# NMR Search for Charge Order in $HgBa_2CuO_{4+\delta}$

Hirata, M.; Wu, T.; Mayaffre, H.; Krämer, S.; Julien, M.H. (LNCMI Grenoble, France); Lee, J.A.; Mounce, A.M.; Halperin, W.P. (Northwestern University); Chan, M.K.; Dorow, C.J.; Greven, M. (University of Minnesota)

## Introduction

Whether high- $T_c$ cuprates are generically prone to charge-density-wave (CDW) formation and whether this has any importance for understanding their superconductivity has been debated for more than twenty years. Recently, high field NMR measurements in $YBa_2Cu_3O_y$ (YBCO) have demonstrated that superconductivity coexists, but competes, with CDW order at low temperatures, which has been argued to support the view that cuprates are generically unstable towards CDW formation [1]. Subsequent measurements using X-ray scattering [2] and NMR [3] have found that short-range CDW correlations persist in the normal state of YBCO and, more recently, short-range CDW order was indeed confirmed in Bi-, La- and Hg-based hole-doped cuprates as well as in electron-doped cuprates. While its universality is now established, the nature and the importance of the CDW remain, however, controversial. Especially, how the CDW in high fields and low temperatures relates to the CDW in low fields and/or high temperatures appears to be a key question.

## Experimental

We have investigated two single crystals of $HgBa_2CuO_{4+\delta}$ (Hg1201) with $T_c$ = 57 K and 76 K, using NMR in the hybrid magnet. Both samples were grown in Greven's group. The 76 K sample was substituted with $^{17}O$ isotope in Halperin's group.

## Results and Discussion

In contrast with YBCO, no anomalous field-induced broadening or splitting of the NMR lines were found here (see figure). This negative result can be explained in several possible ways: either long-range, static, charge order occurs only for fields greater than 45 T, or it occurs over a very narrow doping range in-between our two samples, or the CDW amplitude is too weak to be resolved in the NMR lines of Hg1201, which are significantly broader than in ortho-II YBCO.

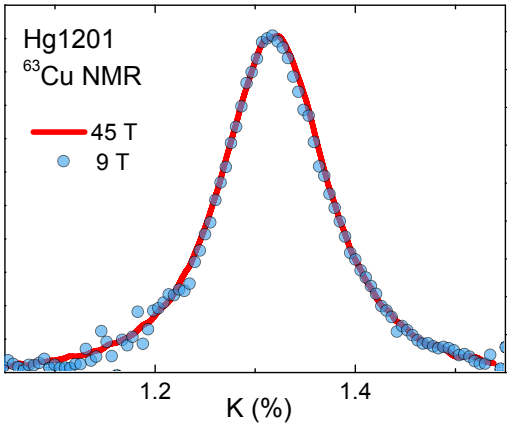


Fig.1 $^{63}Cu$ central line in the $T_c$ = 57 K sample. No change is observed with field. Similar results are obtained for satellite $^{63}Cu$ lines as well as for $^{17}O$ NMR lines in the 76 K sample.

## Conclusions

In order to determine whether field-induced charge order is absent below 45 T in Hg1201 or not, we crucially need a crystal of, if possible, even higher quality and especially with a $T_c$ of exactly 72 K, instead of 76 K, that is, the very same $T_c$ as the crystals in which quantum oscillations and charge order have been observed [4].

## Acknowledgements

A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490, the State of Florida, and the U.S. Department of Energy. Work in Grenoble is funded by the Université Joseph Fourier and by the French Agence Nationale de la Recherche (ANR) under reference AF-12-BS04-0012-01 (Superfield). Work at the University of Minnesota is funded by the U.S. Department of Energy, Office of Basic Energy Sciences. Worth at Northwestern University is funded by US DOE Award No. DE-FG02-05ER46248.

## References

[1] Wu, T. *et al.* Nature 477, **191** (2011). Nature Commun. **4**, 2113 (2013).
[2] Ghiringhelli, G. *et al*. Science **337**, 821 (2012). Chang, J. *et al*. Nature Phys. **8**, 871 (2012). Achkar, A.J. *et al*. Phys. Rev. Lett. **109**, 167001 (2012).
[3] Wu, T. *et al*. arXiv:1404.1617.
[4] Barisic, N. *et al*. Nature Phys. **9**, 761 (2013). Tabis, W. *et al*. arXiv:1404.7658.