

Closing Remarks

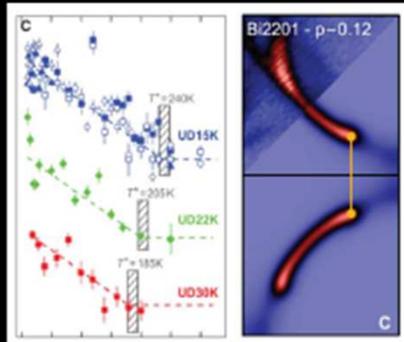
After almost 30 years of intensive research on HTSCs, even if the fundamental mechanisms of SC are still missing, our knowledge in this field has enormously increased and several related collective and quantum phenomena has been discovered.

The experimental techniques that have played a key role:

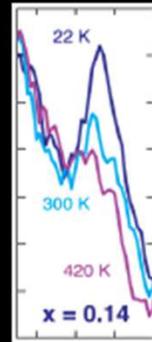
- Photoemission spectroscopy (ARPES)
- X-ray diffraction/scattering (elastic & inelastic)
- Optical/IR/THz spectroscopies and recently time-resolved spectroscopy

Mutual benefits

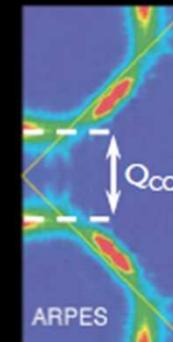
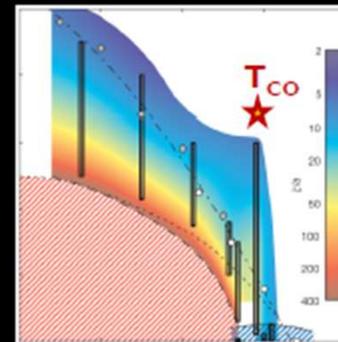
Charge order in cuprates: hole to electron doping



R. Comin et al., Science 340, 390 (2014)

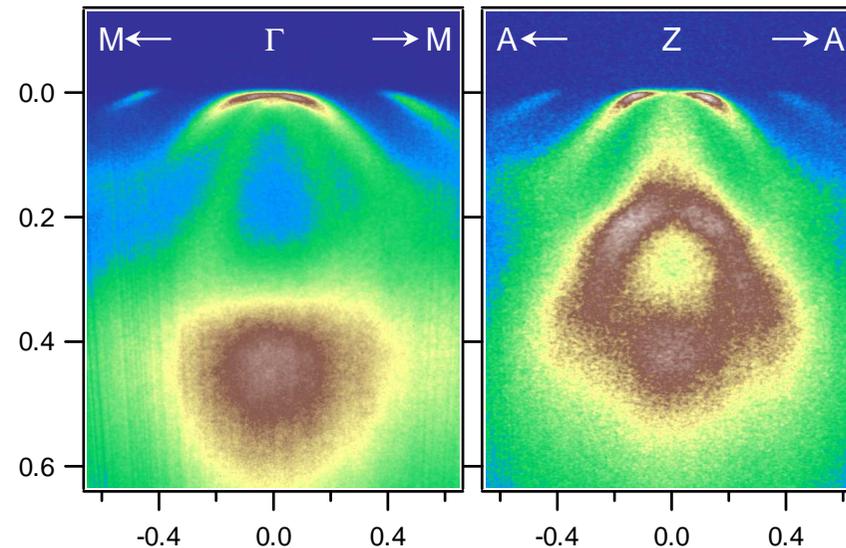


E.H. da Silva Neto et al., arXiv:1410.2253 (2014)

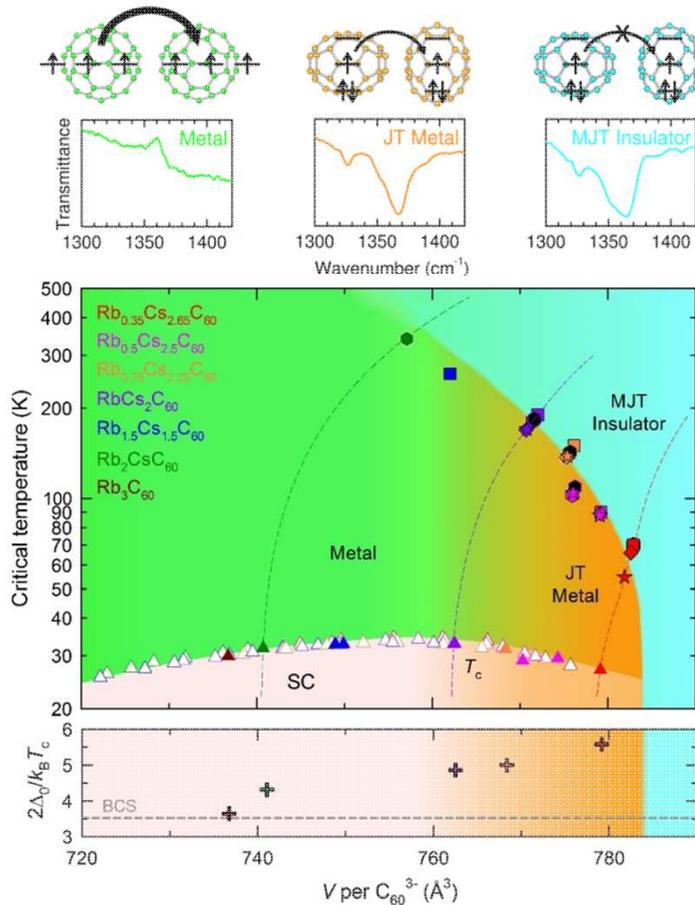


ARPES
REXS
STM

Spin-orbit splitting
and $3z^2-r^2$ band
in iron-based
superconductors



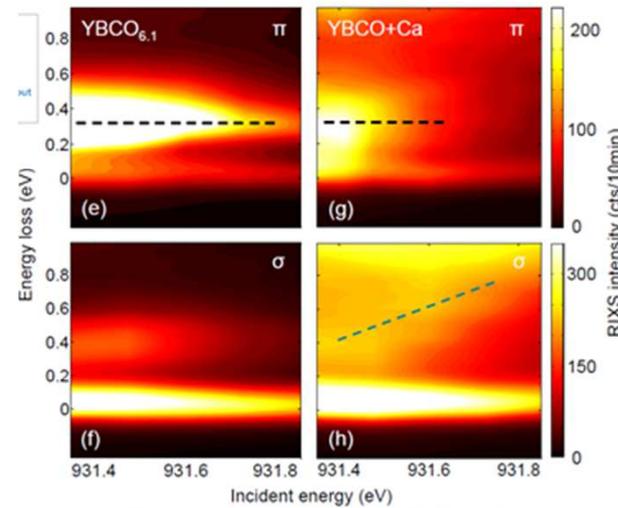
Fullerene-based molecular SCs



XRD, IR & THz spectroscopies

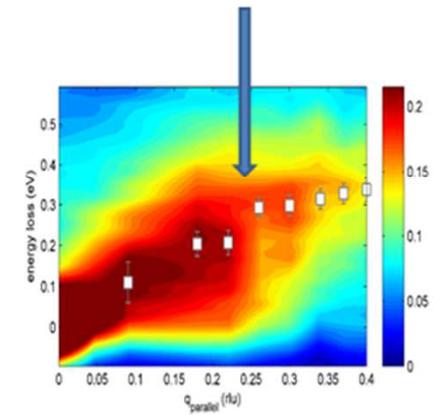
Cu L₃ RIXS

Incident energy dependence demonstrates that spin excitations have collective nature (paramagnons), rather than being e-h pair excitons with spin-flip



M. Minola, H. Gretarsson, Y. Lu, J. Porras, T. Loew, B. Keimer, M. Le Tacon, G. Dellea, Y. Peng, G. Ghiringhelli, L. Braicovich, F. Yakhov, N. B. Brookes, T. Schmitt, Y. Huang, and J. Pellicciari, unpublished

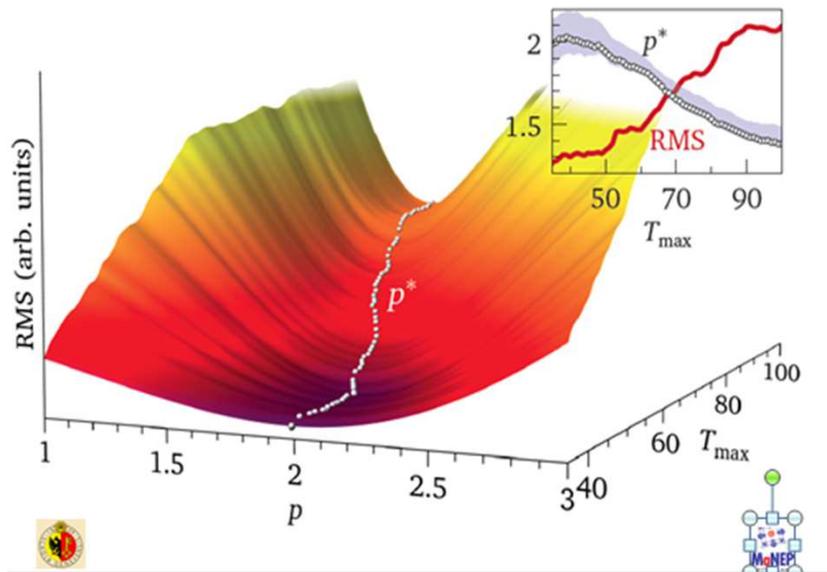
Anomalous paramagnon dispersion in Bi2201 indicate a coupling of the spin excitations to phonons around the charge ordering wave vector



Y. Y. Peng, M. Hashimoto, M. Moretti Sala, A. Amorese, N. B. Brookes, G. Dellea, W.-S. Lee, M. Minola, T. Schmitt, Y. Yoshida, K.-J. Zhou, H. Eisaki, T. P. Devereaux, Z.-X. Shen, L. Braicovich, and G. Ghiringhelli, to be submitted to PRB

Sr_2RuO_4 - "Swiss Mountain landscape"
of the scaling collapse of

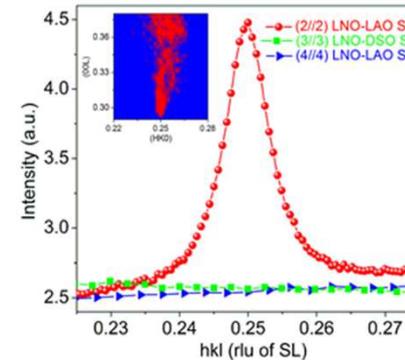
$$1 / \tau_{opt}(\omega, T) \propto (\hbar\omega)^2 + (2\pi k_B T)^2$$



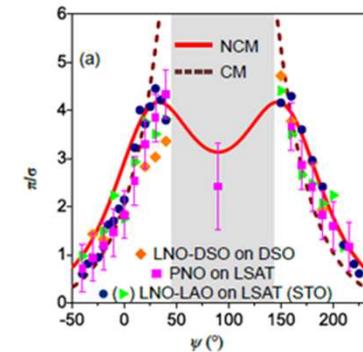
Control/design of collective quantum
phenomena in metal-oxide superlattices

Magnetic order in LaNiO_3 - LaAlO_3 superlattices

resonant x-ray diffraction



dimensionality-controlled
magnetic order

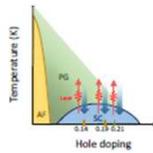


Alex Frano et al., PRL 2013

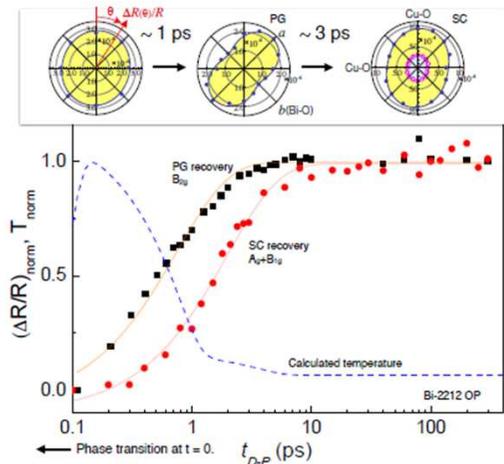
strain-controlled
spin polarization



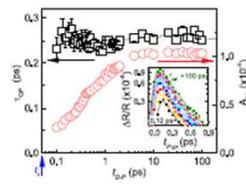
Time-resolved exp



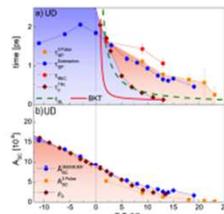
Emergence of broken symmetry in real time BiSCO-2212 (UD-OP-OD)



Ultrafast carrier localisation in the PG state not proper CDW



Phase coherence and pairing timescales vs. T

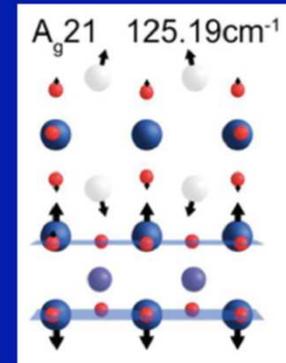
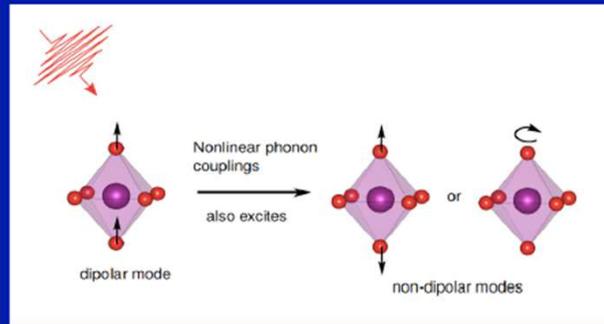


Toda, Y. et al. PRB 90, 094513 (2014) Madan, I. et al. to be published (2014)
Toda, Y. et al. PRB 84, 174516 (2011). L. Stojchevska et al. Science (2014);344:177
Madan, I. et al. Sci Rep 4, 5656 (2014).



Take-Home Message: Selective Control of Quantum Materials through Non-Linear Phononics

Qualitative idea: Först et al. Nature Phys 7, 854 (2011)
Microscopic theory: Subedi, Cavalleri and AG, PRB 89 22031R (2014)



Transient structure of driven YBCO:
Mankowsky et al. Nature 516, 71 (2014)

From light-induced MIT... to light-induced SC.
Theory:
how the structure changes in time after the pulse.

Closing Remarks

What is probably still missing is an integration of the different techniques, i.e. spectroscopies based on photon-matter interaction should be integrated with the magnetic ones (NMR), and the others probing phase transitions and matter out of equilibrium.

These materials are quite complicated and show a complex physics. The role of the O stoichiometry and of the local stress due to the local deformation of the lattice have not completely considered yet, as also the lack of phase homogeneity.

Should be better explored the relationship between the different ordered phases (stripes, CDW, SDW, pseudogap...) and SC. It seems they compete with SC instead of collaborate...

A further contribution to the understanding of these materials and superconductivity will certainly come from new space- and time-resolved techniques and on the study of magnetic dynamics.

...to be continued !

Fonda-Fasella Award Winner – Congrats !!



Riccardo Comin

Acknowledgements

List of Invited Speakers

- **Sergey Borisenko** (IFW Dresden, Germany)
- **Riccardo Comin** (University of Toronto, Canada) - *Fonda-Fasella Award 2014*
- **Andrea Damascelli** (University of British Columbia, Canada)
- **Donglai Feng** (Fudan University, China)
- **Atsushi Fujimori** (University of Tokyo, Japan)
- **Antoine Georges** (Collège de France, France)
- **Giacomo Ghiringhelli** (Politecnico di Milano, Italy)
- **Makoto Hashimoto** (SLAC National Accelerator Laboratory, USA)
- **Bernhard Keimer** (Max Planck Institut für Festkörperforschung, Germany)
- **Dragan Mihailovic** (Jožef Stefan Institute, Slovenia)
- **Luca Perfetti** (École Polytechnique, France)
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- **Dirk van der Marel** (Université de Genève, Switzerland)



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Scientific Committee

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**Thank you to all attendees and
have a nice continuation!**

