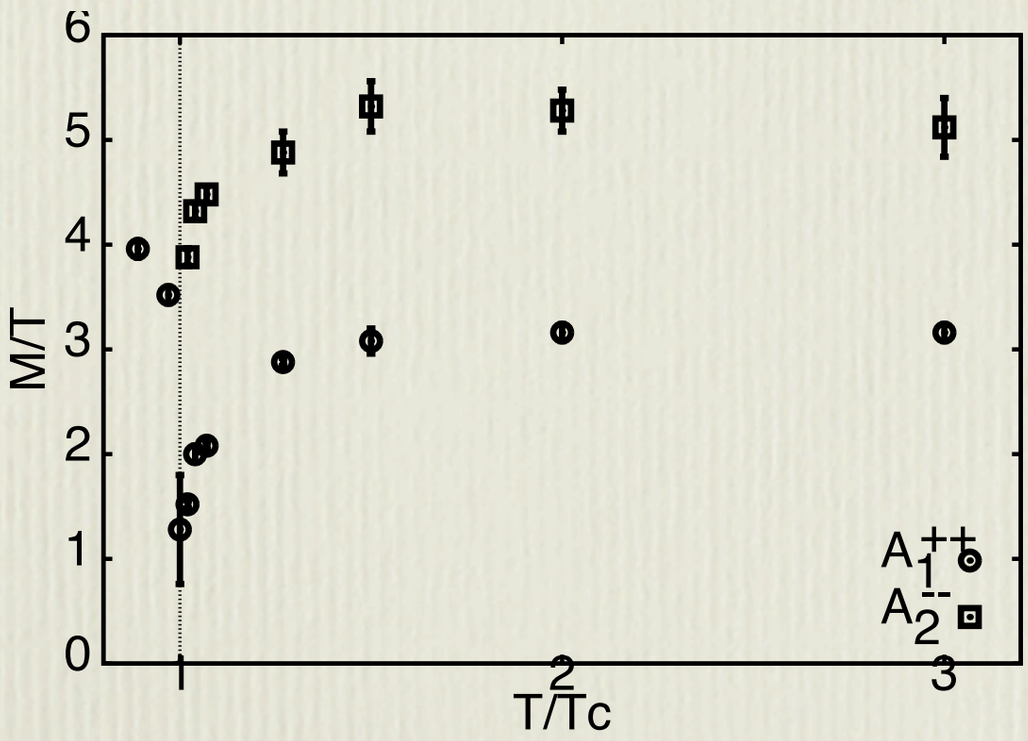
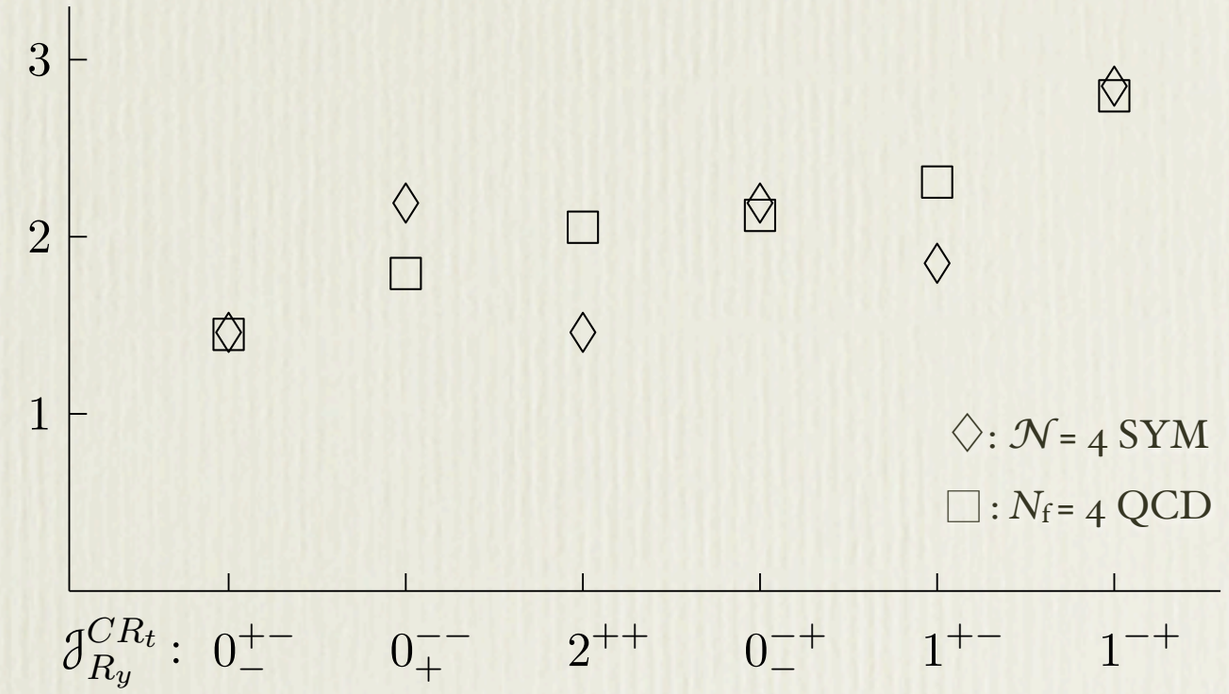
Thermal screening masses

QCD screening masses vs. T



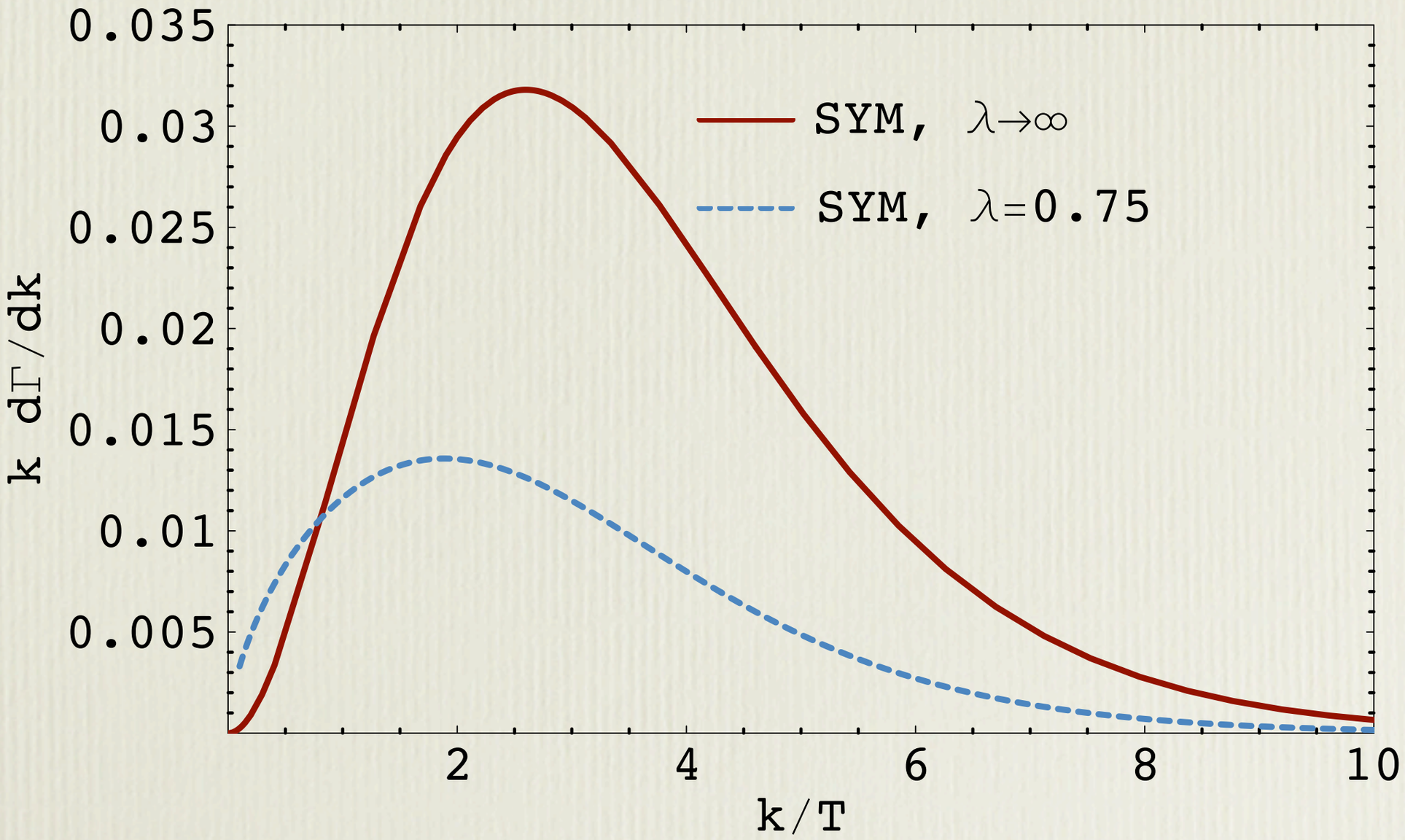
Datta & Gupta

screening mass ratios: QCD vs SYM

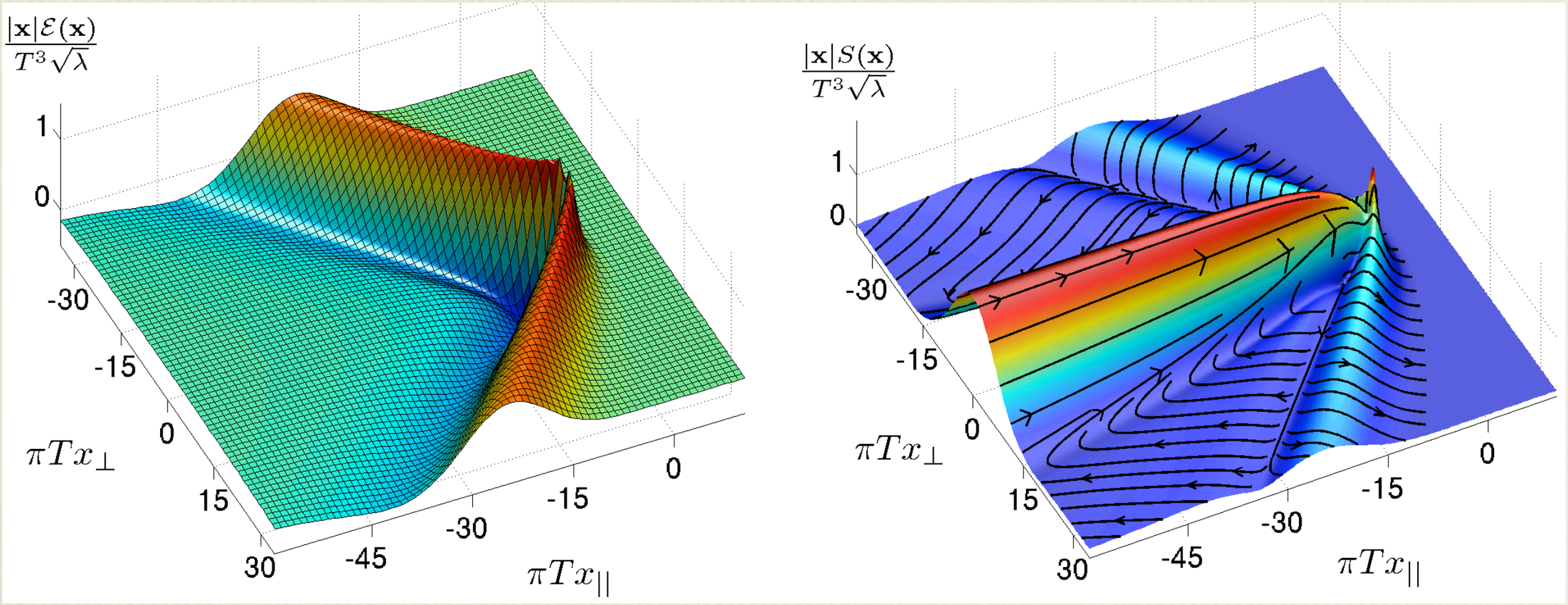


Bak, Karch, L.Y.

SYM photoemission spectrum



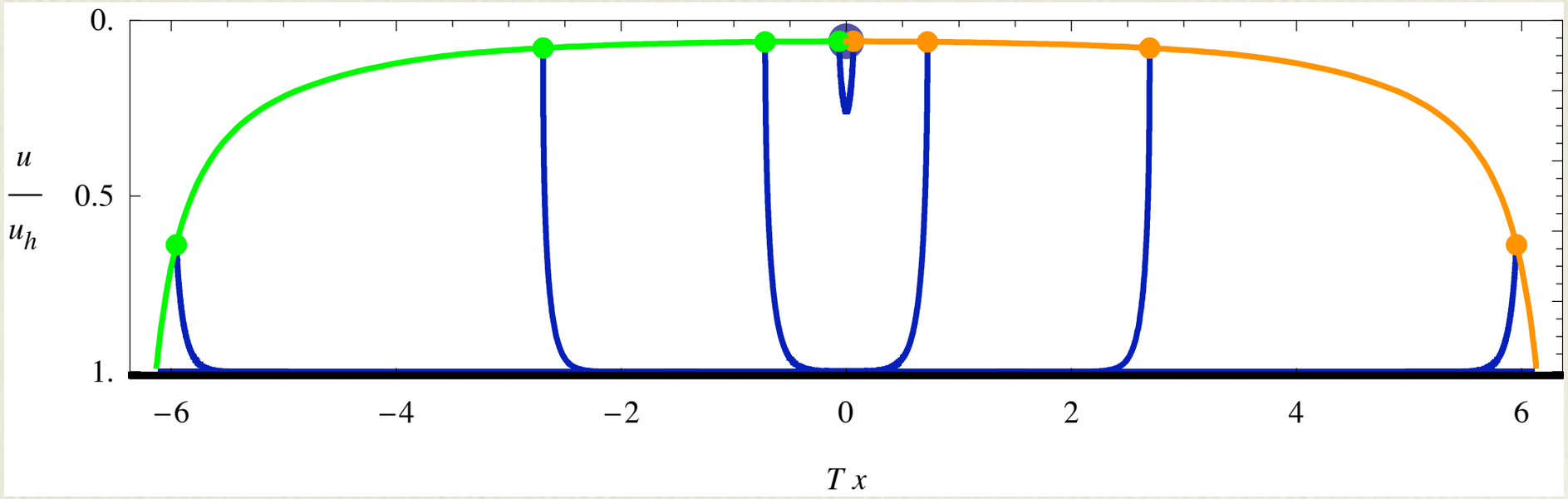
Supersonic quark wake



P. Chesler

Energy density (left) and energy flux (right) for $v = 0.75$

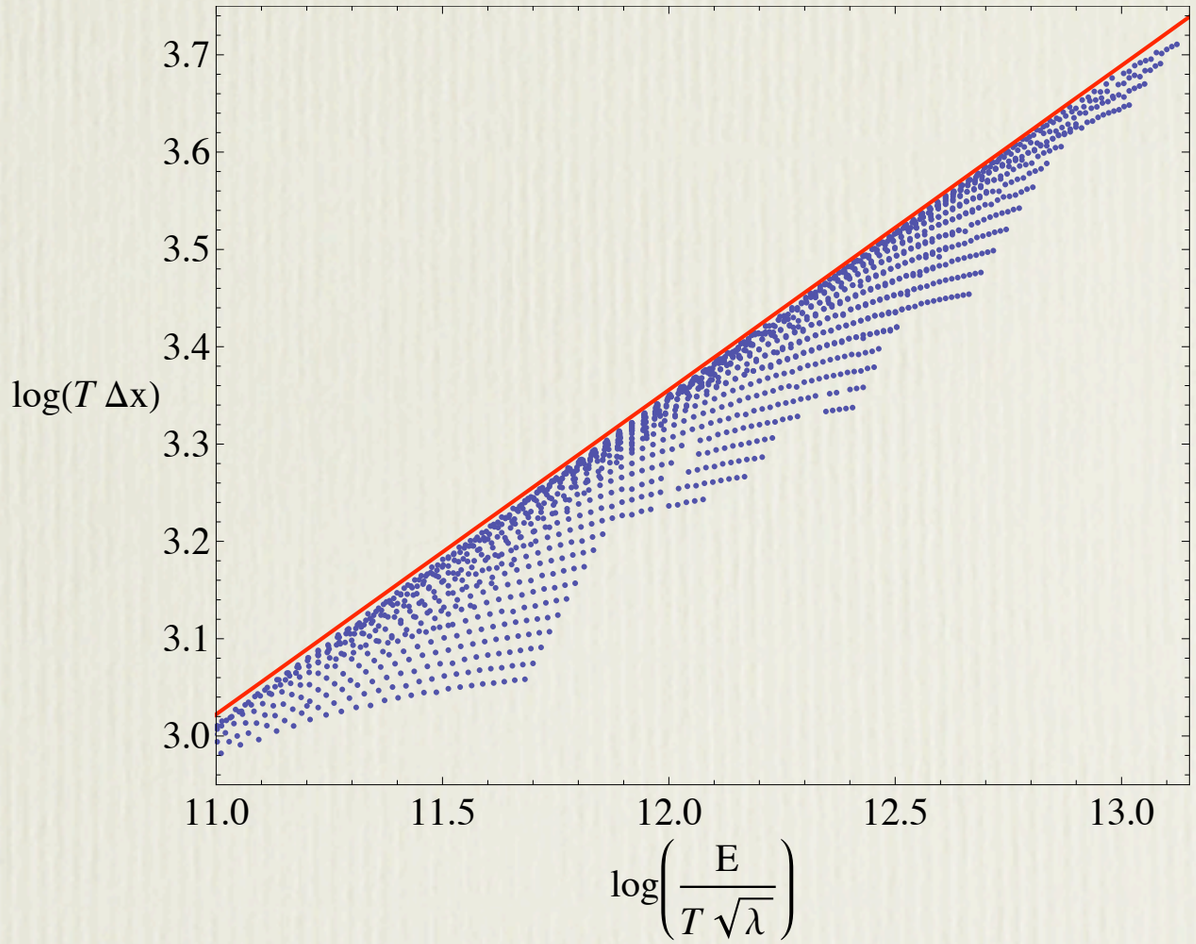
Falling strings = light quark jets



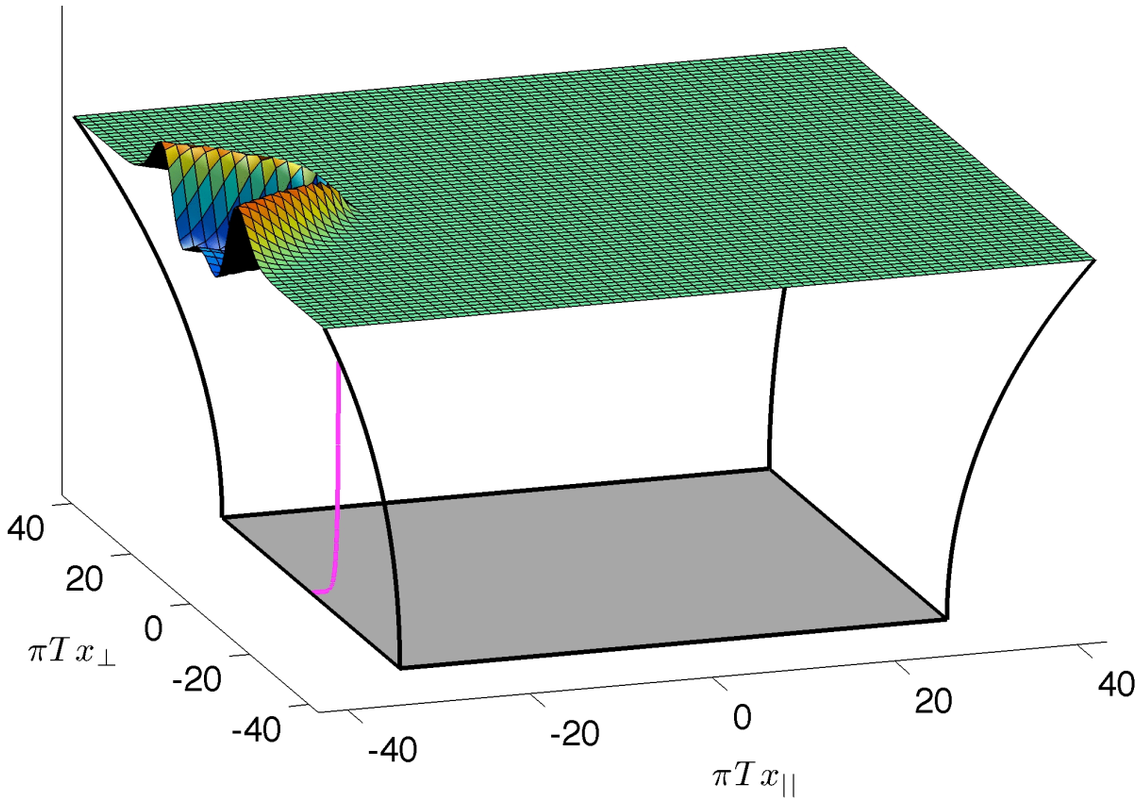
- asymptotic analysis + numerics

➠ $$\Delta x_{\max}(E) = \frac{C}{T}\left(\frac{E}{\sqrt{\lambda}T}\right)^{1/3}$$

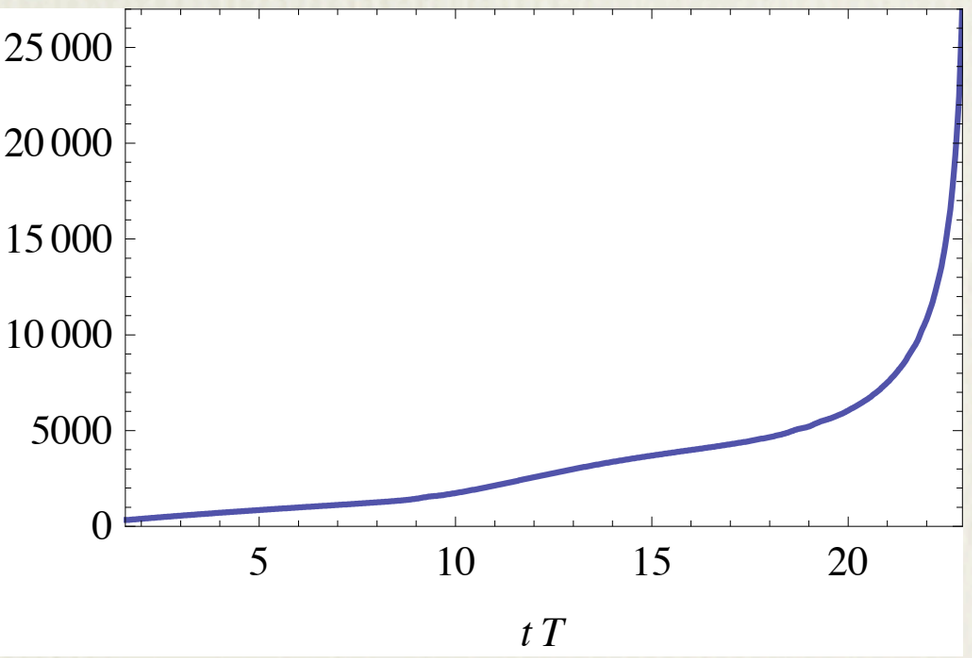
$$C \approx 0.53$$



Light quark wake & energy loss rate



$$-\frac{1}{T^2\sqrt{\lambda}}\frac{dE}{dt}$$



Far from equilibrium dynamics

gauge/gravity duality: QFT non-equilibrium initial value problem ⟷ *5d* gravitational initial value problem

Is it feasible to study:

- plasma formation ?
- isotropization ?
- early thermalization ?
- shock wave collisions ?

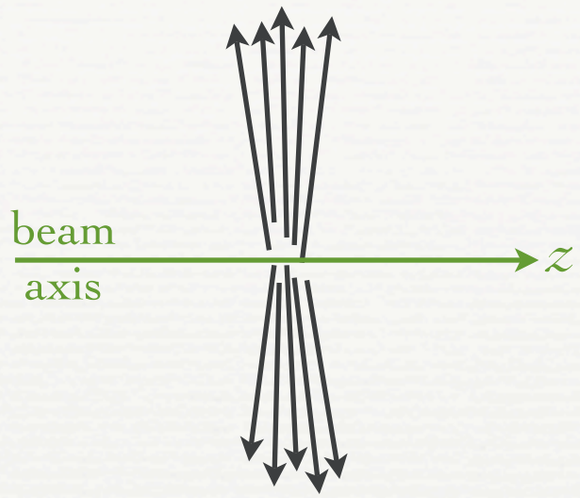
} work with Paul Chesler

- turbulence ?

⋮

Motivation: Isotropization at RHIC

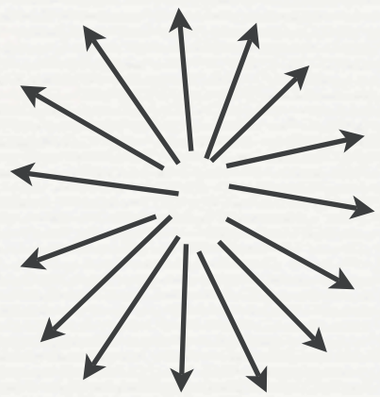
$t = 0$



mid-rapidity momentum distribution: highly anisotropic (oblate),

$T_{xx} = T_{yy} \gg T_{zz}$

$t \approx$ few fm/c



expanding fluid in approx. local equilibrium,

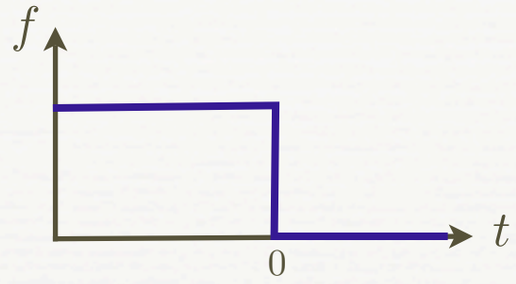
$T_{ij} \propto \delta_{ij}$ in local fluid frame

Time scale? Relevant dynamics?

Non-equilibrium initial state

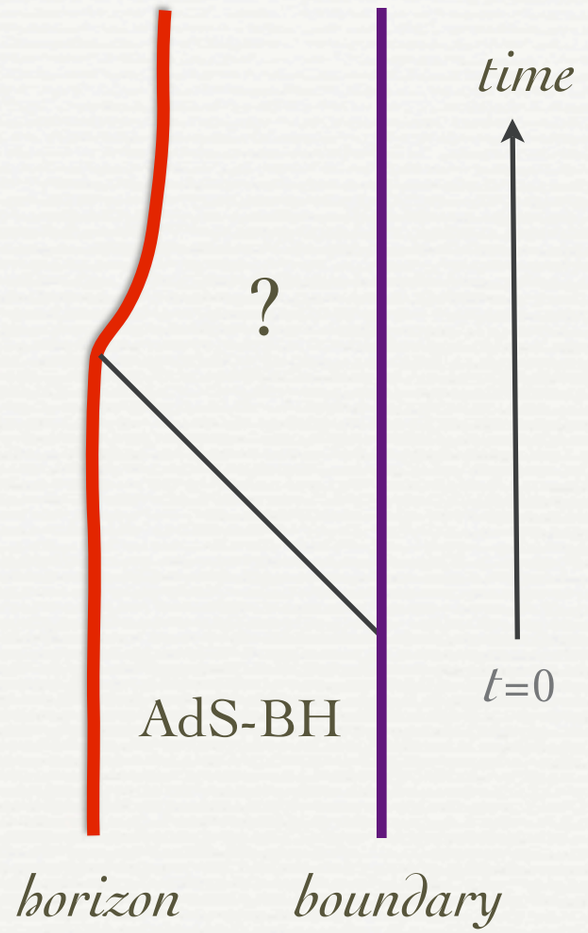
- Classic relaxation: $\hat{H} \to \hat{H} - f(t)\hat{\mathcal{O}}$

  Equilibrate in presence of external field, then turn off field.

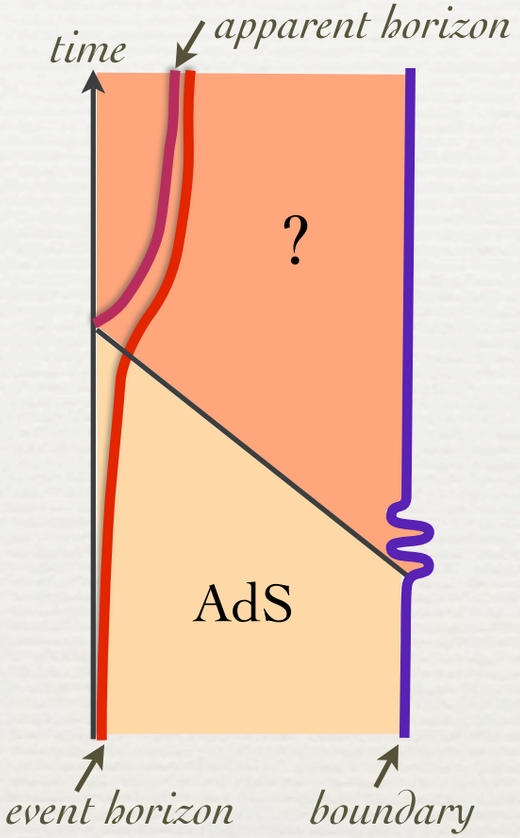


- Generate anisotropy with metric perturbation: $\hat{\mathcal{O}} = T_{ij},\ f(t) = h_{ij}(t)$

- Gravity dual: time-dependent horizon, non-flat boundary metric



Gravitational isotropization

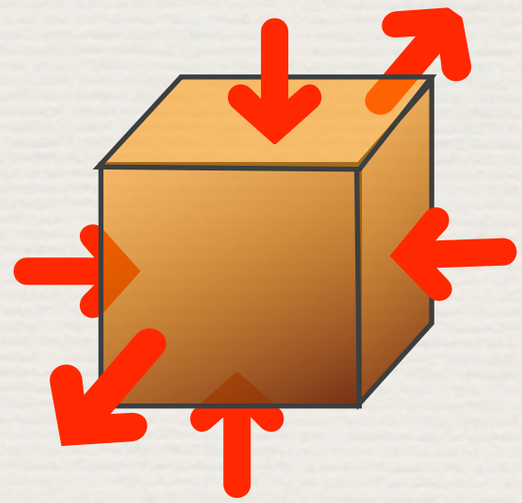


- Create homogeneous, anisotropic plasma via time-dependent spatial shear
- Oblate anisotropy: $\hat{\mathcal{O}} = T_{11} + T_{22} - 2T_{33}$
- Good coordinates: incoming null (Eddington-Finkelstein)
- Perfect homogeneity:
  - $ds^2 = -A(v,r)\,dv^2 + 2\,dv\,dr + \Sigma(v,r)^2\left[e^{B(v,r)}(dx^2+dy^2) + e^{-2B(v,r)}dz^2\right]$

$v = \text{const.}$: null infalling radial geodesic

$v > 0$: causal future of t=0 boundary slice

boundary asymptotics: $A \sim r^2,\ \Sigma \sim r,\ B \sim f(v)$



Einstein equations

- non-trivial components: *vv, rr, vr, zz, xx=yy* ➠ 5 equations for 3 functions (A,B,Σ):

$$
\begin{aligned}
0 &= \Sigma\,(\dot\Sigma)' + 2\,\Sigma'\,\dot\Sigma - 2\,\Sigma^2 \\
0 &= \Sigma\,(\dot B)' + \tfrac{3}{2}\big(\Sigma'\,\dot B - B'\,\dot\Sigma\big) \\
0 &= A'' + 3\,B'\,\dot B - 12\,\Sigma'\,\dot\Sigma/\Sigma^2 + 4 \\
0 &= \ddot\Sigma + \tfrac{1}{2}\,(\dot B)^2\,\Sigma - \tfrac{1}{2}\,A'\,\dot\Sigma \\
0 &= \Sigma'' + \tfrac{1}{2}\,(B')^2\,\Sigma
\end{aligned}
$$

$$
\begin{aligned}
h' &\equiv \partial_r h \\
\dot h &\equiv \partial_v h + \tfrac{1}{2}\,A\,\partial_r h
\end{aligned}
$$

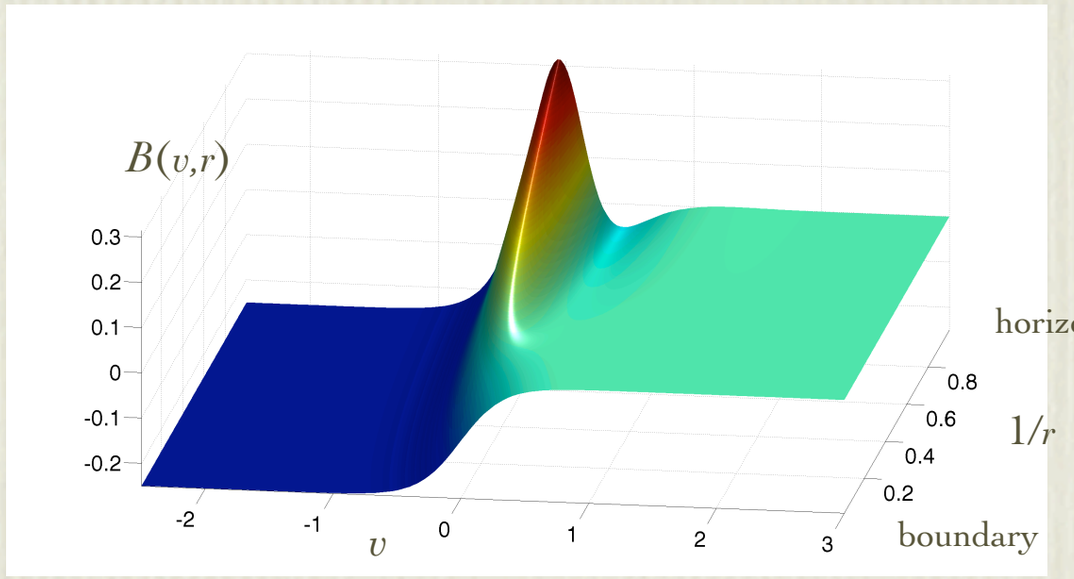
boundary value constraint

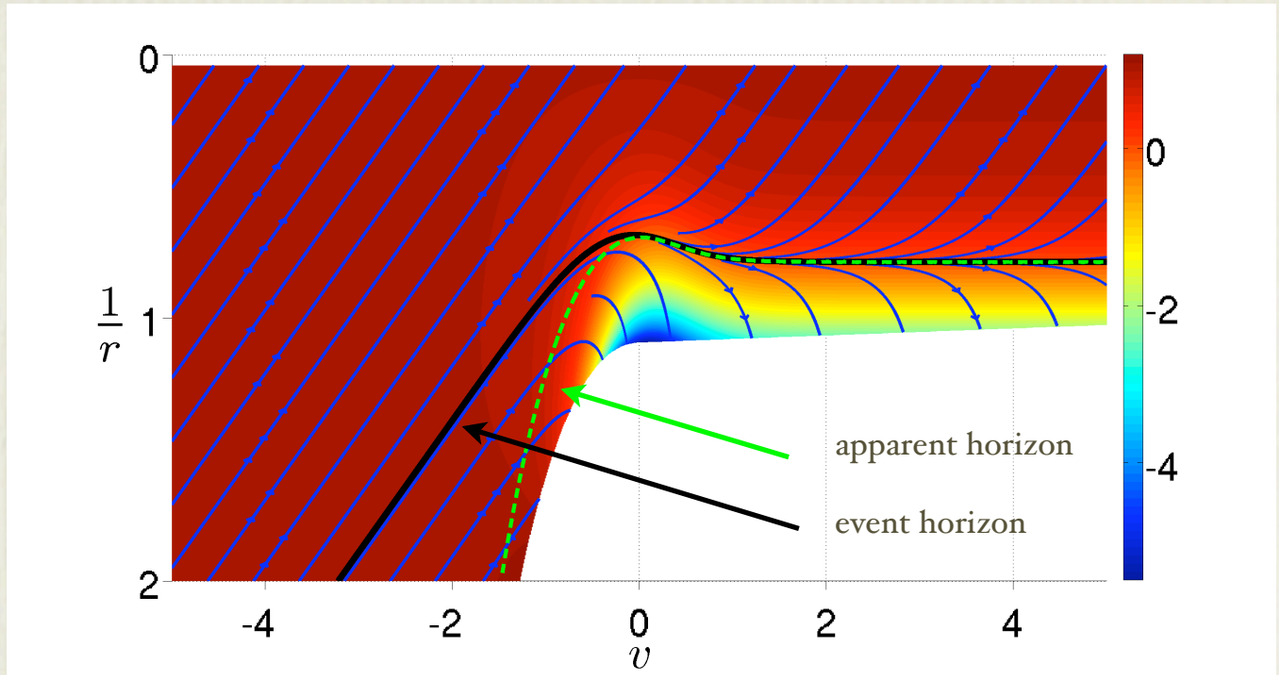
initial value constraint

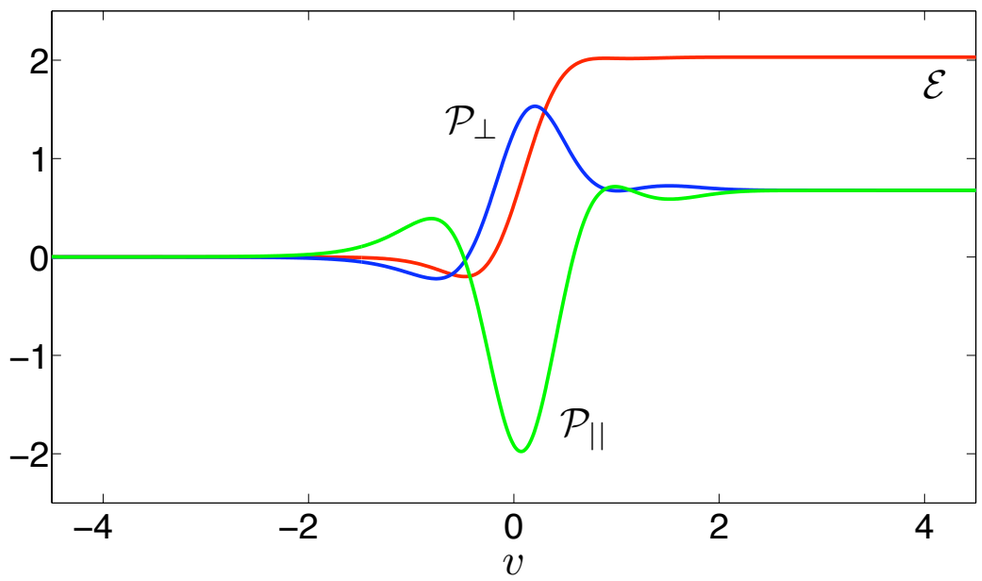
- Solve for $\dot\Sigma,\ \dot B,\ A$ ➠ good initial value problem
- Discretize radial coordinate ➠ system of coupled stiff ODEs
- Ensure good boundary behavior ➠ match asymptotic expansion & numerics
- Deal with residual gauge freedom ➠ time-dependent shifts in r
- Choose $f(v)$ ∝ smoothed step function
- Integrate...

Plasma isotropization results

arXiv:0812.2053







$\tau_{iso} \approx 0.7/T$ ➡ $\tau_{iso} \approx 0.5$ fm/c for

$T \approx 350$ MeV --- relevant at RHIC?

Boost invariant expansion

arXiv:0906.4426

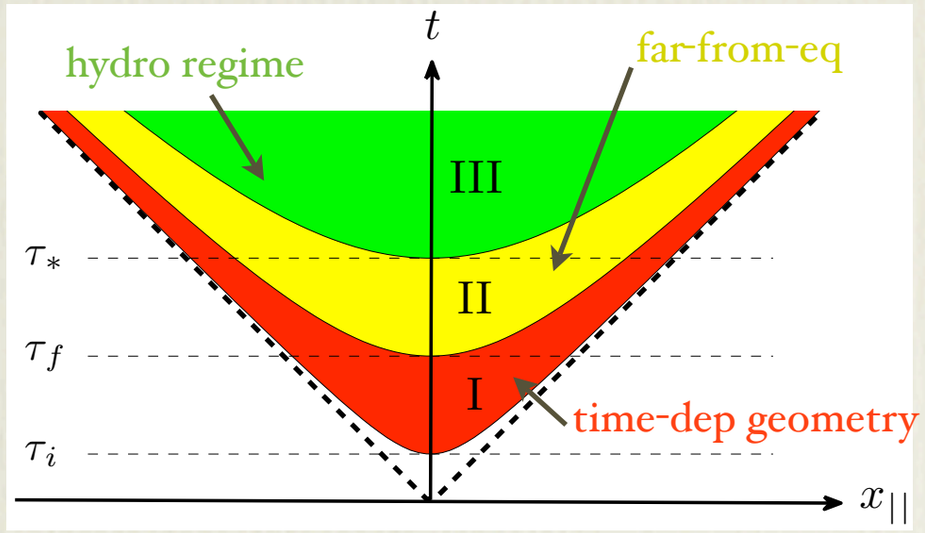
$$ds^2 = -d\tau^2 + e^{\gamma(\tau)}\, d\boldsymbol{x}_\perp^2 + \tau^2\, e^{-2\gamma(\tau)}\, dy^2$$

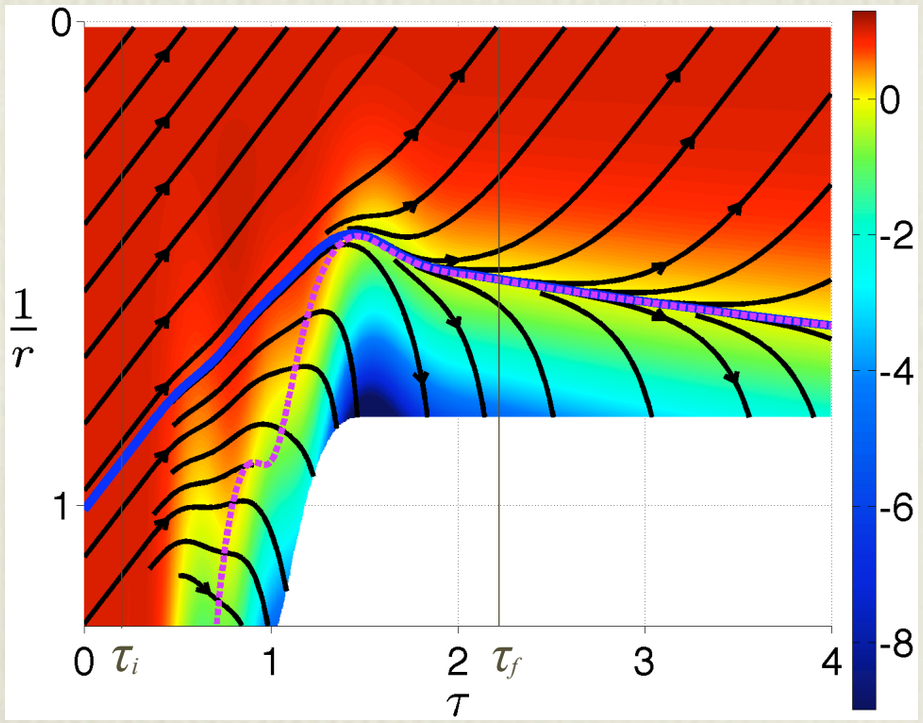
proper time

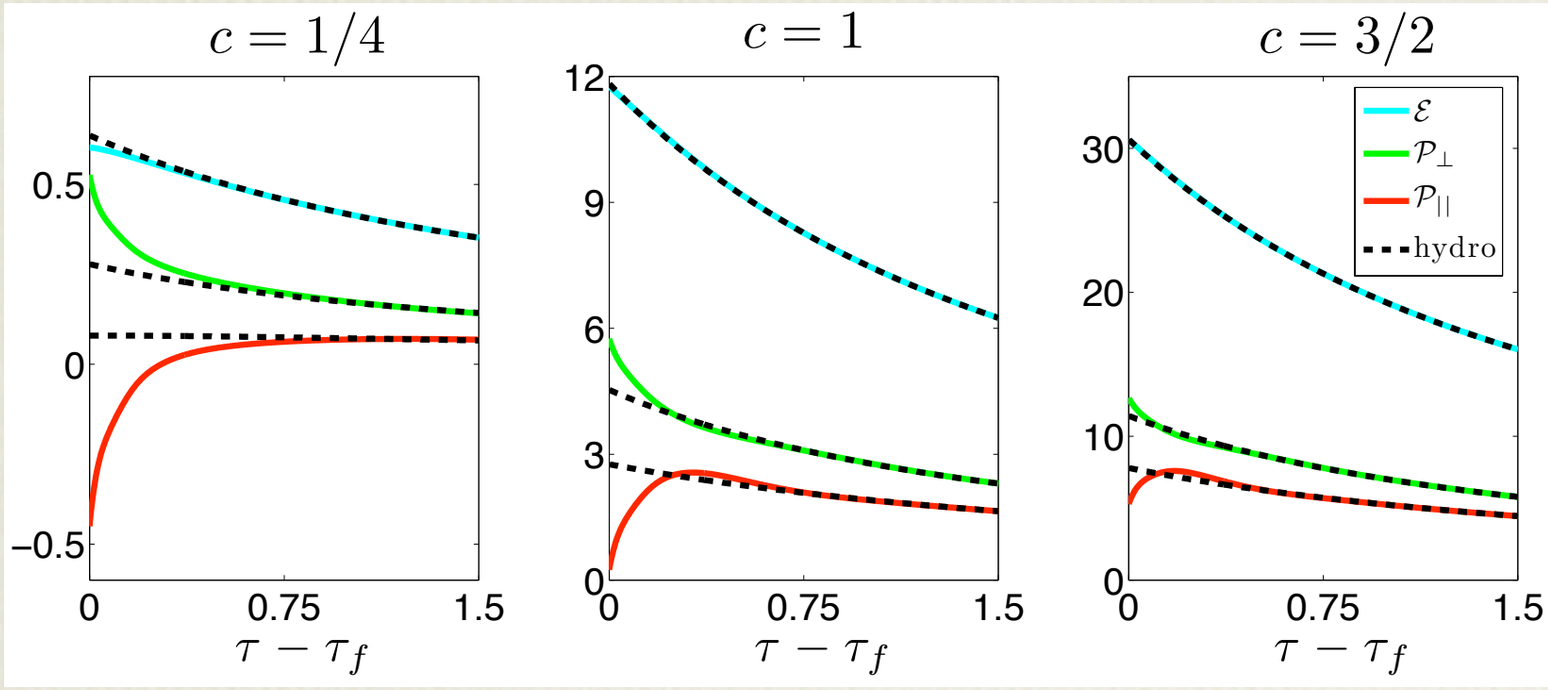
rapidity

$$\gamma(\tau) = c\, h(\tau-\tau_0)^6\, e^{-1/h(\tau-\tau_0)}$$

$$h(\delta\tau) = 1 - (\delta\tau)^2/\Delta^2$$



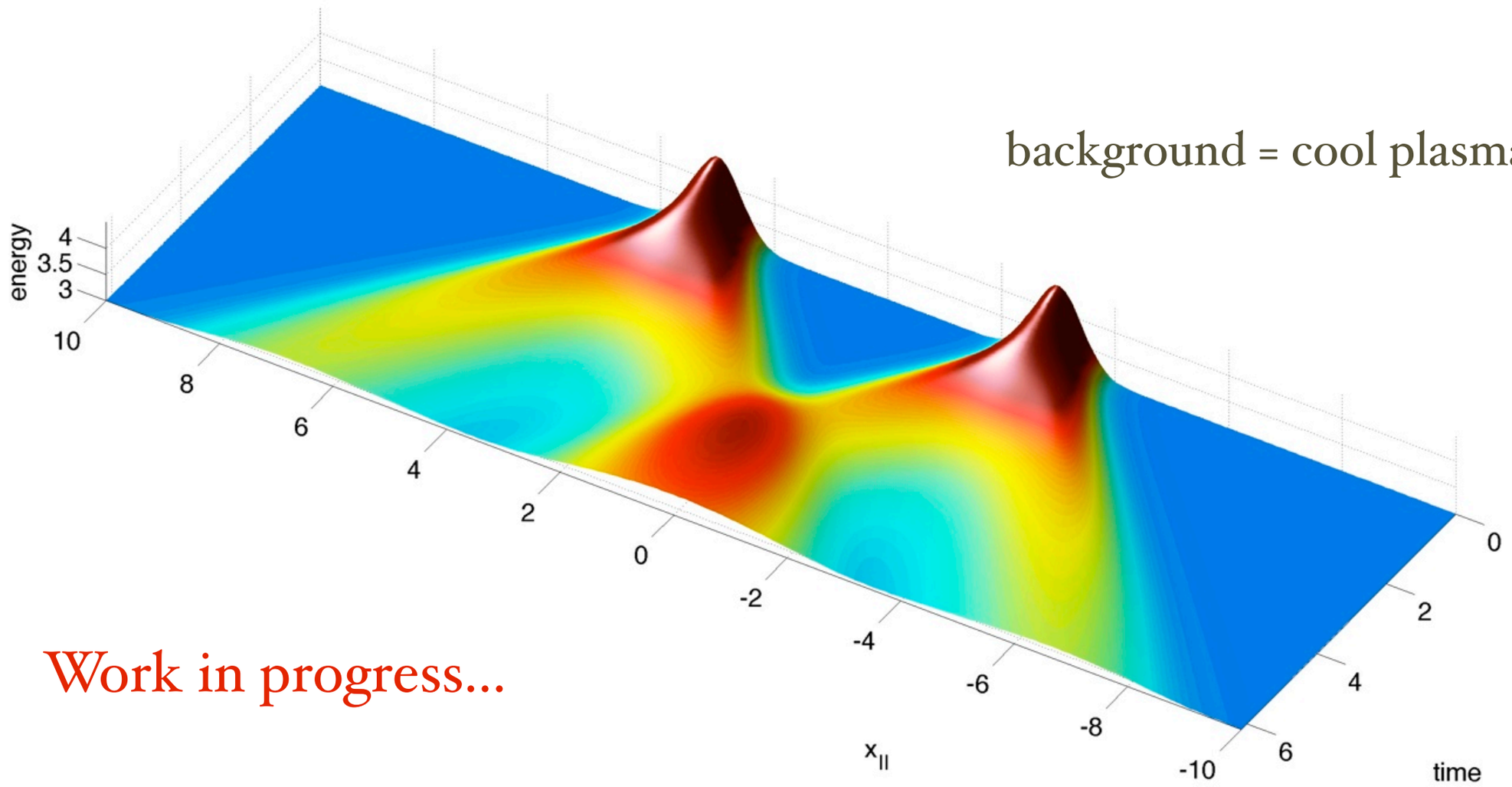




Limit of validity of hydro controlled by relaxation of non-hydro modes, not by growth of higher-order viscous terms

Colliding shocks

- Transverse homogeneity ➡ *5d* Einstein eqns. reduce to 2+1*d* ODEs



background = cool plasma

Work in progress...