BPS Lorentz-violating vortex solutions.

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The Model.

- Lagrangian density $(1,3)$:

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{4}W_{\mu\nu\alpha\beta}F^{\mu\nu}F^{\alpha\beta} + |D_\alpha\phi|^2 - \frac{\lambda^2}{4}\left(|\phi|^2 - \upsilon^2\right)^2 , \tag{1}$$

where $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$ and $D_\alpha\phi = \partial_\alpha\phi + ieA_\alpha\phi$.

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- Euler-Lagrange Equations:

$$\partial_\alpha F^{\lambda\alpha} + W^{\lambda\alpha\mu\nu}\partial_\alpha F_{\mu\nu} = ie\left(\phi\overline{D^\lambda\phi} - \overline{\phi}D^\lambda\phi\right) , \quad (2)$$

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- We use (U^{μ} and b^{ν} arbitrary)

$$W^{\mu\nu\alpha\beta} = \frac{1}{2}\left(\eta^{\mu\alpha}k^{\nu\beta} - \eta^{\nu\alpha}k^{\mu\beta} + \eta^{\nu\beta}k^{\mu\alpha} - \eta^{\mu\beta}k^{\nu\alpha}\right) \ , \tag{4}$$

$$k^{\mu\nu} = \frac{1}{2}\left(U^{\mu}b^{\nu} + U^{\nu}b^{\mu}\right) - \frac{1}{4}\eta^{\mu\nu}U^{\alpha}b_{\alpha} \ , \tag{5}$$

according to Phys. Rev. D **82**, 125006 (2010).

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Vortex solutions.

- Vortex *ansatz*:

$$\phi\left(r,\theta\right)=\upsilon g\left(r\right)e^{in\theta} \quad \text{and} \quad \mathbf{A}\left(r,\theta\right)=-\frac{\widehat{\theta}}{er}\left(a\left(r\right)-n\right)\ , \qquad (12)$$

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$$\frac{d^2 a}{dr^2} - \frac{1}{r}\frac{da}{dr} = \frac{2e^2 v^2 g^2 a}{(1 + U_z b_z)} \ (\theta\text{-component}), \qquad (13)$$

$$(U_\theta b_z + U_z b_\theta)\left(\frac{d^2 a}{dr^2} - \frac{1}{r}\frac{da}{dr}\right) = 0 \ (z\text{-component}). \qquad (14)$$

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- We must also satisfy $\mathbf{U} \cdot \mathbf{b} = U_r b_r + U_\theta b_\theta + U_z b_z = 0$.
- Many trivial configurations. Ex.: $\mathbf{U} = (U_r, 0, 0)$ and $\mathbf{b} = (0, 0, b_z)$.

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- Many trivial configurations. Ex.: $\mathbf{U} = (U_r, 0, 0)$ and $\mathbf{b} = (0, 0, b_z)$.
- We choose configurations as $U_\theta = b_\theta = 0$ and $U_z b_z = -U_r b_r$.

Energy density and boundary conditions.

- The energy density $\varepsilon(r)$ is (note $U_r b_r < 1$)

$$\varepsilon = \frac{1 - U_r b_r}{2} \left(\frac{1}{er} \frac{da}{dr} \right)^2 + \upsilon^2 \left(\left(\frac{dg}{dr} \right)^2 + \frac{g^2 a^2}{r^2} \right) + \frac{\lambda^2 \upsilon^4}{4} \left(1 - g^2 \right)^2 \ .$$

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- Boundary conditions:

$$g(r \to \infty) \to 1 \quad \text{and} \quad a(r \to \infty) \to 0 \ , \tag{15}$$

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- We rewrite the energy density as

$$\varepsilon(r) = \frac{1}{\lambda^2}\left(\frac{1}{r}\frac{da}{dr} \pm \frac{\lambda^2\upsilon^2}{2}\left(1-g^2\right)\right)^2 + \upsilon^2\left(\frac{dg}{dr} \mp \frac{ag}{r}\right)^2 \mp \frac{\upsilon^2}{r}\left(\frac{da}{dr} - \frac{d}{dr}\left(g^2 a\right)\right) \ , \tag{17}$$

where

$$2e^2 = \left(1-U_r b_r\right)\lambda^2 \ . \tag{18}$$

BPS vortex solutions.

- BPS Equations:

$$\frac{1}{r}\frac{da}{dr} = \mp\frac{\lambda^2 v^2}{2}\left(1 - g^2\right) \ , \tag{19}$$

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Total energy:

$$E = \int \varepsilon\left(r\right) d^2 r = e v^2 \left|\Phi_B\right| \ , \quad (22)$$

where

$$\Phi_B = \int B\left(r\right) d^2 r = \frac{2\pi n}{e} \quad (23)$$

is the magnetic flux.

BPS vortex numerical solutions.

- Using the constraint

$$2e^2 = (1 - U_r b_r)\,\lambda^2 \ , \tag{24}$$

we fix e and $U_r b_r$ (remember $U_r b_r < 1$) to obtain λ^2. Then, we numerically solve BPS Equations.

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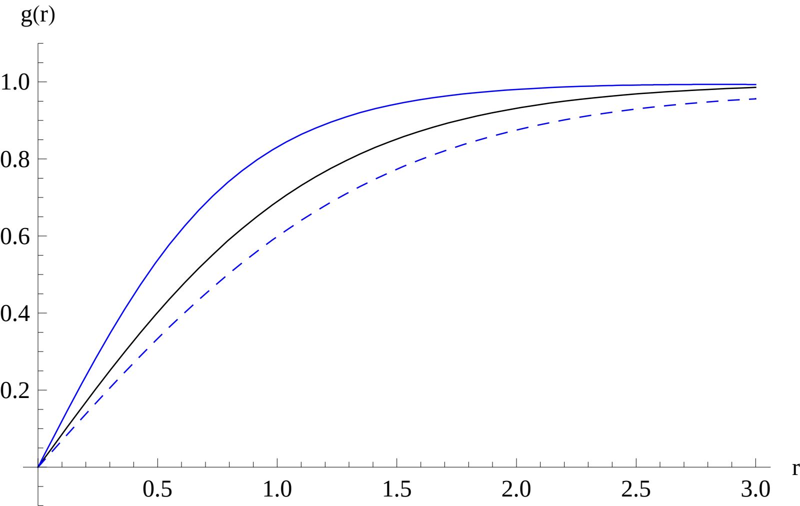
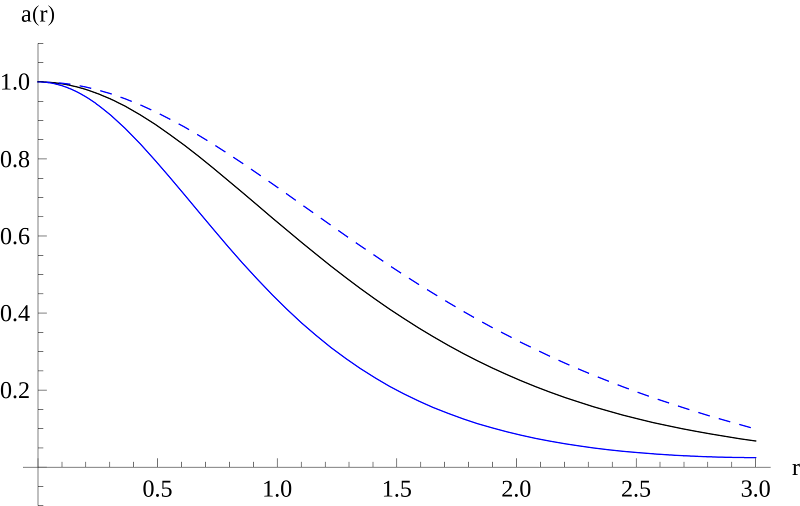

g(r)
1.0
0.8
0.6
0.4
0.2
0.5
1.0
1.5
2.0
2.5
3.0
r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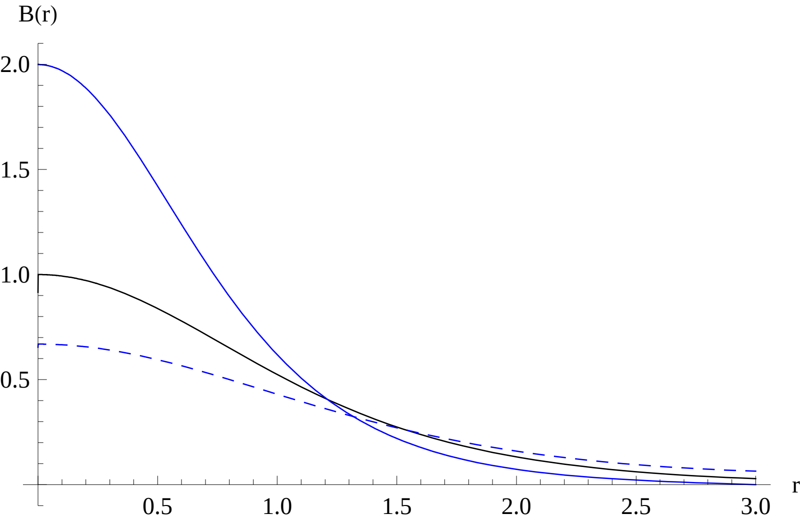
B(r)
2.0
1.5
1.0
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1.0
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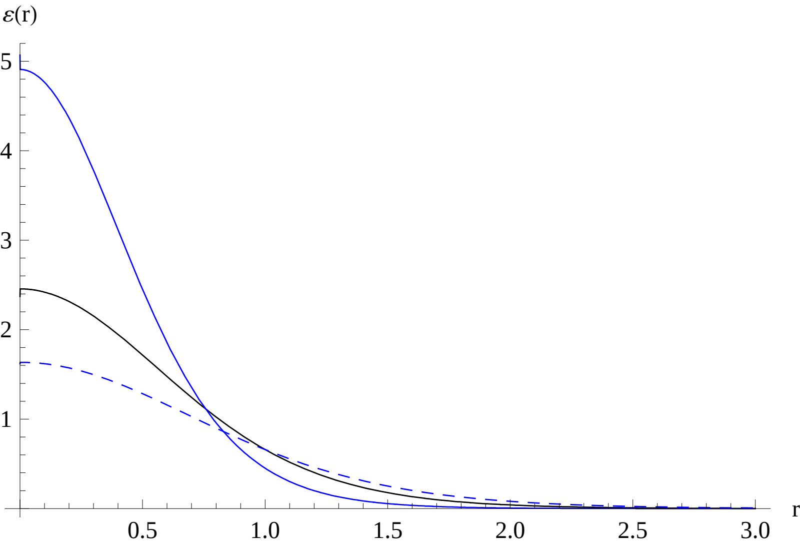
r



ε(r)
5
4
3
2
1
0.5
1.0
1.5
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3.0
r

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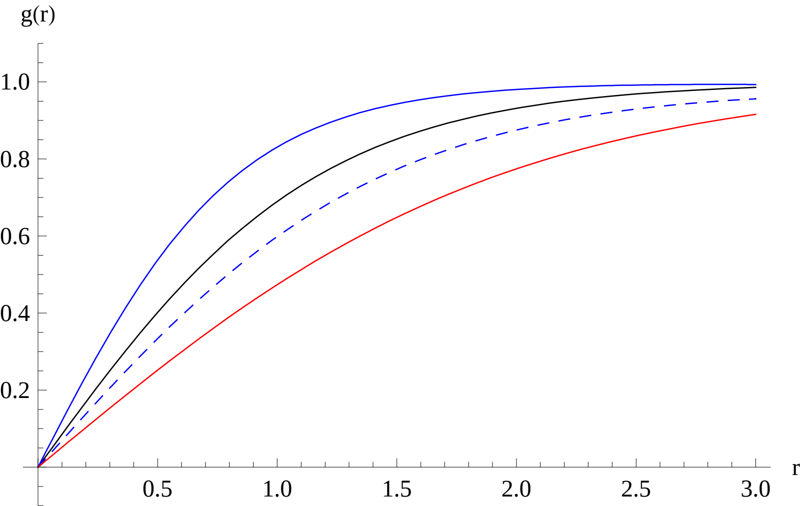

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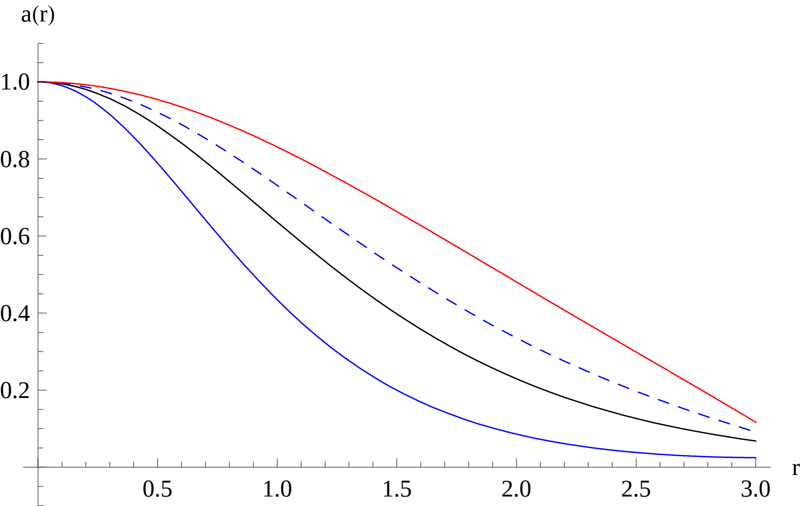

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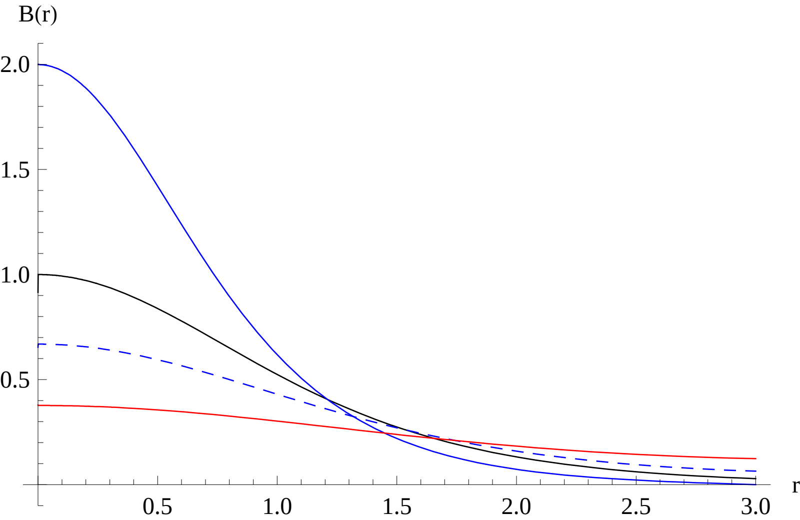
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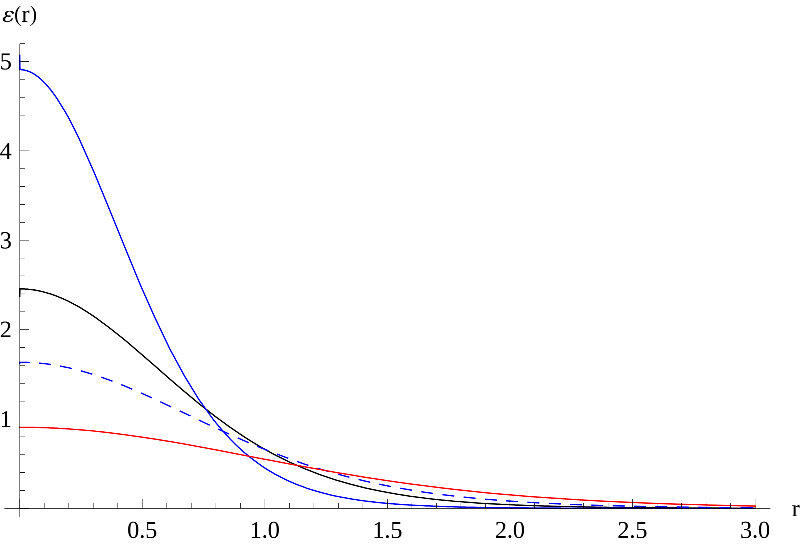

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- All these cases have a constant total energy equal to 2π.

Summary and perspectives.

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