Discussion session

The late-inspiral and merger: challenges beyond general relativity

Panelists: Maxence Corman, Néstor Ortiz, Masaru Shibata
Chair: Harald Pfeiffer

Thursday, June 15th 2023
3:40-4:40 pm

Themes for discussion

Fundamental questions

Including matter

Implicit assumptions based on GR

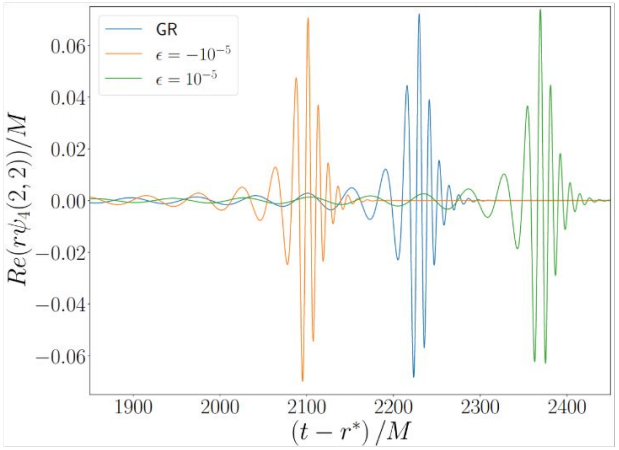
Tools of the trade

Environmental impact

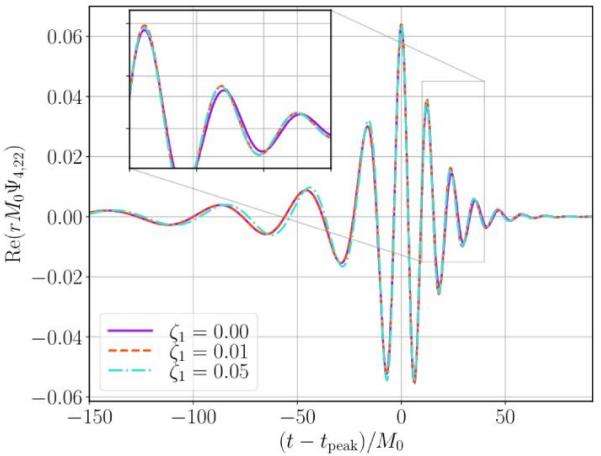
Predicting the future

Fundamental questions

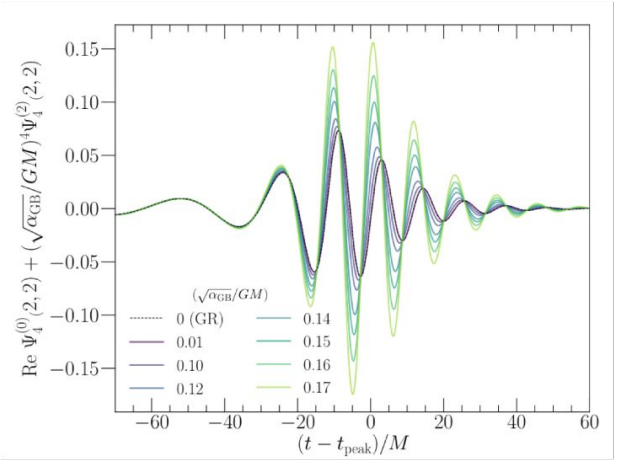
- What does it mean to be **‘close’ to a well-posed theory**?
  - How much can we trust results from approximate methods such as ‘fixing the equations’ and order reduced approaches where one linearizes around GR (see figures on next page)
- What do you make of a theory that ***sometimes* leads to ill-posedness**?
  - ‘elliptic regions’ that appear for *generic* initial data
  - GR: naked singularities only in fine-tuned critical collapse (subset of *measure zero*)
- Can we provide a notion of hyperbolicity which is **independent of any gauge-fixing procedure**?
- Is **BH/NS** in alternative theories of gravity **always stable**?
  - Before going ahead, it might be better to confirm this.



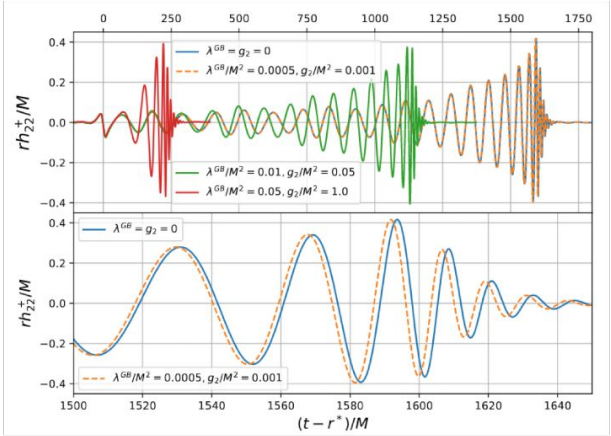
Fixing the equations (Courtesy of Ramiro Cayuso, based on 2303.07246



Modified GH (Corman+ 2210.09235)



Order reduction (Okounkova+ 2001.03571)



Modified CCZ4 (Salo+ 2208.14470)

Including matter

- **Mergers with neutron stars**
    - Inspiral: tides & resonances
    - near merger: NS disruption, prompt ejecta
    - post-merger: accretion disk, collapse to BH, GRB, neutrino transport, winds, r-process, kilonova
  - What are the challenges when going ‘beyond GR’?
  - Do EM counterparts give information about testing GR?
  - Can we distinguish ‘beyond-GR’ effects from EoS degeneracy and/or tidal deformability?

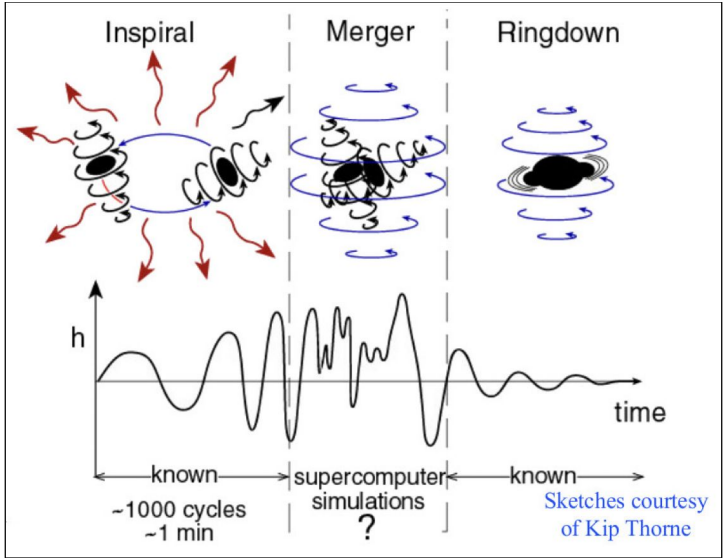
- Supernova core-collapse
    - Strong gravity & highly dynamic. But incredibly complicated micro-physics.
  - Do we need to think about beyond GR here?

- Coupling of ‘beyond GR fields’ to matter / EM?
  - ‘beyond GR’ fields are usually only coupled to curvature — do we need to go beyond?

Implicit assumptions based on GR

- Field has decades of experience with GR, which has shaped our thinking and led to codes adopted to GR. As we go 'beyond GR', do we have deeply ingrained implicit assumptions that break?
  - Structure of Scri+, GW extraction?
  - Will BH excision continue to work? It relies on existence of *apparent horizon* inside *event horizon*
  - Will puncture method continue to work?
  - Does cosmic censorship apply?
  - Does BH area theorem apply?
  - Is a more 'violent/dramatic/chaotic' merger possible?

- Are certain theories particularly suited to challenge our GR assumptions?



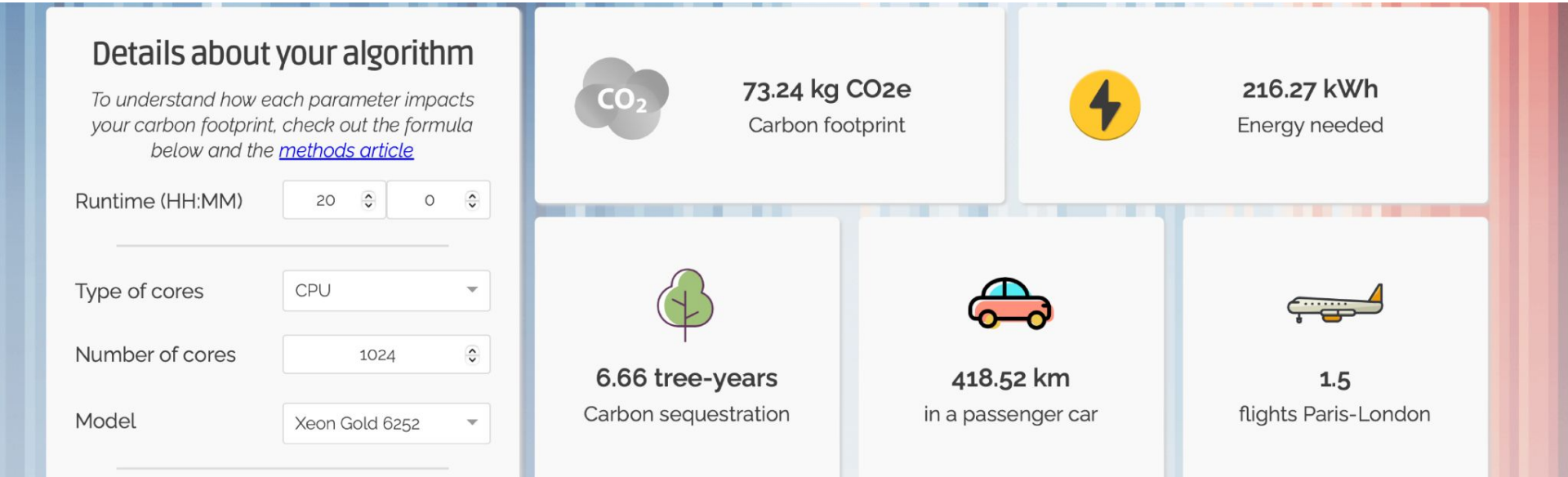
Tools of the trade

- Can we construct generic initial data in beyond-GR theories?
- What codes and evolution systems are capable of beyond GR sims (or can be adopted)?
- Beyond GR sims to-date explore vanishing portion of (mass, spin, ecc) parameter space. How badly will codes break across parameter space, and where?
- Connecting inspiral to remnant:
  - Can we do remnant formulae in beyond GR?
  - Predict QNM amplitudes?
  - For which theories should we attempt this?

Environmental impact of our simulations (Dina Traykova)

- Rules of thumb
  - CPU compute-core uses 10W
  - German electricity (2021 average): 350g CO2 / kWh
- One moderate BBH simulation: 20,000 core-h = 200kWh = 70kg CO2

www.green-algorithms.org



Predicting the future

- What are the current biggest challenges in beyond GR merger-simulations?
- What are biggest challenges for beyond GR waveform templates?
  - Spins? Well-posedness? Merger? Sheer size of parameter space?

- Where will we be in five years?