ARPES and spin-resolved investigations on the 8-1500eV High resolution CASSIOPEE beamline

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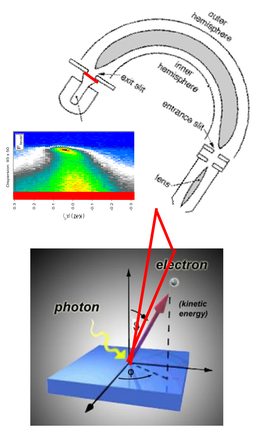
ARPES



PHOTOELECTRIC EFFECT

Energy Conservation

$$E_{kin} = h\nu - \phi - |E_B|$$

Momentum Conservation

$$\mathbf{p}_{\parallel} = \hbar \mathbf{k}_{\parallel} = \sqrt{2mE_{kin}} \cdot \sin\vartheta$$

MEASURE OF THE BAND STRUCTURE IN THE RECIPROCAL SPACE

- FERMI SURFACE MAPPING
- FERMI VELOCITY / EFFECTIVE MASS (m*)
- STRENGHT OF INTERACTIONS

Correlations in " *misfit* " cobaltates investigated by ARPES and the first measurements on CASSIOPEE
Coll: V.Brouet, LPS, Orsay, France
PhD Alessandro Nicolaou
to be published

SOURCES

2 Helical ondulators:

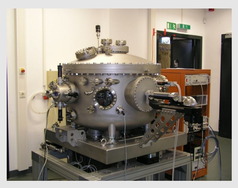
Energy range: **8 - 1500 eV**

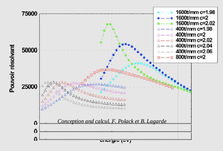
(electromagnetic)

(permanent magnets)

Polarisation: Linear Horizontal/Vertical,Circular

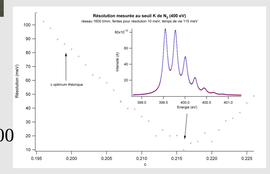
VLS,VGD MONOCHROMATOR





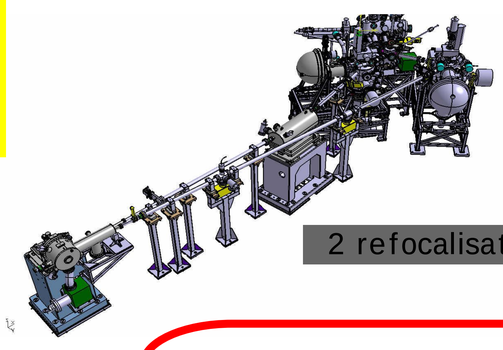
- 10^{13} ph/s
- 4 gratings
- Bandwidth25000<R.P<70000

By optimizing c was obtained the



Petersen condition:
cos d
cos

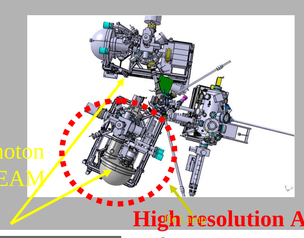
CASSIOPEE



2 refocalisation branches

UHV end-stations

Spin-resolved photoemission
(250 µm x 200 µm)

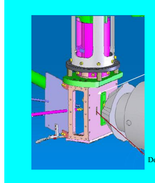


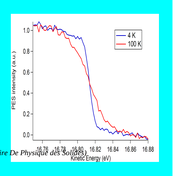
Sample preparation chamber
Growth and characterization of the surfaces
(heating samples by current flow or electron bombardment, sputtering, multiple evaporator, LEED, AUGER)

High resolution ARPES
(beam< 50 µm x 30 µm)

LOW TEMPERATURE CRYOSTAT

(CONTINUOUS FLOW LIQUID He)

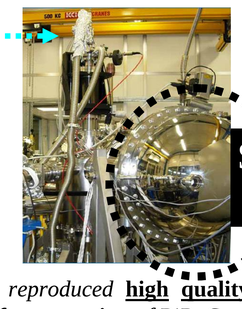


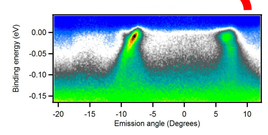


MINIMUM TEMPERATURE 3 K
ON THE COLD FINGER

INSTALLED IN THE *UHV* ARPES CHAMBER
(PRESSURE IN LOW 10 mbar)

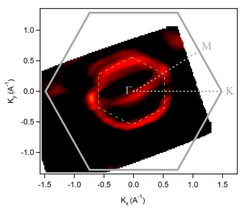
FIRST *TEST* on Au sample with He lamp





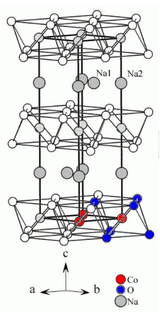
SCIENTA R4000

We reproduced **high quality Fermi surface mapping** *of BiBaCo-O*
With the **improved angular window** *was possible to measure the* **entire FS diameter** *in one shoot*



PRESENT **ENERGY RESOLUTION** ~7 meV
(Synchrotron Beam (14eV) on sputtered Nb)

INVESTIGATION of the physics of ELECTRON DOPED CoO_2 SLABS



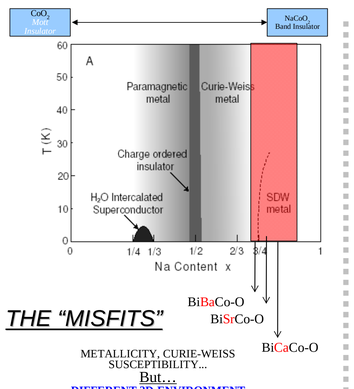
APPLIED RESEARCH:

- High Thermo-power (Seebek effect)
- Batteries
  - Metallic along CoO_2 planes
  - 'Insulating' along c
  - Mobility of the interposed Ions (Li, Na,...)

FONDAMENTAL PHYSICS:

- 2003 - Discovery of superconductivity in a parent compound (Tc=4K)
- Fermions on a 2D triangular lattice
- *Strange metals:* coexistence of metallicity and Curie-Weiss susceptibility
- Expected strong correlations (d-band)
- ORBITAL, CHARGE, SPIN, LATTICE DEGREES OF FREEDOM

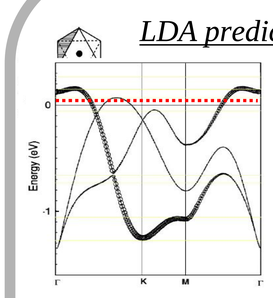
What is intrinsic of the CoO_2 triangular lattice ?

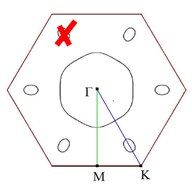


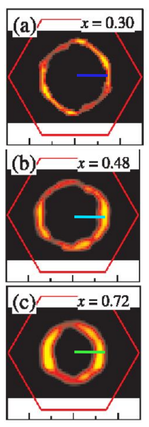
THE "MISFITS"

METALLICITY, CURIE-WEISS SUSCEPTIBILITY...
But…
DIFFERENT 3D-ENVIRONMENT
INCOMMENSURABILITY

LDA predictions for Na Cobaltates







H.B. Yang *et al.* **Phys. Rev. Lett. 2005**

CORRELATIONS NOT INCLUDED

EFFECTS OF CORRELATIONS:

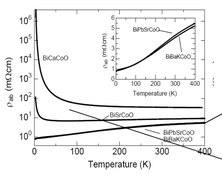
REDUCTION OF THE BANDWIDTHS - REDUCTION OF THE FERMI VELOCITY

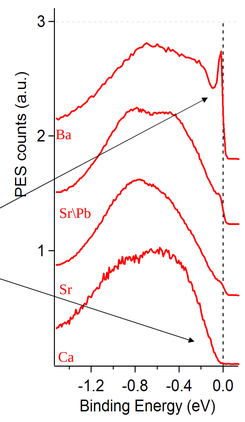
PEAK-DIP-HUMP lineshape for a_{1g} (both in BiBaCo-O and Na_XCoO_2)

When **adding more electrons to the CoO_2 planes** (and changing the RS structure), we have observed the **disappearance** of the sharp peak (**quasi-particle peak**) crossing the Fermi level and tracing the hexagonal Fermi surface expected from LDA for the a1g band. We are trying to **understand** its possible **connection** with the observed **concomitant increase in the in plane resistivity**.

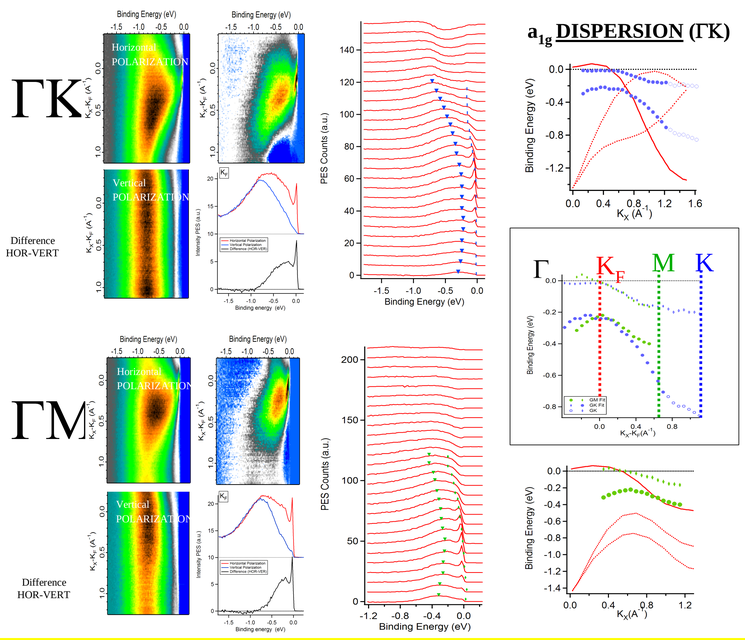
(V. Brouet et al PRB 2007)

RESISTIVITY

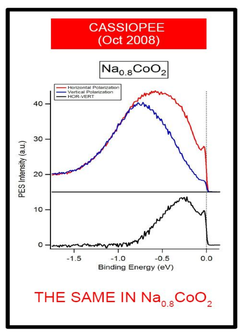




By taking advantage of the **POLARIZATION SELECTION RULES** we were able to extract the **REAL LINESHAPE** OF a_{1g}. Both in "misfits and NaXCoO2 we find a COMPLEX **PEAK-DIP-HUMP STRUCTURE** for a_{1g} --> COHERENT BAND + **QUASIPARTICLE EXCITATIONS**



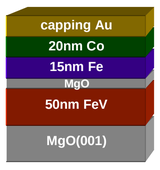
a_{1g} DISPERSION (ΓK)

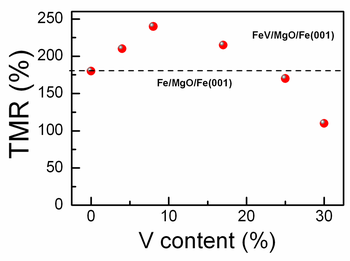


PRESENCE OF **STRONG MANY BODY EFFECTS** IN THE ARPES LINESHAPE OF THE BAND THAT IS CROSSING THE FERMI LEVEL

Spin polarization and first spin resolved photoemission experiments on Cassiopée (coll S. Andrieu and F. Bonell (PhD) LPM Nancy/SOLEIL)

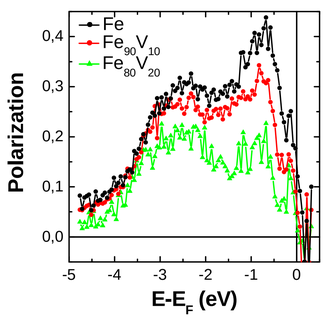
1st experiments : FeV/MgO/Fe(001) Magnetic Tunnel Junctions (MTJs)





TMR limited to 180% in Fe/MgO/Fe(001) MTJ : change Fe by FeV to decrease the misfit with MgO => decrease the dislocation density in MgO : impact on the TMR ?

TMR increases for low V content !



FeV Magnetization : M decrease with V content (Slater-Pauling)
Decrease of the polarization at the Fermi energy expected
=> Spin resolved photoemission for the Δ states along (001)

SR-PES for FeV covered with 2ML of MgO
Spin polarization decreases with V content

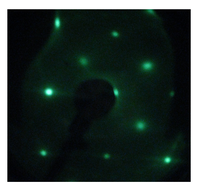
Despite the polarization decrease with V content, TMR increases : underline the strong effect of dislocation defects in the barrier on magnetotransport properties

F. Bonell et al, INTERMAG2009, Sacramento, may2009, *invited talk*, to be published in IEEE Proc.

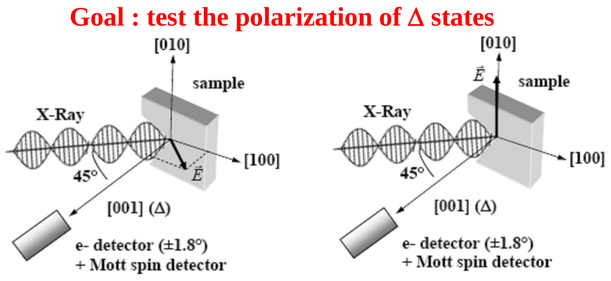
2nd experiments : Fe(001) Δ states polarization

Fe(001) epitaxially grown on MgO in the MBE coupled to the beamline

Controlled by LEED



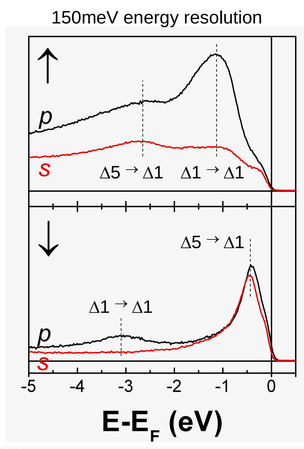
Goal : test the polarization of Δ states

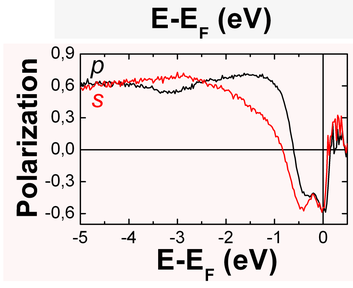


$\vec{E}$	Initial state	Final state
// [001]	Δ_1	Δ_1
// [100]	Δ_5	Δ_1

$\vec{E}$	Initial state	Final state
// [010]	Δ_5	Δ_1

150meV energy resolution





CASSIOPEE: Combined Angle and Spin SpectroscopIes Of PhotoEmitted Electrons *http://www.synchrotron-soleil.fr*