A variety of physical phenomena can be found in complex oxide interfaces due to the presence of competing interactions with similar characteristic energies. In particular, ferromagnetic/superconducting (FM/SC) heterostructures based on combining a colossal magnetoresistant manganite such as La$_2$/3Ca$_1$/3MnO$_3$ (LCMO) with a high Tc superconducting cuprate like YBa$_2$Cu$_3$O$_{7-\delta}$ (YBCO) have attracted much attention. These heterostructures allow studying the interaction between superconductivity and magnetism in strongly correlated systems. Also, the competition between electrostatic effects and orbital physics can give rise to exotic electronic reconstructions. It has been reported that electronic charge can be transferred from the manganite to the cuprate \cite{1,2}, inducing a net magnetic moment in the Cu atoms as well as changes in orbital occupation \cite{3-5}. In this talk we present a study of the structure, chemistry and electronic properties of oxide FM/SC interfaces combining electron microscopy with theoretical calculations. By means of atomic resolution scanning transmission electron microscopy and electron energy-loss spectroscopy (EELS), we find that the interfaces display high structural quality and are chemically sharp (Fig. 1). Through the analysis of the EELS fine structure, we can produce maps of the transition metal oxidation state profile across the interface. These maps suggest a non-monotonic modulation of the d-orbital occupancy across the layers, resulting from a transfer of electrons into the cuprate. Model calculations will be used to explain these profiles in terms of the competition between standard charge transfer tendencies (due to band mismatch), strong chemical bonding effects across the interface, and chemical disorder with different characteristic length scales. Research at ORNL supported by the U.S. Dept. of Energy, Basic Energy Sciences, Materials Sciences & Engineering Division, and through the Center for Nanophase Materials Sciences, sponsored by the Scientific User Facilities Division, DoE-BES. JSal was supported by the ERC Starting Investigator Award STEMOX and Juan de la Cierva JCI-2011-09428. Research at UCM supported by Spanish MICINN/MINECO through MAT2011-27470-C02 and Consolider Ingenio 2010 - CSD2009-00013 (Imagine), and by CAM grant S2009/MAT-1756 (PHAMA). Computations supported by the National Center for Supercomputing Applications (US DoE, contract no. DE-AC02-05CH11231).

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Fig. 1: Z-contrast image of a LCMO/YBCO/LCMO trilayer. The inset shows the result of overlaying EELS maps using normalized integrated intensities for the Mn L2,3 (red), Ba M4,5 (blue), and La M4,5 (green) edges, on a matching scale. Data from a Nion UltraSTEM100, at 100 kV, equipped with a Gatan Enfina spectrometer. Adapted from ref. [6].