The explosive life of massive binaries

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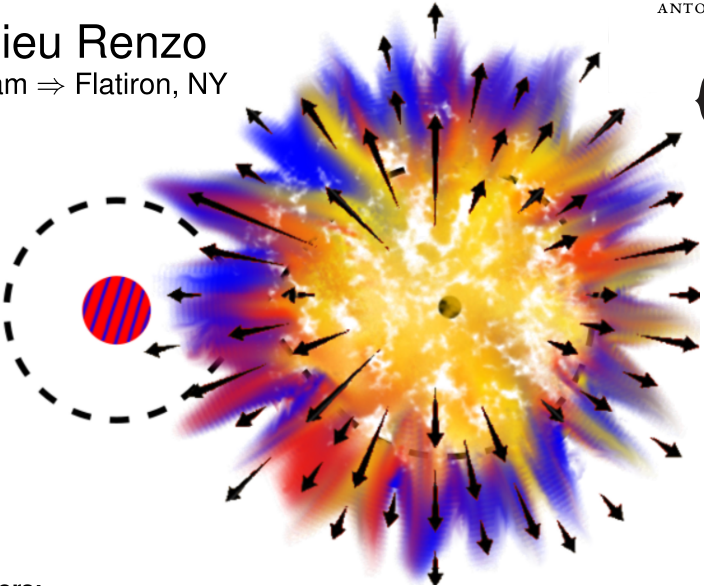
BinCosmos

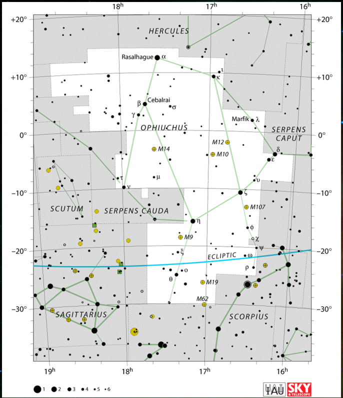
Mathieu Renzo

Amsterdam ⇒ Flatiron, NY



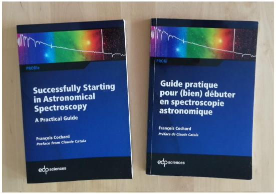
Collaborators:
S. E. de Mink, E. Zapartas, Y. Götberg, S. Justham, R. Farmer, R. G. Izzard, S. Toonen, D. J. Lennon, D. Hendricks, E. Laplace, A. van Son, S. N. Shore, V. van der Meij, ...

ζ Ophiuchi: nearest O type star to Earth



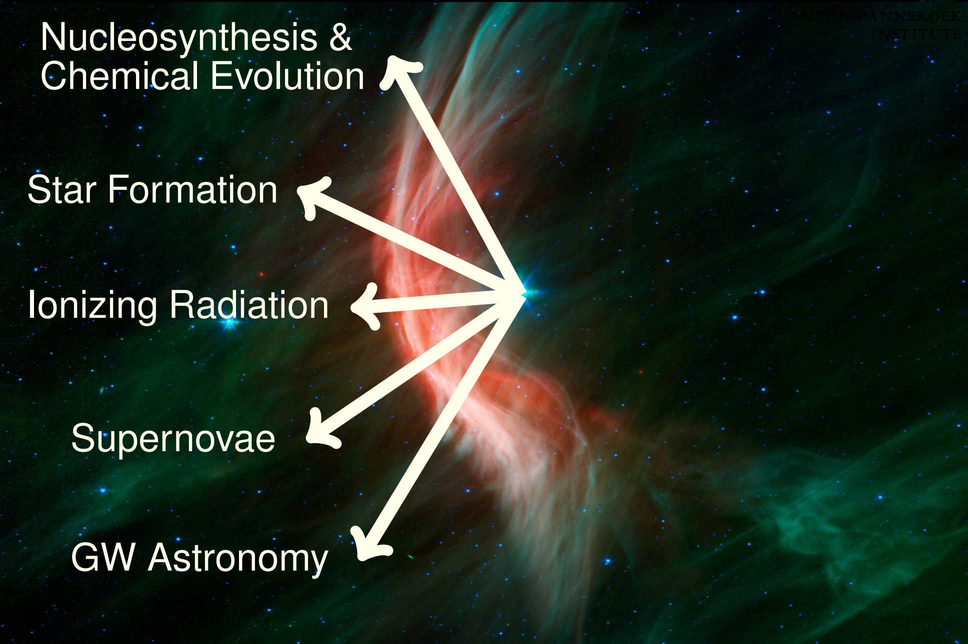
NASA, JPL-Caltech, Spitzer Space Telescope

Successfully starting in Astronomical Spectroscopy



Author: F. Cochard

Why are massive stars important?



NASA, JPL-Caltech, Spitzer Space Telescope

Why are massive stars important?

Nucleosynthesis &
Chemical Evolution

Star Formation

Ionizing Radiation

Supernovae

GW Astronomy

~70% of O type stars are born in close binaries

(e.g., Mason *et al.* '09, Sana & Evans '11, Sana *et al.* '12, Kiminki & Kobulnicky '12, Kobulnicky *et al.* '14, Almeida *et al.* '16)

NASA, JPL-Caltech, Spitzer Space Telescope

How explosions can affect the binaries

The most common massive binary evolution path

“Widowed” stars as runaways and walkaways

How binaries can affect the explosions

Does binarity make the explosions easier?

SN rates & binarity

Binaries with a compact object

The case of 4U1700-37

SNe typically break binaries

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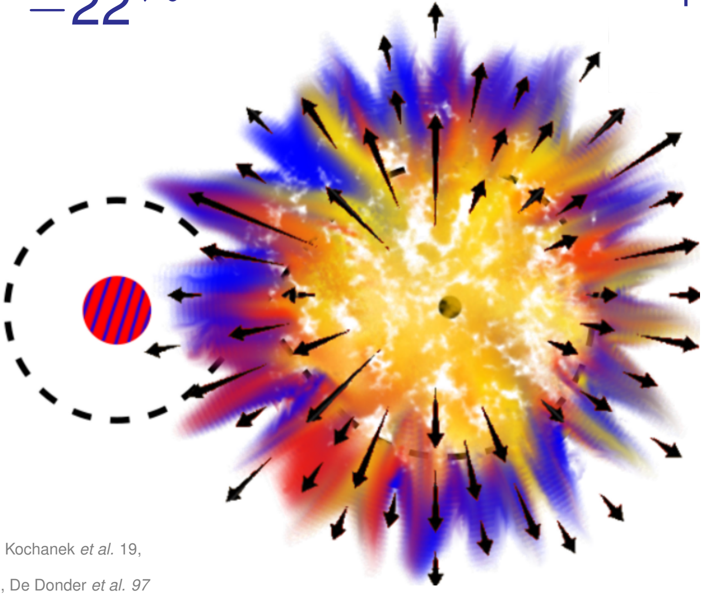
$86^{+11}_{-22}\%$ of massive binaries are disrupted



Renzo *et al.* 19b, Kochanek *et al.* 19,

Eldridge *et al.* 11, De Donder *et al.* 97

Most common massive binary evolution

Credits: ESO, L. Calçada, M. Kornmesser, S.E. de Mink

Spin up, pollution, and rejuvenation

The binary disruption shoots out the accretor

Spin up: Packet ’81, Cantiello *et al.* ’07, de Mink *et al.* ’13
Pollution: Blaauw ’93
Rejuvenation: Hellings ’83, Schneider *et al.* ’15

What exactly disrupts the binary?

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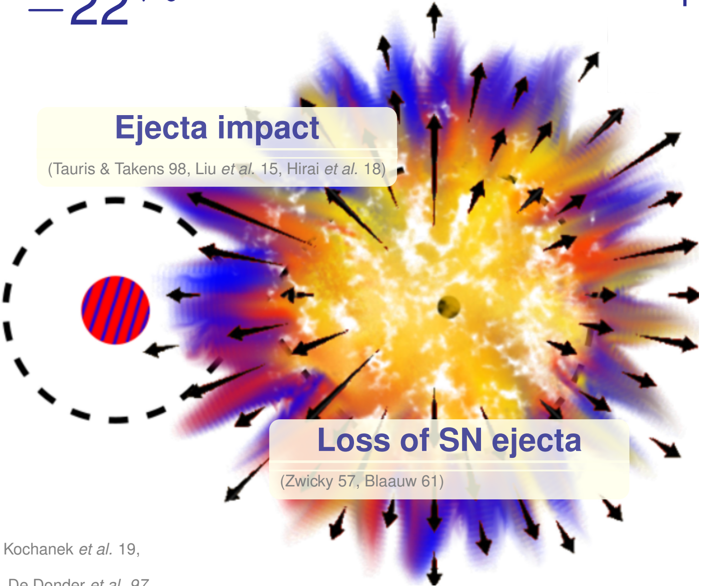

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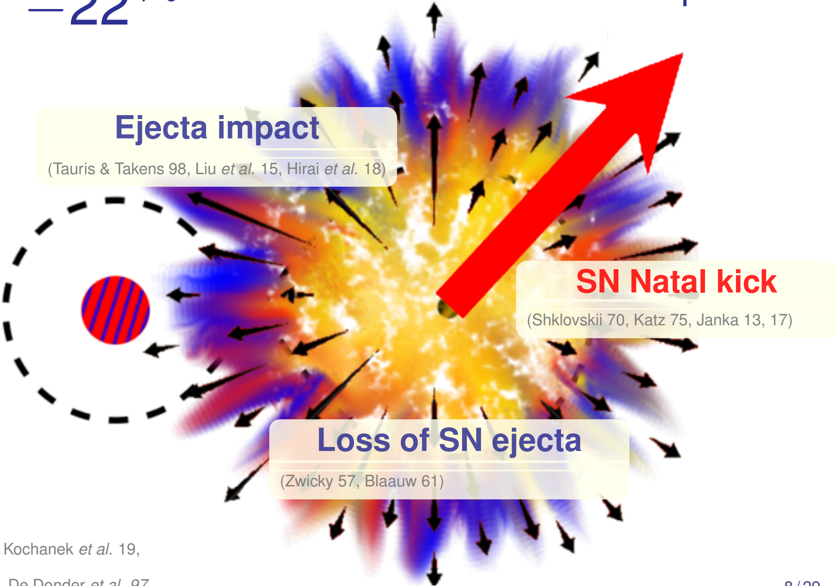

Renzo *et al.* 19b, Kochanek *et al.* 19,

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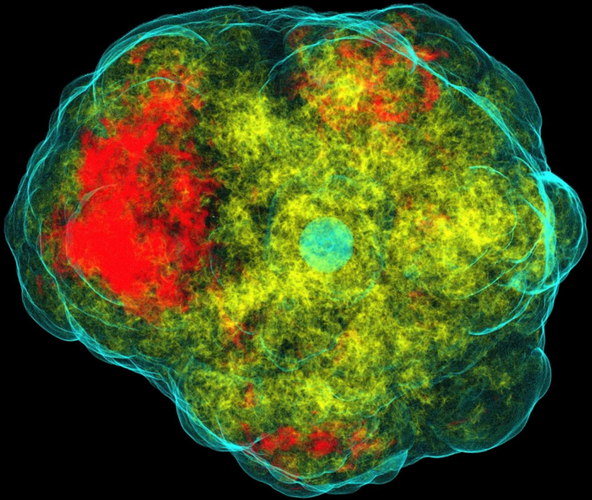
SN natal kick

Observationally: $v_{\mathrm{pulsar}} \gg v_{\mathrm{OB-stars}}$

Physically: ν emission and/or ejecta anisotropies



Credits: C. D. Ott, S. Drasco

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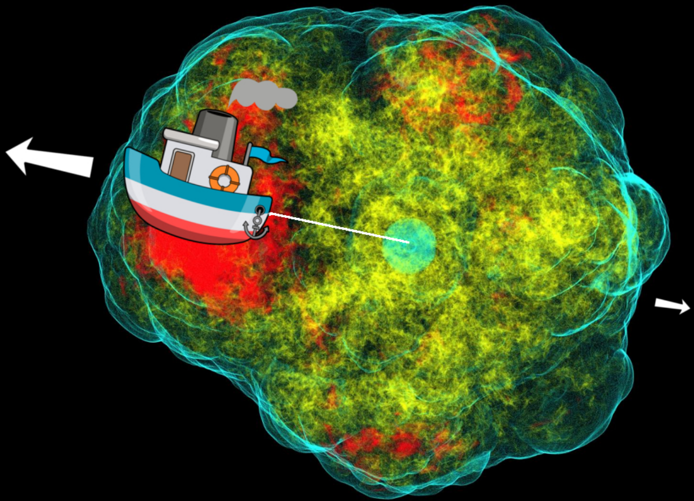


Credits: C. D. Ott, S. Drasco

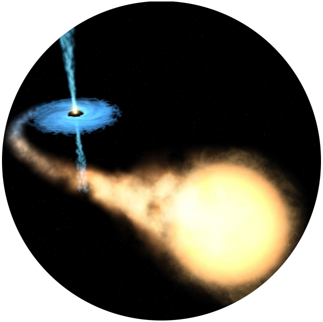
Do BHs receive kicks?

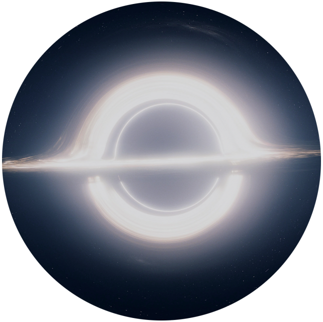
NO

$\Rightarrow$ most remain together with their widowed companion

YES

$\Rightarrow$ most are single and we can't see them...





e.g., Repetto *et al.* 12, Mandel 16, O'Shaugnessy *et al.* 17, Janka 17, Renzo *et al.* 19b, Atri *et al.* 19

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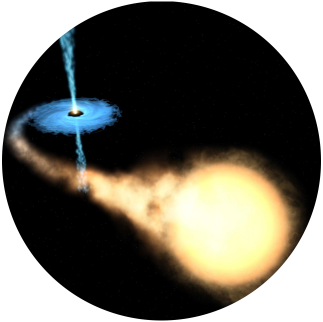

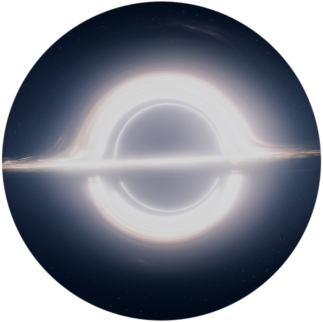

...but we can see the widowed companion

e.g., Repetto *et al.* 12, Mandel 16, O'Shaugnessy *et al.* 17, Janka 17, Renzo *et al.* 19b, Atri *et al.* 19

A way to constrain BH kicks with Gaia

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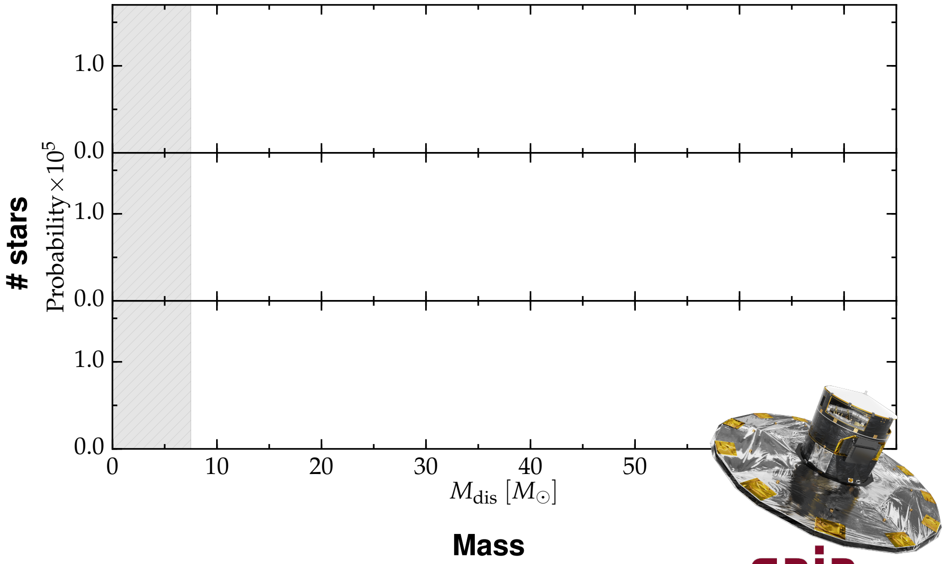
Massive runaways mass function ($v \geq 30\,\mathrm{km\ s^{-1}}$, $M \geq 7.5\,M_\odot$)



gaia

Renzo *et al.* 19b

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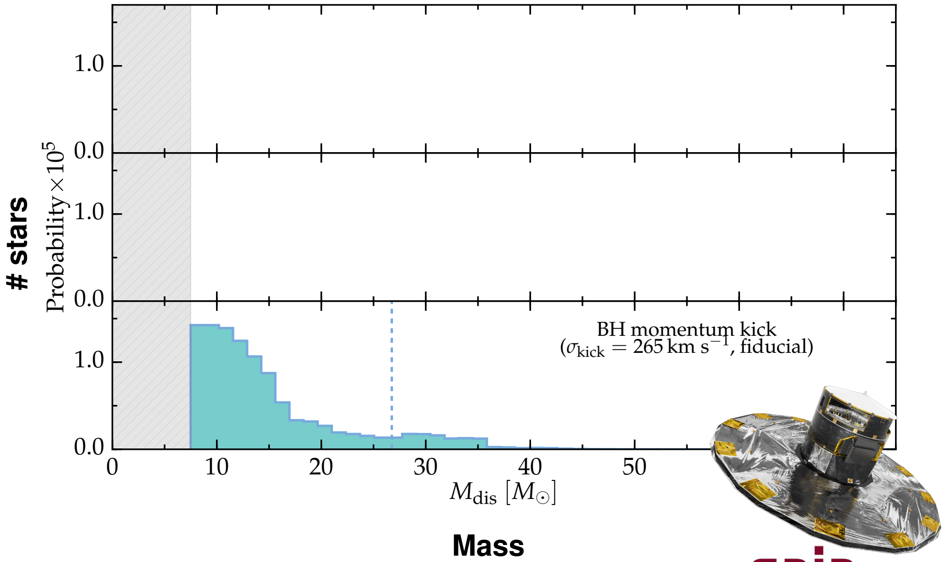

gaia

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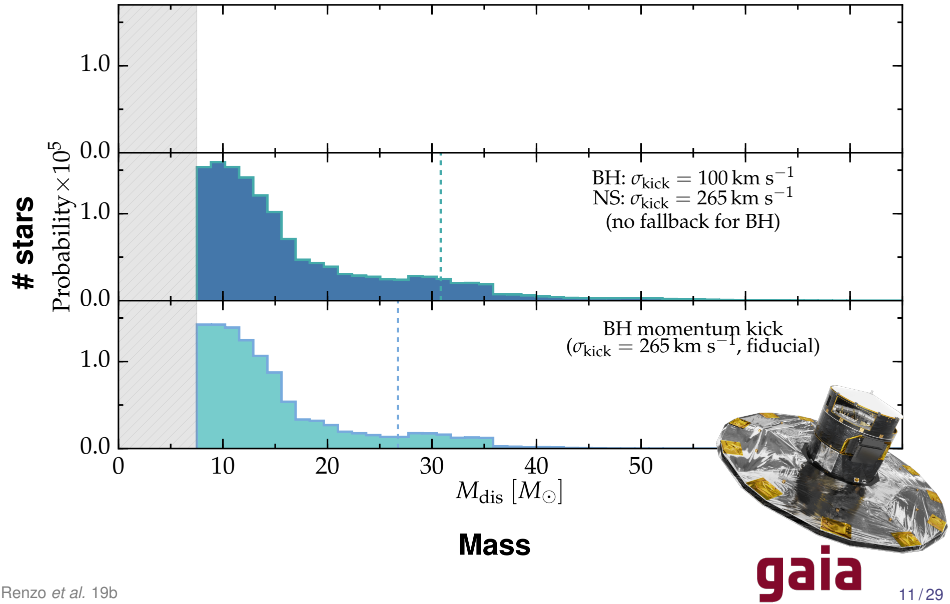

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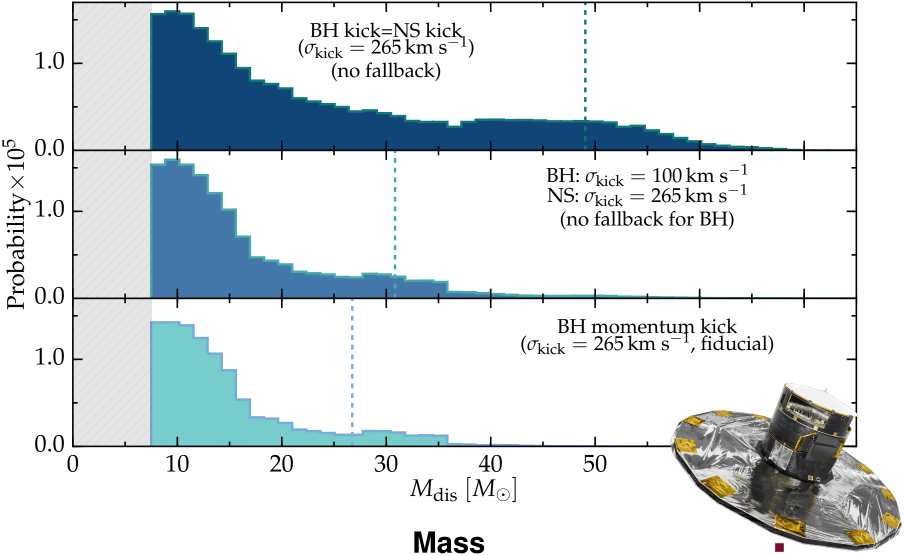

stars

Mass

gaia

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The most common massive binary evolution path

"Widowed" stars as runaways and walkaways

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Does binarity make the explosions easier?

SN rates & binarity

Binaries with a compact object

The case of 4U1700-37

Kicks do not change companion velocity

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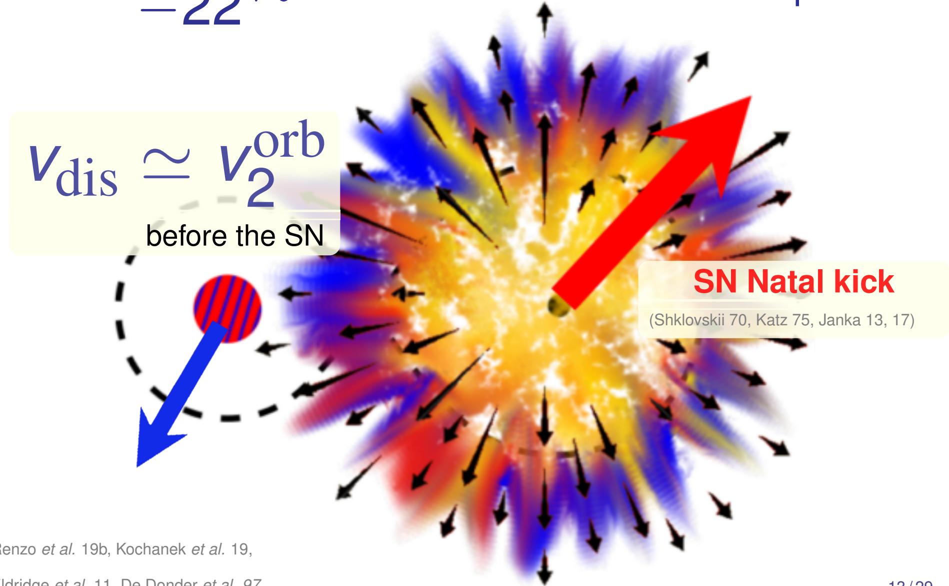
$86^{+11}_{-22}\%$ of massive binaries are disrupted



Renzo *et al.* 19b, Kochanek *et al.* 19,

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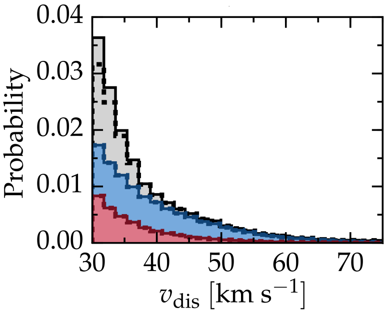

Renzo *et al.* 19b

Velocity distribution: **Walkaways**

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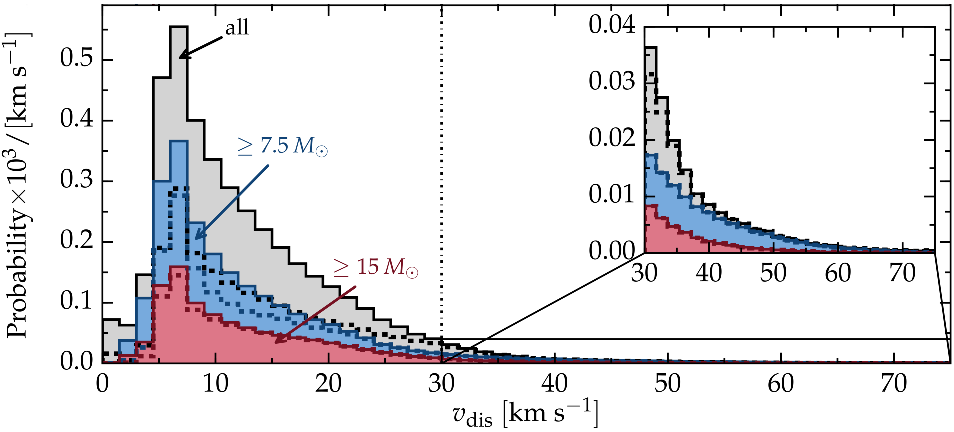
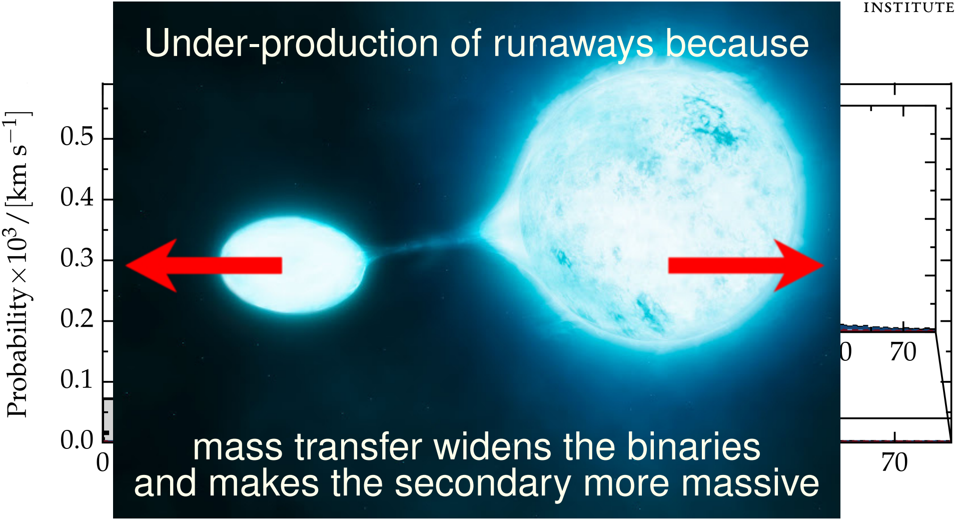


Velocity respect to the pre-explosion binary center of mass

Renzo *et al.* 19b

Velocity distribution: **Walkaways**



Velocity respect to the pre-explosion binary center of mass

Outline

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How explosions can affect the binaries

The most common massive binary evolution path

“Widowed” stars as runaways and walkaways

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The case of 4U1700-37

Mass transfer changes the core evolution

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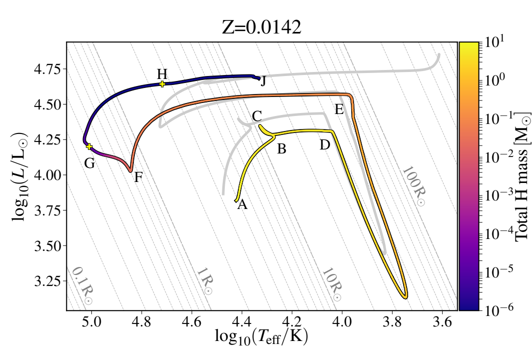
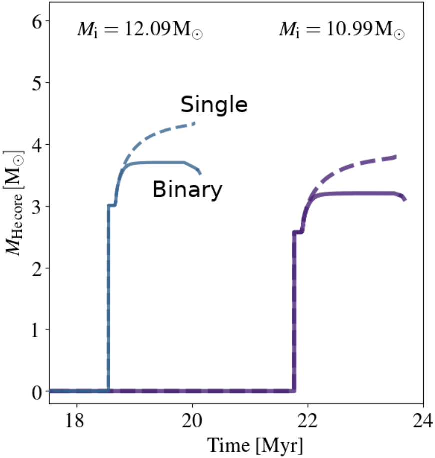


Vartanyan, Laplace, MR, Götberg *et al.* (in prep.)

Mass transfer changes the core evolution



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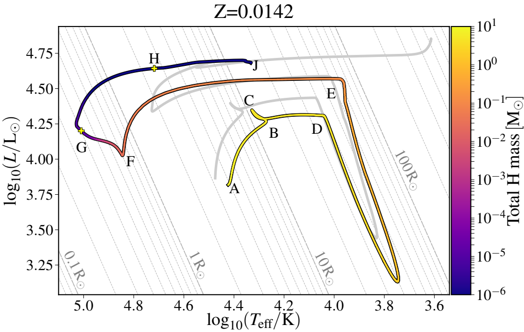

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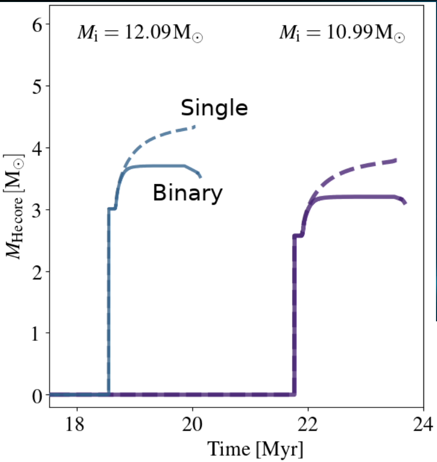
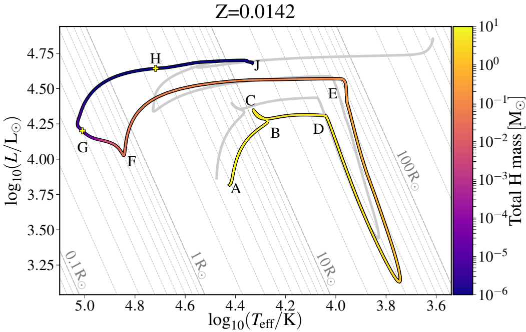


naked He cores ≠ binary donor



Vartanyan, Laplace, MR, Götberg *et al.* (in prep.)

Preliminary: Binaries explode more easily

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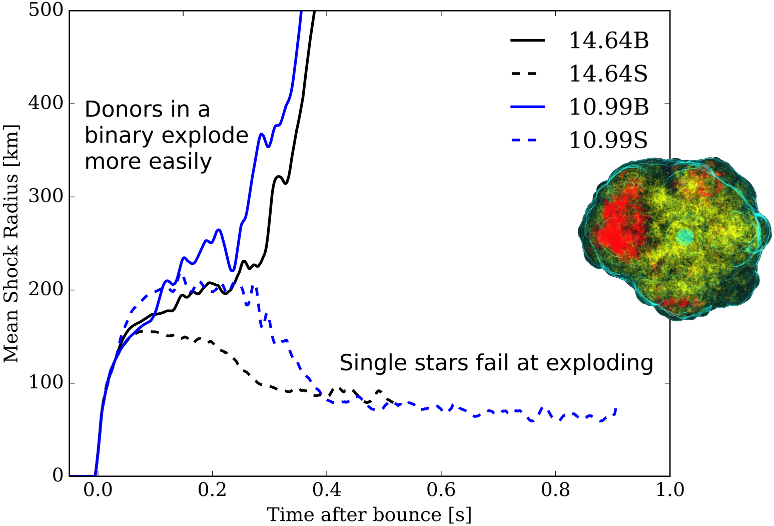
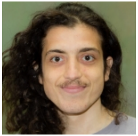
MESA + **FORNAX** (2D)



E. Laplace

D. Vartanyan



Y. Götberg

He core evolution ⇒ Si/O interface ⇒ Easier explosions

Vartanyan, Laplace, MR, Götberg *et al.* (in prep.)

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SN rates & binarity

Binaries with a compact object

The case of 4U1700-37

Oversimplified: If not merging ⇒ two SNe

(because of mass loss & reverse interactions)

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Explodes after accreting mass

SN type II

except if wind strong enough to remove H envelope, or if reverse binary interactions if binary not disrupted

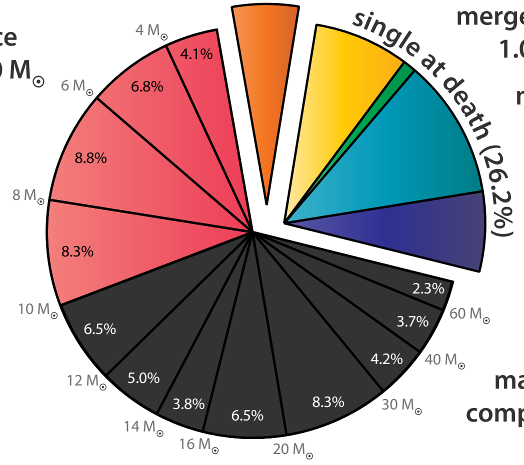
Explodes after losing envelope

SN type IIb/Ib/Ic

depending on winds (and thus Z)

e.g., Zapartas *et al.* (incl. MR) 17a, 17b, 19, Eldridge *et al.* 11, 18, 19

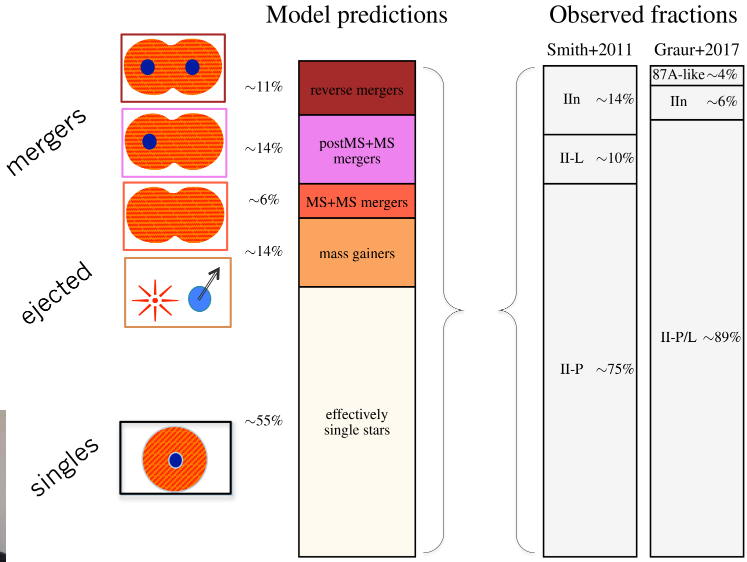
Companions to H-less SNe (type IIb/Ib/Ic)



Stripped-envelope SNe (Z = 0.0055)

e.g., Zapartas *et al.* (incl. MR) 17b

Type II SNe also know about binarity



e.g., Zapartas *et al.* (incl. MR) 19, Eldridge *et al.* 18, 19, Smartt *et al.* 09, Arcavi *et al.* 10, Li *et al.* 11, Shivvers *et al.* 16

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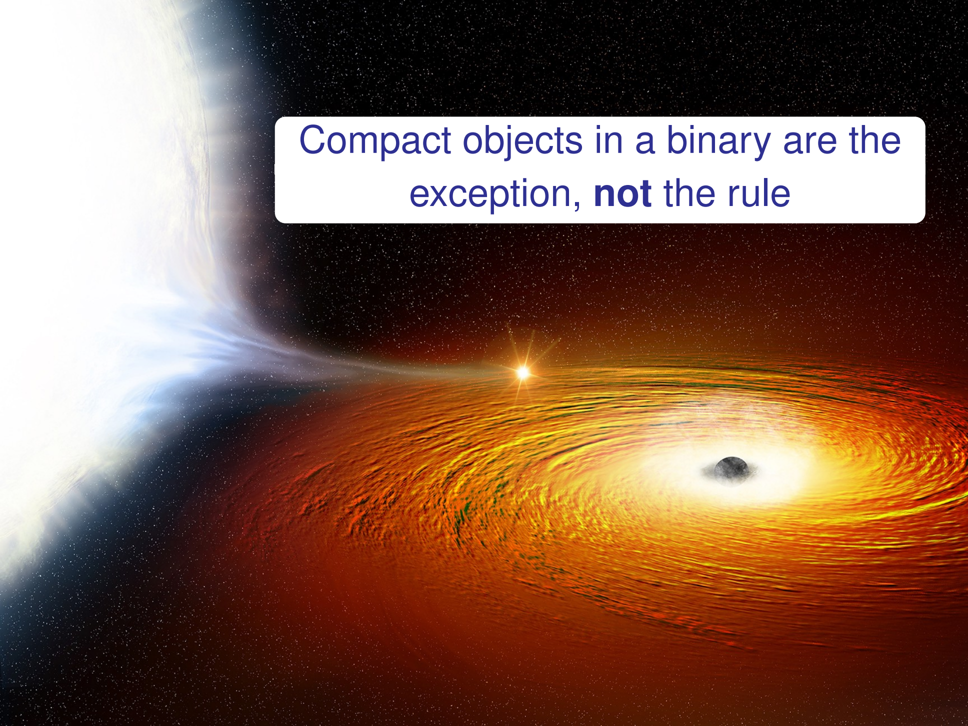
Compact objects in a binary are the exception, **not** the rule



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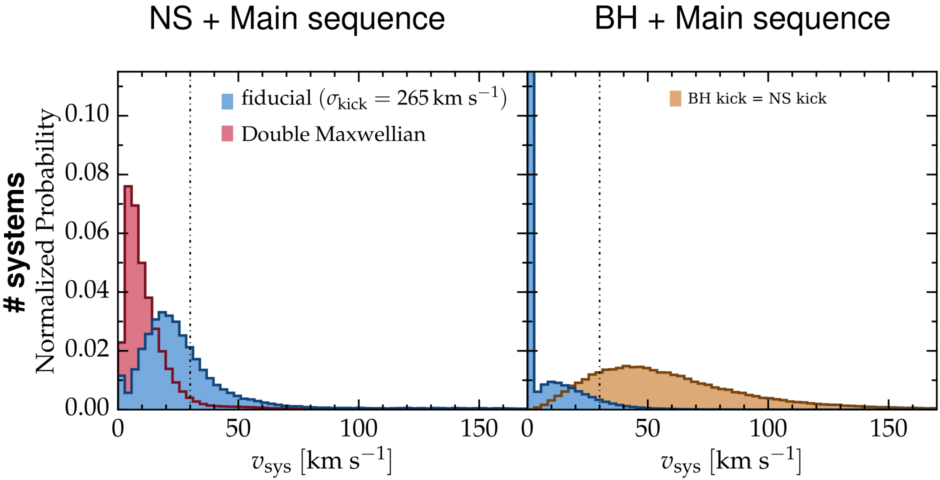
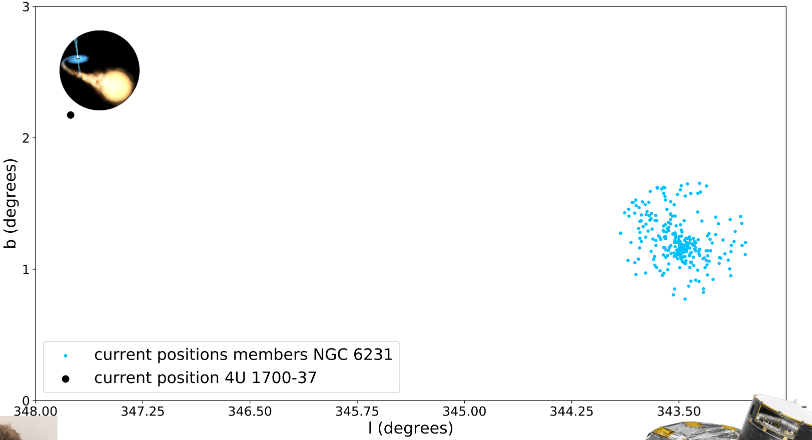


Velocity respect to the pre-explosion binary center of mass

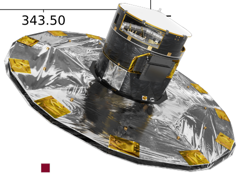
Preliminary: The case of 4U1700-37

$M \simeq 2.5\, M_\odot\ ,\ M_* \simeq 60 \pm 10\, M_\odot\ ,\ P \simeq 3.4\,\mathrm{days}\ ,\ e \simeq 0.22\ ,\ v \simeq 60\,\mathrm{km\ s^{-1}}$

Galactic longitude



Galactic latitude



gaia

van der Meij *et al.* (incl. MR), in prep.

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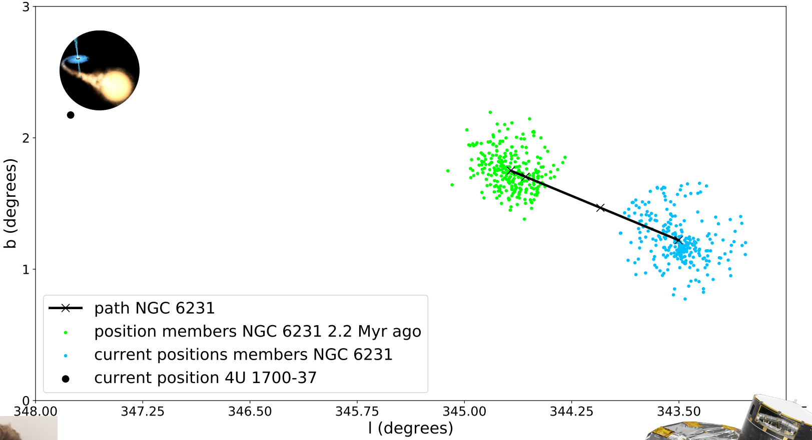

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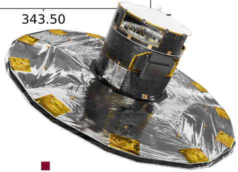

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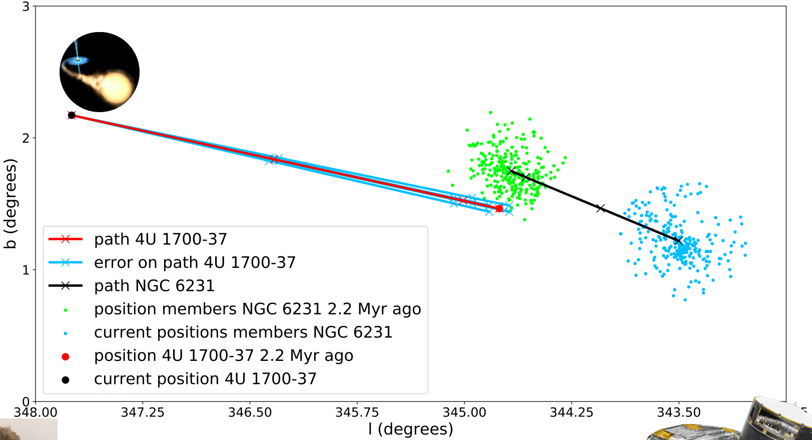

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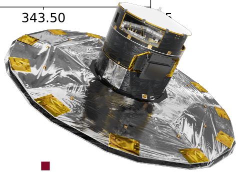
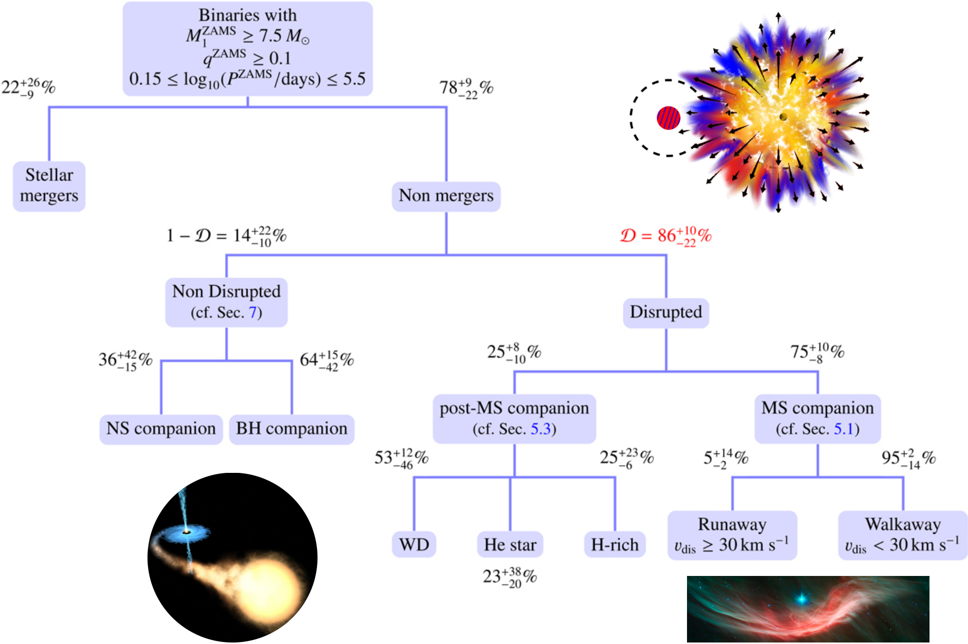


gaia

van der Meij *et al.* (incl. MR), in prep.

Conclusions

The variety of binary products



e.g., Renzo *et al.* 19b

Take home points

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- $86^{+11}_{-22}\%$ of massive binaries are disrupted

$\Rightarrow$ NSs and BHs with companion are the exception, **not** the rule

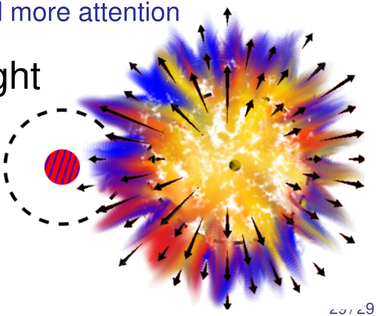
- Even single stars can be binary products

$\Rightarrow$ if found, “widowed” stars can constrain BH formation and orbital evolution

- Binarity changes the initial conditions for explosions

$\Rightarrow$ Initial conditions for core-collapse SNe need more attention

- Up to $\sim$50% of H-rich SNe might have binary progenitors



$\Rightarrow$ Diversity of transients is related to binarity

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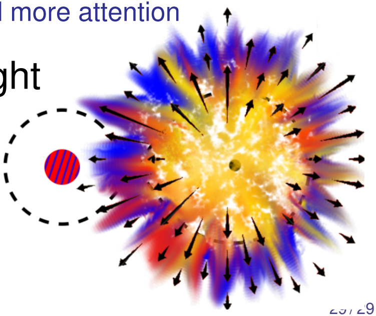

Thank you!

Backup slides

Contamination from dynamical ejections

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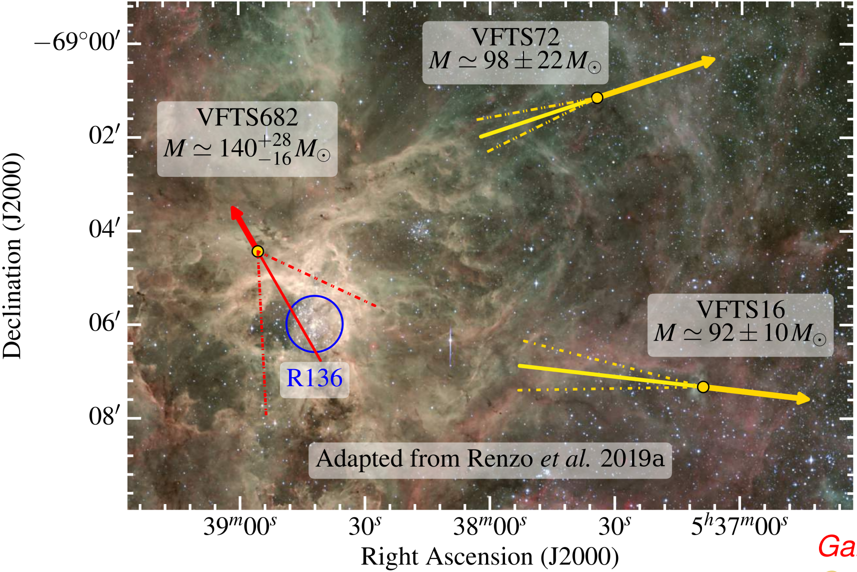
Proper motions relative to the cluster R136



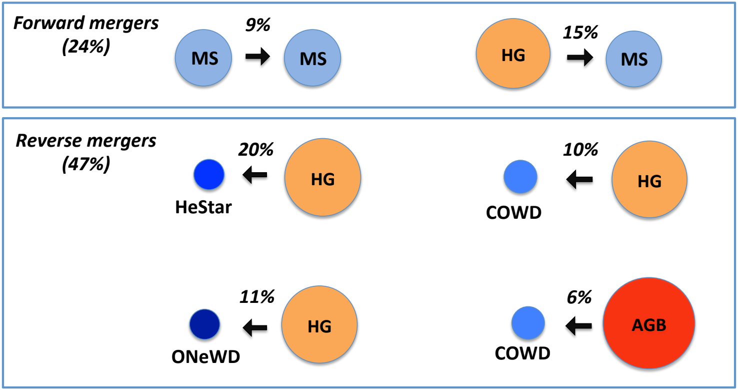
Gaia+HST

Gaia

see also Lennon *el al.* (incl. MR) 18, Drew *et al.* 18, Kalari *et al.* 19

Mergers and reverse mass transfer can produce a variety of transients

Evolutionary channels for “late” core-collapse Supernovae

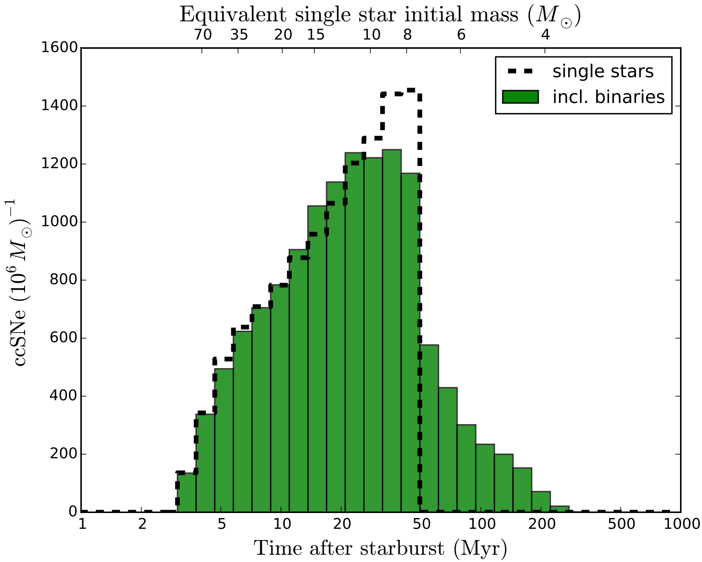


Other merger channels combined (16%)

Non-merger channels combined (13%)

e.g., Zapartas *et al.* (incl. MR) 17a

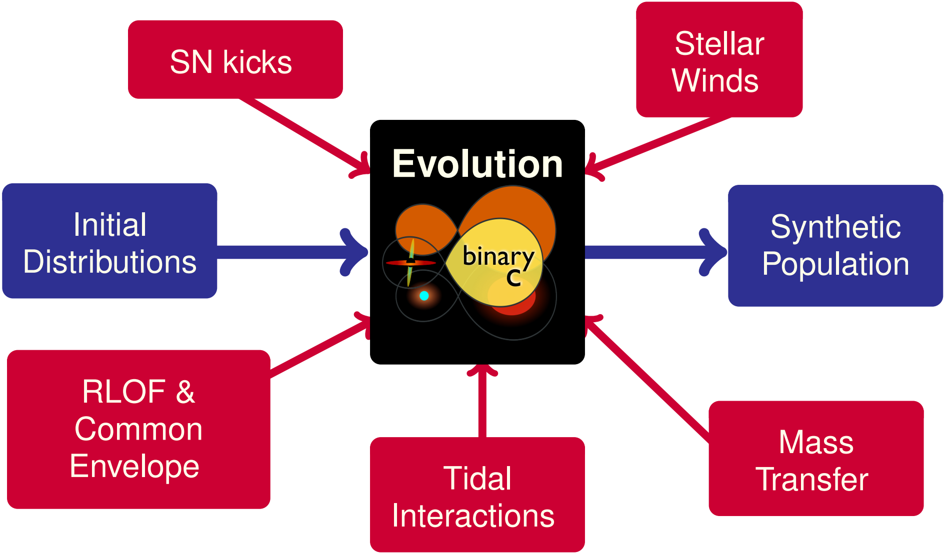
Delay time distribution of CCSNe events



e.g., Zapartas *et al.* (incl. MR) 17a

Methods: Population Synthesis

Fast ⇒ Allows statistical tests of the inputs & assumptions



Izzard *et al.* 04, 06, 09, 18; de Mink *et al.* 13; Schneider *et al* 15