

Expected compact-object merger rates

LSC

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Outline

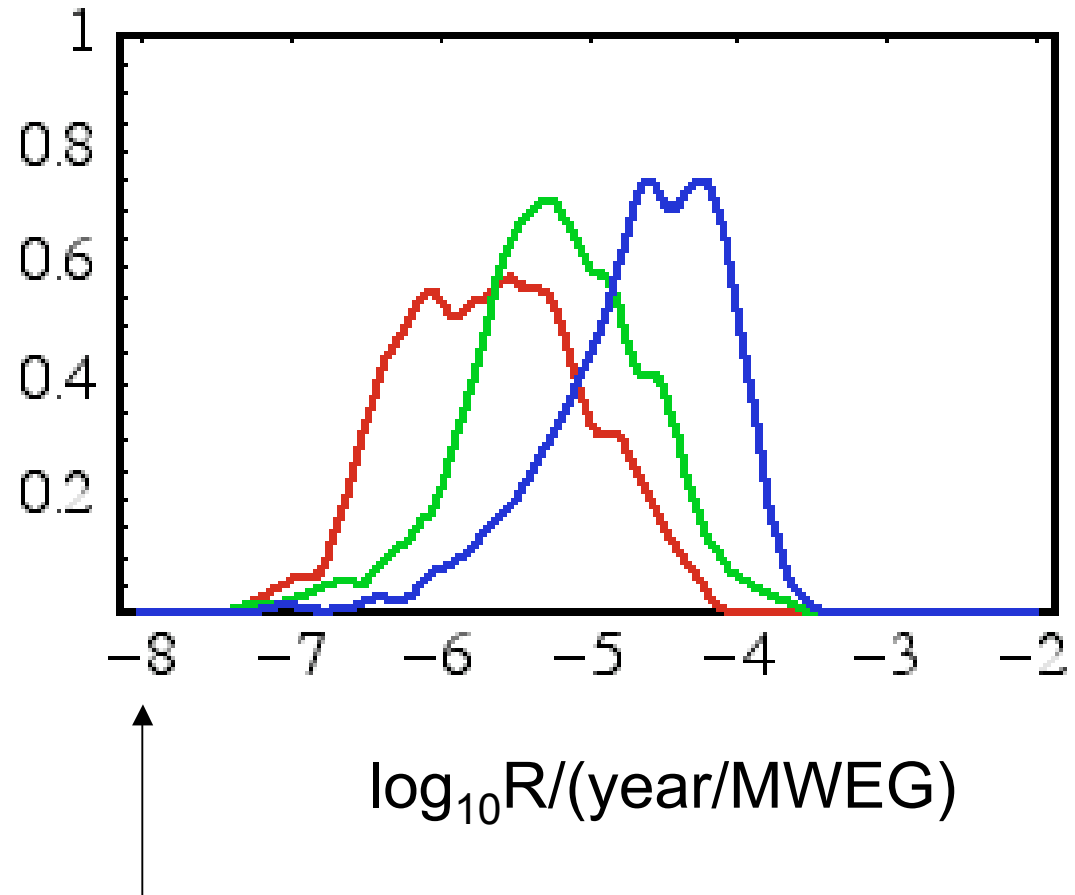
- Prior predictions
 - Population synthesis
 - Results: BH-BH, NS-NS, BH-NS rates
- Observational constraints (preliminary)
 - Observations
 - Constrained predictions
 - Merging NS-NS (recycled)
 - Wide NS-NS (recycled)
 - Both
- Advanced LIGO event rate
 - Results
 - Significance for astrophysics (!)

Prior predictions

- Population synthesis:
 - Evolve N binaries from birth to present
 - Stop when **n** events (e.g., mergers) occur
 - rate known to $1/\sqrt{n}$
 - **Repeat :**
 - many parameters for unknowns (7 matter)
 - Many objects of interest (BH-BH, NS-NS, etc)
- Practical necessities:
 - *Filters*: Speed up code by rejecting some binaries a priori (ApJ 620, 385)
 - *Fitting*: Fit rates to allow constraints to be imposed

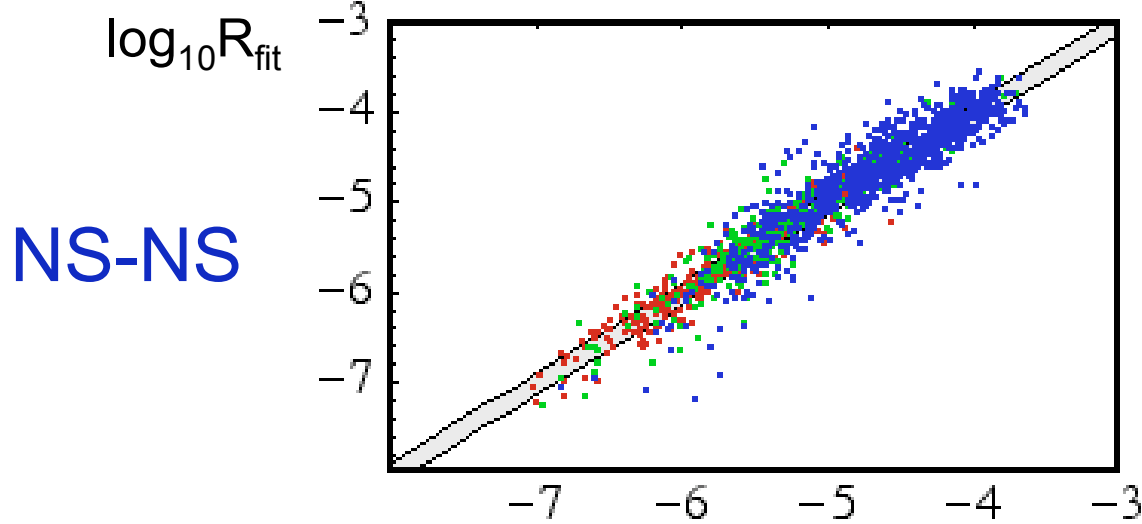
Prior Results: Rate Histograms

- **NS-NS**
– N=933
- **BH-BH**
– N=306
- **BH-NS**
– N=357

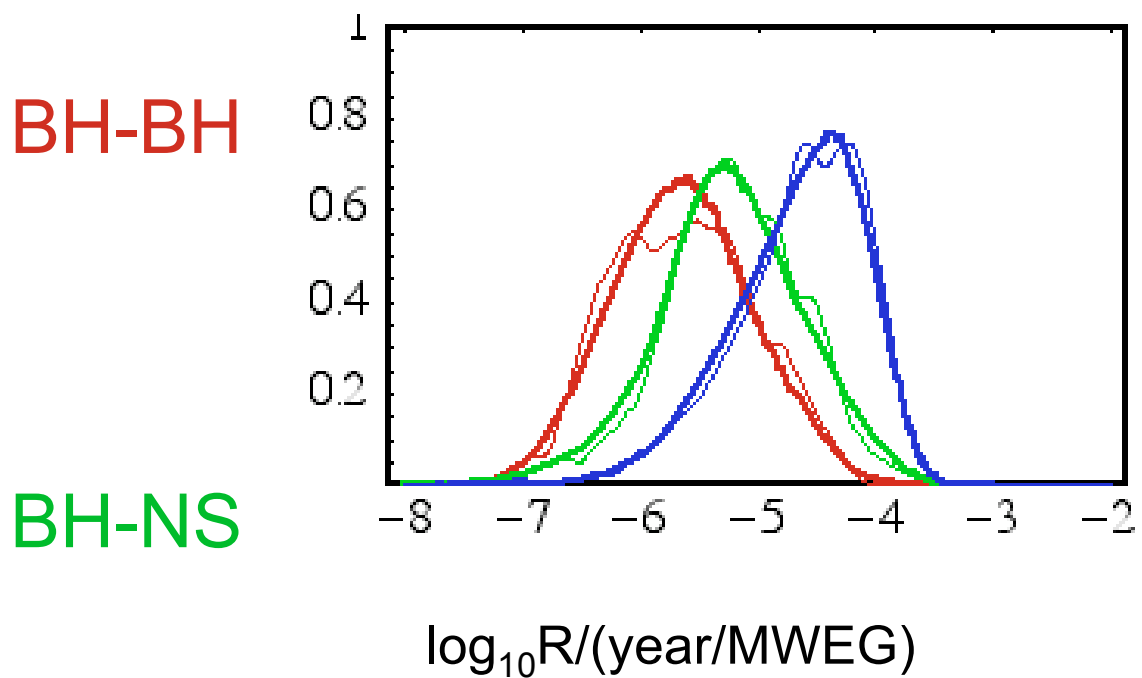


Lower bound is well-resolved

Prior Results: Fits



• Fits work over large range



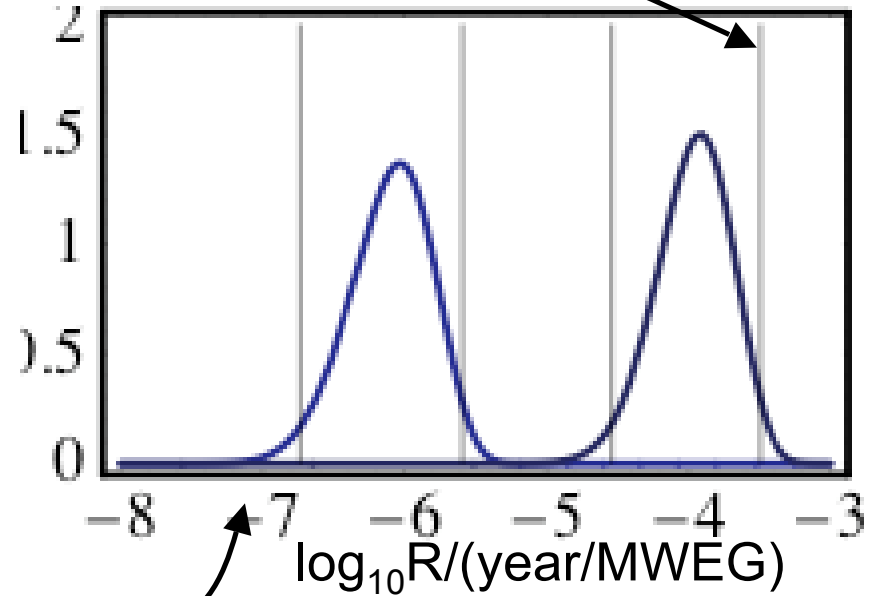
• Monte carlo again...
--> recover ~ **same**
distributions

➔ Fits ok surrogate
for full PS

NS-NS observations

- **Merging Binaries (3)**

- 3 seen [J0737, B1913, B1534]
- Will merge through GW emission
- Recycled pulsars only (selection)
- Merger rate **CI** (95%):
 - 29/Myr $R < 320 / \text{Myr}$



- **Wide Binaries (3)**

- 3 seen [J1811, J1518, J1829]
- Not merging w/in age of galaxy
- Recycled pulsars only (selection)
 - ...and **few recycled pulsars occur in wide binaries**
- Merger rate CI (95%):
 - $0.16/\text{Myr} > R > 1.8 / \text{Myr}$

R=formation rate

Constraining rate 1: Merging NS-NS

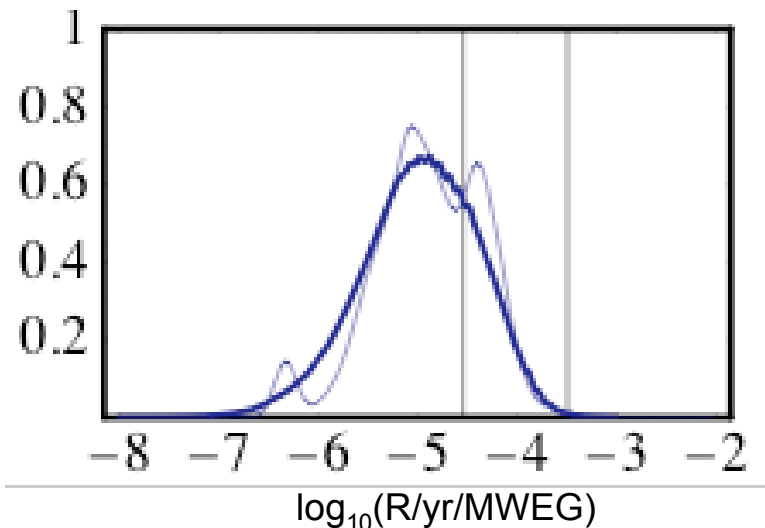
- Method

- Use data for **recycled** merging NS-NS binaries
- Fit rate for above
- Monte carlo +
Reject inconsistent models
[= outside 95% confidence interval of **observed** merging NS-NS]
 - Excludes 76% of models
- Regenerate histograms

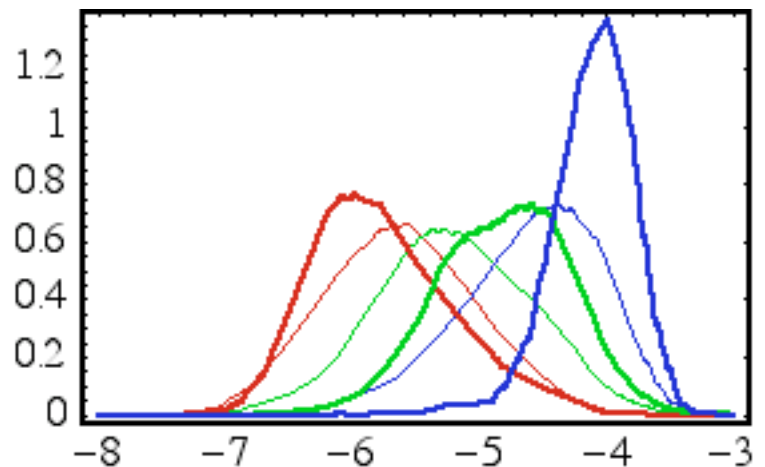
- Results:

- $\langle R_{bh} \rangle = 1.8 / \text{Myr}$
 - down x 0.75
- $\langle R_{ns} \rangle = 63 / \text{Myr}$
 - up x 3.2
- $\langle R_{bh-ns} \rangle = 15 / \text{Myr}$
 - up x 2.6

Merging **recycled** NS-NS



Constrained results

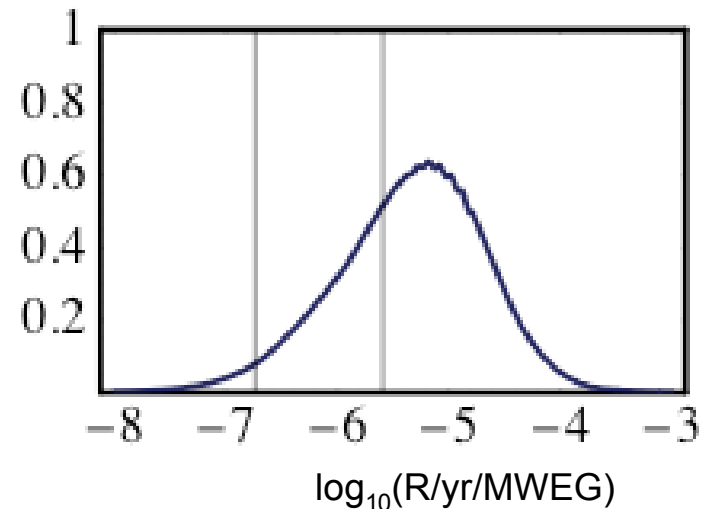


Constraining rate 2: Wide NS-NS

- Method

- Find (rare) **wide recycled NS-NS** in data
- Fit rate for above
- Monte carlo + reject
 - Excludes **70%** of models
- Regenerate histograms

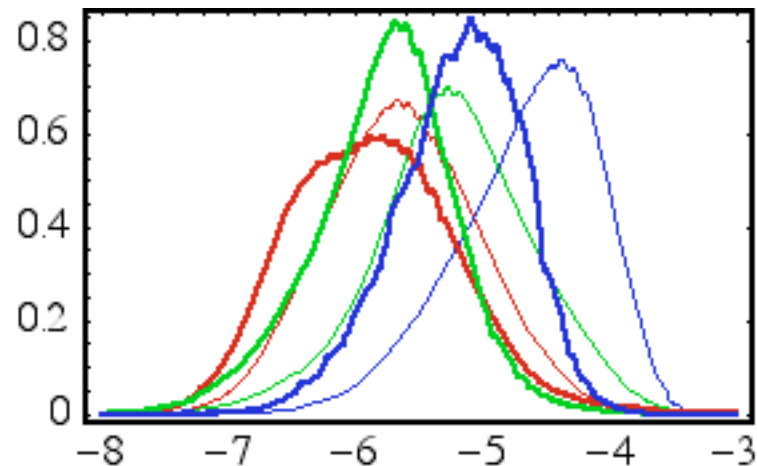
Wide recycled NS-NS



- Results:

- $\langle R_{\text{bh}} \rangle = 1.4 / \text{Myr}$
 - down x 0.6
- $\langle R_{\text{ns}} \rangle = 6.6 / \text{Myr}$
 - down x 0.3
- $\langle R_{\text{bh-ns}} \rangle = 1.6 / \text{Myr}$
 - down x 0.3

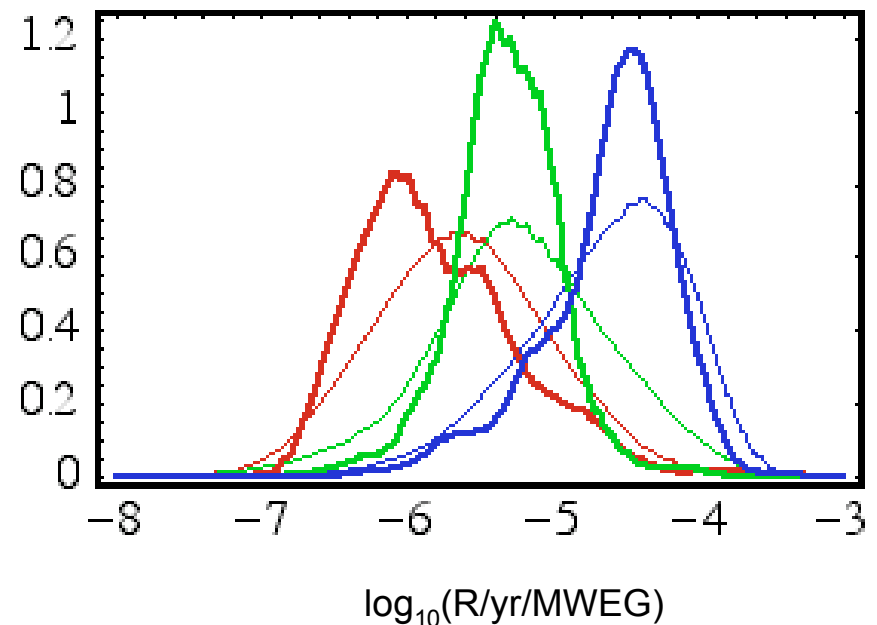
Constrained results



Constraining rate 3: All (recycled) NS-NS

- Method:
 - Monte carlo + reject
 - ...**require both** constraints

- Results:
 - $\langle R_{bh} \rangle = 1.4 / \text{Myr} * (3.3)^{\pm 1}$
 - down x 0.6
 - $\langle R_{ns} \rangle = 25 / \text{Myr} * (2.4)^{\pm 1}$
 - up x 1.1
 - $\langle R_{bh-ns} \rangle = 4.7 / \text{Myr} * (2.3)^{\pm 1}$
 - down x 0.84



...consistent with prior
...narrower distributions

Advanced LIGO Detection rate

- Formulae

$$D = 191 \text{Mpc} (M_c / 1.2 M_o)$$

$$R_{LIGO} = 0.038 R_{Myr} \langle (M_c / M_o)^3 \rangle$$

- Chirp mass distribution

...**must** assume fixed (b/c of fake data/fits)

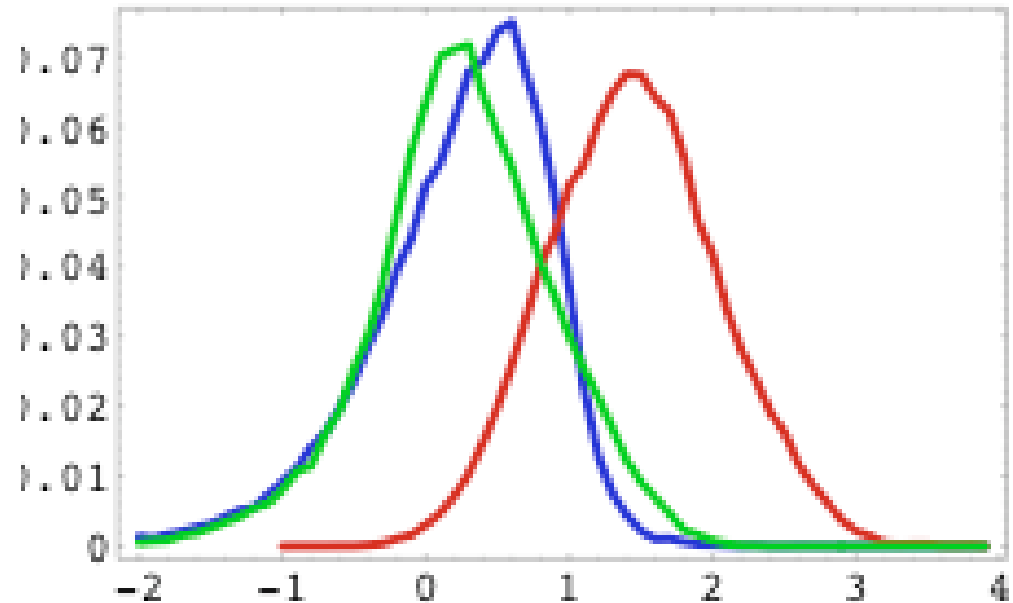
- NS-NS: $\langle M_c^3 \rangle = 2.3 M_o^3$ [vs 1.8]

- BH-NS: $\langle M_c^3 \rangle = 9.2 M_o^3$ [vs 27]

- BH-BH: $\langle M_c^3 \rangle = 355 M_o^3$ [vs 670]

Advanced LIGO Detection rate

- Advanced LIGO **will** see (many) BH-BH mergers
- Small increases in range matter: guarantee BH-NS and NS-NS mergers



Accurate BH-BH rate determination expected
--> **strong** constraint on astrophysics

Note: Single-detector rates shown

Conclusions

- Present Status
 - Applying constraints from NS-NS observations
 - Merging
 - Wide
 - Both simultaneously
 - Results:
 - Rates better constrained (=smaller variance)
 - Advanced LIGO **will** see mergers
- Future Directions
 - Additional observational constraints
(eccentric PSR-WD, supernova rates, absence of BH-PSR)
 - Further constraints on PS model input parameters
(e.g. tighter constraints on SN kicks)