Hyperbolic-like Encounters of Binary Black Holes with the Numerical Relativity Code SpEC

Hannes Rüter
Departamento de Física, University of Coimbra

Harald Pfeiffer
Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

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black-holes.org

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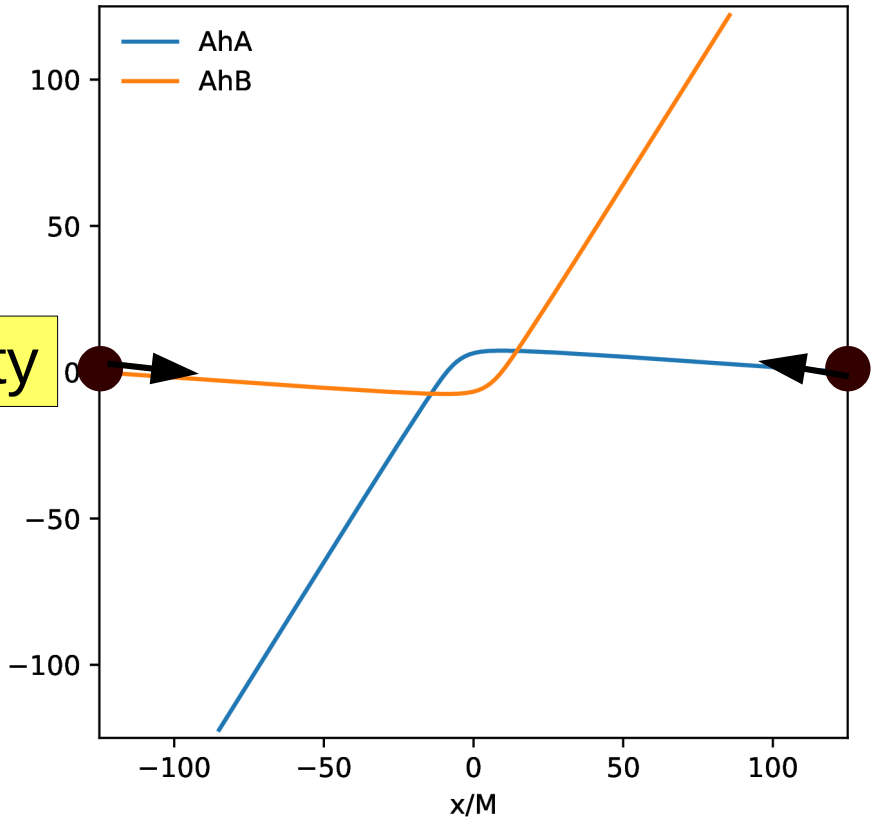
DMINBNS - EXPL/FIS-AST/0735/2021

Hyperbolic-like orbits

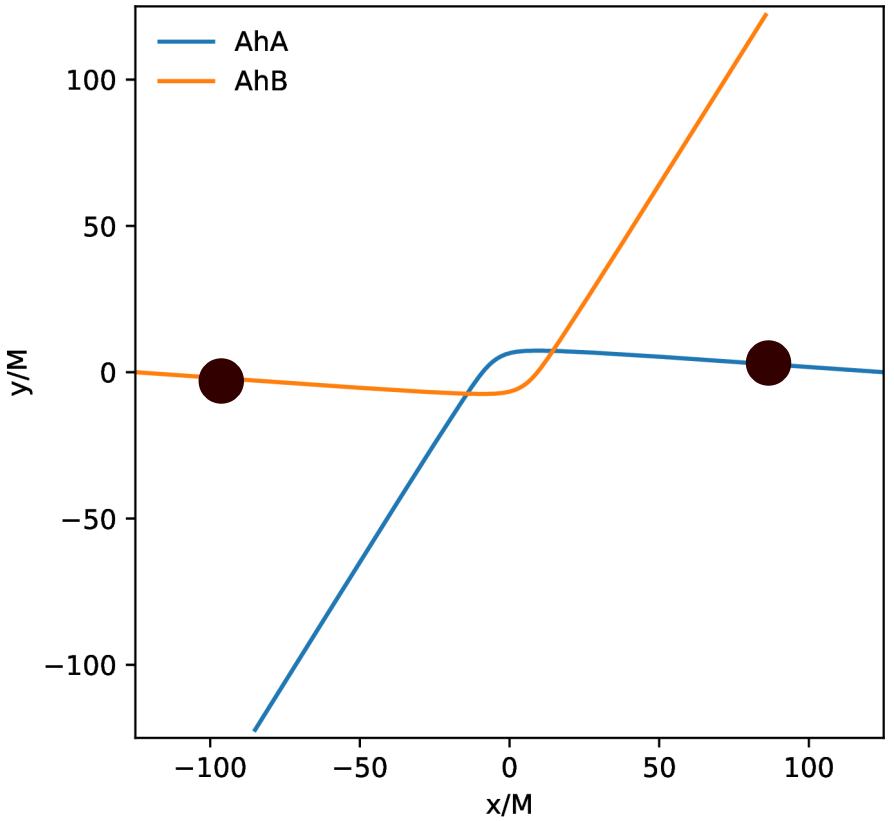
From infinity



E_{ADM} = 1.02230 M
J_{ADM} = 1.78000 M^2

m_A = 0.5 M
m_B = 0.5 M

Hyperbolic-like orbits



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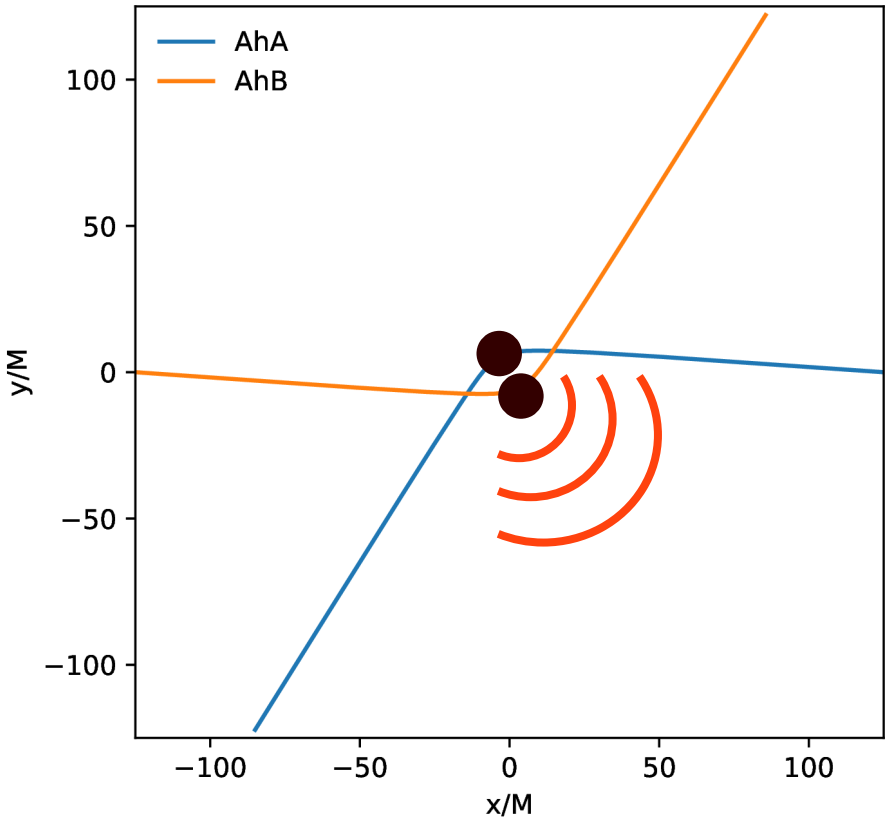
Hyperbolic-like orbits



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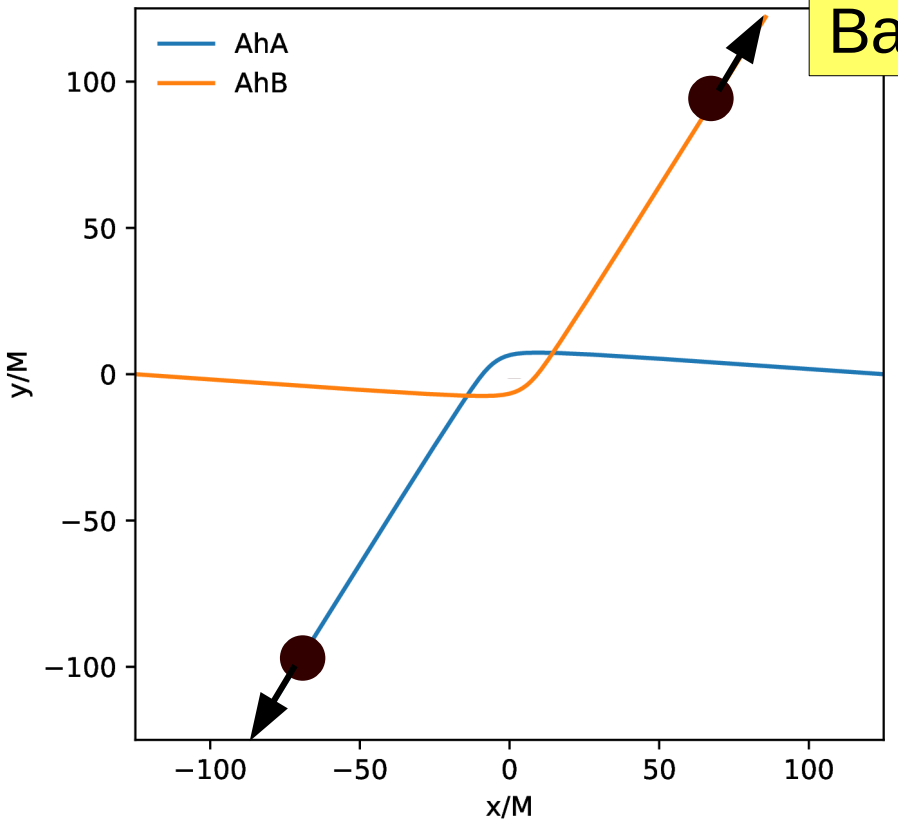
Hyperbolic-like orbits



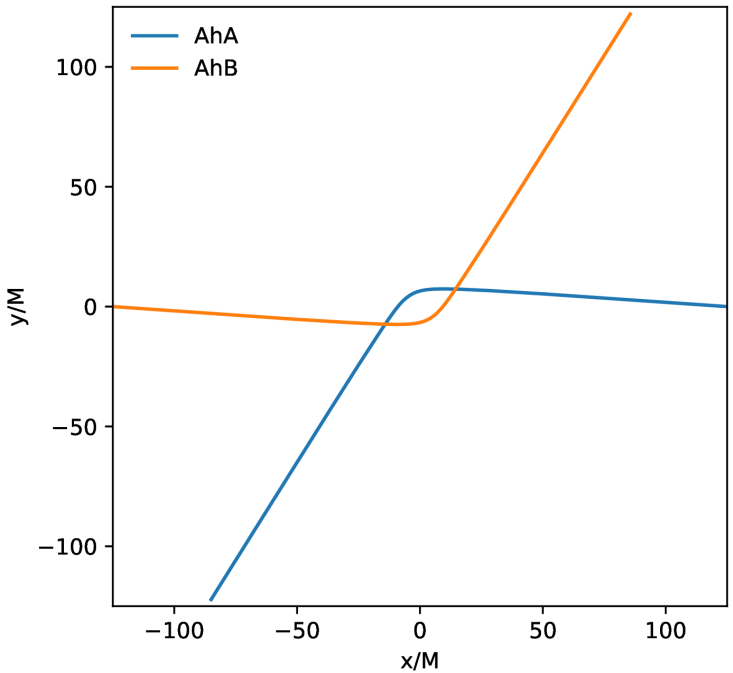
Back to infinity

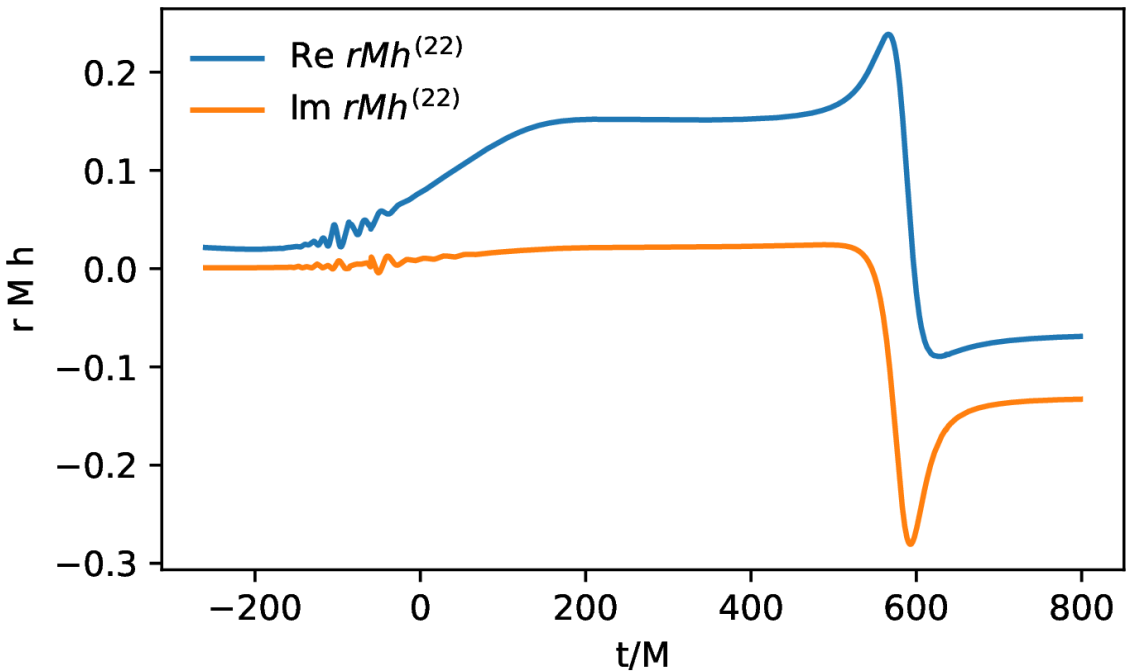
E_{ADM} = 1.02230 M
J_{ADM} = 1.78000 M^2

m_A = 0.5 M
m_B = 0.5 M

Gravitational Wave Strain

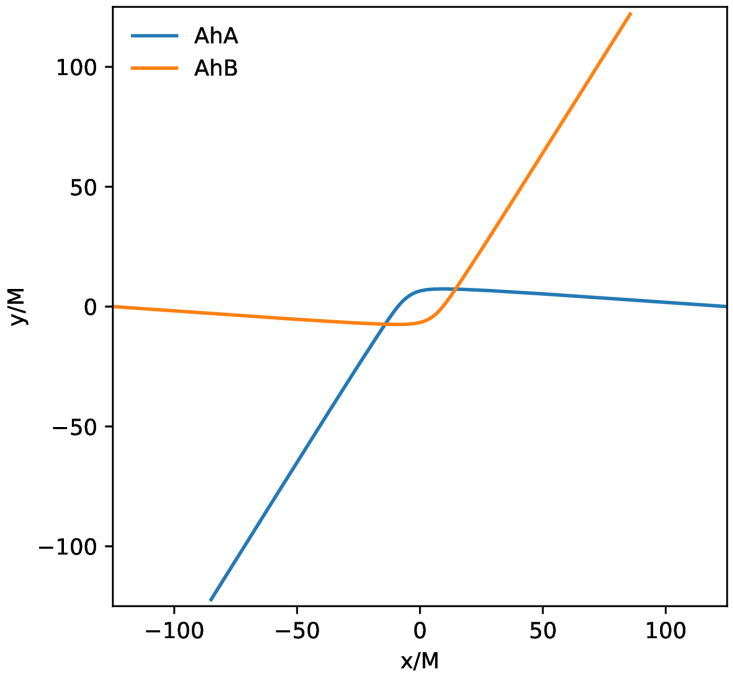
E_{ADM} = 1.02230 M J_{ADM} = 1.78000 M^2

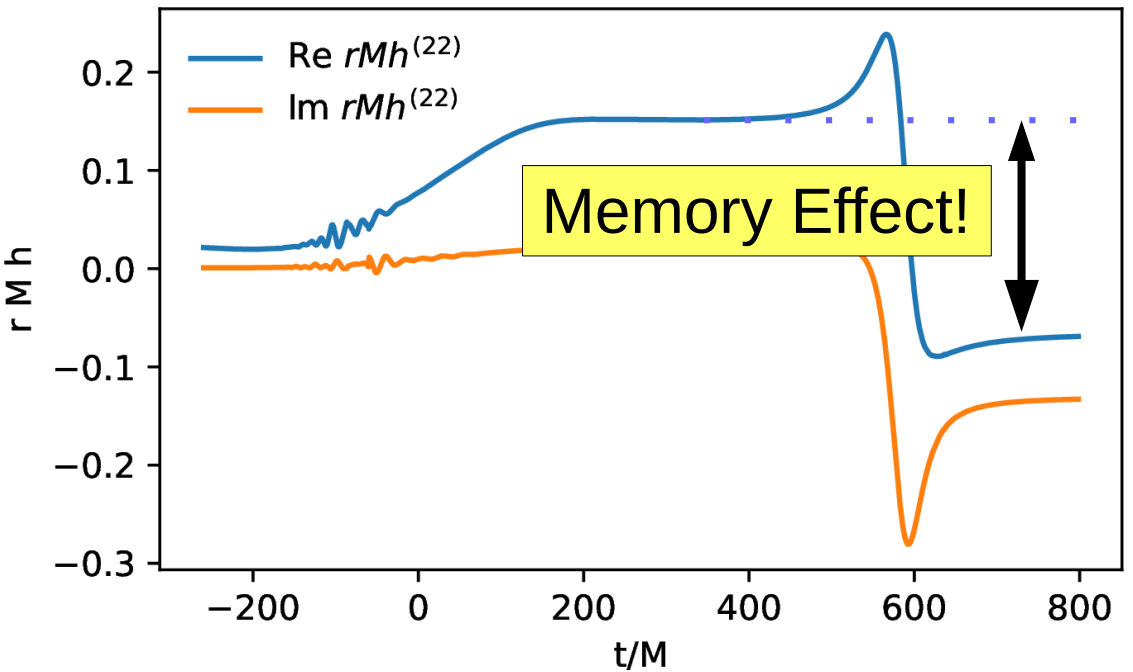




Gravitational Wave Strain

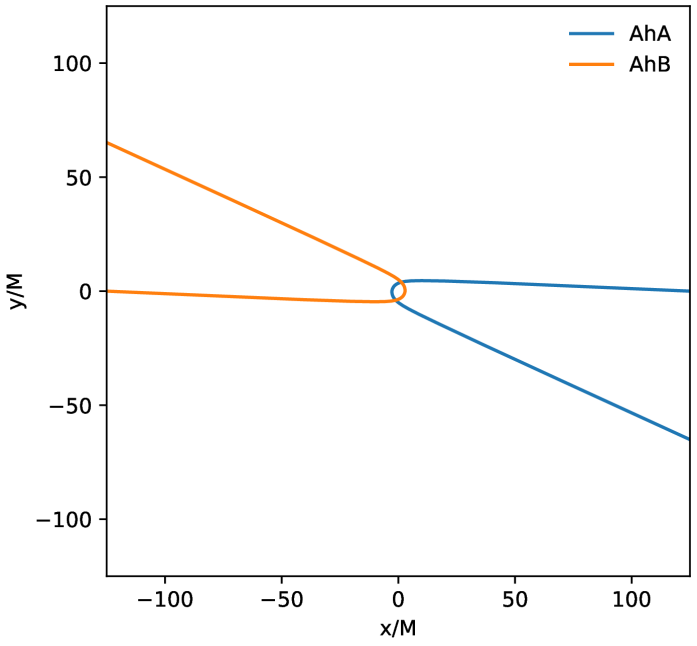
$E_{ADM} = 1.02230\ M$ $J_{ADM} = 1.78000\ M^2$

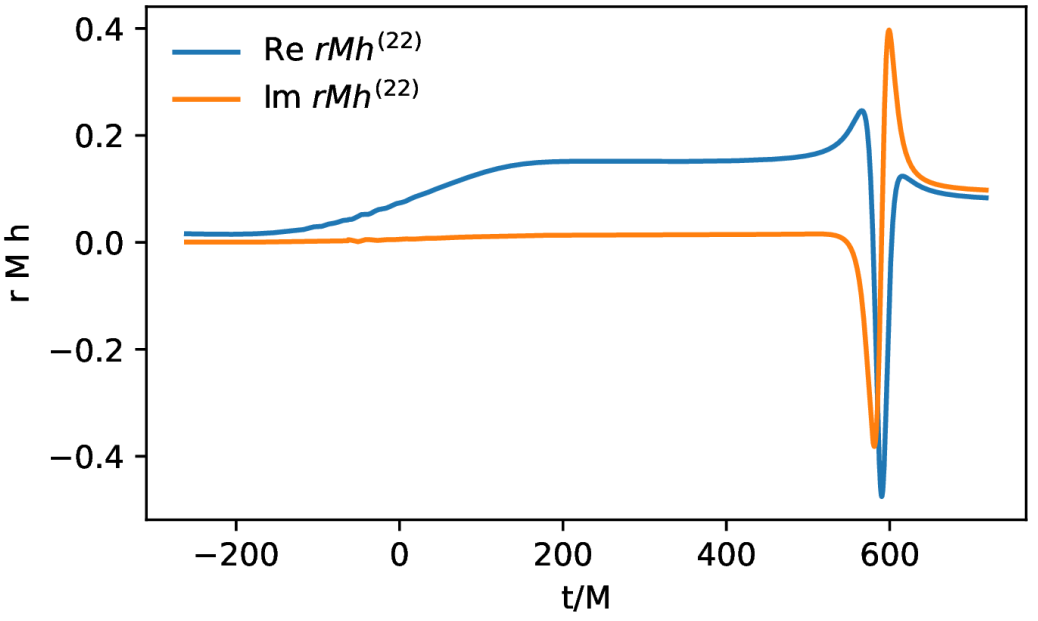




Gravitational Wave Strain

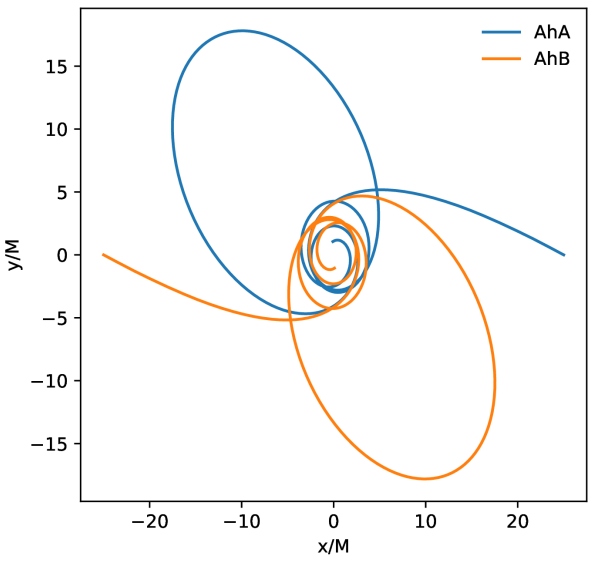
E_{ADM} = 1.02230 M J_{ADM} = 1.10304 M^2

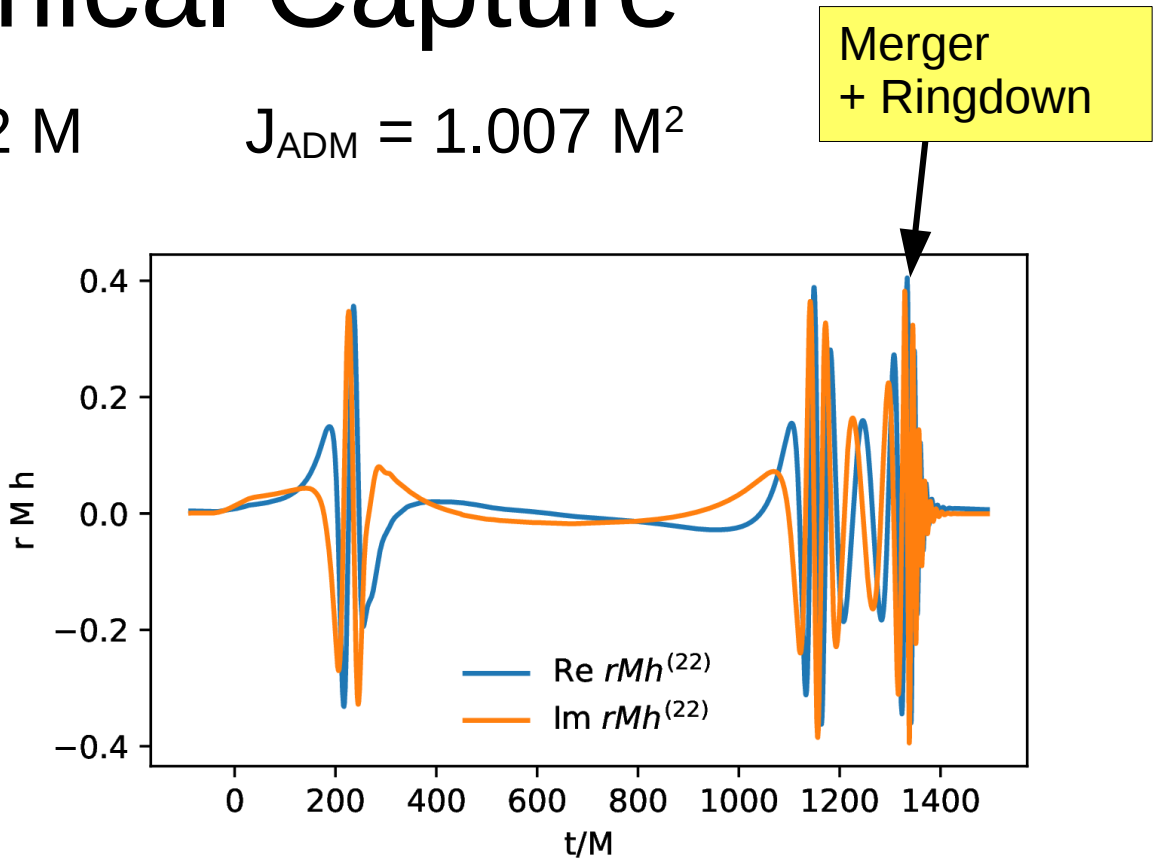




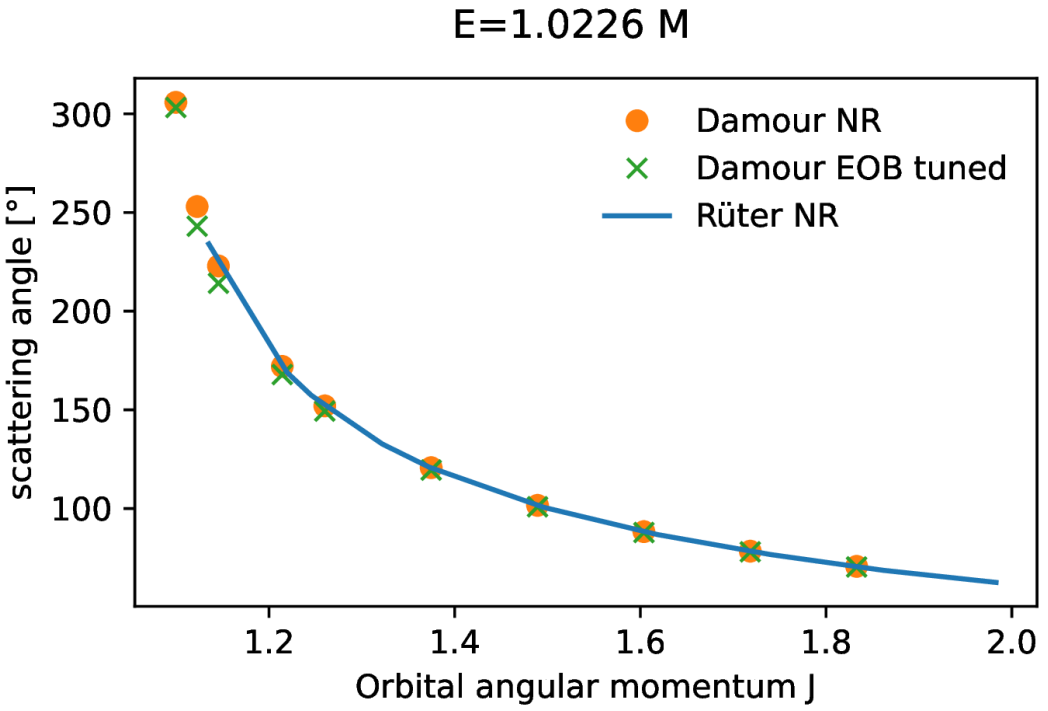
Dynamical Capture

E_{ADM} = 1.00052 M J_{ADM} = 1.007 M^2





Scattering Anles

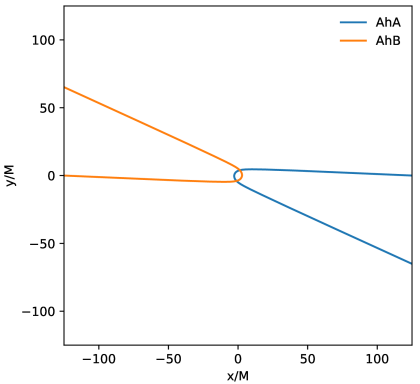


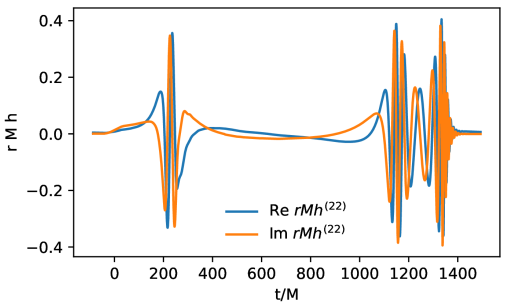
Damour NR:
Damour et al.
PRD 89, 081503 (2014)

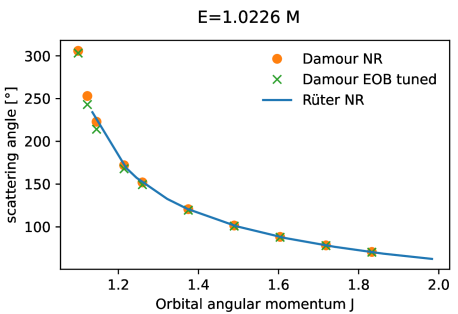
Damour EOB tuned:
Nagar et al.
PRD 103, 064013 (2021)

Summary

- We perform simulations of hyperbolic-like black hole encounters
- We extract the strain wave form
- Binary can become bound
- We extract the scattering angles





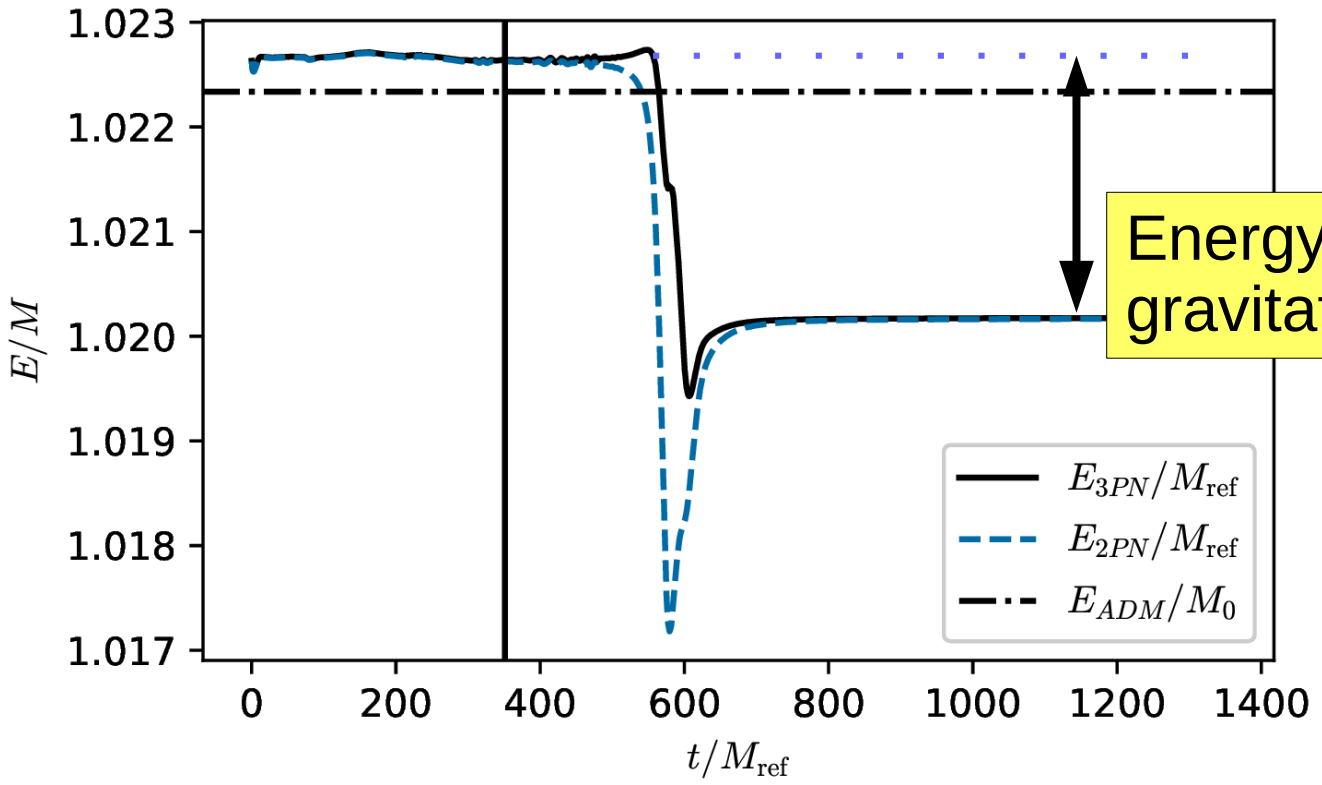


Bonus: Computation of E_{orb} and J_{orb}

- Coevolve harmonic coordinates X^μ
  [Prayush Kumar]
- Use PN expressions for orbits in harmonic coordinates [Memmesheimer *et al.* - PRD **70** 104011 (2004)]

$\rightarrow \quad E_{\rm orb}(X^\mu, V^\mu) \qquad J_{\rm orb}(X^\mu, V^\mu)$

Bonus: Orbital Energy

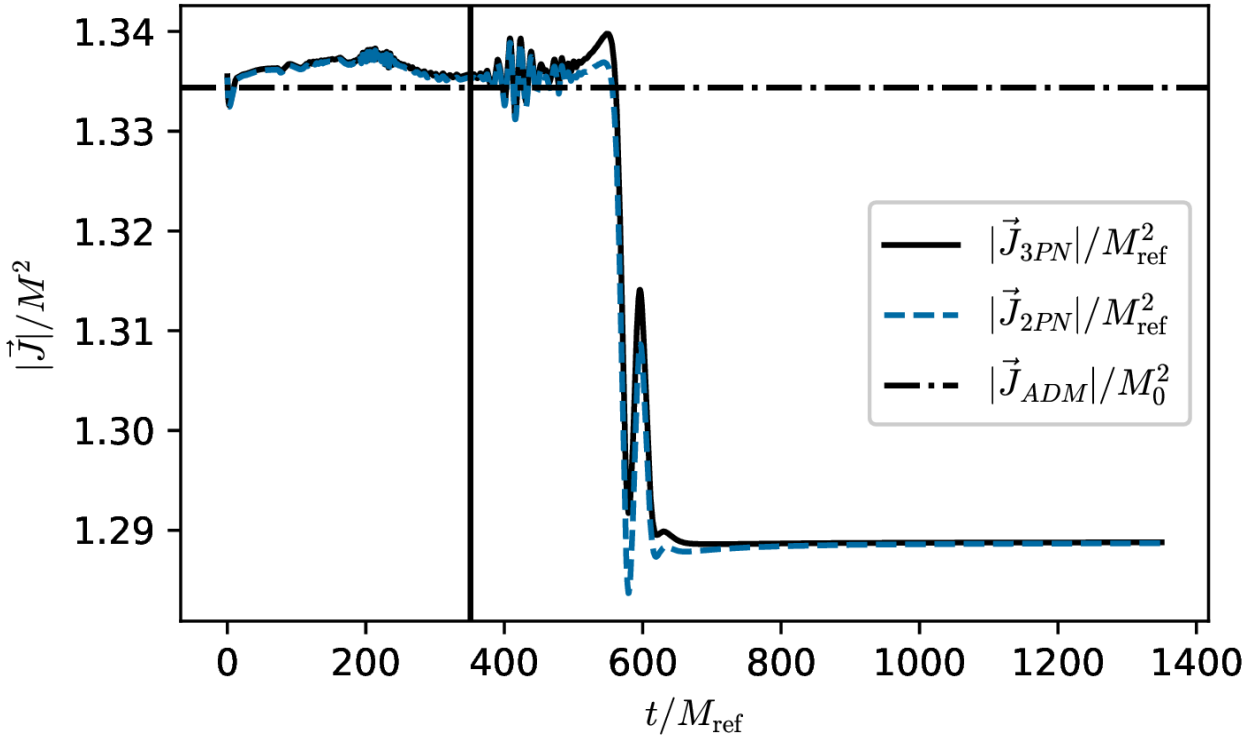


E_{in} = 1.02166 M

J_{in} = 1.33261 M^2

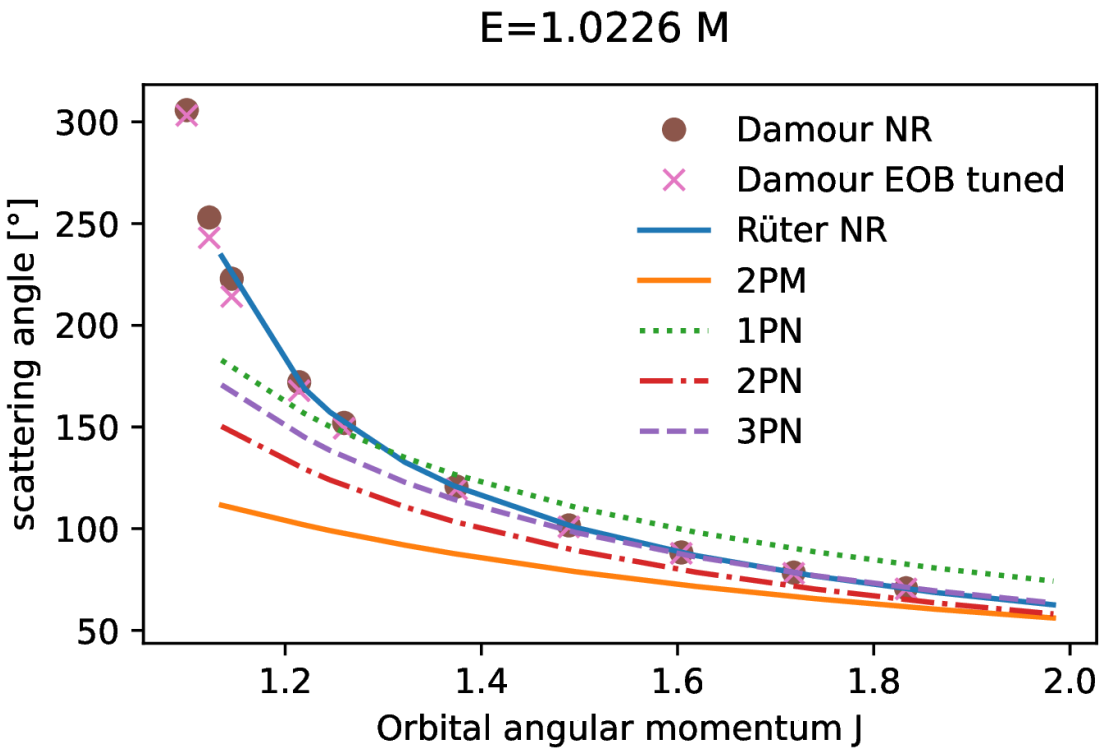
Energy lost in gravitational waves

Bonus: Orbital Angular Momentum



E_{in} = 1.02166 M
J_{in} = 1.33261 M^2

Bonus: Scattering Anles



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PN:
Scattering angle from quasi-Keperian orbits derived in [Memmesheimer et al. PRD 70, 104011 (2004)]