Rates from binaries: current status

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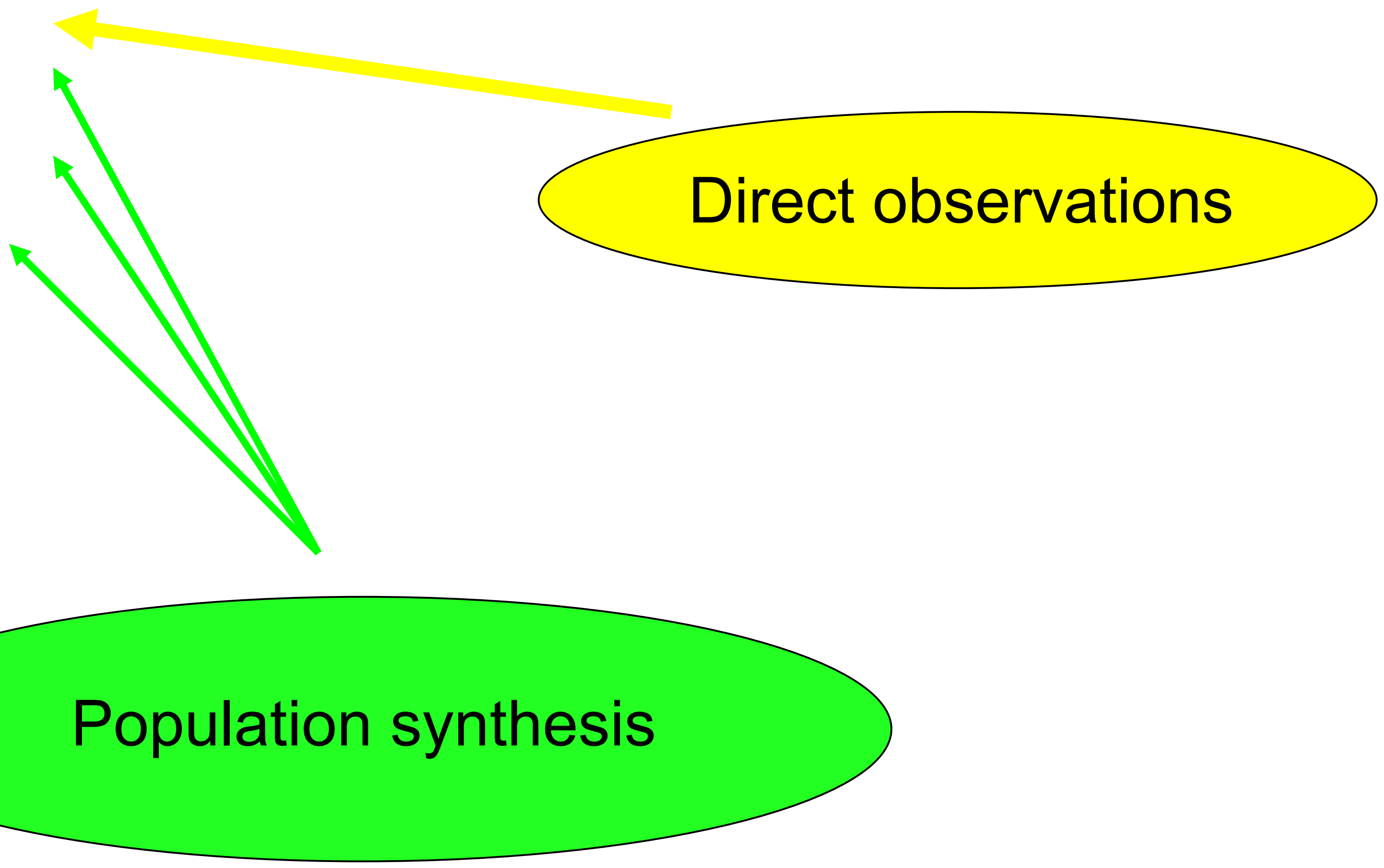
Plan

- Rates based on observations
  - Discoveries of new double pulsars
- Population synthesis: results and current issues

- Short Gamma-Ray Bursts
- Studies of exotic objects

Inspiral sources

- Compact object binaries
  - NS NS
  - BH NS
  - BH BH



Rates

Kalogera et al 2004:

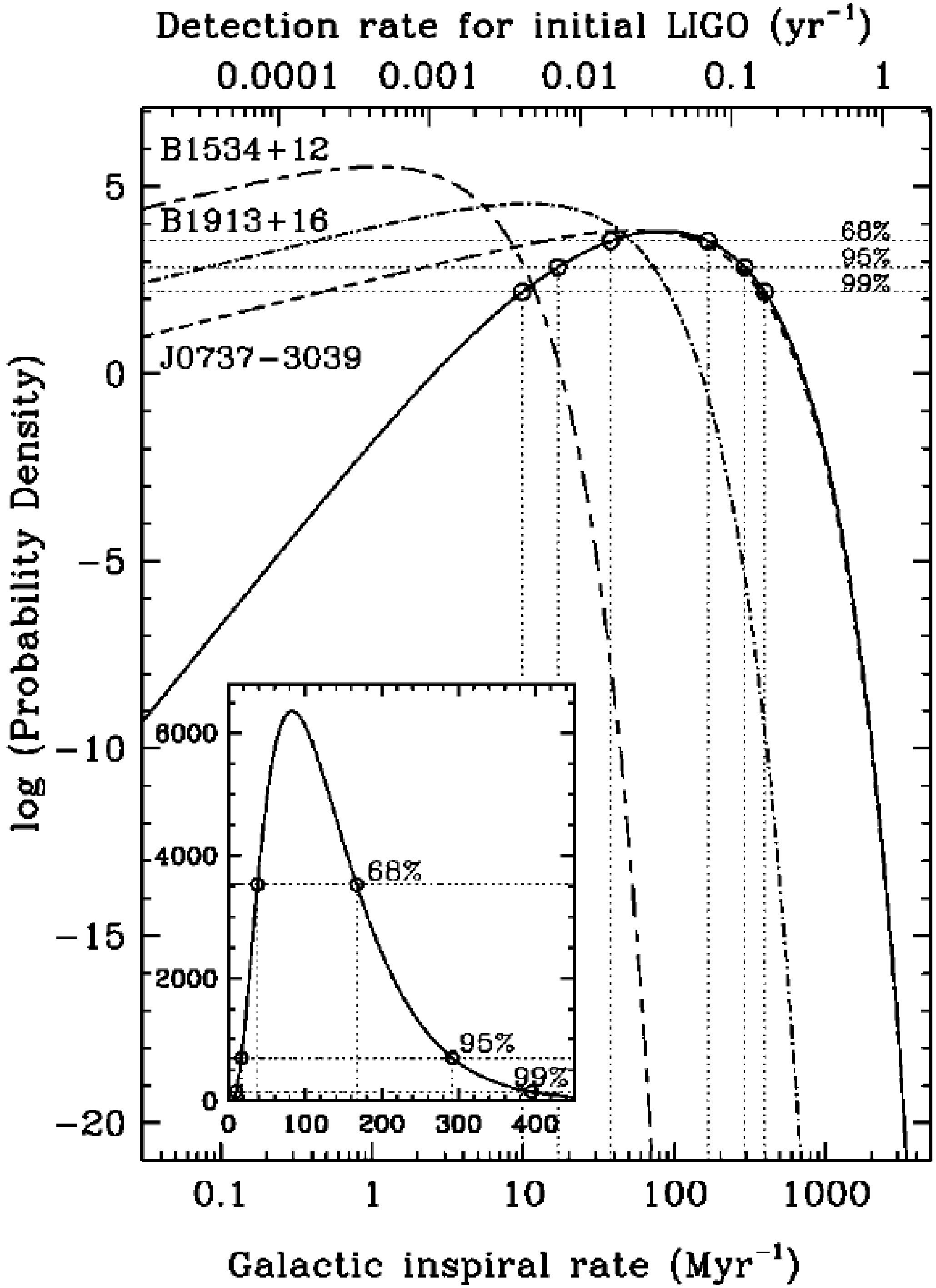
<u>Galactic coalescence rate at 95% including all the models:</u>

1-800 per Myr per Galaxy

The LIGO/VIRGO detection rate

0.4-350 per kyr

But:
only DNS systems observed
no BHNS
no BHBH binaries



Double pulsar inventory

Coalescing in Hubble time

B1534+12
B1913+16
J0737-3039A+B

J1756-2251 new!
J1906+0746 new!

B2127+11C (Globular cluster)

Long coalescence times

J1518+4904
J1829+2456
J1811-1736

J1906+0746

$$P = 144\,\mathrm{ms}$$
$$\dot{P} = 2.02 \times 10^{-14}$$
$$P_b = 0.166\,\mathrm{days}$$
$$e = 0.085$$
$$D \approx 5.4\,\mathrm{kpc}$$
$$\tau = 112\,\mathrm{kyr}$$
$$\tau_{GW} = 300\,\mathrm{Myrs}$$
$$M_1 + M_2 = 2.6\,M_\odot$$

Birthrate: 0.3/ Myr

Contribution to the Galactic rate:

increase by a factor of ~2

Kim & Kalogera 2006

$$t_{radio} \approx 10^8 \left(\frac{P_f}{3s}\right)^2 \mathrm{yr}$$

Very short lifetime – an extremely rare detection?

Could be an NS – WD system

Lorimer et al. 2006, ApJ, 640 428.

J1756-2251

$$P = 28\,\mathrm{ms}$$
$$\dot{P} = 1.01 \times 10^{-18}$$
$$P_b = 0.31\,\mathrm{days}$$
$$e = 0.18$$
$$D \approx 2.5\,\mathrm{kpc}$$
$$\tau = 443\,\mathrm{Myr}$$
$$\tau_{GW} = 1690\,\mathrm{Myrs}$$
$$M_1 = 1.40\,M_\odot$$
$$M_2 = 1.18\,M_\odot$$

Similar to B1534+12

Pulsars of this type already taken into account in the rate calculation.

Negligible change in the expected rates.

Low mass of the companion an NS WD system ?

A. Faulkner et al. 2005, ApJ 618, L119

All binary pulsars but one detected via recycled pulsars

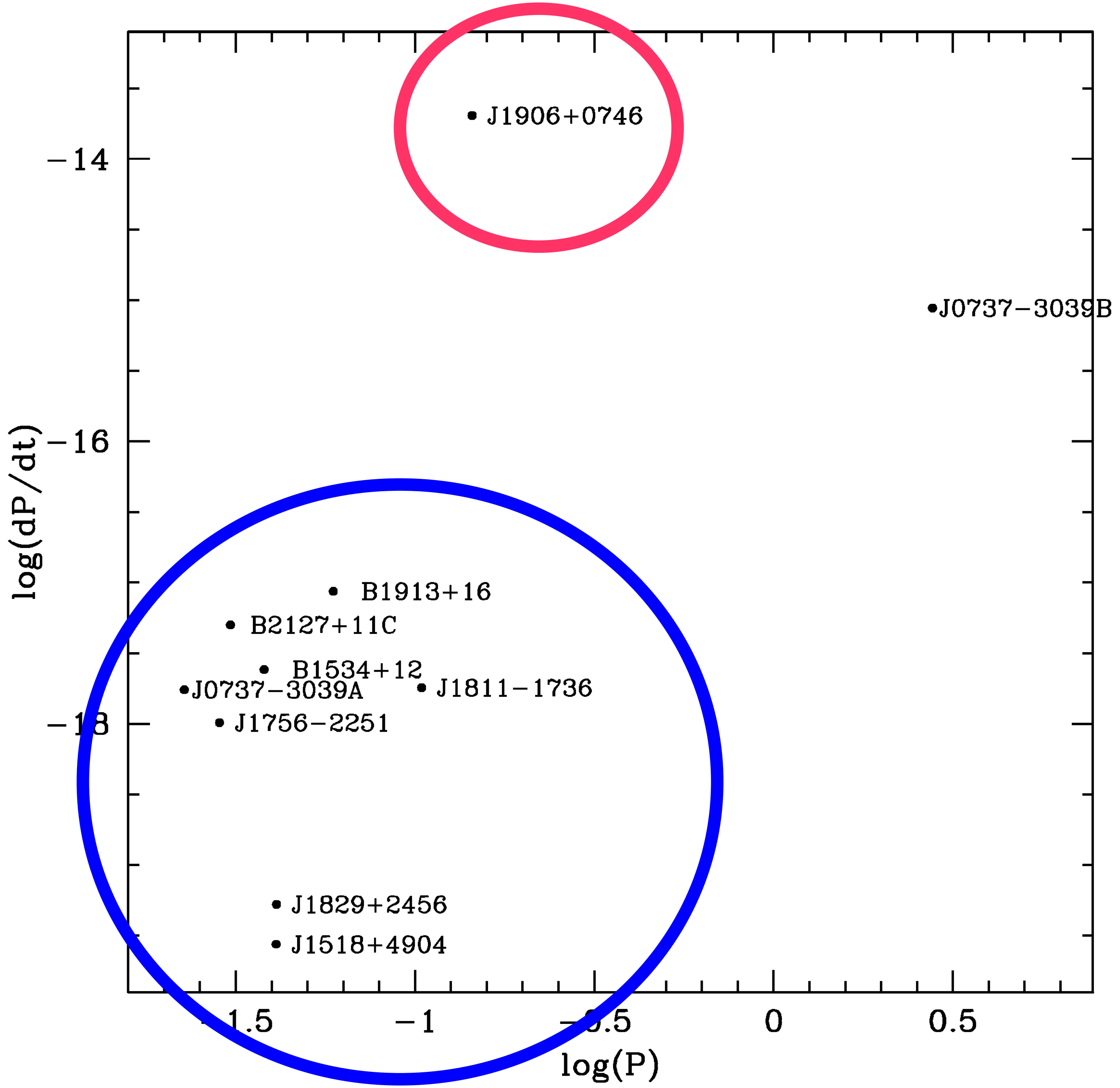
Pulsars in BHNS systems – classical

Detectability of BHNS systems:

Ratio of radio lifetimes ~ 10^{-2}

But we now see one classical binary pulsar!

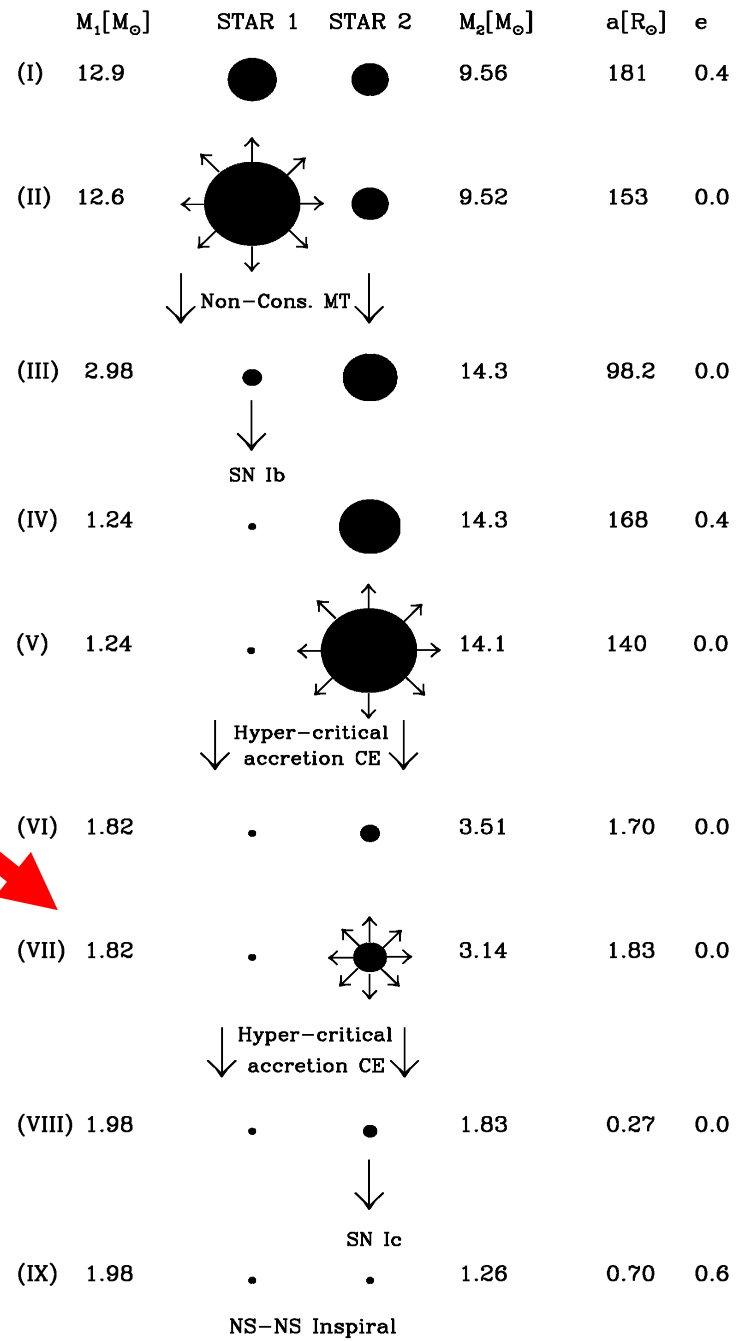
Makes detection of BHNS binaries more likely!



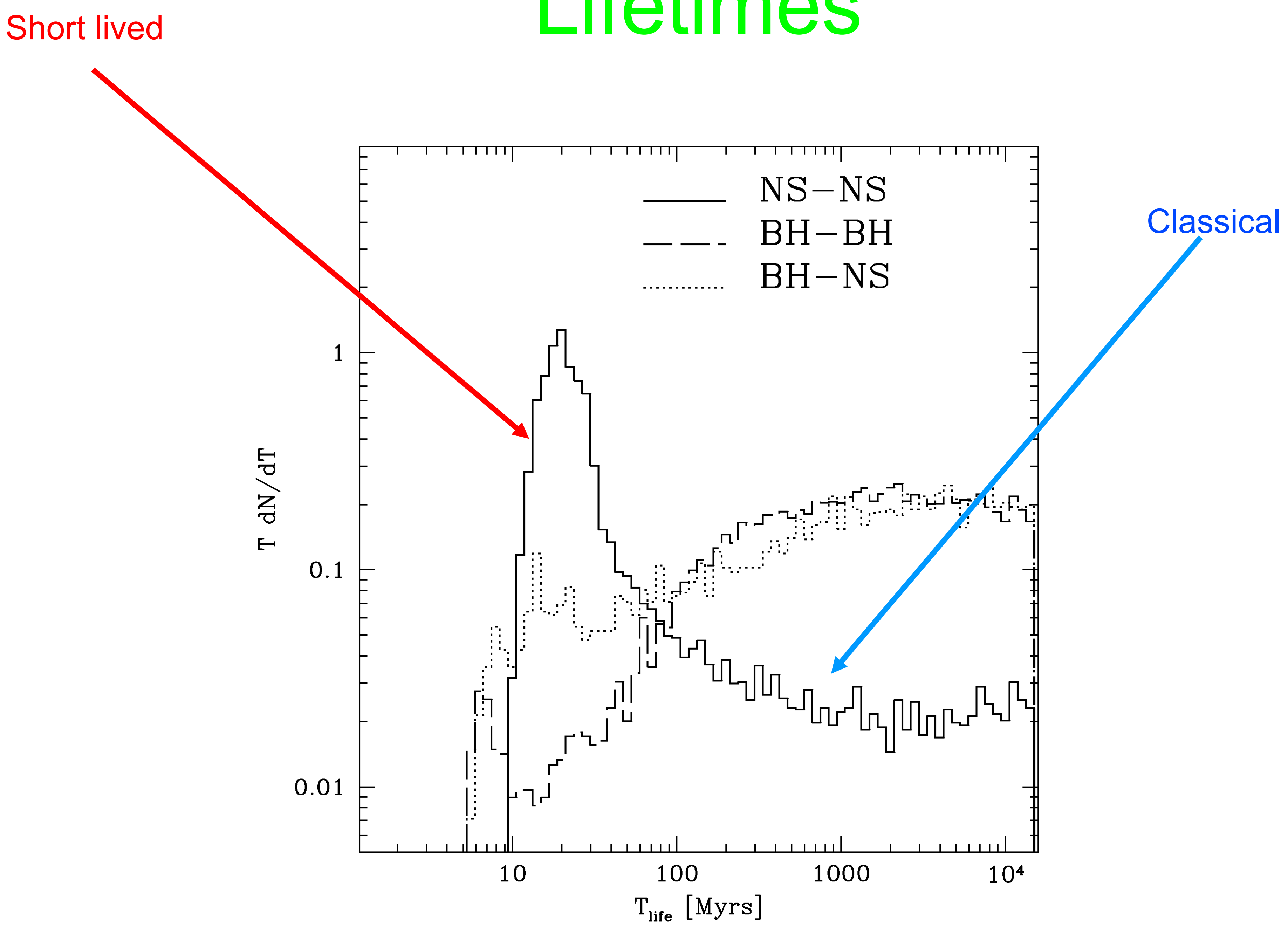
Population synthesis

NS NS binaries

- Classical binaries
- Short lived binaries produced via common envelope with Helium stars
- Significant contribution of the latter class



Lifetimes

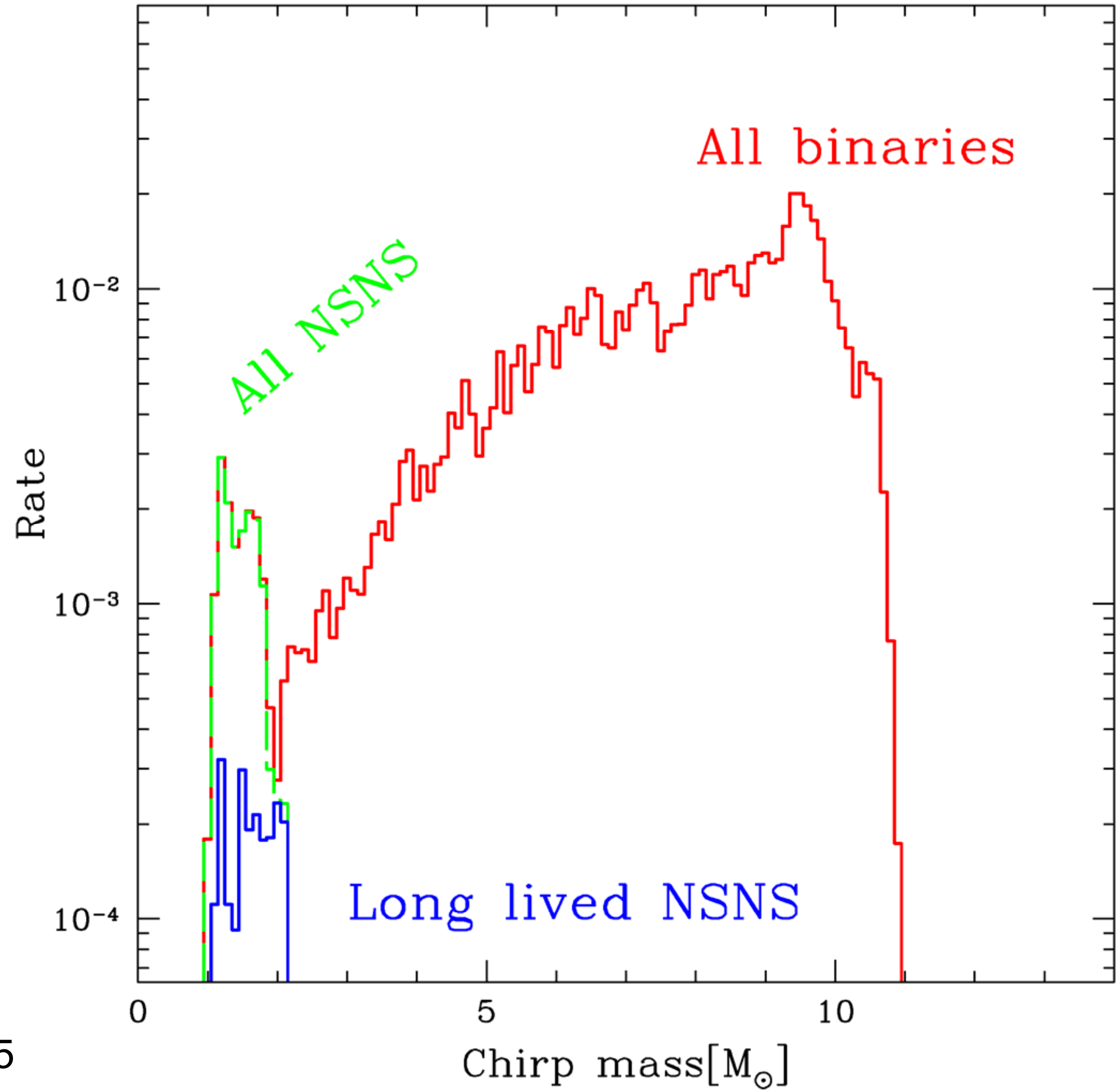

Short lived
Classical
NS−NS
BH−BH
BH−NS
T dN/dT
1
0.1
0.01
10
100
1000
10⁴
T_life [Myrs]

Rate from Population Synthesis

<u>The good news:</u>

Population synthesis predicts:

- many more DNS systems
- about similar number of detectable BHNS
- Many more detectable BHBH coalescences

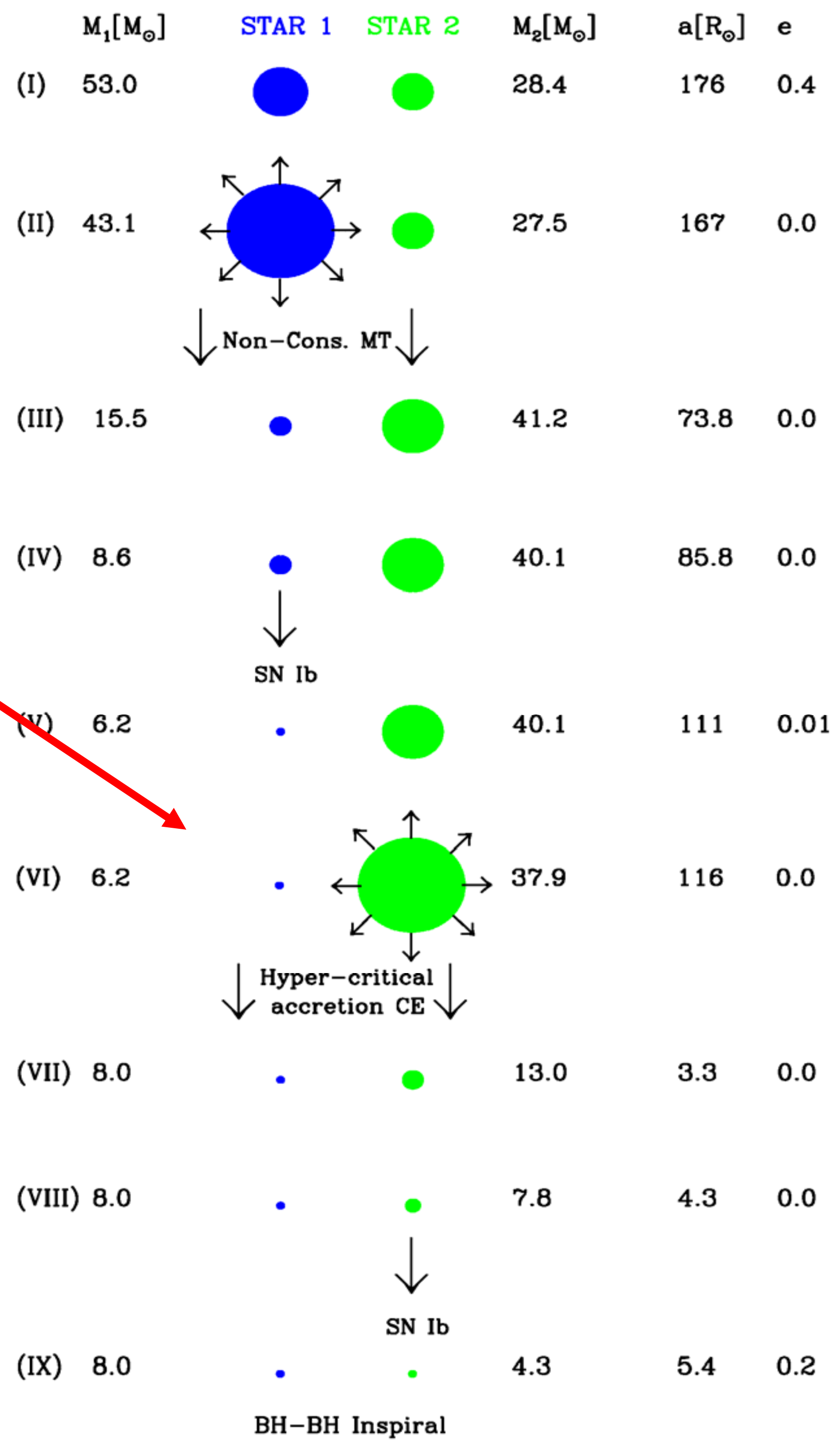


TB + K. Belczynski, 2002-2005

Bad News

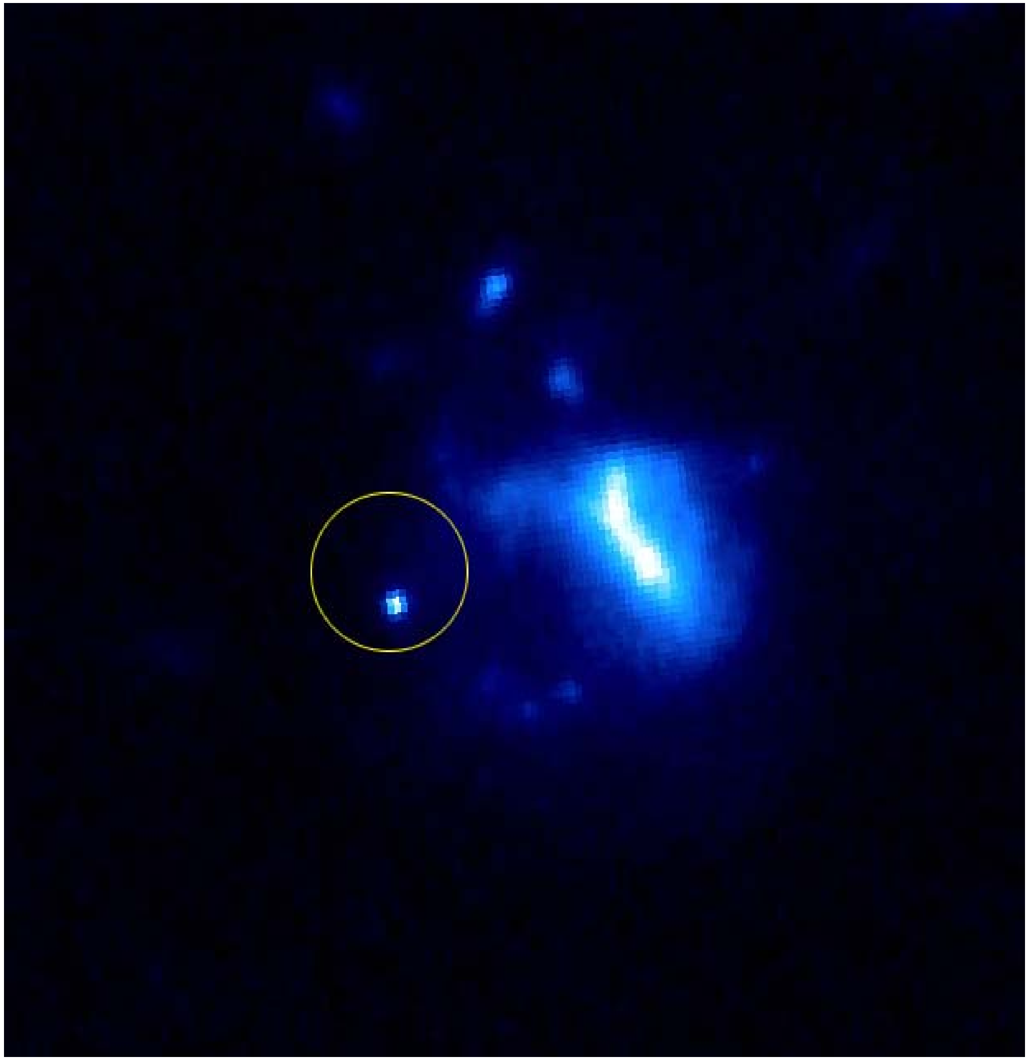
Formation of BHBH and BHNS binaries depends crucially on the outcome of the CE phase

Recent simulation show that the binaries may not survive and merger will occur thus blocking the dominant formation scenario of BHBH and BHNS binaries.



GRBs

- Short ones!
- Short GRBs are likely to be connected with binary coalescences
- Several short GRBs with identified host galaxies and reshifts



GRB 050709 host galaxy observed by the HST

Short GRB observations

Burst	z	host
GRB 050509B	0.226	Elliptical
GRB 050709	0.160	Star forming
GRB 050724	0.258	Elliptical
GRB 051221A	0.546	Star forming
GRB 050813	1.7-1.9?	Galaxy cluster
GRB 060121	1.5 or 4.6	Faint star forming galaxy

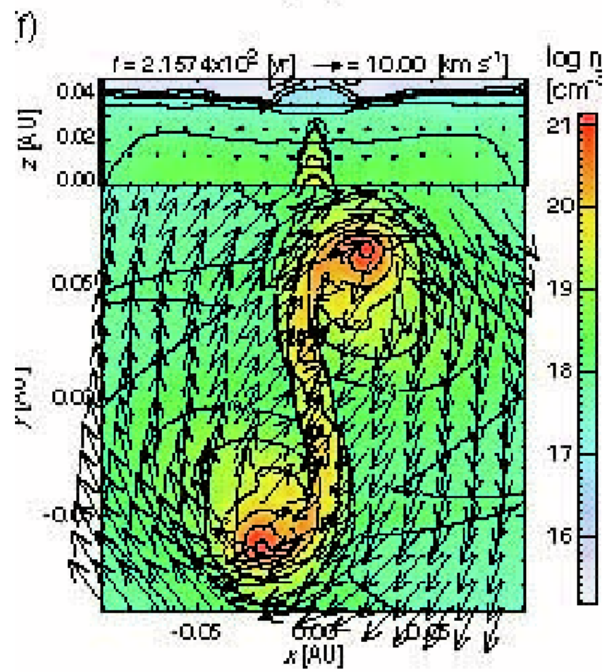
Implications

- Short bursts in elliptical galaxies: evidence for old mergers – long delays, low z
- Small redshifts – may indicate a large local rate – and long delay
- But we see two high z candidates!
- Short GRBs in star forming galaxies: evidence for short lived compact object binaries, high z
- Origin: field – globular clusters?
- Diverse population of Short GRB sources

Exotic objects

Population III stars

- Existed at z=10-25
- Maximum masses up to 1000 M_sun
- Negligible mass loss
- Initial mass function is top heavy
- Did they form binaries?
- Evolve through pair instability supernovae
- Produce BH with nearly no mass loss

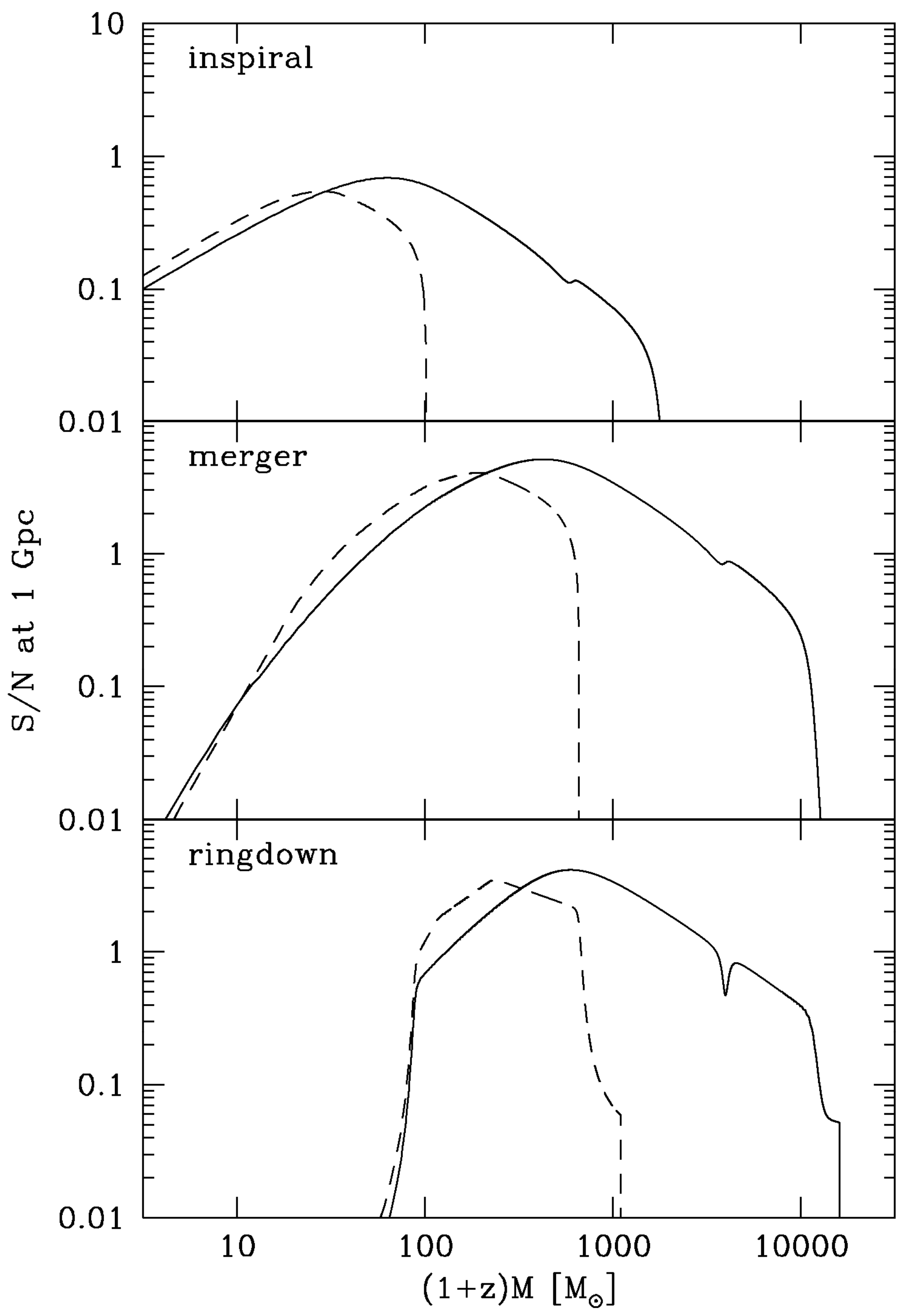


Saigo Matsumoto Umemura, 2005, Apj Lett.

Detectability of Pop III binaries in GW:

Possible in merger and ringdown

VIRGO especially well prepared for this task due to sensitivity below 100Hz

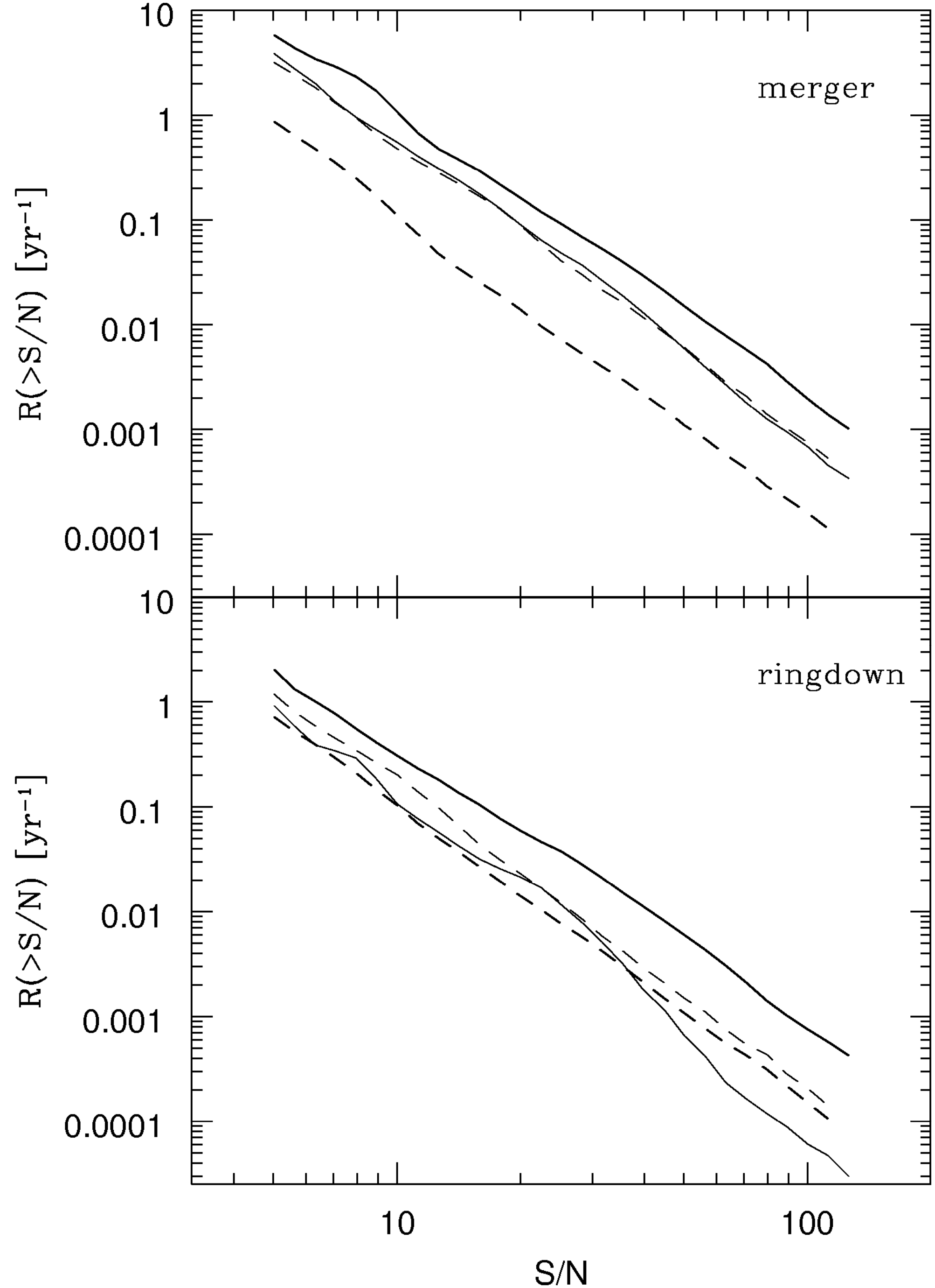


Kulczycki et al. 2006

Expected rates

The rates are similar to the ones expected for the Population I binaries yet depend on a number of assumptions on

- binary fraction
- initial mass function
- evolution of Pop III stars
- interaction with stars and ISM



Kulczycki et al. 2006

Belczynski +TB + Rudak, 2004

Summary

- Modest increase of the NSNS inspiral rate
- Possible insights into the BHNS inspiral rate from pulsar observations
- BHBH and BHNS depend on detail of CE phase
- GRBs may lead to additional constraints on the compact object population
- Exotic objects, like Population III binaries may be observable