



The Lazarus Project: Modeling gravitational radiation from coalescing binary black holes

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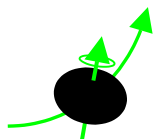
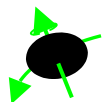
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Lazarus = PN + interface + FN + interface + CL

inspiral
FL/PN

plunge/merger
FN

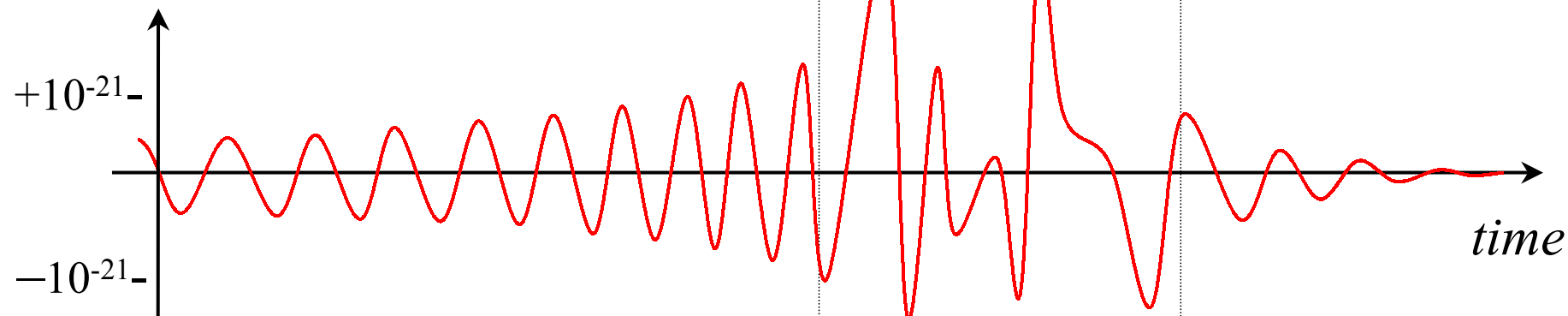
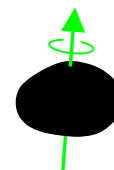
ring-down
CL



IBBH

~ 40 M

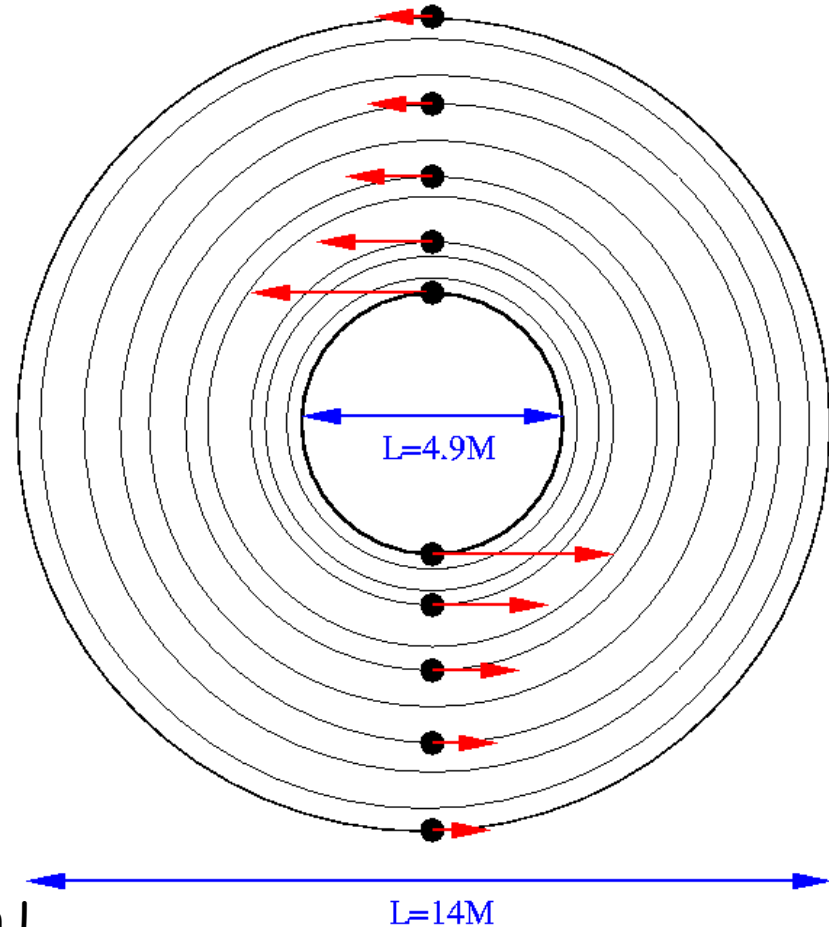
~ 100 M



interface:
cross-checking

interface:
cross-checking

Binary black holes in quasi-circular orbits



$P=0.095M$

$P=0.12M$

$P=0.15M$

$P=0.21M$

$P=0.33M$

$S=0$

$J=0.77M^2$

$J=0.79M^2$

$J=0.84M^2$

$J=0.9M^2$

$J=0.98M^2$

$L=14M$

$L=4.9M$

- We need a model and some early robust results:

(Flanagan & Hughes, 98)

- A first 'early stage' model:
equal mass and non spinning BBH

Conformally flat puncture data

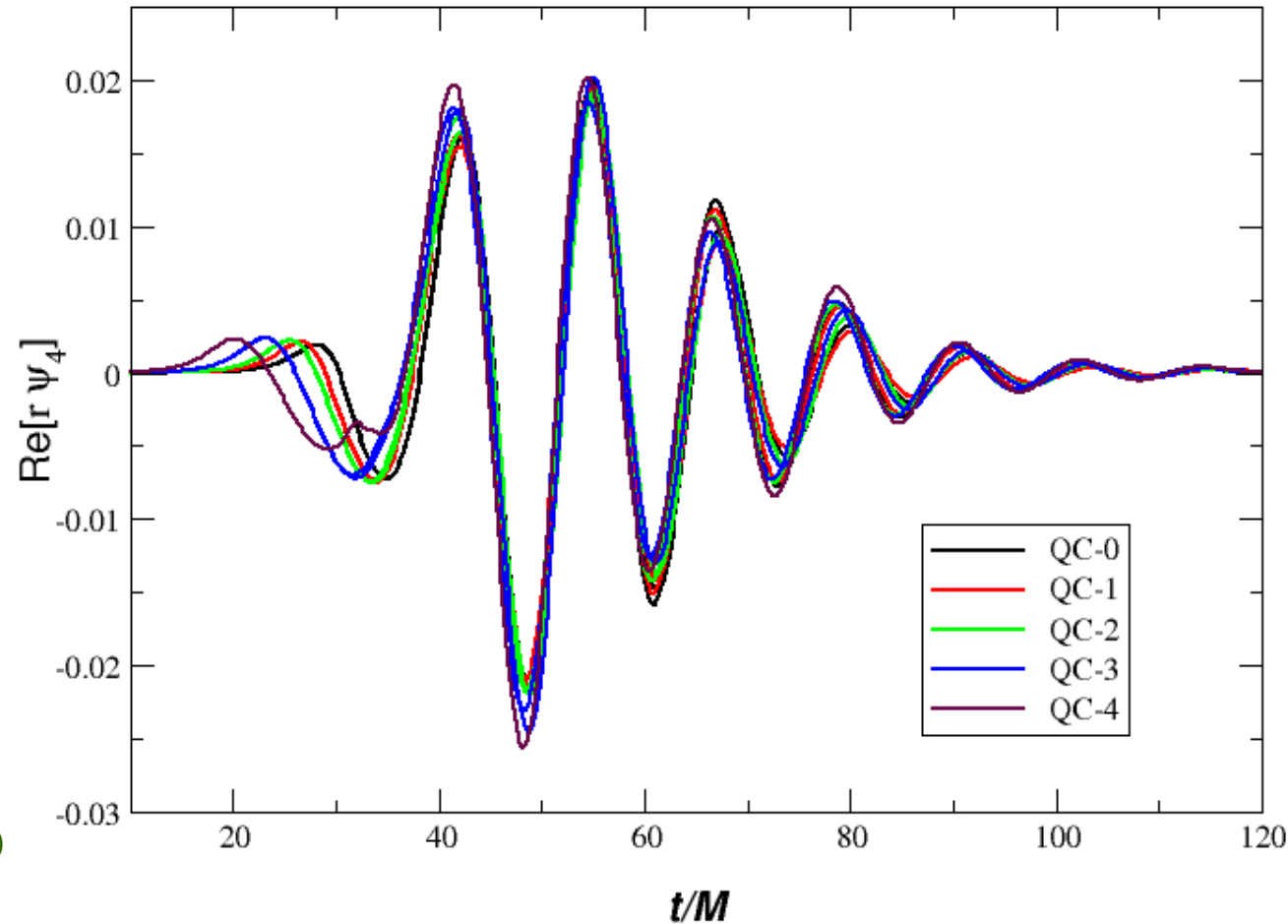
(Cook 94; Brandt, Brüggmann 97)

- Meet PN regime at larger separation L

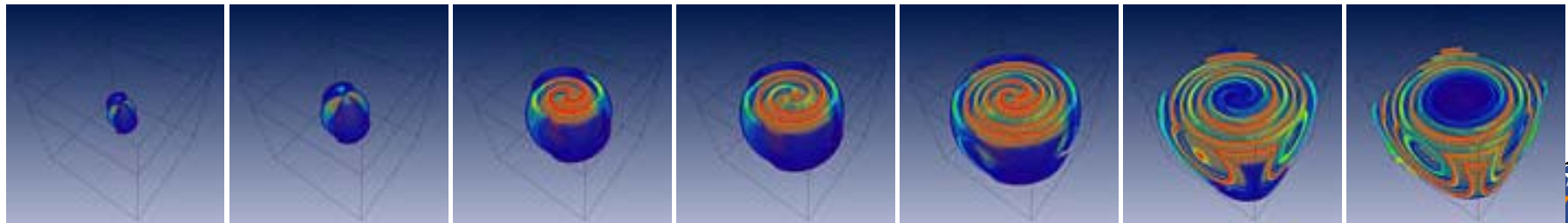
Assess the validity of initial conditions dynamically

What are the robust features of the plunge waveforms?

A first glimpse on Plunge Radiation



- 3% total mass
- 12% angular momentum (polar axis)
- Merge in less than orbital time.
- Spectrum peak close to QNR of the final Kerr hole $f \sim 300$ Hz for $35 M_{\odot}$.
- Internal consistency: vary transition time (accuracy 20%)



Manuela Campanelli, LSC
Workshop 3/20/2002

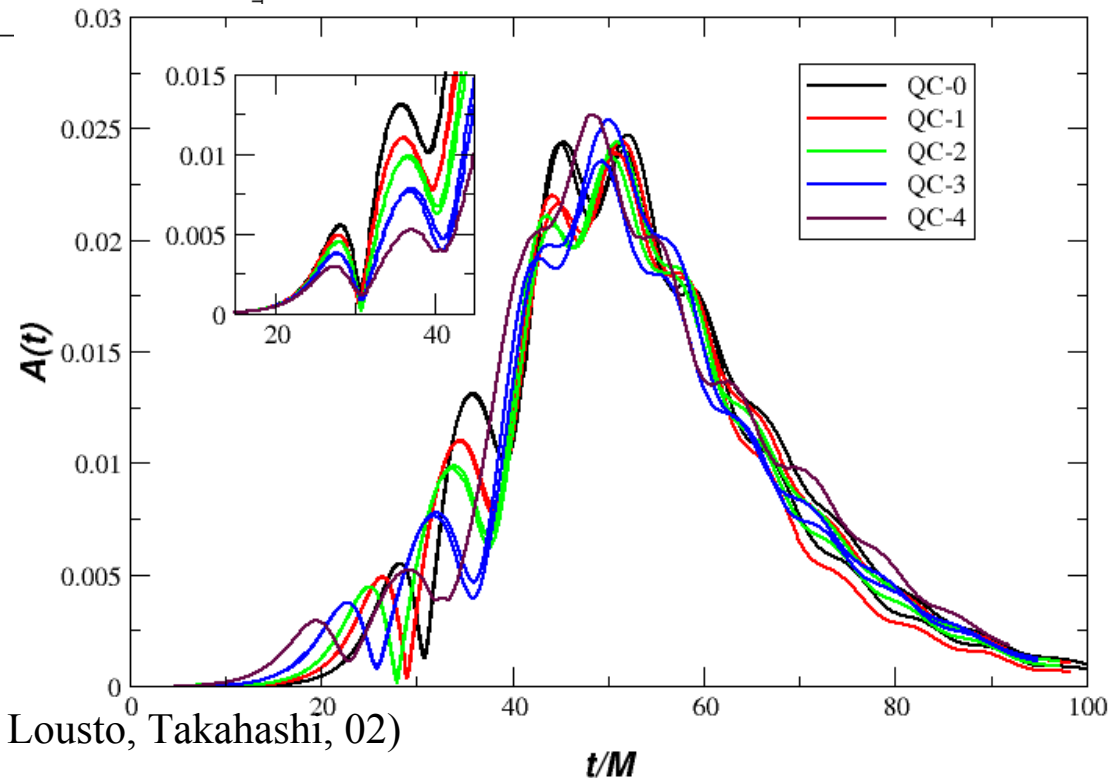
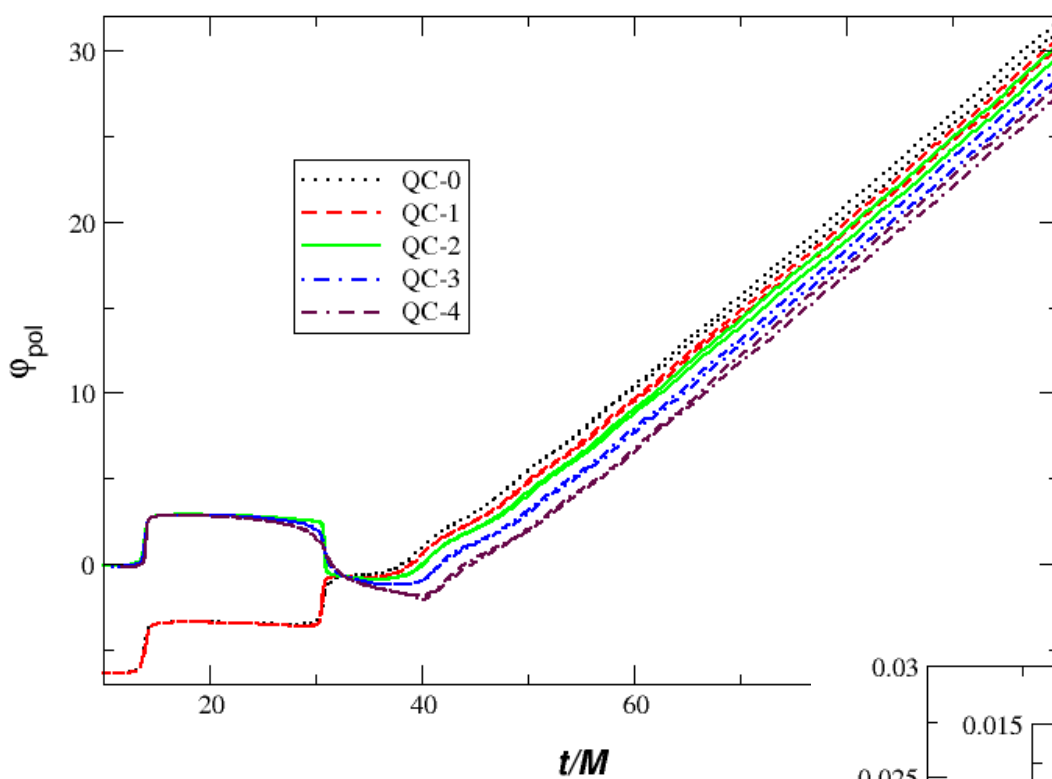
(Baker, Campanelli, Lousto, Takahashi, 02)

Circular polarization

$Re \psi_4$ and $Im \psi_4$ 90 deg out of phase

$$\Psi_4 = A(t) e^{i \phi(t)}$$

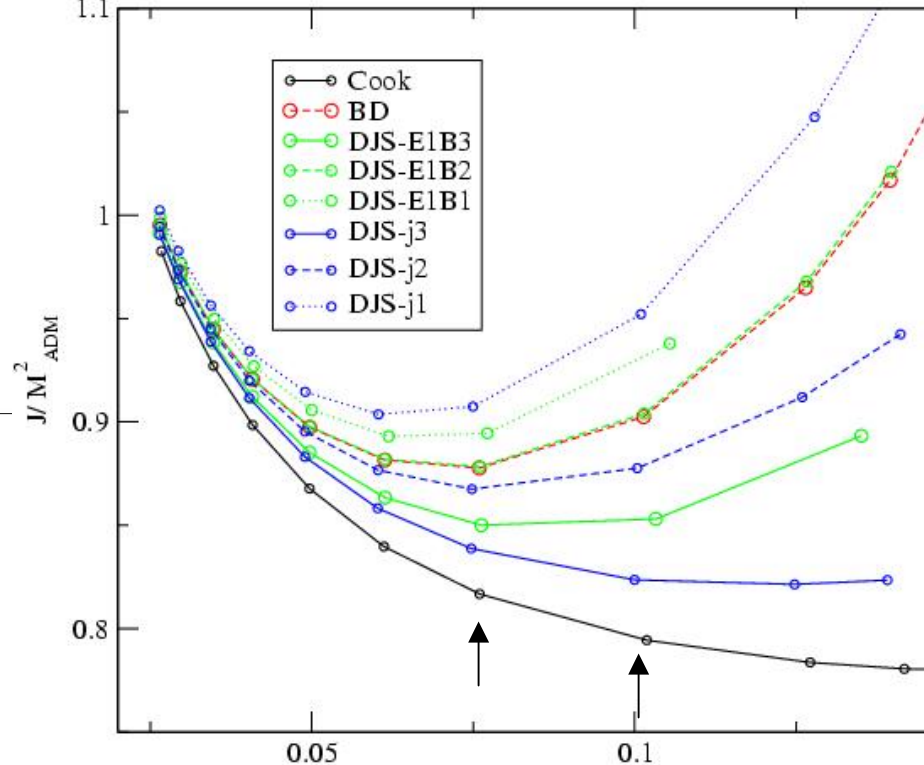
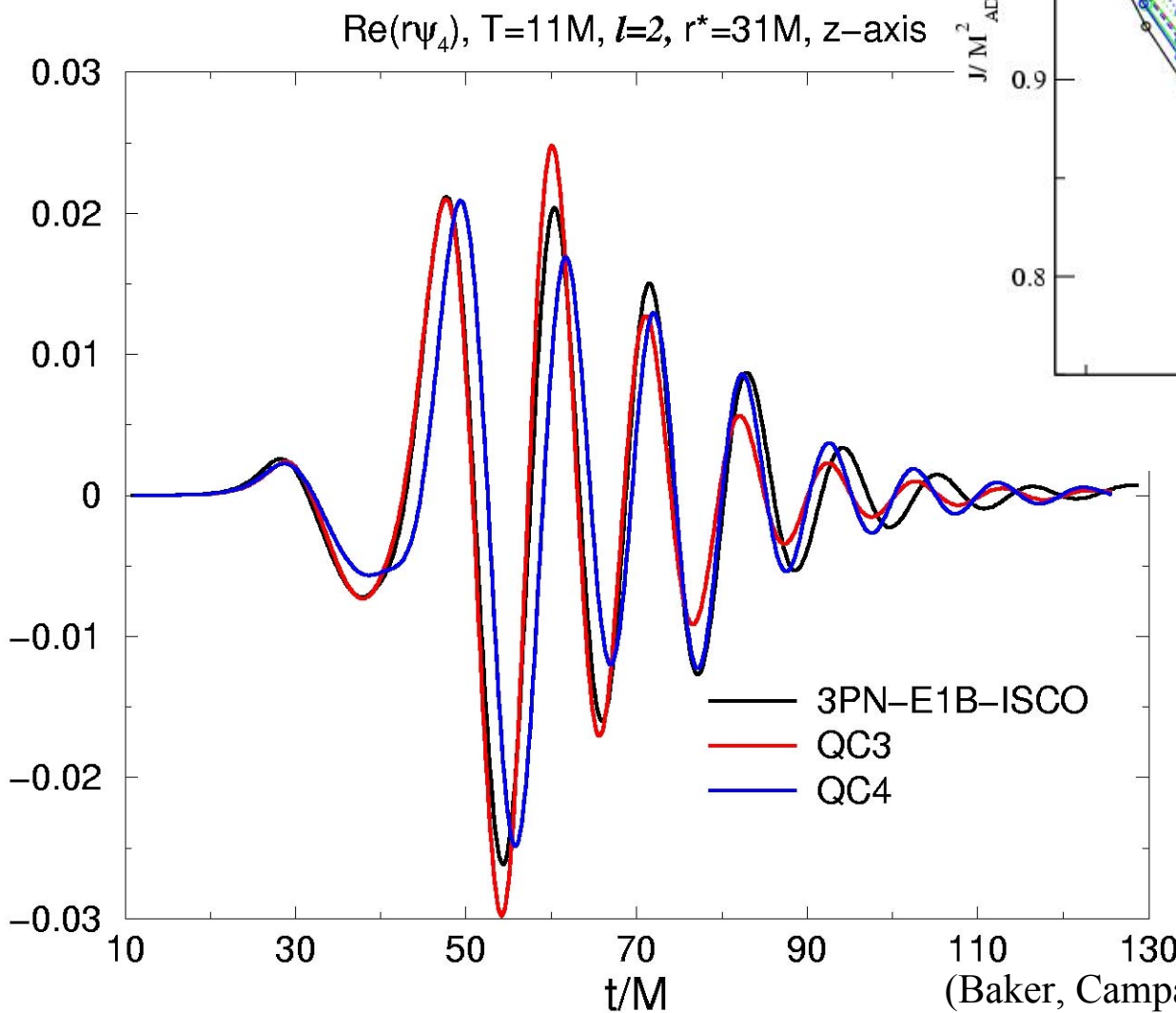
(Observer along the polar axis)



- Dynamics dominated by rotational motion.
- ID artifact (not circularized) shrinks with increasing L . Not so bad ...

Comparisons with PN

- **3PN-E1B-ISCO** and **QC3/QC4** parameters are very close, but **PN** not converging ...



Going beyond **QC4** ...

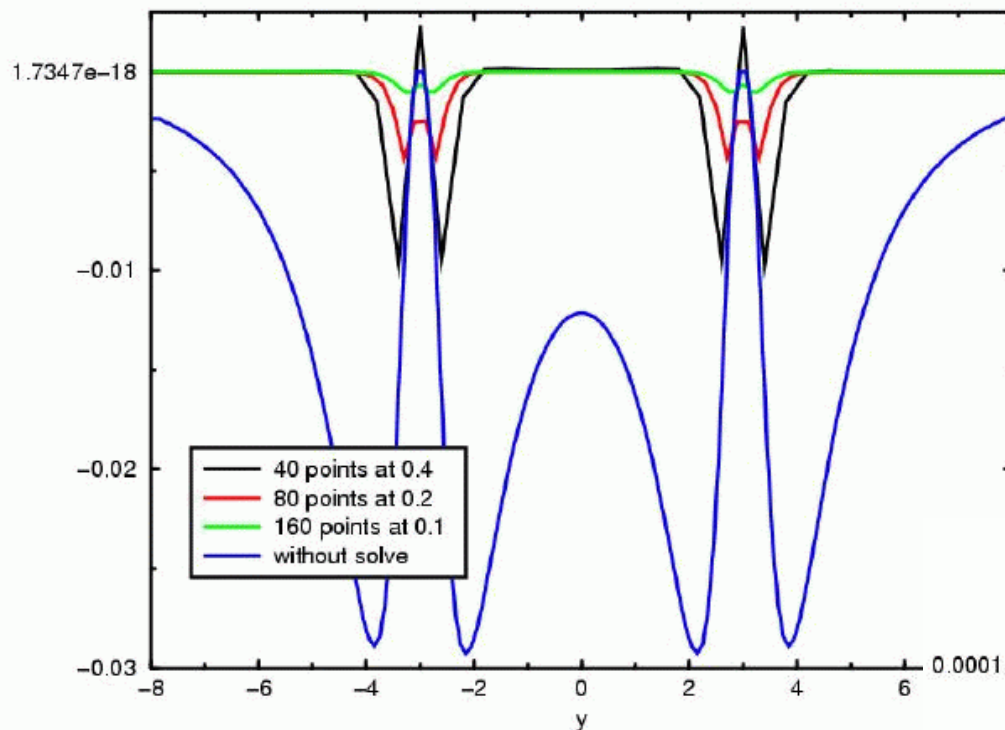
- Longer numerical simulations!
- Comparisons with **FN** needed!

(work in progress ... AEI)

(Baker, Campanelli, Lousto, Takahashi 02)



Hamiltonian constraint



Quadratic convergence

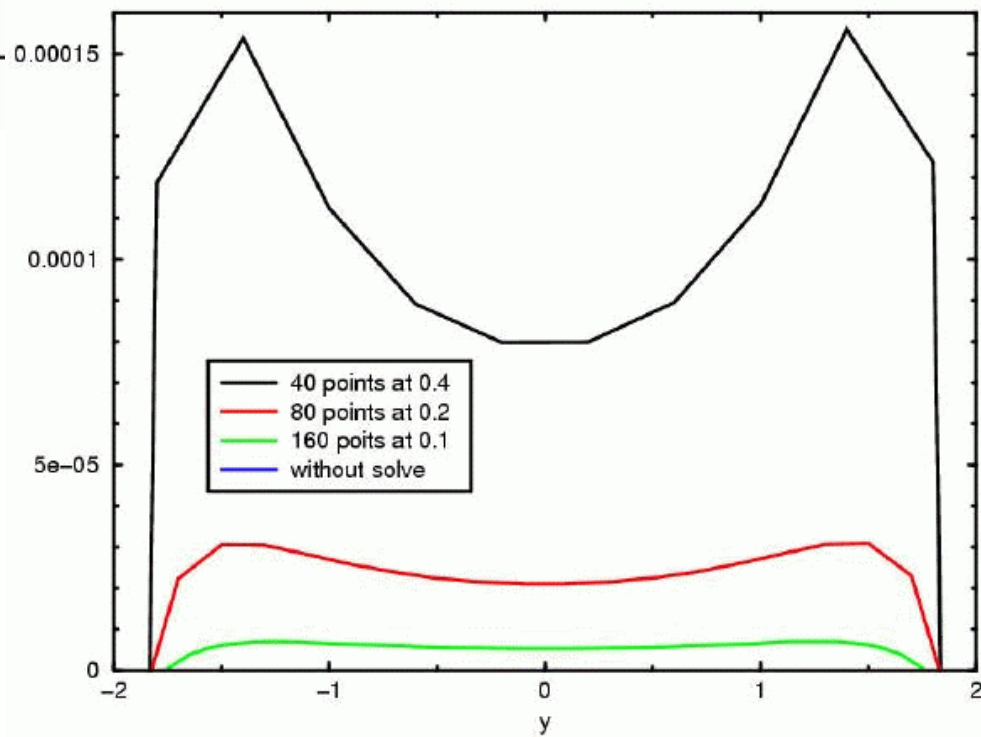
(Bruegman, Campanelli, Diener, Tichy)

(work in progress ... UTB/AEI/PSU)

PN initial data

- Solving the Einstein's constraints including free PN information.
- Evolve and compare waveforms to explore dependencies on ID !

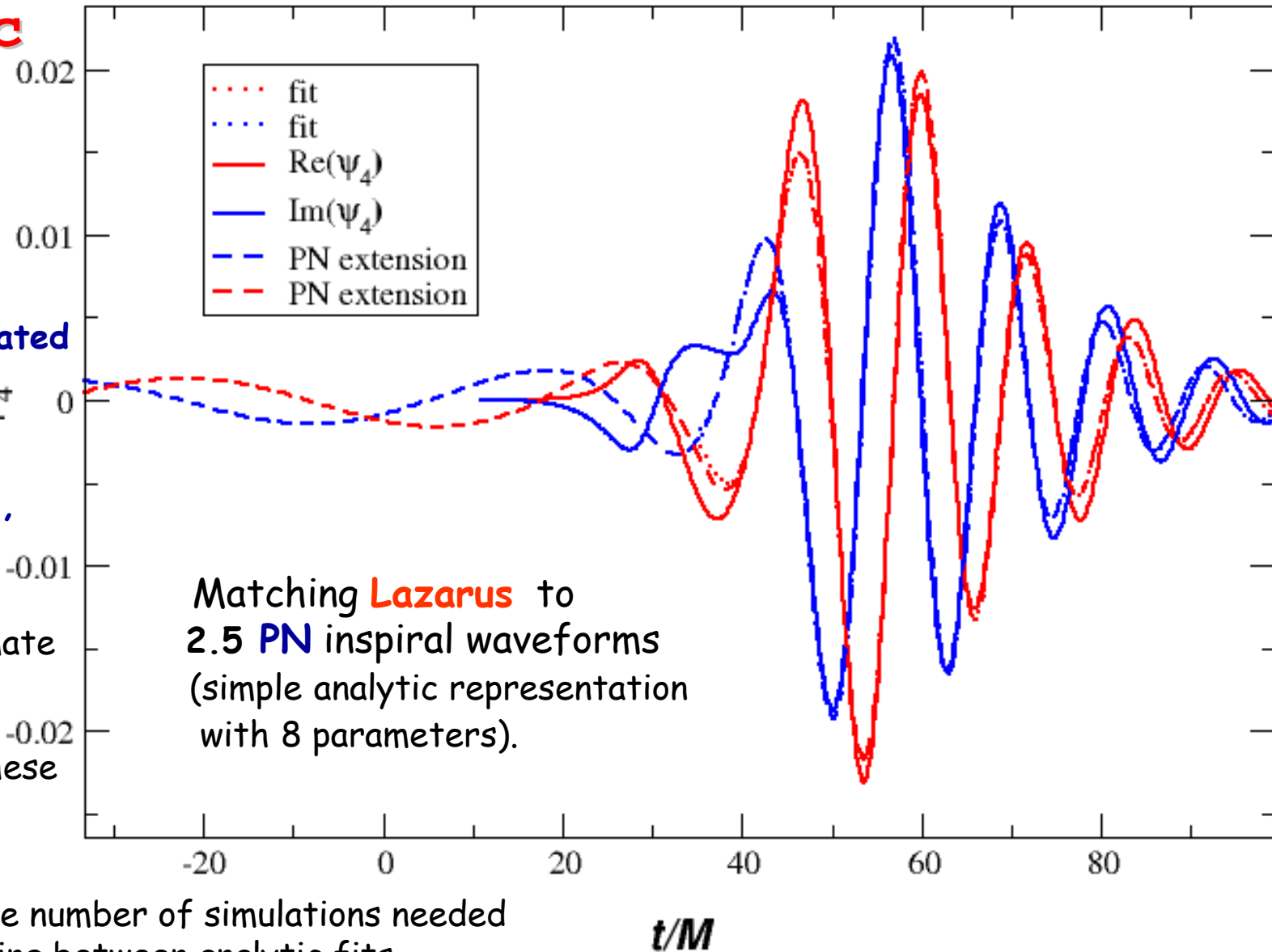
Hamiltonian constraint



Analytic Fitting

Explore the transition to more complicated dynamics of spinning and unequal-mass, black holes.

$r\psi_4$



-0.02

-0.01

0

0.01

0.02

-20

0

20

40

60

80

t/M

- To give estimate on how waveforms depend on these parameters.

- To reduce the number of simulations needed by interpolating between analytic fits.



Black hole mergers: from simulation to detection

The Kudu Project:

A proposal to use **Lazarus** waveforms for a first small step in the interface between source modeling and data analysis. (a) Determine robust features of the waveforms. (b) Explore parameter space dependencies of the waveforms. (c) Design optimal detection strategies.

