Updated merger rates

BH-BH, BH-NS, NS-NS rates via best-constrained population synthesis

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Richard O'Shaughnessy
(with Kalogera, Kim, Belczynski)

Northwestern University

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Outline

- Concept review
- Constraints
  - NS-NS (eccentric, merging)
  - SN Ib/c and II
  - WD-NS (eccentric, merging)

new !

- Revised predictions

Population synthesis for rates

- Population synthesis for rates:
  - *Evaluation*:

    Monte Carlo over initial conditions

    Follow binary evolution (w/o interactions)

  - *Uncertainties*:

    parameterize

    …supernova kicks, CE efficiency, wind strength, …

    …binary fraction **new !**

Population synthesis for rates

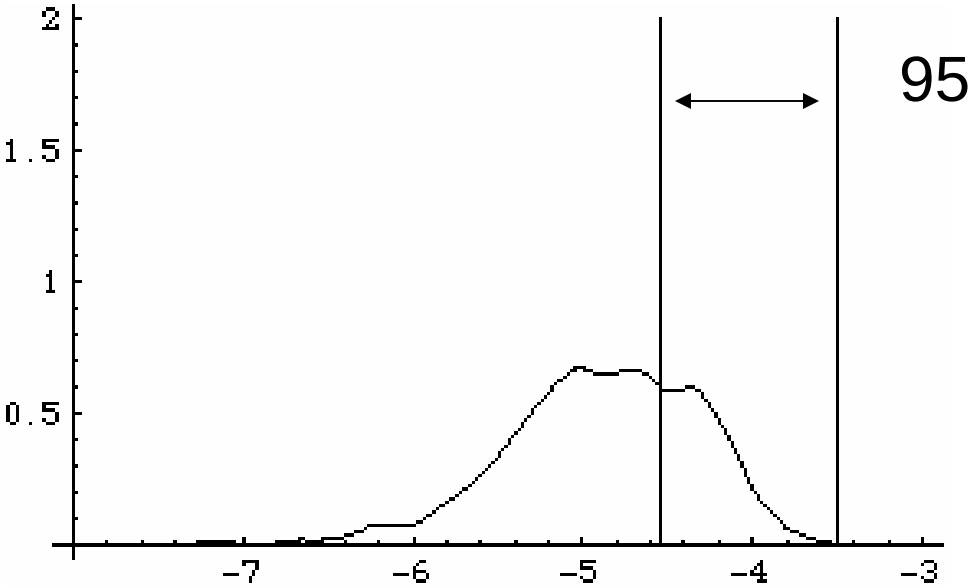
- Evaluating rates:
  - Single stars
    - **Vary** wind strength only
    - **Collect** SN statistics
    - **Fit** rate versus wind strength, assuming all singles

    new !
  - Binary stars
    - **Vary** 7 parameters
    - **Collect** SN statistics; merger rate statistics; …
    - **Fit** rates versus all 7 parameters, assuming all binaries
  - Mixture
    - Weight and combine the two rates
      - **8 parameters** now, (7 + binary fraction)

    new !
- ==> make predictions

Constraints

- **NS-NS** (visible, merging)



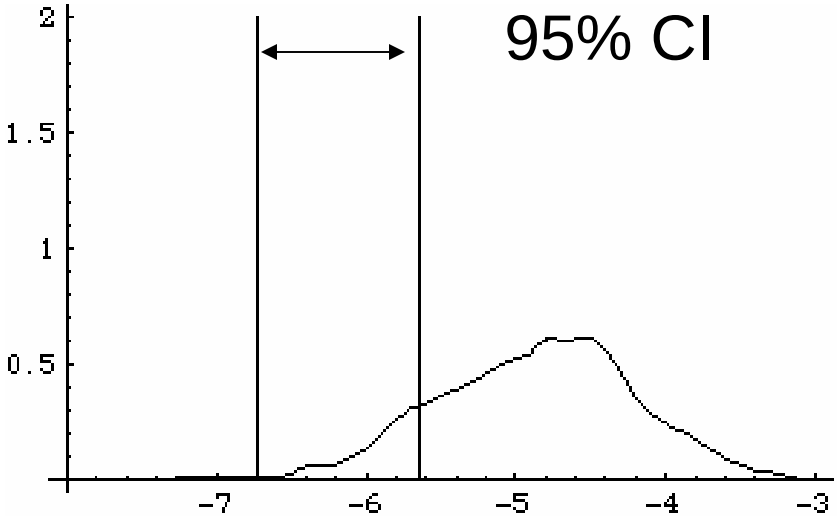
95% CI

$\log_{10}$ (R/yr/MWEG)

Kim, Kalogera, Lorimer, ApJ 584, 985
Kalogera et al, ApJ L 601, 179
O'Shaughnessy et al 2005

Constraints

- **NS-NS** (visible, wide)



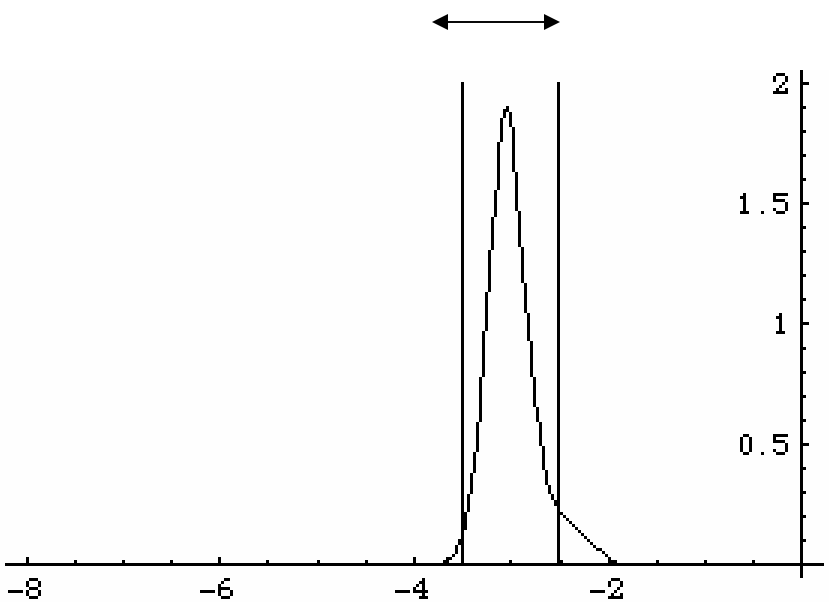
$\log_{10}$ (R/yr /MWEG)

O'Shaughnessy et al 2005, astro-ph/0504479

Constraints

- **SN I b/c**

new !



$\log_{10}$ (R/yr /MWEG)

3-σ CI **(?)**

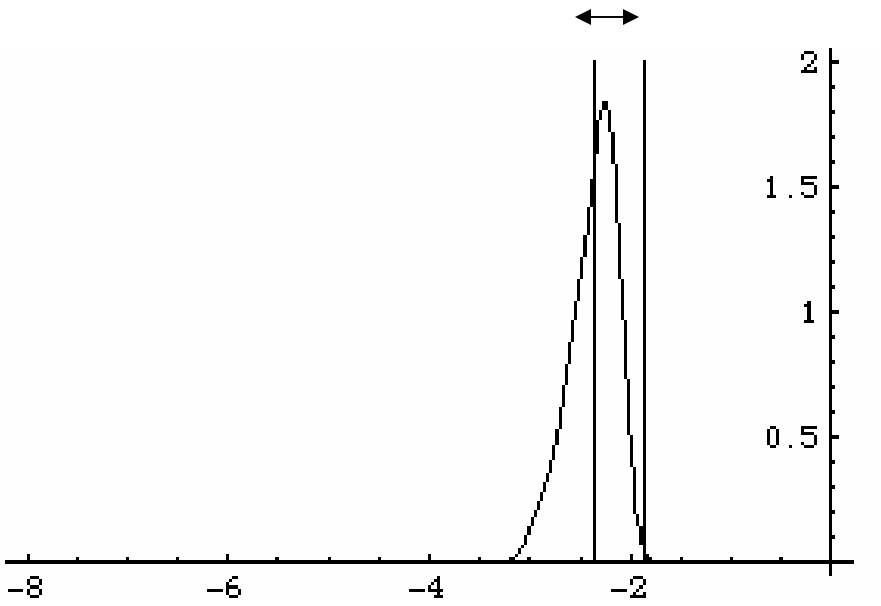
[=quoted CI in paper]

Capellaro et al 1999

Constraints

- **SN II**

new !



$\log_{10}$ (R/yr /MWEG)

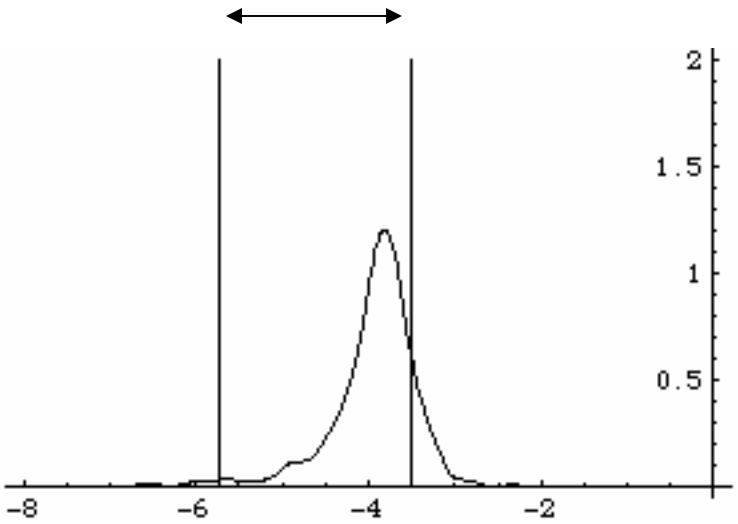
3-σ CI **(?)**

[=quoted CI in paper]

Capellaro et al 1999

Constraints

- **WD-NS** (merging) **new !**



$\log_{10}$ (R/yr /MWEG)

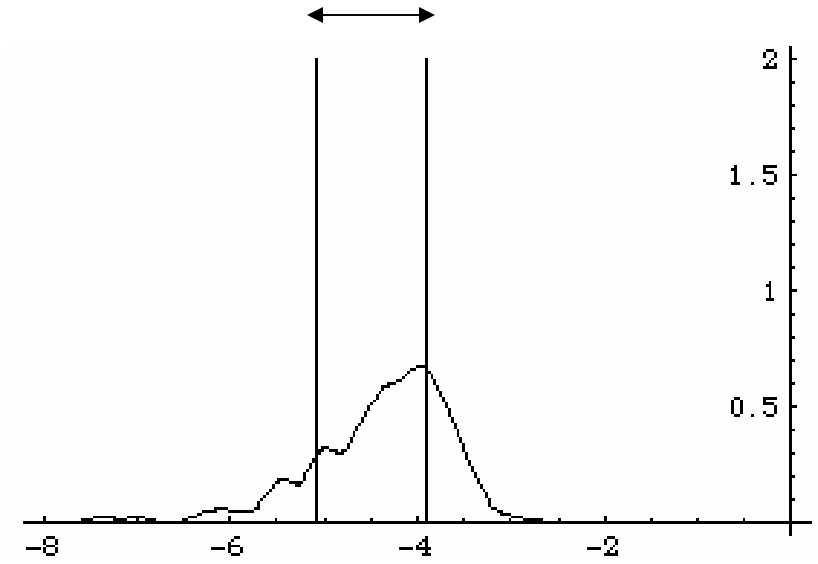
95% CI (paper)

…corrected for expected beaming fraction

Kim et al ApJ 616, 1109

Constraints

- **WD-NS** (eccentric) **new !**



$\log_{10}$ (R/yr /MWEG)

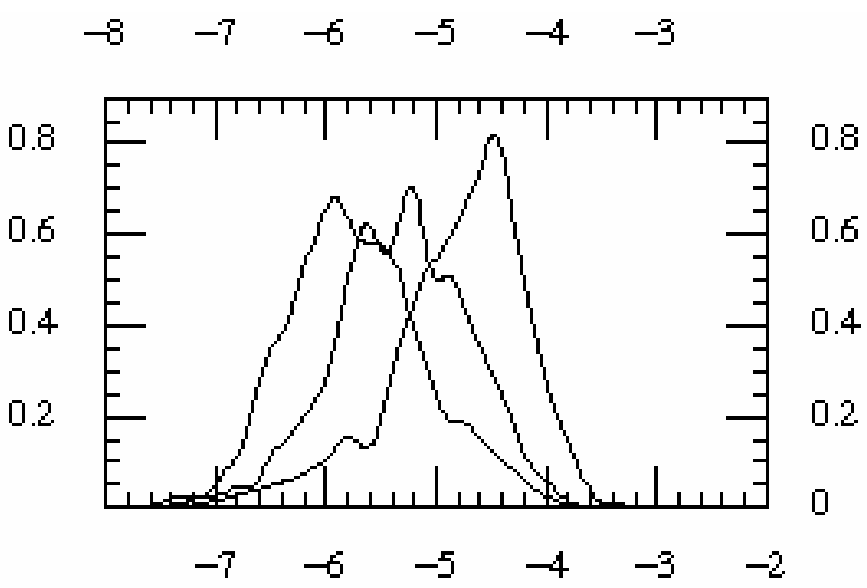
95% CI (paper)

…corrected for expected beaming fraction

Kim et al astro-ph/0408247

Results

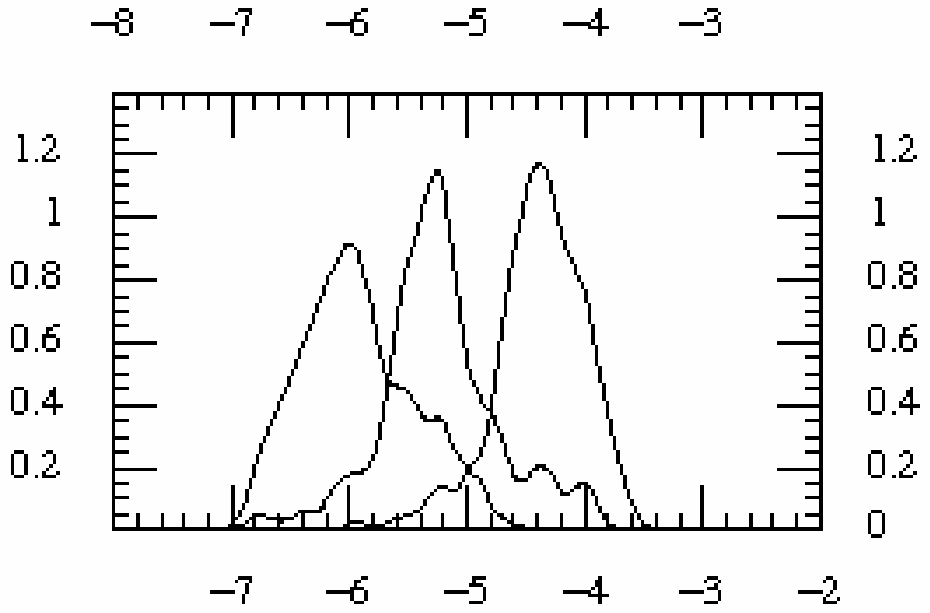
Before



$\log_{10}$ (R/yr/MWEG)

(a priori popsyn result)

After

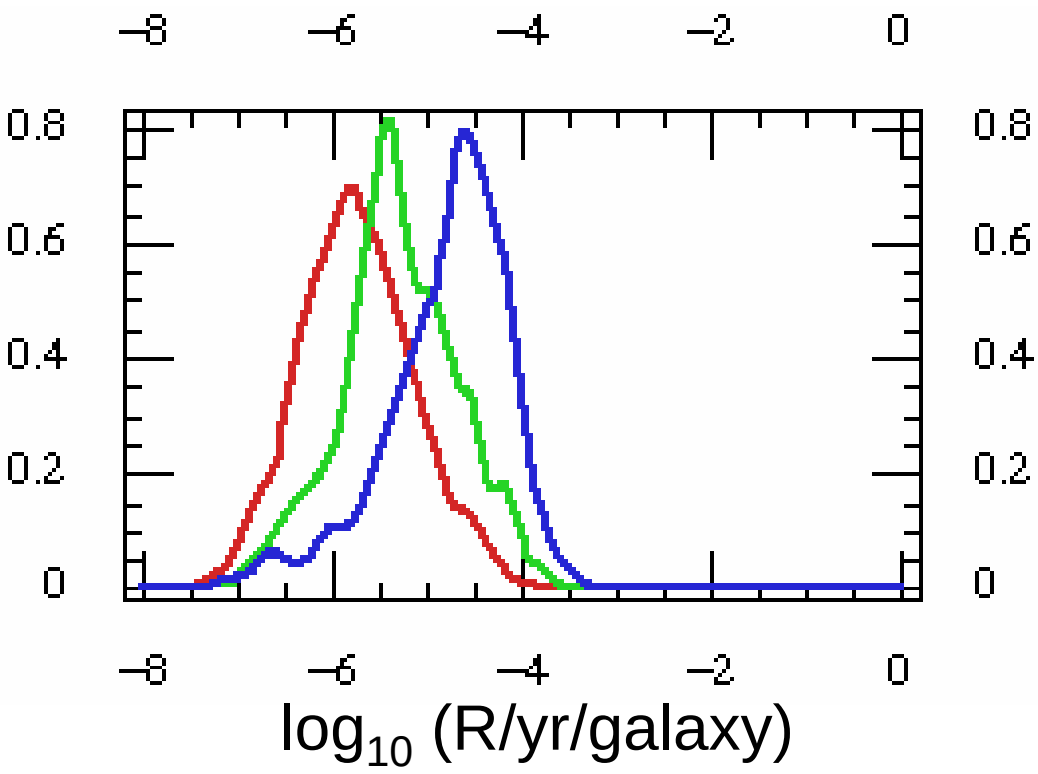


$\log_{10}$ (R/yr/MWEG)

(only models satisfying all constraints)

Results

Before



- $<R_{BH\text{-}BH}>$= 1.8 / Myr * $4^{\pm 1}$
- $<R_{BH\text{-}NS}>$= 5 / Myr * $4^{\pm 1}$
- $<R_{NS\text{-}NS}>$= 16 / Myr *$(4.4)^{\pm 1}$

(a priori popsyn result)

Results

- $<R_{BH-BH}>= 1.2 / Myr * 3^{\pm 1}$

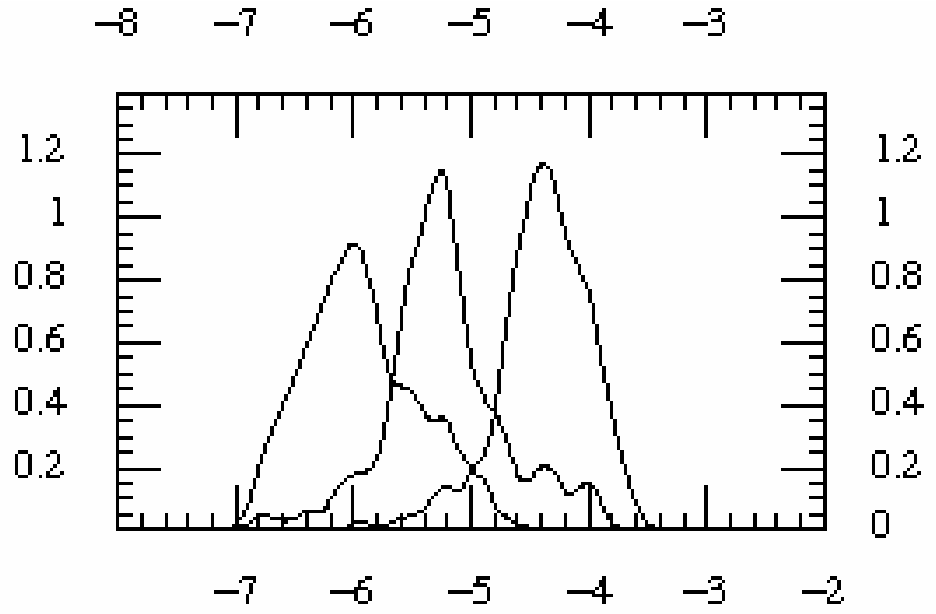
- $<R_{BH-NS}>= 5.8 / Myr * 3^{\pm 1}$

- $<R_{NS-NS}>= 40 / Myr * (2.4)^{\pm 1}$

... compared with previous work

+ more BH-BH accuracy
+ slightly higher NS-NS rate

After



$\log_{10}$ (R/yr/MWEG)

Constraining rate 3: All (recycled) NS-NS

- Method:
  - Monte carlo + reject

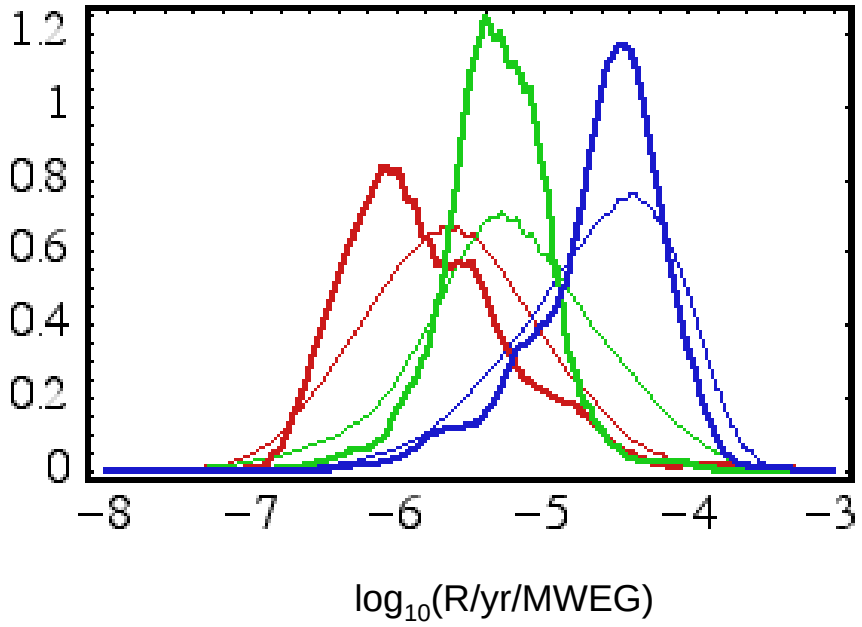
    …**require both** constraints

- Results:

  $\langle R_{bh} \rangle$ = 1.4 / Myr * $(3.3)^{\pm 1}$
    - down x 0.6

  $\langle R_{bh\text{-}ns} \rangle$= 4.7/ Myr * $(2.3)^{\pm 1}$
    - down x 0.84

  $\langle R_{ns} \rangle$ = 25 / Myr * $(2.4)^{\pm 1}$
    - up x 1.1



…consistent with prior
…narrower distributions

Results: LIGO-II rate

Assumptions:

+ euclidean universe (no cosmology)
+ all models have **same** chirp mass distrib:

$< M_c^{15/6} >$ = 111 $M_O^{15/6}$ BH-BH (i.e. $M_{BH} < 10$)

= 5.8 $M_O^{15/6}$ BH-NS

= 2 $M_O^{15/6}$ NS-NS (i.e. $M_{NS} > 1.4$)

Explicitly:

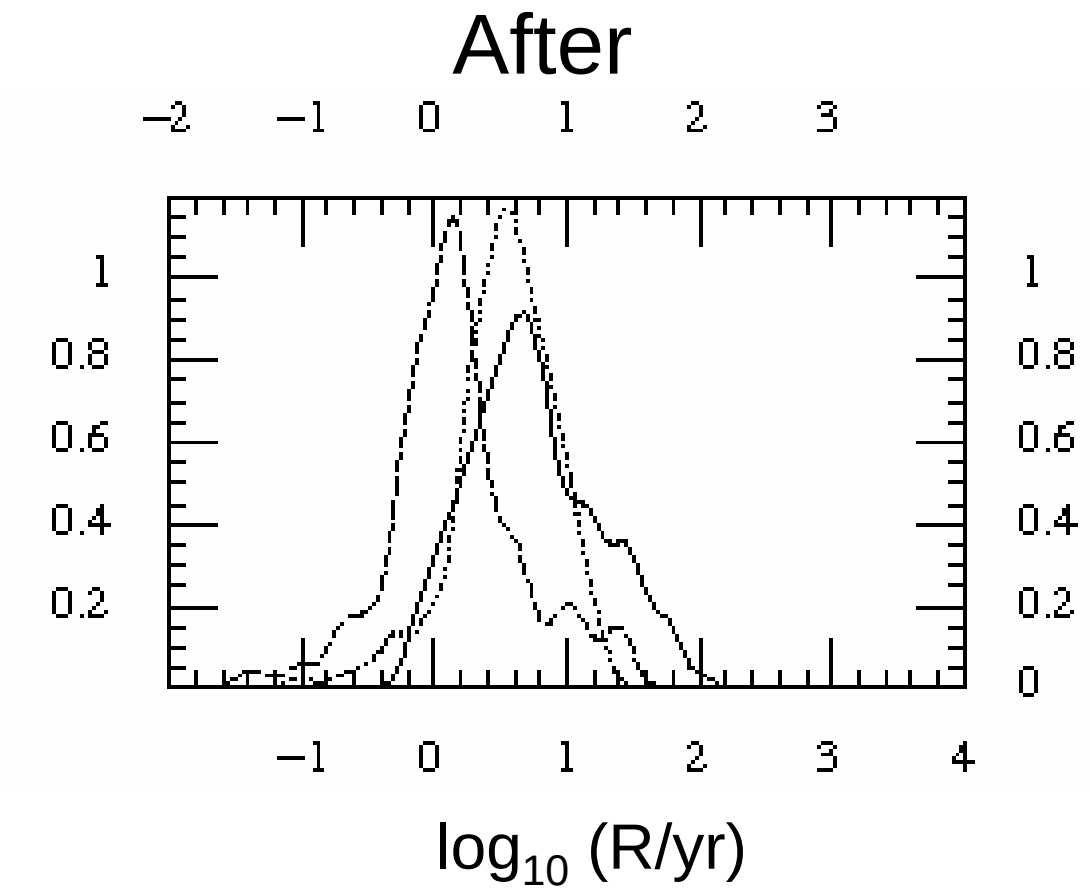
$$R_{LIGO} = 0.042 R_{MW} < (M_c / M_O)^{15/6} >$$

Results: LIGO-II rate

- $\langle R_{BH\text{-}BH} \rangle = 5 / yr \ * 3^{\pm 1}$
  (mod cosmological corrections)

- $\langle R_{BH\text{-}NS} \rangle = 1.4 / yr * 3^{\pm 1}$

- $\langle R_{NS\text{-}NS} \rangle = 3 / yr * (2.4)^{\pm 1}$



(only models satisfying all constraints)