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Entropy production in highly transparent colliding systems

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T^{ik} Everything has its energy-mom. tensor

n^i Particle current(s) surely must exist

t^i The anisotropy in momentum space

s^i Thermodynamics!

$T^{ir}{}_{;r} = 0$

$n^r{}_{;r}$ = source

$s^r{}_{;r} \geq 0$ Second Law!

And this will be enough!

My coworkers in getting the dynamical/thermodynamical equations:

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The most general T^{ik} with two fundamental vector fields: u^i, t^k

$$T^{ik} \equiv \alpha u^i u^k + \beta(u^i t^k + t^i u^k) + \gamma t^i t^k + d^i u^k + u^i d^k + b^i t^k + t^i b^k + c^{ik}$$
$$d^r u_r = d^r t_r = b^r u_r = b^r t_r = c^{ir} u_r = c^{ir} t_r = 0,$$

Without conductions:

$$b^i = d^i = 0,$$
$$c^{ik} = k\{g^{ik} + \frac{1}{t^2 + (ut)^2}(t^2 u^i u^k - (ut)(u^i t^k + t^i u^k) - t^i t^k\},$$
$$t^2 \equiv t^r t_r; \quad (ut) \equiv u^r t_r.$$
$$T^{ik} = \alpha u^i u^k + \beta(u^i t^k + t^i u^k) + \gamma t^i t^k + k\{g^{ik} + u^i u^k - t^i t^k / t^2\}.$$

$$\alpha \equiv e.$$

Entropy current.

$$s^i \equiv s u^i + z t^i.$$

Second Law $s^r{}_{;r} \geq 0$ and its conseq.

$$s \equiv s(e,n,t),$$
$$s,_t \dot{t} + \theta(s - ns,_n - es,_e - ks,_e) + t^r(z,_r - s,_e \beta,_r) + t^r{}_{;r}(z - s,_e \beta) - s,_e \beta t^r u_{r;s} u^s - s,_e(\gamma - k/t^2) t^r t^r u_{r;s} \geq 0.$$

$$\dot{t} = \lambda + \nu(T,_r + T u_{r;s} u^s) t^r + \vartheta t^r t^s u_{r;s} + \omega\theta; \quad T \equiv 1/s,_e,$$

where the new scalars λ, ν, ϑ, ω satisfy the (un)equalities

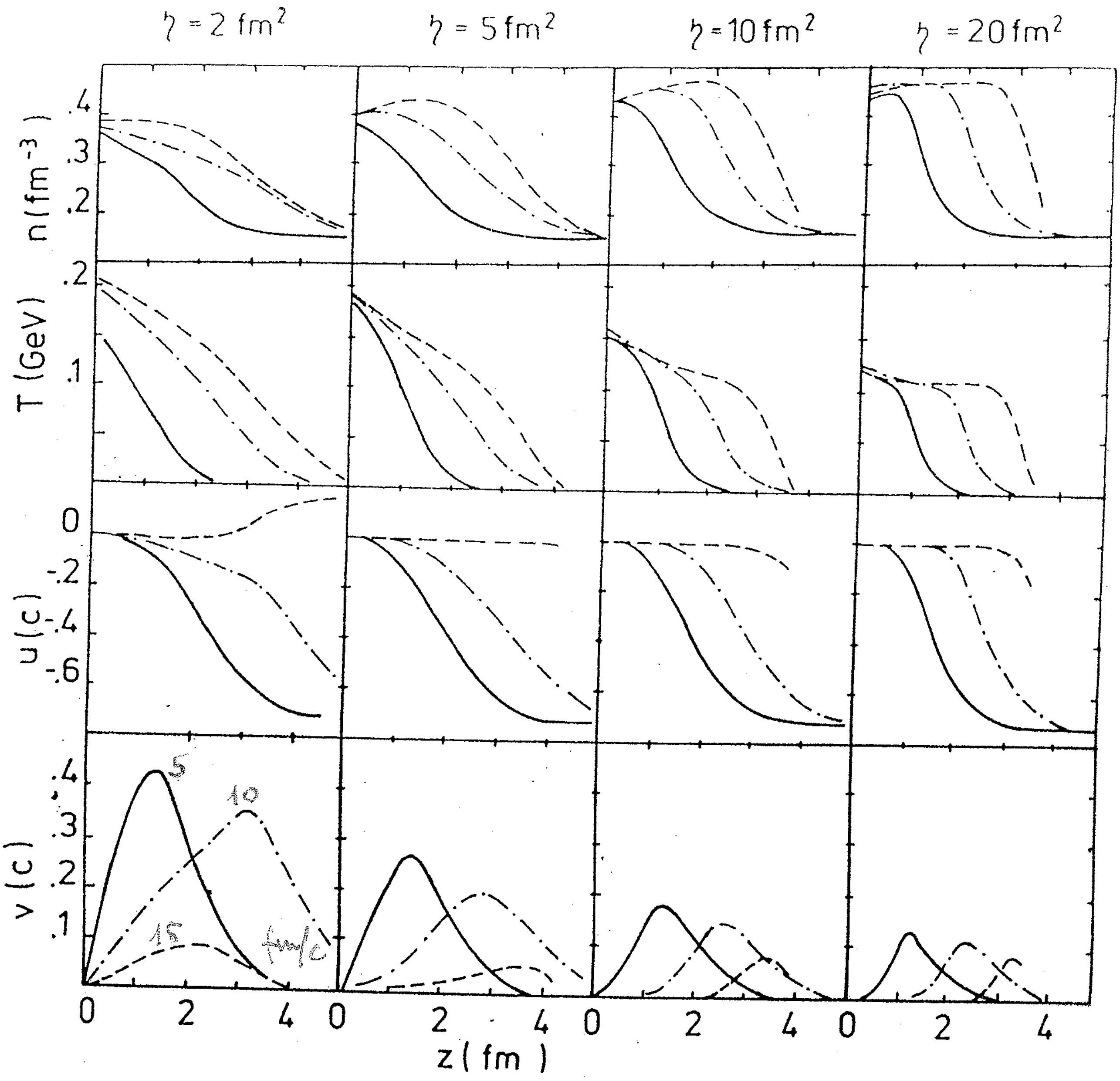
$$k = p(e,n,t) + \omega T s,_t + \delta\theta;$$
$$p \equiv T\{s - ns,_n - es,_e\},$$
$$z = \beta/T,$$
$$\nu = \beta/T^2 s,_t,$$
$$\vartheta = (k/t^2 - \gamma)/s,_t,$$
$$\delta \geq 0,$$
$$s,_t \lambda \geq 0,$$

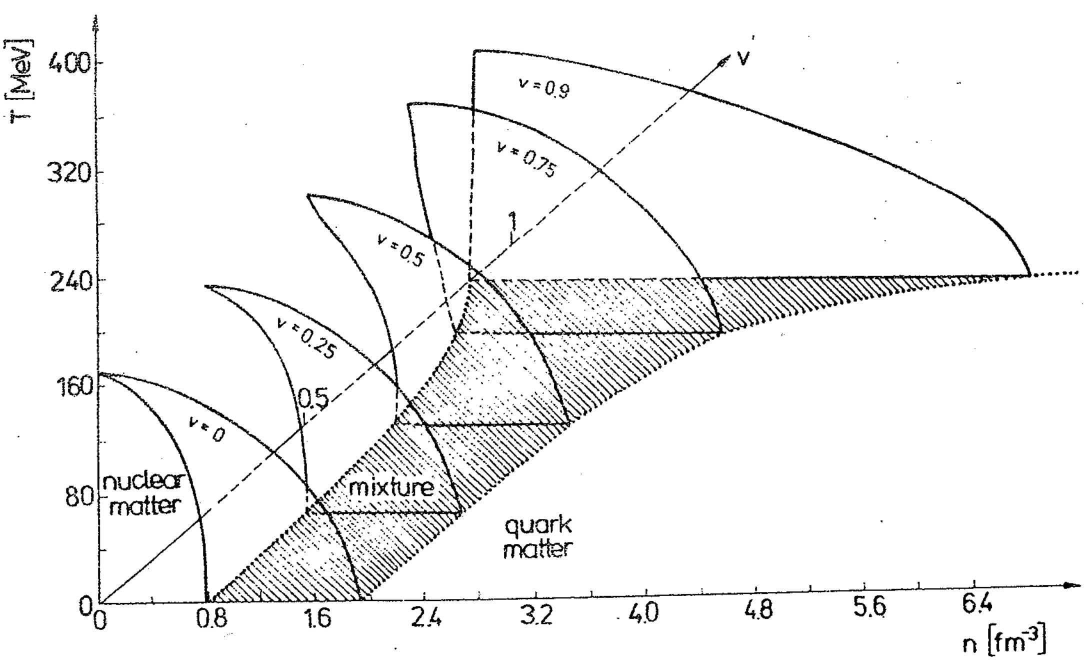
The evolution eqs.:

$$\dot{n} + n\,\Theta = 0,$$
$$\dot{e} + (e + p + q)\,\Theta = 0,$$
$$\dot{u} + (e + p + q)^{-1}((p + q)^{\cdot} + \partial(p + q)/\partial x) = 0,$$
$$\dot{q} + (q + q/v)\,\Theta - \lambda = 0,$$
$$p = p(e,n,q).$$

Eq. of state for an ideal gas + parabolic compressibility:

$$p = nT + (\pi^2/30)\,T^4 + (K/9)\,n_0 x^2\,(v\,\mathrm{arctg}(v) - 1 + x(2/y - y)),$$
$$e = m\,n\,y + (3/2)\,n\,T + (1/10)\,\pi^2\,T^4 + (K/18)\,n\,(x - 1)^2 + (K/9)\,n\,(y - 1)(x\,y^{-2}\,(y + 1)(x/y - 1) + (1/2)(1 - x^2/y)),$$
$$q = m\,x\,n_0\,\ln(v + y) + (K/9)\,n_0\,((x/2)\ln(v + y) - x^2\,\mathrm{arctg}(v) + v\,x^2\,((3x/2y) - y^{-2} - x\,v^2\,y^{-9})),$$
$$y = (1 + v^2)^{1/2},\quad x = n/n_n,\quad n_n = 0.16\ \mathrm{fm}^{-9},\quad m = 938\ \mathrm{MeV},$$


η = 2 fm²
η = 5 fm²
η = 10 fm²
η = 20 fm²
n (fm⁻³)
T (GeV)
u (c)
v (c)
5
10
15
fm/c
z (fm)


T [MeV]
n [fm⁻³]
v'
v = 0.9
v = 0.75
v = 0.5
v = 0.25
v = 0
0.5
1
nuclear matter
mixture
quark matter