Chains of Boson Stars

Shixian Sun(Lanzhou University)

1.Introduction

Many non-linear physical systems support solitons solutions, which represent spatially localized field configurations. One of the simplest examples in flat space is given by Q-balls. Q-balls have some solutions which placed along the axis of symmetry. There also exist solutions which correspond to chains of BSs with the scalar field potential with quartic and sextic self-interaction terms.

BSs, unlike Q-balls, can form chains without self-interaction potential. And we found a type of solutions, which accord with chains of (rotating) boson stars without self-interaction potential.

2.The model

- We consider Einstein's gravity coupled minimally to a free, complex massive scalar field, with the Lagrangian density

$$\mathcal{L} = \frac{R}{16\pi G} - \nabla_a \psi^* \nabla^a \psi - \mu^2 |\psi|^2 \,,$$

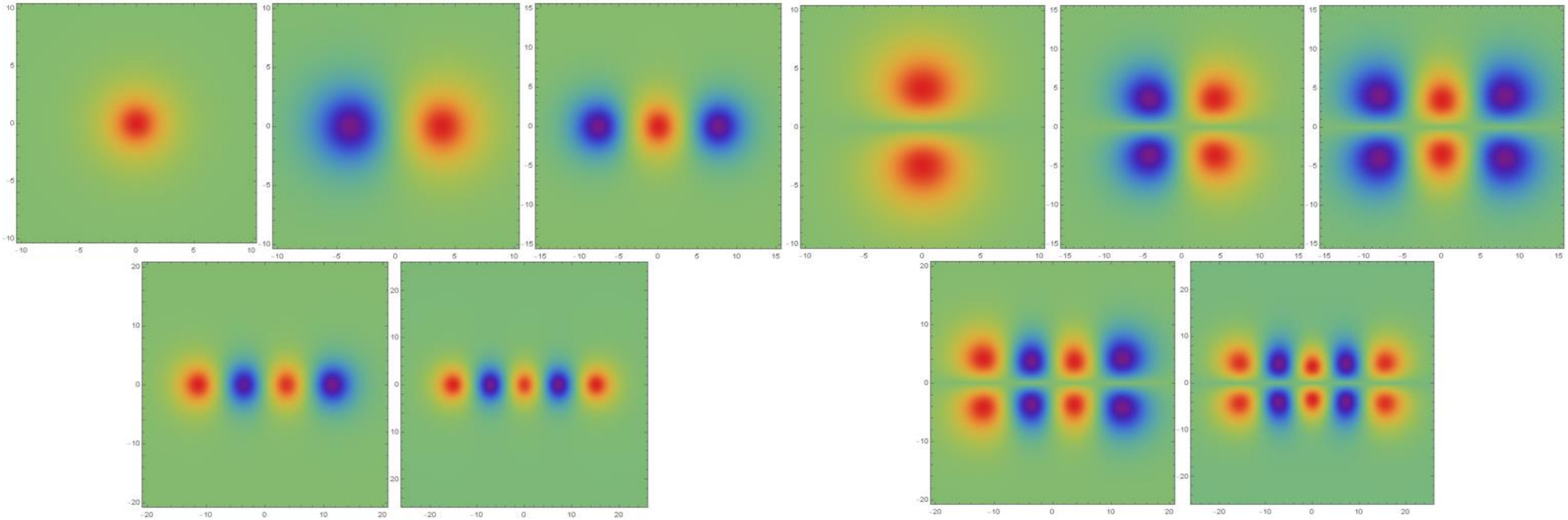
- We choose the axisymmetric metric with Kerr-like coordinates within the following ansatz:

$$ds^2 = -e^{2F_0(r,\theta)} dt^2 + e^{2F_1(r,\theta)} \left(dr^2 + r^2 d\theta^2\right) + e^{2F_2(r,\theta)} r^2 \sin^2\theta \left(d\varphi - W(r,\theta) dt\right)^2$$

- For the complex scalar field, we adopt the ansatz as follows,

$$\psi = \phi(r,\theta) e^{i(m\varphi - \omega t)},$$

3. Numerical results



The scalar field ϕ of chains of boson stars (Left) and rotating boson stars (right) in the $z-\rho$ plane. The color close to red have the positive ϕ, and the color close to purple have the negative ϕ for $\omega = 0.85$ with the coordinates $\rho = r\sin\theta$ and $\mathrm{z} = r\cos\theta$.

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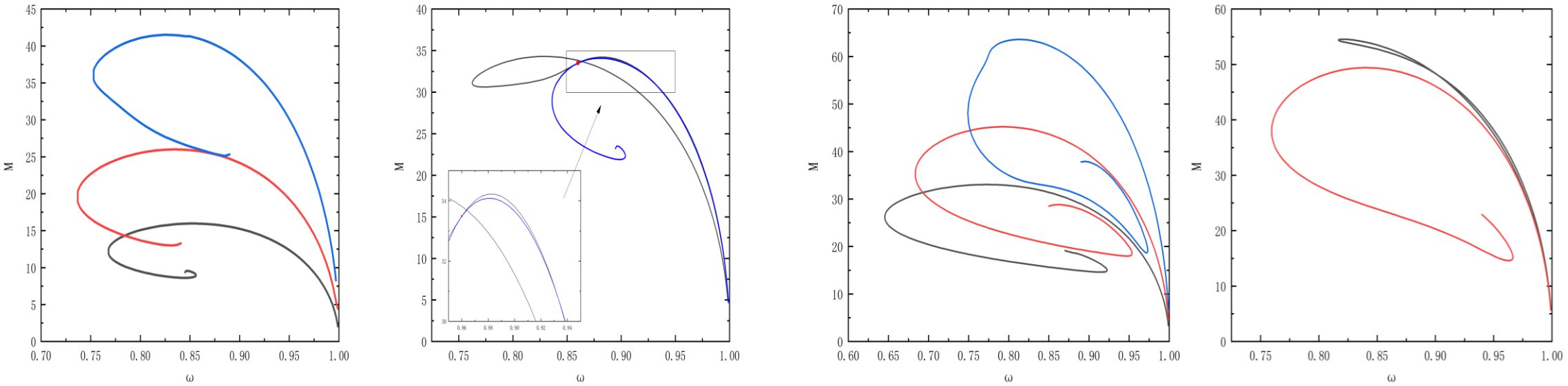
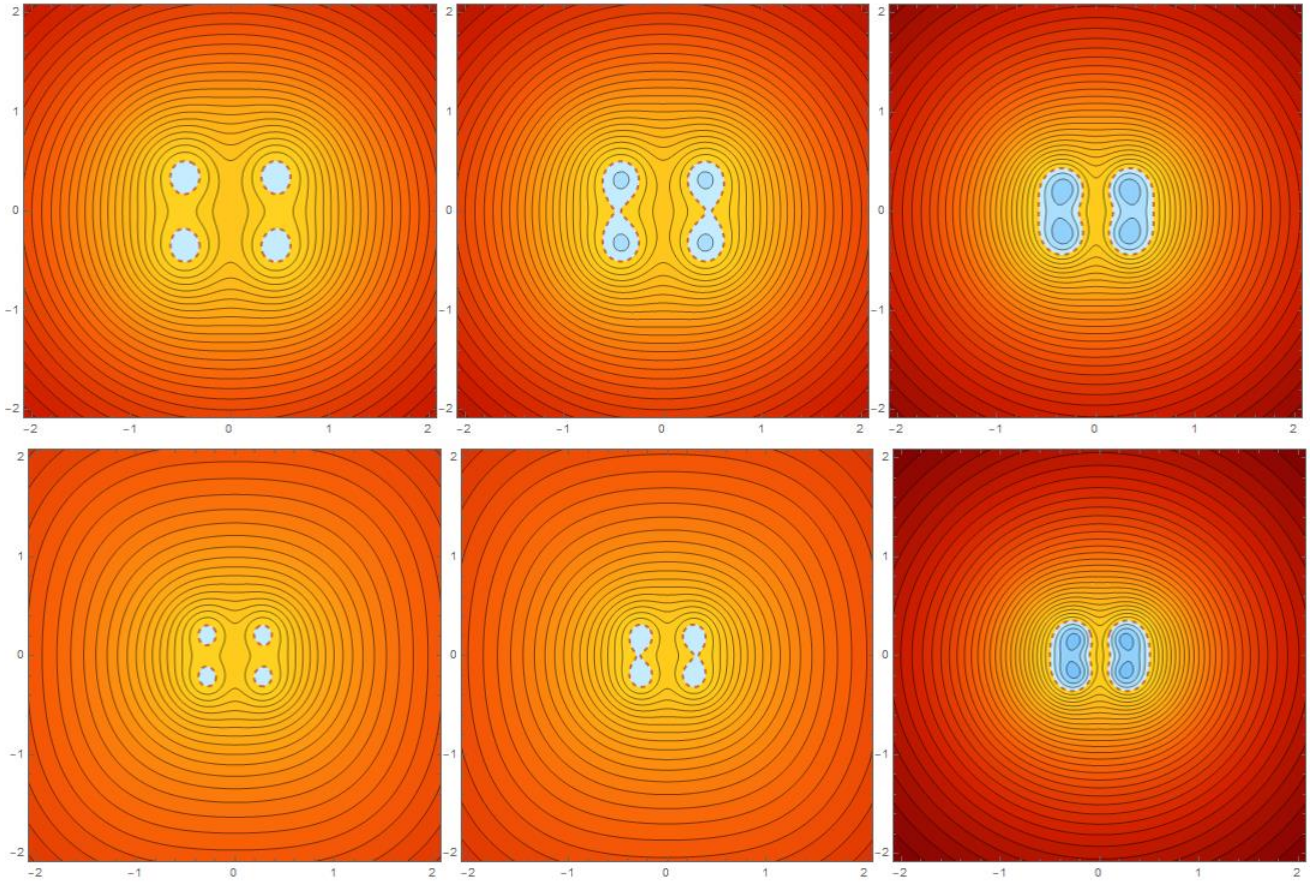


There are the comparison of one (black), two (red) and four (blue) BSs and the comparison of three BSs (black) and the excited state BS with a radial node (The left two figures). And the rotating cases are the right two figures.

3. Numerical results



We also consider if there could exist ergospheres. This figure shows g_{tt} of the Chains of rotating BSs with two (top) or four (bottom) constituents for different ω.

When g_{tt} is negative, there are warm colors. When g_{tt} is positive, there are cold colors. And on the red dash line, $g_{tt} = 0$. There are two ringlike ergosphere at the beginning. As ω increasing, two ergosphere merge into one ergosphere.