Highly Eccentric Kozai mechanism and GW Observation for NS-NS binaries

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N Seto, arXiv:1304.5151
K. Kyutoku & N. Seto, arXiv:1213.2953

Outline of this poster

- 1. Introduction
  - Kozai mechanism and GW observation
    - traditional averaging method (secular theory)
- 2. Direct three body integral (PN): new results (Seto 2013)
  - evolution of inner binary: quite different
    - merger time: shorter, residual eccentricity; larger
  - Why?
- 3. GW search for Eccentric binaries (Kyutoku & Seto 2014)
  - preferable for counterpart search

1.Introduction

Kozai mechanism and GW

- Kozai mechanism works for hierarchical triple and oscillates inner eccentricity (e_1) and inclination (I_1)

e_1 larger, I_1 smaller — e_1 smaller, I_1 larger

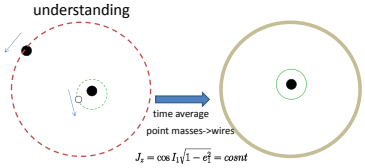
GW emission: strong dependence on $(1-e_1)$

Many works on Kozai and GWs

Blaes et al. 2001, Coleman & Hamilton 2002, Wen 2002, ... Thompson 2011

Previous studies: secular theory

- Averaging "fast" orbital revolutions (as wires)
  - follow long-term evolutions of orbital elements (e.g. semi-major axes, eccentricities, etc) by interaction of two wires
  - simplify calculations, also good for analytical understanding



$$J_z = \cos I_1 \sqrt{1-e_1^2} = const$$

2. My work 1: direct three body integral

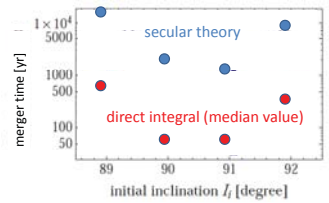
Seto 2013

- 2.5PN EoM is used
- need initial orbital phases
  - 3-body problem : very sensitive to initial conditions
  - randomly distributed and study statistical trends

initial orbital parameters
- semi-major axis a_1=0.05AU, a_2=3AU
- eccentricity e_1=0.2, e_2=0.6

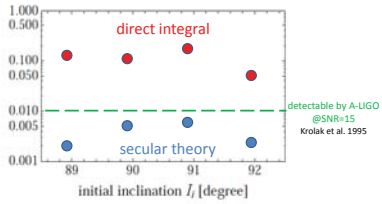
Merger times (direct vs sec)

initial inclination: 89°, 90°, 91°, 92° (each 50 runs)



More than 10 times smaller!!

Residual eccentricity at f_{orb}=5Hz



More than 10 times larger than previous estimations!!

Why so different?

Shorter merger time & larger residual e_1

- averaging picture of the secular theory
  - if orbital elements (e.g. 1-e) ~const in one inner revolution
    - averaging method : effective
  - not satisfied for highly eccentric case 1-e<<1
    - stochastic nature due to outer point masses (Katz & Dong 2012, Antognini et al. 2013, Antonini et al. 2013)
    - also resolve orbital phase for handling radiation reaction
- **pericenter distance: smaller in direct calculations**
  - residual eccentricity ↑
  - merger time↓ (rate↑?)

2.GW search for Eccentric binaries

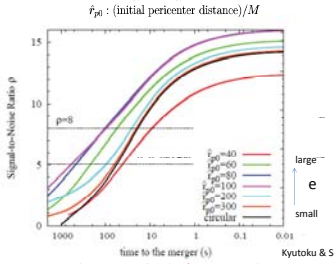
(Kyutoku & Seto 2013)

- eccentric binary (compared with a circular one)
  - emits higher frequency GWs for given semimajor axis
  - can have longer life time in LIGO band
- preferable for multi-messenger GW astronomy
  - premerger alert
  - localization at early stage

Accumulation of SNR as a function of time

$1.4M_{sun}$+$1.4M_{sun}$ @100Mpc

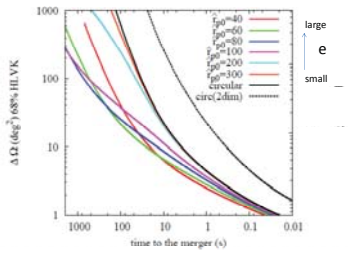
$\hat{r}_{p0}$: (initial pericenter distance)/M



Kyutoku & Seto 13

might generate earlier alert for an eccentric binary

better localization at early stage



we can (in principle) realize better premerger localization for eccentric ones

Summary

- Kozai mechanism (hierarchical triple)
  - oscillates inner eccentricity
  - mainly analyzed with the secular theory (averaging)
    - potentially inappropriate for highly eccentric cases
  - direct three body calculations
    - min pericenter distance: smaller (e.g. by 1/10)
    - residual eccentricity ↑, merger time ↓
- eccentric binary: good for GWA
  - better SNR and localization at early stage
  - (in practice) need to develop effective detection method