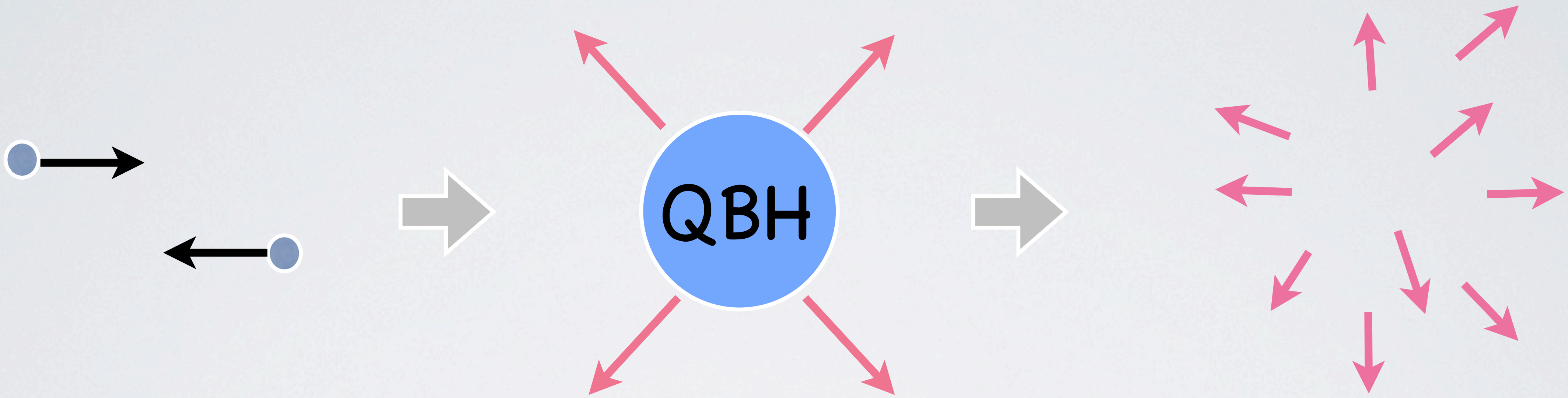
TOWARDS NONVIOLENT RESOLUTION OF THE UNITARITY CRISIS



Steve Giddings, UC Santa Barbara

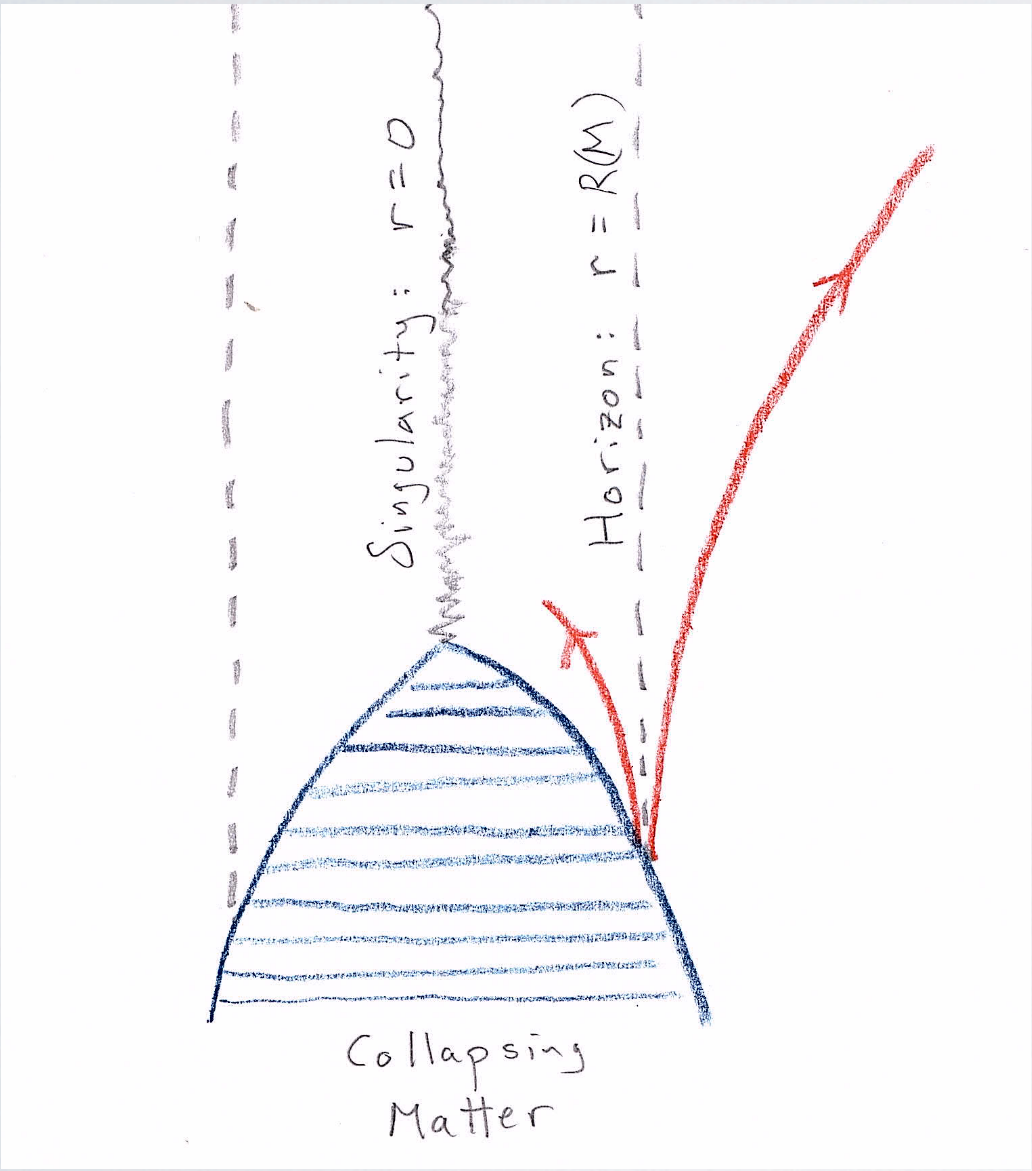
SBG: 0911.3395, 1108.2015, 1201.1037, 1211.7070, 1302.2613, 1308.3488, 1401.5804

SBG & Y. Shi: 1205.4732, 1310.5700

Proposal to save QM: nonlocality* (apparently necess.)

SG, hep-th/9203059; 't Hooft, gr-qc/9310026;
Susskind hep- th/9409089

Local picture:



Two questions:

What form does it take?

Transfer vs. delocalization

On what scale?

$\sim l_{\mathrm{Pl}}$ $\quad = R(M) \pm l_{\mathrm{Pl}}$

$\sim R(M)$ $\quad \sim R^3(M)$

* with respect to semiclassical geometry

Present proposal:

Localization valid to good approximation

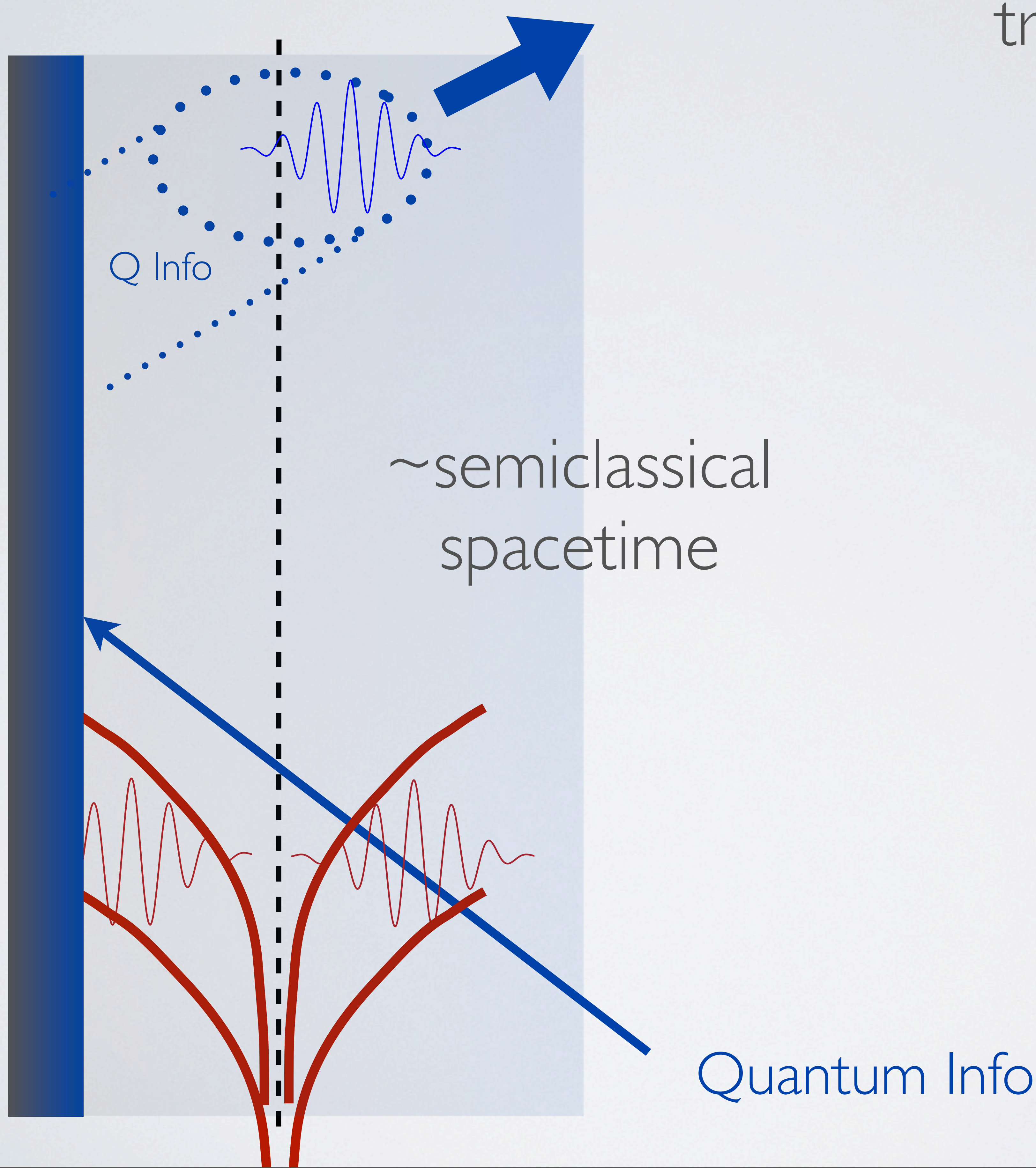
Information transfer, nonlocal wrt SC geometry

Relevant scale ~R

(“Goldilocks principle!”)

Basic picture

"Nonviolent entanglement transfer"



How to realize/describe in a consistent framework?

- Fundamental framework

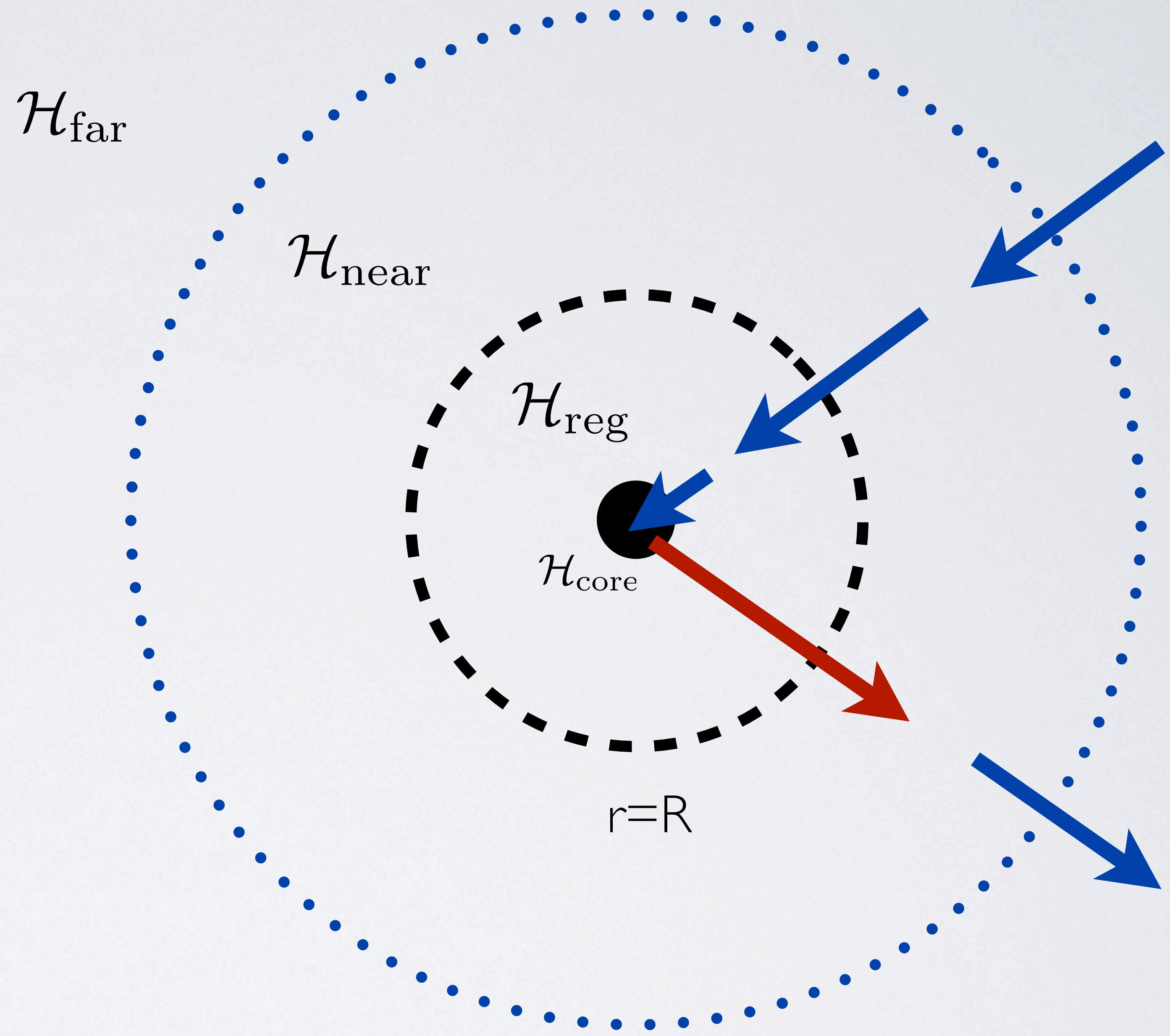
- Effective framework

Possible fundamental approach

1. Localization: subsystem structure

2. Transfer: interactions

Qs:
Hilb space struct, symmetries, etc.



LQFT evolution vs. "NL" modification

Possible effective approach: test consistency

- know SC geom + LQFT is valid for many purposes

- can try to parameterize departures from this in QFT framework

If consistent picture: clue to fundamental theory

Effective description: possible desiderata:

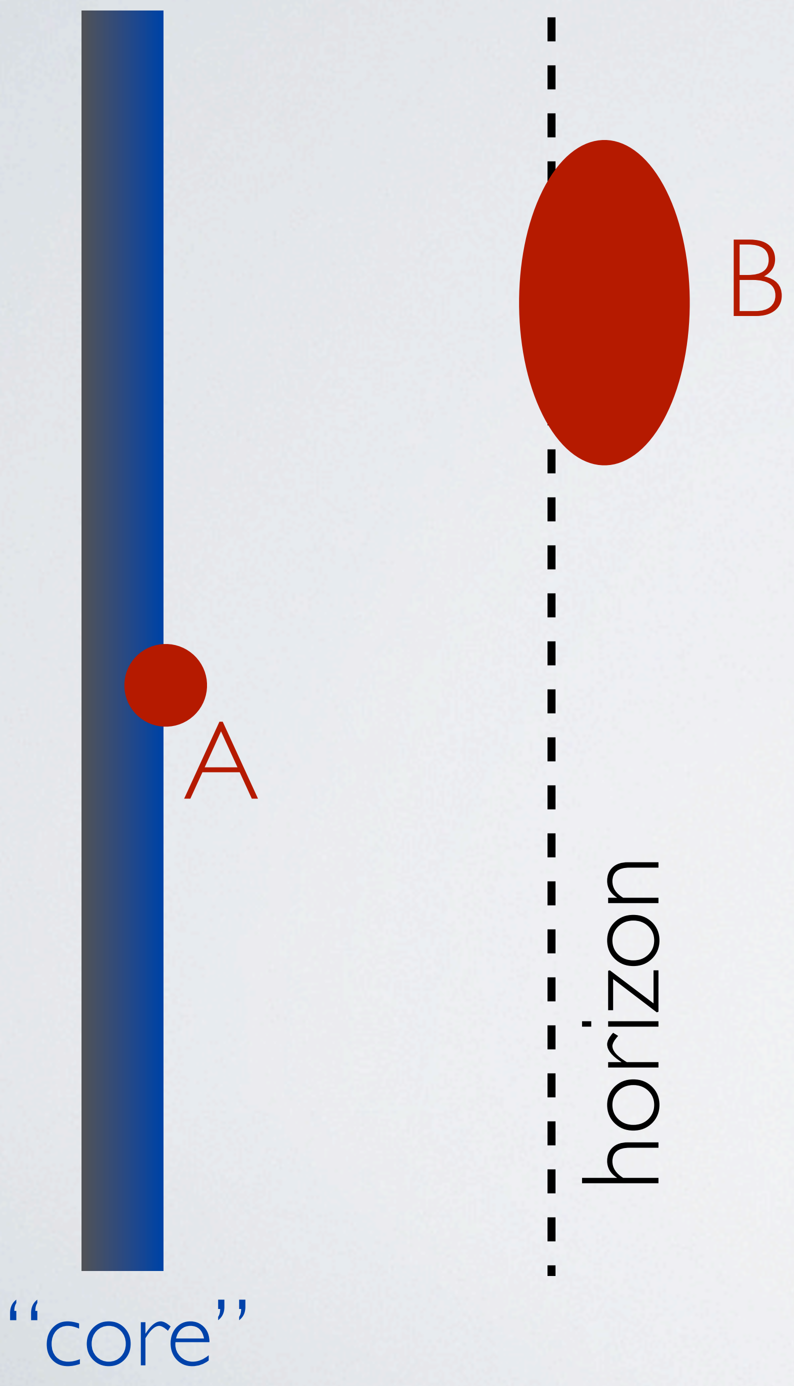
- nonviolent (to physics, and to infalling observers!)

- correspondence: large R, small R

- consistent with realizable mining

- consistent w/ stat mech. (but: $S_{\rm bh} \neq S_{\rm BH}$?)

Effective description: model



$$S_{NL} = \sum_{AB} \mathcal{O}_A G_{AB} \mathcal{O}_B$$

~ local operators

(compare G=const. : ~wormholes)

E.g. $\mathcal{O}_{A,B} = \phi^I \;,\; T_{\mu\nu} \;,\; \ldots$

To answer questions: focus on outside:

The *effective source approximation*

$$S_{NL} \to \sum_{Ab} \int dV_4 \mathcal{O}_A G_{Ab}(x) \mathcal{O}_b(x) \to \sum_b \int dV_4 J_b(x) \mathcal{O}_b(x)$$

E.g. $\int dV_4 J(x) \Phi(x)$, $\int dV_4 J^{\mu\nu}(x) T_{\mu\nu}(x)$ ...

(~"horizon fluctuations")

For purposes of near-horizon dynamics: can such effective sources 1) get needed info out 2) not have unacceptable ("violent") consequences

E.g. scalar $\int dV_4 J(x)\Phi(x)$

Can achieve:

- needed info. flux
- nonviolent
- correspondence: large-R, small-R

  (from scaling)
- extra info. flux when mining channel for extra energy flux

  (avoid "overfull" black holes)

arXiv:1302.2613

arXiv:1310.5700, w/ Y. Shi

Possible concern: generic extra flux

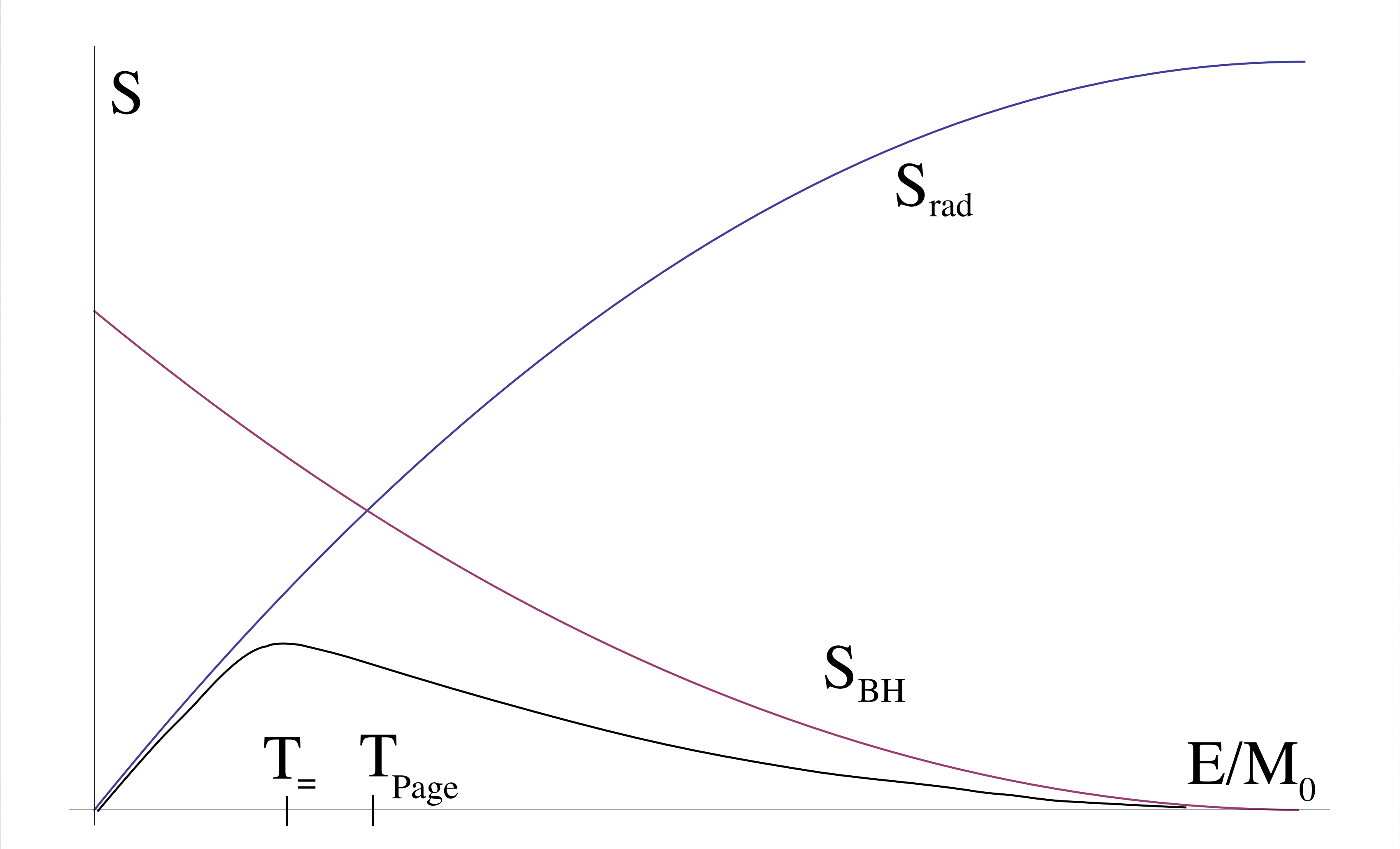
Consistency w/ thermodynamics/stat mech?

1308.3488

In simple models, $\frac{dE}{dt} > \frac{dE}{dt}^{\text{Hawk}}$: *extra flux*

Indicates $S_{bh} < S_{BH}$ e.g. $\frac{dE}{dt} \uparrow \Rightarrow T_{\text{equilib}} \uparrow$

$\Rightarrow \frac{\partial S_{\text{bh}}}{\partial M} \downarrow$



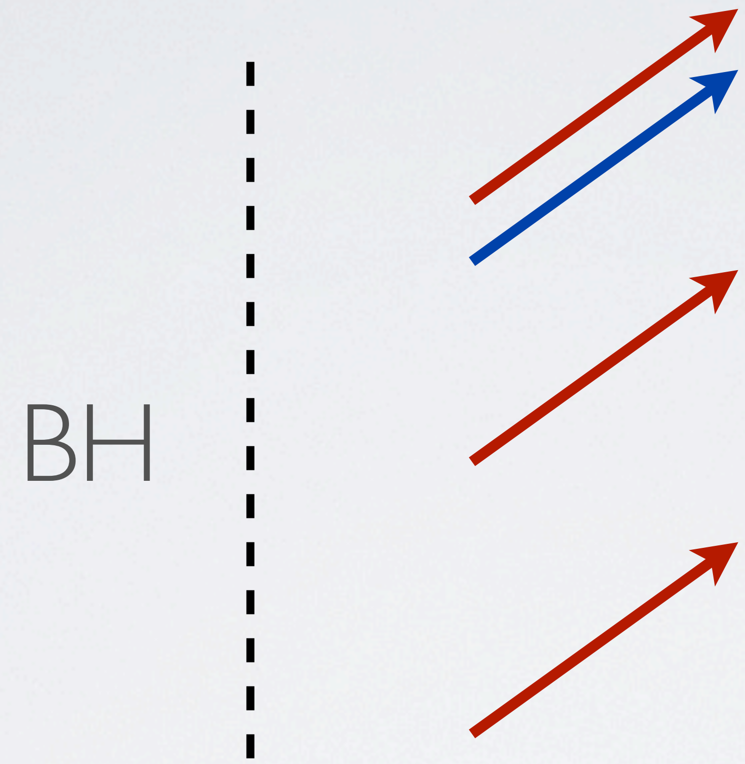
no contradiction w/ basic principles

✓

(any sharp contradiction with known facts?)

If Hawking flux already present: need information without extra energy

Modulate ~ radio signal



One way to describe:

$$\sum_a \int dV \mathcal{A}_a G_a^{\mu\nu}(x) T_{\mu\nu}(x) \longrightarrow \int dV H^{\mu\nu}(x) T_{\mu\nu}(x)$$

Results

- explicit 2d model (~partial waves)

- extra flux w/out extra energy (lin. order)

$$\delta_H T_{uu} \neq 0 \qquad \delta P_u = \int_{-\infty}^{\infty} \delta_H T_{uu} = 0$$

- can generalize beyond linear

- nonviolent

$$\delta\mathcal{R} \sim 1/R^2$$

Induced flux: stress tensor couplings

$$S_H = -\int dV\, H^{\mu\nu} T_{\mu\nu}$$

$$\langle H, t | T_{\mu\nu}(x) | H, t\rangle - T^{\mathrm{Hawk}}_{\mu\nu} = -i \int dV' H^{\lambda\sigma}(x') \langle 0 | \left[T_{\mu\nu}(x), T_{\lambda\sigma}(x') \right] | 0 \rangle$$

e.g. 2d ($\xrightarrow{\text{PW}}$ 4d) $\quad u, v = t \pm r_* \quad ds^2 = -\left(1 - \frac{R}{r}\right) du dv$ ← $f(r)$

$$[T_{uu}, T_{u'u'}] = i(:T_{uu}: + :T_{u'u'}:)\delta'(u-u') - \frac{i}{24\pi}\delta'''(u-u')$$

⟶ δT_{uu} $\qquad \delta P_u(u) = \int^u du' \delta T_{uu}$

e.g. $\quad H^{uu} \underset{u\to\infty}{\to} 0$: $\qquad = 0$

Added bonuses of stress-tensor coupling/HR modulation

(~ near-horizon metric fluctuations)

- Universal addresses mining.

energy channels become information channels

- Effects of couplings suppressed when HR suppressed

e.g. weak coupling to mining apparatus

If a picture like this is correct, important clue to fundamental framework

Based on successively-refined subsystem structure?

~Banks/Fischler?; 1201.1037?

... but puzzles

... to be discussed