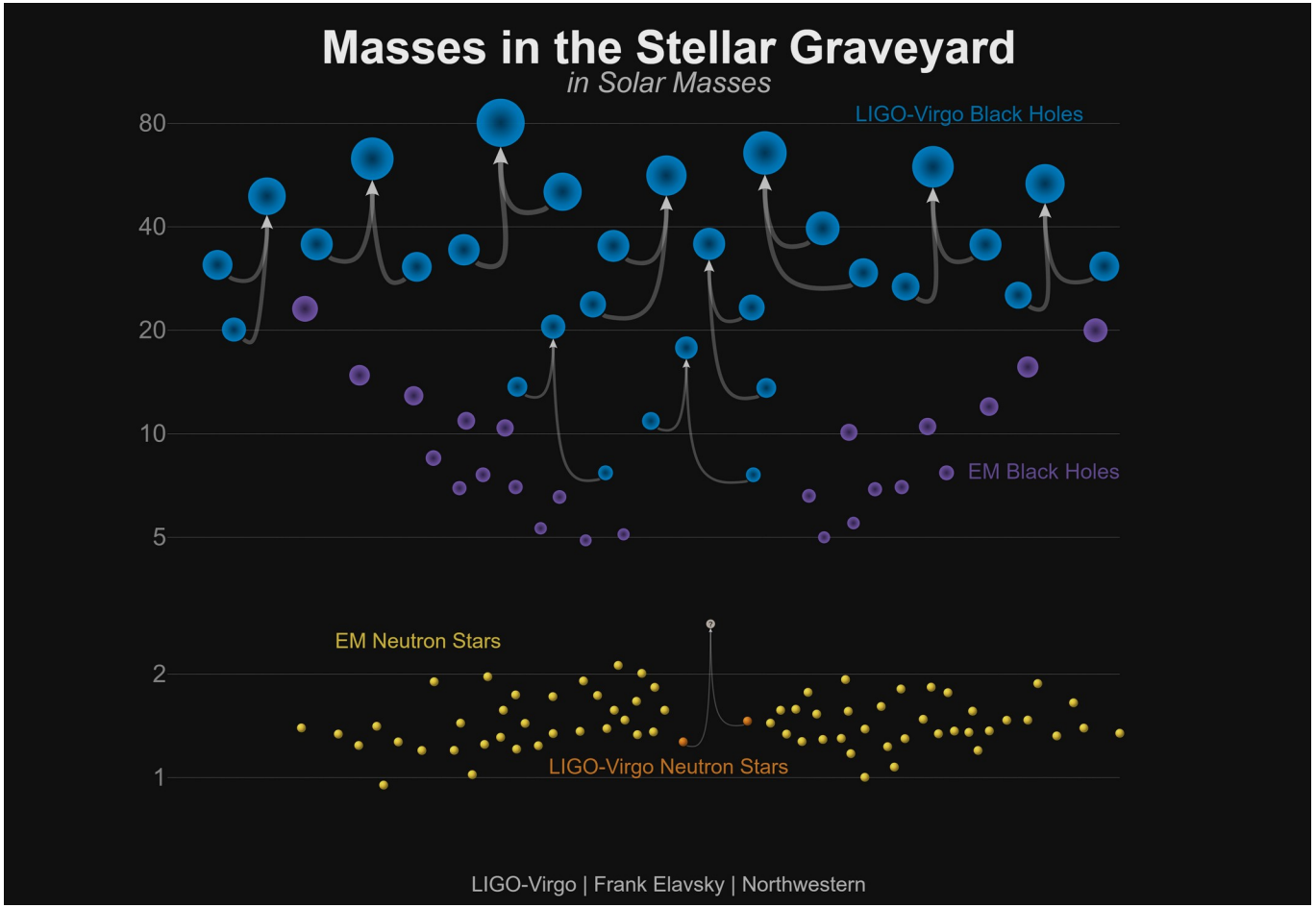
The origin of the coalescing compact object binaries

Tomek Bulik
University of Warsaw, Poland
Astrocent – CAMK, Warsaw, Poland

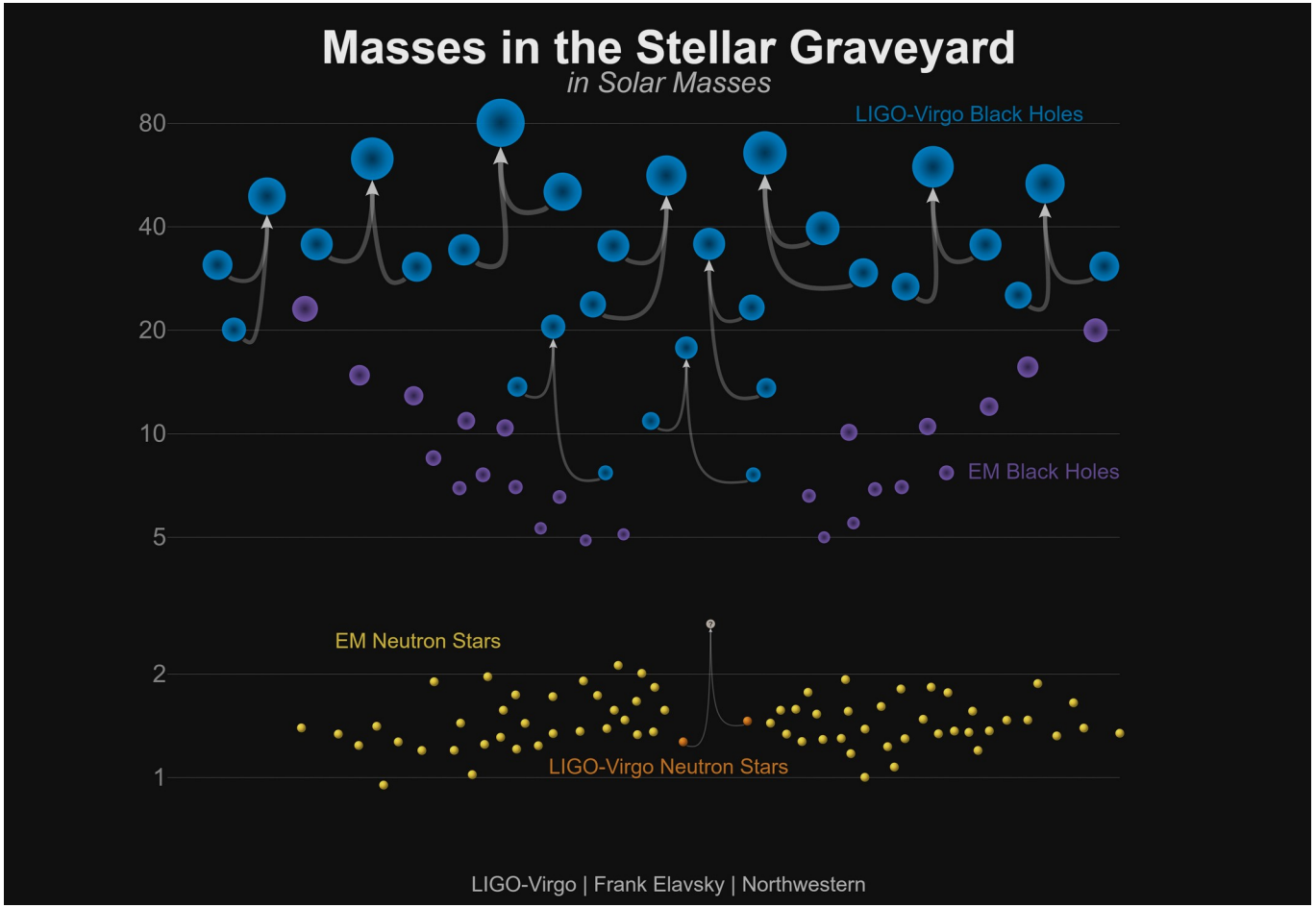
Observations

- Masses
- Spins
- Rate densities
- Distances
- Locations
- Counterparts



Observations

- Masses
- Spins
- Rate densities
- Distances
- Locations
- Counterparts



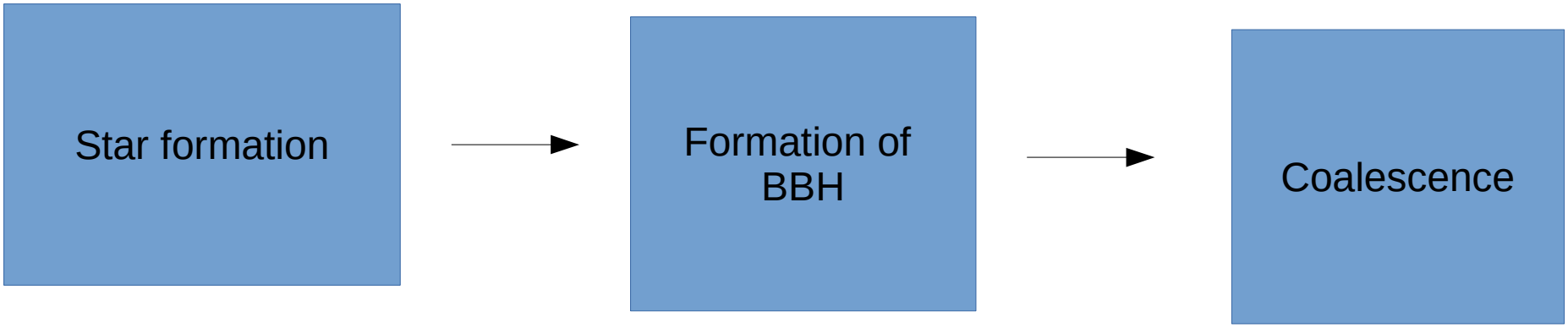
What options do we have?

- Binary evolution
  - Standard
  - Chemically homogenous case
- Evolution in the clusters
- Exotica
  - Pop III stars
  - Exceptional environments.

The merger rate densities

- BBH estimate $R = 9.7 - 101 \mathrm{Gpc}^{-3}\mathrm{yr}^{-1}$
- BNS estimate $R = 110 - 3840 \mathrm{Gpc}^{-3}\mathrm{yr}^{-1}$
- The local supernova rate ~ $10^5 \mathrm{Gpc}^{-3}\mathrm{yr}^{-1}$
- The BH formation rate is ~ $10^4 \mathrm{Gpc}^{-3}\mathrm{yr}^{-1}$
- About 1 black hole in a 100-1000 ends up in a merging binary
- Similarily NS: 1 in 100-1000 is in a merging binary!

Rates



Trace the evolution backwards to orginal SFR population to estimate the rate

Rates

- BHBH production efficiency:
  - Number of merging BBH per unit mass
- Delay times
- Mass distribution
  - Intrinsic vs observed: range and redshift effect

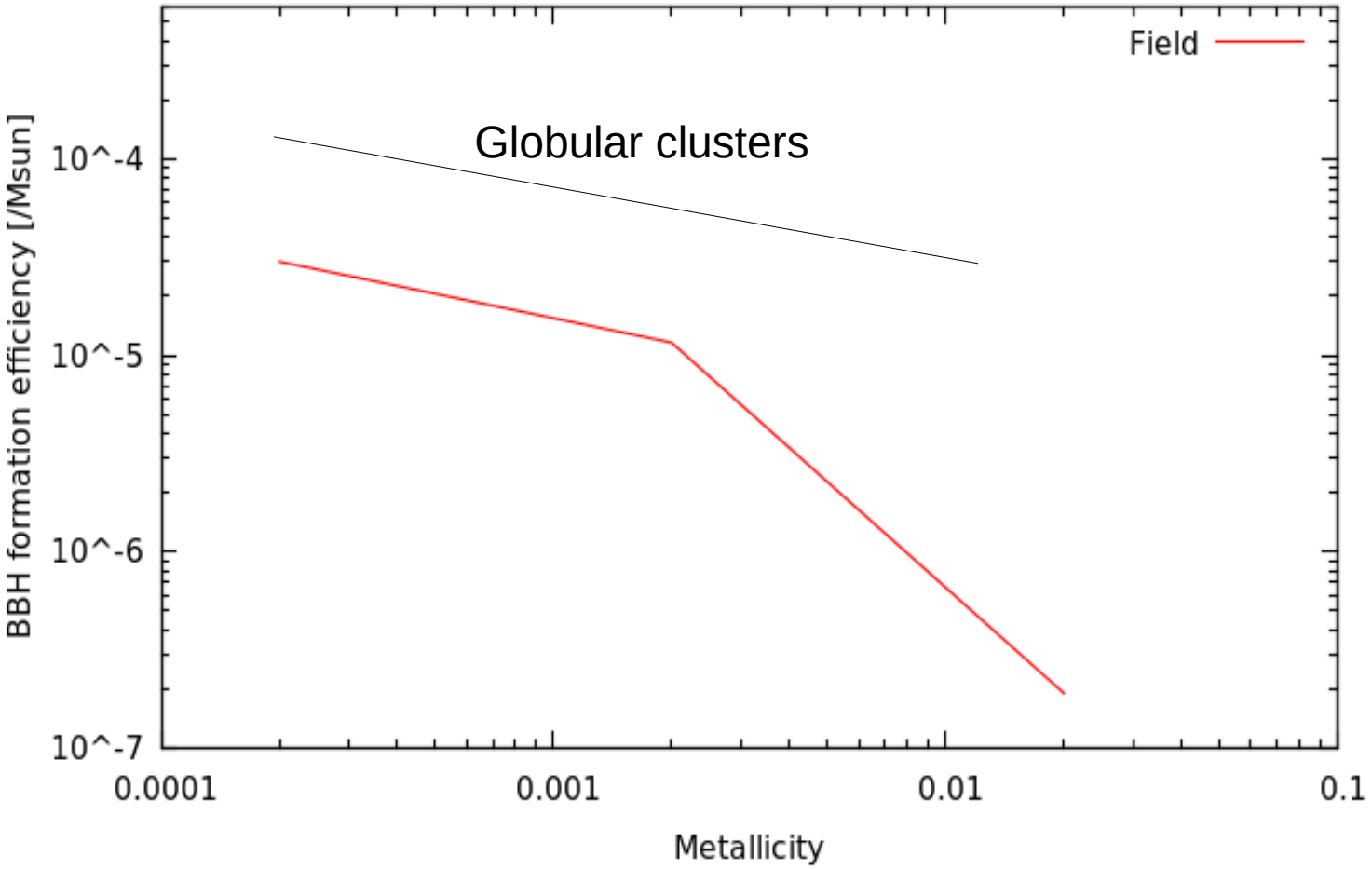
- Rate density: local and as a function of redshift

BHBH formation efficiency

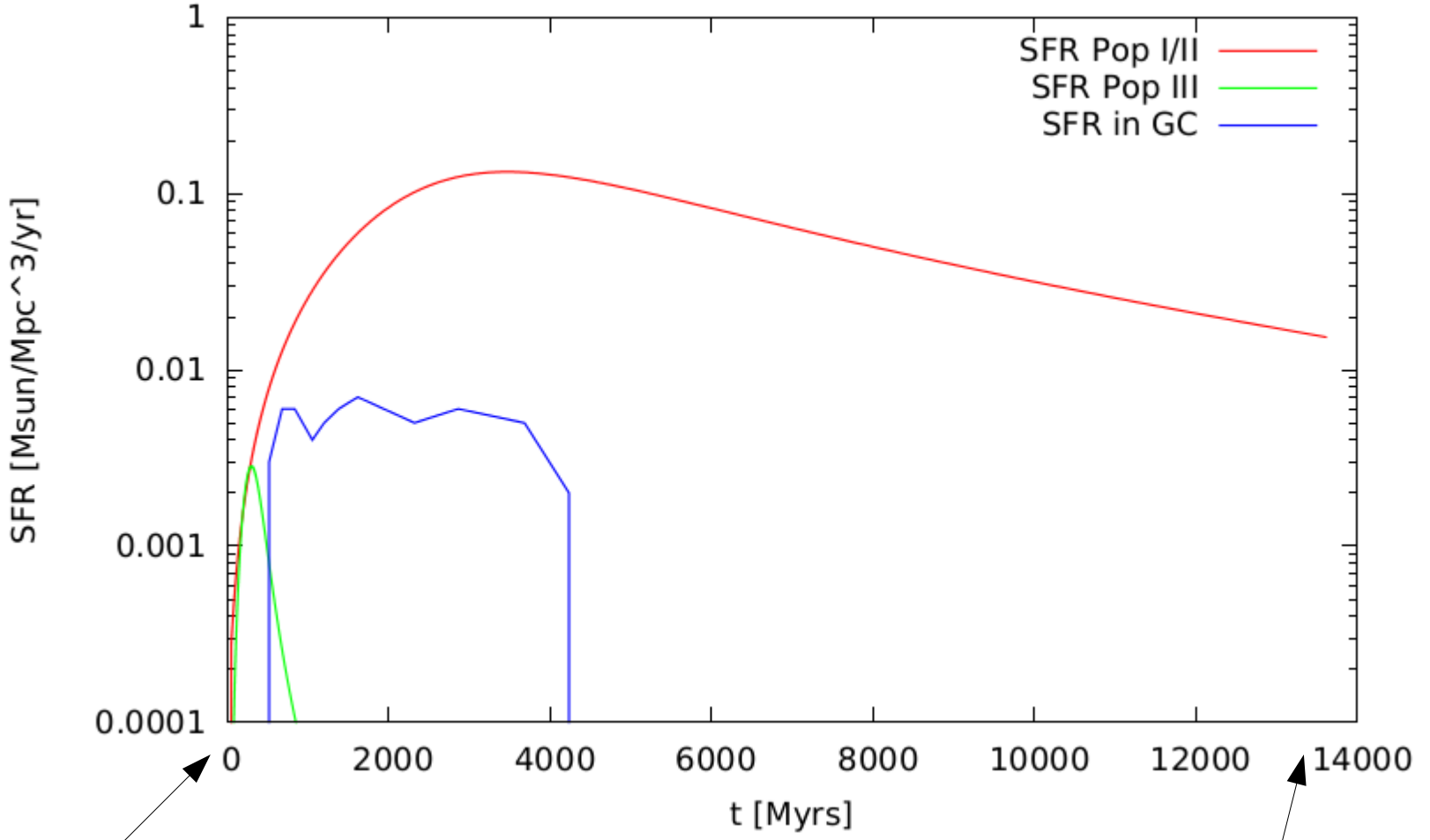
$$X_{BHBH} = \frac{N_{BHBH}}{M_*}$$

If all BHs end up in merging binaries and with Salpeter IMF

$$X_{BHBH}^{max} = 1.8 \times 10^{-3} M_{\odot}^{-1}$$



SFR



Big Bang

Today

Basic rate arguments

- Formation scenario must be generic
- Exceptional environments must produce BBH and BNS with extremly high efficiency
- Globular clusters are not favoured, but can contribute
- I am sceptical about exotic models

The rate implications

- Total GW luminosity density in the sky from NSNS mergers

$$\mathcal{L}_{GW} = 1500 \frac{0.025 M_\odot c^2}{3.1 \times 10^7 \mathrm{s}} \approx 2.5 \times 10^{48} \mathrm{ergs}^{-1} \mathrm{Gpc}^{-3}$$

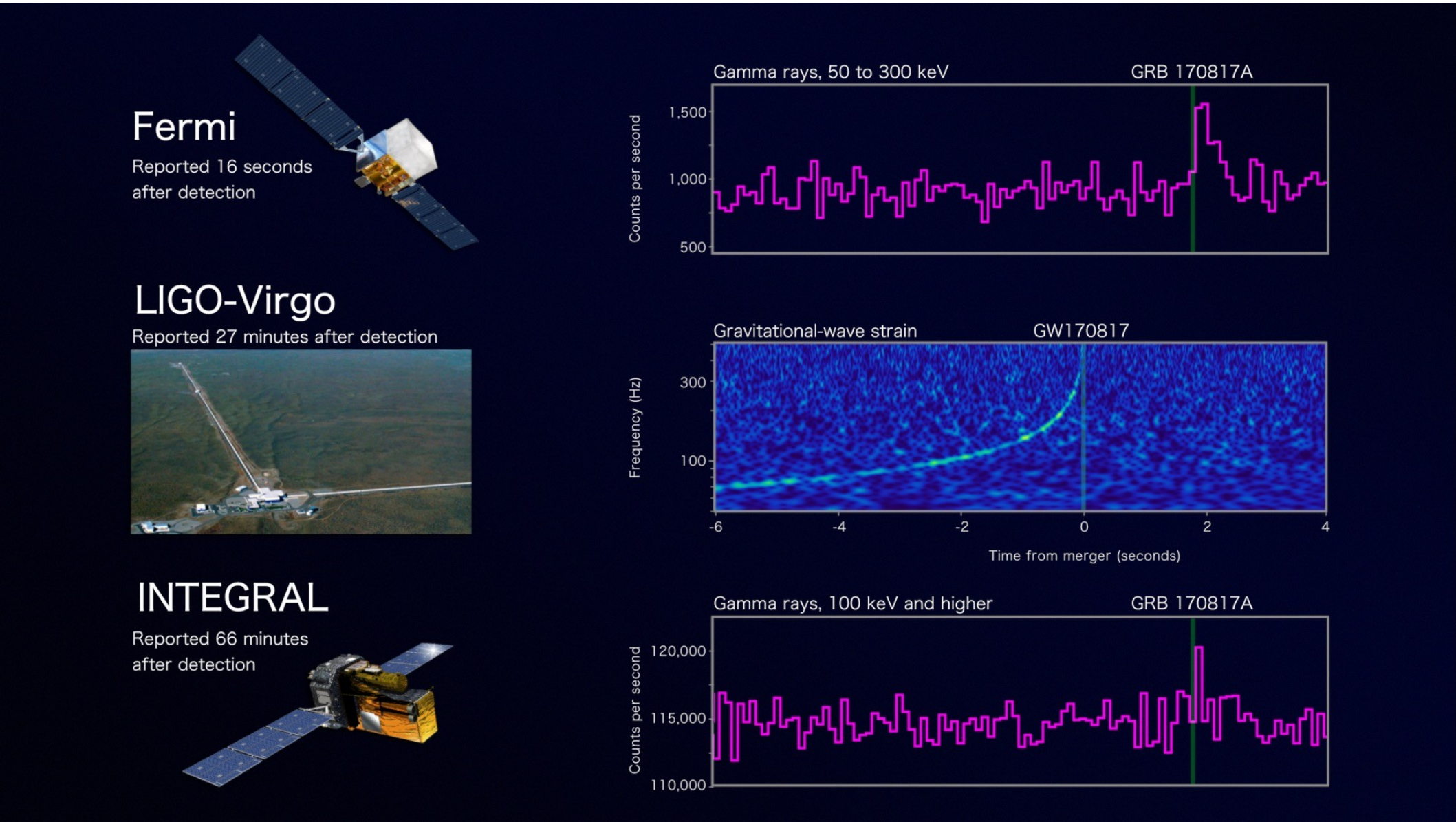
- The luminosity density of BHBH mergers is about 10 times larger

$$\mathcal{L}_{GW} = 50 \frac{2.0 M_\odot c^2}{3.1 \times 10^7 \mathrm{s}} \approx 10^{49} \mathrm{ergs}^{-1} \mathrm{Gpc}^{-3}$$

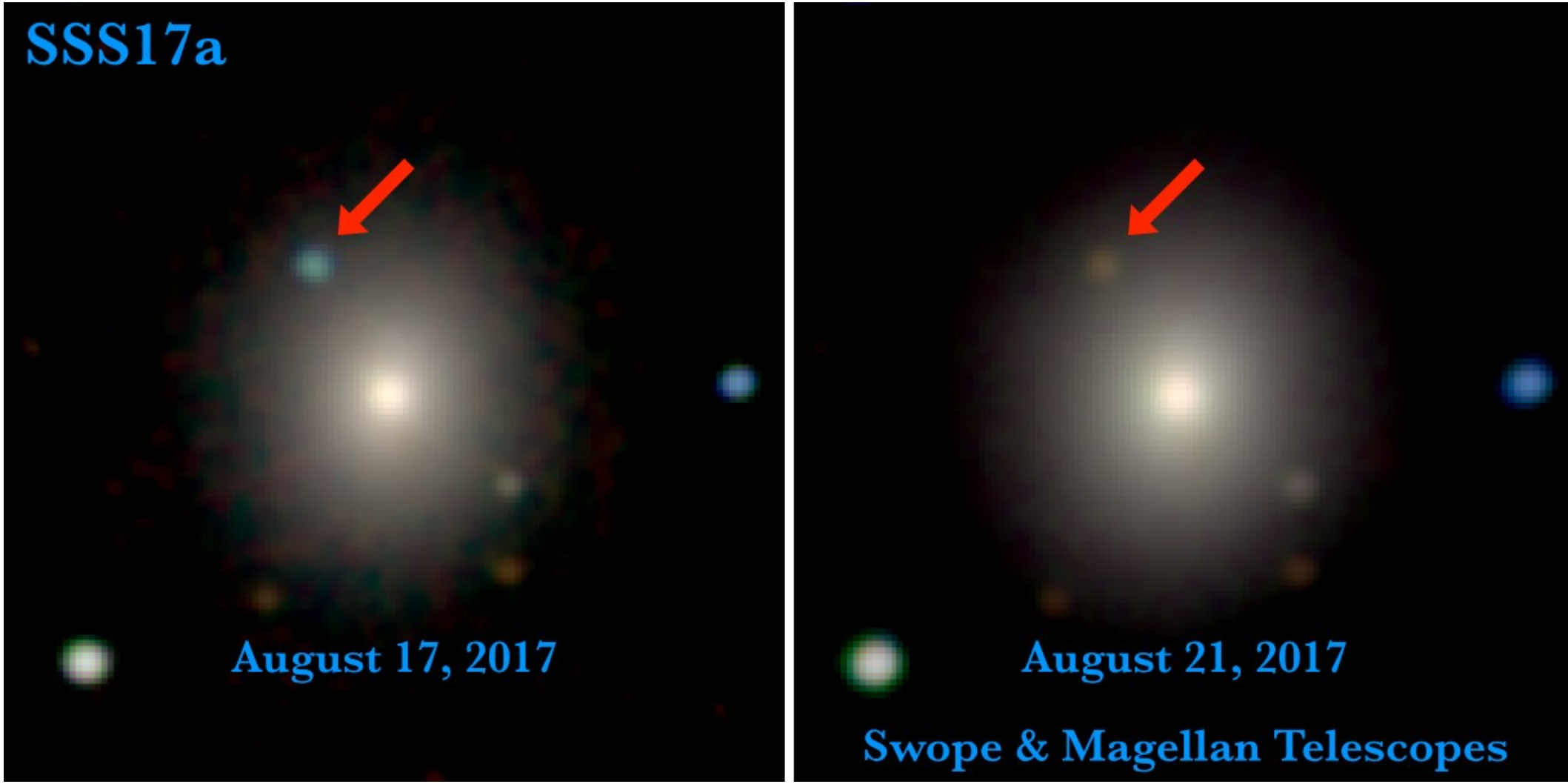
- EM luminosity density of all galaxies:

$$\mathcal{L}_{EM} \approx 10^{50} \mathrm{erg\,s}^{-1} \mathrm{Gpc}^{-3}$$

The binary neutron star GW170817

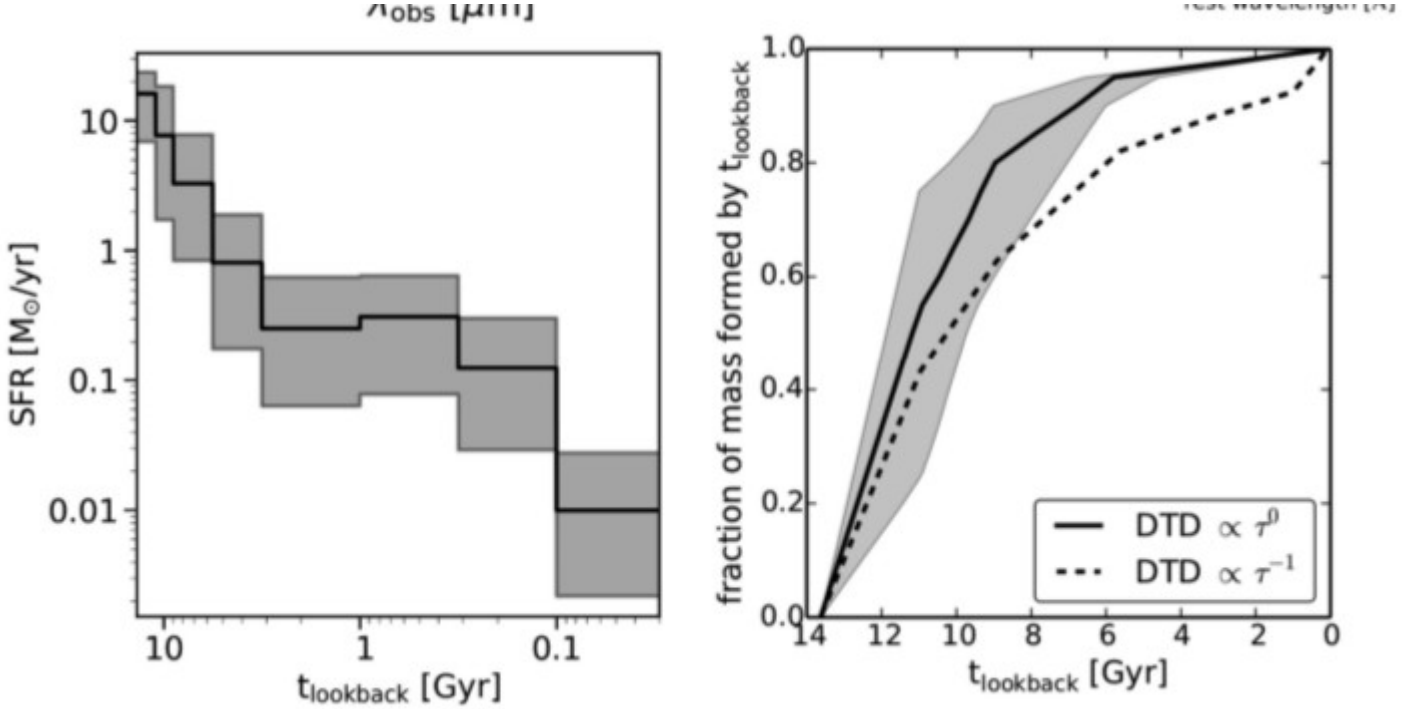


BNS: all that + host galaxy



NGC 4993 – old elliptical with no traces of str formation for th last 1-2Gyrs, merger on the ourskirts of the galaxy.

Star formation history estimate



Blanchard 2017

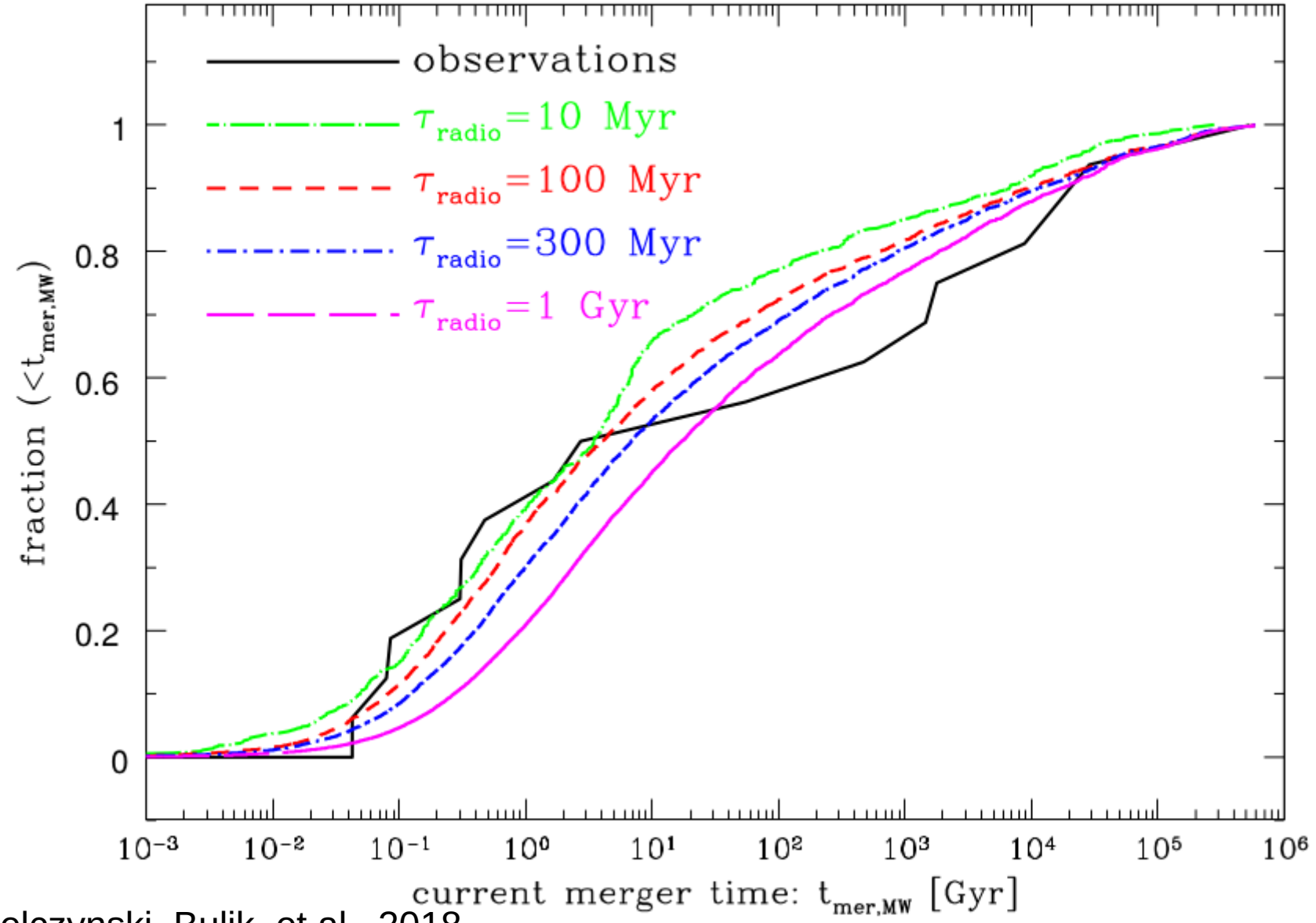
Delay time distributions

$$\frac{dN}{dt} \propto t^{-\alpha}, \quad \alpha \geq 1$$

Delay distribution goes down after about 50-100 Myrs

After 2 Gyrs the merger raet goes down by a factor 20-40

Just a check in the Milky Way



Belczynski..Bulik. et al.. 2018

Open issues

- Place the scenarios within astrophysical landscape
- Rates are not that high anymore!
  - There are models that are consistent with the rates
  - Globular cluster origin – tough to reconcile with all observations
  - Many paths may contribute, new ideas
- How exceptional was GW170817?
  - Long delay time
  - Unusual GRB

Open issues

- Place the scenarios within astrophysical landscape
- Rates are not that high anymore!
  - There are models that are consistent with the rates
  - Globular cluster origin – tough to reconcile with all observations
  - Many paths may contribute, new ideas
- How exceptional was GW170817?
  - Long delay time
  - Unusual GRB