New Results on Charged Compact Boson Stars

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In this work we present some new results which we have obtained in a study of the phase diagram of charged compact boson stars in the theory involving massive complex scalar fields coupled to the U(1) gauge field and gravity in a conical potential in the presence of a cosmological constant Λ which we treat as a free parameter taking positive and negative values and thereby allowing us to study the theory in the de Sitter and Anti de Sitter spaces respectively. In our studies, we obtain four bifurcation points (possibility of more bifurcation points being not ruled out) in the de Sitter region. We present a detailed discussion of the various regions in our phase diagram with respect to four bifurcation points. Our theory is seen to have rich physics in a particular domain for positive values of Λ which is consistent with the accelerated expansion of the universe.

Introduced long ago [1–3], boson stars represent localized self-gravitating solutions studied vary widely in the literature [4–23]. Such theories are being considered in the presence of positive [14–16] as well as negative [17–20] values of the cosmological constant Λ. The theories with positive values of Λ (corresponding to the de Sitter (dS) space) are relevant from observational point of view as they describe a more realistic description of the compact stars in the universe since all the observations seem to indicate the existence of a positive cosmological constant. Such theories are also being used to model the dark energy of the universe. However, the theories with negative values of Λ (corresponding to the Anti de Sitter (AdS) space) are meaningful in the context of AdS/CFT correspondence [24–26].

In fact, cosmological constant, the value of the energy density of the vacuum of space is the simplest form of dark energy and it provides a good fit to many cosmological observations. A positive vacuum energy density resulting from a positive cosmological constant (implying a negative) pressure gives an accelerated expansion of the universe consistent with the observations. Our theory is seen to have rich physics in a particular domain for positive values of Λ.have studied

In a recent paper [15], we have studied the boson stars and boson shells in a theory of complex scalar field coupled to $U(1)$ gauge field A_μ and the gravity in the presence of a fixed positive cosmological constant Λ (i.e. in the de Sitter space). In the present work we study this theory of complex scalar field coupled to $U(1)$ gauge field A_μ and the gravity in the presence of a potential: $V(|\Phi|) := (m^2|\phi|^2 + \lambda|\phi|)$ (with m and λ are constant parameters) and a cosmological constant Λ which we treat as a free parameter and which takes positive as well as negative values and thereby allowing us to study the theory in the dS as well as in the AdS space. We investigate the properties of the solutions of this theory and determine their domains of existence for some specific values of the parameters of the theory. Similar solutions have also been obtained by Kleihaus, Kunz, Laemmerzahl and List, in a V-shaped scalar potential.

We construct the boson star solutions of this theory numerically and we study their properties. In our studies we investigate in details the phase diagram of the theory for the scalar and the vector fields. In our studies we obtain four bifurcation points (possibility of more bifurcation points being not ruled out) in the dS region. We present a detailed discussion of the various regions in our phase diagram with respect to three bifurcation points.

We study the theory defined by the action:

$$S = \int \left[\frac{R-2\Lambda}{16\pi G} + \mathcal{L}_M\right]\sqrt{-g}\; d^4x$$
$$\mathcal{L}_M = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} - (D_\mu\Phi)^*\,(D^\mu\Phi) - V(|\Phi|)$$
$$D_\mu\Phi = (\partial_\mu\Phi + ieA_\mu\Phi) \quad , \quad F_{\mu\nu} = (\partial_\mu A_\nu - \partial_\nu A_\mu) \qquad (1)$$

Here R is the Ricci curvature scalar, G is Newton's Gravitational constant and Λ is cosmological constant. Also, $g = det(g_{\mu\nu})$ where $g_{\mu\nu}$ is the metric tensor and the asterisk in the above equation denotes complex conjugation. Using the variational principle, equations of motion are obtained as:

$$G_{\mu\nu} \equiv R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = 8\pi G T_{\mu\nu} - \Lambda g_{\mu\nu}$$
$$\partial_\mu\left(\sqrt{-g}F^{\mu\nu}\right) = -i\,e\sqrt{-g}\,[\Phi^*(D^\nu\Phi) - \Phi(D^\nu\Phi)^*]$$
$$D_\mu\left(\sqrt{-g}D^\mu\Phi\right) = 2m^2\sqrt{-g}\,\Phi + \frac{\lambda}{2}\sqrt{-g}\,\frac{\Phi}{|\Phi|}$$
$$\left[D_\mu\left(\sqrt{-g}D^\mu\Phi\right)\right]^* = 2m^2\sqrt{-g}\,\Phi^* + \frac{\lambda}{2}\sqrt{-g}\,\frac{\Phi^*}{|\Phi|} \qquad (2)$$

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