# Population Boundaries for Galactic White Dwarf Binaries in LISA's Amplitude-Frequency domain.

Ravikumar Kopparapu
Department of Physics and Astronomy
Louisiana State University,
Baton Rouge LA

LIGO-LLO
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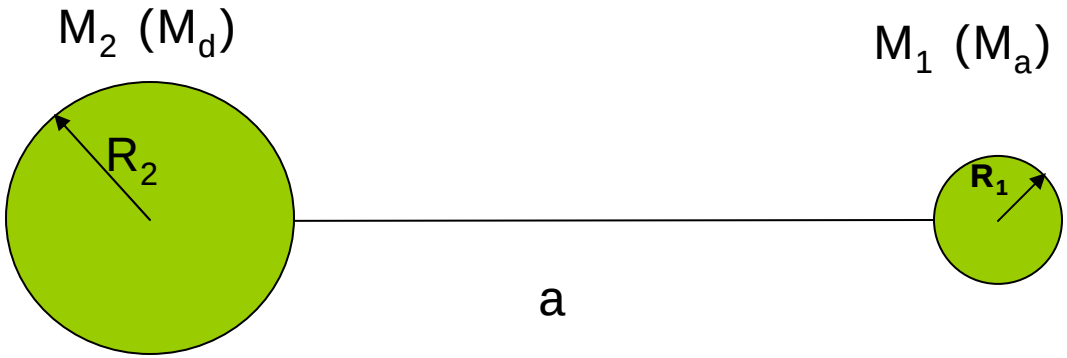
# Overview

- Double White Dwarf (DWD) binaries (properties, evolution, population)
- Constraints on DWD population in the LISA Spectrum
- Bounds on various sources of astrophysical significance

# Double White Dwarf

- Properties
- Evolution
- Population




$$M_{tot} = M_a + M_d = M_1 + M_2 \qquad q = \frac{M_d}{M_a} = \frac{M_2}{M_1}$$

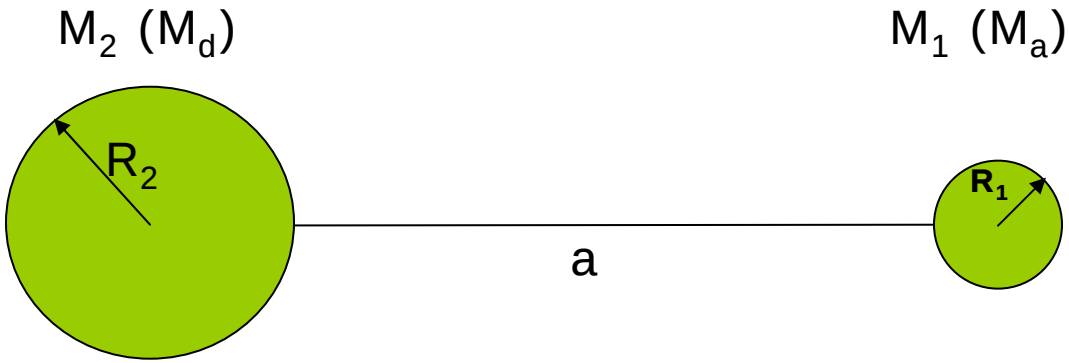
$M_1 < M_2$

Radius inversely proportional to mass

Max. mass $M_{ch} = 1.44\ M_\odot$

# Double White Dwarf

- Properties
  - Radius inversely proportional to mass.
  - Max. mass $M_{ch} = 1.44\ M_{\odot}$
- Evolution
  - Inspiral – Loss of angular momentum due to GR (separation decreasing)
- Population




$$\Omega_{orb}{}^2 = \frac{GM_{tot}}{a^3}$$

$$J = J_0\left(1-\frac{t}{\tau_{ch}}\right)^{1/8}$$

$$\tau_{ch} = \frac{5c^5}{256G^3}\frac{a_0{}^4}{(M_{tot})^3}\frac{(1+q)^2}{q}$$

$$h_{norm} = \frac{4G^3}{c^4}\frac{(M_{tot})^{5/3}}{J^2}\frac{q^3}{(1+q)^6}$$

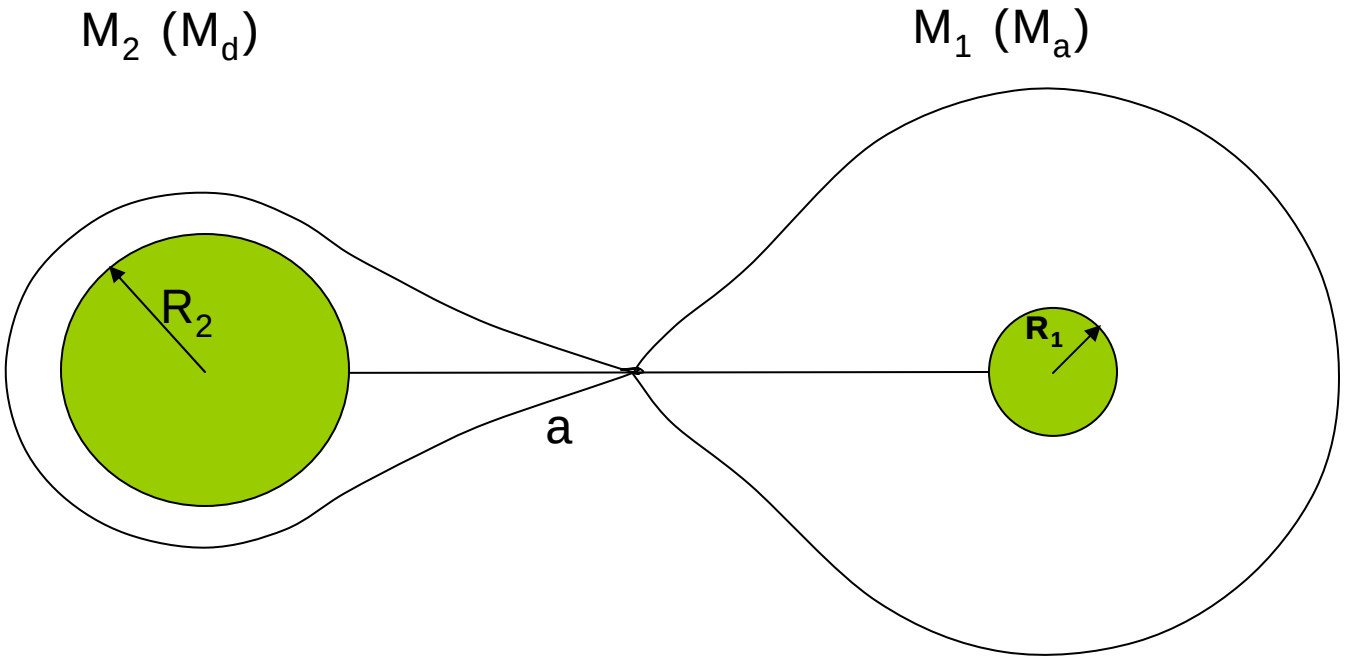
$$h_{norm} = \sqrt{h_+{}^2 + h_\times{}^2}$$

$$f = \frac{G^2}{\pi}\frac{(M_{tot})^5}{J^3}\frac{q^3}{(1+q)^6}$$

$$h_{norm}\alpha(f^{2/3})$$

# Double White Dwarf

- Properties
  - Radius inversely proportional to mass.
  - Max. mass $M_{ch} = 1.44\ M_{\odot}$
- Evolution –
  - Inspiral – Loss of angular momentum due to GR (separation decreasing)
  - Mass Transfer – Less massive star fills Roché lobe (separation increasing)
- Population




$$M_{tot} = M_a + M_d = M_1 + M_2$$

$$q = \frac{M_d}{M_a} = \frac{M_2}{M_1}$$

$$J = M_1 M_2 \frac{(Ga)^{1/2}}{M_{tot}}$$

$$\frac{\dot{a}}{a} = \frac{2\dot{J}}{J}^{0} + \frac{2(-\dot{M}_2)}{M_2}\left(1 - \frac{M_2}{M_1}\right)$$

# Double White Dwarf

- Properties
  - Radius inversely proportional to mass.
  - Max. mass $M_{ch}$ = 1.44 $M_{\odot}$
- Evolution –
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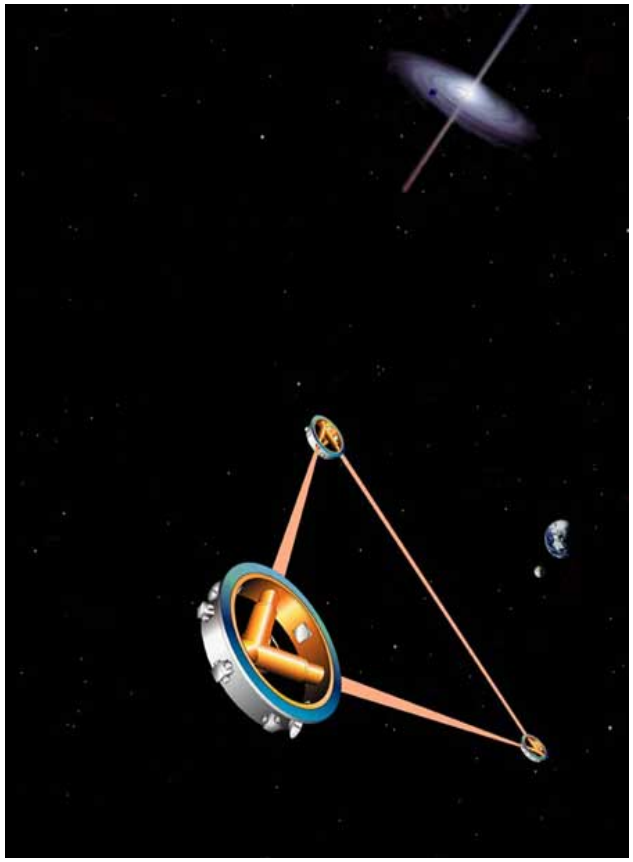
- Population
  - Milkyway ~ 2.5 x $10^8$ (Nelemans, 2001a)

# LISA *(Laser Interferometer Space Antennae)*



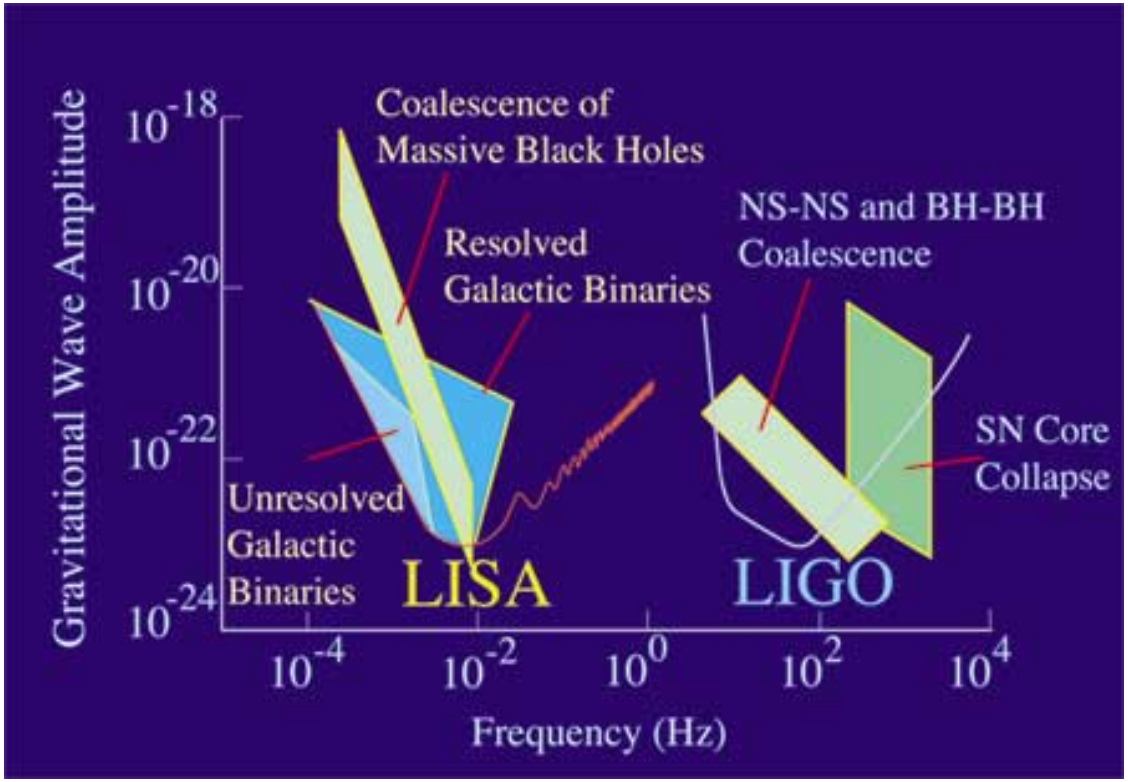
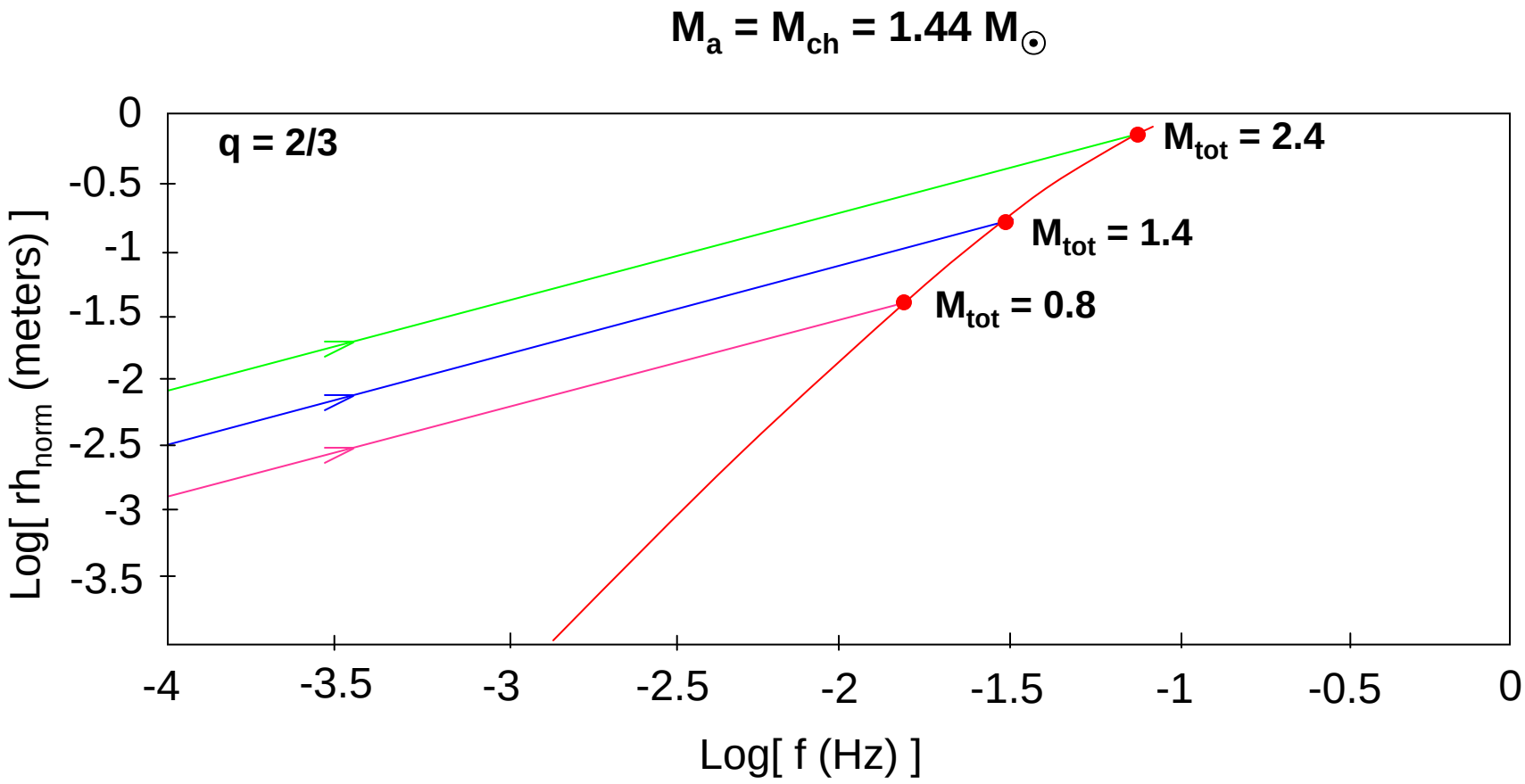
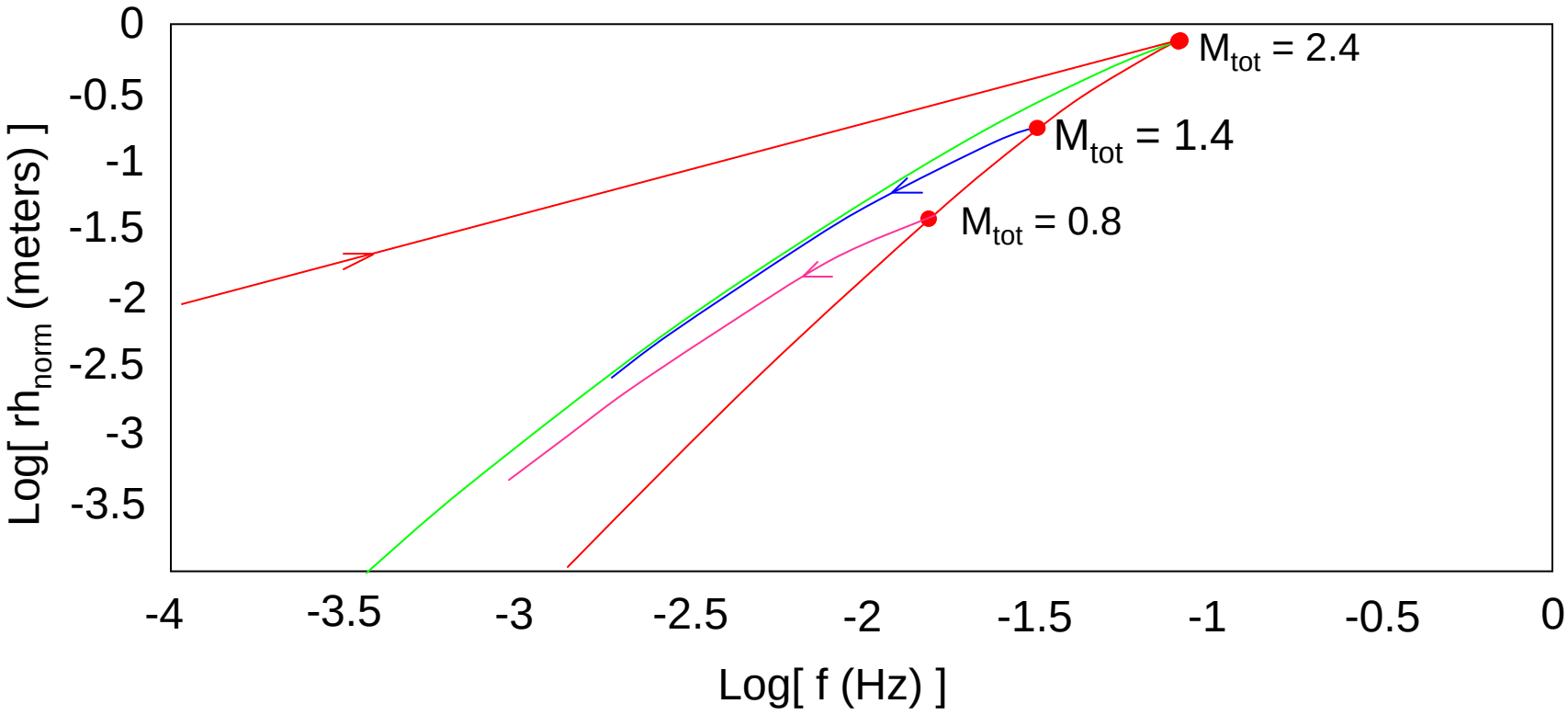


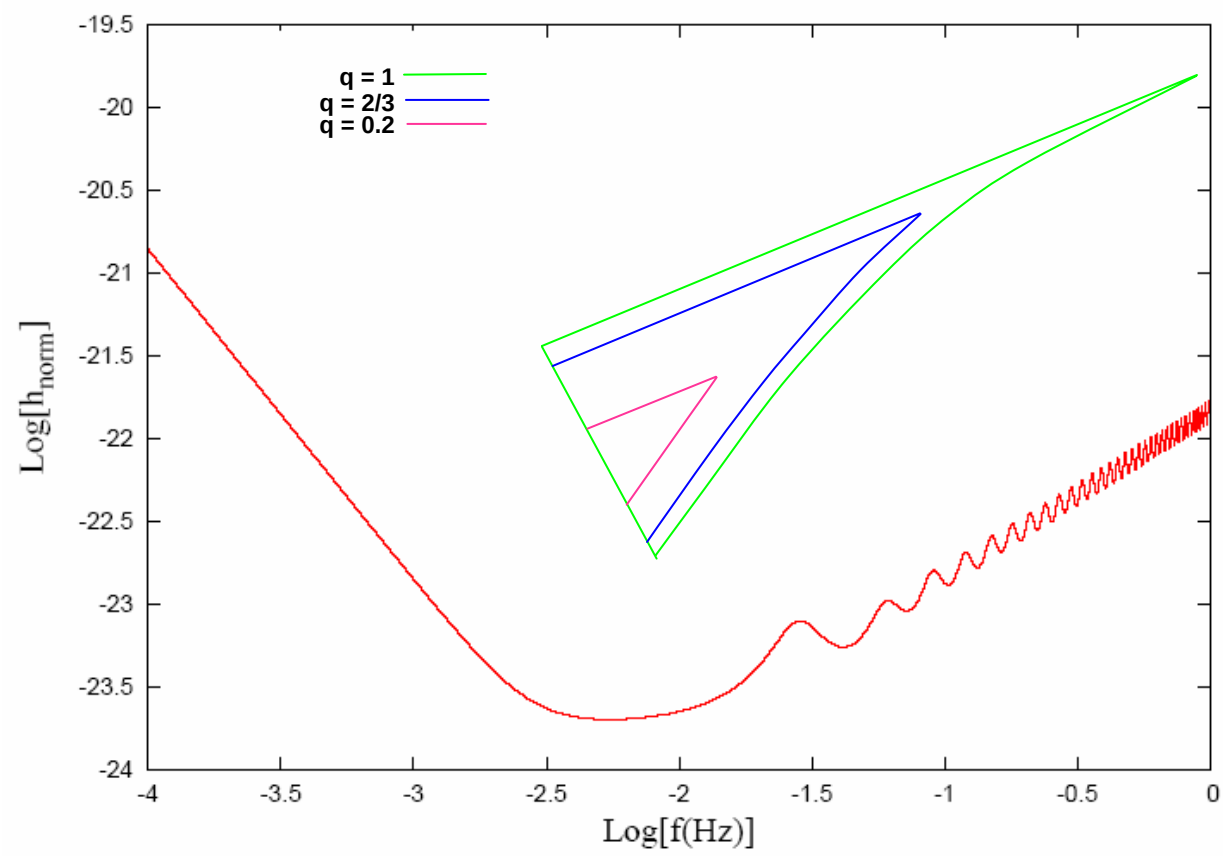

Image courtesy: http://lisa.nasa.gov/

# Constraints on DWD population

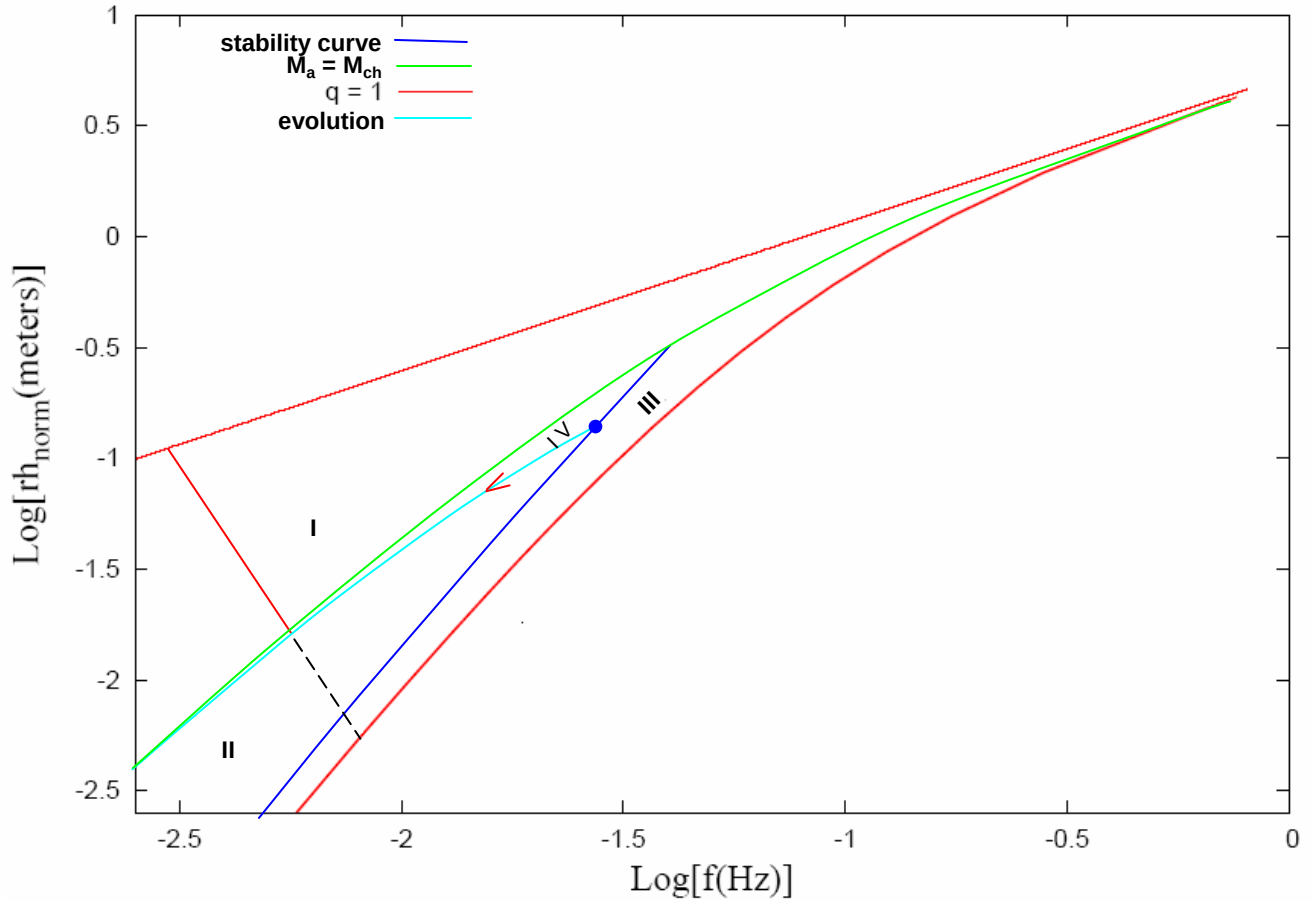


# Constraints on DWD population



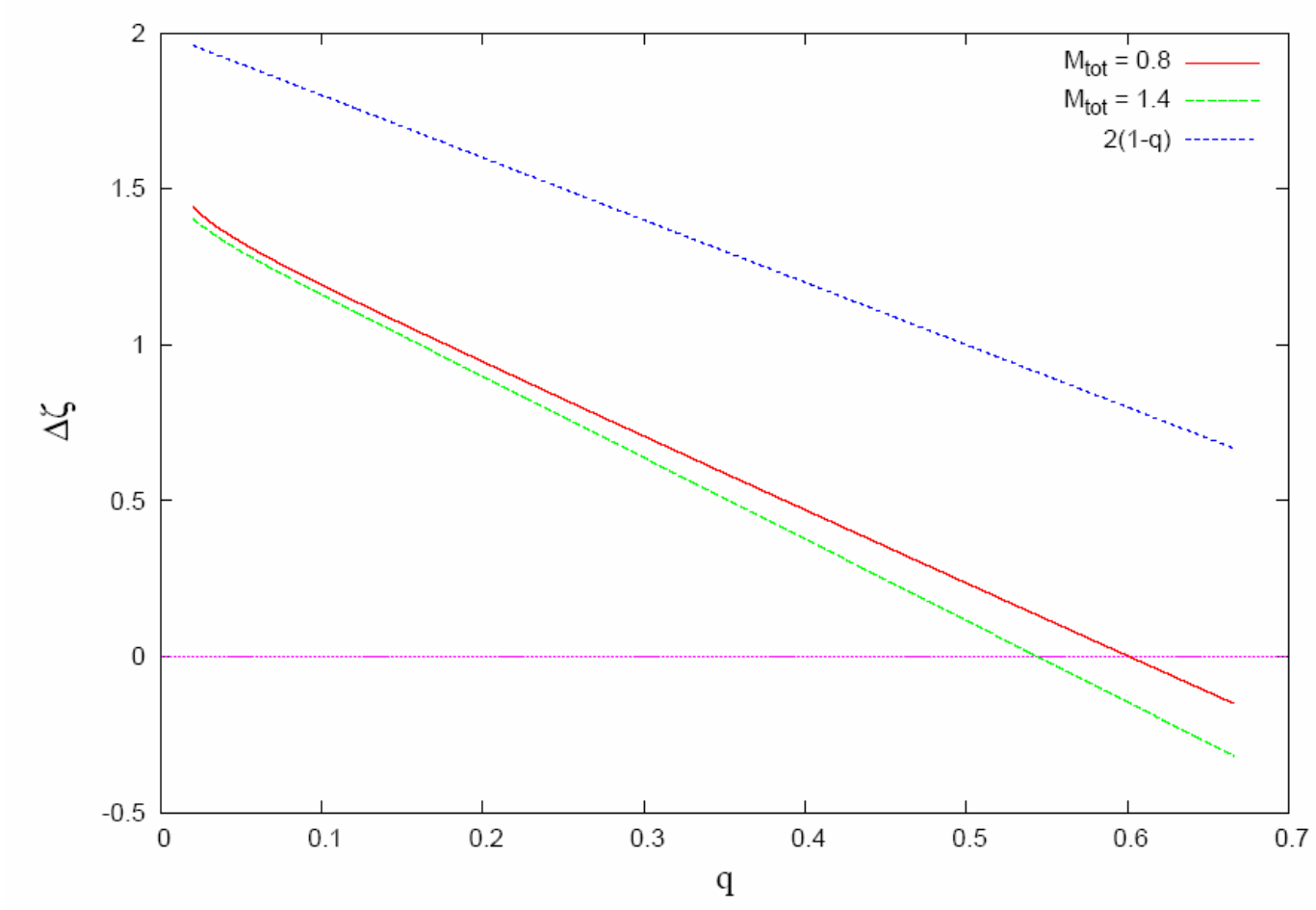

q = 1
q = 2/3
q = 0.2
-19.5
-20
-20.5
-21
-21.5
-22
-22.5
-23
-23.5
-24
-4
-3.5
-3
-2.5
-2
-1.5
-1
-0.5
0
Log[h_norm]
Log[f(Hz)]

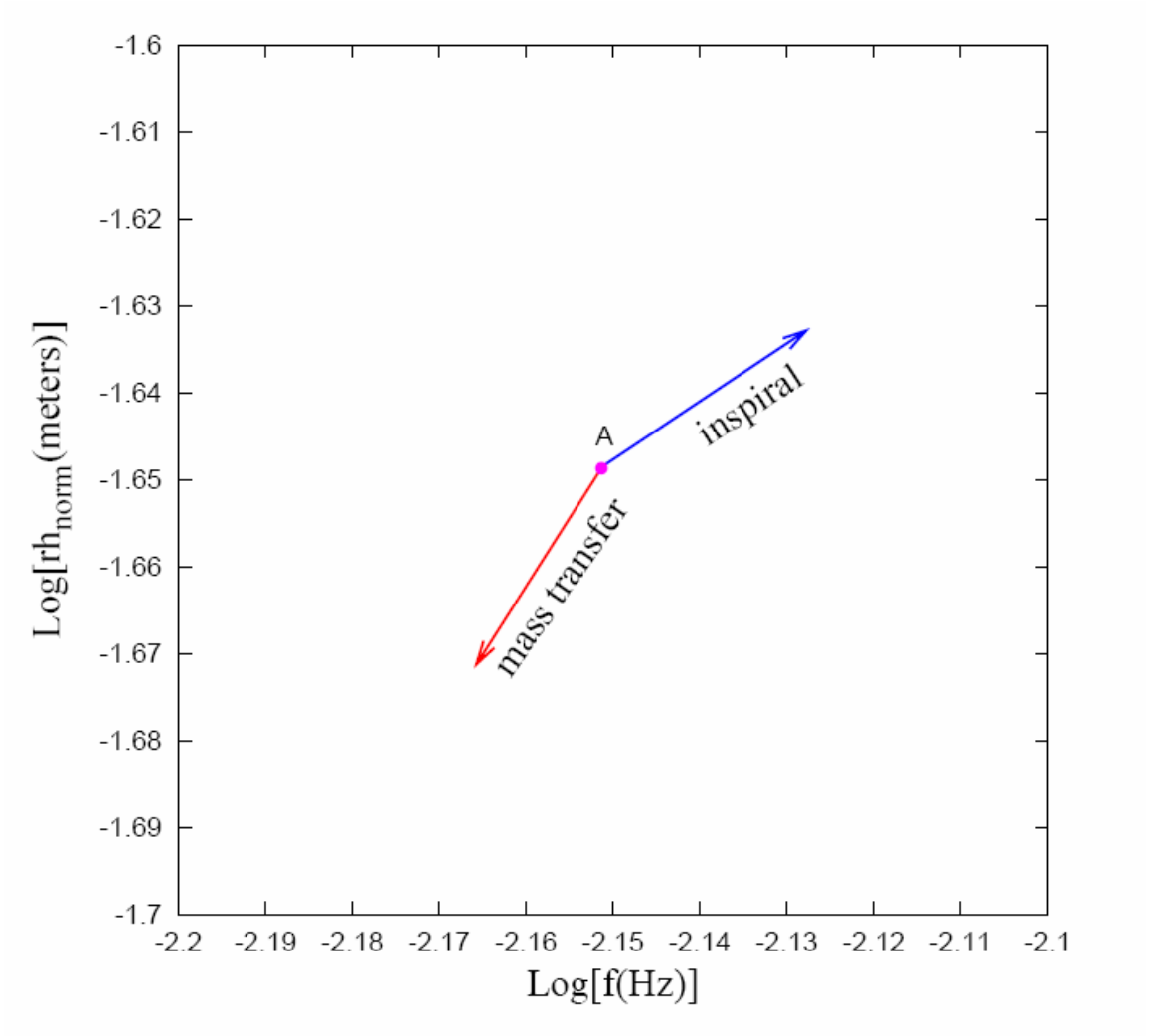
# Bounds on DWD population



# Summary

- DWD population - Important sources for LISA
- Huge number of galactic binaries
- Evolution - Inspiral and Mass Transfer
- Progenitors of Type Ia supernovae
- Limits on existence of DWD population in the amplitude-frequency domain


2
1.5
1
0.5
0
-0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Δζ
q
M_tot = 0.8
M_tot = 1.4
2(1-q)


-1.6
-1.61
-1.62
-1.63
-1.64
-1.65
-1.66
-1.67
-1.68
-1.69
-1.7
-2.2
-2.19
-2.18
-2.17
-2.16
-2.15
-2.14
-2.13
-2.12
-2.11
-2.1
Log[rh_norm(meters)]
Log[f(Hz)]
A
inspiral
mass transfer

$$\Phi_0(t) = 2\pi \int_0^t f_0[1 + f't]dt = 2\pi\left[t + \frac{1}{2} f't^2\right]$$

# Terminology

- $M_1(M_a)$, $M_2(M_d)$, $M_{tot} = M_1 + M_2$, $q = M_2 / M_1$
- Inspiral:

$$J = J_0\left(1 - \frac{t}{\tau_{ch}}\right)^{1/8}$$

where

$$\tau_{ch} = \frac{5c^5}{256G^3}\frac{{a_0}^4}{(M_{tot})^3}\frac{(1+q)^2}{q}$$

- Mass transfer:

$$J = M_1 M_2\left(\frac{Ga}{M_{tot}}\right)^{1/2}$$

$$\frac{\dot{a}}{a} = \frac{2\dot{J}}{J}^{0} + \frac{2(-\dot{M}_2)}{M_2}\left(1 - \frac{M_2}{M_1}\right)$$