Massive runaways from binaries

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Runaways enhance feedback

Nucleosynthesis & Chemical Evolution

Star Formation

Ionizing Radiation

Supernovae

GW Astronomy

$\sim$ 70% of O type stars are in close binaries

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

$\sim$ 10% of O type stars are runaways ($v \gtrsim 30$ [km s^{-1}])

(e.g., Blaauw '61, Gies '87, Stone '91)

NASA, JPL-Caltech, Spitzer Space Telescope

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How to make Runaways

Physics lessons

Astrophysical implications

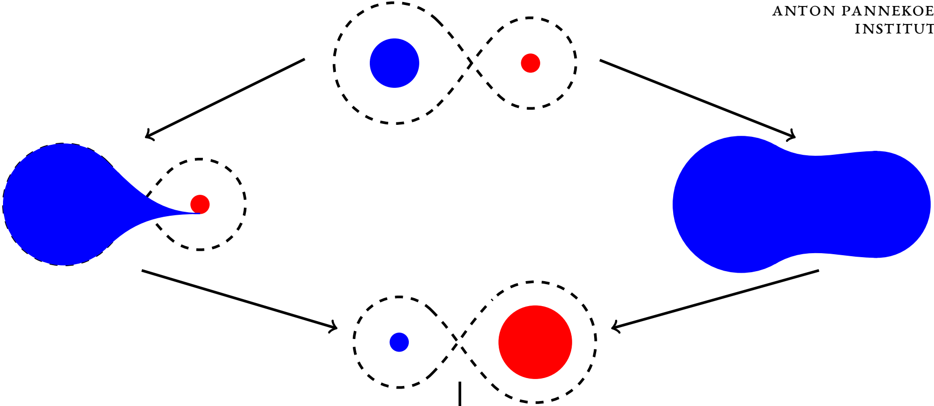
Population synthesis of 30 Doradus

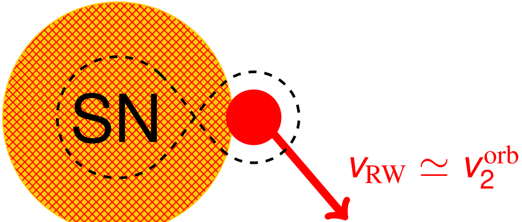
Preliminary results

Current challenges

Conclusions

Binary Disruption





- Unbinding Matter

  (e.g., Blaauw ’61)

- Ejecta Impact

  (e.g., Tauris & Takens ’98)

- SN Natal Kick

  (e.g., Cordes *et al.* ’93, Janka ’16)

Spin up

Runaways from binary disruption are accretors

e.g., Packet ’81, Cantiello *et al.* ’07, de Mink *et al.* ’13

Cluster ejection

N-body interactions

least massive thrown out

...binaries are still important

- (Binding) Energy reservoir
- Cross section $\propto a^2 \gg R_*^2$

Poveda *et al.*, 1967

Outline

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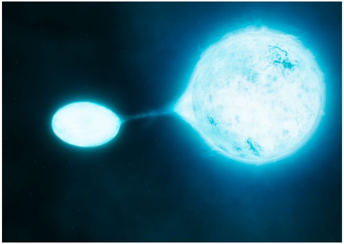
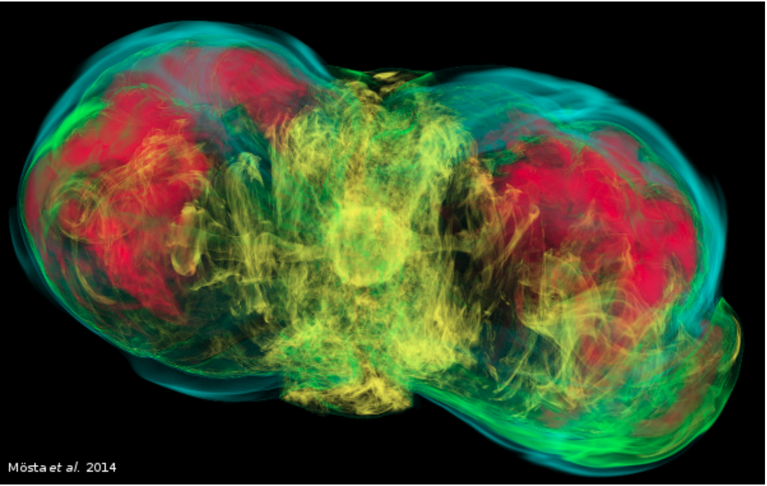


Statistical constraints on:

- Orbital evolution
  - pre (1^{st}) SN orbital period distribution
- Mass transfer efficiency
  - pre (1^{st}) SN M_2 distribution
- Angular momentum loss
  - isotropic re-emission from donor or accretor, or circumbinary disk

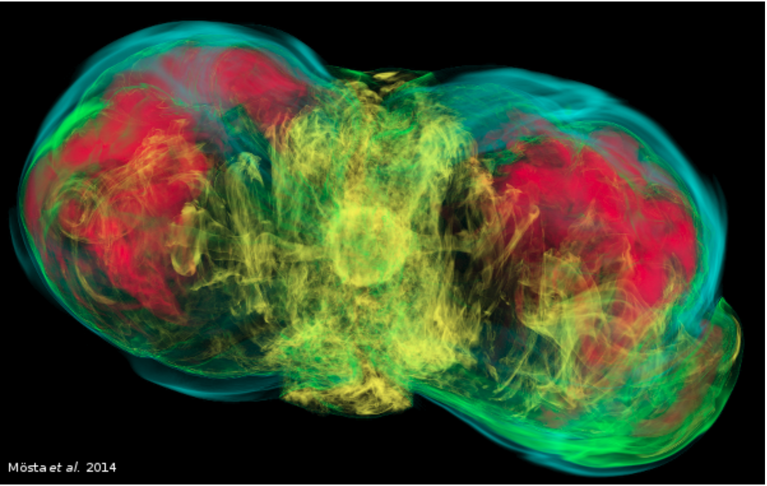
SN natal kick



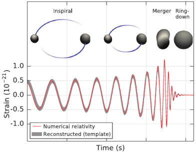
ν emission and/or ejecta anisotropies

SN natal kick

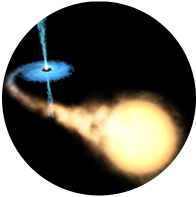
do BH receive a kick?



Runaways



Gravitational Waves



XRBs

ν emission and/or ejecta anisotropies

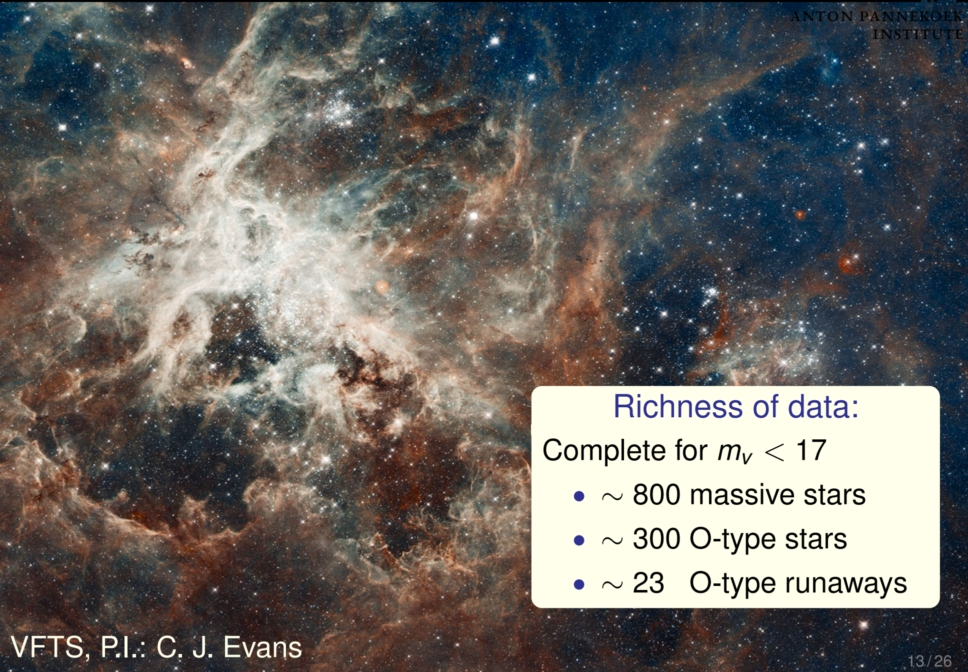
Outline

...of disrupting binaries:

- Enhancement of massive stars feedback
  - Larger volume & spatial spread of CCSN
- Contamination of field with binary products
  - Are “single” stars really single?
- Massive star formation
  - are isolated massive stars formed “in situ”?
- LBV phenomenon
  - e.g., Smith & Tombleson ’15, Smith ’16, Aghakhanlootakanloo *et al.* ’17
- Gravitational wave sources
  - Disrupted binaries are “failed” GW sources!

Outline

30 Doradus



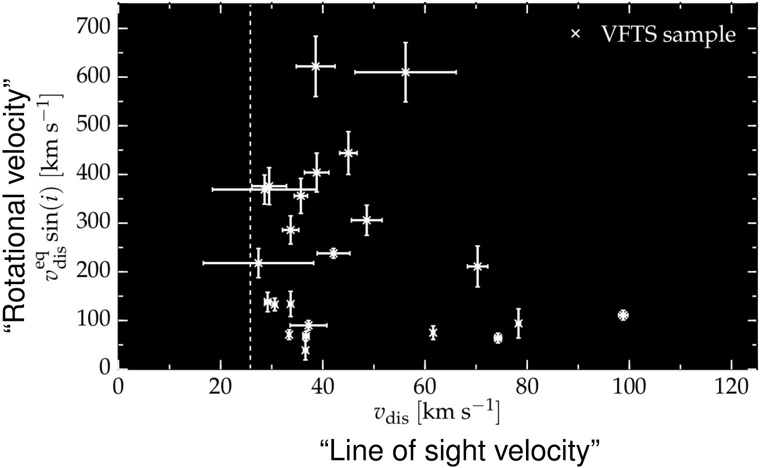
Richness of data:

Complete for $m_V < 17$

- $\sim$ 800 massive stars
- $\sim$ 300 O-type stars
- $\sim$ 23 O-type runaways

VFTS, P.I.: C. J. Evans

Largest homogeneous sample of O-type Runaways



Sana *et al.*, in prep.

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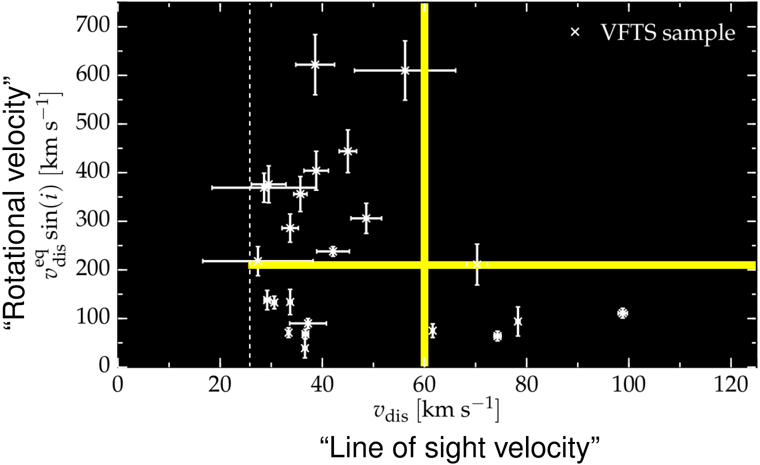
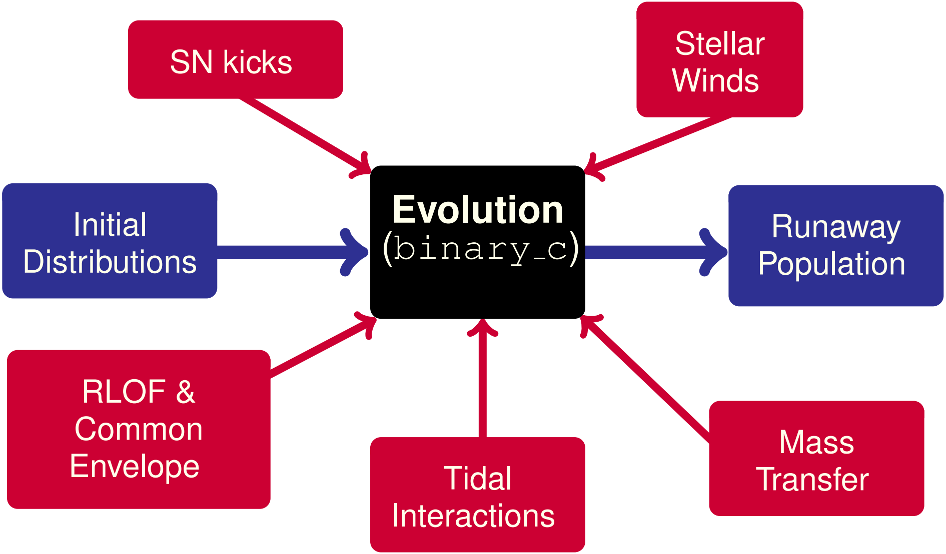


Sana *et al.*, in prep.

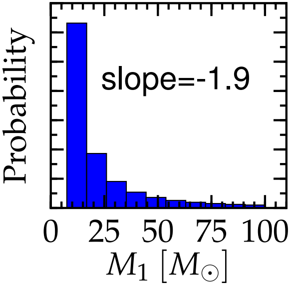
What I do: Population Synthesis

Fast ⇒ Allows statistical tests of the inputs & assumptions

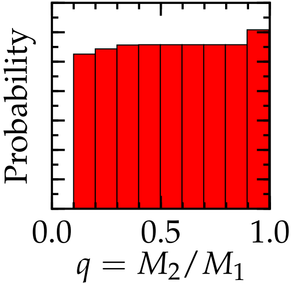


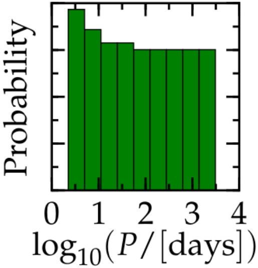
Izzard *et al.* ’04, ’06, ’09; de Mink *et al.* ’13

Initial Distributions



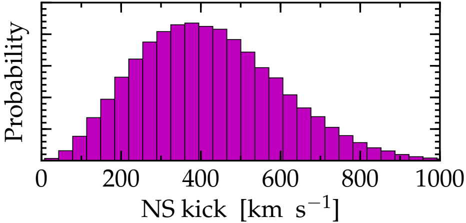
Schneider *et al.*, submitted





Öpik ’24 + Sana *et al.* ’12

Maxwellian $\sigma_{v_{\rm kick}} = 265\ [\rm km\ s^{-1}]$ + Fallback rescaling



Hobbs *et al.* ’05

Outline

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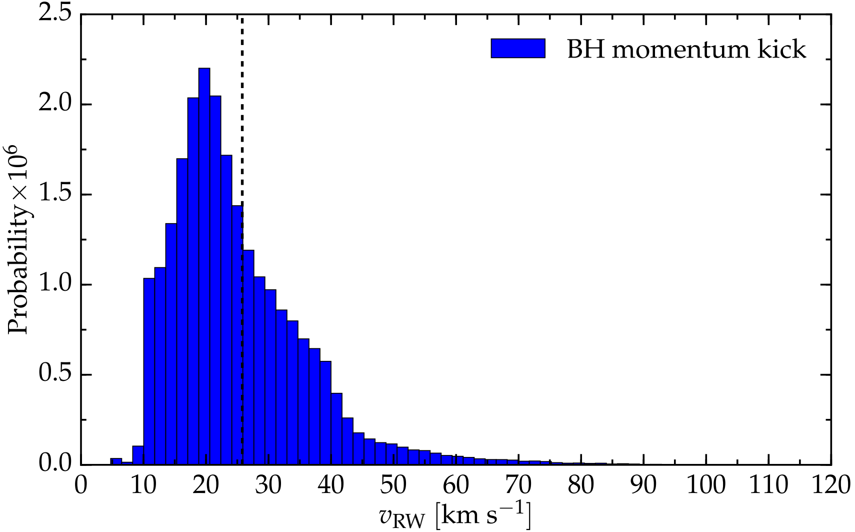
O-type from disrupted binaries only



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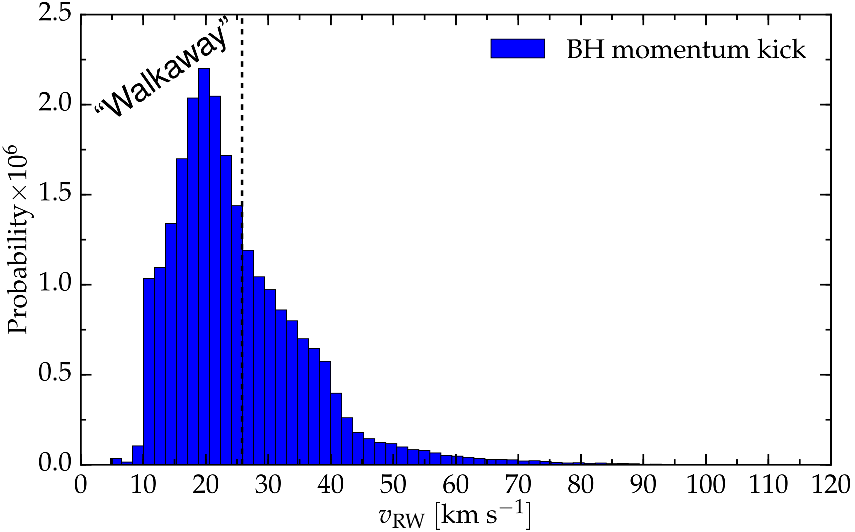
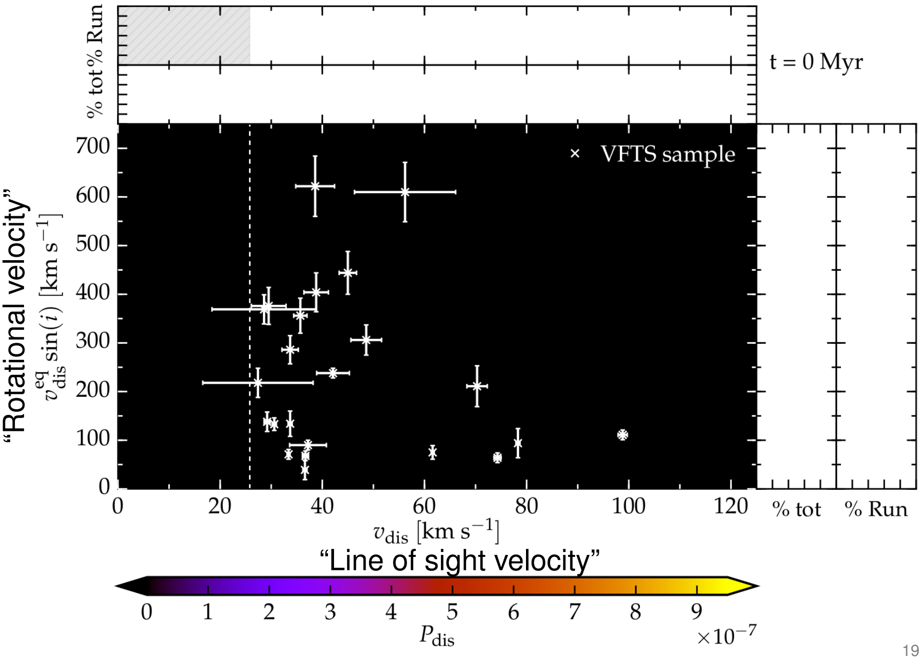


O stars from disrupted binaries



O stars from disrupted binaries

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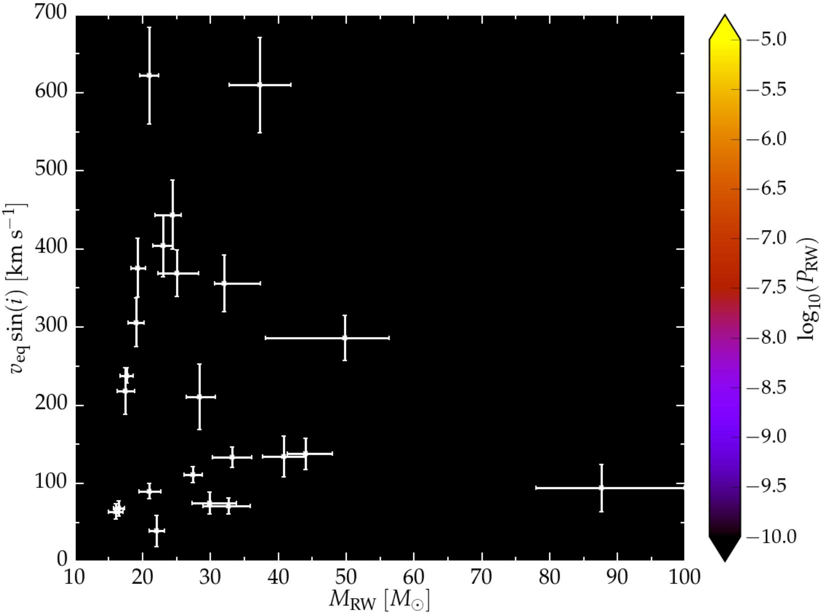
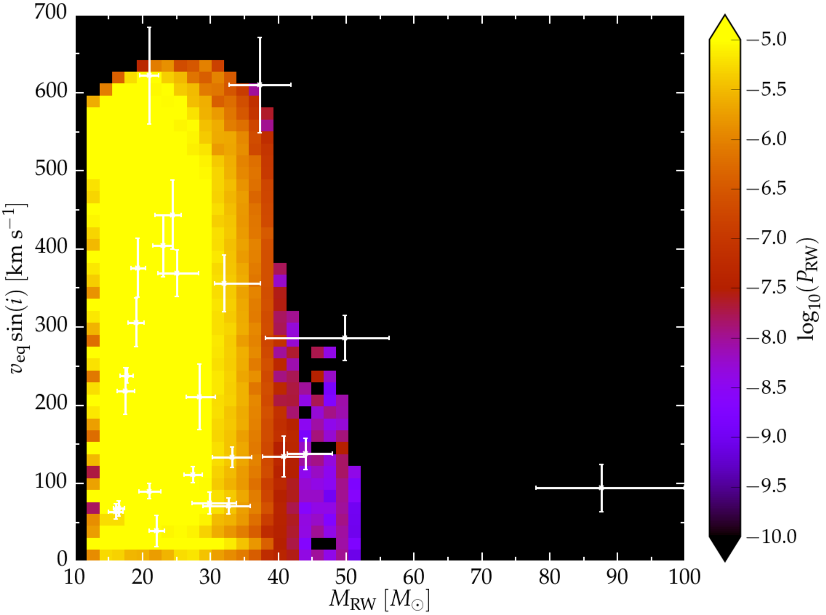
“Rotational velocity”

“Line of sight velocity”

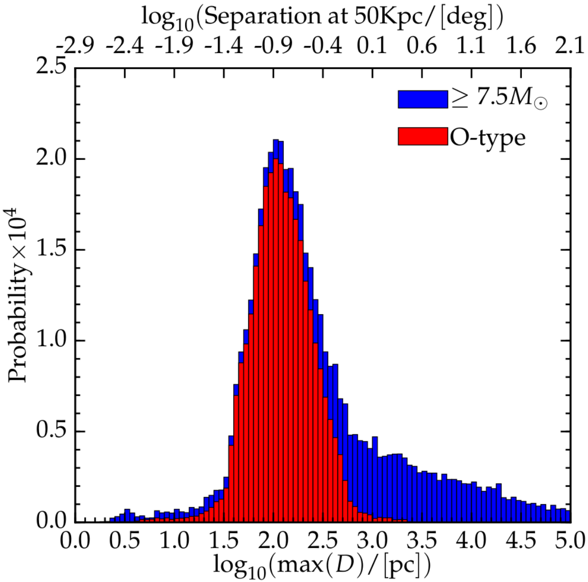
Mass-rotation correlation



Mass-rotation correlation



Where do they die?



"Distance traveled"

No potential well, Starburst, $\sigma_{\rm kick} = 265\,{\rm km\ s^{-1}}$

Outline

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Tension with observed runaway fraction

Observed: $\frac{\#\text{O Runaways}}{\#\text{O stars}} \simeq \frac{23}{300} \sim 8\%$

cf.

Simulated: $\sim 2\%$

Tension with observed runaway fraction

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Observed: $\frac{\#\text{O Runaways}}{\#\text{O stars}} \simeq \frac{23}{300} \sim 8\%$

cf.

Simulated: $\sim 2\%$

Possible “solutions”:

- SFH?
- Orbital evolution?
- Need larger SN kicks...
- ... and/or less fallback?

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Conclusions

Large fraction of binaries disrupted by first SN

Massive walk/runaways stars...

- ..."pollute" the field with binary products
- ...carry info on previous binary evolution
- ...can be used to learn about companion explosion
- ...enhances role of massive stars in galaxies

30 Doradus: largest homogeneous sample of runaways

To do list:

- Test robustness varying parameters, and distributions
- Do I need larger SN kicks/less fallback?
- Which "other outcomes" to use as anchors?

Conclusions

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Thank you!