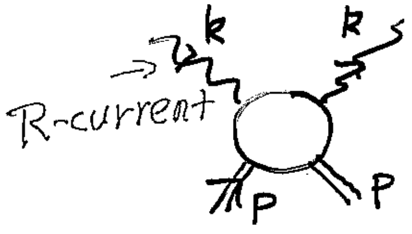
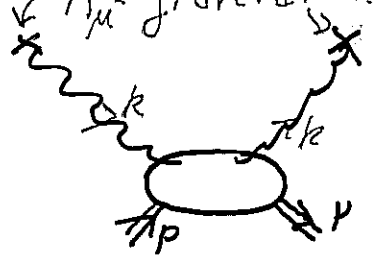
1. Review of Polchinski-Strassler

Study DIS on dilaton, Break susy at $r=r_0$.

Use R-current as hard probe



$\longleftrightarrow$



Gravitational wave induced at $r=\infty$, propagates in bulk and interacts with dilaton which mostly lives at $r=r_0$

On Field theory side use operator product expansion.

$$\gamma_j = \tfrac{1}{2} - \sqrt{\tfrac{\sqrt{\lambda}}{2}(j-j_0)} \qquad j_0 = 2 - 2/\sqrt{\lambda}$$

analog of BFKL intercept

$$\gamma_2 = 0 \qquad \gamma_j \underset{j=4,6,\dots}{\simeq} -\frac{\lambda^{1/4}}{\sqrt{2}}(j-j_0)^{\frac{1}{2}}$$

large and negative

Strong violation of scaling! Partons live only at small x at

$$x = \frac{1}{Q^2 r_0^{\,2}}\, e^{-\sqrt{\lambda}/4}$$

and below.

Difficult to get reasonable model of DIS for hadrons in AdS.

DIS For a Plasma in AdS/CFT

with Y. Hatta
E. Iancu

Object is to see what the $N=4$ SYM plasma is made of at strong coupling.

A first step toward understanding hard probes of a strongly coupled plasma.

$N=4$ SYM $\longleftrightarrow$ type IIB string theory on $AdS_5 \times S^5$

$$g^2 = 4\pi g_s$$

$$\sqrt{\lambda} \equiv \sqrt{g^2 N_c} = R^2/\alpha'$$

$$ds^2 = \frac{r^2}{R^2}\left(-dt^2 + d\vec{x}^2\right) + \frac{R^2}{r^2} dr^2 + R^2 d\Omega_5$$

At large $g^2 N_c$ and small g^2 string theory $\Rightarrow$ supergravity in $AdS_5 \times S^5$

2. DIS on the strongly coupled $N=4$ SYM plasma

Goal is to evaluate

$$\mathrm{Im}\, i\int d^4x\, e^{-ik\cdot x} \langle R(j_\mu(x)\, j_\nu(0))\rangle_{\text{plasma}} = \frac{1}{T} W_{\mu\nu}(k)$$

at large $k^2 = \vec{k}^2 - k_0^2$, in order to see what the plasma is made of.

Do calculation on gravity side. Metric corresponding to plasma is

$$ds^2 = \frac{r^2}{R^2}[-f dt^2 + d\vec{x}^2] + \frac{R^2}{r^2}\frac{dr^2}{f}$$

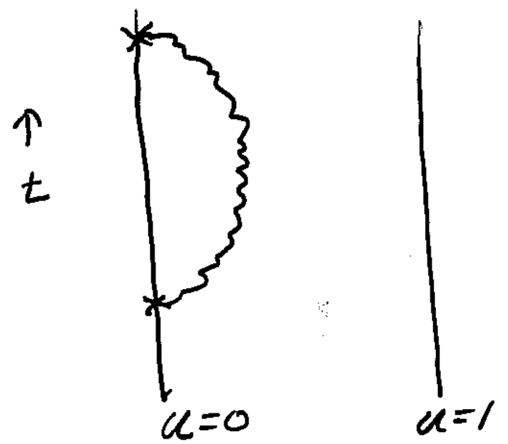
with $f = 1 - \frac{r_0^4}{r^4}$ and $r_0 = \pi R^2 T$ the black hole horizon.

For technical reasons let $u = r_0^2/r^2$; then

$$ds^2 = \frac{(\pi R T)^2}{u}[-f dt^2 + d\vec{x}^2] + \frac{R^2}{4u^2 f} du^2 \qquad f = 1 - u^2$$

Now $r = \infty$ boundary is at $u = 0$ and horizon is at $u = 1$.

Gravity Field induced by R-current obeys Yang-Mills equation



$$g^{\alpha\beta}\nabla_\alpha F_{\beta\gamma}=0$$

Fix $A_\mu = A_\mu^{(0)}$ on $u=0$ boundary.

Evaluate

$$S = \frac{-N_c^2}{64\pi^2 R}\int d^4x\,du\sqrt{-g}\,g^{\alpha\beta}g^{\gamma\delta}F_{\alpha\gamma}F_{\beta\delta}$$

and use, For $A_\mu^{(0)}(x) = e^{ikz-i\omega t}A_\mu^{(0)}$,

$$R_{\mu\nu}(k) = -2\,\frac{\delta}{\delta A_\mu^{(0)}}\frac{\delta}{\delta A_\nu^{(0)}}\,S\Big|_{A_\mu^{(0)}=0} \qquad \frac{1}{T}W_{\mu\nu} = \mathrm{Im}\,R_{\mu\nu}$$

In gauge where $A_u=0$, one can write essential equation in terms of

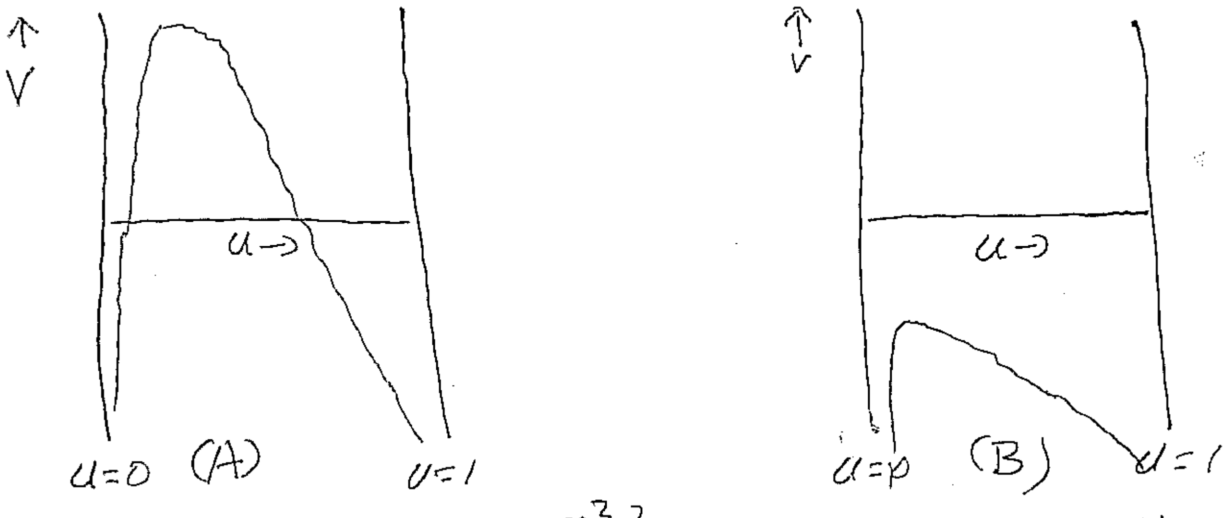
$$\psi(u) = \sqrt{u(1-u^2)}\ d/du\ A_0(u)$$

as

$$\psi''(u) = \frac{1}{u^2(1-u^2)^2}\overbrace{\left[-\frac{1}{4} + Q^2 u - q^2 u^3\right]}^{V}\psi$$

$$q = \frac{k}{2\pi T} \qquad Q^2 = \left(\frac{1}{2\pi T}\right)^2\left[k^2-\omega^2\right]$$

$$V = \frac{1}{u^2(1-u^2)^2}\left[-1/4 + Q^2 u - g^2 u^3\right]$$



$g/Q^3 \ll 1/4$ $\quad$ Q^2 large, $g/Q > 1$ $\quad$ $g/Q^3 \gg 1/4$

(A) Large barrier so gravity wave lives near $u=0$. Imaginary part of correlator, coming from tunneling to $u=1$, is small.

(B) Gravity easily flows from $u \simeq 0$ to $u=1$ and is absorbed into black hole and hence a large $W_{\mu\nu}$.

$$S = -\frac{N^2}{32\pi^2}\left[k A_0^{(0)} + \omega A_3^{(0)}\right]^2 \text{Volume}\cdot\text{time}\left[\tfrac{2}{3}(\gamma + \ln \tfrac{g}{3}) - i\tfrac{\pi}{3}\right]$$

$$\Rightarrow \langle J_\mu J_\nu \rangle_k \sim \left(\frac{k_\mu k_\nu}{K^2} + g_{\mu\nu}\right) K^2 N^2$$

$$\boxed{\frac{1}{x}\frac{dF_2}{d^3b} \sim K^2 T N^2}$$

3. Interpretations

Partonic

Coherence time for $\langle JJ \rangle$ correlator is

$$t_c \simeq \frac{2k}{K^2} = \frac{1}{xT} \qquad x = \frac{K^2}{2kT}$$

length of matter involved is $\Delta z = t_c = \frac{1}{xT}$

$$\frac{dF_2^{\Delta z}}{d^2b} = x \cdot \underbrace{\frac{1}{x}\frac{dF_2}{d^3b}}_{K^2TN^2} \cdot \underbrace{\frac{1}{xT}}_{\Delta z} = K^2N^2 \qquad \frac{k}{K^3} > \frac{1}{T^2} \text{ or } \underline{\underline{\frac{1}{x} > \frac{K}{T}}}$$

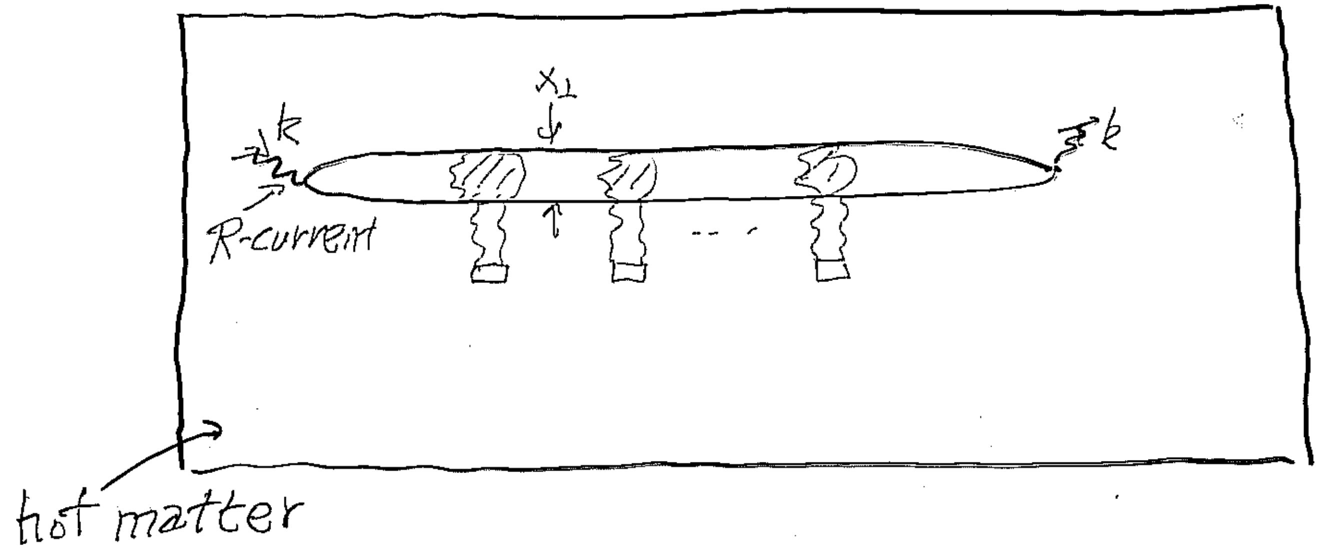
To see partons boost material by η where $\cosh\eta = (K/T)\frac{1}{x}$

Then $\Delta z' \simeq 1/K$ and current measures one layer of partons in $\Delta z'$

$$\frac{dF_2^{\Delta z'}}{d^2z} \underset{x \ll T/K}{\sim} N^2K^2 \qquad \text{(saturation)}$$

When measured at scale K all energy is located in partons with $\underline{x = T/K}$.

Multiple scattering



In multiple scattering usual factor

$$\text{rate} = \rho\sigma \sim \rho x_\perp^2 \, xG(x, 1/x_\perp^2) \frac{\alpha N_c}{N_c^2-1}$$

$$\downarrow$$

$$i\rho x_\perp^2 \frac{c}{x} \qquad\qquad \frac{1}{x} = kT x_\perp^2$$

Now real, not absorptive potential. $1/x$ factor determined by operator product expansion with $\Theta_{\mu\nu}$ as only allowed operator.

Potential forces $x_\perp$ to grow with passage through material. When $x_\perp \sim 1/T$ interaction becomes <u>strong</u>.