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Pairing in Neutron Stars

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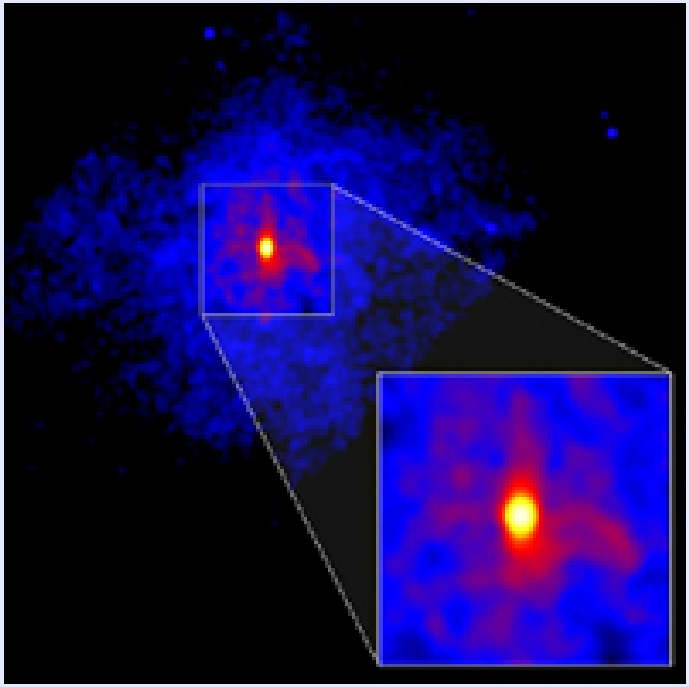

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Outline

- Introduction
- Coherence effect due to short range interaction
- Treatment of Pairing using BCS approach
- Future Study

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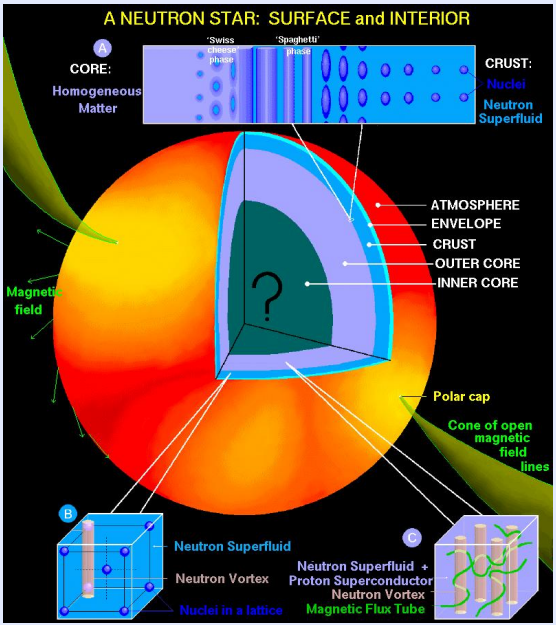
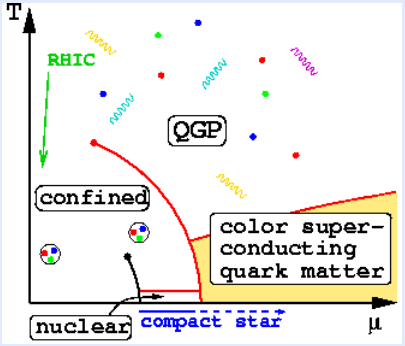
Introduction

- The Structure of Neutron Stars
- SC and SF in nuclei, the inner crust, and the core of Neutron Stars
- Phase transitions and some phenomenological aspects in Neutron Stars





(www.astro.umd.edu/ miller/nstar.html)

(www.physics.wustl.edu/ alford/high density.html)

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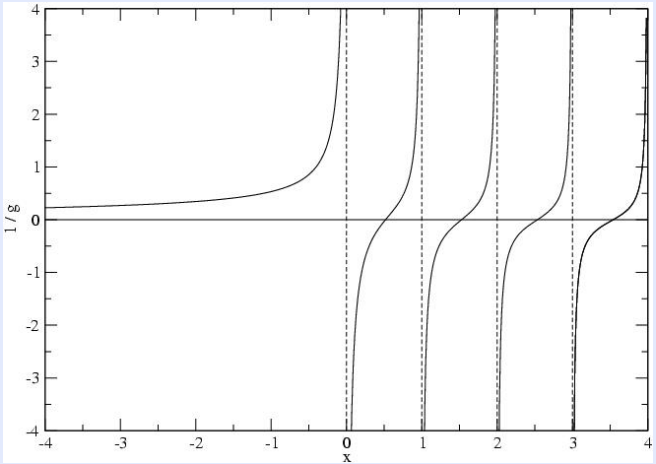
Coherence effect due to short range interaction

- Simple harmonic oscillator plus a short range interaction
- Hamiltonian $H = H_0 - g\delta(x)$
- Solve the problem exactly, we get :

$$\frac{1}{g(x)} = \frac{1}{2\sqrt{\pi}} \sum_{k=0,1,2\ldots}^{\infty} \frac{(2k-1)!!}{(2k)!!(k-x)} \tag{1}$$

- Spectrum of energies (numericaly)
- Wave function (numericaly)



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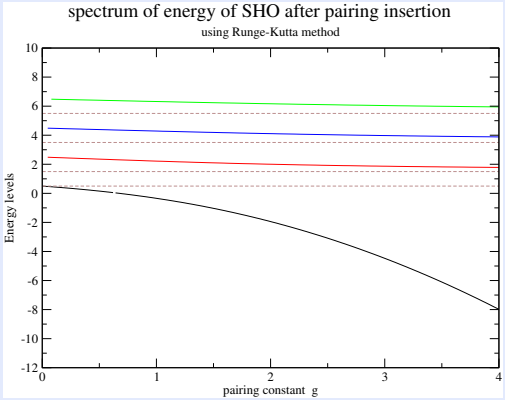
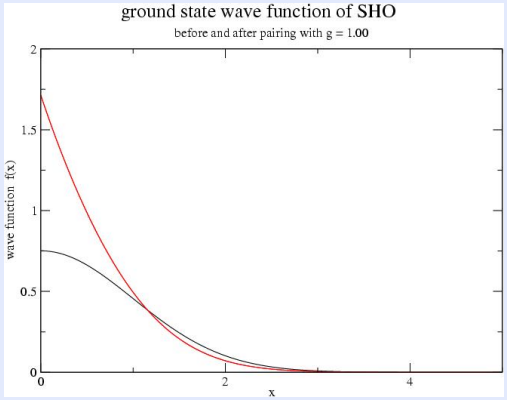
Coherence effect due to short range interaction

n(state)	SHO	SHO+Pairing (g=1.00)
0	0.5000	-0.3428
2	2.5000	2.2187
4	4.5000	4.2863
6	6.5000	6.3198
8	8.5000	8.3401





BCS approach

- Large system $\Longrightarrow$ BCS approach
- Apply BCS gap equation to the simple nuclear systems

$$\Delta_k = \frac{1}{2}\sum_{k'>0}\frac{\Delta_{k'}}{\sqrt{\varepsilon_{k'}^2+\Delta_{k'}^2}}V_{kk'} \tag{2}$$

- One level/degenerate states problem
- Two levels problem $\Rightarrow$ compare with realistic potential

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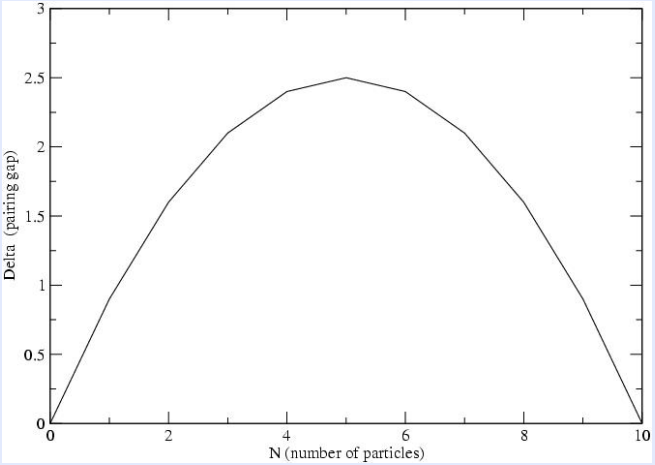
BCS approach, One level/degenerate states problem



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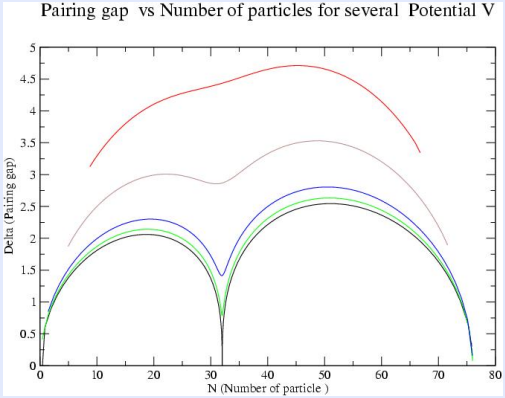
BCS approach, Two levels problem



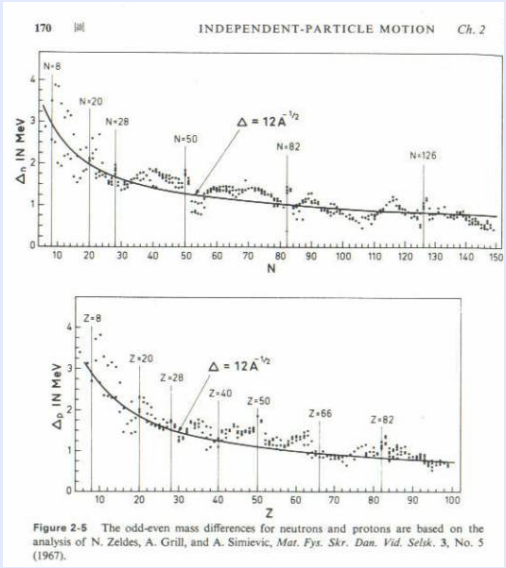


Figure 2-5 The odd-even mass differences for neutrons and protons are based on the analysis of N. Zeldes, A. Grill, and A. Simievic, *Mat. Fys. Skr. Dan. Vid. Selsk.* 3, No. 5 (1967).

(A.Bohr, B.R.Mottelson, Nuclear Structure, World Scientific, 1998)

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Future Study

- BCS in nuclei ⇒ discretized continuum
  - Development of BCS code for large system
  - Comparison with the experiment
- Pairing in Neutron Stars (inner crust)
- Pairing in quark matter and modes of condensate (cores)
- BCS in configuration space ⇒ clustering phenomena

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Acknowledgment

- Alexander Volya
- Jorge Piekarewicz