Revelation of new magnetic domain wall category in the itinerant antiferromagnet Chromium

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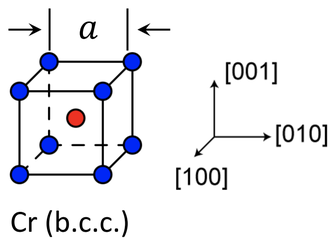
1. Introduction

❖ **Crystal structure of Cr**

$a = 0.289$ nm

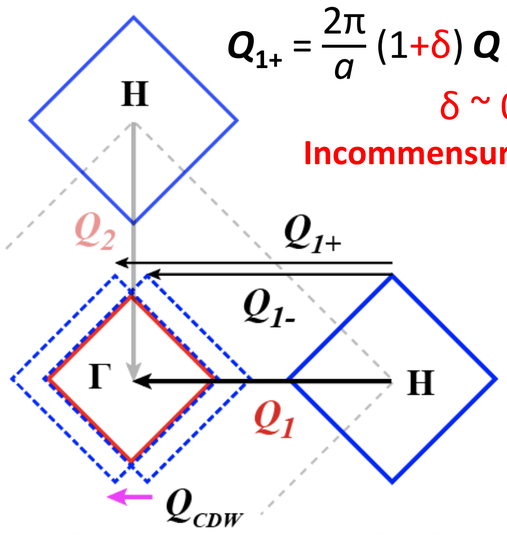


Cr (b.c.c.)

Spin-density wave (SDW)
$Q_{IC-\mathrm{SDW}} = 2\pi\delta/a$

Charge-density wave (CDW)
$Q_{IC-\mathrm{CDW}} = 2Q_{\mathrm{IC-SDW}}$

❖ **Imperfect Fermi surface nesting in Cr**

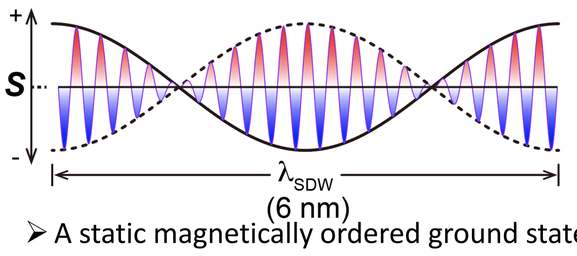


$Q_{1+} = \frac{2\pi}{a}(1+\delta)$ $Q_{1-} = \frac{2\pi}{a}(1-\delta)$

$\delta \sim 0.05$

Incommensurate(IC) factor

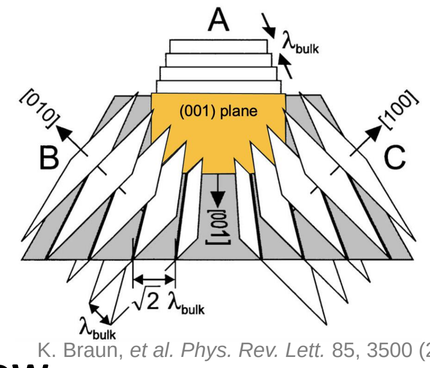
❖ **Spin-density wave (SDW)**



➢ A static magnetically ordered ground state

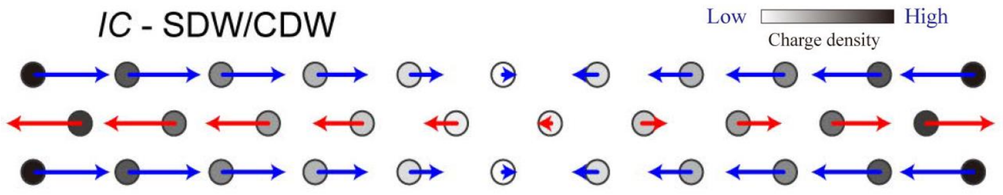
➢ Spin **amplitude modulates** in real space

❖ **Bulk SDW domains of Cr**



K. Braun, *et al. Phys. Rev. Lett.* 85, 3500 (2000).

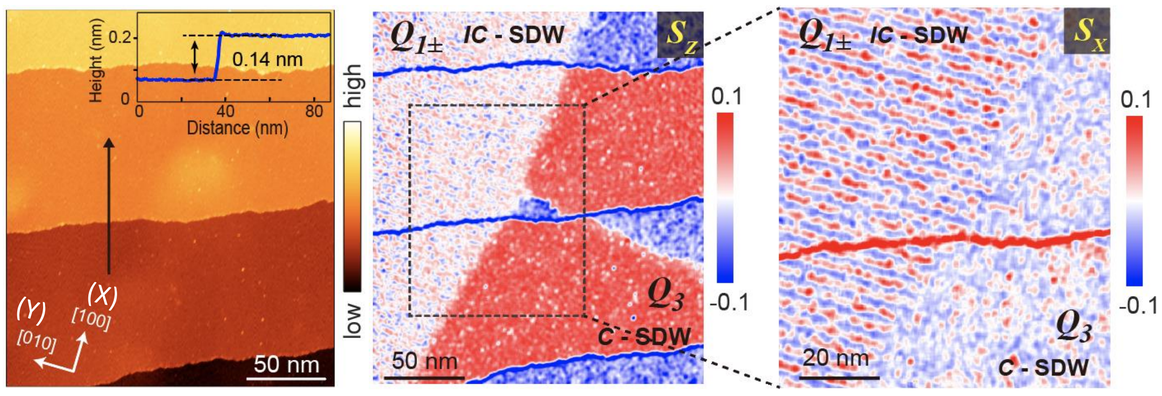
❖ **Spin/charge structure of IC-SDW/CDW**



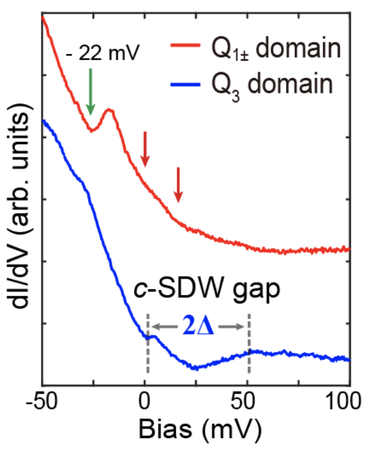
- How will SDW behave when encountered a boundary?

2. SDW domains with different *Q* orientations

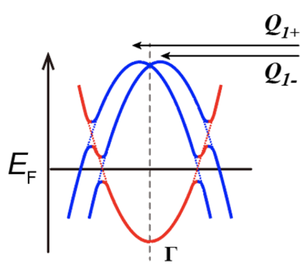
Topography on Cr(001) **S_z-sensitive DOS map** **S_x-sensitive DOS map**



Spectroscopies



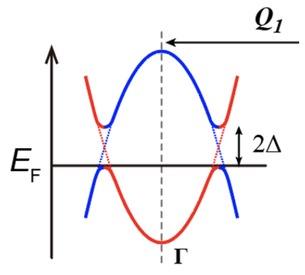
Incommensurate(IC-) SDW



$Q_{\mathrm{IC-SDW}} = \frac{Q_{1+} - Q_{1-}}{2}$

$\lambda_{\mathrm{IC-SDW}} = 6.0\mathrm{nm}$

Commensurate(C-) SDW



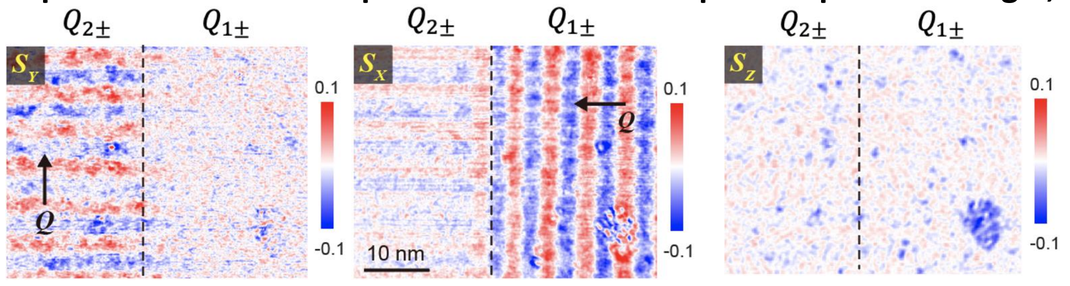
$Q_{\mathrm{C-SDW}} = Q_1 = \frac{2\pi}{a}$

$\lambda_{\mathrm{C-SDW}} = a$

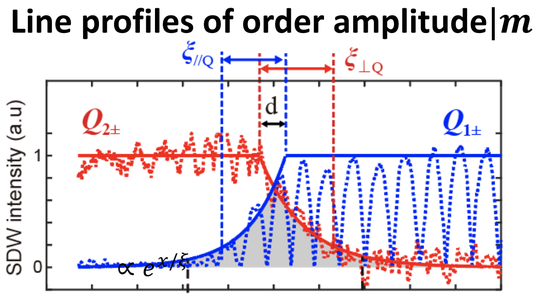
- Different STS behavior in IC- and C- domain is consistent with nesting conditions

3. Boundary structure between IC-SDW domains

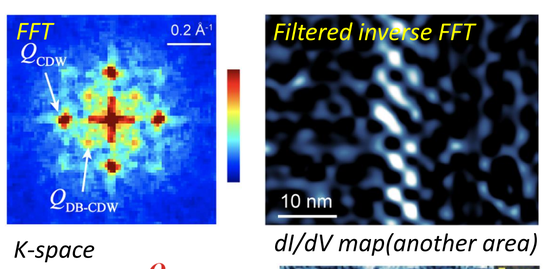
❖ **Spin-sensitive DOS maps: measures surface spin component along X, Y, Z**



❖ **Line profiles of order amplitude $|m|$**



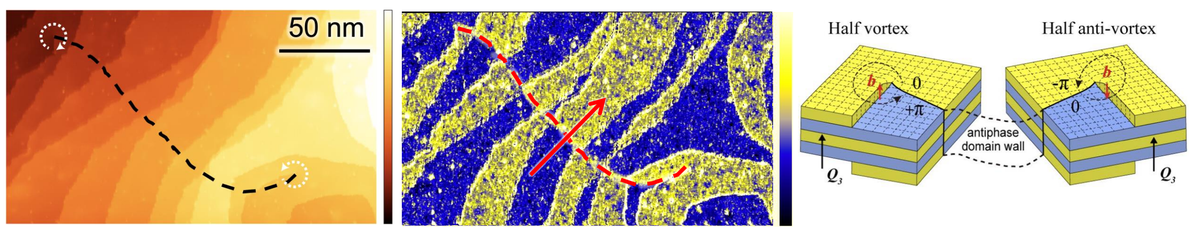
❖ **New CDW order at domain boundary**



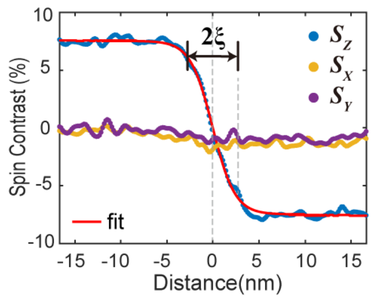
- SDW order parameter $\boldsymbol{\eta} = \boldsymbol{m}e^{i(\boldsymbol{Q}\cdot\boldsymbol{r}+\varphi_0)}$ penetrates into the opposite domain and forms double-Q state at boundary.
- Exponential decay of $\boldsymbol{\eta}$.
- A new type of second-order Fermi surface nesting emerges at domain boundary.

4. Antiphase domain boundary of C-SDW

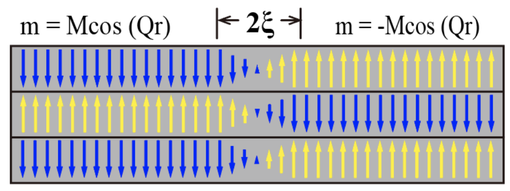
STM topography **SP-DOS map (Fe tip, *B* // Z)** **A pair of screw dislocations**



Measured spin components

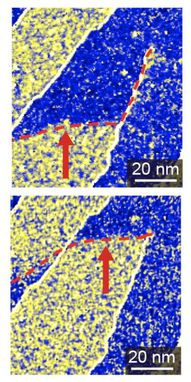


Sketch of phase boundary



$$\oint d\varphi = \oint \boldsymbol{Q}_3 \cdot d\boldsymbol{\mu} = \boldsymbol{Q}_3 \cdot \boldsymbol{b} = \pm\pi$$

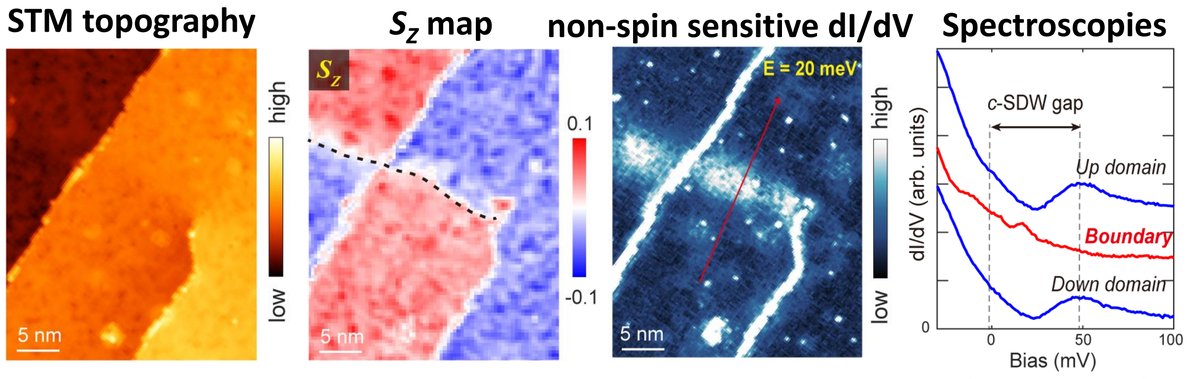
Movable boundary



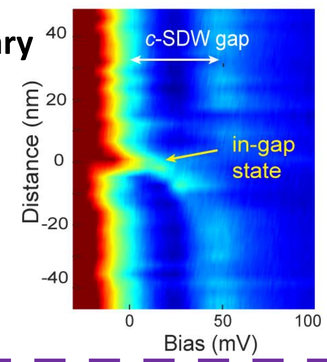
- Total spin vanishes at boundary!
- Distinct from Néel/Bloch wall

5. SDW quasiparticle bound states

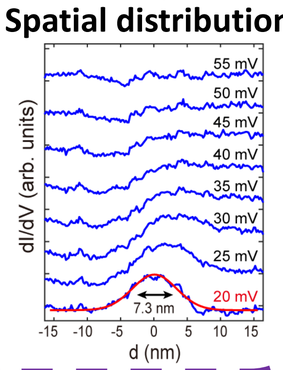
STM topography **S_z map** **non-spin sensitive dI/dV** **Spectroscopies**



STSs across boundary



Spatial distribution



- Quasiparticle bound states appear when SDW order parameter vanishes at boundary

6. Conclusion

Reference: arXiv:2402.15999

A systematic discovery about the domain boundary structures in itinerant antiferromagnet.

- ➢ At the boundary of two IC-SDW domains, the spins display finite-scale decay rather than reorientation. A novel double-Q SDW is generated with a second-order charge modulation.
- ➢ In C-SDW domains, a clear SDW gap is observed. A pair of screw dislocations are connected by antiphase domain wall. This domain wall is characterized by vanishing spin density, where intriguing SDW in-gap states emerge.