Photon and Particle orbits near Reissner-Nordström Black Holes and Naked Singularities

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The Reissner-Nordström spacetime

the line element: $ds^2 = -c^2 d\tau^2 = -fc^2 dt^2 + \frac{dr^2}{f} + r^2(d\theta^2 + \sin^2\theta d\phi^2)$,

the metric function:

$f = -g_{\rm tt} = 1 - 2M/r + Q^2/r^2$

$r_{\rm h} = M + \sqrt{M^2 - Q^2}$

the geodesic equation: $\frac{d^2x^k}{d\lambda^2} + \Gamma^k_{ij}\frac{dx^i}{d\lambda}\frac{dx^j}{d\lambda} = 0$

$\Gamma^k_{ij} = \frac{1}{2}g^{kl}(\partial_j g_{il} + \partial_i g_{lj} - \partial_l g_{ji})$

initial conditions: $\sin\theta = 1$, $\dot\theta = 0$,

$\dot t = -g^{tt}/b$, $\dot\phi = g^{\phi\phi}$, $g_{\mu\nu}\dot x^\mu \dot x^\nu = 0$:

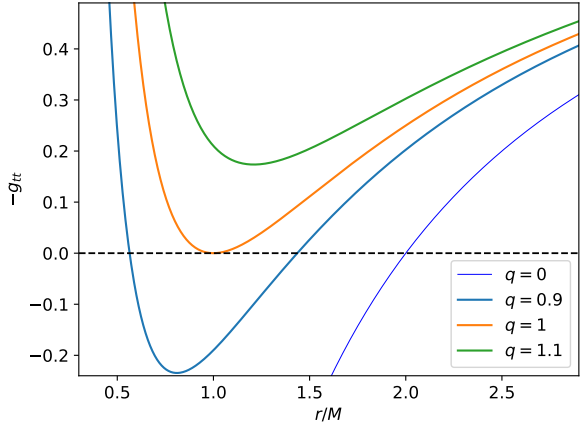
$\dot r = -\sqrt{g^{rr}(0 - g^{tt}/b^2 - g^{\phi\phi})}$.

the equation of motion:

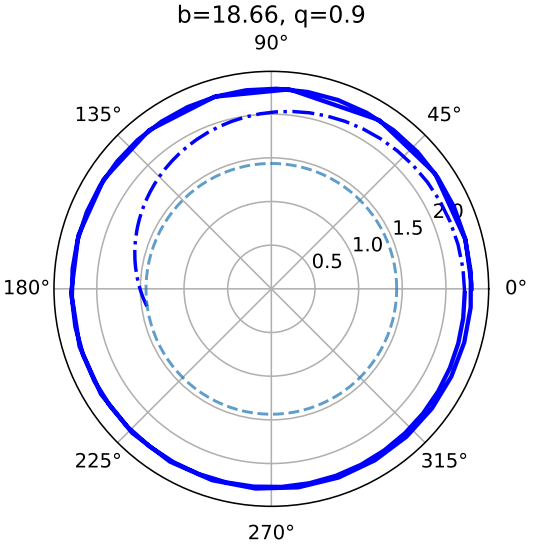
$1/b^2 = \dot r^2 + V_{\rm ph}$

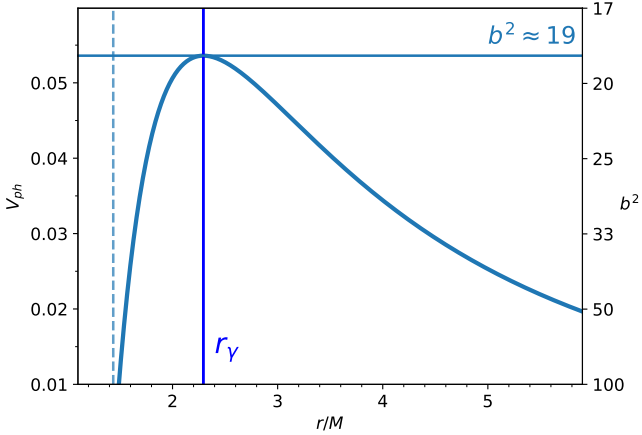
the null effective potential:

$V_{\rm ph}(r, M, Q) = -\frac{g_{tt}}{g_{\phi\phi}} = f/r^2$

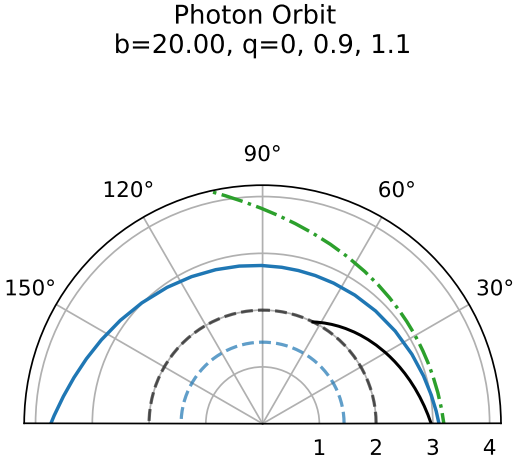


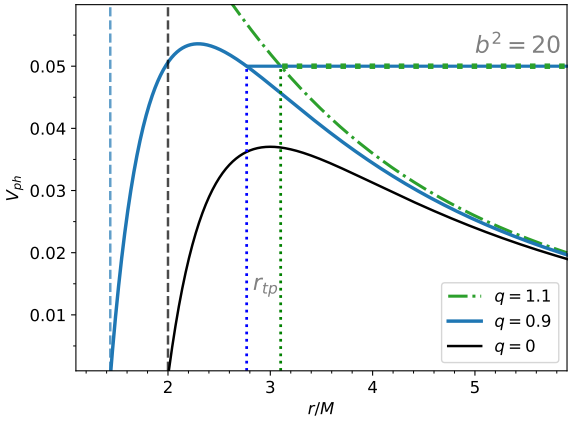
Unstable Circular orbit





Photon Orbits around BHs and Naked Singularities





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