Discovery of Weyl semimetal TaAs

Hong Ding

Institute of Physics, Chinese Academy of Sciences

B. Q. Lv et al., "Discovery of Weyl semimetal TaAs", arXiv:1502.04684

B. Q. Lv et al., "Observation of Weyl nodes in TaAs" arXiv:1503.09188

Swiss-Sino Workshop, May 5, 2015

Collaborators

ARPES:

IOP: B.Q. Lv, T. Qian, J.Z. Ma, X.P. Wang, J. Ma, P. Richard

PSI: N. Xu, M. Shi, C. Matt, F. Bisti, V. Strokov, J. Mesot

Theory:

IOP: H.M. Weng, X. Dai, Z. Fang

Samples:

IOP: G.F. Chen , X.C. Huang, L.X. Zhao

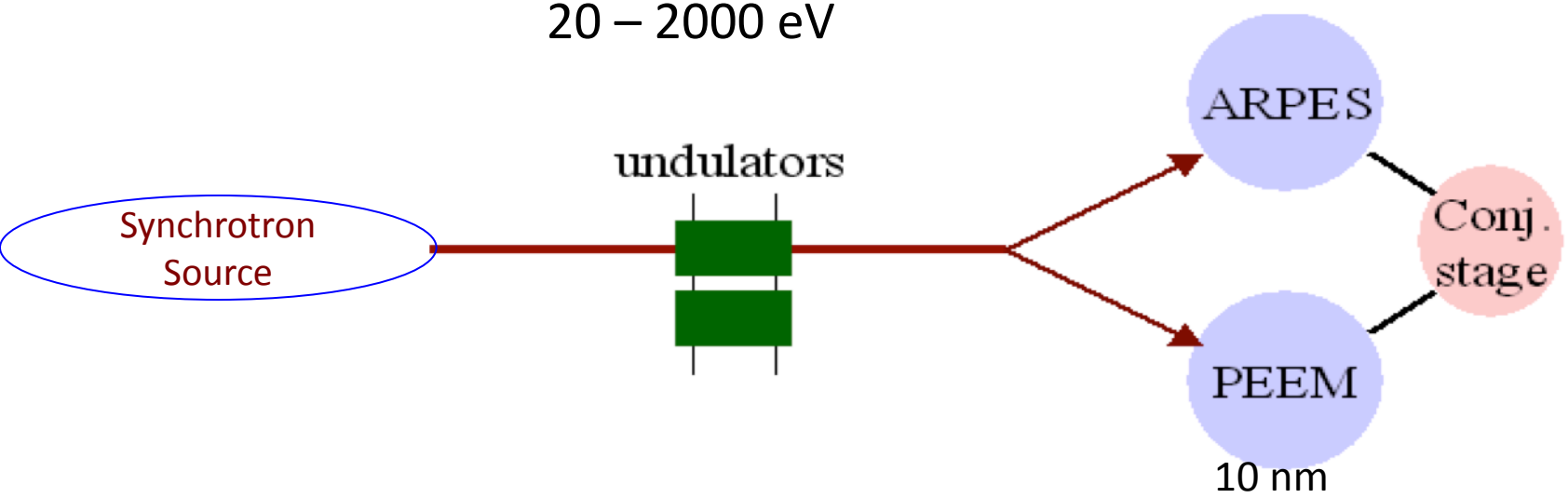
Synchrotron beamlines:

SSRF: Dreamline

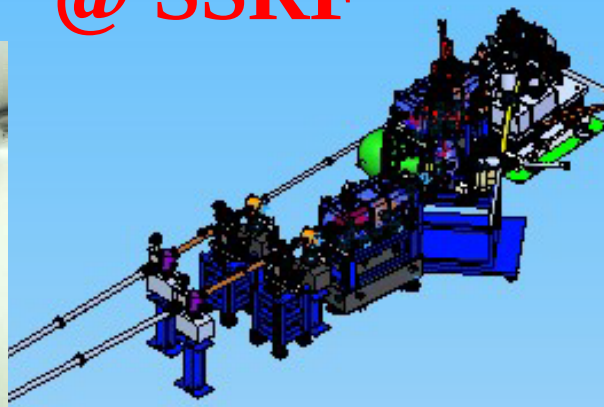
SLS: ADRESS, SIS

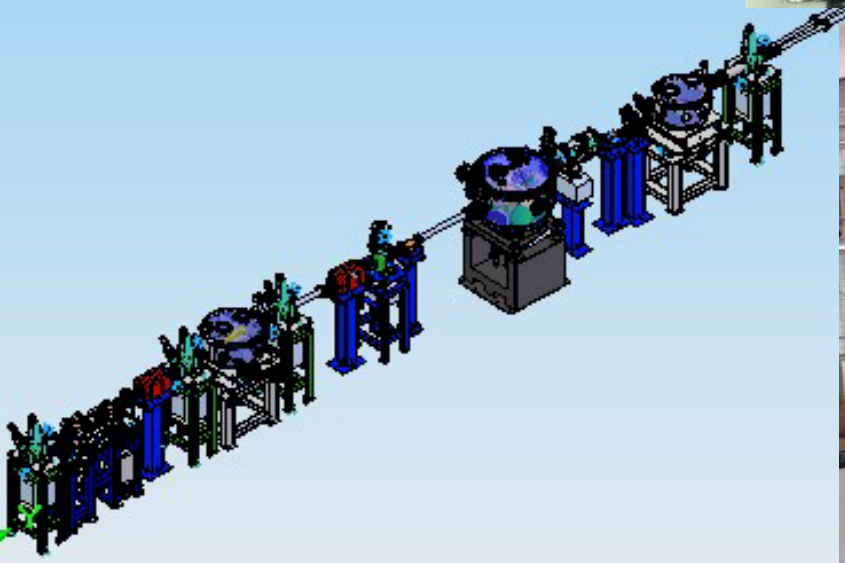
Dreamline Project

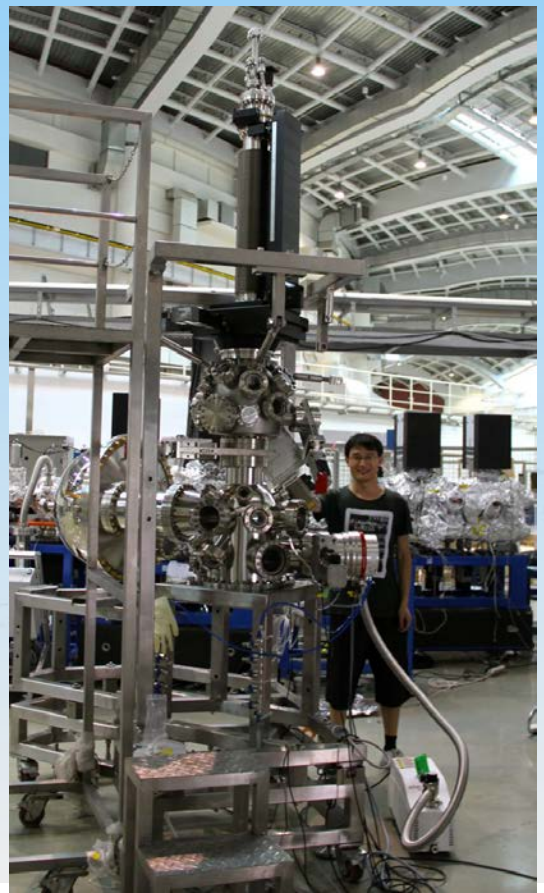
Design goal: 1 meV@20 eV； 10 meV@1000 eV
20 – 2000 eV



Completion of “Dreamline” @ SSRF

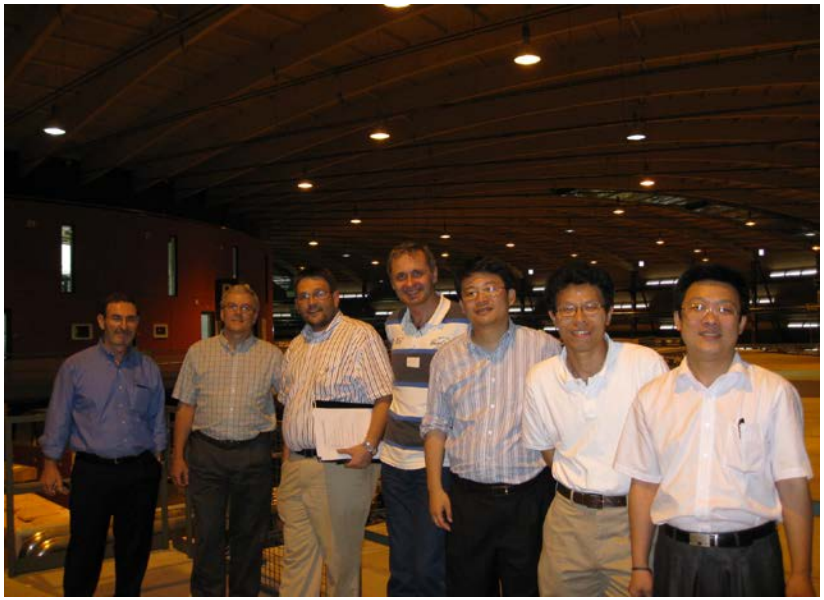






Commission Oct. 2014

International Review Meeting (PSI, Sep 09)

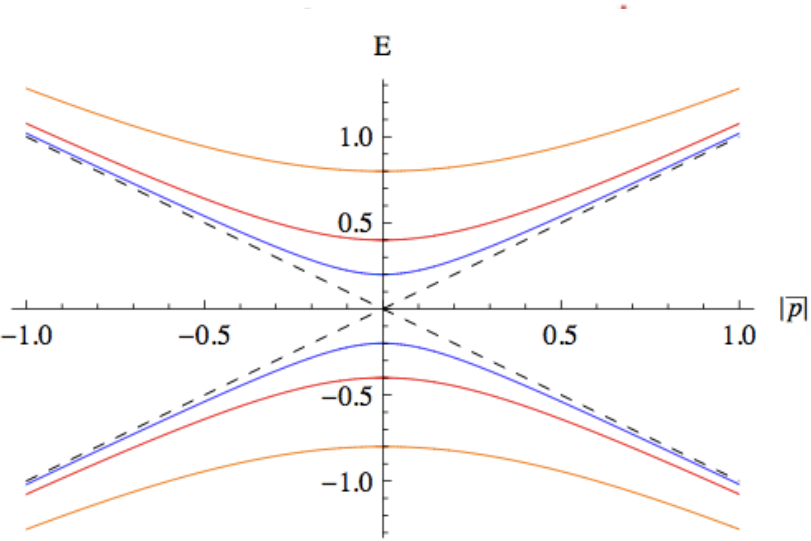


Outline

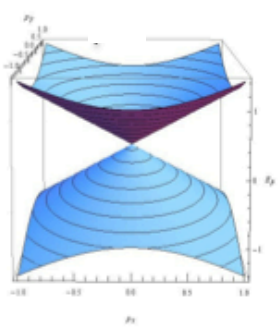
- ***Introduction to Weyl semimetal***
- **Observation of Weyl nodes in TaAs**
- **Observation of Fermi arc surface states in TaAs**

Introduction to Weyl semimetal

3D Weyl Semimetals



$$E = \pm\sqrt{p_x^2 + p_y^2 + p_z^2 + m^2}$$



Copy of Ashvin Vishwanath

- A pair of 3D bands cross (non-degenerate bands - break T or Inversion).
- Excitations near the touching points described by Weyl Eqn.

Half of Dirac's 4 component equation.
No mass term allowed.

$$H_{\text{Weyl}} = (p_x\sigma_x + p_y\sigma_y + p_z\sigma_z)$$

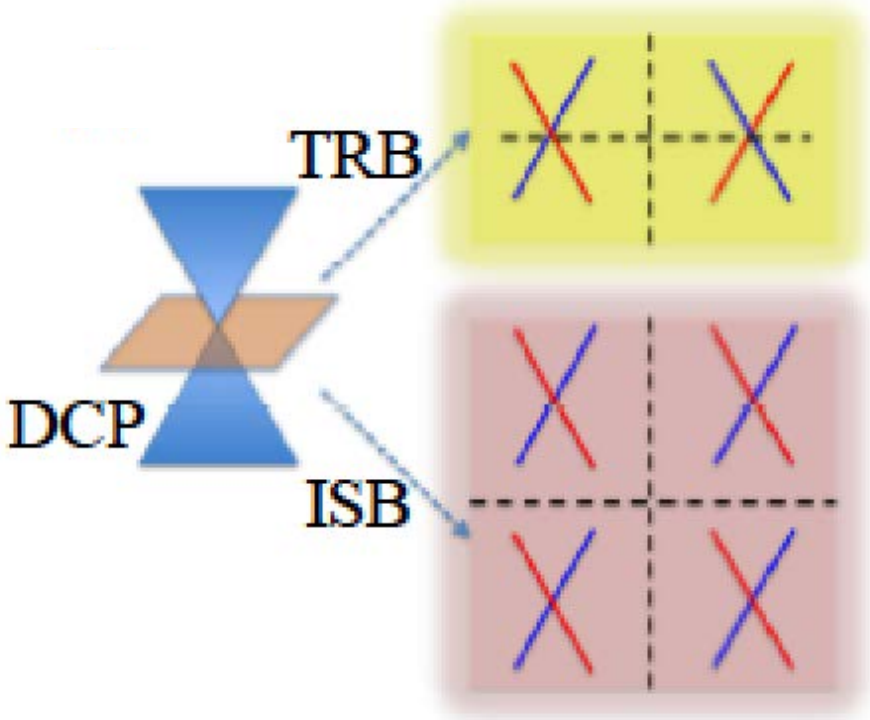
I always tried to unite the truth with the beautiful, but when I had to choose, I usually chose the beautiful. - Hermann Weyl (1885-1955)

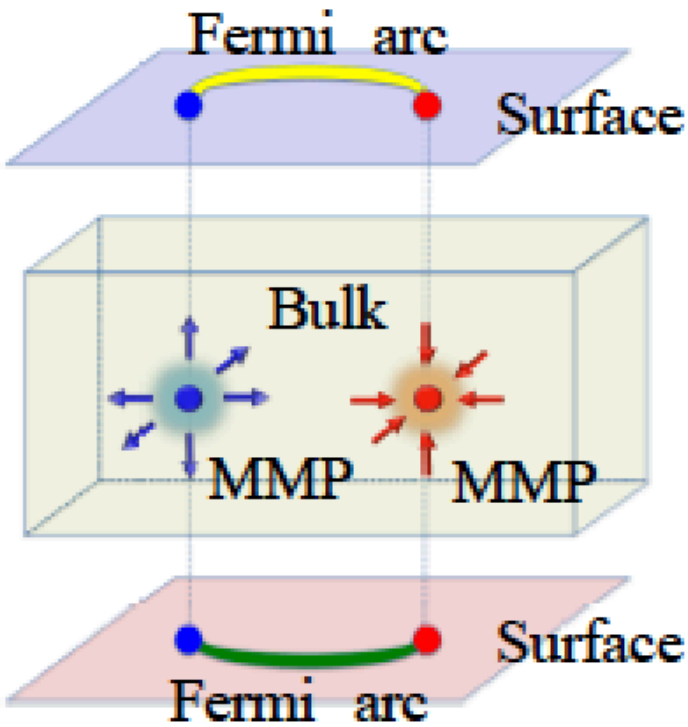
H. Weyl

No known Weyl fermion..... Realize in solids?

Introduction to Weyl semimetal

What's Weyl semimetal ?





DCP: Dirac-cone point
TRB: time-reversal symmetry breaking
ISB: inversion-symmetry breaking

Exotic properties:

Chiral anomaly
Negative magnetoresistance
Nonlocal transport
Quantum anomalous Hall effect
Unconventional superconductivity
……

Introduction to Weyl semimetal

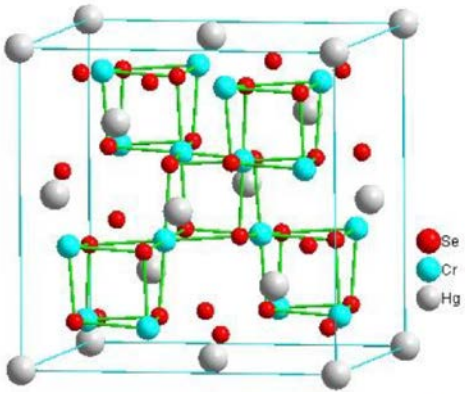
Weyl semimetal -Rn2Ir2O7 、 HgCr2Se4 ……

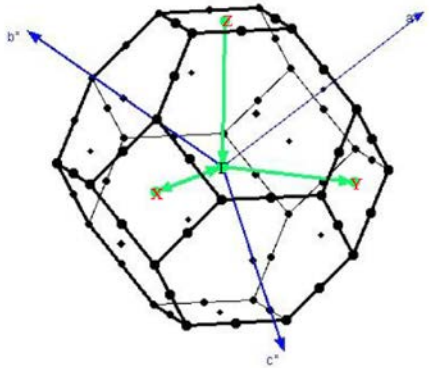
Breaking time reversal symmetry

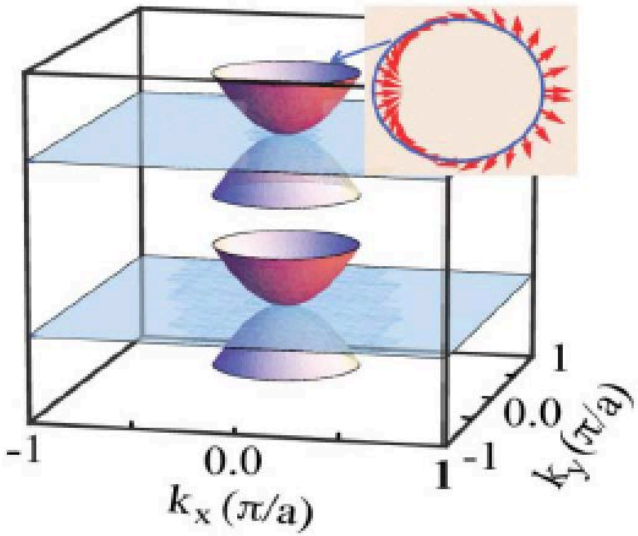
Magnetic materials- difficult to measure with ARPES

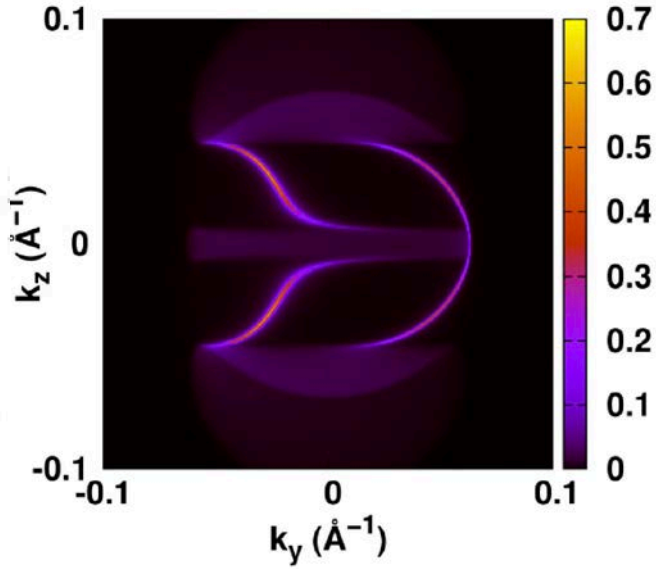
Rn2Ir2O7:

The first proposal to realize WSM (*X. Wan et al., Phys. Rev. B 83, 205101 (2011)*).









HgCr2Se4:

One single pair of magnetic monopoles in the bulk;

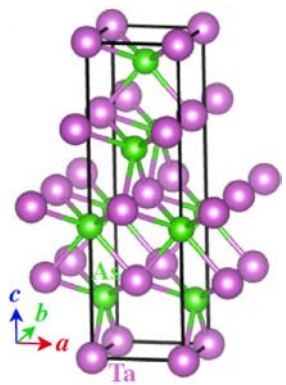
Two Fermi arcs located on each surface side;

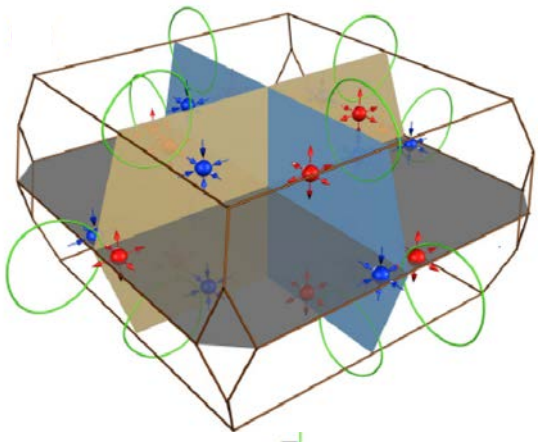
G. Xu et al., Phys. Rev. Lett. 107, 186806 (2011).

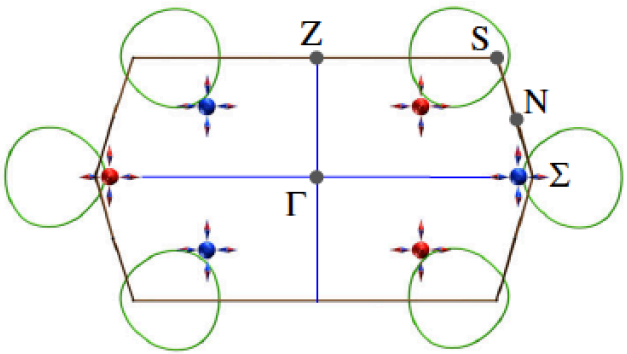
Introduction to Weyl semimetal

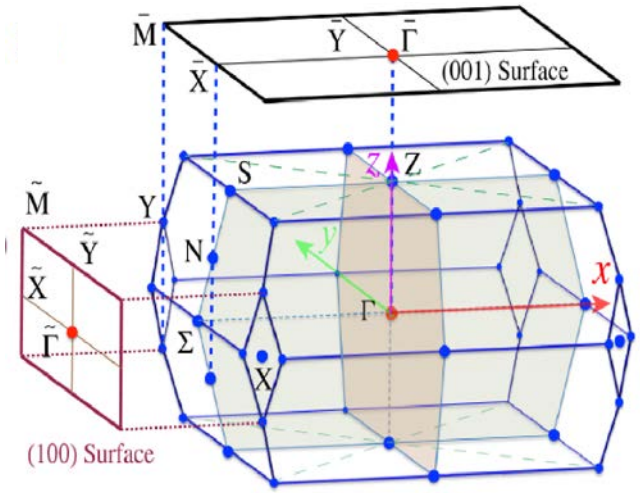
***Breaking* inversion symmetry**

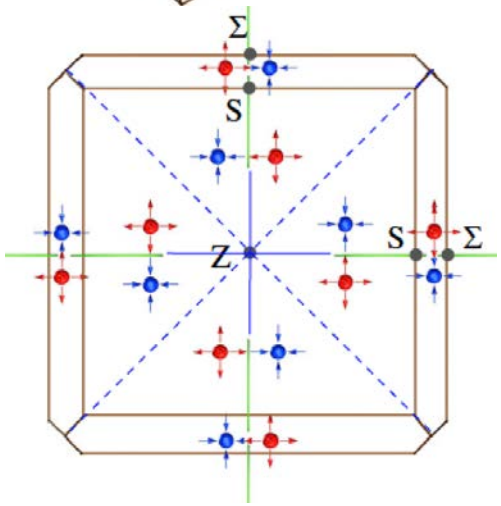
Nonmagnetic materials - ***easy to grow and measure with ARPES***











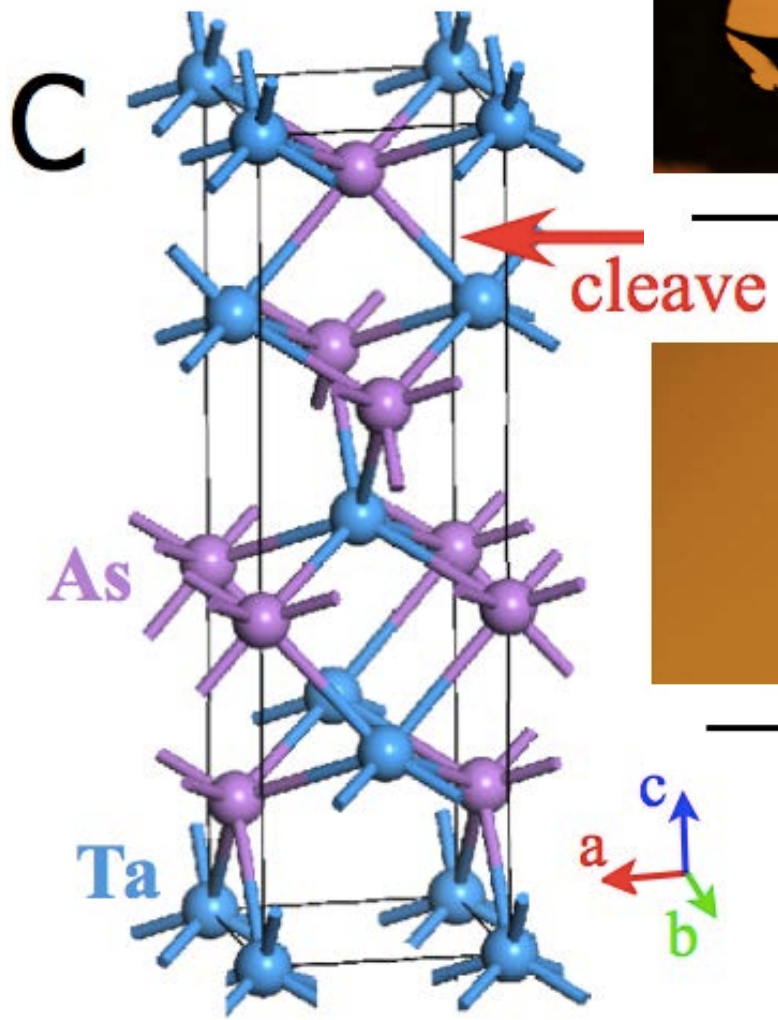
TaAs : 24 Weyl points in the bulk

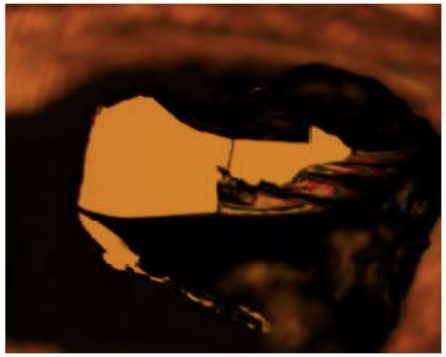
*H.M. Weng et al., Phys. Rev. X **5**, 011029 (2015)*

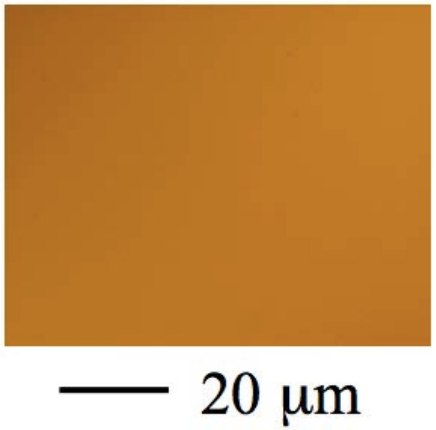
Outline

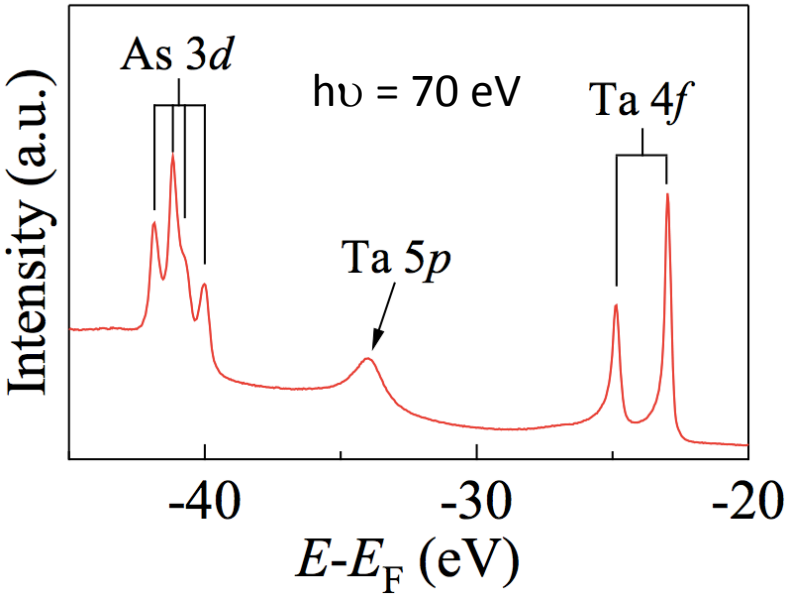
- **Introduction to Weyl semimetal**
- ***Observation of Weyl nodes in TaAs***
- **Observation of Fermi-arc surface states in TaAs**

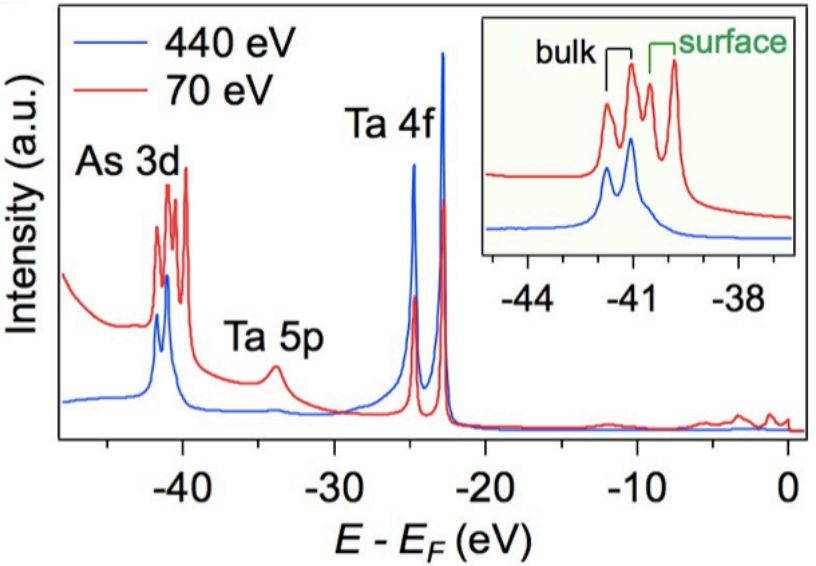
Observation of Weyl nodes in TaAs





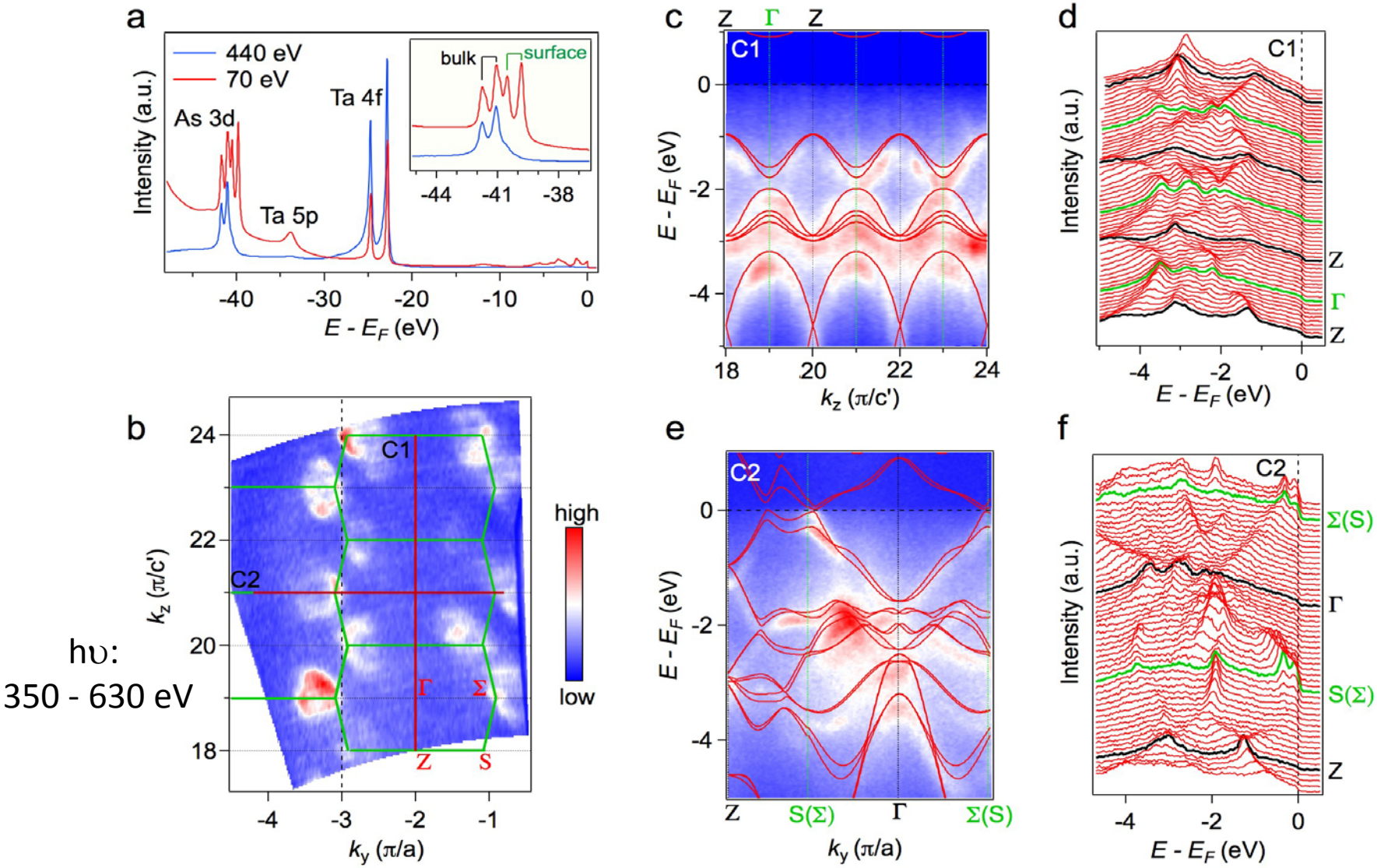






Observation of Weyl nodes in TaAs

Electronic structure in the $k_x = 0$ plane (soft x-ray)

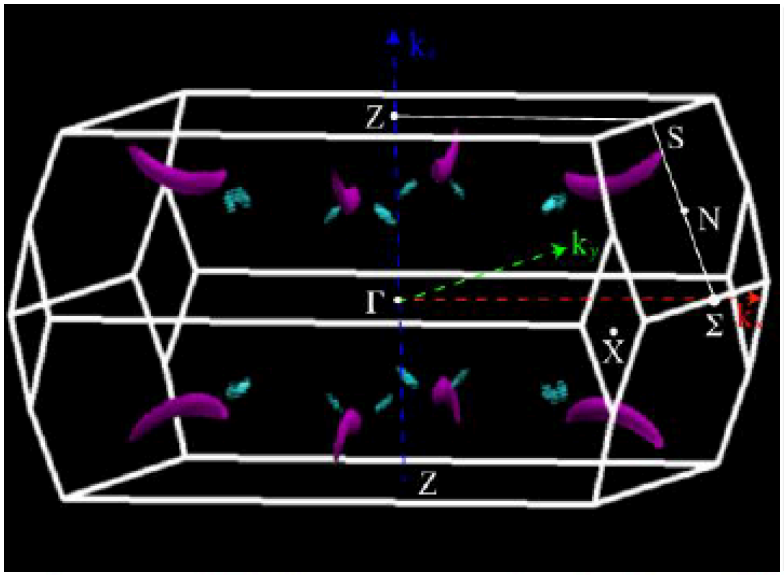


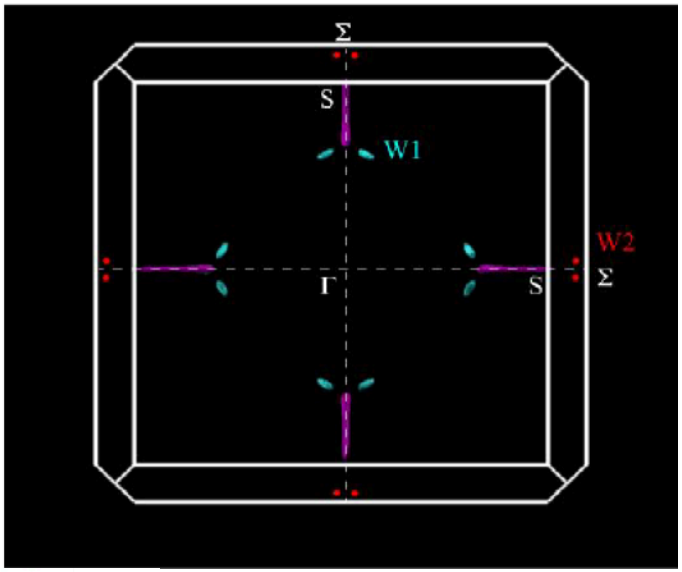
hυ:
350 - 630 eV

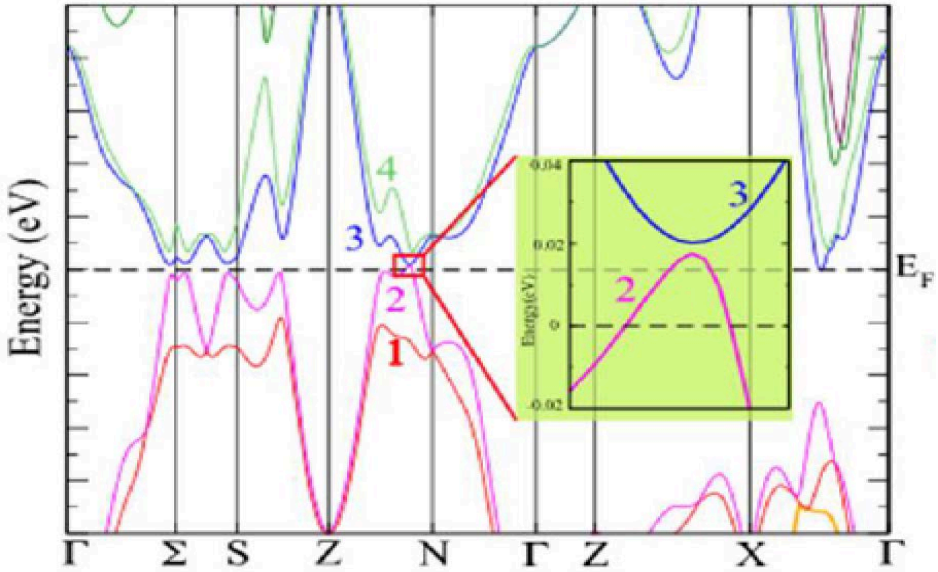
B. Q. Lv et al., arXiv:1503.09188

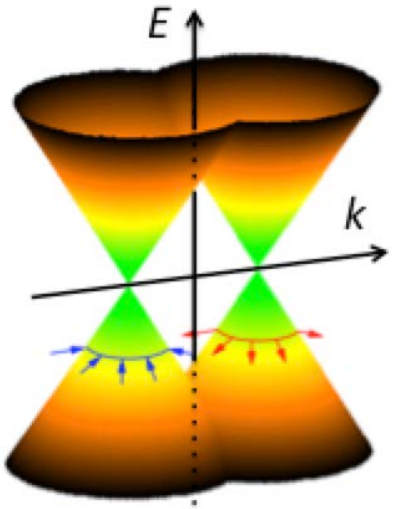
Observation of Weyl nodes in TaAs

Calculation: TaAs has 12 pairs Weyl nodes (8 W1, 4 W2)

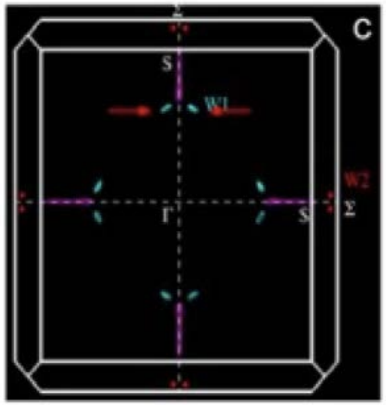




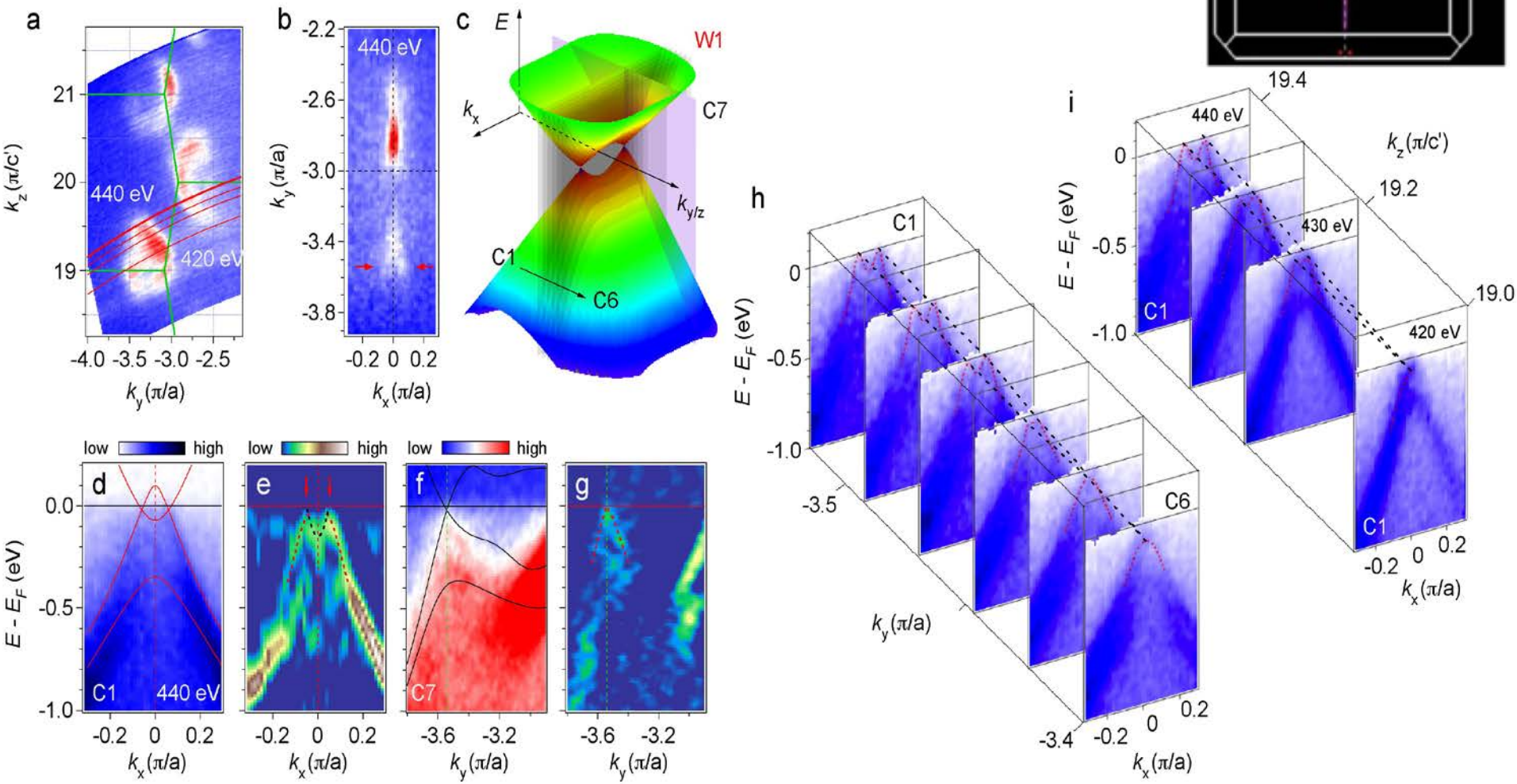




Observation of Weyl nodes in TaAs



Band dispersions near the Weyl nodes W1



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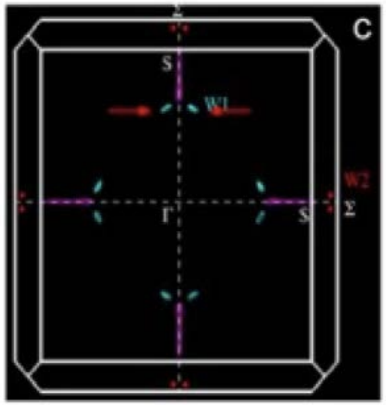
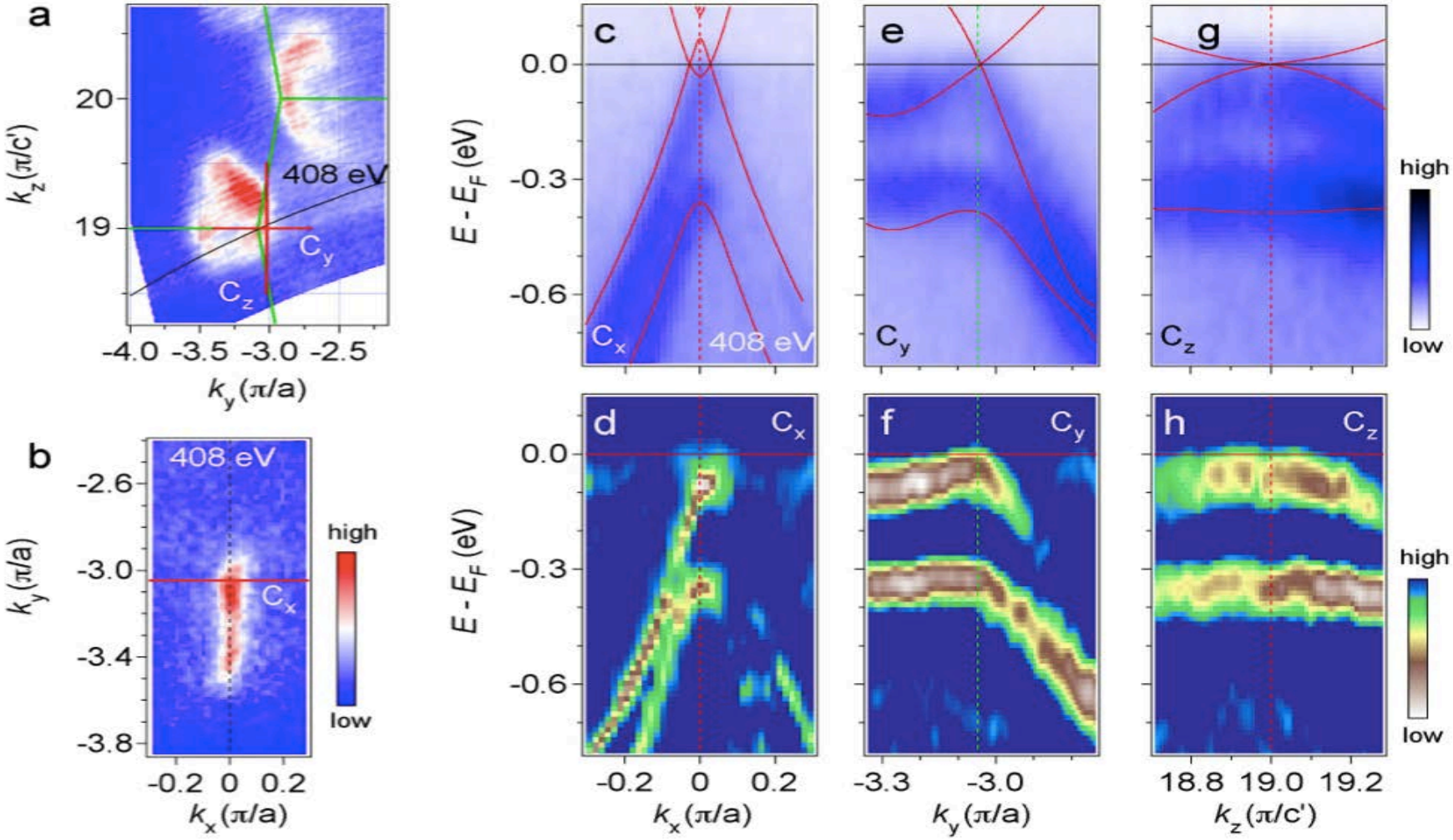
Observation of Weyl nodes in TaAs



Band dispersions near the Weyl nodes W2

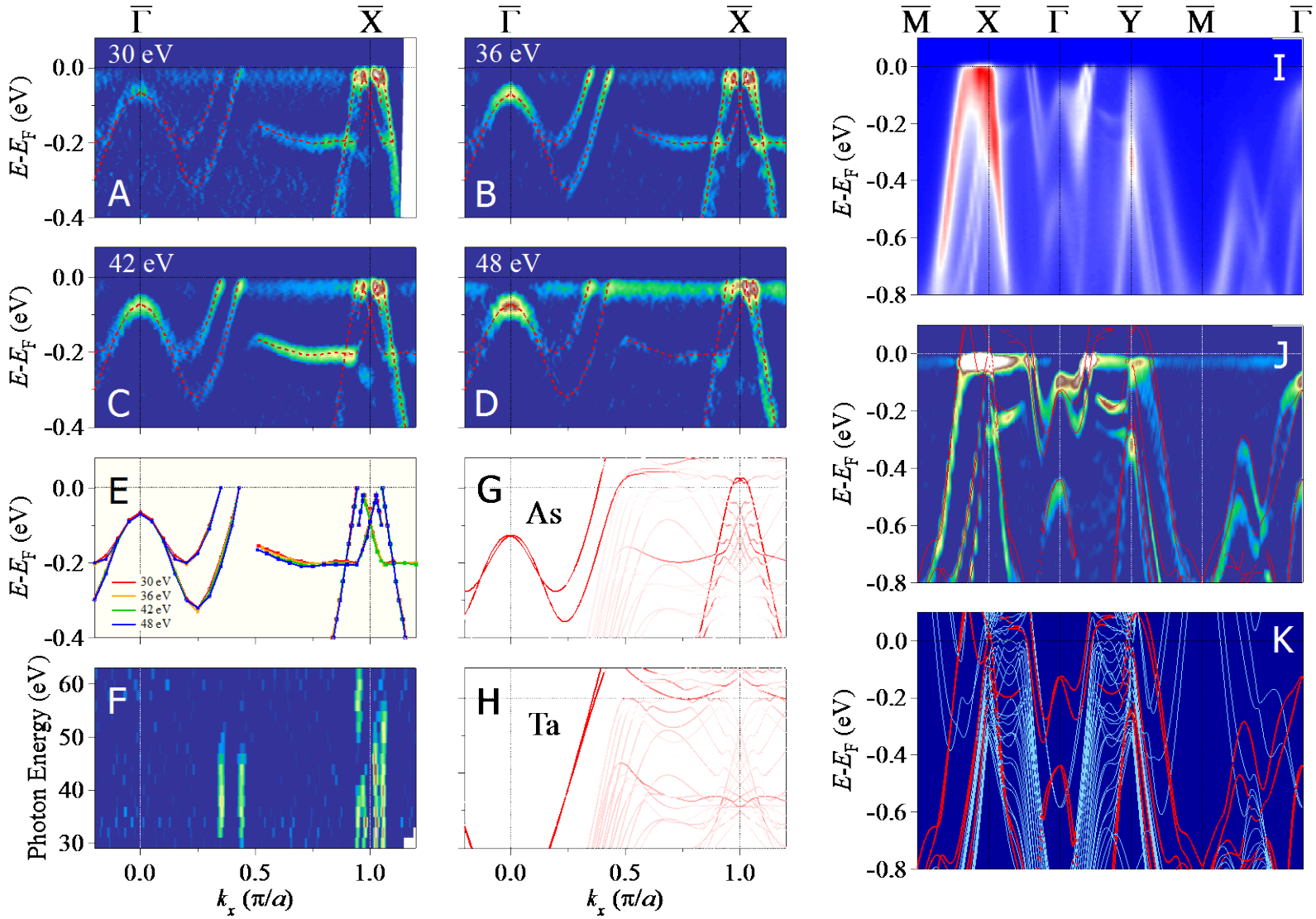


Outline

- **Introduction to Weyl semimetal**
- **Observation of Weyl nodes in TaAs**
- ***Observation of Fermi-arc surface states in TaAs***

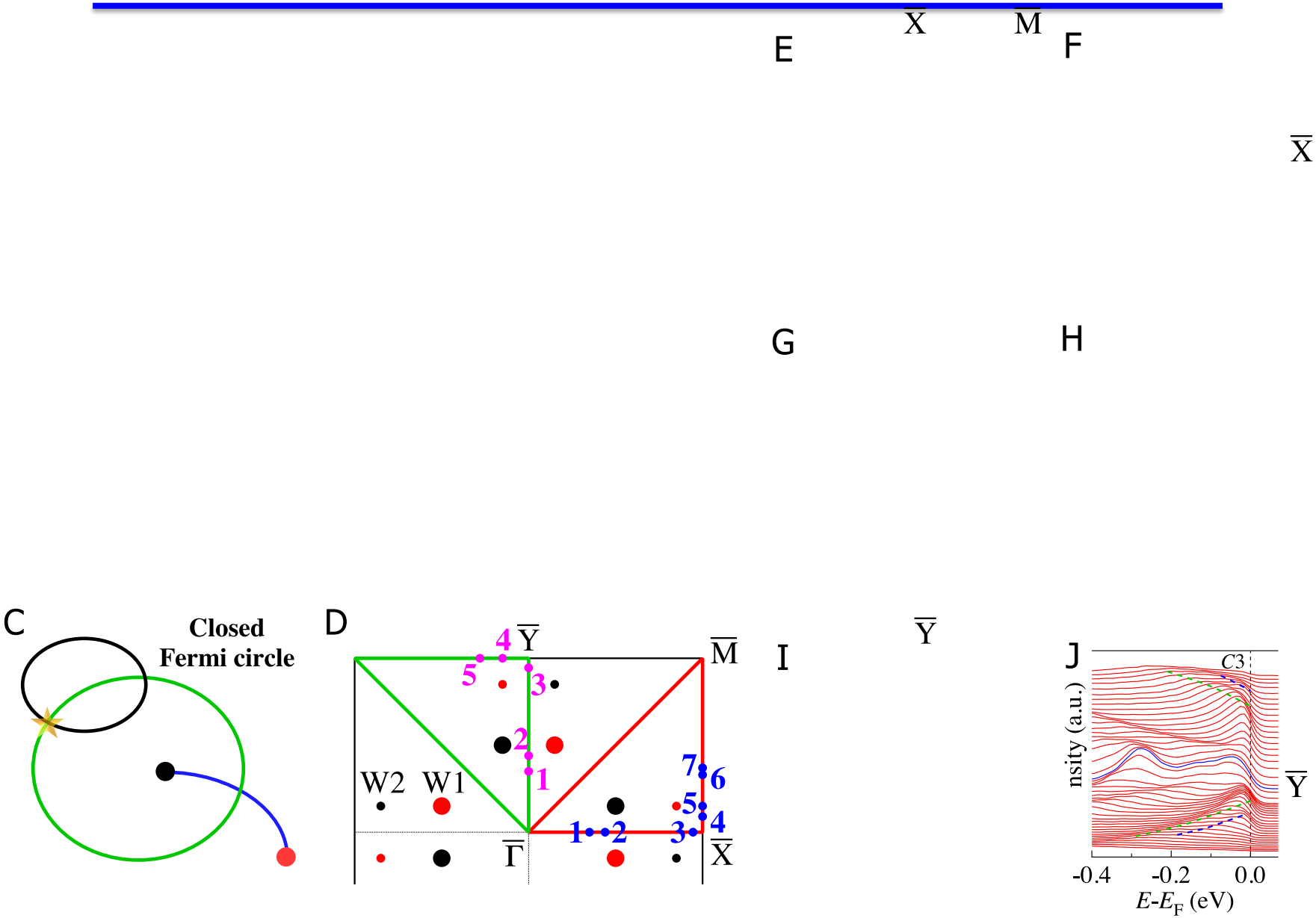
Observation of Fermi-arc surface states in TaAs

Electronic structures on the (001) As-terminated surface BZ (VUV)



B. Q. Lv et al., arXiv:1502.04684

Observation of Fermi-arc surface states in TaAs



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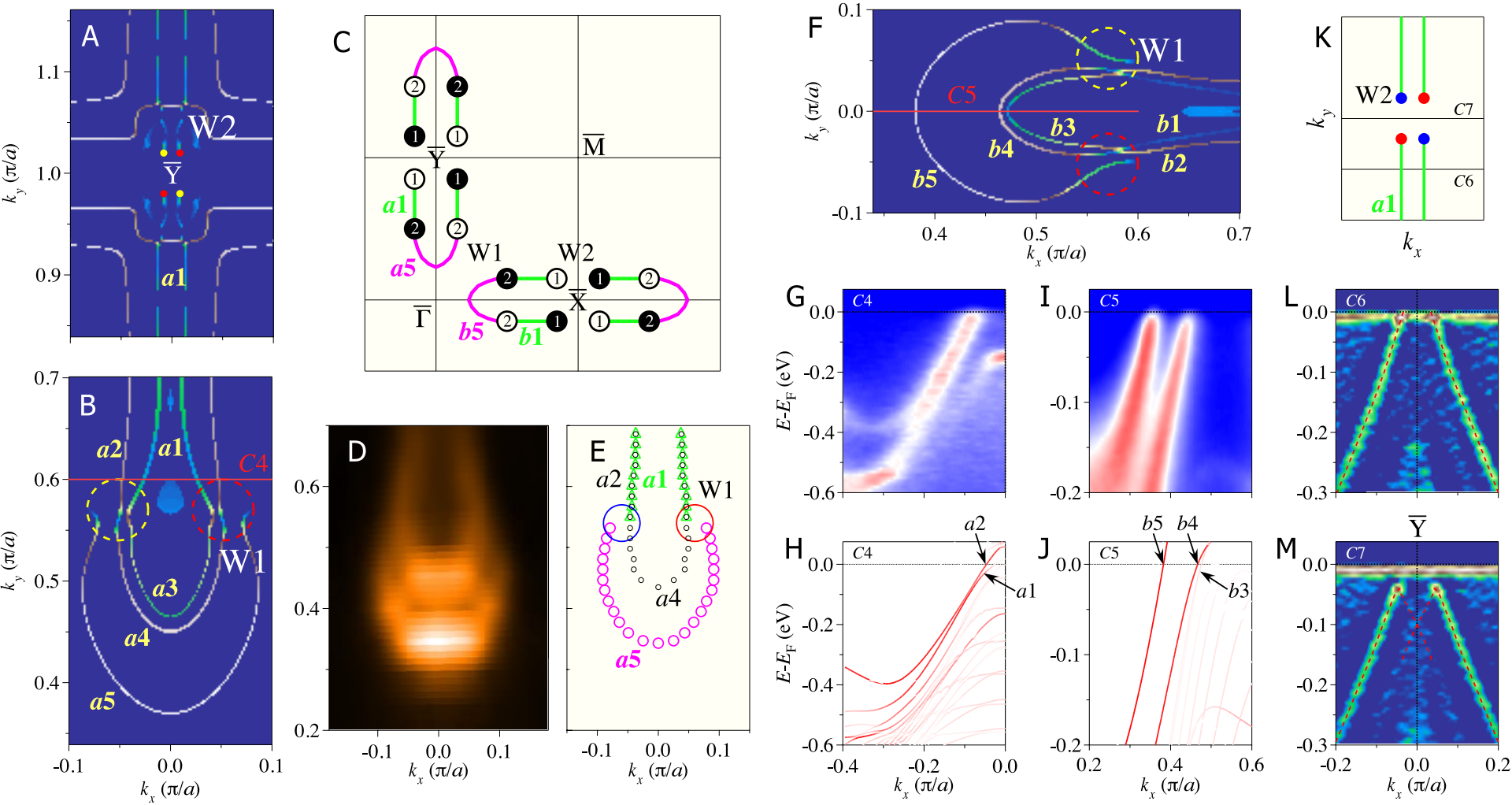
Observation of Fermi-arc surface states in TaAs



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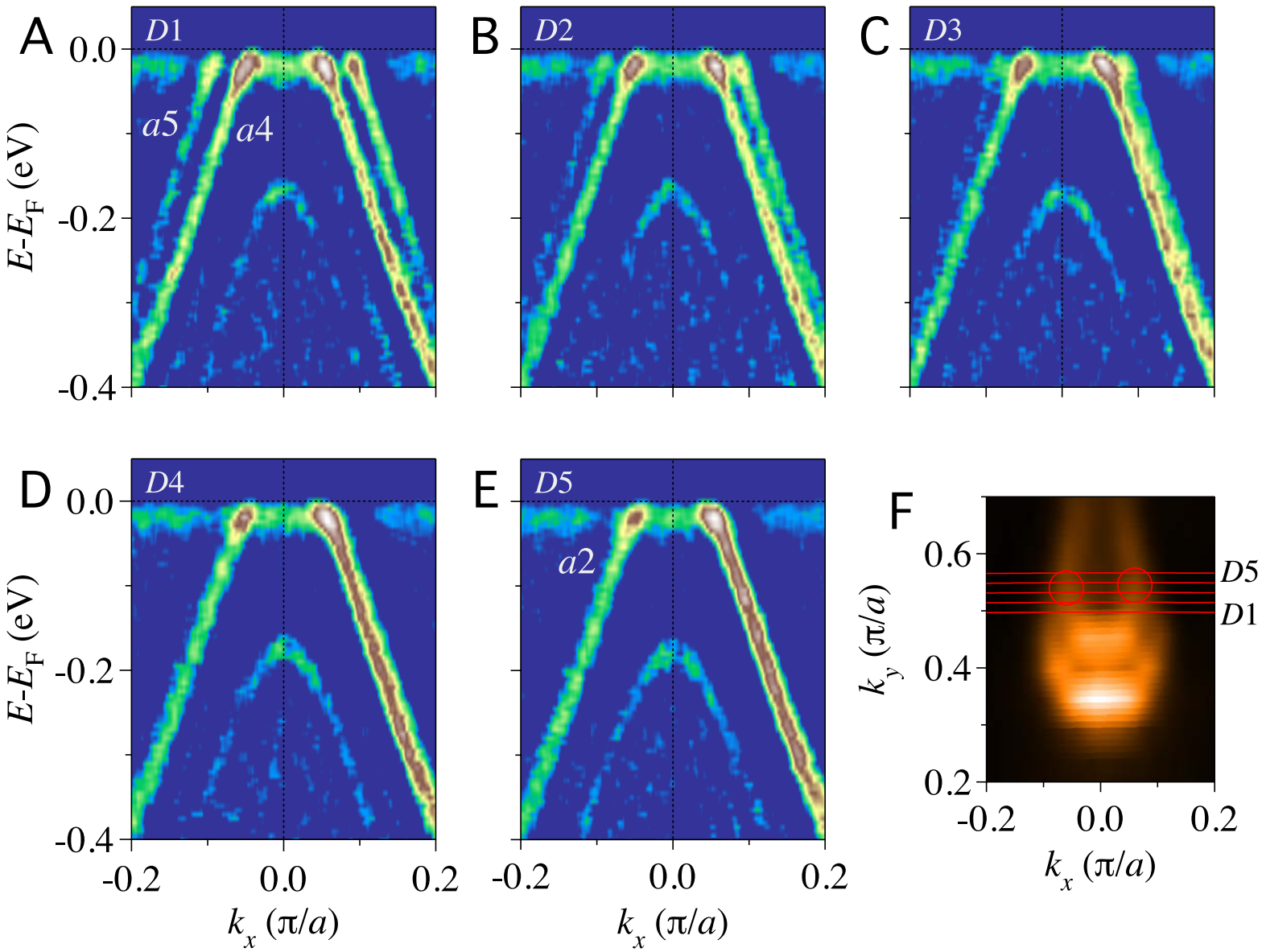
Observation of Fermi-arc surface states in TaAs



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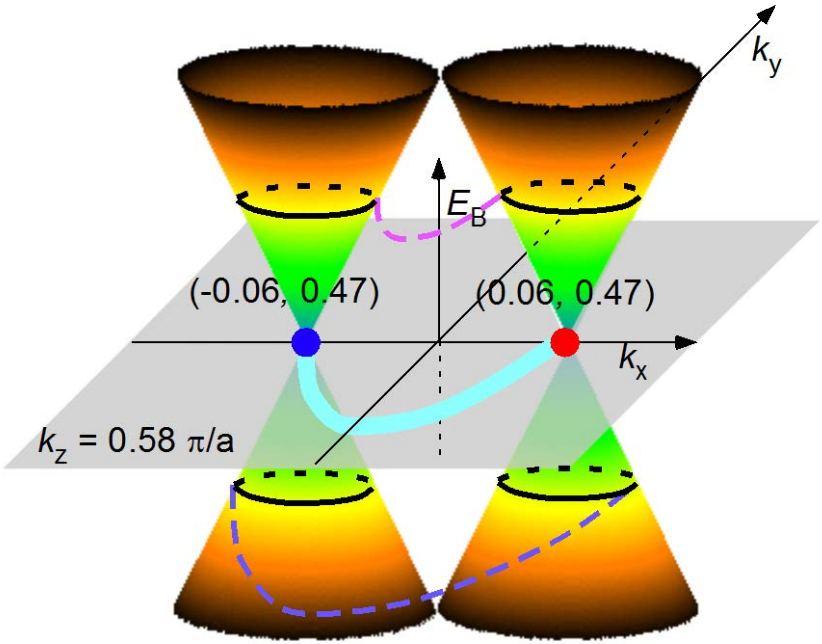
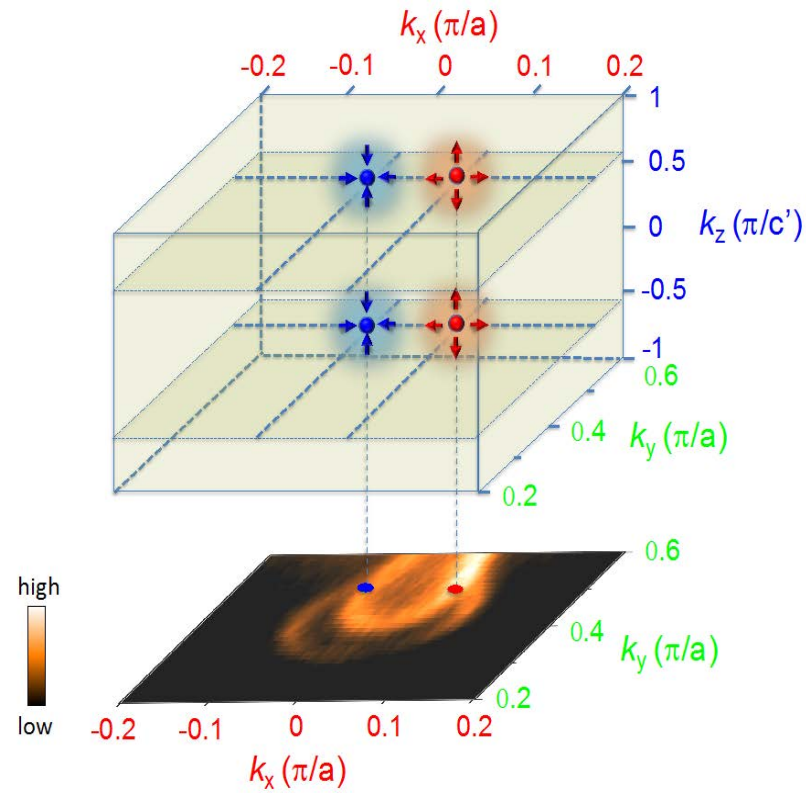
Summary





Weyl semimetal TaAs:

- ***Pairs of Weyl nodes in the bulk***
- ***Fermi arc surface states on (001) As- terminated surface.***

B. Q. Lv et al., arXiv:1502.04684

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