Effective field theory for dilute Fermi systems at fourth order

Hammer & Furnstahl, NPA **678**, 277
Kaplan, Savage, and Wise, NPB **534**, 329

For decades, the dilute Fermi gas has been a central problem for many-body calculations; especially due to recent progress in experiments with ultracold atomic gases.

We calculated the Fermi-momentum (or k_F–a_s) expansion for the ground-state energy of the dilute Fermi gas completely up to fourth order in cutoff and dimensional regularization.

$$E(k_F) \simeq \varrho \frac{k_F^2}{2M}\left[\frac{3}{5} + (g-1)\left\{\frac{2}{3\pi}k_F a_s + \frac{4}{35\pi^2}(11-2\ln 2)(k_F a_s)^2 + \big(0.0755732 + 0.0573879(g-3)\big)(k_F a_s)^3\right\} + \frac{1}{10\pi}(g-1)(k_F a_s)^2 k_F r_s + \frac{1}{5\pi}(g+1)(k_F a_p)^3 + E_4(k_F) + \mathcal{O}(k_F^5 \ln k_F)\right]$$

0 1 2 3 4

k_F–a_s expansion

diagram	g factor	value
I1*	1	+0.0383115(0)
I2*+I3+I4*+I5*	1	+0.0148549(0)
I6	1	−0.0006851(0)
IA1	$g(g-3)+4$	−0.003623(1)
IA2	$g(g-3)+4$	−0.001672(1)
IA3	$g(g-3)+4$	−0.003343(1)
II1*+II2*	$g-3$	+0.058359(1)
II3+II4	$g-3$	−0.003358(1)
II5**	$g-3$	+0.0645(1)
II6**,*	$g-3$	−0.0265(2)
II7+II12	$g-3$	+0.003923(1)
II8+II11	$g-3$	+0.007667(1)
II9	$g-3$	−0.000981(1)
II10	$g-3$	−0.000347(1)
IIA1**	$3g-5$	+0.0647(1)
IIA2+IIA4	$3g-5$	+0.004122(1)
IIA3	$3g-5$	−0.000461(1)
IIA5	$3g-5$	+0.003542(1)
IIA6	$3g-5$	+0.003331(1)
III1***,**,*+III7+III8***,*	$g-1$	−0.0513(2)
III2***+III9+III10***	$g-1$	+0.001650(1)
$(\text{II5}+\text{IIA1})_{g=2}$	1	+0.00018(1)
$(\text{II6}+\text{III1}+\text{III7}+\text{III8})^*_{g=2}$	1	−0.0248(1)
$\sum_{\text{diagrams},g=2}$	1	−0.0425(1)

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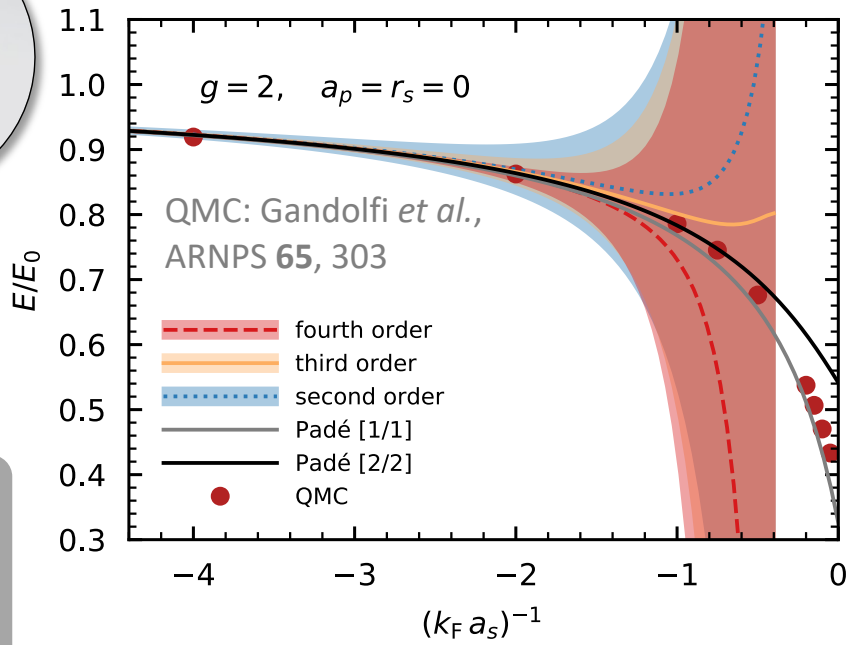
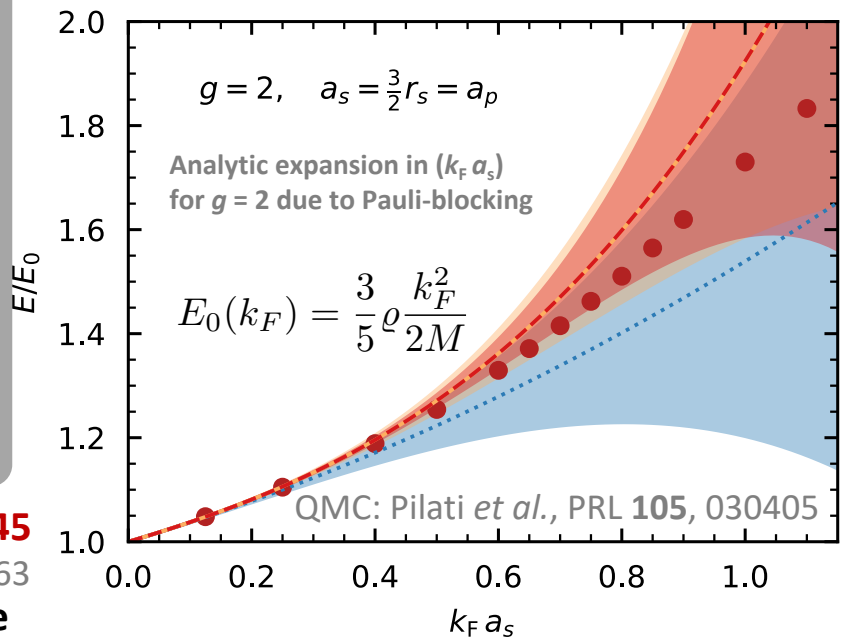
cf. Baker, PRC **60**, 054311 & RMP **43**, 479, and Kaiser, NPA **860**, 41

For spin one-half fermions, the (analytic) expansion is well-converged for $|k_F a_s| \lesssim 0.5$ and its convergence can be improved for $|k_F a_s| \lesssim 1$ with resummation methods.





The extracted Bertsch parameter $\xi_n = 0.33\ldots0.54$ is consistent with cold atomic gases: $\xi_n = 0.45$

Ku *et al.*, Science **335**, 563

Our results for provide constraints for ultracold atoms and dilute neutron matter and may be used to construct improved models of neutron star crusts.

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Wellenhofer, CD, Schwenk, PRC **104**, 014003
Wellenhofer, CD, Schwenk, PLB **802**, 135247