

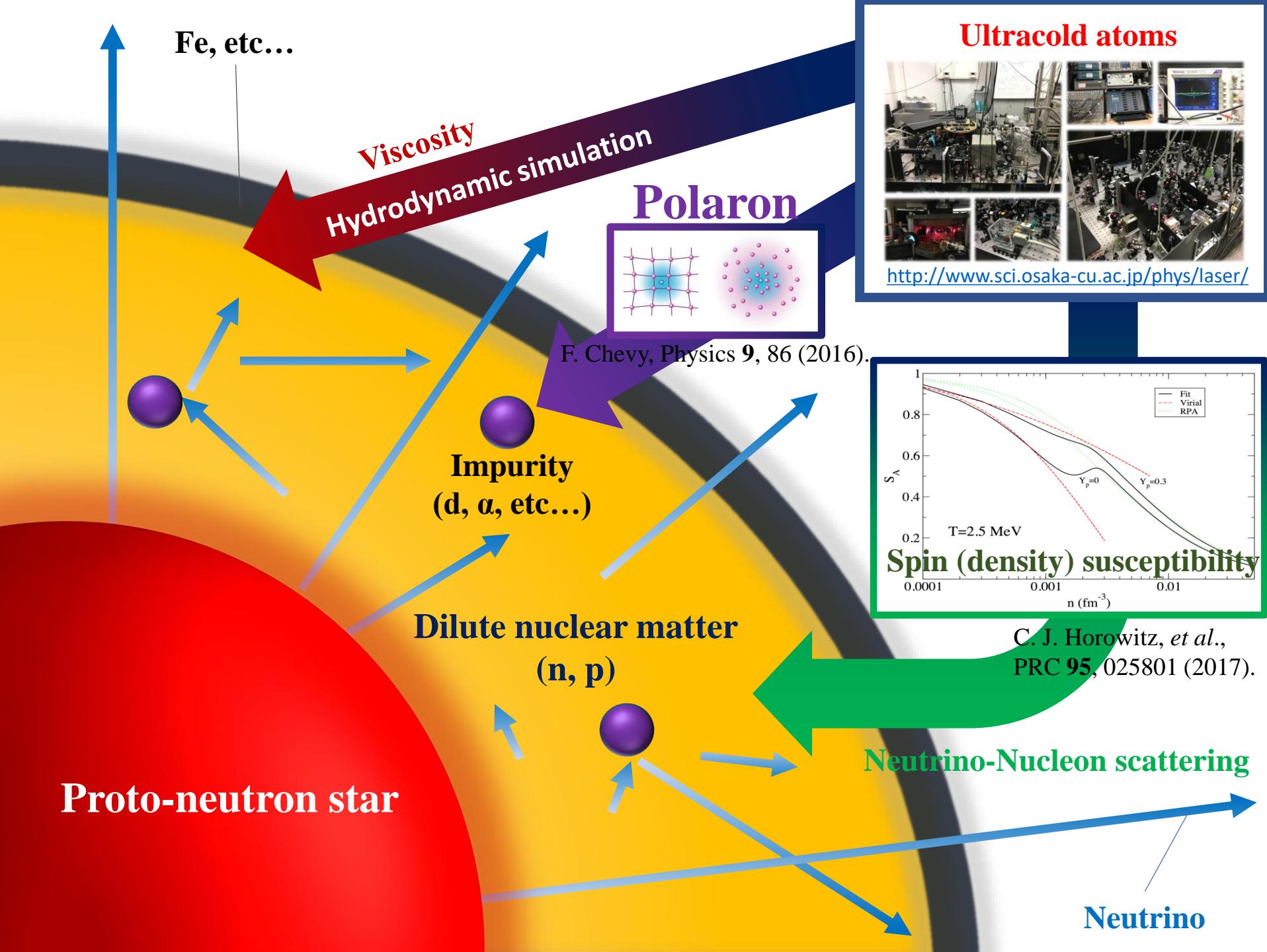
Quantum many-body problem from the viewpoint of polarons: From cold atoms to nuclear matter

C02 report

Hiroyuki Tajima

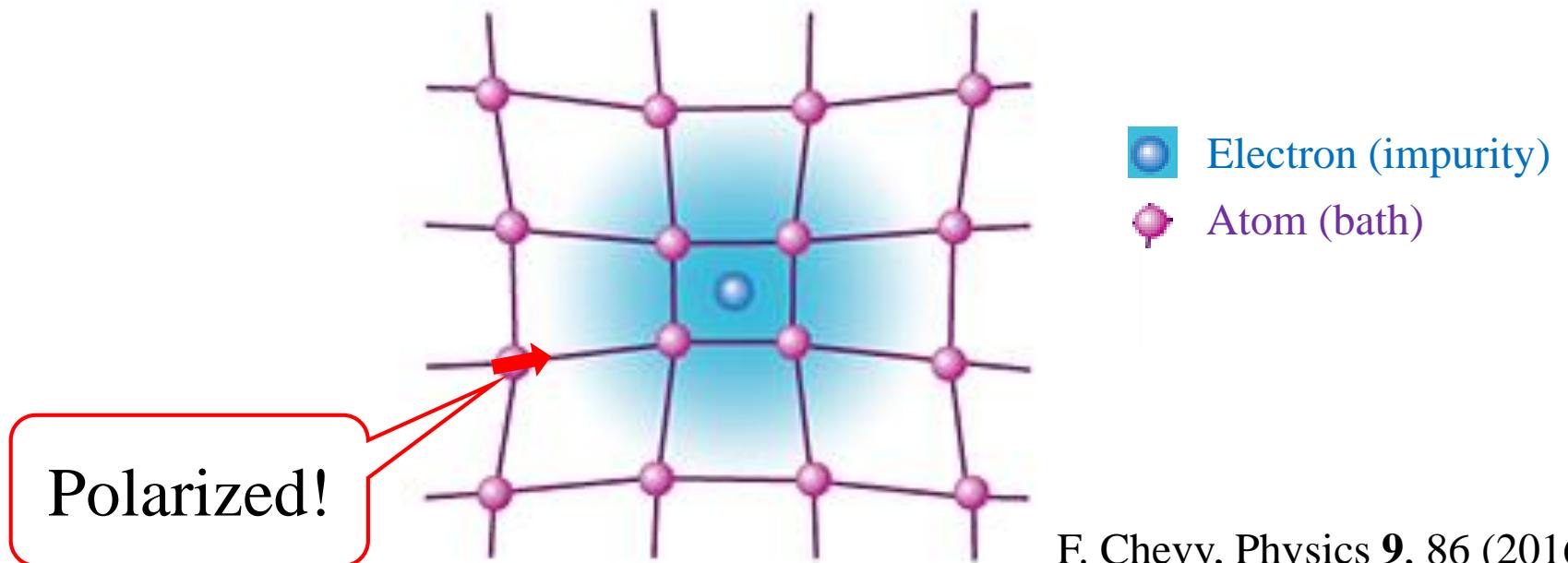
Kei Iida's Group, Kochi University

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Junnichi Takahashi (Waseda), Kazuya Nishimura (Kochi), Tomohiro Hata (Kochi),
Kazunari Ochi (Kochi), Takahiko Miyakawa (Aichi Univ. of Education),
Hiroyuki Yabu (Ritsumeikan)



What is a polaron?

- Quasiparticle picture to understand the **interaction effect** between **electrons** and **atoms** in solid material

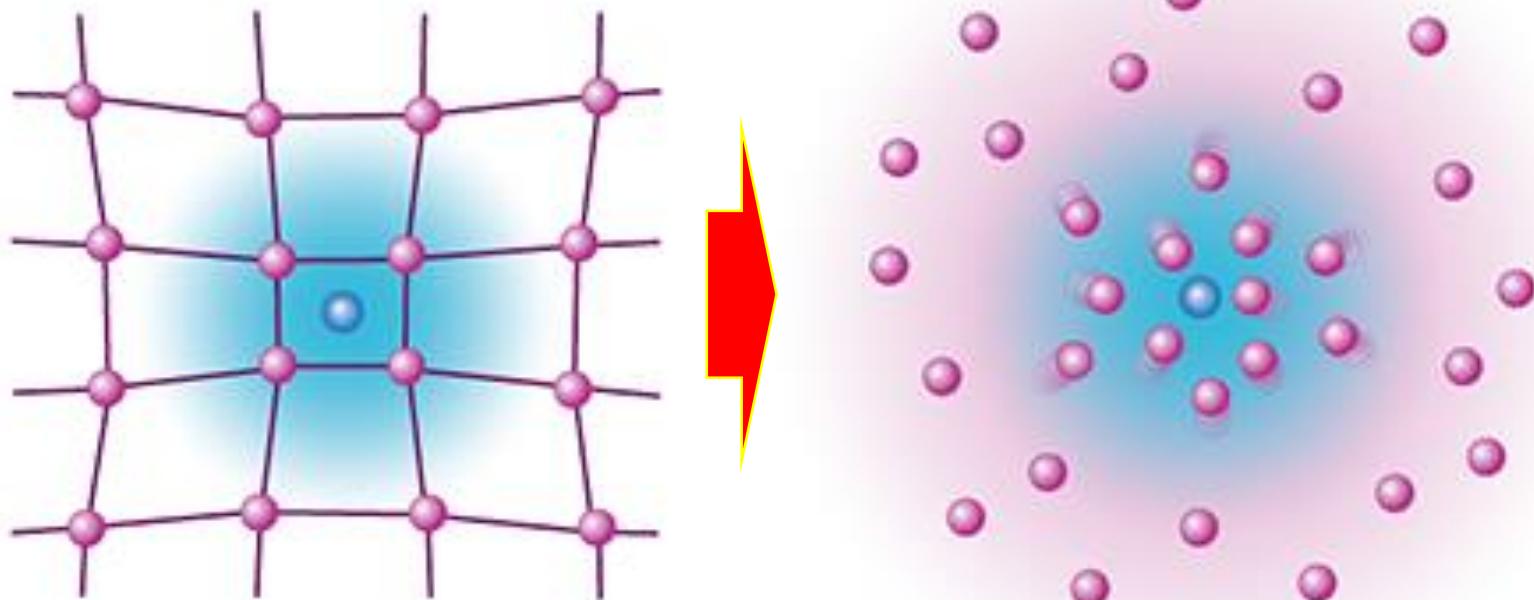


- Dressing phonon clouds → electron transport in material
- Bipolaron formation → origin of high- T_c superconductor

“Polarons” in ultracold atoms

- “Universal” relation among **minority particles**, **majority particles**, and **their interactions**

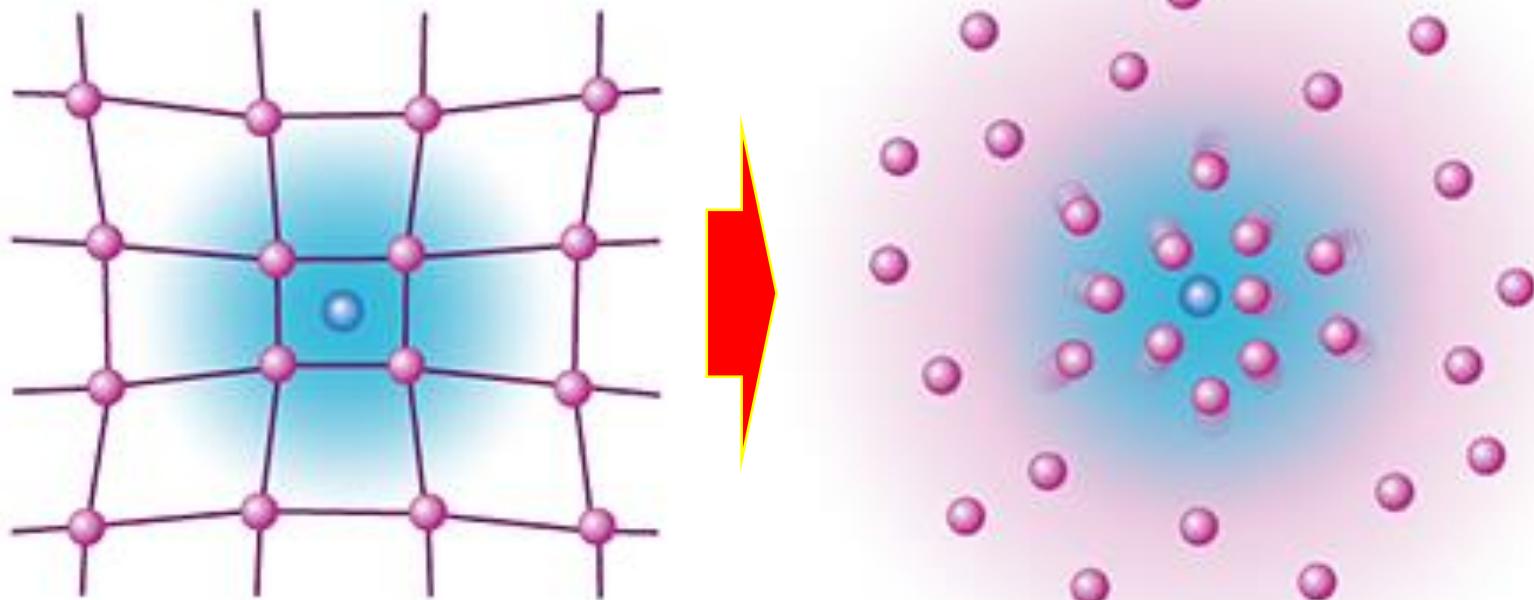
- Electron (impurity)
- Atom (bath)
-  Electron-phonon coupling (interaction)
-  Ultracold atom “A” (impurity)
-  Ultracold atom “B” (bath)
-  Feshbach resonance (interaction)



“Polarons” in neutron matter

- “Universal” relation among **minority particles**, **majority particles**, and **their interactions**

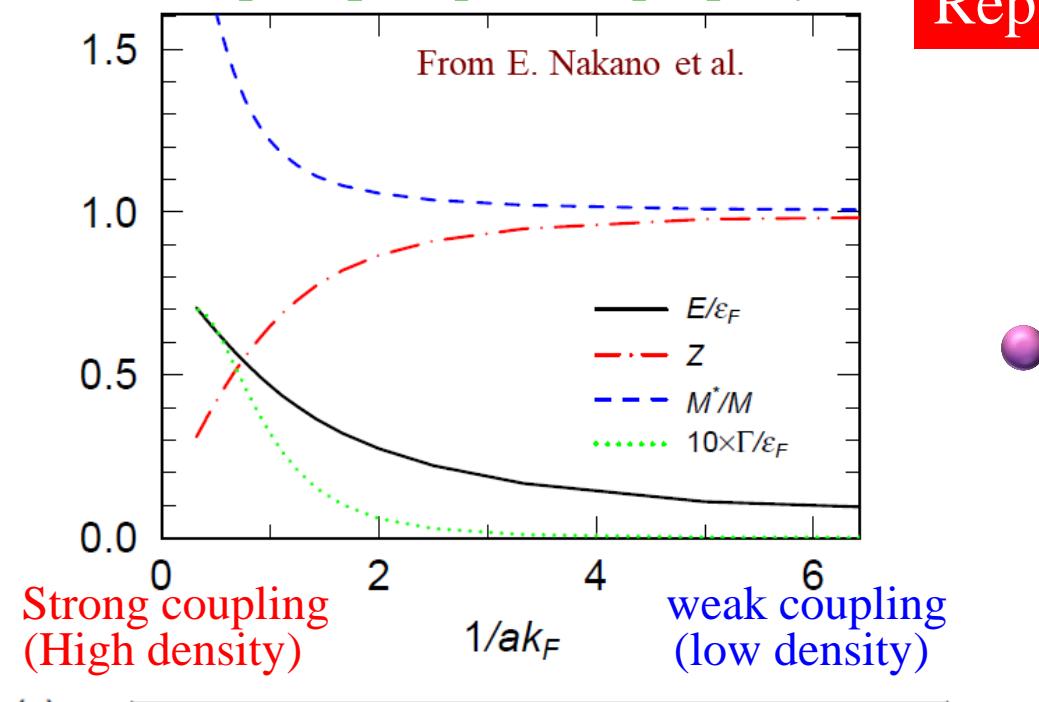
- Electron (impurity)
- Atom (bath)
-  Electron-phonon coupling (interaction)
-  Cluster such as alpha (impurity)
-  Neutron matter (bath)
-  αN interaction



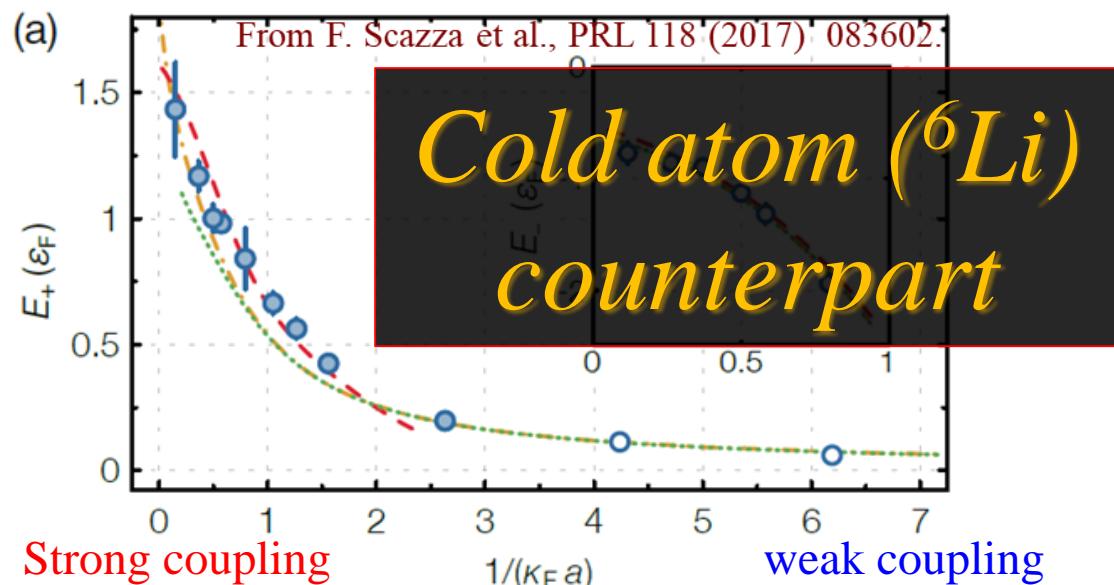
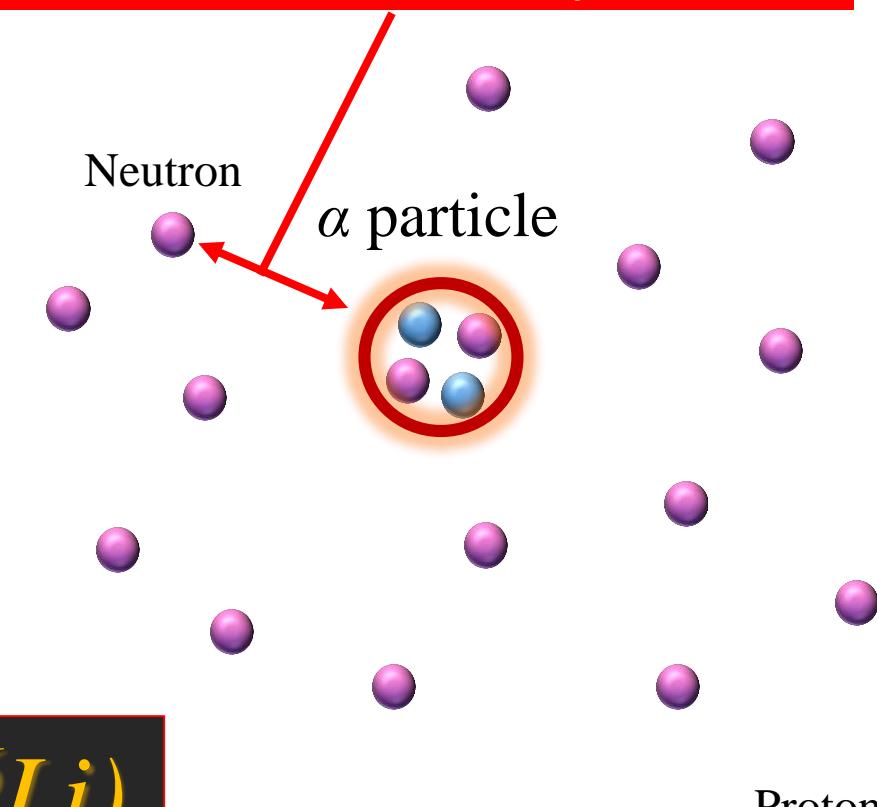
Alpha particle in neutron matter

E. Nakano *et al.*, arXiv:2005.13196 (Today!)

Alpha quasiparticle property



Repulsion ($a=2.6$ fm, $r_0=1.4$ fm)

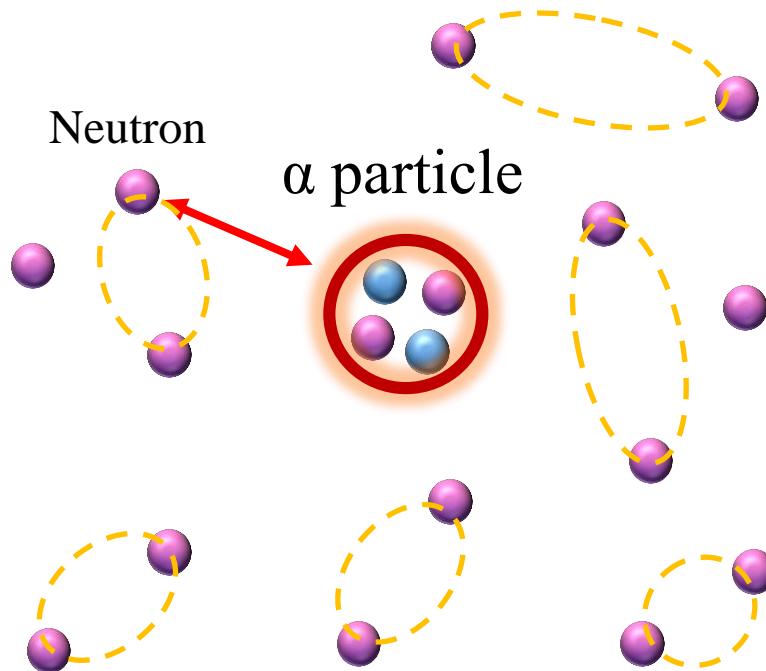


“Universality”

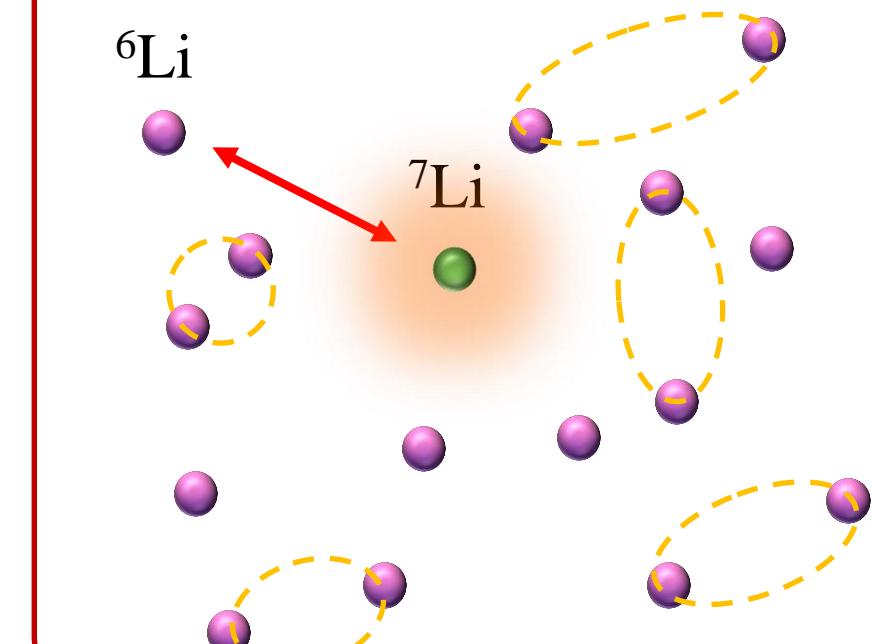
- Heavy effective mass
- Energy shift
- Small compositeness

Polarons in Fermi superfluids

Polaronic alpha particle in superfluid neutron matter

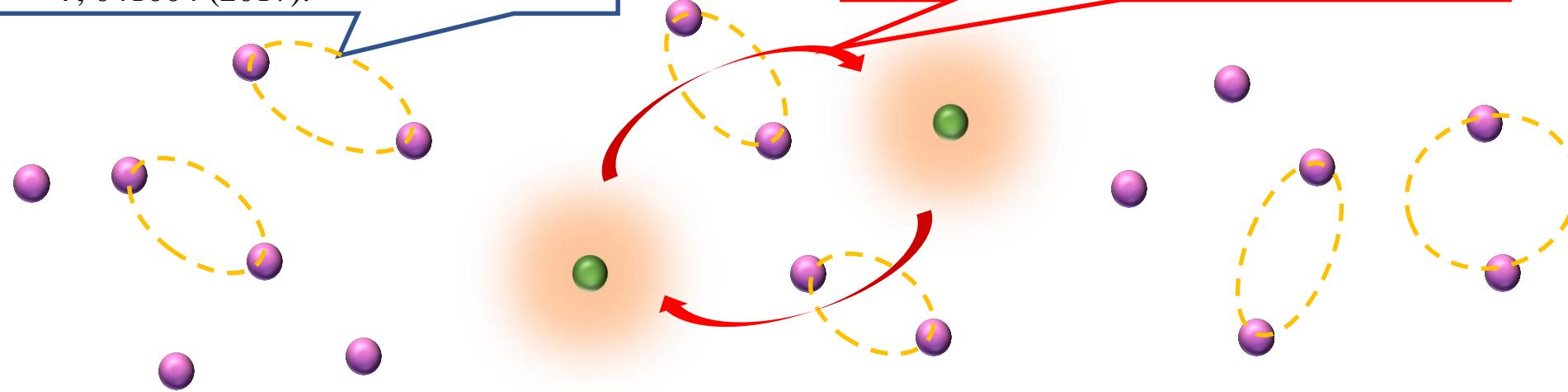
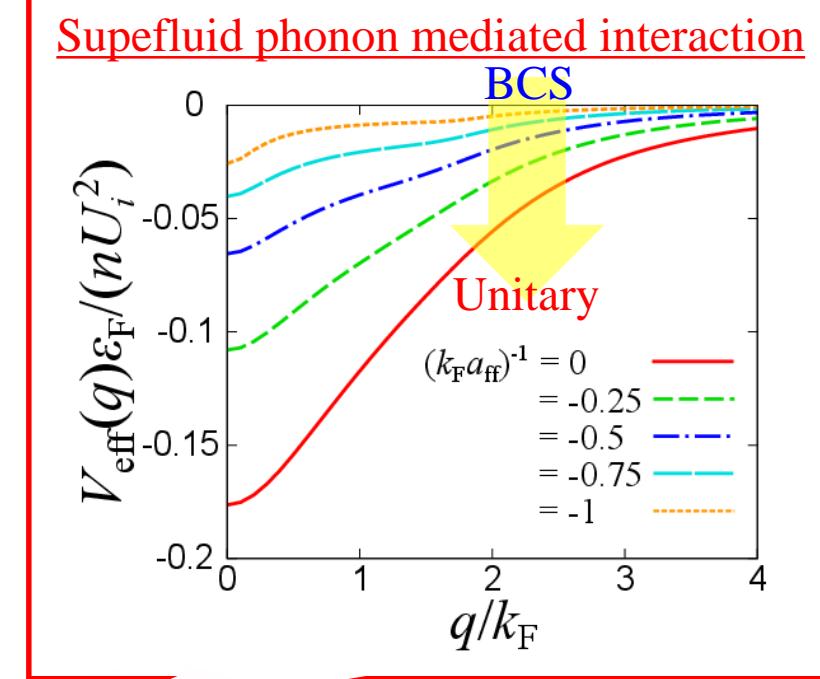
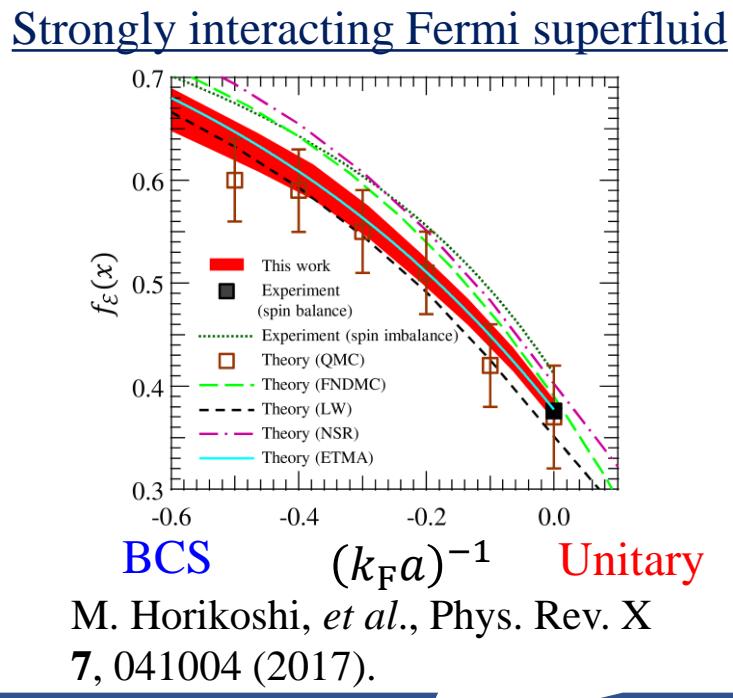


Impurity atoms immersed in a superfluid Fermi gas



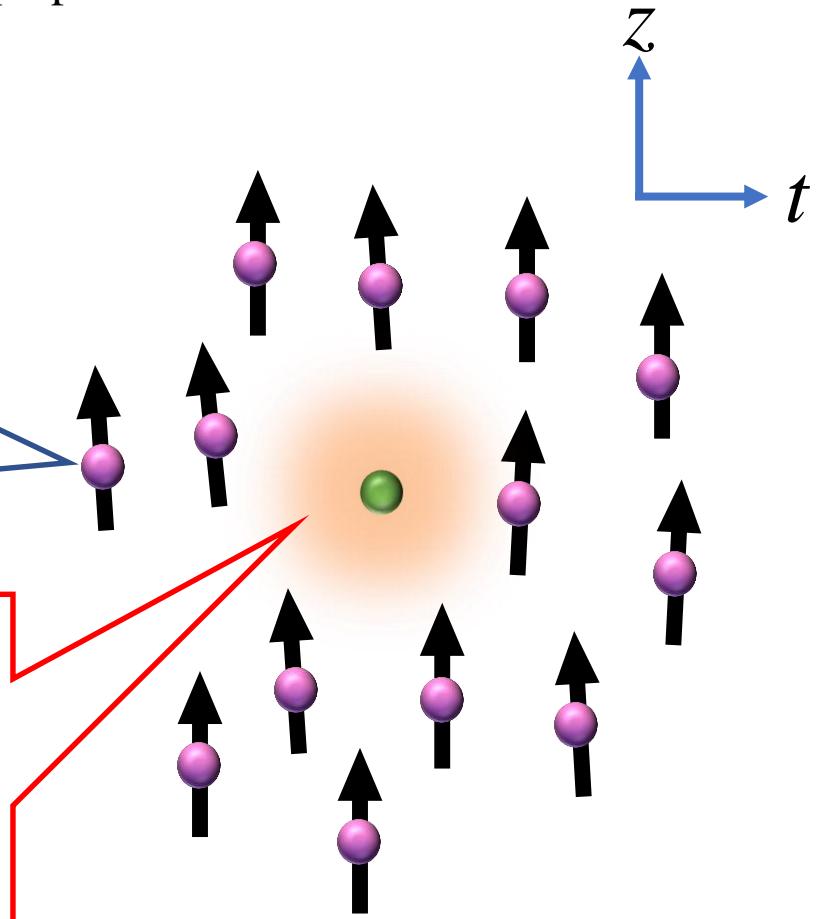
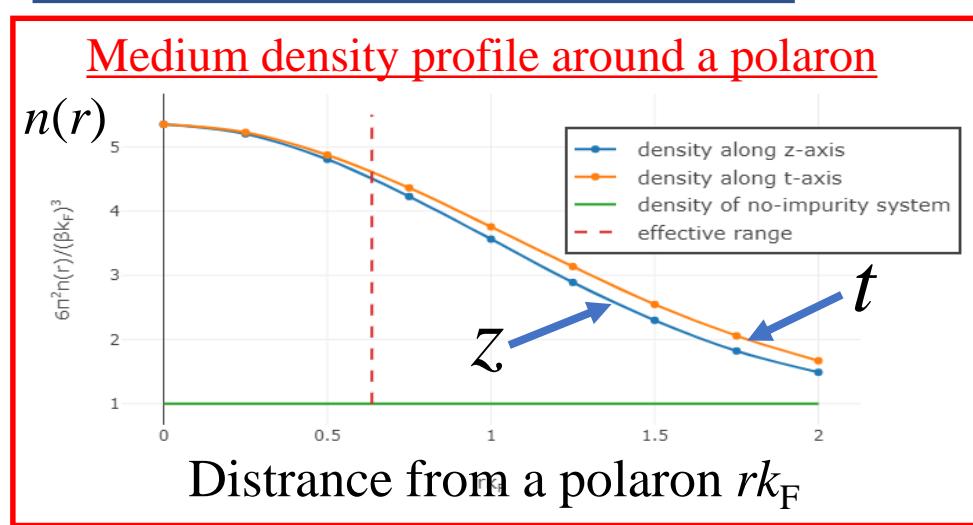
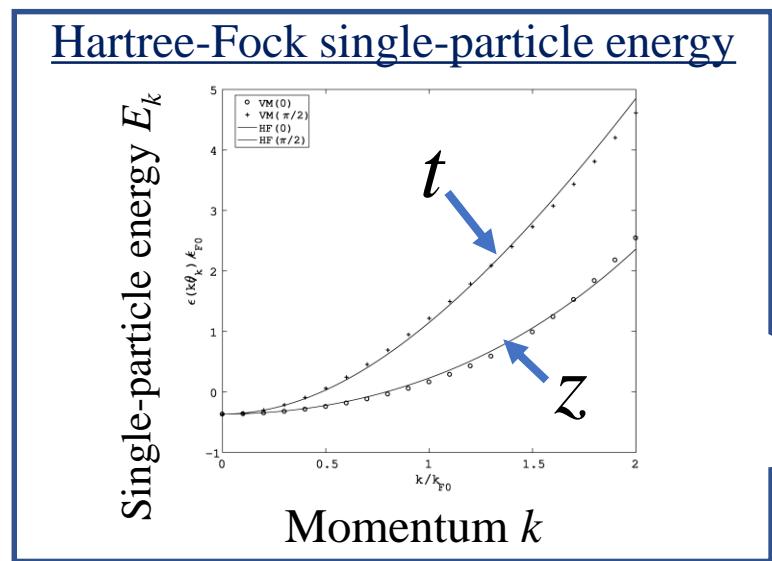
Polarons in Fermi superfluids

H. Tajima, *et al.*, in preparation



Polarons in dipolar Fermi gases

K. Nishimura, *et al*, in preparation

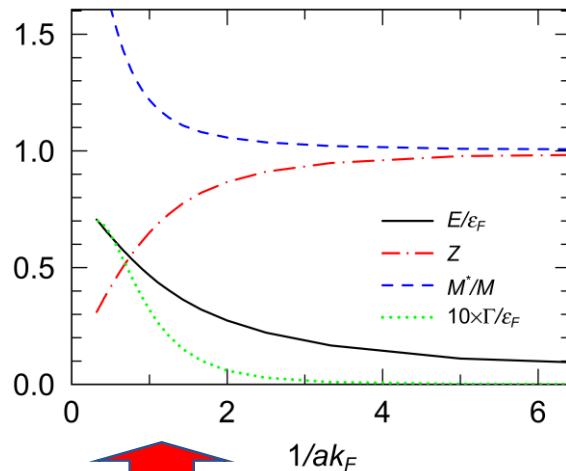


Summary

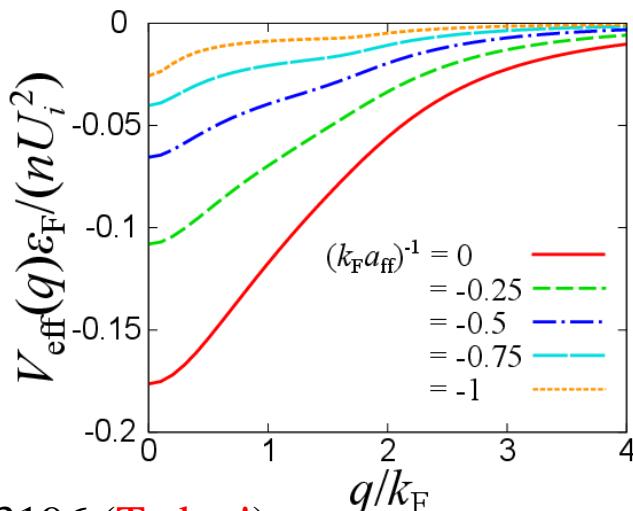
- Polaron picture gives us “universal” relations among minority and majority particles, and interactions in many-body problems.
- We are now in progress for polaronic properties and inter-polaron interaction in exotic many-body backgrounds.

Future perspective Droplet formation due to the superfluid phonon mediated long-range interaction in an “ideal” Bose gas immersed in Fermi superfluids

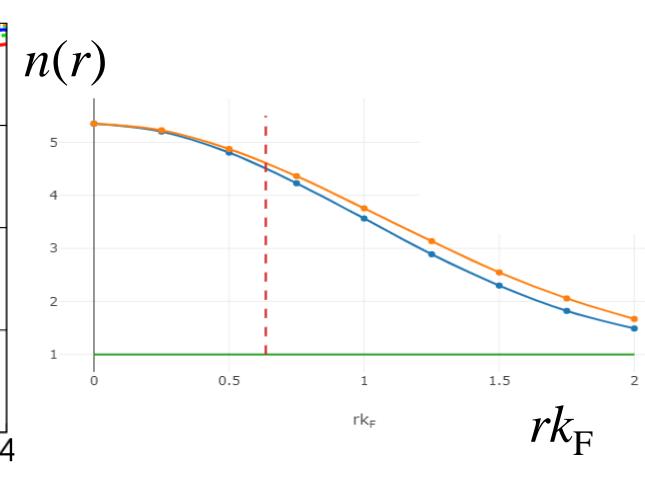
Alpha in neutron matter



Polarons in a Fermi superfluid



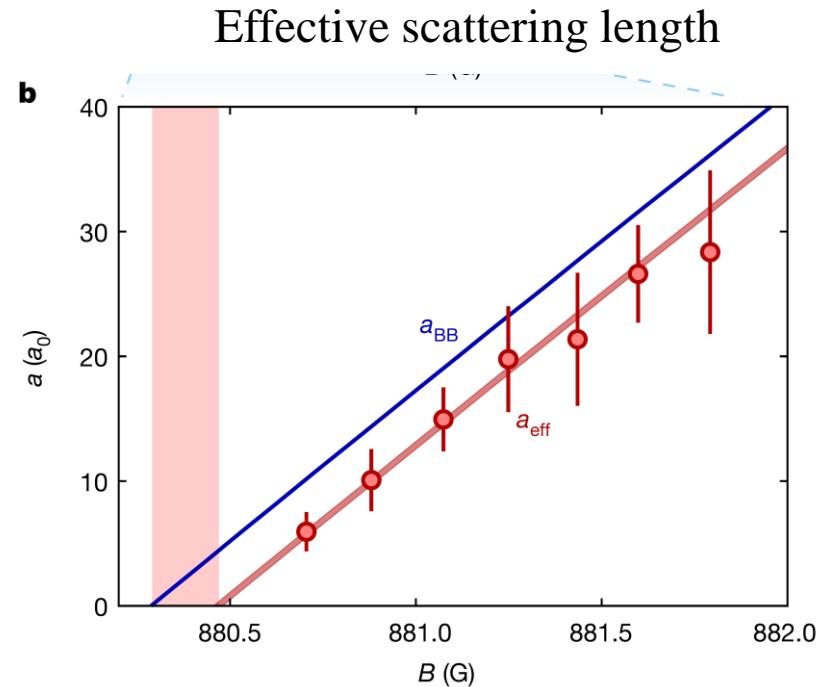
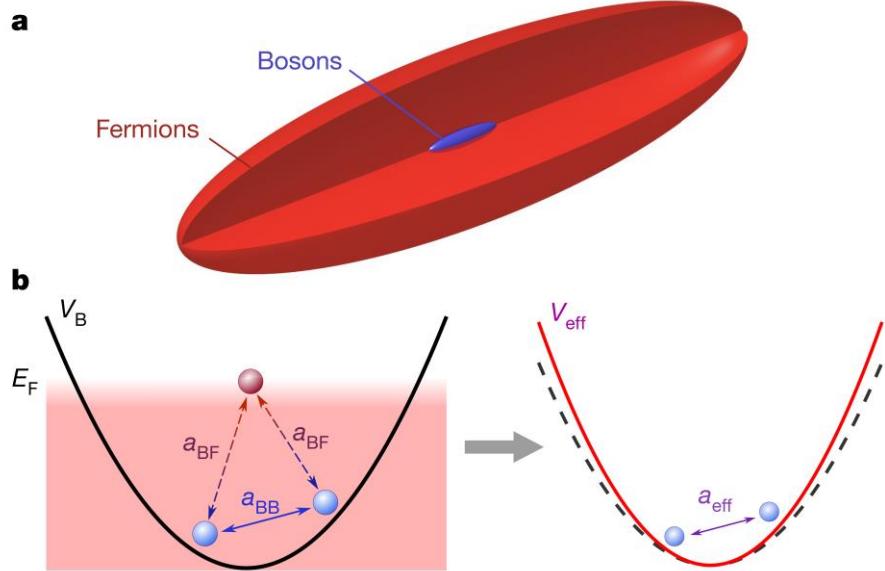
Polarons in dipolar Fermi gases



Backup slides

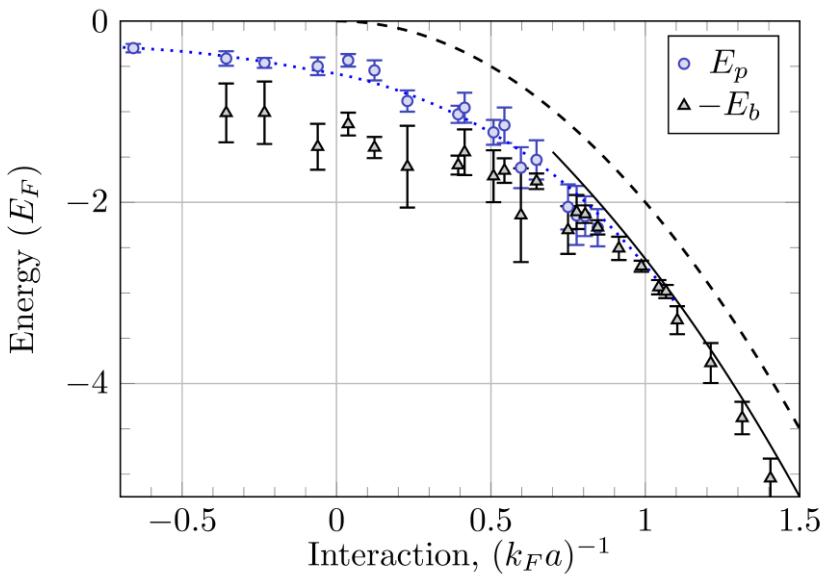
The observation of fermion-mediated interaction

B. J. DeSalvo, *et al.*, Nature **568**, 61 (2019).

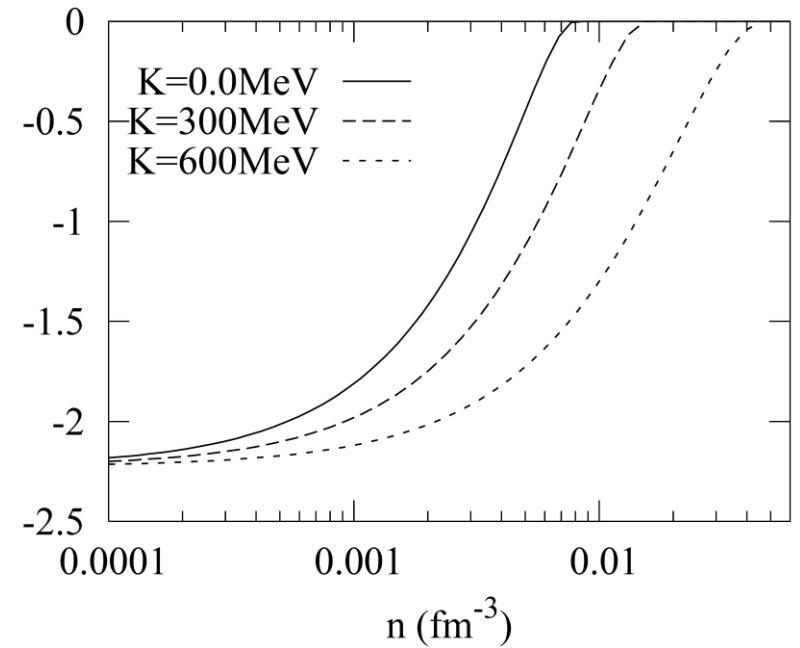


Two-body molecules in medium

“Transition” from polaron to molecule



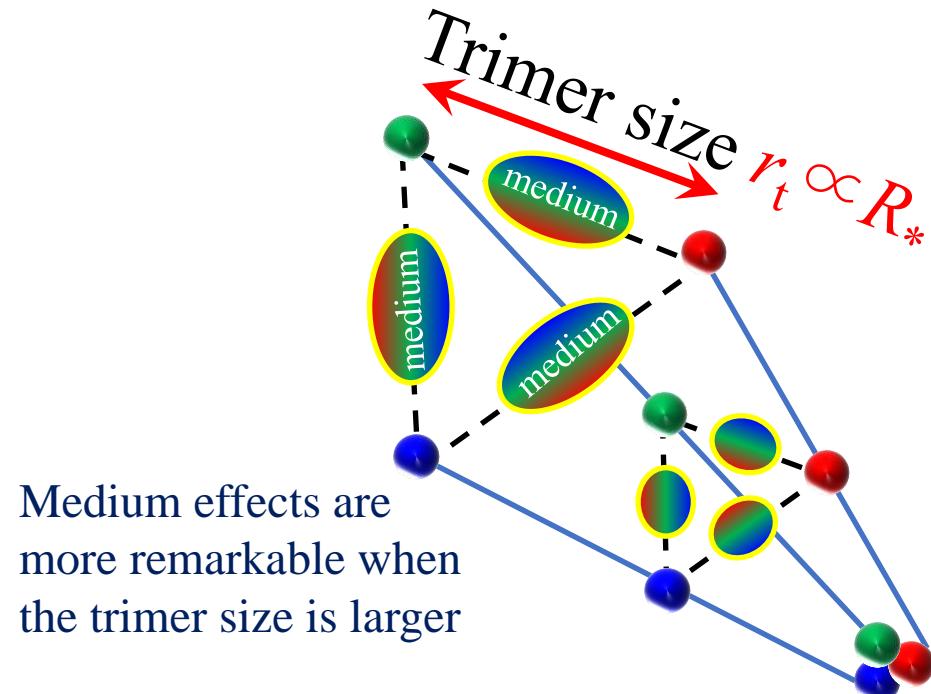
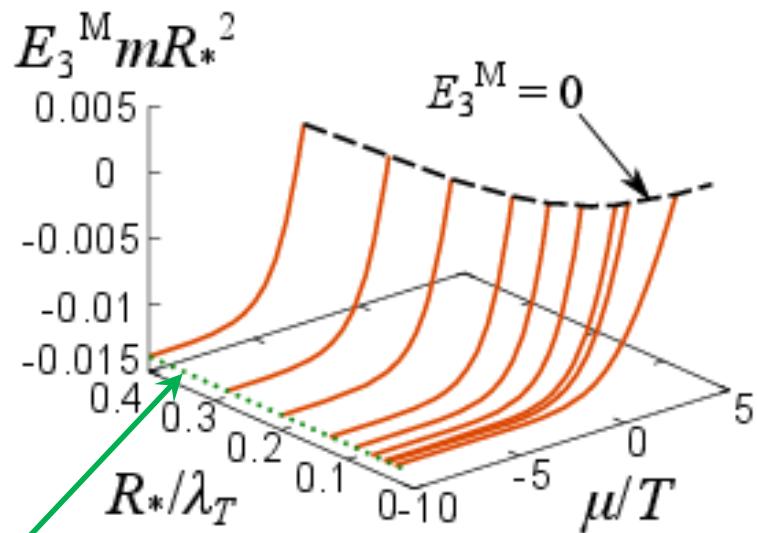
Deuteron binding energy in SNM



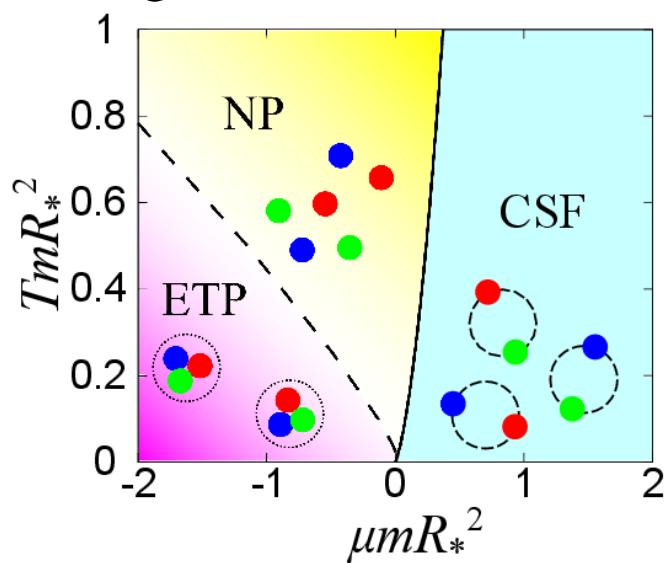
G. Ness, *et al.*, arXiv:2001.10450

M. Jin, *et al.*, Phys. Rev. C **82**, 024911 (2010).

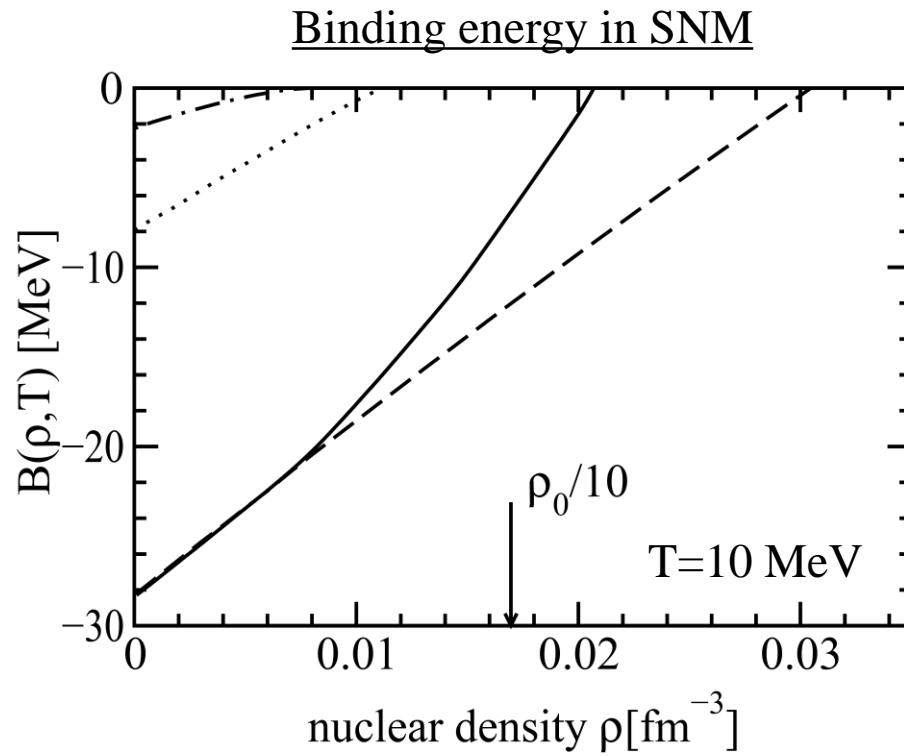
Trimer energy in medium



Phase diagram of SU(3) Fermi gas



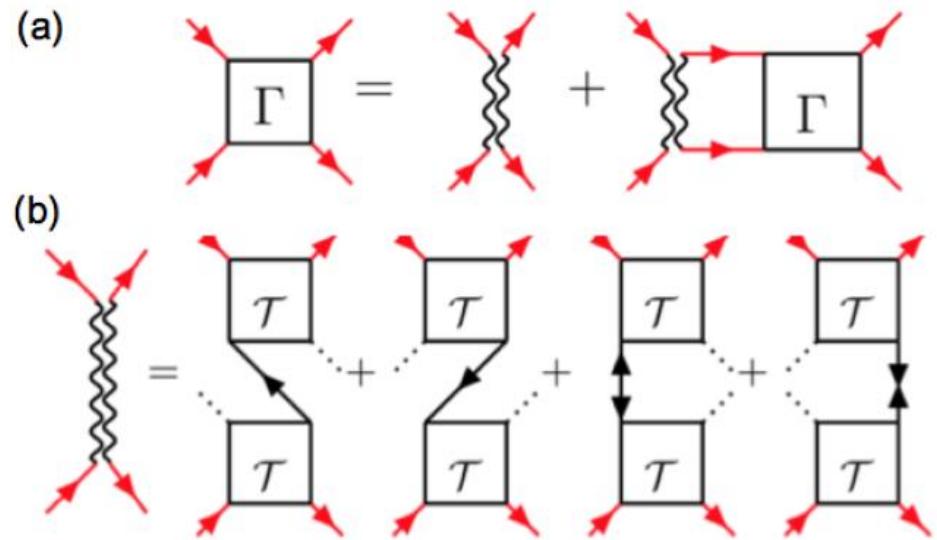
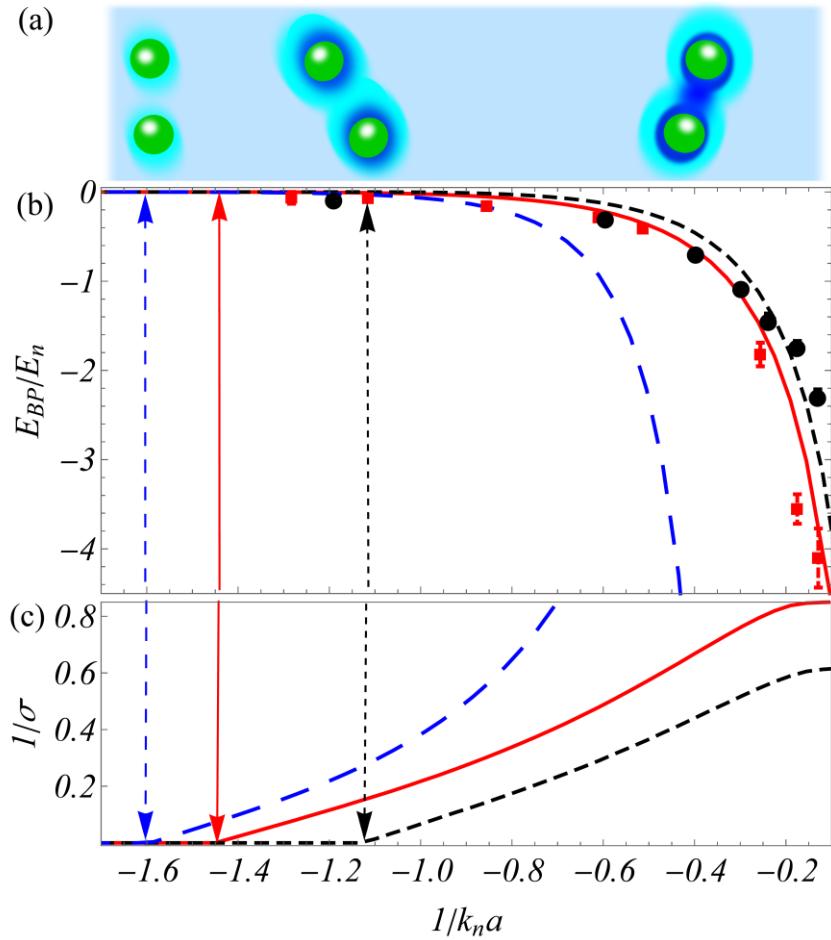
Alpha (4-body molecule) in medium



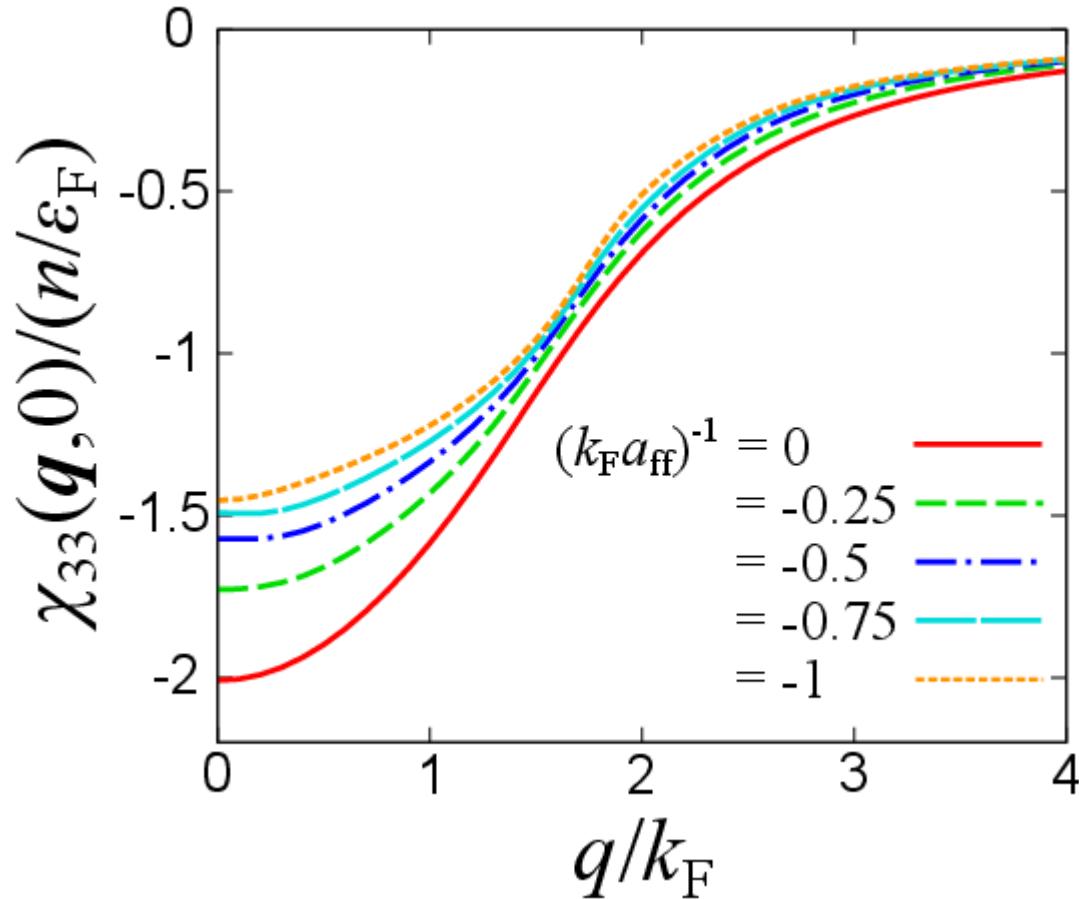
P. Schuck, *et al.*, J. Phys. Conf. Proc. **413**, 012009 (2013).

Bipolaron formation in Bose superfluids

A. Camacho-Guardian, *et al.*, Phys. Rev. Lett. **121**, 013401 (2018).



Density correlation function



Nambu-Goldstone mode

