

# **double white dwarfs and SN Ia**

Aug 22nd, 2022, Tianqin workshop

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→ IAS & PI

# what are visible in TianQin?

$$\frac{r^3}{T^2} = M + m$$

kilo second = 1 / 3e4 year

need orbit shrinkage  
need compact object

$\sim 1/200$  AU = solar radius

isolated

Source	$N$	$N^{\text{detected}}$
WD+WD	$\sim 10^8$	6,000–10,000
NS+WD	$\sim 10^7$	100–300
BH+WD	$\sim 10^6$	0–3
NS+NS	$\sim 10^5$	2–100
BH+NS	$\sim 10^4 - 10^5$	0–20
BH+BH	$\sim 10^6$	0–70

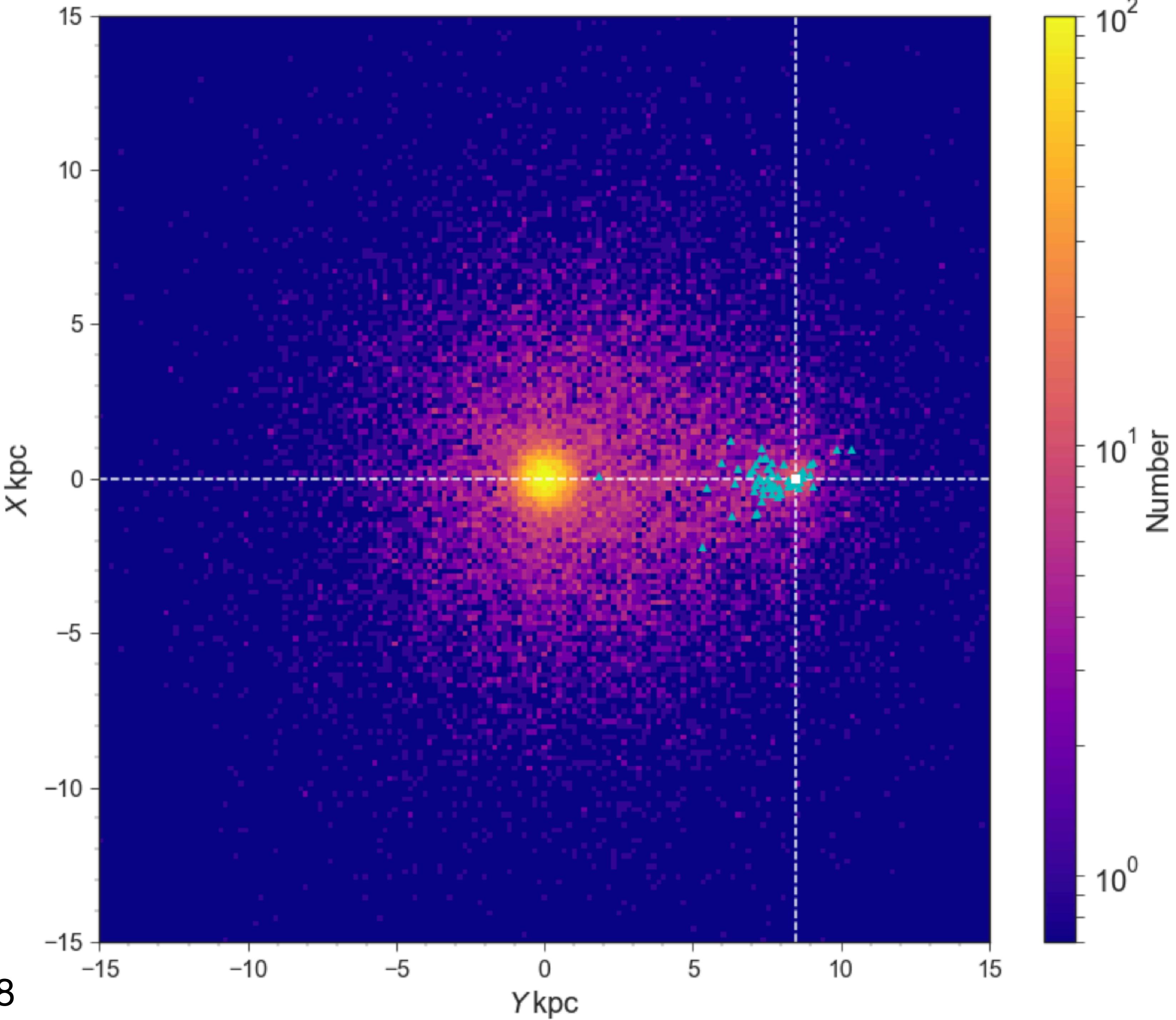
in clusters

Source	$N$	$N^{\text{detected}}$
WD+WD	$\sim 2 \times 10^4$	4–20
NS+WD	$\sim 10^3$	3–6
BH+WD	$\sim 10^2$	2–4
NS+NS	$\sim 40$	1
BH+NS	$\sim 4$	0
BH+BH	$\sim 2 \times 10^2$	4–7

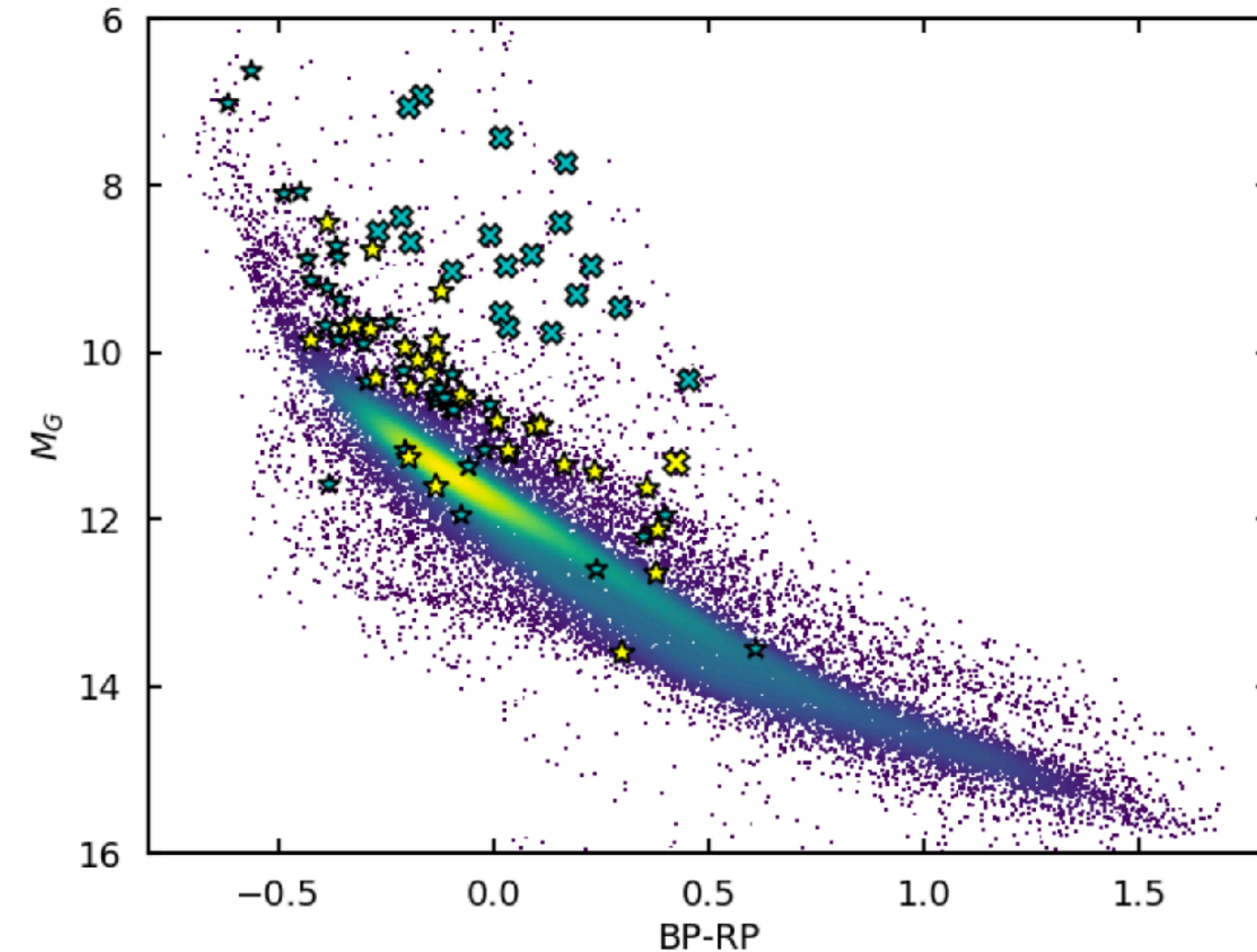
# why care about white dwarfs?

# GW vs. EM

Korol+ 2018

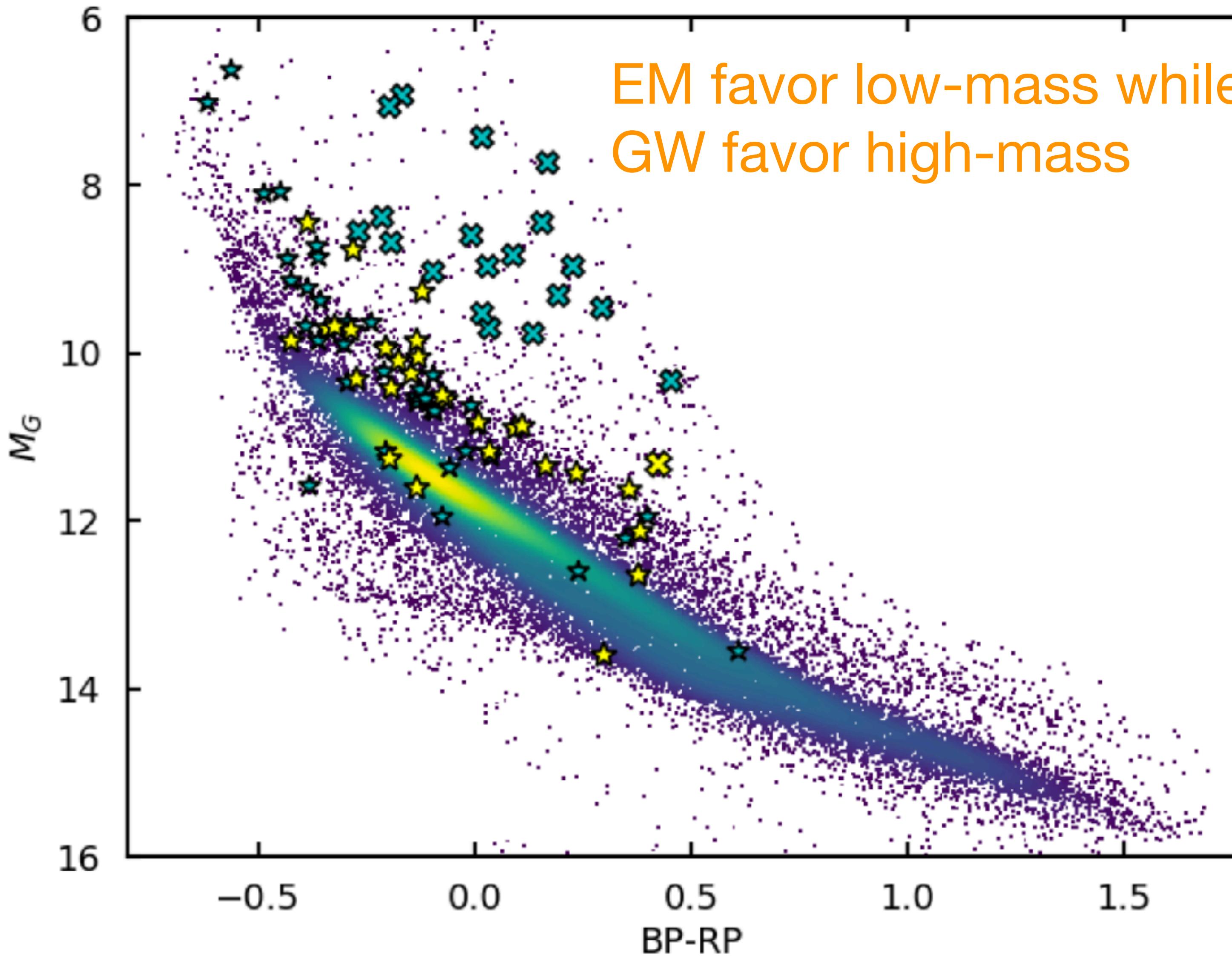


# GW vs. EM



$$\text{EM} \propto M^{-0.7} f^0 d^{-2}$$
$$\text{GW} \propto M^{1.7} f^{0.7} d^{-1}$$

# GW vs. EM



$$\mathbf{EM} \propto M^{-f^0} d^-$$
$$\mathbf{GW} \propto M^{+f^+} d^-$$

GW can help to select  
target for EM  
GW~M+f+, good for SN Ia  
progenitor search

# type-Ia supernova progenitors

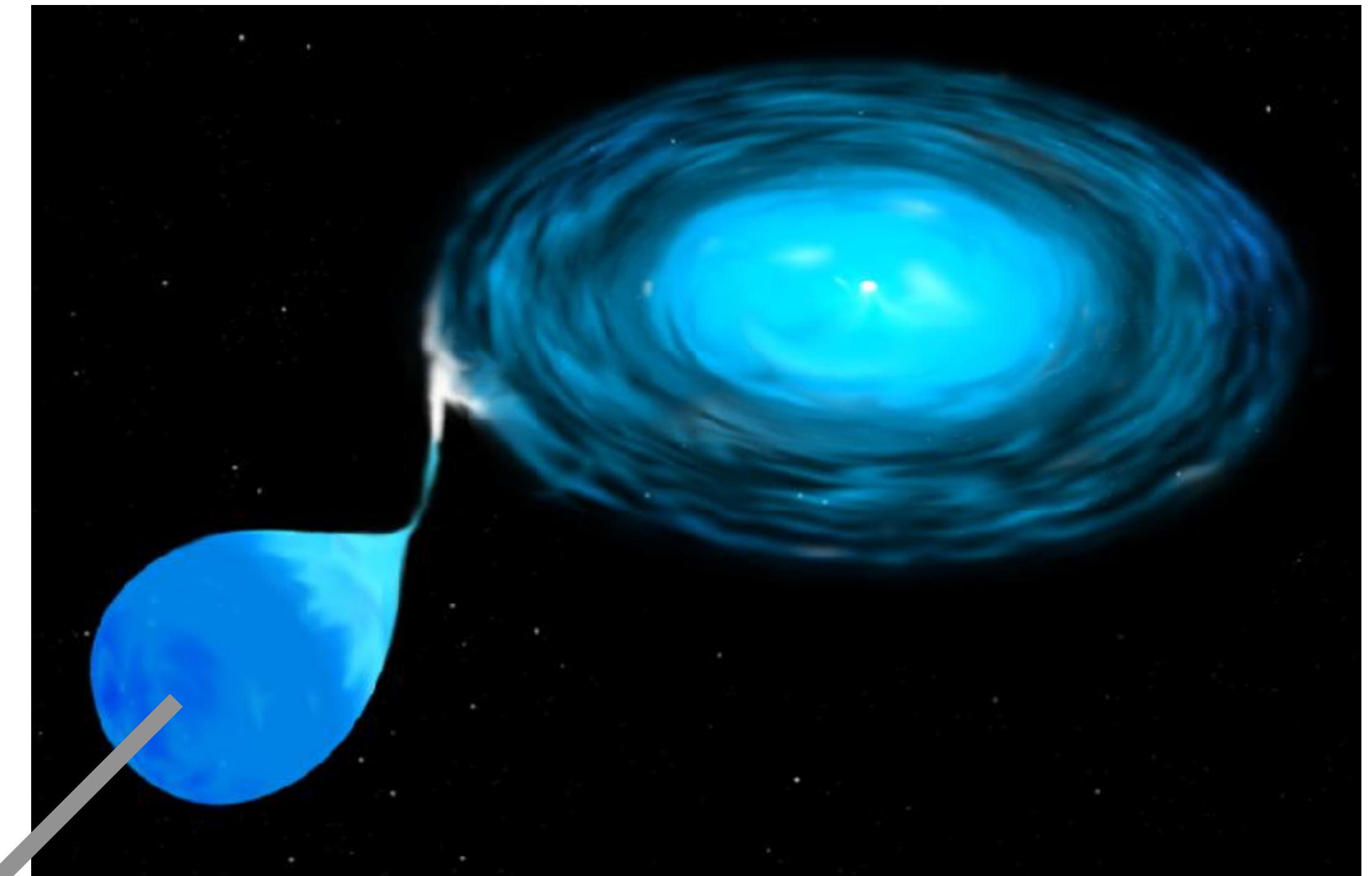
single white dwarf accretion

Whelan & Iben 1973 ...

difficult to grow:

too fast → merge

too slow → run-away explosion



main sequence, sub-giant, He star, red giant

# type-Ia supernova progenitors

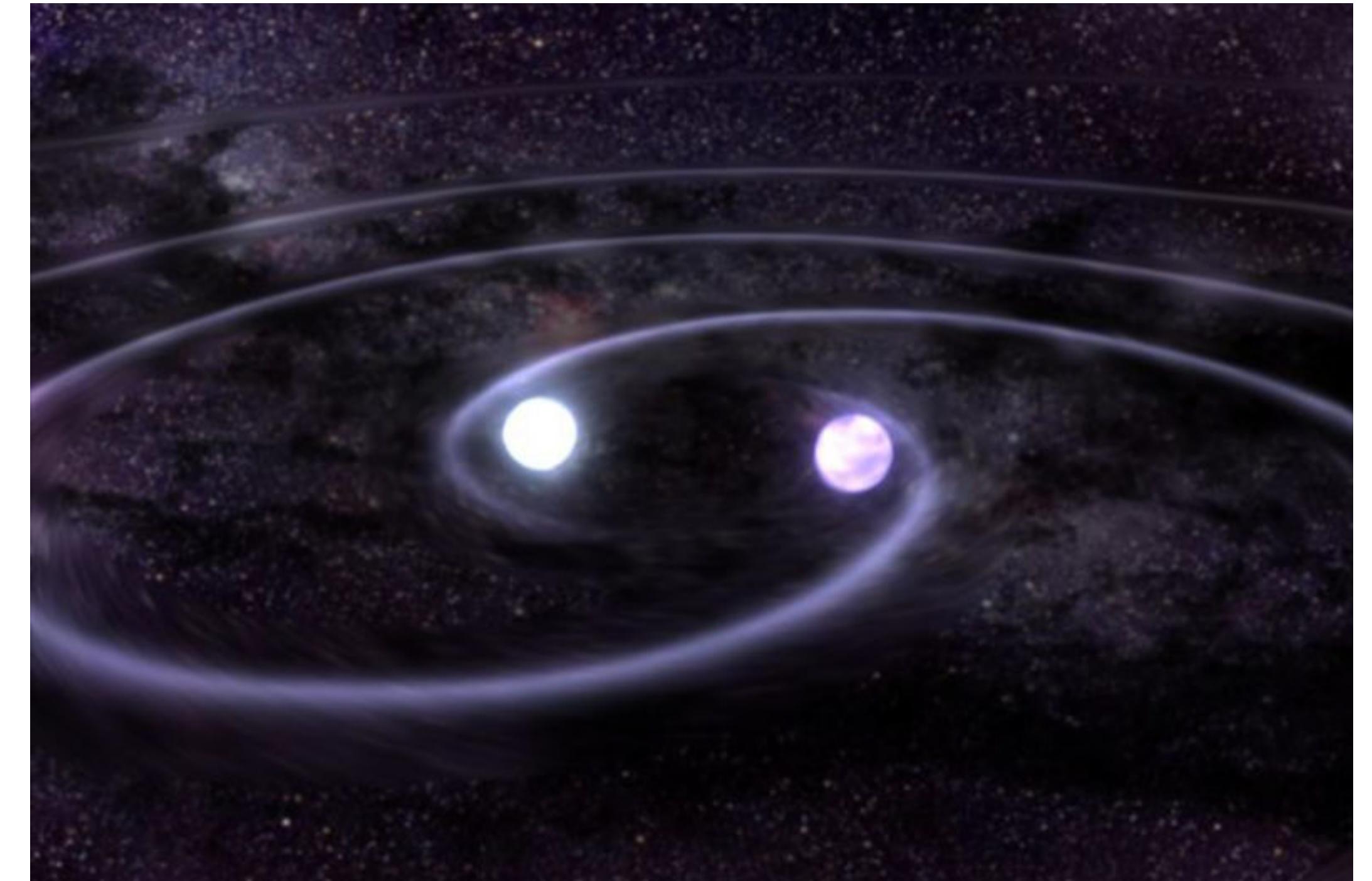
single white dwarf accretion

Whelan & Iben 1973 ...

double white dwarf merger

Iben & Tutukov 1984, Webbink 1984 ...

difficult to explode



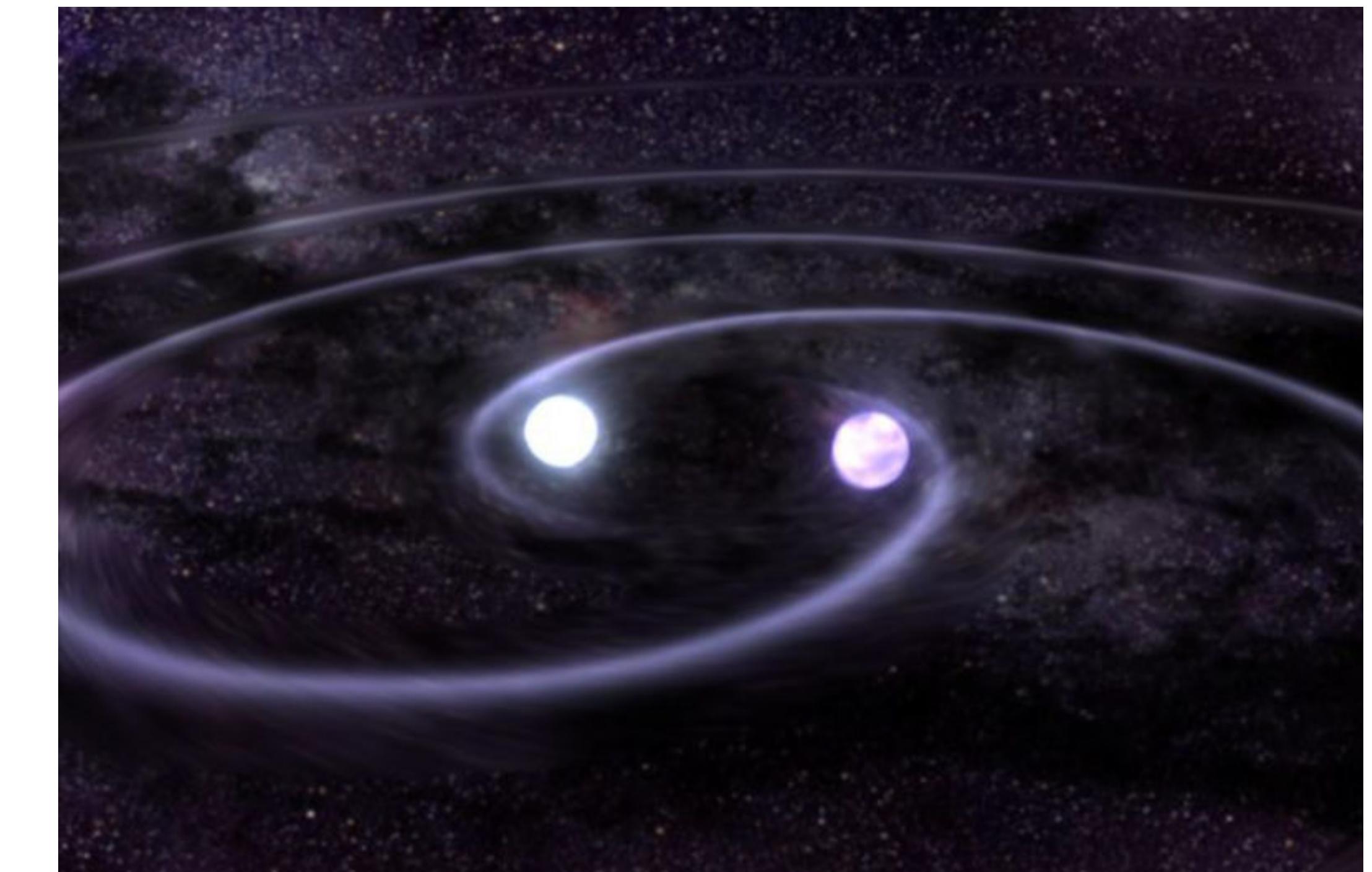
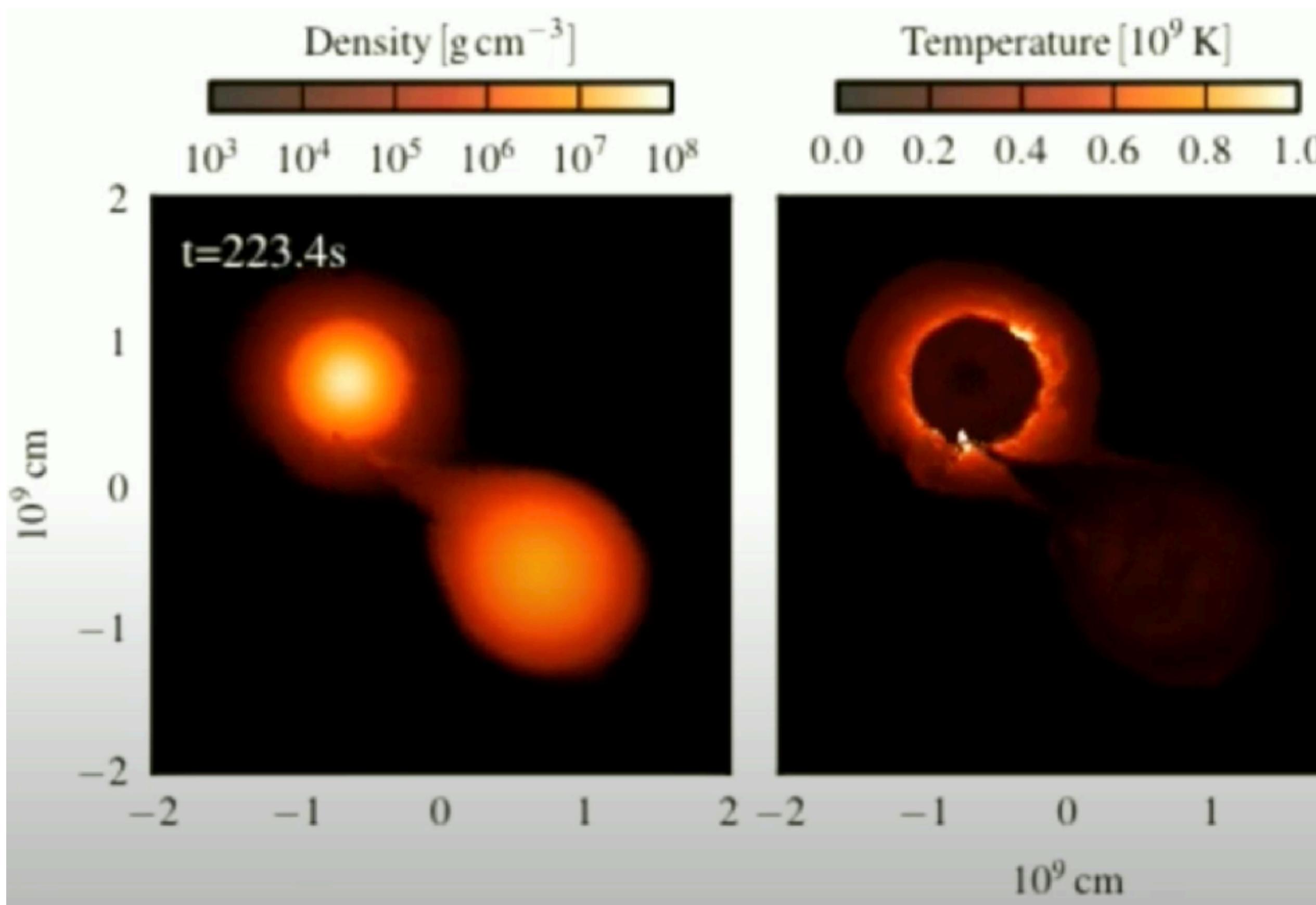
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# type-Ia supernova progenitors

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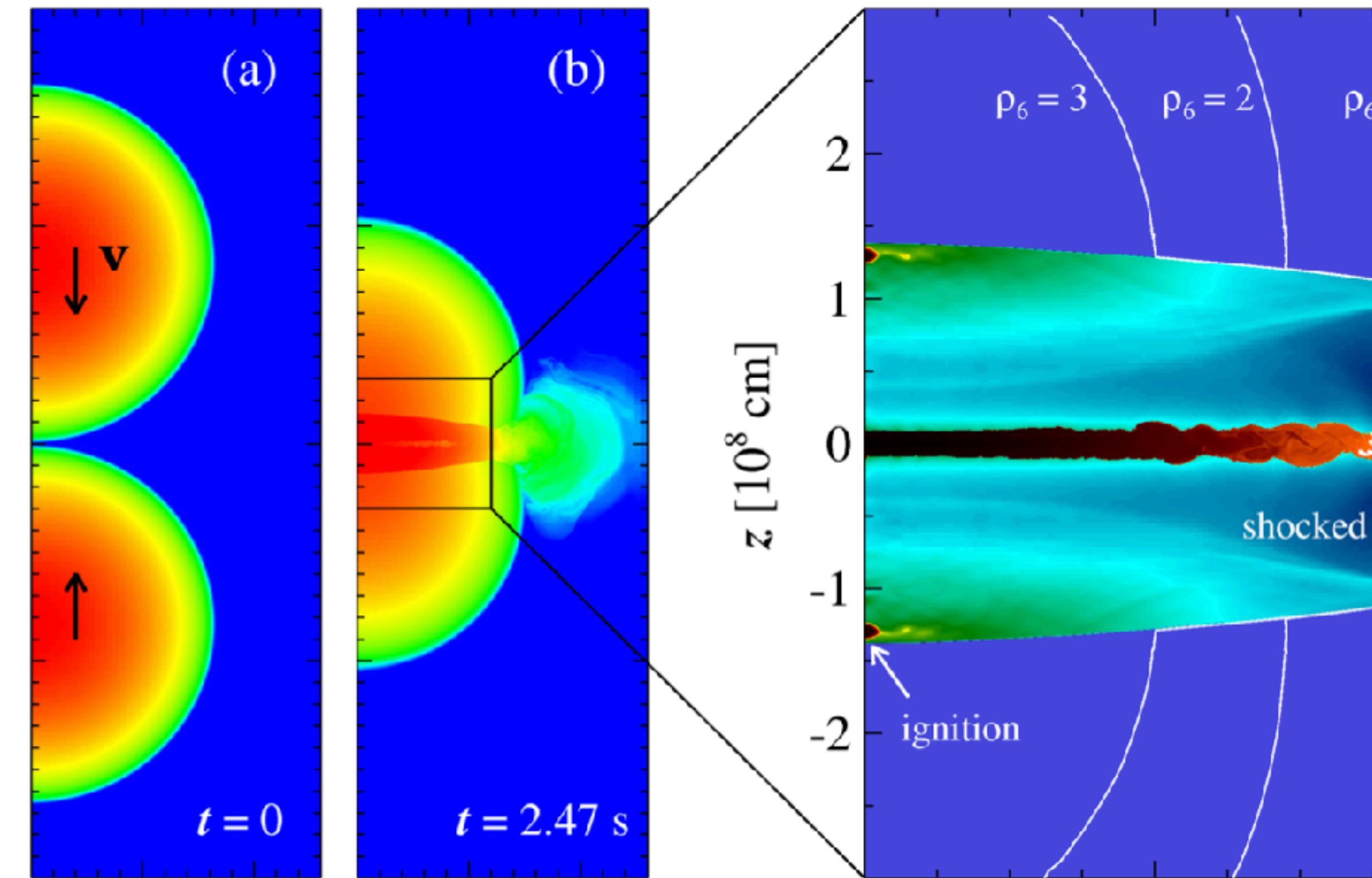
double white dwarf collision

Whelan & Iben 1973 ...

Iben & Tutukov 1984, Webbink 1984 ...

Thompson 2011, Katz&Dong 2012 ...

difficult to happen

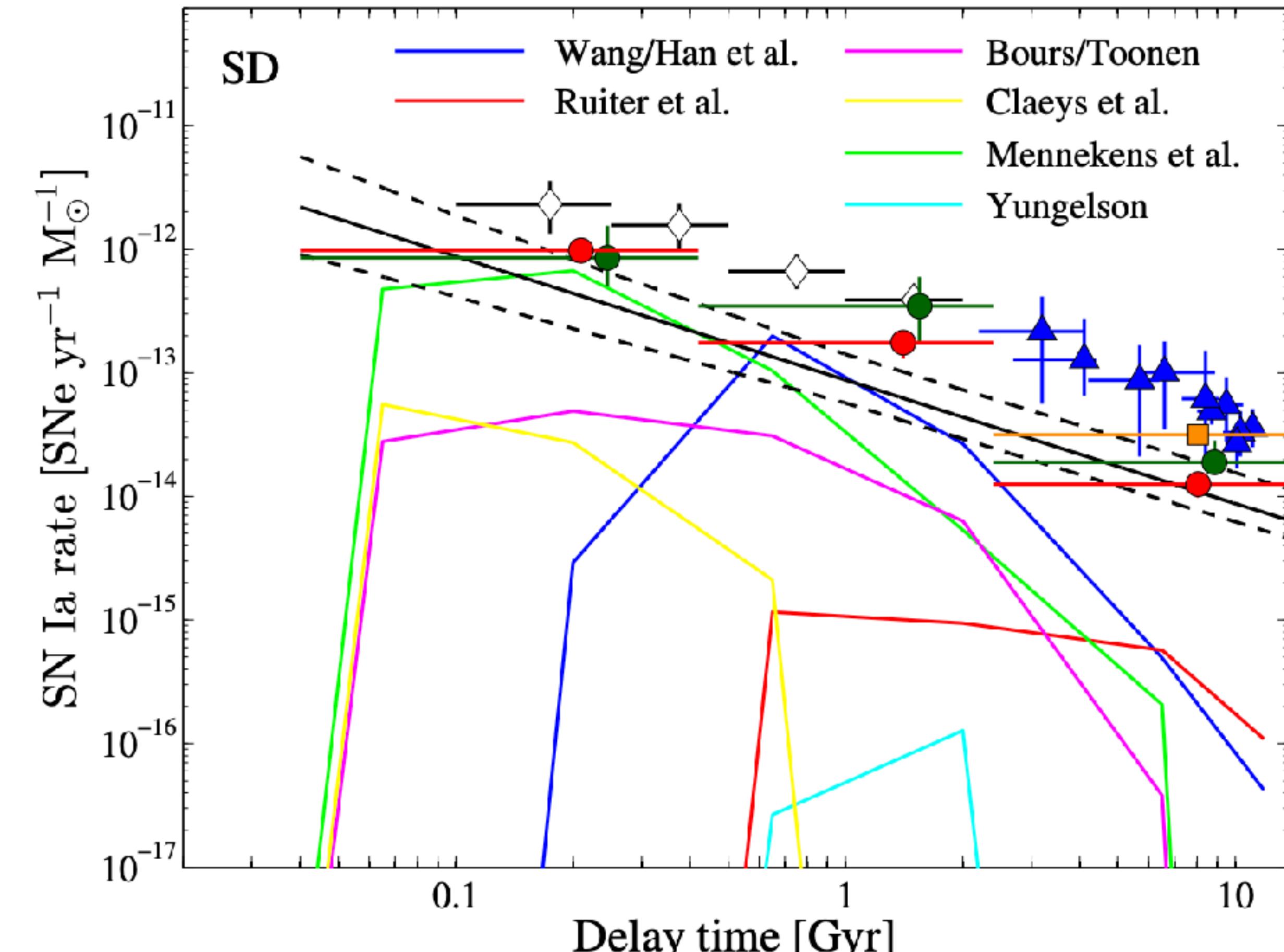
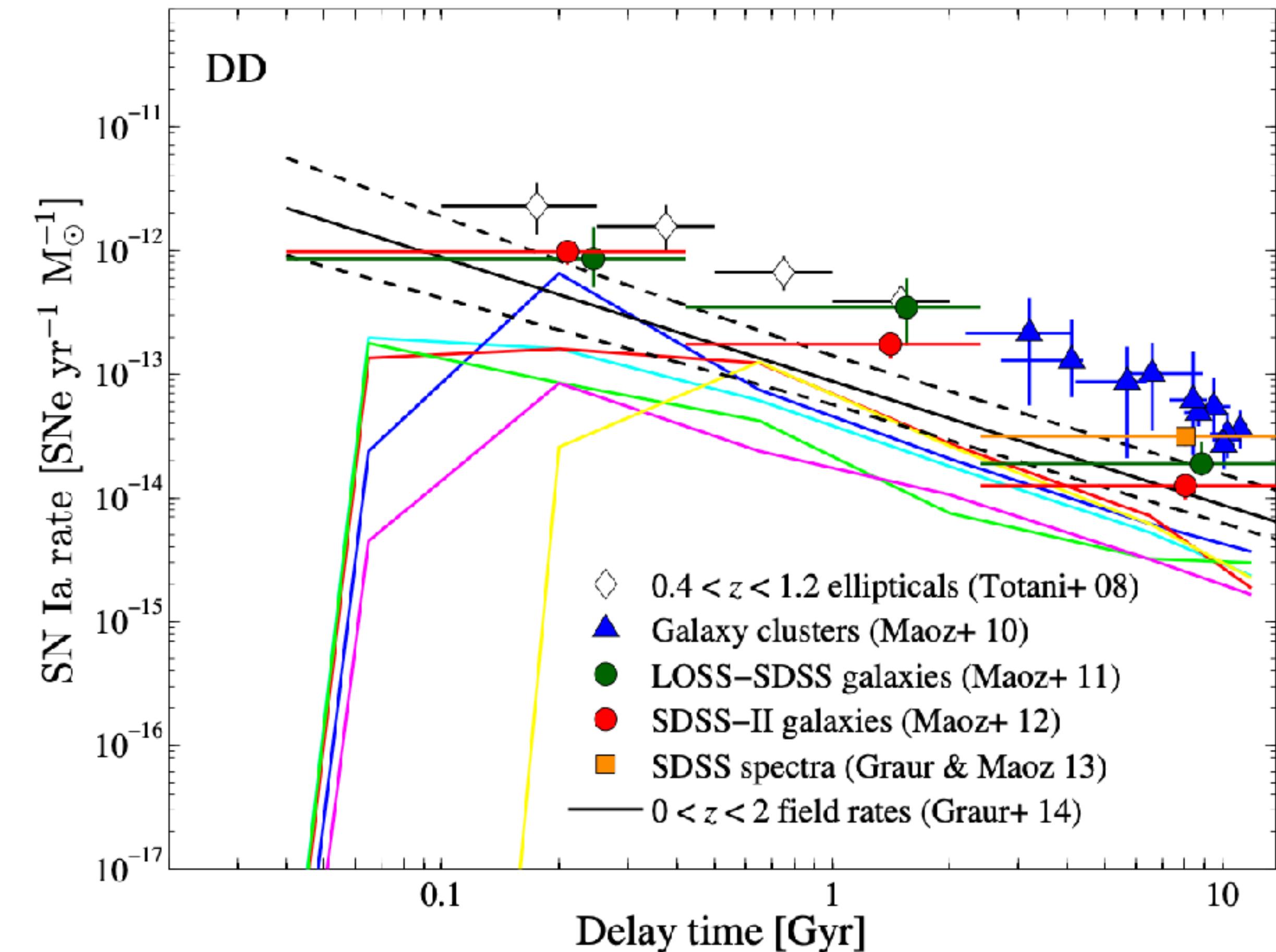


Kushnir+ 2013

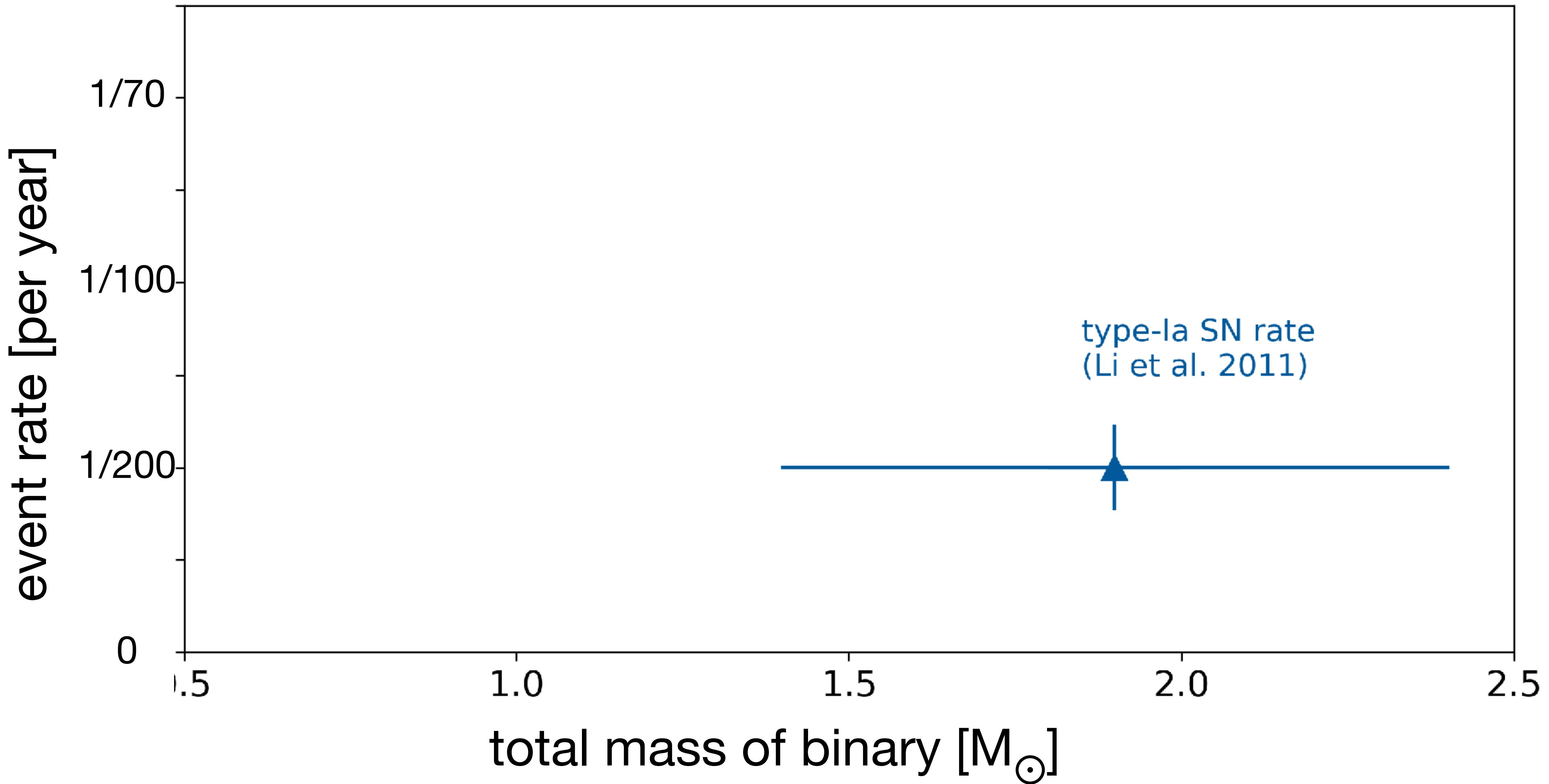
# type-Ia supernovae rate

binary population synthesis < SN Ia observation

what about all binary white dwarfs?

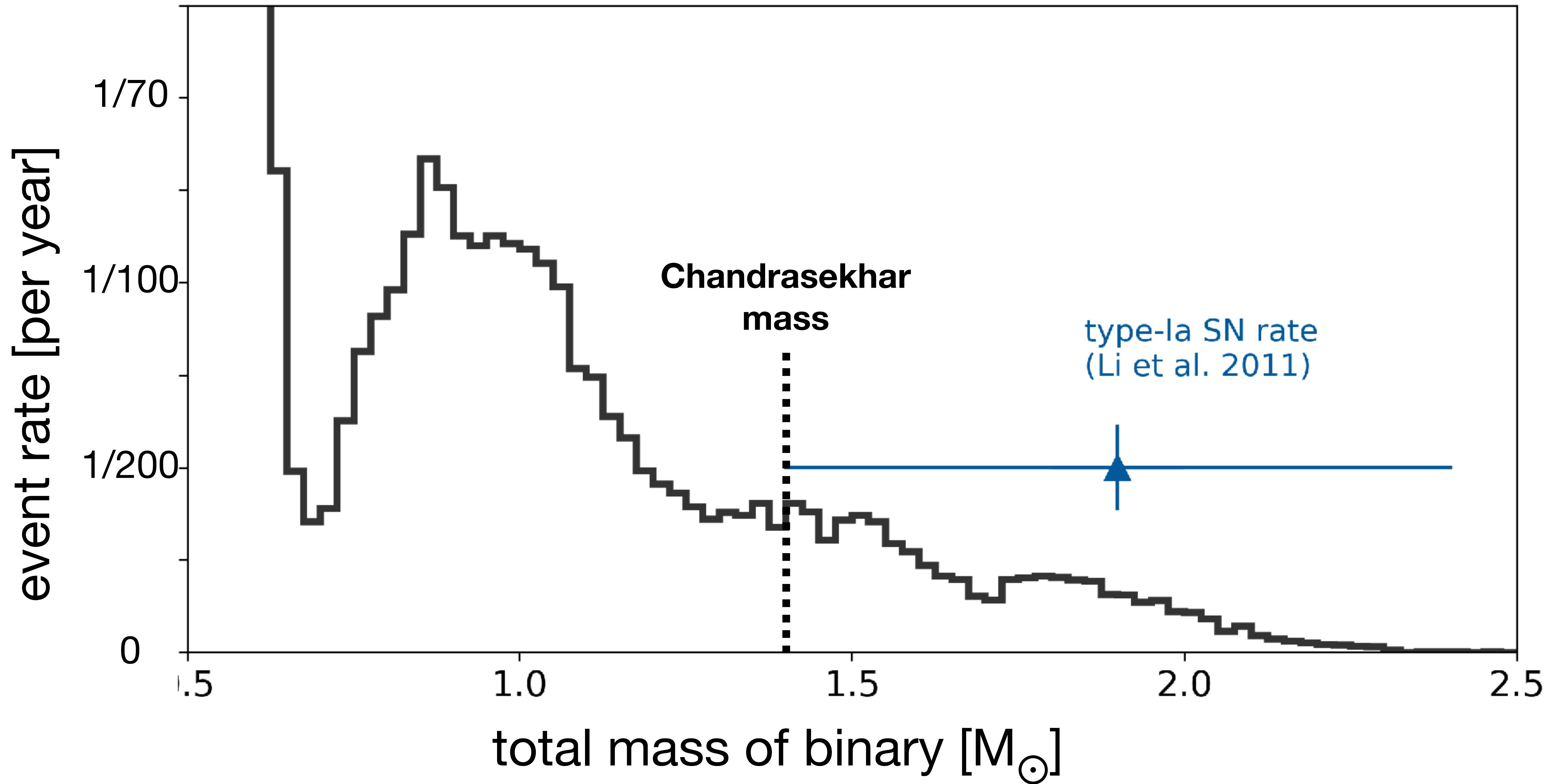


# double-WD mergers

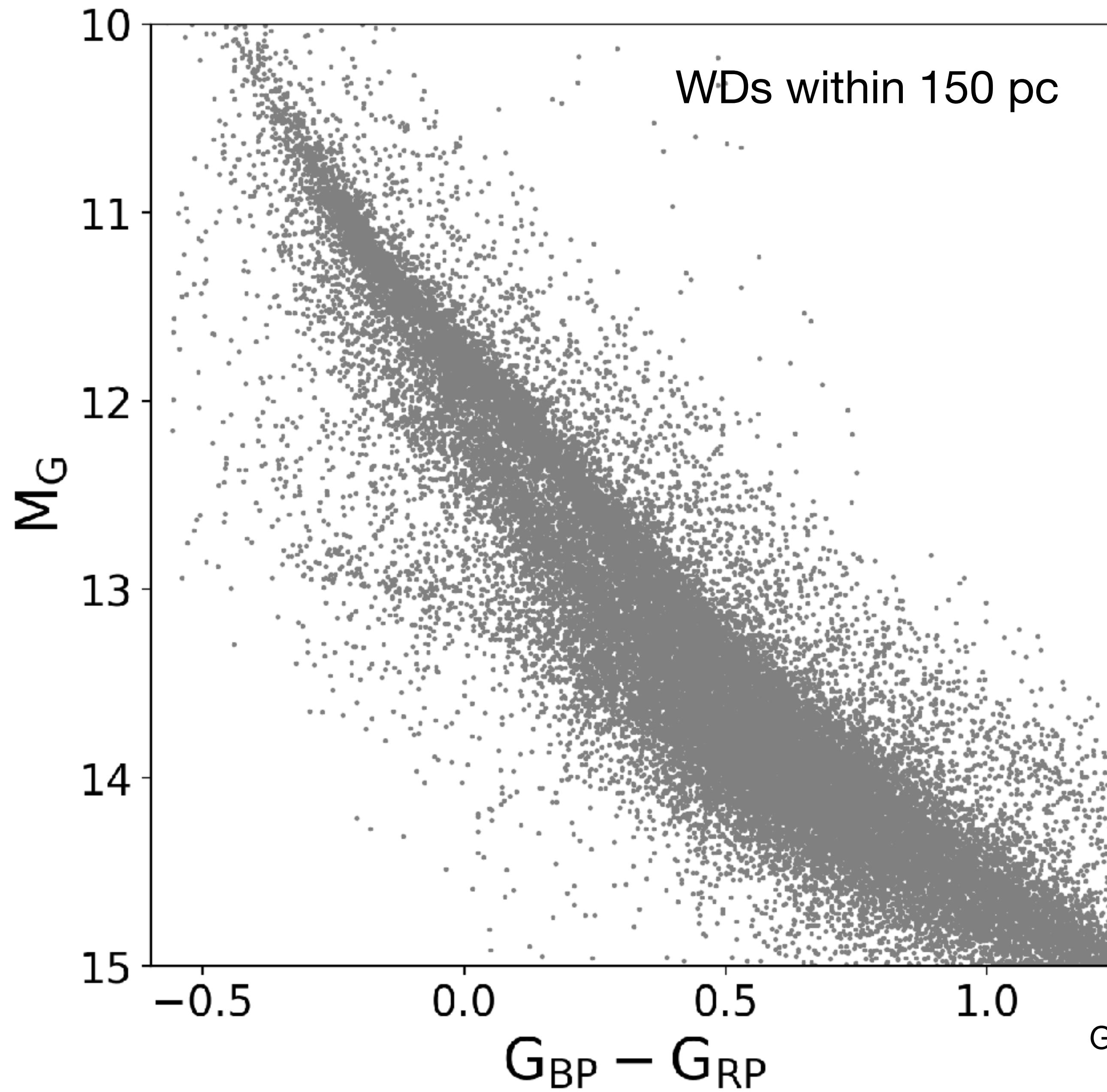


# double-WD mergers

population synthesis results  
with SeBa Code, by Silvia Toonen

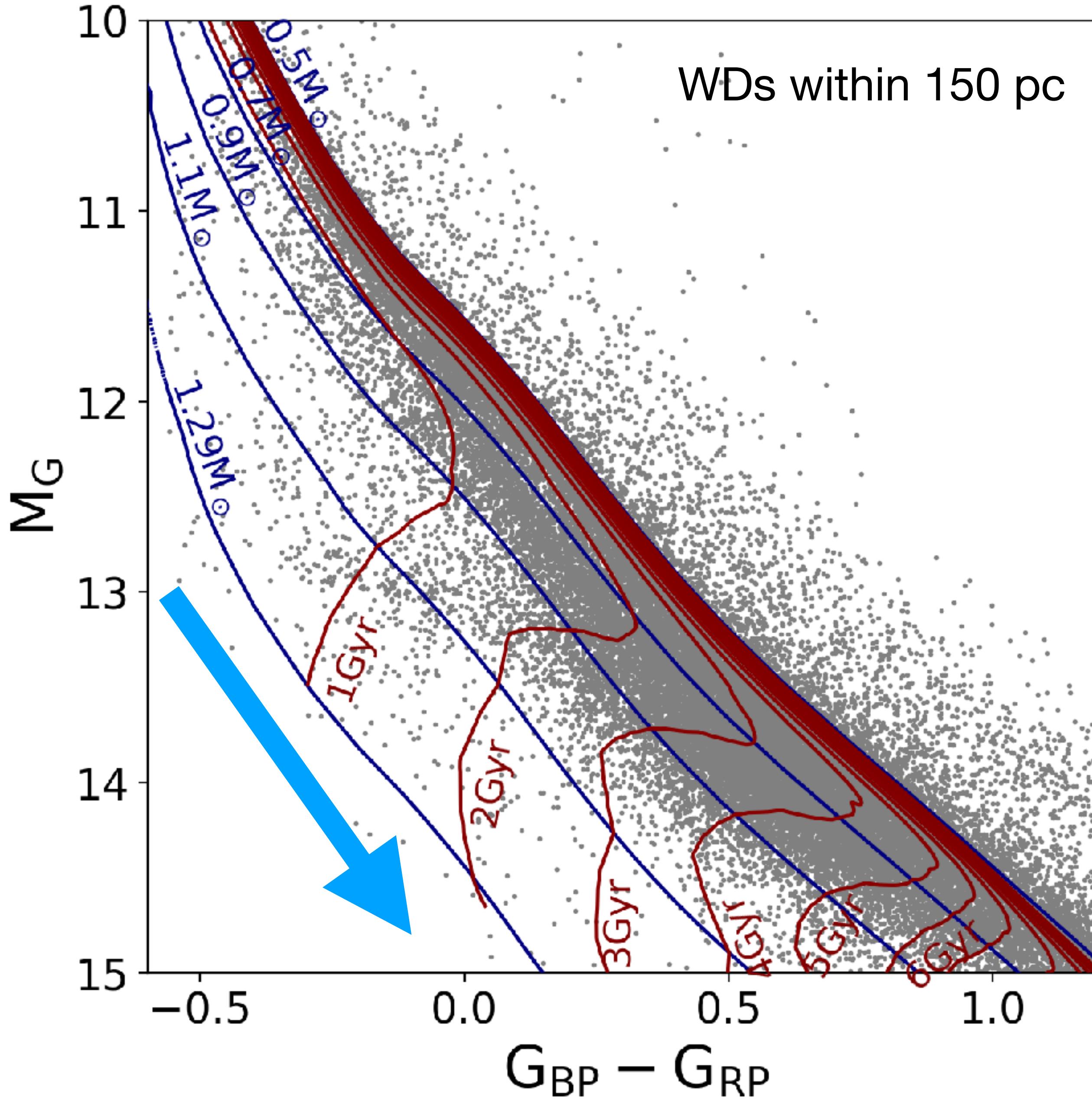


# white dwarfs in *Gaia*

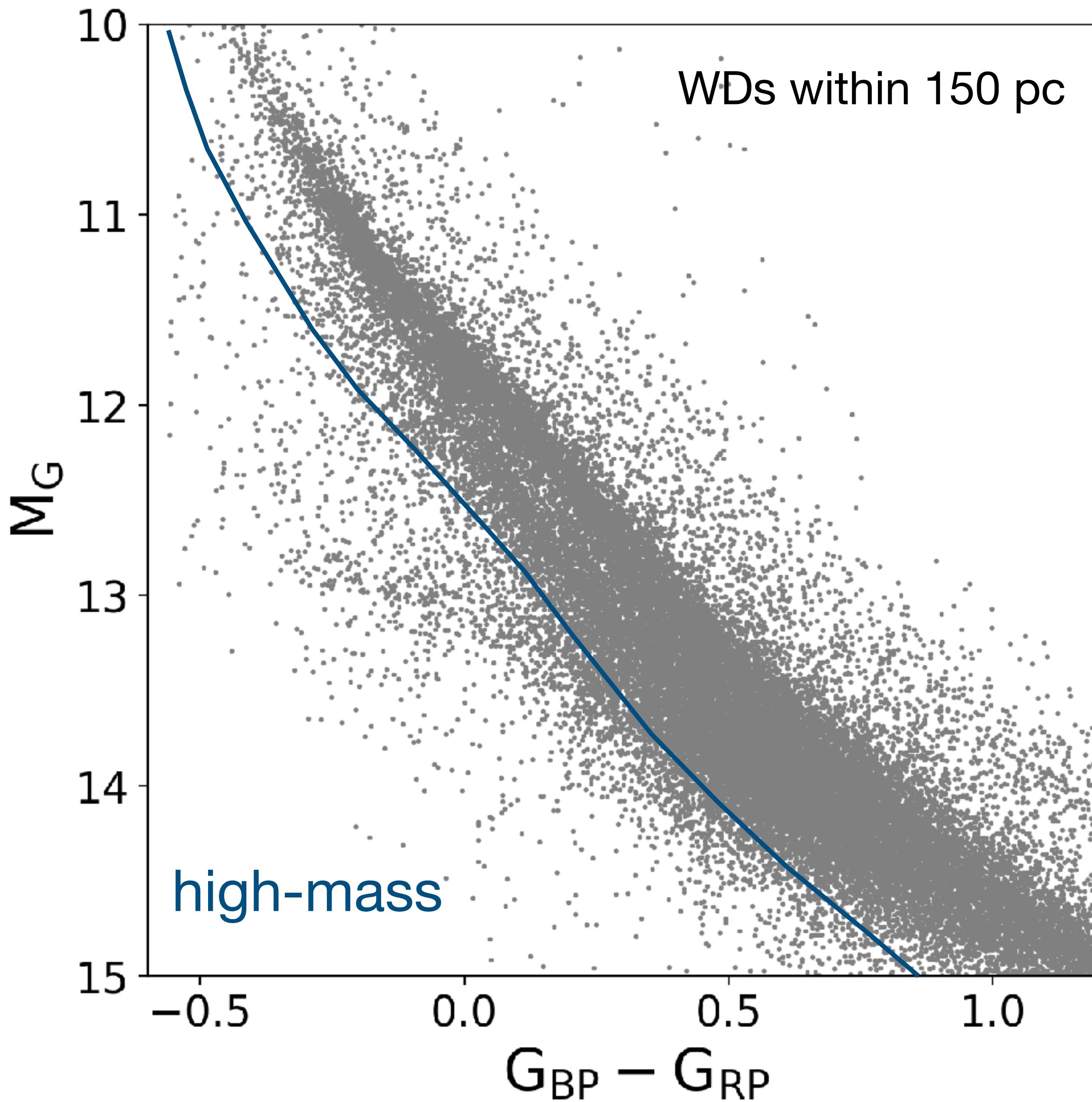


Gaia Collaboration et al. 2018  
Gentile-Fusillo et al. 2019

# white dwarfs in Gaia

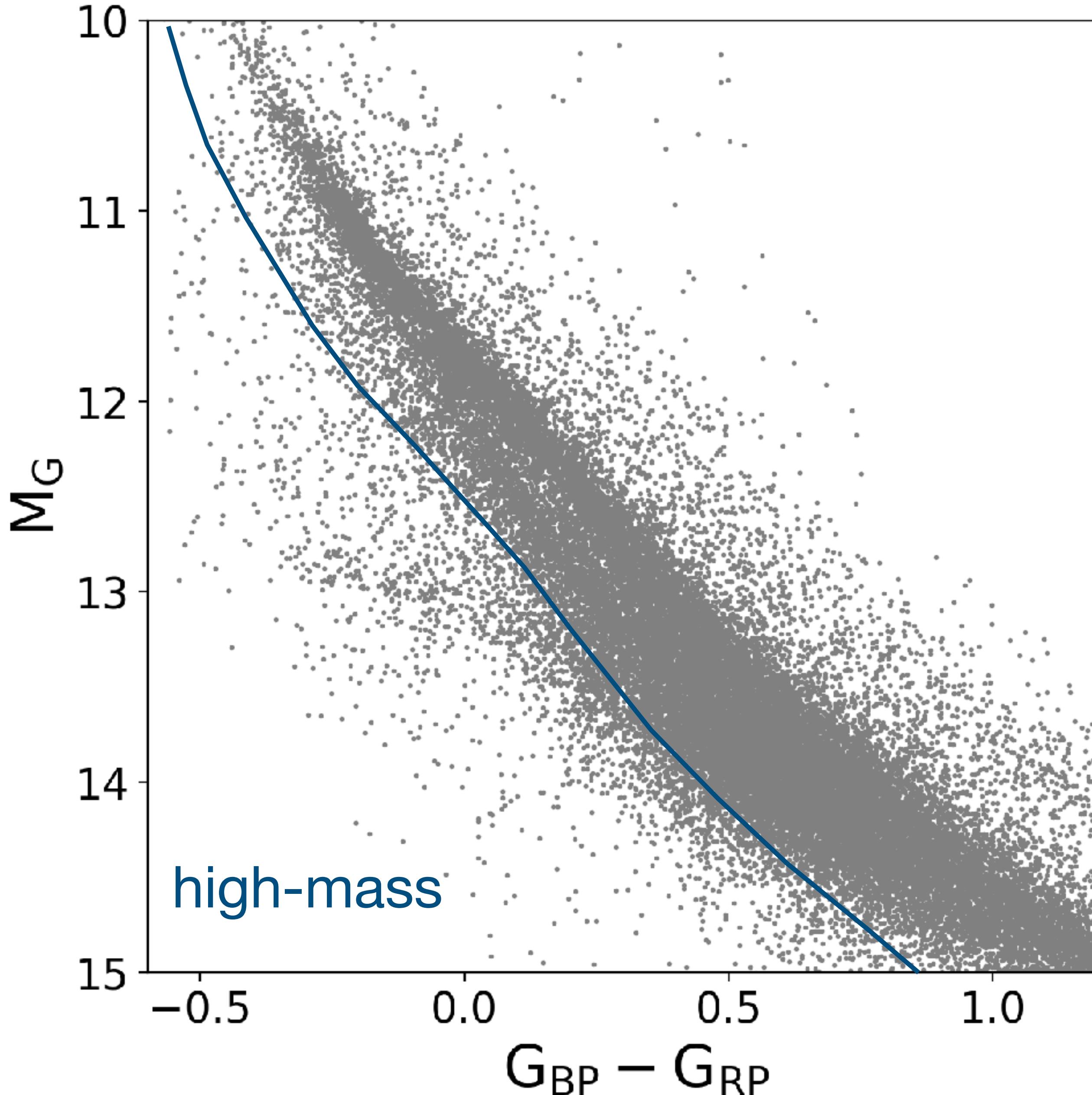


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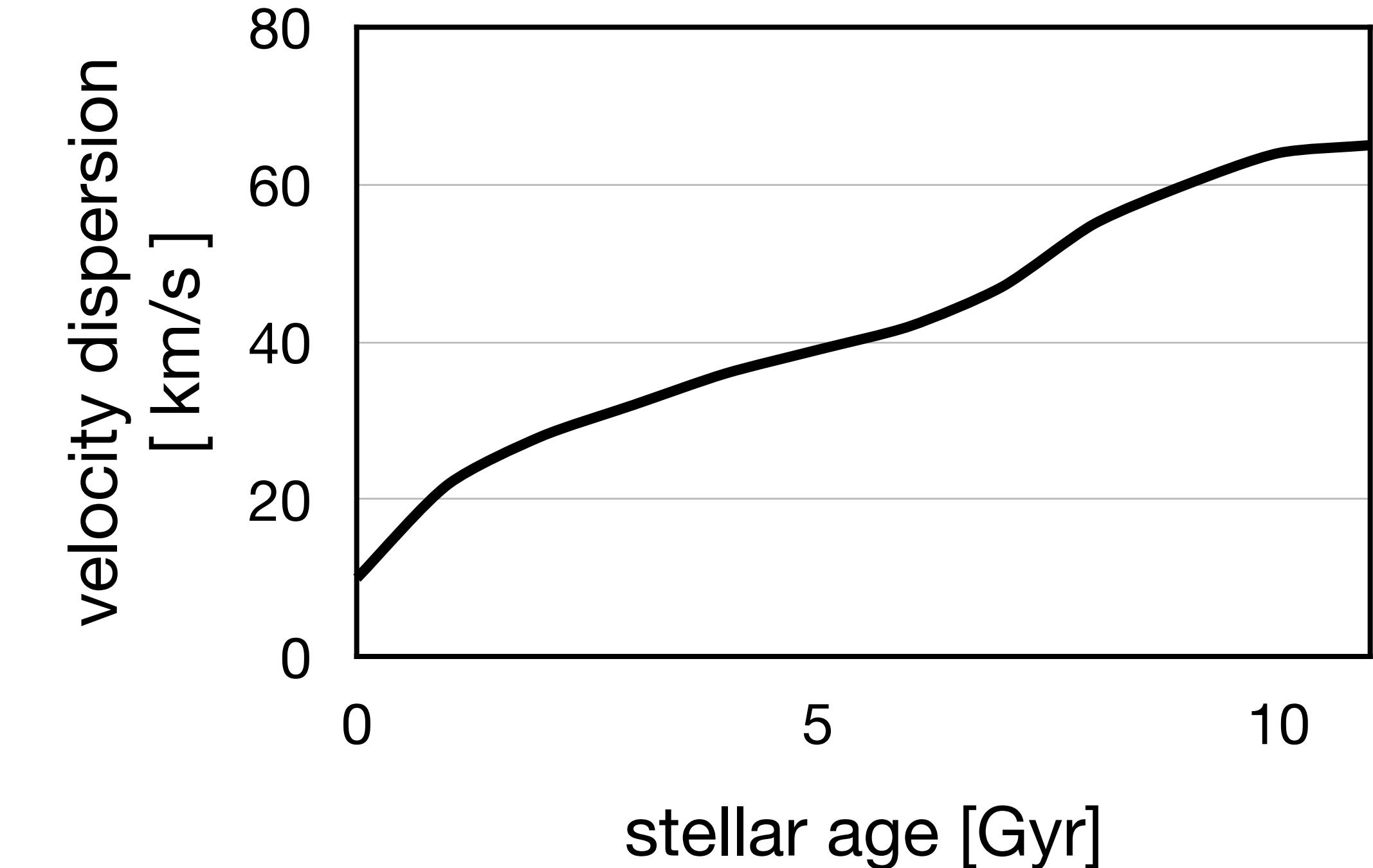
# origins of massive white dwarfs



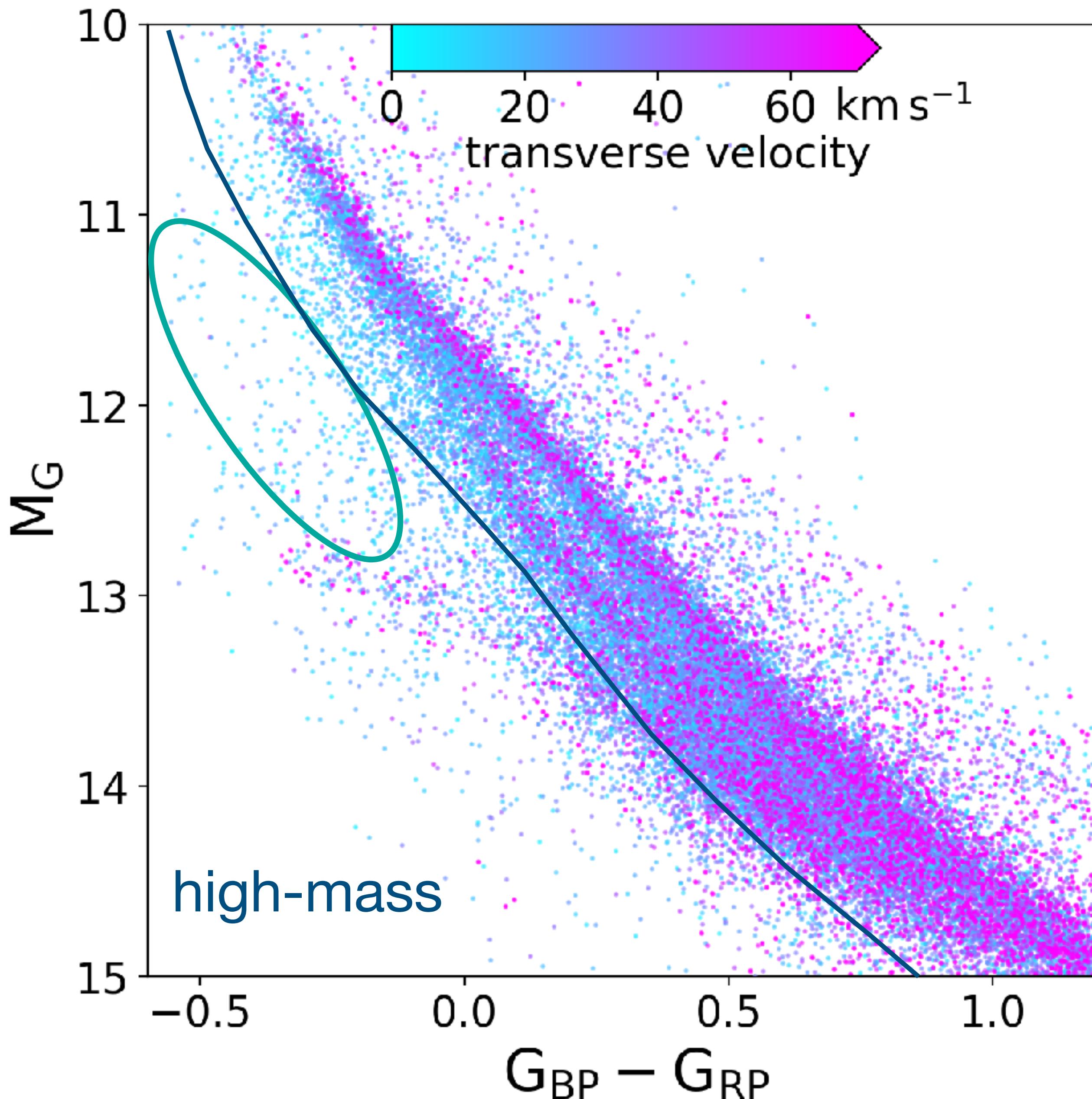
- single-star evolution
- merger products

**what fraction?**

in milky way, **old = moving fast**



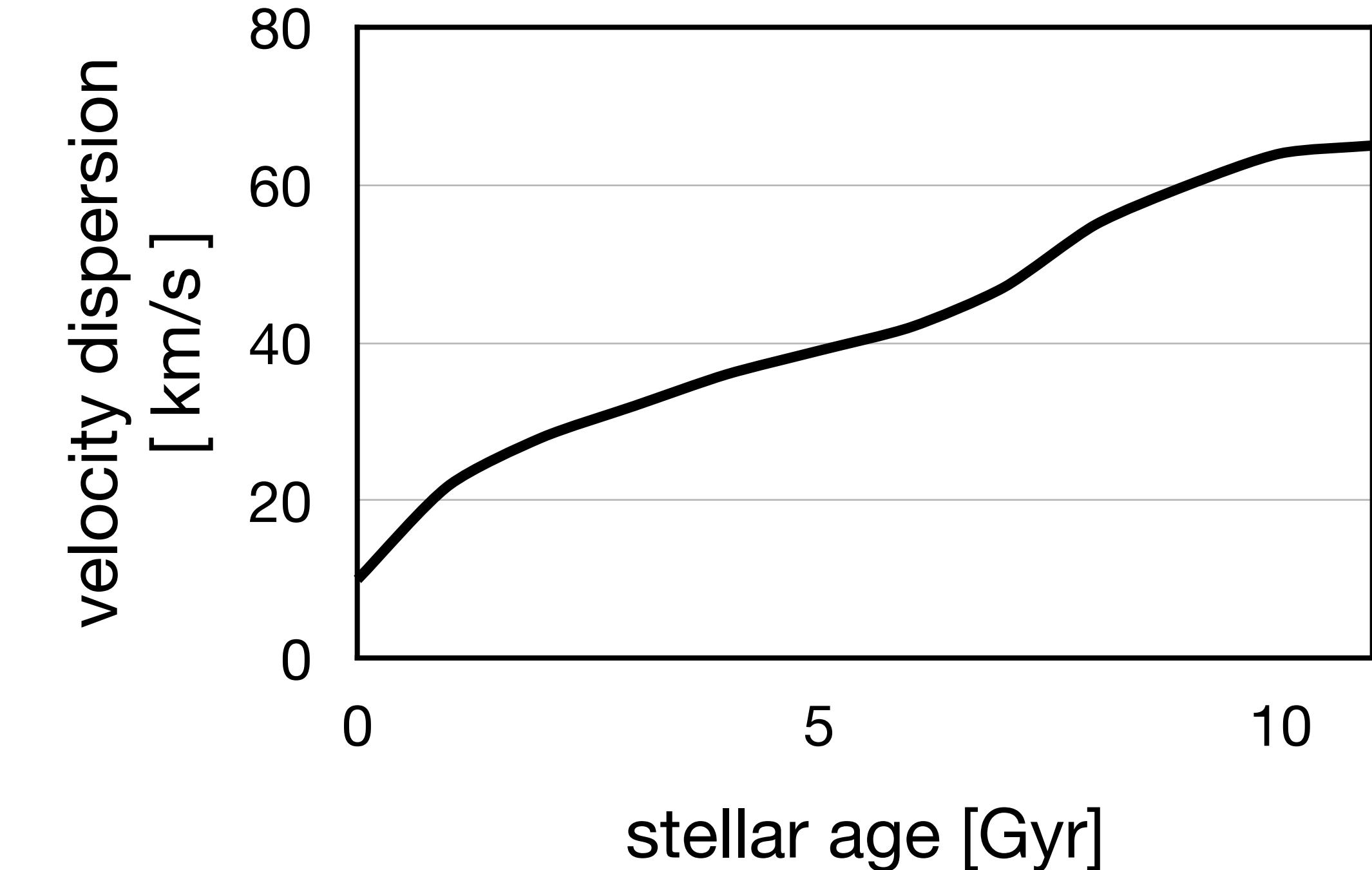
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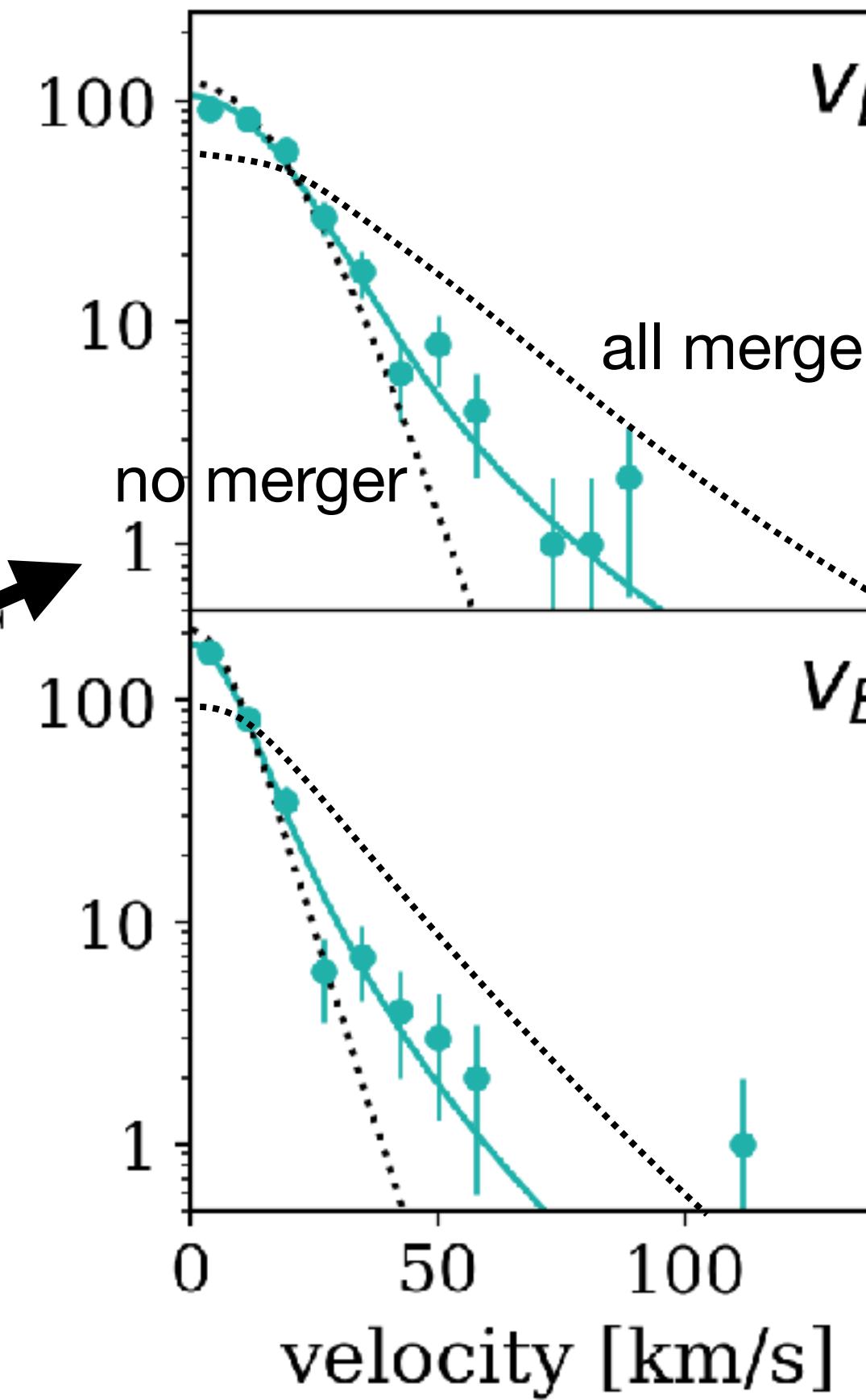
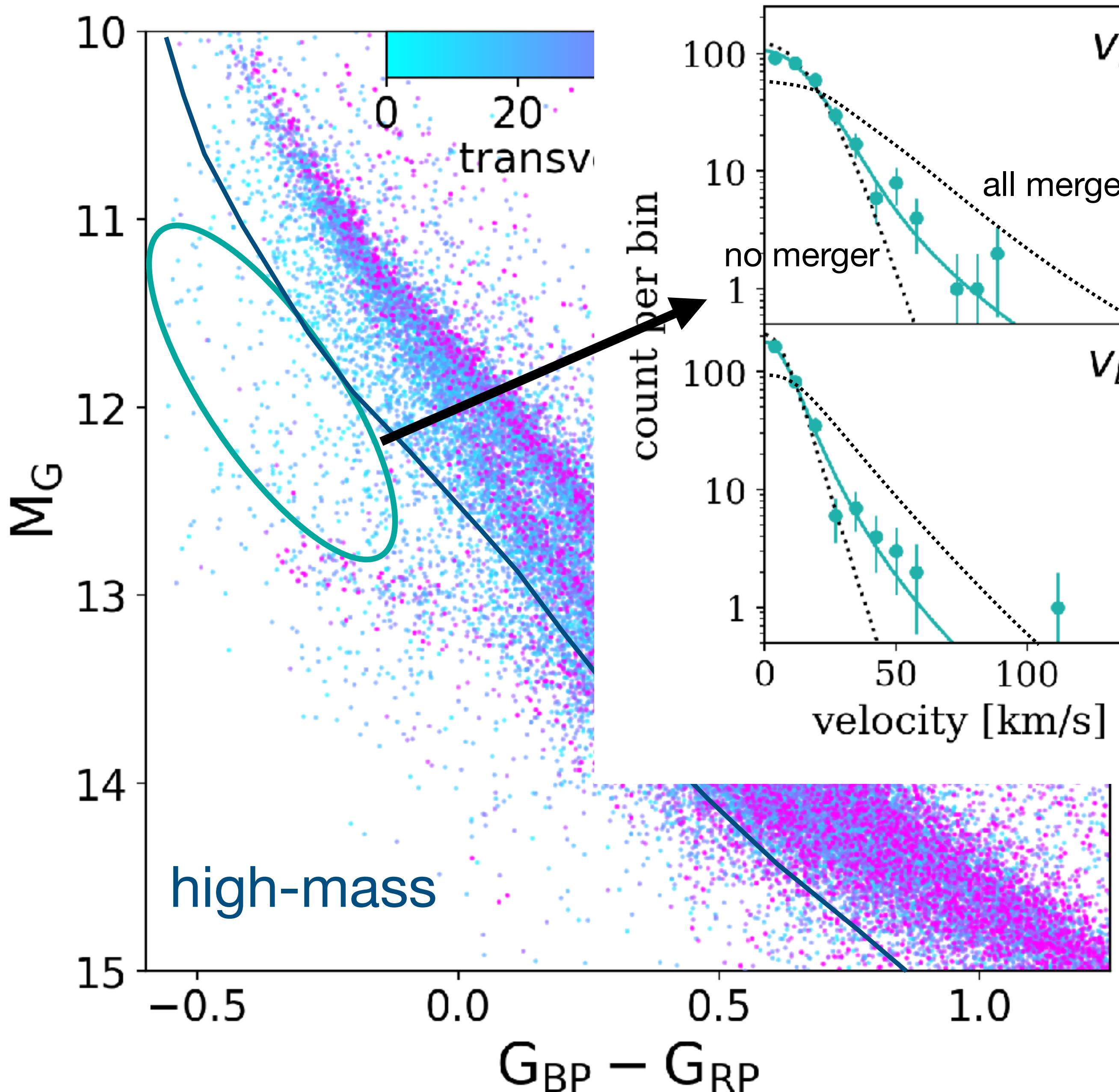
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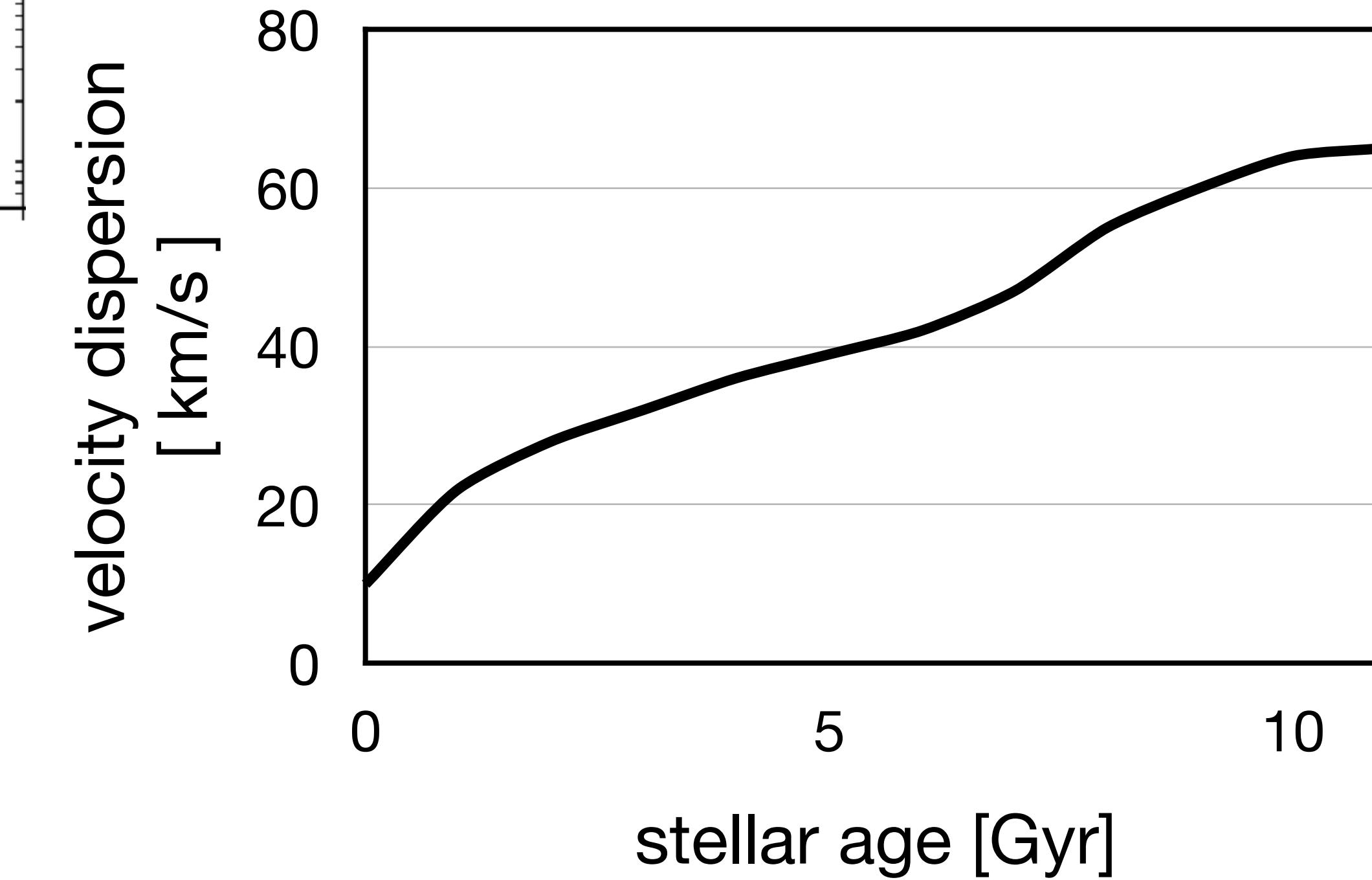


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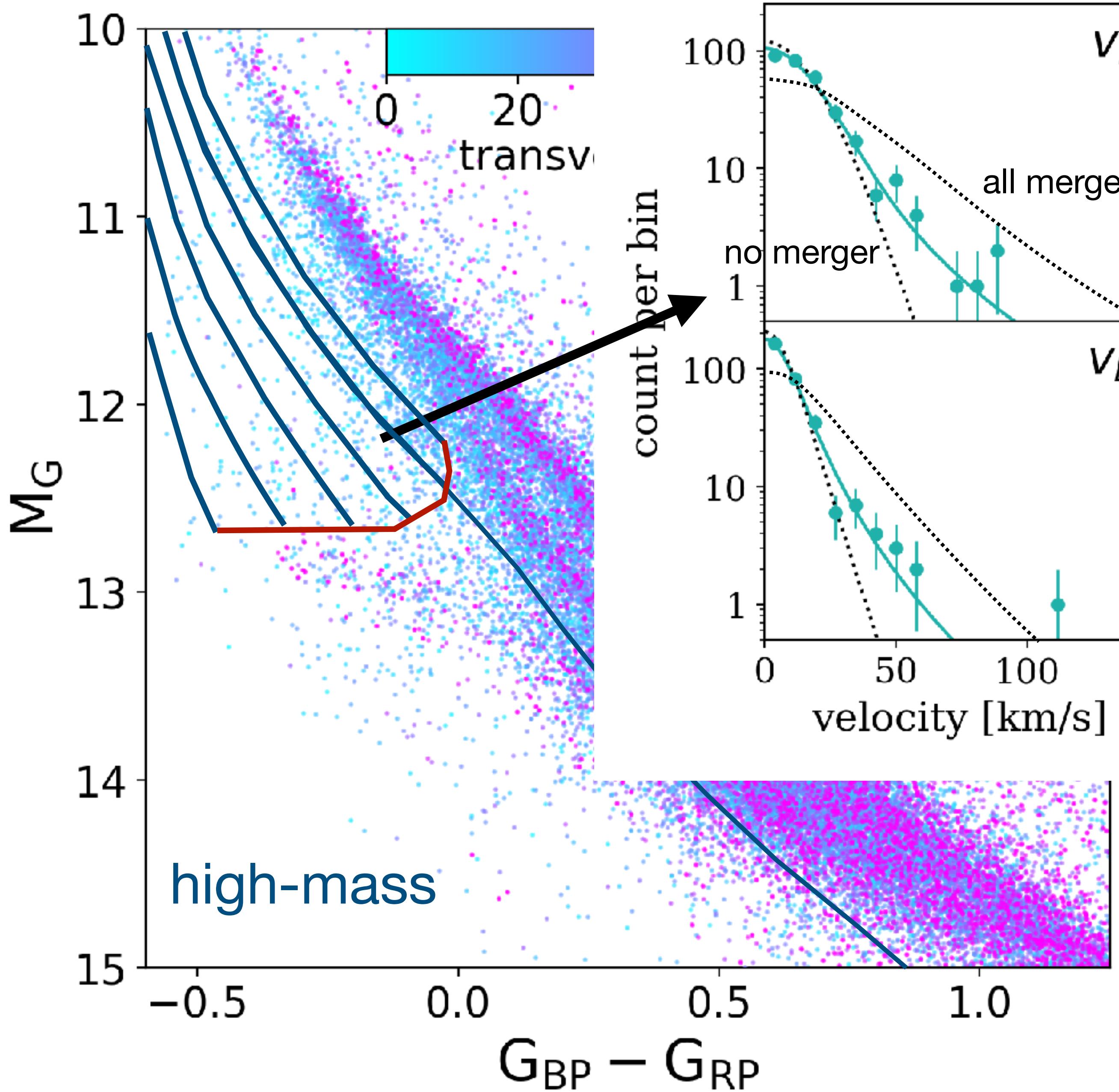


- single-star evolution
- merger products: **20%**

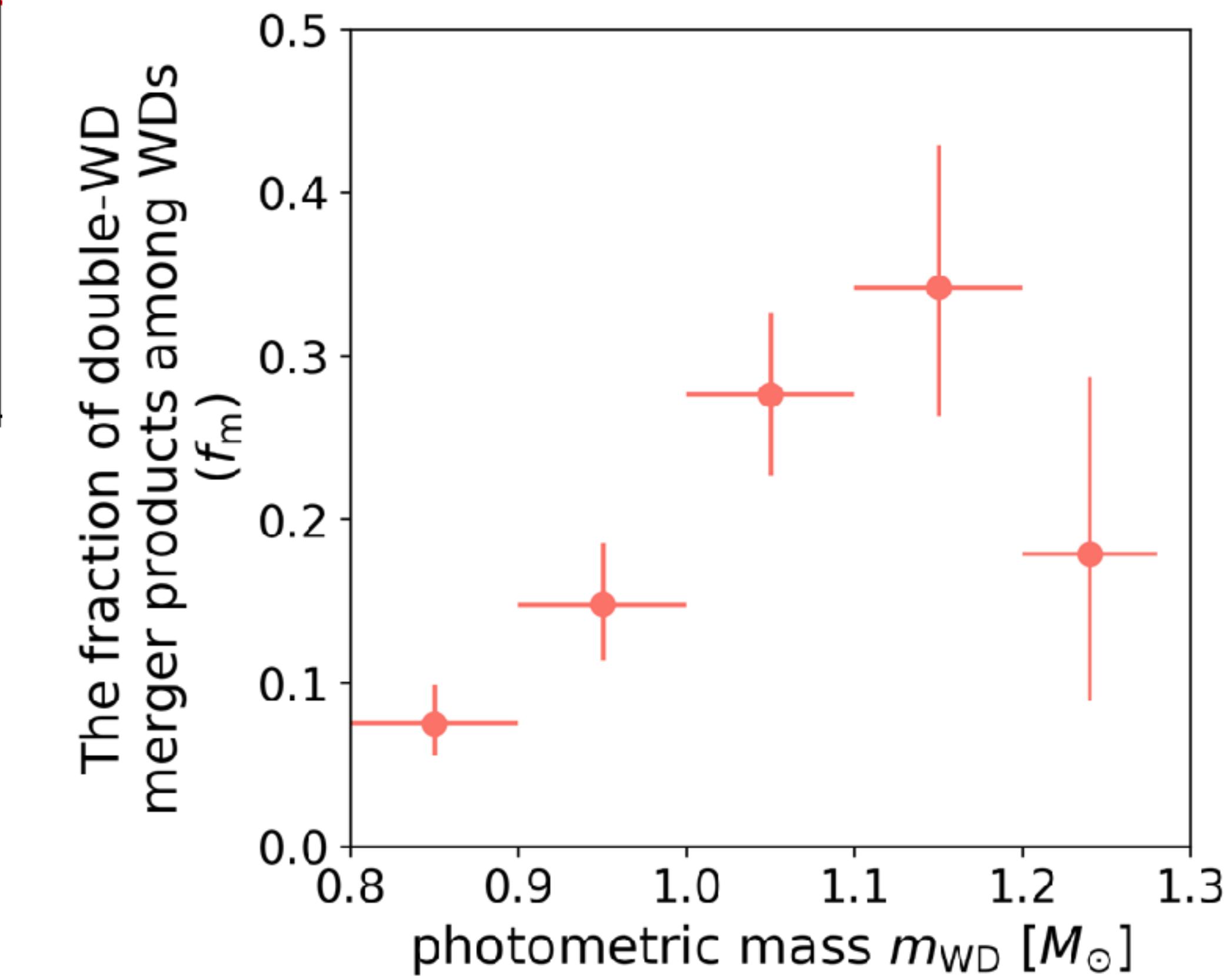
in milky way, old = moving fast



# origins of massive white dwarfs

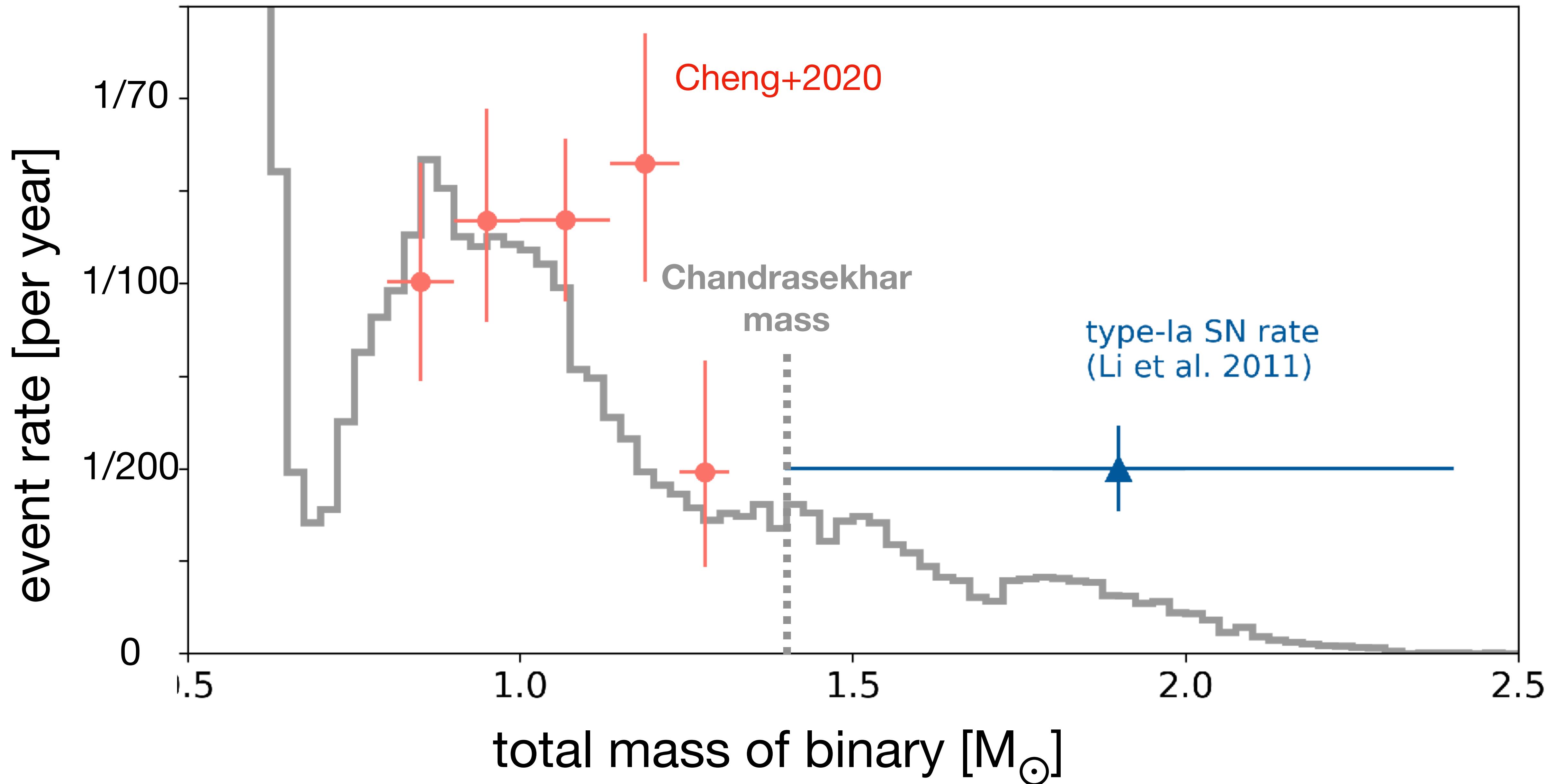


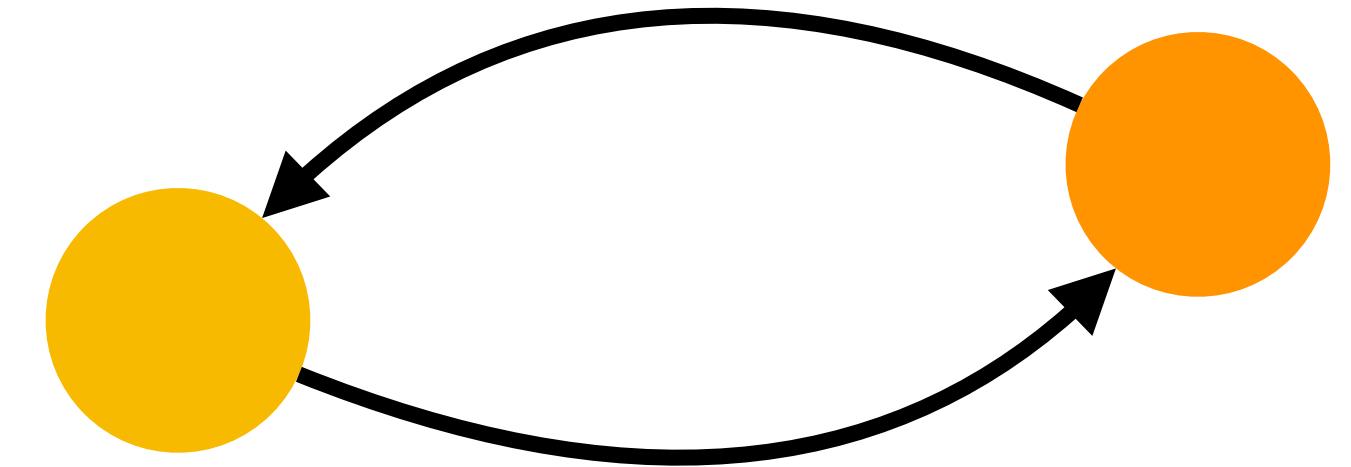
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# double-WD merger and type-Ia supernovae

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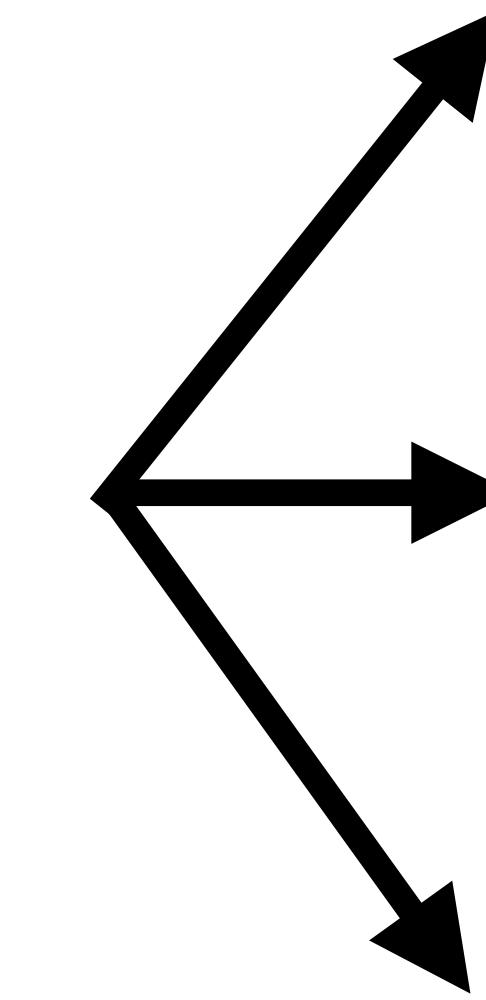
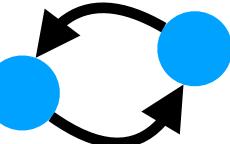




MS binary



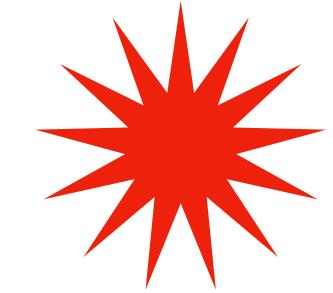
double WD binary



massive WD

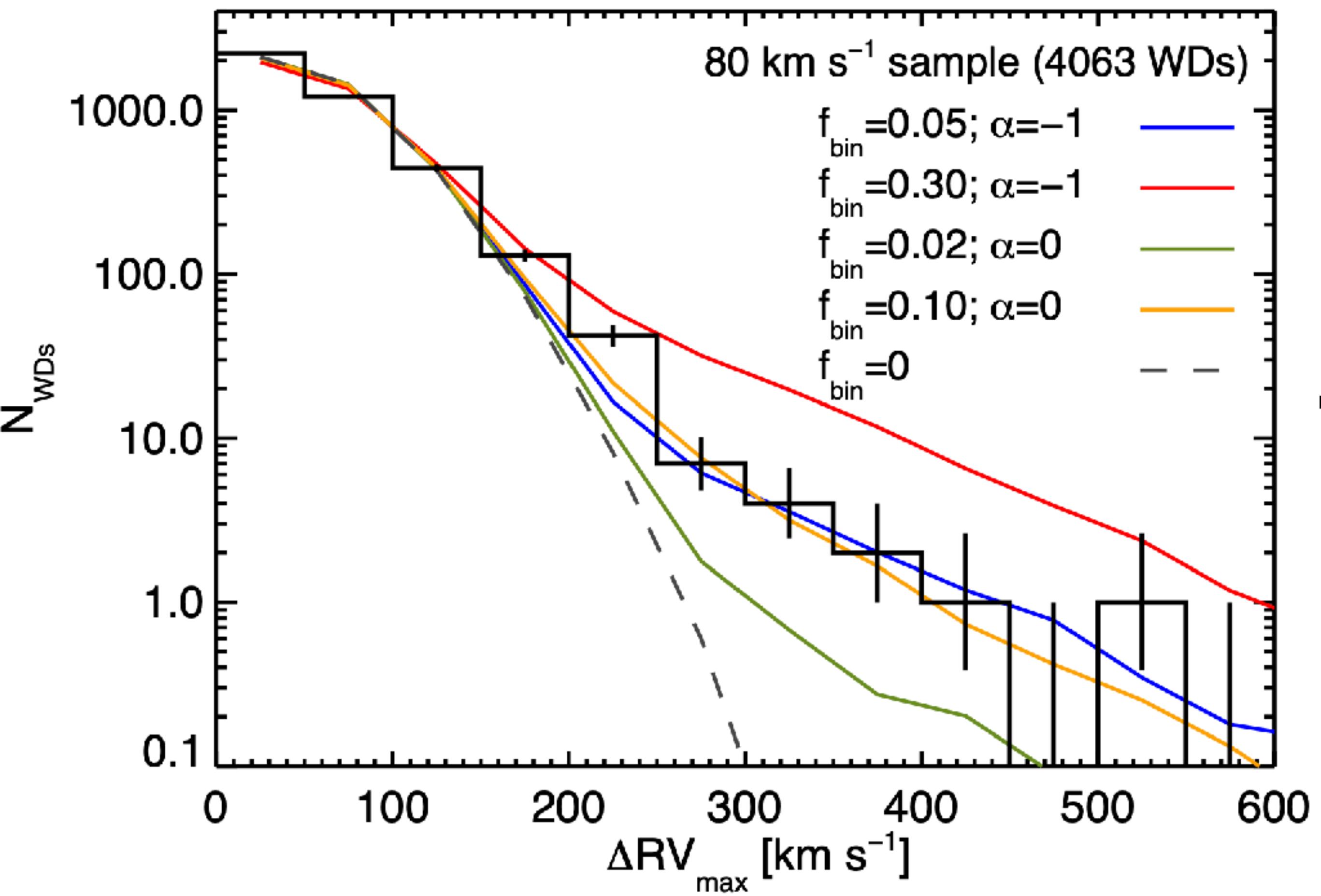


neutron star

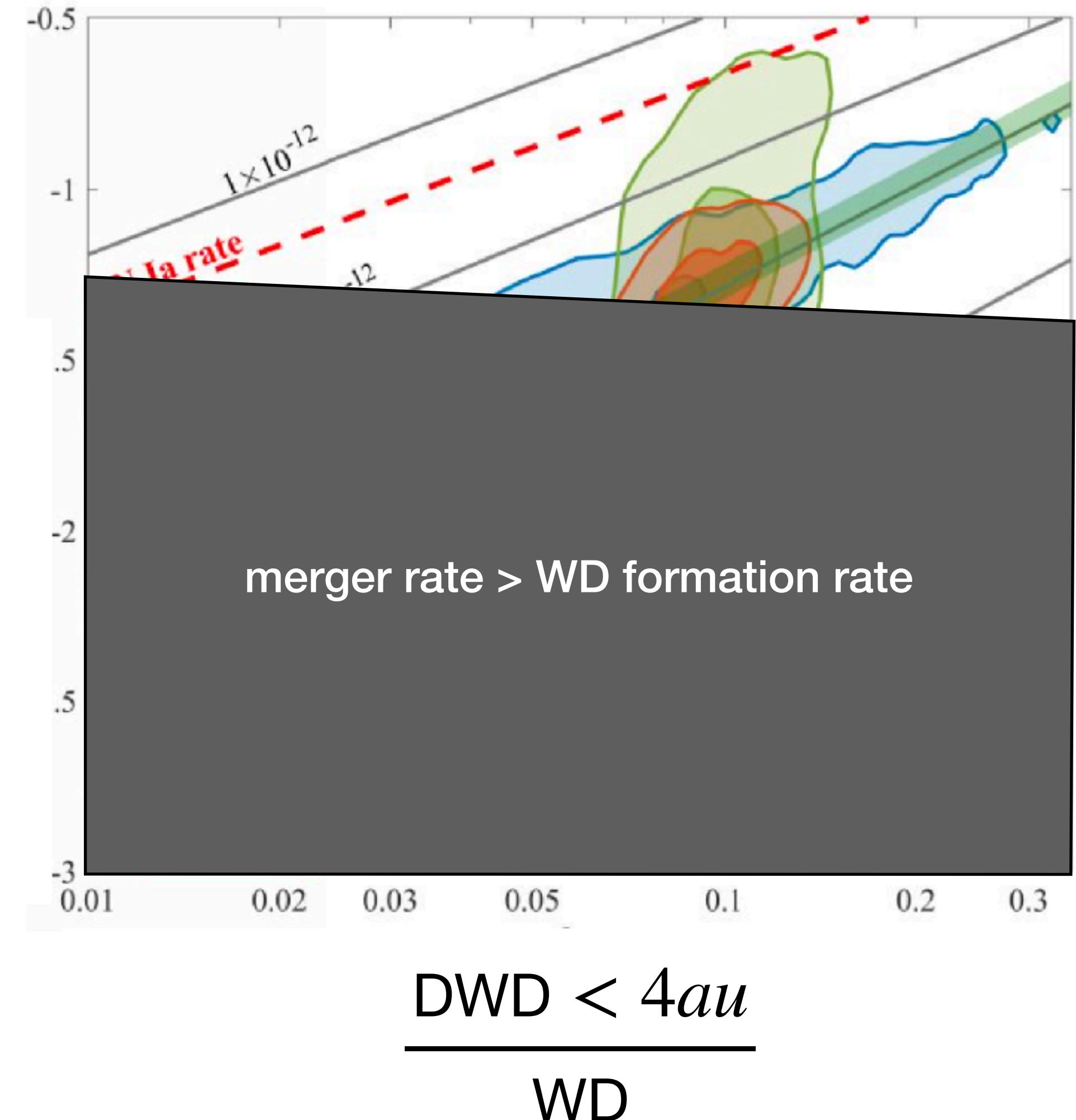


type-Ia supernova

all massive white dwarfs  
are merger products?



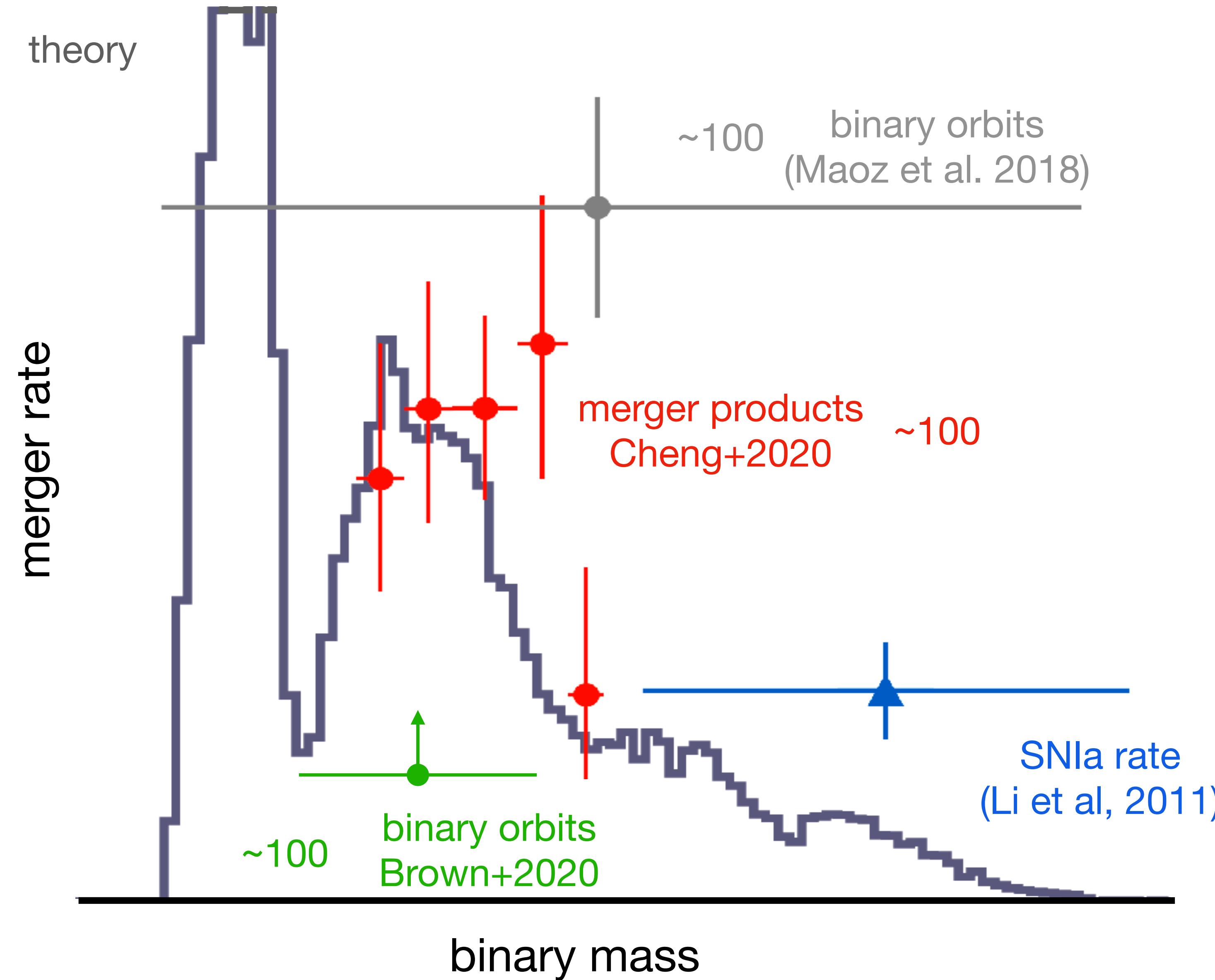
DWD orbit power index



Badenes&Maoz 2012

Maoz+2018

# double-WD merger and type-Ia supernovae



**10+ years from now, what can we imagine?**

**LISA white paper, and beyond?**