Experimental Observation of Bethe Strings

Zhe Wang[1,2], Jianda Wu[3], Wang Yang[3], A. K. Bera[4,5], D. Kamenskyi[6], A. T. M. N. Islam[4], Shenglong Xu[3], J. M. Law[7], B. Lake[4,8], Congjun Wu[3], A. Loidl[2]

[1]*Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany*
[2]*Experimental Physics V, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, 86135 Augsburg, Germany*
[3]*Department of Physics, University of California, San Diego, California 92093, USA*
[4]*Helmholtz-Zentrum Berlin für Materialien und Energie, 14109 Berlin, Germany*
[5]*Solid State Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, India*
[6]*High Field Magnet Laboratory, Radboud University, 6525 ED Nijmegen, The Netherlands*
[7]*Hochfeld Magnetlab Dresden, Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany*
[8]*Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany*

Email: wangzhe.nju@gmail.com

Almost one century ago, string states - complex bound states (Wellenkomplexe) of magnetic excitations - have been predicted to exist in one-dimensional quantum magnets [1] and since then become a subject of intensive theoretical studies [2-7]. However, experimental realization and identification of string states in a condensed-matter system remain an unsolved challenge up to date. Here we use high-resolution terahertz spectroscopy to resolve string states in the antiferromagnetic Heisenberg-Ising chain $SrCo_2V_2O_8$ in strong longitudinal magnetic fields [8]. In the field-induced quantum critical regime, we identify strings and fractional magnetic excitations, which are precisely described by the Bethe ansatz [7]. Close to the quantum criticality, the string excitations govern the quantum spin dynamics, while the fractional excitations, dominant at low energies, reflect the antiferromagnetic quantum fluctuations.

References

[1] H. Bethe, 1931 *Z. Phys.* **71**, 205-226.
[2] C. N. Yang, C. P. Yang, 1966 *Phys. Rev.* **150**, 327.
[3] M. Gaudin, 1971 *Phys. Rev. Lett.* **26**, 1301-1304.
[4] M. Takahashi, M. Suzuki, 1972 *Prog. Theor. Phys.* **48**, 2187-2209.
[5] G. Müller, H. Thomas,, H. Beck, & J. C. Bonner,1981 *Phys. Rev. B* **24**, 1429.
[6] N. Kitanine,, J. M. Mailet, & V. Terras, 1999 *Nucl. Phys. B* **554**, 647.
[7] Wang Yang et al, 2017 arXiv:1702.01854
[8] Zhe Wang et al, 2017 *Nature* accepted, arXiv:1706.04181