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Reply to "Comment on 'Superconductivity in Kagome Metal YRu_3Si_2 with Strong Electron Correlations'"

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We thank Talantsev for his insightful comment [1] on our work. He points out that the simplified Ginzburg–Landau (GL) equation for the lower critical field $\mu_0 H_{c1}(0)$ will yield two mathematical roots for zero-temperature penetration depth $\lambda_{GL}(0)$ given the fixed zero-temperature coherence length $\xi_{GL}(0)$ and $\mu_0 H_{c1}(0)$. In our original paper [2], we chose one $\lambda_{GL}(0)$ root with small value and derived the values of zero-temperature thermodynamic critical field $\mu_0 H_c(0)$ and GL parameter κ_{GL}. Dr. Talantsev mentioned that this value of $\lambda_{GL}(0)$ is much smaller than that measured from subsequent μSR experiment [3] and thus other $\lambda_{GL}(0)$ root could be reasonable.

Using our experimentally determined values $\xi_{GL}(0) = 22.43$ nm and $\mu_0 H_{c1}(0) = 28.0$ mT, the simplified GL equation

$$\mu_0 H_{c1} = \frac{\phi_0}{4\pi\lambda_{GL}^2} \ln \frac{\lambda_{GL}}{\xi_{GL}}, \tag{1}$$

will yield two roots $\lambda_{GL}(0) = 24.8$ nm and 90.6 nm. Which one is physically reasonable can not be determined. To solve this problem, Dr. Talantsev proposed an alternative expression [1,4] that can yield a unique root

$$\mu_0 H_{c1} = \frac{\phi_0}{4\pi\lambda_{GL}^2} \ln\left(1 + \sqrt{2}\frac{\lambda_{GL}}{\xi_{GL}}\right). \tag{2}$$

Using this formula and our experimental data, the calculated $\lambda_{GL}(0) = 110.4$ nm and $\kappa_{GL} = 4.92$. This result is in good agreement (within approximately 20 %) with the large $\lambda_{GL}(0)$ root derived from our original simplified GL equation, further supported by the μSR results. Thus, this large $\lambda_{GL}(0)$ value rather than the small one should be more physically reasonable.

Based on this discussion, the relevant superconducting parameters of YRu_3Si_2 should be revised accordingly. Using Eq. (2), the calculated $\lambda_{GL}(0)$ is 110.4(6) nm, Ginzburg–Landau parameter $\kappa_{GL} = 4.92(3)$, and thermodynamic critical field $\mu_0 H_c(0) = 0.094(1)$ T. The following key conclusions of our original paper remain unaffected: YRu_3Si_2 is a type-II superconductor because the revised $\kappa_{GL} = 4.92(3)$ is still well above the threshold $1/\sqrt{2}$. The values of $\Delta C_{ele}/\gamma T_c = 1.21(4)$ and $\lambda_{e\text{-}ph} = 0.50(2)$ are unchanged, indicating YRu_3Si_2 is a weak to moderate coupling superconductor. YRu_3Si_2 should have the strong electron correlation effects because of the large Kadowaki–Woods ratio ($A/\gamma^2 = 3.15(2)$ $\mu\Omega\cdot cm\cdot mol^2\cdot K^2\cdot J^{-2}$) and Wilson ratio ($R_W = 1.49(4)$). We acknowledge Dr. Talantsev's proposal of using the alternative expression that yields a reasonable single unique root of $\lambda_{GL}(0)$.

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