The Vortex Structure of a Neutron Star with CFL core

M.K. Shahabasyan
Department for Theoretical Physics, Yerevan State University
Yerevan, Armenia

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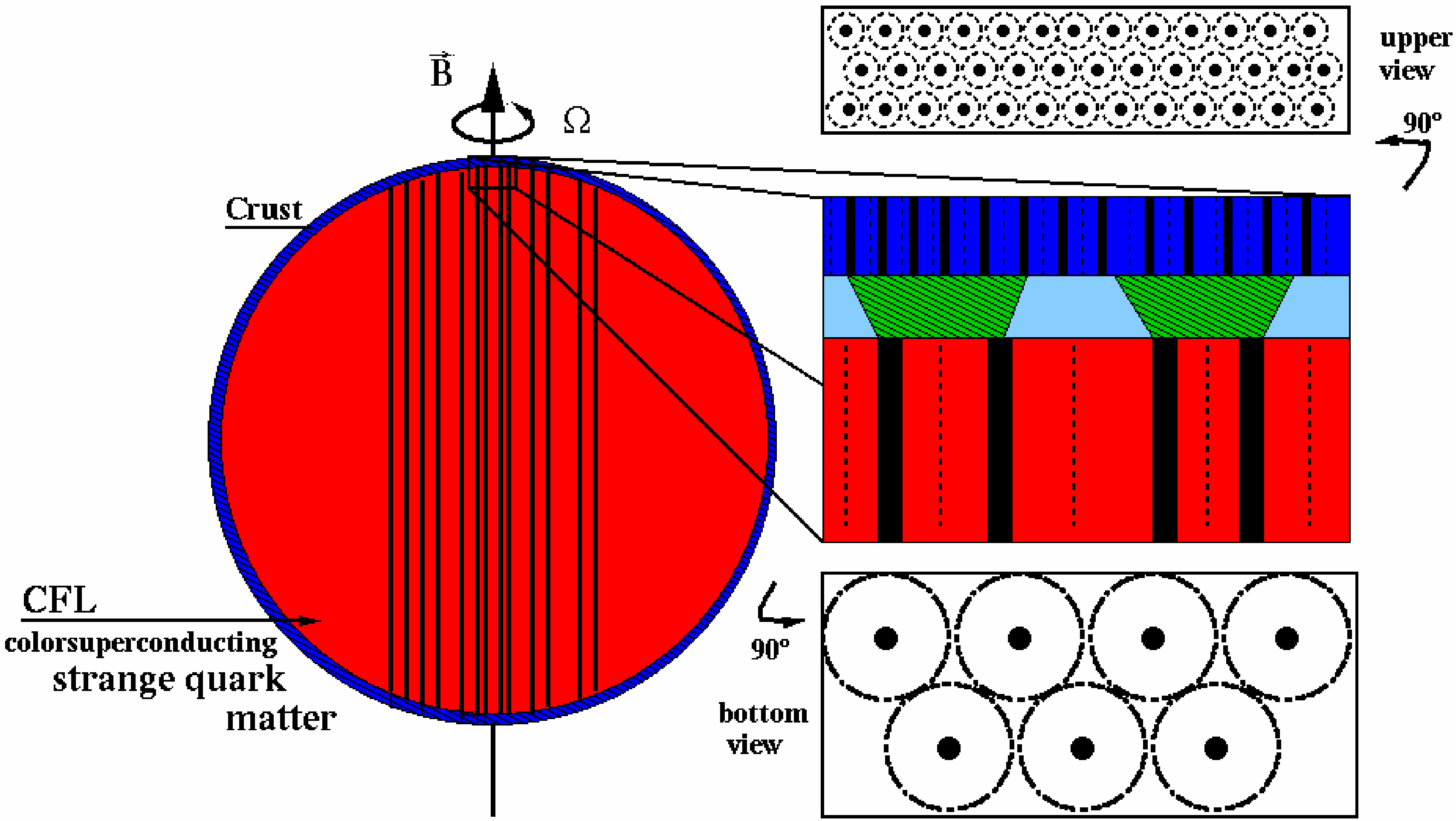
Contents



$\vec{B}$
Ω
Crust
upper
view
90°
CFL
colorsuperconducting
strange quark
matter
90°
bottom
view

Introduction

- It is widely accepted with high level of confidence that inside a different phases of a neutron star quantum vortical filaments exists.
- Due to their existence, rotational dynamics of NS can be described` glitches, relaxation, quasi-sinusoidal oscillations of angular velocity.
- In the dense core of NS there is a possibility of quark matter to exist in the 2 possible phases` 2SC and CFL

Introduction

- CFL phase was the stable in temperatures near the critical in the limit of weak interaction
- Quarks are forming condensate of Cooper pairs (diquarks) with
- In the work of *K. Iida, G. Baym, Phys. Rev., D66 , 014015, 2002* and *M. M. Forbes, A. R. Zhitnitsky, Phys. Rev., D65, 085009, 2002* one consider superfluid quark vortices due to violation of global $U(1)_B$ symmetry.

Introduction

- *A. P. Balachandran, S. Digal, T. Matsuura, Phys. Rev., D73, 074009, 2006* where find new semi-superfluid vortex filaments M_1 and M_2 with properties of both` superfluid and magnetic vortices.
- It was shown that two s-s vortices will reject each other.

G-L equations

- for s-s vortices M_1

$$\lambda_q^2 \mathrm{rotrot}\vec{A} + \vec{A}\sin^2\alpha = \frac{\Phi_x \sin\alpha \nabla \vartheta}{2\pi} - \vec{A}^8 \sin\alpha\cos\alpha$$

$$\lambda_q^2 \mathrm{rotrot}\vec{A}^8 + \vec{A}^8 \cos^2\alpha = \frac{\Phi_x \cos\alpha \nabla \vartheta}{2\pi} - \vec{A}\sin\alpha\cos\alpha$$

where $\vec{A}$ and $\vec{A}^8$ are the vector potentials of magnetic and gluomagnetic fields

G-L equations

- after integrating by the contour that are passed by the boundary of quark core full flux of will be M_1

$$\Phi_M = 2\pi\hbar c / e = 2\Phi_0$$

where $\Phi_0 = 2 \cdot 10^{-7} gauss \cdot cm^2$ is a magnetic flux quantum.

- So, M_1 quantum is a twice as large as that of elemantary one.

G-L equations

- for M_2`

$$\lambda_q^2 \mathrm{rotrot}\vec{A} + \vec{A}\sin^2\alpha = \frac{2\Phi_x \sin\alpha \nabla\vartheta}{2\pi} - \vec{A}^8 \sin\alpha\cos\alpha$$

$$\lambda_q^2 \mathrm{rotrot}\vec{A} + \vec{A}\sin^2\alpha = \frac{2\Phi_x \sin\alpha \nabla\vartheta}{2\pi} - \vec{A}^8 \sin\alpha\cos\alpha$$

and flux $4\Phi_0$

Vortices in the quark core

- Critical angular velocity for $U(1)_B$

$$\omega_{c1}^{B} = \frac{3\hbar}{2m_B R_q^2} \ln \frac{R_q}{\xi}$$

- for M_1

$$\omega'_{c1} = \frac{\hbar}{2m_B R_q^2} \ln \frac{R_q}{\xi}$$

- and M_2

$$\omega''_{c1} = \frac{\hbar}{m_B R_q^2} \ln \frac{R_q}{\xi}$$

Vortices in the quark core

- In hadronic phase neutron vortices start to appear when

$$\omega > \omega_{c1}^{n} = (\hbar / 2m_B R_n^2 \ln(R_n / \xi_n)$$

- For hadronic core with $R_n = 5\cdot 10^5 cm$ and proton coherence length $\xi_n = 3.1\cdot 10^{-12} cm$`

$$\omega_{c1}^{n} = 5\cdot 10^{-14} \sec^{-1}$$

Vortices in the quark core

- For s-s vortices $R_q = 10^5 cm$ so

$$\omega'_{c1} = 1.3 \cdot 10^{-12}$$

- Density of M_1-s is equal $n_v = 10^3 \omega.$

Conclusions

- The Ginzburg Landau equations for semi-superfluid vortices in the CFL phase quark core were derived
- Asymptotic energy values and critical angular velocities for s-s. vortices are calculated
- It was shown that inside the rotating star core, lattice of s-s. vortices appears with smallest magnetic flux quantum
- While hadronic phase consist of stable lattice of neutron vortices

Conclusions

- In transition region each neutron vortex joining with M_1 vortex in the core

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