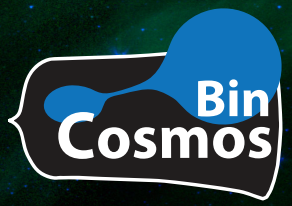
Massive Runaways: Constraints on Binary Interactions and Explosion Physics

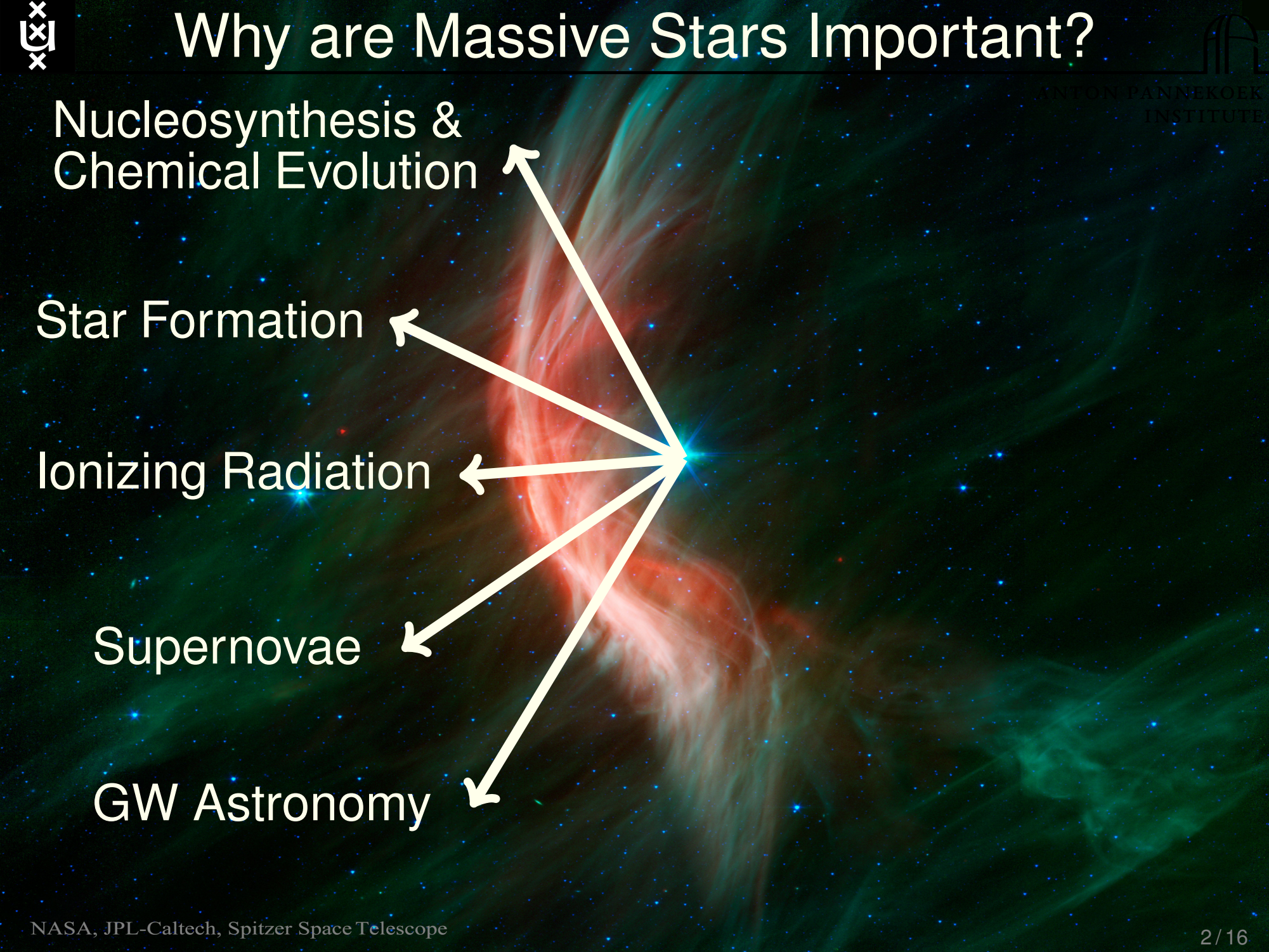
Mathieu Renzo
PhD in Amsterdam



Collaborators: S. E. de Mink, E. Zapartas, Y. Götberg, C. J. Neijssel, R. G. Izzard, H. Sana

NASA, JPL-Caltech, Spitzer Space Telescope

Why are Massive Stars Important?



NASA, JPL-Caltech, Spitzer Space Telescope

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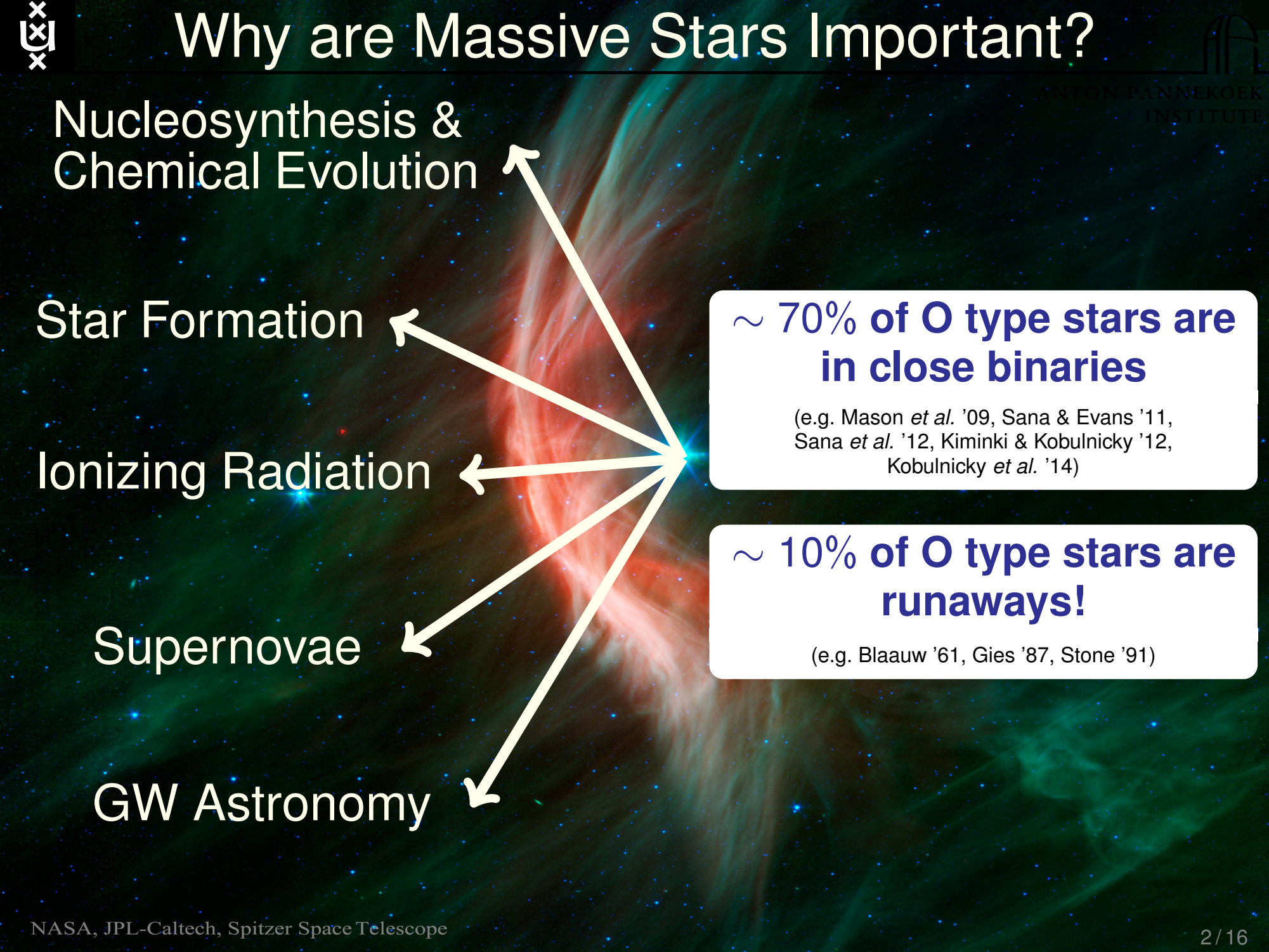

$\sim$ 70% of O type stars are in close binaries

(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!

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

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From Binary to Runaway

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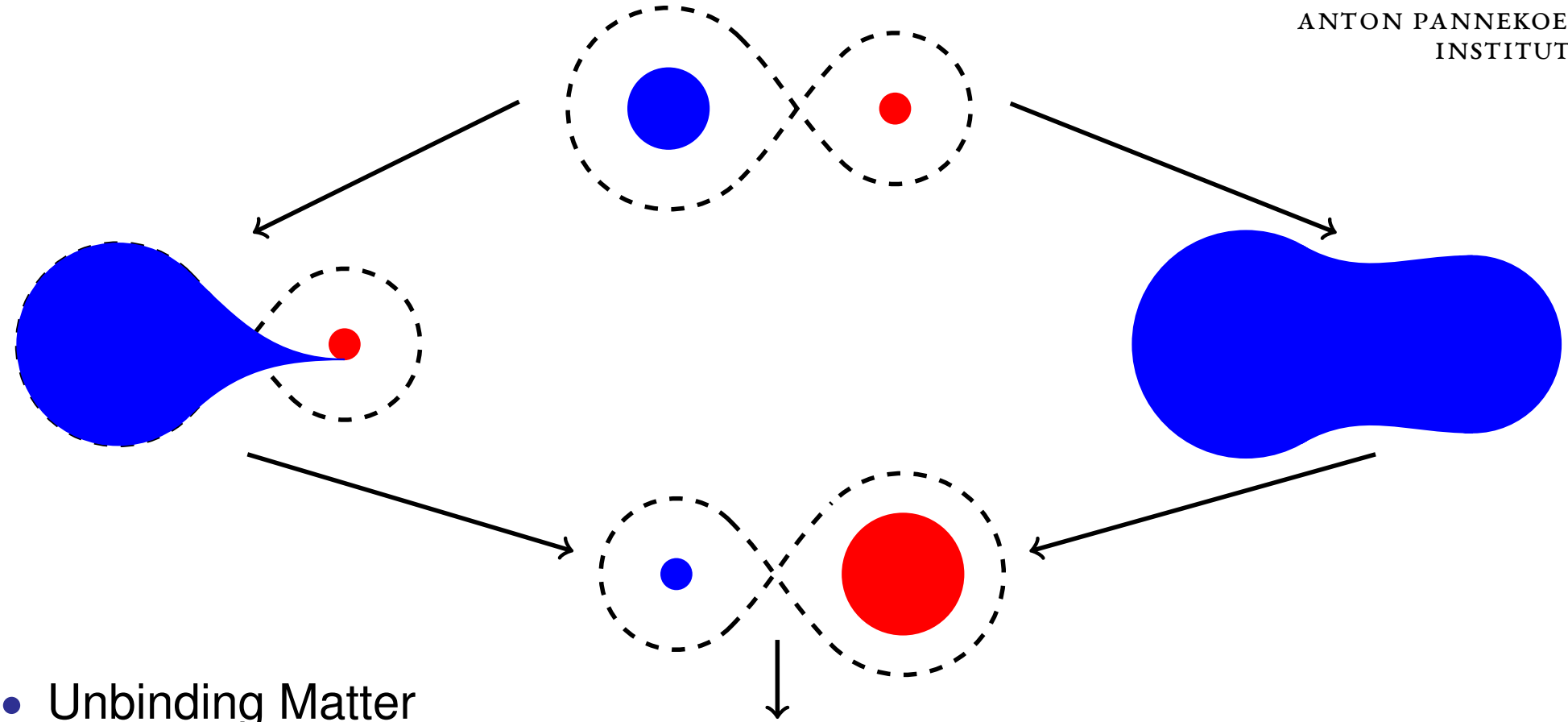


- Unbinding Matter

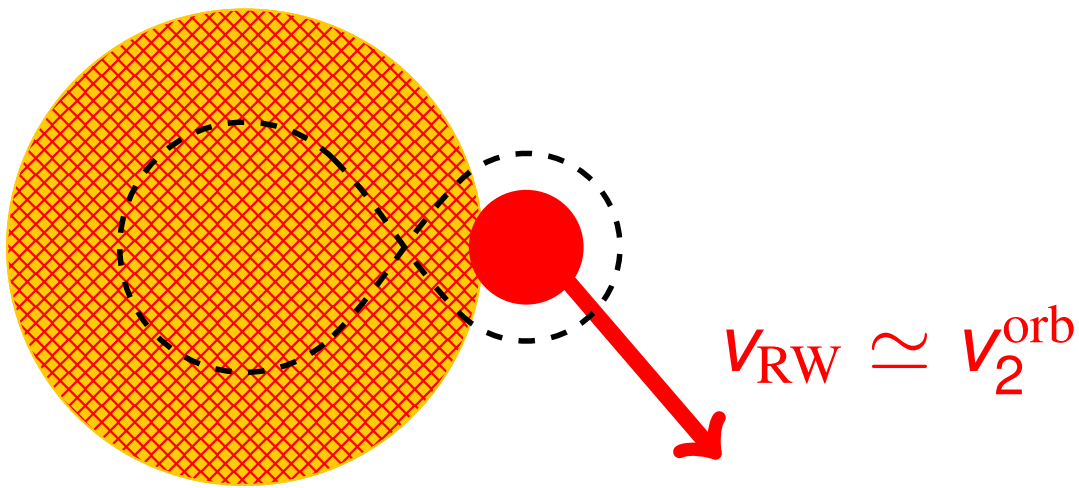
  (e.g. Blaauw '61)

- Ejecta Impact

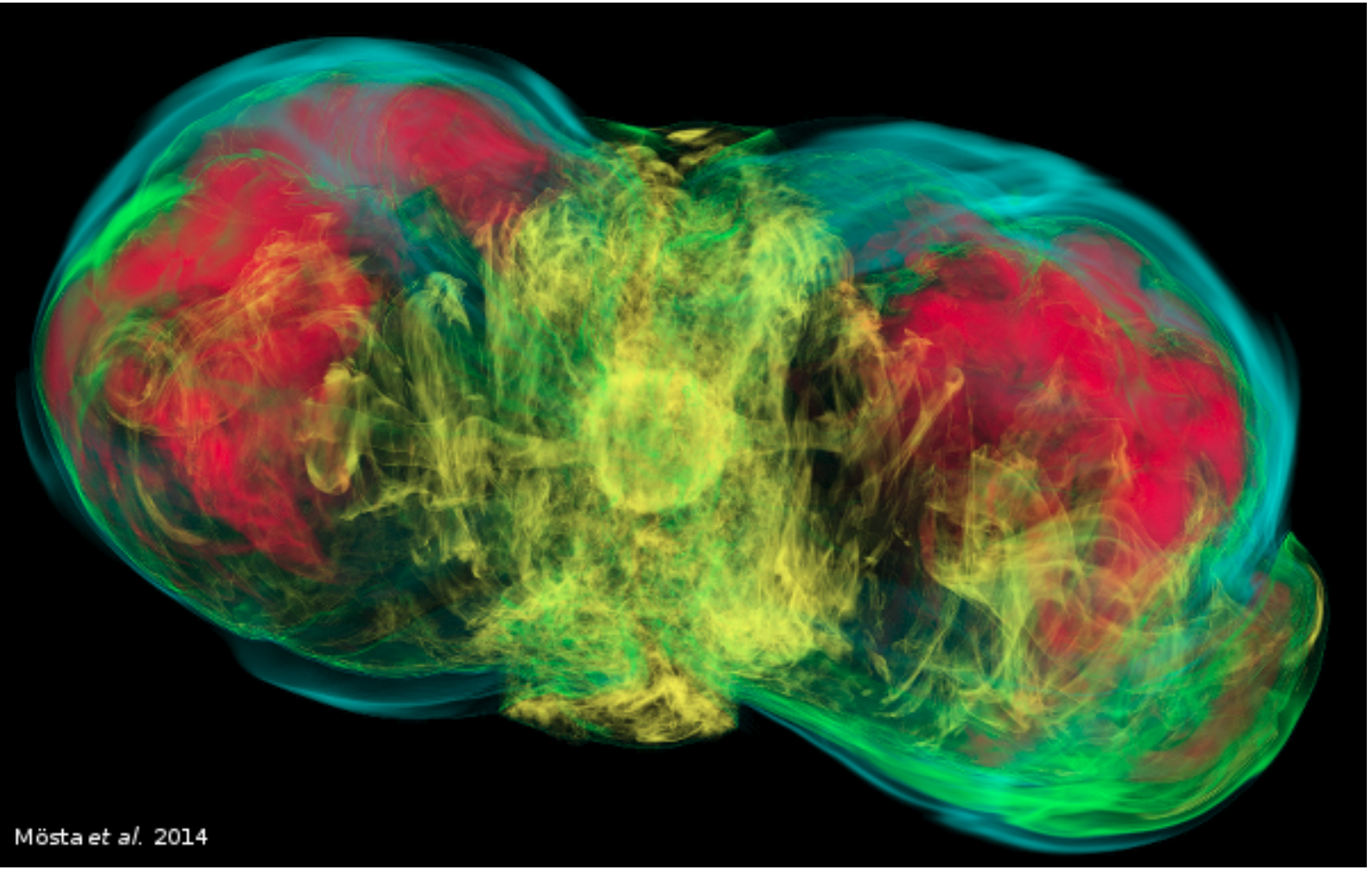
  (e.g. Tauris & Taken '98)

- SN Natal Kick

  (e.g. Cordes *et al.* '93)

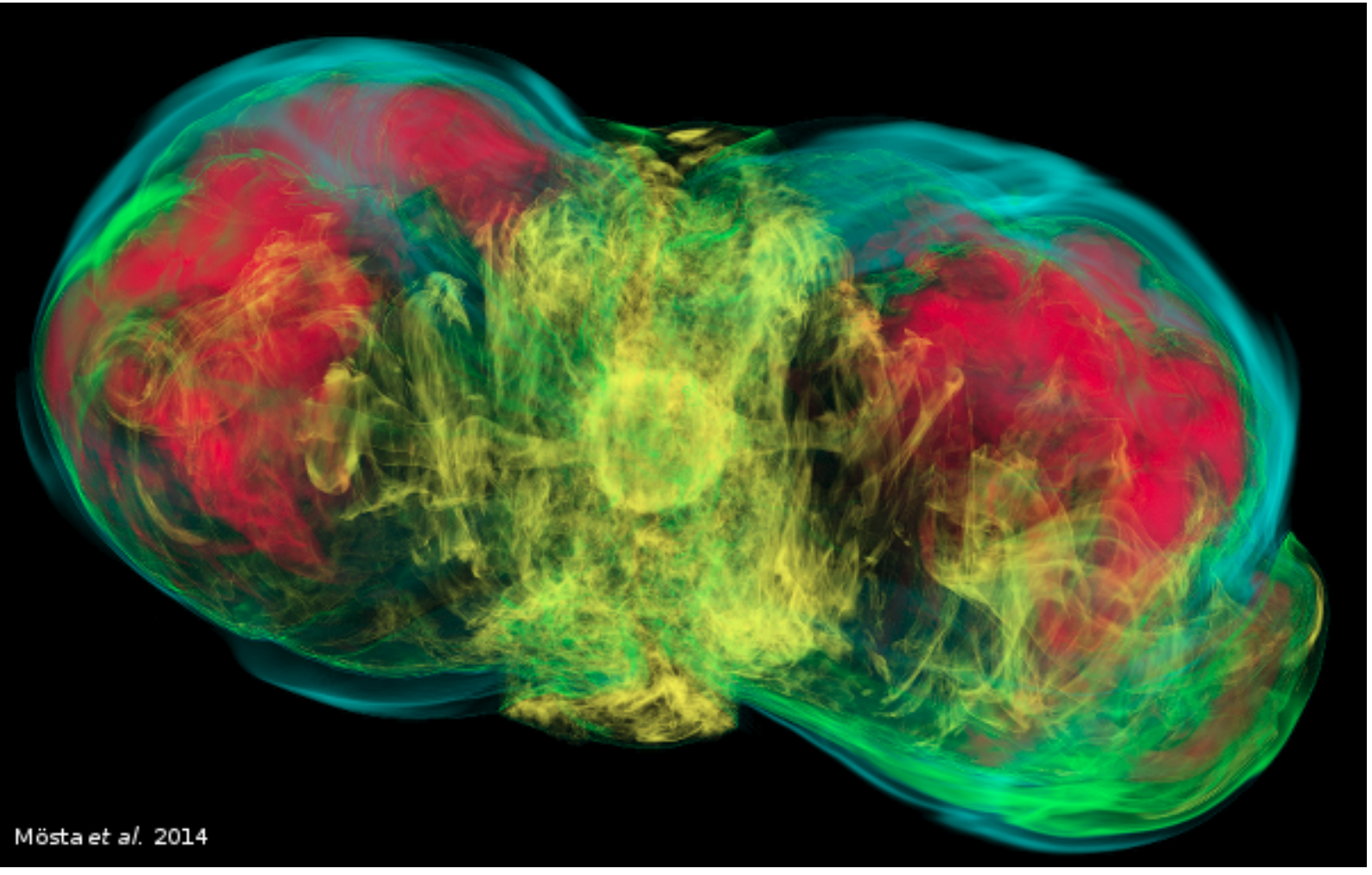


SN natal kick

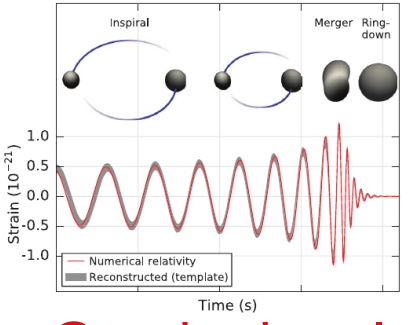


ν emission and/or ejecta anisotropies

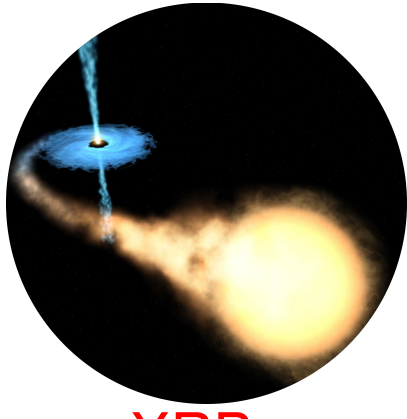
SN natal kick



Runaways



Gravitational Waves



XRBs

ν emission and/or ejecta anisotropies

Outline

Population Synthesis

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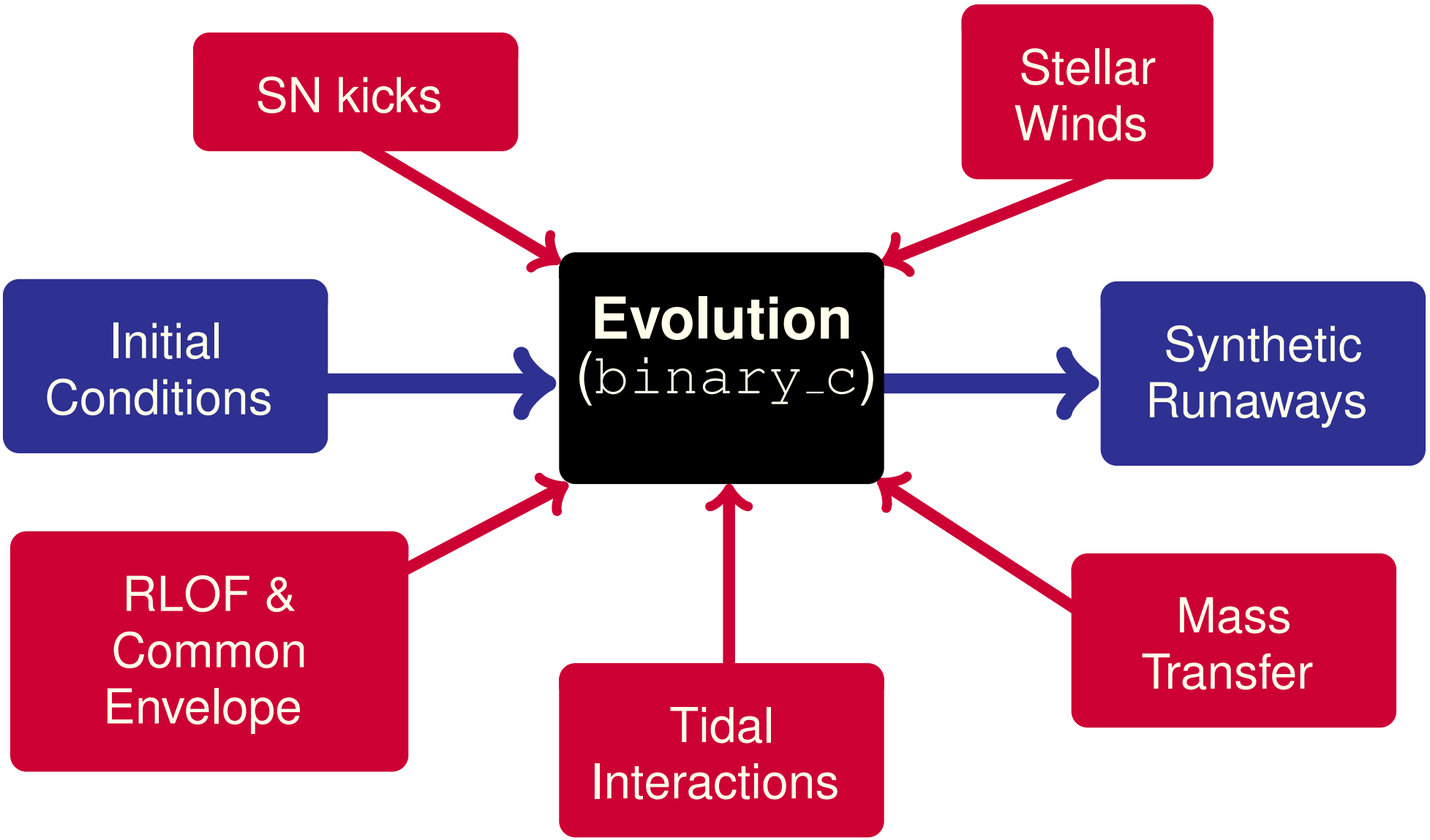
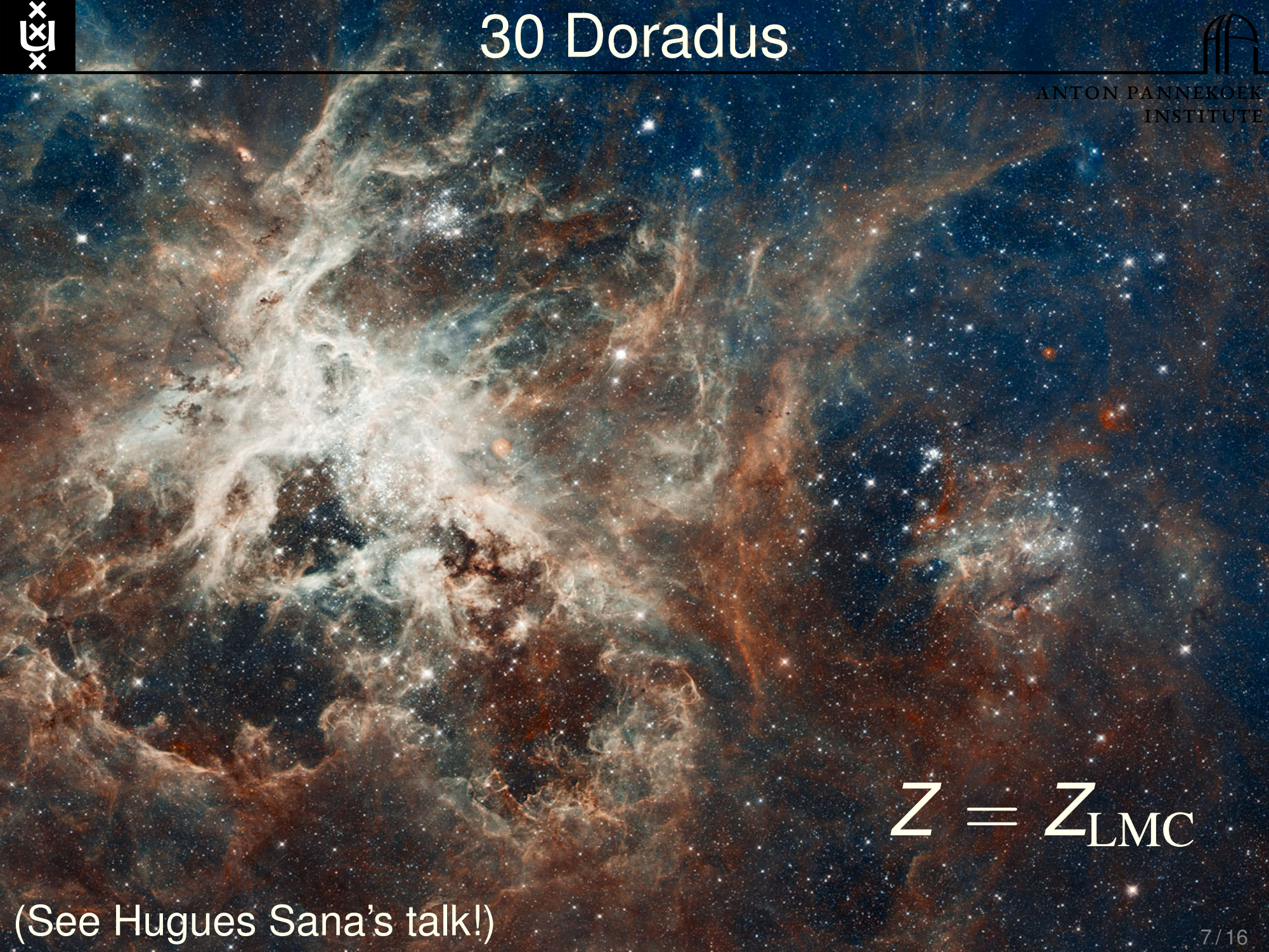
Fast $\Rightarrow$ Allows statistical tests of the inputs & assumptions



binary_c: R. G. Izzard *et al.* '04, '06, '09; S. E. de Mink *et al.* '13

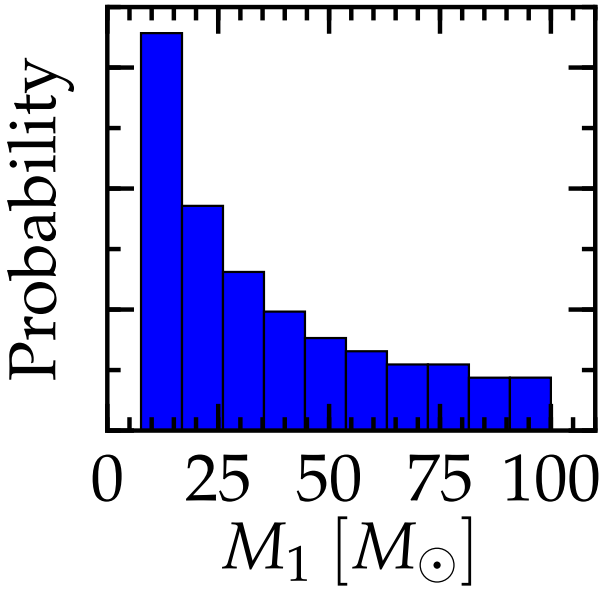
30 Doradus



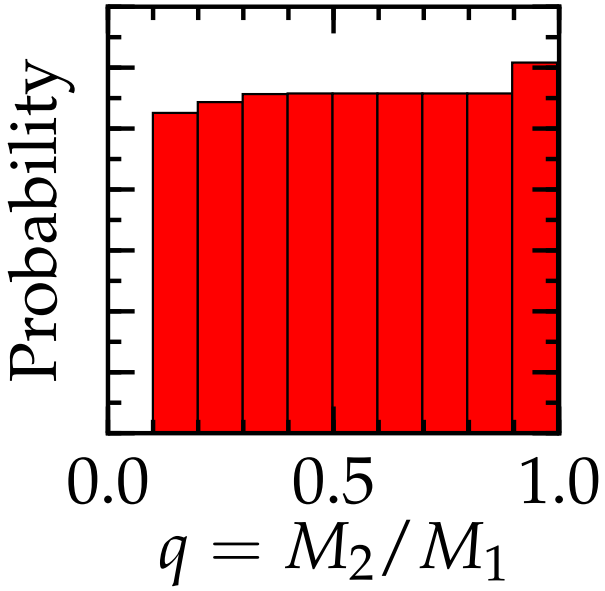
$Z = Z_{\mathrm{LMC}}$

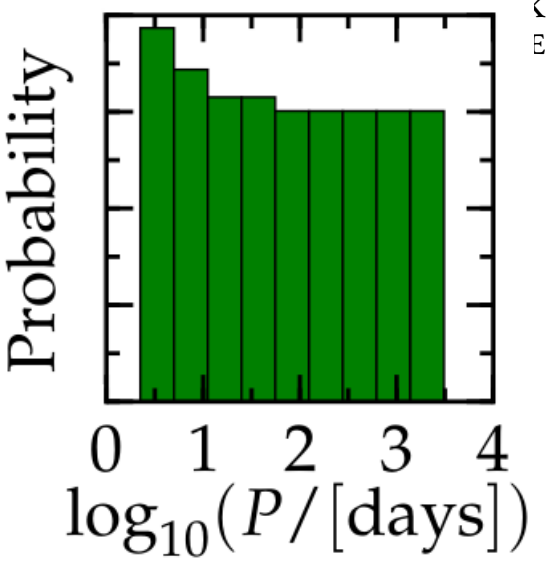
(See Hugues Sana's talk!)

Initial Distributions



Kroupa '01

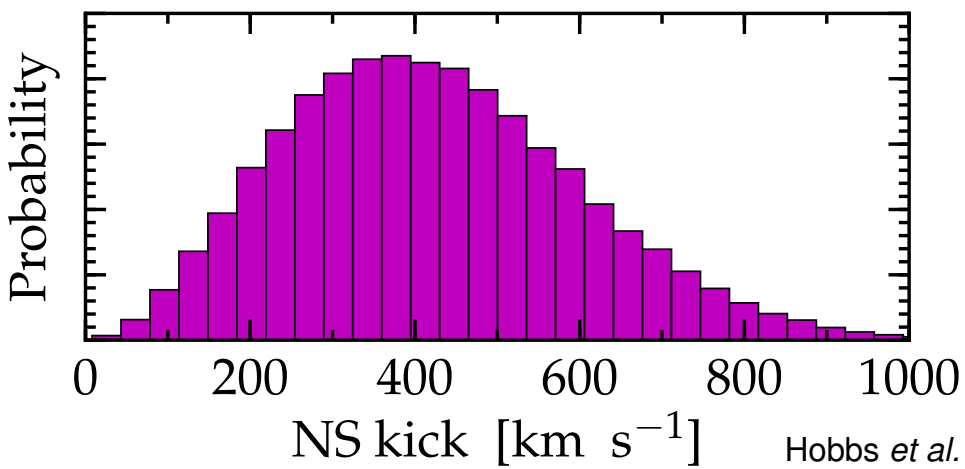




Sana *et al.* '12

Total Population: 2×10^6 stars

Maxwellian $\sigma_{v_{\text{kick}}} = 265[\text{km s}^{-1}]$



Hobbs *et al.* '05

Preliminary: Cluster or Binary?

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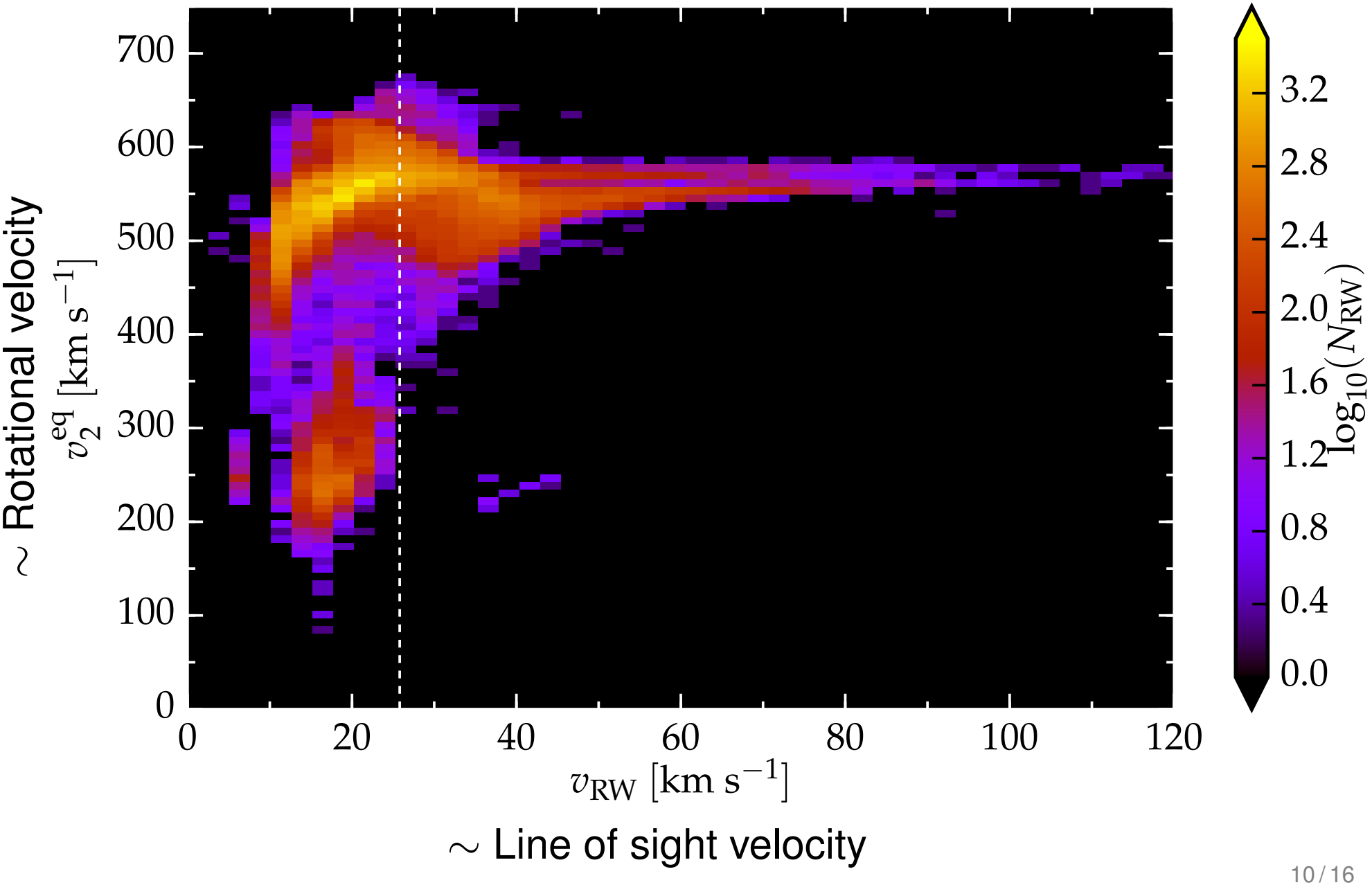

Preliminary: Velocity Distribution

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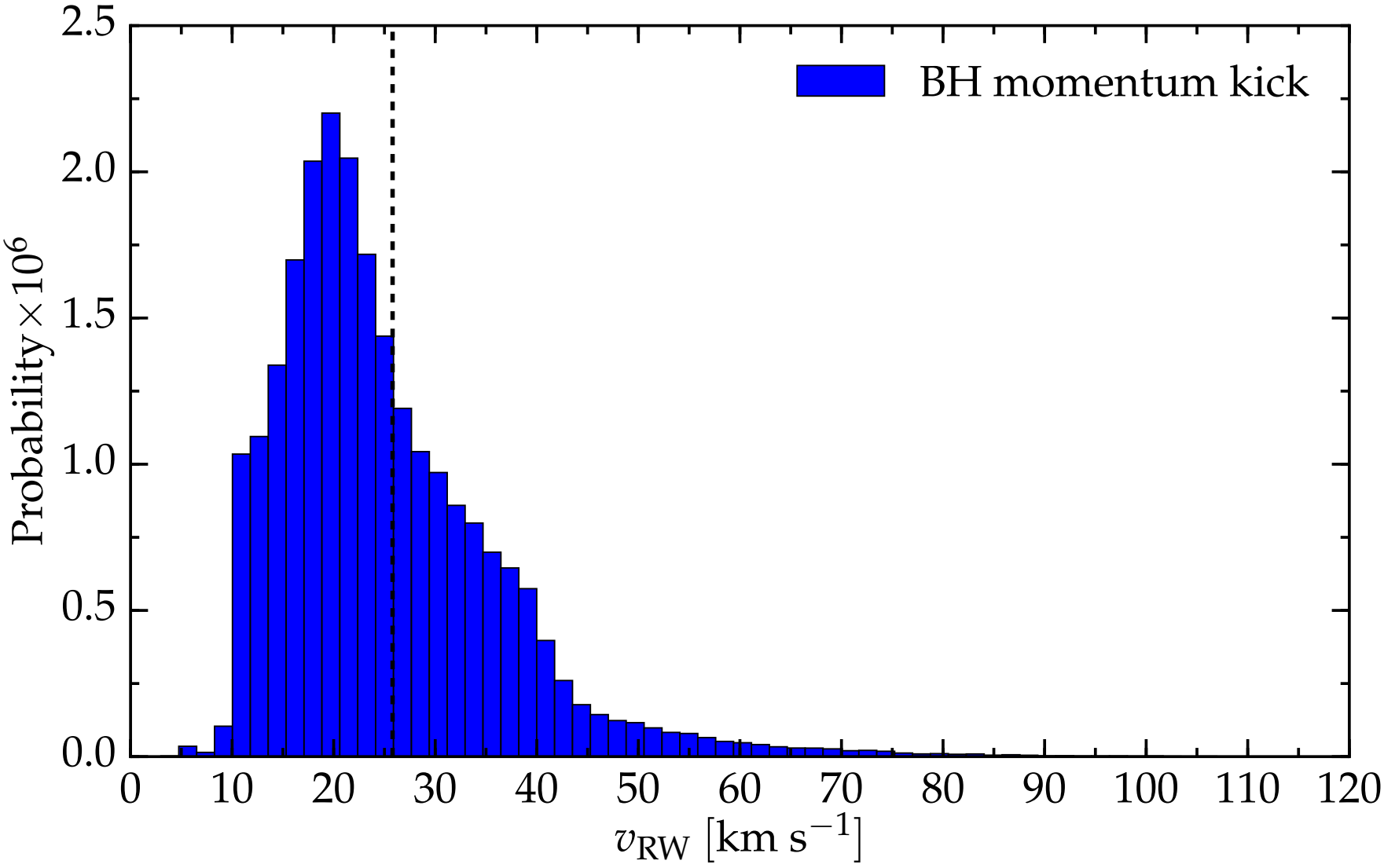
O-type from disrupted binaries only



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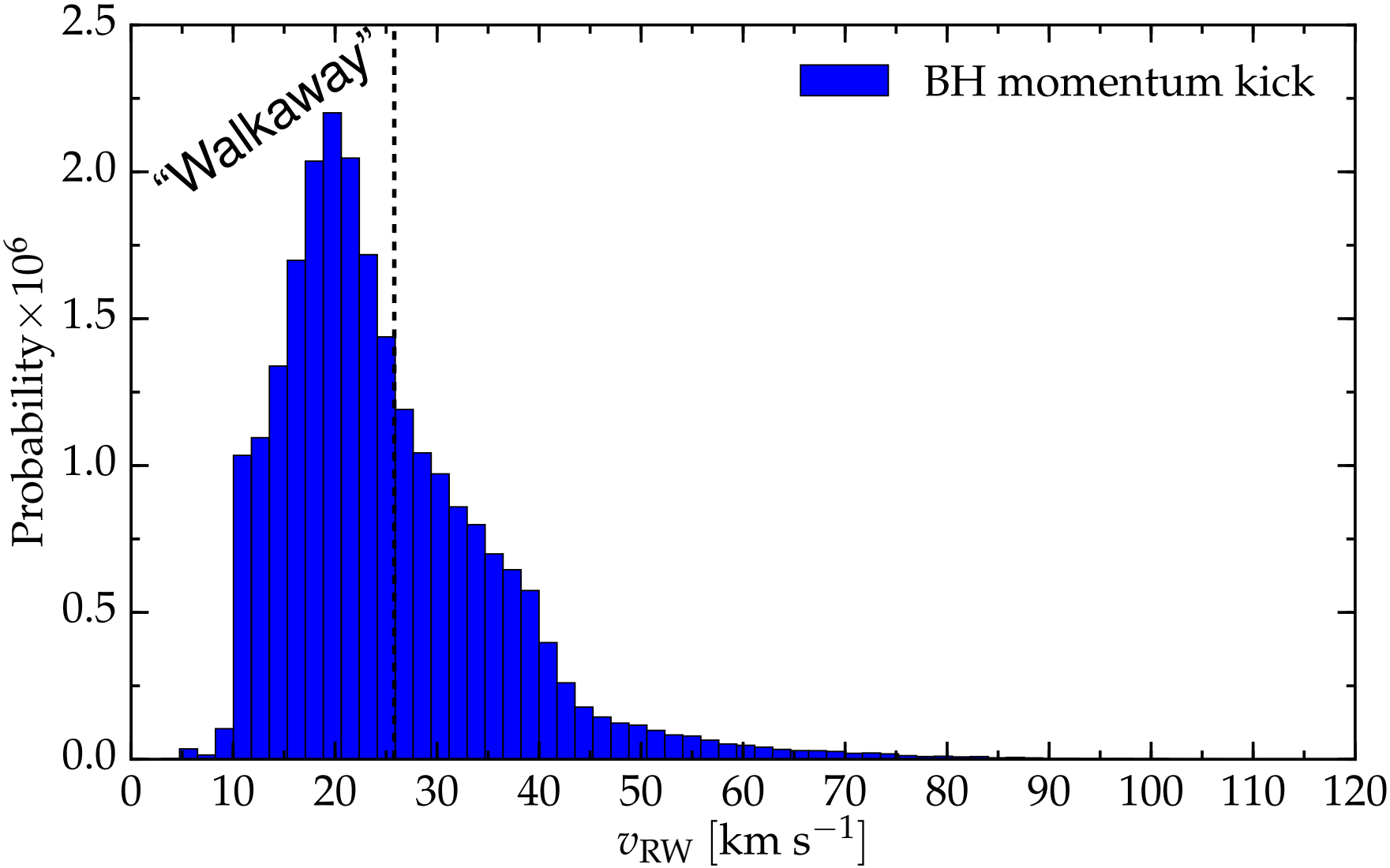

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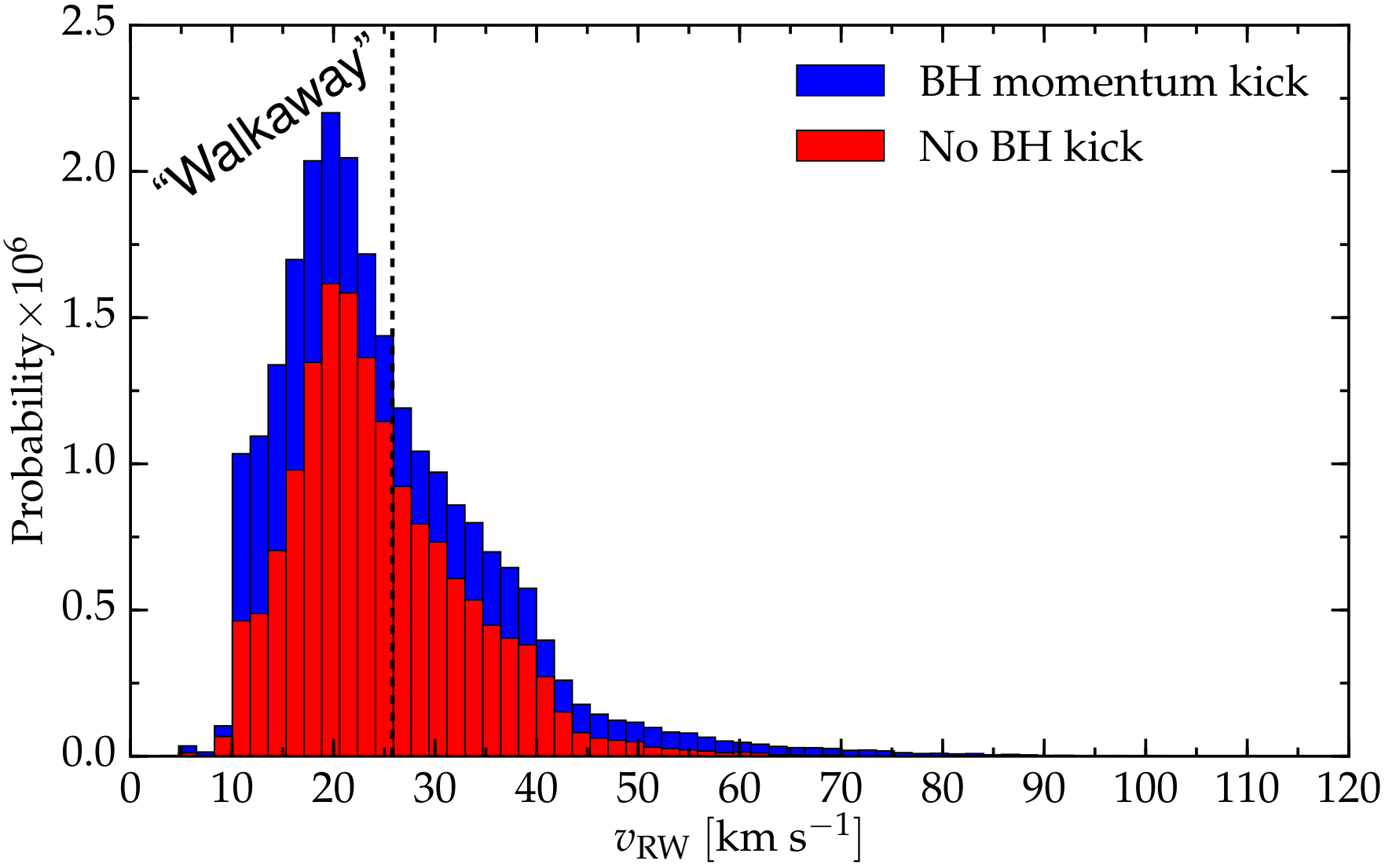

Preliminary: RW Mass Function

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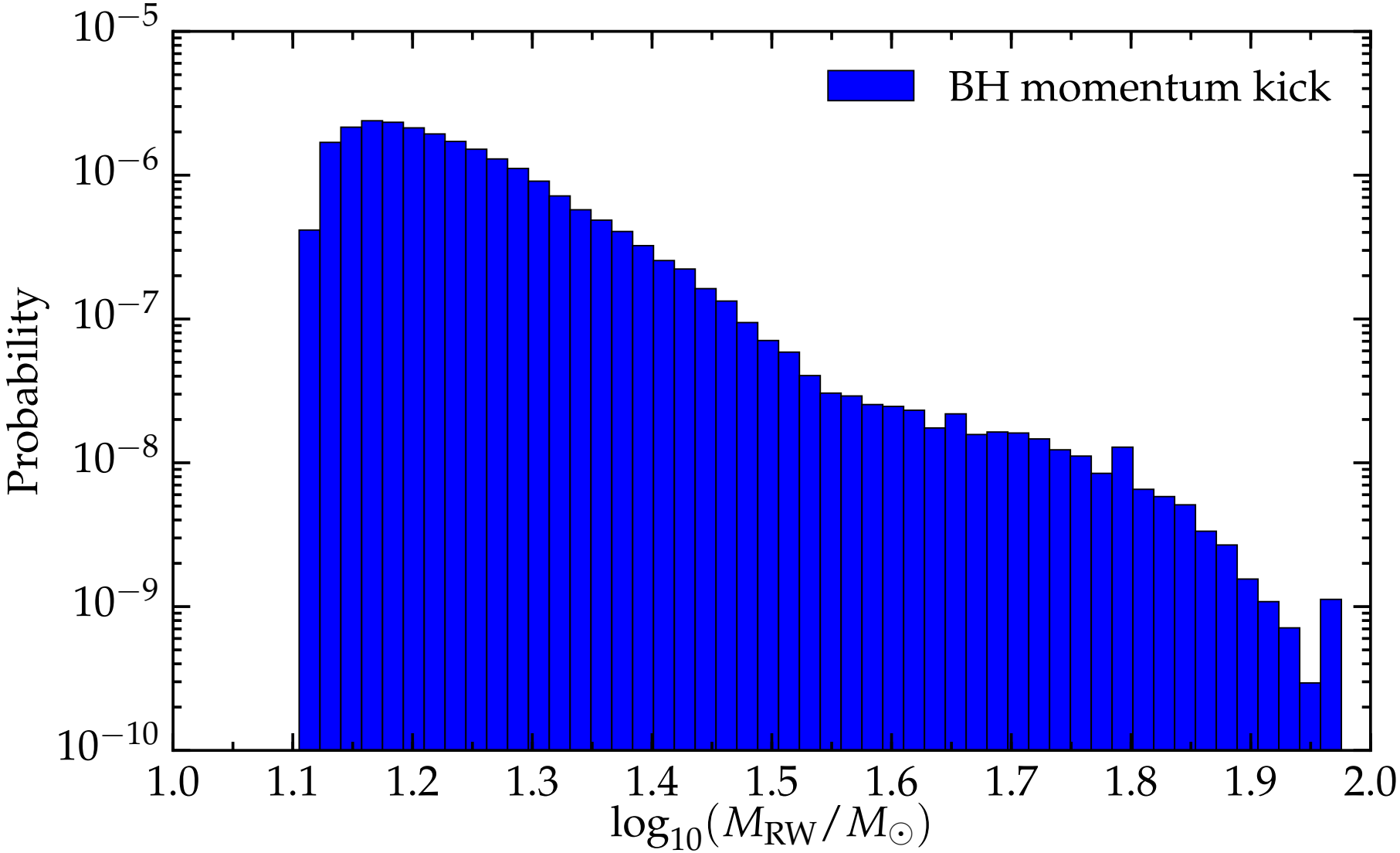
O-type from disrupted binaries only



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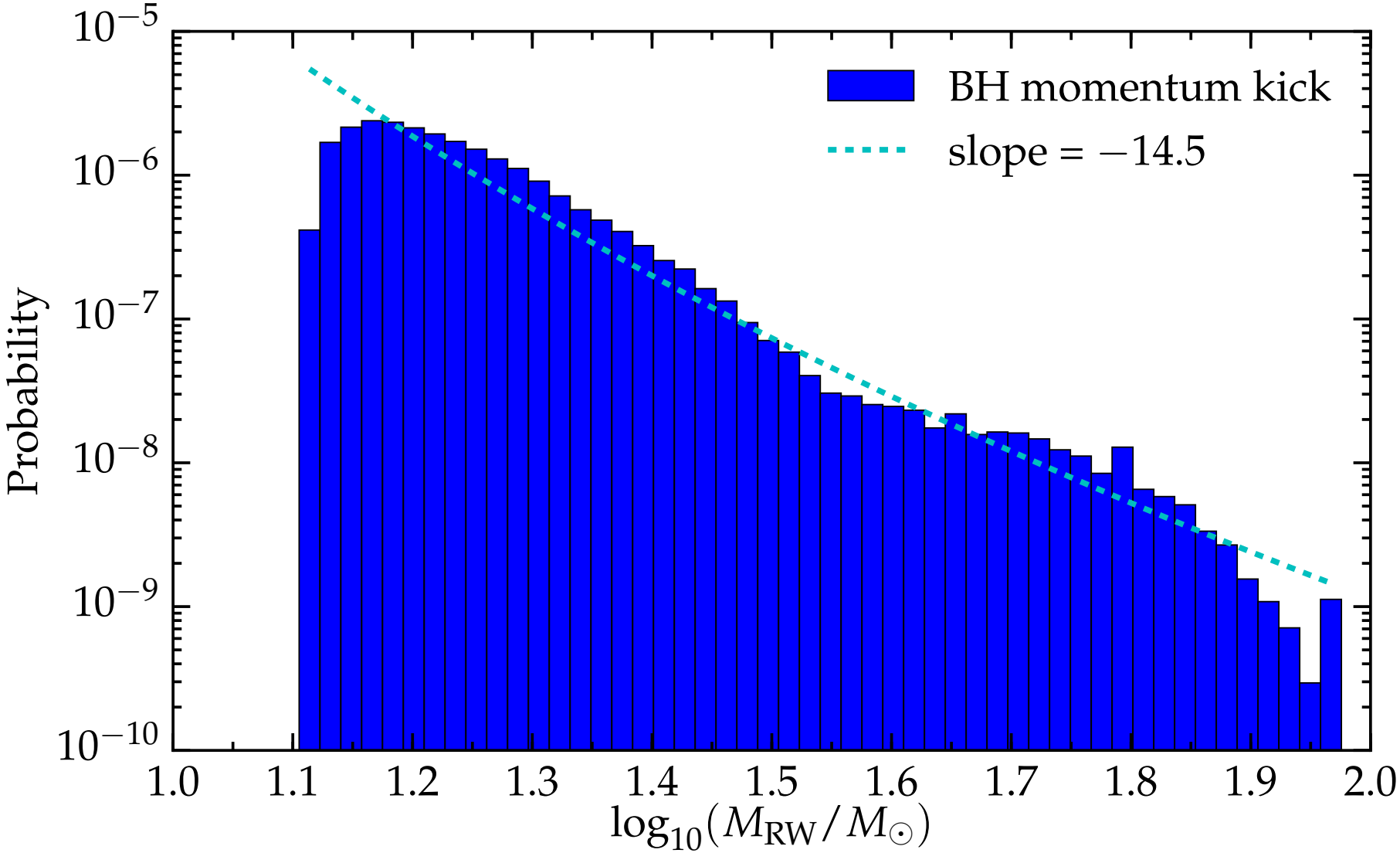

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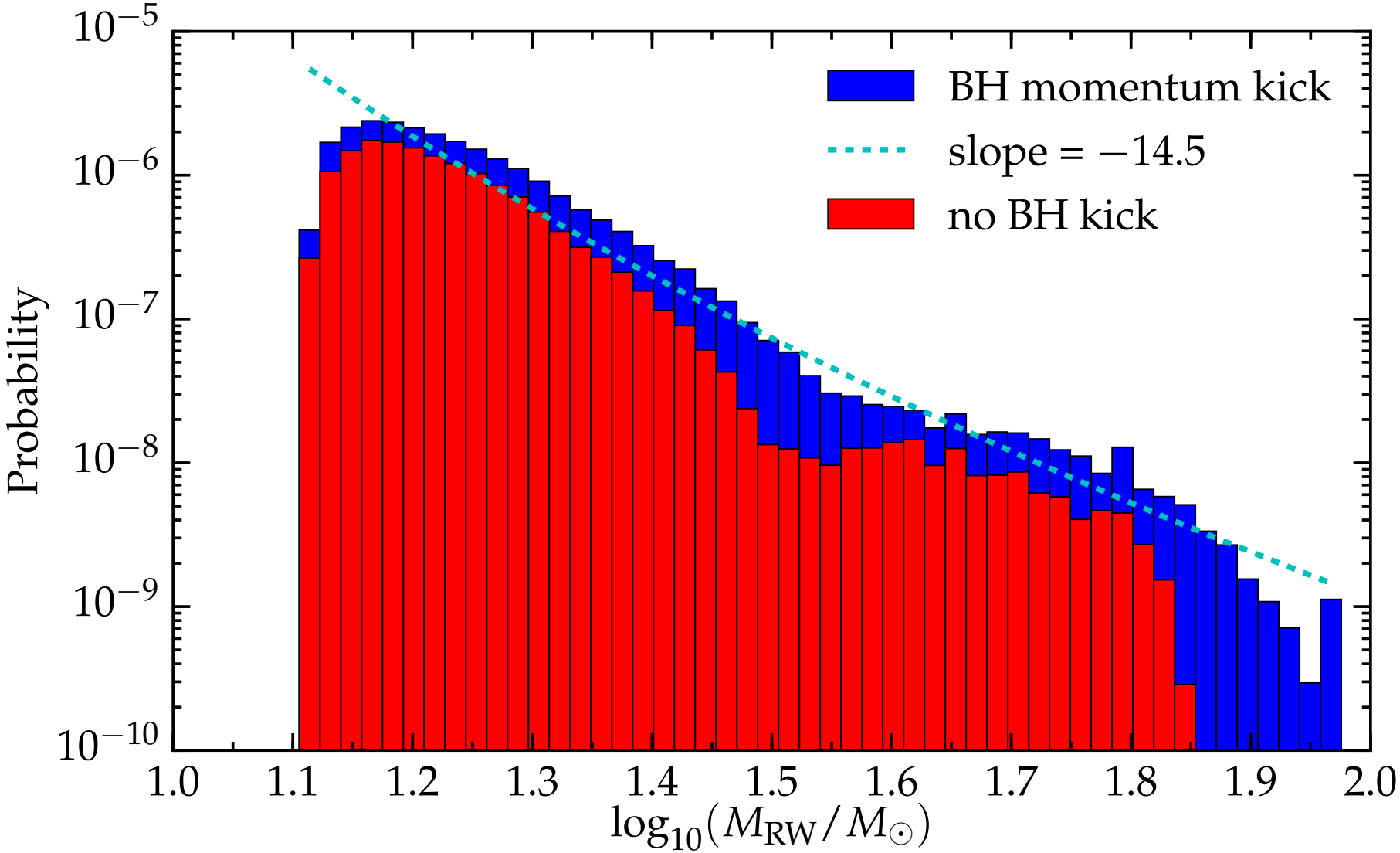

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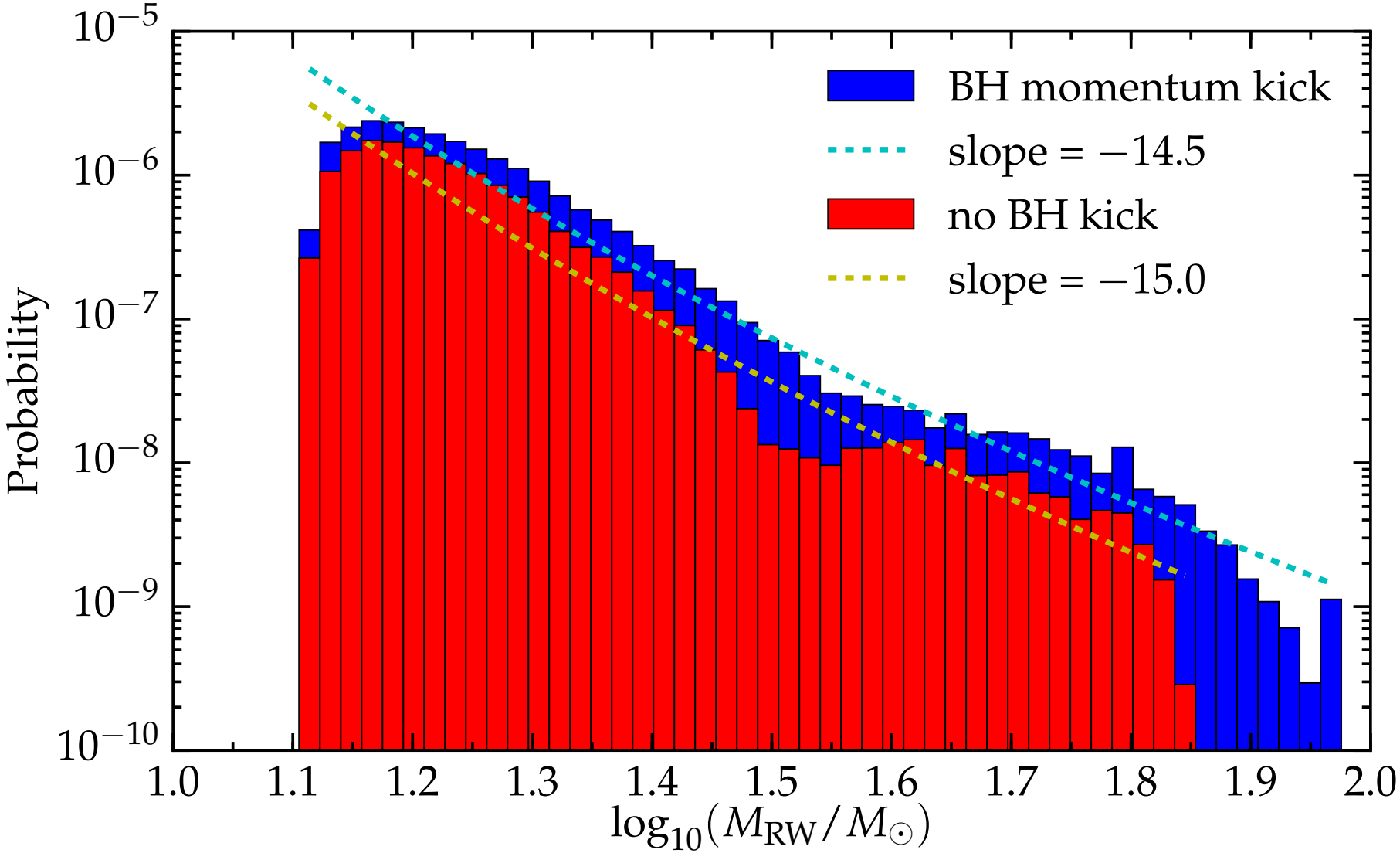

Preliminary: Mass vs. $v_{\rm RW}$ velocity

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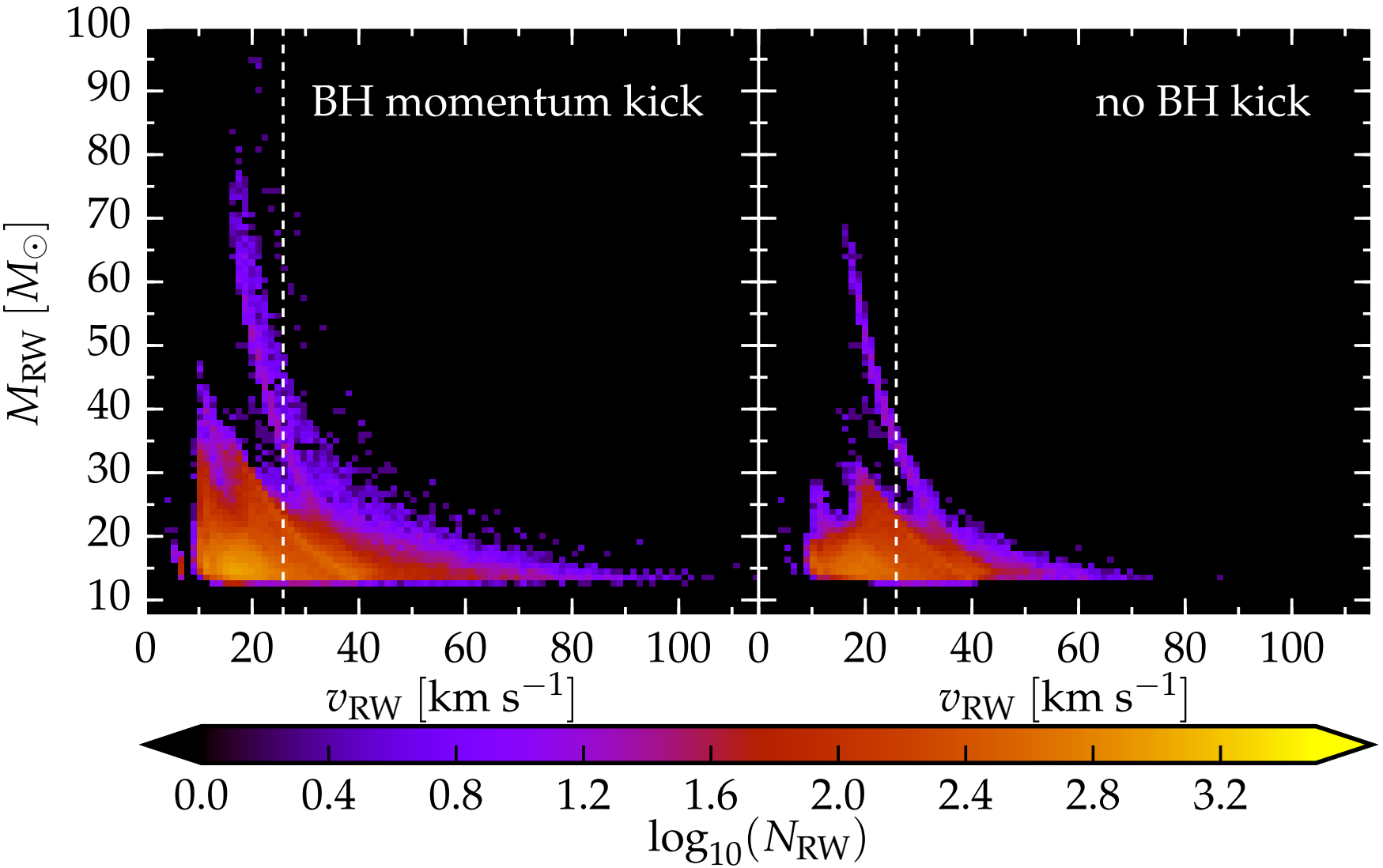
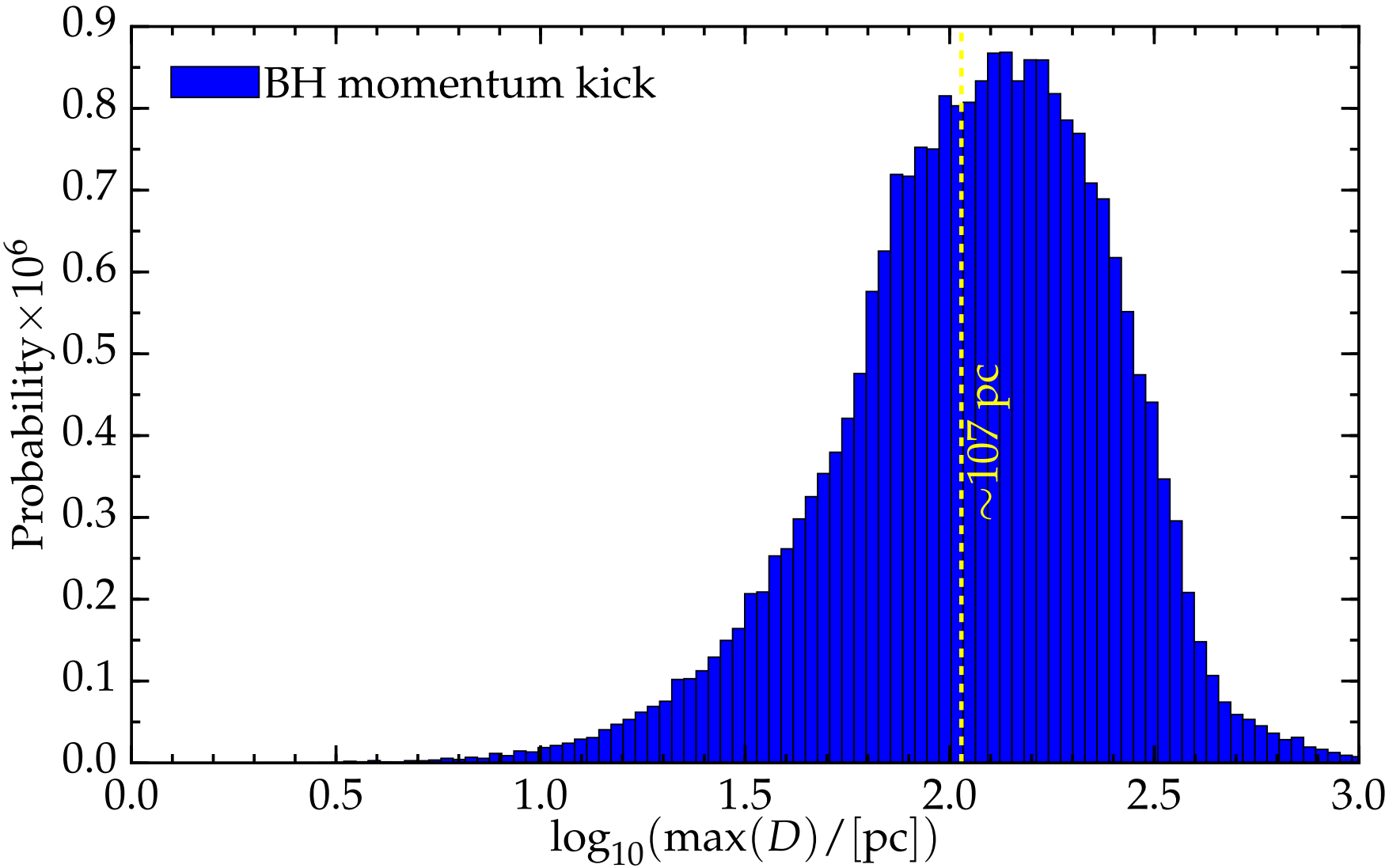
O-type from disrupted binaries only



Preliminary: How far can they go?



Upper limit on distance traveled

$\max(D) \stackrel{\text{def}}{=} v_{\text{RW}} \times \Delta t_{\text{RW}} \Rightarrow$ No potential well $\quad 1\,\text{km s}^{-1} \simeq 1\,\text{pc Myr}^{-1}$

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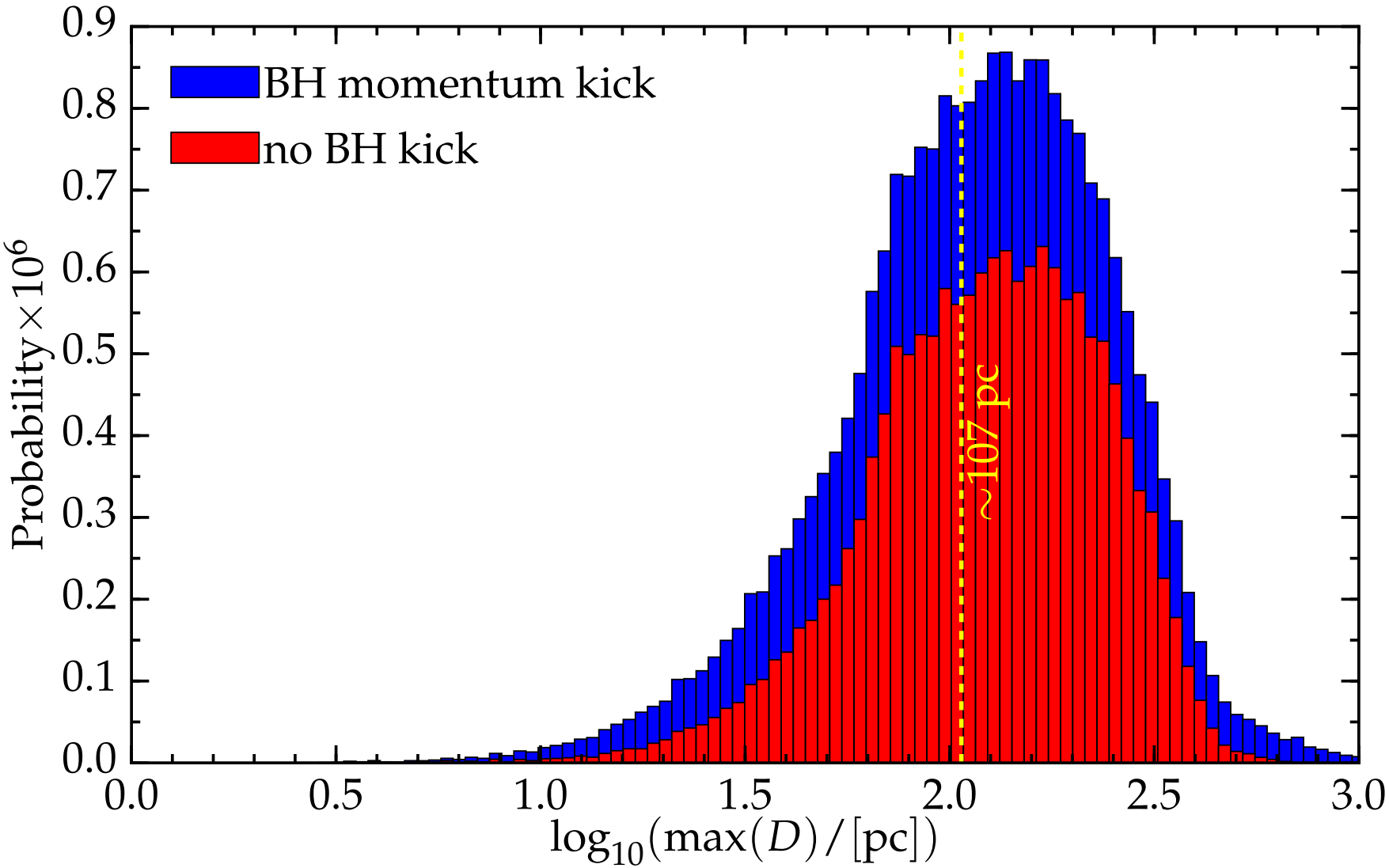

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Outline

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Introduction

Methods: Binary Population Synthesis

Preliminary Results

- Can runaways have had a BH companion?
  - How far can massive runaways go ?

Conclusions

Future Plans & Conclusions

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Robustness checks:

- Binary physics assumptions ;
- Initial distributions;
- Star Formation History;
- Different BH-kick models.

Take home message:

Statistical studies of RW populations can constrain explosion physics, and in particular BH natal kicks.

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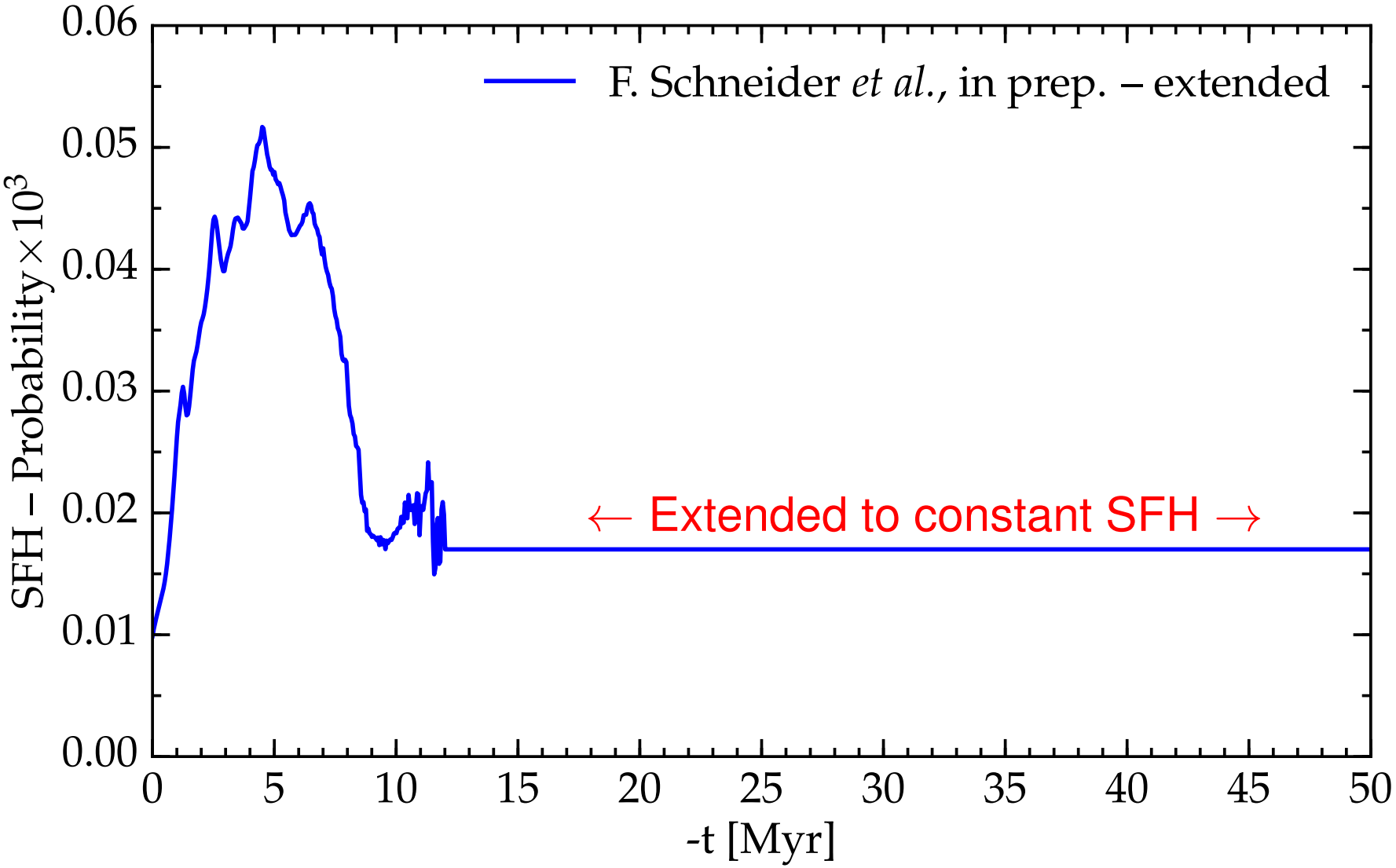
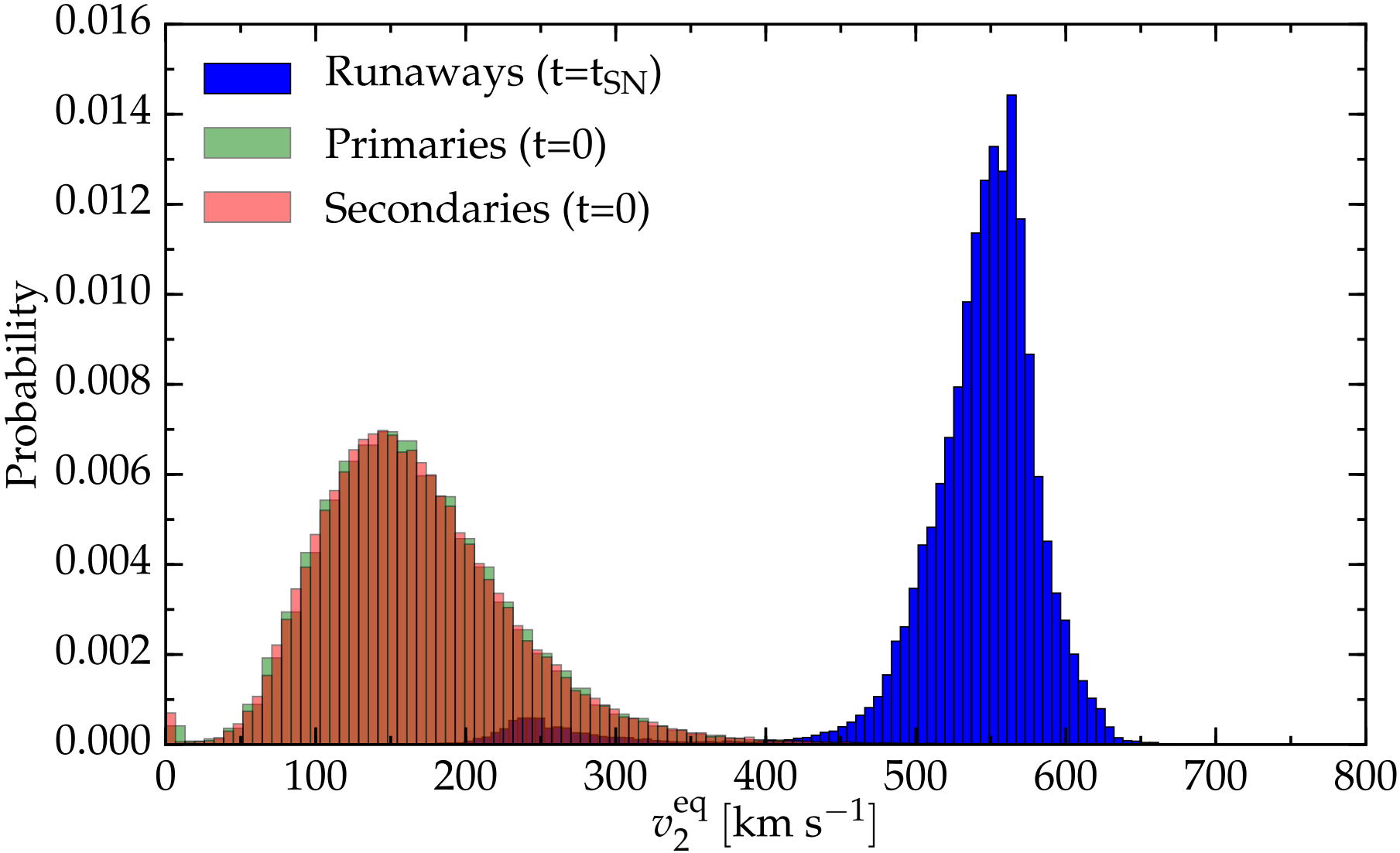
Thank you!

Backup slides

Star Formation History

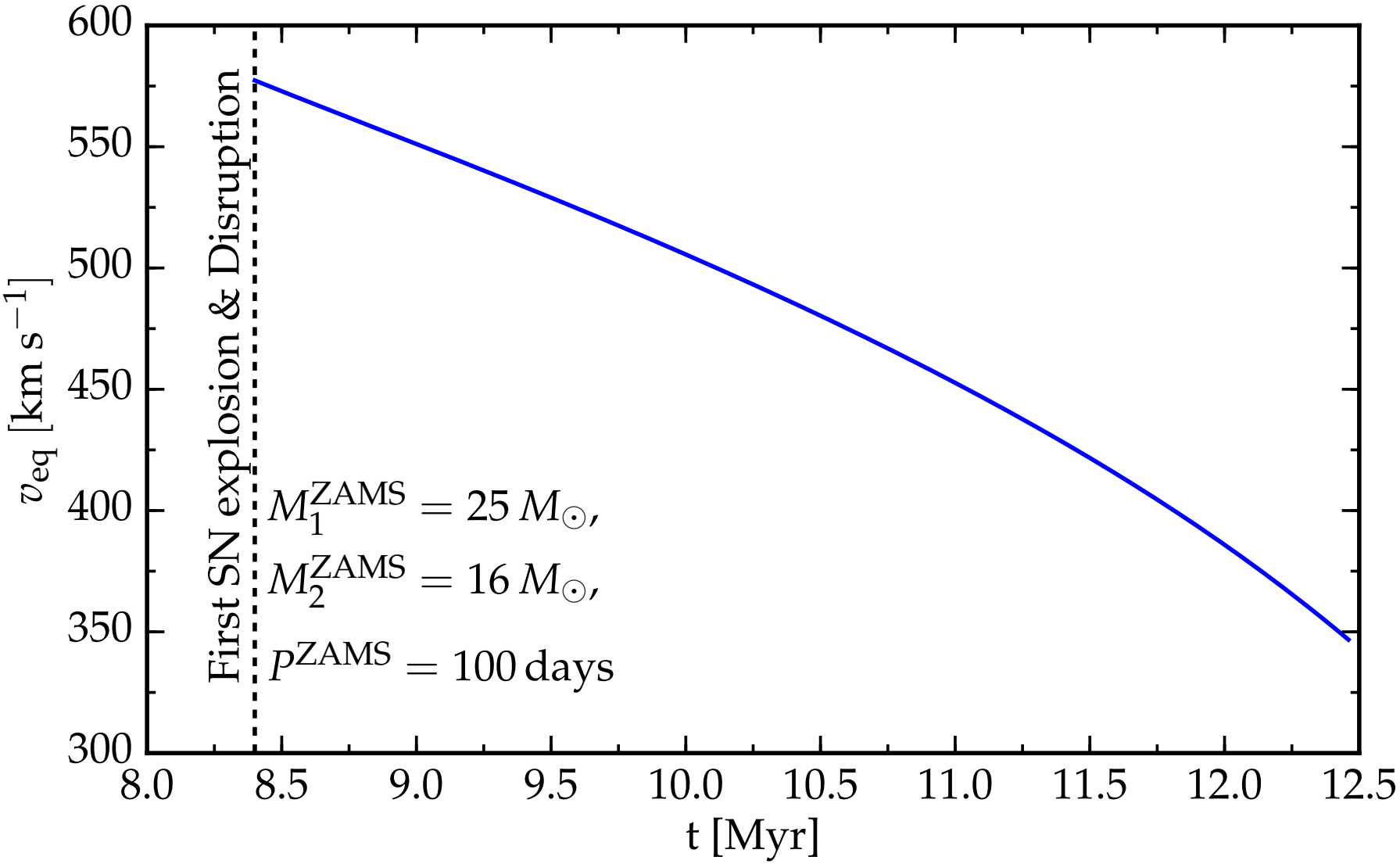


Rotational Velocities



Rotation @ t=0 from O. Ramirez-Agudelo *et al.* '15

Spin Down: Winds



“Fast” vs “Slow” RWs from Binaries

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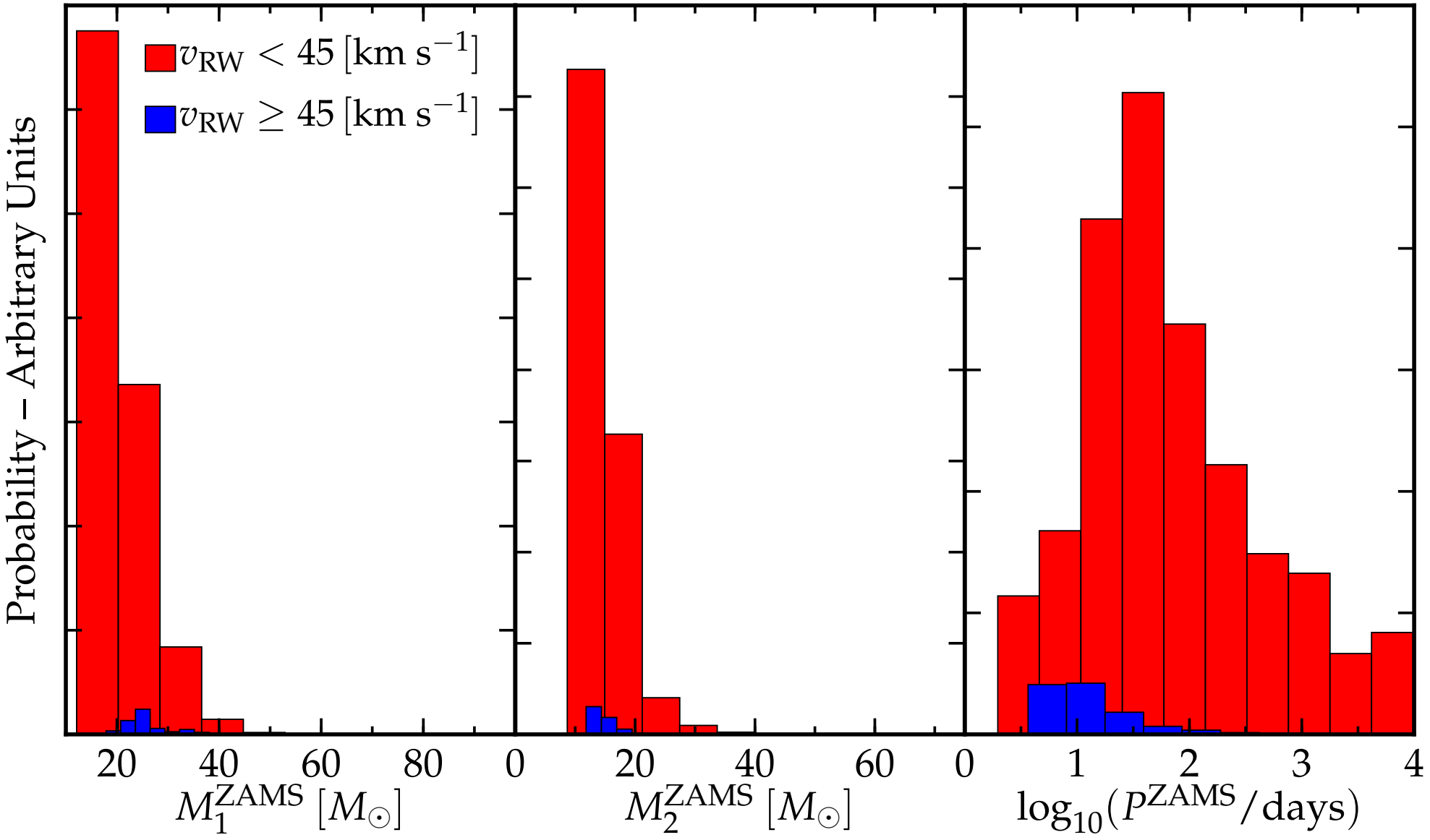
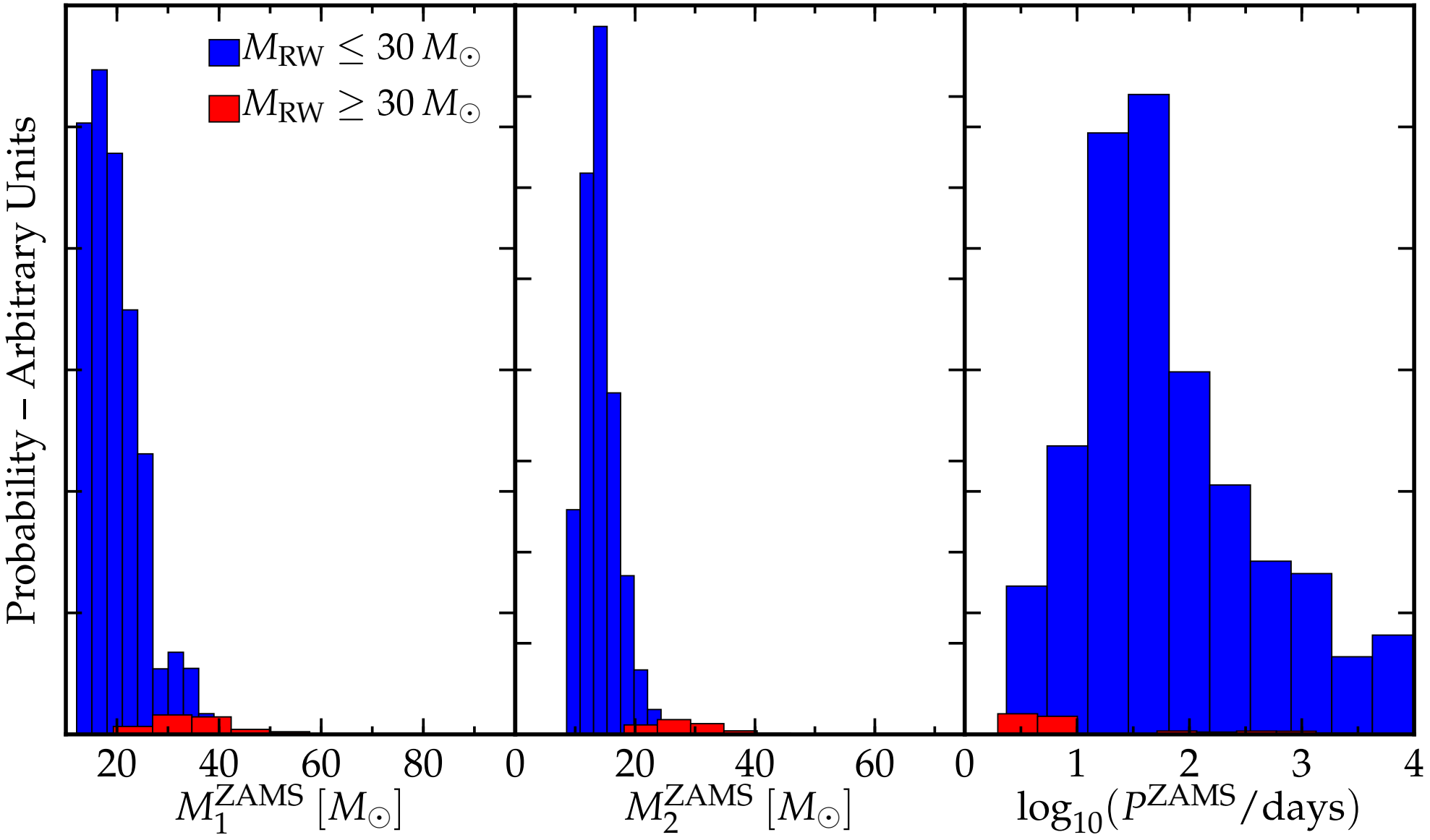


Bumps in RW Mass Function



IMF O Stars (Including Secondaries)

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