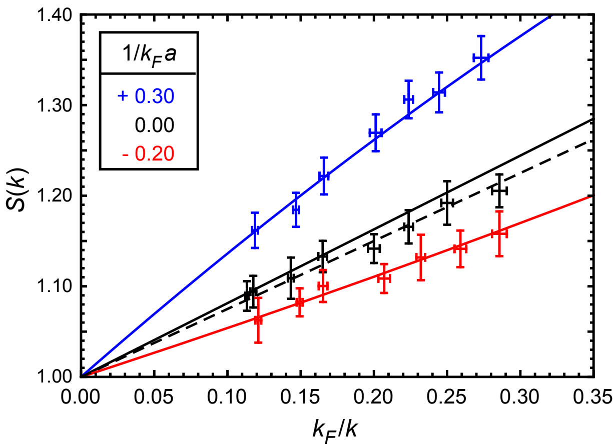

Figure 3. Universal dependence of the static structure factor of a strongly interacting Fermi superfluid. Measured and calculated static structure factor versus k_F/k for $1/(k_F a) = +0.3$, 0.0, and -0.2. Bragg momentum k is fixed while k_F is varied by changing the mean trapping frequency $\bar{\omega}$. Vertical error bars are due to atom number fluctuations and uncertainties in measuring the center of mass and horizontal error bars are due to atom number fluctuations and uncertainties in $\bar{\omega}$. Solid lines are the zero temperature theory and the dashed line is a straight line fit to the $1/(k_F a) = 0$ data yielding a slope of 0.75 ± 0.03.

which may be due to reduced pairing at the finite temperature ($T/T_F = 0.10 \pm 0.02$ at unitarity). At $1/(k_F a)$ = -0.2 the temperature will be lower following the adiabatic magnetic field sweep [34] while at $1/(k_F a) = +0.3$ the temperature will be higher but pairing takes place at much higher temperatures. At $T \ll T_C$ ($\simeq 0.2\,T_F$), phonons dominate the excitations and the contact should increase as $(T/T_F)^4$ [35]. In the relevant temperature window, we estimate this increase to be only 0.1% which could easily be negated by normal single-particle excitations localized at the cloud edge. At $1/(k_F a) = +0.3$ the data depart from a straight line displaying the downward curvature consistent with the first order term in Eq. (2). A similar upward curvature is seen at $1/(k_F a)$ = -0.2. Our simple relation Eq. (2) is seen to accurately describe $S(k)$ on both sides of the Feshbach resonance demonstrating the wide applicability of the Tan relations.

In summary, we have shown that the structure factor of a strongly interacting ultracold Fermi gas follows a universal law which is a direct consequence of Tan's relation for the pair correlation functions. Our measurements provide one of the first demonstrations of a broadly applicable exact result for Fermi gases in the BEC-BCS crossover. This work opens the way to a complete temperature and interaction dependent map of the contact through the BEC-BCS crossover and may provide a new means for obtaining the equation of state.

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[1] H. Heiselberg, Phys. Rev. A **63**, 043606 (2001).
[2] T.-L. Ho, Phys. Rev. Lett. **92**, 090402 (2004).
[3] H. Hu, P.D. Drummond, and X.-J. Liu, Nat. Phys. **3**, 469 (2007).
[4] S. Jochim *et al.* Science **302**, 2101 (2003).
[5] M. Greiner, C. A. Regal, and D. S. Jin, Nature **426**, 537 (2003).
[6] M. W. Zwierlein *et al.*, Nature **435**, 1047 (2005).
[7] J. Kinast *et al.*, Science **307**, 1296 (2005).
[8] G. B. Partridge *et al.* Phys. Rev. Lett. **95**, 020404 (2005).
[9] S. Nascimbène *et al.* Nature **463**, 1067 (2010).
[10] N. Navon S. Nascimbène, F. Chevy and C. Salomon, Science **328**, 729 (2010).
[11] S. Giorgini, L. P. Pitaevskii, and S. Stringari, Rev. Mod. Phys. **80**, 1215 (2008).
[12] S. Tan, Ann. Phys. **323**, 2952 (2008).
[13] S. Tan, Ann. Phys. **323**, 2971 (2008).
[14] S. Tan, Ann. Phys. **323**, 2987 (2008).
[15] R. Combescot, S. Giorgini, and S. Stringari, Europhys. Lett. **75**, 695 (2006).
[16] H. Hu, X.-J. Liu, and P. D. Drummond, Europhys. Lett. **74**, 574 (2006).
[17] E. Braaten, and L. Platter, Phys. Rev. Lett. **100**, 205301 (2008).
[18] S. Zhang and A. J. Leggett, Phys. Rev. A 79, 023601 (2009).
[19] F. Werner, L. Tarruell, and Y. Castin, Eur. Phys. J. B **68**, 401 (2009).
[20] J. T. Stewart, J. P. Gaebler, T. E. Drake, and D. S. Jin, Phys. Rev. Lett. **104**, 235301 (2010).
[21] L. Luo *et al.*, Phys. Rev. Lett. **98**, 080402 (2007).
[22] G. E. Astrakharchik, J. Boronat, J. Casulleras, and S. Giorgini, Phys. Rev. Lett. **93**, 200404 (2004).
[23] X.-J. Liu, H. Hu, and P. D. Drummond, Phys. Rev. Lett. **102**, 160401 (2009).
[24] D. Pines, and P. Nozières, *The Theory of Quantum Liquids, Vol. I* (Benjamin, New York, 1966).
[25] J. Stenger *et al.*, Phys. Rev. Lett. **82**, 4569 (1999).
[26] F. Zambelli, L. P. Pitaevskii, D. M. Stamper-Kurn, and S. Stringari, Phys. Rev. A **61**, 063608 (2000).
[27] D.M. Stamper-Kurn *et al.*, Phys. Rev. Lett. **83**, 2876 (1999).
[28] J. Steinhauer, R. Ozeri, N. Katz, and N. Davidson, Phys. Rev. Lett. **88**, 120407 (2002).
[29] G. Veeravalli, E. Kuhnle, P. Dyke, and C. J. Vale, Phys. Rev. Lett. **101**, 250403 (2008).
[30] C. H. Schunck, Y. Shin, A. Schirotzek, and W. Ketterle, Nature **454**, 739 (2008).
[31] J. T. Stewart, J. P. Gaebler, and D. S. Jin, Nature **454**, 744 (2008).
[32] J. Fuchs *et al.*, J. Phys. B: At. Mol. Opt. Phys. **40**, 4109 (2007).
[33] A. Brunello *et al.* Phys. Rev. A **64**, 063614 (2001).
[34] L. D. Carr, G. V. Shlyapnikov, and Y. Castin, Phys. Rev. Lett. **92**, 150404 (2004).
[35] Z. Yu, G. M. Bruun, and G. Baym, Phys. Rev. A **80**, 023615 (2009).