NR FOR I/EMRI (PROPOSAL FOR DISCUSSION)

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AIM

- Numerical relativity simulations with large mass ratios $\boldsymbol{\varepsilon} = m_2/m_1$ are difficult because space and time resolution scale ~ $\boldsymbol{\varepsilon}$, and of course the inspiral time ~ $1/\boldsymbol{\varepsilon}$.
- But if $\boldsymbol{\varepsilon} \ll 1$, *nothing happens* on the scale of the smaller mass — no interesting dynamics. Exterior forcing on timescales >> longest period normal mode, so hole reacts adiabatically to good approx.
- Proposal is to excise a region of order $m_2/\sqrt{\boldsymbol{\varepsilon}}$ around the small mass and treat the interior analytically. Orbit integration done by NR.
- This could speed up the NR computation of each orbit by ~ $\boldsymbol{\varepsilon}^2$, but of course it does not change the number of orbits per inspiral time.

INTERIOR ZONE

- Adam Pound's talk gave good summary of possible ways to handle the interior.
- Talks by Diener and by Thornburg also use an interior region.
- My preferred method goes back to Futamase (1985), the strong-field point-particle limit (SPL), a more rigorous approach to matched asymptotic expansions, doing pN for NS or BH binary components.
  - A matching surface is identified and the EOM comes by doing an integral over the surface of the outer solution.
  - Later papers by Itoh, Futamase, and collaborators went up to 3.5PN without the ambiguities at 3PN that point-mass regularization methods encountered, since the SPL method involves no infinities. Method no longer being pursued (Futamase retired).

INTERIOR SOLUTION

- As in SPL, I want to put a Kerr solution inside. The excision surface is at a distance $\geq m_2/\sqrt{\varepsilon}$ from horizon. The solution should be stationary: adiabatic approximation.
- At the surface, one needs to match the Kerr intrinsic and extrinsic curvatures, with parameters for the location of the BH and the orientation of the spin.
- Open question whether one needs a tidally distorted Kerr: could use the solution provided by Poisson (2015).
- If necessary one could also put in tidal heating of Kerr using Chatziioannou et al (2016): additional dissipation effect on orbit.

EXTERIOR INTEGRATION

- The exterior is still done in full GR NR.
- The boundary conditions are as usual except that the world tube that is excised has to have data inherited from inside. Match intrinsic and extrinsic curvatures.
- How this is done in detail depends on the numerical method - finite differencing grid, SPEC, finite elements, ….
- May put serious demands on accuracy if **ε** is small. Possible solution would be to treat exterior as a **Δ** on a background Kerr, as per East & Pretorius (2013).
- No idea about instabilities, possible reflection of waves by world tube boundary, ….

APPLICATIONS

- Hopefully extend full NR BBH simulations to significantly smaller **ε**, perhaps from 10-1 to 100-1 (may be useful for LIGO).
- Do segments of 10-100 orbits in other problems with even smaller **ε** to compare with perturbation-theory methods.
- Would be interesting to see how this performs at resonances.