Function and structure of strongly correlated electron systems

T. Arima: SR X-ray studies on magnetic order

Spiral magnetic order; Spin helicity (vector spin chirality) detection
Competition between L-S coupling and ligand field int. in 5d ssytem

K. Amemiya: Magnetic and atomic strct. studied by soft x-ray spec

XMCD detecting spin/orbital moments and their anaisotropy; XRMS detecting nano-scale spin-orbital order; XAFS with depth-resolution probing surface/interface

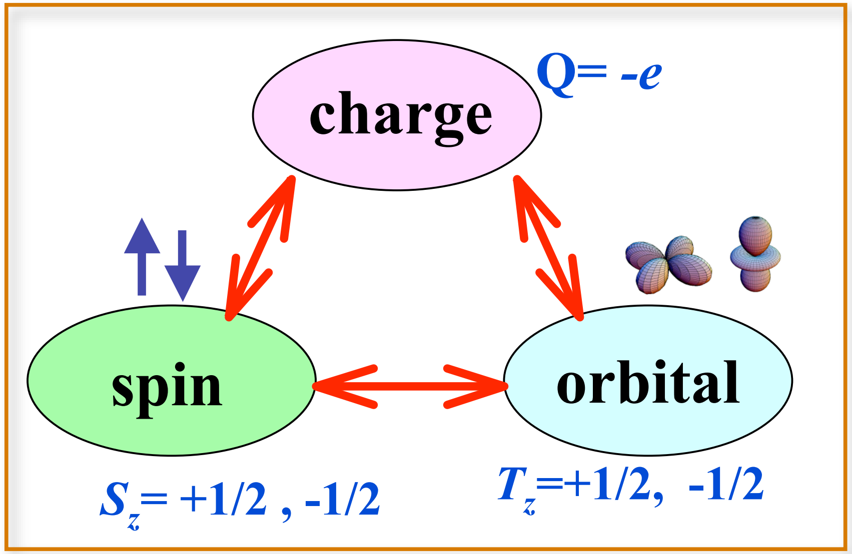
H. Nakao: Orbital orderins in TM oxides studied by RXS tehcnique

RXS probing orbital order

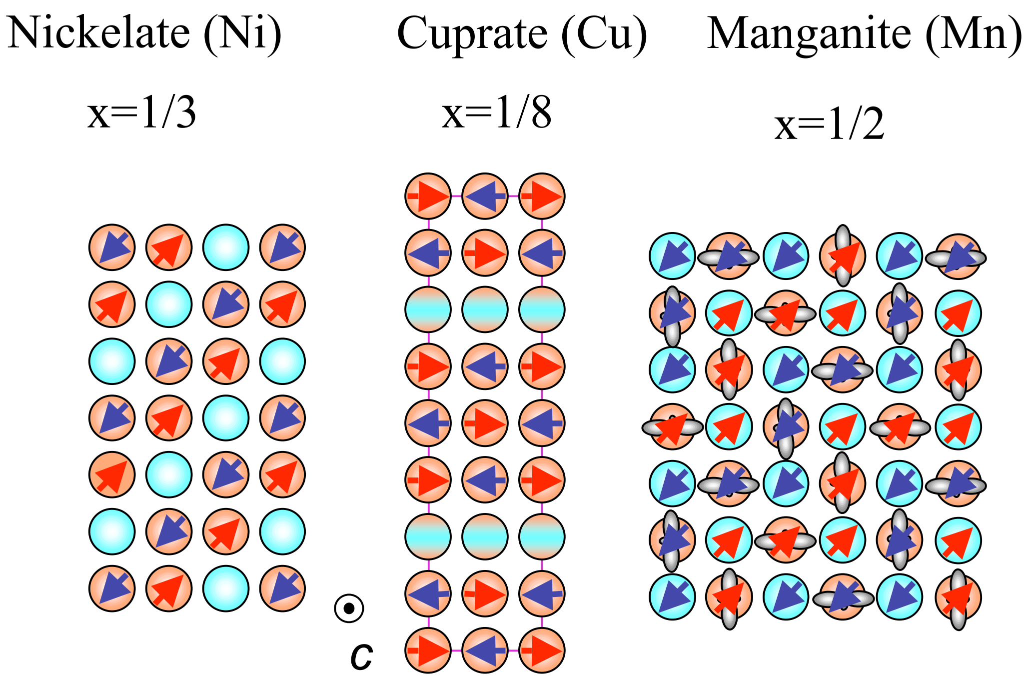
M. Arai: Neutron scattering approach on SCES

Neturon scattering studies on spin and lattice dynamics in energy-momentaum space
Potential of J-PARC

Self-organization of electrons - carriers of cross-correlation-

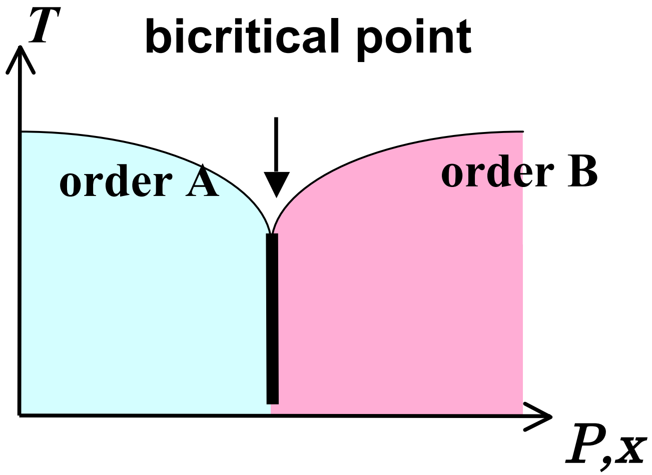


Charge/orbital/spin ordering in 2D sheets



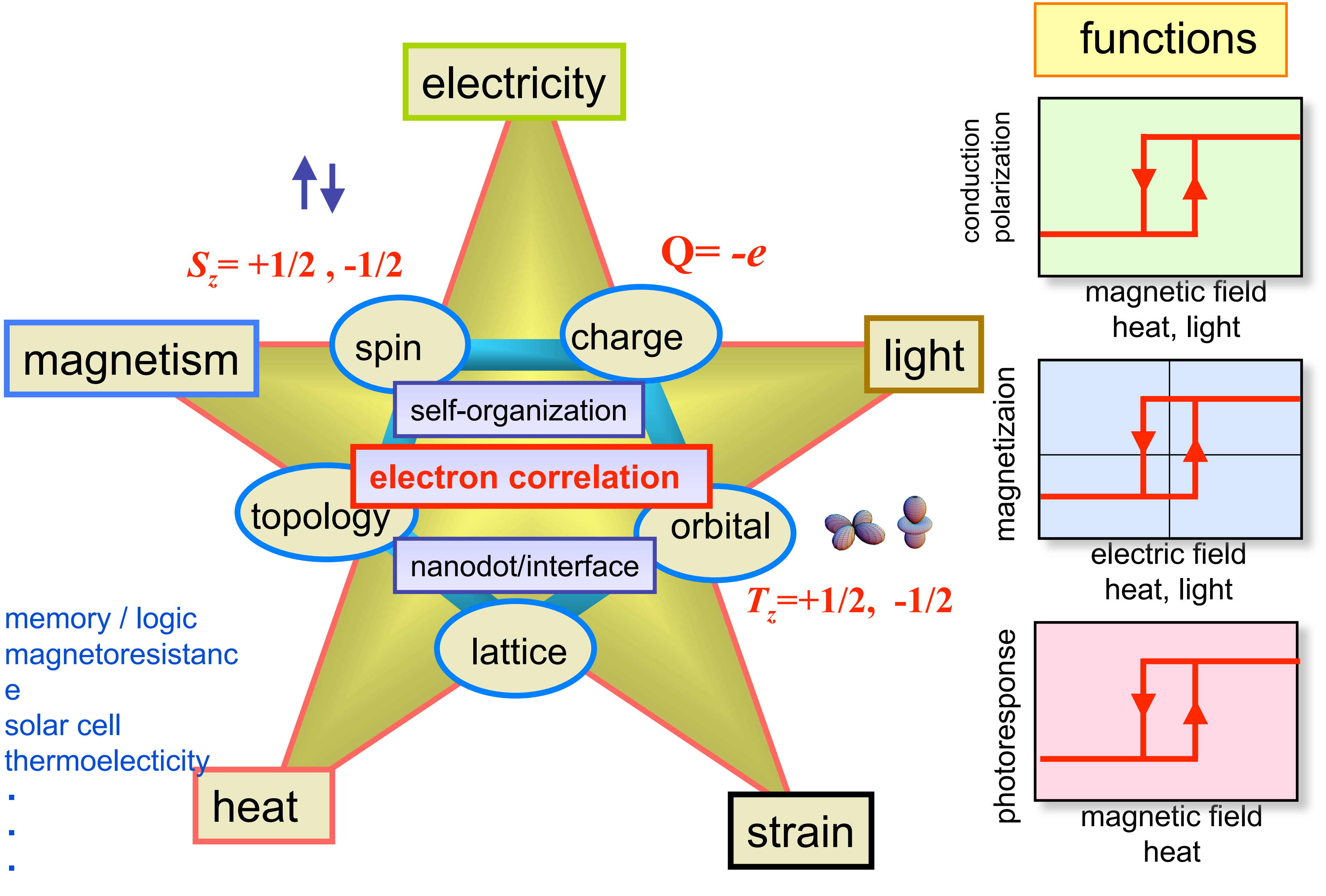
cf. Y. Tokura, Physics Today, 56 (2003)

Phase competition and control with the spin-charge-orbital superstructure



Coupled multiple-order-parameters lead to 1st order phase transition.

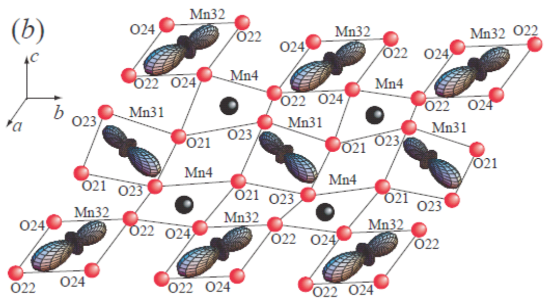
Emergent cross-correlation function



Probing "electron" structure ~ Can we see electrons?

1. structural analysis of wide use

powder (polycrystalline) samples
glass (broad q-region)
phase separation (broad length-scale up to 500nm))



via channel of ele-lattice int.

2. electron-density profiling

co-experiment with high-resolution SR&N diffraction

- electronic cloud around proton
  e.g. hydrogen-bonded ferroelectrics
- orbital ordering (spin cloud around nucleus)

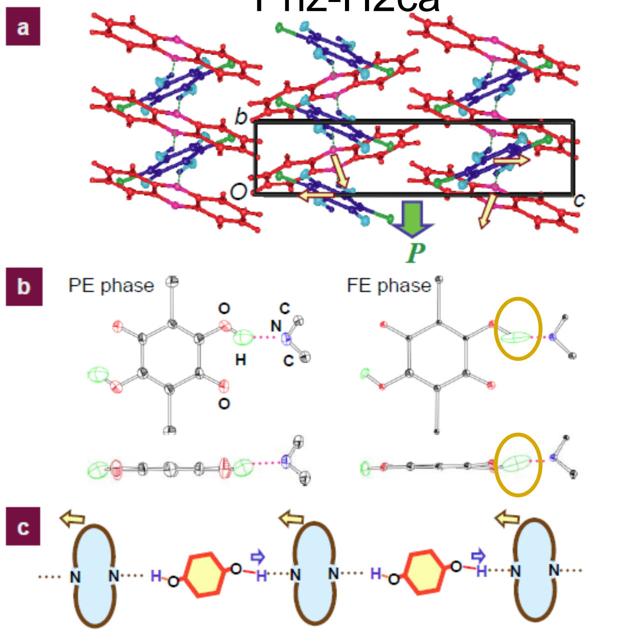
3. Dynamics

phonon, orbiton

low-energy structural dynamics (spin echo)
dynamical structure (pump&probe)

→ S. Koshihara (this symposium)

Phz-H2ca

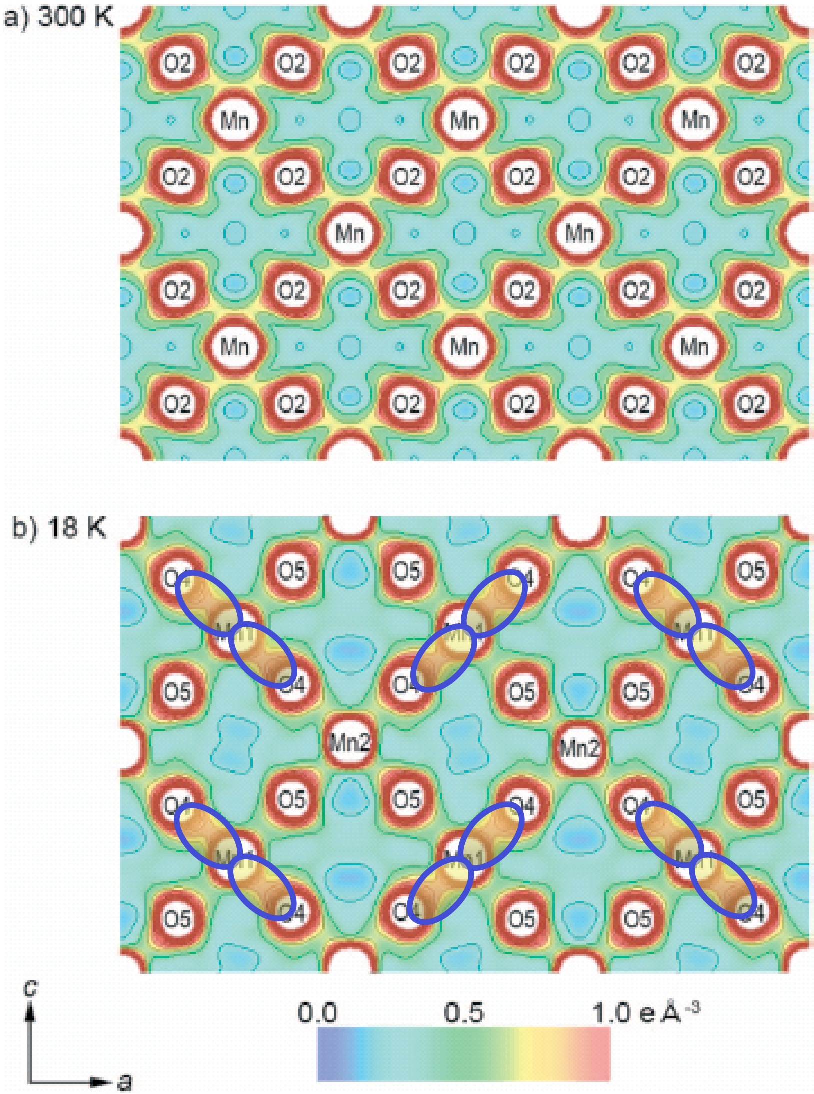


RT organic ferroelectics (Horiuchi)

Probing obital order & dynamics

MEM (M. Takata)

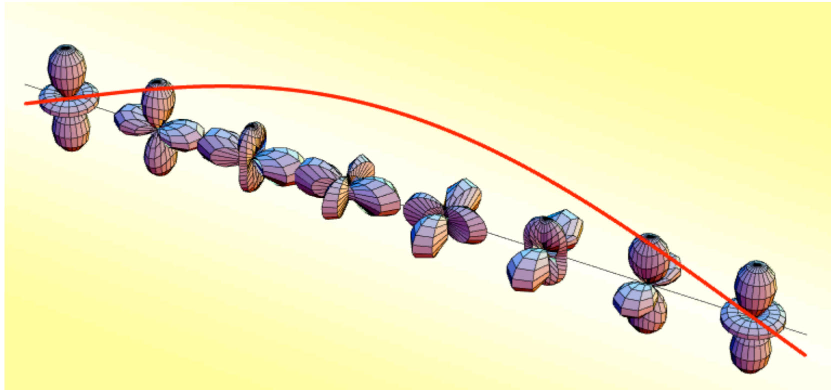
Kato et al. PRB77, 081101(2008)



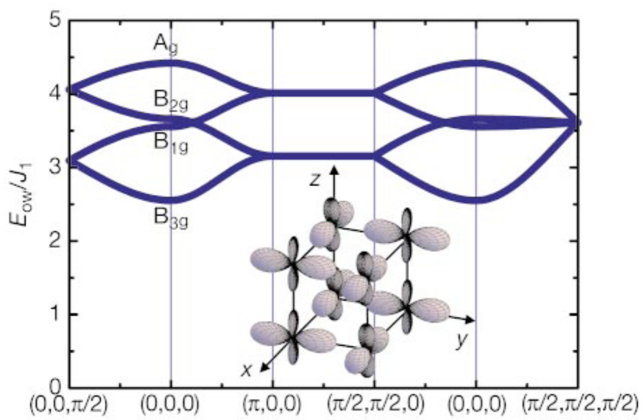
ATS (Y. Murakami method)

et al.

orbiton?



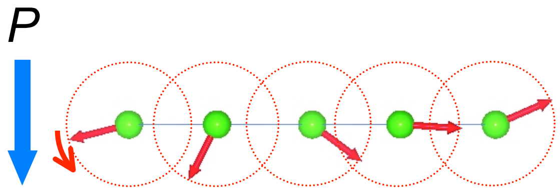
S. Maekawa



E. Saitoh et al. Nature, 480, 180 (2001).

Spin state variables relevant to ME coupling

a



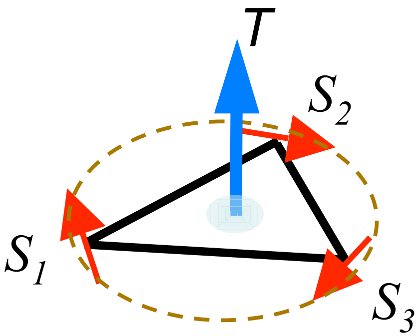
$$C = S_1 \times S_2$$

vector spin chirality

spontaneous spin current

spin-driven ferroelectricity

b



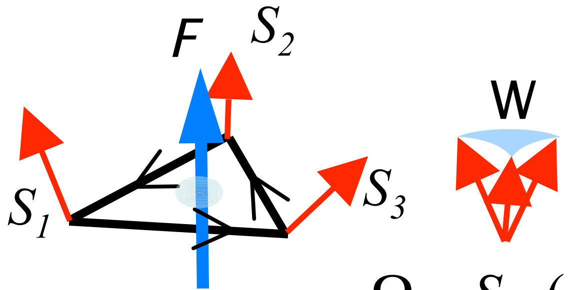
$$T = \frac{1}{2}\sum_i r_i \times S_i$$

toroidal moment

built-in vector potential

$$E = -\frac{\partial T}{\partial t}$$ ac magnetoelectic effect

c



$$\Omega = S_1 \cdot (S_2 \times S_3)$$

scalar spin chirality

fictitious magnetic field

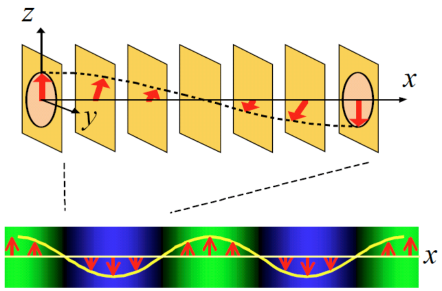
anomalous Hall current

Y Tokura & HY Hwang, Nat. Mater. (2008)

Probing magnetism: higher-order structure

Spiral/chiral spin objects as source of emergent properties

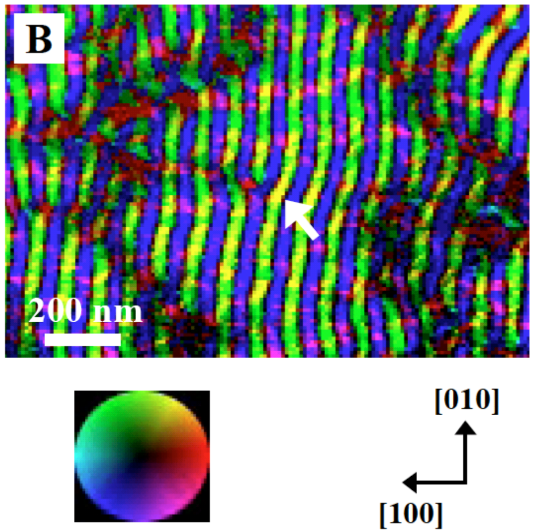
real-space observation of helical spin structr. by Lorenz TEM



Uchida et al. Science (2006)

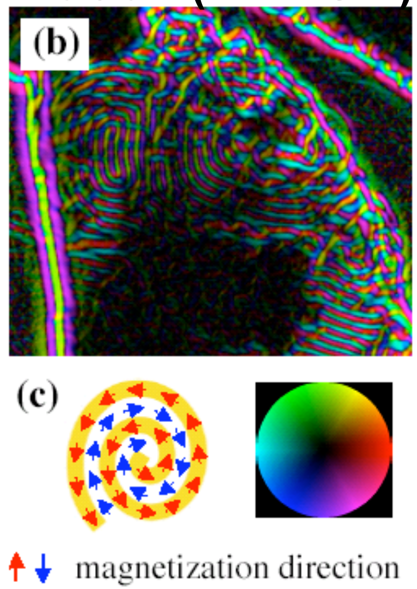
knife-edge dislocation

(Fe,Co)Si



Swiss-roll like vortex

FeGe (→MnSi?)



Importance of mesoscopic higher-order spin-structures

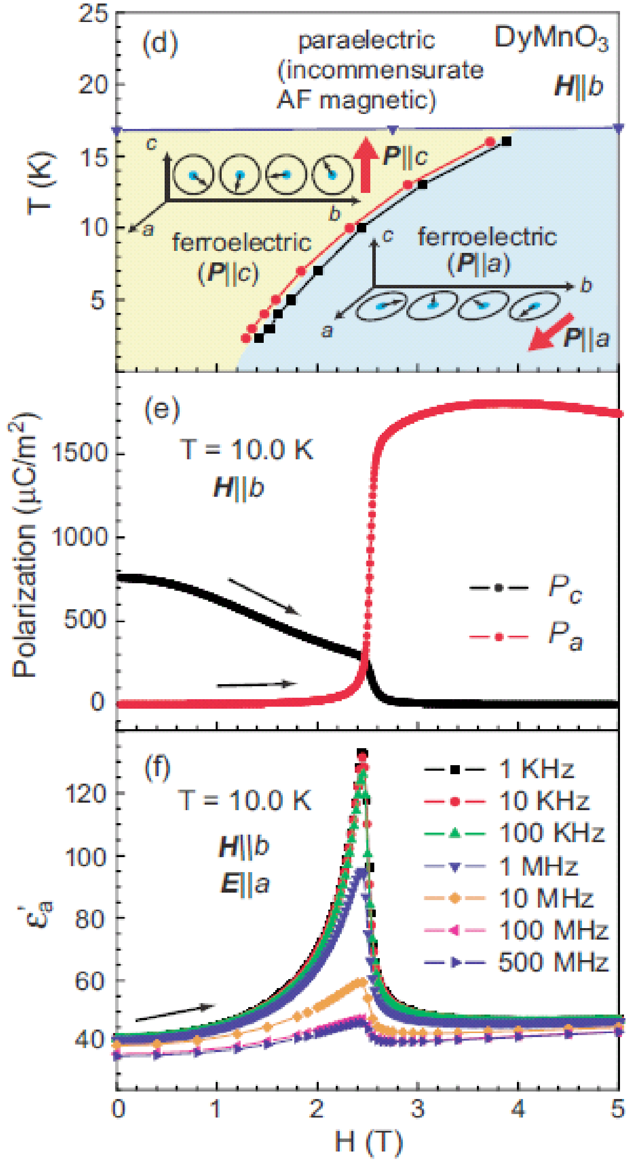
magnetic dislocation, vortex, skyrmion, domain walls, etc

10-1000nm scale

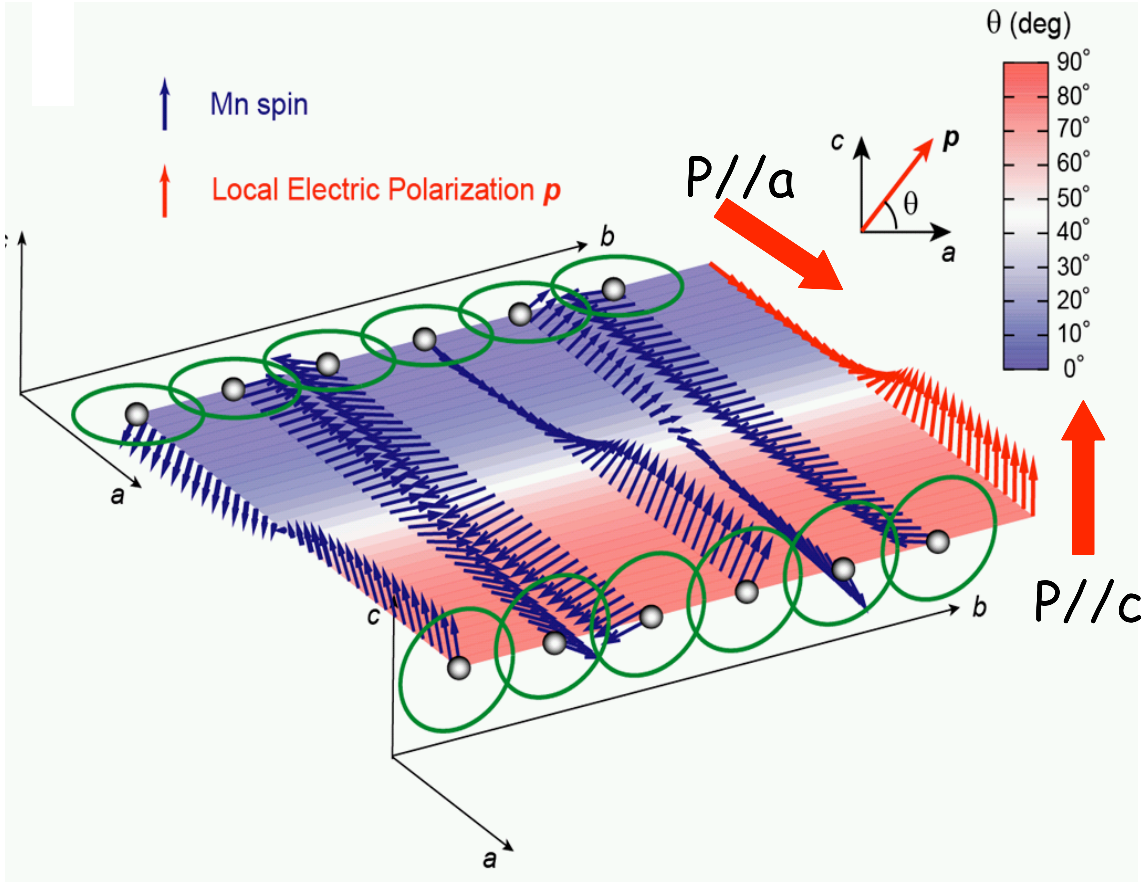
high-to-low q-scan, real-space resolution, spin-polarized photon/neutron?

Gigantic magnetocapcitance – motion of domain wall

Kagawa et al.



multiferroic domain walls



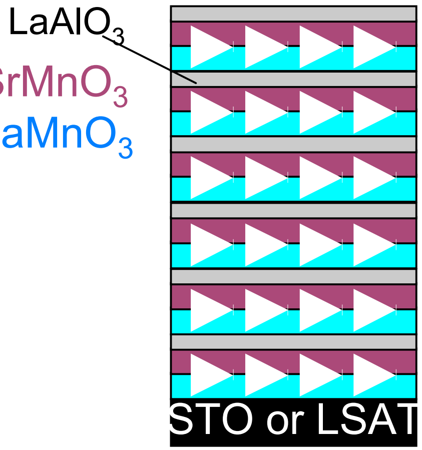
nano spin superstructure

micro spin higher-order

Probing magnetism : Interface

The surface was invented by the devils. (Wolfgang Pauli)
but
The interface is the device. (Herbert Kroemer)

thin film → junction → interface



The interface magnetism has seldom been elucidated in spite of its importance in the device.

Area to be probed less than $10mm^2$ (at most $100mm^2$)

- **interface sensitivity**

  XAS by ATR, polarized- neutron reflectometer

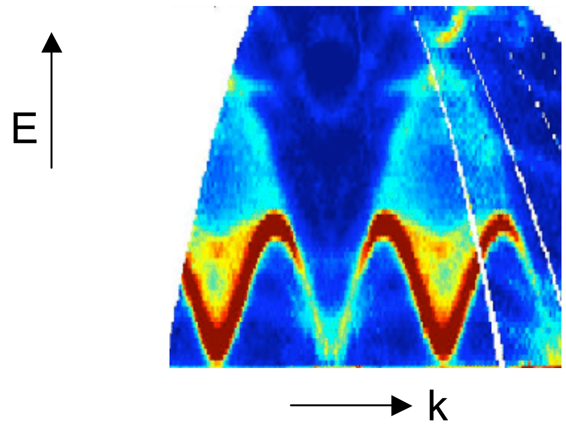
- **depth profile/ sensitivity** **~nm resolution , φ<1mm**

  XAFS, ultraslow μ^+ source

Probing magnetism : Dynamics

1. Magnetic excitation over a wider range with more accuracy

- smaller samples
- polycrystalline sample
- shorter measurement-time



spinons (Arai et al.)

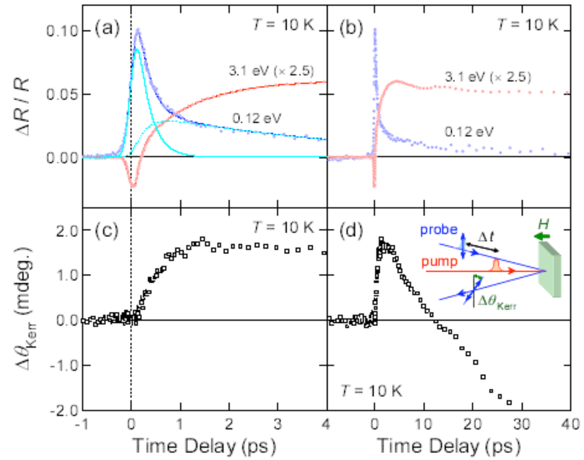
2. high energy-resolution

cross-correlation between phonons and excitations
e.g. acoustic phonon vs. q.p. gap in superconductor
optical phonon vs. electromagnon in multiferroics

3. real-time pump-probe experiment

neutron/muon pulses coincident
with pulse stimulation

optical
pump&probe



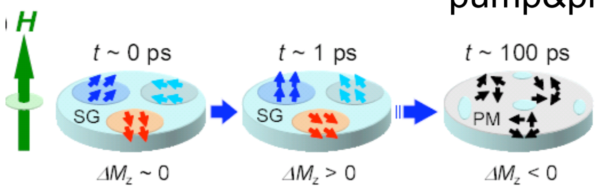
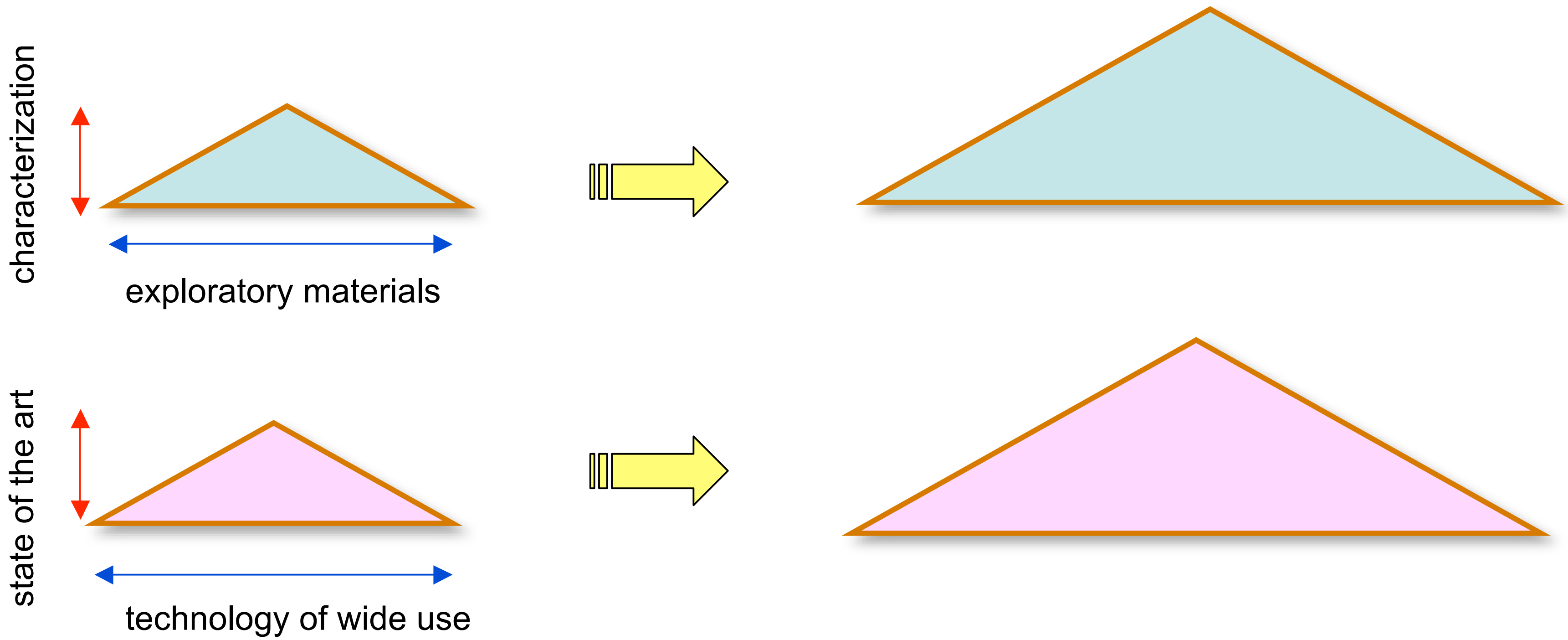


photo-induced ferromag. in manganite

Advanced characterization and exploratory materials science

Similar-figure Rule for the relation between advanced tools and advanced materials



Enlarge both base and height of the pyramid

big research facility ↕
small laboratory tools ↔

↕ development of forefront technology
enlargement of wide/common use ↔