There are 32 rare-earth ions in the RE_2O_3 unit cell, belonging to two crystallographically distinct sites with inequivalent saturated moments[3]. At the $(2,0,0)_c$ reflection, the contributions from the two rare-earth sites interfere destructively, which should lead to a peak in the observed scattering intensity in the paramagnetic phase if the moments saturate at different fields. Although the magnetic structure and spin hamiltonian of epitaxial, quasi-two-dimensional $(Nd,Ce)_2O_3$ are unknown, it is possible to devise simple experiments to test whether the field-induced scattering is due to NCCO or $(Nd,Ce)_2O_3$.

Kang *et al.* find that at a temperature of 5 K, the (1/2,1/2,0) (that is, $(2,0,0)_c$) intensity reaches a peak at a field of about 6.5 T, and argue that this peak is associated with the upper critical field B_{c2} of NCCO. Figure 1a summarizes the field dependence of an $x=0.18$ superconducting sample of ours in the temperature range 1.9–10 K. Our data agree with those of Kang *et al.* The figure shows that the intensity scales with B/T and exhibits a peak consistent with two-moment paramagnetism. Furthermore, as the upper critical field of a superconductor increases with decreasing temperature, this implies that the reported correspondence of the peak position with B_{c2} at 5 K is coincidental. We do not observe spontaneous neodymium ordering of either $(Nd,Ce)_2O_3$ or NCCO down to 1.4 K.

Figure 1b, c shows that the field effects reported by Kang *et al.* are also observable in a non-superconducting, oxygen-reduced, $x=0.10$ sample, both at the previously reported positions and at positions that are unrelated to the NCCO lattice but equivalent in the cubic lattice of $(Nd,Ce)_2O_3$. Not only are the incommensurate positions (0,0,2.2) and (1/4,1/4,1.1) unrelated to the proposed NCCO magnetic order, but the physical situation of the magnetic field applied parallel (in the cases of the (0,0,2.2) and (1/4,1/4,1.1)) or perpendicular (in all other cases) to the CuO_2 planes is fundamentally different in that the upper critical fields for the two geometries differ significantly. Note that (1/2,0,0) and (1/4,1/4,1.1) correspond to $(1,1,0)_c$ and $(1,0,1)_c$, respectively. Care was taken to ensure that in all cases the magnetic field was applied along a cubic axis of $(Nd,Ce)_2O_3$ and perpendicular to the scattering wavevector.

These simple experimental tests demonstrate that the observed field effects in oxygen-reduced NCCO result from an epitaxial secondary phase of $(Nd,Ce)_2O_3$.

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1. Kang, H. J. *et al. Nature* **423**, 522–525 (2003).
2. Tokura, Y., Takagi, H. & Uchida, S. *Nature* **337**, 345–347 (1989).
3. Moon, R. M., Koehler, W. C., Child, H. R. & Raubenheimer, L. J. *Phys. Rev.* **176**, 722–731 (1968).

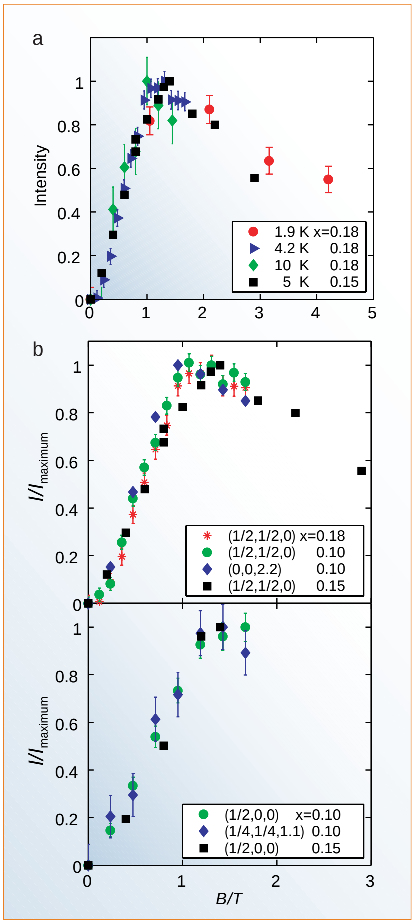

Figure 1 Field and temperature dependence of magnetic scattering. **a,** Arbitrarily scaled scattering intensity at (1/2,1/2,0) for a superconducting sample of NCCO (nominal cerium concentration $x=0.18$; $T_c=20$ K) as a function of B/T with the field along [0,0,1]. The results are compared with the data of Kang *et al.*[1] ($x=0.15$; $T=5$ K). **b, c,** Comparison of the results of Kang *et al.* with data taken at $T=4$ K for a superconducting sample ($x=0.18$) and a non-superconducting sample ($x=0.10$). Superconductivity in NCCO can be achieved only for $x>0.13$. The magnetic field is applied along $[1,\bar{1},0]$ for (0,0,2.2) and (1/4,1/4,1.1) and along [0,0,1] in all other cases. Data were normalized by maximum intensity. Full details are available from the authors.

Kang et al. *reply* — Mang *et al.* observe a cubic $(Nd,Ce)_2O_3$ impurity phase grown epitaxially in annealed samples of electron-doped $Nd_{2-x}Ce_xCuO_4$ (NCCO). They claim that this impurity phase has long-range order parallel to the CuO_2 planes of NCCO but extending only about $4a_c$ perpendicular to the planes, thus forming a quasi-two-dimensional $(Nd,Ce)_2O_3$ lattice matched with the *a–b* plane of NCCO.

Although we have confirmed the presence of such an impurity phase, $(Nd,Ce)_2O_3$ in our samples forms a three-dimensional long-range structural order[1] and is unrelated to the quasi-two-dimensional superlattice reflections[1,2]. In the paramagnetic state of $(Nd,Ce)_2O_3$, a field will induce a net moment on magnetic Nd. By arbitrarily scaling the impurity scattering at (0,0,2.2) for fields less than 7 T to our *c*-axis field-induced scattering of NCCO at (1/2,1/2,0), Mang *et al.* argue that our observed magnetic scattering[2] is due entirely to $(Nd,Ce)_2O_3$. We disagree, however.

There are three ways to resolve this impurity problem. First, if the magnetic scattering at (1/2,1/2,0) (ref. 2) is due entirely to $(Nd,Ce)_2O_3$, one would expect the field-induced intensity to be identical when *B* is parallel to the *c*-axis and when it is parallel to the $[1,-1,0]$ axis, as required by the cubic symmetry of $(Nd,Ce)_2O_3$. Experimentally, we find that the field-induced effect at (1/2,1/2,0) is much larger when *B* is parallel to the *c*-axis[1], which is inconsistent with the cubic symmetry of $(Nd,Ce)_2O_3$ but consistent with the upper critical field of NCCO being much smaller in this geometry[1,2].

Second, as the lattice parameter of $(Nd,Ce)_2O_3$ does not match the *c*-axis lattice parameter of NCCO (ref. 1), measurements at non-zero integer *L* cannot be contaminated by $(Nd,Ce)_2O_3$. Our experiments indicate that the (1/2,1/2,3) peak shows an induced antiferromagnetic component when the field is along the *c*-axis and hence superconductivity is strongly suppressed[1], but not when in the *a–b* plane and superconductivity is only weakly affected[2]. This is direct proof of the connection between field-induced antiferromagnetic order and suppression of superconductivity in NCCO. We also note that the qualitatively different behaviour observed when *B* is perpendicular to *c*, in comparison with when it is parallel to *c*, directly violates the cubic symmetry of $(Nd,Ce)_2O_3$.

Finally, an independent report[3] confirms our principal findings[1,2] in studies of annealed superconducting $Pr_{0.89}LaCe_{0.11}CuO_4$ (PLCCO), a similar electron-doped material in which the cubic impurity phase $(Pr,La,Ce)_2O_3$ has a non-magnetic ground state and no field dependence below 7 T (our unpublished observations). For fields up to 5 T, Fujita *et al.*[3] find enhanced antiferromagnetic order at (1/2,3/2,0) with increasing field in PLCCO. Above 5 T, this order decreases with increasing field, which is consistent with the field dependence of (1/2,1/2,0) of NCCO (ref. 2). The agreement between two different electron-doped systems in two independent experiments[1–3] confirms the quantum phase transition from the superconducting to an antiferromagnetic state in electron-doped, high-T_c superconductors[2].

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1. Matsuura, M. *et al. Phys. Rev. B* **68,** 144503 (2003).
2. Kang, H. J. *et al. Nature* **423,** 522–525 (2003).
3. Fujita, M., Matsuda, M., Katano, S. & Yamada, K. *Physica B* (in the press).