

不純物で探る量子物質の性質 Probing quantum matter with impurities

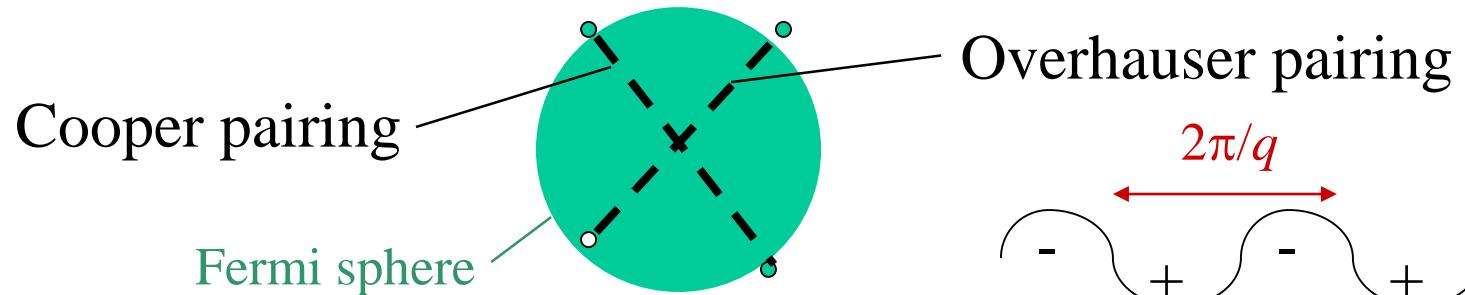
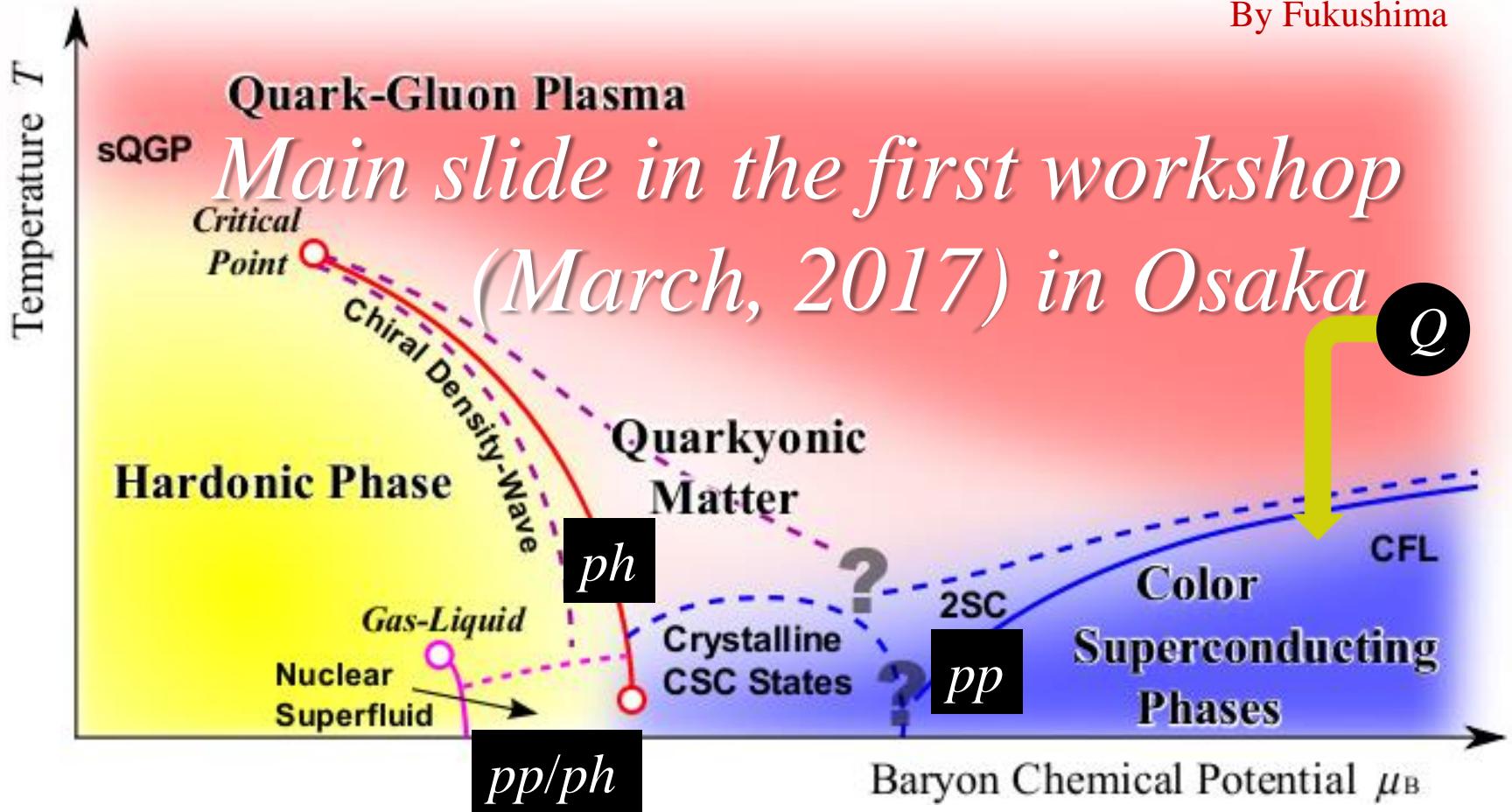
飯田 圭（高知大学）

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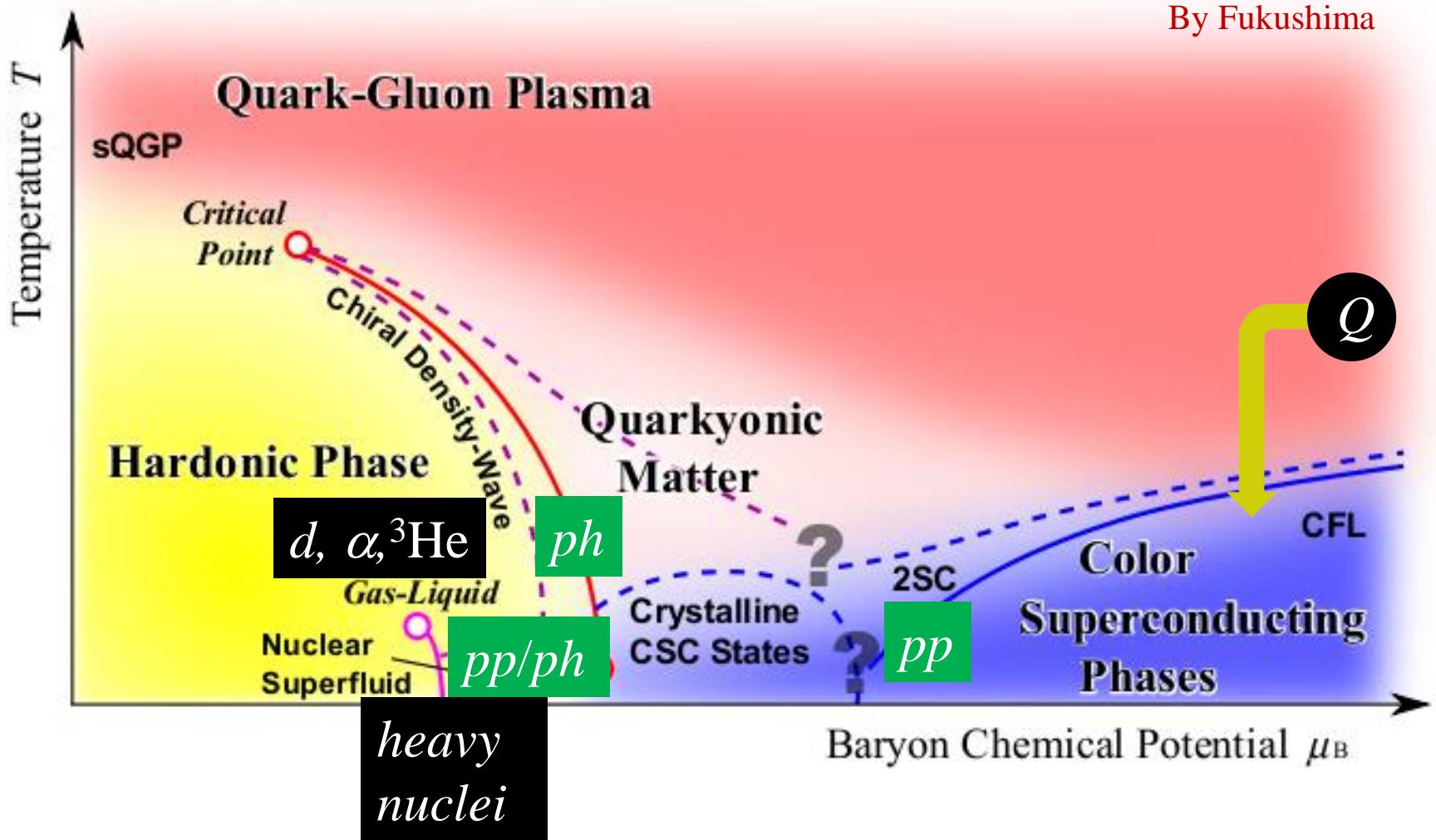
Pairing correlations and polarons in strong-force interacting many-body systems

By Fukushima



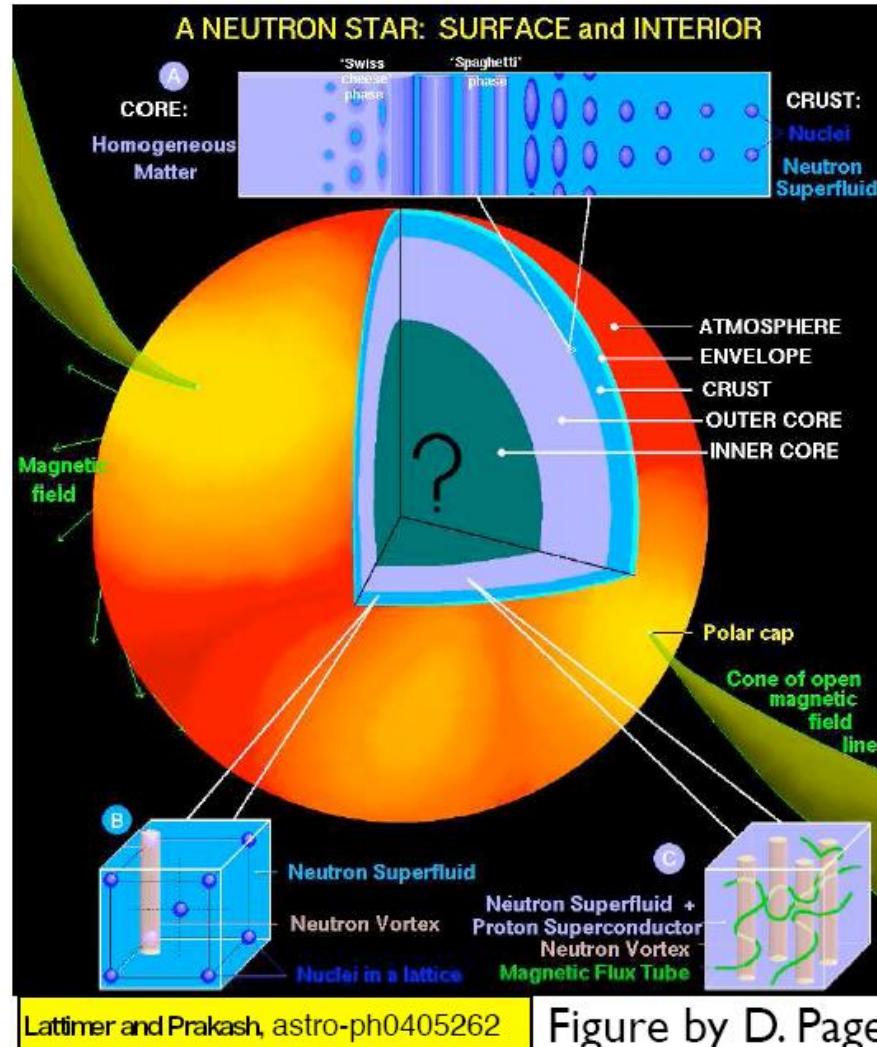
Pairing correlations and polarons in strong-force interacting many-body systems

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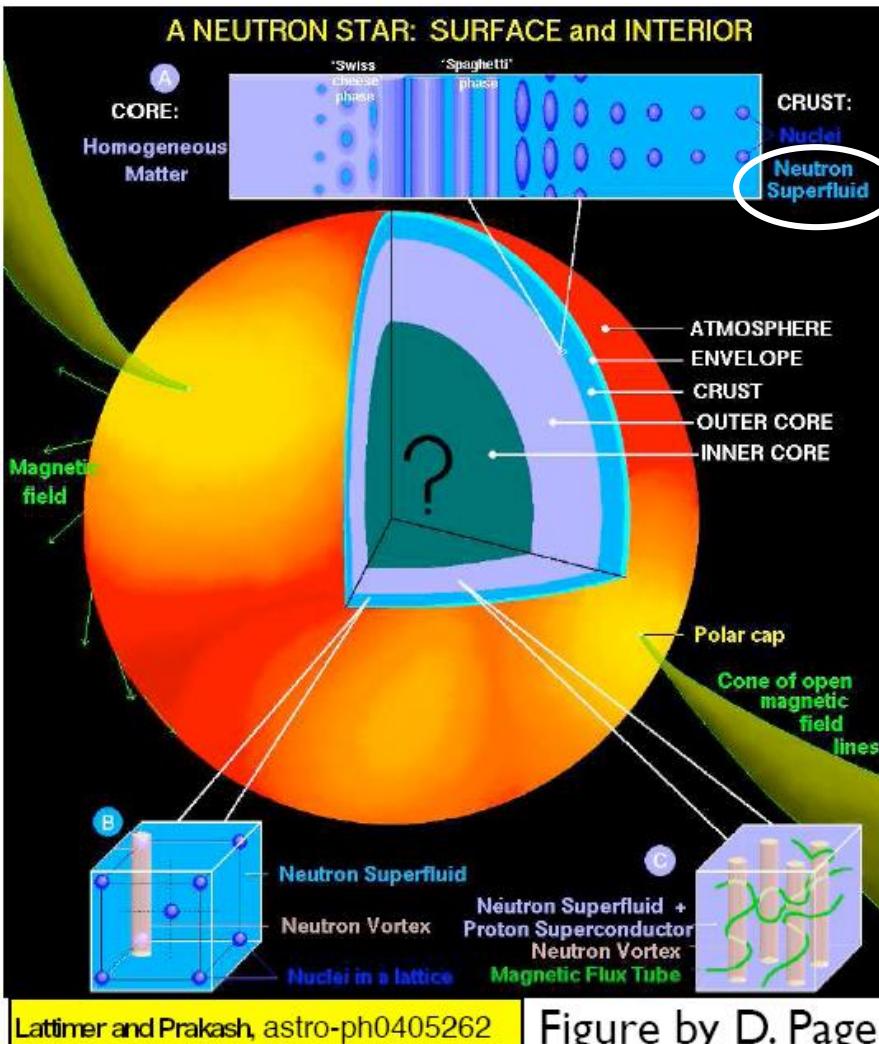
*Impurities (“clusters”) play a role
in probing the medium properties*

Neutron stars made of pp and/or ph condensates, whose properties could be probed by impurities



Typical examples of pp correlations: Neutron matter and trapped cold atoms

Low density neutron matter



Cold Fermi atoms near Feshbach resonance

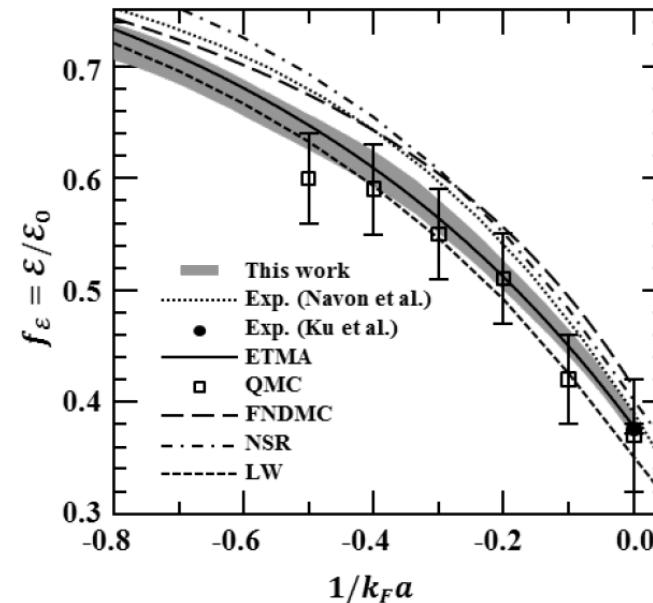
Universal Interaction Energy at Unitarity

In-situ absorption images $|1\rangle$ $|2\rangle$ Size of real space distribution reveals interaction and pairing energies

The figure shows two heatmaps, labeled $|1\rangle$ and $|2\rangle$, representing the size of the real space distribution of cold Fermi atoms. The distributions are elongated and oriented along the same axis, with the second one being significantly larger than the first.

At unitarity, the chemical potential is reduced by pairing: $\mu = E_F(1 + \beta)^{1/2}$
where β is a *universal* many-body parameter $\beta = -0.54 \pm 0.05$

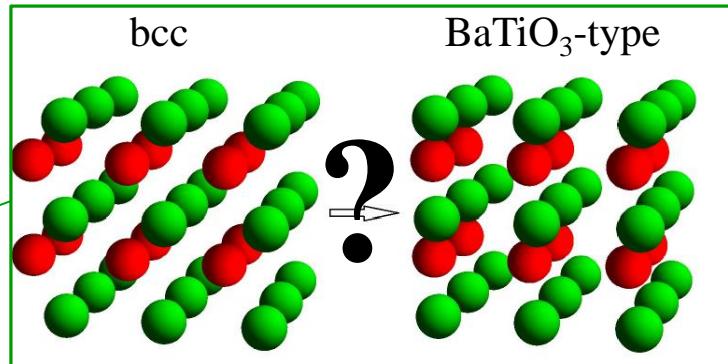
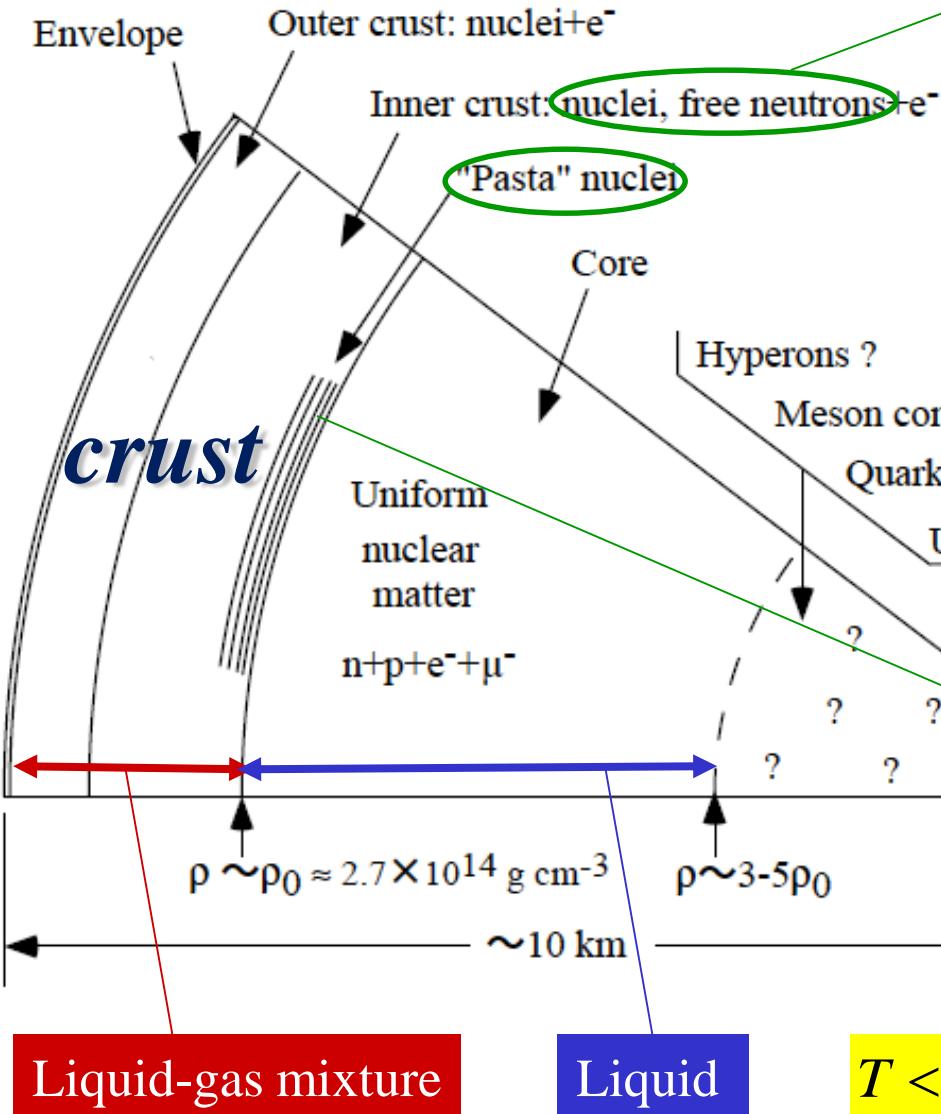
From R. Hulet



From M. Horikoshi

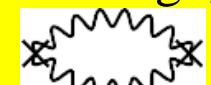
Nuclear matter in neutron stars

Schematic cross-section of a neutron star

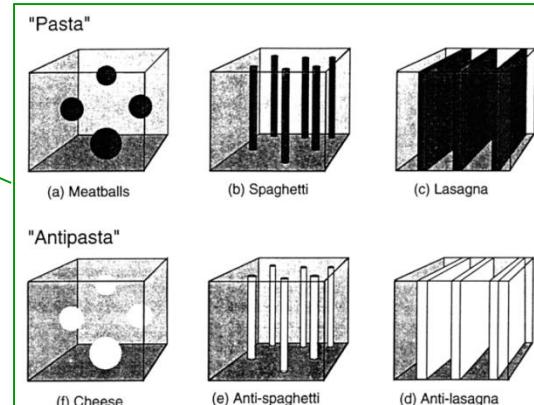


From Kobyakov and Pethick (2013, 2016).

Internuclear interaction
via SF-phonon exchange,
e.g.,

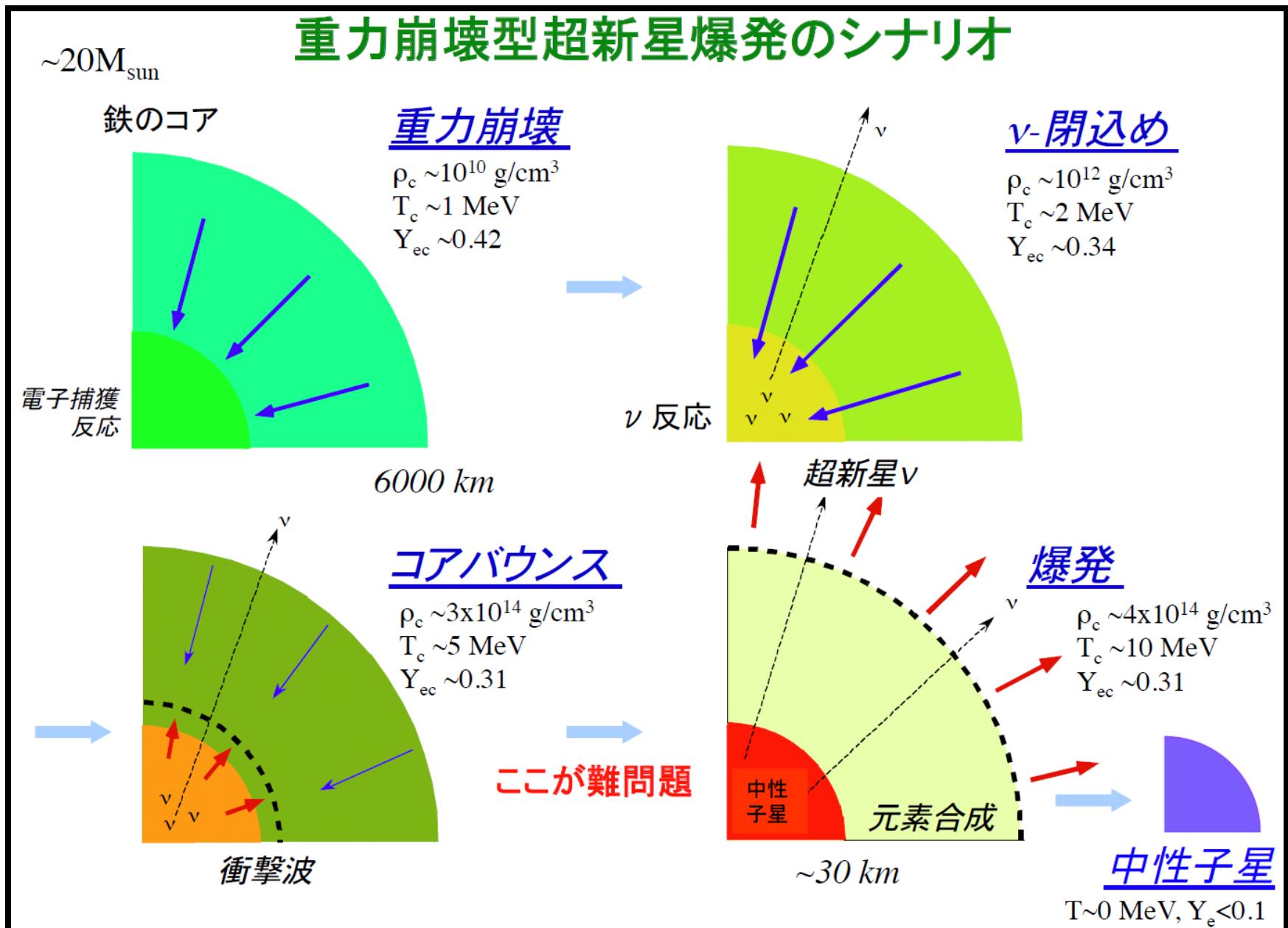


Long-range Casimir-Polder form ($\sim 1/r^7$)



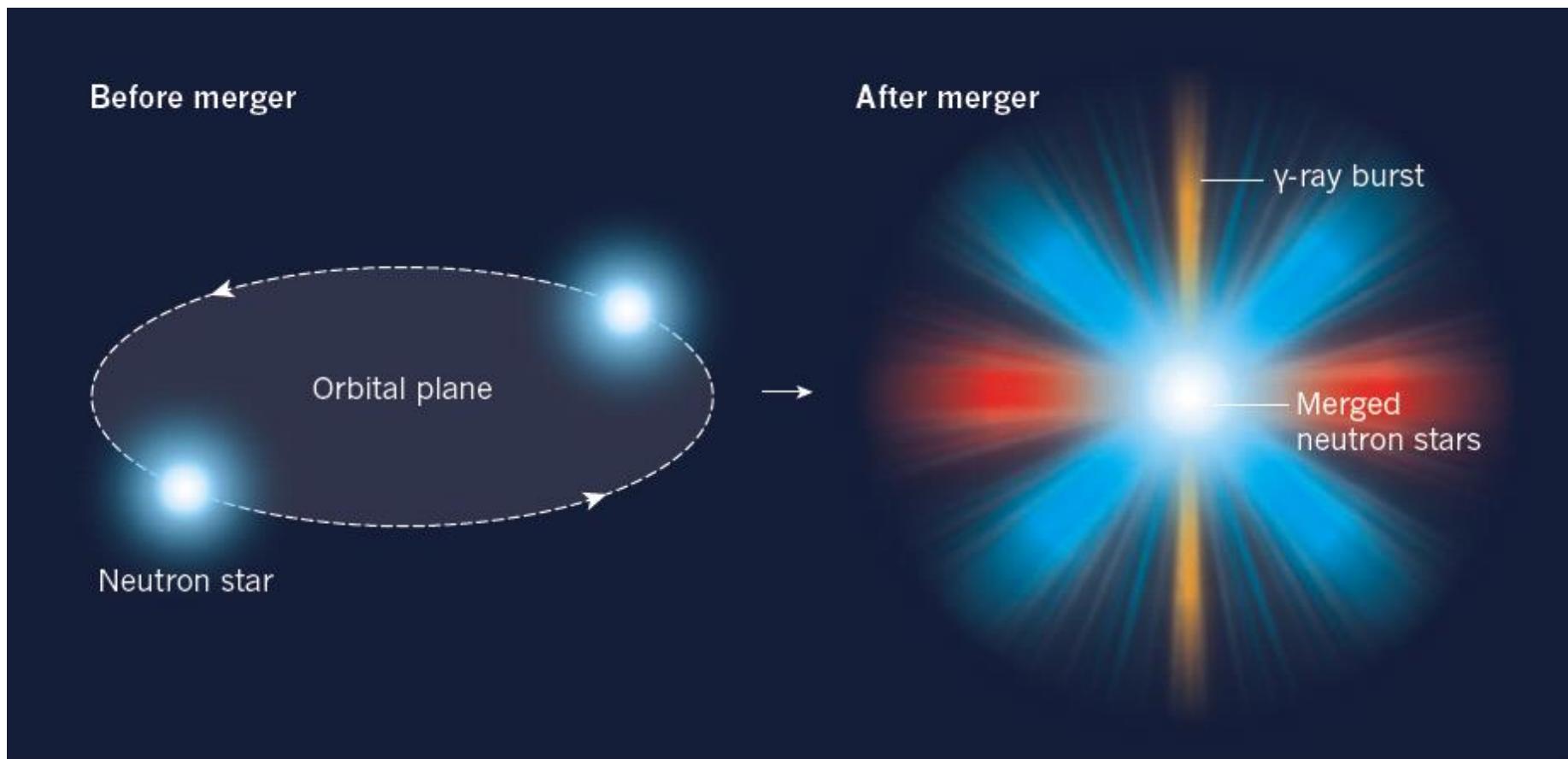
From Lamb (1991).

Core-collapse supernovae



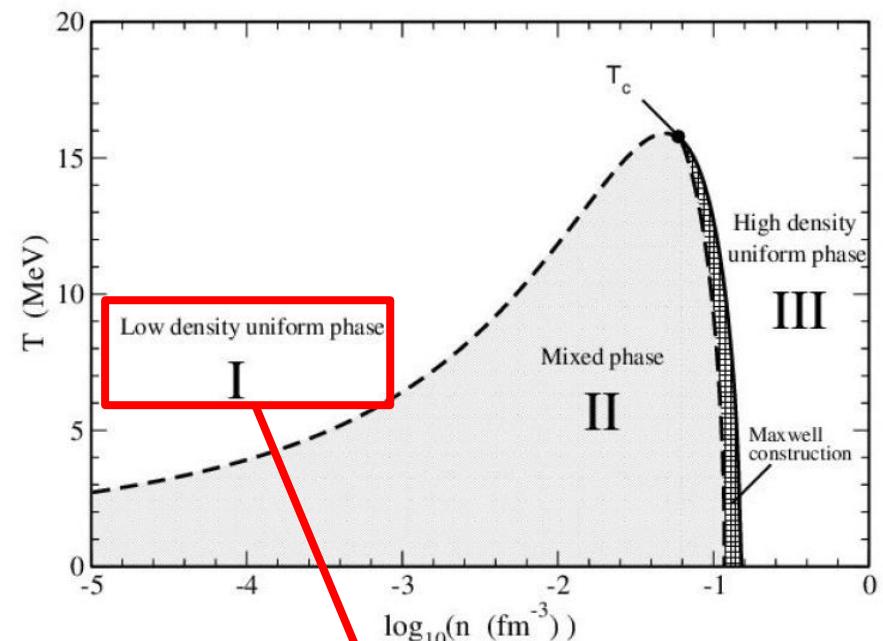
Hot dense matter (contd.)

Neutron star – neutron star mergers



From Coleman Miller
(Nature **551**, 36 (2017))

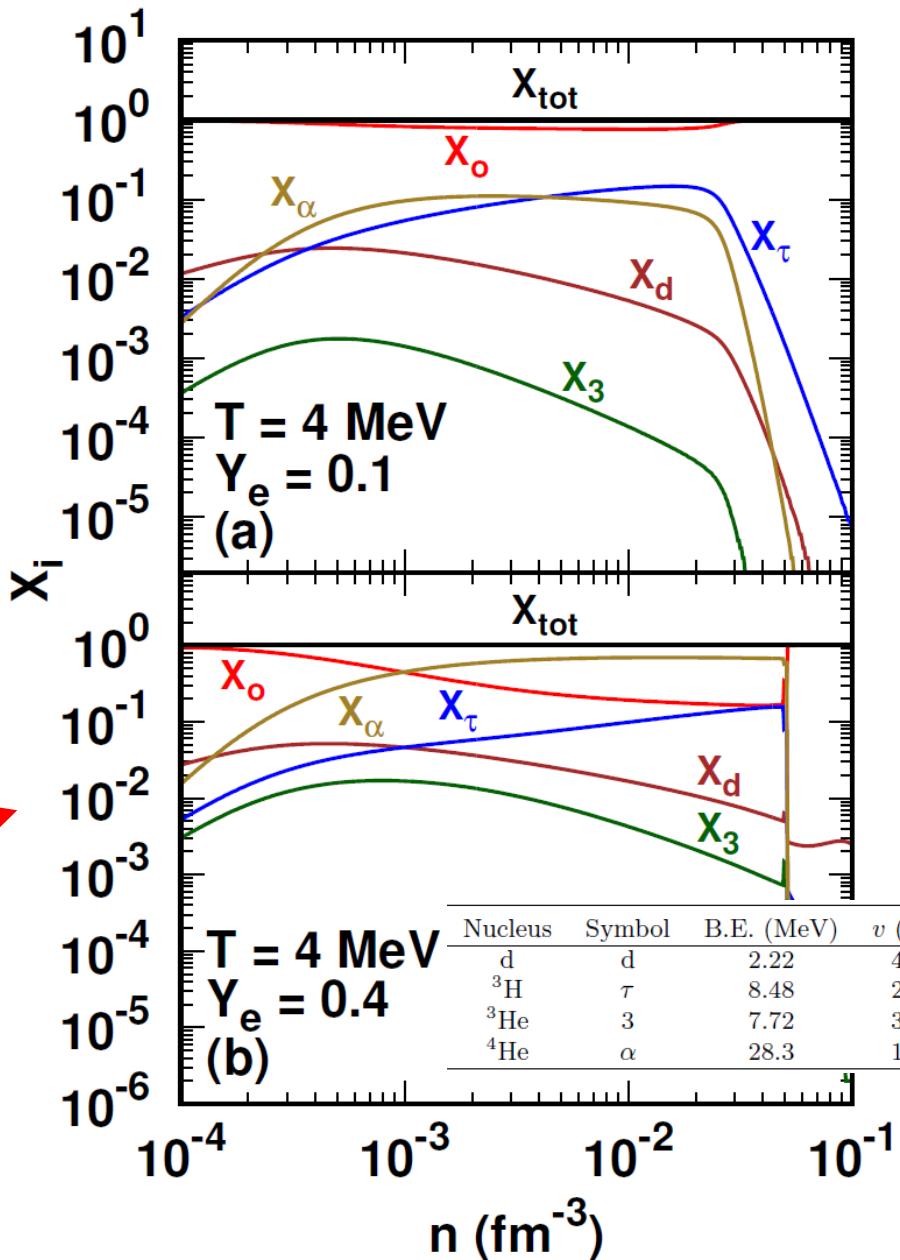
Schematic phase diagram in dense stellar matter



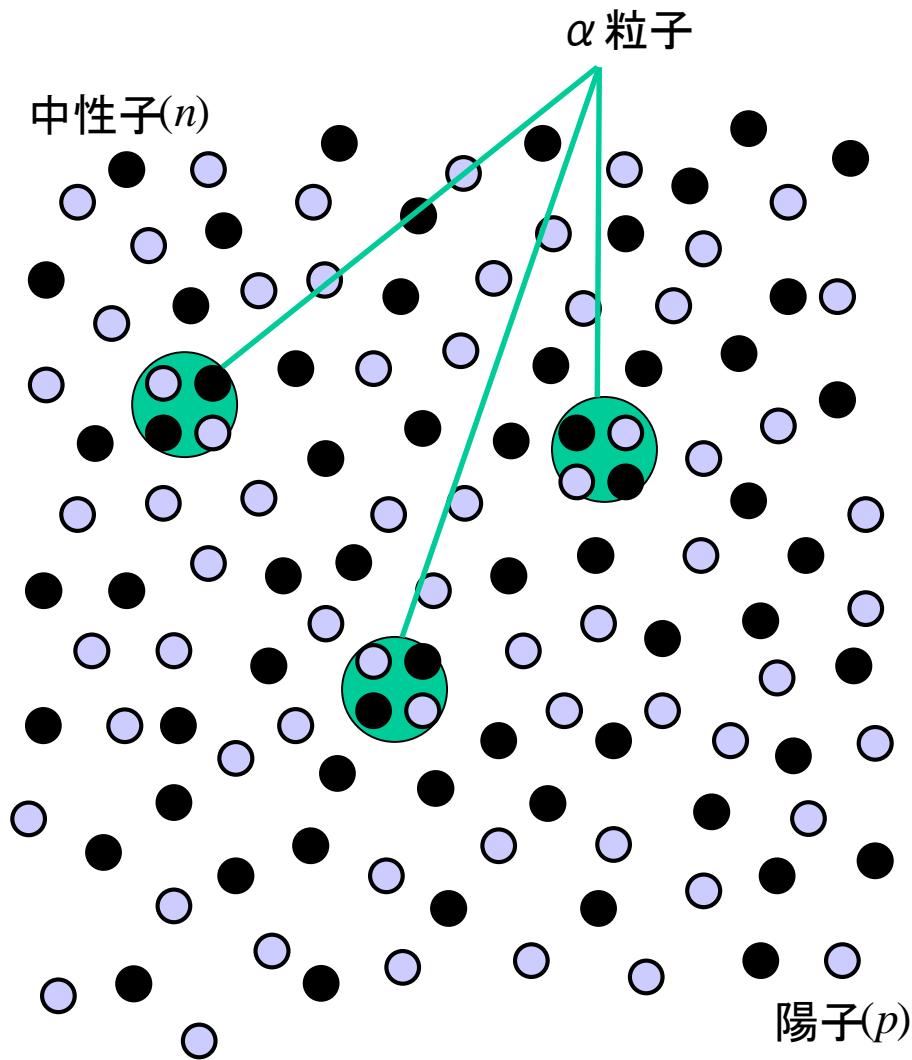
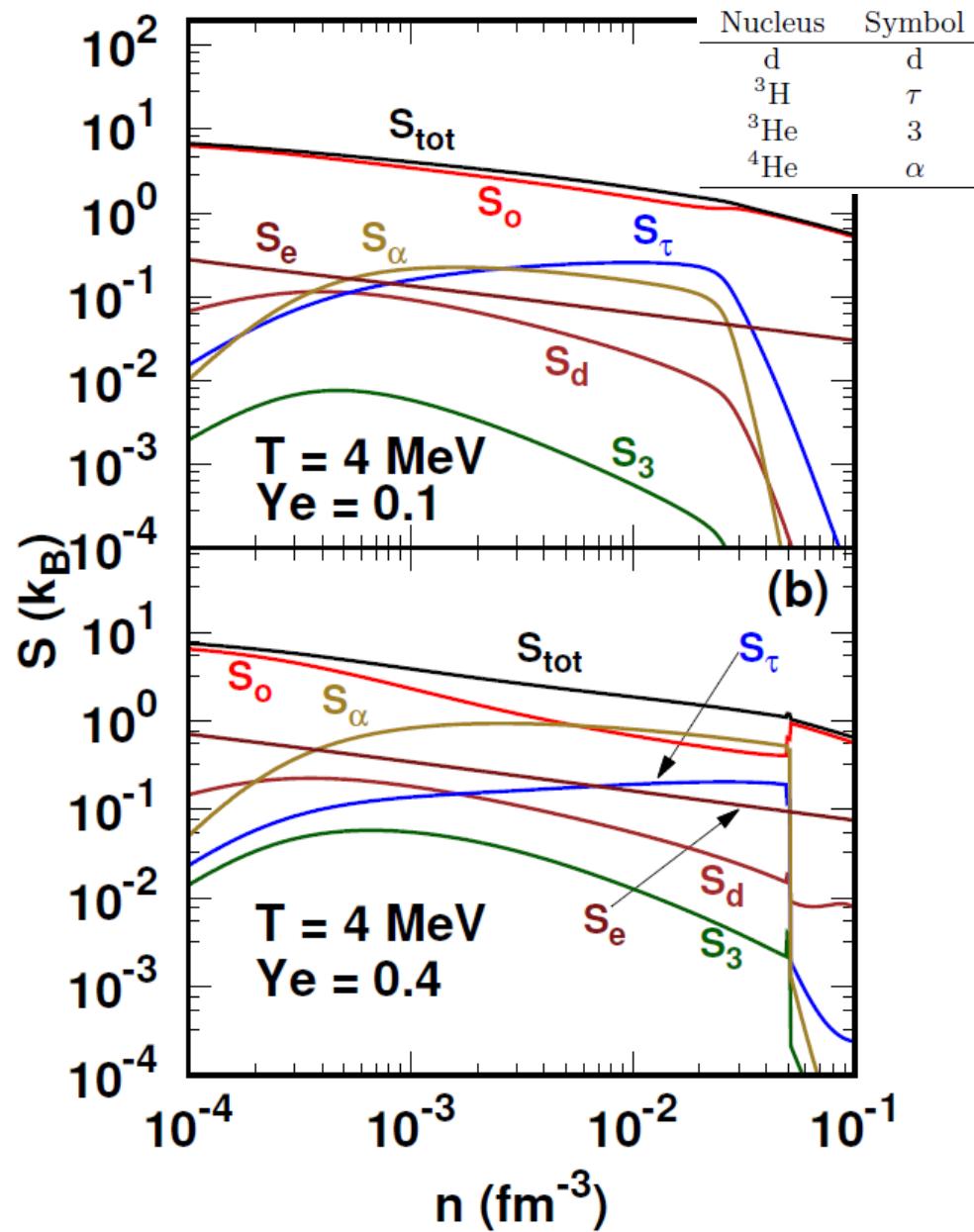
Light elements in I contribute significantly to entropy!

Mass fractions X_i obtained from excluded volume effects (see also Togashi EOS) are reliable?

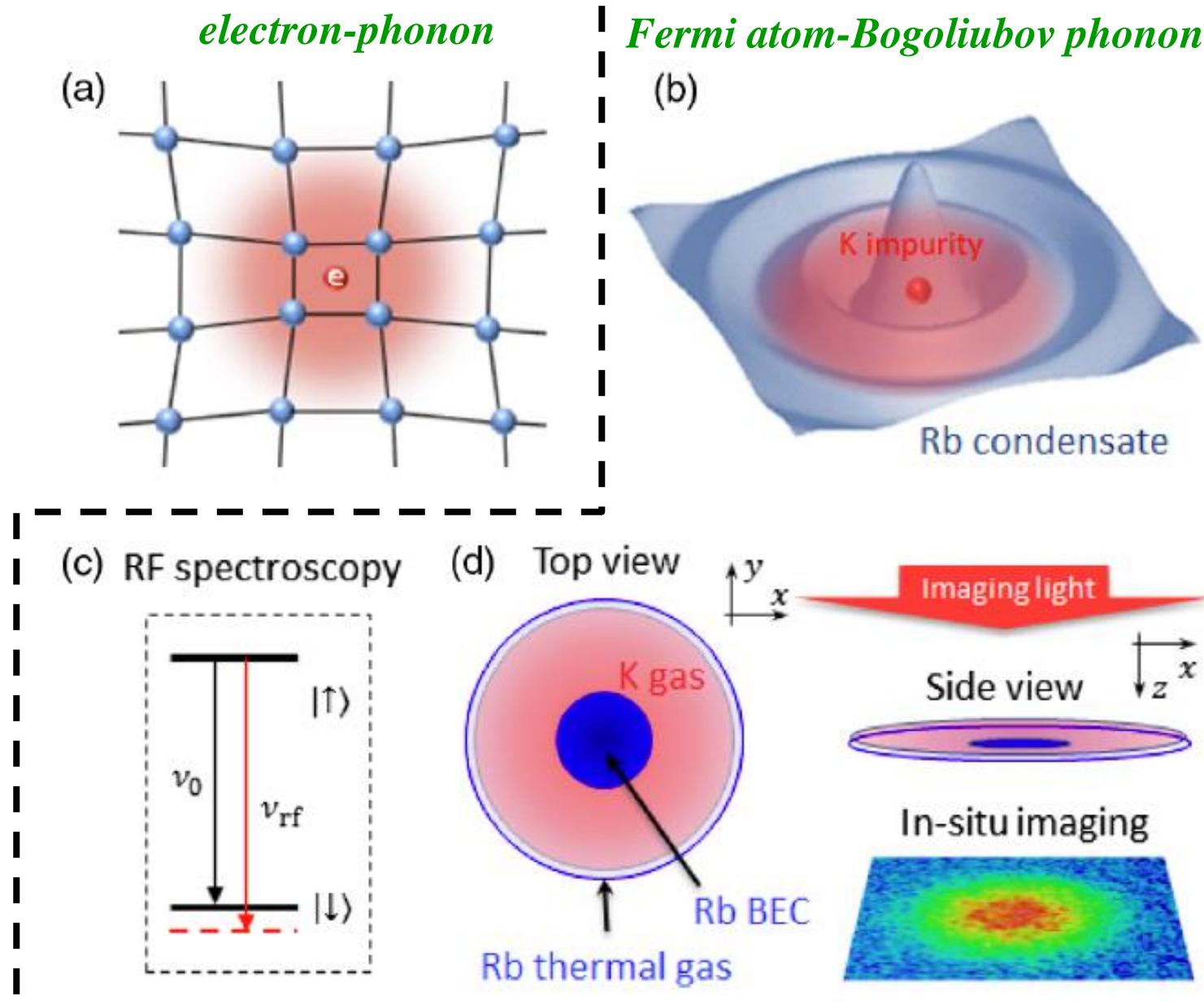
Mass fractions of light elements



Entropy per baryon

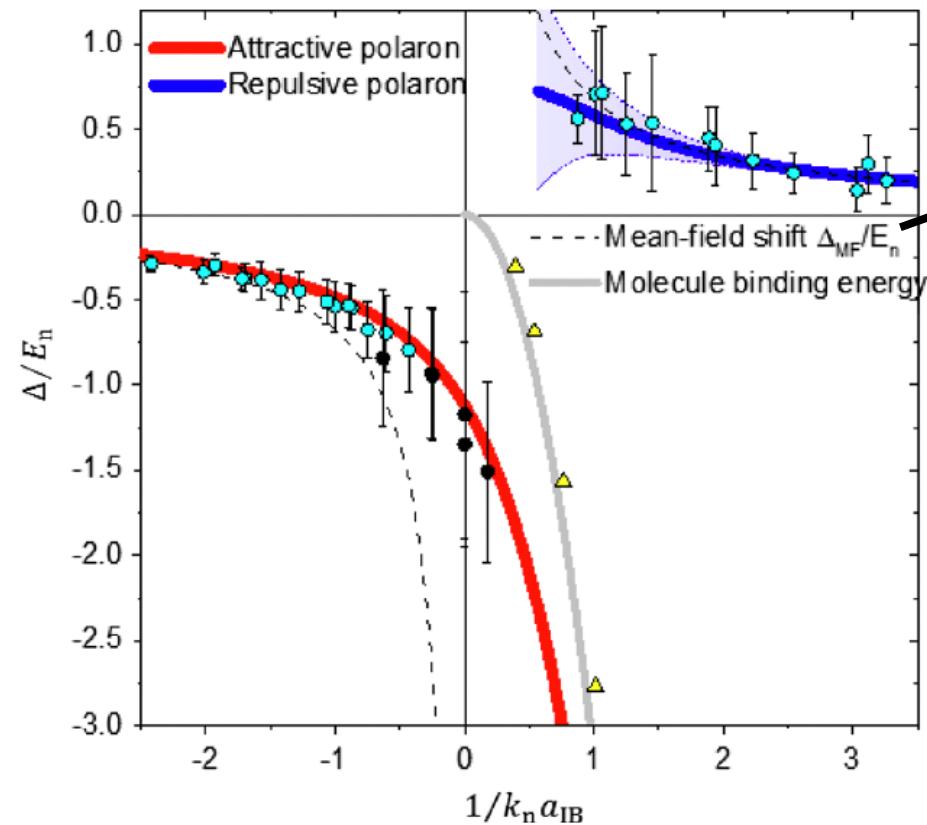


Polaron problems in trapped cold atoms



Polaron problems in trapped cold atoms (contd.)

Fermi ^{40}K impurity in a Bose ^{87}Rb gas



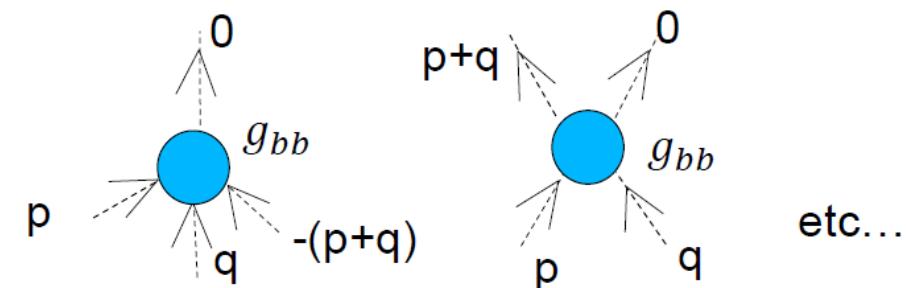
From M.-G. Hu et al., PRL 117 (2016) 055301.

Another version: impurity atoms in a trapped Fermi gas

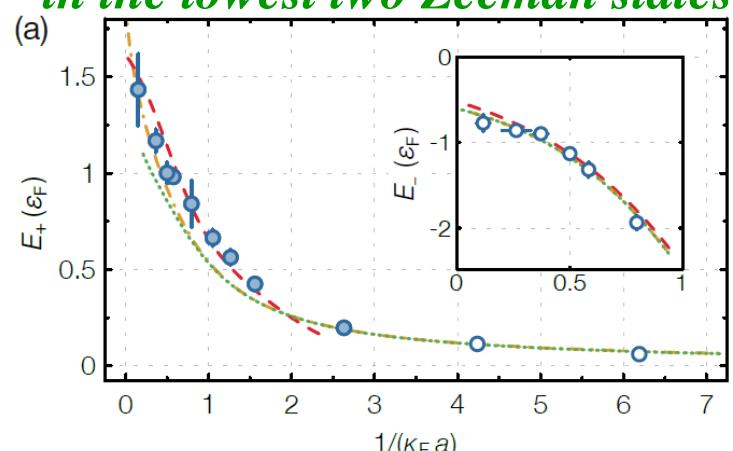
2フォノン過程まで

$$E = E_{pol} + E_{sub}$$

フオノン-フオノン3点相互作用項



*imbalanced mixtures of ^6Li atoms
in the lowest two Zeeman states*



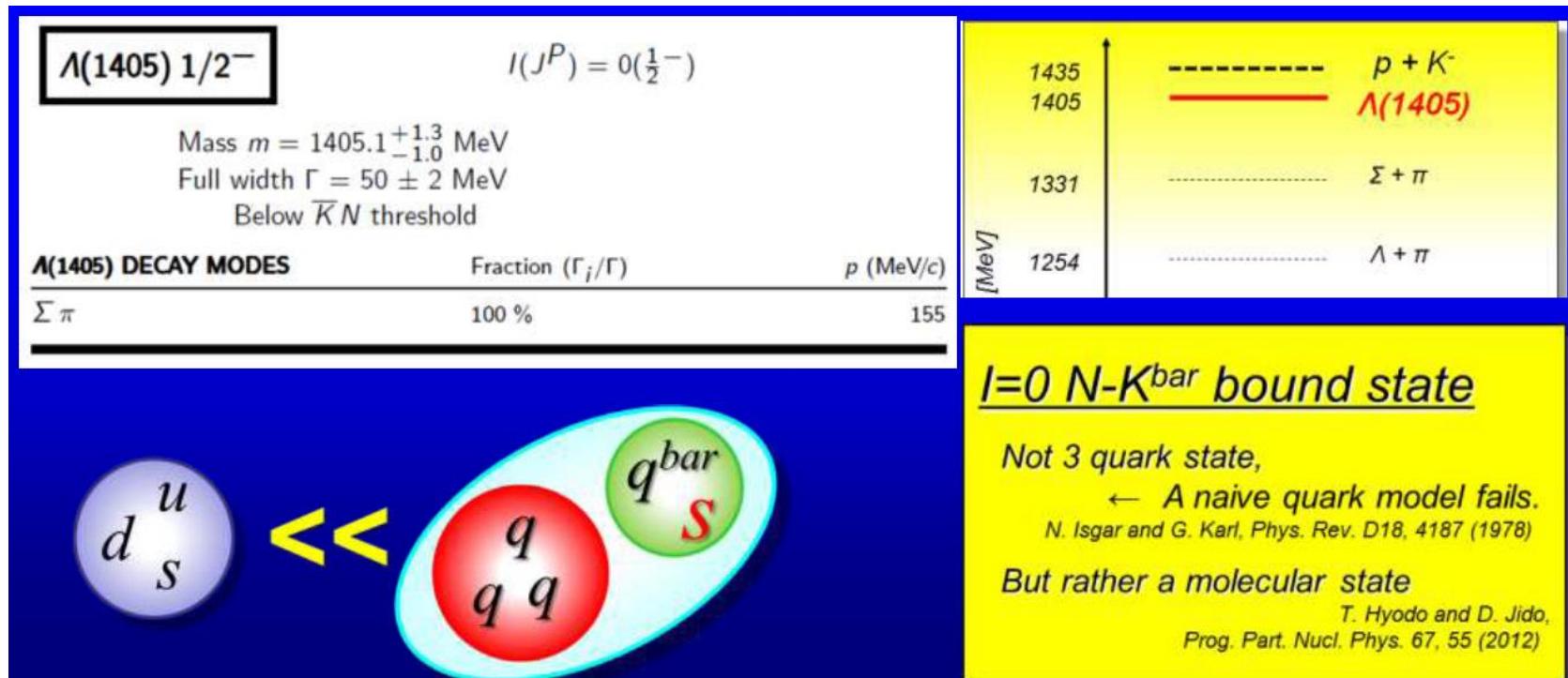
From F. Scazza et al., PRL 118 (2017) 083602.

From K. Nishimura

Polaron problems in exotic hadrons and trapped cold atoms

Lambda(1405)

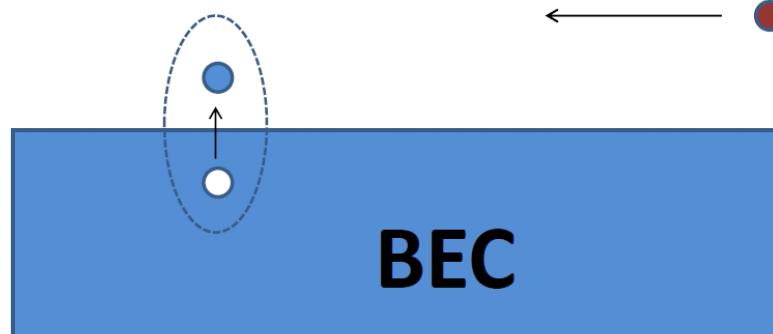
From A. Dote



Impurity Fermi atom in Bose condensates

ボゴリューボフ・フォノン

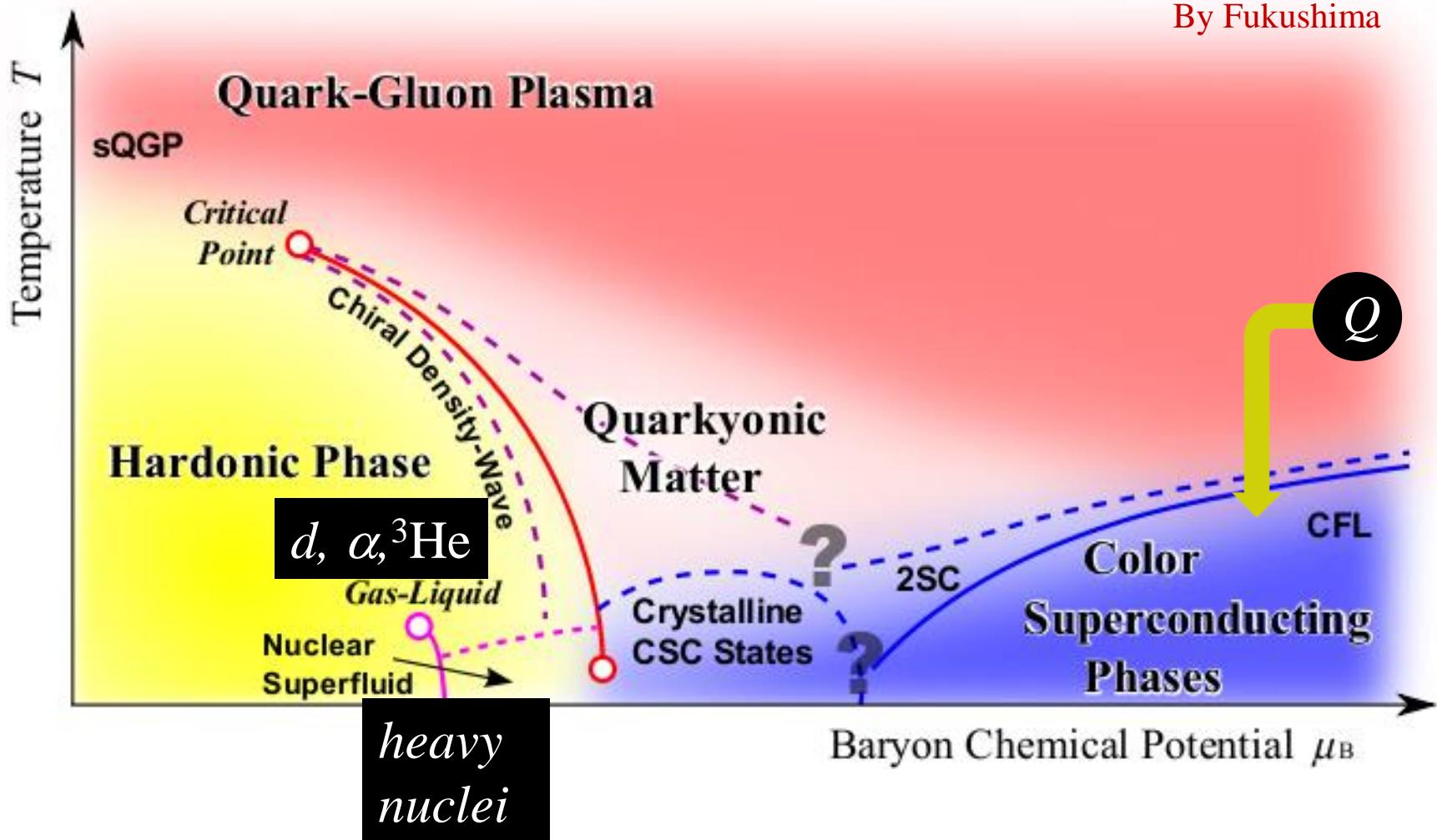
異種原子



From E. Nakano

Conclusion

By Fukushima



Mass shift of a “cluster” &
“cluster”-“cluster” interactions
induced in medium

Good probe of the medium
properties, e.g., Fermi
degeneracy, superfluidity