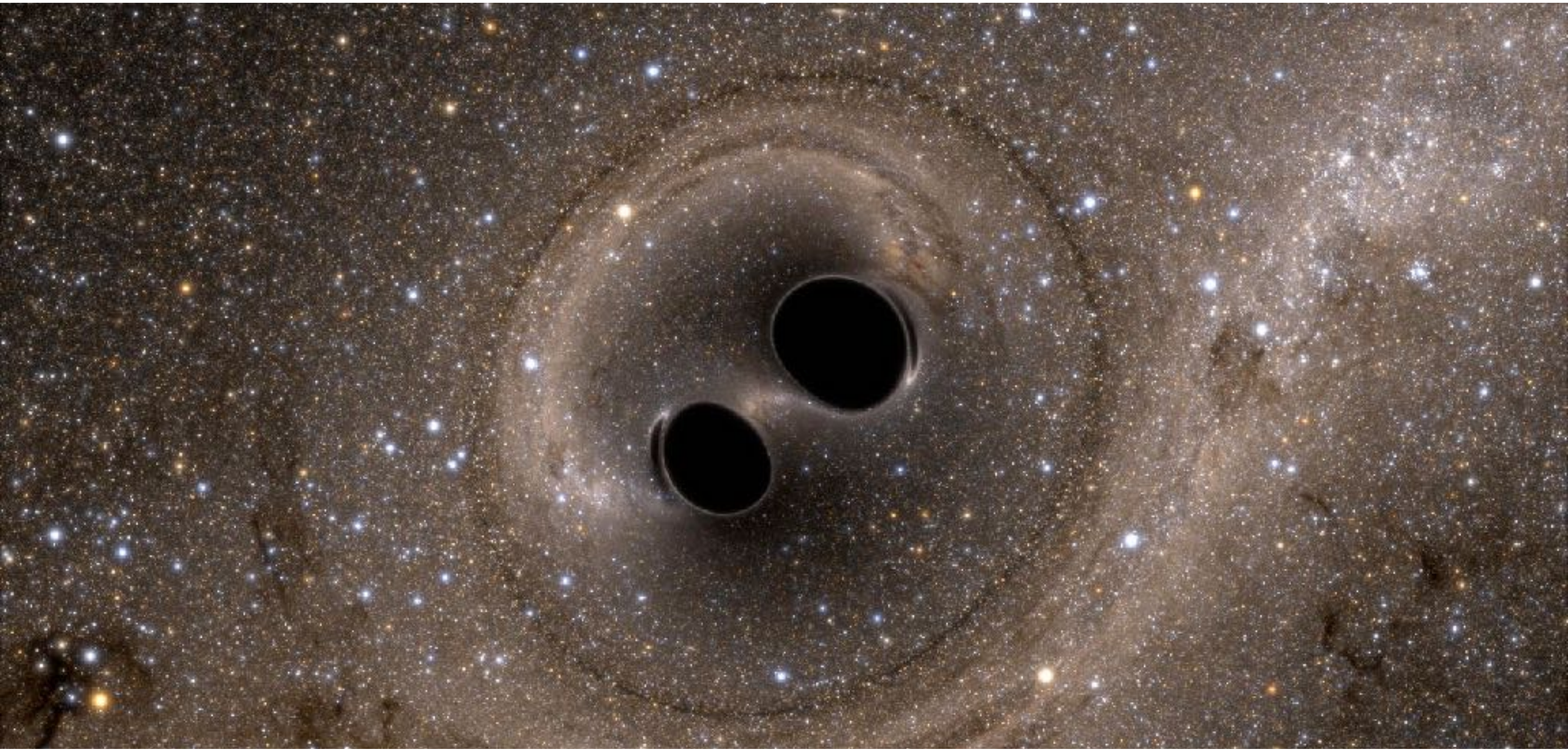
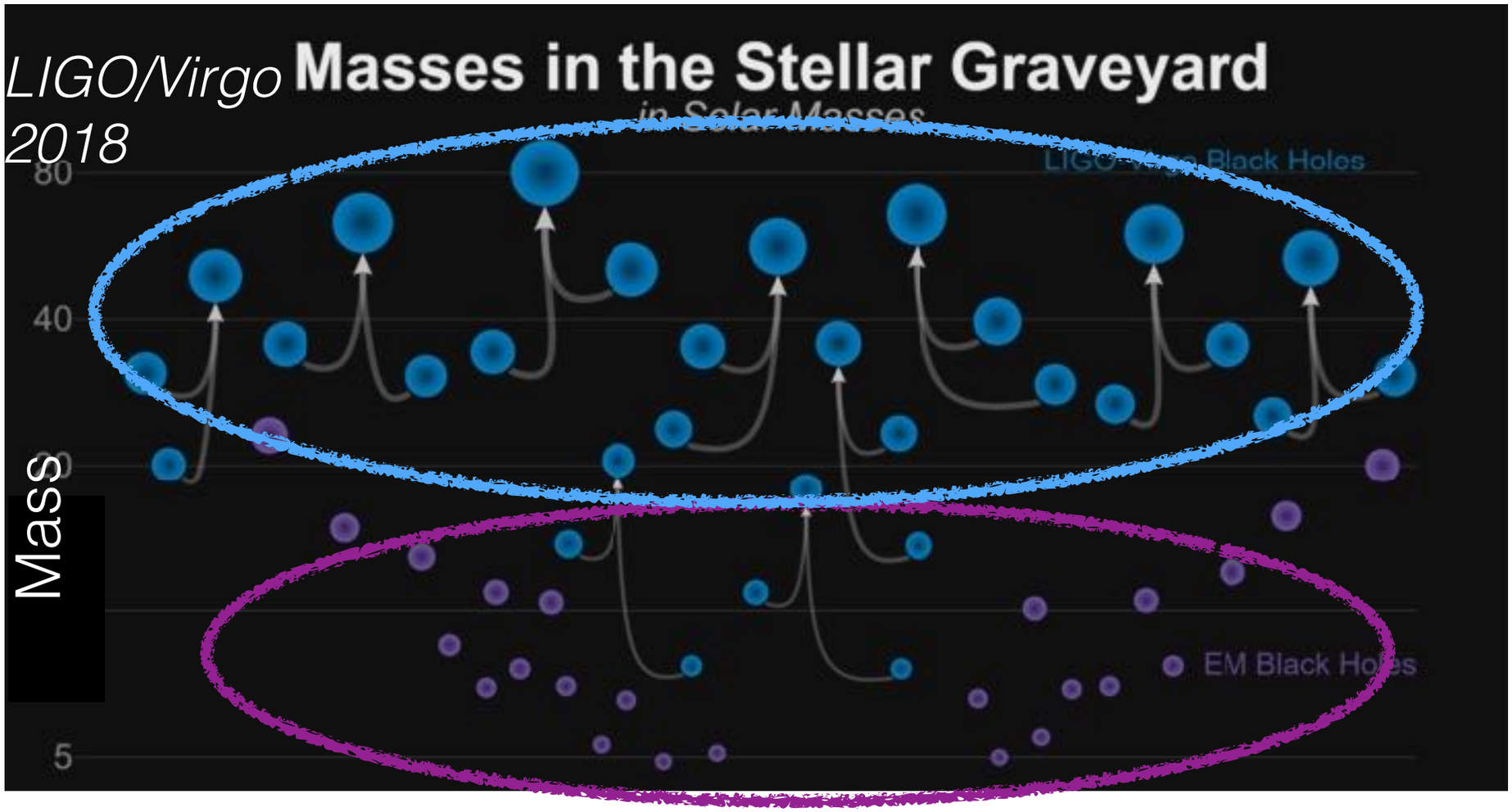
MERGING MASSIVE BLACK HOLES:
THE RIGHT PLACE, THE RIGHT TIME

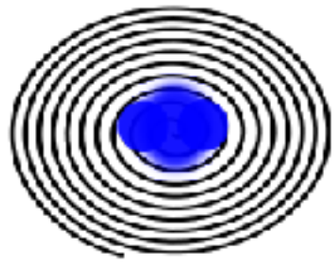


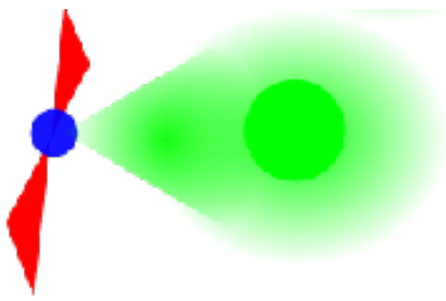
Astrid Lamberts
Lagrange/Artémis

TS2020, Sept. 25 2019

LIGO/VIRGO REVEAL MASSIVE BLACK HOLES





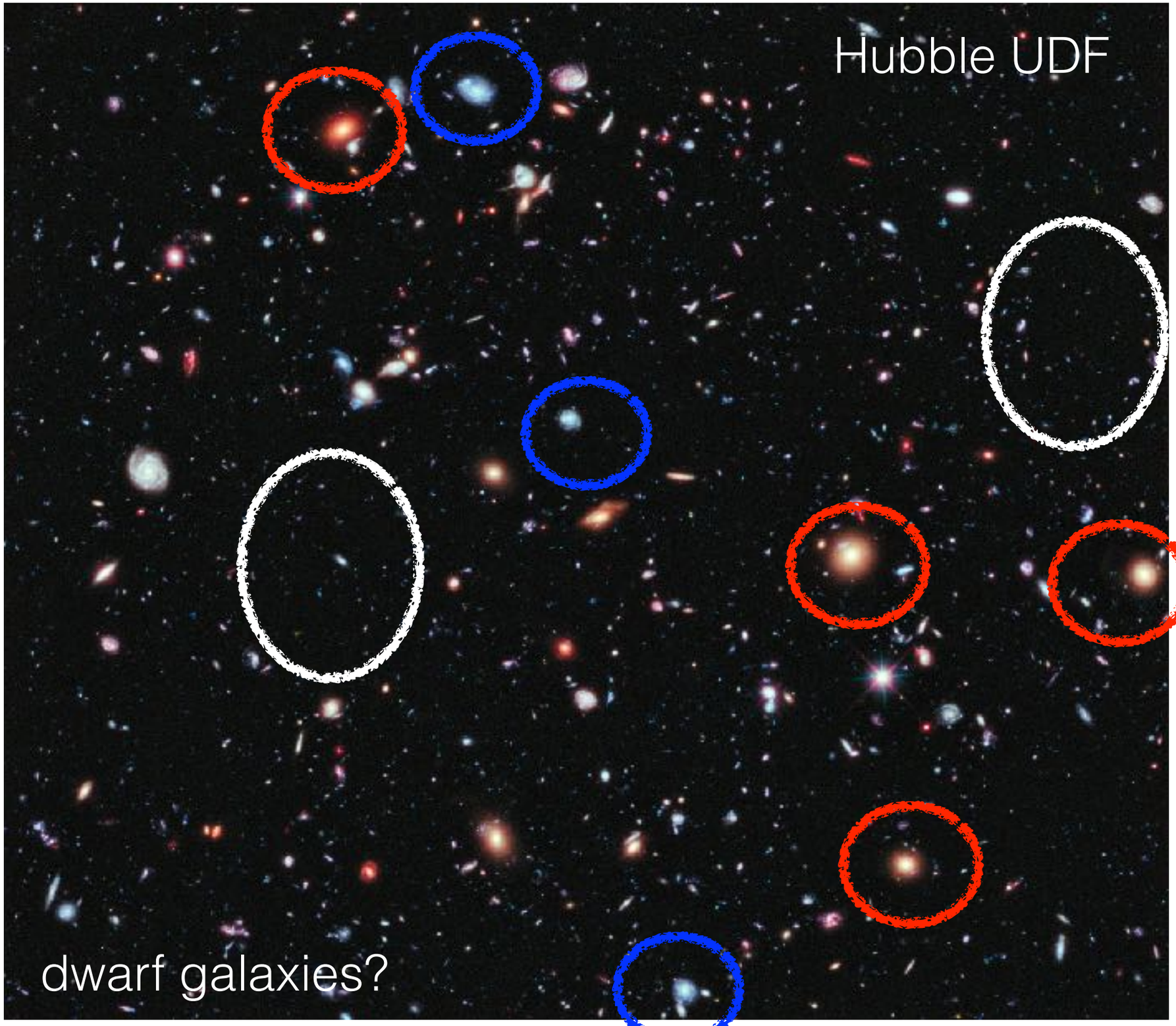


Question: where do black hole mergers come from?

low metallicity binaries: specific conditions for star formation

Multiple mergers in star clusters: specific conditions of star formation

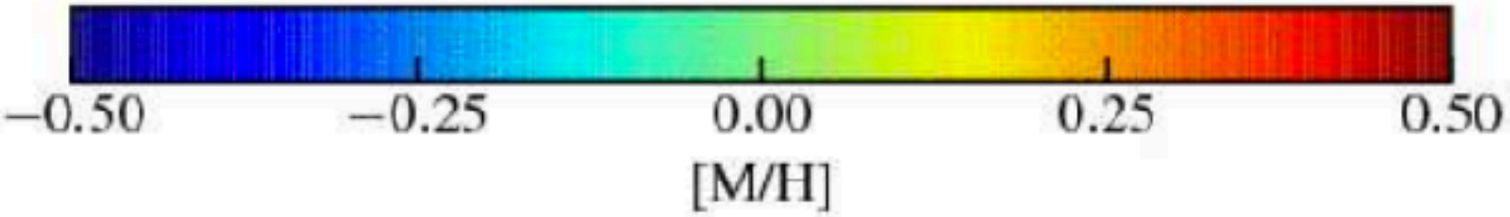
WHERE ARE LOW-METALLICITY STARS?

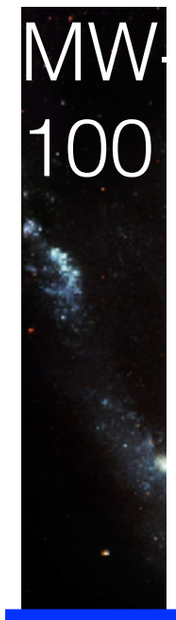


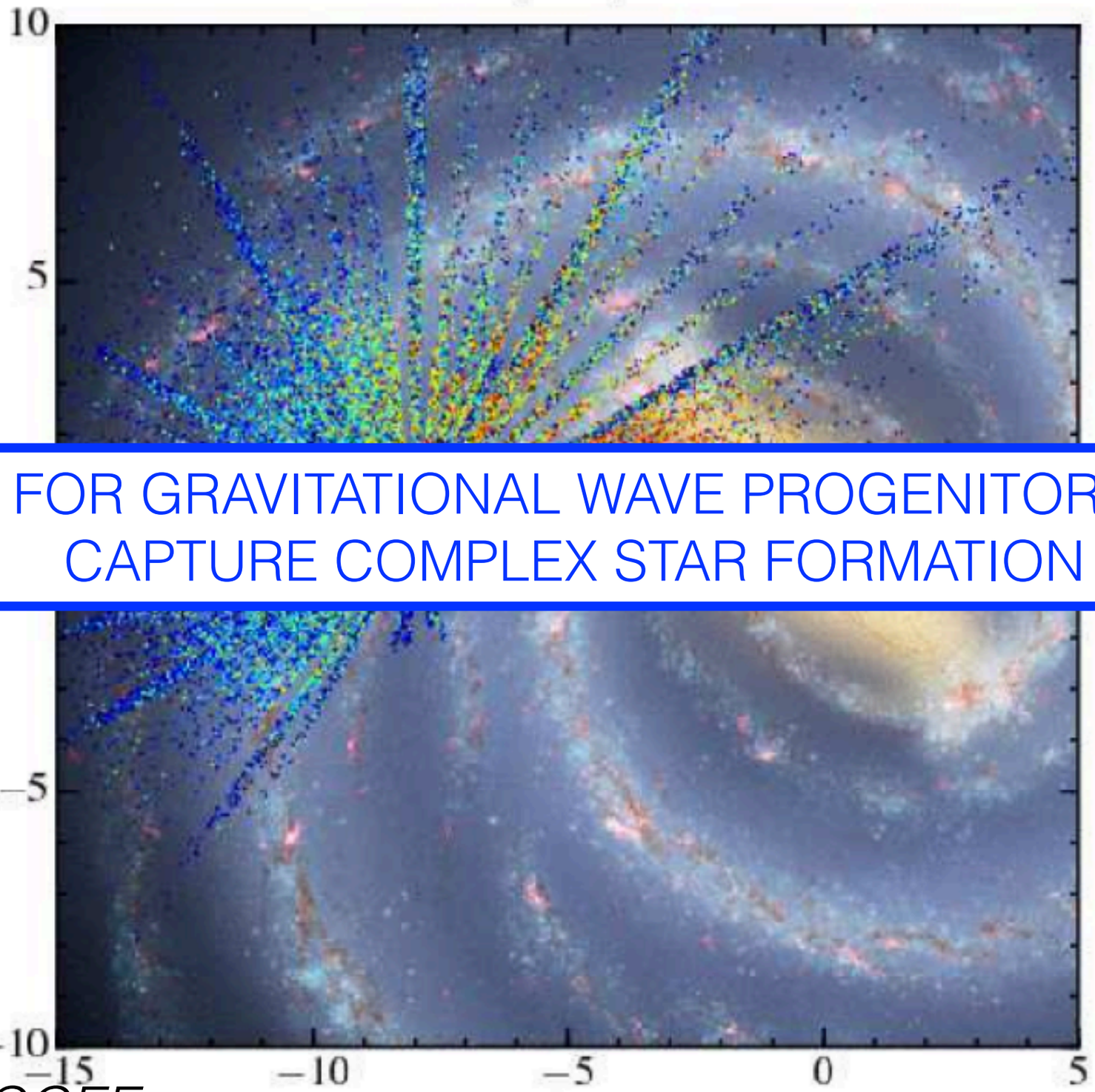
recent star formation?

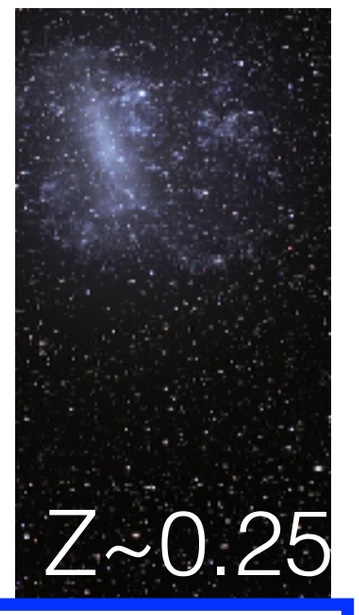
older star formation?

DIFF ALLICITY

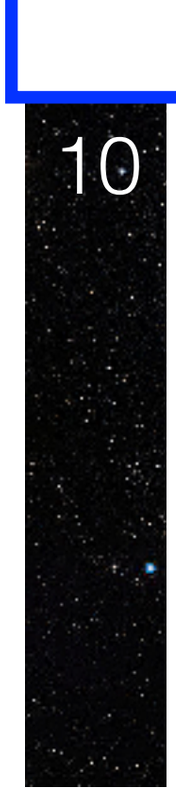








MODELS FOR GRAVITATIONAL WAVE PROGENITORS SHOULD CAPTURE COMPLEX STAR FORMATION



:ulum II :
)0 stars

.01 Z_{sun}

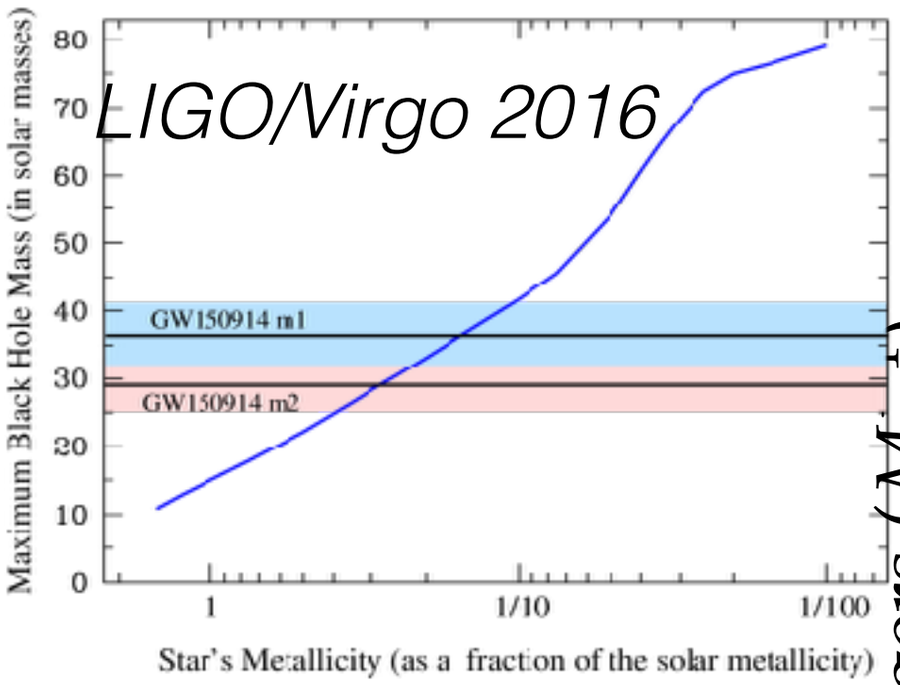
APOGEE survey

NEW COMBINATION:
BINARY MODEL + GALAXY MODEL

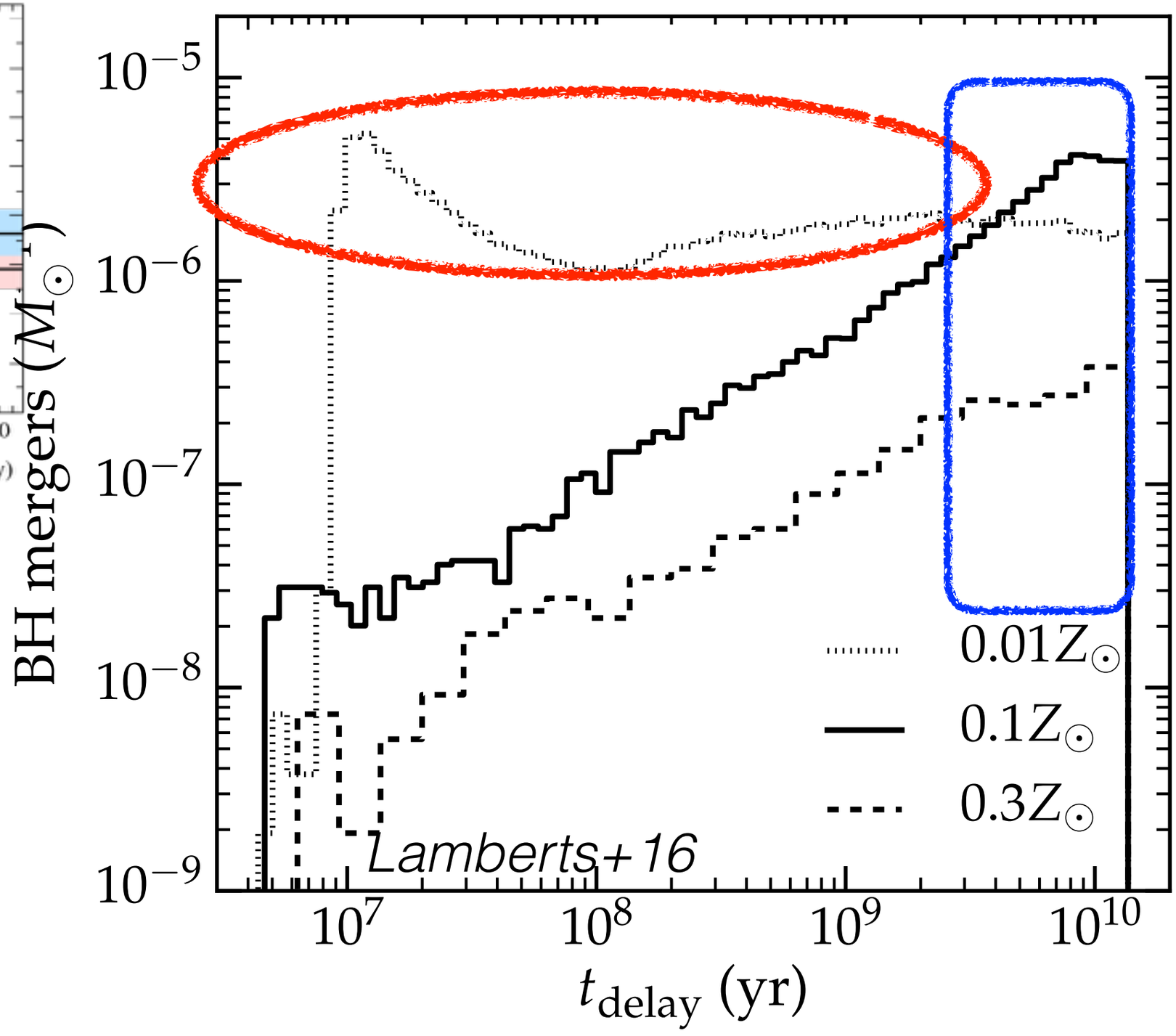
Binary population synthesis code (BSE, Hurley+2002)

- Input: Initial mass function, distribution of periods and eccentricity
- Simplified current model of binary evolution
- Explore metallicity from 1% of Solar to Solar
- Make database of final binary black holes(many other binaries are possible)

INGREDIENT: LONG DELAYS TO MERGERS

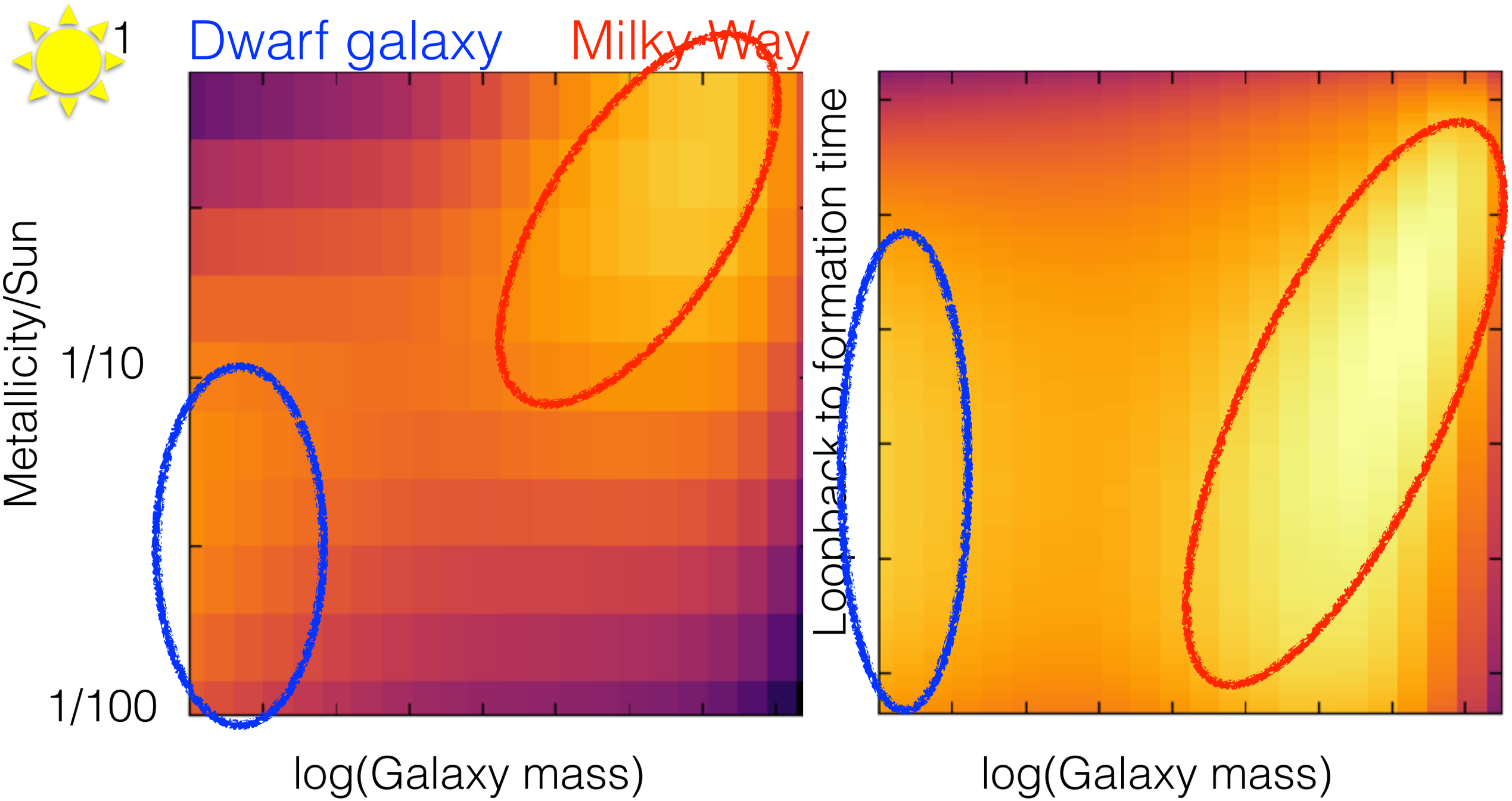


- Low metallicity: most massive remnants
- higher metallicity : long delay



INGREDIENT: LOW METALLICITY STAR FORMATION

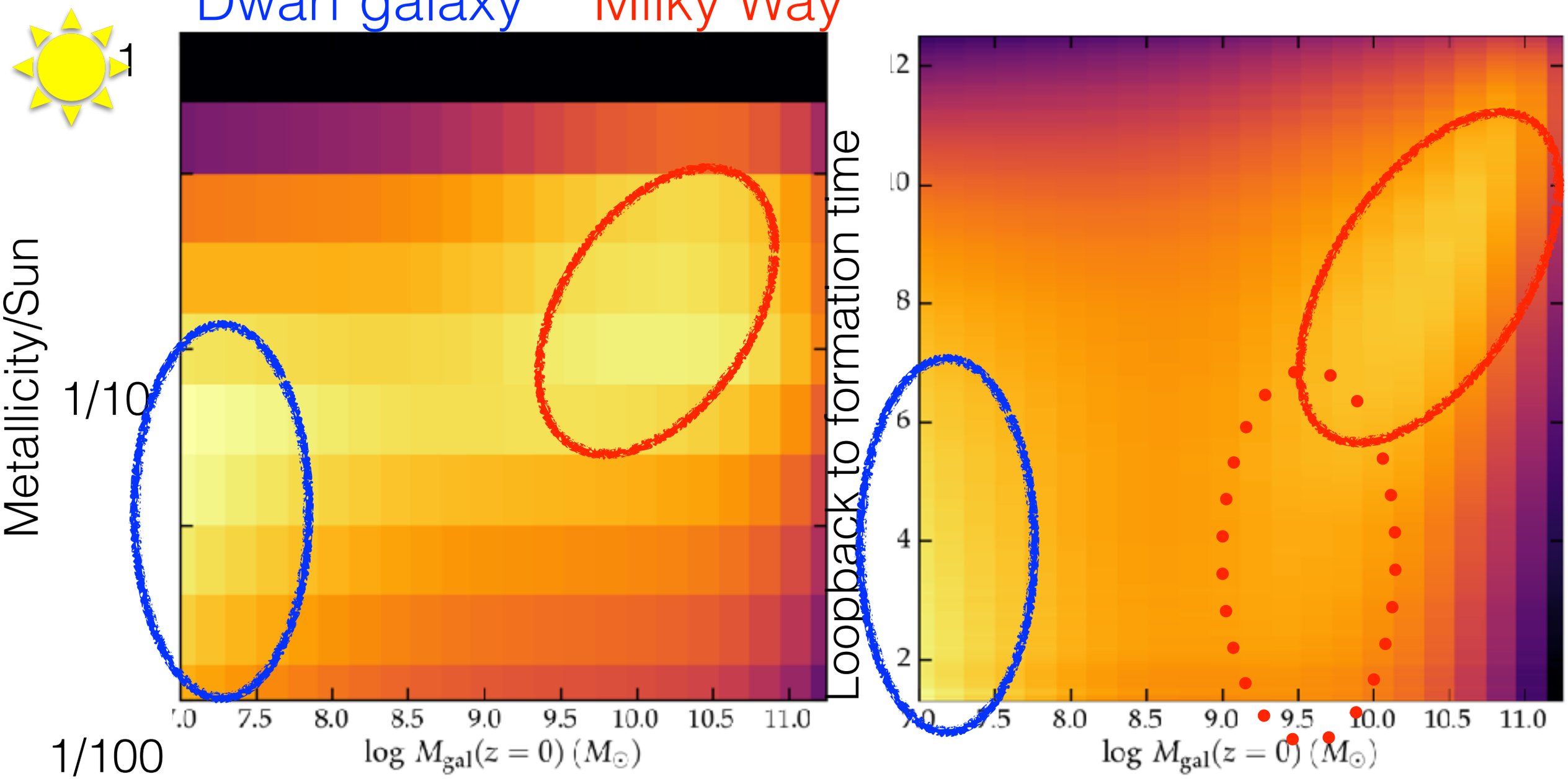
"homemade" semi-analytic model (*Lamberts+16)*



Lamberts+16

BIMODAL FORMATION OF MASSIVE BLACK HOLE PROGENITORS

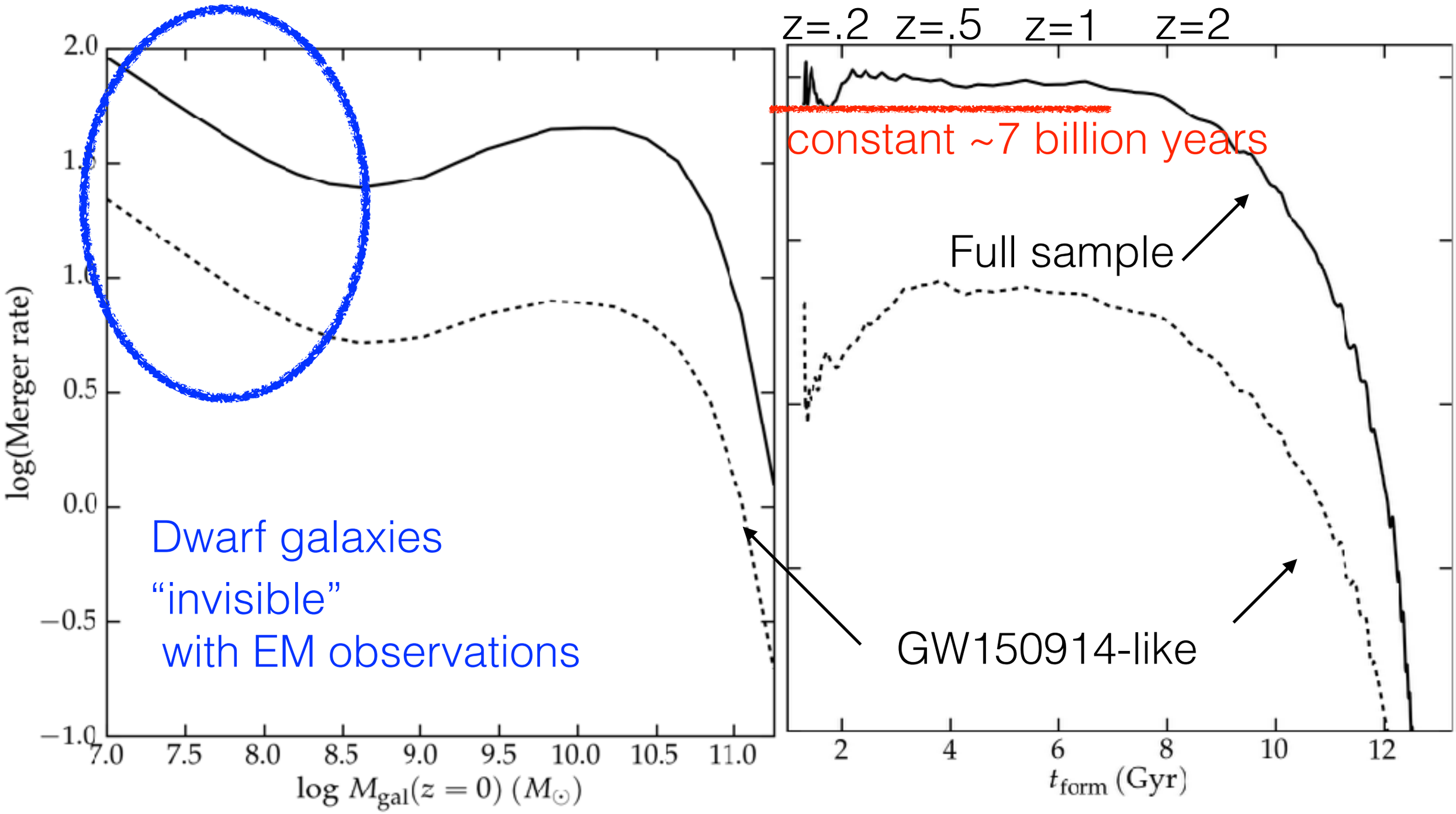
Dwarf galaxy Milky Way



log(Galaxy mass) log(Galaxy mass)

Lamberts+16, data public, confirmed in Elbert+17, Mapelli+17

STAR FORMATION IN DWARF GALAXIES



(Lamberts+16)

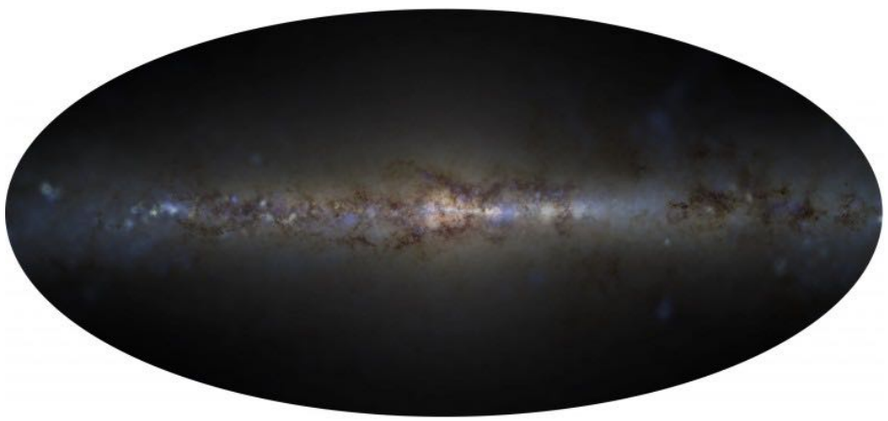
Wetzel+16
FIRE collab.

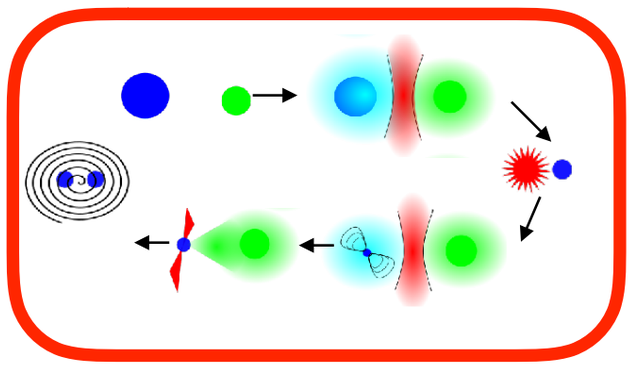
SIMULATION?

OBSERVATION?

Stellar halo/satellites
Gaia DR2

GROWING COMPACT BINARIES IN THE MILKY WAY

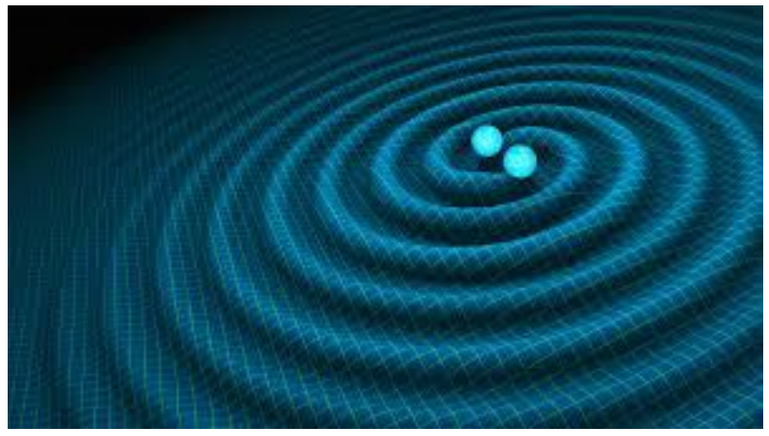




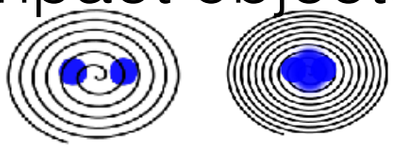
Star formation history
Metallicity
Positions/Trajectory

+

13 bins: $Z=0.005$ -1.3 Z_{sun}
M_1,M_2, t_{form}, orbit



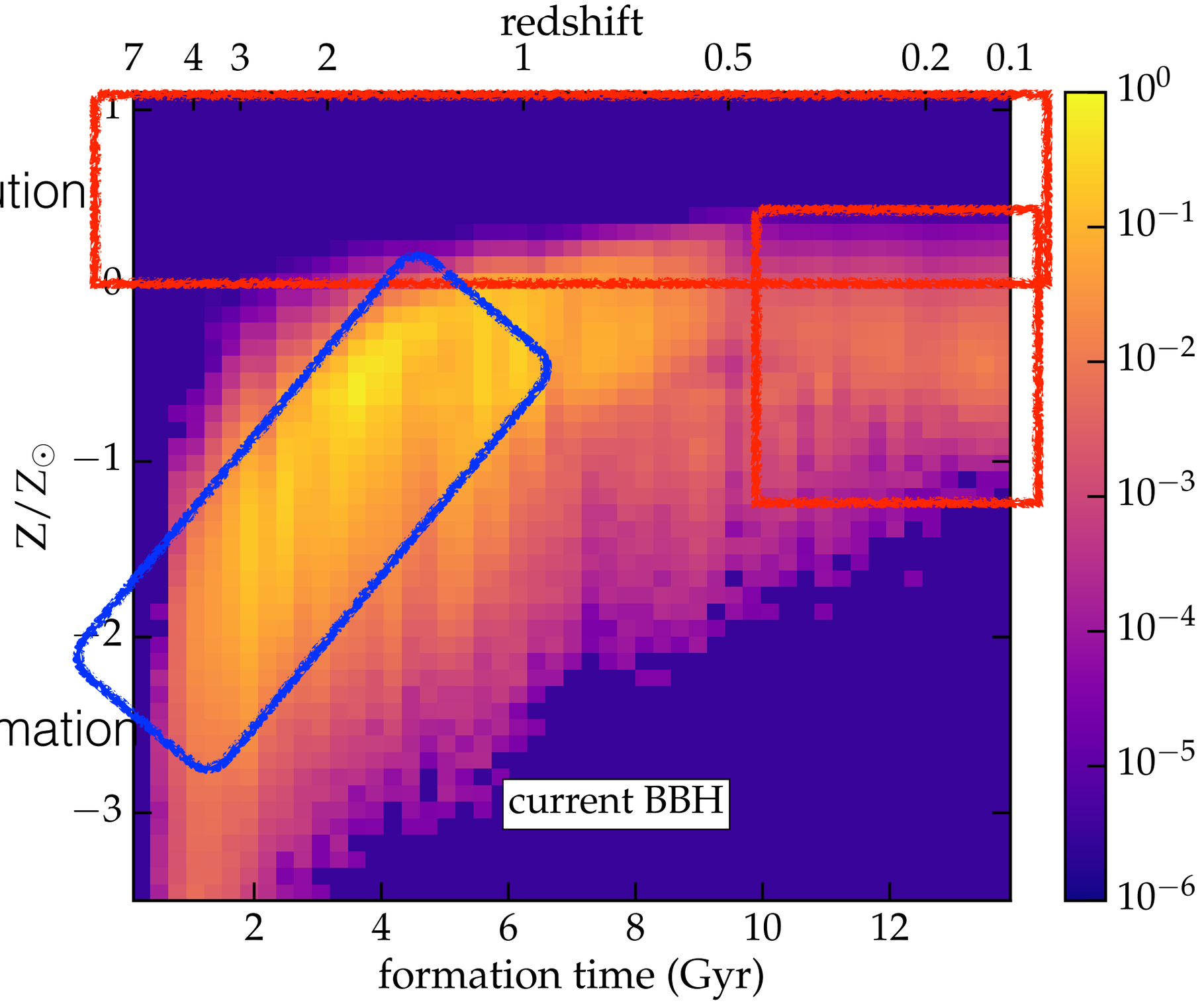
Keep track of binary compact objects



Final evolution through GW emission

WHICH STARS FORM BINARY BLACK HOLES?

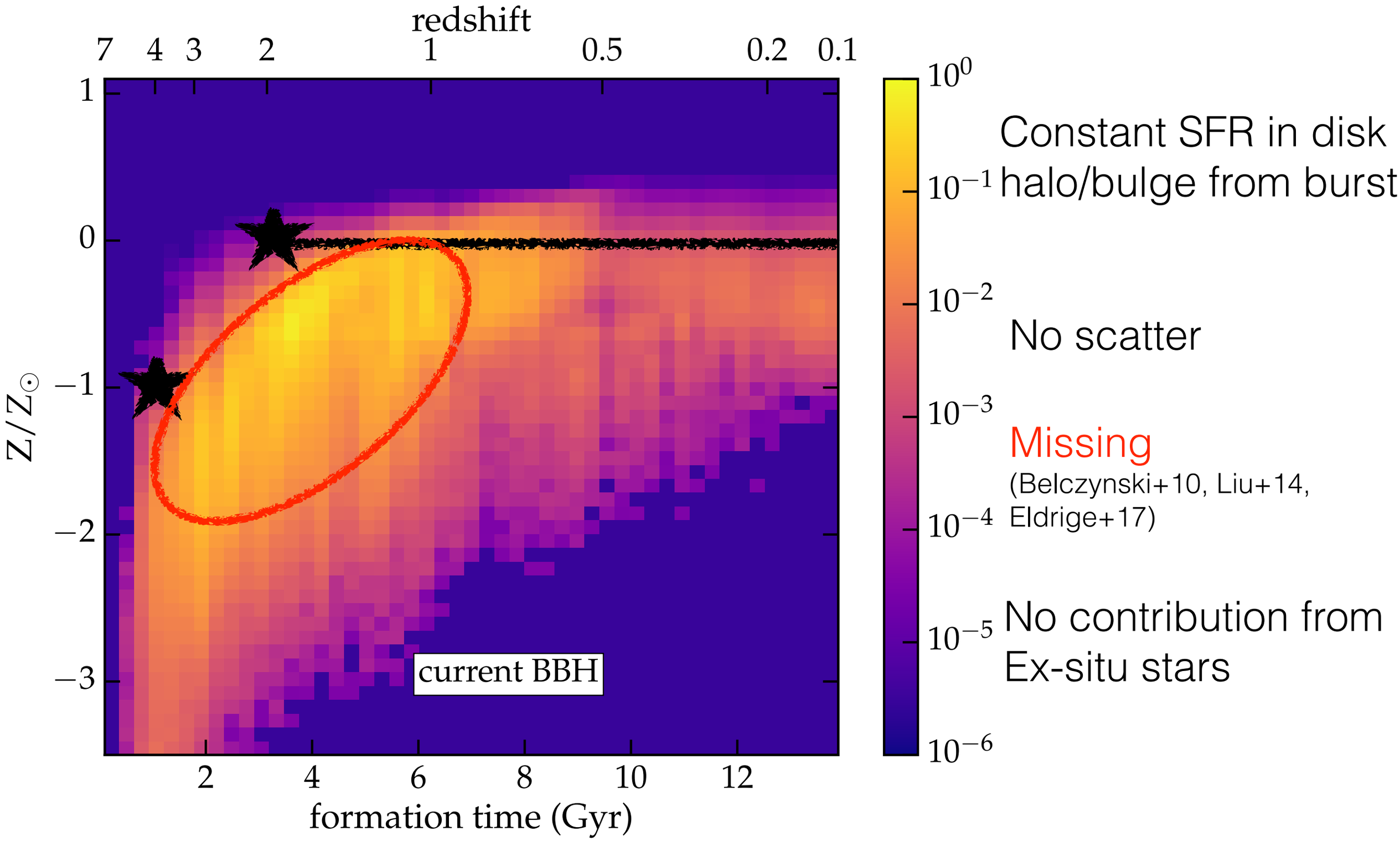
No contribution



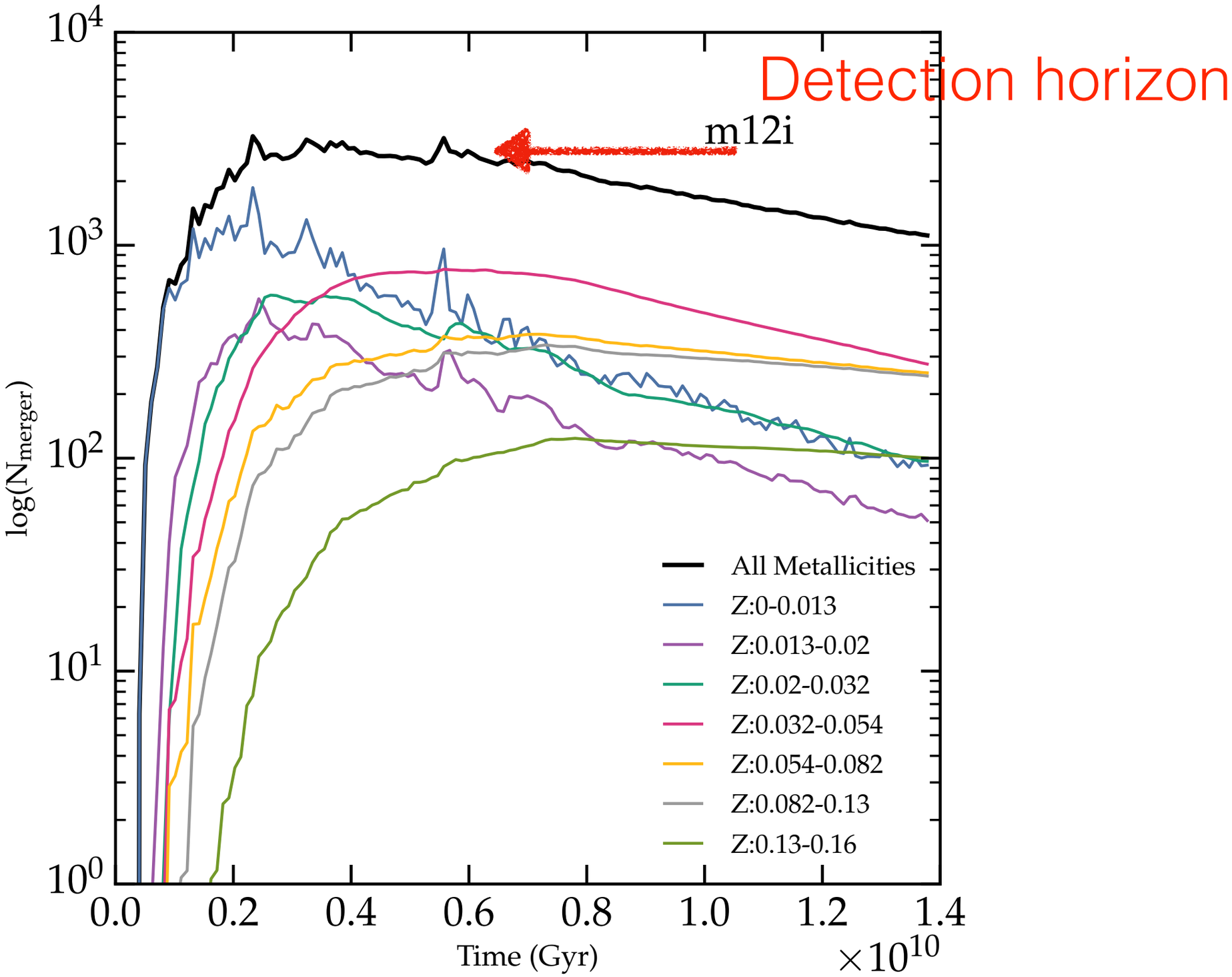
Old star formation

Confirms Lamberts+16

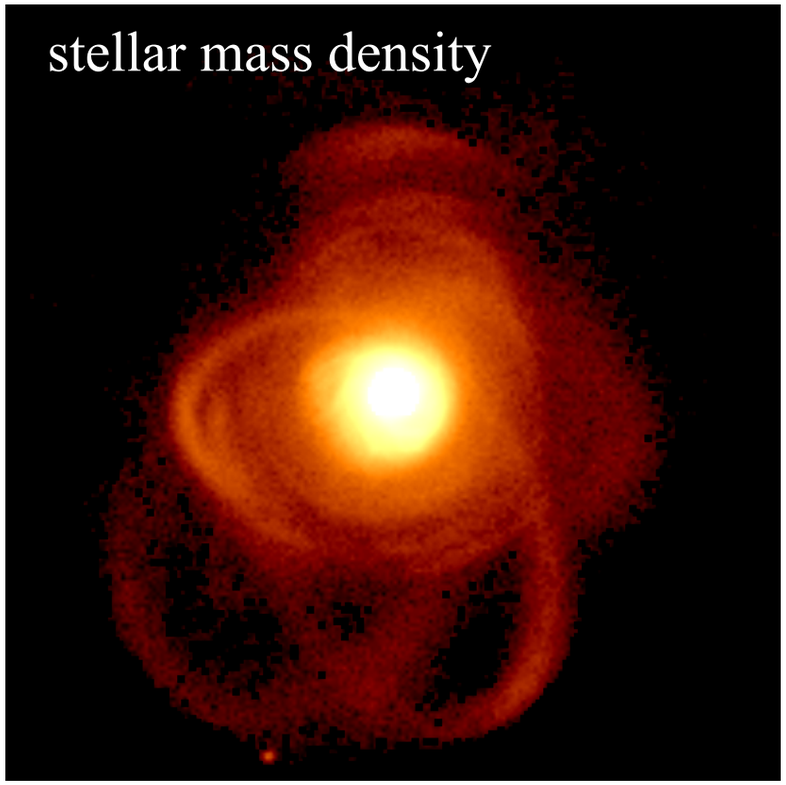
CORRECT STAR FORMATION MATTERS

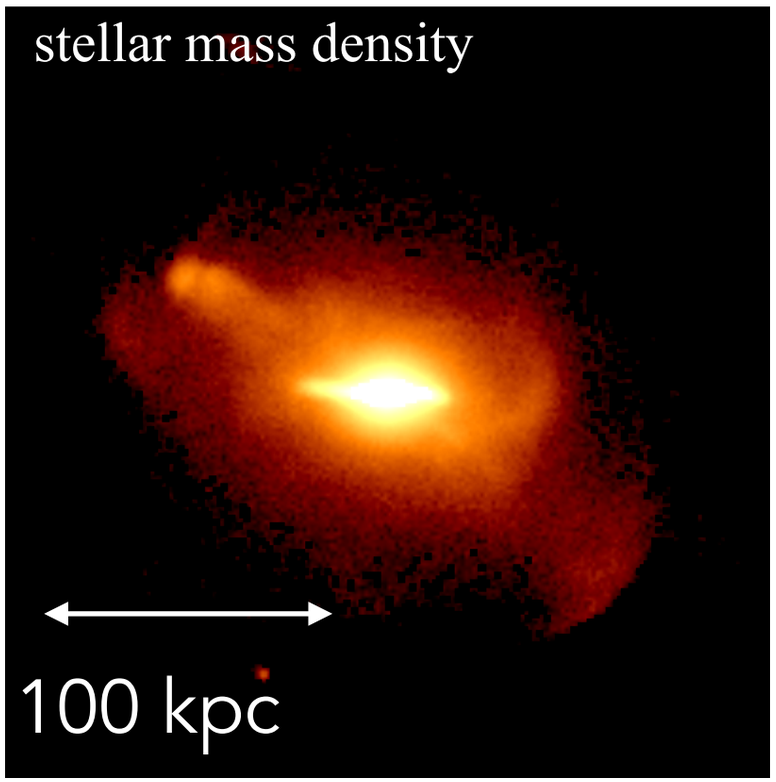


MERGERS VS METALLICITY

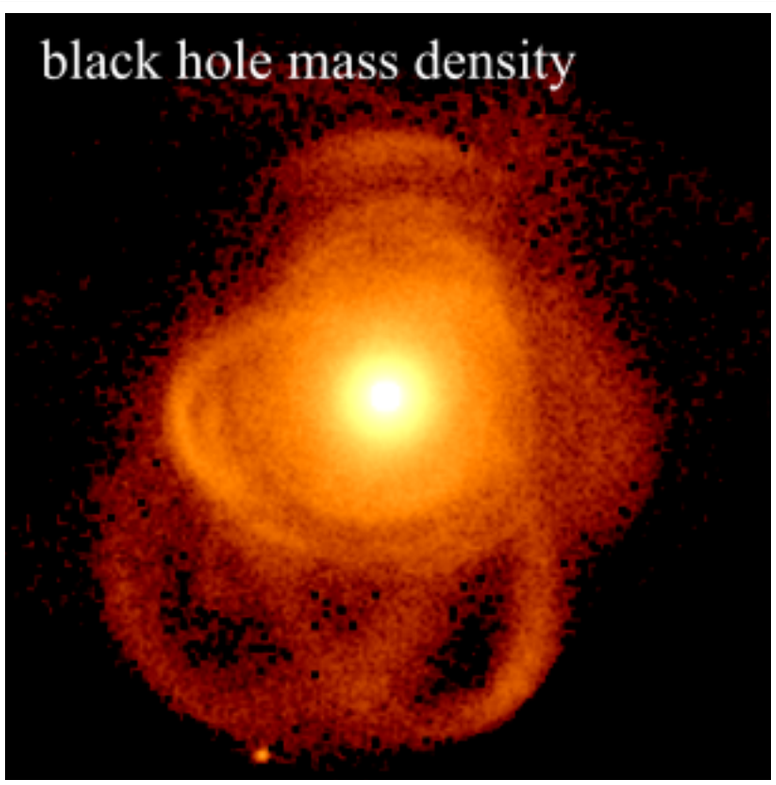


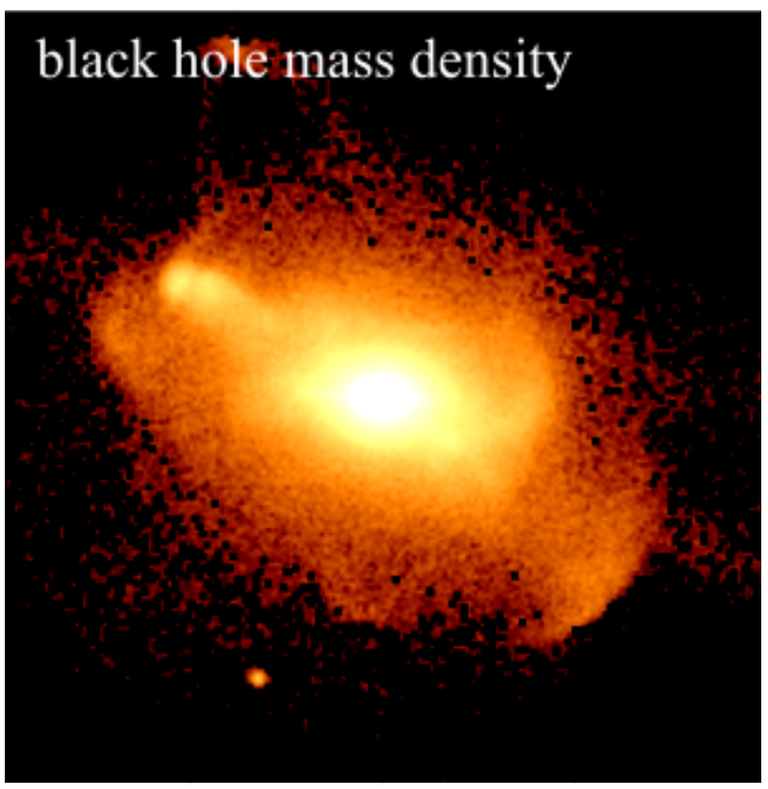
IMPACT OF COMPLEX STAR FORMATION





$>10^{10}$ stars

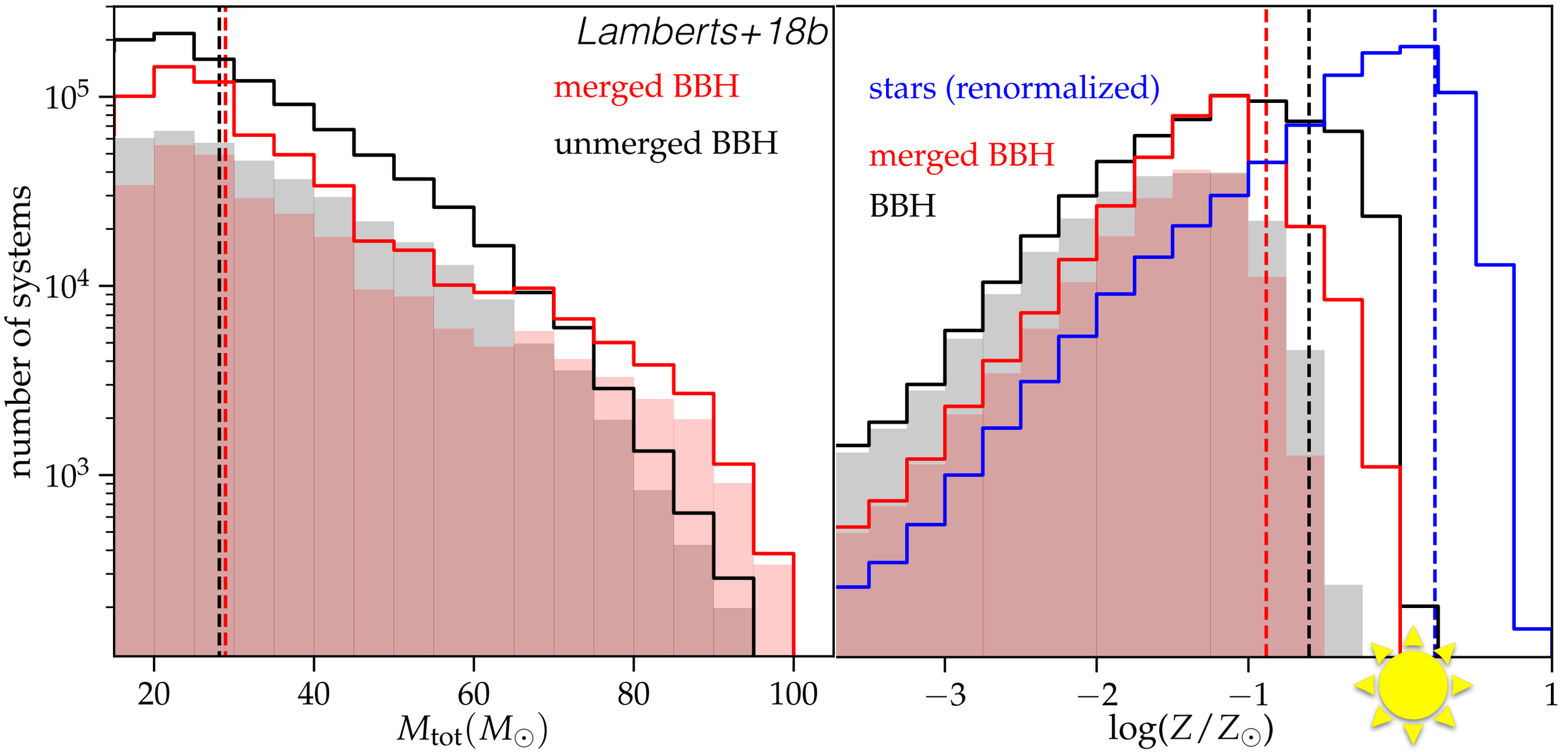




1 million
black holes

Outer galaxy :
Stellar halo and
satellites

A MILLION BINARY BLACK HOLES IN THE MILKY WAY



Masses compatible with LIGO/Virgo

Mean metallicity 15-30% of Sun

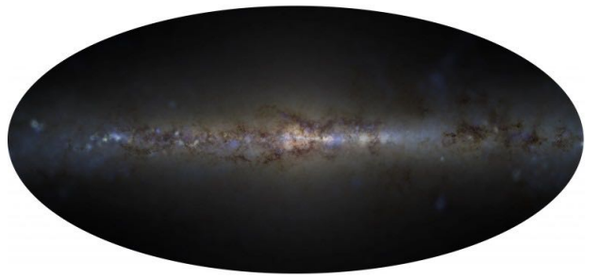
1/3 of black holes were Formed outside Milky Way
-> dwarf galaxies matter
-> needs high resolution

STELLAR BINARIES WITH GRAVITATIONAL WAVES

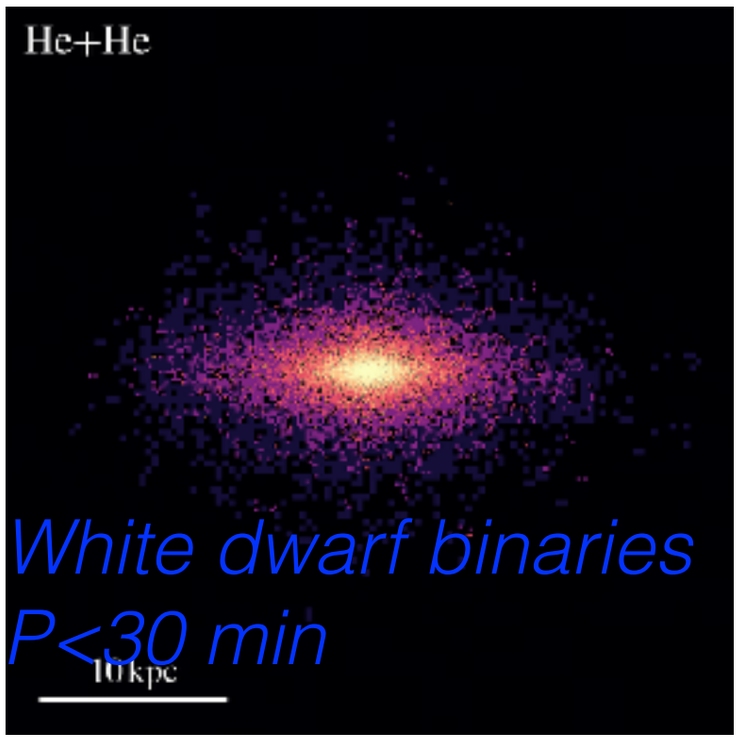
Now: Virgo/LIGO O3

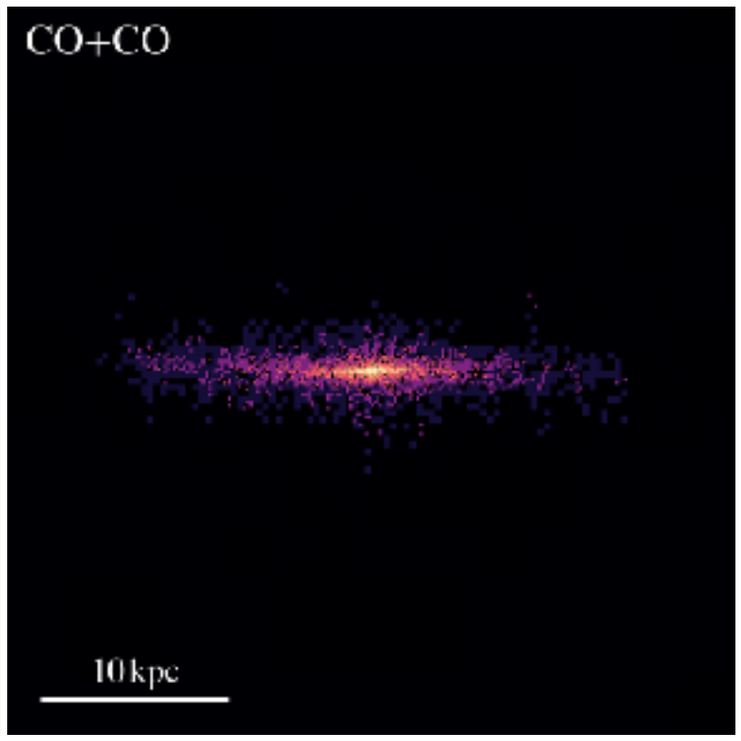
~25 binary black holes: statistics soon!
Importance of star formation models

Origin of mergers? Binaries or clusters?
Constraints on binary evolution



Cluster Mergers





White dwarf binaries
P<30 min

Similar method for other transients
CVs, XRB in the MW
Extragalactic sources

Lamberts+, accepted