The compact object binary population in ET: what are the rates and what astrophysics can we learn?

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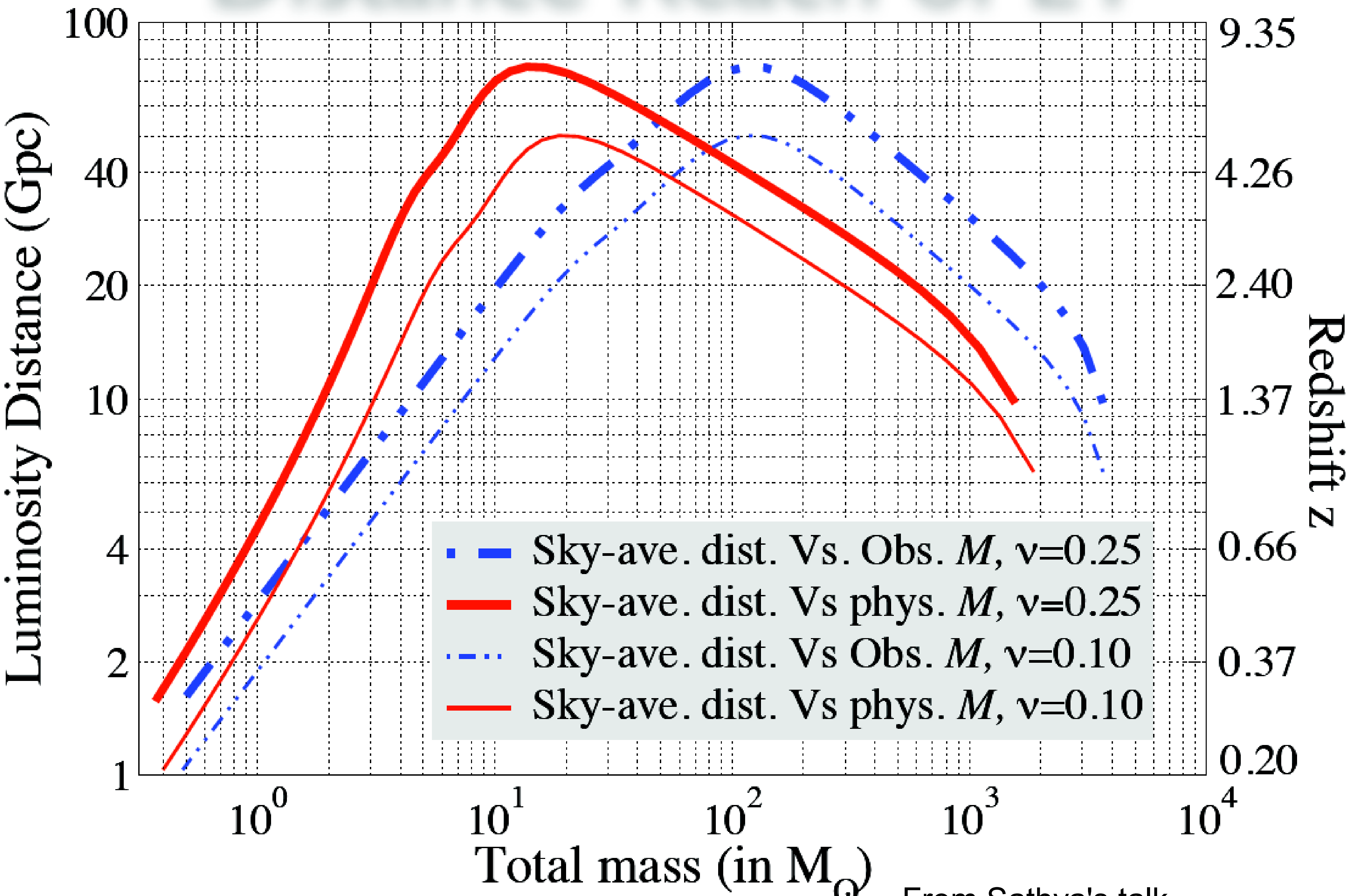
Range



From Sathya's talk

- Formation of compact object binaries
- Metallicity dependence
- Rates
- Properties
- Observables
- Astronomy with GW observations of comact object binaries

Formation of a binary black hole system

The principal CE phase: a solution but also a bottleneck....

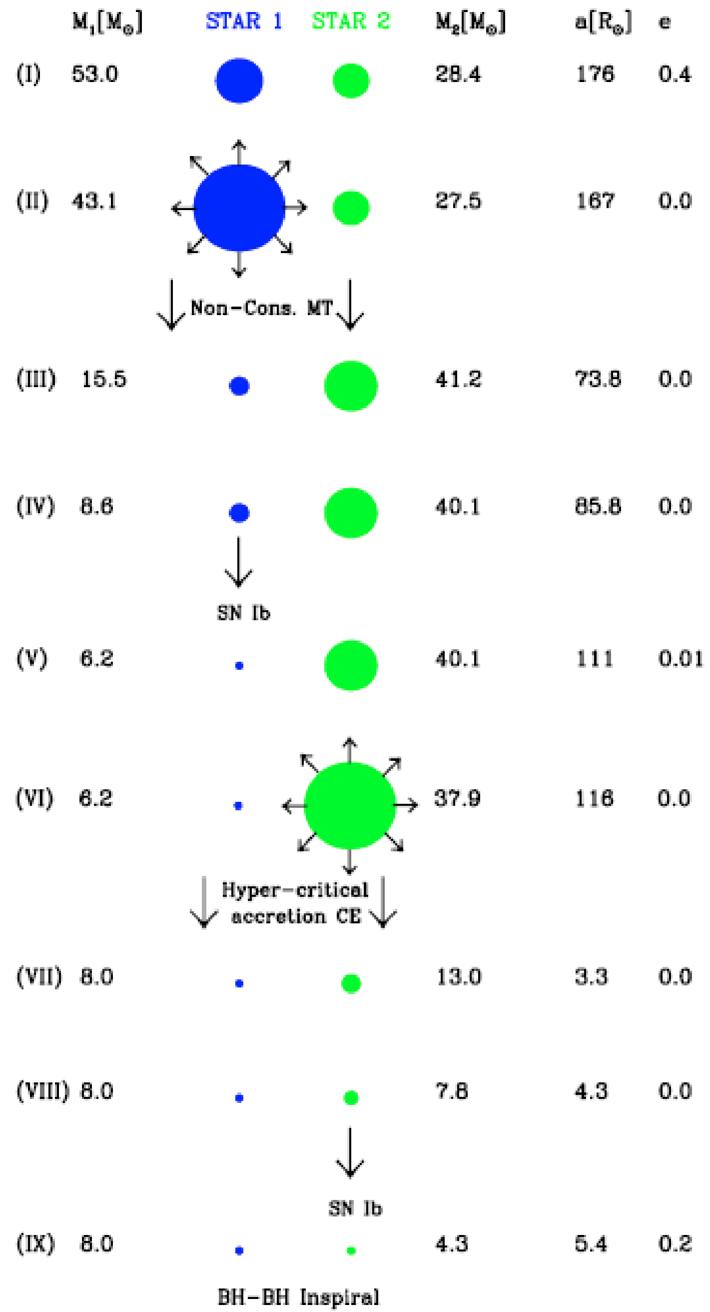
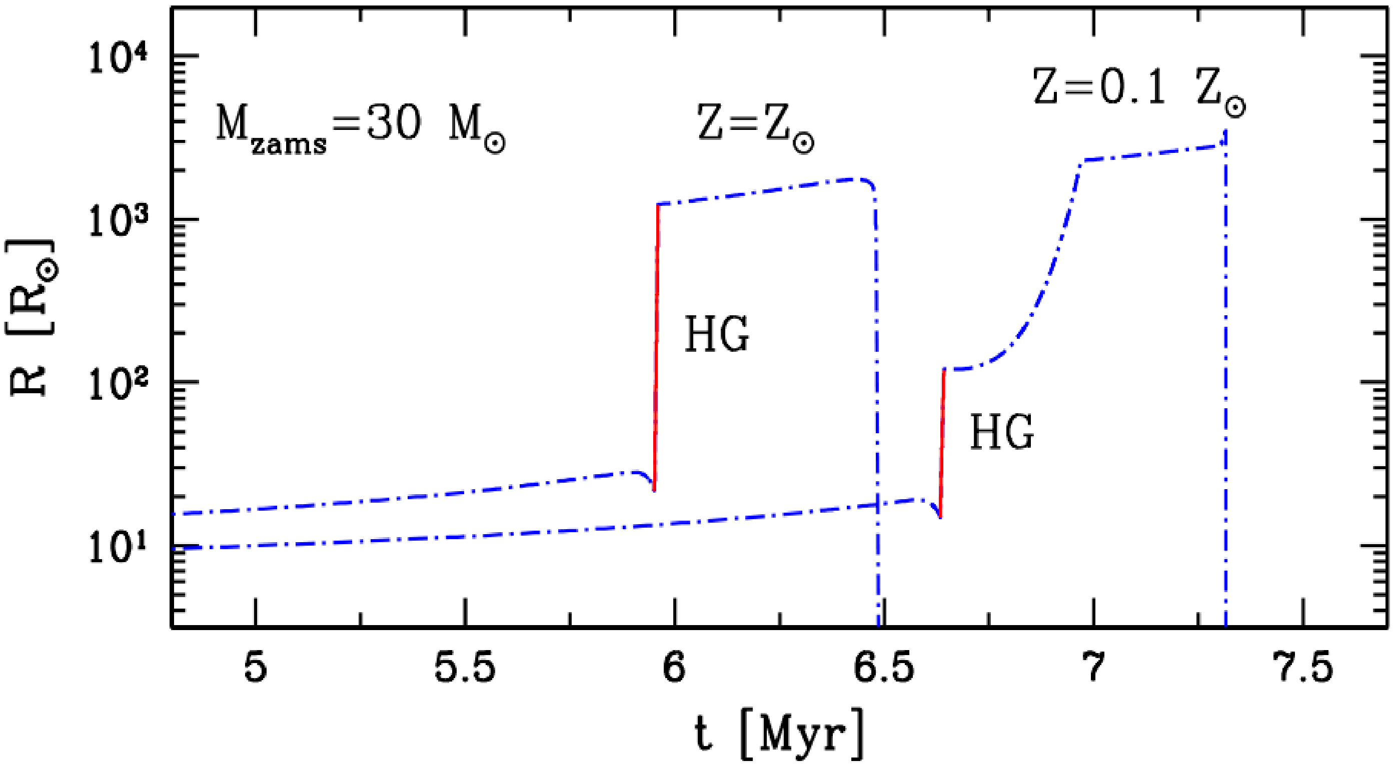


Fig. 1. An example evolutionary scenario leading to formation of a double black hole binary. For details see the text.

The role of metallicity

- Opacities
- Stellar radii and structure
- BH masses



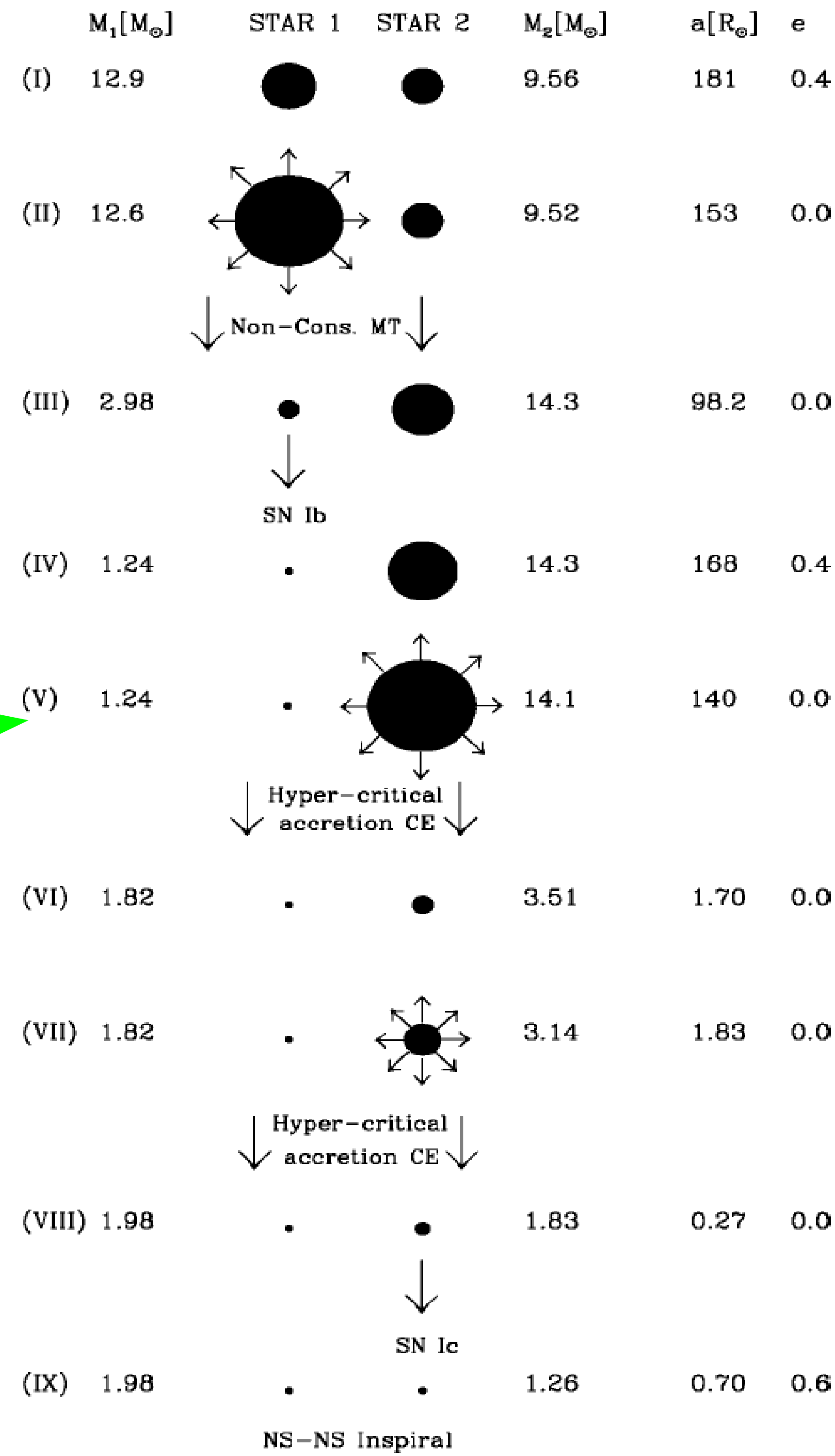
Binary neutron stars

Possible two common envelope phases:

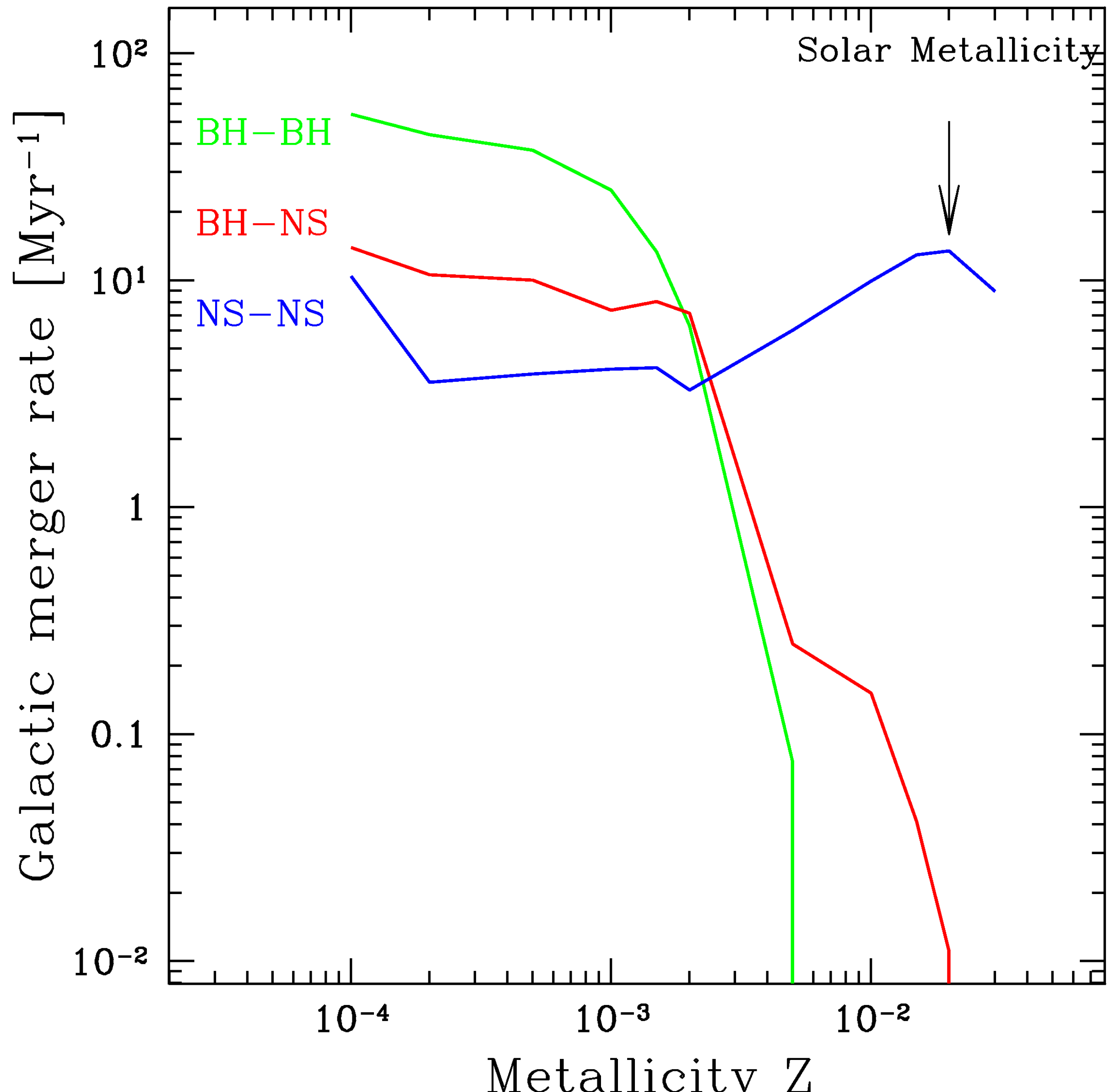
- with a giant

- with a naked helium star

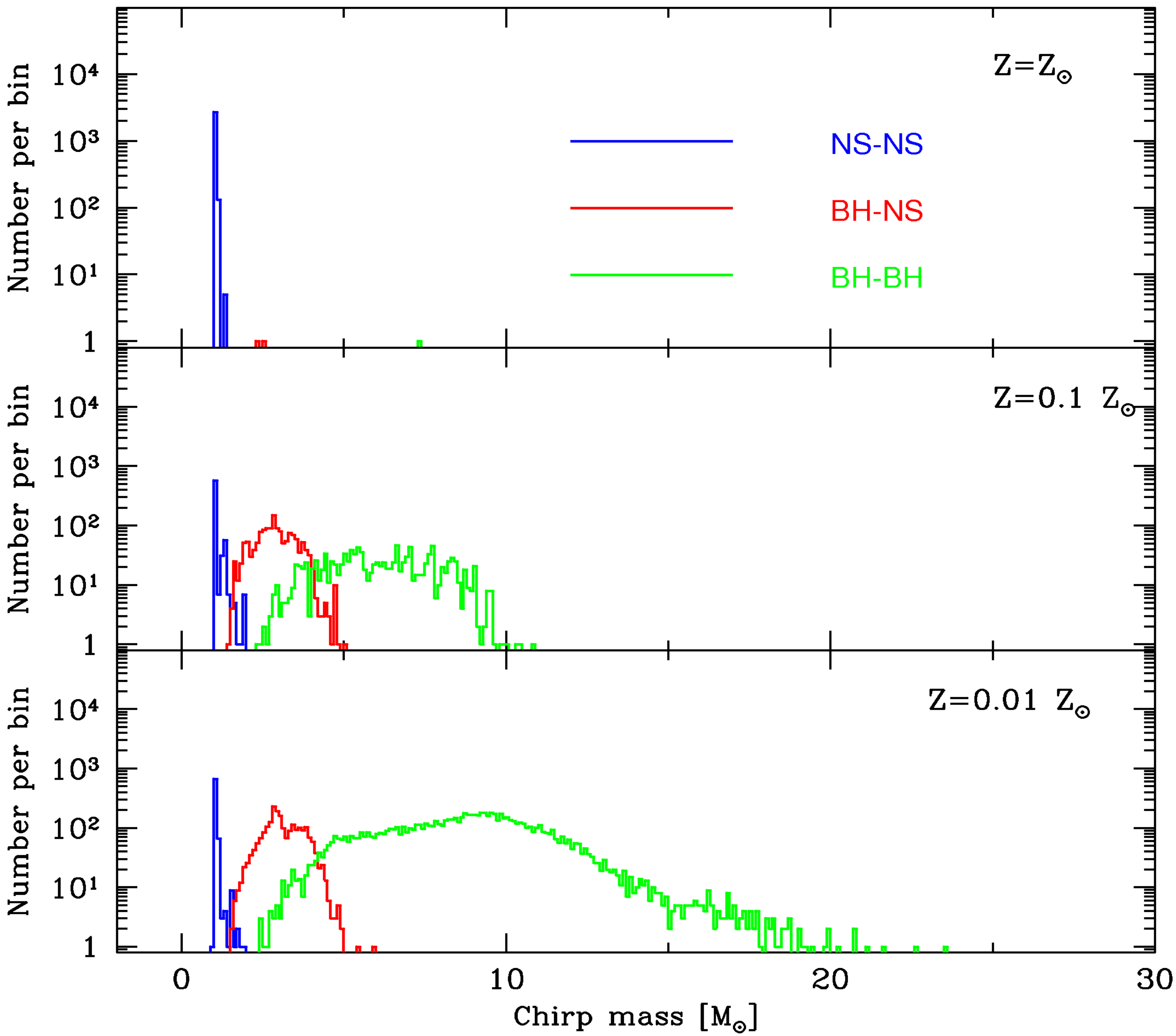
Two classes of sources: standard and ultracompact



Formation rate as function of metallicity

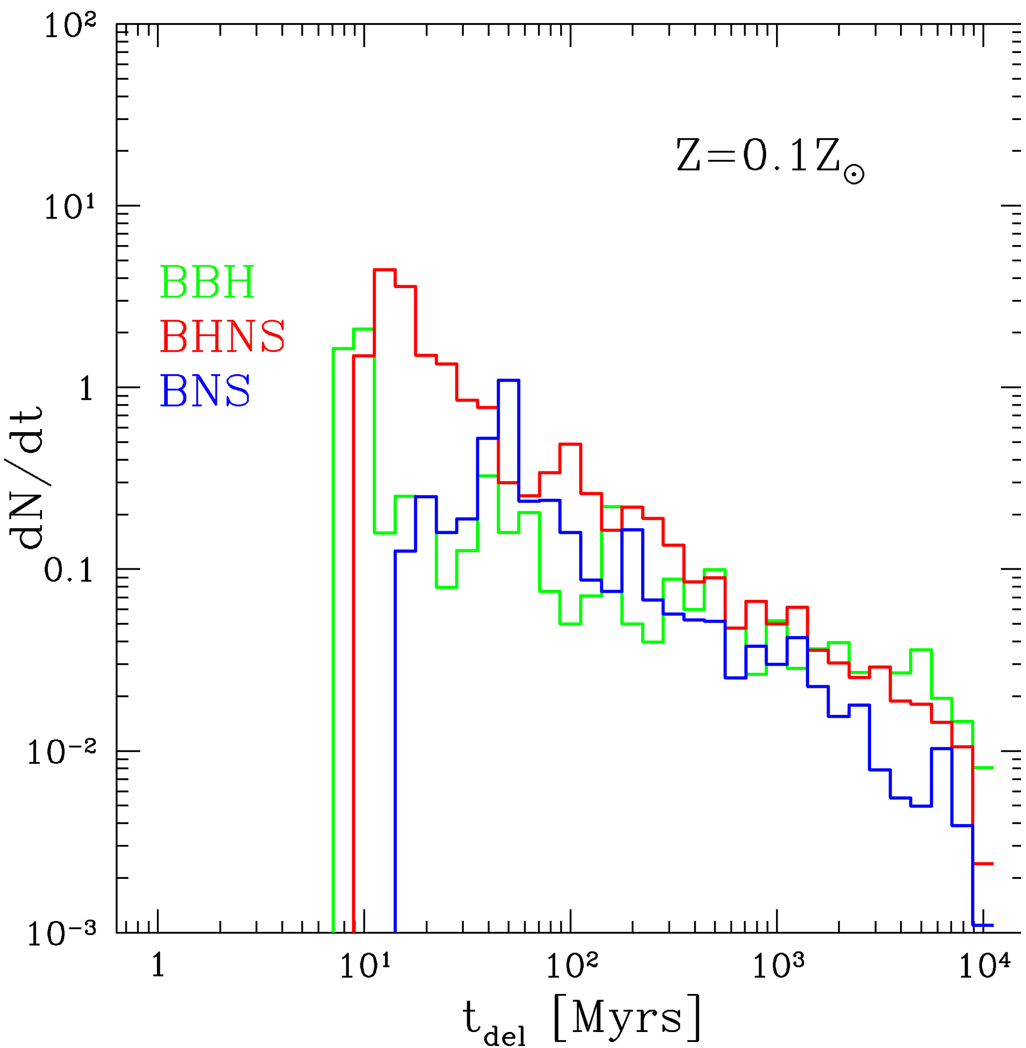


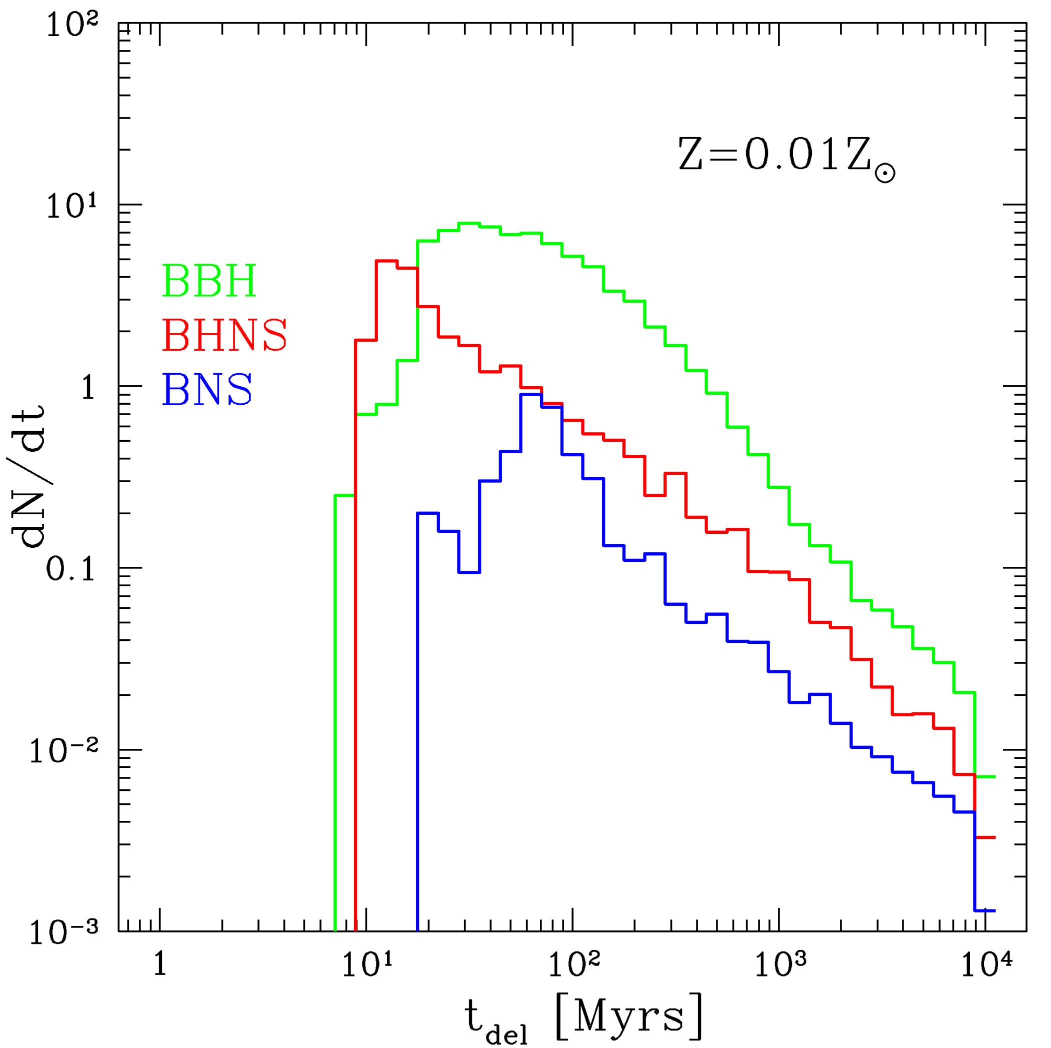
Expected intrinsic chirp mass



Evolutionary delays

$$\frac{dN}{dt} \approx t^{-1}$$





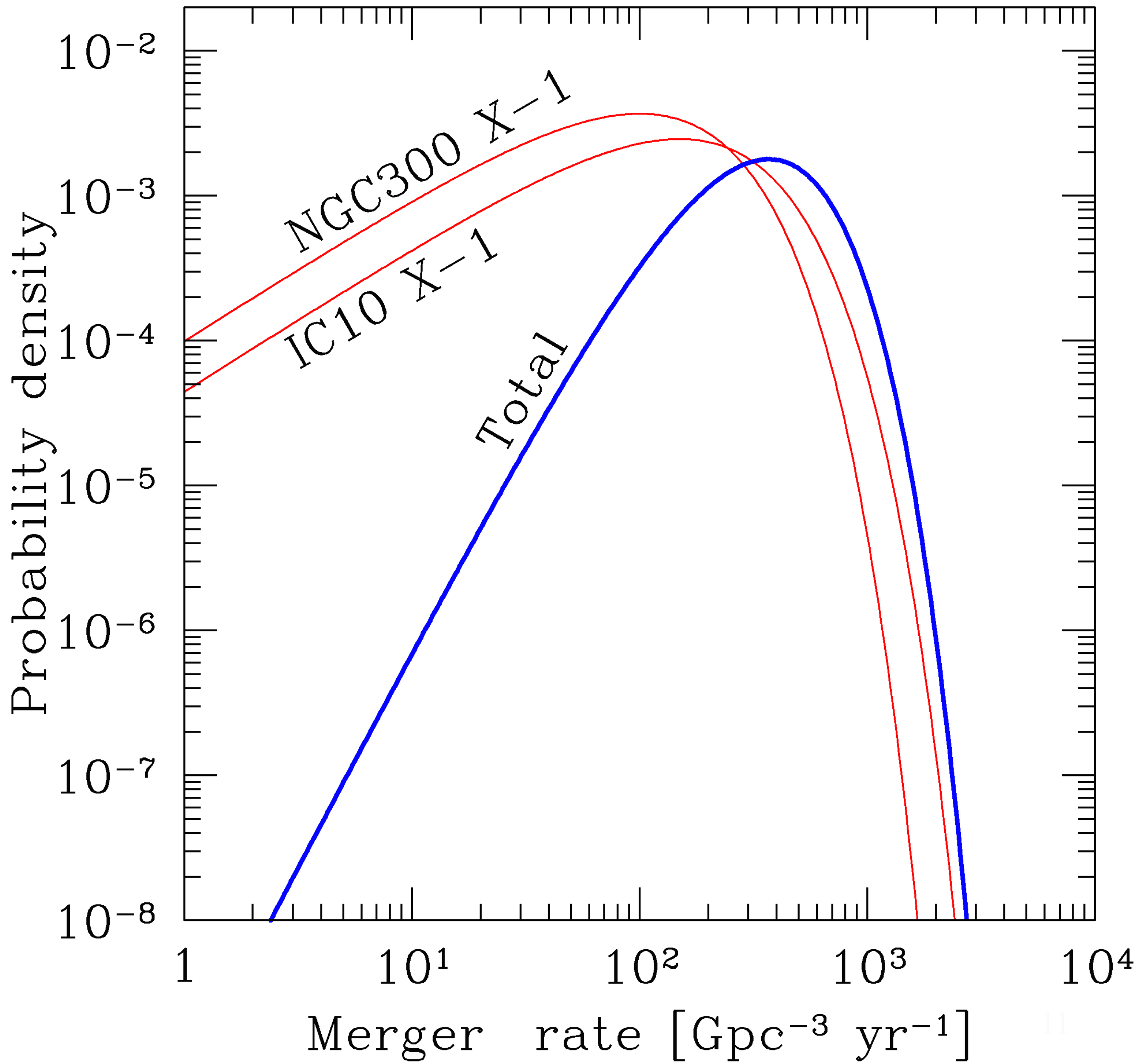
Observational evidence for metallicity dependence of BBH formation

- Interesting systems: IC10 X-1, NGC300 X-1
- Both are BHs accreting from massive helium stars
- Mass ratio: BH more massive than the donor
- Both will form BBH in about 100 kyrs.
- Both reside in low metallicity galaxies
- BBHs will merge in a few Gyrs

Rate estimate

Formation rate:

- **Volume searched**
- **X-ray active time**
- **Coalescence rate is the same as formation rate**



Binary BH coalescence rate estimate

- Population synthesis based:

$$R \approx 5 \times 10^{2}\, Gpc^{-3}\, yr^{-1}$$

- Observation based

$$R \approx 4 \times 10^{2}\, Gpc^{-3}\, yr^{-1}$$

- This is on the high end of range – see rates paper.

Observations

Properties

- Masses
- Orbits
- Spins
- Distance

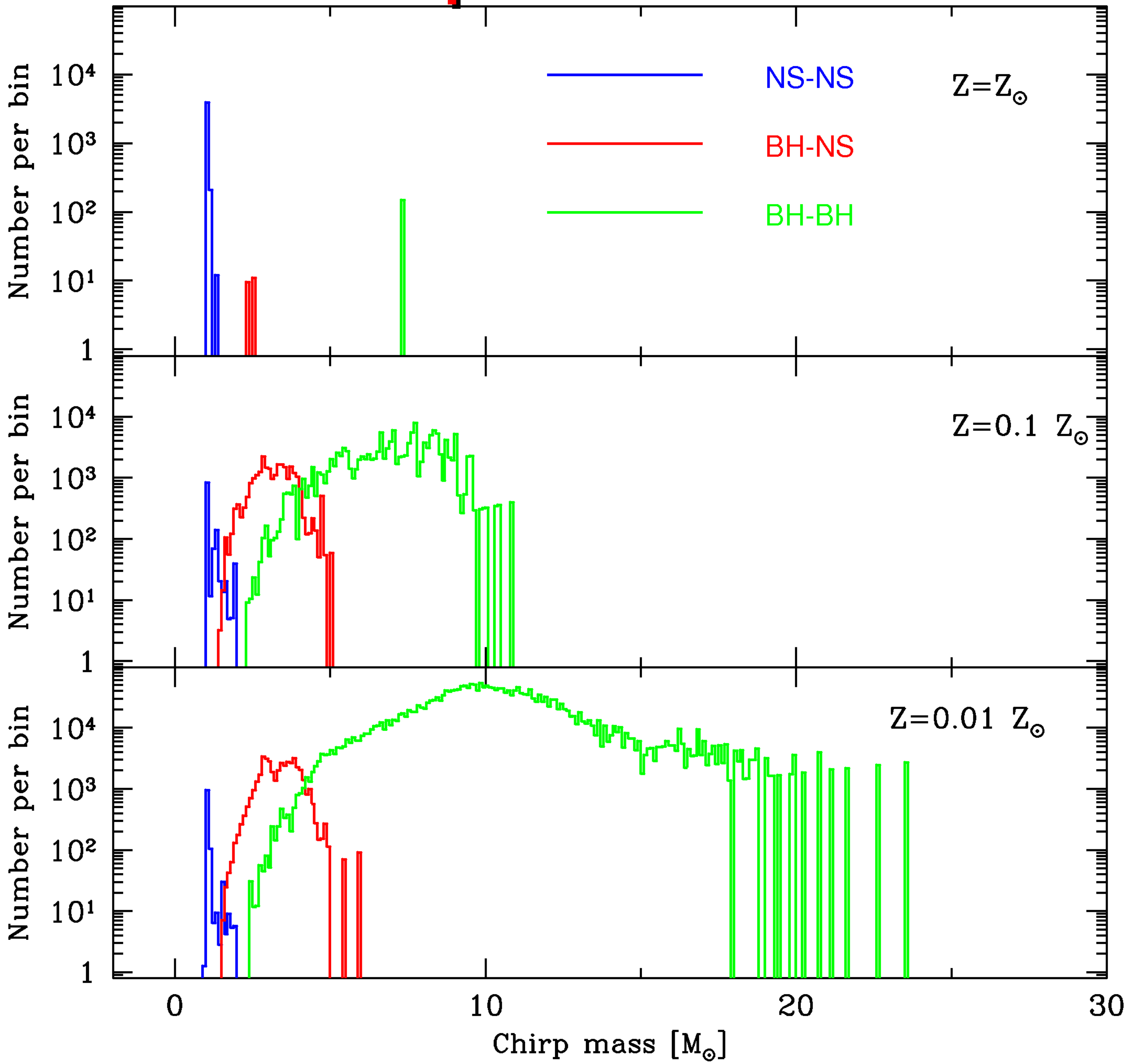
Observables

- Redshifted chirp mass
- Amplitude
- Ellipticity
- Mass ratio

What can be inferred?

- Redshifted mass + amplitude + cosmological model gives redshift and chirp mass
- Distribution of chirp masses depends on the binary evolutionary scenario and metallicity
- Redshift distribution of mergers
- Ellipticities carry information about initial orbits

Observable chirp mass distributions

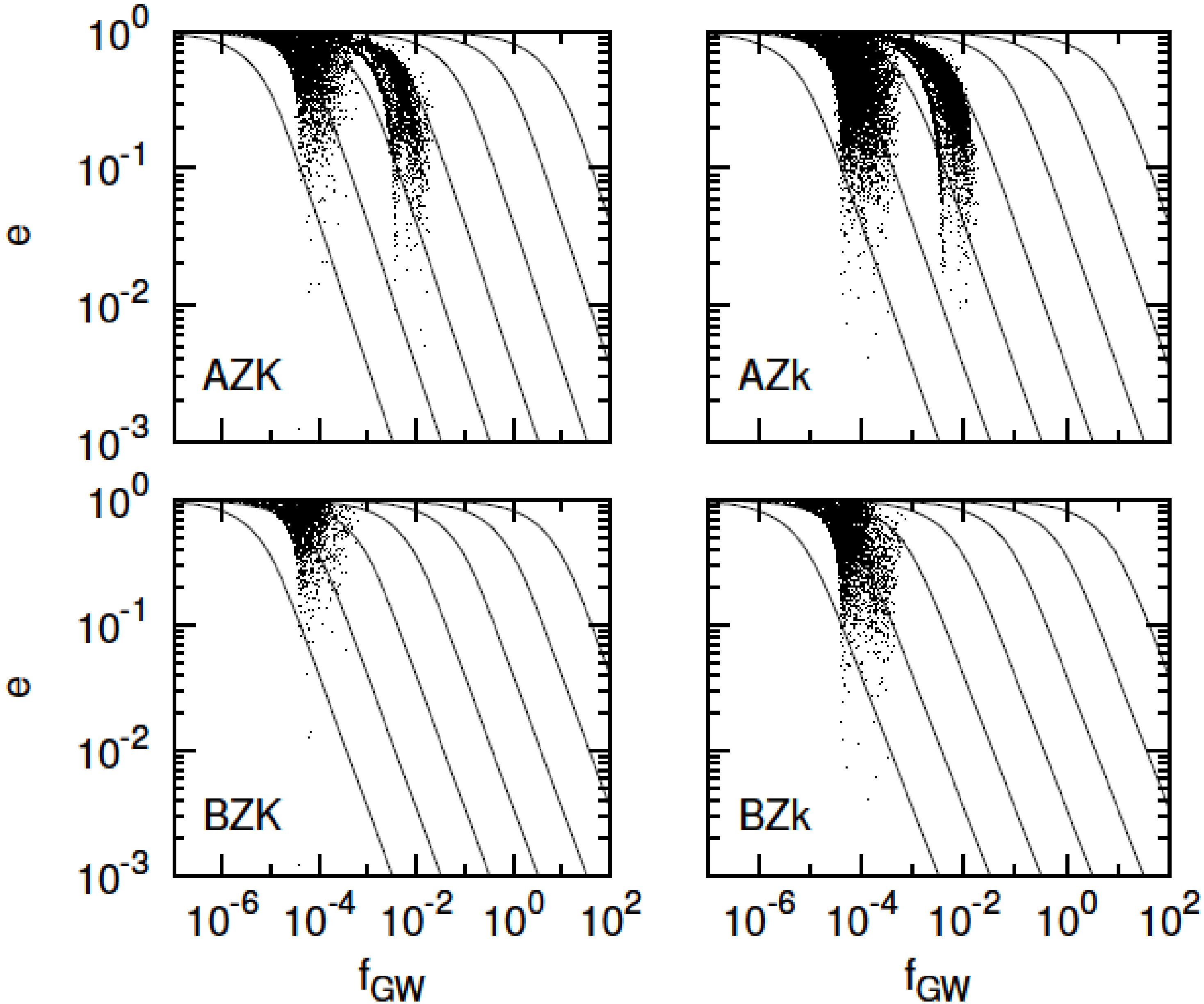


Note: Simplified results: redshift neglected, assumes constant star formation rate!

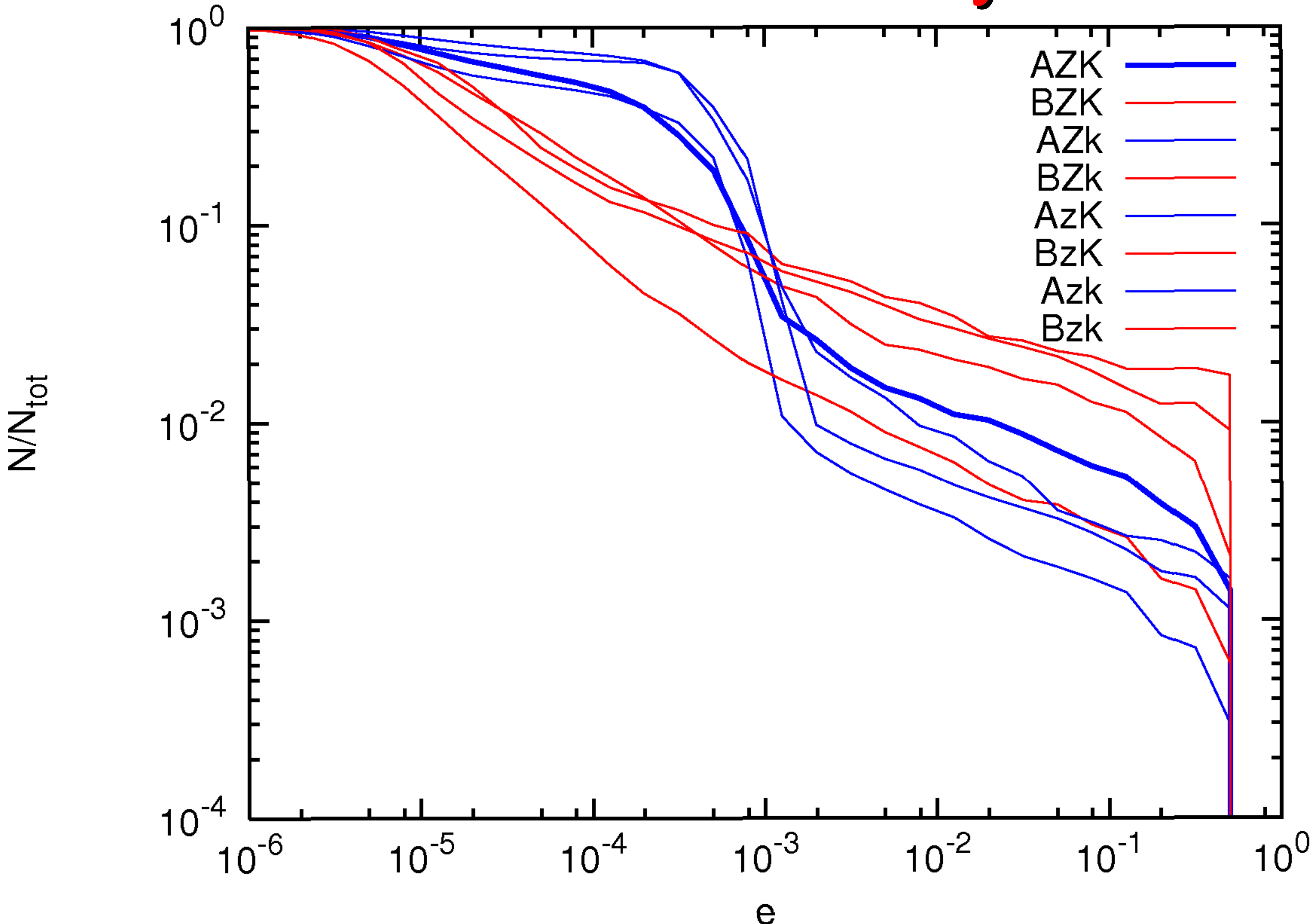
Astronomy with BBHs

- Observed sample to be dominated by BBH from low metallicity regions
- Low metallicities imply to higher BH masses
- Trace the evolution of metallicity
- Modeling star formation requires to untangle formation rate and delay distribution
- But delay distribution is simple

Eccentricities of BNS binaries



Distribution of eccentricity at 3Hz



Astronomy with BNS

- Two formation paths
- Do ultracompact binaries exist?
- Between 0.5%-4% BNS will have eccentricities above 0.01 at 3Hz
- If e~0.001 is measureable then ultracompact binaries can be distiguished

SUMMARY

- Theoretical and observational indications of a large BBH rate
- Rate is a very strong function of metallicity
- Metallicity evolution can be traced up to the time of first stars (including the delay modeling)
- Small fraction of BNSs may be eccentric
- Eccentricity indicates ultracompact binaries DNS binary formation channel