Onari and Kontani Reply: In Ref. [1], we studied the nonmagnetic impurity effect in the multiorbital model for iron pnictide superconductors. In the sign-reversing s-wave state ($s_\pm$), we found that (i) T_c is substantially suppressed by the interband impurity scattering, since the T matrix has large interband matrix elements. (ii) This result holds even in the unitary limit ($I \sim \infty$), contrary to the fact that (iii) interband scattering vanishes in the unitary limit if the bare impurity potential in the band-diagonal basis $\hat{I}^b$ is a constant matrix and $\det\{\hat{I}^b\} \neq 0$. In iron pnictides, statement (ii) holds since $\hat{I}^b$ shows large k dependence due to the orbital degree of freedom.

In Ref. [2], Bang claimed that statement (iii) is incorrect. However, this result had been found by many authors [3–7] based on the "conventional T-matrix approximation" that is exact when the impurity concentration n_{imp} is dilute, and it was also confirmed by the authors of Ref. [8] recently. The results (i) and (ii) are the main findings in Ref. [1].

Here, we explain the conventional T-matrix approximation when $\hat{I}^b$ is a constant matrix and elucidate the error in Ref. [2]. The normal and anomalous self-energies up to $O(n_{\mathrm{imp}})$ are

$$\hat{\Sigma}^n(i\omega_n) = n_{\mathrm{imp}}\hat{T}^b(i\omega_n), \tag{1}$$

$$\hat{\Sigma}^a(i\omega_n) = n_{\mathrm{imp}}\hat{T}^b(i\omega_n)\hat{f}(i\omega_n)\hat{T}^b(-i\omega_n), \tag{2}$$

where $\hat{T}^b = (\hat{1} - \hat{I}^b\hat{g}^b_{\mathrm{loc}})^{-1}\hat{I}^b$ is the T matrix; $\hat{g}^b_{\mathrm{loc}}$ is the local normal Green function that is diagonal in the band-diagonal basis. In general, $\hat{T}^b$ is not diagonal. However, it becomes diagonal in the unitary limit unless $\det\{\hat{I}^b\} = 0$ [1]. In Eq. (2), $\hat{f}(i\omega_n)$ is the local anomalous Green function near T_c, and $\hat{\Sigma}^a$ represents the impurity scattering of Cooper pairs: In the $s_\pm$-wave state with $\Delta_e = -\Delta_h$, T_c is suppressed by the cancellation of two gaps due to the interband scattering described by $T^b_{e,h} \neq 0$. That is, the impurity effect on T_c is absent in the unitary limit since $T^b_{e,h} = 0$.

By using Eqs. (1) and (2), the normal and anomalous Green functions just below T_c are given as

$$\hat{G}_k(i\omega_n) = [(i\omega_n + \mu)\hat{1} - \hat{\Sigma}^{n,\mathrm{ren}}(i\omega_n) - \hat{H}^0_k]^{-1}, \tag{3}$$

$$\hat{F}_k(i\omega_n) = \hat{G}_{-k}(-i\omega_n)\hat{\Sigma}^a(i\omega_n)\hat{G}_k(i\omega_n), \tag{4}$$

where $\hat{\Sigma}^{n,\mathrm{ren}}(i\omega_n) \equiv \hat{\Sigma}^n(i\omega_n) - \delta\mu\hat{1}$ is the renormalized normal self-energy. $\delta\mu$ is the change in the chemical potential due to impurities to fix the electron number $N = \sum_{k,n}\mathrm{Tr}\hat{G}_k(i\omega_n)e^{i\omega_n\delta}$: $\delta\mu \sim \Sigma^n_{ll}$, where Σ^n_{ll} denotes the (average of the) diagonal part of the normal self-energy; $\delta\mu \sim n_{\mathrm{imp}}I^b_{ll}$ in the Born limit.

In Ref. [2], Bang claimed that the T matrix should be renormalized as $\hat{T}^{b,\mathrm{ren}} \equiv \hat{T}^b(i\omega_n) - \hat{I}^b$. However, this renormalization occurs only for the normal self-energy in Eq. (1), while it is absent for the anomalous self-energy in Eq. (2). Therefore, $\hat{T}^b$ in Eq. (2) should not be replaced with $\hat{T}^{b,\mathrm{ren}}$ contrary to the claim by Bang [9]. Since $\hat{T}^b$ is band-diagonal in the unitary limit, the pair breaking due to interband scattering is absent in the unitary limit. This result had been confirmed by many authors [3–8].

On the other hand, Fe-ion substitution in iron pnictides induces the orbital-diagonal local impurity potential. Then, $\hat{I}^b$ is given as $\hat{I}^b_{k,k'} = I\hat{U}^\dagger_k\hat{U}_{k'}$, where $\hat{U}_k$ is the transformation matrix between orbital and band bases. Because of its large k dependence in iron pnictides, $\hat{T}^b$ is not diagonal even in the unitary limit, and therefore the $s_\pm$-wave state is fragile against impurities. This is the main result in Ref. [1].

In summary, our studies of the impurity effect in iron pnictides [1] are correctly calculated based on the conventional T-matrix approximation that is exact in the dilute limit. The replacement of $\hat{T}$ with $\hat{T} - \hat{I}$ proposed by Bang [2] breaks the perturbation theory and is therefore erroneous.

Seiichiro Onari[1] and Hiroshi Kontani[2]
[1]Department of Applied Physics
Nagoya University and JST
TRIP Furo-cho, Nagoya 464-8602, Japan
[2]Department of Physics
Nagoya University and JST
TRIP, Furo-cho, Nagoya 464-8602, Japan

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[9] If we replace $\hat{T}^b \to \hat{T}^b - \hat{I}^b$ in Eq. (2), the depairing due to interband scattering is $\gamma_{\mathrm{inter}} \sim n_{\mathrm{imp}}(T^b_{e,h} - I^b_{e,h})^2N(0)$ for the $s_\pm$-wave state. Then, T_c disappears by *infinitesimally small* n_{imp} for $I_{e,h} \to \infty$. This unphysical result comes from the violation of the perturbation theory.

