GR22 and Amaldi13 in Valencia, Spain

Joule-Thomson expansion of charged Gauss-Bonnet black holes in AdS space

Shanquan Lan[1]
1. Department of Physics, Lingnan Normal University, China
• Address correspondence to shanquanlan@126.com

PHYSICAL REVIEW D 98, 084014 (2018)

Joule-Thomson expansion process is studied for charged Gauss-Bonnet black holes in AdS space. Firstly, in five-dimensional space-time, the isenthalpic curve in T-P graph is obtained and the cooling-heating region is determined. Secondly, the explicit expression of Joule-Thomson coefficient is obtained from the basic formulas of enthalpy and temperature. Our methods can also be applied to van der Waals system as well as other black hole systems. And the inversion curve $\tilde{T}(\tilde{P})$ which separates the cooling region and heating region is obtained and investigated. Thirdly, interesting dependence of the inversion curves on the charge (Q) and the Gauss-Bonnet parameter α is revealed. In $\tilde{T}-\tilde{P}$ graph, the cooling region decreases with charge, but increases with the Gauss-Bonnet parameter. Fourthly, by applying our methods, the Joule-Thomson expansion process for α=0 case in four dimension is studied, where the Gauss-Bonnet AdS black hole degenerates into RN-AdS black hole. The inversion curves for van der Waals systems consist of two parts. One has positive slope, while the other has negative slope. However, for black hole systems, the slopes of the inversion curves are always positive, which seems to be a universal feature.

D-dimensional Einstein-Maxwell theory with a cosmological constant and a Gauss-Bonnet term

$$S=\frac{1}{16\pi}\int d^Dx\sqrt{-g}[R-2\Lambda+\alpha_{GB}(R_{\gamma\delta\mu\nu}R^{\gamma\delta\mu\nu}-4R_{\mu\nu}R^{\mu\nu}+R^2)-F^2]$$

Static black hole solution with maximal symmetry

$$ds^2=-Y(r)dt^2+\frac{dr^2}{Y(r)}+r^2d\Omega^2_{D-2}$$

$$Y(r)=1+\frac{r^2}{2\alpha}(1-\sqrt{1+\frac{4\alpha m}{r^{D-1}}-\frac{4\alpha q^2}{r^{2D-4}}-\frac{4\alpha}{l^2}})$$

Mass and temperature of black hole for D=5

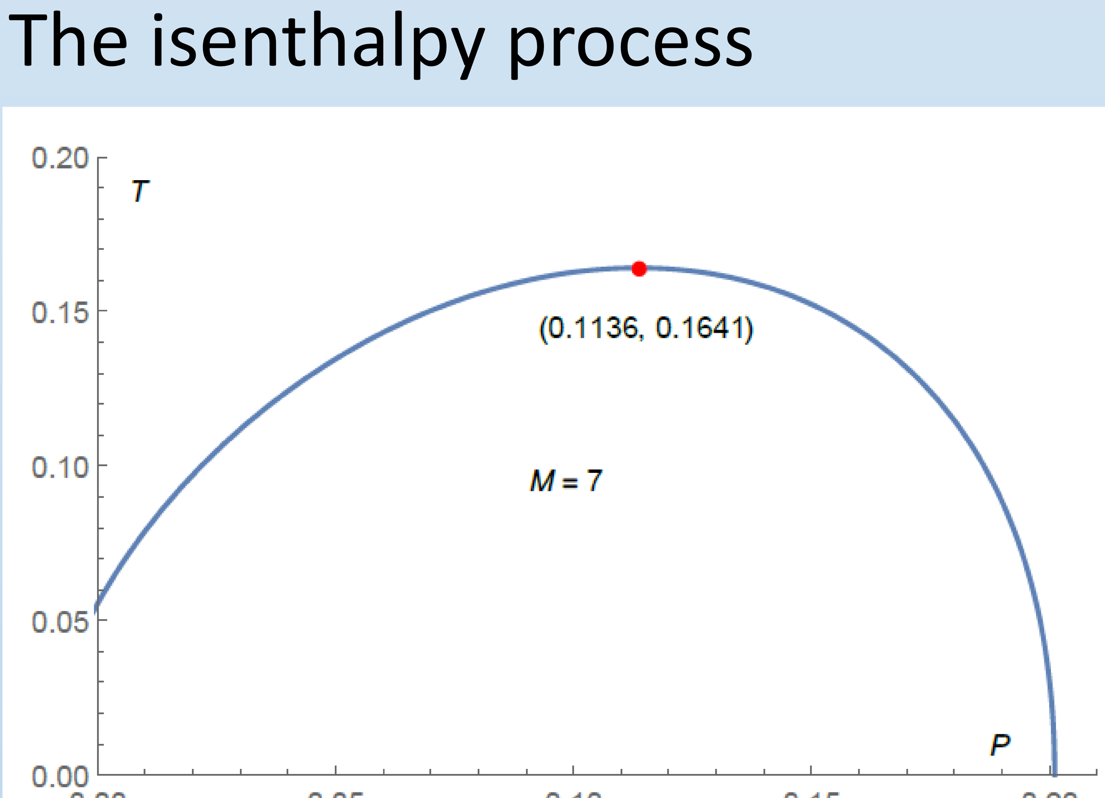
$$M=\frac{3\pi}{8}(\alpha+r_+^2+\frac{4Q^2}{3\pi^2r_+^2}+\frac{4}{3}\pi P r_+^4),$$
$$T=\frac{\pi^2r_+^4(3+8\pi P r_+^2)-4Q^2}{6\pi^3r_+^3(2\alpha+r_+^2)}.$$

Results

(1)The Joule-Thomson coefficient

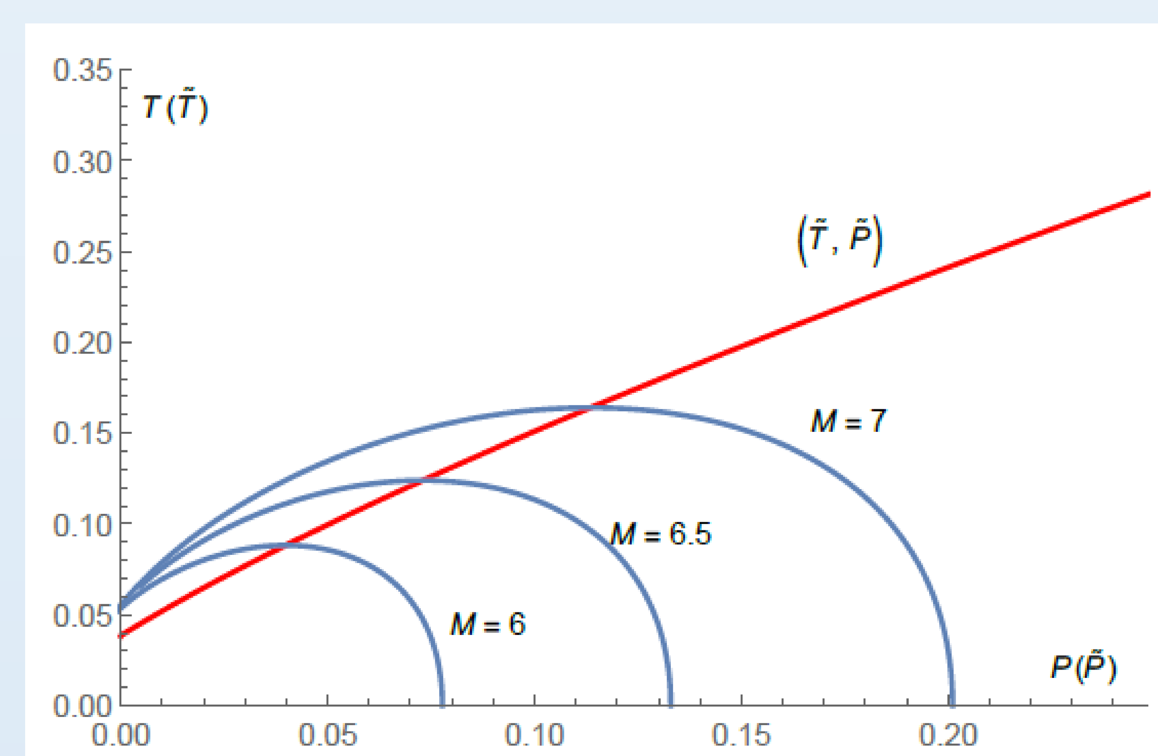
$$\mu=(\frac{\partial T}{\partial P})_M=(\frac{\partial T}{\partial P})_{r_+}+(\frac{\partial T}{\partial r_+})_P(\frac{\partial r_+}{\partial P})_M=(\frac{\partial T}{\partial P})_{r_+}+(\frac{\partial T}{\partial r_+})_P/(\frac{\partial P}{\partial r_+})_M$$
$$=\frac{4r_+^3}{3(2\alpha+r_+^2)}+\frac{r_+^3(20Q^2r_+^2+\pi^2r_+^6(8\pi Pr_+^2-3)+6\alpha(4Q^2+\pi^2r_+^4(1+8\pi Pr_+^2)))}{3(2\alpha+r_+^2)^2(12Q^2+\pi r_+^2(3\pi(2\alpha+r_+^2)-16M))}$$

(2) The isenthalpy process



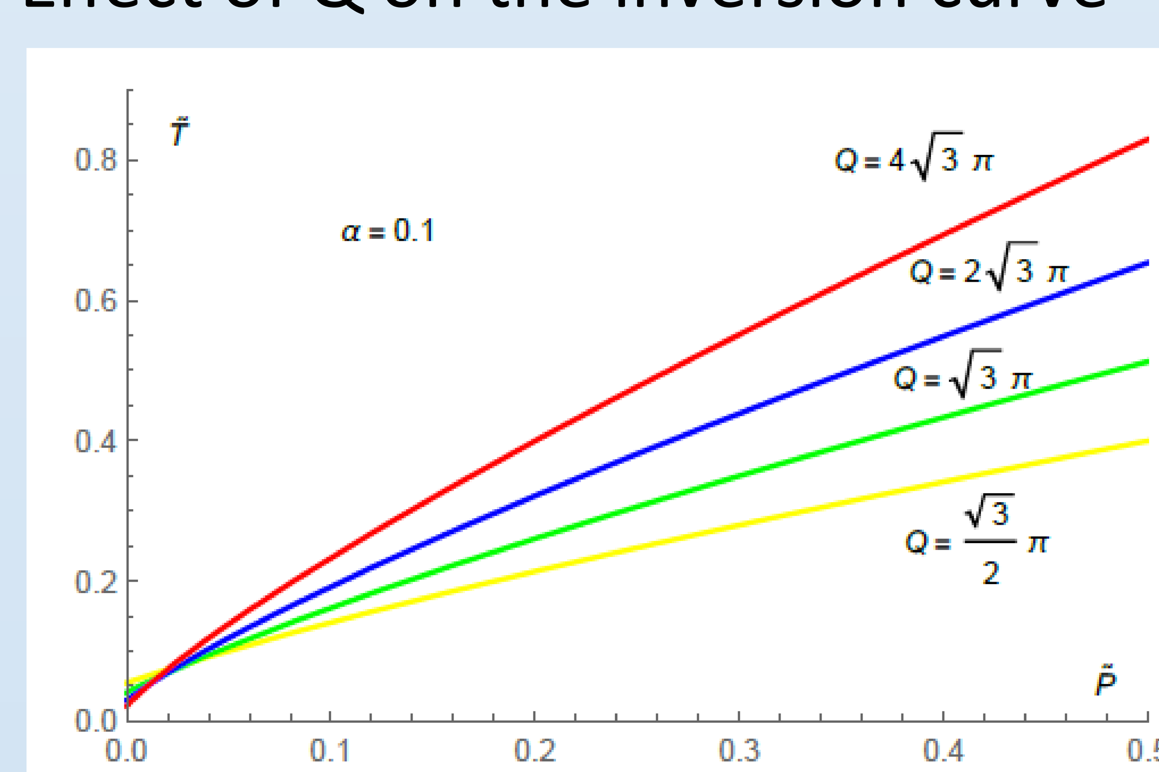
The isenthalpy process in T-P graph at α=0.2, Q=$\sqrt{3}\pi$

(3) The inversion curve



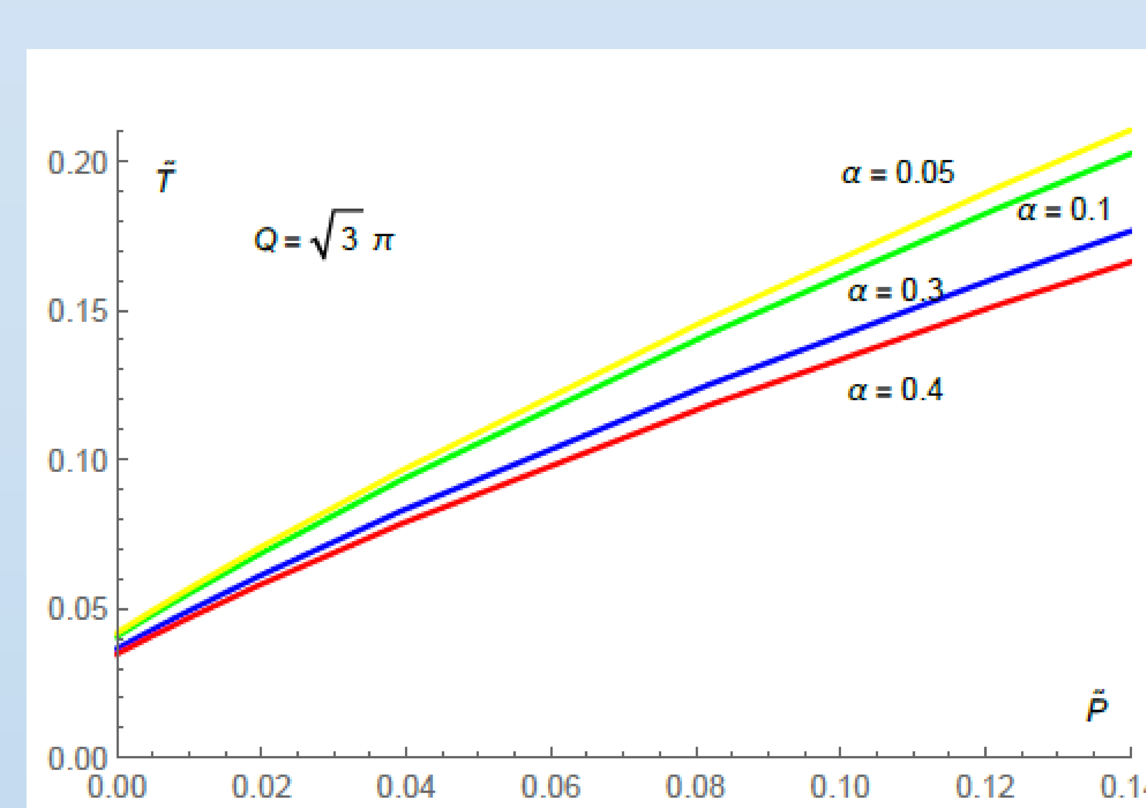
The red one is the inversion curve $\tilde{T}(\tilde{P})$ which separates the cooling region and heating region.

(4) Effect of Q on the inversion curve



The slope of the inversion curves increase with charge

(5) Effect of α on the inversion curve



The slope of the inversion curves decrease with Gauss-Bonnet parameter