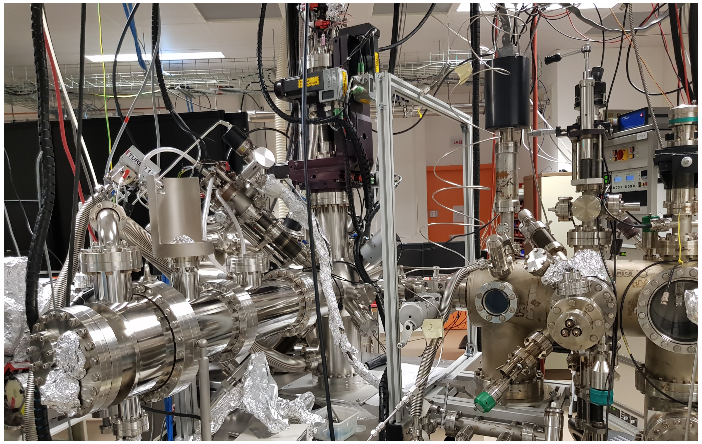
First solid-state photoemission experiments on the FAB10 beamline

LPMS, Université de Cergy-Pontoise,
DSM, IRAMIS, SPEC, CEA-Saclay



M. C. Richter, O. Heckmann, K. Hricovini
W. Ndiaye, M. Fancuilli, M. Lee
J. Schusser, Z. El Youbi, E. Boiakinov, F. Alarab

L. Nicolaï , J.-M. Mariot, C. Cacho, J. Minar, M. Battiato...

*** time and spin resolved ARPES**

*** Attolab NB Beamline characterisation**

*** Transion Metal DiChalcogenides**

*** electron spin dynamics, proof of half metallicity:**

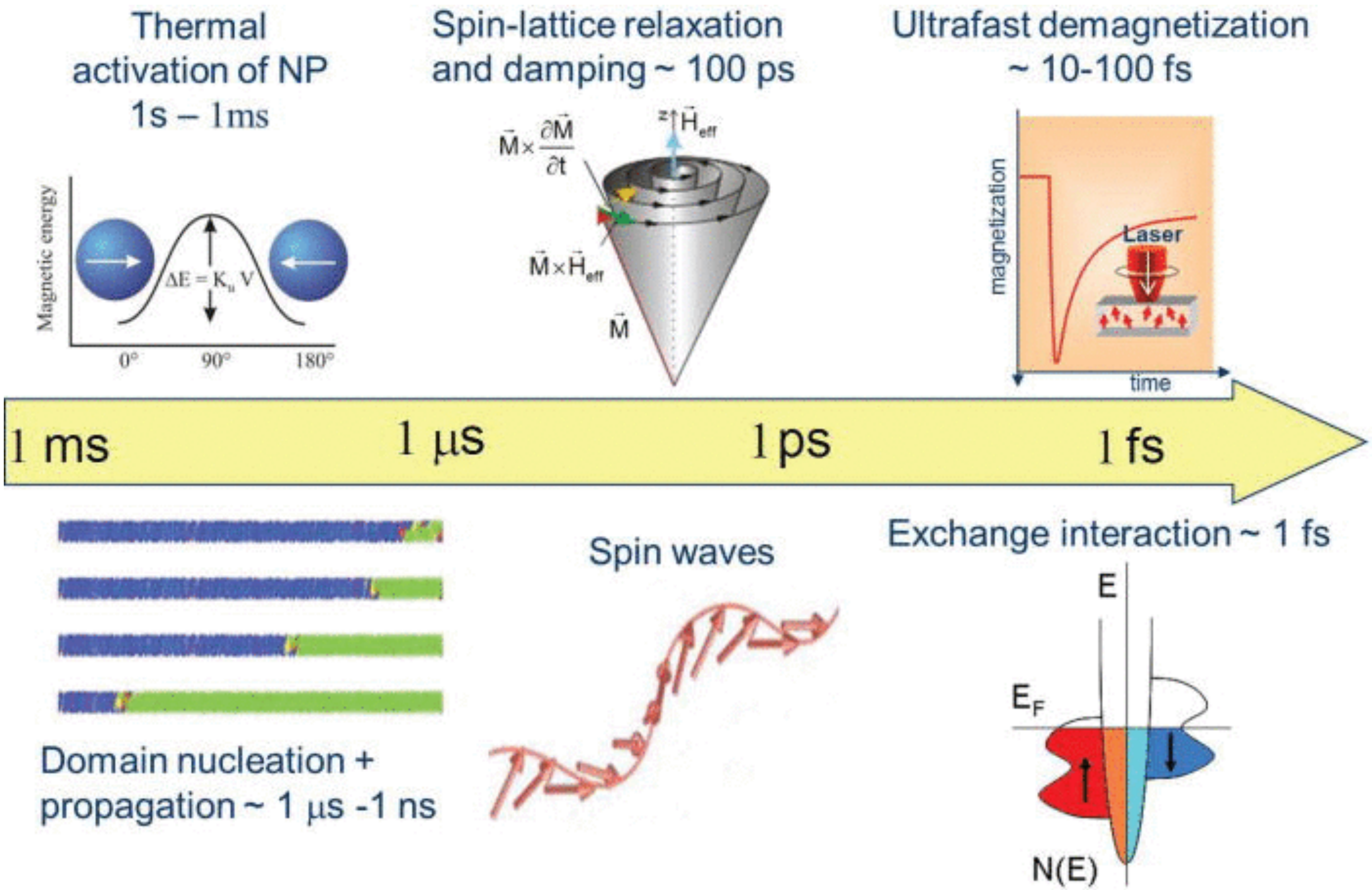
application to $La_{0.7}Sr_{0.3}MnO_3$

*** ultrafast demagnetisation of Fe(001)**

*** spin measurement and Rabbit**

time and spin resolved ARPES

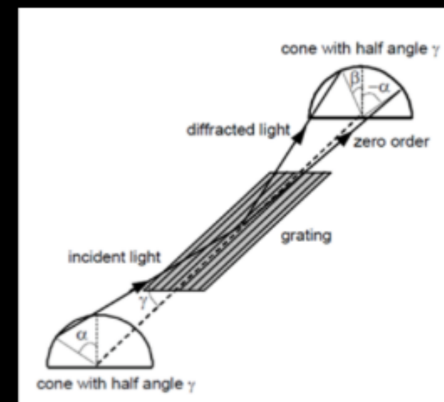
timescales in magnetism

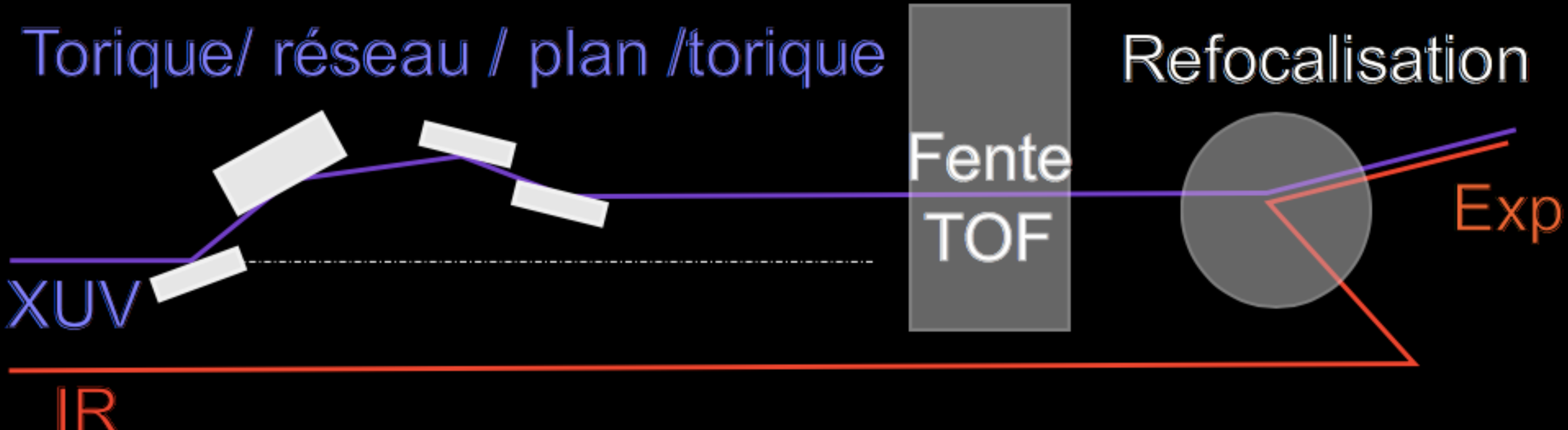


Zabel JAP 2014

Ligne de lumière NB

- Spectre étroit (0.1 eV FWHM)
- Durée 20-30 fs
- 3 réseaux (couvrent de 30 à 100 eV)
- Pompe IR externe
- Stabilité de 100 nm



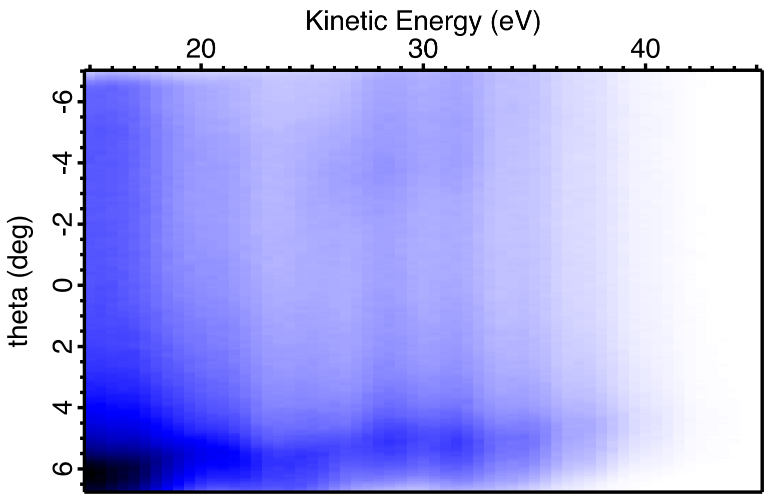


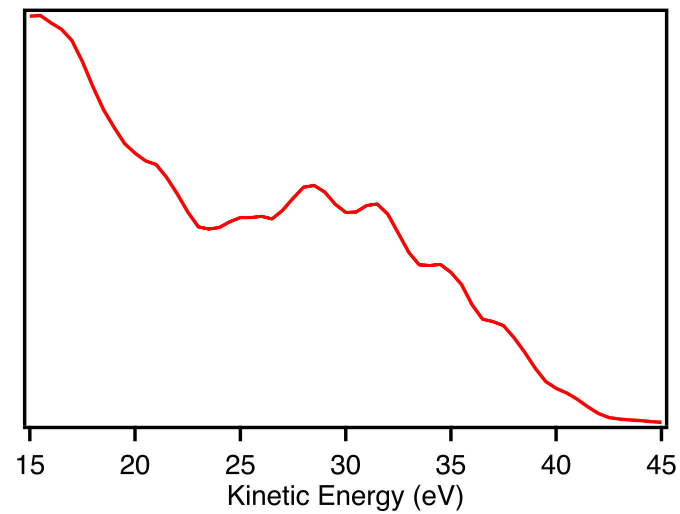
beamline characterisation

with Au (111)

9 Novembre: HHG photons arrivent

without grating





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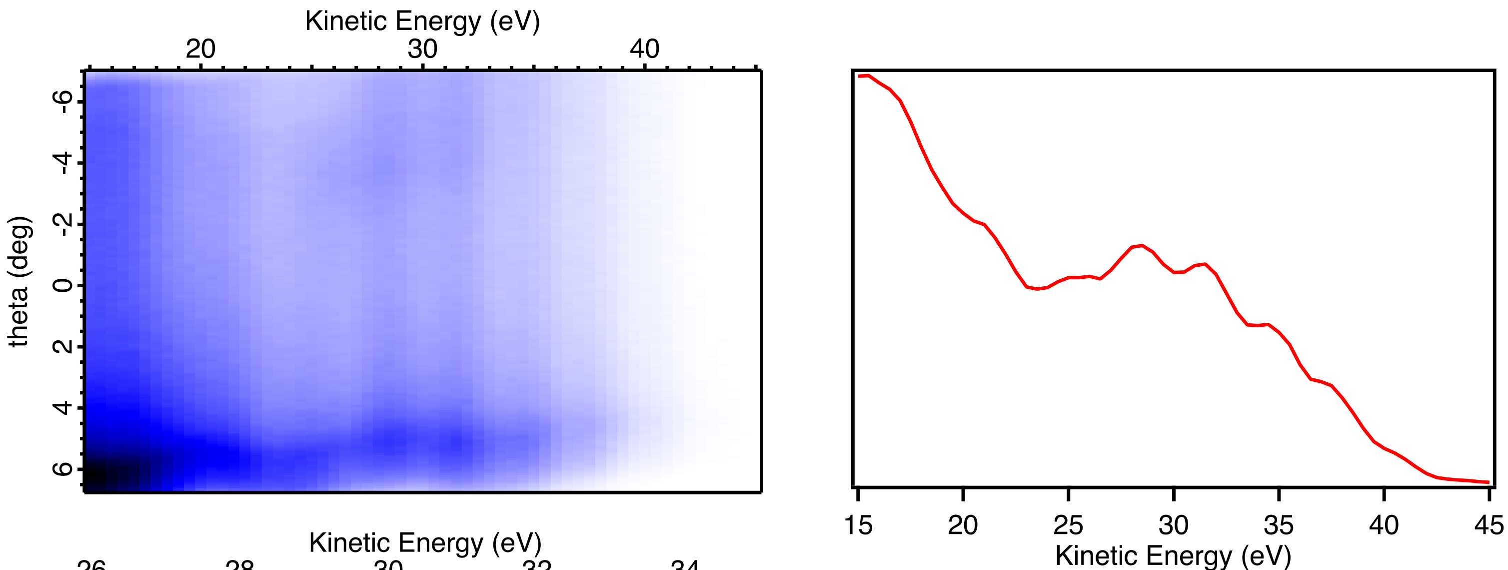
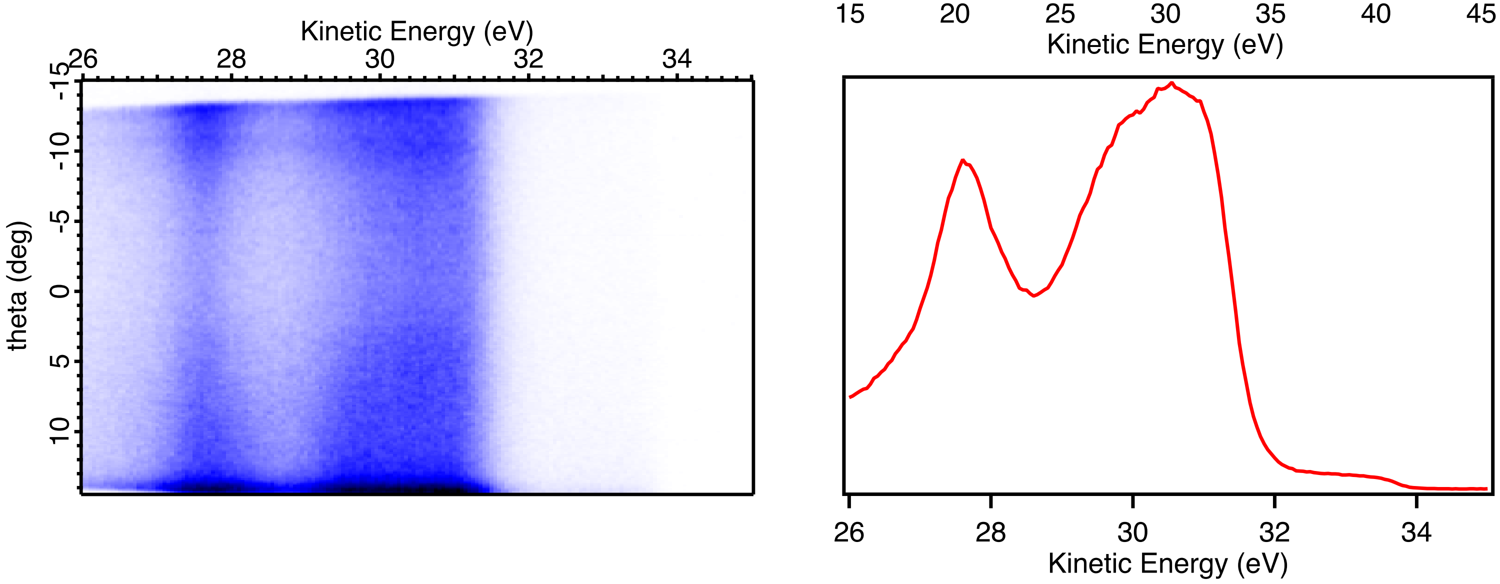
without grating



with grating



beamline characterisation

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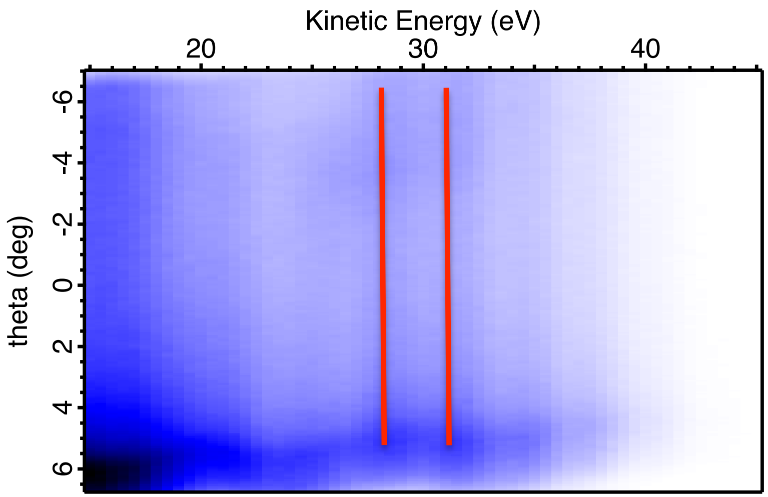
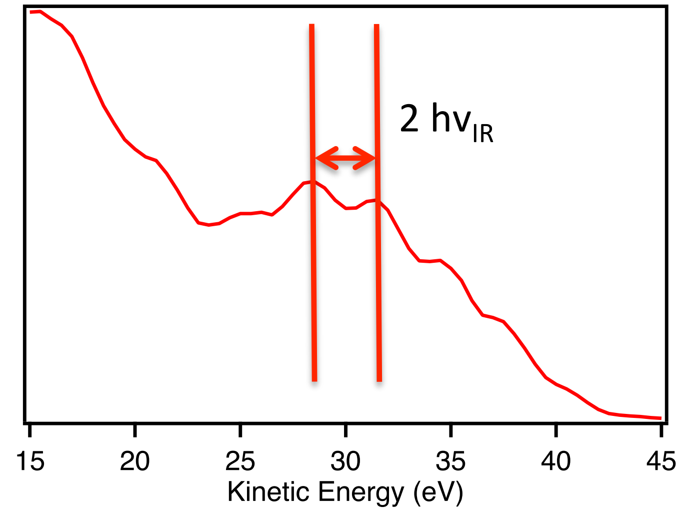
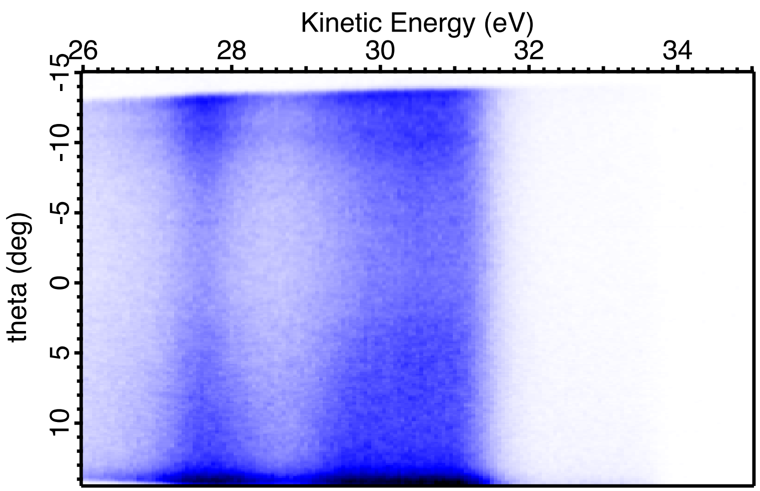
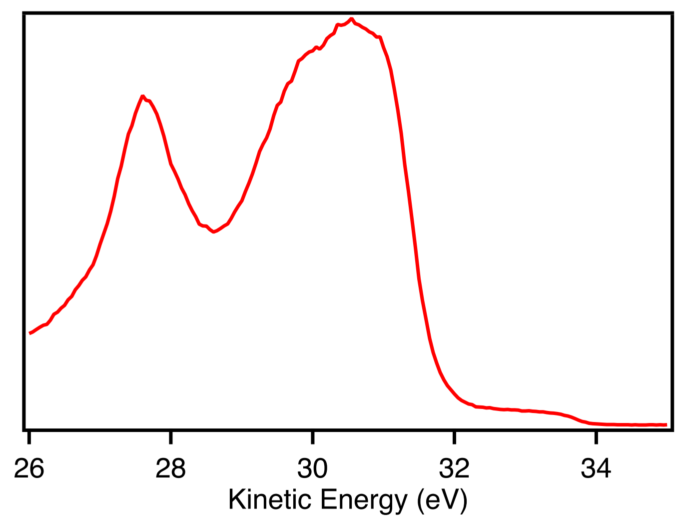


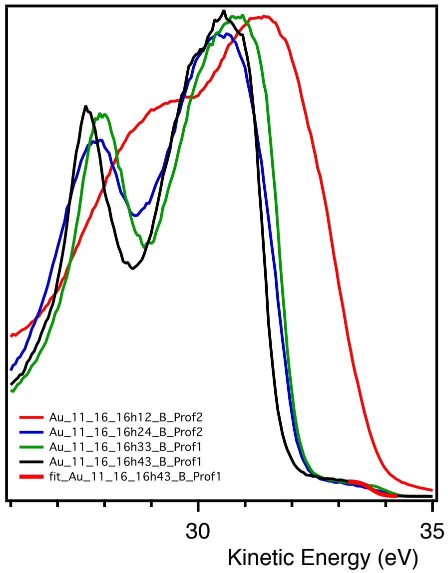


with grating



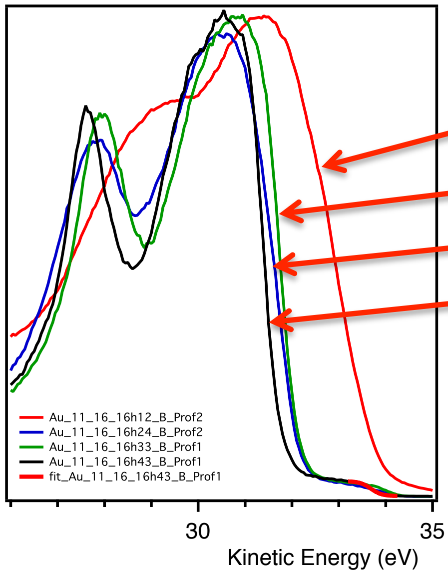


beamline characterisation



beamline characterisation

space charge



beamline exit slits

200 μm

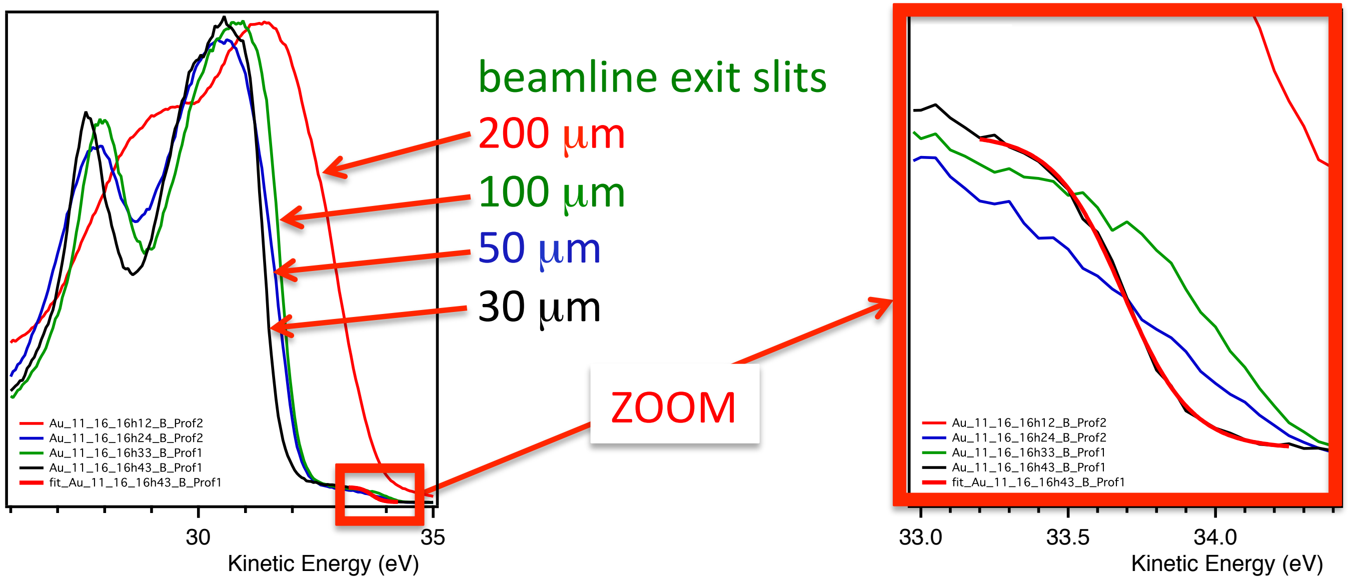
100 μm

50 μm

30 μm

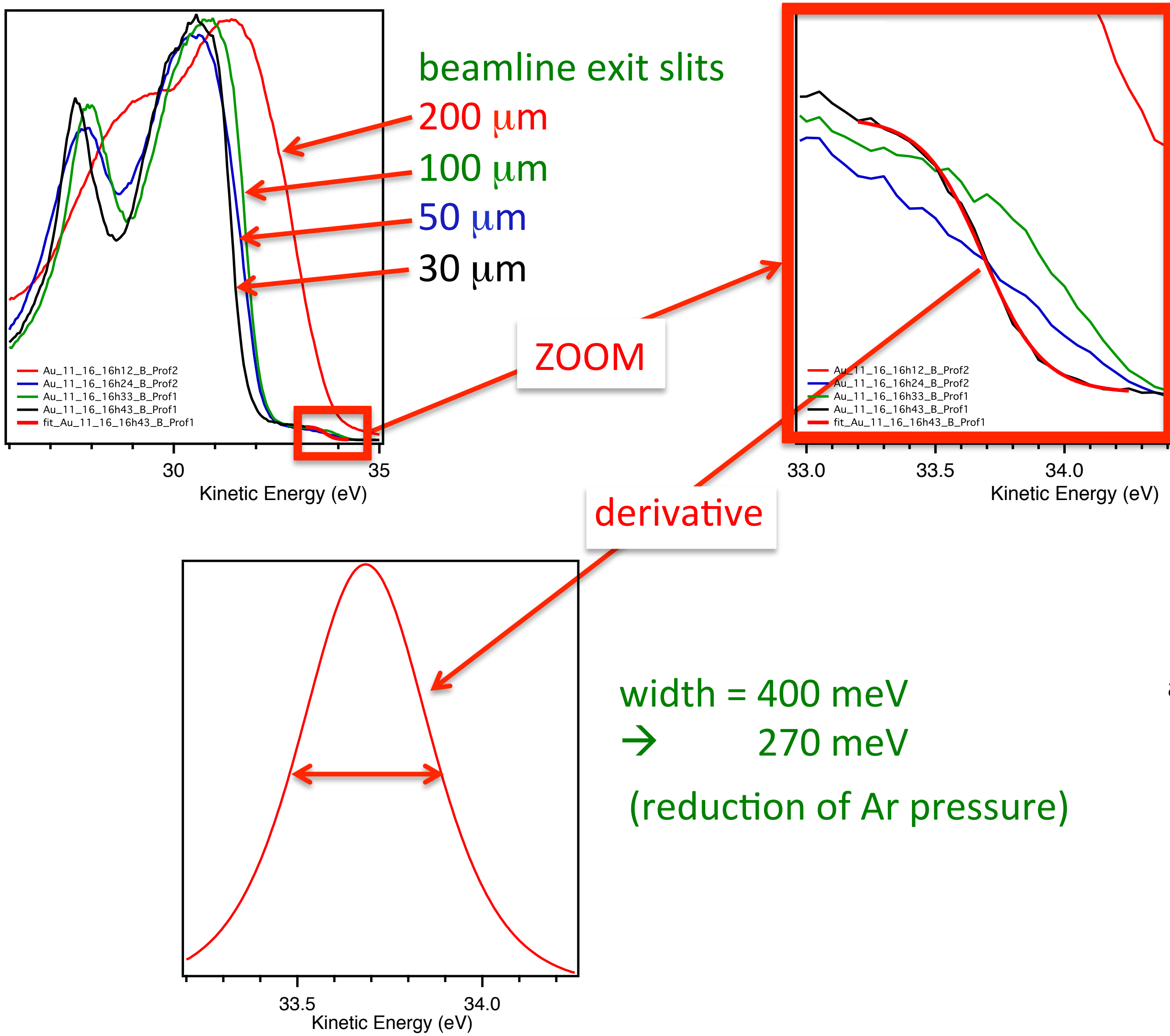
beamline characterisation

space charge



beamline characterisation

space charge



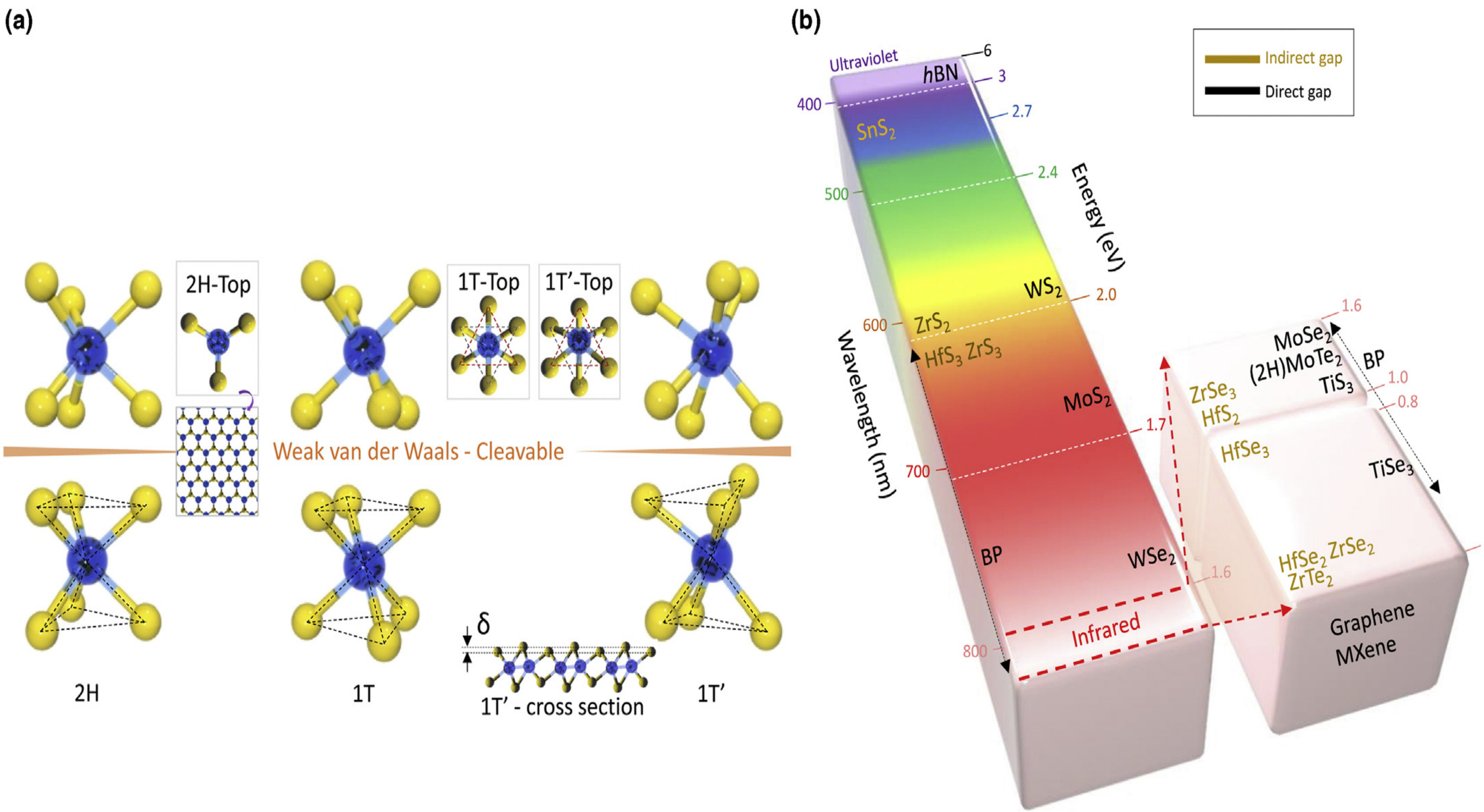
width = 400 meV

→ 270 meV

(reduction of Ar pressure)

analysis:
Ep = 5eV, slit 2

Transion Metal DiChalcogenides



Transion Metal DiChalcogenides

application:

flexible nanotechnology
thin film transistors, displays, sensors, transducers,
solar cells
energy storage

heavier elements: W, Hf

strong spin– orbit coupling (SOC), strong spin-valley coupling

fundamental interest:

WTe_2 is a type-II Weyl semimetal
Dirac cone , spinpolarized Weyl points

heterostructures

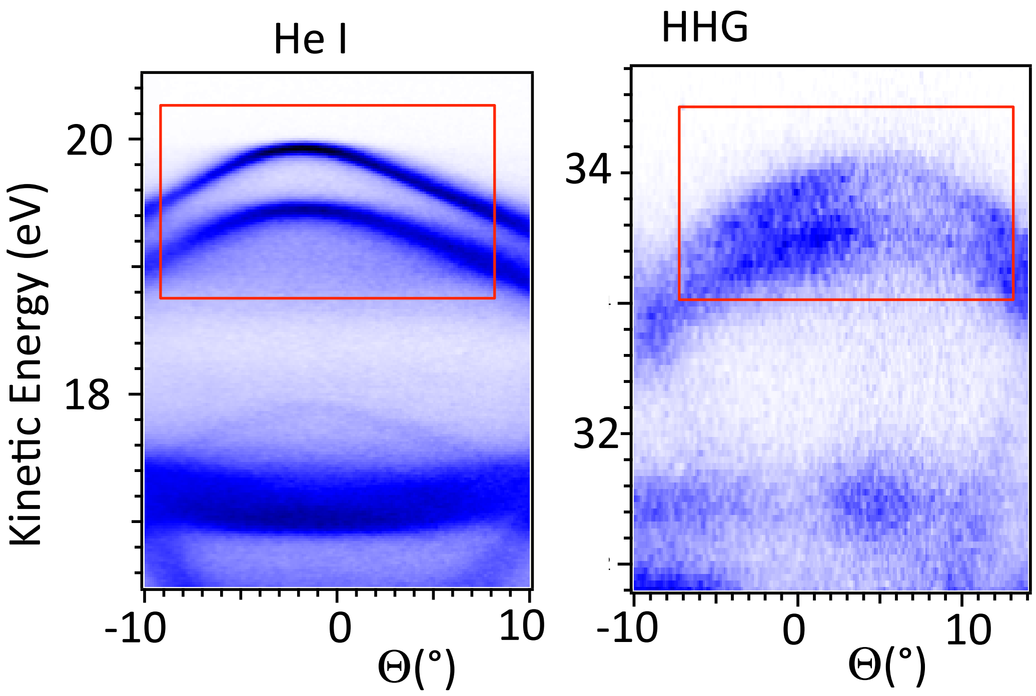
2D semiconductors embedded in a van der Waals-bonded heterostructure

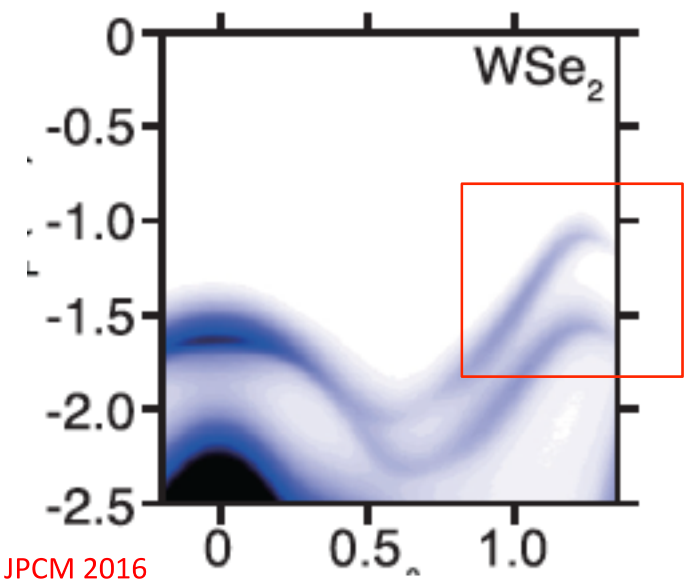
Transion Metal DiChalcogenites

Premiers tests sur la ligne FAB 10

photoémission angulaire
monochromateur narrow band

WSe_2 cristal, clivage sous vide



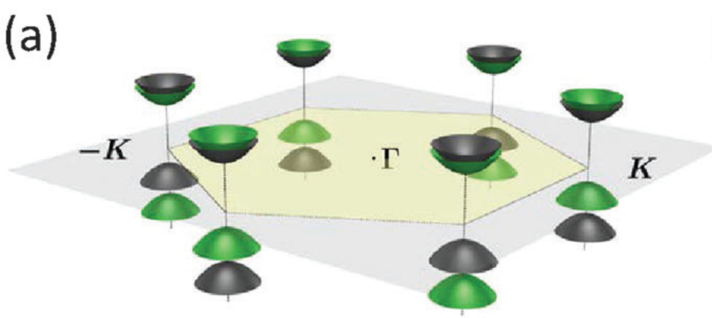


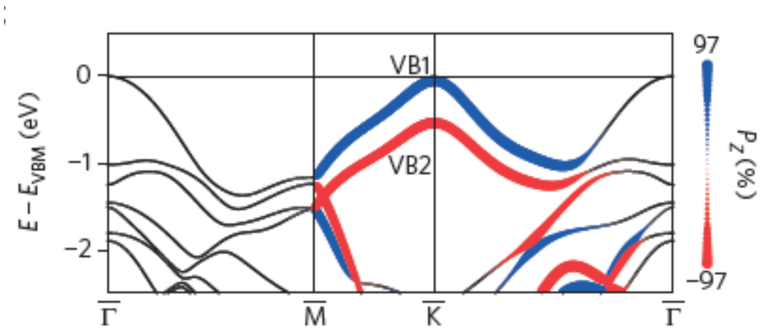
Mo et al. JPCM 2016

Transion Metal DiChalcogenides

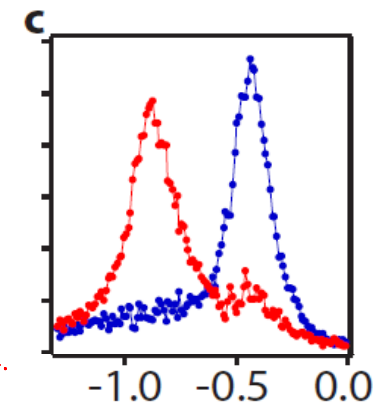
TMDCs (WSe_2, WTe_2 , $HfTe_2$) are very interesting candidates to explore their different degrees of freedom (valley pseudospin, layer pseudospin and spin).

- strong spin-orbit coupling (spin-polarization at the K point)





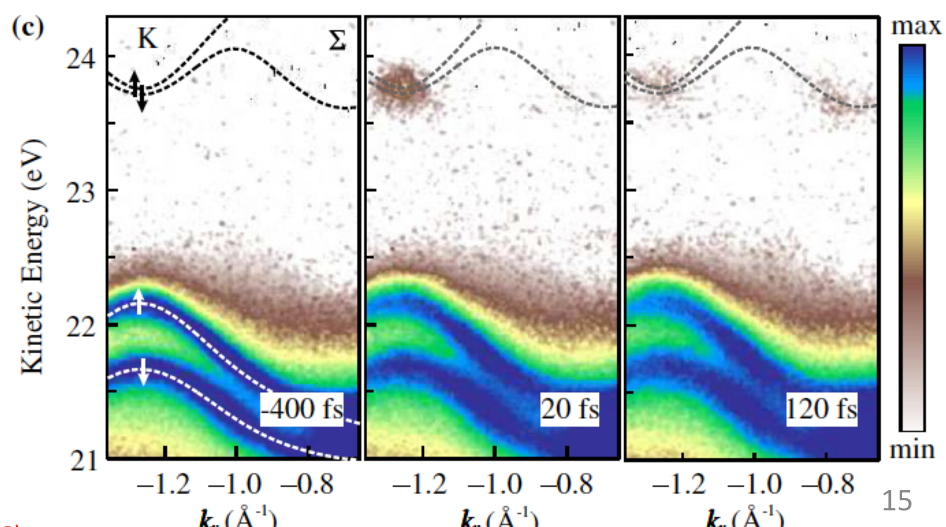
J. M. Riley et al., *Nat. Phys.*, vol. 10, no. 11, pp. 835–839, 2014.



WSe_2

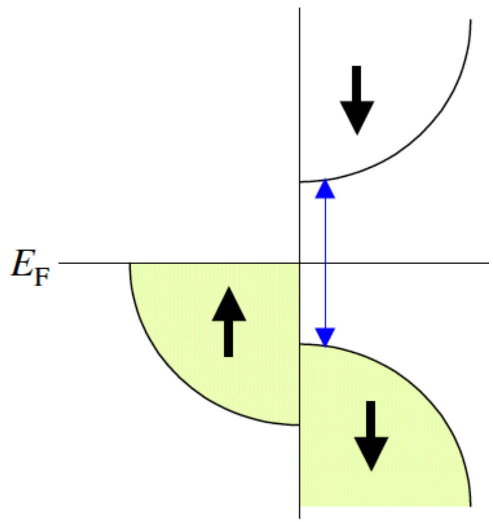
- valley structure of the conduction band makes the electron dynamics particularly interesting

pump-probe experiment



R. Bertoni et al. PRL 117, 277201 (2016)

electron spin dynamics, proof of half metallicity: application to Fe_3O_4



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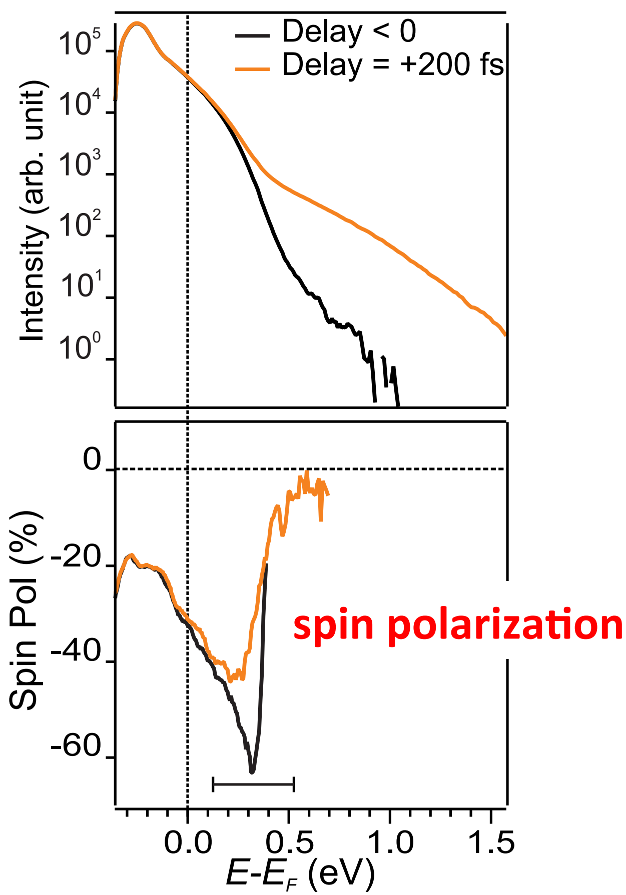
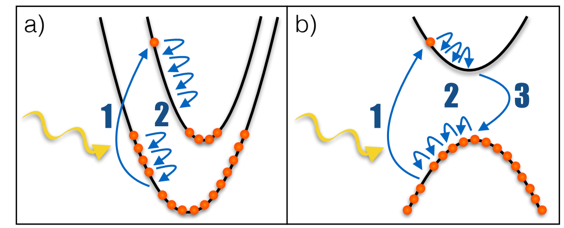
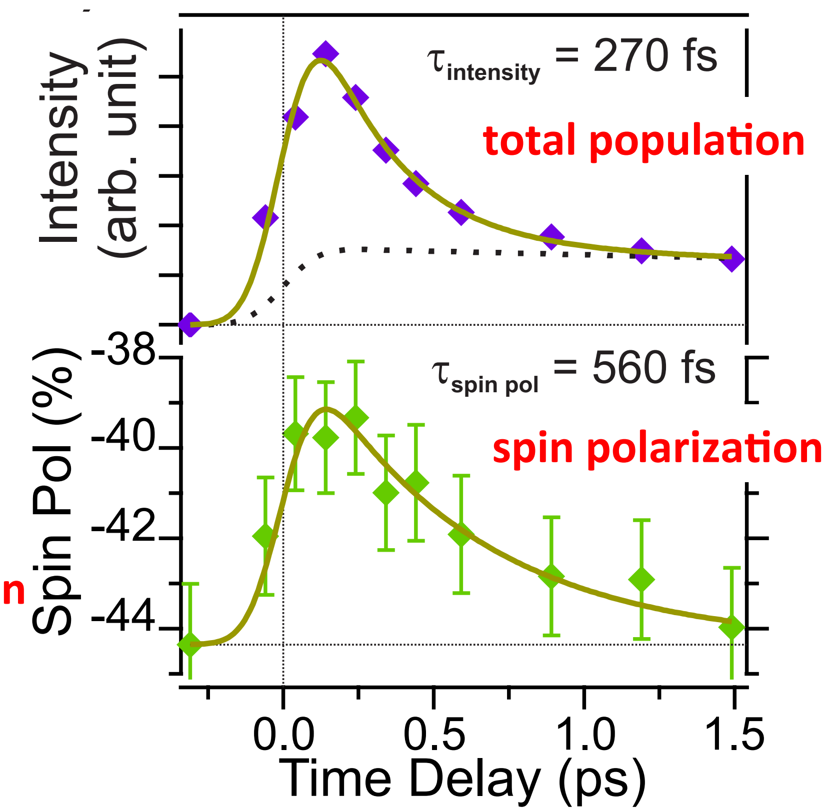
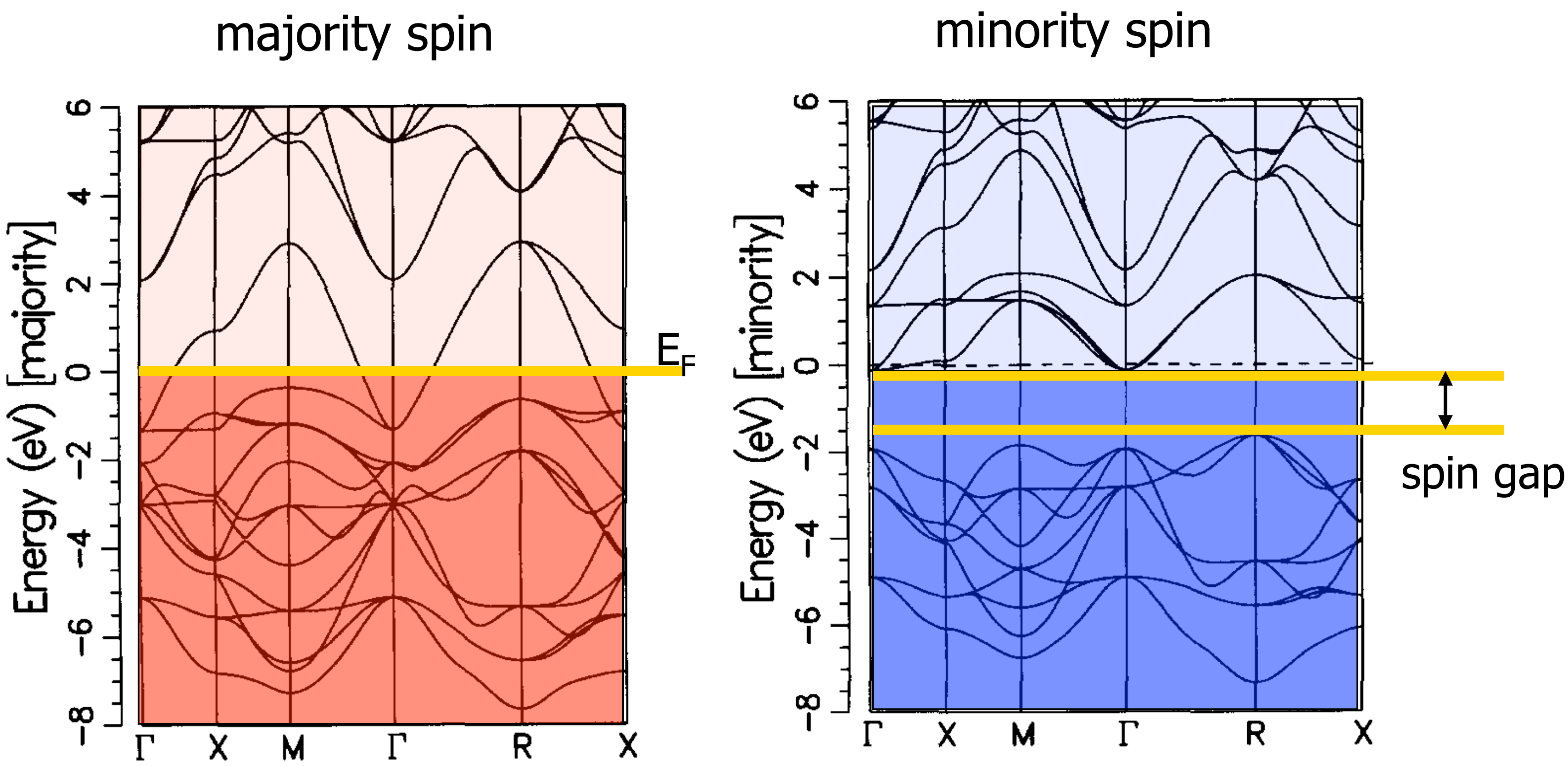






Battiato PRL 2017

electron spin dynamics, proof of half metallicity: application to $La_{0.7}Sr_{0.3}MnO_3$



E A Livesay et al J. Phys. Condens. Mat. 11 (1999) L279
W.E. Picket and D.J. Singh, JMM 172 (1997)237

ultrafast demagnetization of Fe(001)

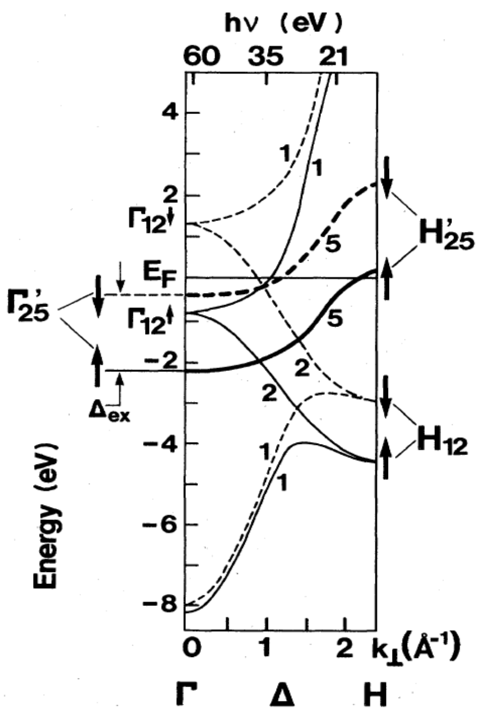
context:

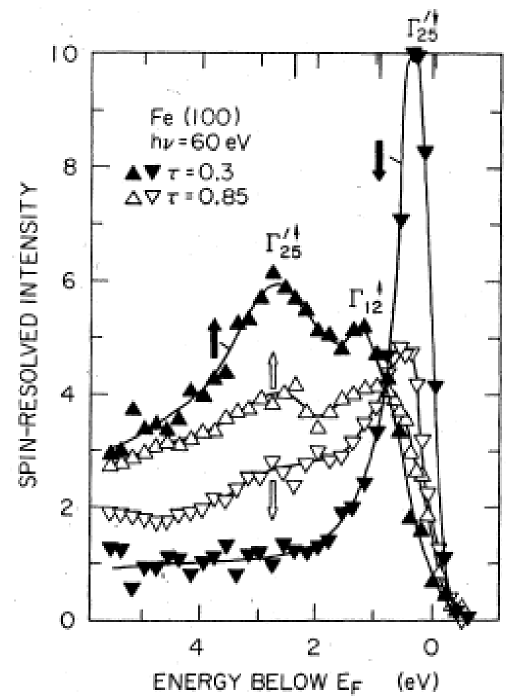
- **demagnetization of Ni < 1 ps [Beaurepaire PRL 1996] with 40fs pulse**
- **microscopic processes involved to explain the dissipation of angular momentum remain debated**

aim:

- **follow the temporal evolution of the Fe(001) electronic structure**

study the spin response of a ferromagnet during strong laser excitation to characterise the coupling between the electromagnetic field and electron spin in a relativistic regim





EDC at Γ
~2 eV exchange splitting

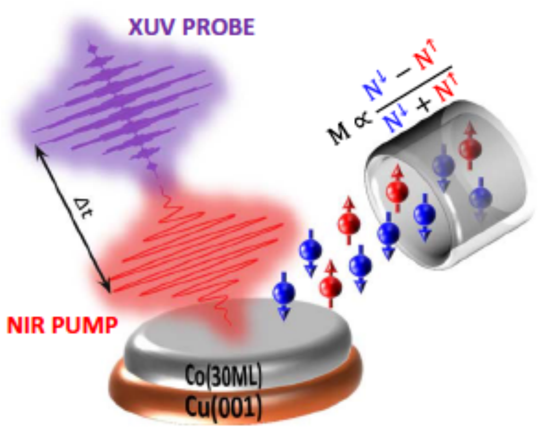
[Kisker 1984]

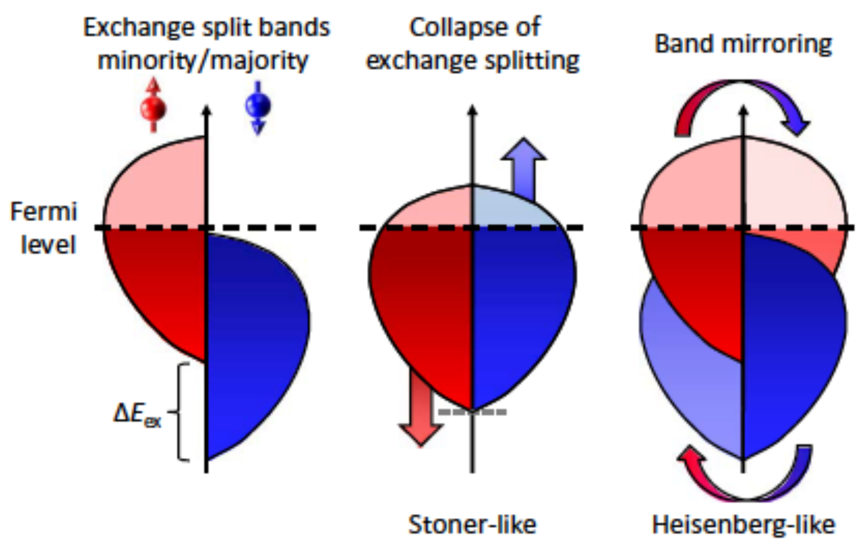
ultrafast demagnetization of Fe(001)

recent work on Co(001)

band structure evolution during the ultrafast ferromagnetic-paramagnetic phase transition:

two fundamentally different limiting models of itinerant (Stoner) and localized (Heinsenberg)





Eich SciAdv 2017

ultrafast demagnetization of Fe(001)

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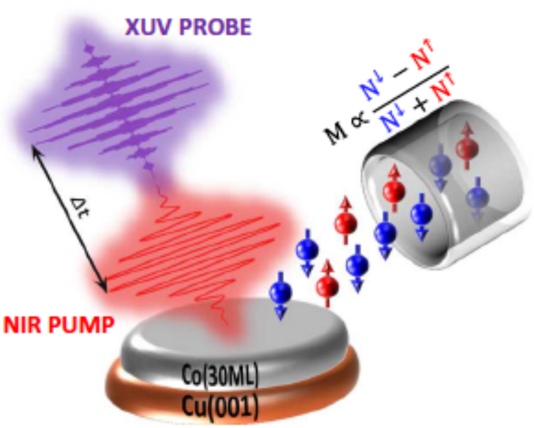
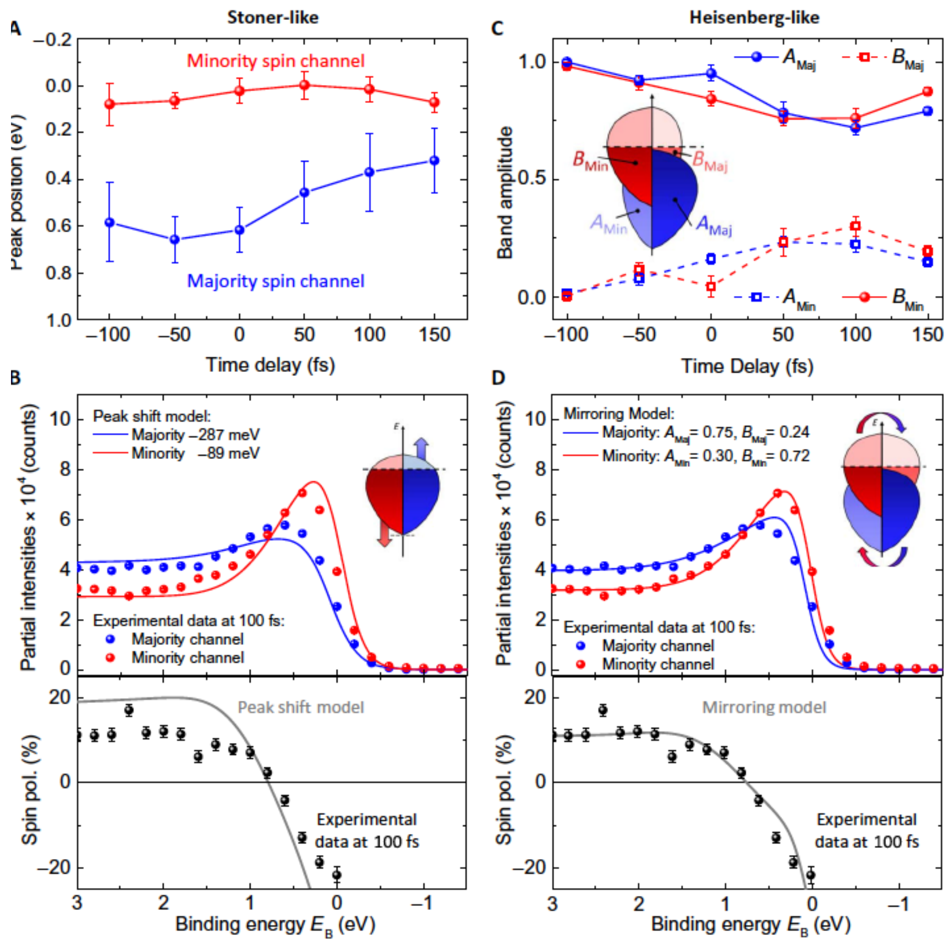




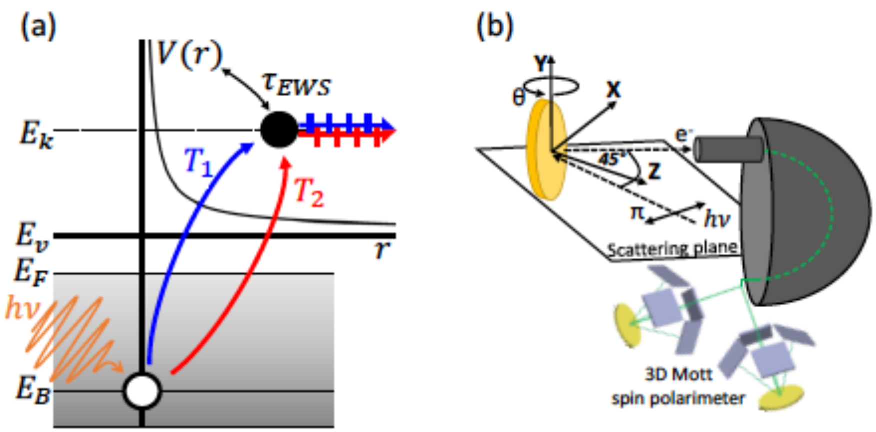
Eich SciAdv 2017

time-delay by spin polarisation and time-resolved measurement via RABBIT or AST

- **time scale of the photoemission process: static spin-resolved ARPES**

  absolute time duration of the transition from the initial to the final state

photon absorption: $\ell \rightarrow \ell \pm 1$



Eisenbud-Wigner-Smith: the time delay is due to a phase shift of different transitions

$$\tau_{\text{EWS}} = \hbar \frac{\partial \phi}{\partial E_k}$$

$$\tau_{\text{EWS}} = \frac{-\hbar}{\partial P / \partial \phi} (\dot{P} - \dot{r} \partial P / \partial r)$$

derivative of **spin-polarisation P** with respect to the binding energy

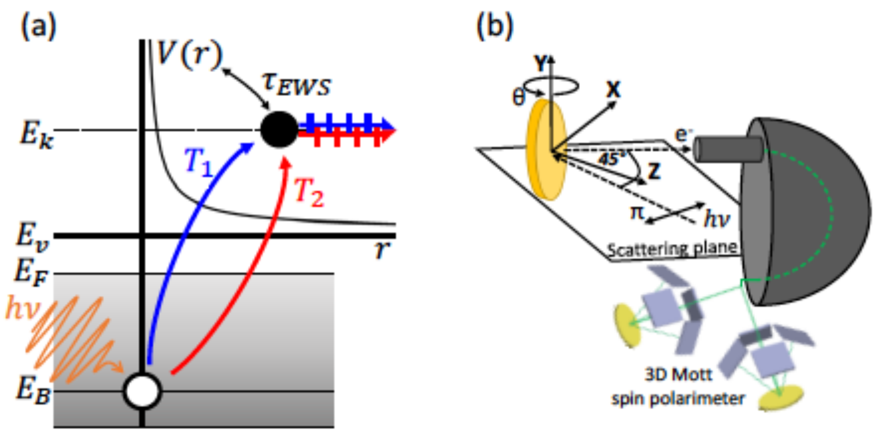
Fanciulli PRL 2017

time-delay by spin polarisation and time-resolved measurement via RABBIT or AST

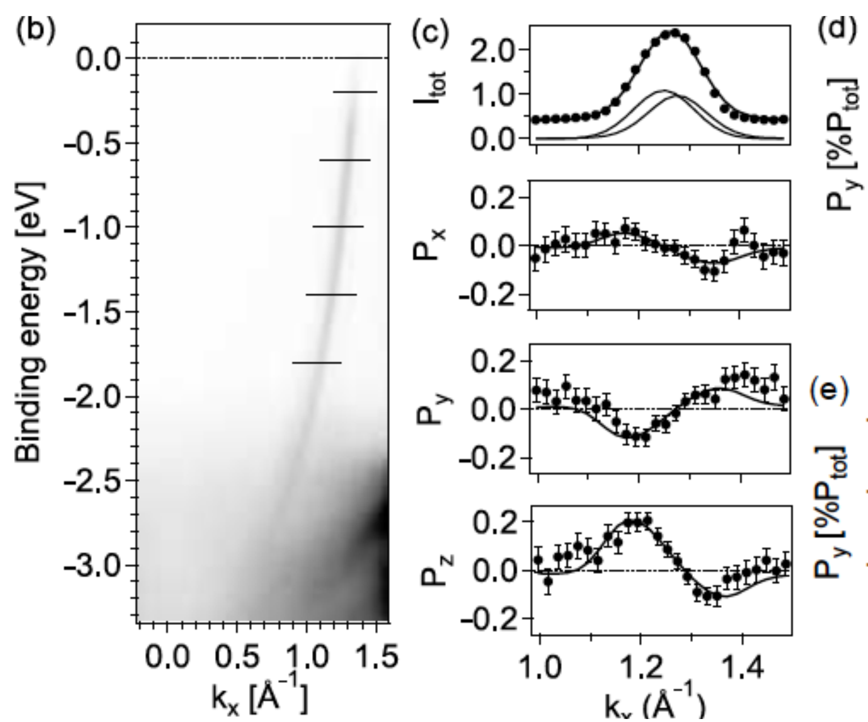
- **time scale of the photoemission process: static spin-resolved ARPES**

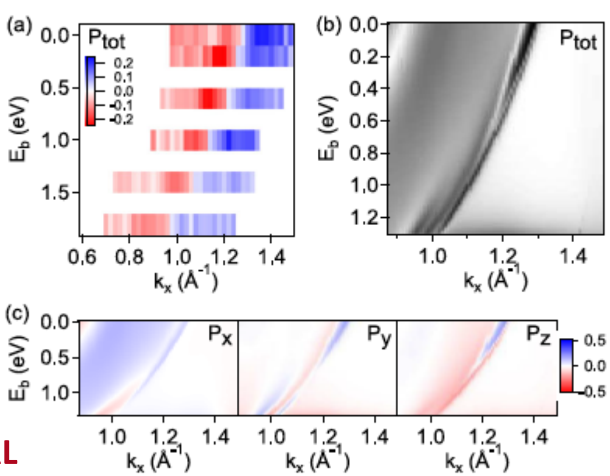
  absolute time duration of the transition from the initial to the final state

photoelectron interaction time



Cu(111)



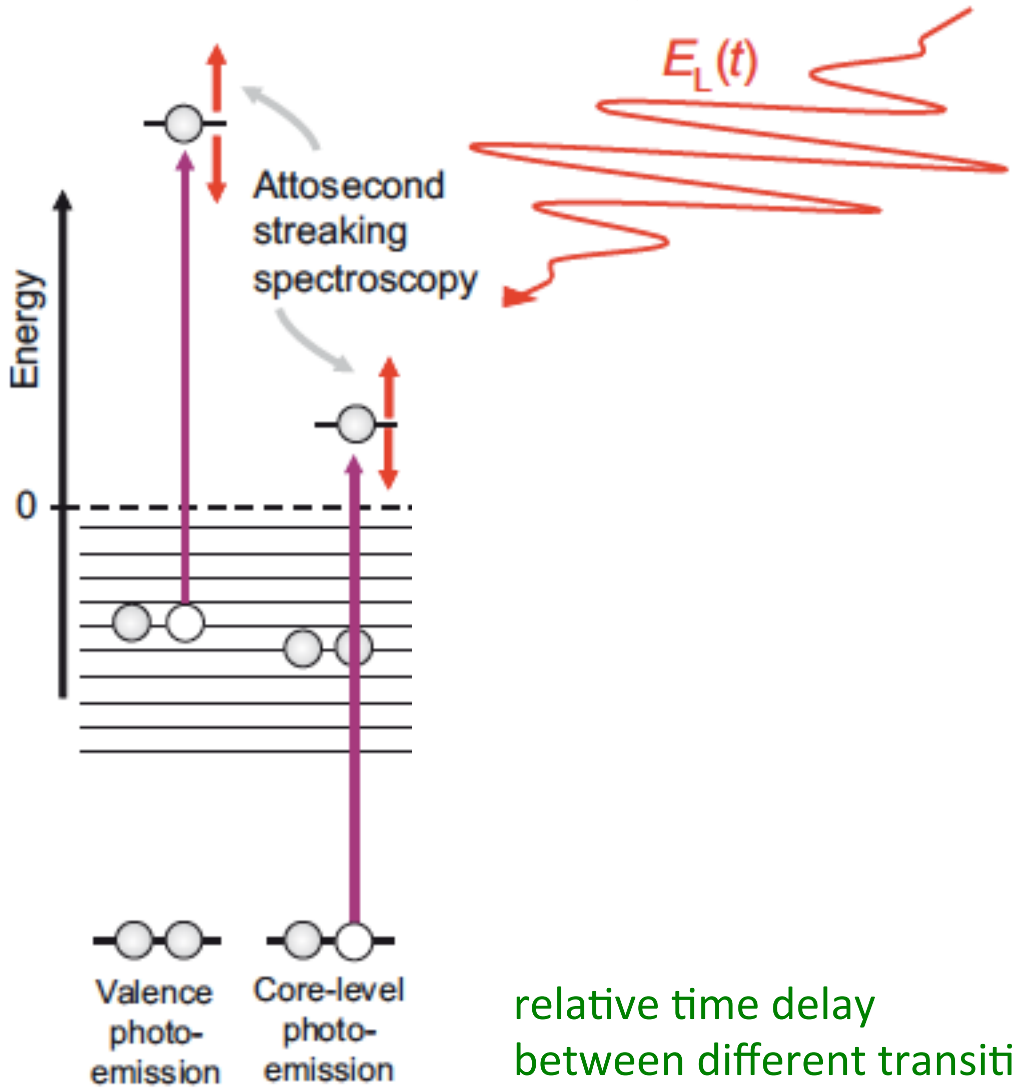


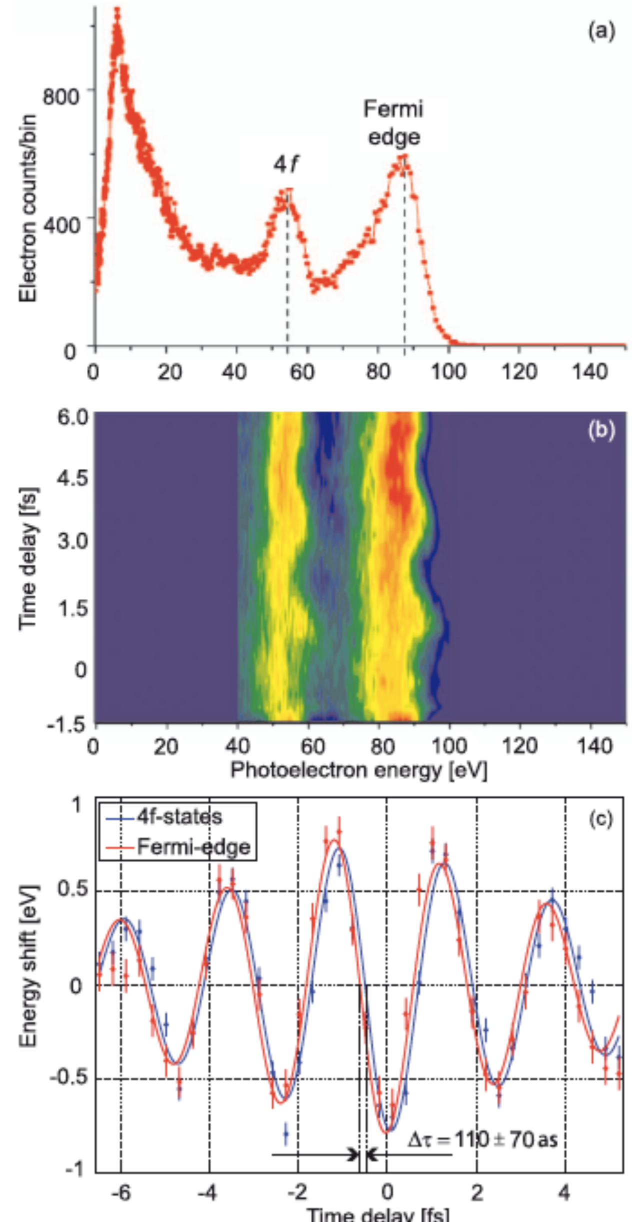
time delay $\tau_{EWS} \geq 26$ as

Fanciulli PRL 2017

time-delay by spin polarisation and time-resolved measurement via RABBIT or AST

AST: Attosecond streaking spectroscopy





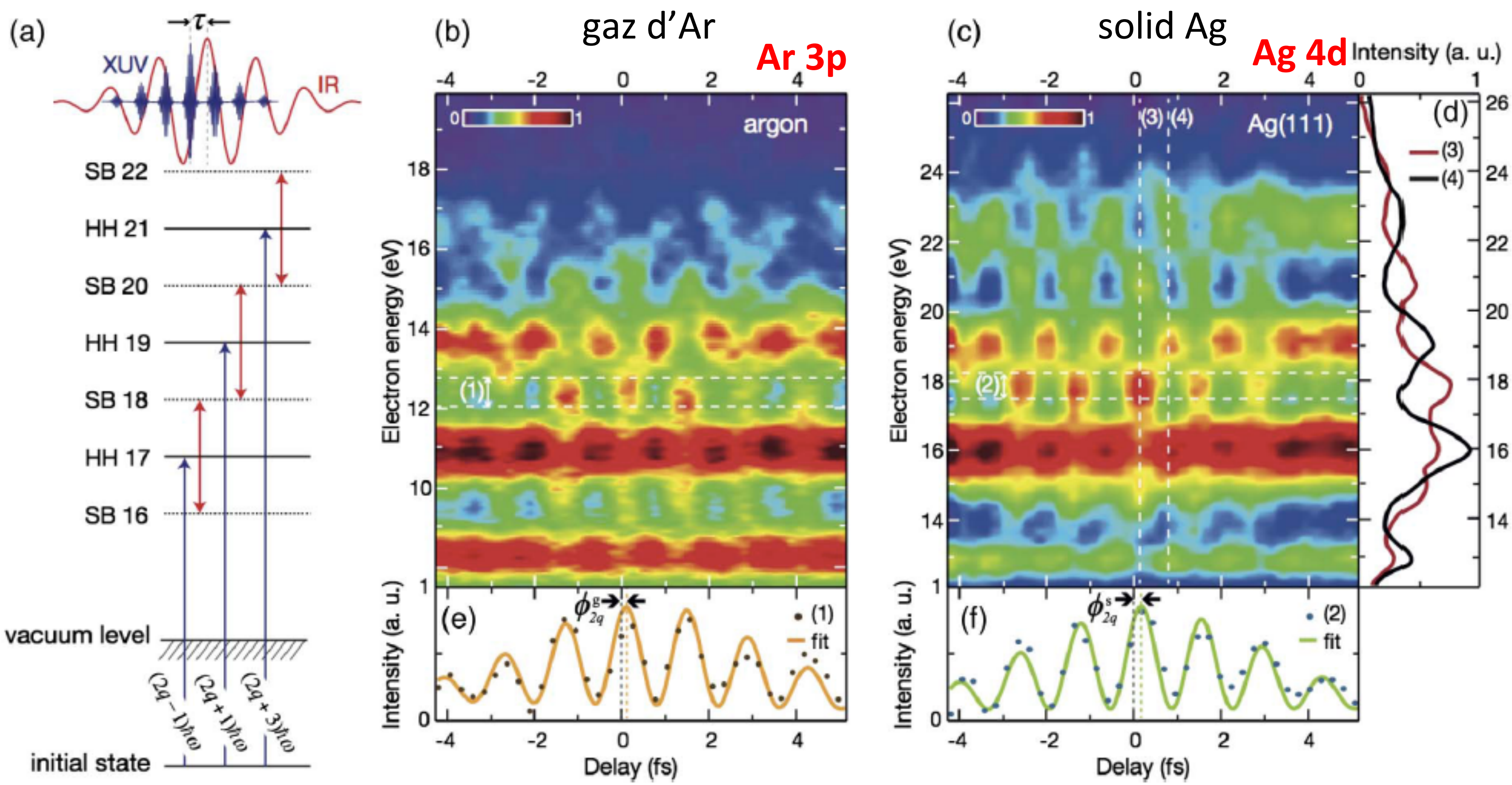
relative time delay
between different transitions

Cavalieri et al., Nature 2007

time-delay by spin polarisation and time-resolved measurement via RABBIT or AST

RABBITT: reconstruction of attosecond beating by interference of two-photon transitions

Interaction of the outgoing electron emitted by the attosecond extreme ultraviolet (XUV) pulse with an intense few-cycle infrared (IR) field leads to the formation of sidebands (RABBITT) or changes in the electron momentum (streaking)

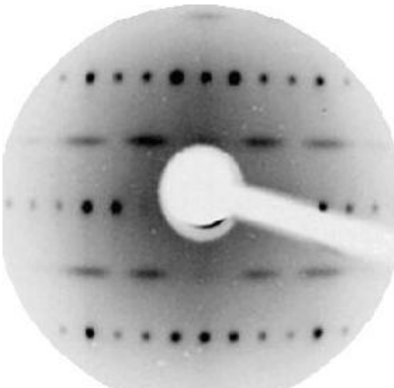


Locher et al , Optica 2015

merci

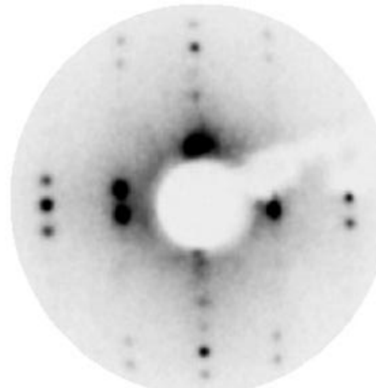
1D system Bi/InAs(100)

InAs(100) – 4x2



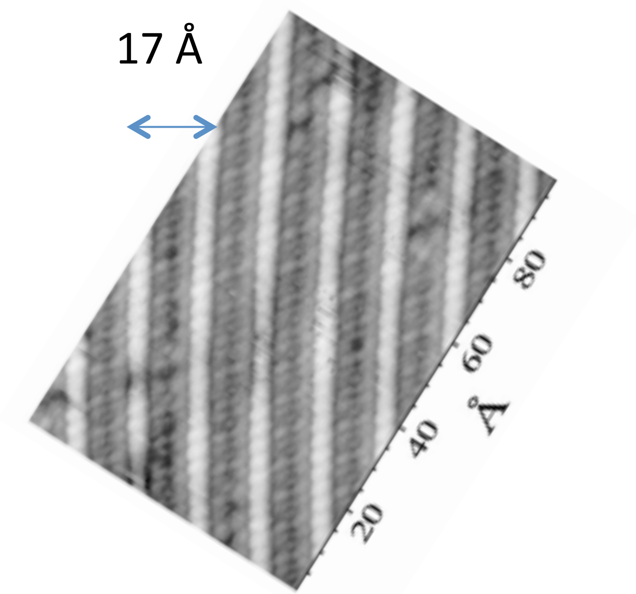
E = 64 eV

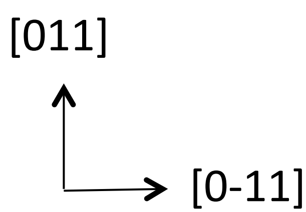
Bi/InAs(100) – 2x6



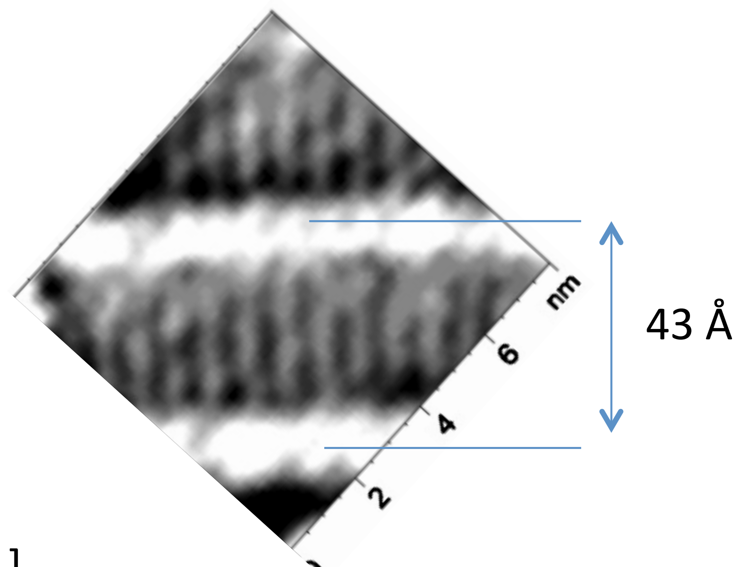
E = 44 eV

K. Szamota-Leandersson et al., Surf. Sci. 2009





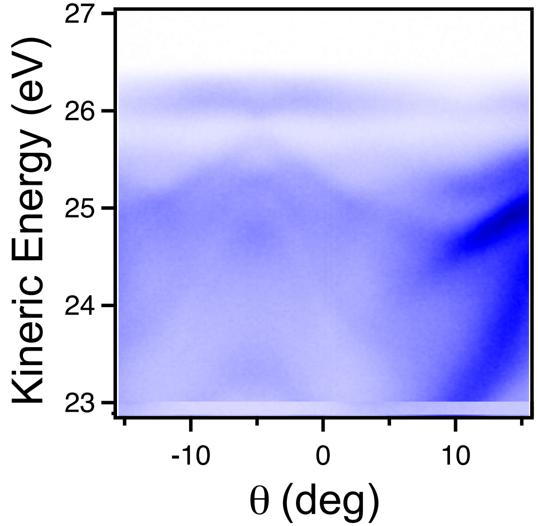
P. De Padova et al., Appl Surf Sci 2003



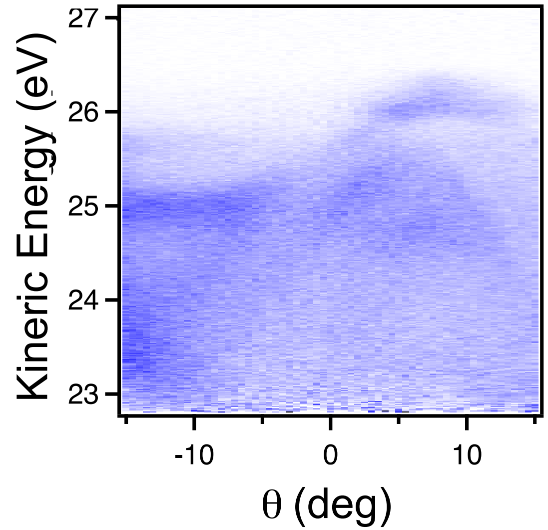
M. Ahola-Tuomi et al., Phys Rev B 2011

1D system Bi/InAs(100)

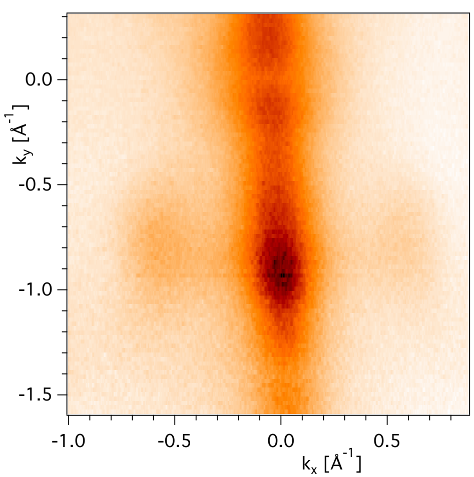
along Bi-lines



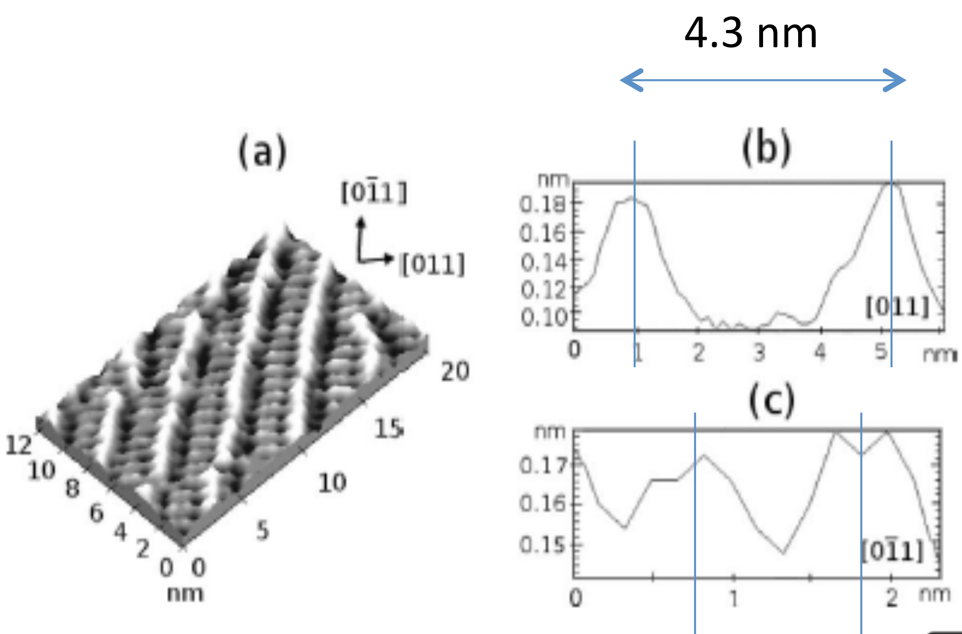
perpendicular to Bi-lines



Fermi surface



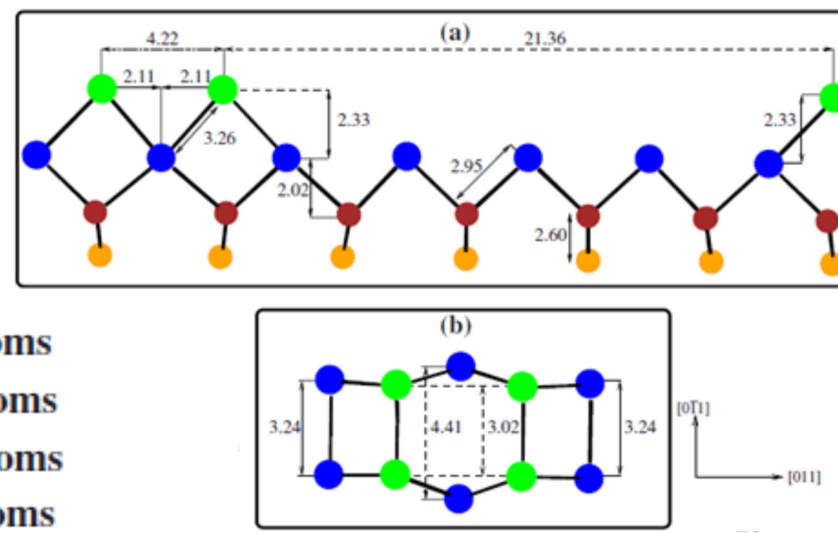
1D system Bi/InAs(100)



a{InAs(111)} = 0.43 nm

Ahola-Tuomi et al. Appl. Phys. Lett 2008

Alzhrani et al. J App Phys 2009



- 1st layer Bi atoms
- 2nd layer Bi atoms
- 3rd layer In atoms
- 4th layer As atoms