Perturbation theory vs. nonlocality

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hep-th/0605196)

Plausible resolution of the info. paradox:
nonlocality

How does Hawking's calculation miss the critical physics ?

Could be answered in two ways:

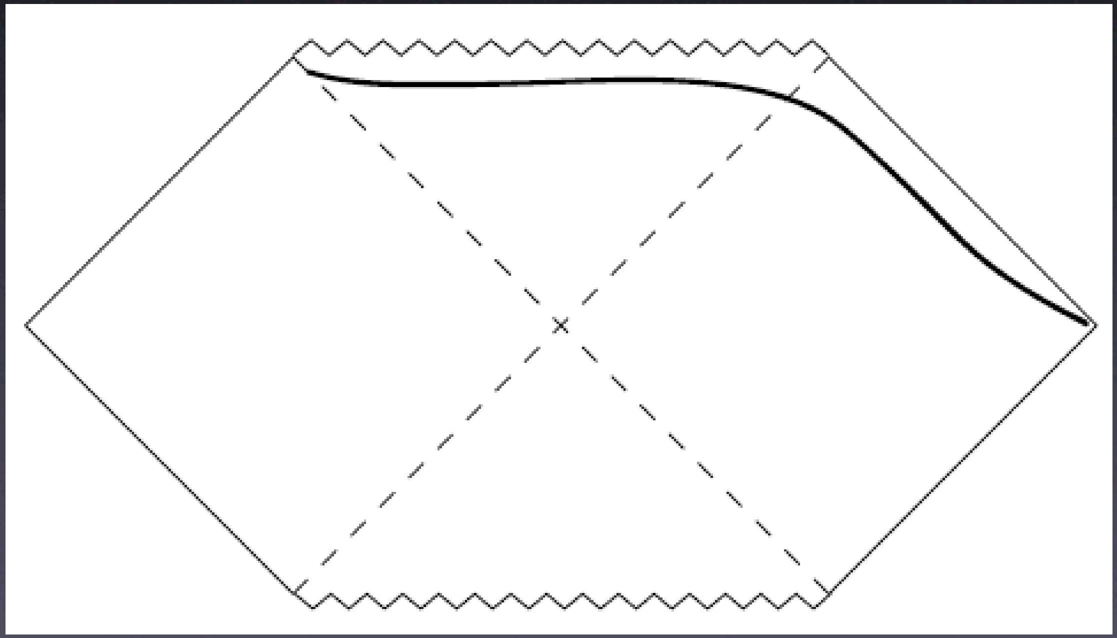
A. Compare classical - quantum, the H atom: classical physics doesn't break down at r_{atom} , it is replaced

B. Actual breakdown of semiclassical gravity

evidence for B...

Hawking's calculation (w/ updates):

$$\Delta I = S \quad \leftarrow \rho \quad \leftarrow |\psi\rangle \quad \leftarrow |\psi\rangle_{NS}$$



Hawking's result: leading contribution - perturbative expansion in $1/M_P$

(fix $M_P^{-2}M$)

$\leftrightarrow$ QFT in semiclassical background (matter: ϕ)

$$|\Psi\rangle \sim \int_{\Psi_{in}} \mathcal{D}h\mathcal{D}\phi e^{iS}$$

$$g_{\mu\nu} = g^0_{\mu\nu} + M_P^{-1} h_{\mu\nu}$$

$$S \sim \int d^4x \sqrt{-g_0} \Big\{ -(\nabla_0 \phi)^2 + h \Delta_L^0 h$$

semiclassical

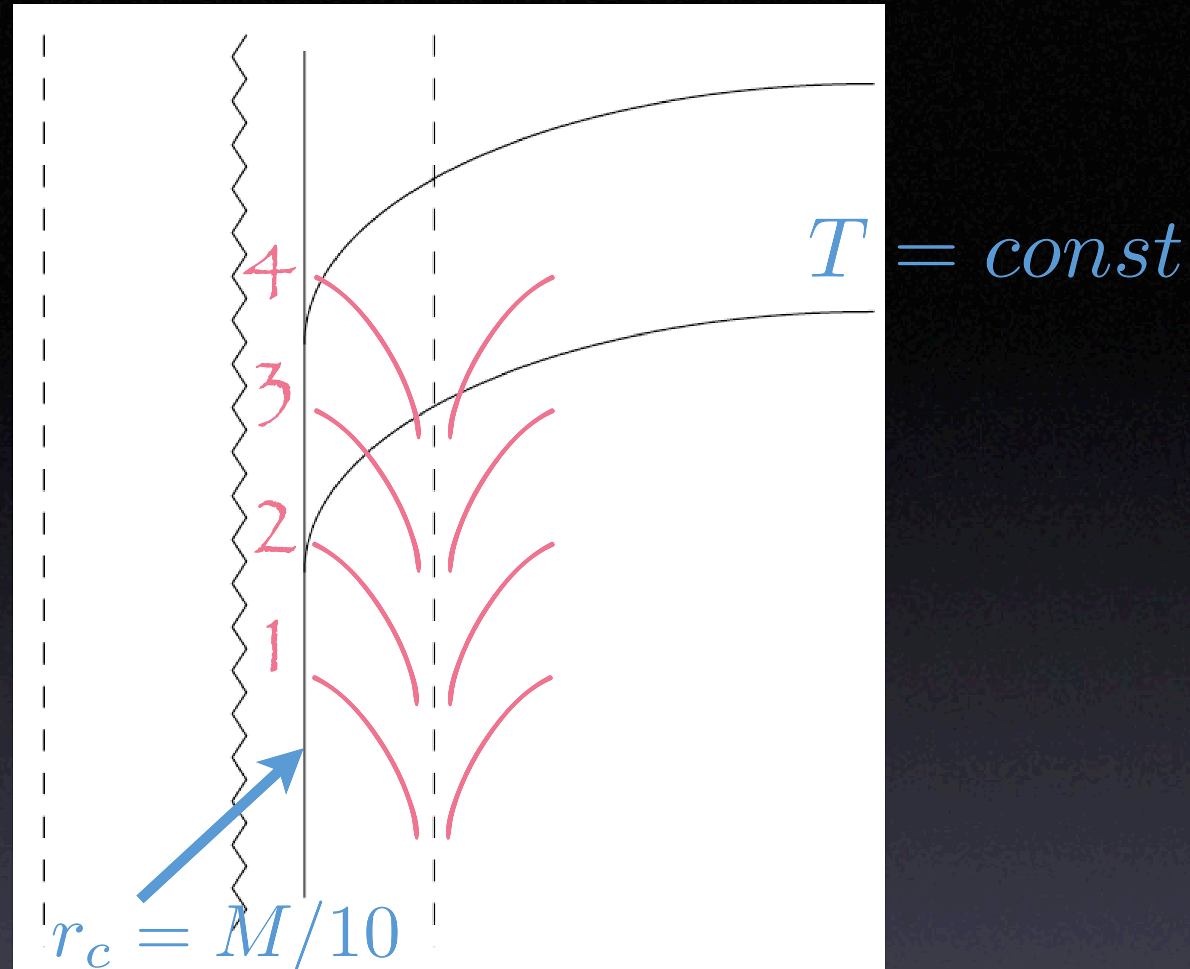
$$+ \frac{h}{M_P} \left[T^{\phi}_{\mu\nu} + (\nabla h)^2 \right] \cdots \Big\}$$

$\frac{1}{M_P^n}$ terms

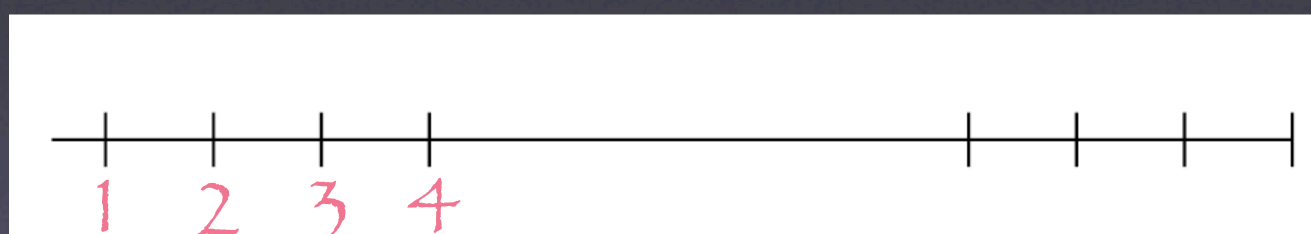
$$= \sum_n M_p^{2-n} S_n$$

IMPORTANT?

Nice slices:

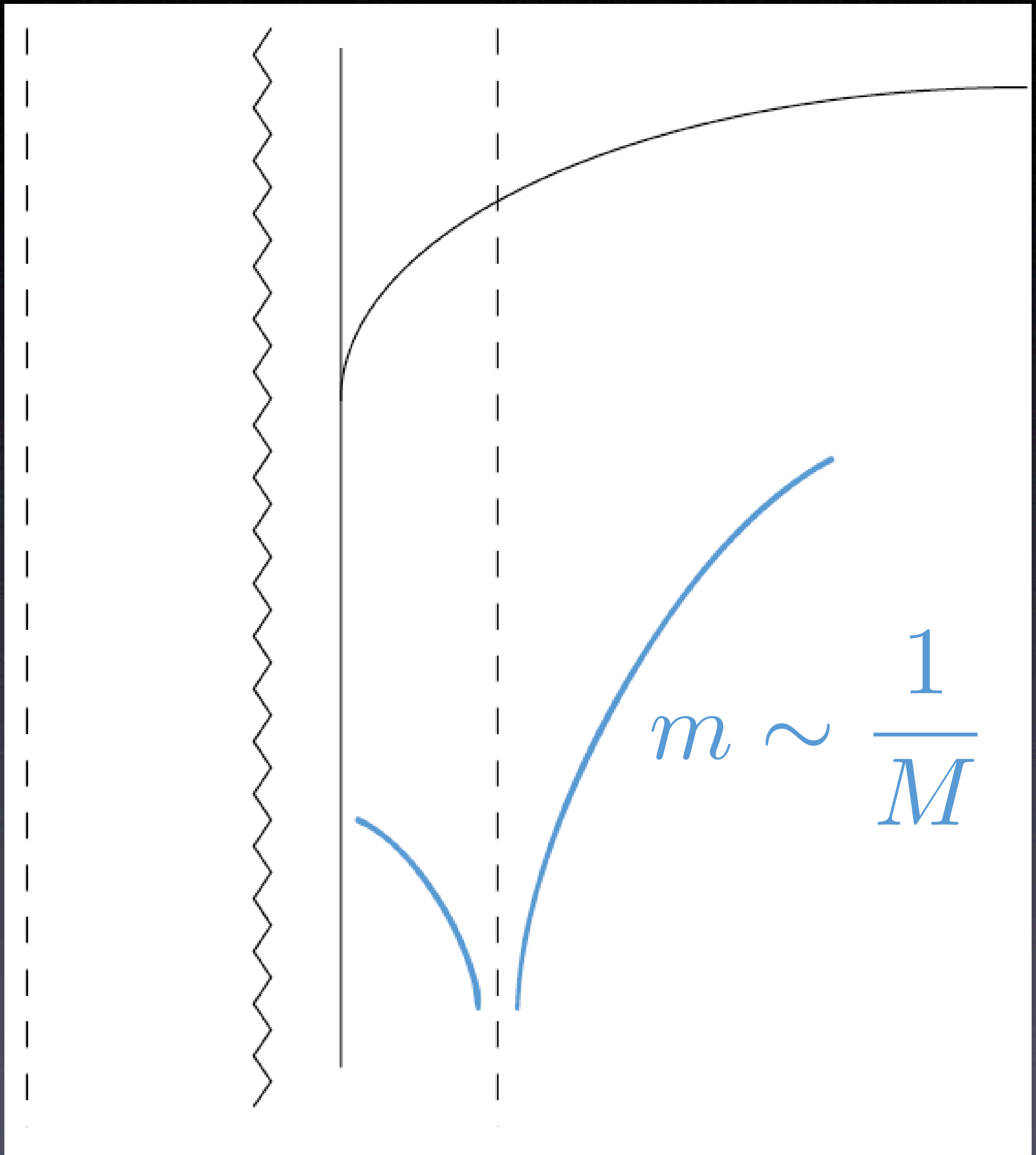


State:



$$\delta s \sim M\sqrt{\frac{2M}{r_c} - 1}$$

Consider a typical small fluctuation:



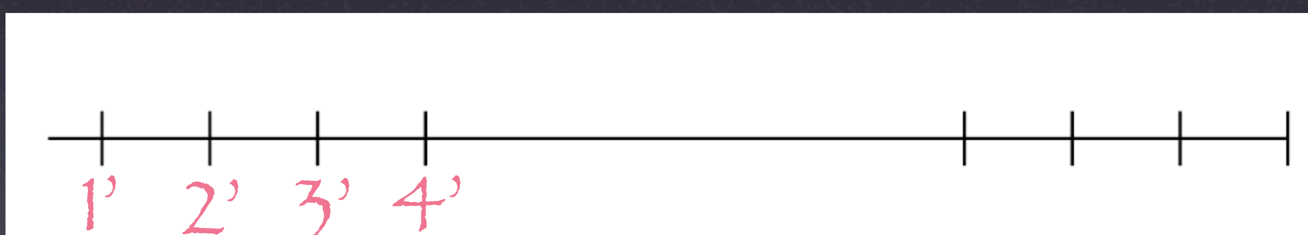
Extra quantum out,
or throw one in

What is effect on state w/ or w/out M_P^{-1} terms ?

Leading order: $S = S_2$

QFT in background. No backreaction, no effect.

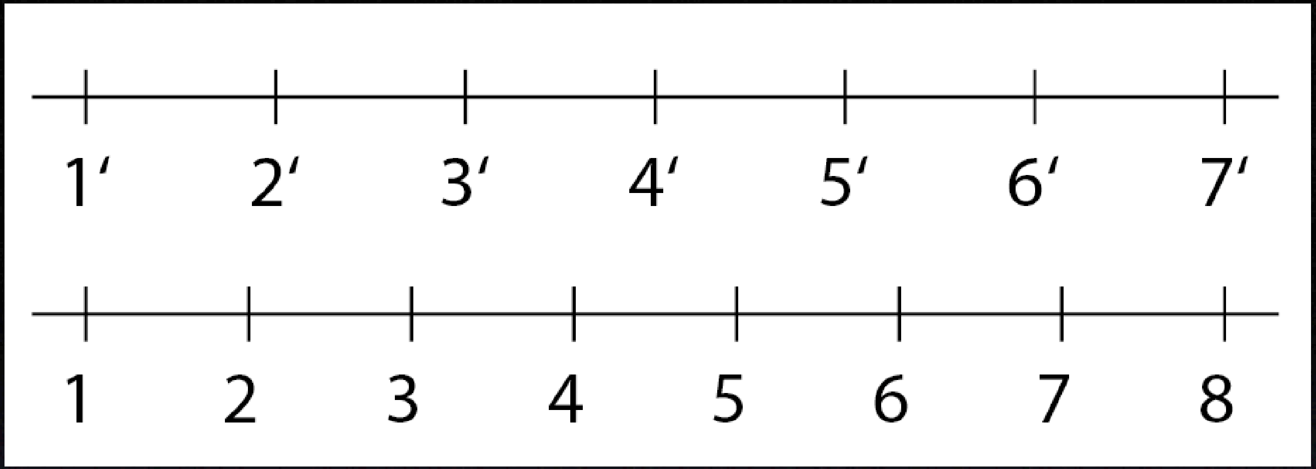
Perturbed: $S = \sum_n M_p^{2-n} S_n$



$$\delta s' \sim \delta s \left[1 + \mathcal{O}\left(\frac{m}{r_c} \right) \right]$$

$$\mathcal{O}\left(\frac{1}{M^2} \right)$$

But:



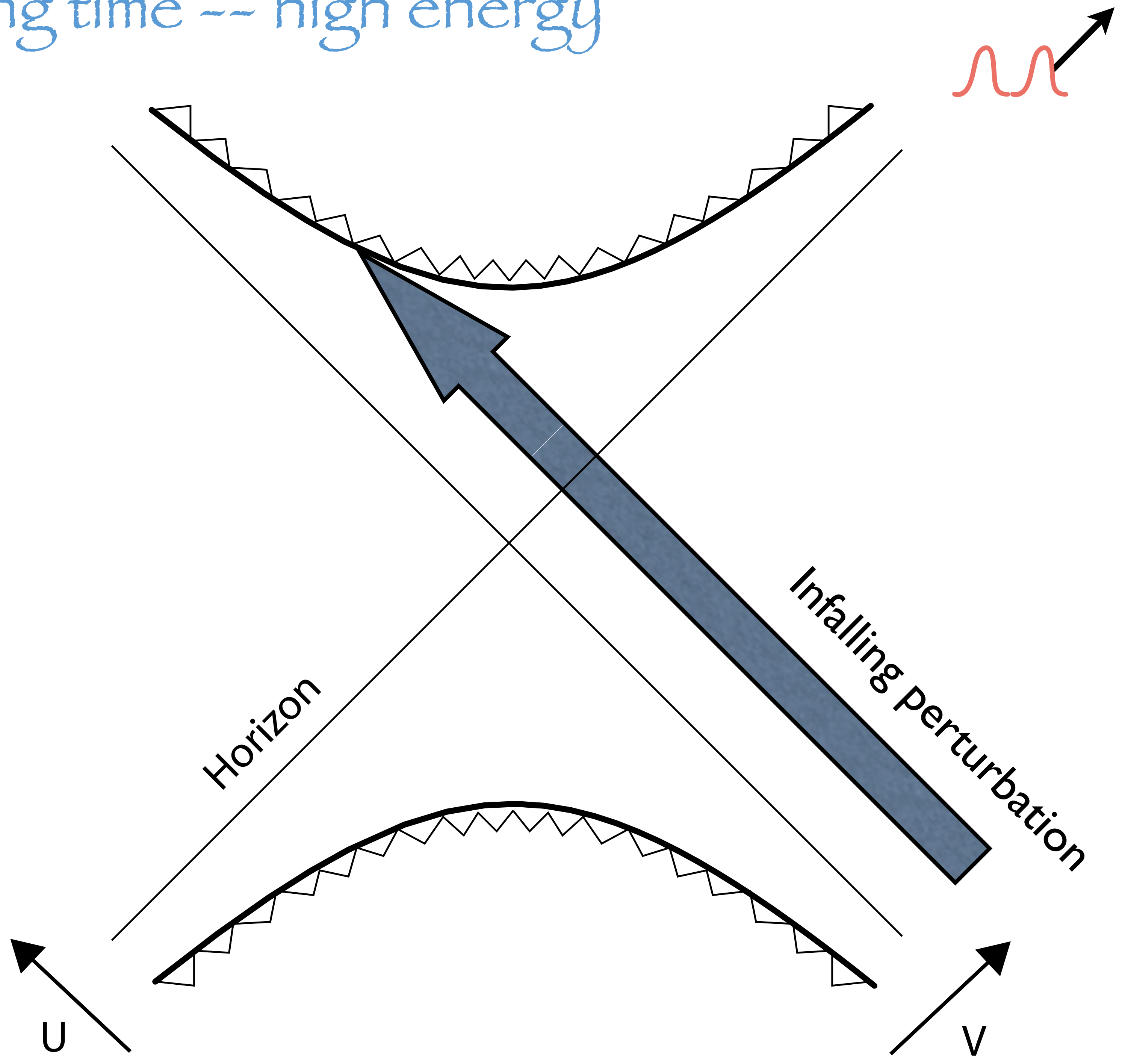
Long time: order one effect

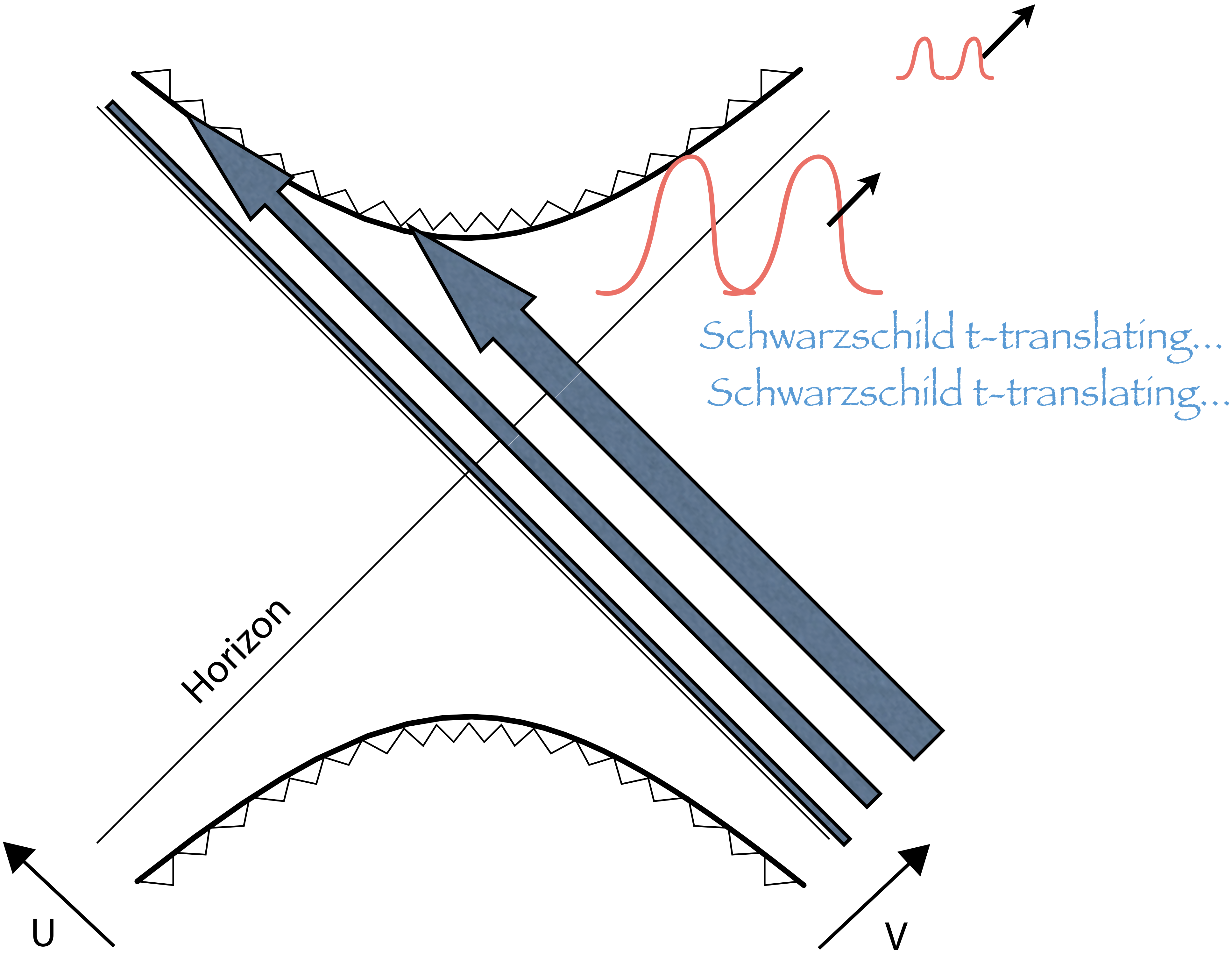
$$T\frac{m}{r_c} \sim M \quad \longleftrightarrow \quad T \sim M^3 \quad !$$

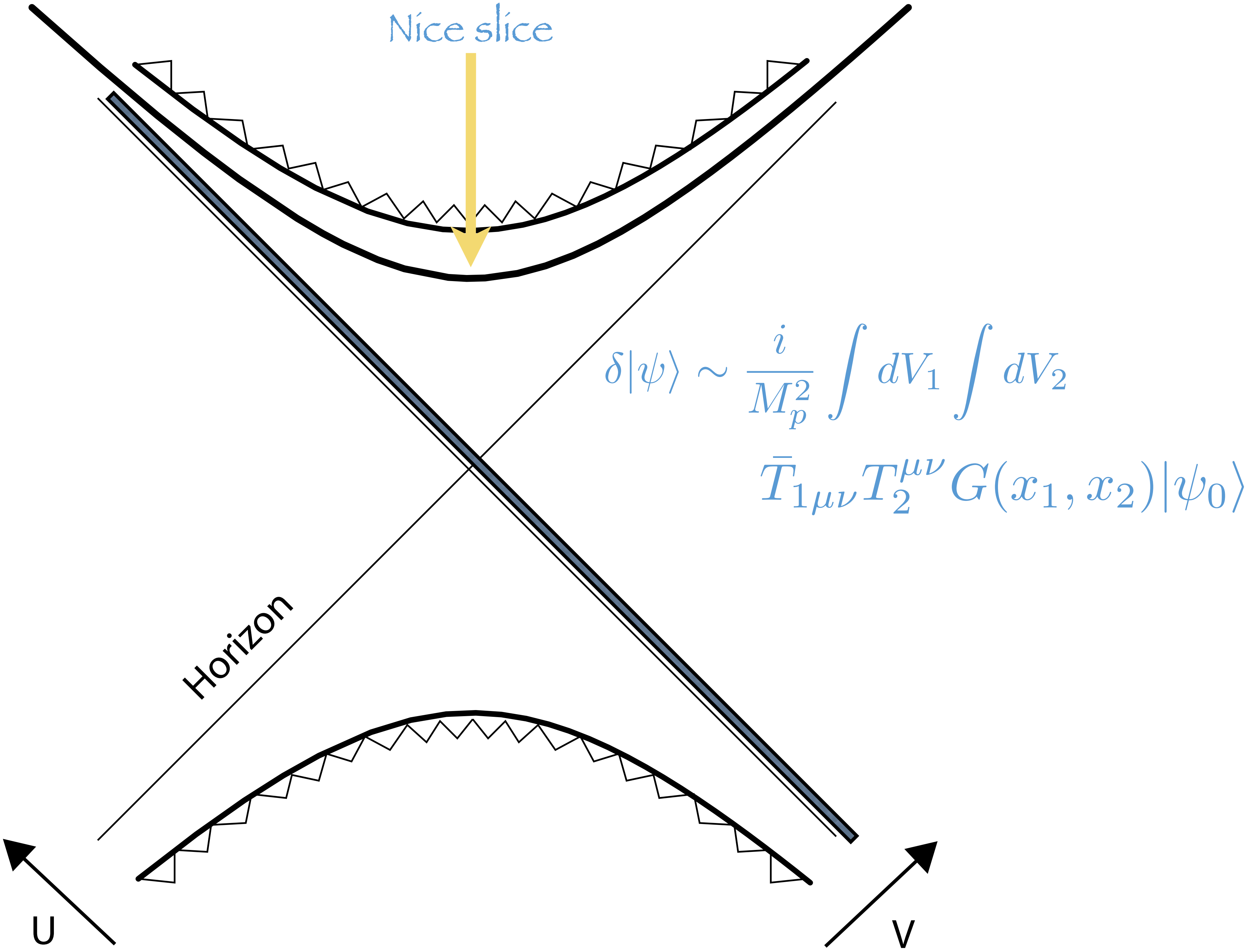
(cf. Page, 1993)

Large correlations between early perturbations/fluctuations and late state

Long time -- high energy




Schwarzschild t-translating...
Schwarzschild t-translating...
Horizon
U
V


Nice slice
$\delta|\psi\rangle \sim \frac{i}{M_p^2}\int dV_1 \int dV_2$
$\bar{T}_{1\mu\nu}T_2^{\mu\nu}G(x_1,x_2)|\psi_0\rangle$
Horizon
U
V

Other large geom effects; gauge subtleties ...

Earlier estimate: deformation of geodesics

$$\Rightarrow T \sim M \ln M$$

Large effect on nice slice state

$$\Rightarrow T \sim M^3$$

True gauge invariant? (Bohr's dictum ...)

Drop in "depth charge" detectors

(~relational obs.)

Large effect by $T \sim M^3$

(hep-th/0703116)

- Can't trust this perturbative approach beyond this time (semiclassical approx)
- Such a calculation of the state apparently breaks down
- But this was our argument for information loss!
- If no reliable argument for info loss -- no paradox

general argument: locality?

Nonperturbative gravity:

why should it be local?