a finite T_c even at very large doping (see also Fig. S8 in Supplemental Material [17]).

While the above analysis can accurately reproduce the T_c versus voltage phase diagram of dichalcogenides, an appropriate description of the superconducting state must be also able to account for the experimentally measured superconducting gap. In particular, the superconducting gap has a distinctive V shape [8] that is not compatible with a standard s -wave phonon-mediated pairing in the clean limit, as the gap would be substantially larger and no V shape would occur [13]. We now show that within our framework explicitly including disorder we obtain an extremely accurate description of the superconducting gap and its dependence on temperature.

The modified gap equation in the presence of homogeneous disorder reads

$$1 = V^{\text{BCS}} \left[\sum_n \frac{\tanh(\frac{E_n}{2T})}{E_n} + \tilde{R}_{HF} + \tilde{R}_v \right], \quad (8)$$

where V^{BCS} is the BCS potential and we assumed a single band for simplicity, while $\tilde{R}_{HF}$ and $\tilde{R}_v$ are disorder-induced corrections in the superconducting state, defined in Supplemental Material [17], Sec. S3, where we give the full derivation and a generalization to the multiband case. In the isotropic approximation, this equation leads to an exponential suppression of the gap at $T = 0$ K with respect to the disorder parameter $x = -1/N(0)(\tilde{R}_{HF} + \tilde{R}_v)$:

$$\Delta_0(x) \sim \theta_D e^{-1/\lambda} e^{-x}, \quad (9)$$

where θ_D is the Debye frequency. As it is reasonable to speculate that disorder is horizontally inhomogeneous across the sample, x does not take a single value, but it can vary from point to point. For simplicity, we assume that x is uniformly distributed in an interval $[a, b]$, where a is the value leading to the calculated T_c in Fig. 1 (≈ 0.2 at the experimental doping), while b is a much larger value, which we fix to 2.3. We then solve the self-consistent gap equation for many values of x and calculate the tunneling conductance defined as [60]:

$$R_N \frac{dI}{dV}(V) = -\frac{1}{e^-} \int_{-\infty}^{\infty} d\varepsilon \frac{N_S(\varepsilon)}{N(0)} \frac{\partial f}{\partial V}(\varepsilon + e^-V, T), \quad (10)$$

where f is the Fermi-Dirac distribution, $N_S(\varepsilon)$ is the superconducting density of states, defined as

$$N_S(\varepsilon) = N(0) \text{Re} \left\{ \frac{|\varepsilon + i\Gamma|}{\sqrt{(\varepsilon + i\Gamma)^2 - \Delta^2}} \right\}, \quad (11)$$

and R_N is the normal state resistance. In Eq. (11), Γ is the quasiparticle linewidth Γ [61], which we set to an infinitesimal value, $\Gamma = 0.01$ meV, without the necessity to include an unphysical quasiparticle linewidth to fit the tunneling spectra (see the discussion in Supplemental

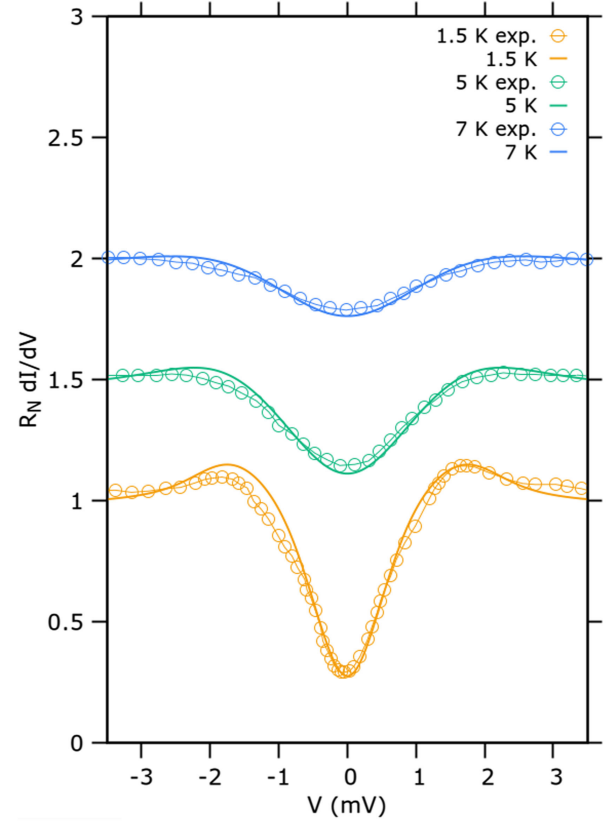


FIG. 2. Theoretical versus experimental differential tunneling conductance for single-side gated MoS₂ at $n_e \approx 1.5 \times 10^{-14}/\text{cm}^2$ as a function of voltage at 1.5 (orange), 5 (green), and 7 (blue) Kelvin. Experimental data have been extracted from Ref. [8].

Material of Ref. [8] and Supplemental Material of the present Letter [17], Secs. 3 and 8).

Our results on the superconducting gap calculations in the presence of disorder are validated against experiments in Fig. 2 for MoS₂ thick (> 1 layer) samples. Our calculations are in excellent agreement with experiments and explain (i) the reduction of the superconducting gap with respect to the clean limit (see Fig. 22 in [13]), (ii) the V-shaped feature, (iii) the presence of a kink at approximately ± 1 mV in the 1.5 K tunneling spectra, and, finally, (iv) the temperature dependence of the tunneling spectra. In the present scenario, the V-shaped feature is not a signature of unconventional pairing symmetry; rather, it reflects the action of nonhomogeneous disorder in proximity of an Anderson transition on a BCS gap. Multiband effects are negligible in these systems, as shown in [13]; nevertheless, they give rise to interesting considerations, exposed in Sec. S3 in Supplemental Material [17]. Within the current framework, we are able to account for the magnitude, the shape, and the temperature dependence of the superconducting gap.

In conclusion, we demonstrate that strong electron-phonon interaction and disorder enhancement of the Coulomb interaction are the key mechanisms governing the shape of the superconducting dome in ionic-liquid-gated MoS₂. Our results for the superconducting critical

temperature versus voltage in MoS_2 and MoSe_2 are in excellent agreement with experimental data and represent qualitative improvement with respect to all other attempts to explain the phase diagram of gated dichalcogenides. Finally, extending disorder corrections into the superconducting state via a modified BCS framework further allows us to account for the kink observed in tunneling spectra and to reproduce its characteristic V shape.

Our results establish disorder-driven enhancement of Coulomb repulsion due to the proximity of an Anderson transition as a universal feature of ionic-liquid-gated quasi-two-dimensional materials subject to high bias. Our joint many-body and first-principles framework provides a unified interpretation of dome superconductivity and tunneling spectra in gated dichalcogenides, offering new insight into the microscopic origin of superconducting dome physics. In the future, the same approach can be applied to any other gated quasi-two-dimensional material following the same procedure adopted in this Letter.

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Data availability—The program employed to generate data presented in this paper will be made available at [62] upon publication.

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