Matter does not matter: Universality in ultra-relativistic black-hole collisions

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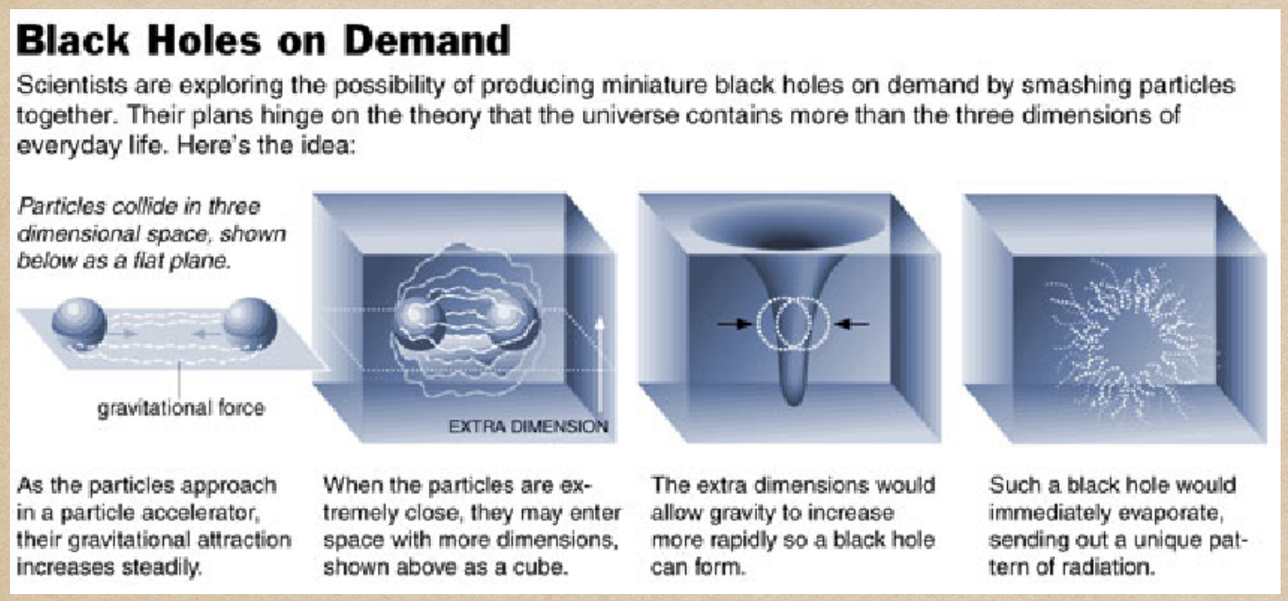
Overview

- Motivation
- High-energy collisions of matter balls
- The impact of BH spins on collisions
- Unequal-mass BH collisions
- Preliminary results: BH collisions in $D > 4$
- Conclusions

Motivation

- Tests of the Hoop conjecture Thorne 1972
- TeV Gravity



- AdS/CFT correspondence

  Study quark-gluon plasma through BH collisions in AdS

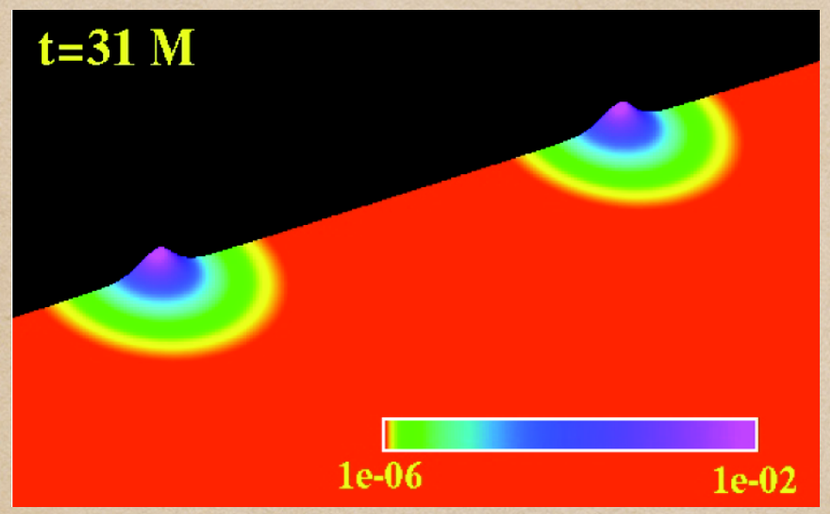
  e.g. Bantilan & Romatschke 1410.4799

  Impact of charge on the collisions / thermalization
- Explore GR in the most non-linear regime

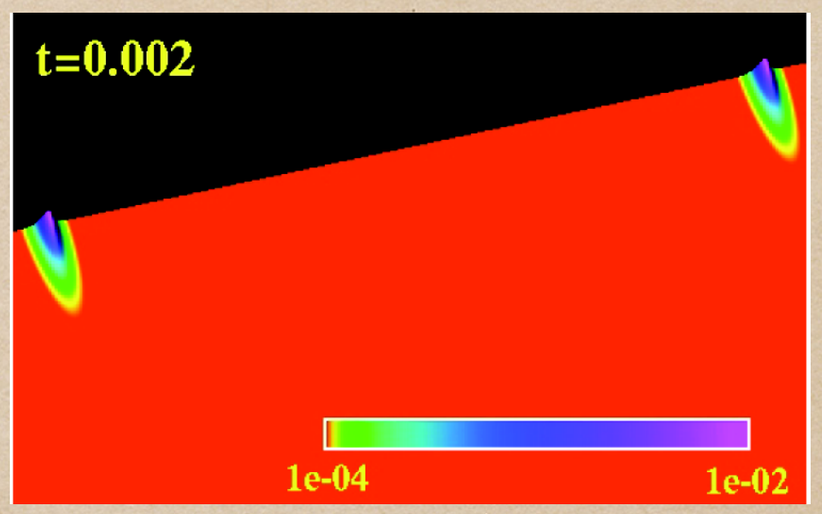
Collisions of matter balls

- Einstein + minimally coupled, complex scalar field

Choptuik & Pretorius PRL (2010)



$\gamma = 1$



$\gamma = 4$

BH formation threshold: $\gamma_{\rm thr} = 2.9 \pm 10\,\% \sim \gamma_{\rm Hoop}/3$

- Einstein + perfect fluid balls

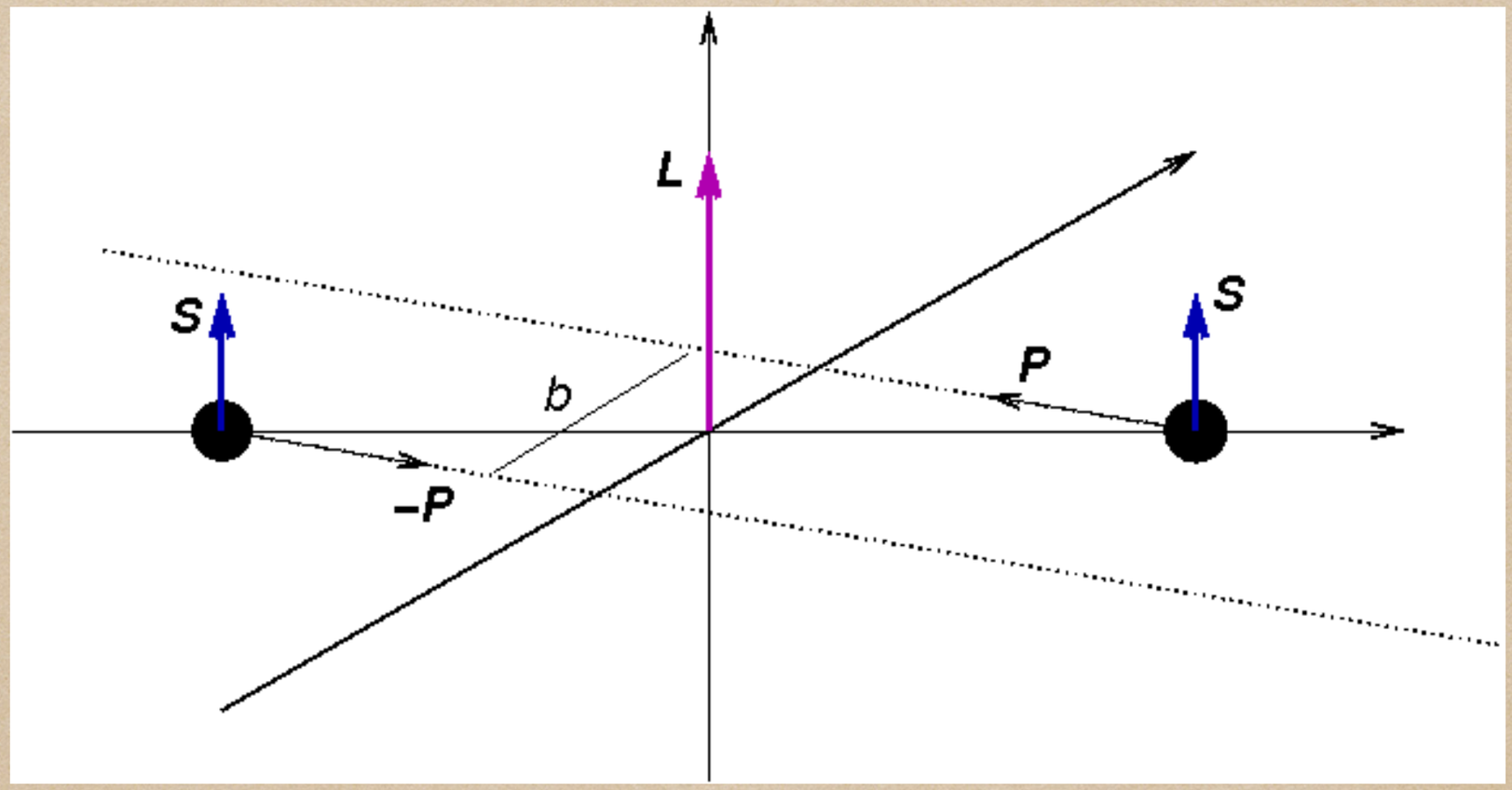
East & Pretorius PRL (2013), Rezzolla & Tanaki CQG (2013)

  - BH formation also compatible with Hoop predictions
  - Signature of Type I critical behavior

Collisions of spinning BHs in D=4

- Orbital hang-up: Campanelli et al. PRD (2006)
- Equal-mass BHs, Boost $\gamma = 1/\sqrt{1-v^2}$

  Impact parameter $b = L/P$



- How are scattering threshold and radiated GW energy affected?

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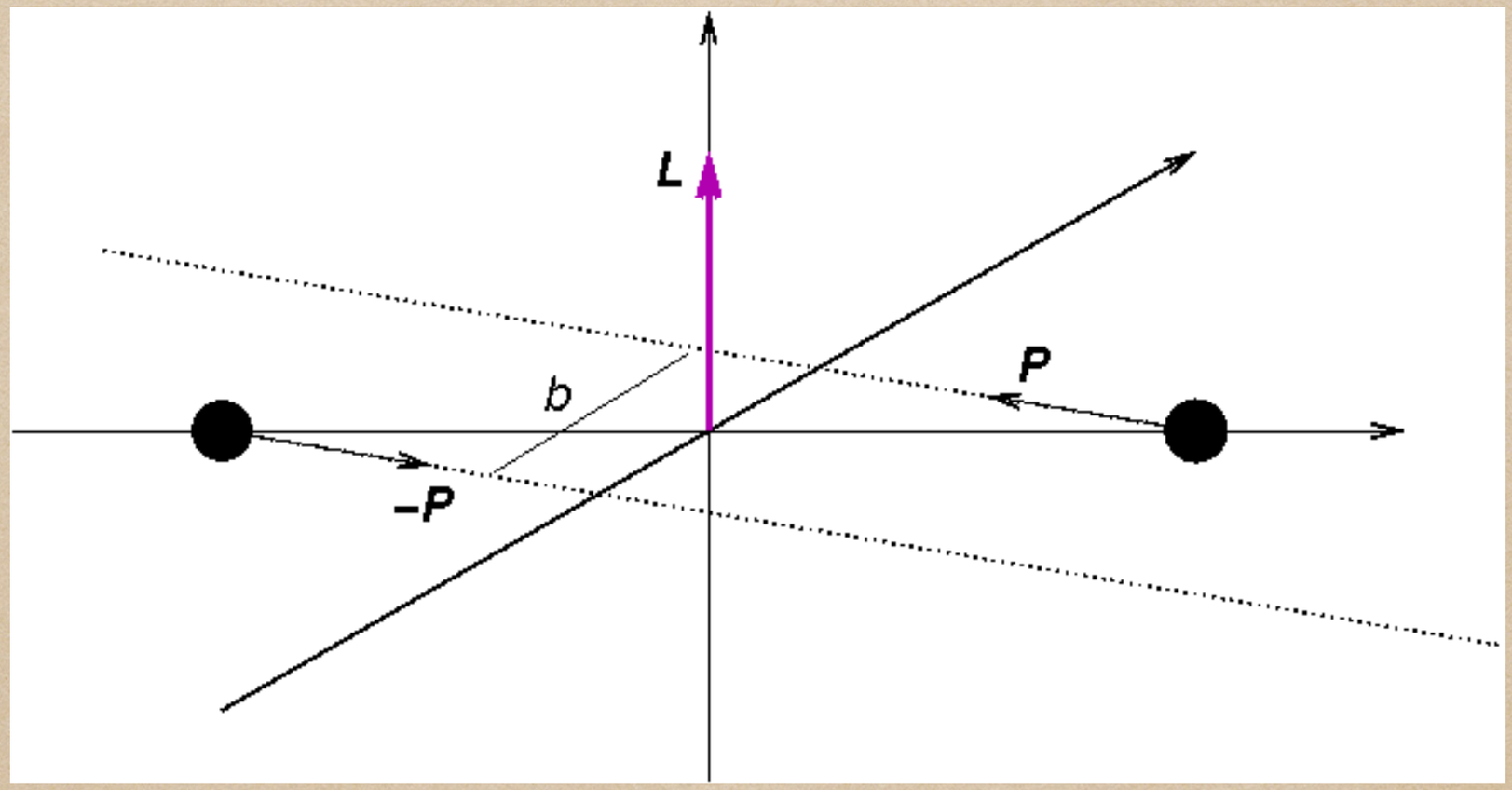

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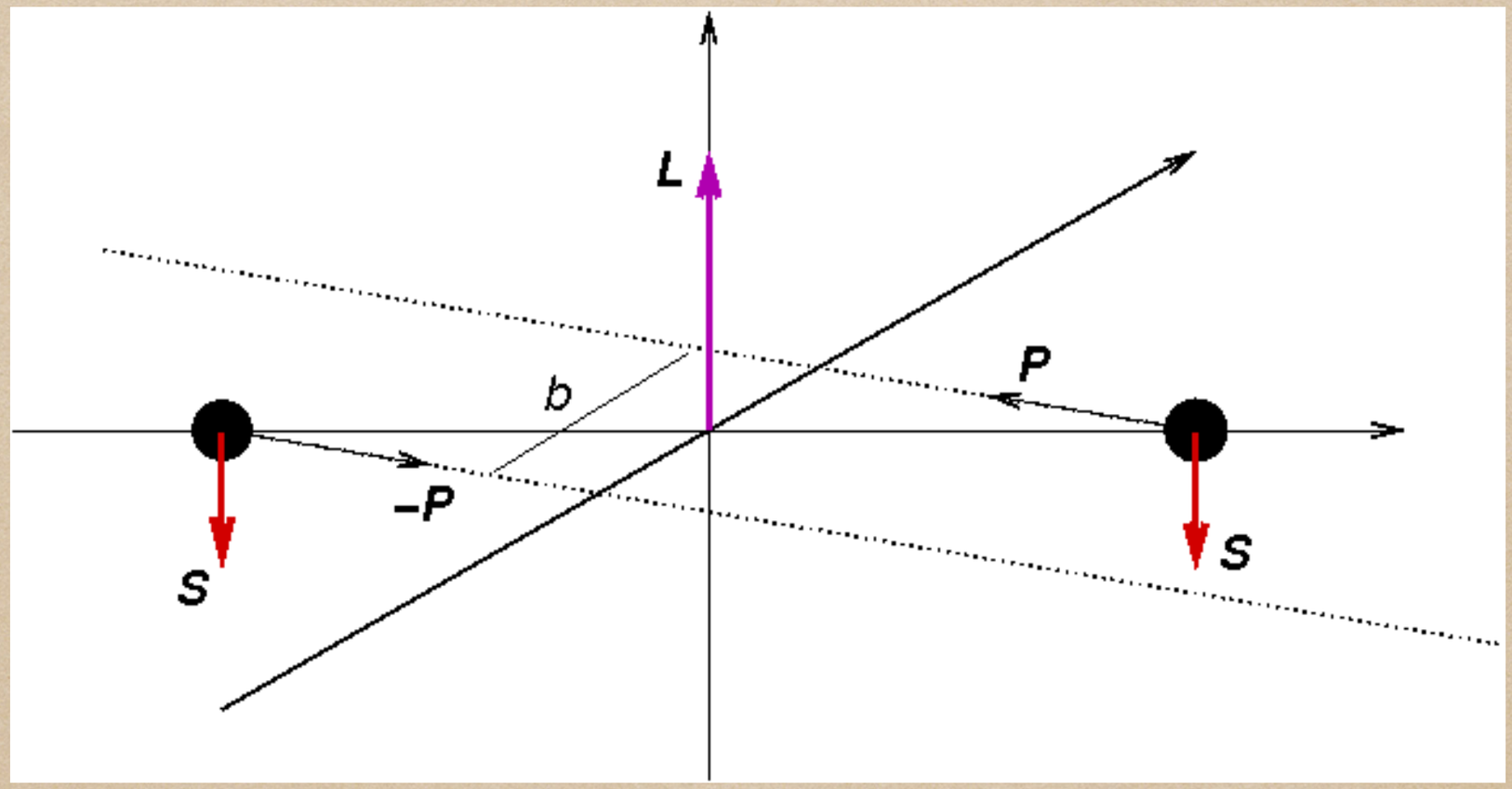

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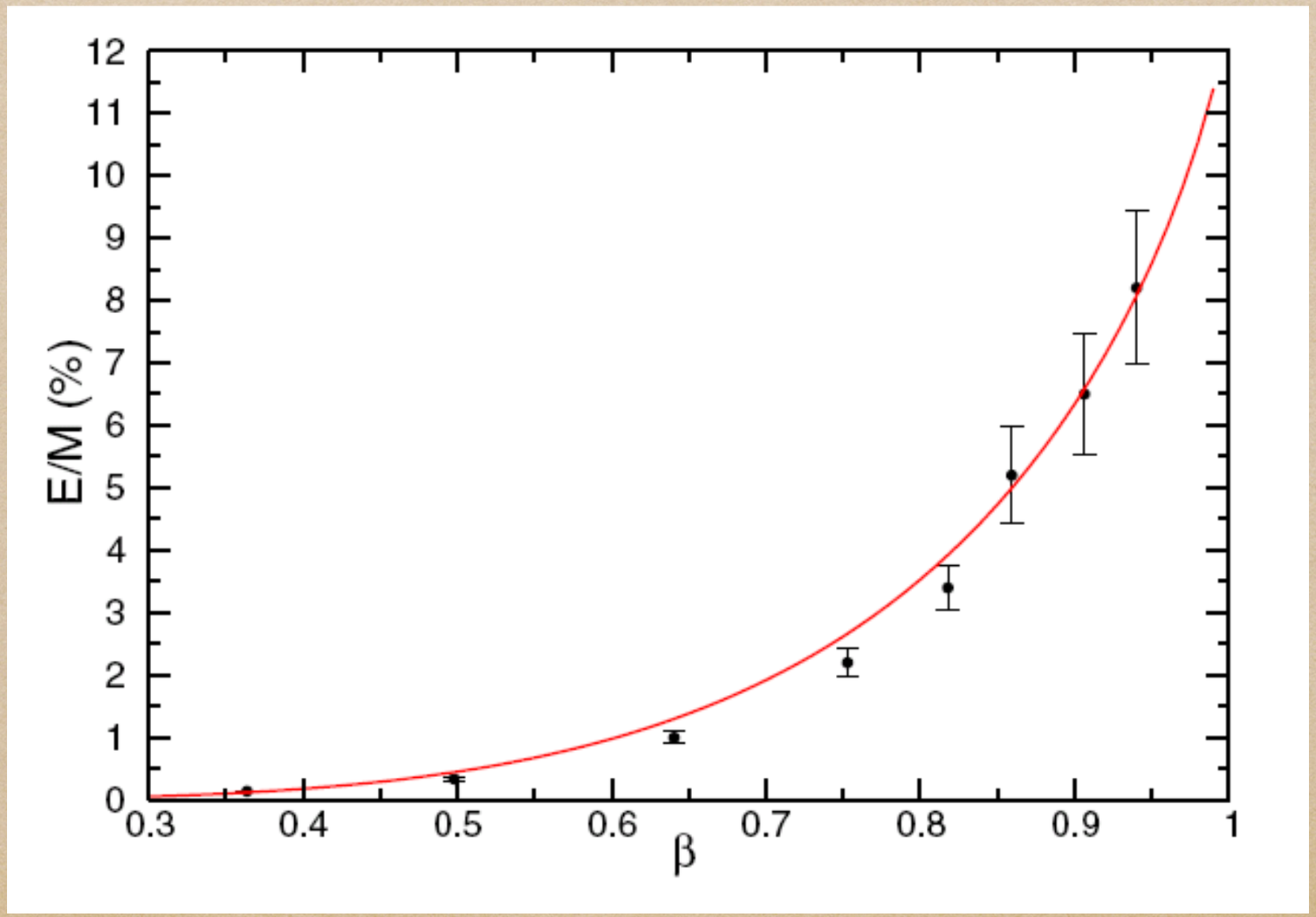
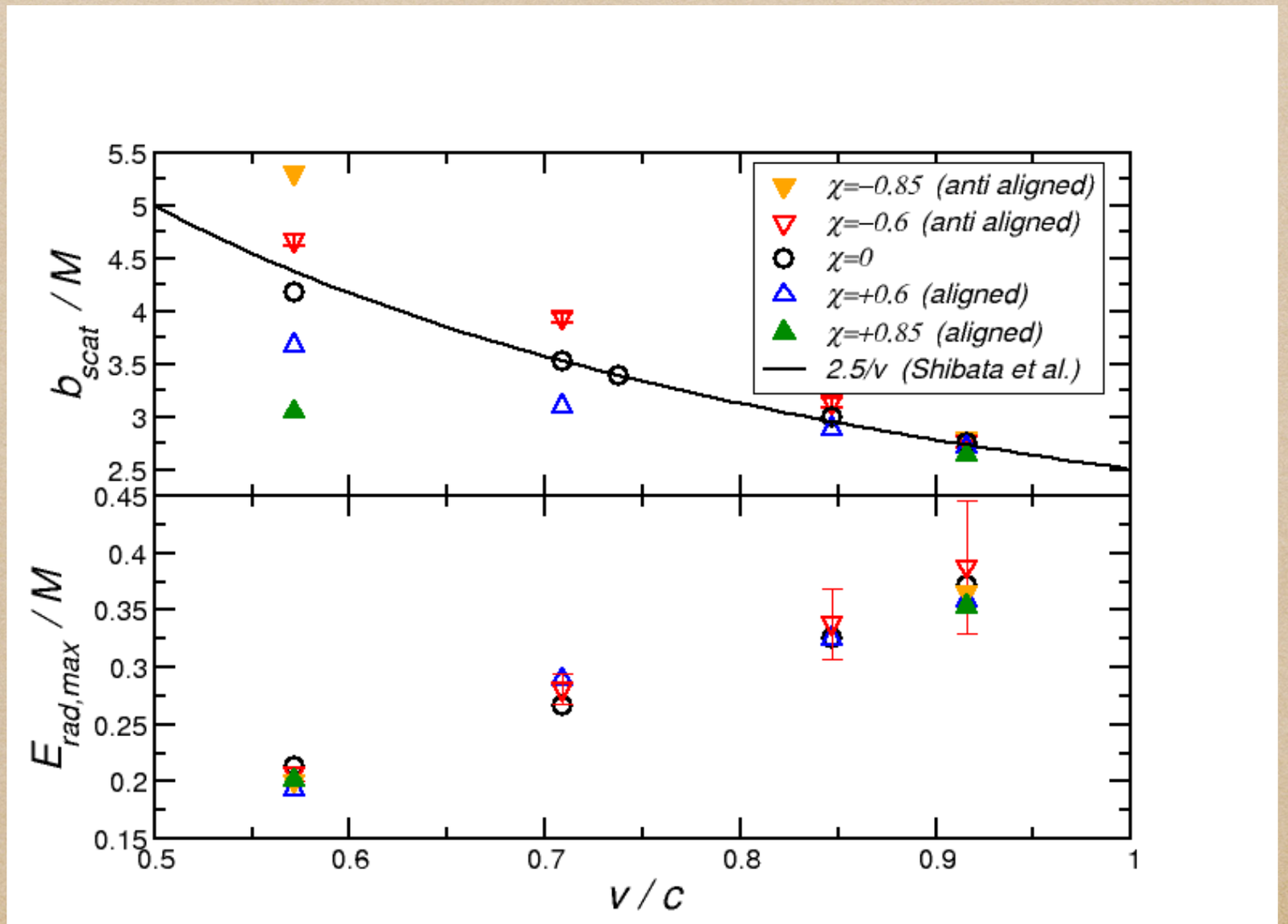
Boosted BH head-on collisions in D=4

- BSSN, Cactus, Carpet, Moving Puncture, TwoPunctures, AHFinderDirect
- Equal-mass BHs, no spin $\lim_{\beta\to 1} E_{\rm rad} = 14 \pm 3\ \%$



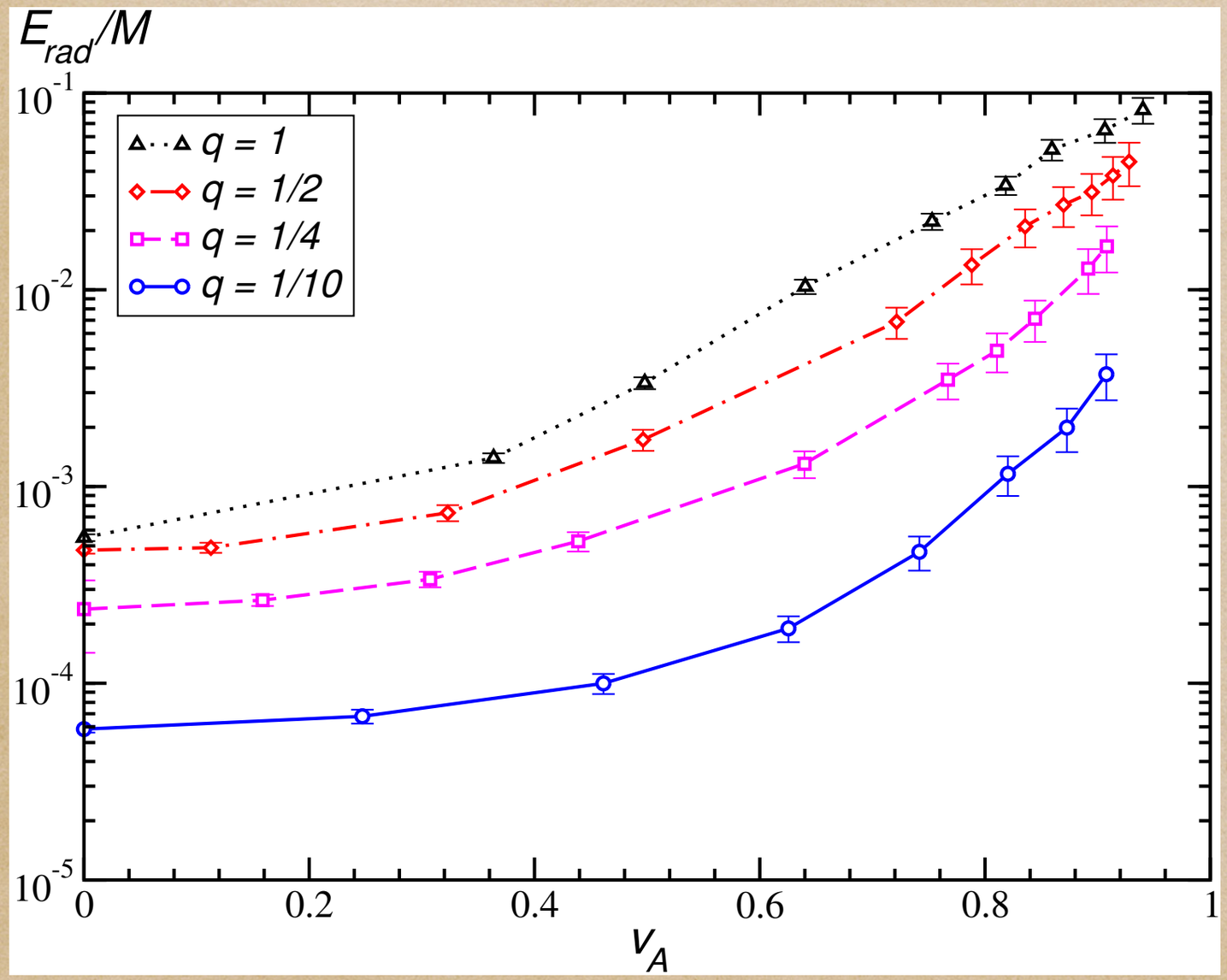
Grazing collisions in D=4

- Spins: aligned, zero, anti aligned US, Berti, Cardoso, Pretorius PRL '13
- $b_{\rm scat}, \quad E_{\rm rad}$: spin effects washed out as $v \longrightarrow c$



Unequal-mass head-on collisions in D=4

- No spins, center-of-mass frame — US, Berti, Cardoso, Pretorius PRD '16
- Mass ratio $q = m_2/m_1 \leq 1$



$$E(q=1) \to 12.7 \pm 1.5\ \%$$
$$E(q=1/2) \to 11.2 \pm 2.7\ \%$$
$$E(q=1/4) \to 11.6 \pm 3.0\ \%$$
$$E(q=1/10) \to 12.0 \pm 3.0\ \%$$

Conclusions

- All studies confirm: ”Matter/structure does not matter”
  - Boson star collisions
  - Fluid balls
  - Black-hole spins
  - Different masses

In the limit $v \to c$ collisions appear to be universal

- How about higher dimensions?