

# Post-Newtonian and Self-Force calculations for EMRI sources

Bernard F Whiting<sup>#</sup> (with input from Steve Detweiler)

University of Florida

<sup>#</sup>University of Orleans (Summer 2008)

# Overview

- Introduction - what are we after?
- What do we get from perturbation analysis?
- Role of Gauge Invariance?
- What should we expect from PN approach
- What do we still need to compare with PN?
- What do we still need to get waveforms?

# Introduction - What are we after?

- We are after waveforms for extreme mass ratio binary inspiral systems - such as from a solar mass black hole in orbit around a super-massive black hole
- We plan to use perturbative methods, in which the the super-massive black hole is fully represented in general relativity, and the solar mass black hole is treated as a (possibly 2<sup>nd</sup> order) perturbation on that background

# What do we get from perturbation analysis?

- From a perturbative perspective we can treat the small black hole as a point source, which, to lowest order, moves on a geodesic
- Coupling the small black hole to a linear perturbative field around the large black hole allows us to calculate a revised orbit for the small black hole
- We also find changes in orbital frequencies

# What is the role of Gauge Invariance?

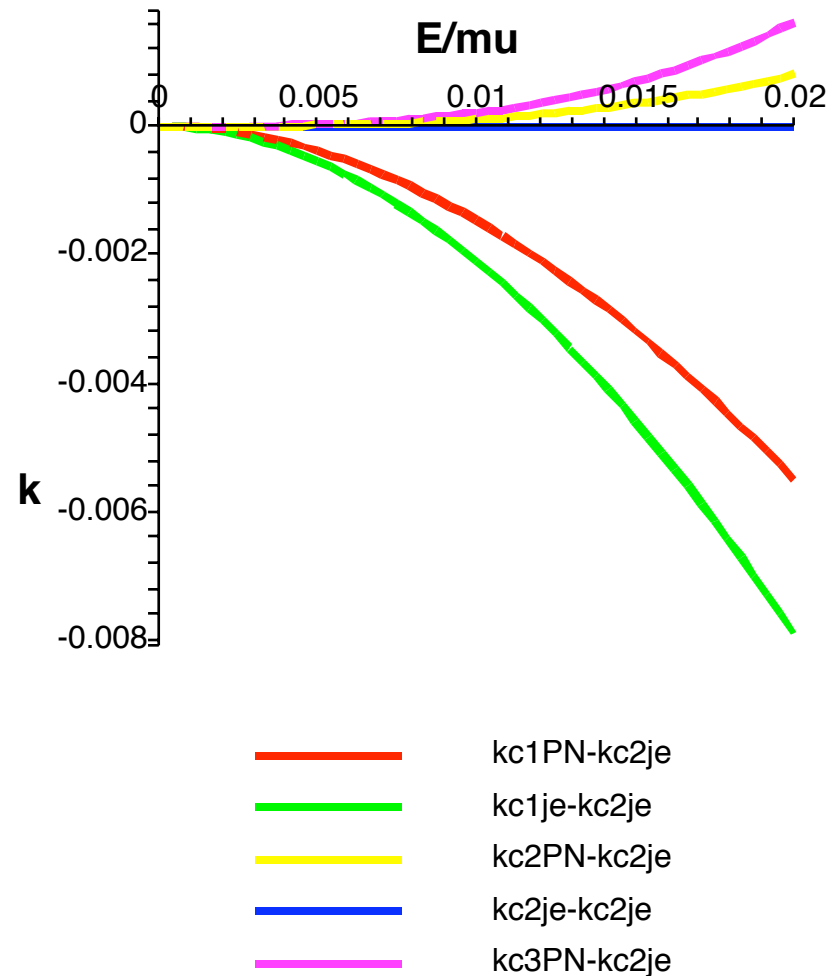
- Extracted waveforms (at infinity) and frequencies are gauge invariant
- PN calculations are not carried out in a gauge invariant manner (eg, for the metric)
- Perturbative wave equations are typically (ie, without sources) gauge invariant
- Orbits are not gauge invariant, nor are perturbative descriptions of orbital dynamics

# What should we expect from the PN approach?

- PN can't give coalescence
- NR can't do small mass ratios
- PN can't do high velocities
- May compare perturbation theory with both
- Can also compare PN with itself
- See smaller errors in higher PN orders

# What does PN give?

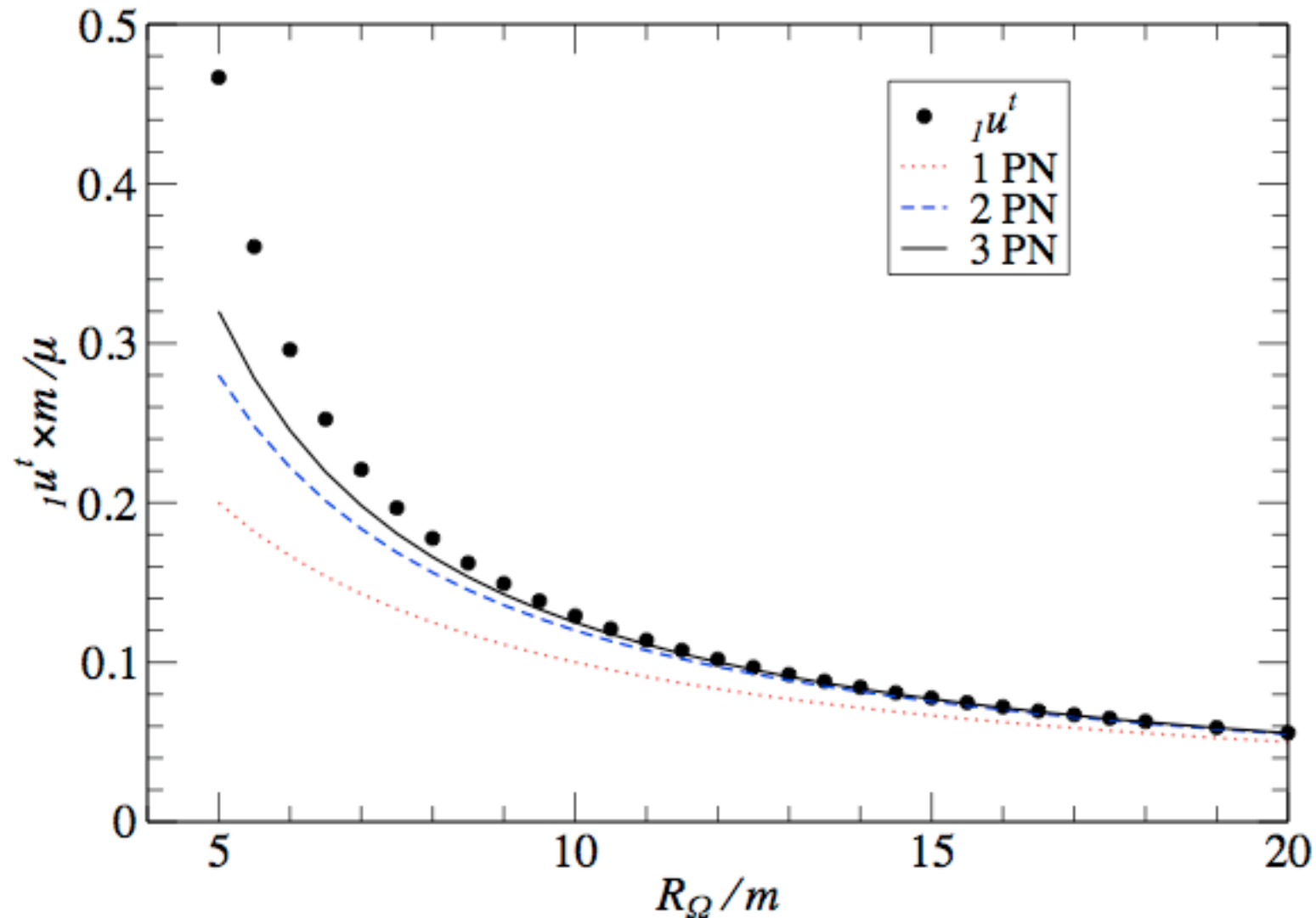
- Solve  $er^2=0$  for  $j(E)$
- Substitute in  $k(j,E)$
- Subtract reference:
  - 1PN (strict)  $r$
  - 2PN (strict)  $y$
  - 3PN (strict)  $p$
  - 1PN(exact)  $g$
  - 2PN(exact)  $b$



# What do we still need to do PN comparisons?

- Can already compare with PN frequencies
- Need PN metric for other comparisons
- Can we get a statement of when PN is known to be reliable?
  - If so, could try to evaluate how far a linear expansion is valid
  - If not, will need to rely on NR comparison

# Self-force results - II (from Detweiler)



# What do we still need to get waveforms?

- Currently, codes evaluate orbital evolution without incorporating evolved wave-field
- If orbit and wave-field are evolved separately we need an unambiguous way to characterize changes in orbital dynamics
- If not, we need to develop new methods to enable combining them (see Detweiler talk)