Mathematical Modeling in Applied Informational Nanotechnologies and Fundamental Research on Pulsar Astrophysics

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1. Information processing in magnetized nematic liquid-crystal devices.

Based on the method of molecular field dominated by magnetic component, it is shown that a homogeneous magnetically aligned nematic liquid crystal governed by equations of nematodynamics In the regime of vortical back-flow coupling, the linear fluctuations of solenoidal flow and local precession of director are governed by equations

$$\rho\frac{\partial\delta v_i}{\partial t}=\frac{1}{2}\nabla_k[\delta n_i h_k-\delta n_k h_i]+2\eta\,\nabla_k\delta\, v_{ik}+\eta_n\nabla_k(n_i n_j\delta v_{kj}+n_k n_j\delta v_{ij})$$
$$\frac{\partial\delta n_i}{\partial t}=\frac{1}{2}(\nabla_i\delta v_k-\nabla_k\delta v_i)n_k\quad\nabla_k\delta v_k=0$$

can respond to a circularly polarized optical field by transverse nemato-magnetic wave characterized by dispersion equation

$$\omega^2=V_v^2k^2\cos^2\theta+i\omega k^2\left(\nu+\frac{\nu_n}{2}\cos^2\theta\right)$$
$$V_v^2=\frac{n_i\,h_i}{4\rho}=\frac{\chi_a H^2}{4\rho}\quad\nu=\frac{\eta}{\rho}\quad\nu_n=\frac{\eta_n}{\rho}.$$

in which velocity of incompressible flow and director undergo coupled oscillations slowly travelling along the axis of magneto-optical anisotropy Fig.1. It is suggested in [1] that the effect may be of practical interest for the magnetically controlled information processing and storage.

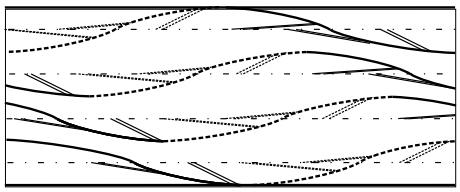

Figure 1: The transverse nemato-magnetic wave propagating in the regime of vortical back-flow coupling in which the velocity of vortical flow and director undergo coupled oscillations travelling along the applied magnetic field

2. Semiclassical model of gyromagnetic plasmons in metal nanoparticles

The effect of externally imposed dc magnetic field threading a metal nanoparticle responding to an incident ac optical field by collective cyclotron oscillations of electrons and ions has been studied. We have found that in the long wavelength limit of electromagnetic radiation the electron-cyclotron response can be properly modeled by equations

of semiclassical electron theory as oscillations of free electrons driven by Lorentz restoring force.

$$\rho\frac{\partial\delta\mathbf{v}}{\partial t}=-\frac{\rho_e}{c}[\delta\mathbf{v}\times\mathbf{B}]\quad\rightarrow\quad\frac{\partial\delta\mathbf{v}}{\partial t}+\omega_c[\mathbf{n}_B\times\delta\mathbf{v}]=0\quad\omega_c=\frac{eB}{m_e^*\,c}\quad\mathbf{n}_B=\frac{\mathbf{B}}{B}.$$

The frequency spectrum of gyromagnetic plasmon resonances derived in [2]:

$$\omega(\ell)=\frac{\omega_c}{\ell(\ell+1)}\qquad\omega_c=\frac{eB}{m_e^*c}\qquad\ell\geq 1$$

is analog of the well-known Mie's spectrum

$$\omega^2_{\rm Mie}(\ell)=\omega_p^2\frac{\ell}{2\ell+1}\qquad\omega_p^2=\frac{4\pi n_e e^2}{m_e^*}\qquad\ell\geq 1$$

for the surface plasmon resonances caused by the Coulomb force driven plasma oscillations of conduction electrons and described by coupled equations equations of electron fluid dynamics and ionic electrostatic

$$\rho\frac{\partial\delta\mathbf{v}}{\partial t}=\rho_e\delta\mathbf{E}\qquad\nabla\cdot\delta\mathbf{v}=0\qquad\rho=m_e n_e\qquad\rho_e=-en_e$$
$$\nabla\cdot\delta\mathbf{E}=0\qquad\nabla\cdot\mathbf{E}_0=4\pi\rho_i\qquad\rho_i=en_i\quad n_i=n_e.$$

It is suggested that in view of the harmlessness to living tissues of the effects of infrared radiation and magnetic field, the considered electron-cyclotron resonant photoabsorption by ultrafine noble metal particles (e.g. gold) can be utilized for biomedical applications.

3. Quasistatic waves of hydrogravity in interstellar medium from pulsating neutron star.

Based on principles of classical hydrodynamics and Newtonian gravity, the theory of hydrogravity, formulated in the manner of hydromagnetic theory, has been developed to account for the gravitational effect of global pulsations of a star on the motions of the ambient gasdust interstellar medium [3]. The self-consistent equations of hydrogravity are given by

$$\frac{d\rho}{dt}+\rho\frac{\partial V_k}{\partial x_k}=0$$
$$\rho\frac{dV_i}{dt}+\frac{\partial}{\partial x_i}\left(P-\frac{\mathrm{g}^2}{8\pi G}\right)+\frac{\partial}{\partial x_k}\left\{\frac{1}{8\pi G}[\mathrm{g}_i\mathrm{g}_k+\mathrm{g}_k\mathrm{g}_i]\right\}=0$$
$$\frac{\partial \mathrm{g}_k}{\partial t}+4\pi G\rho V_k=0.$$

Particular attention was given to gas-dynamical oscillations of quasistatic waves of gravity generated by a pulsating neutron star in an unbounded spherical shell of gas and dust promoted by circumstellar gravitational stresses and damped by viscosity of the interstellar matter. Computed in the long-wavelength approximation, the frequency of spheroidal and poloidal gravity-driven shear oscillations are found to be proportional to that the gravity modes in the neutron star bulk. For spheroidal and toroidal g-modes of

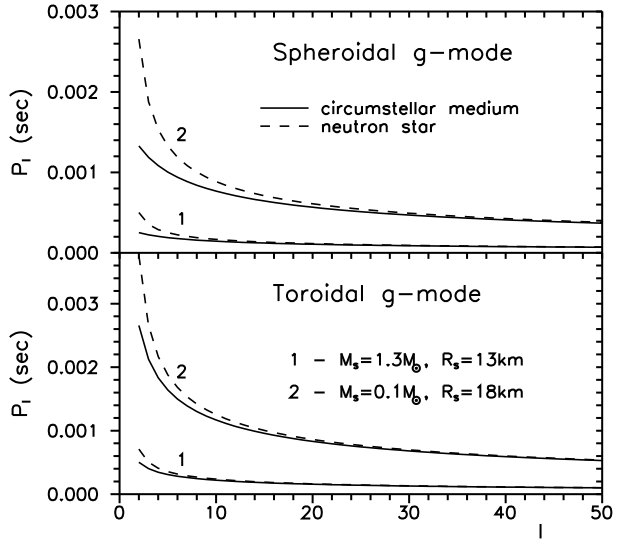

Figure 2: Period P_L, in seconds, as a function of multipole degree L of spheroidal (a) and torsional (b) hydrogravity modes in the circumstellar envelope (solid line) and corresponding g modes in the bulk of a neutron star (dashed line) computed for two models of neutron stars

hydrogravity generated by spheroidally and torsionally pulsating neutron star we found

$$\omega_s^2(\ell) = \frac{4\pi}{3} G\,\rho\,(2\ell+1)\left[\frac{2(\ell+2)}{2\ell+1} + \frac{\rho_s-\rho}{\rho}\right]$$
$$\omega_t^2(\ell) = \frac{2\pi}{3} G\,\rho\,\frac{(2\ell-1)(\ell+2)}{\ell+1}\left[\frac{2(\ell+1)}{2\ell-1} + \frac{\rho_s-\rho}{\rho}\right].$$

where ρ is the density of circumstellar medium and ρ_s is the neutron star density. In the limit $\rho/\rho_s << 1$ the above formulas lead to frequecies of quasistatic waves of hydrogravity proportional to the basic frequency of gravity mode in the star bulk

$$\omega_s^2(\ell) = \omega_G^2\,(2\ell+1) \quad \omega_t^2(\ell) = \omega_G^2\frac{(2\ell-1)(\ell+2)}{2(\ell+1)} \quad \omega_G^2 = \frac{4\pi}{3} G\,\rho_s = \frac{GM_s}{R_s^3}$$

as picured in Fig.2.

Given that collective oscillations of cosmic plasma in the wave under consideration should be accompanied by electromagnetic radiation and taking into account that only the radio waves of this radiation can freely travel through the galactic gasdust clouds, it is conjectured that the considered effect of gravitational coupling between seismic vibrations of a neutron star and fluctuations of the galactic interstellar medium should manifest itself in the radio range of pulsar spectra.

4. Transport Properties of Nuclear Matter.

In [4, 5] it is shown that, at low densities, equations for the energy gap in the spectrum of quasiparticles and chemical potentials of protons and neutrons allow solutions with negative chemical potential, which corresponds to appearance of Bose-Eienstein condensation of deuterons which is expected in outer low-density regions of crust-core interface of neutron stars.

The computer analysis of the collective nuclear dynamics is conducted form perspective of elastodynamical approach to the continuum mechanics of nuclear matter. The numerical estimates for the transport coeffients of shear elasticity and shear viscosity of nuclear matter is derived from data on general trends of energies and widths of giant electric and magnetic resonances of multipole degree $l \geq 2$ which are fitted by equations of the nuclear solid globe model.

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