Black hole mergers via clusters

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Motivation

- Three ingredients:
  - Mass segregation --> many BH mergers

    [Portegeis Zwart & McMillan 2000, ApJL 528 17]

    [O'Leary et al, astro-ph/0508224]

  - Many stars form in massive clusters

    [cluster IMF ~ M^{-2} ; **all** stars form in clusters]

  - Star formation history

    (…doesn't matter much)

new

Simple explanation

See poster!

Simple explanation: Assumptions

- Thermal BH-BH binaries
- $M_{BH} = 10\ M_{O}$

Simple explanation: Ingredients

- Merger rate density
  - Per mass
    …in massive cluster

$$R(t) = 2 \times 10^{-5} M_O^{-1} / t$$

  - Overall, at ‘t’

$$\mathscr{R}(t) = \int_{-T_{uni}}^{t} R(t-\tau) \frac{d\rho_{cl}}{dt} d\tau$$

- Star formation history
  + fraction massive enough (~ 1/3)
  + fraction surviving “infant mortality”

$$\frac{d\rho_{cl}}{dt} = f_{cl} \frac{d\rho_{SFR}}{dt}$$

Simple explanation: Results

- Early only
  - **[Order of magnitude]**
  - Starburst at 13 Gyr

$$\frac{d\rho_{cl}}{dt} = f_{cl}\rho_{stars}\delta(t - 13Gyr)$$

Density in stars:

10% (stars/baryon) * 4%(baryons/total) * closure density

~ 2 x 10^8 M_O/Mpc^3

Merger rate:

~ 3 x 10^{-7} $(3f_{cl})Mpc^{-3}/yr$

LIGO-I detections?

...range ~ 100 Mpc

~ 1.6 $(3f_{cl})/yr$

Simple explanation: Results

- Realistic SFRs:

Models

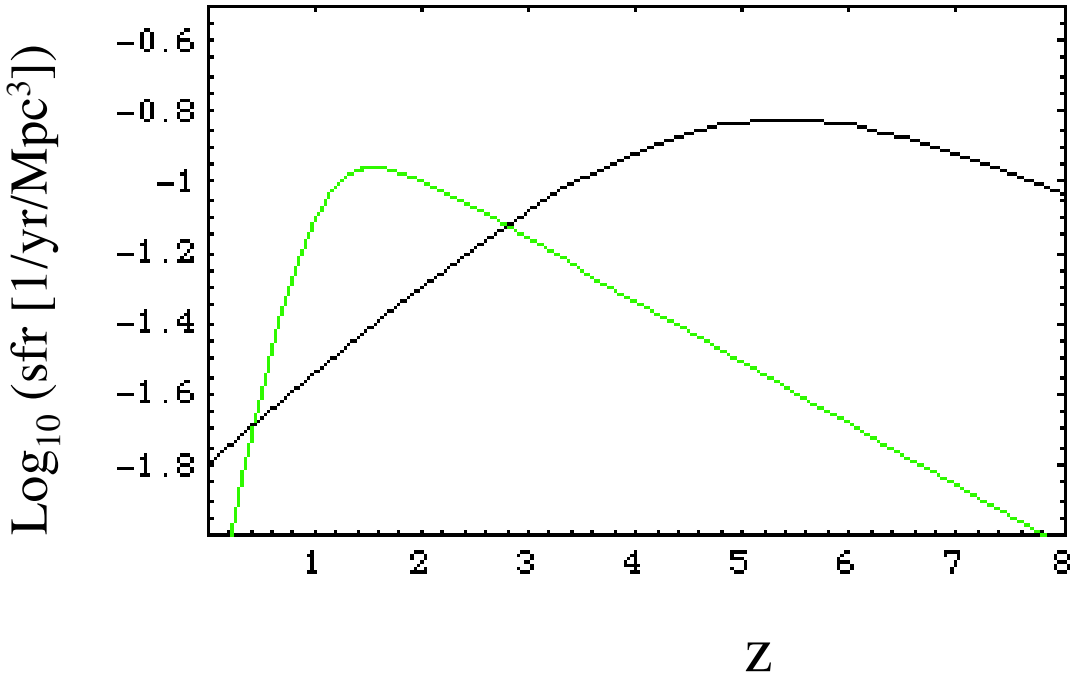
  - Experimental

    Madau, astro-ph/9907268

  - Theory

    Springle & Hernquist

    MNRAS 339 312



Results [preliminary]

LIGO rate **~ 5 (3 f_{cl})/yr** [SH]

~ 1.8 (3 f_{cl})/yr [Madau]

  - Clusters which form **recently** dominate (~ 80%)

    …recent SFR matters most (b/c of 1/t)

Detailed results

- Ingredients:
  - Cluster/ejection modelling

    …not demanding 1/t a priori

  - realistic BH IMF

    … heavier BHs…see **farther**…higher rate
  - LIGO sensitivity vs frequency

    …some BH-BH mergers too massive to see

  - cosmology [LIGO-II]

Detailed results

- Results: (preliminary; network [H1+L1+H2] range)

	LIGO-I (yr)	LIGO-2 (yr)
S-H	1.4 (3 f_{cl})	2.2 x10^4 (3 f_{cl})
Madau	0.81 (3 f_{cl})	2.0 x10^4 (3 f_{cl})

via latest LIGO-I (now!) and LIGO-II sensitivity

MODEST significance

- as test of cluster dynamics
  - cluster formation, survival fraction, mass segregation
- as probe of **birth conditions** of clusters

  …eventually, via LIGO-II