Thermodynamics of *f(R)* Theories

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This work starts from a toy model for inflation in a class of modified theories of gravity in the metric formalism. Instead of the standard procedure – assuming a non-linear Lagrangian *f(R)* in the Jordan frame – we start from a simple Φ^2 potential in the Einstein frame and investigate the corresponding *f(R)* in the former picture. The addition of an ad-hoc Cosmological Constant in the Einstein frame leads to a Thermodynamical interpretation of this physical system, which allows further insight on its (meta)stability and evolution.

JORDAN FRAME

$$L_J = \sqrt{-g^J}\, f(R)$$

Conformal transf.

$$g^E_{\mu\nu} \equiv \Omega^2(x^\alpha)\, g^J_{\mu\nu}\,, \quad \text{where} \quad \Omega^2 \equiv p \equiv f'(R)$$

EINSTEIN FRAME

$$L_E = \sqrt{-g^E}\left[R_E - g_E^{\mu\nu}\phi_{,\mu}\phi_{,\nu} - 2V_E(\phi)\right]$$

then

$$V_E(\phi) \equiv \frac{1}{2p^2}\Big\{p(\phi)R[p(\phi)] - f[R(p(\phi))]\Big\}$$

But if

$$V_E(\phi) \equiv \frac{1}{2}m_\phi^2\,(\phi - a)^2 + \Lambda$$

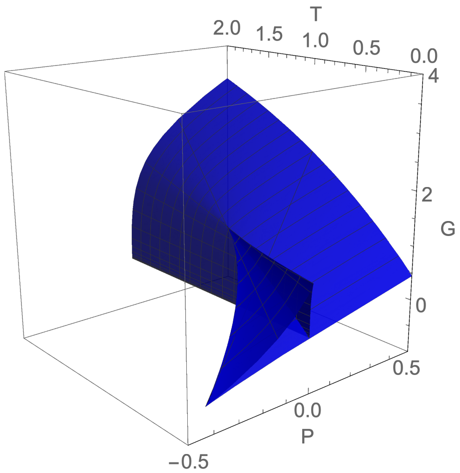
then

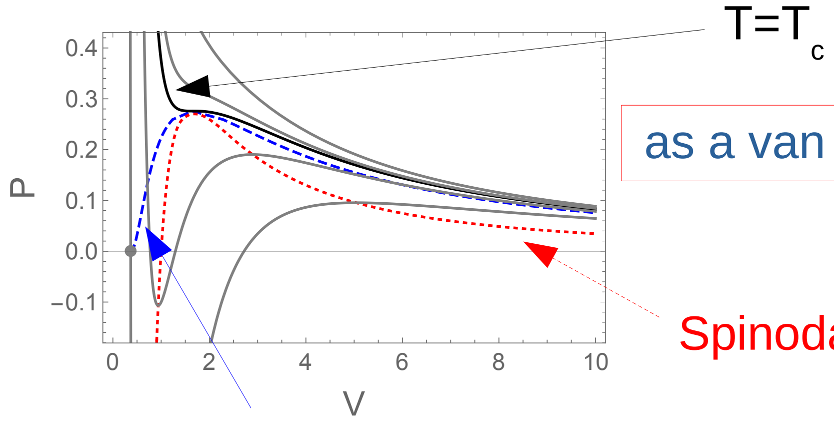
$$\begin{cases} f(\phi) = e^{2\beta\phi}\left[m_\phi^2(a-\phi)\left(a - \phi - \dfrac{2}{\beta}\right) + 2\Lambda\right] \\ R(\phi) = 2e^{\beta\phi}\left[m_\phi^2(a-\phi)\left(a - \phi - \dfrac{1}{\beta}\right) + 2\Lambda\right] \end{cases}$$

G. Magnano and L. M. Sokolowski, Phys. Rev. D50, 5039 (1994), arXiv:gr-qc/9312008 [gr-qc] .

Identifying $\Lambda \equiv T$ $f(R) \equiv P$ $R \equiv G(P,T)$: Gibbs Free Energy

We obtain

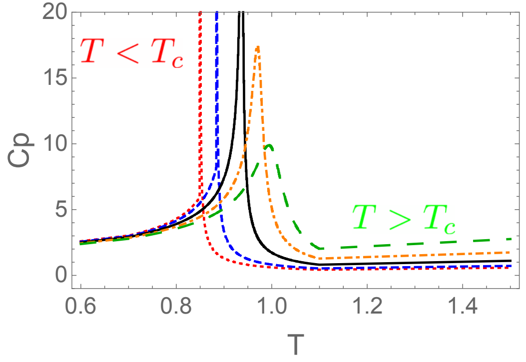




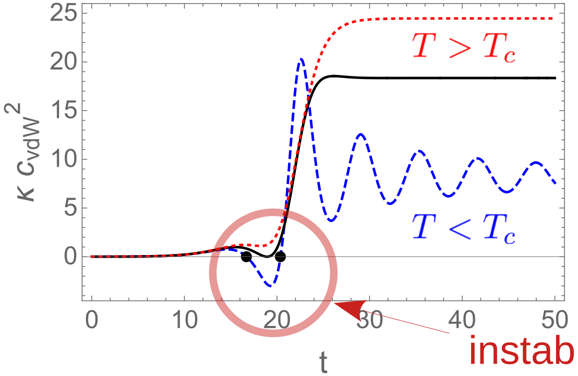
as a van der Waals gas

Spinodal Line

Binodal Line



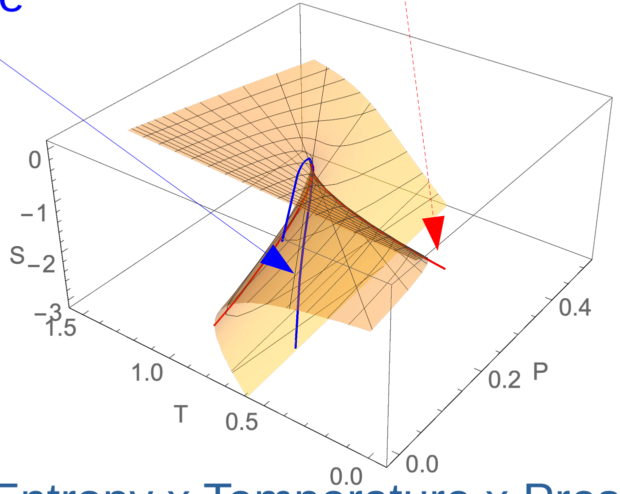
Specific Heat



instabilities!

Sound speed squared

$c_s^2 < 0 \Leftrightarrow f'' < 0$



Entropy x Temperature x Pressure