f-electron Fermi surface exclusion above T_K in $CeRu_2Si_2$

Luttinger counting theorem ⇒

f-electrons counted in Fermi surface
IF f-moments quenched.

(no matter what route to Fermi liquid)

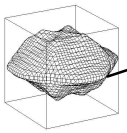
Conjecture (Fulde & Zwicknagl, 1988)

f-electrons **excluded from FS above Kondo temperature T_K**

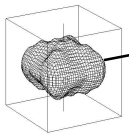
Difficult to test with low-T dHvA.

dHvA paradigm (Tautz et al, 1995)

- **large** Z-point **hole** FS
  - f^0 $LaRu_2Si_2$
  - f^1 $CeRu_2Si_2$ high field (metamag)
  - f^1 $CeRu_2Ge_2$ ferromagnet
- **reduced** "pillow" **hole FS**
  counts ≈ ½ Ce f- electron
  in Kondo $CeRu_2Si_2$
  --at **low temperature**



LDA
"band 4" hole
Fermi surface
no f- electron



≈½ extra f-electron here

(≈½ f-electron in other multiply-connected complex FS piece)

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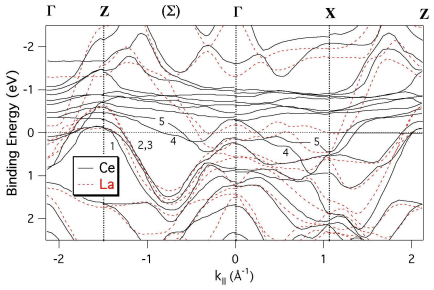
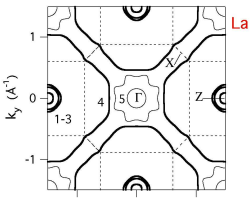
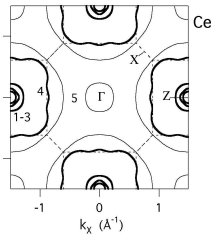
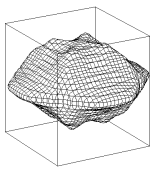
LDA for $LaRu_2Si_2$ and $CeRu_2Si_2$ compared



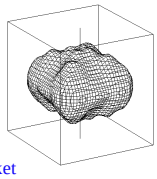




La



Ce



band 4
Z- hole pocket

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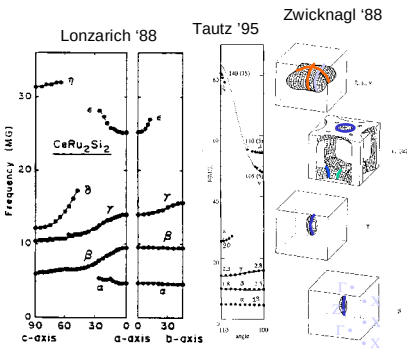
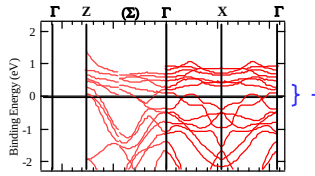
Fermi surface of $CeRu_2Si_2$



	ξ, μ, ν	ε α	δ, γ, β
m^*/m_e	120	20 13	4, 2.5,1.6
C*/T	194	64	

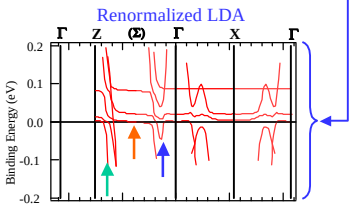
$\gamma = 350$ mJ/mol-K²

Relativistic LDA



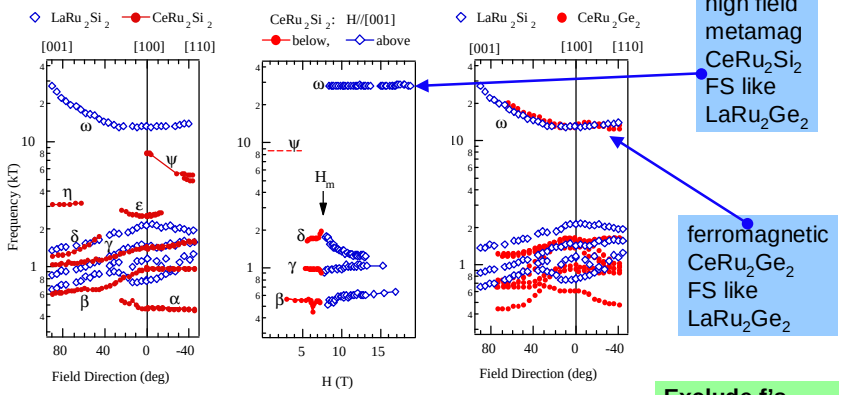
E.K.R. Runge, R.C. Albers, N.E. Christensen & G. Zwicknagl, Phys. Rev B. 51, 10375 (1995).

Renormalized LDA



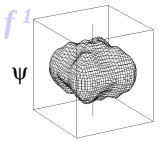
G. Zwicknagl, Adv. Phys. 41, 203 (1992).

Ce Spin State & Fermi Surface of $CeRu_2Si_2$



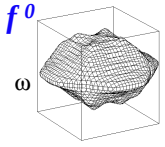
high field metamag $CeRu_2Si_2$ FS like $LaRu_2Ge_2$

ferromagnetic $CeRu_2Ge_2$ FS like $LaRu_2Ge_2$



• $CeRu_2Si_2$: $H<H_m$

& $T<<T_K$



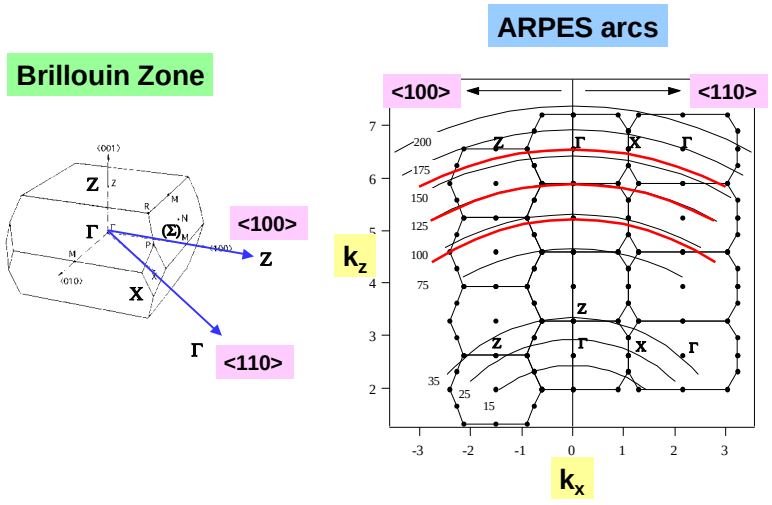
- $LaRu_2Si_2$
- $CeRu_2Ge_2$
- $CeRu_2Si_2$: $H>H_m$

*or $T>>T_K$

Exclude f's from FS for for $T>>T_K$???

*Zwicknagl Physica Scripta T49, 34 (1993)

XRu_2Si_2—3d crystal
k-space arcs for varying photon energy



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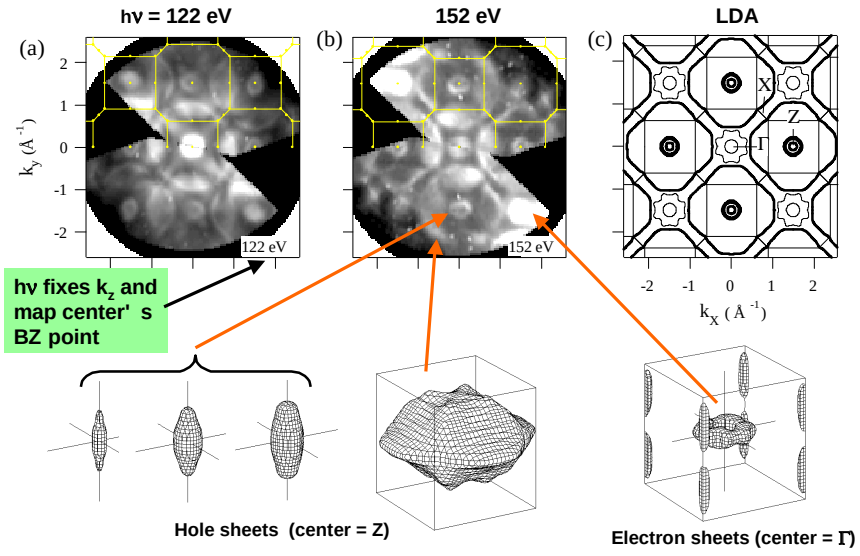
$LaRu_2Si_2$ Fermi surface from ARPES
J.D. Denlinger (data from ALS)



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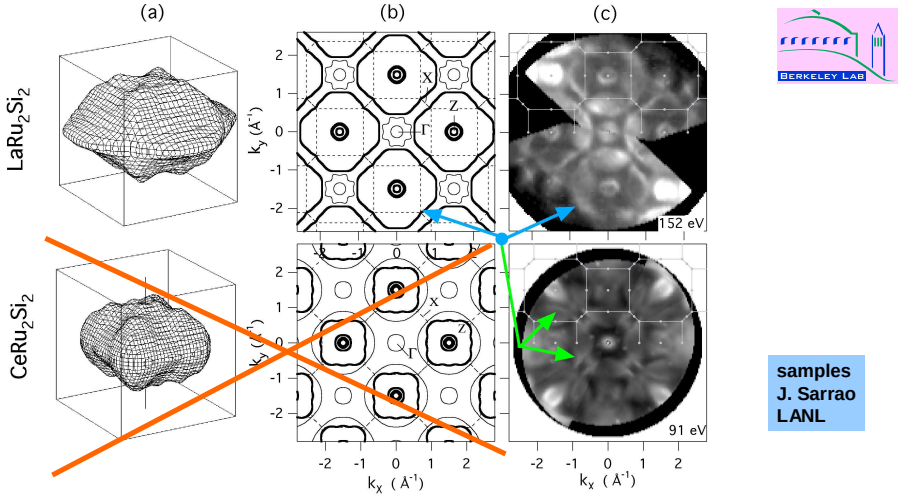
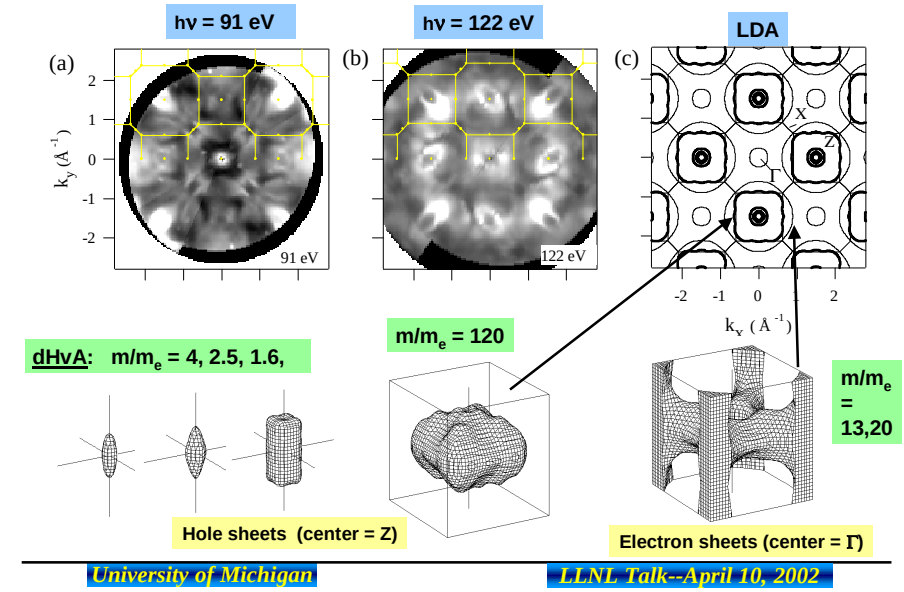
Same large hole FS for $LaRu_2Si_2$ and $CeRu_2Si_2$ for T≈ 120K > $6T_K$

J. D. Denlinger et al, 2001

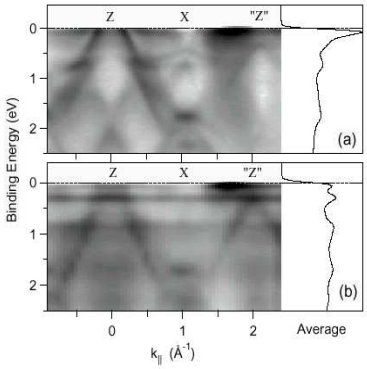


samples
J. Sarrao
LANL

Experimental Fermi Surface — 4f weight at low mass Γ, Z points for $CeRu_2Si_2$



$CeRu_2Si_2$ ARPES good and bad cleaves

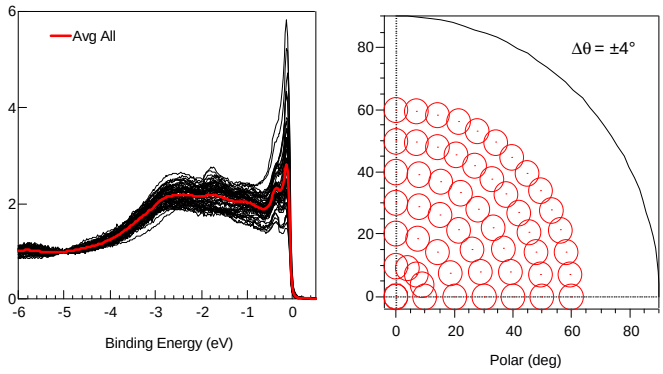


good

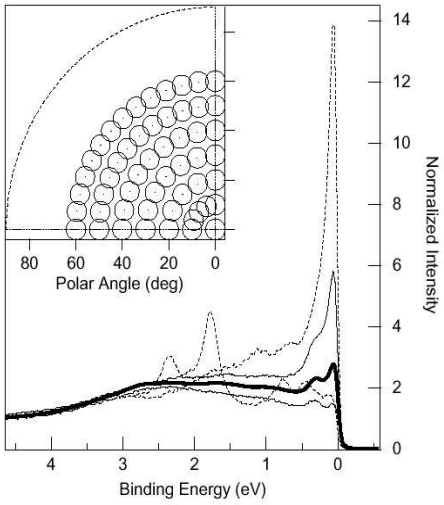
bad

$CeRu_2Si_2$ angle integrated

"Good" surface
angle-integrated 4d RESPES from ARPES
53 angles, normalize at 5 eV, average



Surface effect in $CeRu_2Si_2$



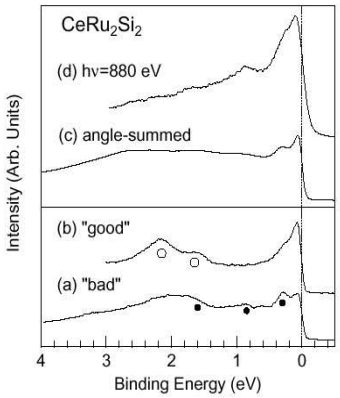
Bold—angle summed spectrum

Solid lines—extremum behavior of this data set

Dashed lines—extremum behavior in set with better angle resolution

Low hν OK for $CeRu_2Si_2$

Evidence that bulk behavior can be seen in 4d RESPES of <u>this</u> material



(d) Ce 3d edge RESPES with 0.2 eV resolution (consistent with SPring8 data)
(c) angle summed 4d edge RES-ARPES

(a) and (b) ARPES from center of normal emission Z-point

Denlinger et al, SCES'01 proceedings

$CeRu_2Si_2$ why bulk at low hν?

- **Crystal structure admits two cleavage planes, with and without Ce**

"Good cleaves" probably from surface without Ce.

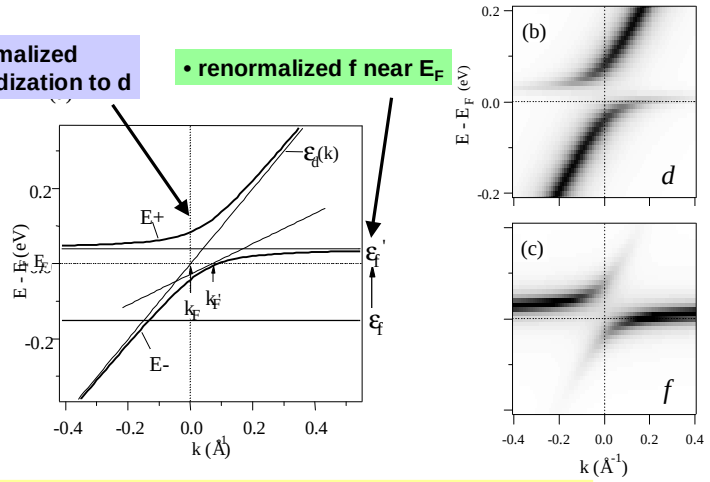
I.e., buried active layer—important for cuprates

- **Really flat surface missing edges and steps, less "surface sensitive.**

Anderson Lattice Model
2-band low energy ansatz

• renormalized hybridization to d

• renormalized f near E_F



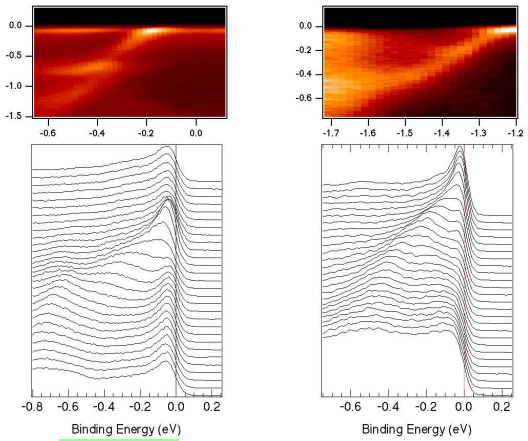
Qualitatively similar to LDA for $CeRu_2Si_2$ possible origin of success for LDA FS of Ce materials

f-d mixing

$CeRu_2Si_2$ (122 eV, ~Z)

URu_2Si_2 (108 eV, ~X)

J. D. Denlinger et al, 2001 samples: Maple, Fisk, Sarrao



4f, γ=350

5f, γ=180