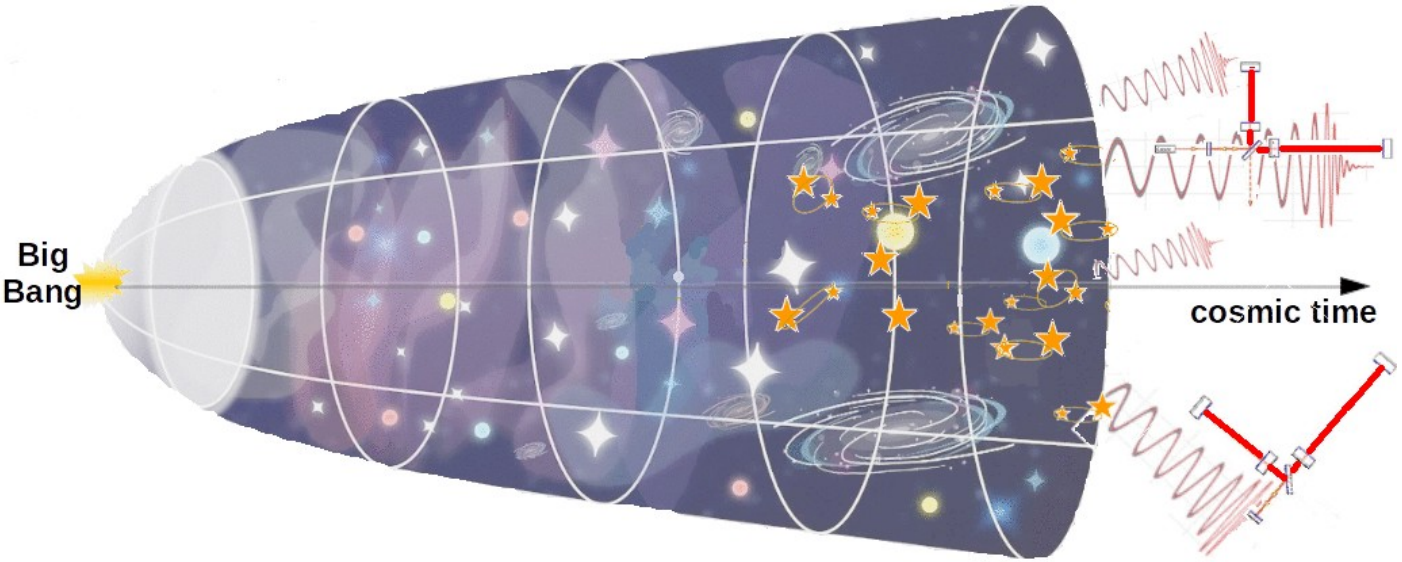
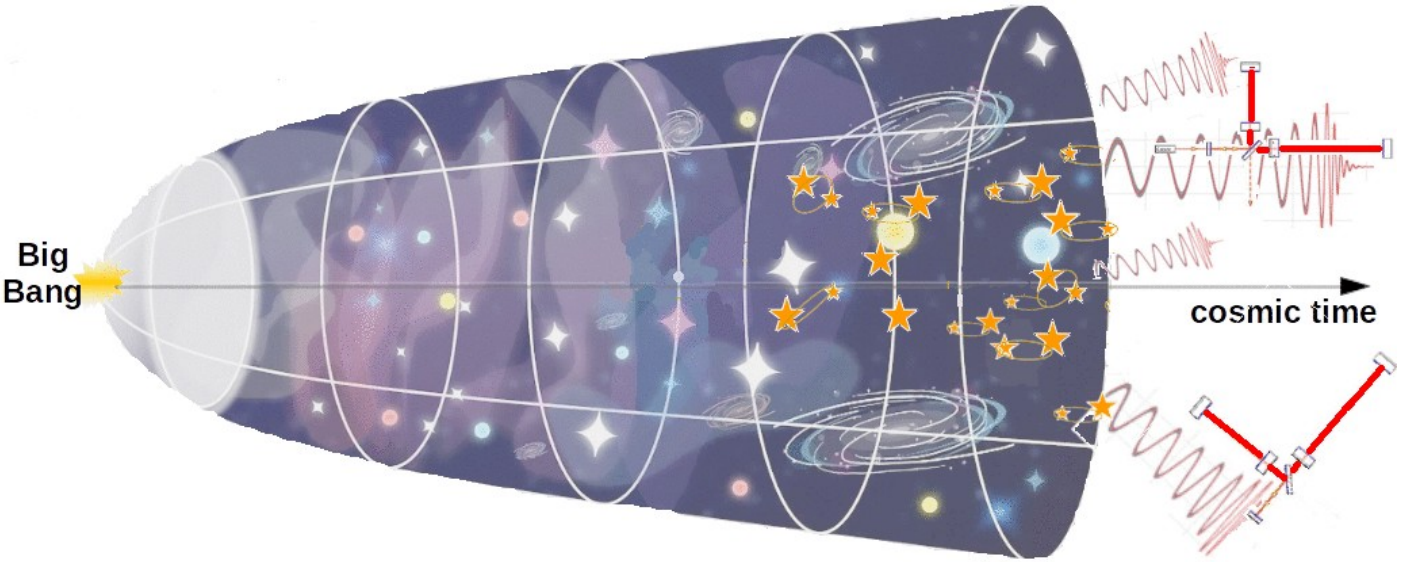
Chemical evolution of the Universe & the properties of merging double compact objects



Martyna Chruślińska
(read: Hroo-shlin-ska)
m.chruslinska@astro.ru.nl
Radboud University, Nijmegen NL

Chemical evolution of the Universe

GW obs. & the properties of merging double compact objects



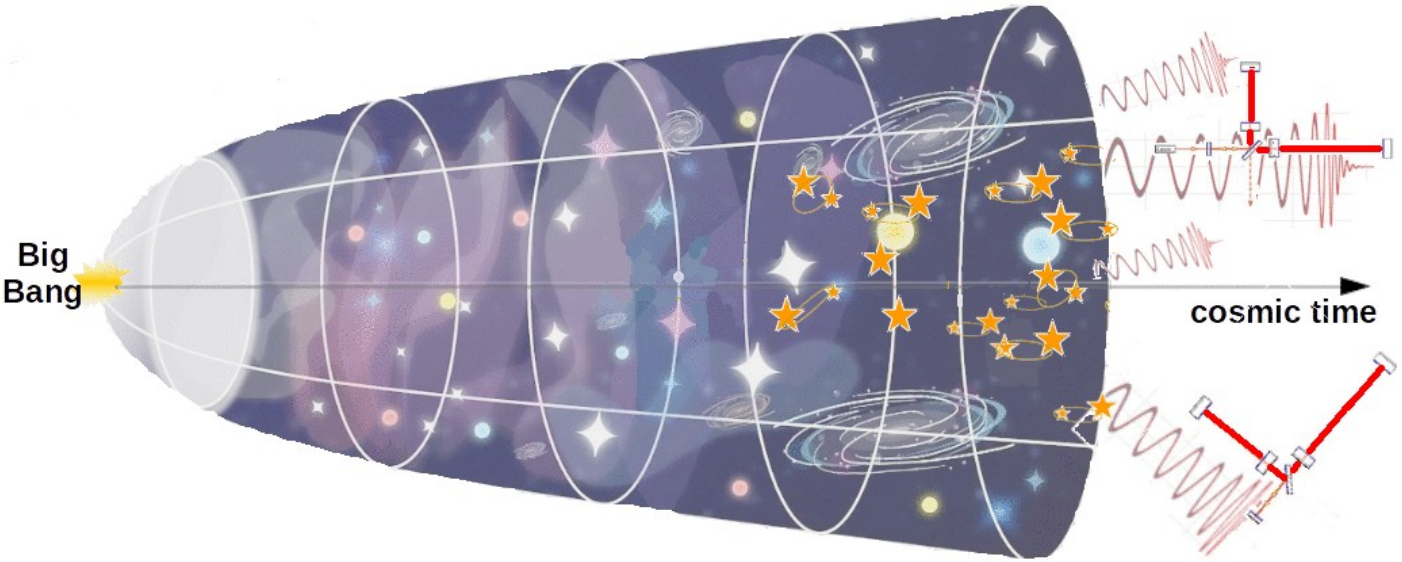
Martyna Chruślińska

(read: Hroo-shlin-ska)

m.chruslinska@astro.ru.nl

Radboud University, Nijmegen NL

GW obs. (& Chemical evolution of the Universe & the properties of merging double compact objects



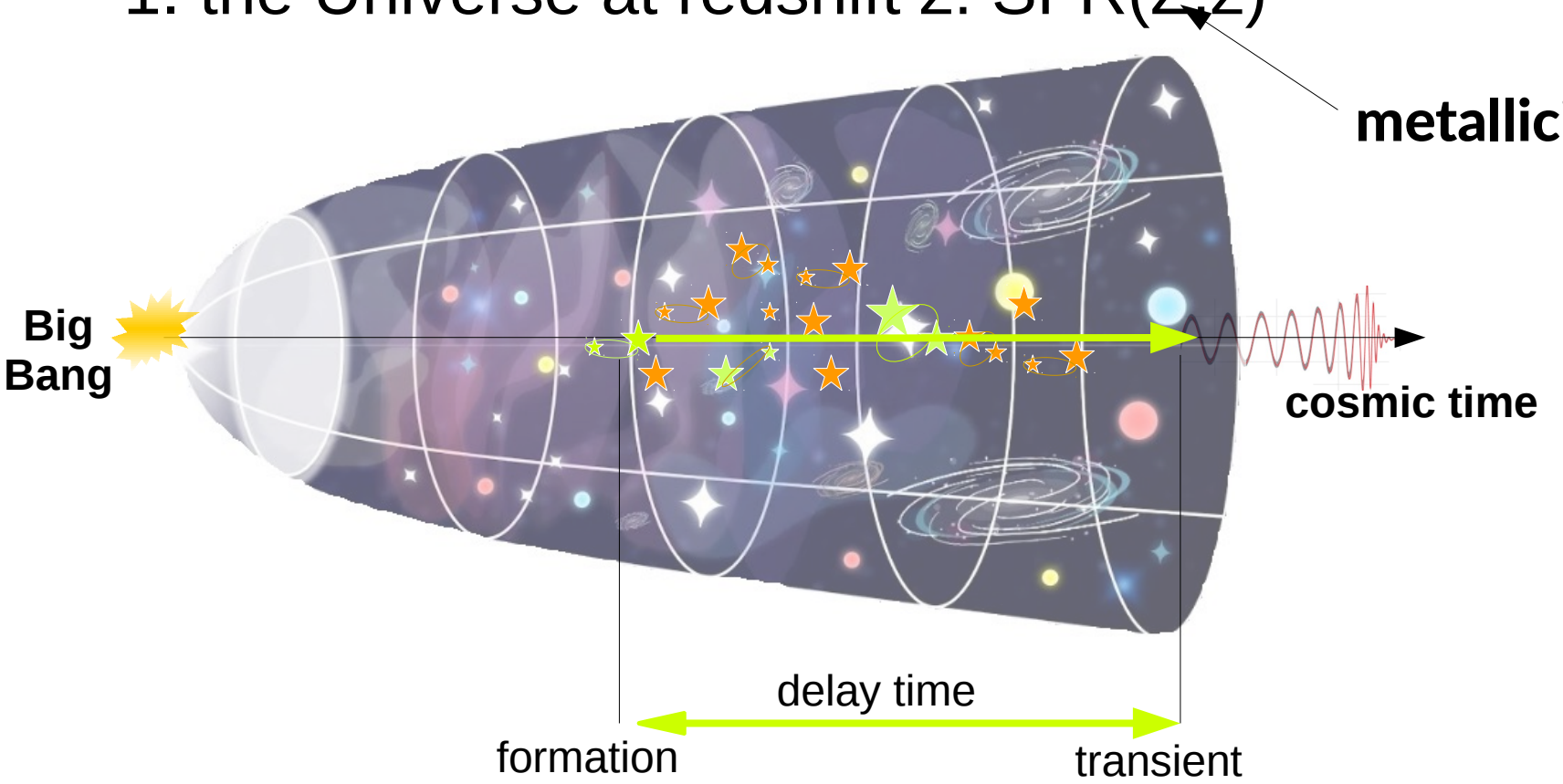
Martyna Chruślińska
(read: Hroo-shlin-ska)
m.chruslinska@astro.ru.nl
Radboud University, Nijmegen NL

Estimating the properties of merging DCOs

1. the Universe at redshift z: SFR(Z,z)
2. Initial parameters (M_1,f_{bin},q,a,e) & Z
3. Evolution

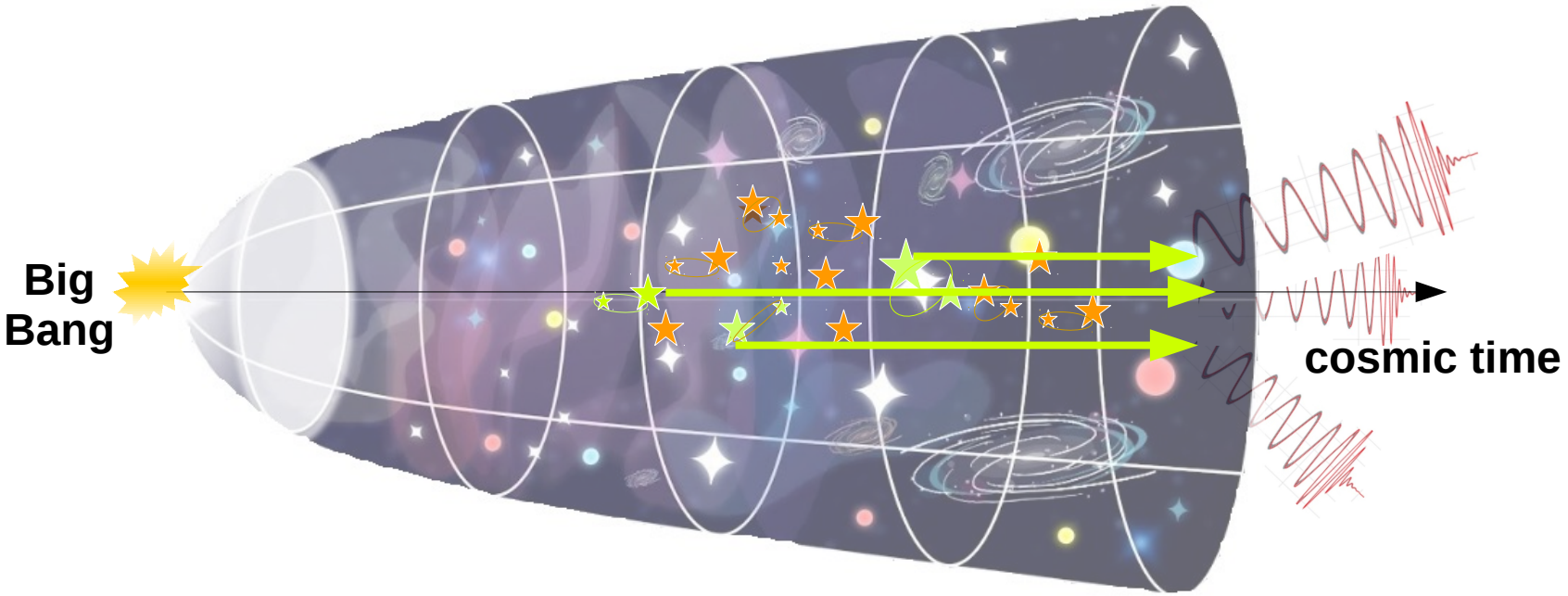
Estimating the properties of merging DCOs

1. the Universe at redshift z: SFR(Z,z)



Estimating the properties of merging DCOs

1. the Universe at redshift z: SFR(Z,z)

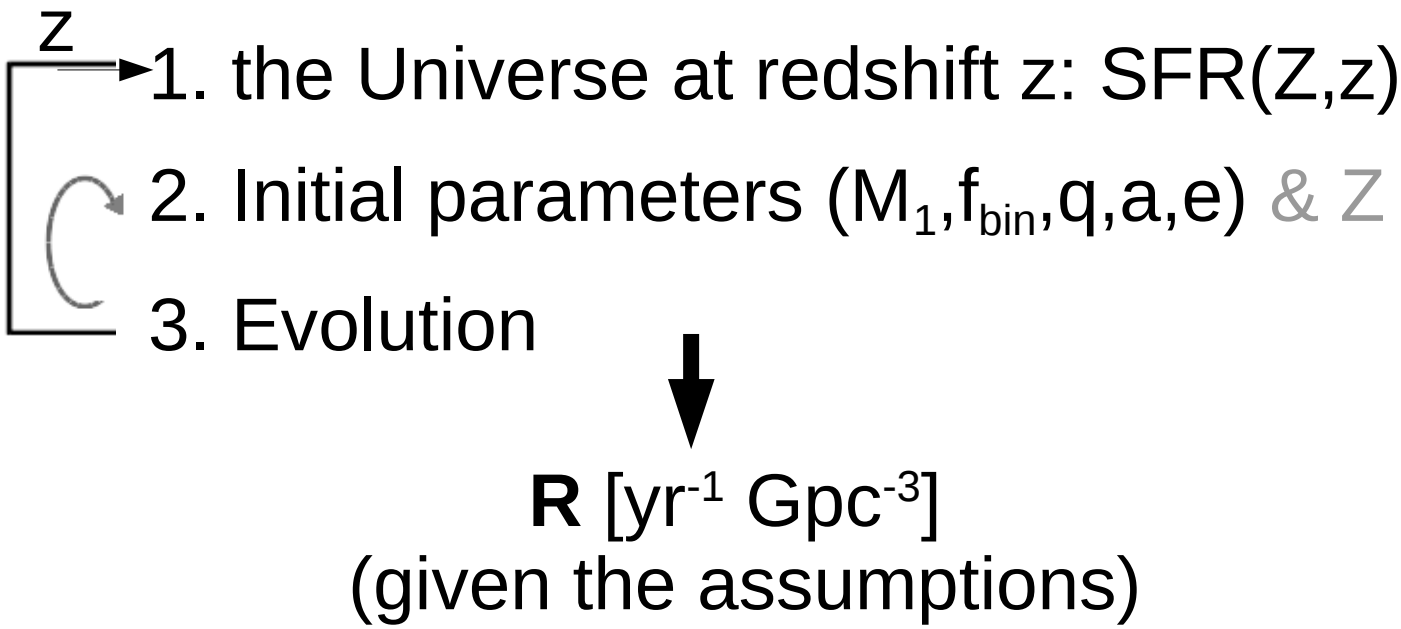


'how many stars & at what metallicities'?

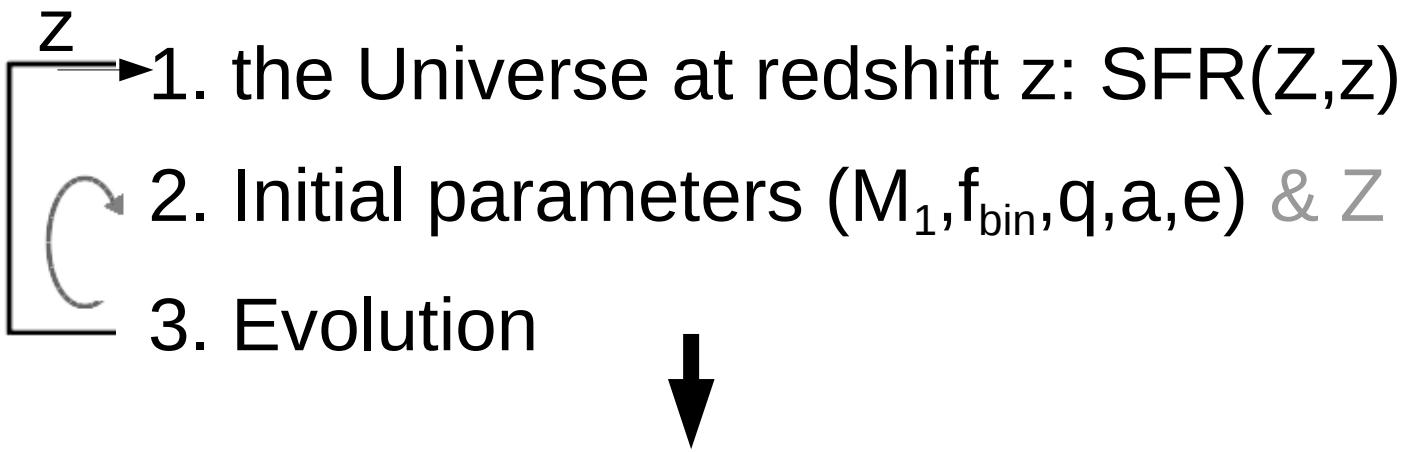
Estimating the properties of merging DCOs

1. the Universe at redshift z: SFR(Z,z)
2. Initial parameters (M_1,f_{bin},q,a,e) & Z
3. Evolution

Estimating the properties of merging DCOs



Estimating the properties of merging DCOs

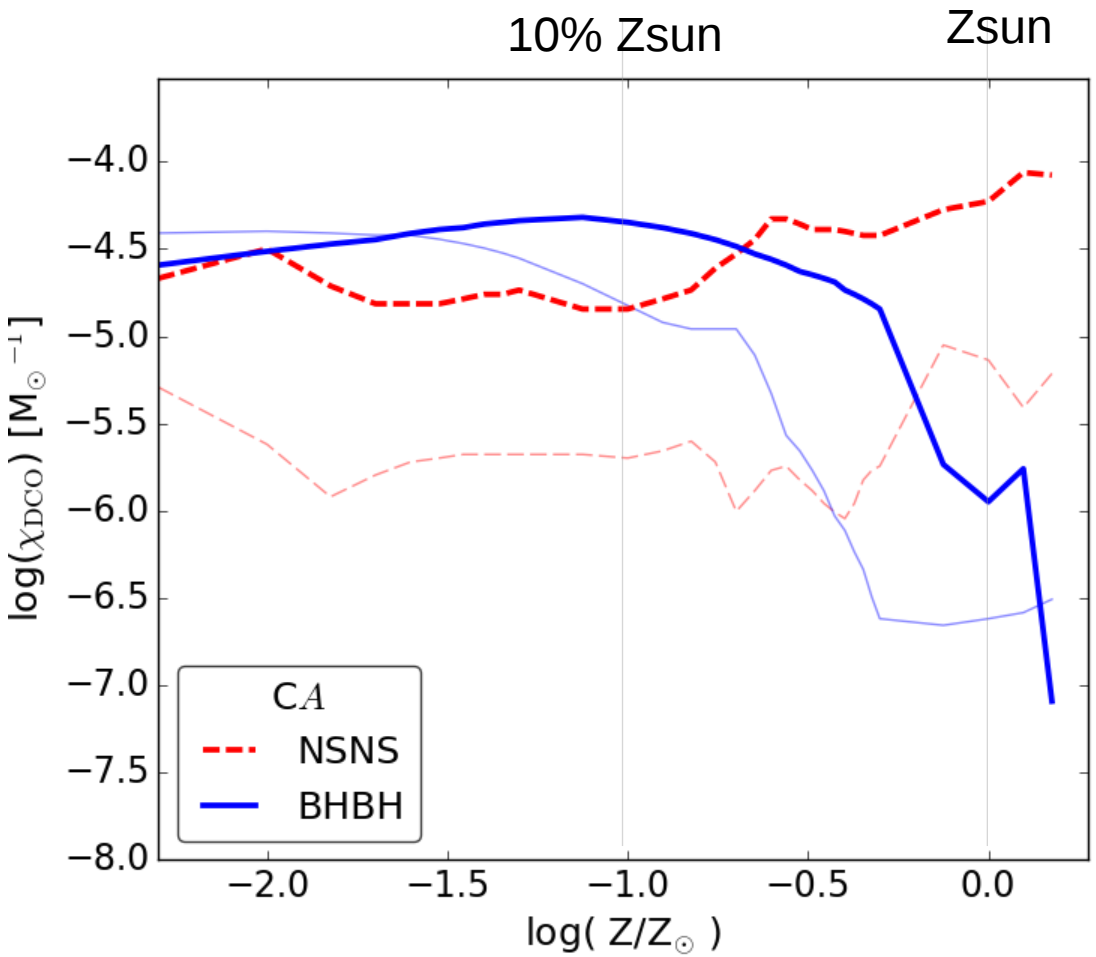


→ a factor of **~2** depending on "**step 2**" (de Mink & Belczynski15, Klencki+18)

→ even **> order of magnitude** depending on "**step 3**"
(e.g. Tutukov&Yungelson93, Voss&Tauris03, Dominik+12, Mennekens&Vanbeveren14, Chruslinska+18, Kruckow+18, Mapelli & Giacobbo18, Eldridge+18, Barrett+18 …)

→ "**step 1**"? Chruslinska, Nelemans & Belczynski'19, Chruslinska & Nelemans'19, Neijssel+19

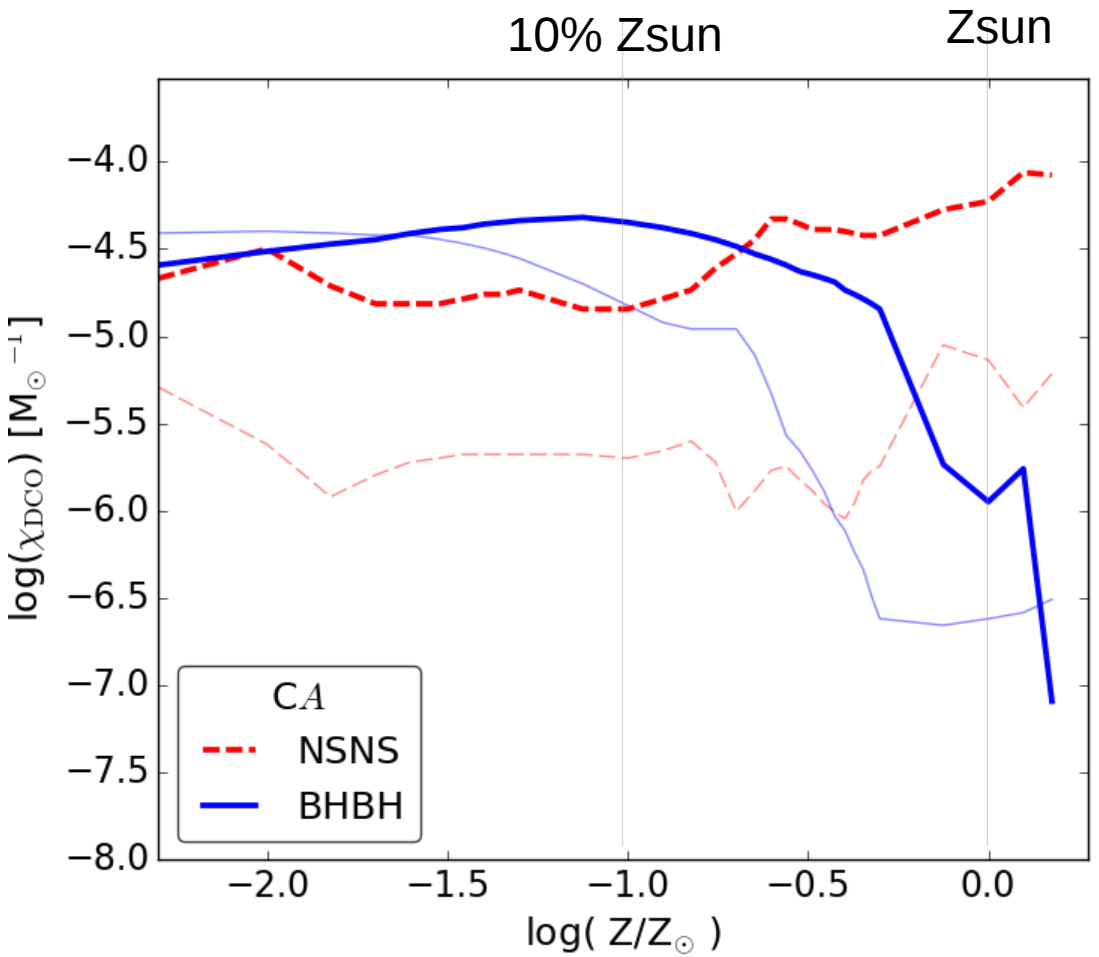
Number of merging binaries
per unit of formed stellar mass vs metallicity



← example population synthesis simulations result (exact shape model dependent!)

→ **Chruslinska M.**, Nelemans G. & Belczynski K. (2019)

Number of merging binaries *per unit of formed stellar mass* vs metallicity



← example population synthesis simulations result (model dependent!)

More SFR at low metallicities:
- more BH-BH mergers
- (a bit) less NS-NS

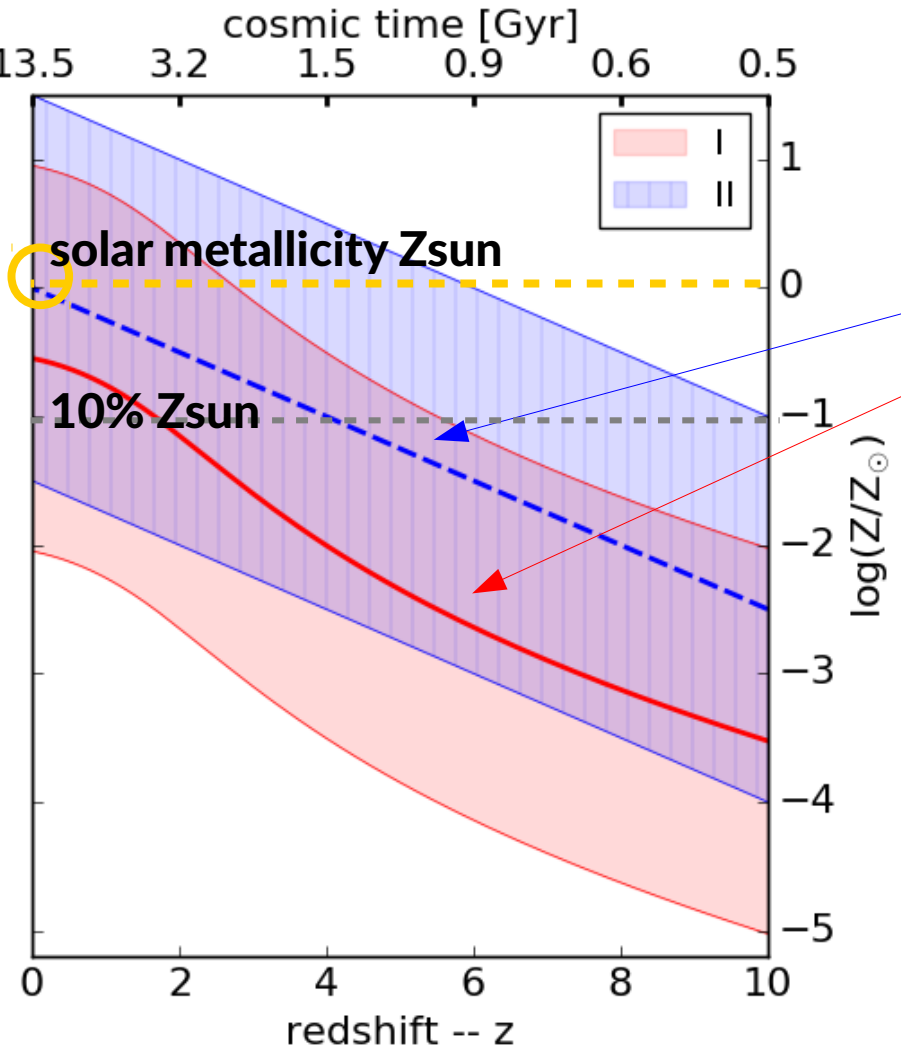
→ also affects e.g. BHBH mass distribution!

→ **Chruslinska M.**, Nelemans G. & Belczynski K. (2019)

SFRD(Z,z): different approaches...

"average metallicity of galaxies"

"average metallicity of the Universe + 0.5 dex"

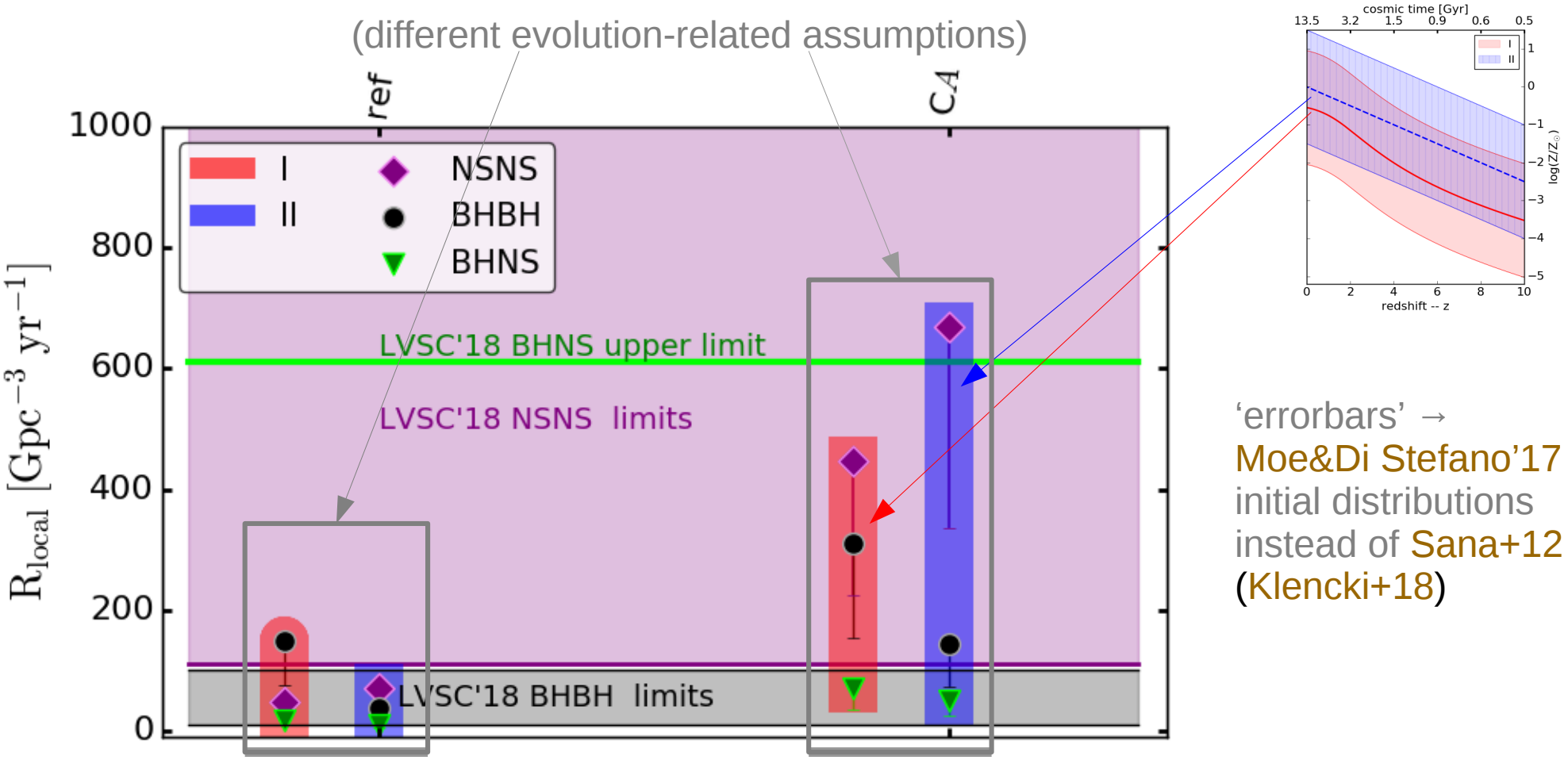


Mean metallicity evolution assumed by Dominik+13 and Belczynski+16

(shaded region – 3σ around the mean; σ=0.5 dex scatter in both cases)

→ **Chruslinska M.**, Nelemans G. & Belczynski K. (2019)

How important is it for the final result?

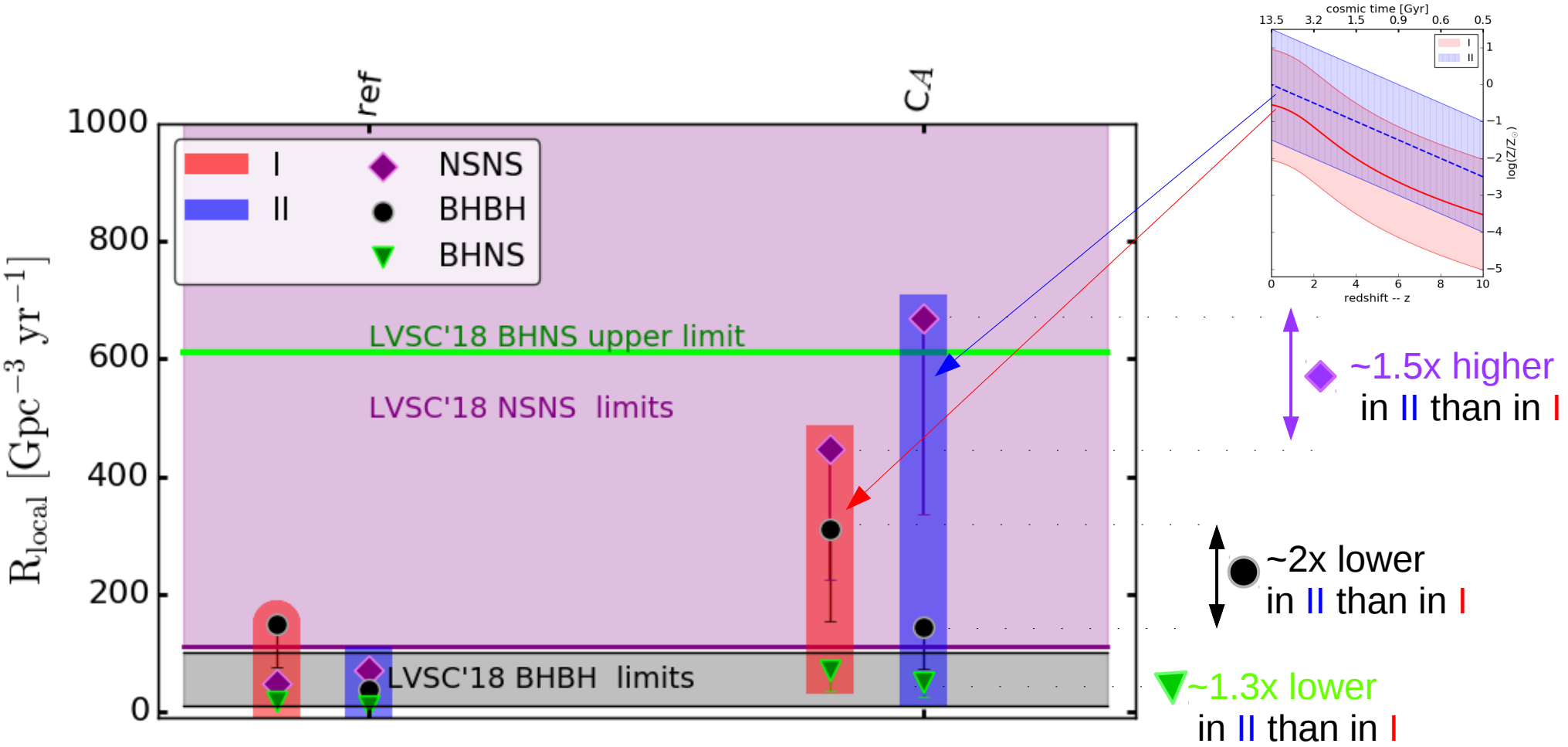


'errorbars' → Moe&Di Stefano'17 initial distributions instead of Sana+12 (Klencki+18)

The effect depends on the model (binary evolution)
→ ...no simple universal 'errorbar' to add

→ **Chruslinska M.**, Nelemans G. & Belczynski K. (2019)

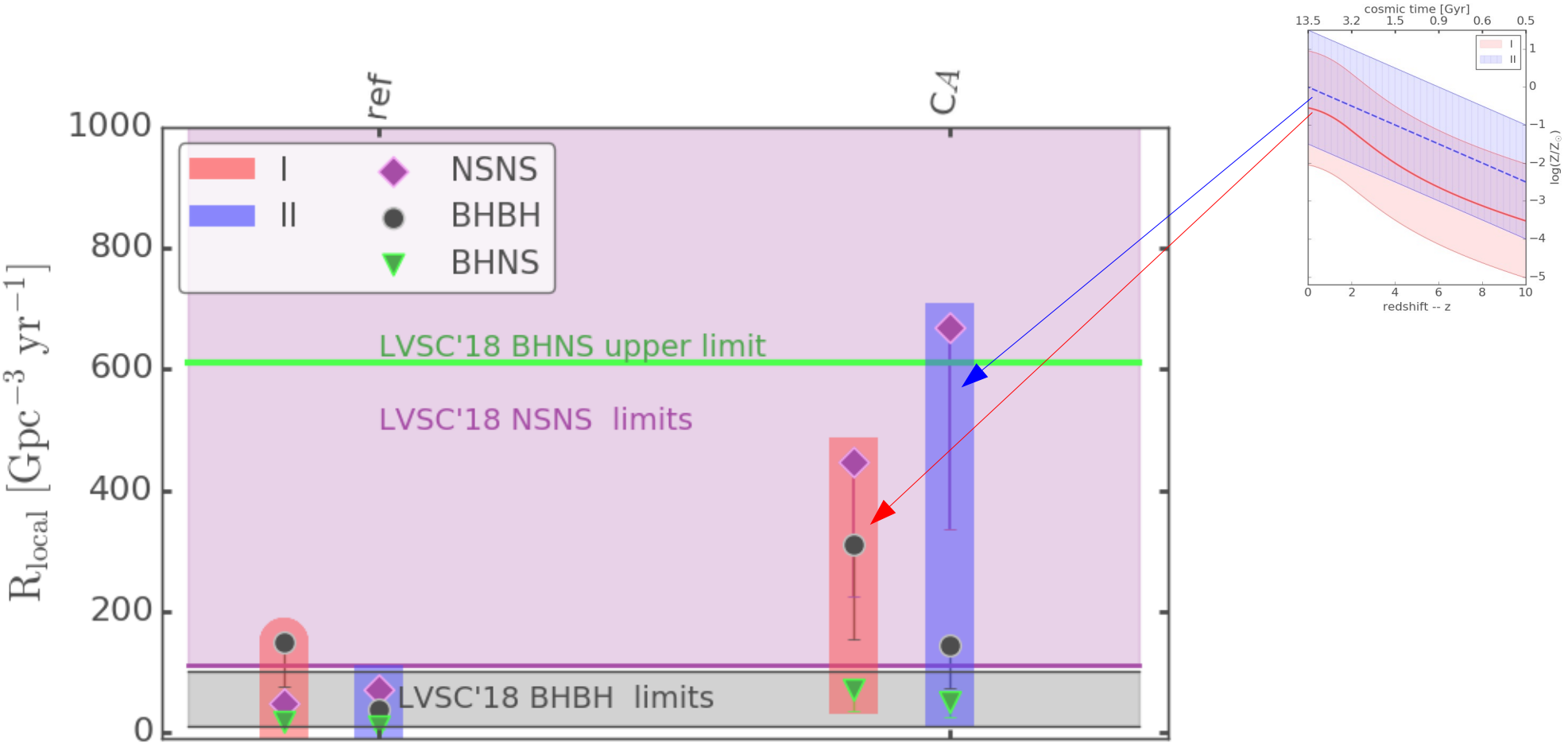
How important is it for the final result?



The effect depends on the binary type (BHBH/NSNS/BHNS)
→ affects the ratios of rates

→ **Chruslinska M.**, Nelemans G. & Belczynski K. (2019)

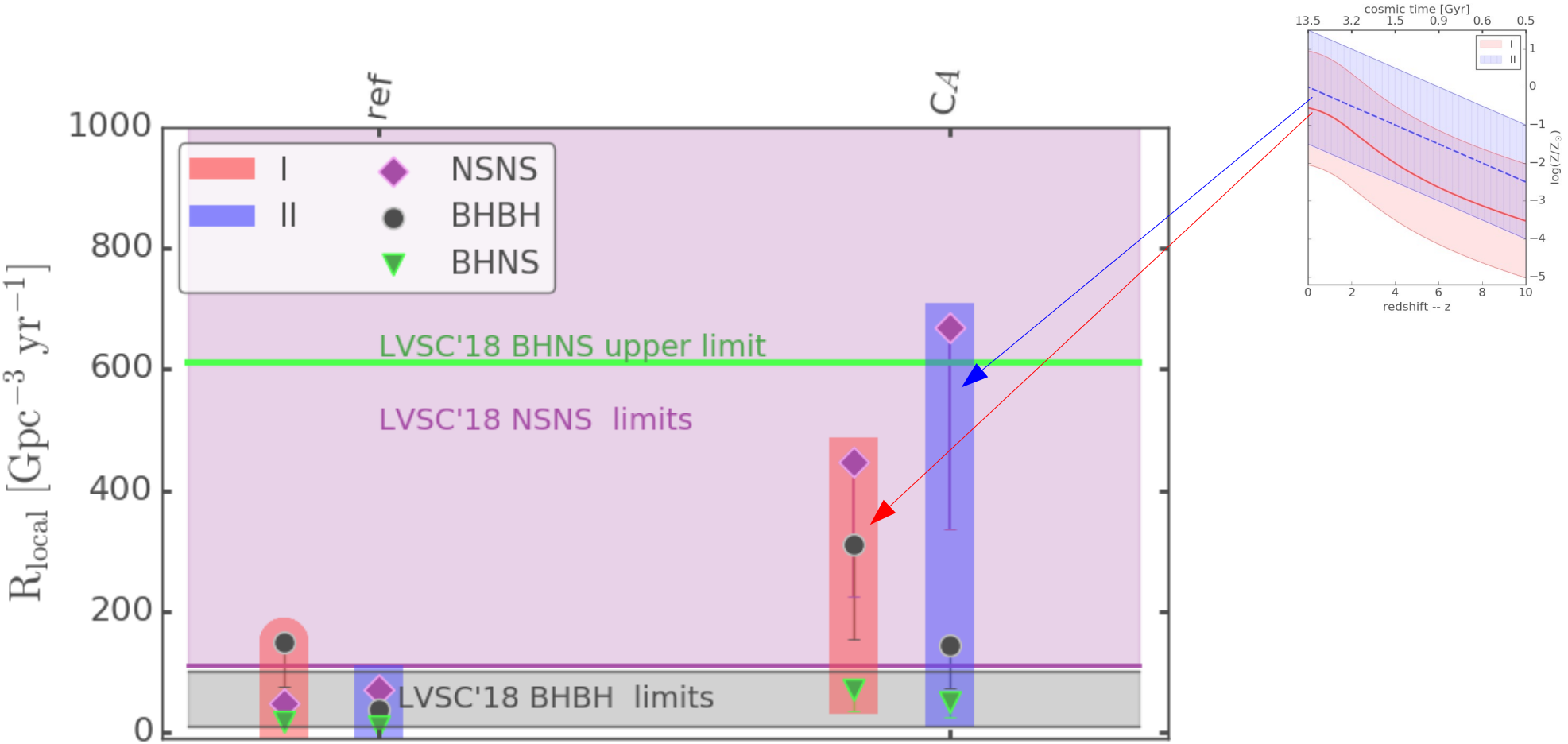
How important is it for the final result?



SFRD(Z,z) can affect the rate estimates by even ~*10!

→ **Chruslinska M.**, Nelemans G. & Belczynski K. (2019)
(→ recently Neijssel+19 reached similar conclusions)

How important is it for the final result?

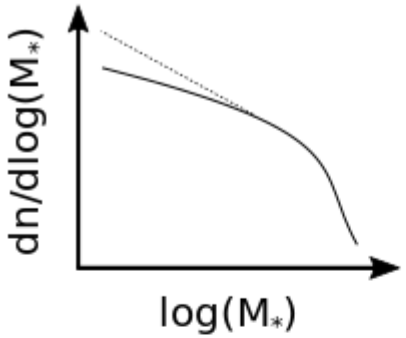


SFRD(Z,z) can affect the rate estimates by even ~*10!

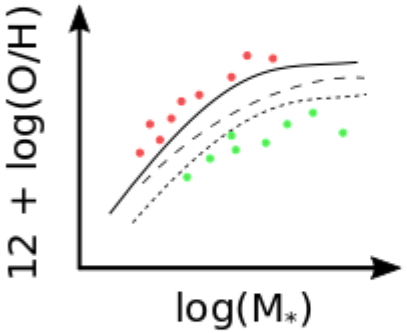
How uncertain is it?

Observation-based SFRD(Z,z)

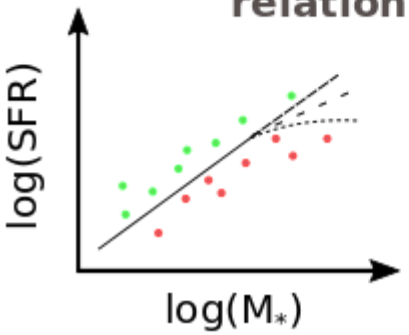
(active) galaxy mass function



mass-metallicity relation

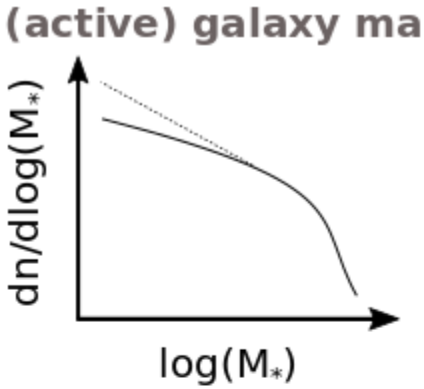


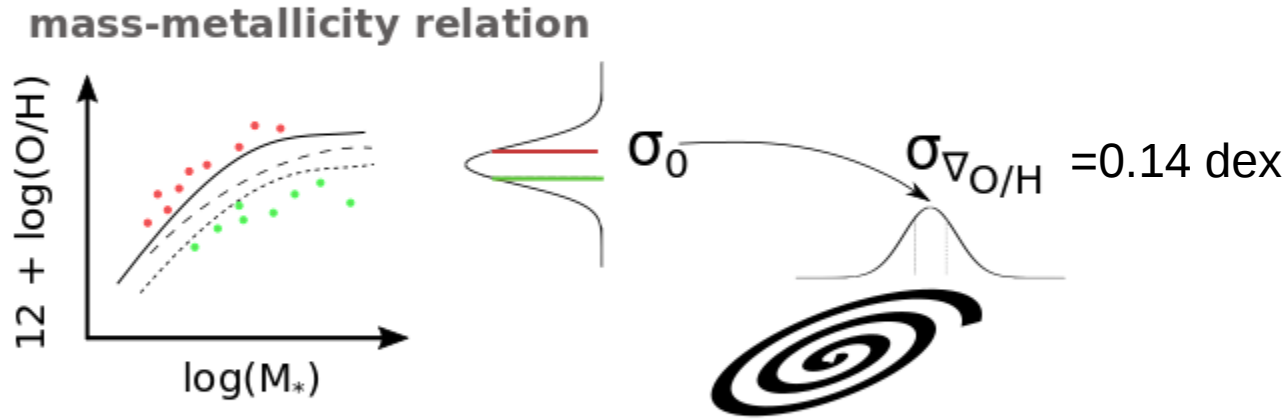
star formation - mass relation

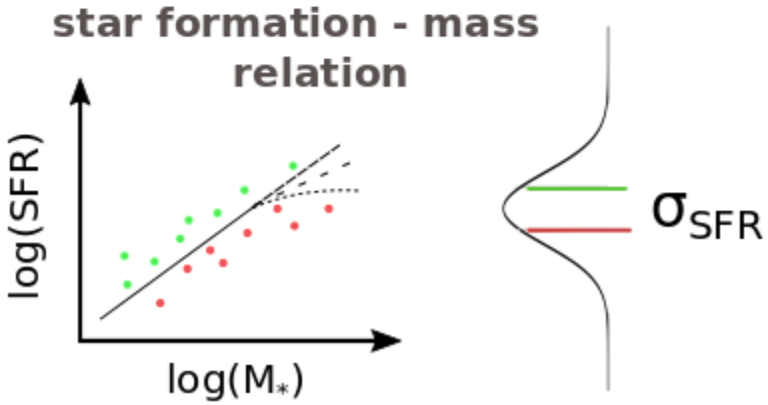


→ Chruslinska M. & Nelemans G (2019)

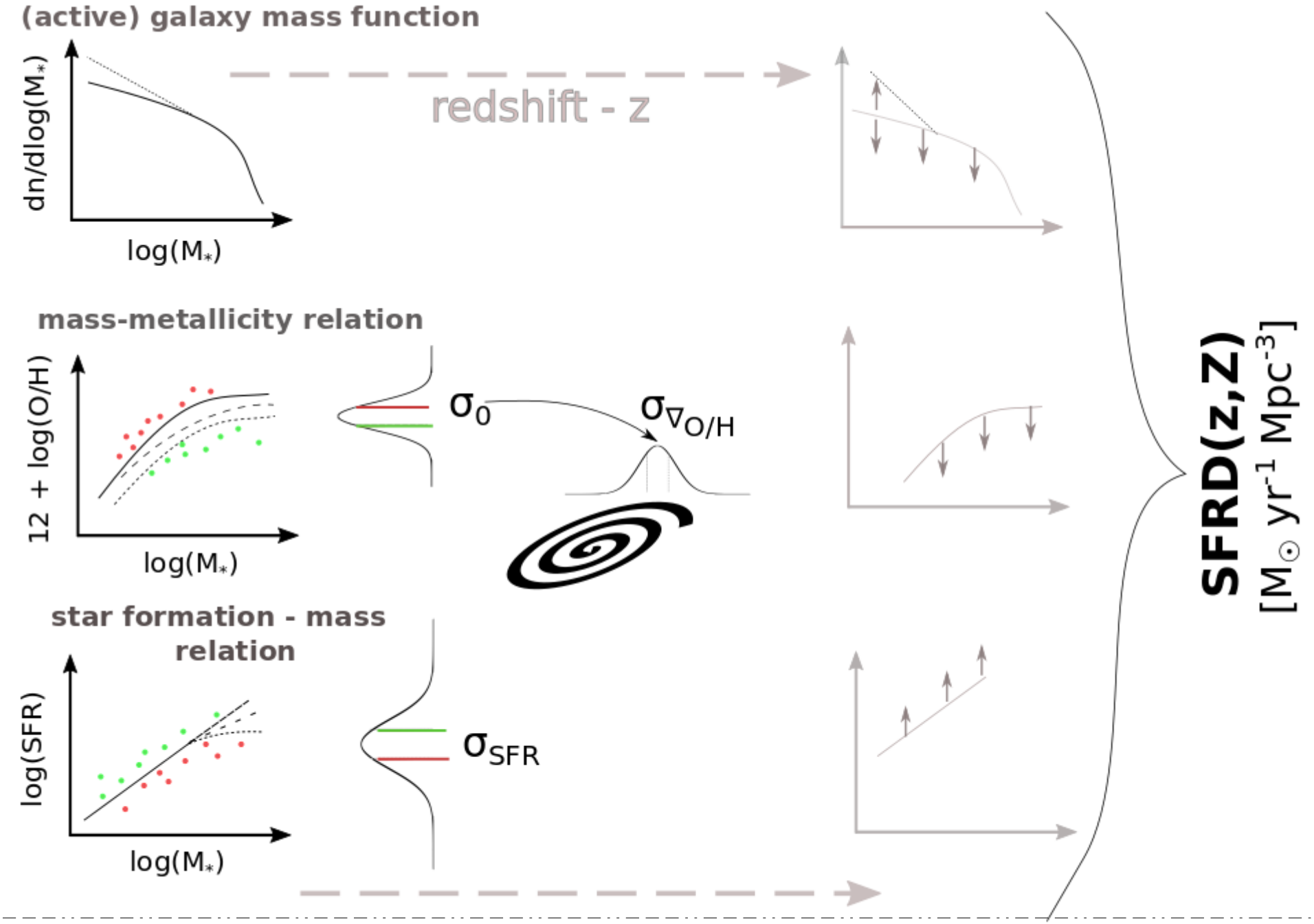
Method: scaling relations

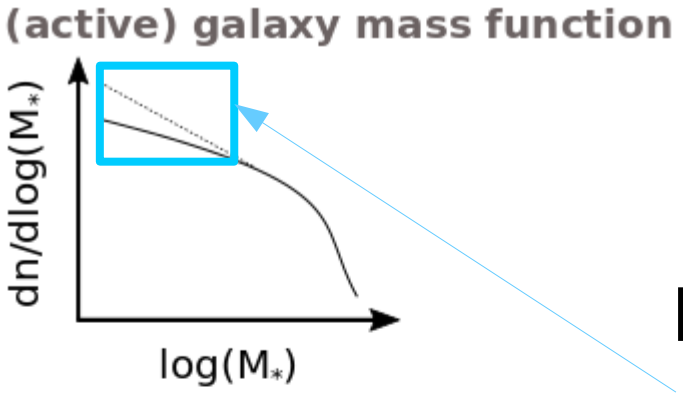


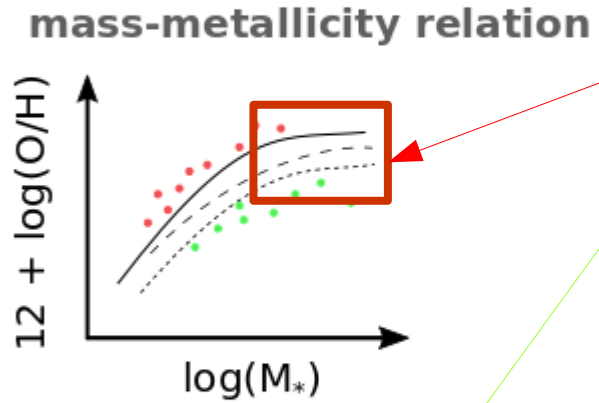


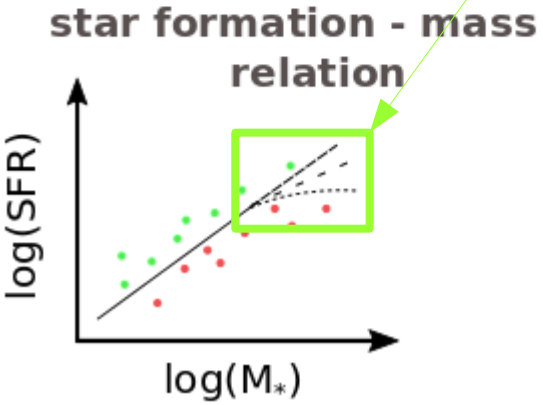


Method: scaling relations









Main sources of uncertainty:
-low mass end of the GSMF
-**MZR: normalization** & shape
-SFMR: flattening (?) at high masses

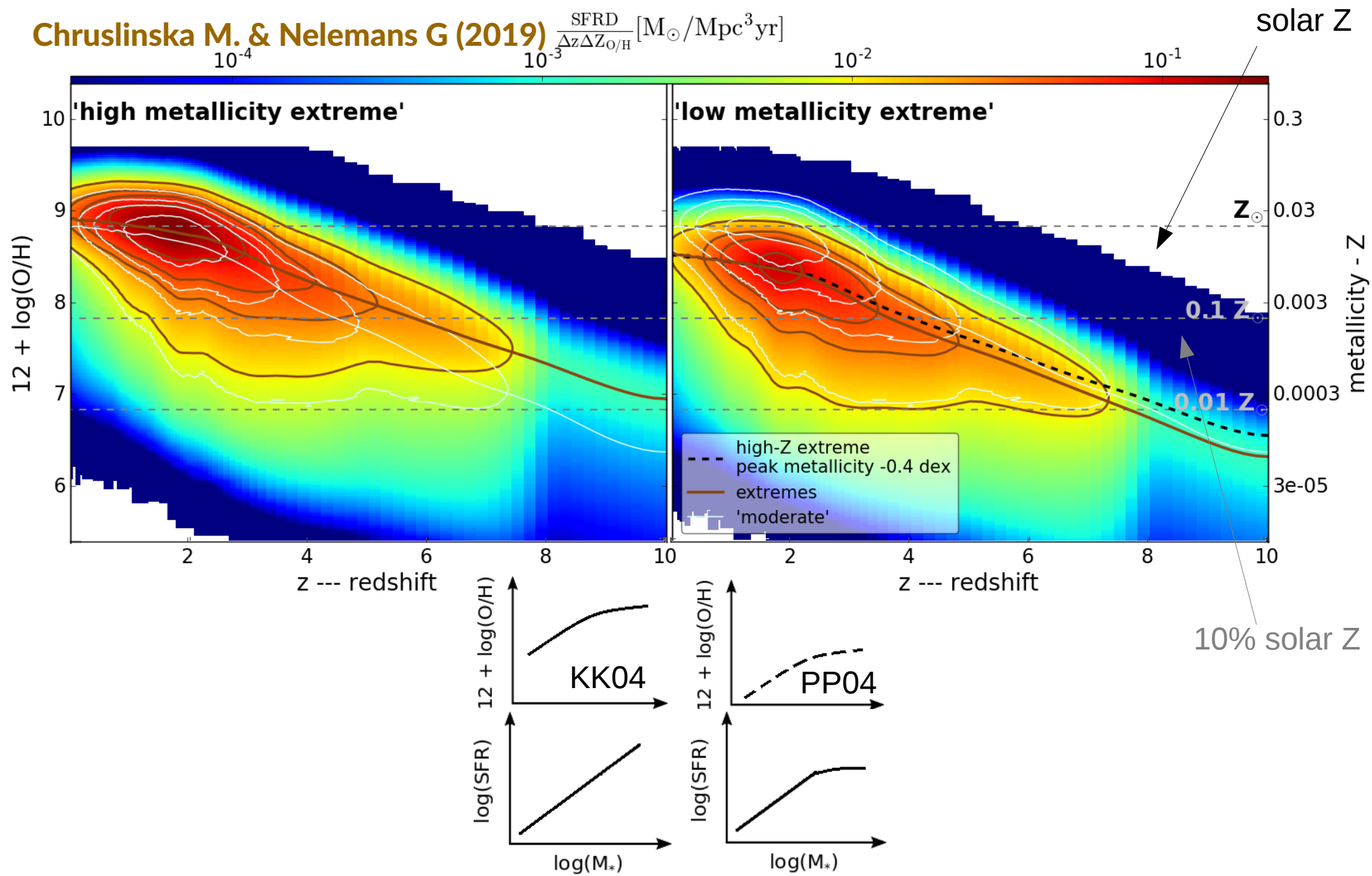
→ MZR unconstrained beyond z>3.5

→ IMF...

→ Chruslinska M. & Nelemans G. (2019)

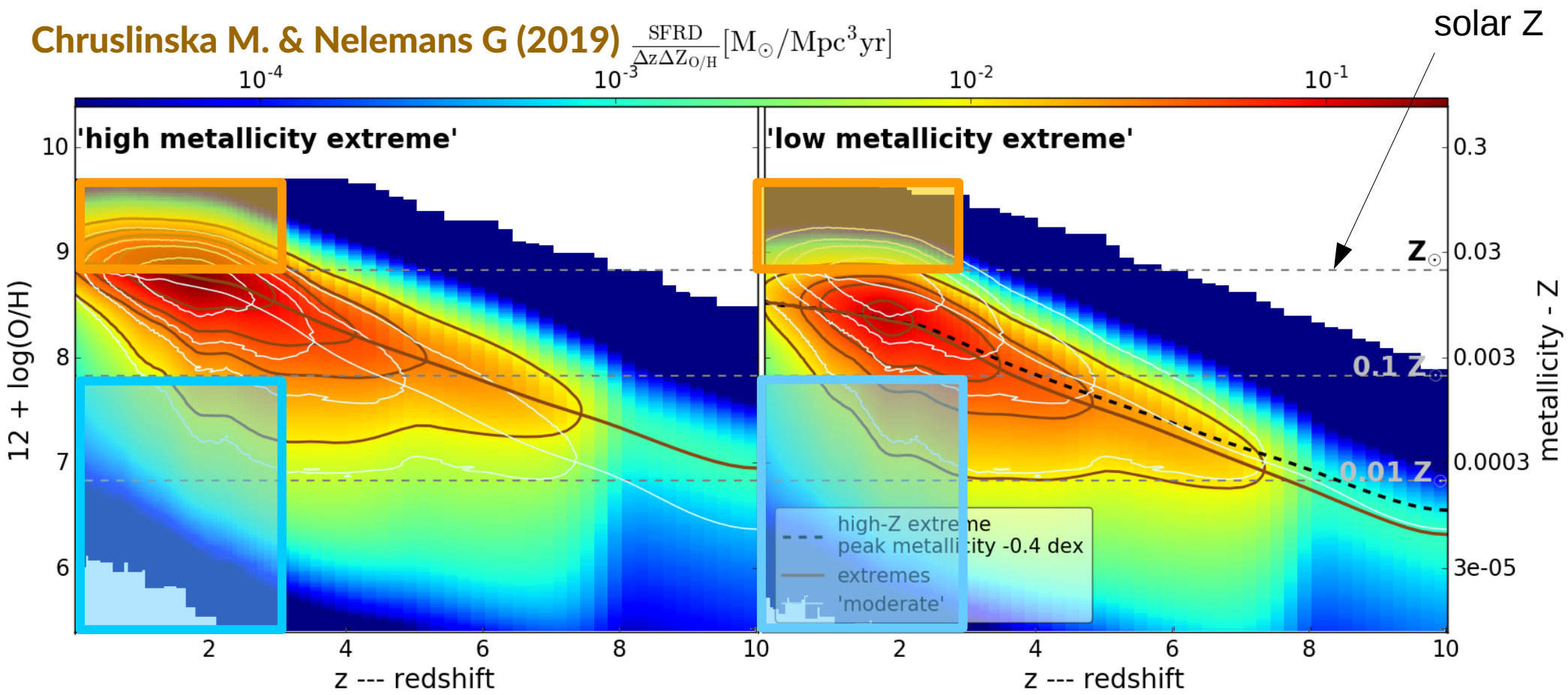
Results: the extremes

Chruslinska M. & Nelemans G (2019)



Results: the extremes

Chruslinska M. & Nelemans G (2019)



since z=3:

~9% of M_* at $Z<0.1\ Z_O$

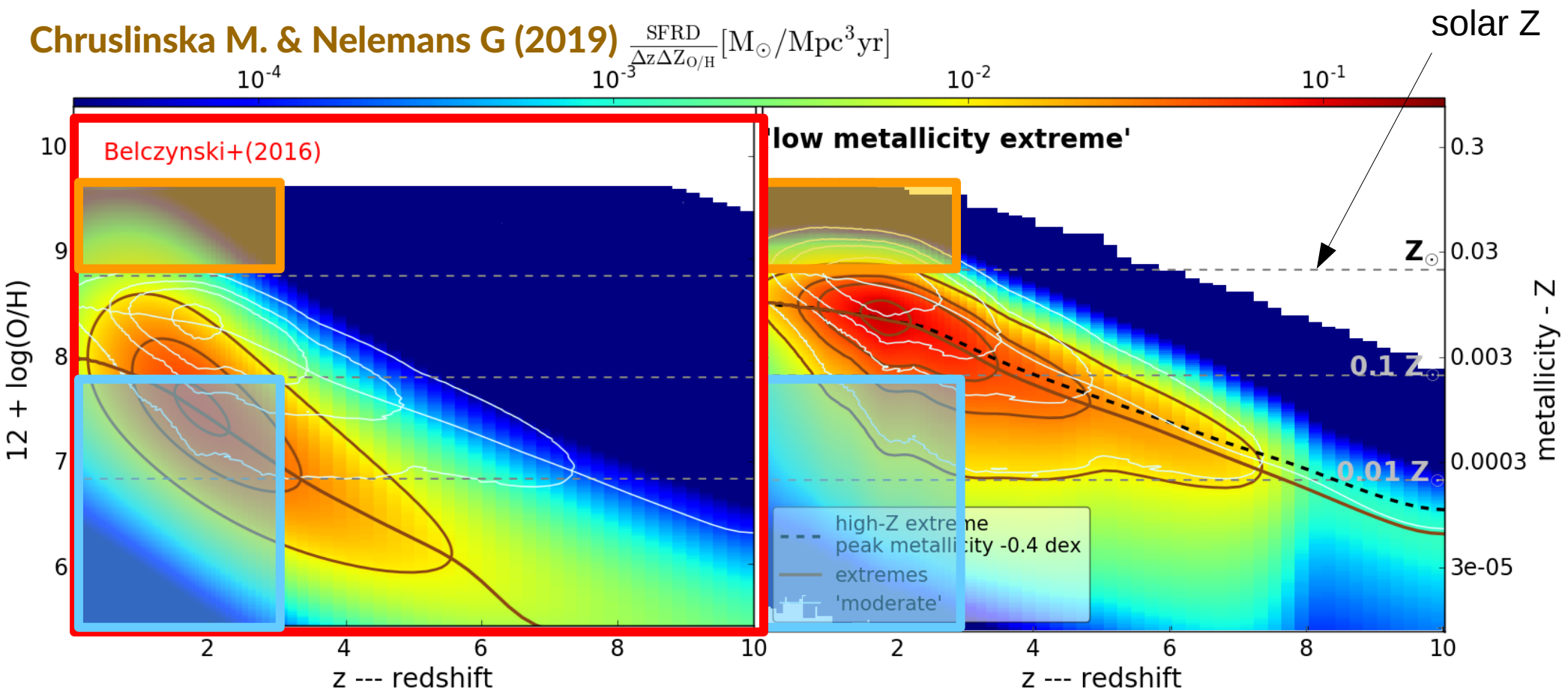
~27% of M_* at $Z>Z_O$

since z=3:

~27% of M_* at $Z<0.1\ Z_O$

~1% of M_* at $Z>Z_O$

Results: the extremes



since z=3:
~9% of M_* at Z<0.1 Z_O
~27% of M_* at Z>Z_O

'Dominik+13'
~15%
~21%

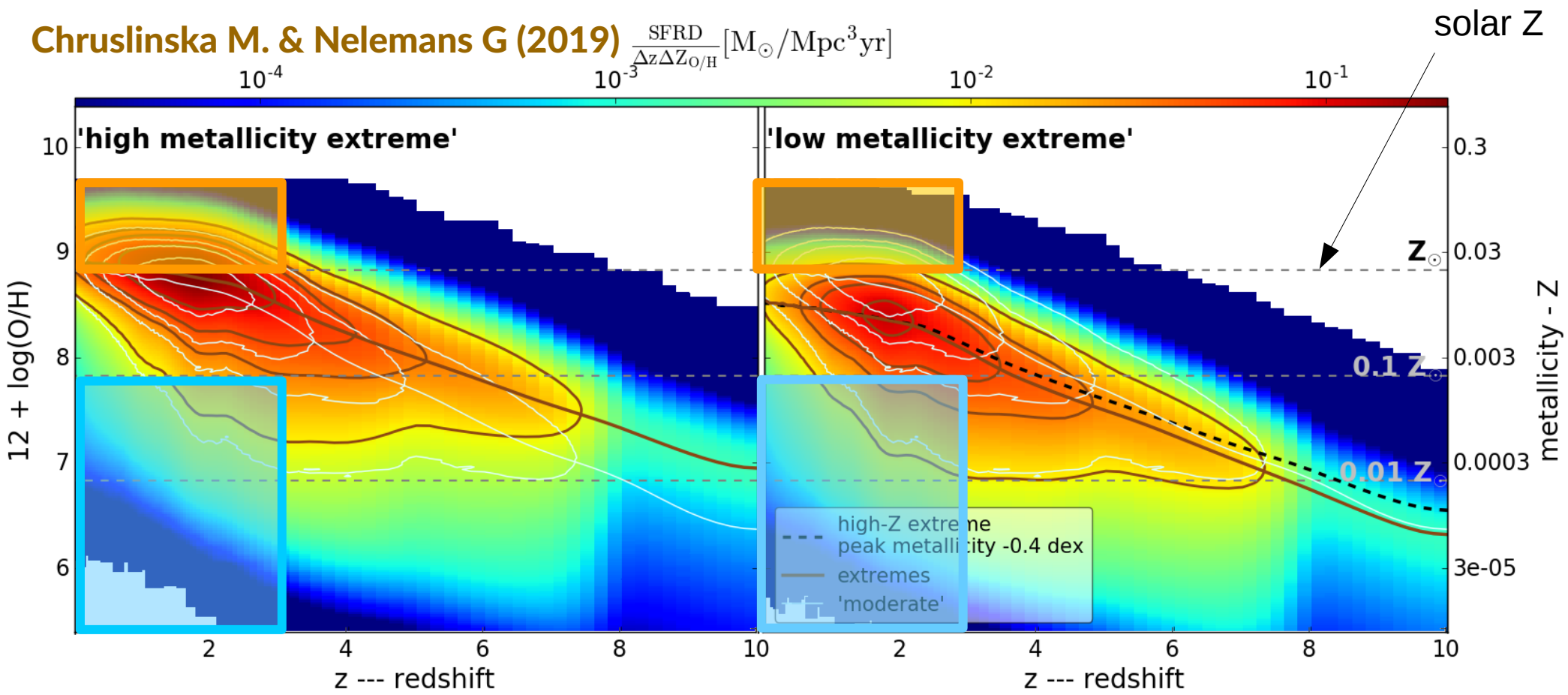
'Belczynski+16'
~75%
<1%

since z=3:
~27% of M_* at Z<0.1 Z_O
~1% of M_* at Z>Z_O

(but also different *shape* of the distribution and *normalization* – SFRD(z) !)

Results: the extremes

Chruslinska M. & Nelemans G (2019)



since z=3:
~9% of M_* at Z<0.1 Z_O
~27% of M_* at Z>Z_O

'Dominik+13'
~15%
~21%

'Belczynski+16'
~75%
<1%

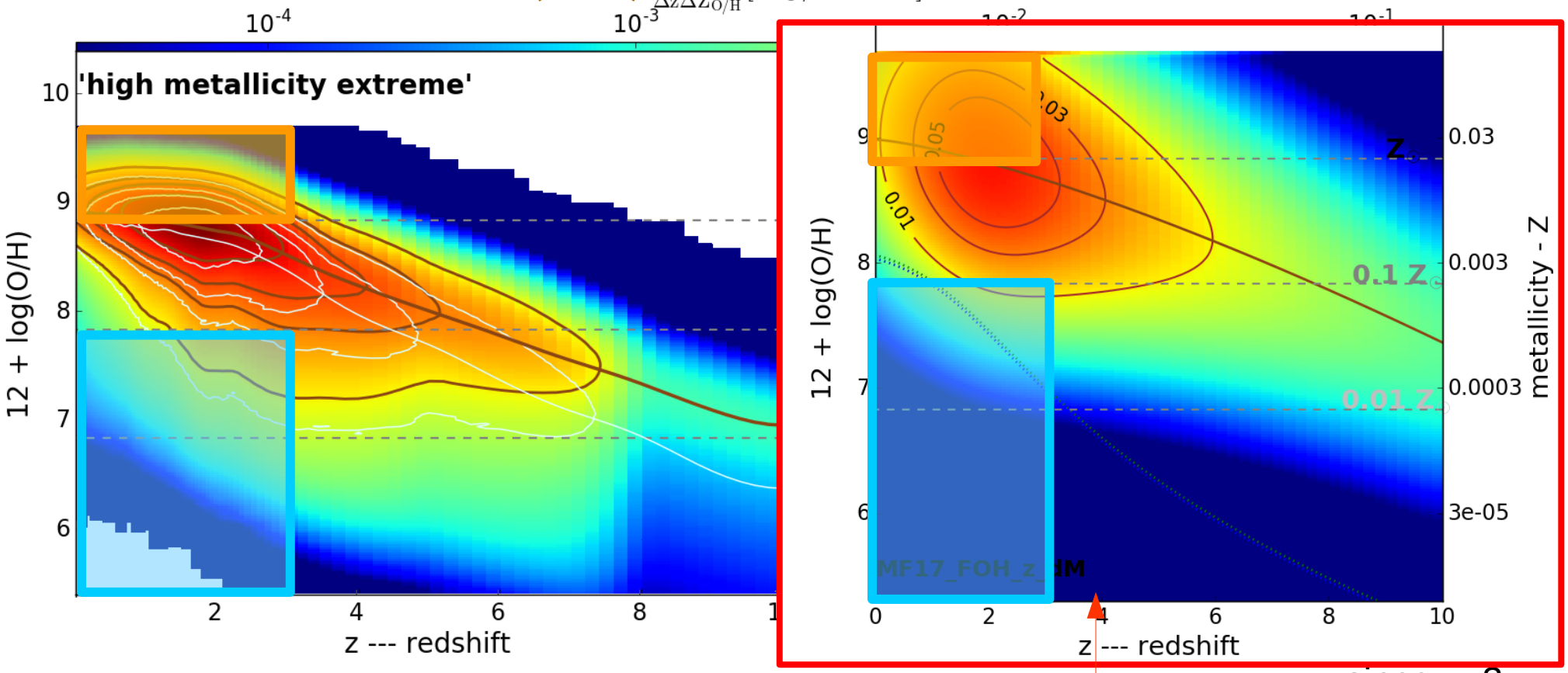
since z=3:
~27% of M_* at Z<0.1 Z_O
~1% of M_* at Z>Z_O

(but also different *shape* of the distribution and *normalization* – SFRD(z) !)

→ still significant uncertainty in the estimated merger rates (in prep.)

Results: the extremes

Chruslinska M. & Nelemans G (2019)



since z=3:

~9% of M_* at Z<0.1 Z_O

~27% of M_* at Z>Z_O

'Dominik+13'

~15%

~21%

'Belczynski+16'

~75%

<1%

since z=3:

~27% of M_* at Z<0.1 Z_O

~1% of M_* at Z>Z_O

using Madau & Fragos (2017):

<3.5%

~46%

Conclusions

→ the observed GW events carry information about the properties of ***binaries*** **& the *Universe* together**

→ **assumptions about SFRD(Z,z)**
can add a significant uncertainty to theoretical estimates (*model dependent, DCO type dependent*)

→ **observation-based SFRD(Z,z) & its uncertainties**
can be used to evaluate the uncertainty due to assumed SFRD(Z,z) (e.g. for the rates)