A Tale Of Two (relatively) Massive Stars

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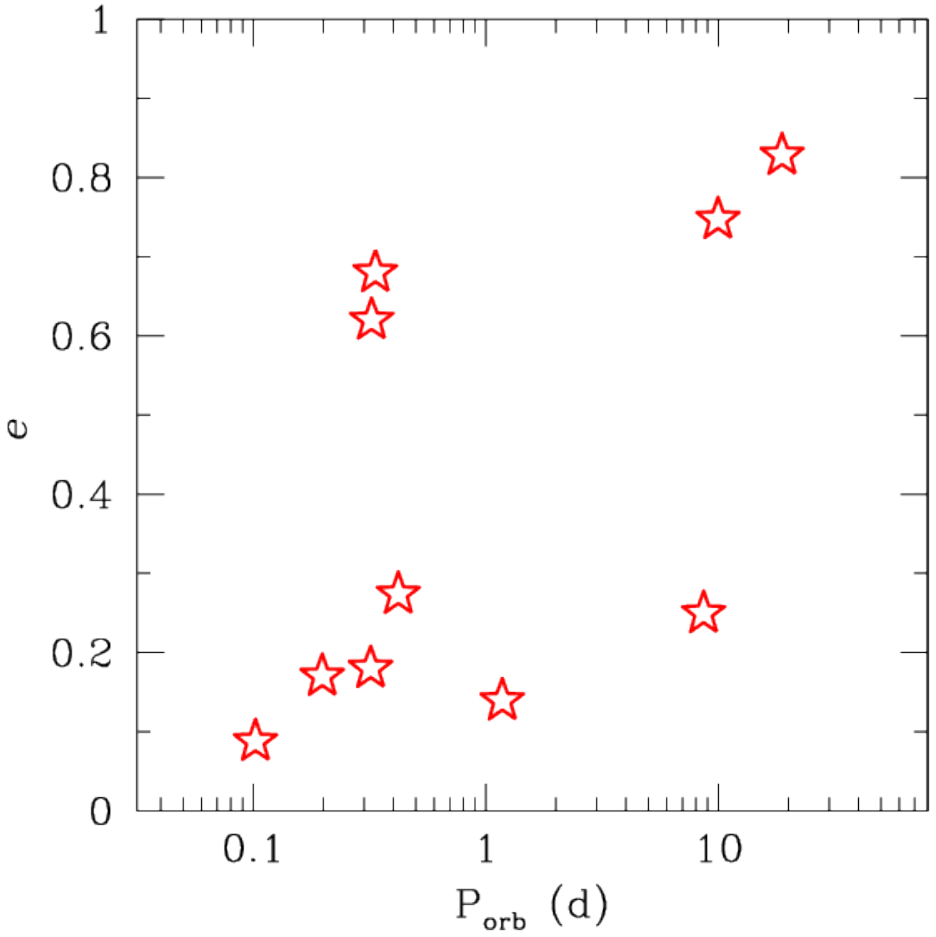
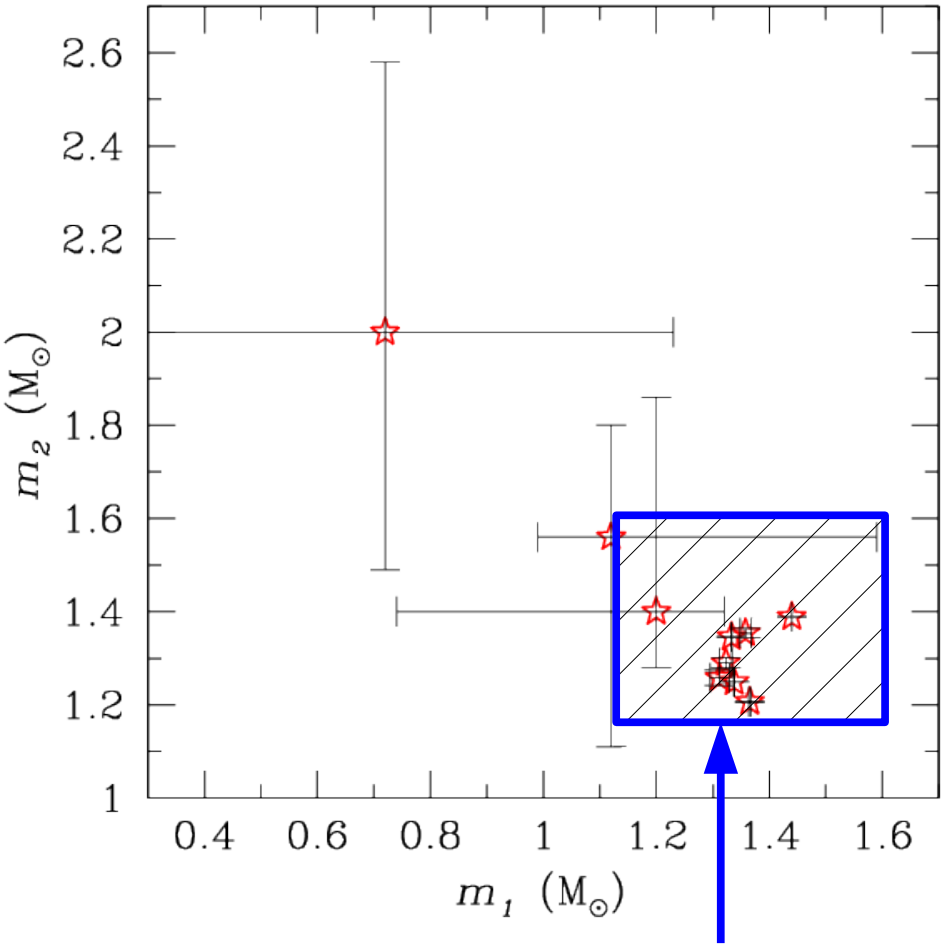
Two neutron stars like several others in the nearby Universe..

~ 10 double NS binaries, https://jantoniadis.wordpress.com/research/ns-masses/



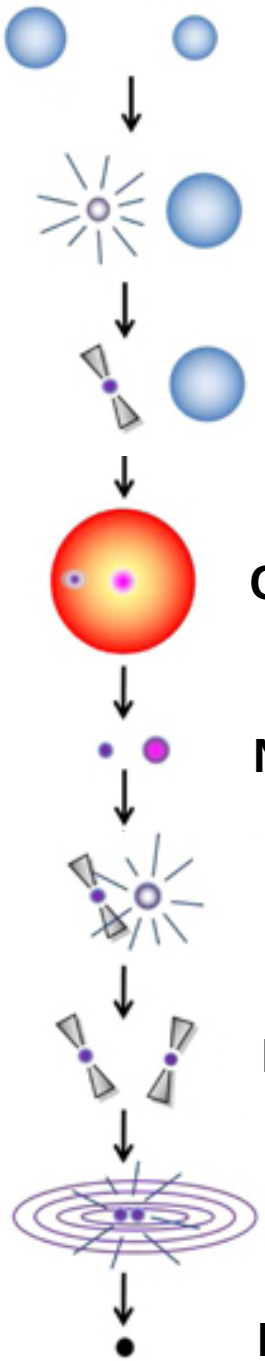


GW170817 masses

But, unlike the others, GW170817 already merged!

Abbott et al. 2017, https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.119.161101

What do we know about their evolution?



ZAMS
mass 8 – 20 Msun

supernova (SN)

NS

Common envelope (CE)

NS + He star

2nd SN

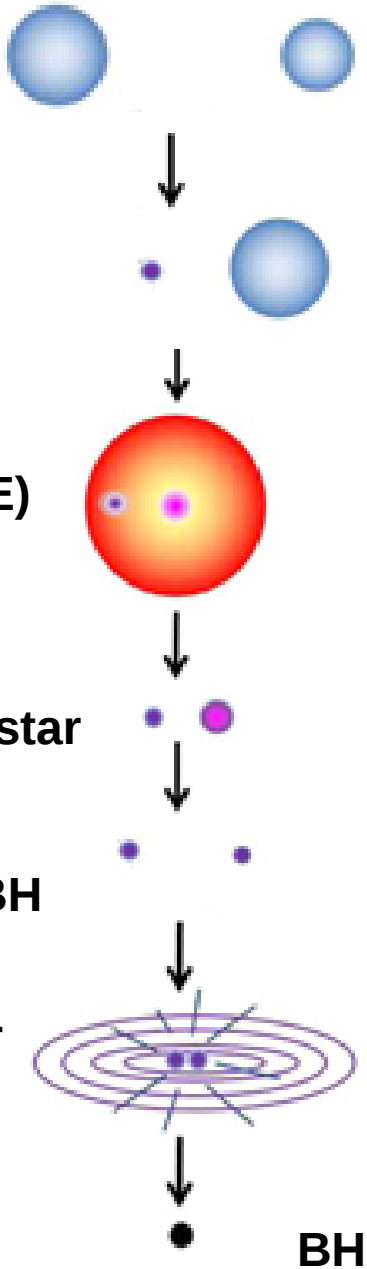
Double NS

Double NS merger

BH

Tauris et al. 2017

ZAMS
mass >> 20 Msun



DIRECT
COLLAPSE
TO BH

Common envelope (CE)

BH + He star

2nd DIRECT
COLLAPSE TO BH

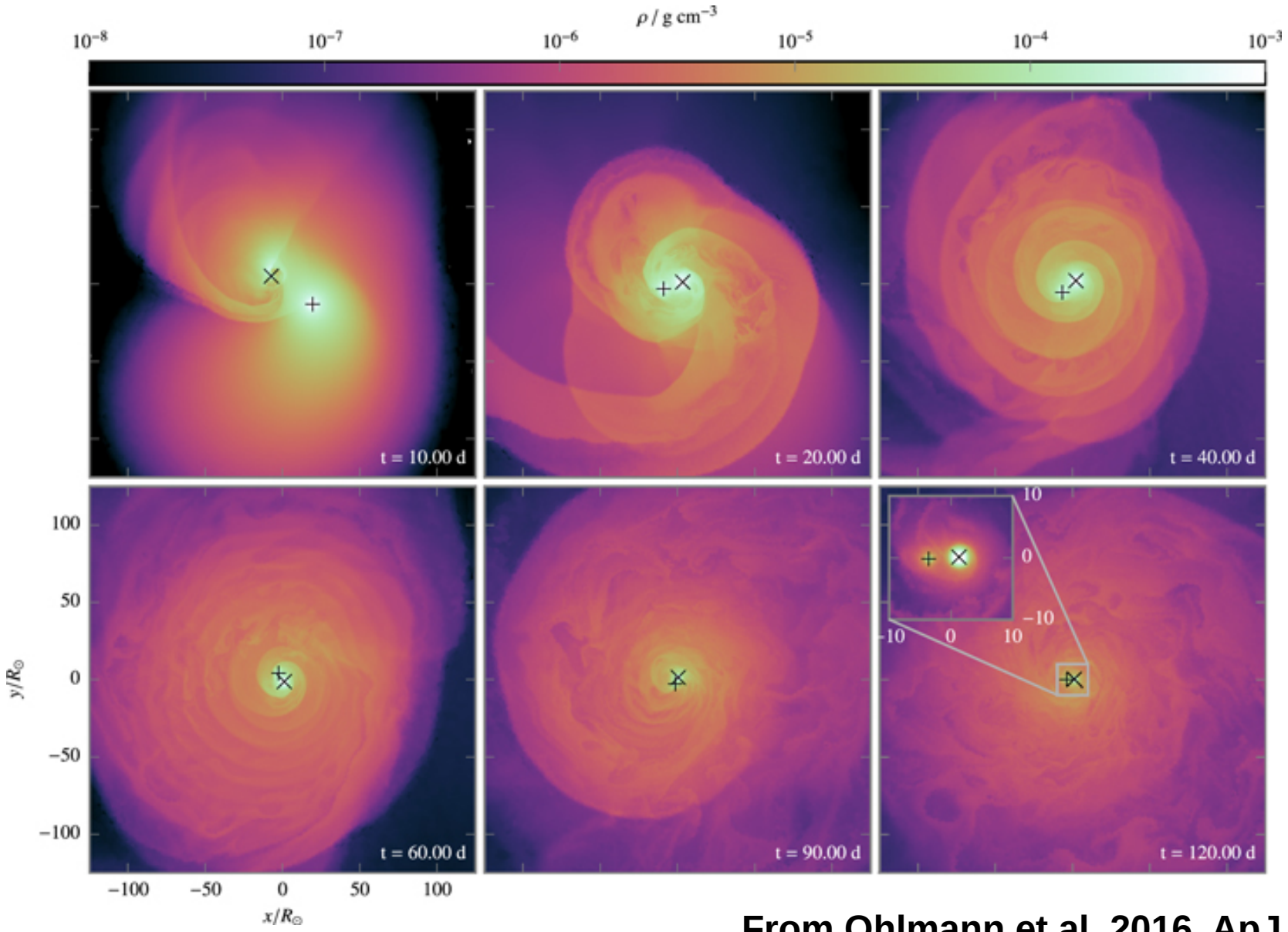
Double BH merger

BH

Belczynski et al. 2016
MM et al. 2017
Stevenson et al. 2017

What are the open questions?

1. Common envelope efficiency: how likely is ejection of the envelope? (problem similar to BHs)



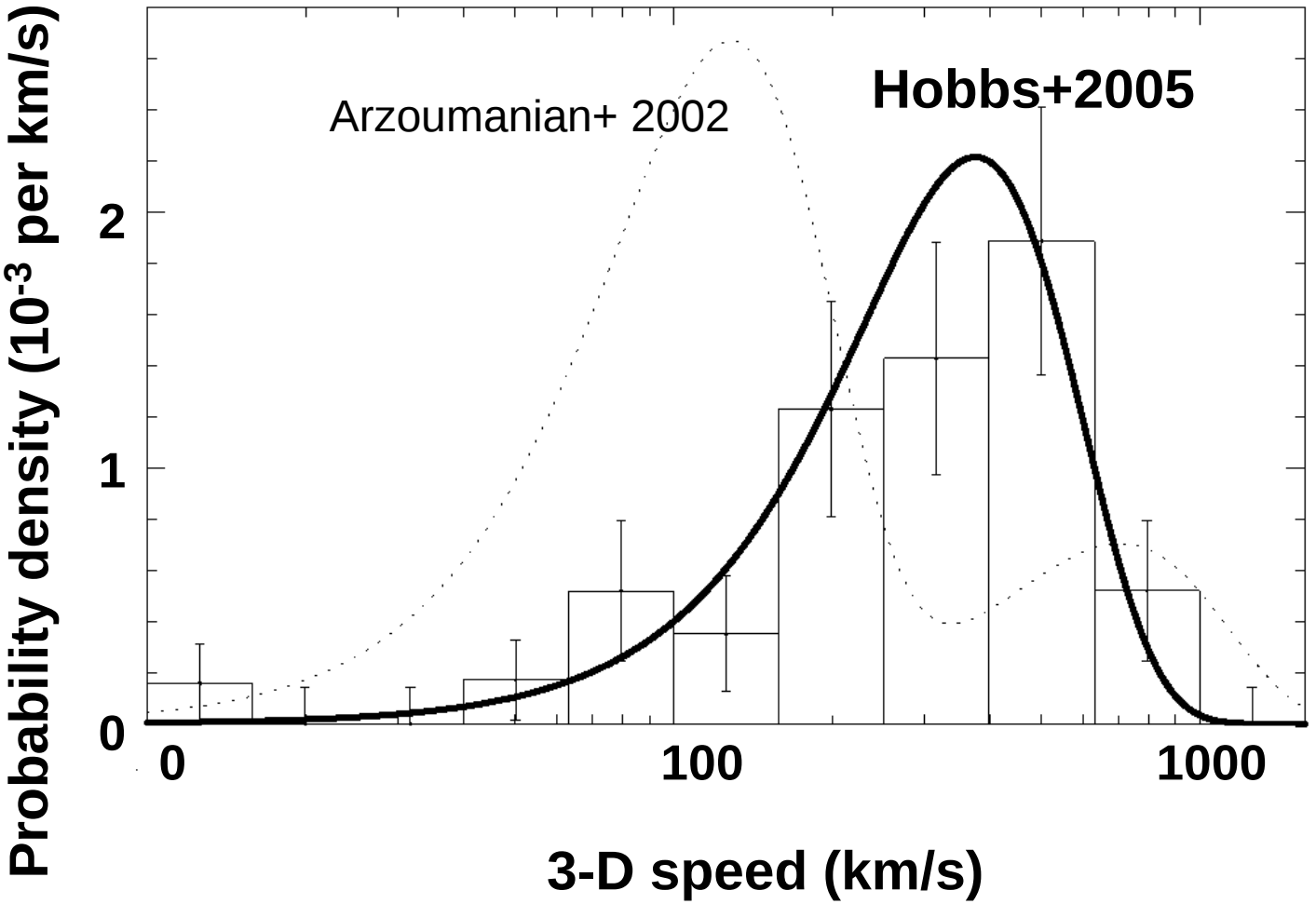
From Ohlmann et al. 2016, ApJ, 816, L9

What are the open questions?

2. Problem of supernova (SN) kicks (not a strong issue for BHs)

Hobbs+ (2005):
3-D velocity distribution of pulsars obtained from the observed 2-D distributions of SINGLE pulsars

→ Maxwellian distribution with sigma ~ 265 km/s



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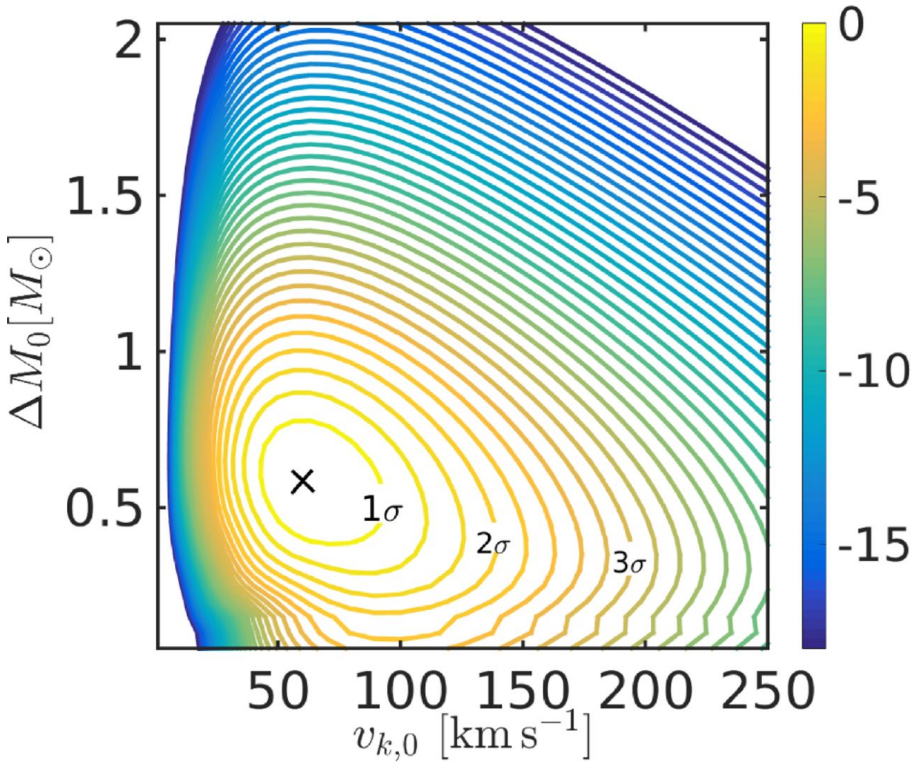
Beniamini & Piran 2016:

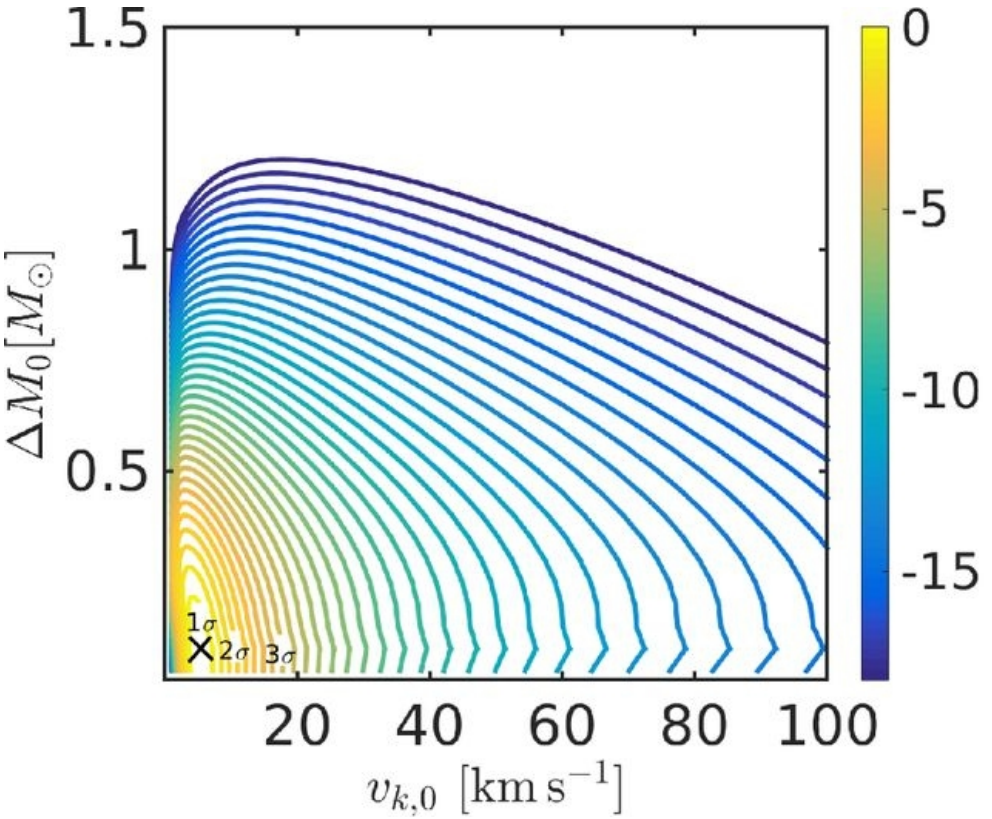
Estimate kick of double neutron stars only

Maximum likely-hood of ejected mass and kick from conservation of energy and angular momentum

10 NS binaries



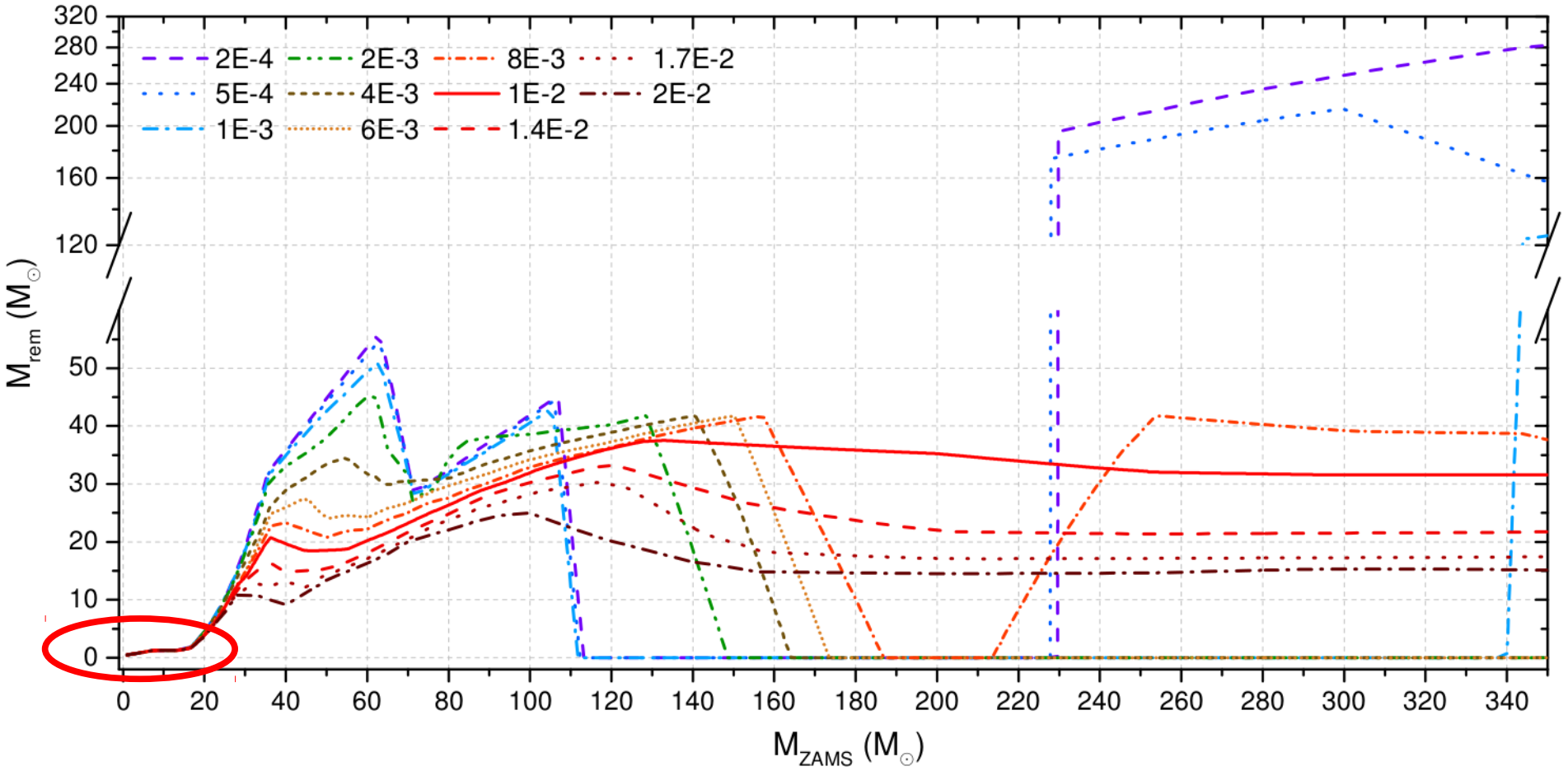
6 NS binaries with small eccentricity



What are the open questions?

3. What kind of SN explosion?

– detail of SN more important for small remnants than for big remnants



Spera & MM 2017

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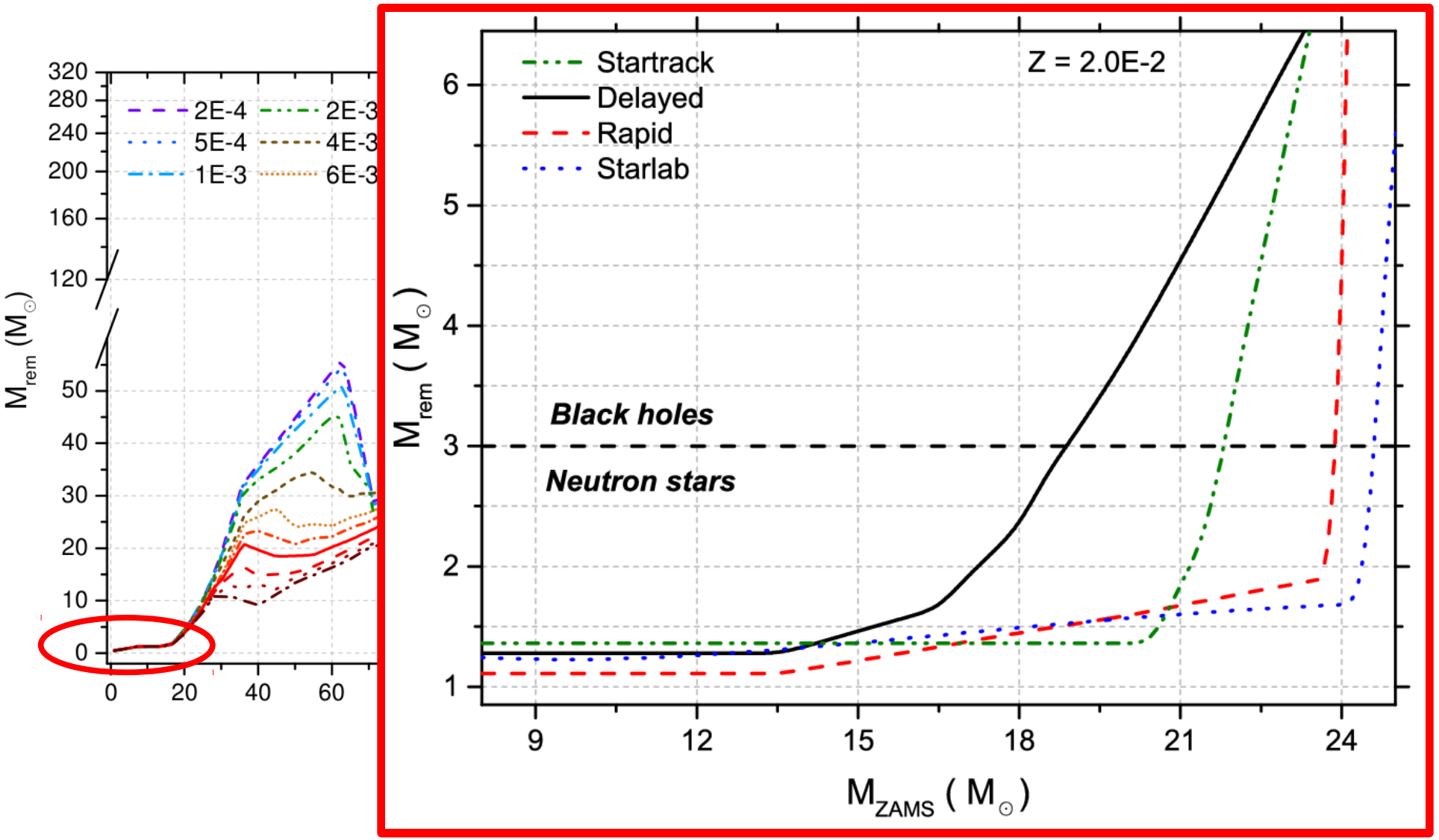


What are the open questions?

3. What kind of SN explosion?

– **detail of SN more important for small remnants than for big remnants**

– **core collapse or electron capture SN?**

Core collapse SN:
collapse at the
end of nuclear burning
(Fe core) of >9 Msun star

*** High kicks?**
*** High mass (>1.4 Msun)?**

Electron-capture SN:
Collapse of ONe core
triggered by electron capture
in 5 – 10 Msun stars

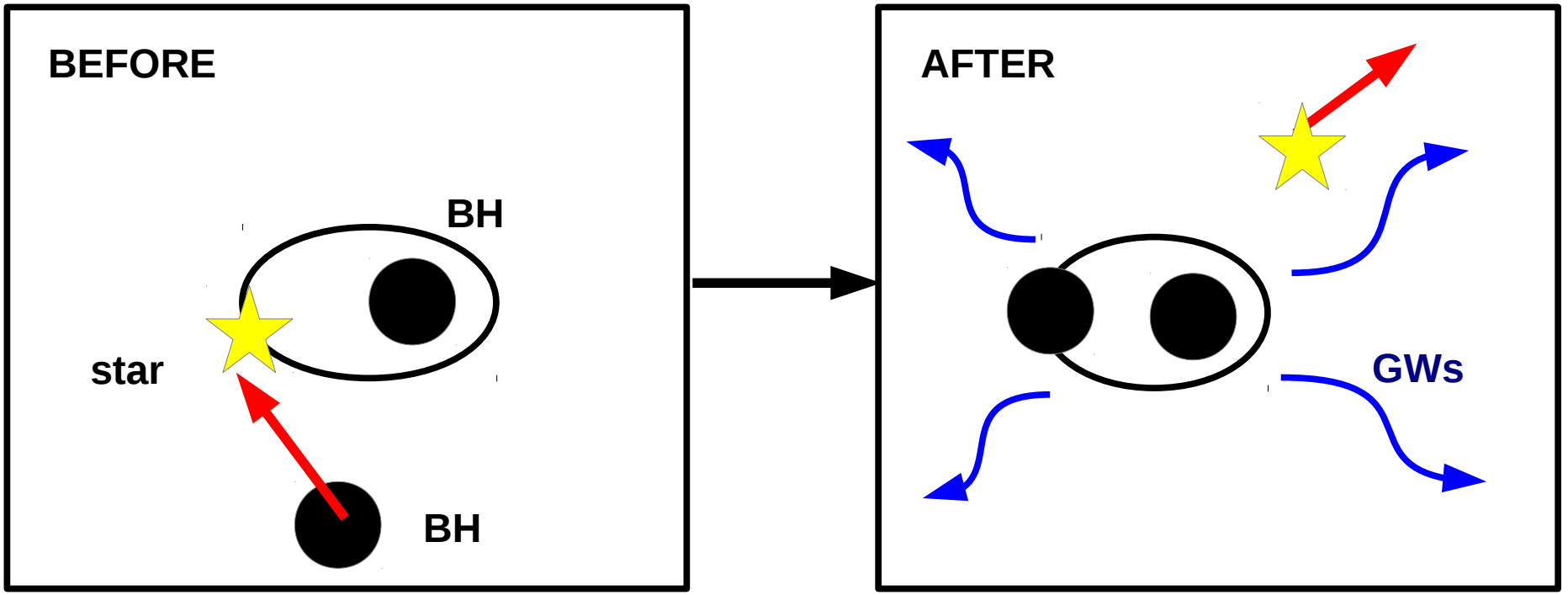
*** Low kicks (<50 km/s)?**
*** Low mass (1.0-1.4 Msun)?**
*** Only in binary evolution?**

van den Heuvel 2007

What are the open questions?

4. Dynamical evolution?

– Less important than for BHs because of small NS mass



What are the open questions?

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– However in old globular clusters NS are more massive than the other stars: may participate in exchanges, three-body encounters, etc.
(Sigurdsson et al. 1995, no recent work)

M15
with HST

What are the open questions?

4. Dynamical evolution?

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– However in old globular clusters NS are more massive than the other stars:
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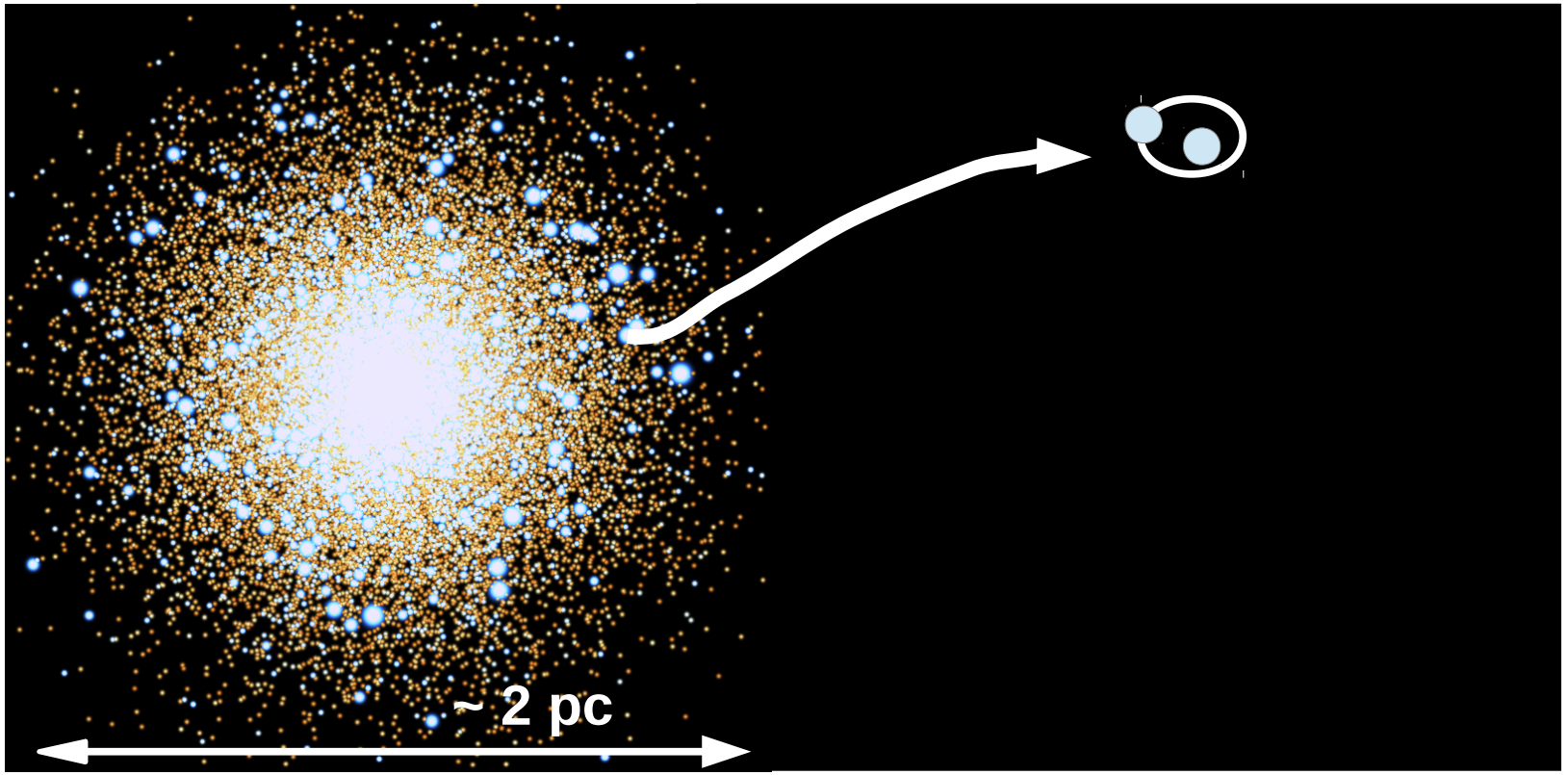
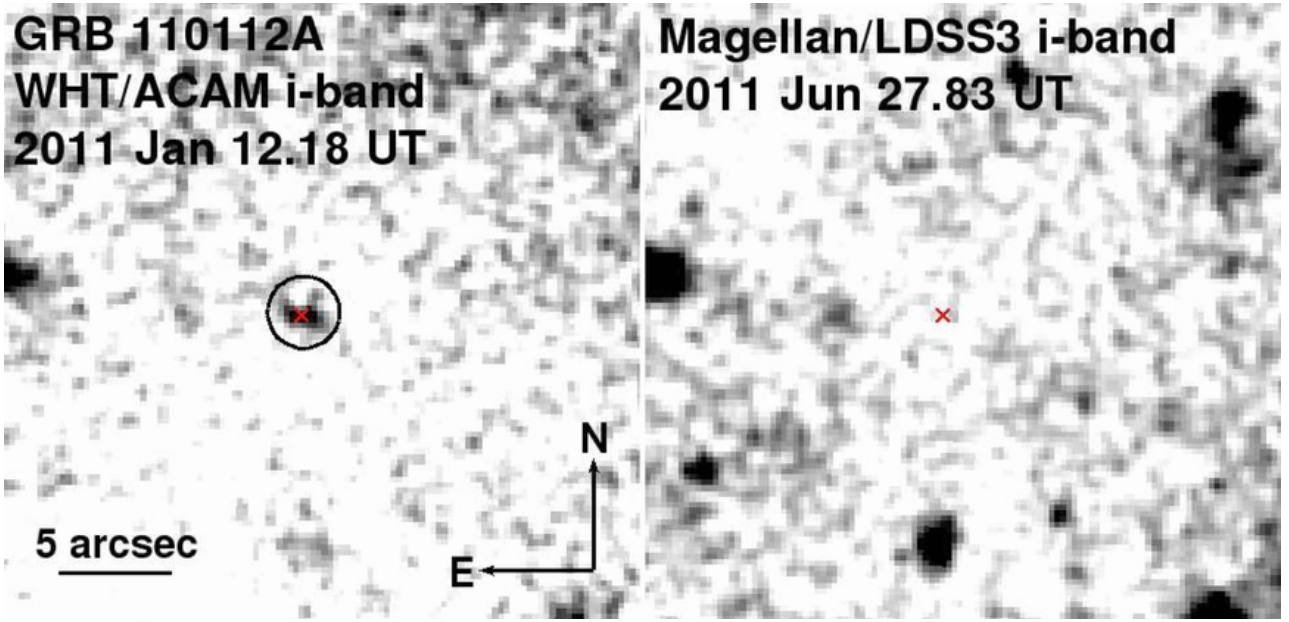
– NS binaries can be dynamically ejected from parent cluster

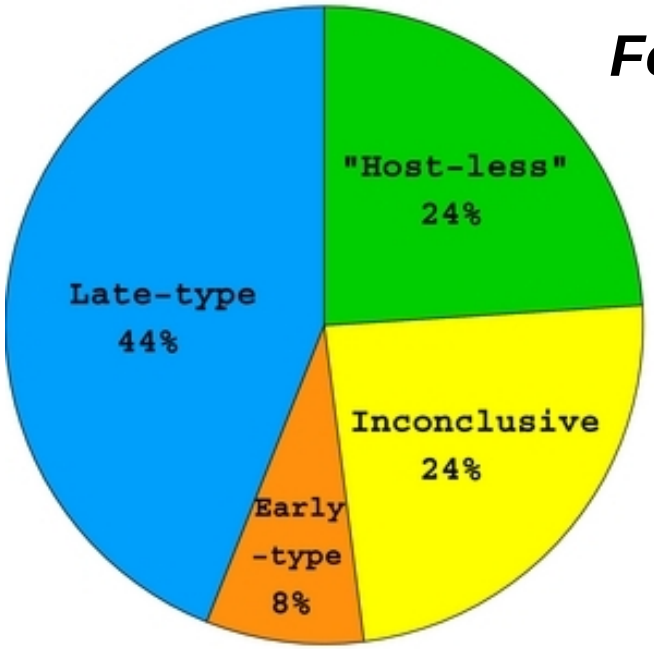


What are the open questions?

Are host-less short GRBs associated with dynamical ejections?



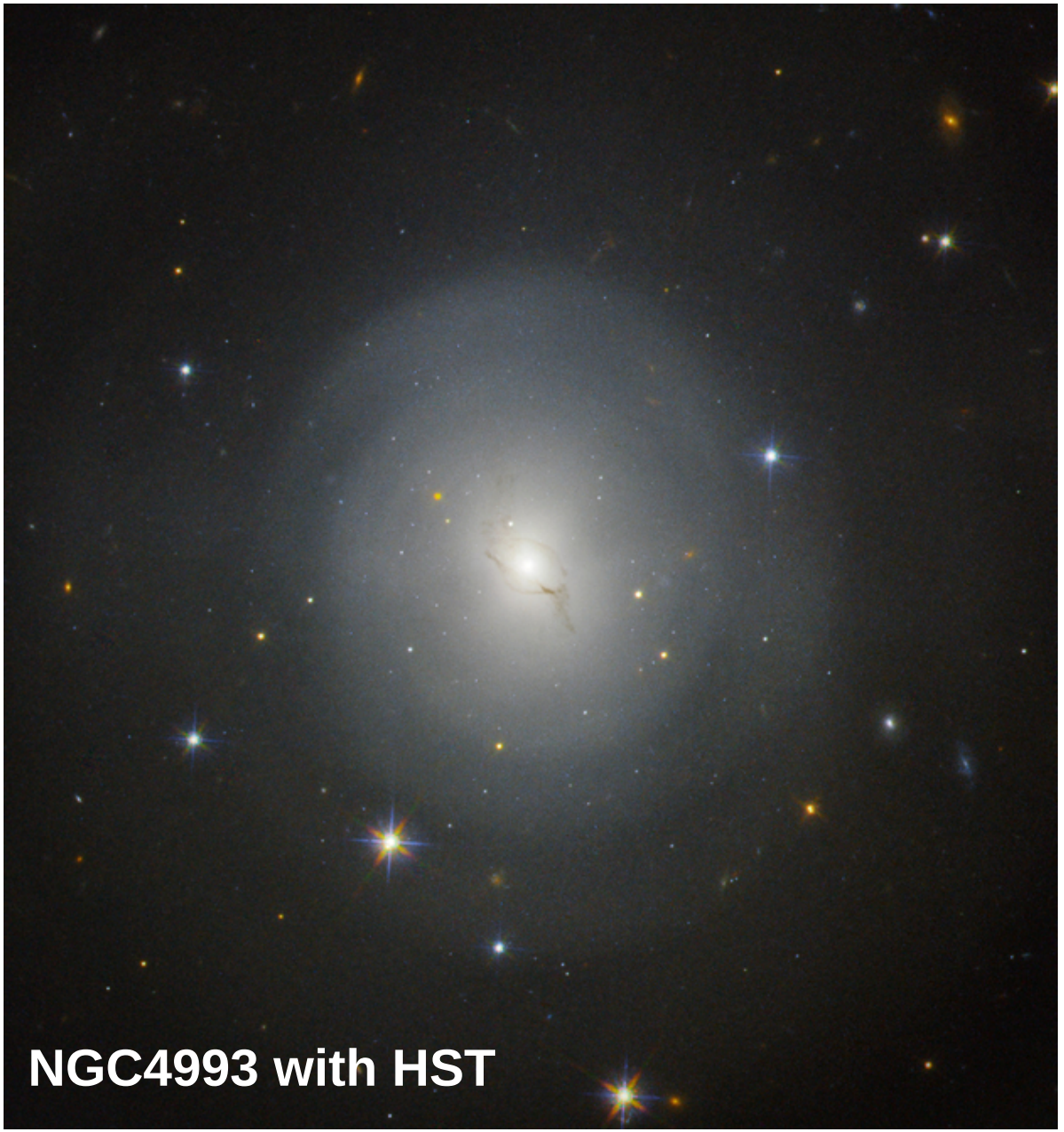
Fong+ 2013, ApJ, 769, 56



ISSUE: dynamical kicks 0 – 200 km/s

not enough to unbind system from host galaxy

What can we learn from the environment of GW170817?



An early-type galaxy:
- mostly old stars
- likely long evolution before merger

No globular clusters:
- either did not form in globular clusters
- or ejected by SN or 3-body kicks

Pian et al. 2017

Features of galaxy merger?

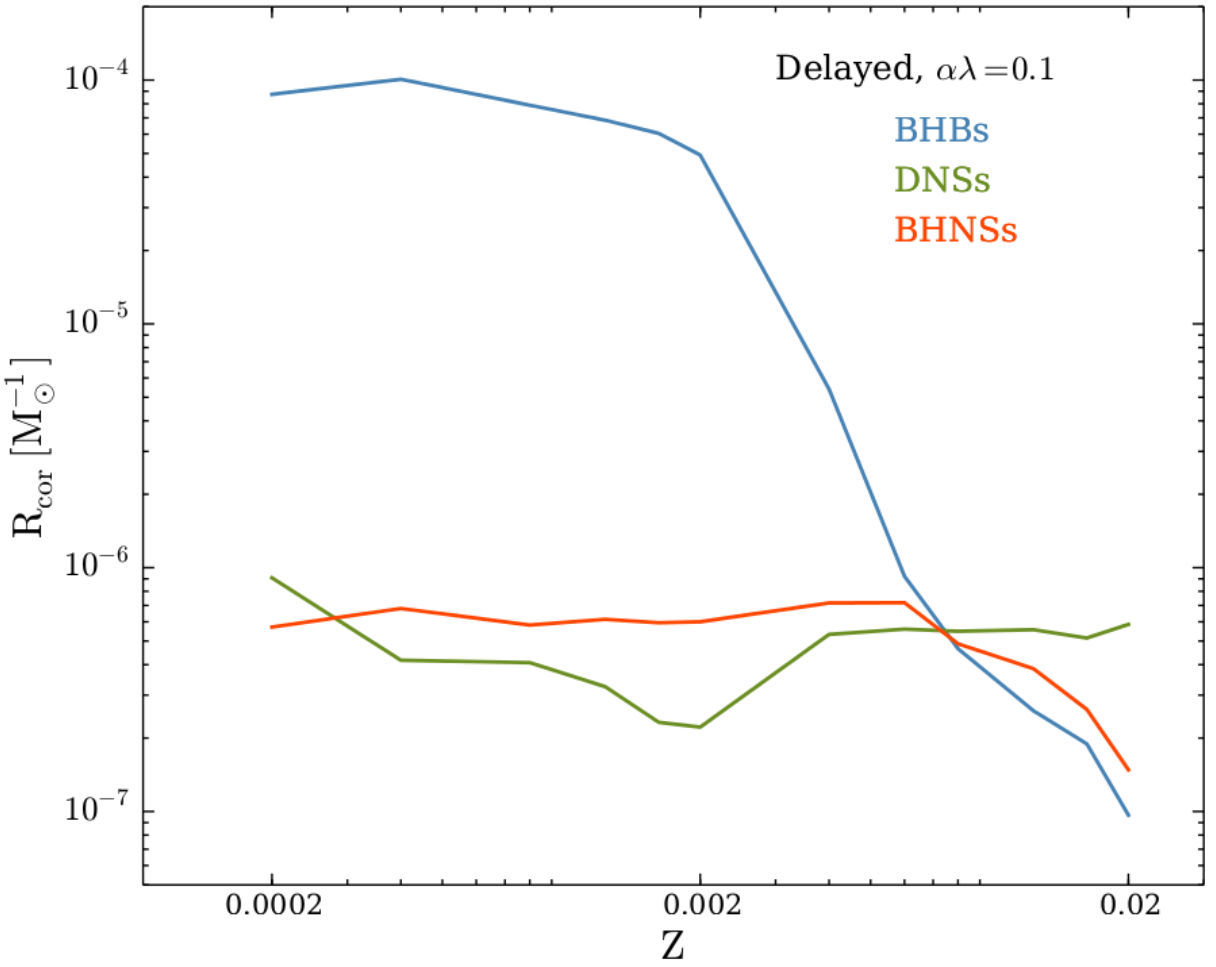
The role of METALLICITY in BH mergers versus NS mergers:

Completely different trend with metallicity

Number of mergers per unit mass (in a given population)

versus

metallicity



Giacobbo+ 2018

we expect NS mergers to be produced with equal probability both in metal poor and in metal rich galaxies

But the redshift ~ 0 Universe is richer of metal rich than metal poor galaxies → dominant formation in metal-rich environment

Short summary:

* properties of NSs in GW170817 similar to 10 DNS in Milky Way

* evolution similar to merging BHs but with lower ZAMS
  and with SNe

* many open issues:
  - common envelope
  - natal kick
  - supernova (core-collapse and electron-capture)
  - dynamics (formation and ejection)

* NGC4993 is an early type galaxy: old population, long evolution

* merging NS binaries much more common than BH binaries
  at high metallicity?