On The Throttling Process Of AdS Black Hole With A Global Monopole

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Outline for Section 1

1. Joule Thomson Effect in van der Waals' fluid
   1.1 Throttling Process
   1.2 Joule Thomson Effect
   1.3 Isenthalpic and Inversion curves
   1.4 van der Waals' fluid

2. The charged AdS black hole with global monopole
   2.1 Thermodynamics of Black Hole
   2.2 Joule Thomson expansion of Black Hole
   2.3 Isenthalpic and Inversion curves
   2.4 Conclusion

Throttling Process

Enthalpy remains constant

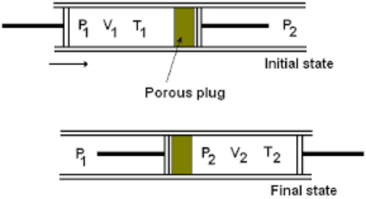
Expansion of a fluid from a region of high pressure to a region of low pressure through a porous plug.

Example

Water passing through a faucet.

Ideal gas - no temp. change.

Real gas - temp. may increase, decrease or remain same.



Joule Thomson Effect

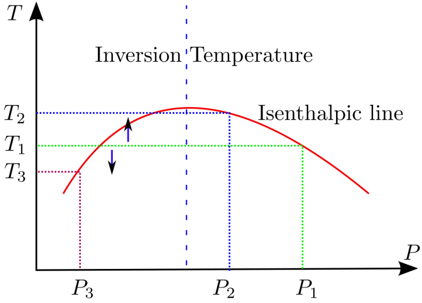
Enthalpy remains constant

Joule Thomson Coeffiecent,

$$\mu_J = \left(\frac{dT}{dP}\right)_H$$

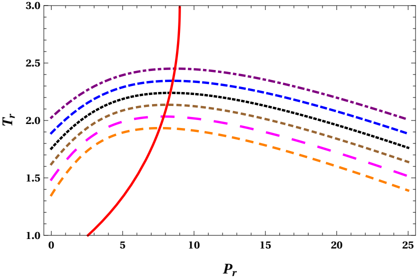
Pure right : heating

Pure left : cooling



Isenthalpic and Inversion curves

for van der Walls' fluid



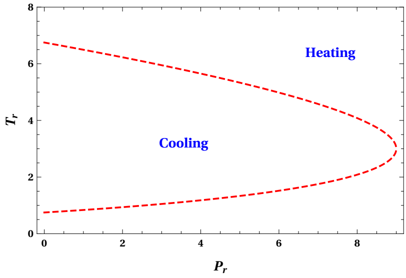
Isenthalpic curve:

the locus of all points

with the same enthalpy

Inversion curve:

locus of inversion temperatures



Region of cooling : μ_J positive

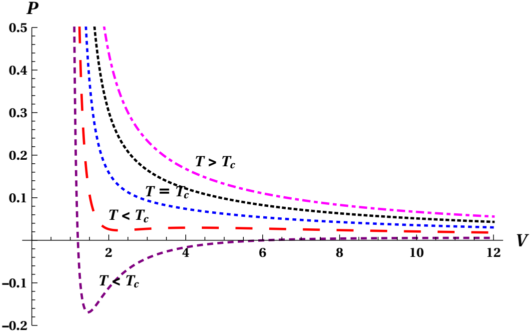
Region of heating : μ_J negative

van der Waals' fluid

shows critical behavior

Equation of state:

$$\left(P + \frac{a}{V_m^2}\right)(V_m - b) = RT.$$



Below critical temperature : Stable - Unstable - Stable states.

Indication of Phase transition

Outline for Section 2

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The charged AdS black hole with global monopole

This is our metric

The Lagrangian :

$$\mathscr{L}_{gm} = \frac{1}{2}\partial_\mu \Phi^a \partial^\mu \Phi^{*\,a} - \frac{\gamma}{4}\left(\Phi^a \Phi^{*\,a} - \eta_0^2\right)^2, \qquad (1)$$

where Φ^a is a multiplet of scalar field, γ is a constant and η_0 is the energy scale of symmetry breaking.

Solving Einstein equation, we have the line element

$$ds^2 = -f(r)dt^2 + f(r)^{-1}dr^2 + (1-\eta^2)r^2 d\Omega^2, \qquad (2)$$

with

$$f(r) = 1 - \frac{2m}{r} + \frac{q^2}{r^2} + \frac{r^2}{l^2}. \qquad (3)$$

The charged AdS black hole with global monopole

ADM Mass and Pressure, Extended Phase space

The ADM mass:

$$M = \frac{(1-\eta^2)}{2} r_+ + \frac{Q^2}{2r_+(1-\eta^2)} + \frac{r_+^3(1-\eta^2)}{2l^2}. \tag{4}$$

In the extended phase space the cosmological constant corresponds to the thermodynamic variable pressure (P), and its conjugate quantity corresponds to the thermodynamic volume (V),

$$P = -\frac{\Lambda}{8\pi} = \frac{3}{8\pi l^2}\ , \quad V = \frac{4}{3}\pi(1-\eta^2)r_+^3. \tag{5}$$

Thermodynamics of Black Hole

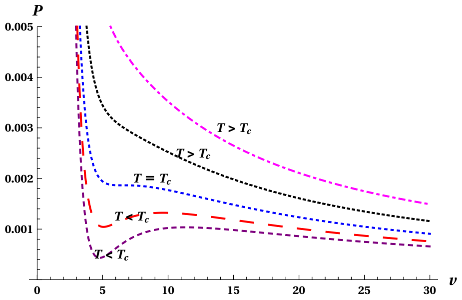
Phase Transition of Black Hole!

The Hawking temperature:

$$T = \frac{1}{4\pi r_+}\left(1 + \frac{3r_+^2}{l^2} - \frac{Q^2}{(1-\eta^2)^2 r_+^2}\right).$$

Equation of state :

$$P = \frac{T}{v} - \frac{1}{2\pi v^2} + \frac{2Q^2}{\pi(1-\eta^2)^2 v^4}.$$



The *Pv* plot is similar to that of van der Waals' fluid.

Joule Thomson expansion of Black Hole

charged AdS blackhole with monopole term

The expression for Joule Thomson coefficient,

$$\mu_J = \left(\frac{\partial T}{\partial P} \right)_H = \frac{1}{C_P} \left[T \left(\frac{\partial V}{\partial T} \right)_P - V \right]. \tag{6}$$

As $\mu_J = 0$ defines the inversion temperature we have

$$T_i = V \left(\frac{\partial T}{\partial V} \right)_P. \tag{7}$$

Joule Thomson expansion of Black Hole

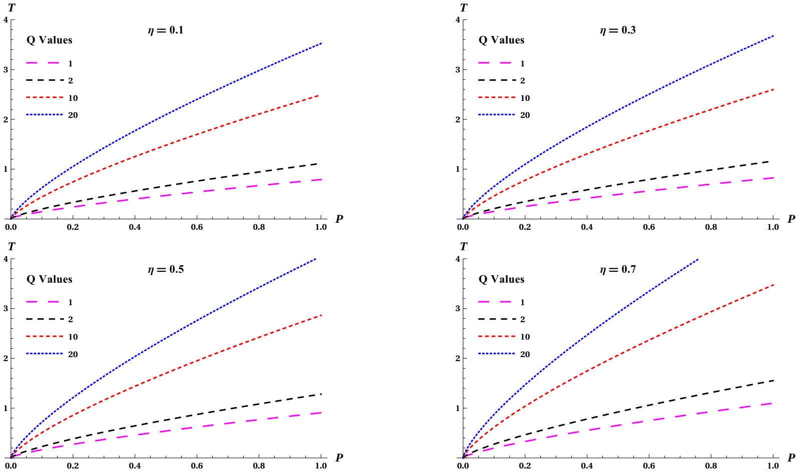
charged AdS blackhole with monopole term

Expression for inversion temperature (T_i) in terms of inversion pressure, charge and monopole parameter ,

$$T_i = \frac{\sqrt{P_i}\left(1 + \frac{16\pi P_i Q^2}{(1-\eta^2)^2} - \frac{\sqrt{24 P_i \pi Q^2 + (1-\eta^2)^2}}{(1-\eta^2)}\right)}{\sqrt{2\pi}\left(-1 + \frac{\sqrt{24 P_i \pi Q^2 + (1-\eta^2)^2}}{(1-\eta^2)}\right)^{3/2}}. \tag{8}$$

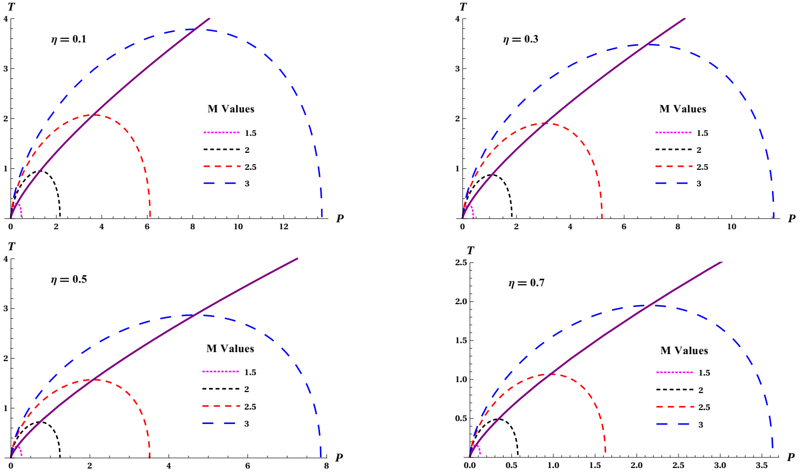
Inversion curves

Inversion curves showing the dependence of charge Q for different η values.



Inversion and isenthalpic curves

Crossing diagrams between inversion and isenthalpic curves for different values of η and Q = 1



Conclusion

Another outcome of AdS-CFT Correspondence

Joule Thomson effect, similar to van der Waals gas is observed in AdS black hole.

Monopole term plays an important role in the thermodynamics and Joule Thomson expansion of AdS black hole.

Bibliography

[1] Ahmed Rizwan C. L., Naveena Kumara A., Deepak Vaid, and K. M. Ajith.
Joule-Thomson expansion in AdS black hole with a global monopole.
arXiv:1805.11053, 2018.

[2] Özgür Ökcü and Ekrem Aydıner.
Joule–Thomson expansion of the charged AdS black holes.
Eur. Phys. J. C, 77, 2017.

[3] David Kubizňák and Robert B. Mann.
P - V criticality of charged AdS black holes.
Journal of High Energy Physics, 2012(7), 2012.

[4] Gao-Ming Deng, Jinbo Fan, Xinfei Li, and Yong-Chang Huang.
Thermodynamics and phase transition of charged AdS black holes with a global monopole.
International Journal of Modern Physics A, 33(03):1850022, jan 2018.

[5] Manuel Barriola and Alexander Vilenkin.
Gravitational field of a global monopole.
Phys. Rev. Lett., 63:341–343, Jul 1989.

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thank you!