The late binary inspital in a quasi-adiabatic approximation

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Current Projects

- dynamical evolution of black holes
- dynamical evolution of single and binary neutron stars
- late binary inspiral in quasi-adiabatic approximation
- collapse of magnetized stars
- collapse of supermassive stars


quasi-adiabatic

The late binary inspiral

- last orbits outside of ISCO
- important for LIGO observations
- binary at fairly small separations

  ⇒ strong fields and tidal interactions may make post-Newtonian point-mass approximations inaccurate

- many orbits

  ⇒ fully dynamical numerical relativity simulations impossible

⇒ need alternative approach

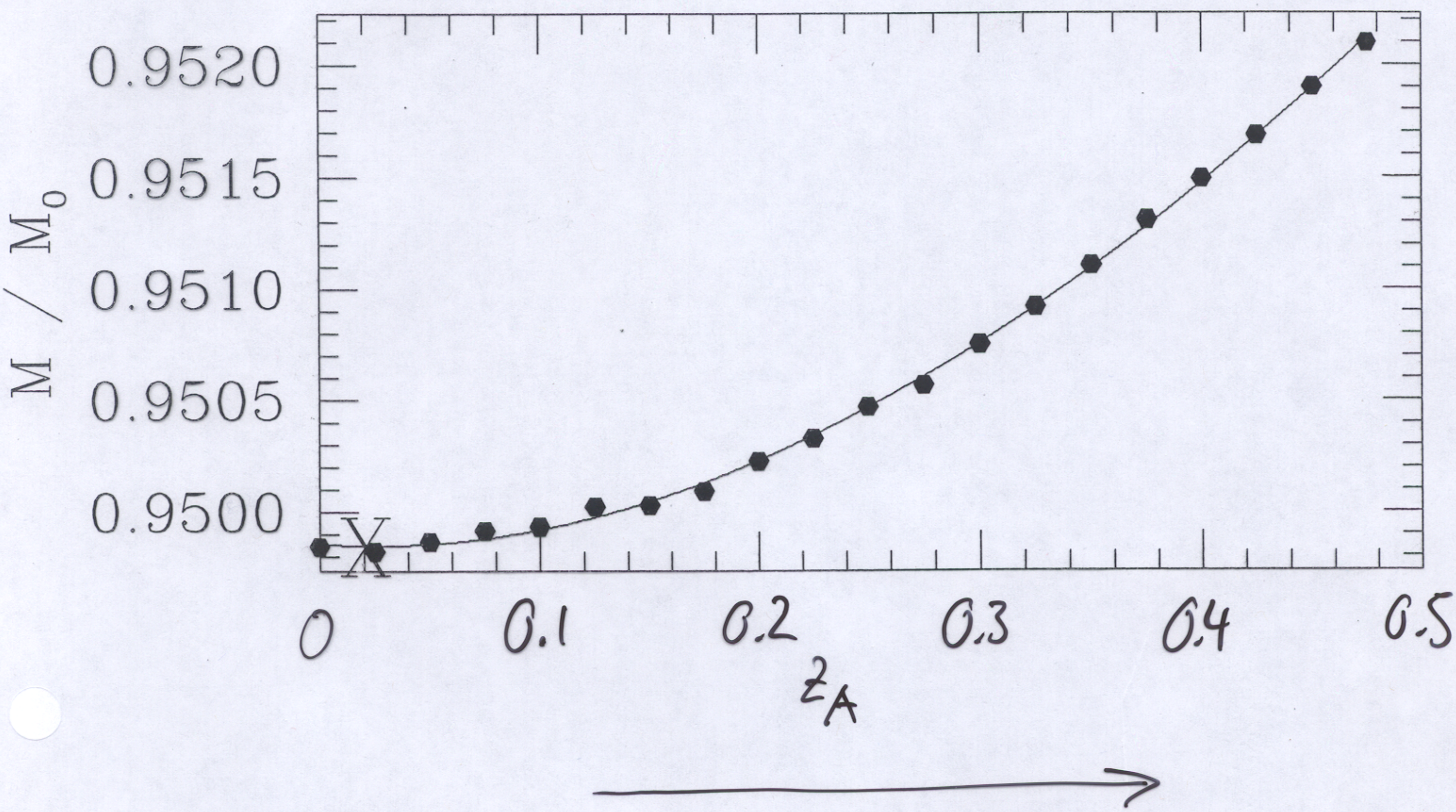
The quasi-adiabatic approximation

During late inspiral binaries are in almost circular orbits

- can approximate binary orbit as exactly circular
- treat inspiral as small correction

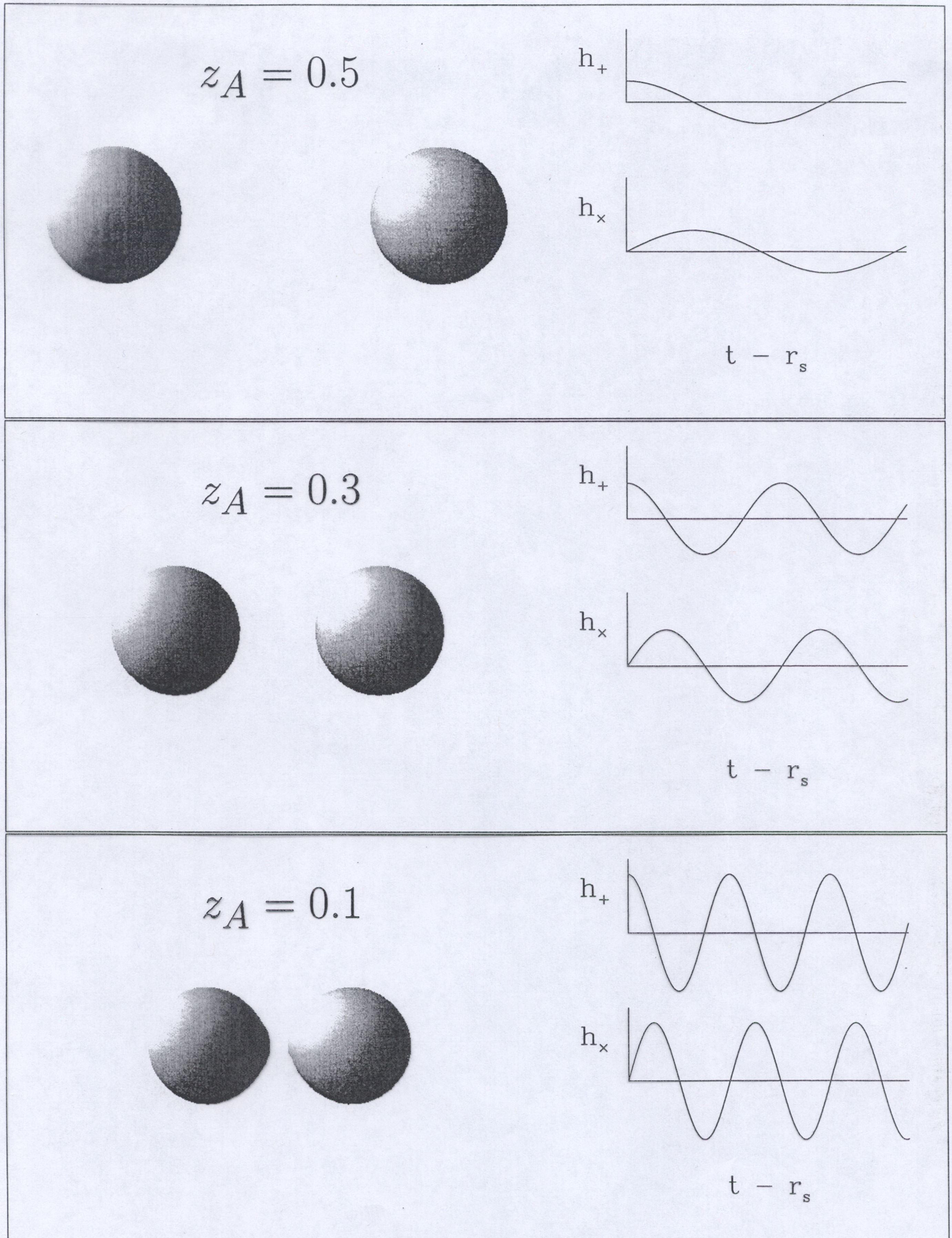
Duez, Baumgarte & Shapiro, 01
Duez et.al., 02
Laguna, 99
Whelan & Romano, 99
Whelan, Krivan & Price, 00
Brady, Creighton & Thorne, 99
Shibata & Uryu, 01
Yo, Baumgarte & Shapiro, 01

Corotational binary neutron stars

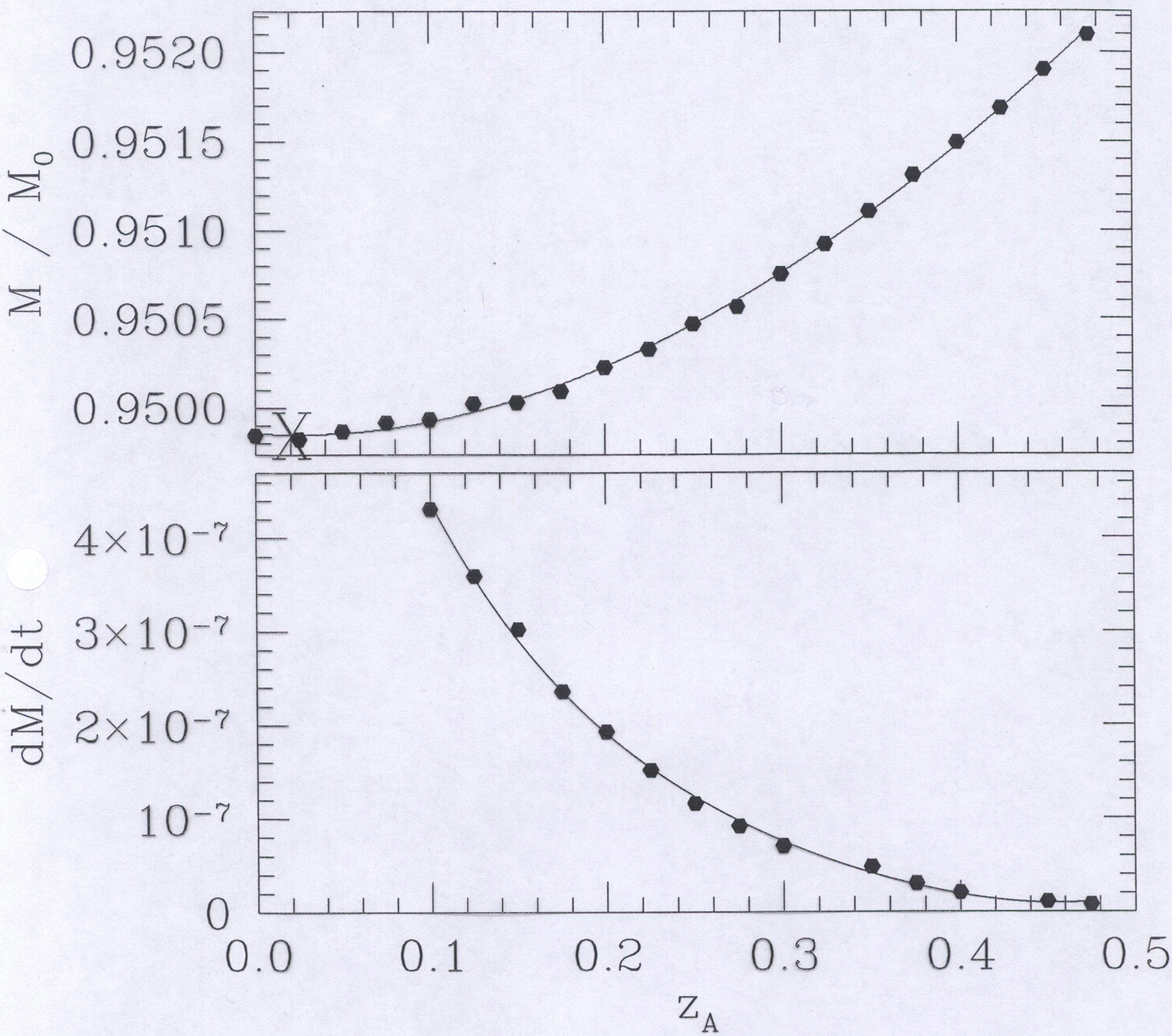


increasing separation

[Baumgarte et.al., 97, 98]



[Duez, Baumgarte & Shapiro, 01]



0.9520
0.9515
0.9510
0.9505
0.9500
M / M_0
X
4×10^{-7}
3×10^{-7}
2×10^{-7}
10^{-7}
0
dM/dt
0.0
0.1
0.2
0.3
0.4
0.5
z_A

Construction of inspiral and waveform

- Construct quasi-equilibrium "background" models of binaries in circular orbit at various separations r

  $\Rightarrow M(r), \quad \frac{dM}{dr}(r)$

- Dynamically evolve grav. fields for given background models of separation r

  $\Rightarrow h_+(r), h_\times(r) \quad \Rightarrow \quad \frac{dM}{dt}(r)$

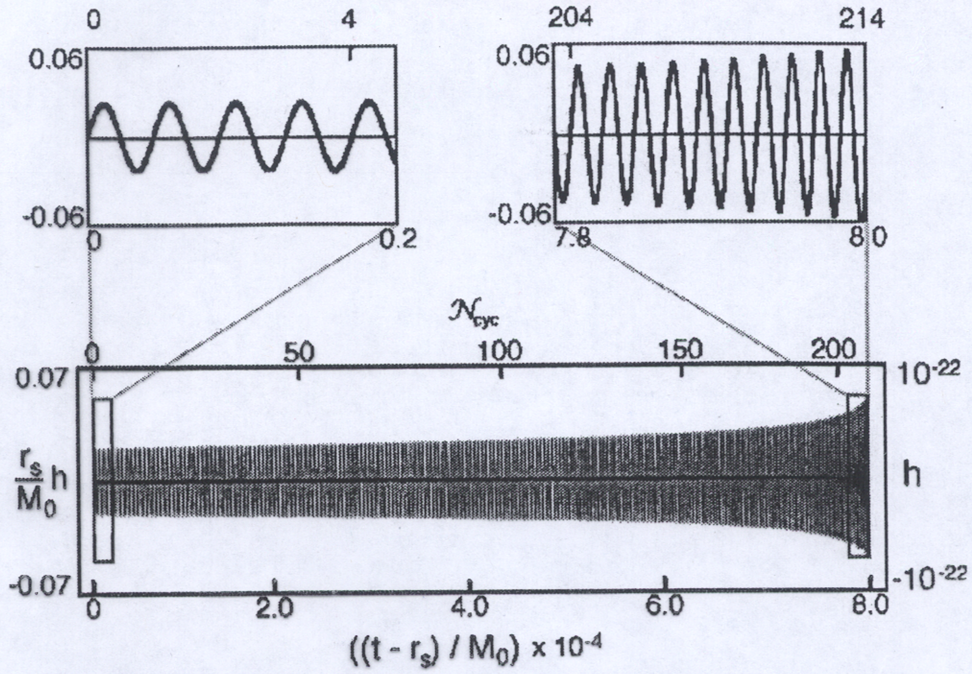
- Construct inspiral

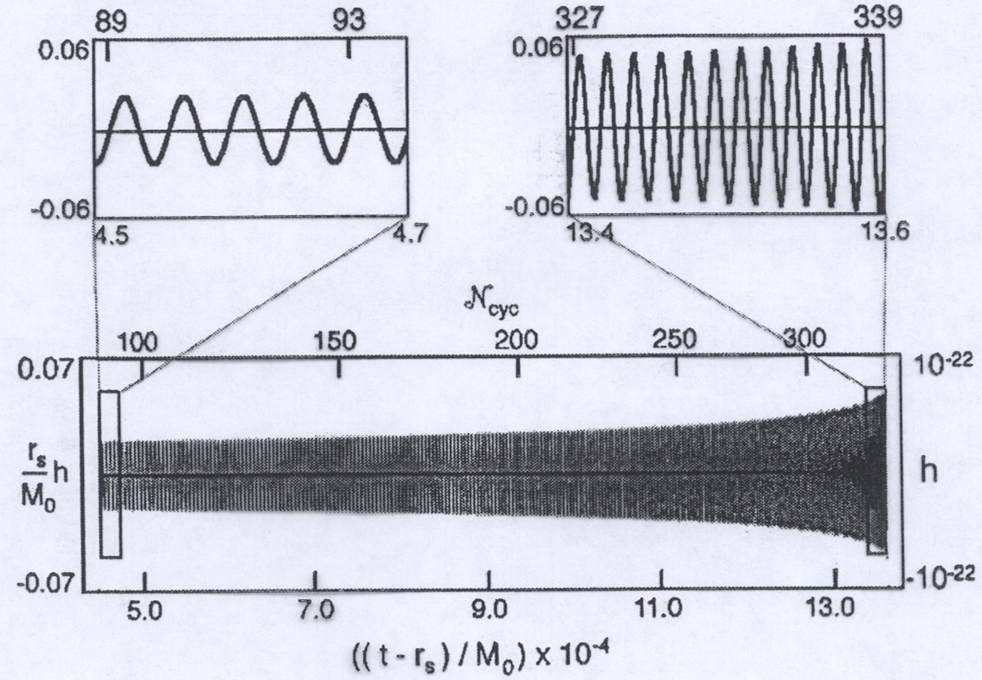
  $$\frac{dr}{dt} = \frac{dM/dt}{dM/dr} \quad \Rightarrow \quad r = r(t)$$

- Construct wave signal

  $$\Rightarrow \boxed{h_+(t), \; h_\times(t)}$$

Corotational BNS [Baumgarte et.al., 97, 98]





Irrotational BNS [Uryū & Eriguchi, 00]

[Duez et.al., 02]

Complete gravitational wavetrain

Match

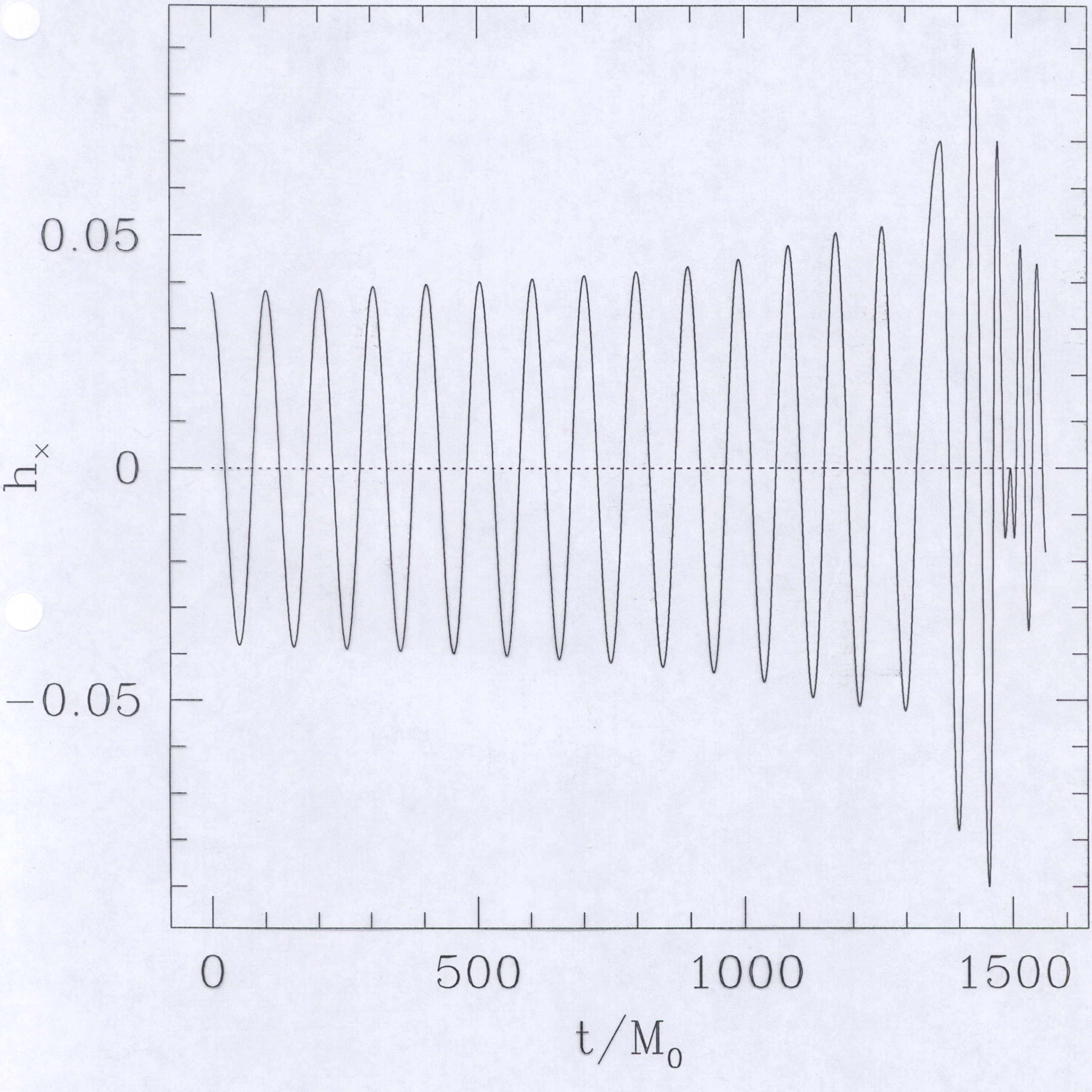
- wavetrain from quasi-adiabatic inspiral

with

- signal from dynamical plunge and merger
  [Shibata & Uryū, 00]

at about one orbital period before reaching "ISCO"

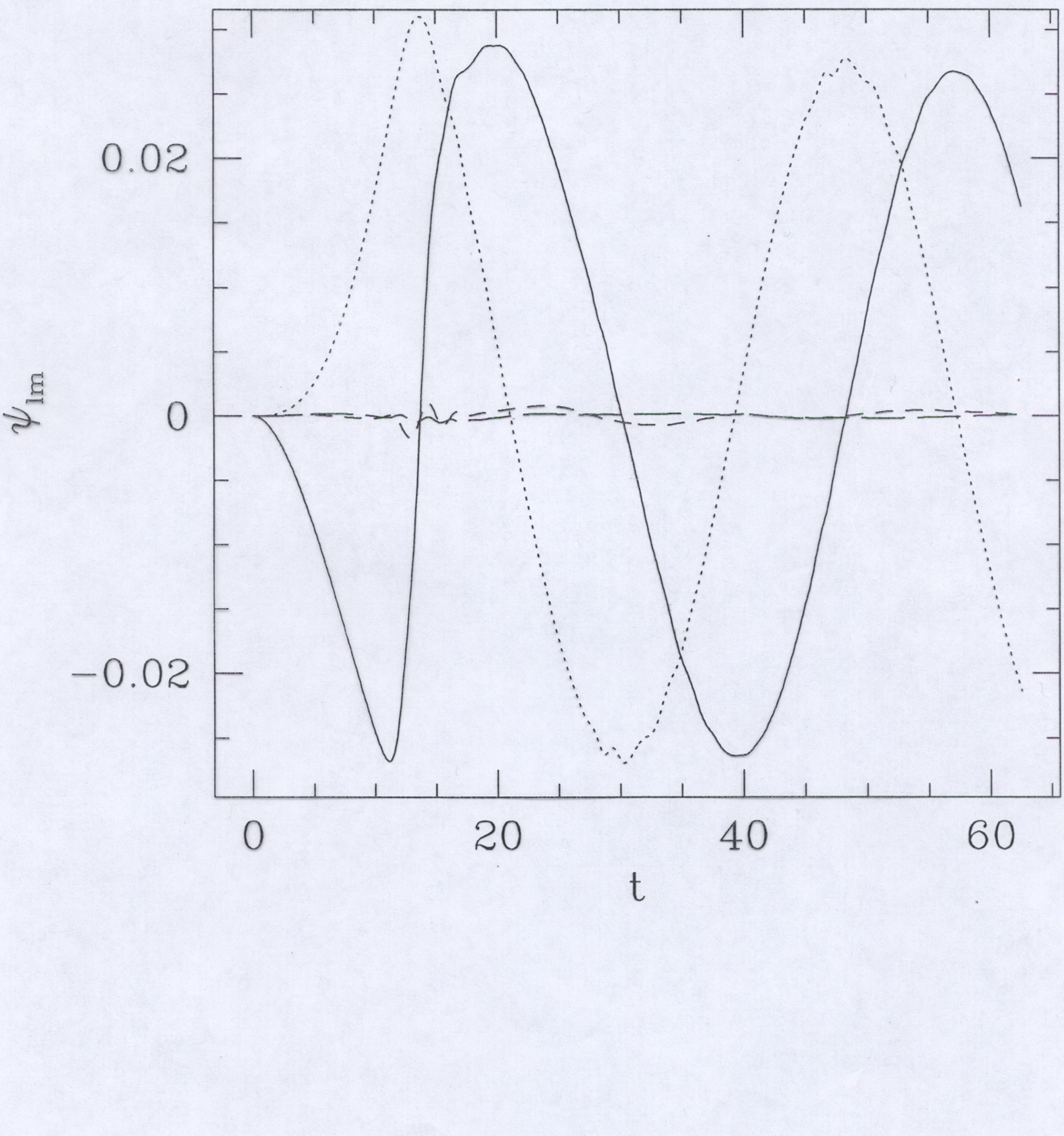
⇒ complete gravitational wavetrain of inspiral, plunge and merger



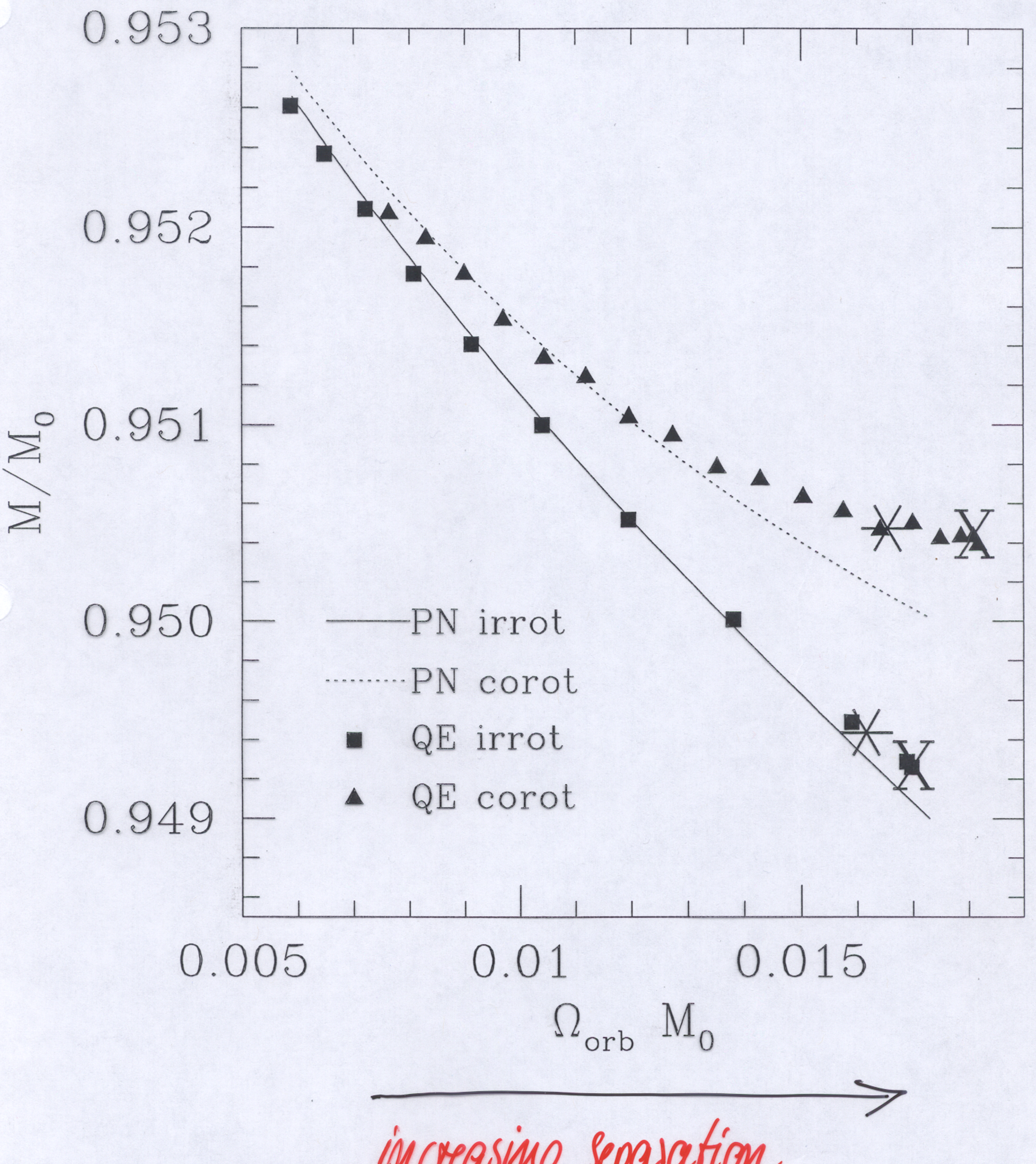
[Duez et.al., 02]

Summary

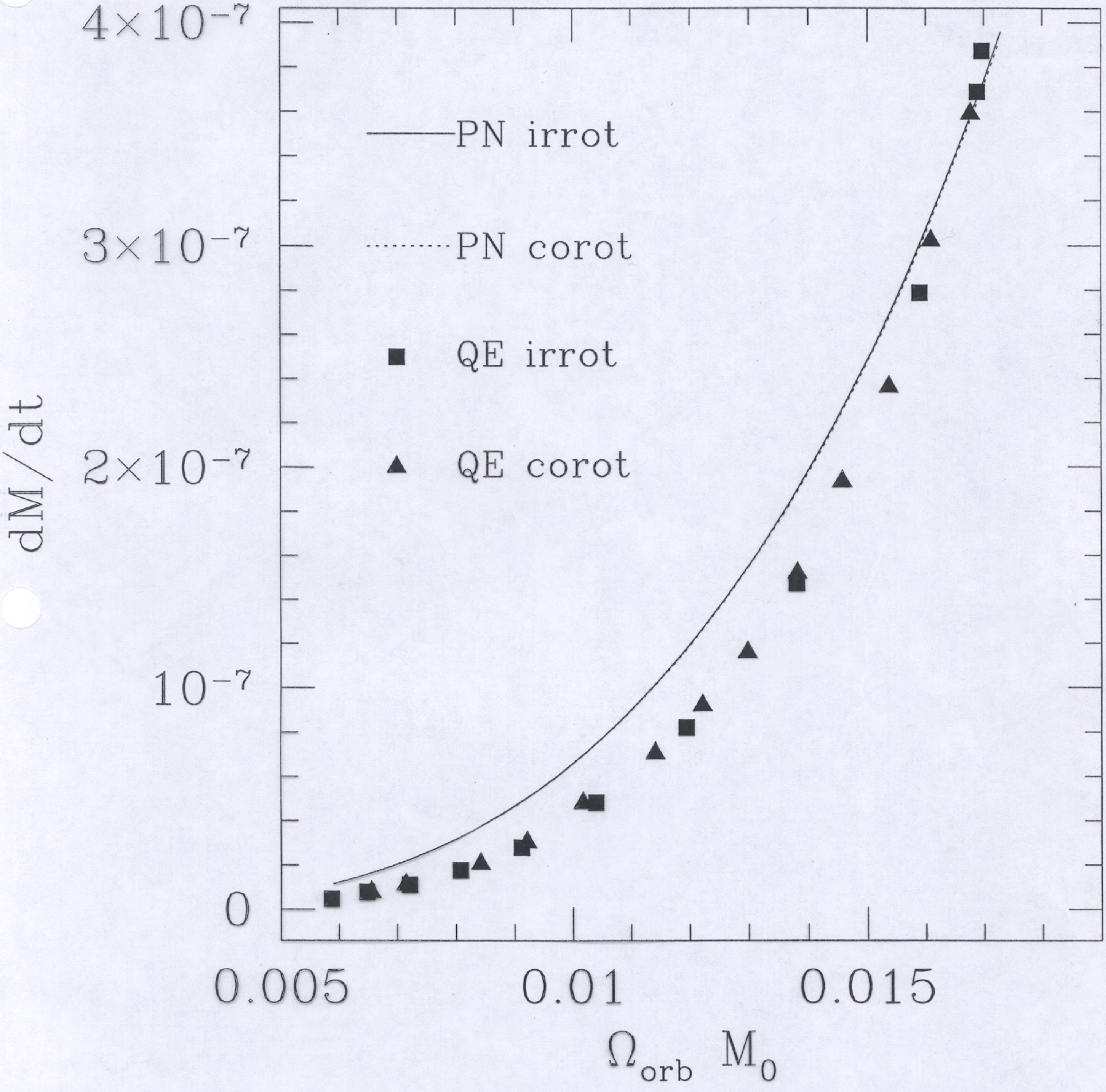
- quasi-adiabatic approximation for late binary inspiral
- illustration for corotational and irrotational binary neutron stars
- future improvements
  - resolution computational domain
  - grav. wave read-off
  - background models
- similar approach possible for binary black holes
  - requires suitable binary black hole background models



0.02
0
−0.02
ψ_{lm}
0
20
40
60
t



0.953
0.952
0.951
0.950
0.949
M/M0
0.005
0.01
0.015
Ωorb M0
PN irrot
PN corot
QE irrot
QE corot
increasing separation



4×10^{-7}
3×10^{-7}
2×10^{-7}
10^{-7}
0
dM/dt
PN irrot
PN corot
QE irrot
QE corot
0.005
0.01
0.015
Ω_{orb} M_0