Using the Apples with Apples tests to study the AA system

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Thanks

Bernd Bruegmann
Wolfgang Tichy
Aleksander Aleseenko
NR group at Penn State

Overview

- Introduction
- The BAM code
- The AA system
- Implementation: Automatic code generation
- The robust stability test
- The gauge wave test
- The linear wave test
- Interpretations
- The crash test
- Conclusions
- Topics for discussion

Introduction

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  - We want to achieve long term evolution of binary black holes
  - We need to do a numerical implementation to explore if a system actually works.
  - The authors of the AA paper were interested in seeing the numerical behavior of their system.

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    - a code that allows 2 to 10 people to collaborate
    - not a community code
    - not a general purpose code or library like Cactus, PetSC, VTK, FTT, ...

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    - not a community code
    - not a general purpose code or library like Cactus, PetSC, VTK, FTT, ...
  - **Your attitude is supposed to be: I am happy if something works at all, and if not, I'll fix or add it :-)**

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  - **The 3-metric g_{ij}, 6 variables**
  - **The extrinsic curvature tensor K_{ij}, 6 variables**
  - **8 additional variables f_{ijk}, antisymmetric in i, j and given by:**

$$f_{ijk} = \frac{1}{2\sqrt{2}}(g_{ik,j} - g_{jk,i} + g_{lj,m}g_{ik}g^{lm} - g_{lm,j}g_{ik}g^{lm} - g_{li,m}g_{jk}g^{lm} + g_{lm,i}g_{jk}g^{lm})$$

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  - Good collaboration with authors.

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- All tensor equations can be input in MathTensor format, and the Mathematica script expands out all terms, writes equations on components for, optimizes the expressions and writes c-code.
- You need to tell the script how to access variables and do finite differences, but this needs to be done once pr. computational environment.

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- ***Huge advantage having all expressions in MathTensor form: once the components of the metric and extrinsic curvature tensor are given we have***
  - Analytical expressions for all components of f_{ijk}.
  - Analytical expressions for all right hand sides.
- ***We can compare the analytical expressions to the numerical results, to check for bugs, or estimate errors introduced by finite differencing. We have done this for Schwarzschild black holes in different coordinates.***

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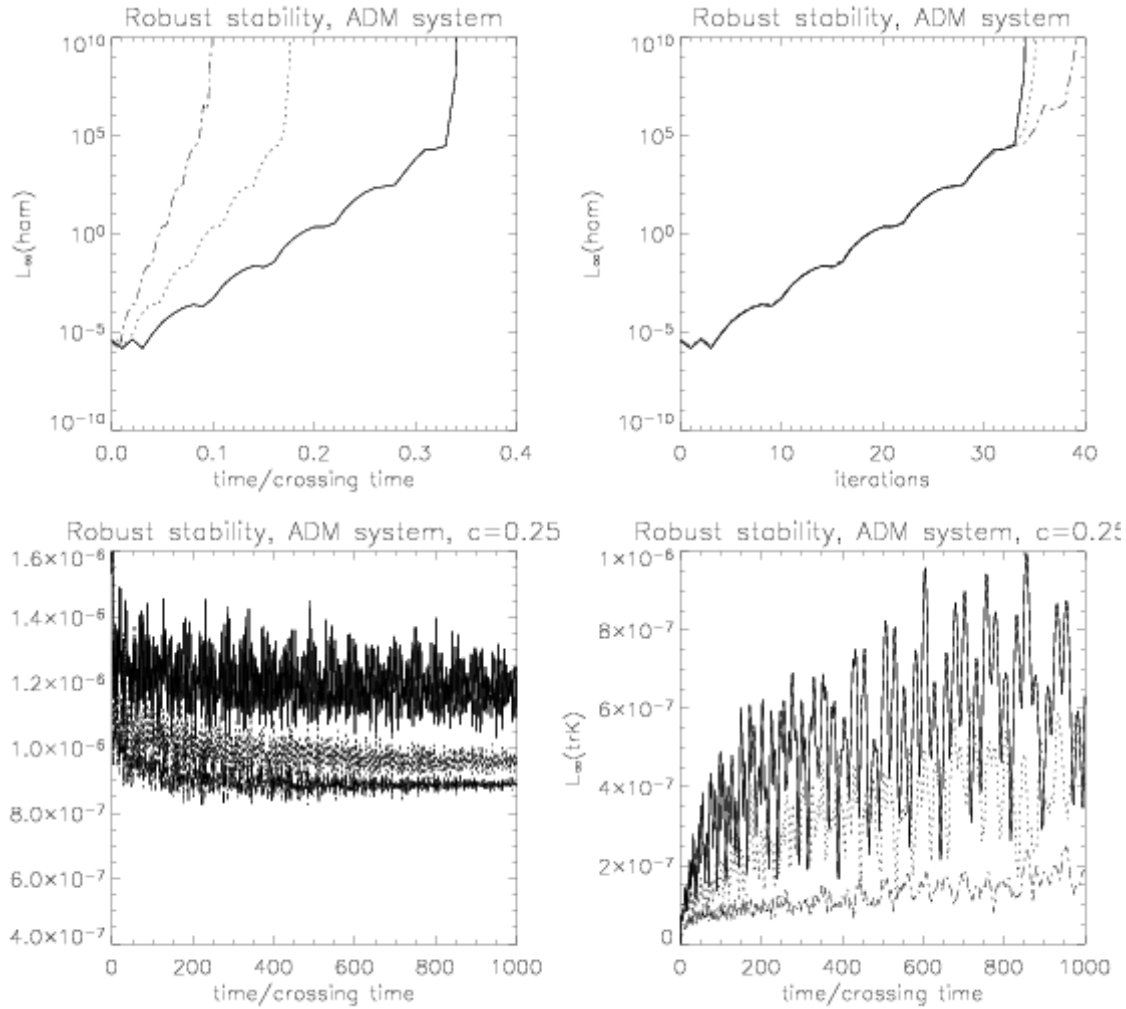

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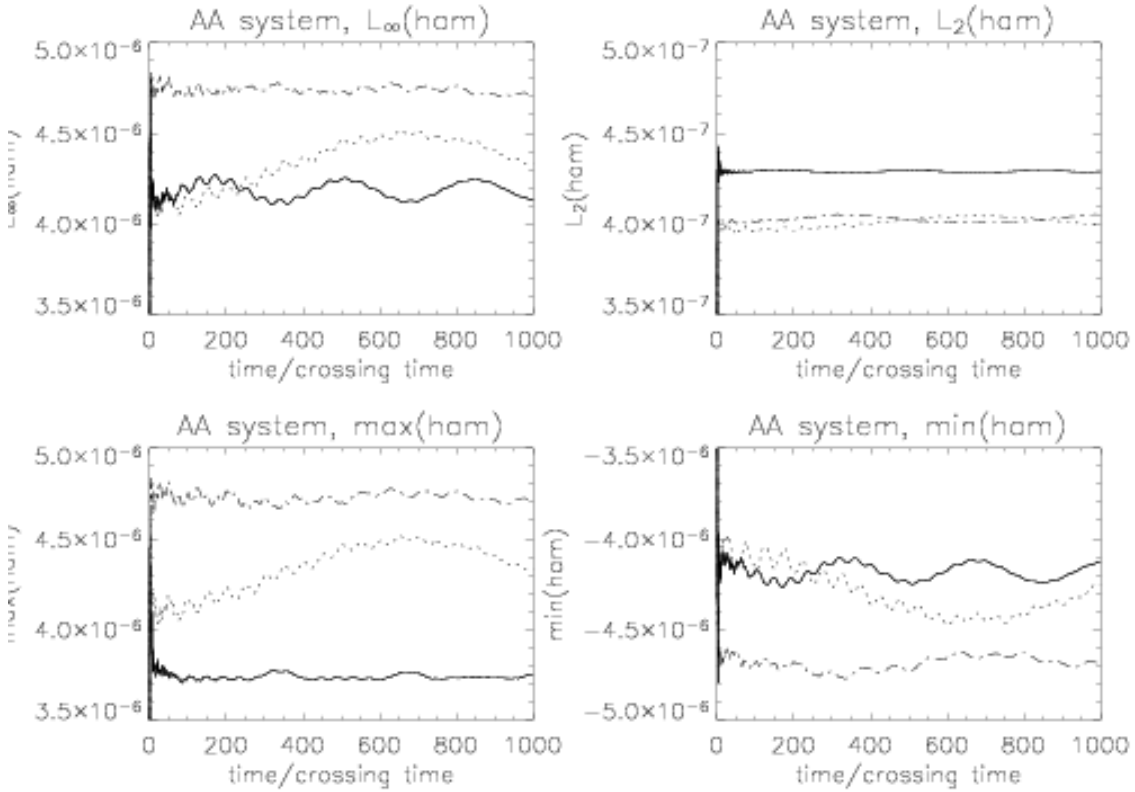

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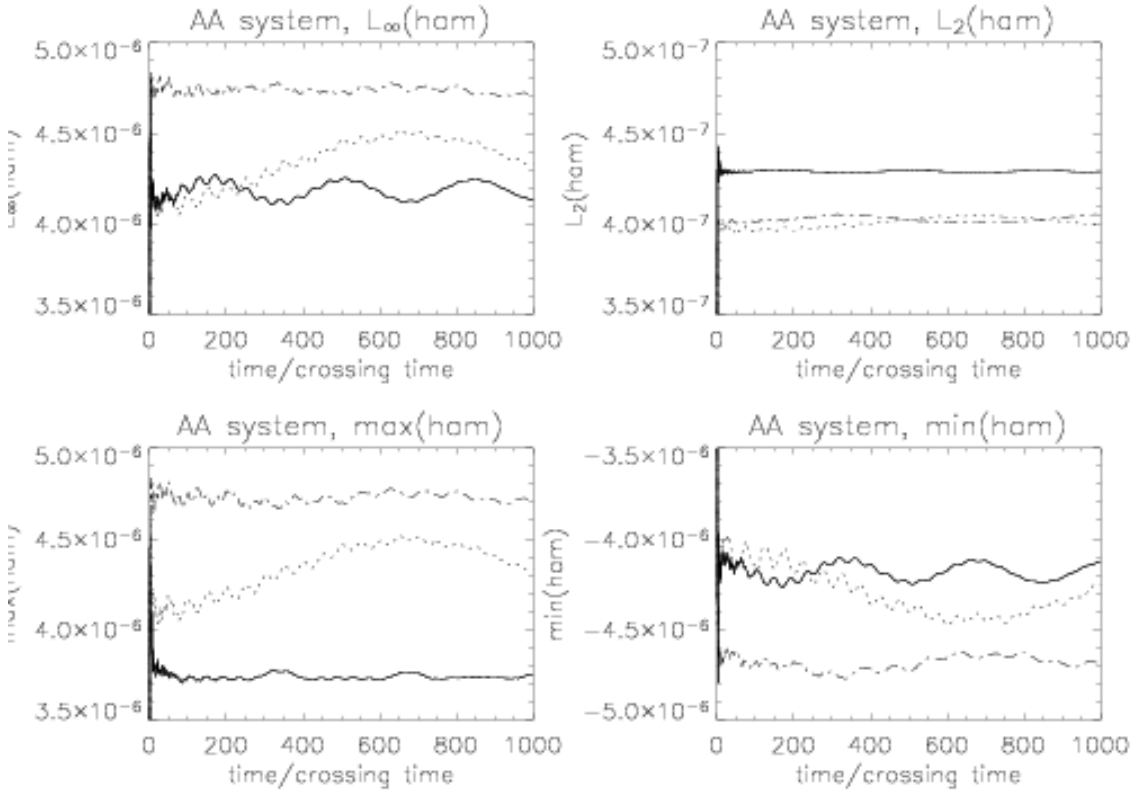

- Not clear if this system passes the test or not

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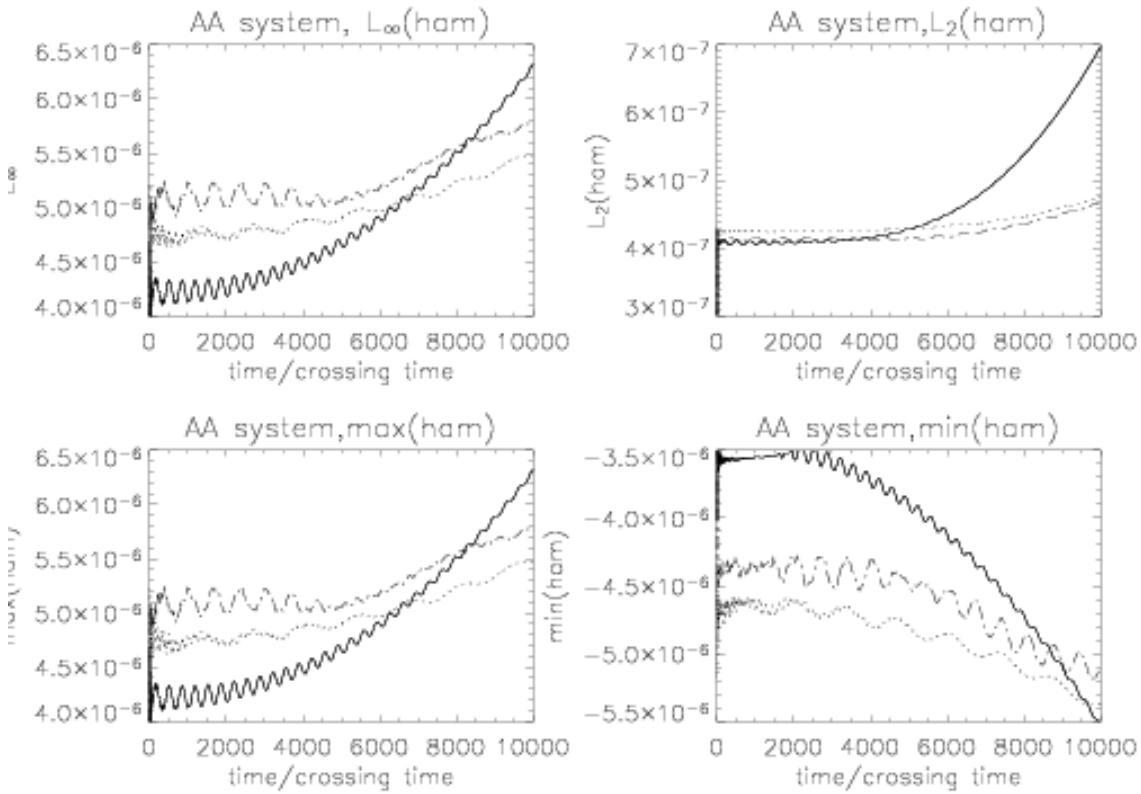

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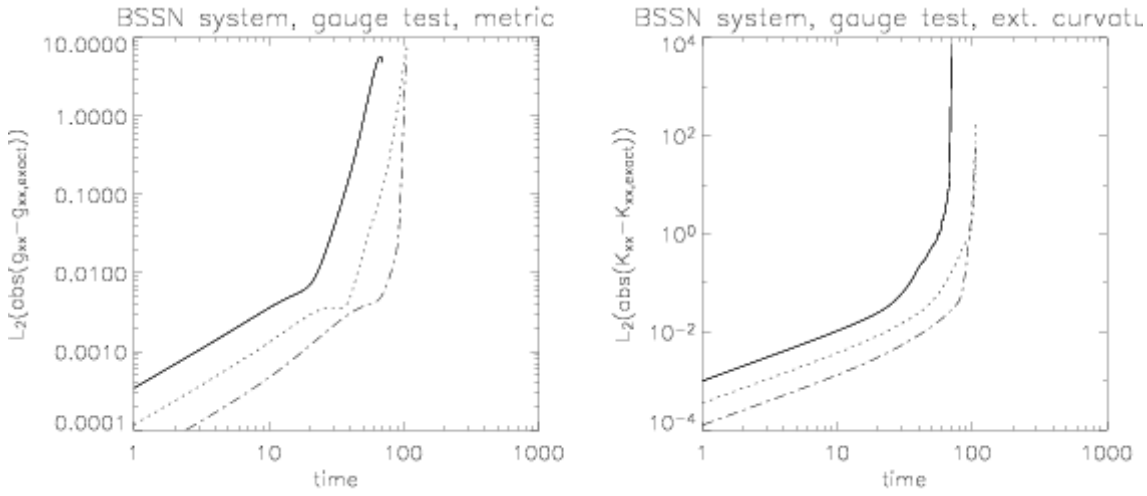

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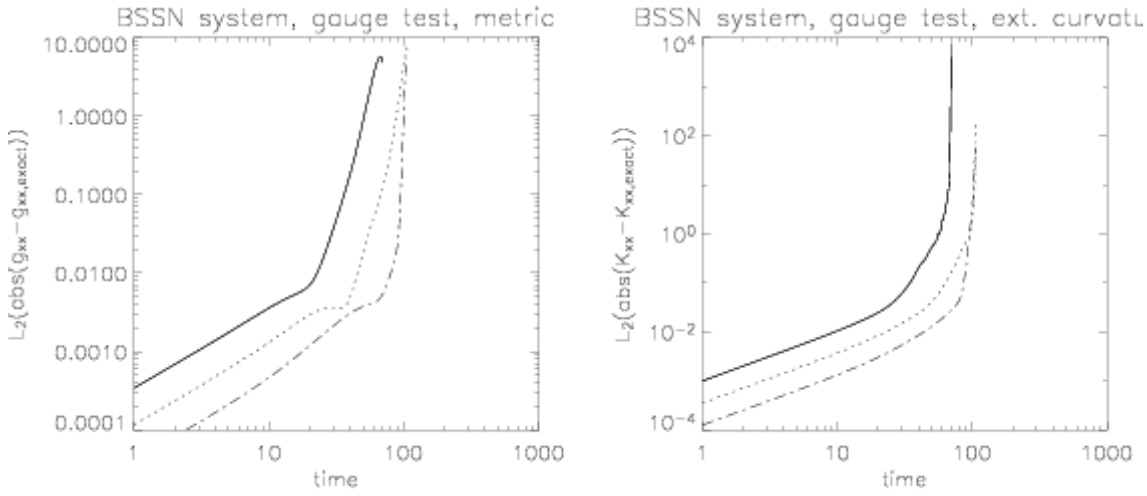

- BSSN in unstable, same result as Maya code and Cactus, crashes at the same time.

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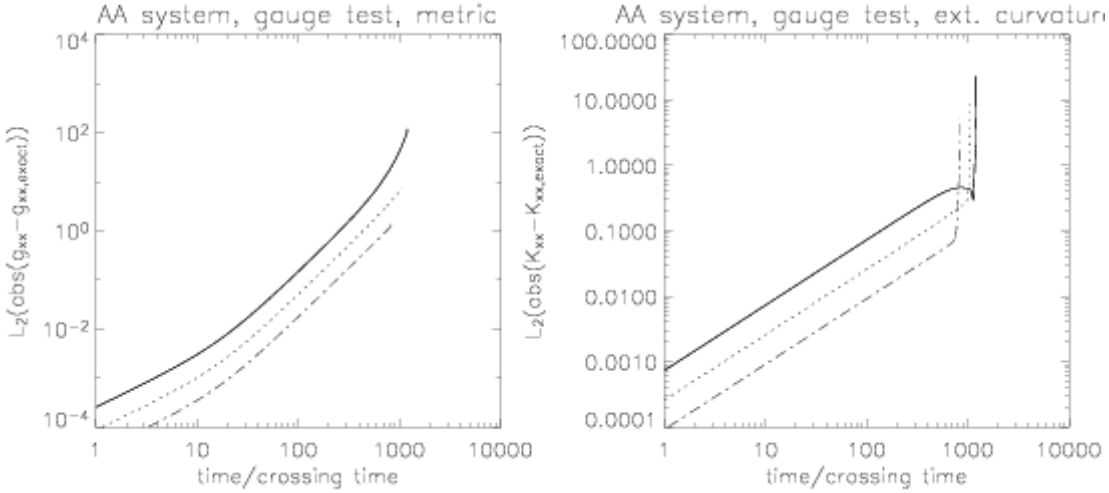

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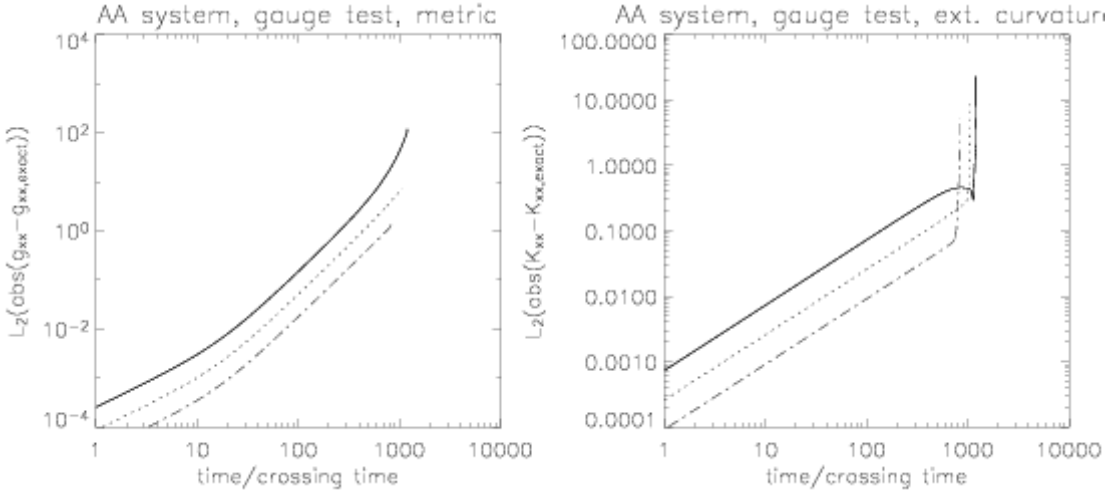

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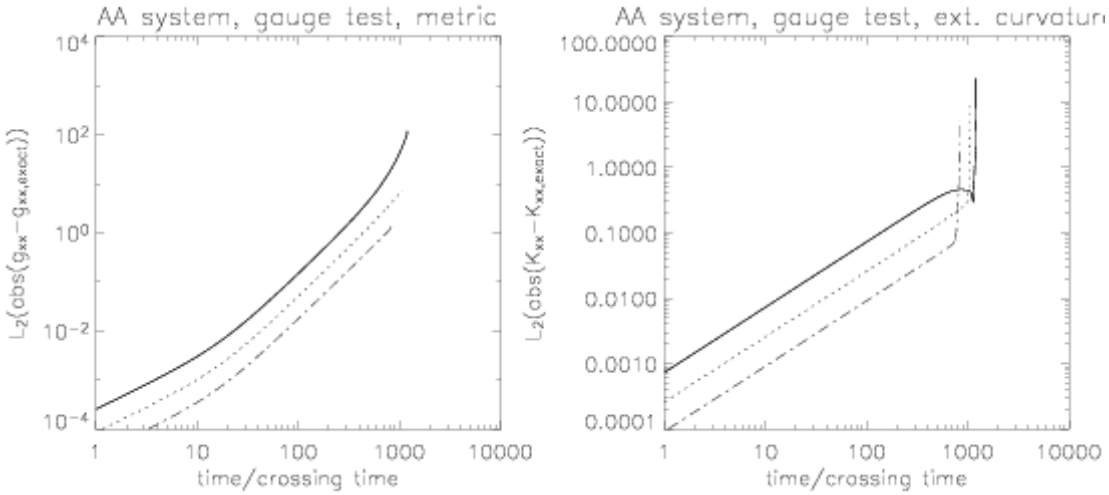

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- In this case, ADM is trivial, because errors cancel.

The linear wave test

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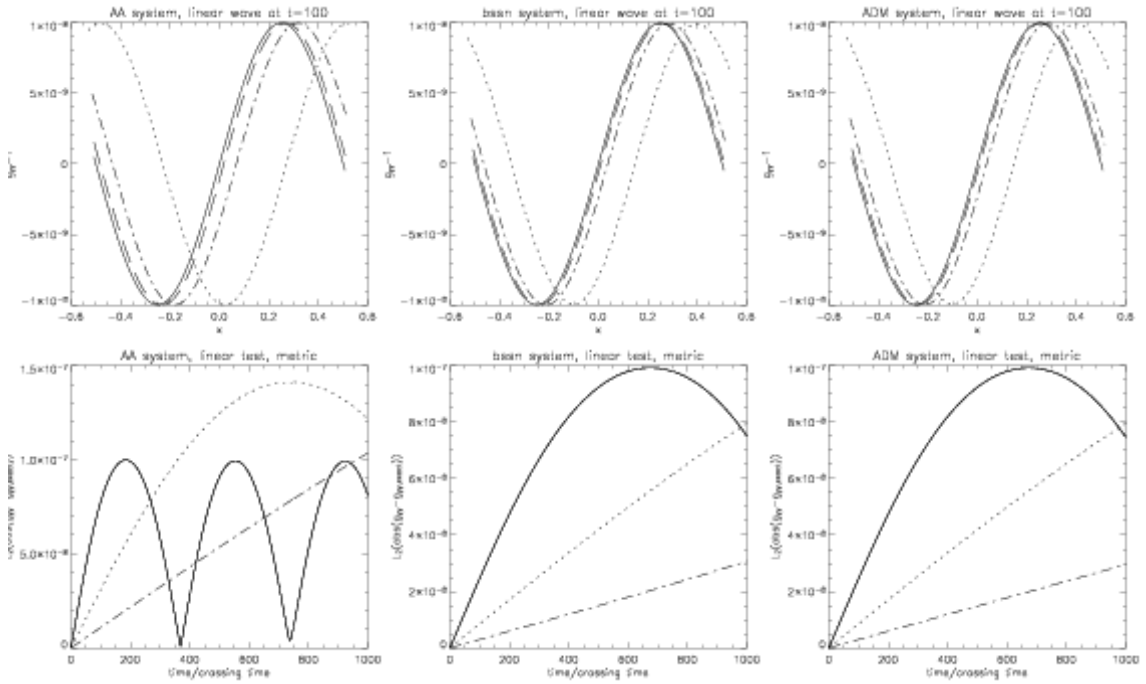

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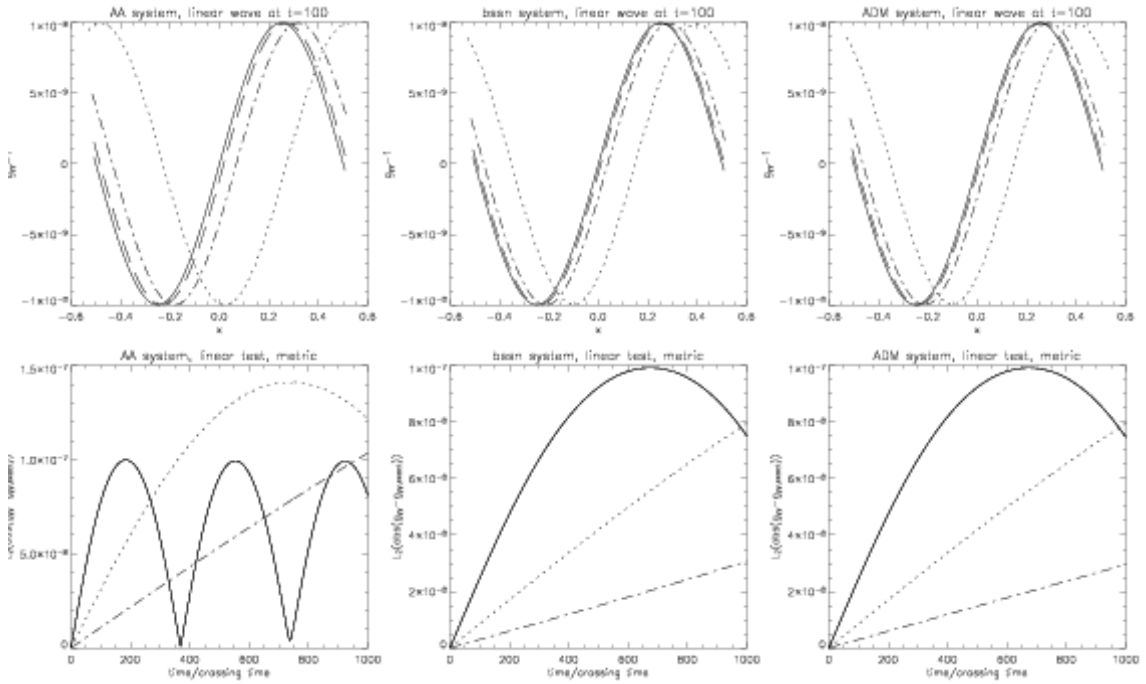

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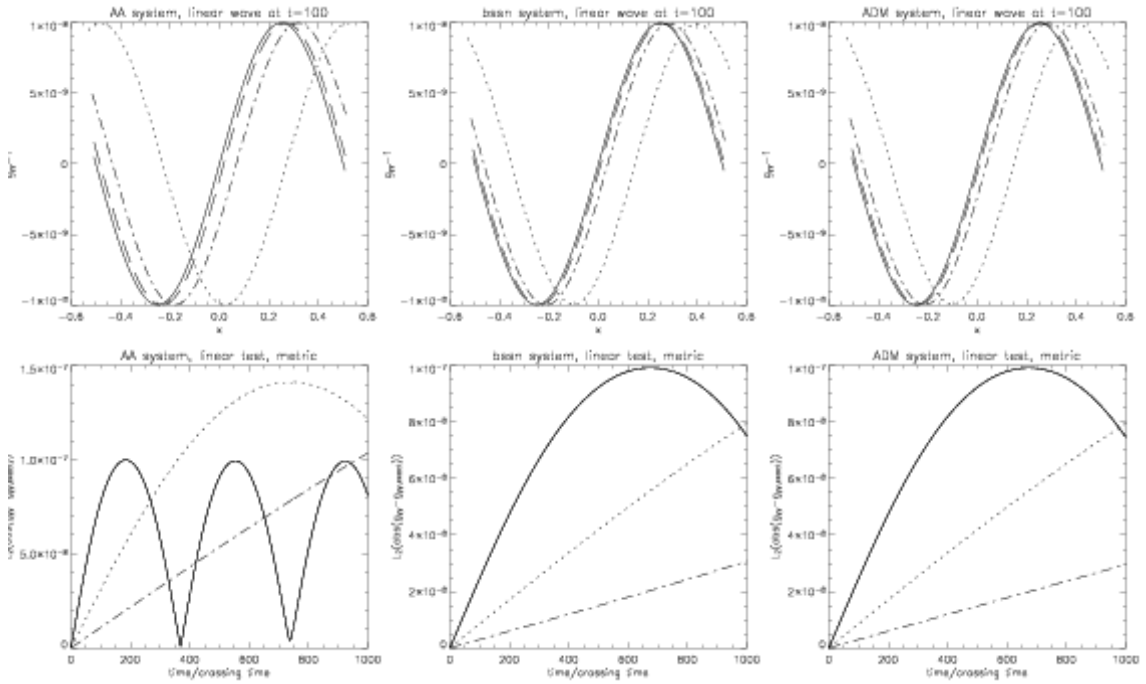

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- Amplitude is not affected in either system

Interpretation?

- *Question for the audience: what conclusions would you draw about the AA system from these results? Should we use it for black hole computations?*

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- *My opinion: these tests are not enough to draw clear conclusions about this systems ability to evolve black holes.*

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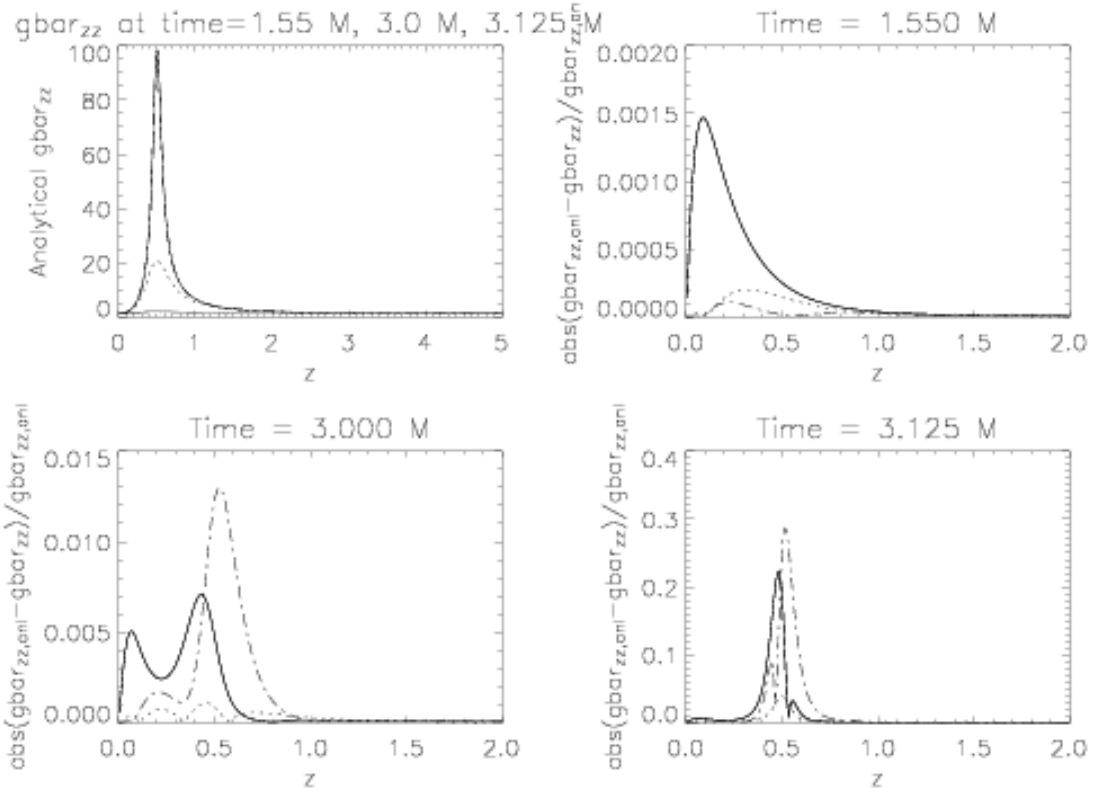

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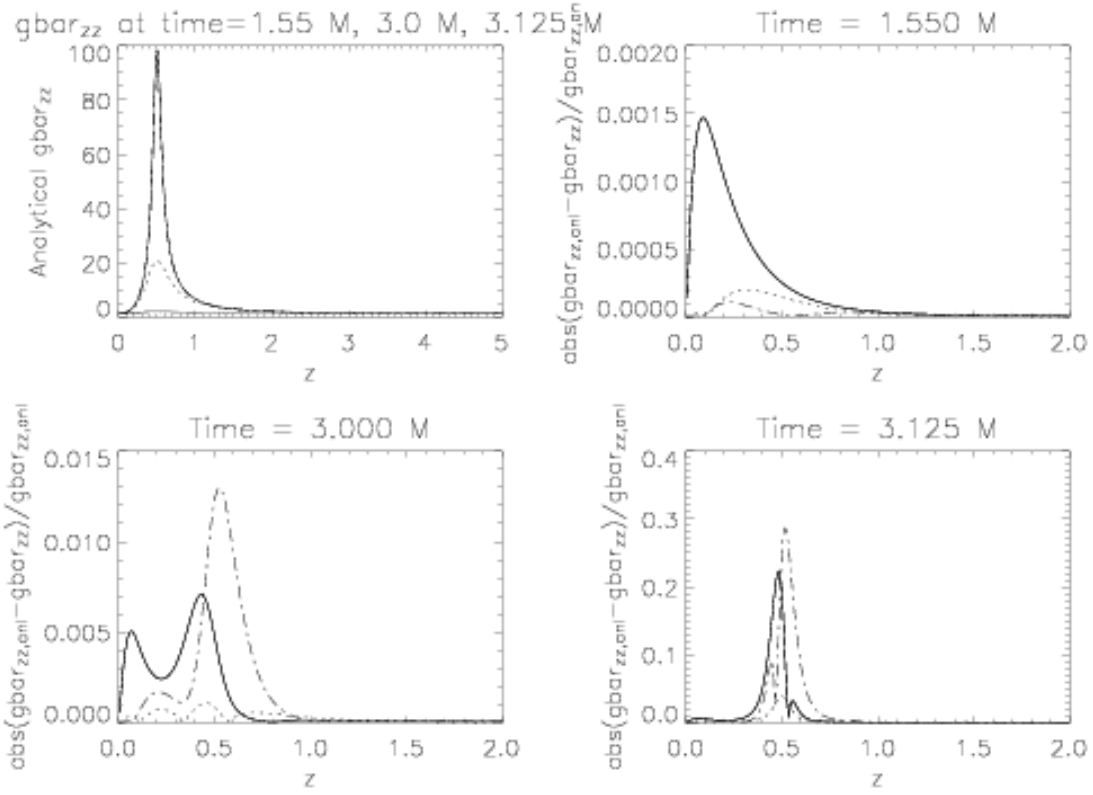

- **The code should crash a time= $M\pi$. Every evolution system should pass this test!**

Conclusions

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- **The first Apples with Apples tests are good for comparing codes using the same or similar system (like BSSN).**
- **The tests, as they are now, are not sufficient to dismiss a system, specifically, we cannot state if the AA system has a future in numerical relativity computations.**

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- *Evolution schemes (ICN, RK, dissipation)??*
- *Should boundary conditions be a part of the system?? How do we test the full package (system, scheme, boundary conditions)??*