Efimov Physics in a Many-Body Background

Nikolaj Thomas Zinner

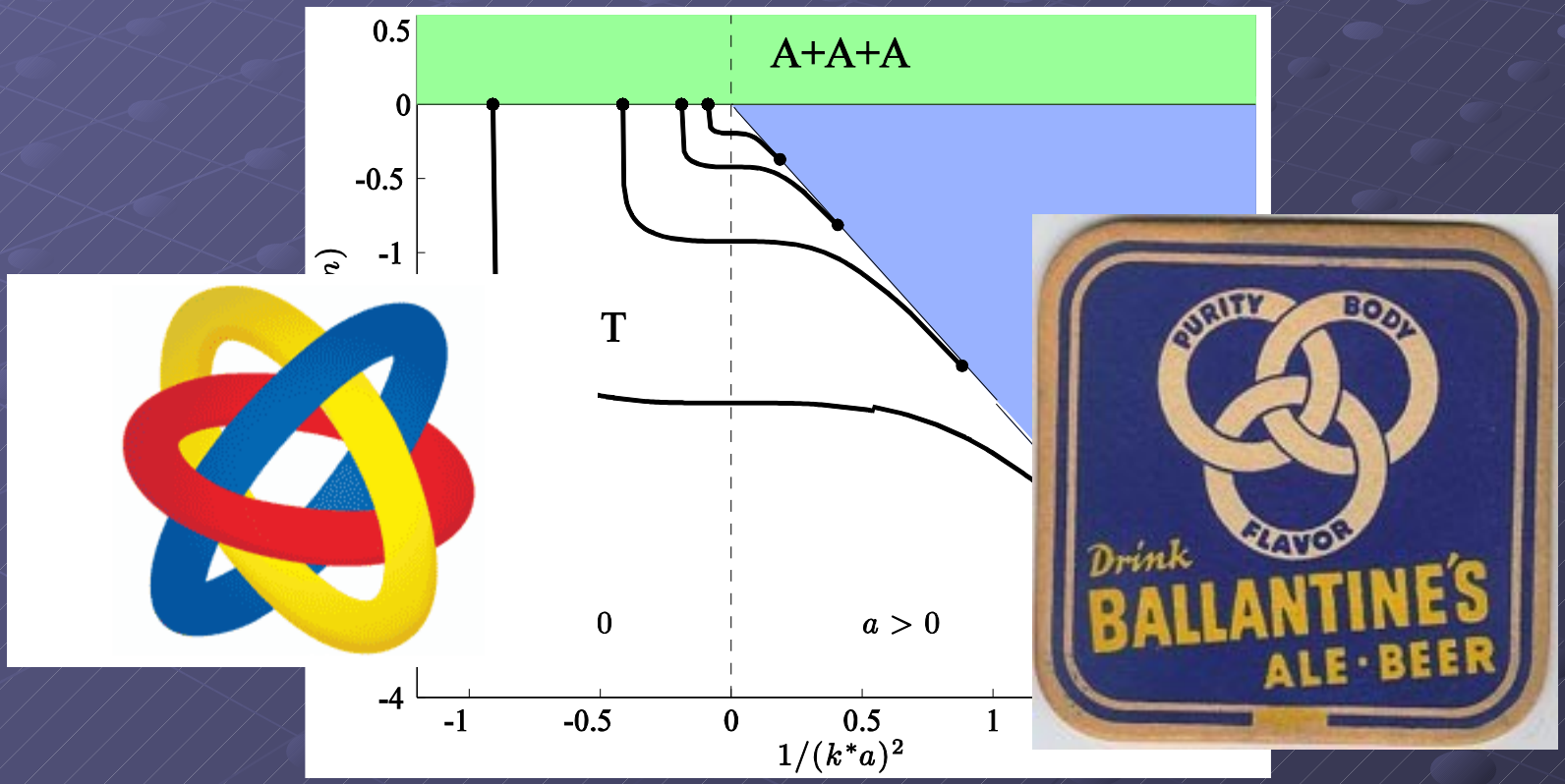
University of Aarhus

Denmark

Efimov Effect

Vitaly Efimov 1970

Identical bosons in 3D have an infinite ladder of three-body bound states when there is a two-body bound state at zero energy



Ultracold atoms

Experimental observation – Grimm group. 133-Cesium Nature **440**, 315 (2006).

Many obse

Florence g

Bar Ilan gr

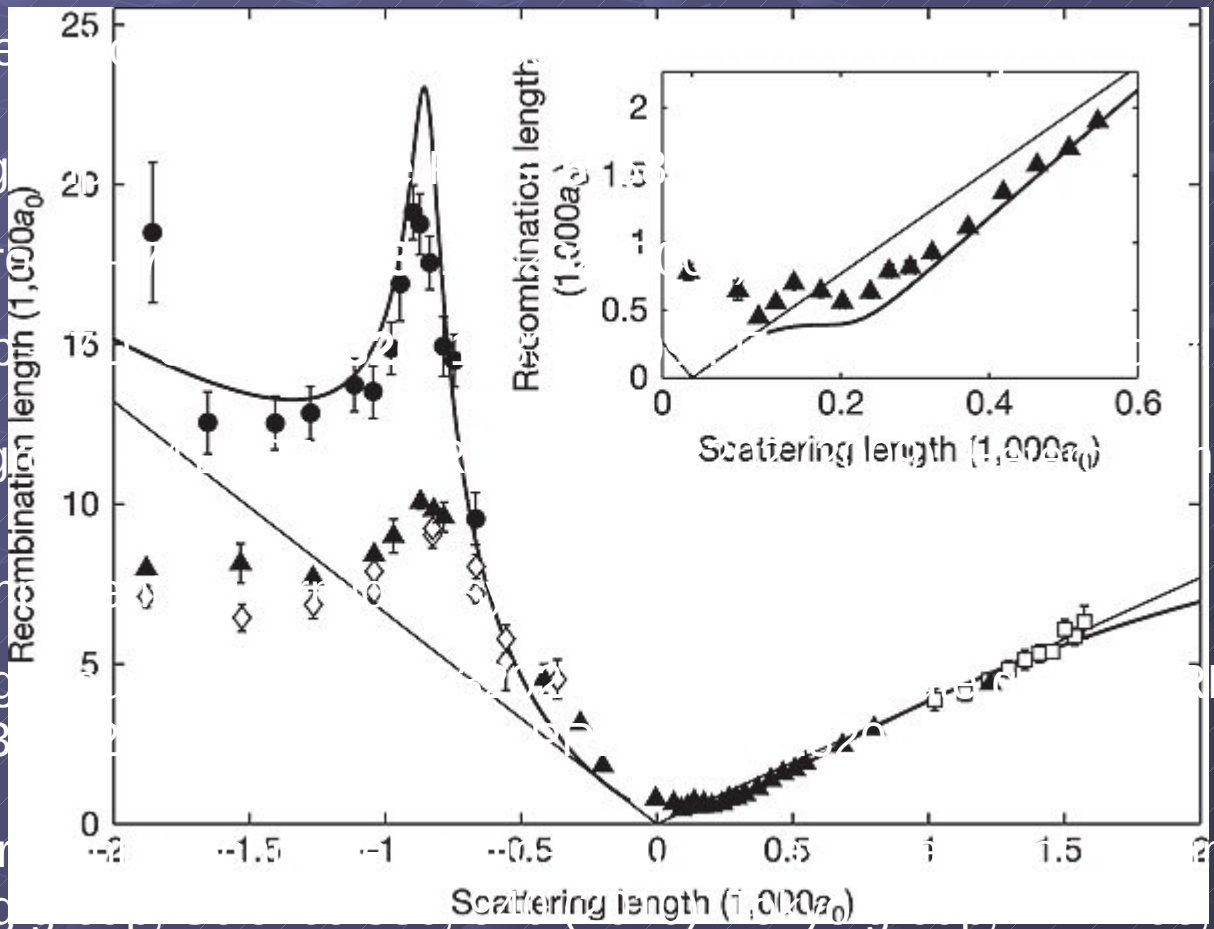
Rice group

Florence g ic mixture!

Three-com

Heidelberg RL **102**, 1653

New exper mers. Heidelberg 143201 (2011).



Background Effects?

External confinement

Non-universality

Finite temperature

Quantum degeneracy

Condensed Bose or degenerate Fermi systems

Outline

Effects of Fermi degeneracy on two-body physics

Implementation in the three-body problem

Spectrum and spectral flow

Realistic three-component 6Li systems

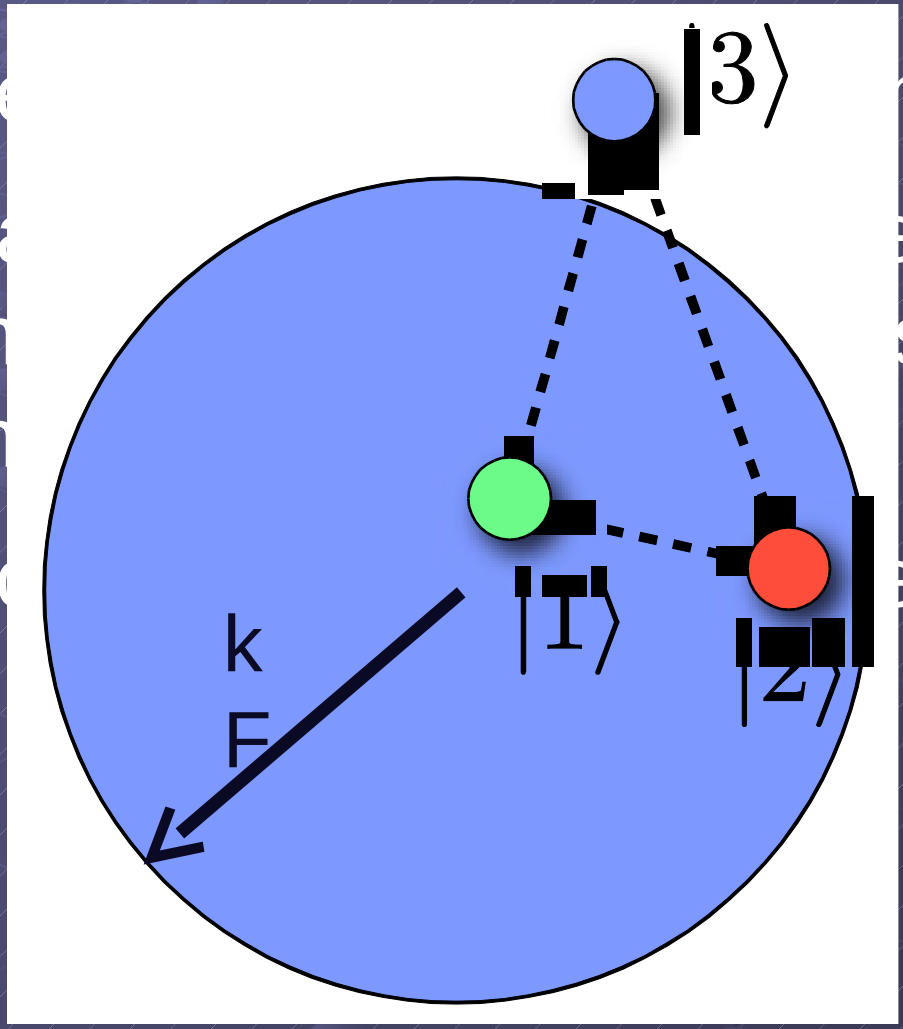
Outlook

Reductionism

Simplify the … mi sea!

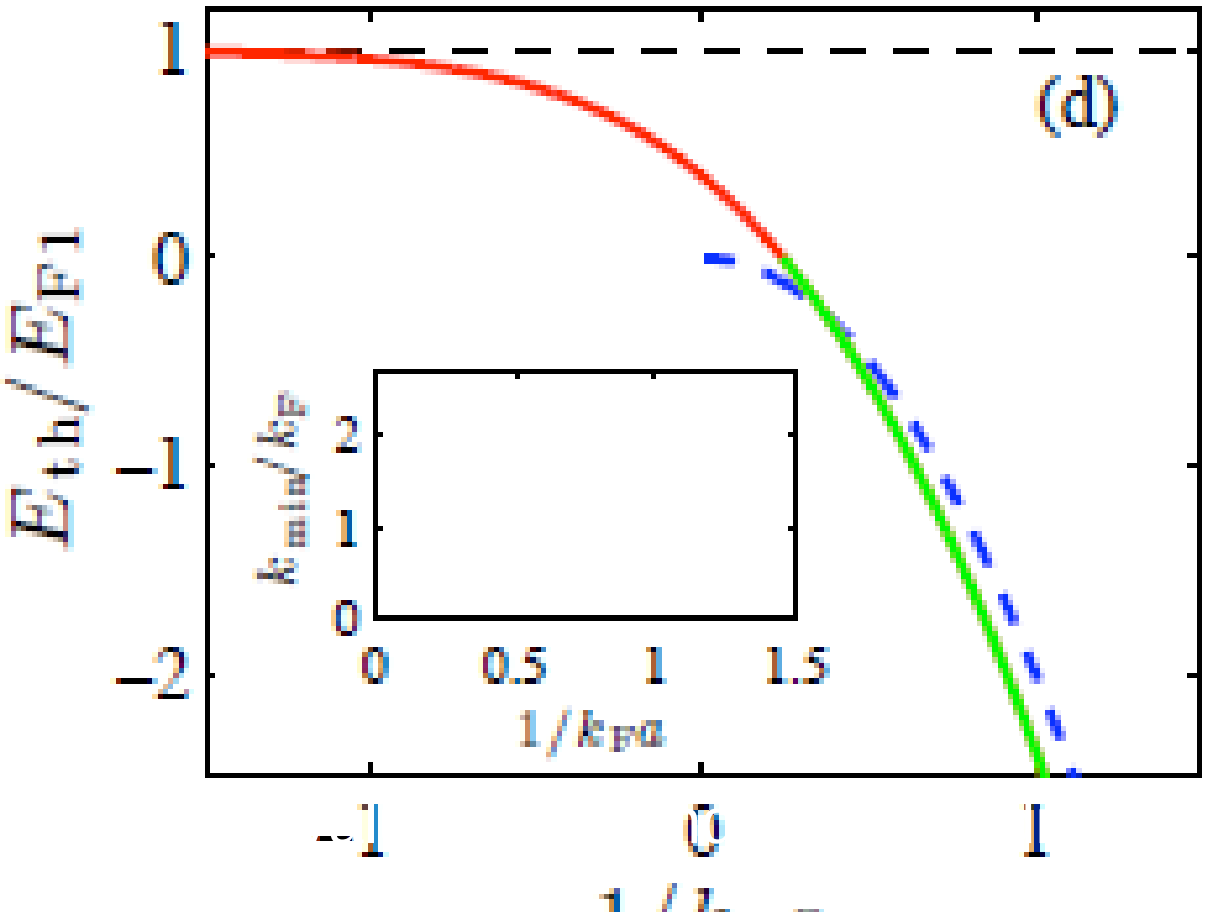
Top-down a… ermi sea in one com… s – consider th…

Natural to … entum space.



Cooper pair inspiration

D(**q**,E)



$$\overline{\overline{E+\mathbf{q}^2/4m}}$$

$$D(\mathbf{q},E$$

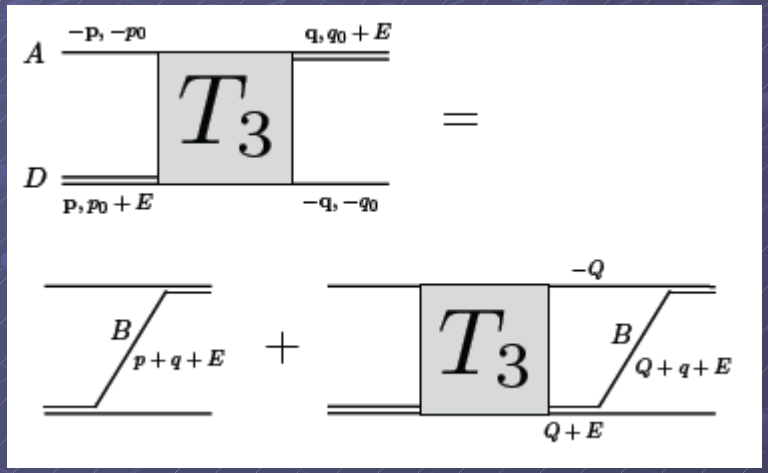
$$\overline{+i\epsilon}$$

$$\frac{1}{a_c}=\frac{2k_F}{\pi}\left(1-\frac{1}{2^{3/2}}\ln\left[\frac{\sqrt{2}+1}{\sqrt{2}-1}\right]\right)=0.24k_F$$

Three-body problem

Momentum-space three-body equations

Skornyakov and Ter-Martirosian, Zh.Eksp. Teor. Fiz. **31**, 775 (1957).

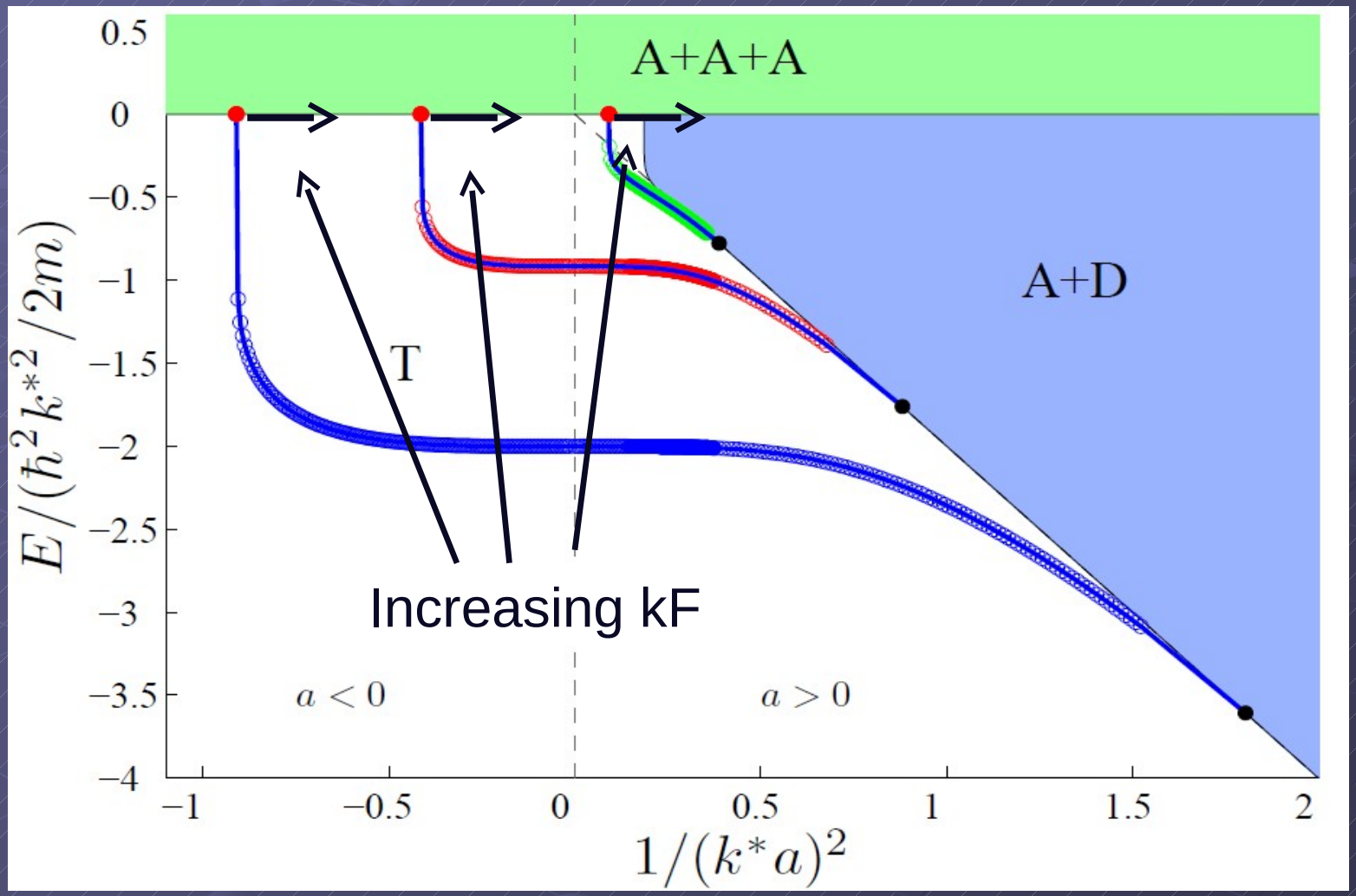


Bound states:

$$B(p) = \frac{\hbar^2}{\pi m_{AB}} \int_0^\infty dq\, q^2 \left[K(q,p) - K(q,k_{\rm reg})\right] \frac{B(q)}{-1/a_{AB} + \sqrt{\frac{m_{AB}}{m_{AD}} q^2 - \frac{2m_{AB}E}{\hbar^2}} - i0+}$$

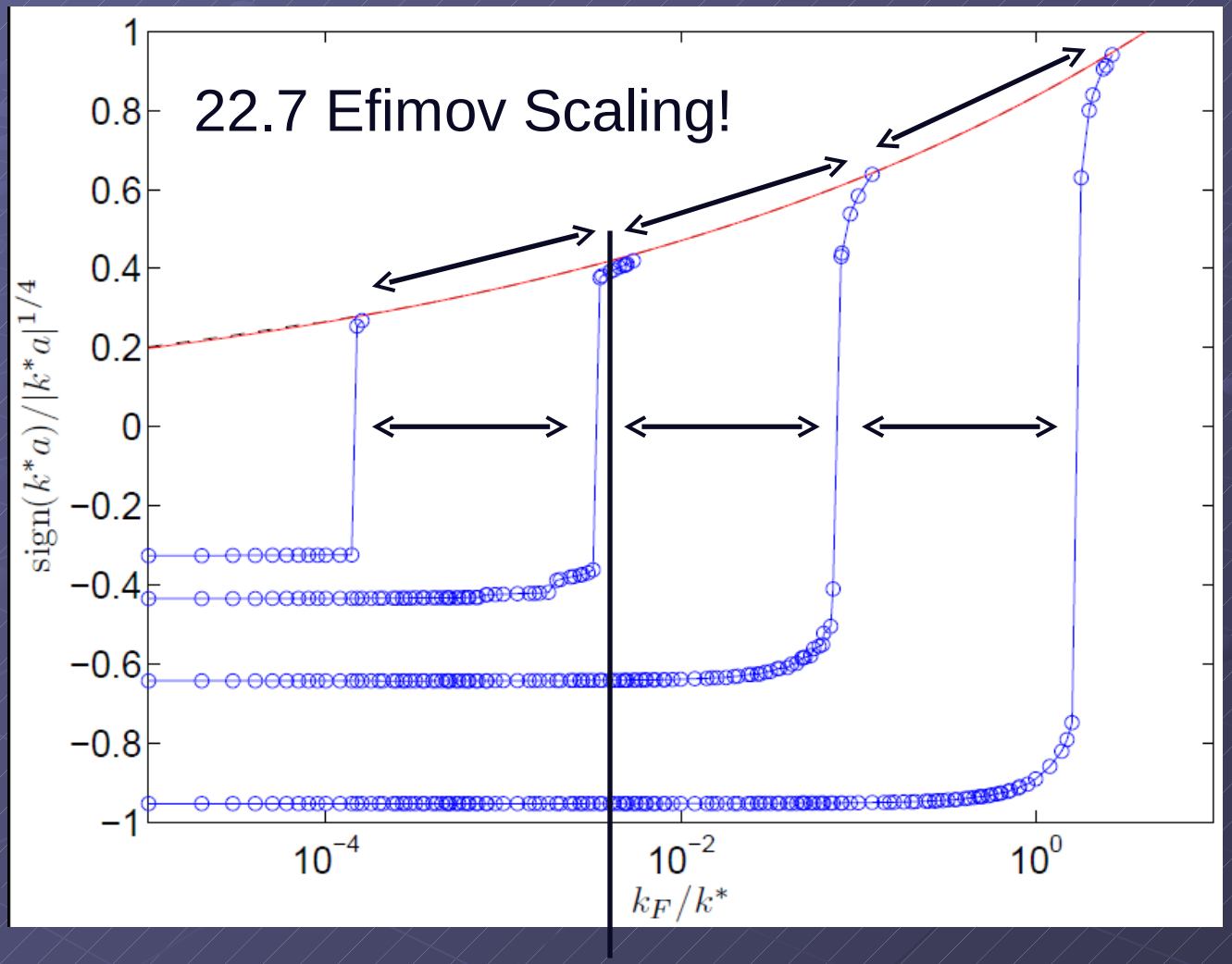
Needs regularization! Use method of Danilov, Zh.Eksp. Teor. Fiz. **40**, 498 (1961). Nice recent discuss by Pricoupenko, Phys. Rev. A **82**, 043633 (2010)

Spectrum with Fermi sea



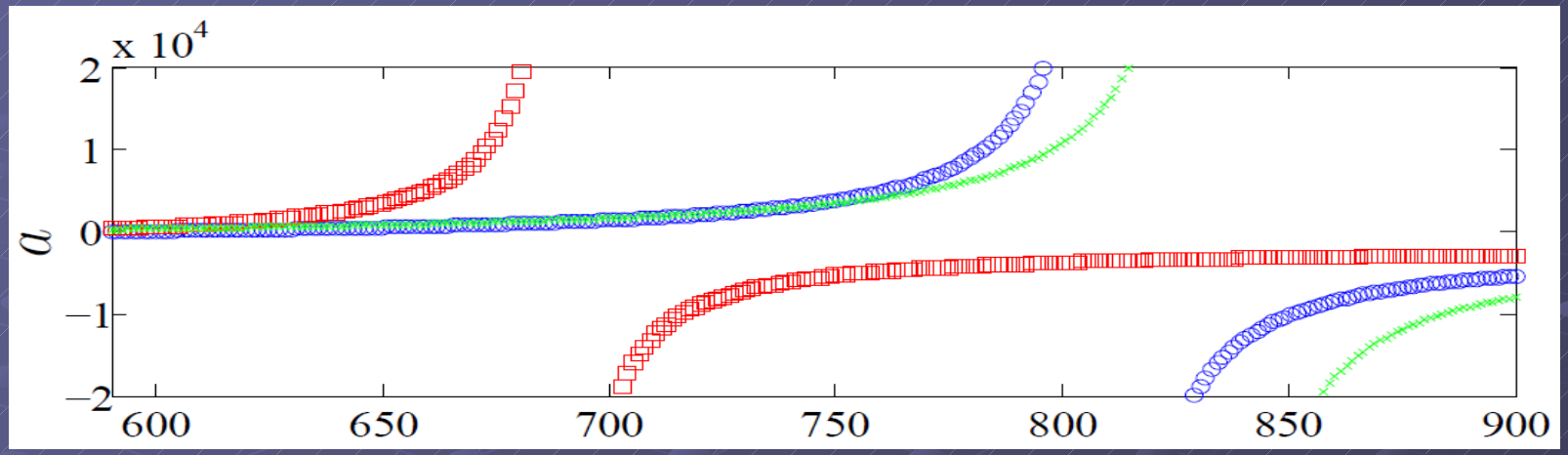
kF/k*=0.05

Spectral Flow

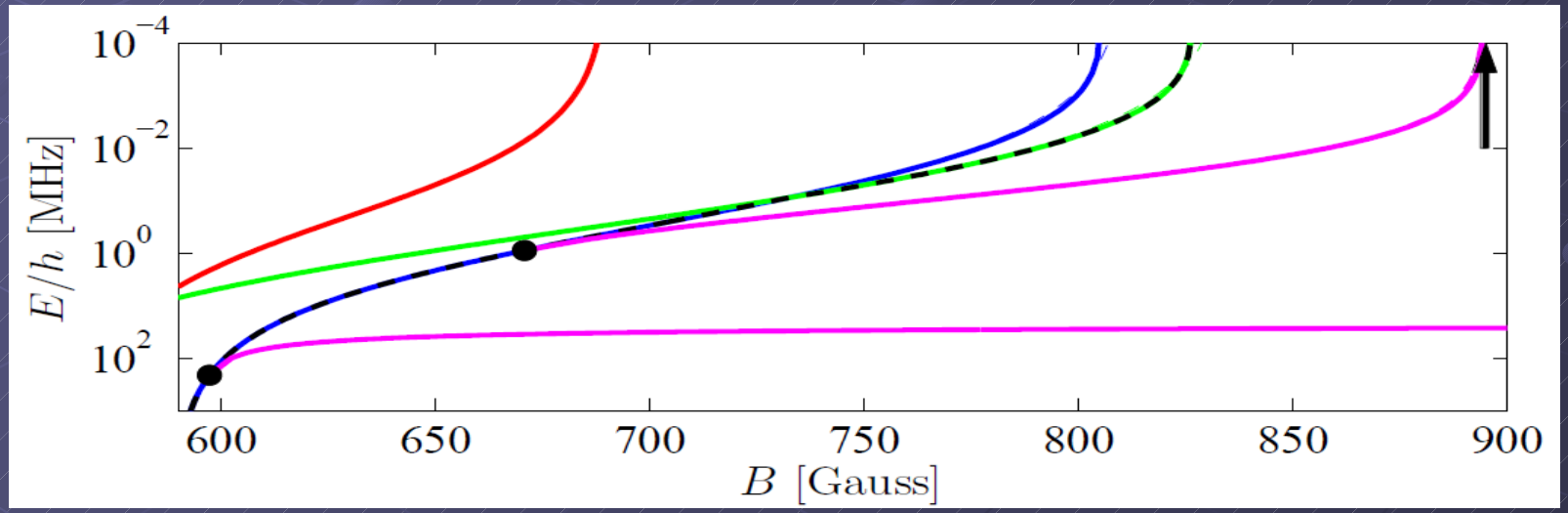


kF/k*=0.05

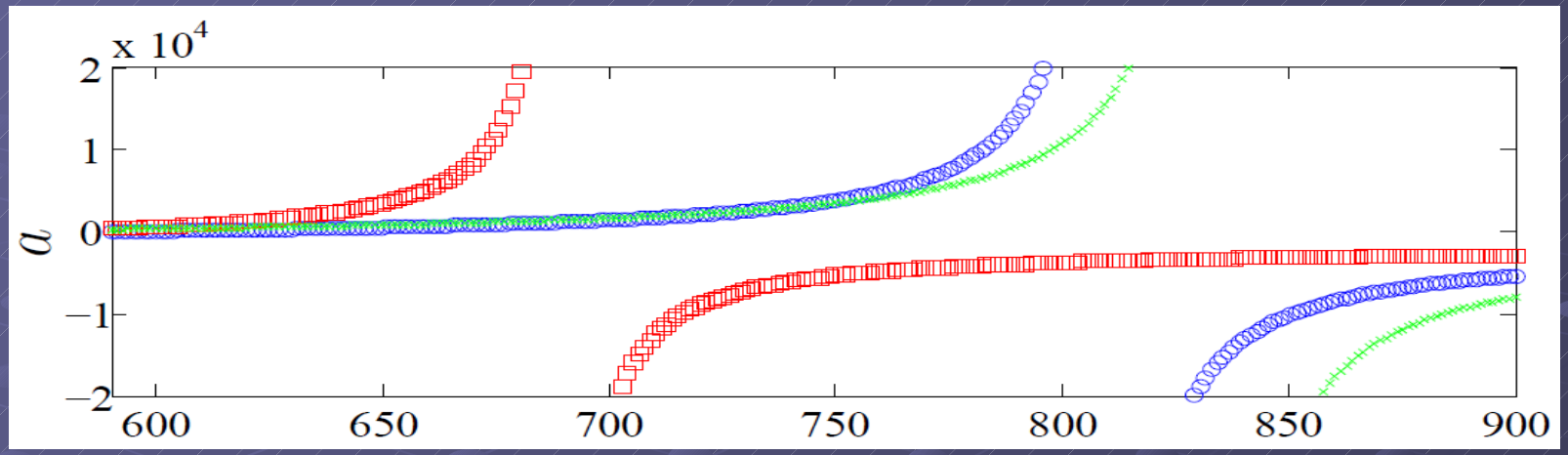
The 6Li system



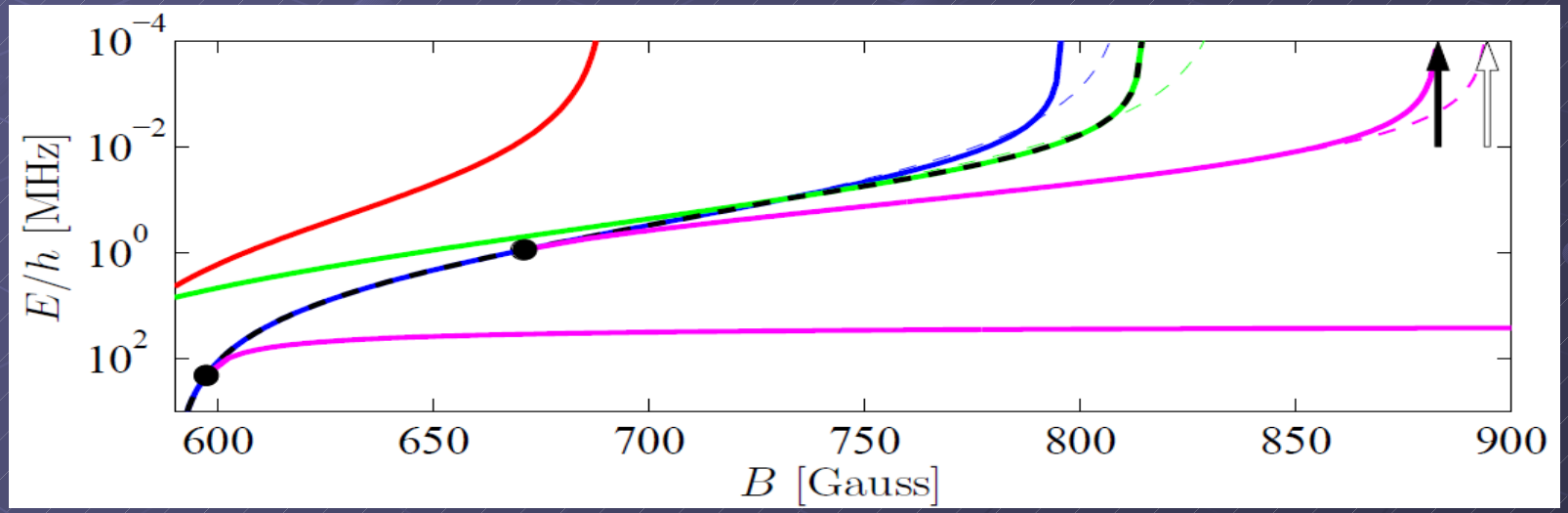
k*=6.9*10-3 a0-1 kF=0.01k* n~1011 cm-3



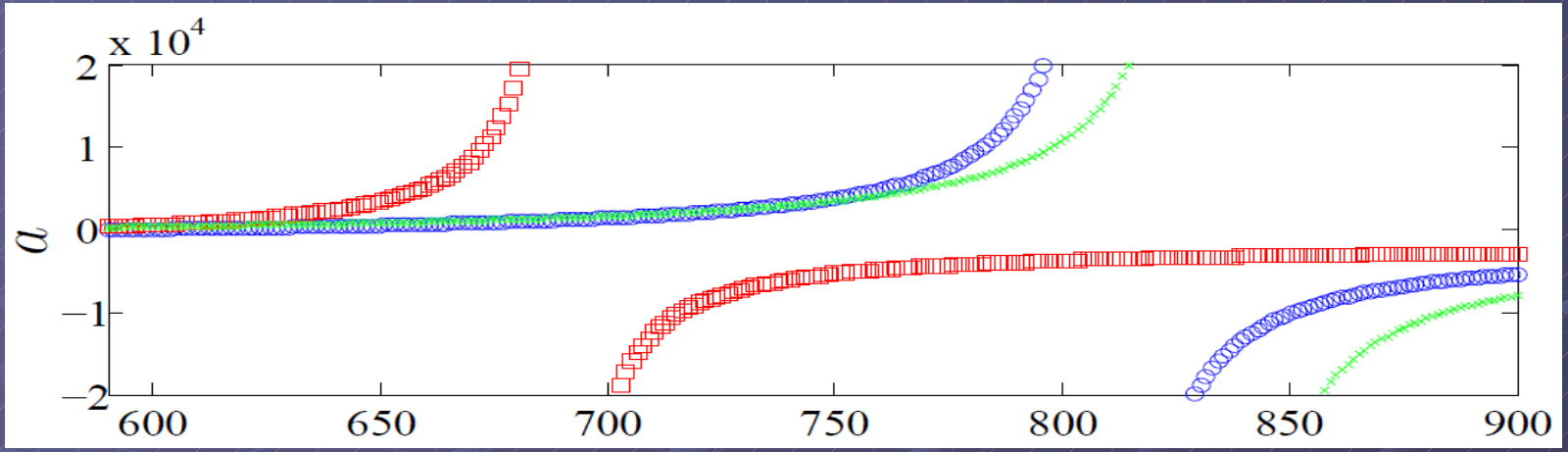
The 6Li system



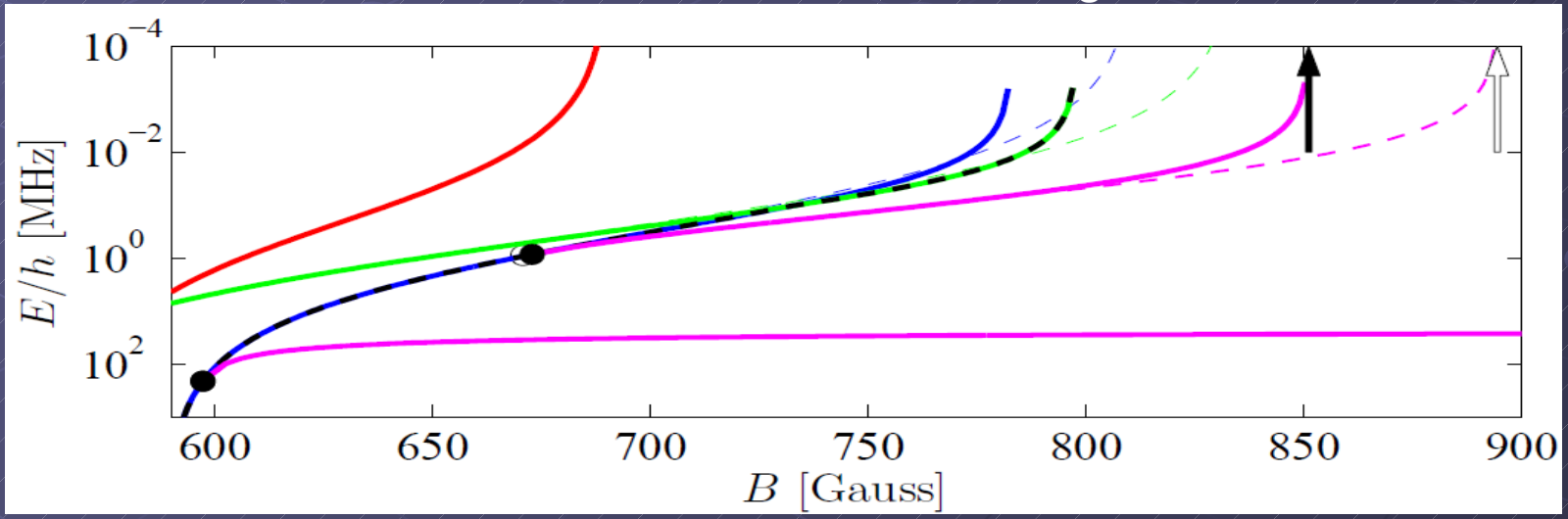
k*=6.9*10-3 a0-1 kF=0.03k* n~1012 cm-3



The 6Li system



k*=6.9*10-3 a0-1 kF=0.06k* n~1013 cm-3



Observability?

Densities have been too small or measurements have not been around the second trimer threshold point.

Trimer moves outside threshold regime D'Incao *et al.* PRL **93**, 123201 (2004).

Perhaps not a problem Wang and Esry New. J. Phys. **13**, 035025 (2011).

Dimer regime is harder since lowest Efimov state has large binding energy.

Outlook

Different masses and interactions.

More Fermi seas.

Normal Fermi liquid can become superfluid.

Bose gases normal and condensed.

Scattering problems in the presence of backgrounds.

Non-universal corrections.

Take-home message

There are background effects in Efimov physics.

They are likely close to experimental regimes.

New universal physics can appear.

Efimov physics ’survives’ many-body physics!

Acknowledgments

Nicolai Nygaard

Aksel Jensen, Dmitri Fedorov, Georg Bruun

Thomas Lompe for experimental details.

Bernhard Wunsch, Eugene Demler, Fei Zhou, Charles Wang.

Born-Oppenheimer limit and analytics – MacNeill and Zhou PRL **106**, 145301 (2011).

Thank you for your attention!

Enjoy the dinner!