Comment on "Strangeness −2 Hypertriton"

In a recent Letter, Garcilazo and Valcarce [1] reported on a $\Lambda\Lambda N - \Xi NN$ coupled-channel three-body Faddeev calculation that binds ${}^{3}_{\Lambda\Lambda}$n and ${}^{3}_{\Lambda\Lambda}$H by about 0.5 MeV below the corresponding $\Lambda\Lambda N$ thresholds. This contrasts with *ab initio* $A \leq 6$ few-body coupled-channel calculations associating a loosely bound ${}^{4}_{\Lambda\Lambda}$H with the onset of $\Lambda\Lambda$ hypernuclear binding [2]. Here, I argue that the $\mathcal{S} = -2$ chiral constituent quark model (CCQM) interactions [3] that bind ${}^{3}_{\Lambda\Lambda}$H [1], as well as the unobserved H dibaryon [4], overbind the uniquely identified NAGARA emulsion event of ${}^{6}_{\Lambda\Lambda}$He [5] by more than 4 MeV, casting doubts on the predictive power of the CCQM for $\mathcal{S} = -2$.

Listed in Table I are $\Delta B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He})$ values obtained in two sets of $\alpha\Lambda\Lambda$ three-body calculations [6,7] which use identical $V_{\Lambda\alpha}$; the $V_{\Lambda\Lambda}$ from Ref. [7] are softer than the $V_{\Lambda\Lambda}$ from Ref. [6]. Within each set, $\Delta B_{\Lambda\Lambda}$ increases with increasing the strength of $V_{\Lambda\Lambda}$, as represented by the listed values of $-a_{\Lambda\Lambda}$. For $a^{\mathrm{CCQM}}_{\Lambda\Lambda} = -3.3$ fm, corresponding to the decoupled $V^{\mathrm{CCQM}}_{\Lambda\Lambda}$ [9], interpolation within the first set [6] suggests that $\Delta B^{\mathrm{CCQM}}_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He}) = 3.2 \pm 0.1$ MeV, at variance with $\Delta B^{\mathrm{exp}}_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He}) = 0.67 \pm 0.17$ MeV [8]. Interpolation within the second set [7] results in a value larger by at least 1 MeV. Since $V^{\mathrm{CCQM}}_{\Lambda\Lambda}$ [4] is softer than the $V_{\Lambda\Lambda}$ of Ref. [7], which is softer than the $V_{\Lambda\Lambda}$ of Ref. [6], $\Delta B^{\mathrm{CCQM}}_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He})$ should be even larger. Furthermore, the inclusion of the Pauli-suppressed $\Lambda\Lambda - \Xi N$ coupling increases $\Delta B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He})$ by another 0.2–0.5 MeV [7], and probably by more in the CCQM, owing to its stronger coupling effects. Altogether, I estimate conservatively that $\Delta B^{\mathrm{CCQM}}_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He}) > 4.7 \pm 0.5$ MeV, overbinding ${}^{6}_{\Lambda\Lambda}$He by more than 4.0 ± 0.5 MeV and thereby destroying the consistency among the bulk of $\Lambda\Lambda$ hypernuclear data [10].

The CCQM $\Lambda\Lambda - \Xi N$ coupled-channel interactions used in Ref. [1] are not unambiguously constrained by the scarce, imprecise free-space scattering data [11]. Figure 5 in Ref. [12] shows a variety of $\mathcal{S} = -2$ interactions satisfying such constraints. In particular, there are no $\Lambda\Lambda$ scattering data to constrain $a_{\Lambda\Lambda}$. Recent analysis of the $\Lambda\Lambda$ invariant mass from the in-medium reaction ${}^{12}\mathrm{C}(K^-, K^+\Lambda\Lambda X)$ [13] results in $a_{\Lambda\Lambda} = -1.2 \pm 0.6$ fm [14], consistently with $a_{\Lambda\Lambda} \sim -0.5$ fm from ${}^{6}_{\Lambda\Lambda}$He [6,15], in disagreement with $a^{\mathrm{CCQM}}_{\Lambda\Lambda} = -3.3$ fm. Furthermore, the very strong CCQM $\Lambda\Lambda - \Xi N$ coupling interaction, which leads to a bound H below the $\Lambda\Lambda$ threshold [4] and is also responsible for binding ${}^{3}_{\Lambda\Lambda}$H, is at odds with the latest HAL QCD lattice-simulation analysis which locates the H dibaryon near the ΞN threshold [16]. For all these reasons, foremost for heftily overbinding ${}^{6}_{\Lambda\Lambda}$He, the predictive power of the CCQM for $\mathcal{S} = -2$, including the prediction of a ${}^{3}_{\Lambda\Lambda}$H bound state [1], is questionable.

TABLE I. $\Delta B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He}) = B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He}) - 2B_{\Lambda}({}^{5}_{\Lambda}\mathrm{He})$ (in MeV) from $\alpha\Lambda\Lambda$ calculations [6,7] with no $\Lambda\Lambda - \Xi N$ coupling, and scattering lengths $a_{\Lambda\Lambda}$ and effective ranges $r_{\Lambda\Lambda}$ (in fm) of the input $\Lambda\Lambda$ interaction $V_{\Lambda\Lambda}$. $\Delta B^{\mathrm{exp}}_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He}) = 0.67 \pm 0.17$ MeV [8].

	Ref. [6]	Ref. [6]	Ref. [6]	Ref. [6]	Ref. [6]	Ref. [7]	Ref. [7]
$-a_{\Lambda\Lambda}$	0.31	0.77	2.81	5.37	10.6	1.90	21.0
$r_{\Lambda\Lambda}$	3.12	2.92	2.95	2.40	2.23	3.33	2.54
$\Delta B_{\Lambda\Lambda}$	0.79	1.51	2.91	3.91	4.51	4.12	8.29

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