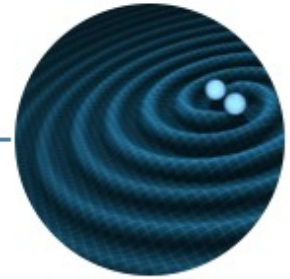
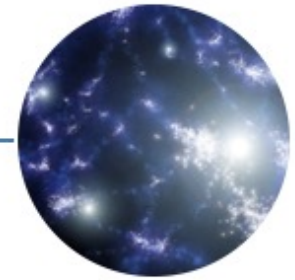
Prof. Hugues Sana

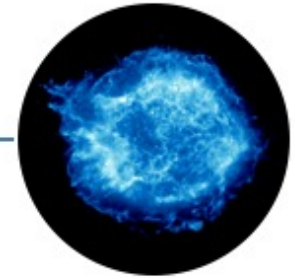
Massive binaries, the Magellanic Clouds and the UVEX connection



Gravitational
wave sources

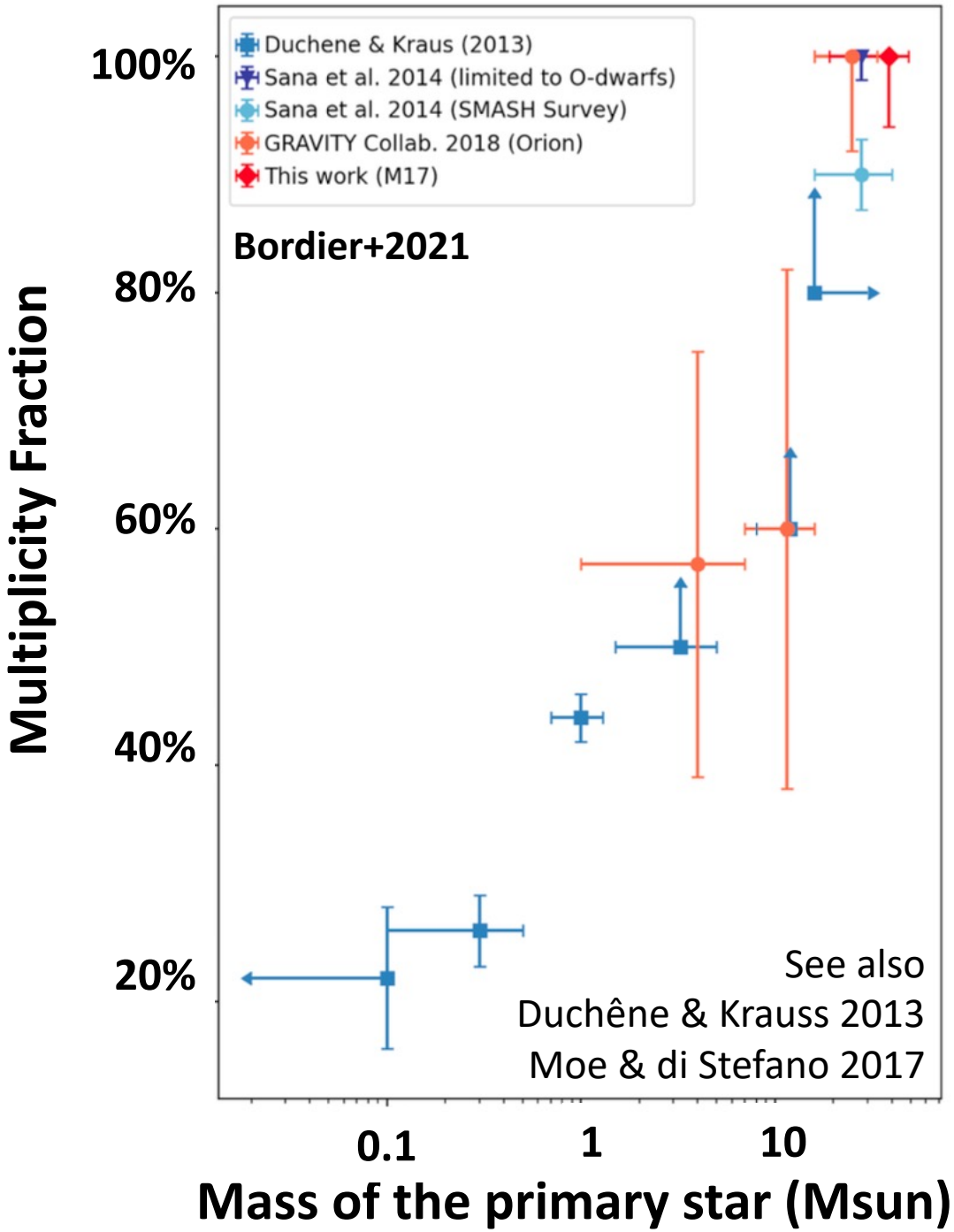


First Stars & Galaxy
formation and evolution



Supernova(progenitors),
GRBs & compact objects

Nucleosynthesis
& Feedback

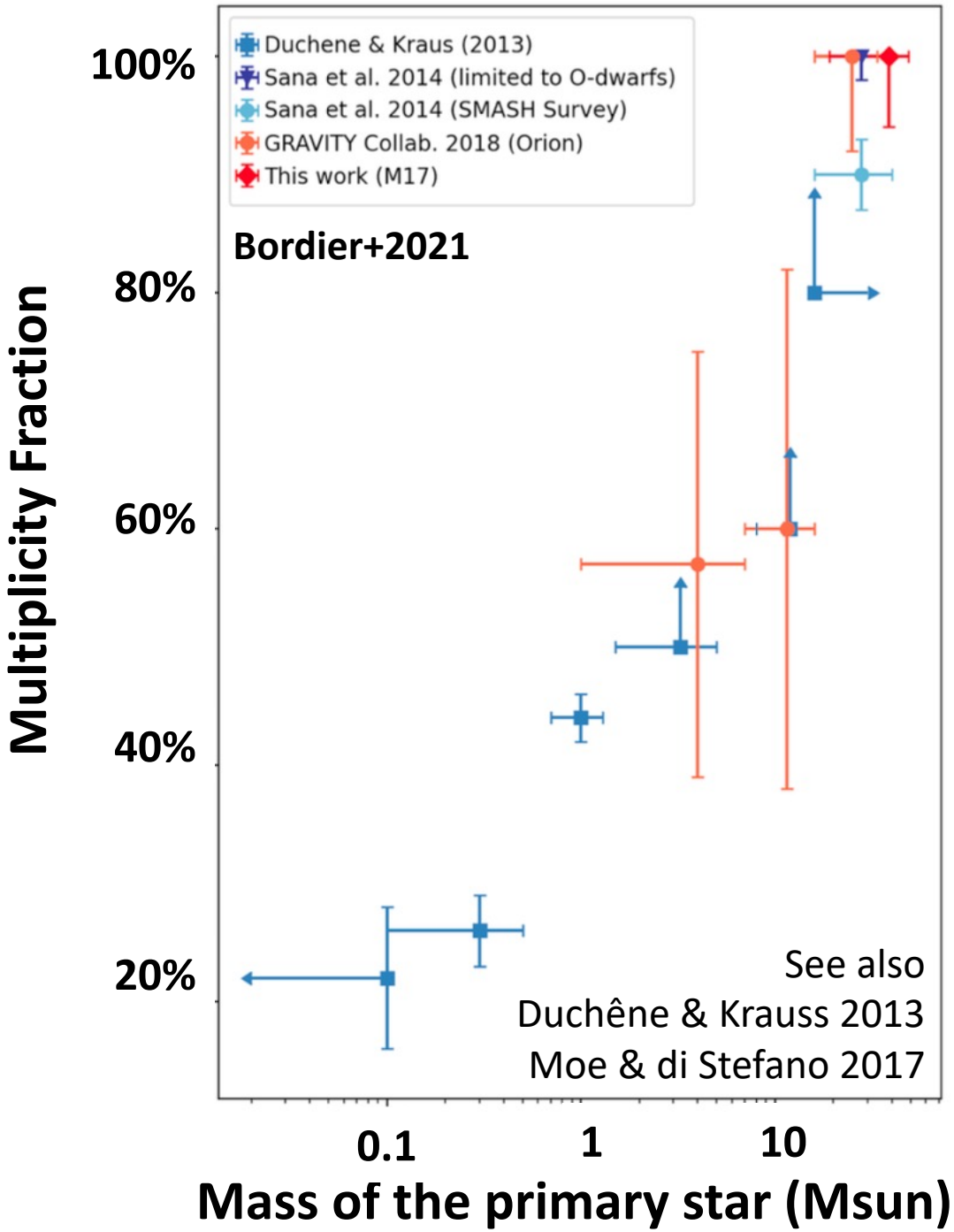


Pairing mechanism

Likely rooted in stellar formation

Clues from

High multiplicity fraction
at very early ages (~1 Myr) **Bordier+2021**



Pairing mechanism

Likely rooted in stellar formation

Clues from

High multiplicity fraction
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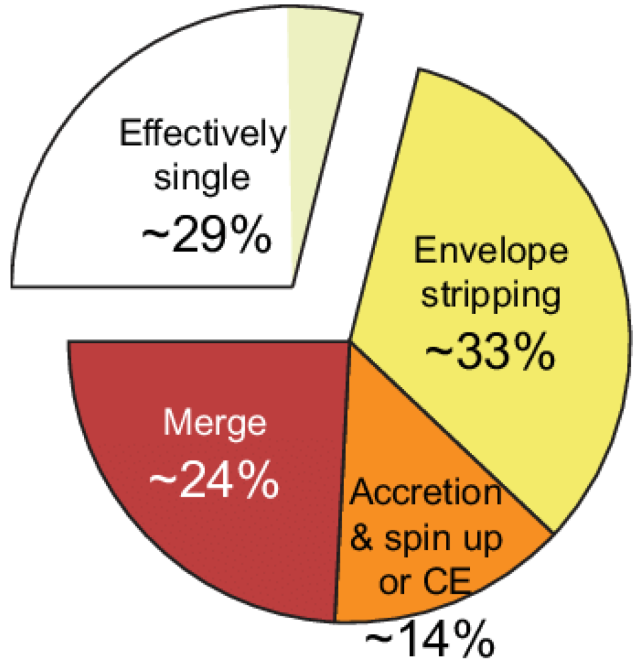
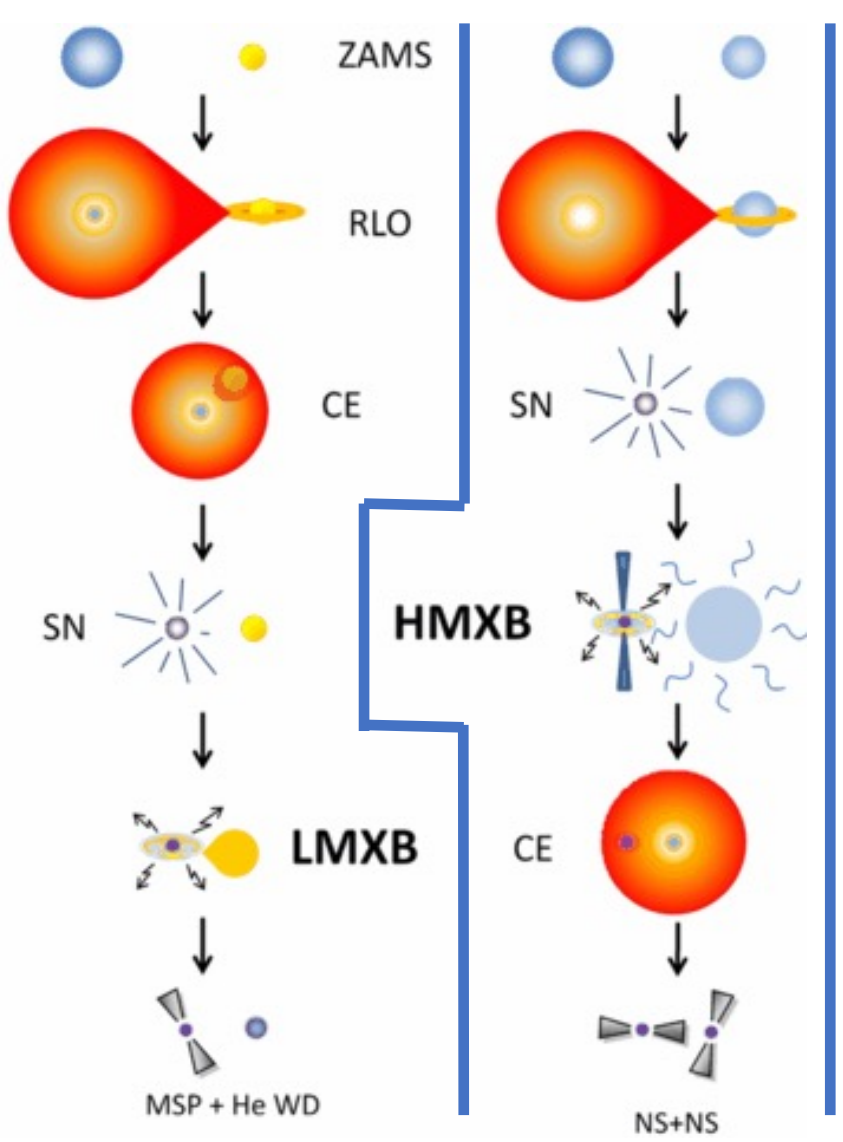
Milky Way
Open Clusters

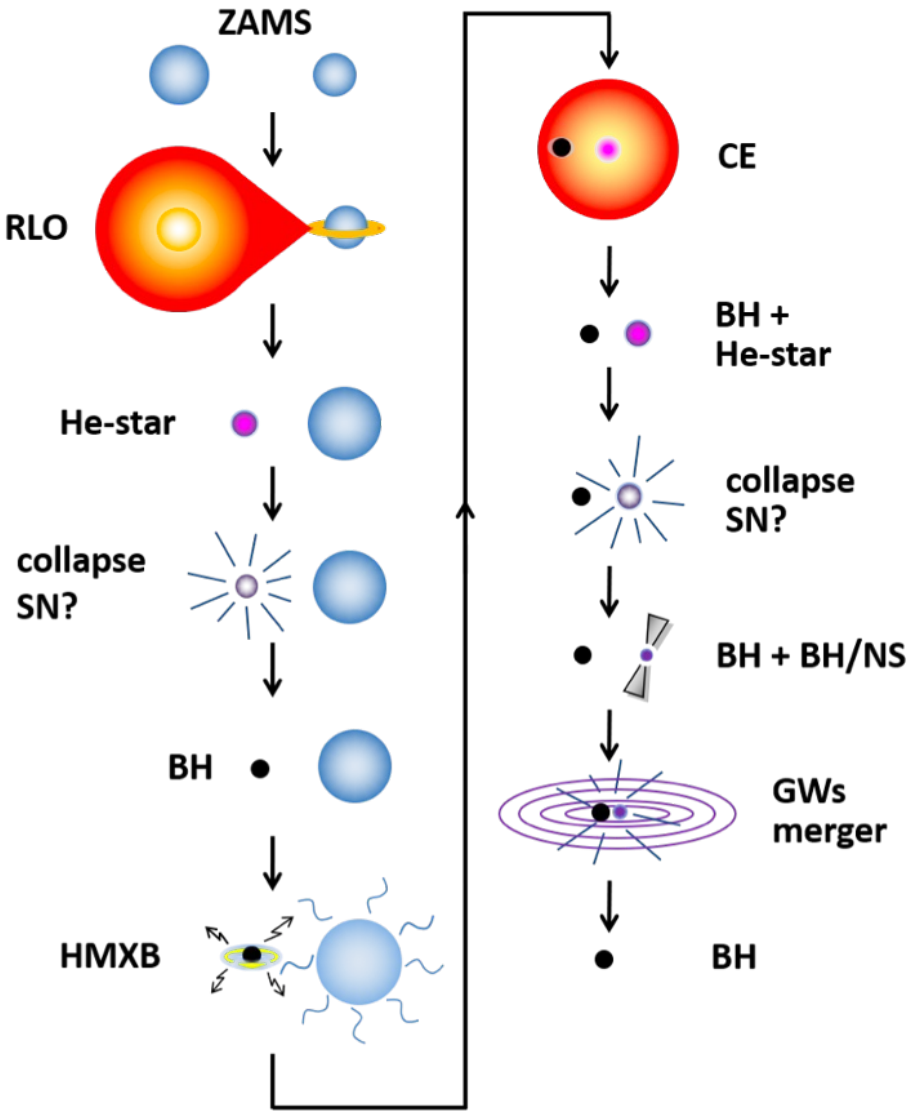
Sana+2012



Challenges

- Statistics of tight binaries
- Diversity of channels
- Uncertain physics
- Rapid interaction phases
- Metallicity dependance





30 Doradus

VLT Flames Tarantula Survey (PI: Evans)
- 800 OB stars
- 6 epochs

Tarantula Massive Binary Monitoring (PI: Sana)
- 100 O-type binaries
- 32 epochs

B-type Binary Monitoring (PI: Taylor)
- 100 B-type binaries
- 25 epochs

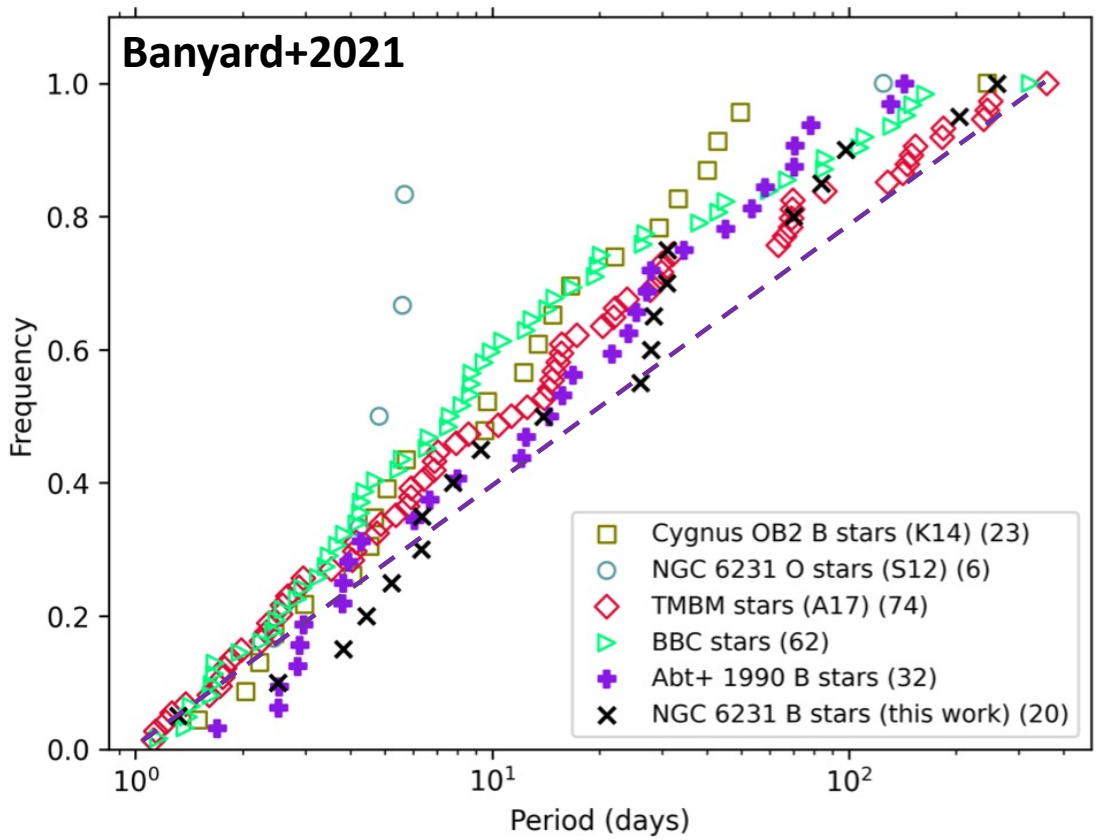
SMC equivalent still missing
(4MOST will do part of it)

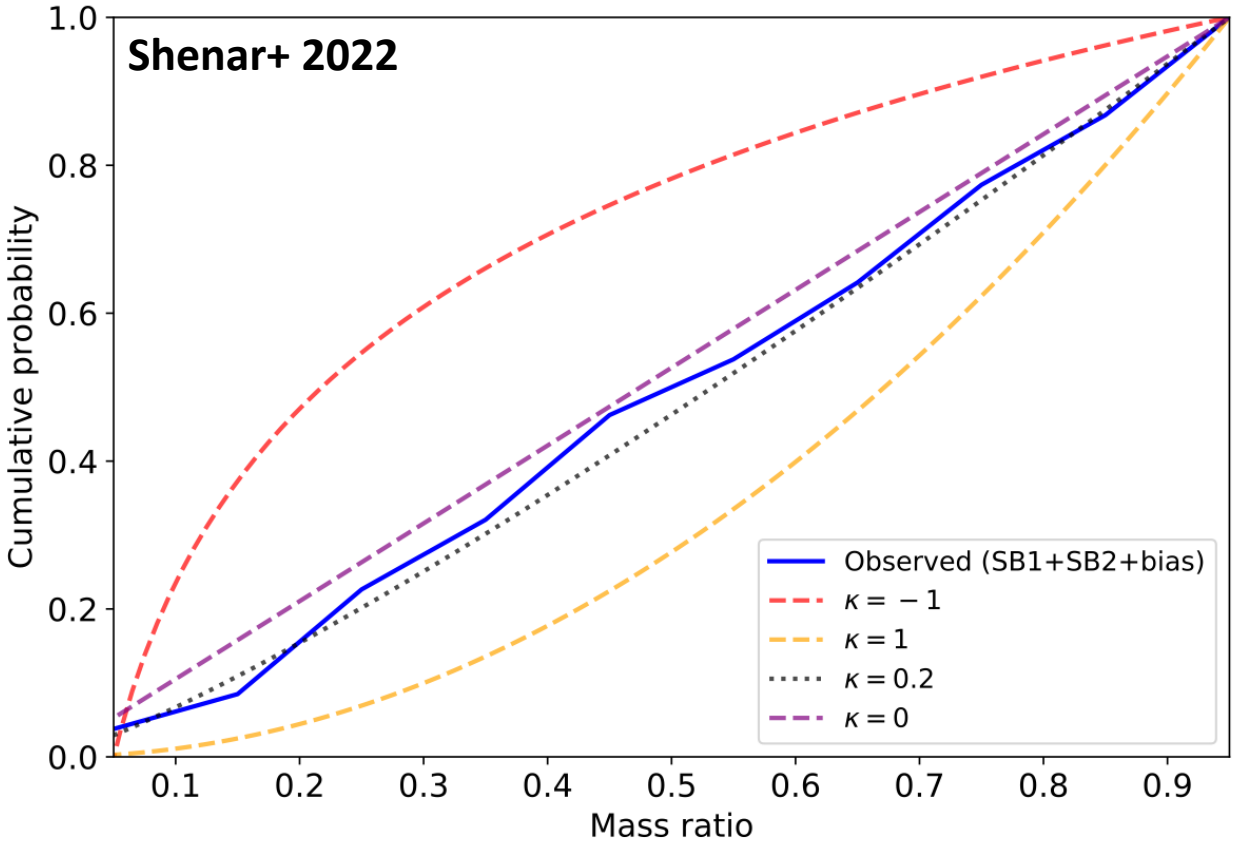
Evans+2011, Almeida+2017, Villasenor+2021

Early-main sequence multiplicity properties

$f_{logP} \propto (\log P)^{\pi}$ *with* $\pi = -0.5 \ldots 0.0$

$f_q \propto (q)^k$ *with* $k \sim 0.0$



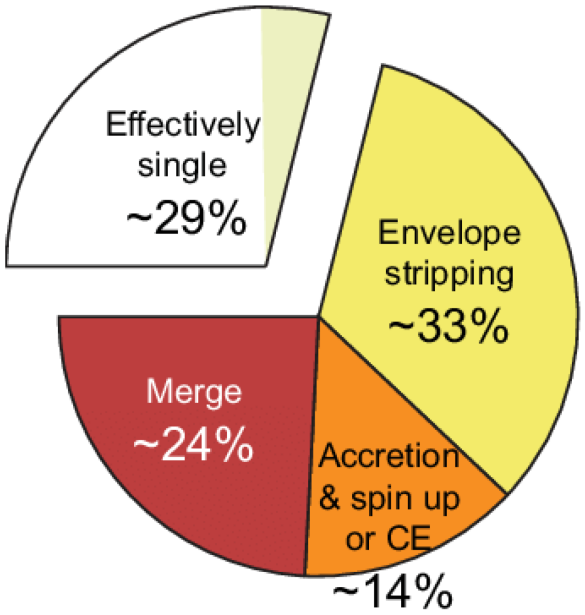


See also Villasenor+2021, Dunstall 2015, Sana 2012, 2013,2014, 2016, Kiminki+2014, Barba 2017, Moe & di Stefano 2017, …

Milky Way: Sana+ 2012
30Dor/LMC: Shenar+ 2022

Binary Evolution is ubiquitous

Milky Way Open Clusters



30 Doradus (VFTS)

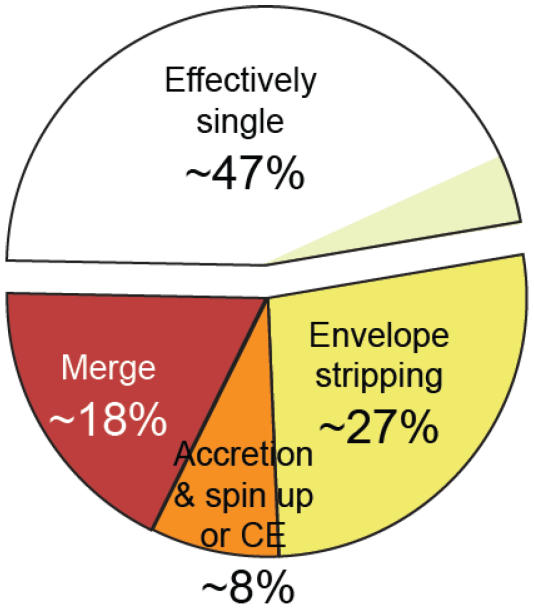
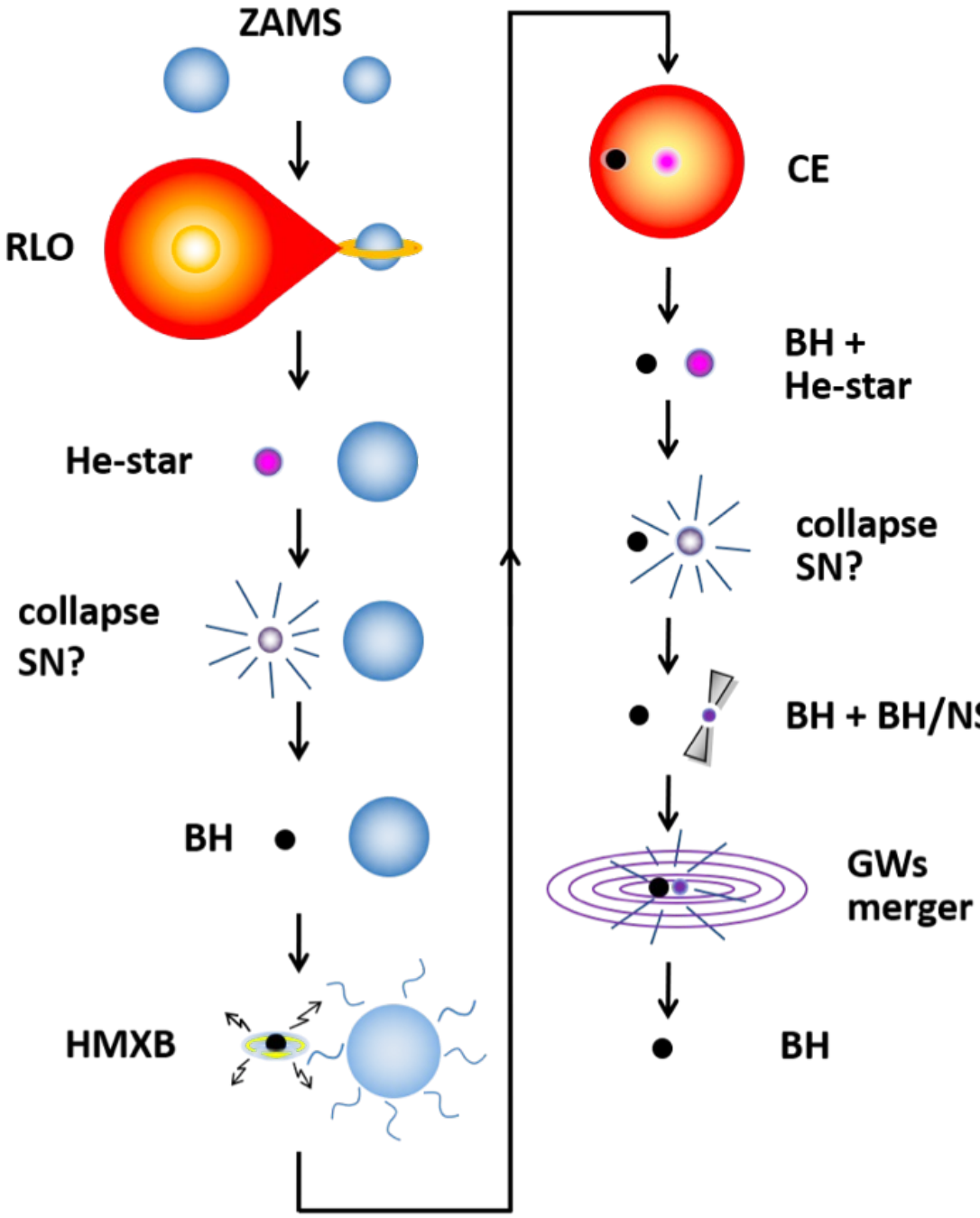
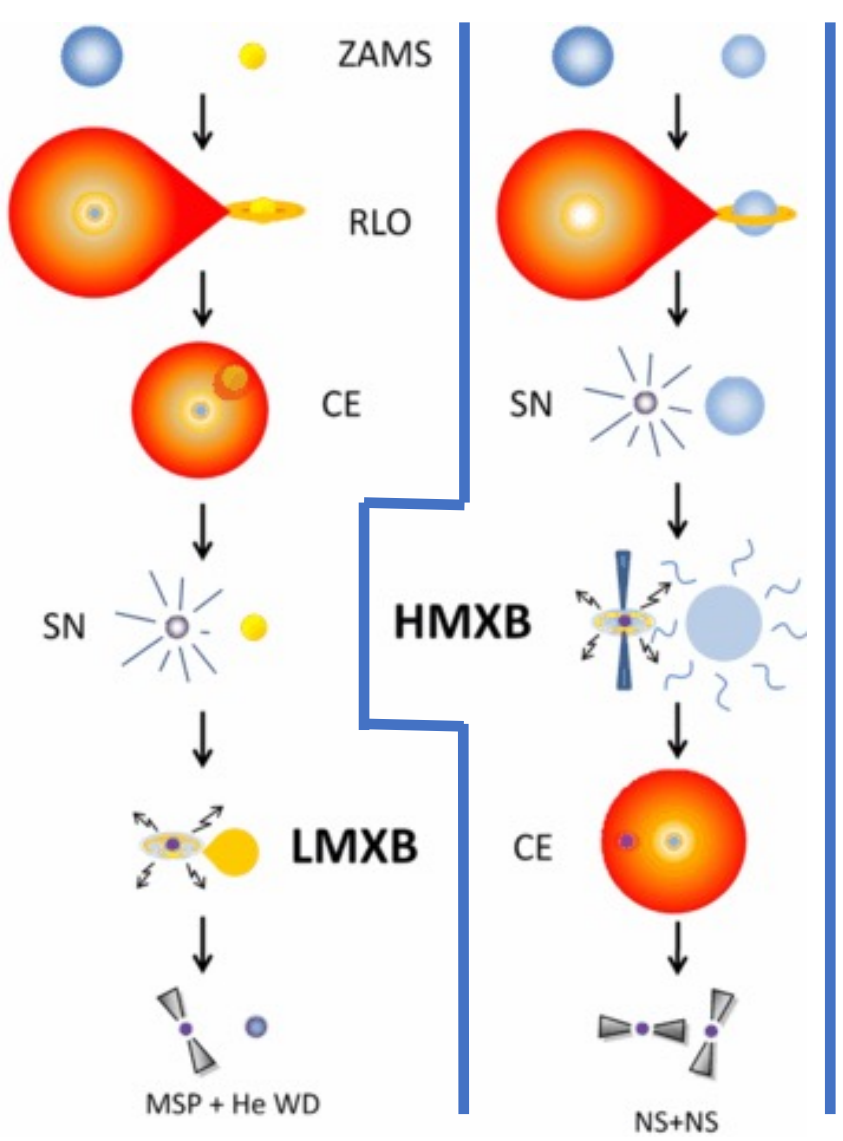
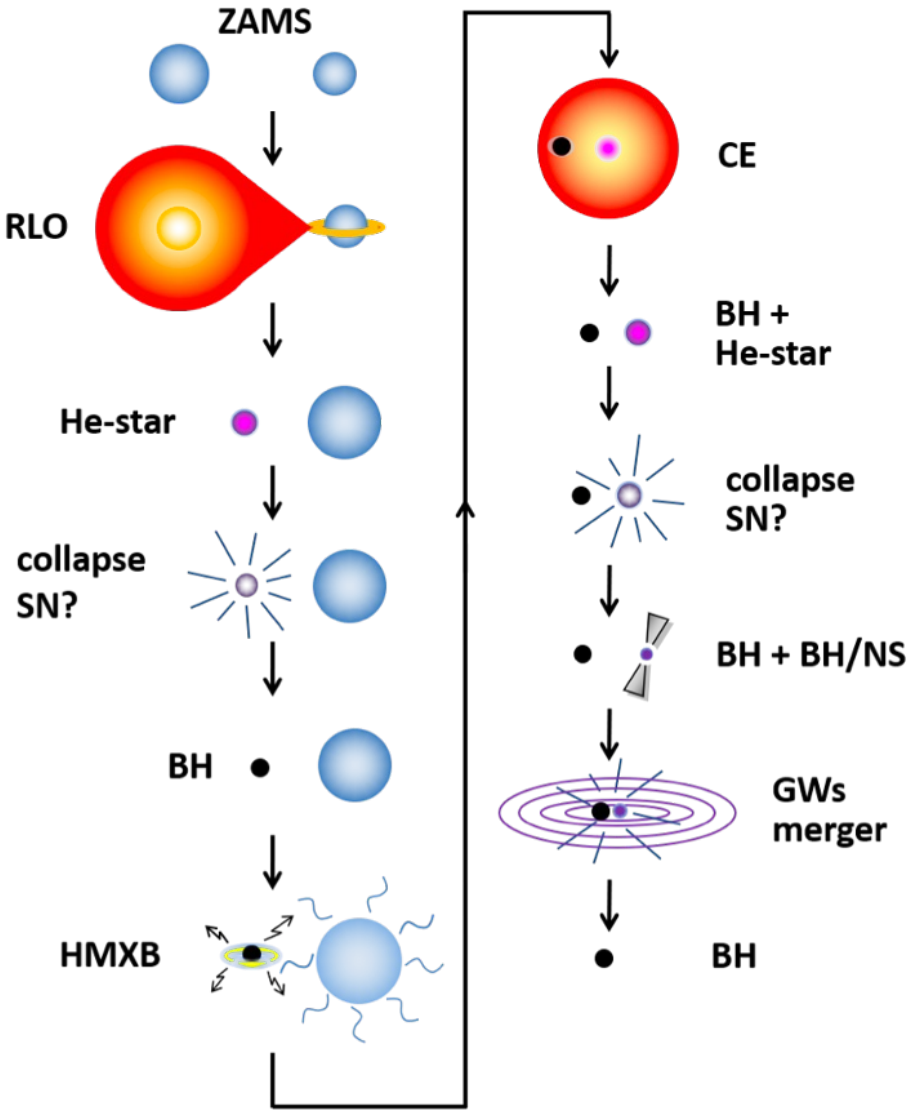


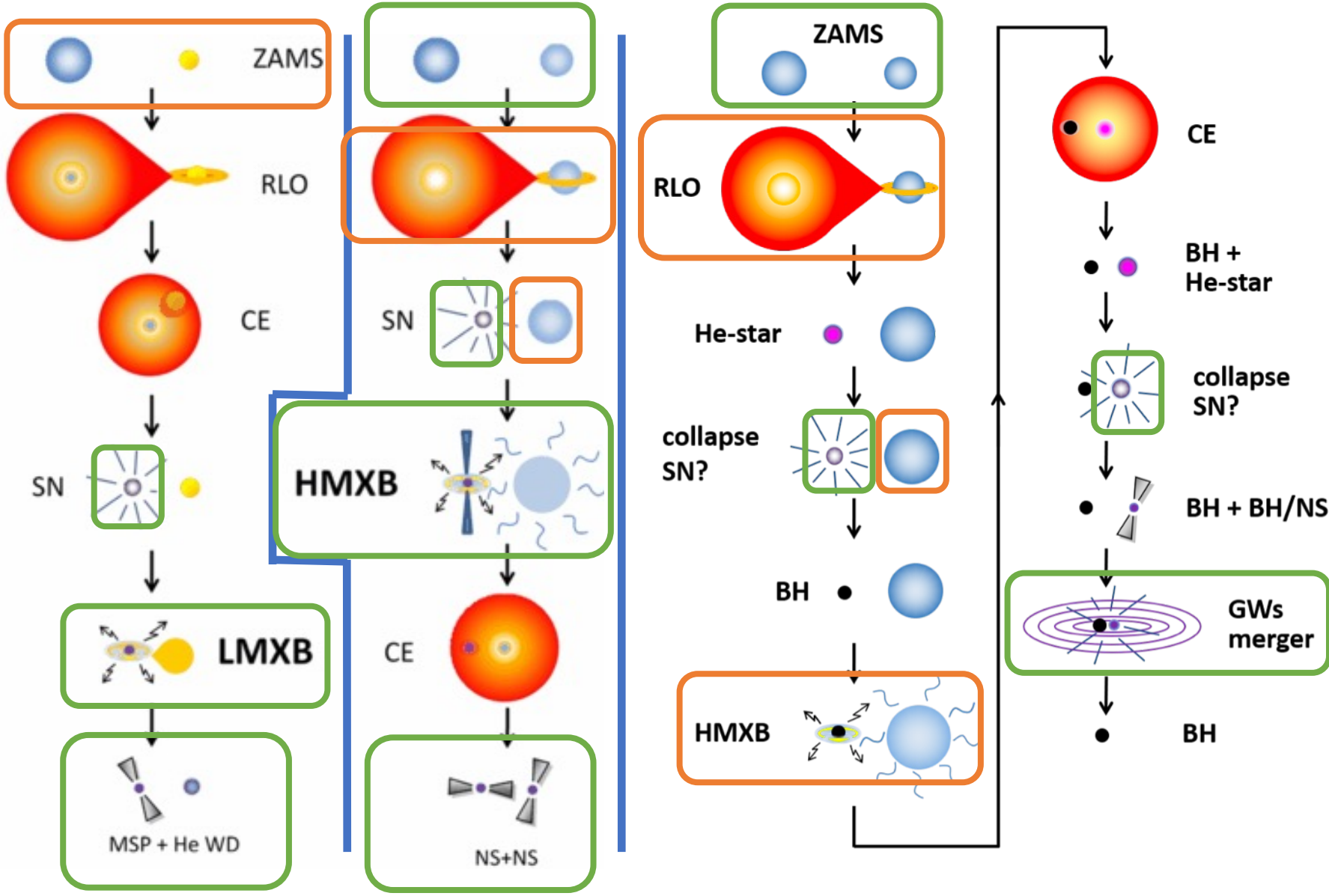
Fig. from Crowther 2019 based on Sana+2012,2013




ZAMS
RLO
CE
SN
LMXB
MSP + He WD
HMXB
SN
CE
NS+NS


ZAMS
RLO
He-star
collapse SN?
BH
HMXB
CE
BH + He-star
collapse SN?
BH + BH/NS
GWs merger
BH

Systematic mapping crucuially missing



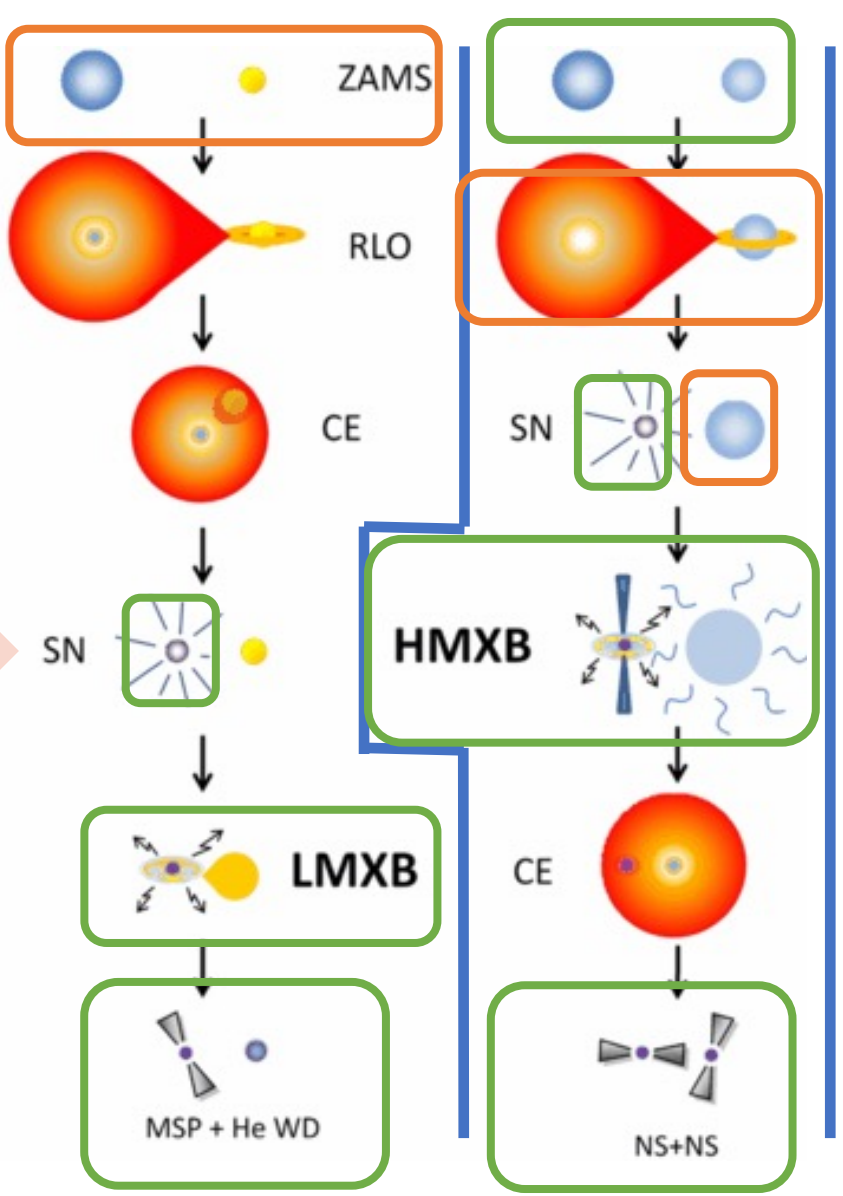
Systematic mapping crucuially missing

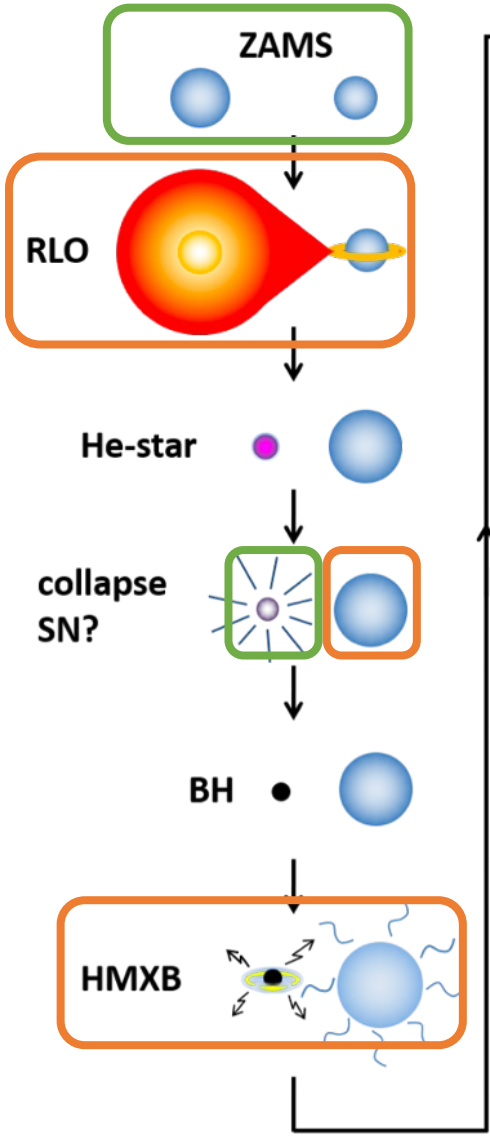
Observation Constraints

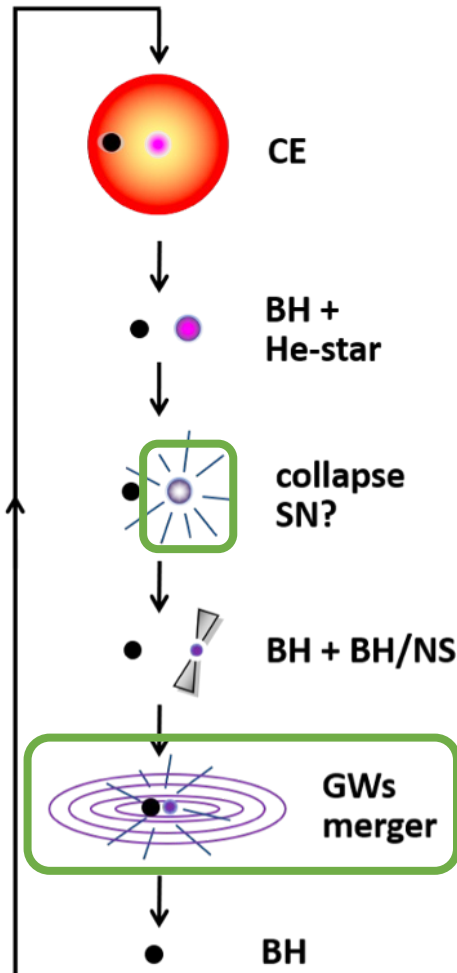
Large samples

Different metallicities

Pre & post interaction Phases







TOPICS TODAY

Characterisation of OB+OB binaries

Binary evolution products / stripped stars

OB + BH systems

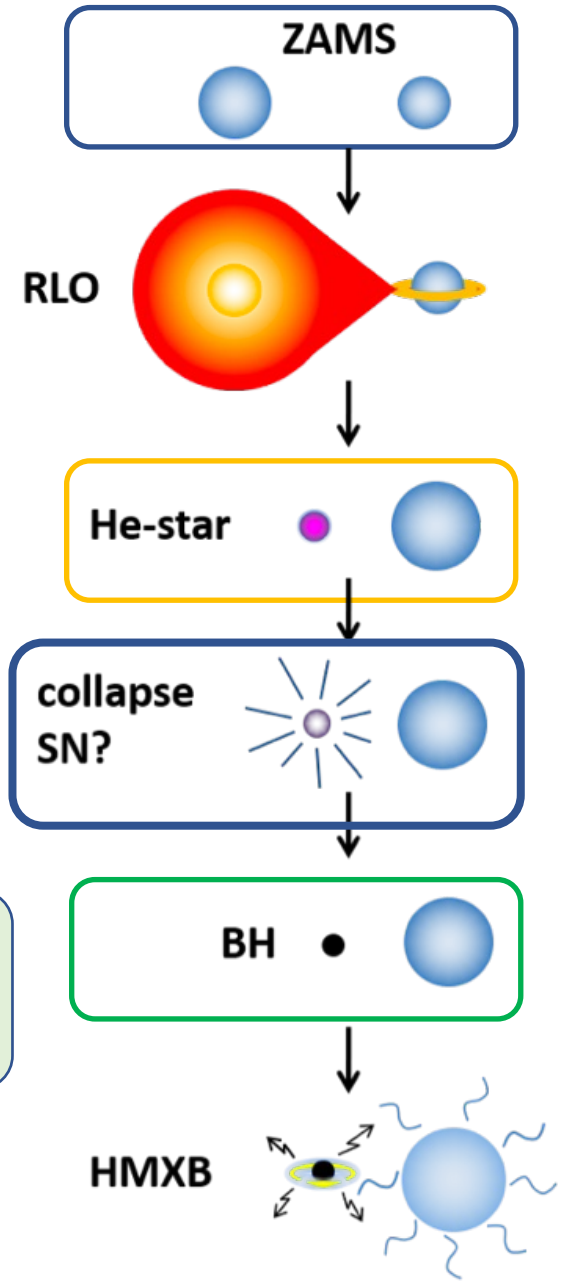
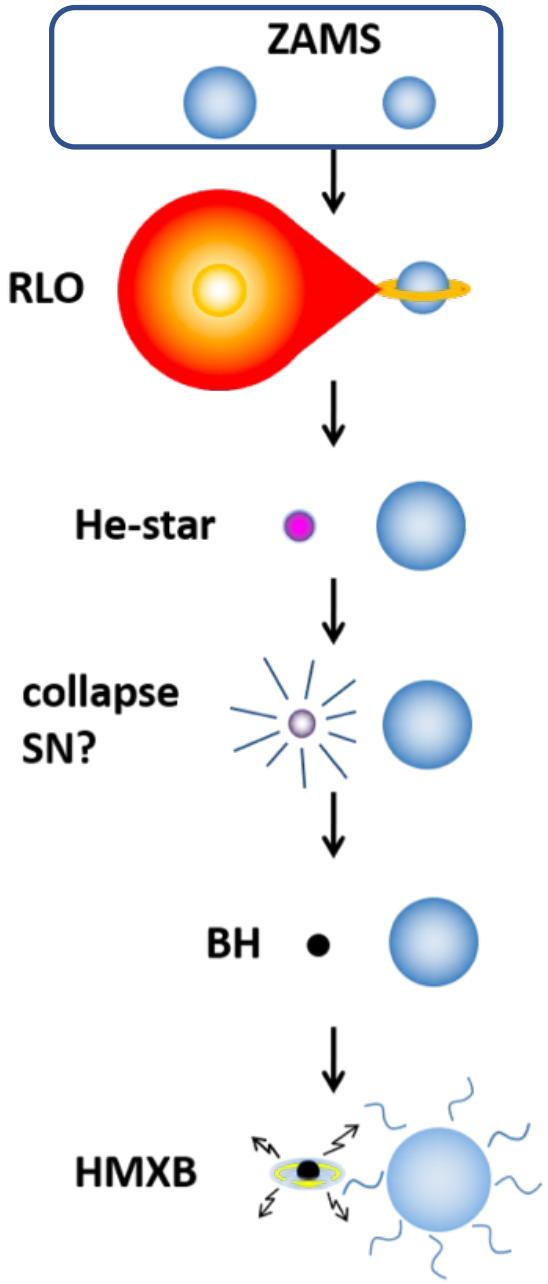
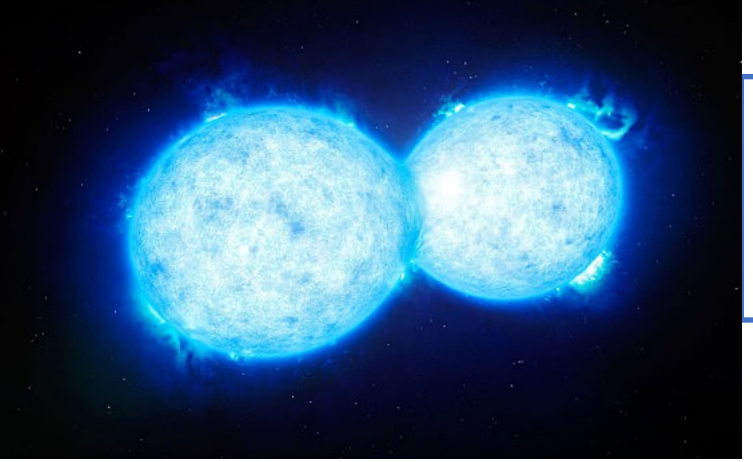


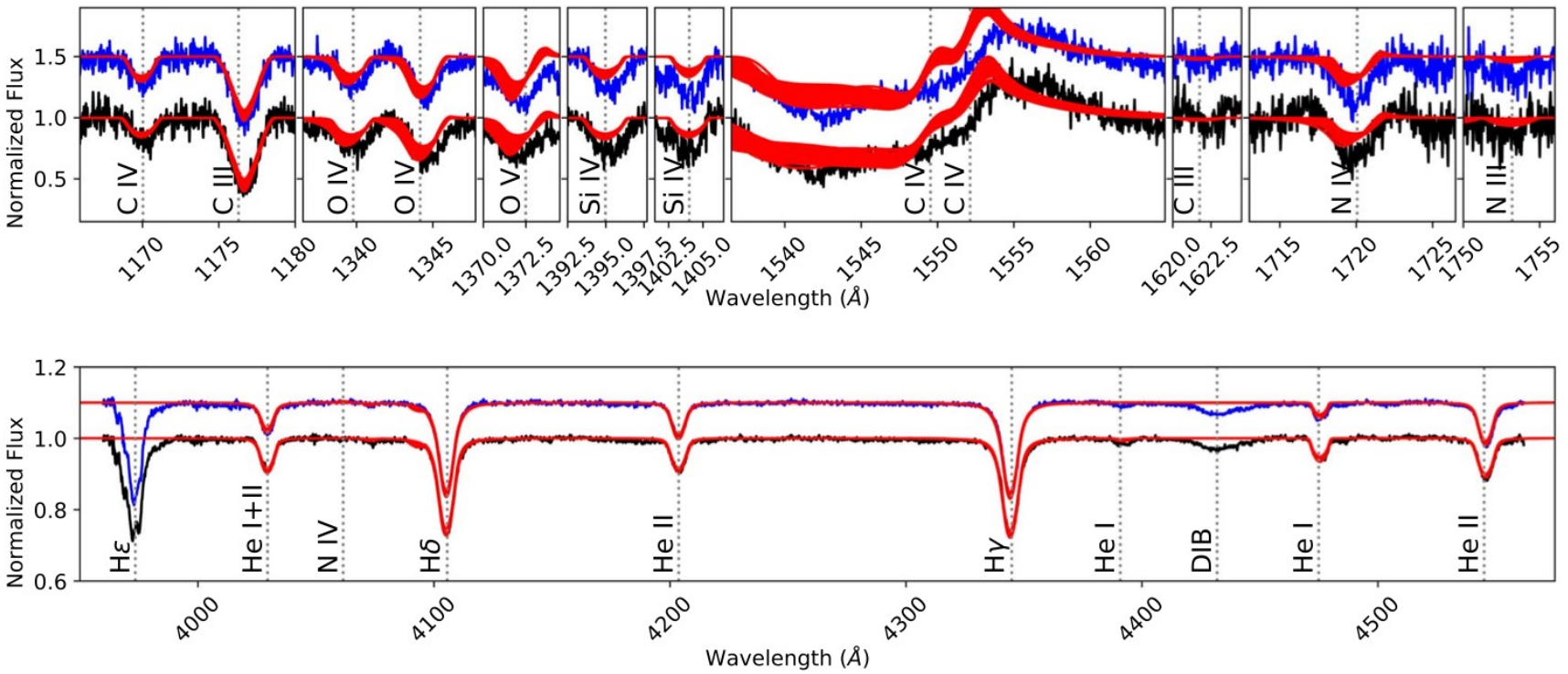
Figure adapted from Langer+20

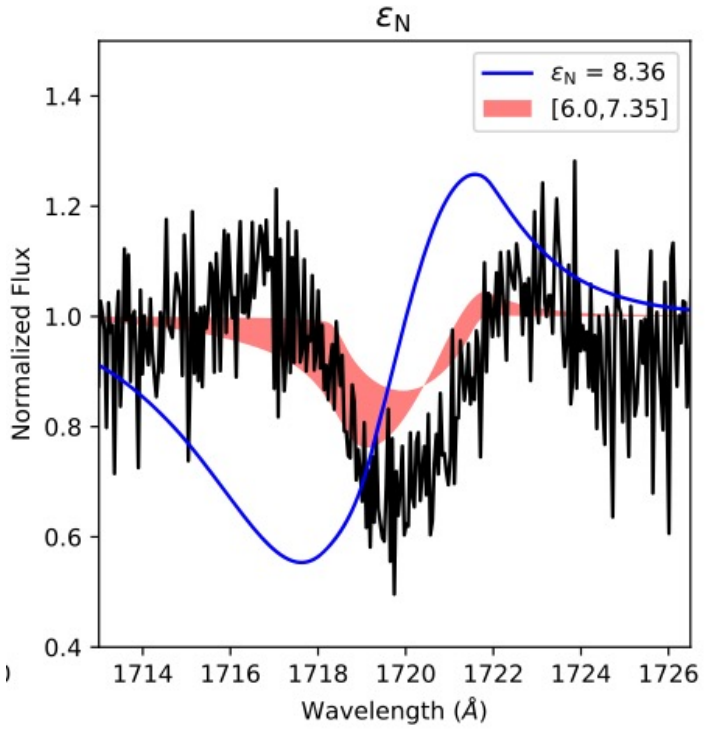
Characterisation of main sequence binaries





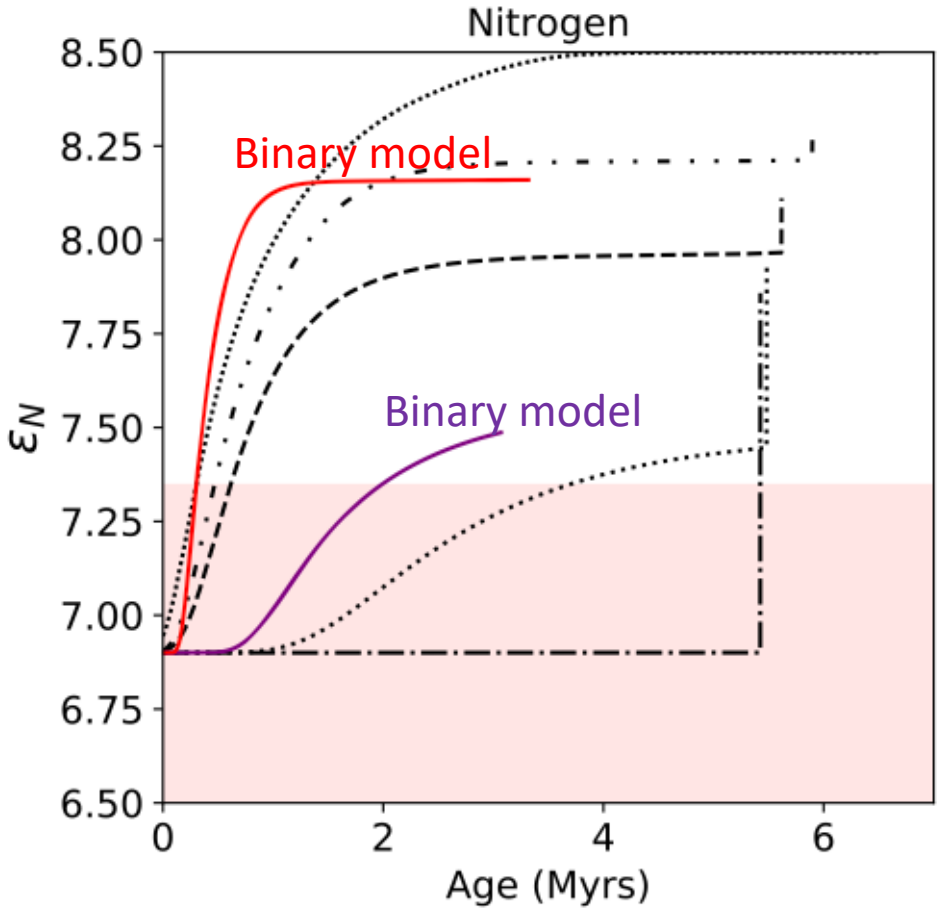
VFTS 352 (LMC): the most massive overcontact system.



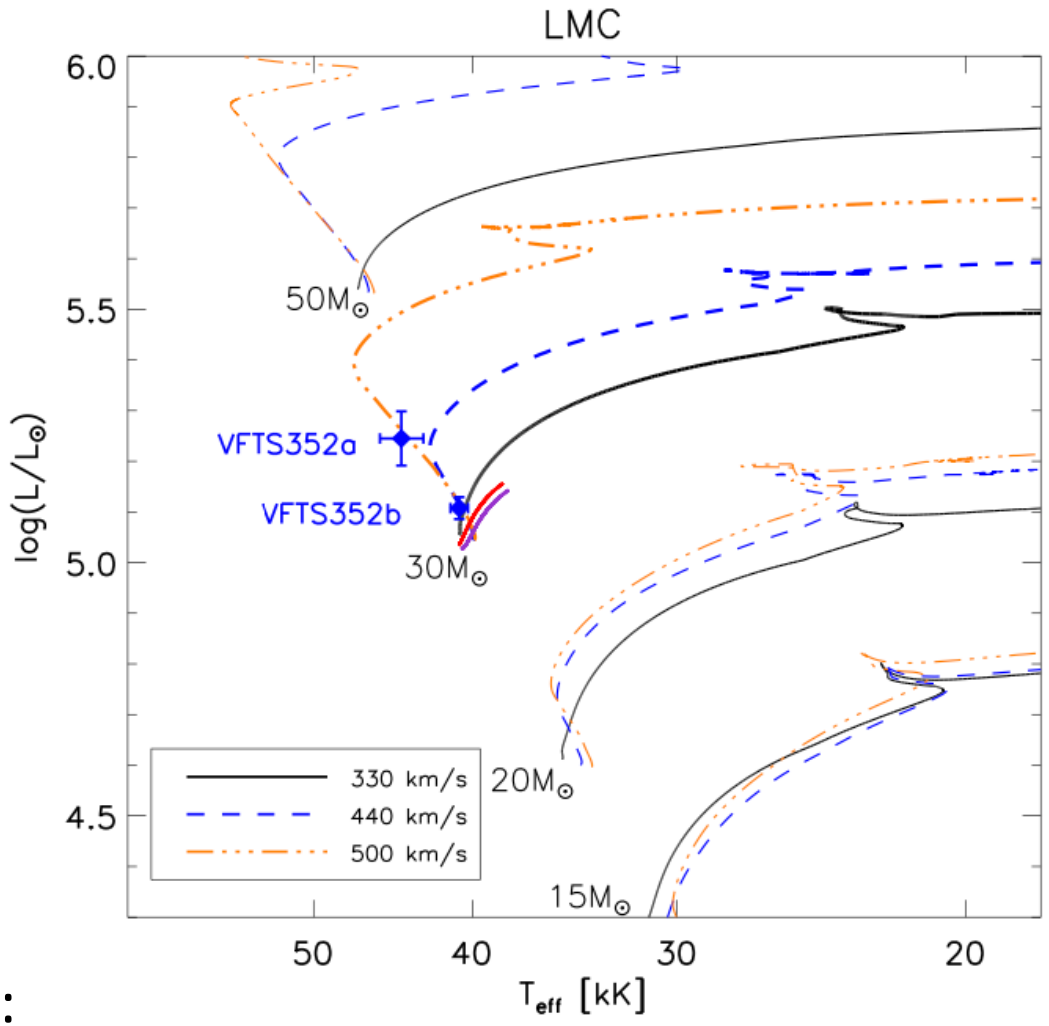


Abdul-Masih+2019

No helium or nitrogen enrichement despite rapid rotation, but hotter than expected
→ no (MESA) model can reproduce this



Abdul-Masih+2019



Ongoing efforts to :

→Study more overcontact systems (patch models, …)

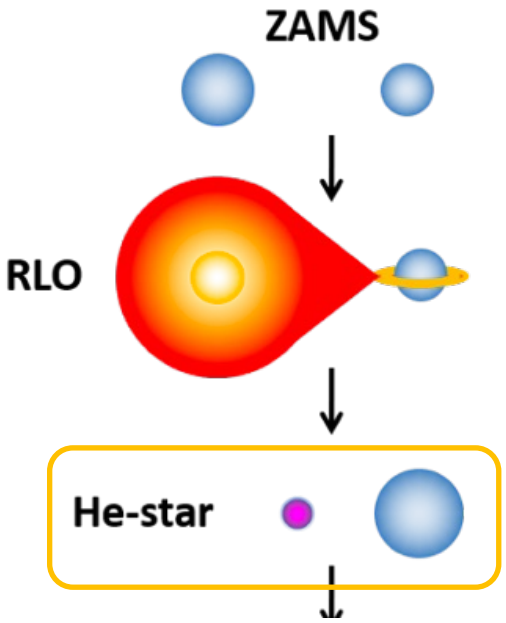
Abdul-masih+2021, 2023

→Investigate statistical properties of overcontact systems

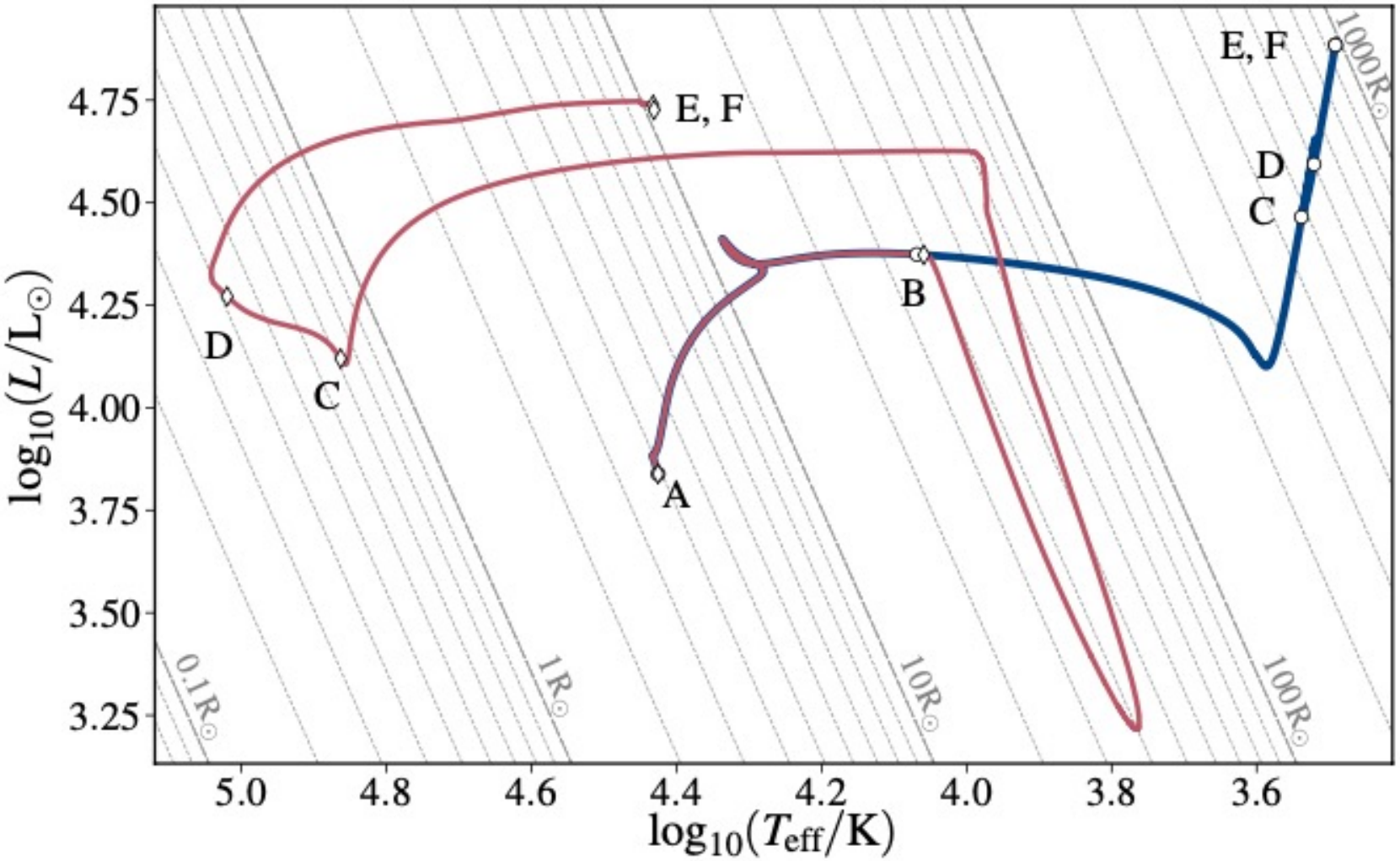
Menon+2021, Abdul-masih+2021

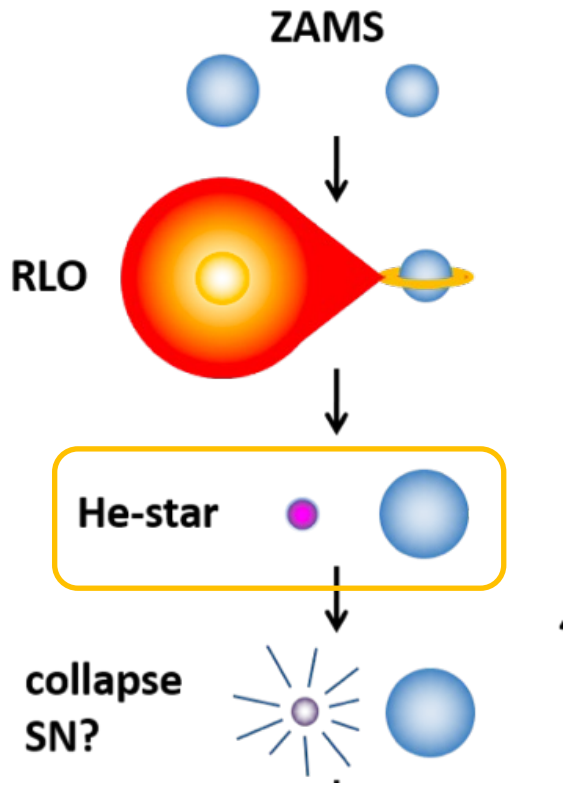
→Understand overcontact structure **(Fabry+2022, 2023)**

POST INTERACTION PRODUCTS AND STRIPPED STARS



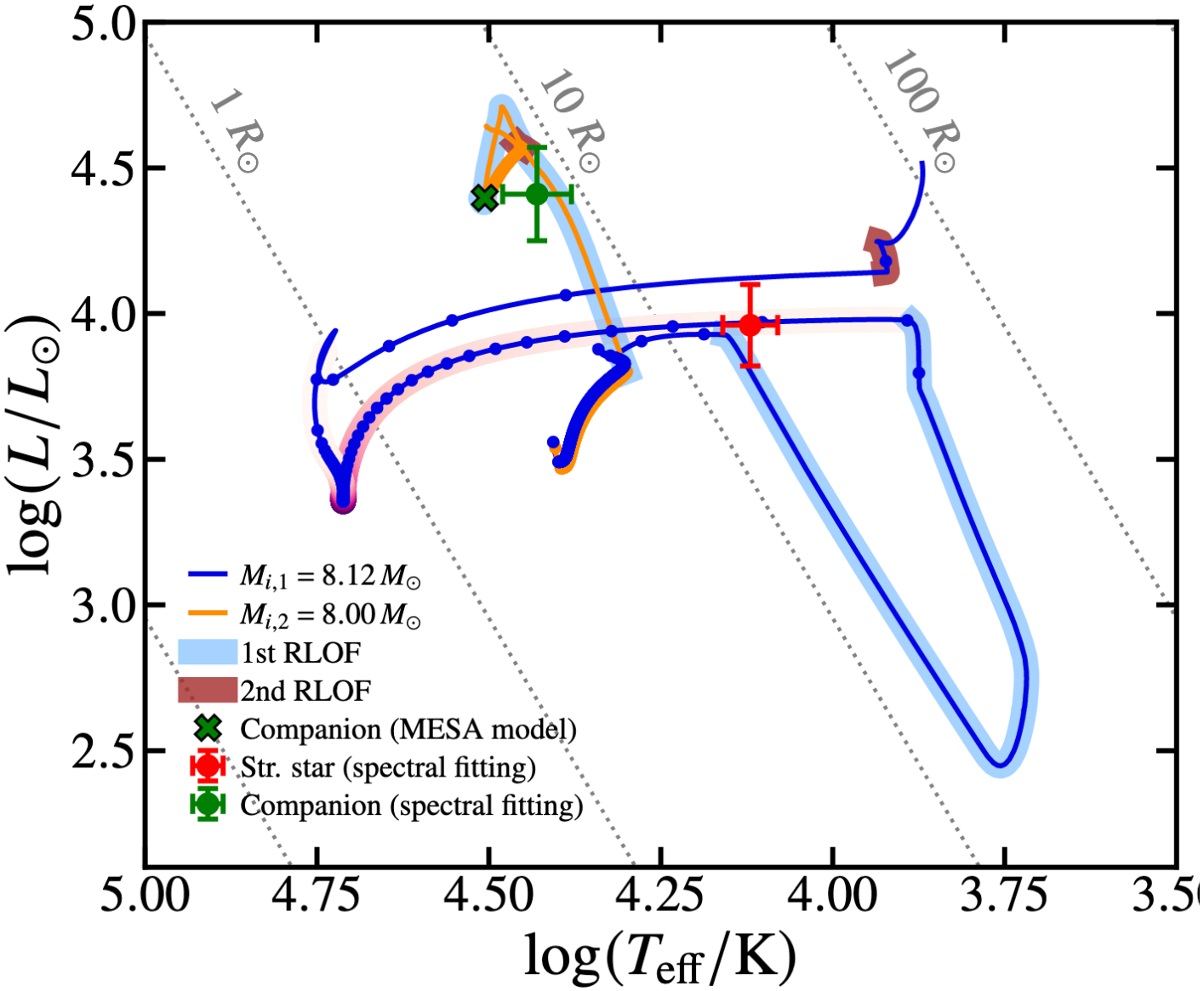
Initial mass: 11Msun, Initial Period ~ 30d

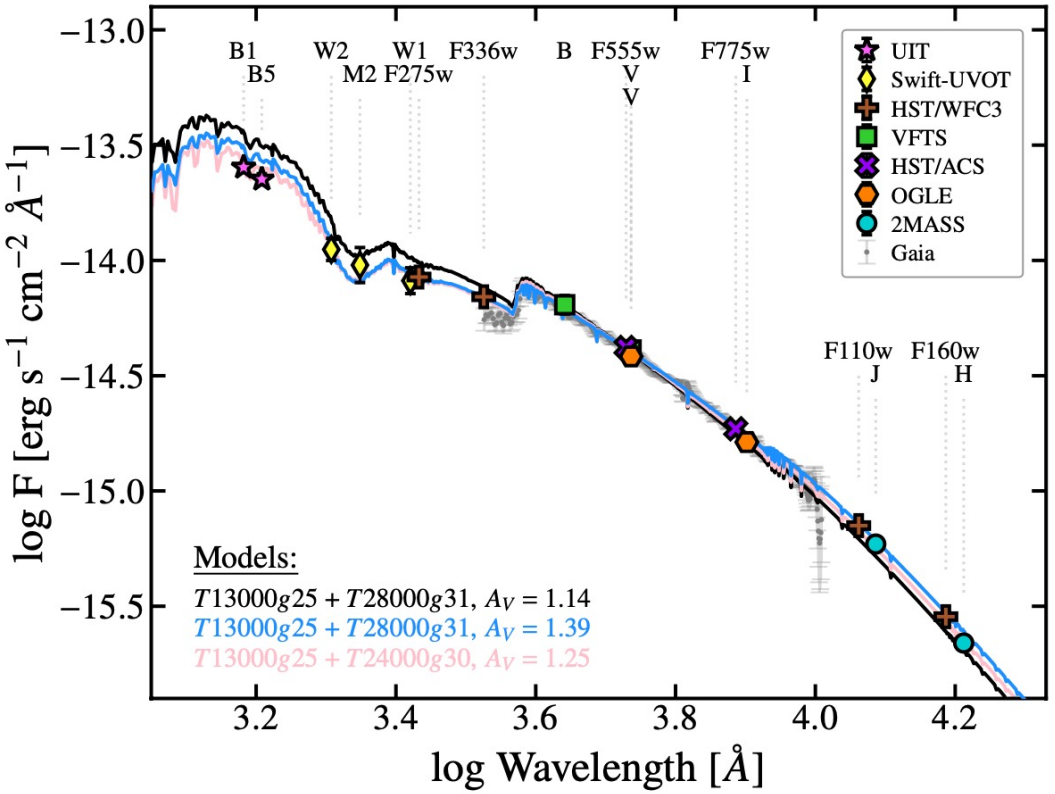




Laplace+ 2021

VFTS 291: 12 B star + 2 Msun stripped star





Villasenor+2023

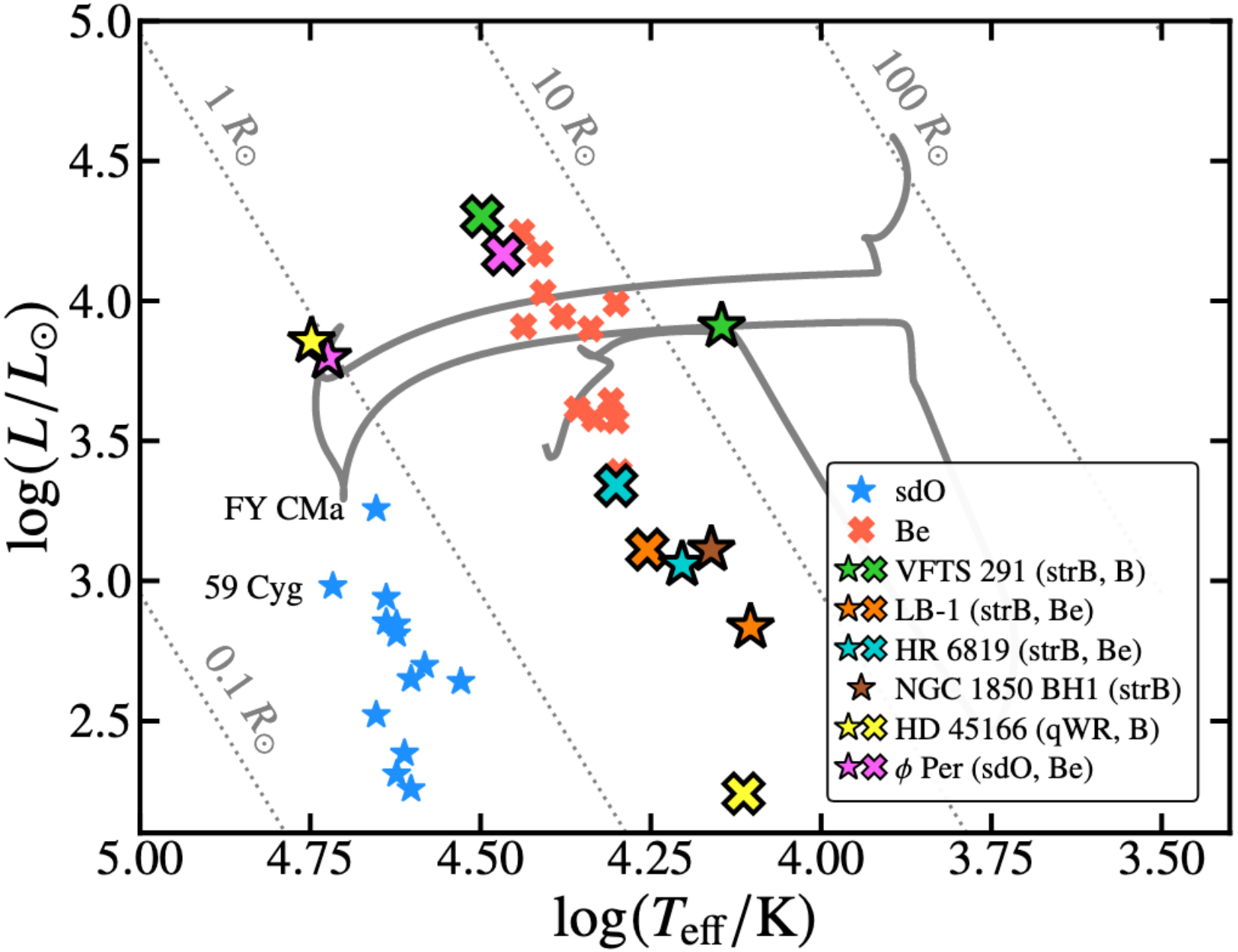


Figure from Villasenor+2023

With result from: Bodensteiner+2022, ElBadry+2020,21ab,22ab, Frost+2022 Saracino+2023, Shenar+2022,2023a,b, Wang+2021

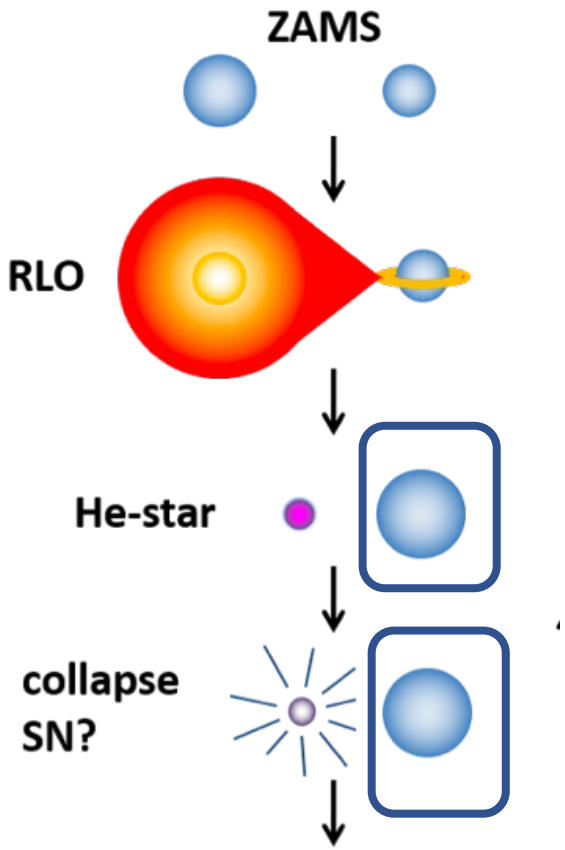
Fast rotators and

Massive Runaways

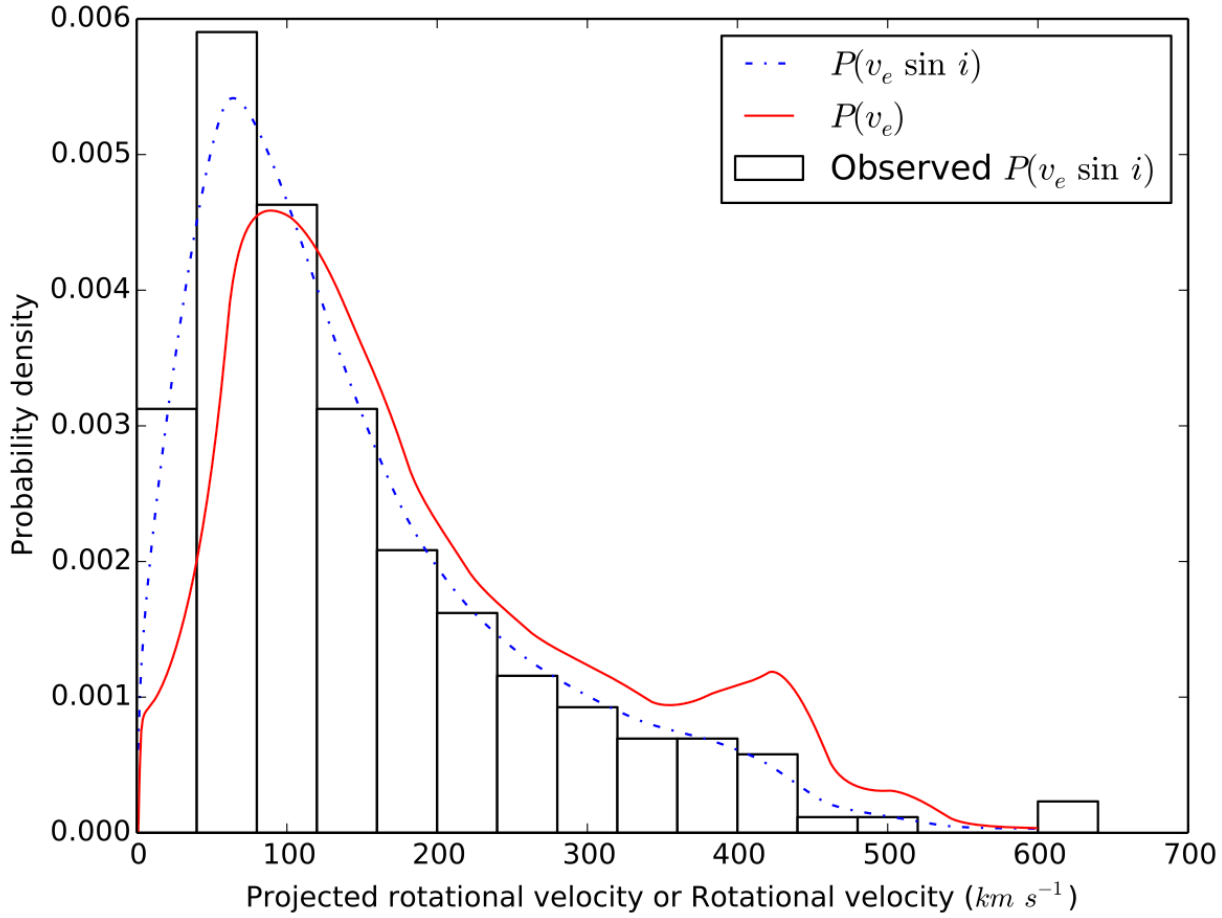
Post supernova binary interaction products

or

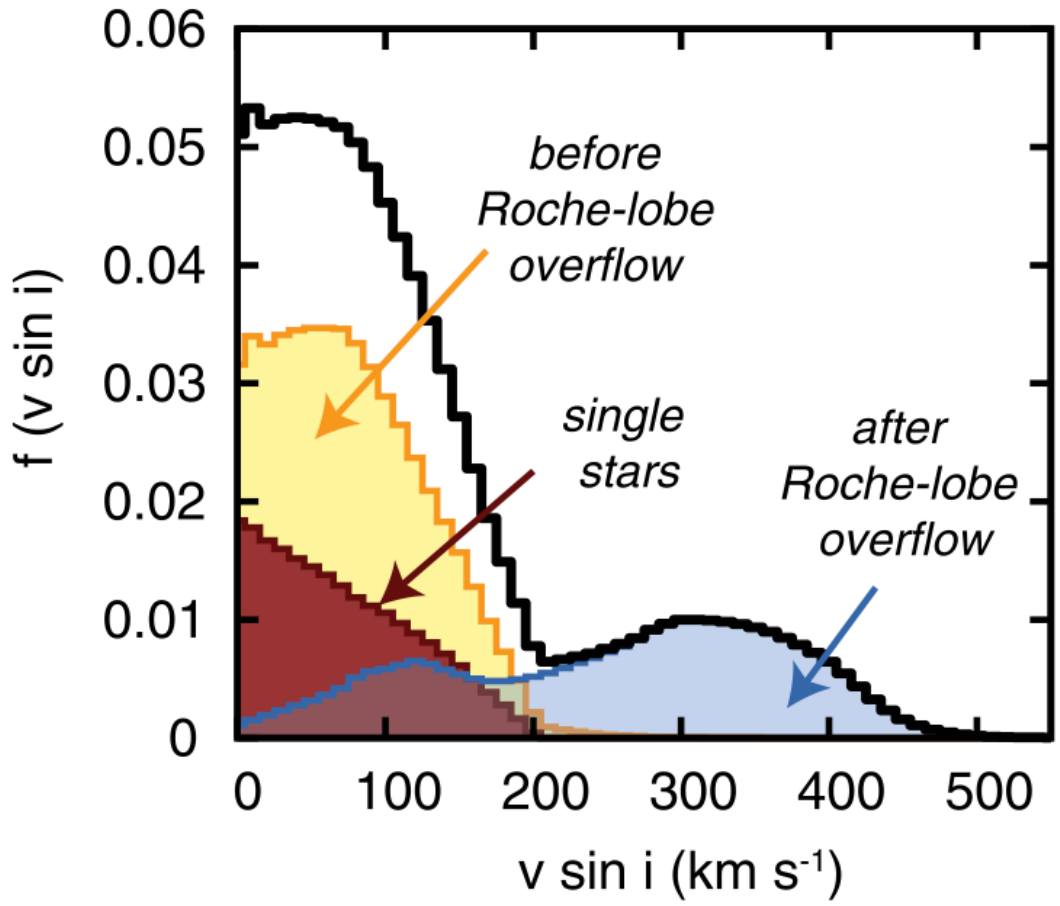
Dynamical Ejection



30 Doradus O stars
Distribution of (projected) rotation rates

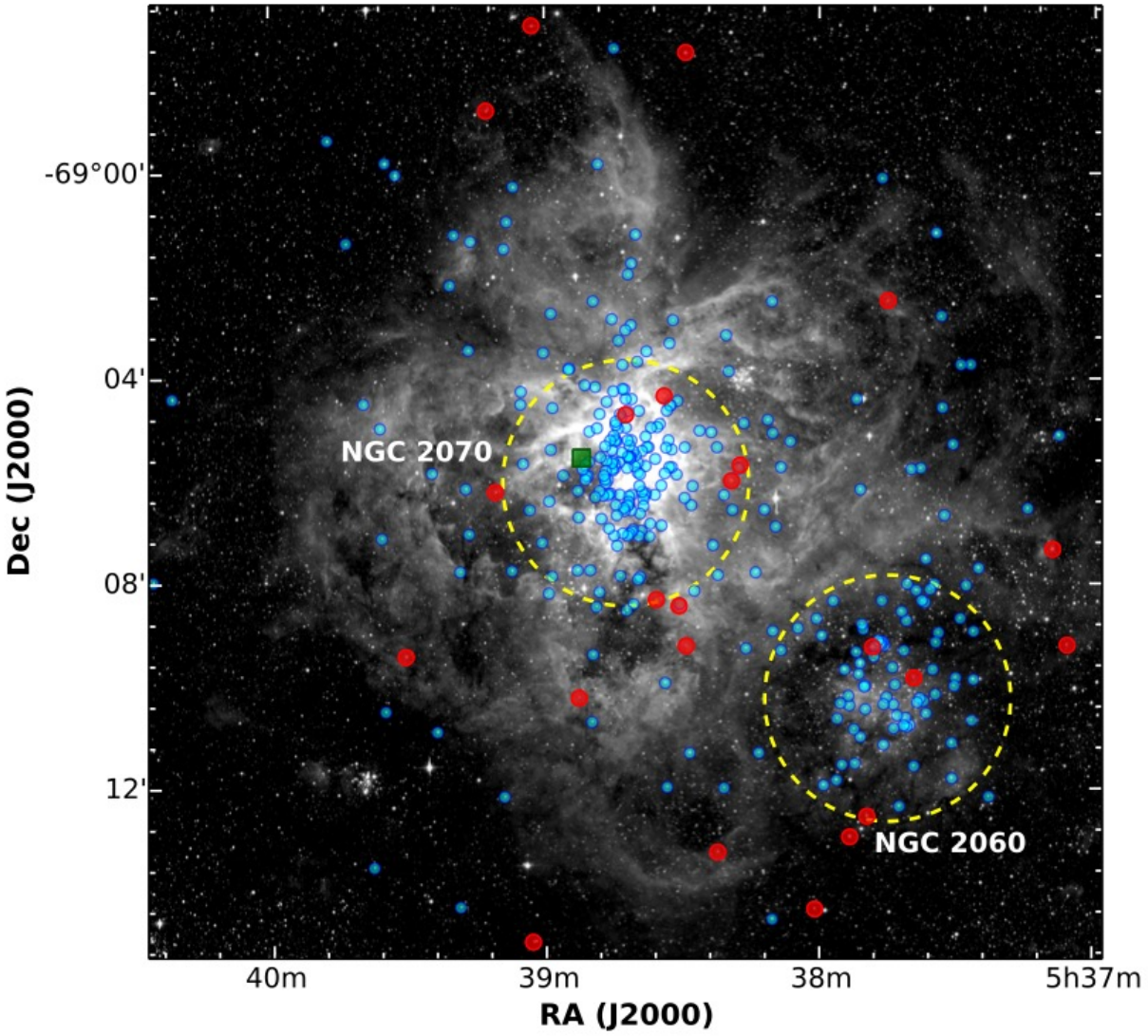


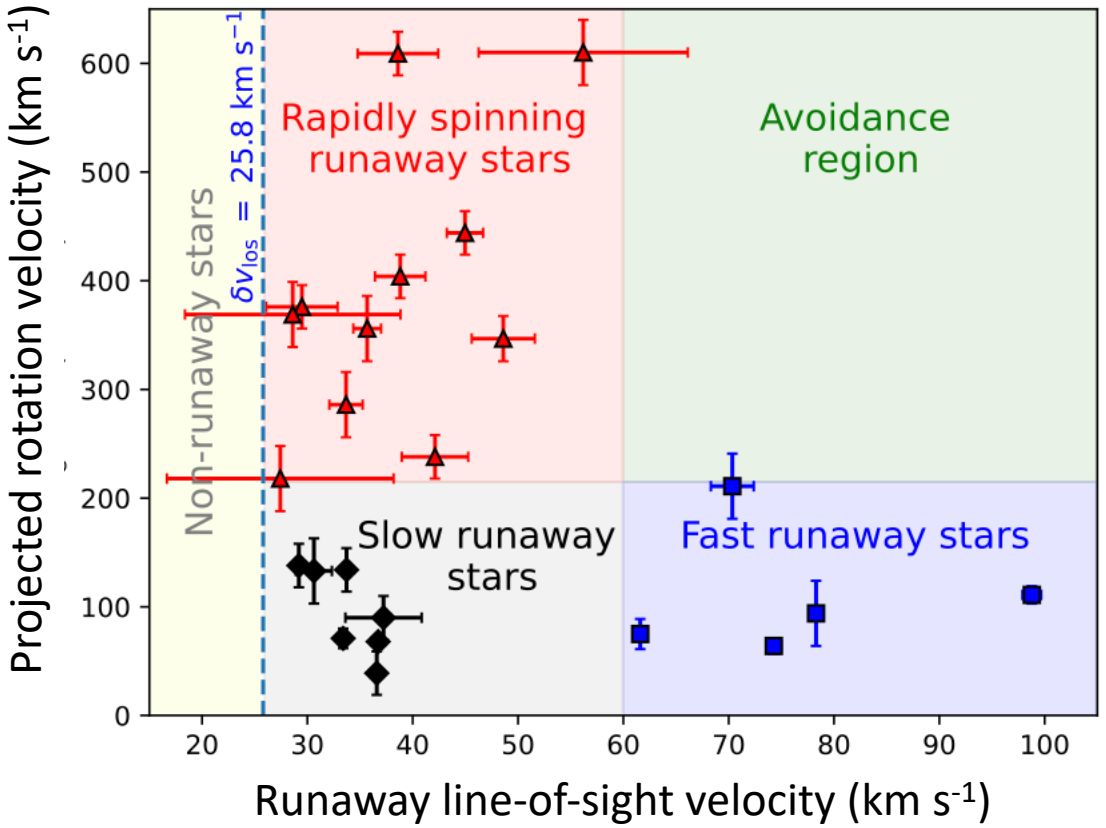
Ramirez-Agudelo+2014



de Mink+2013

O-star runaway in 30 Doradus





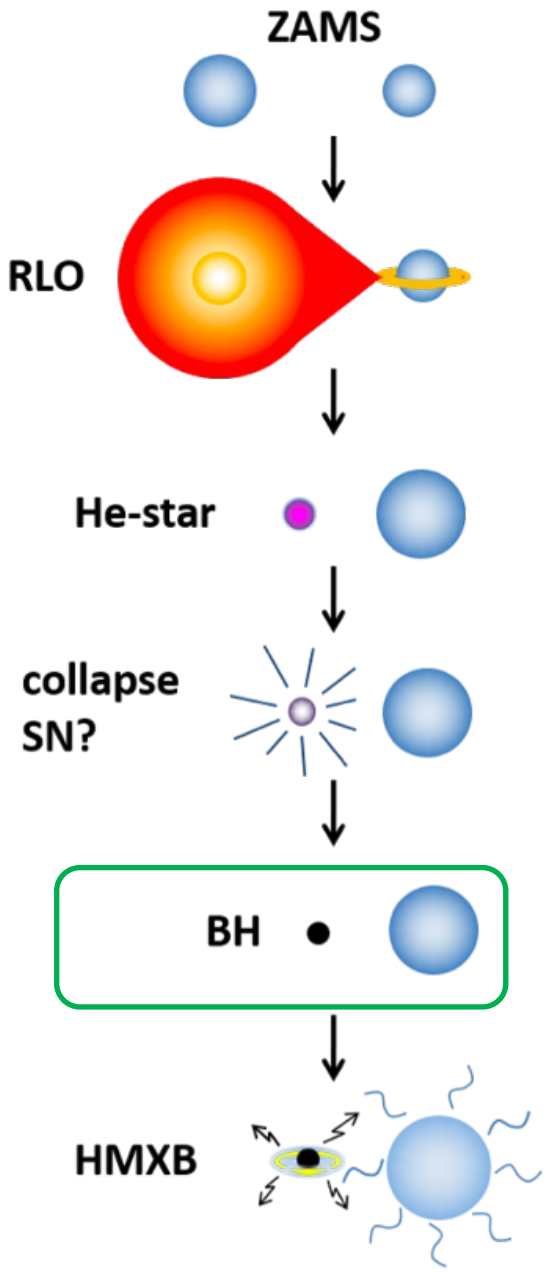
Sana+2023

MASSIVE BINARIES WITH QUIET BLACK HOLES

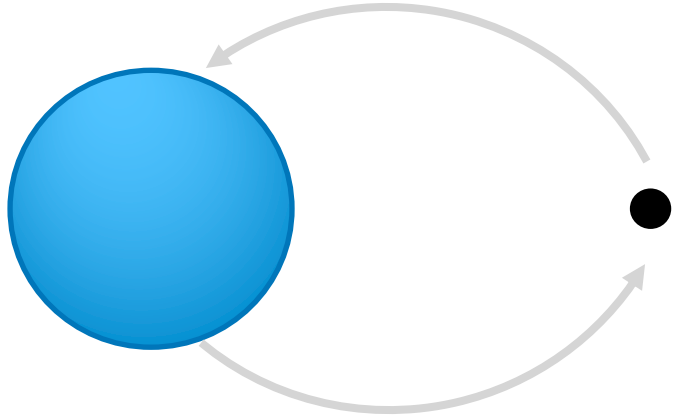
2% of O-type stars should have
a black hole companions (LMC) **Langer+2020**

→ Milky Way: A handfull with 3kpc

→ 30 Dor : 15 O+BH binaries



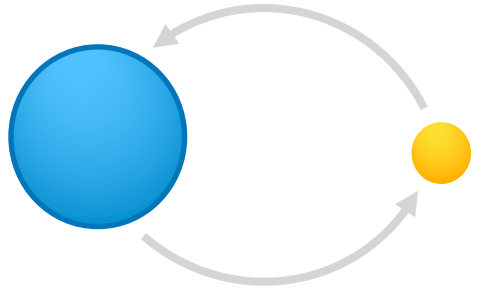
What we are looking for:



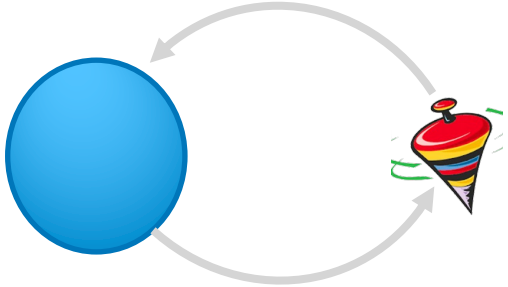
We might find

Black Hole Imposters

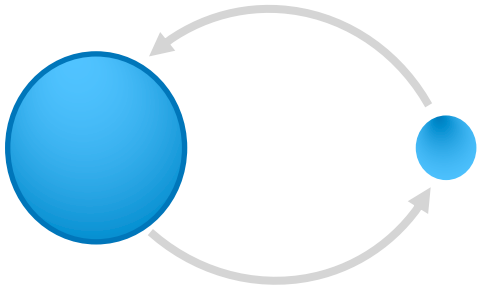
(very) Low mass companion



Rapidly rotating companion



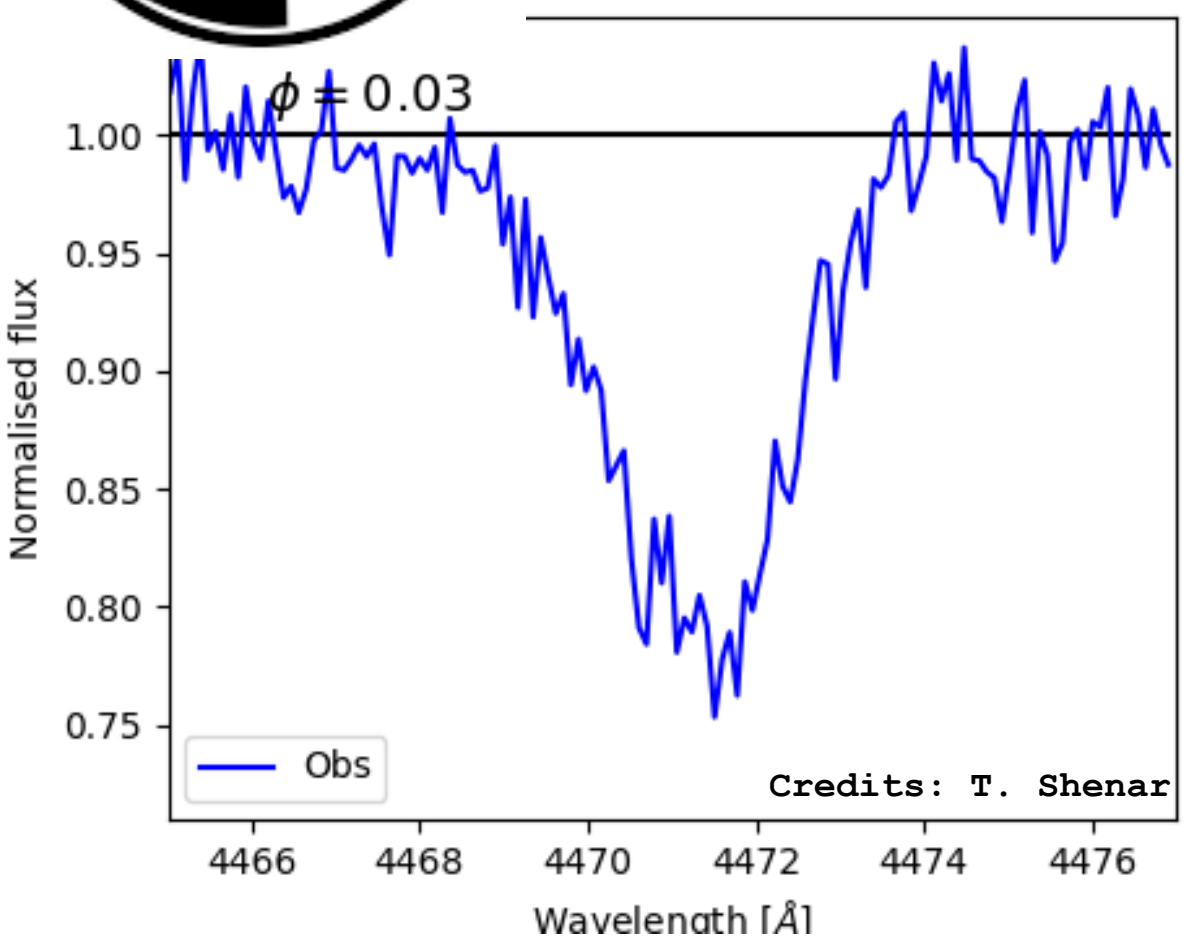
Stripped He-star companion

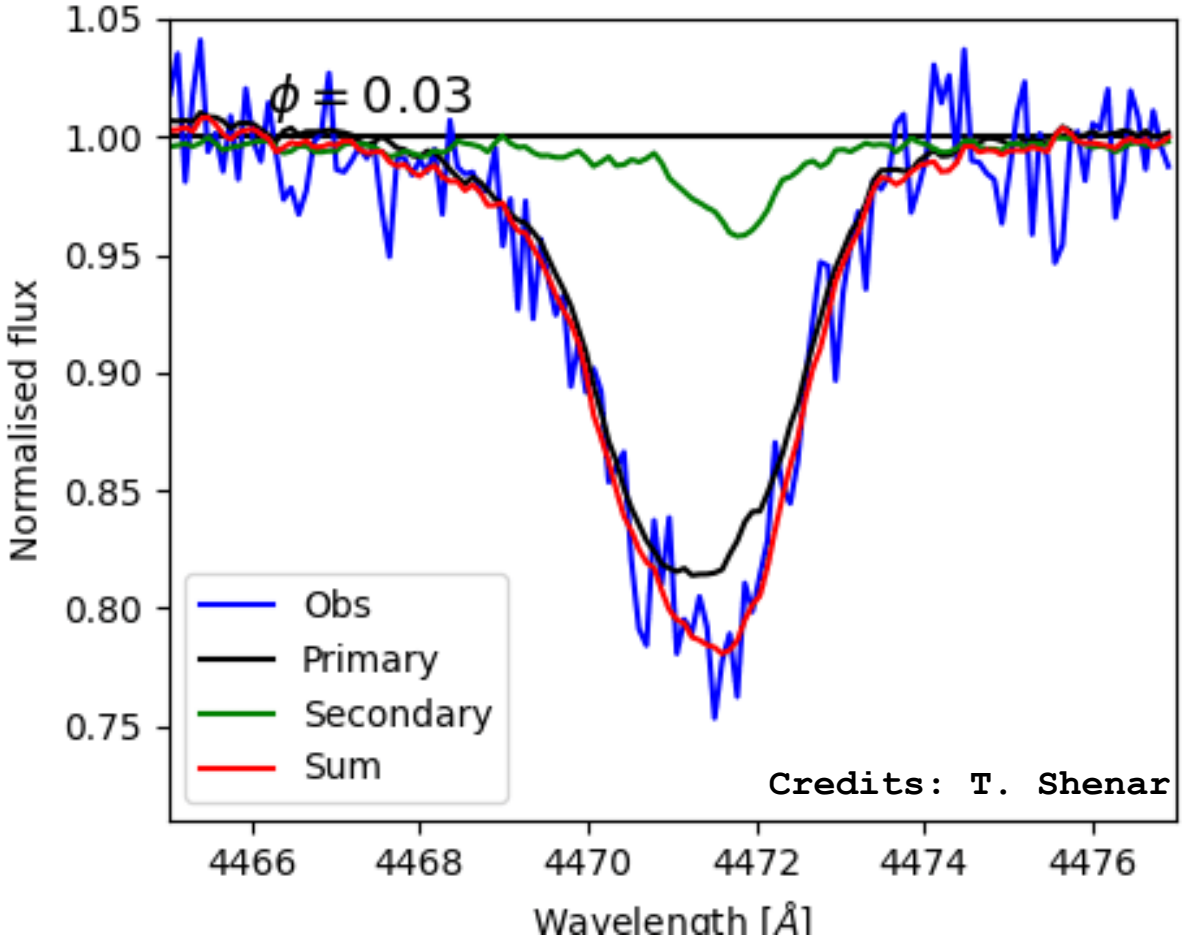


Slide concept: L. Mahy

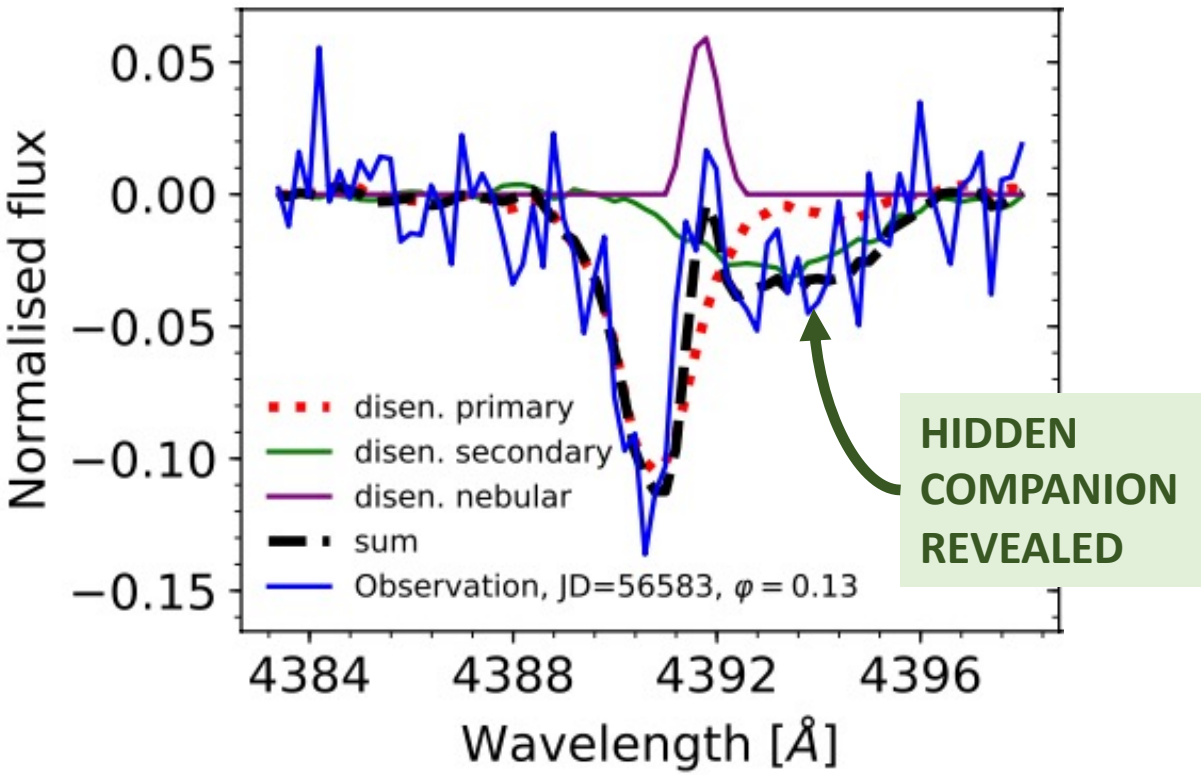
Spectral disentangling as critical ingredient

Leveraging the Doppler effect to extract the signature of the hidden companion



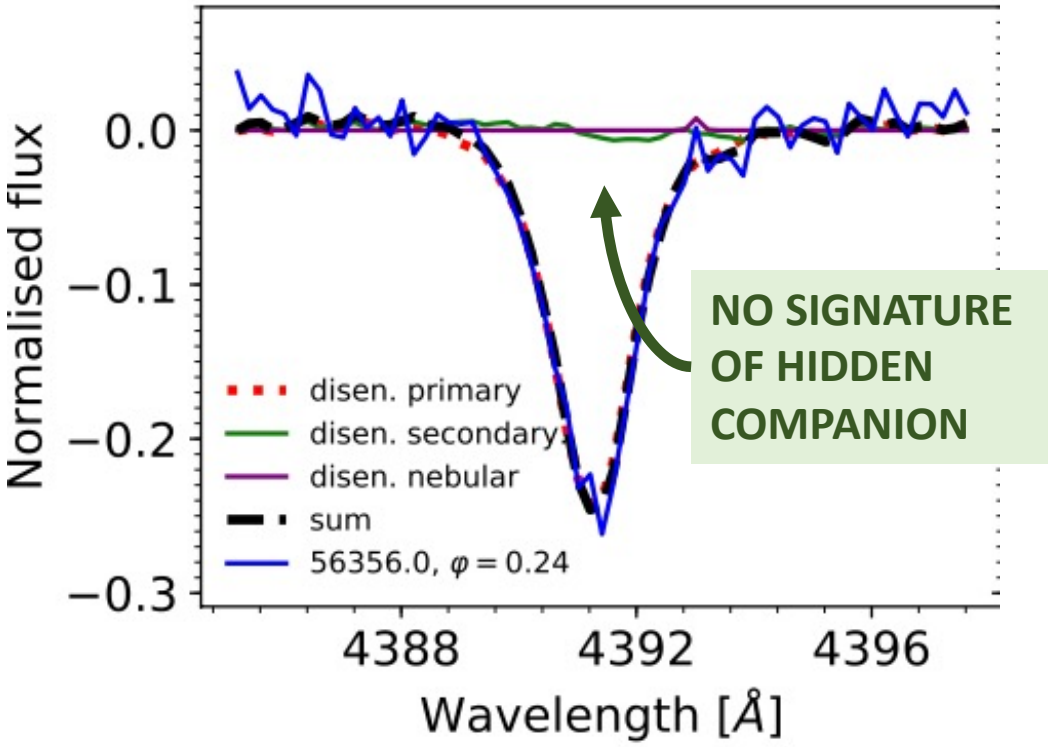


VFTS 350

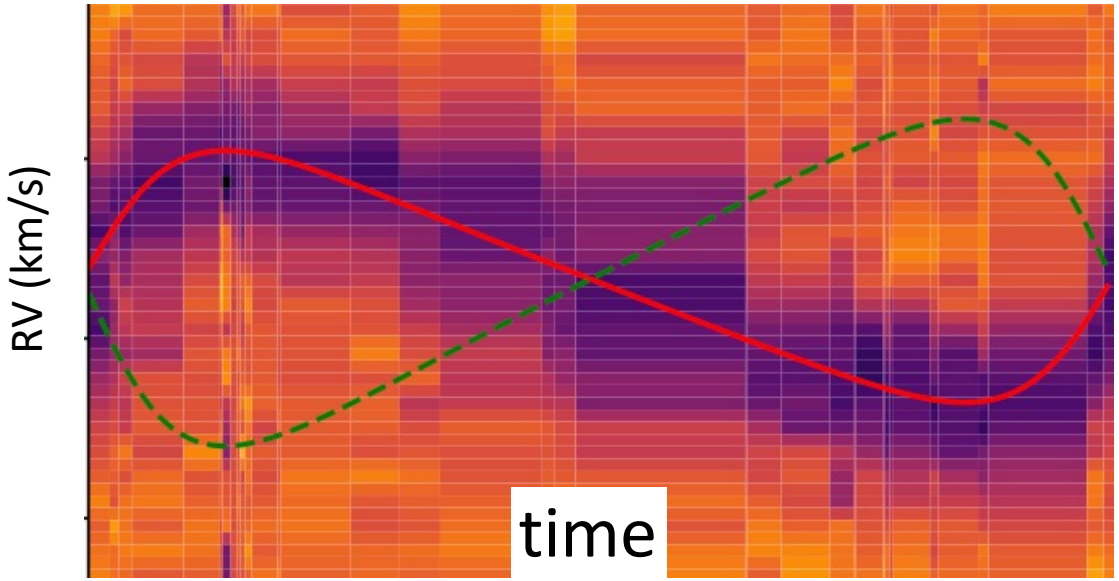


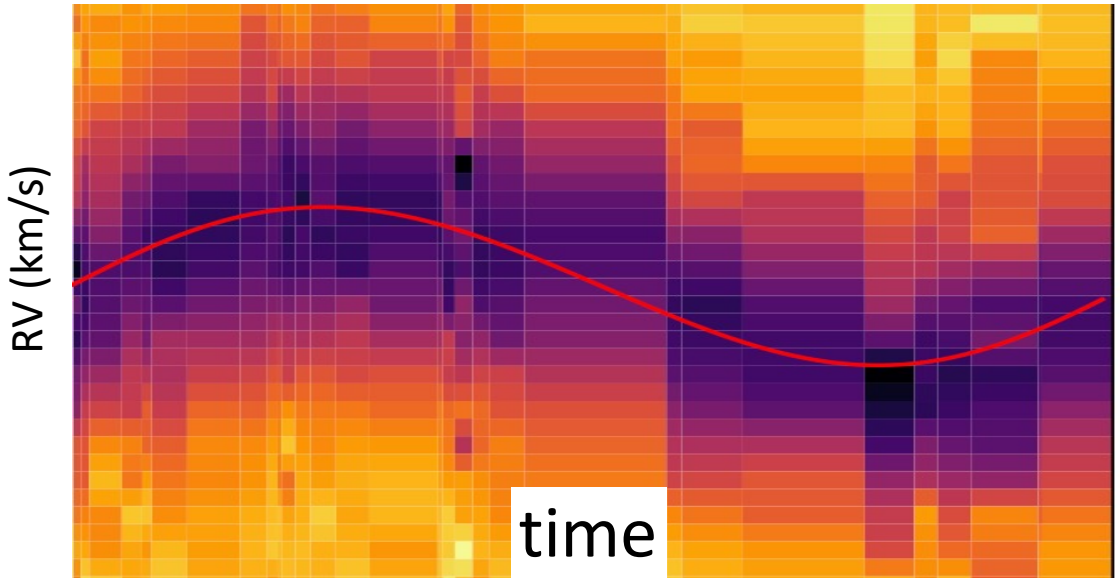
HIDDEN COMPANION REVEALED

VFTS 779



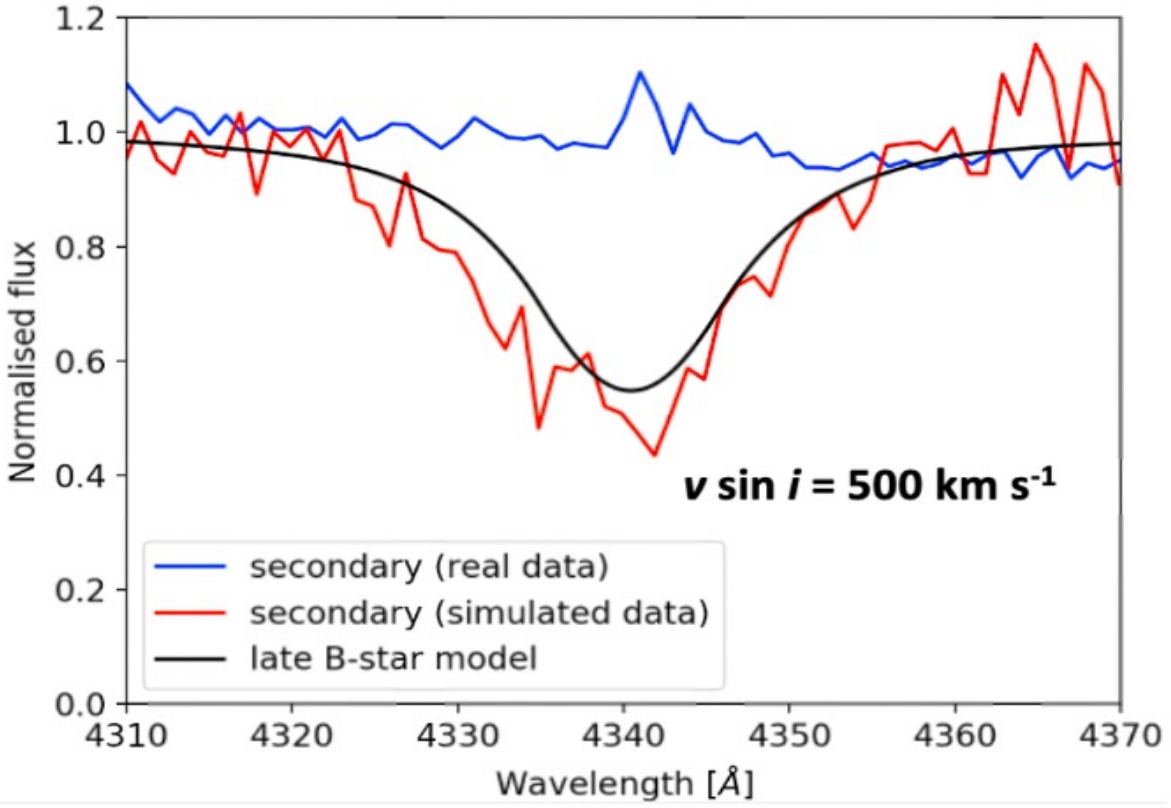
NO SIGNATURE OF HIDDEN COMPANION





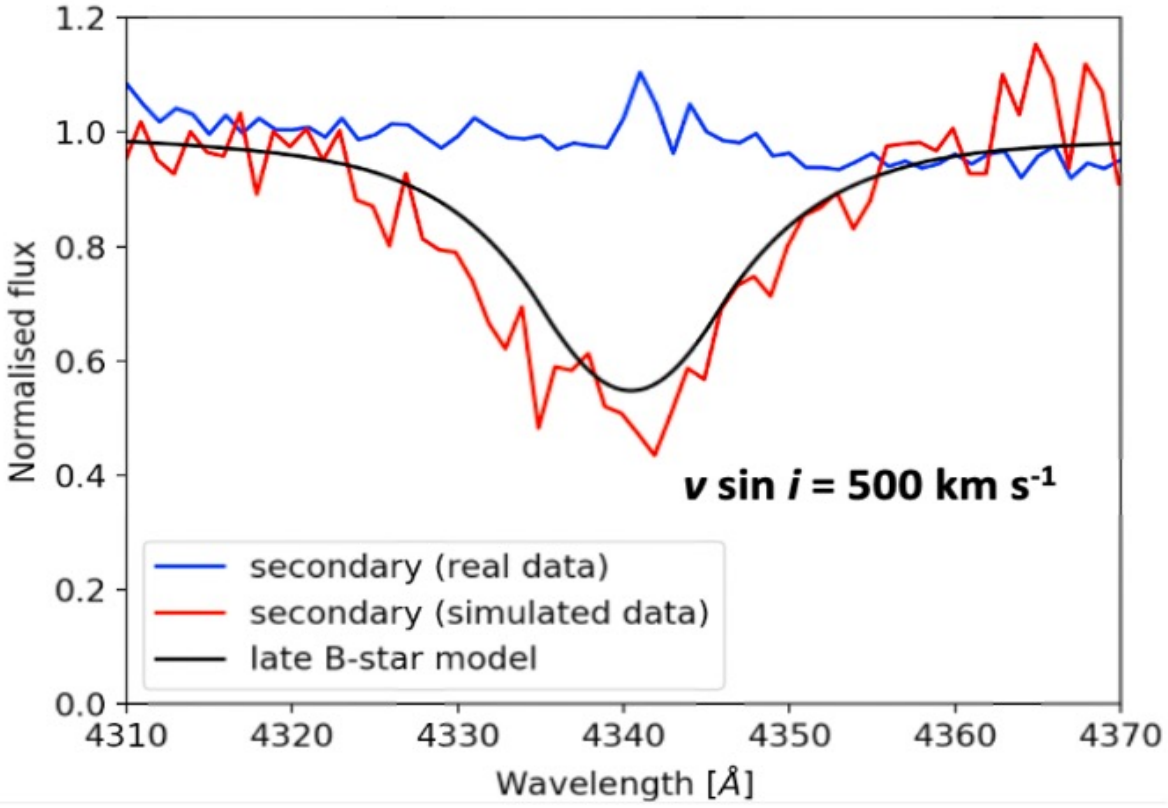
HD130298:
25 $M_\odot$ O star + >7$M_\odot$ BH eccentric binary

Mahy et al. 2022



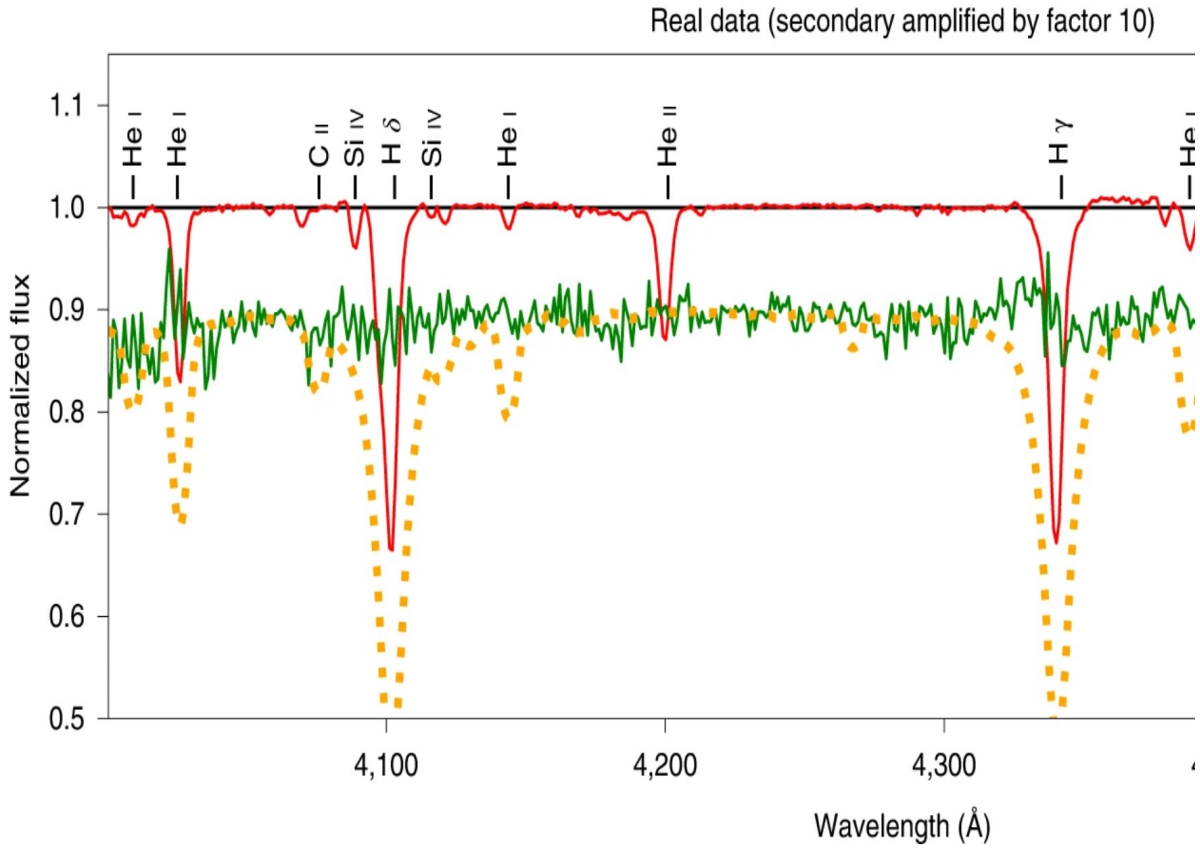
HD130298:
25 $M_\odot$ O star + >7$M_\odot$ BH
eccentric binary

Mahy et al. 2022

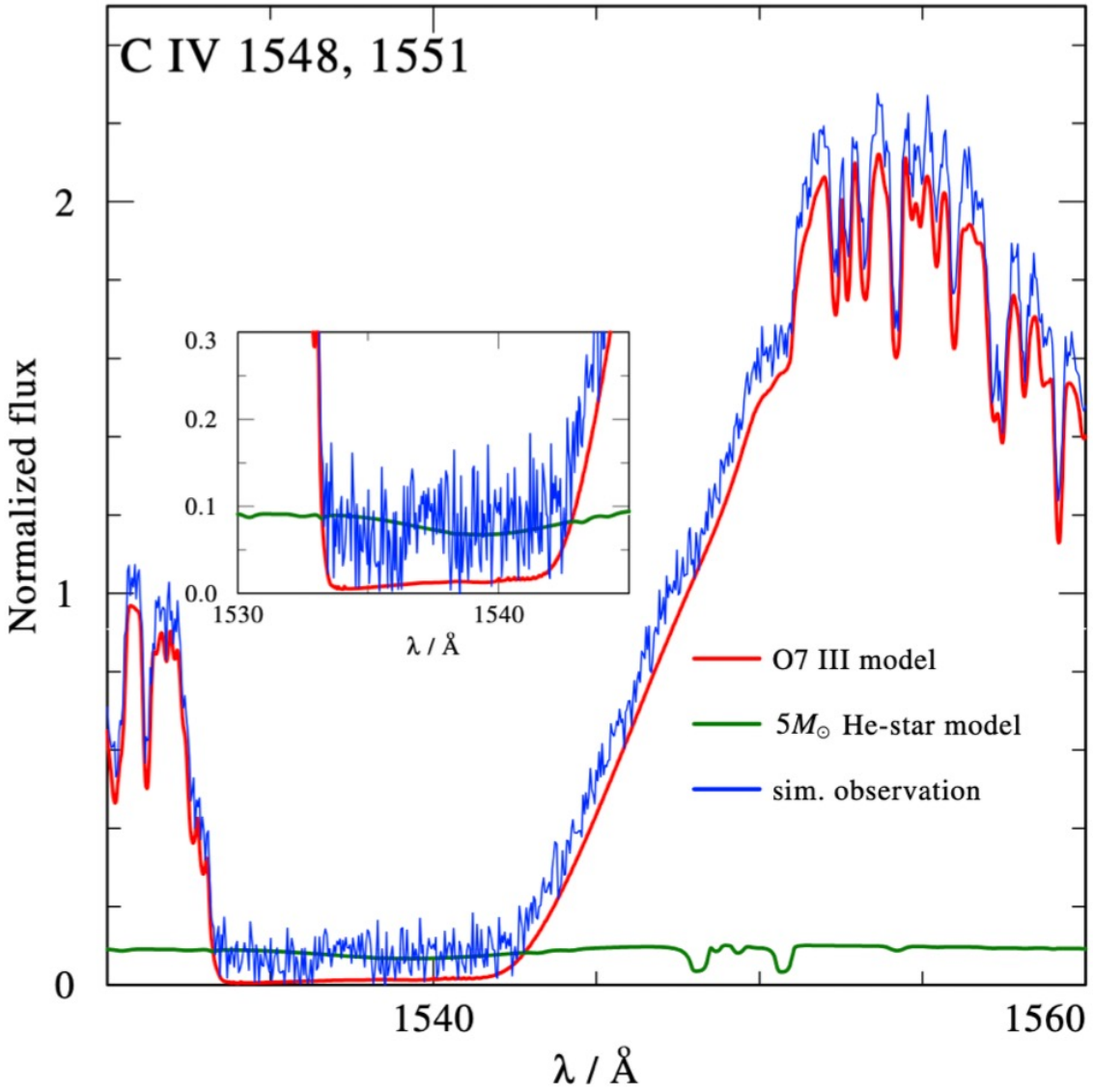


VFTS 243
25 $M_\odot$ O star + 10 $M_\odot$ BH
P = 10.4 d; e < 0. 03

Shenar et al. 2022a



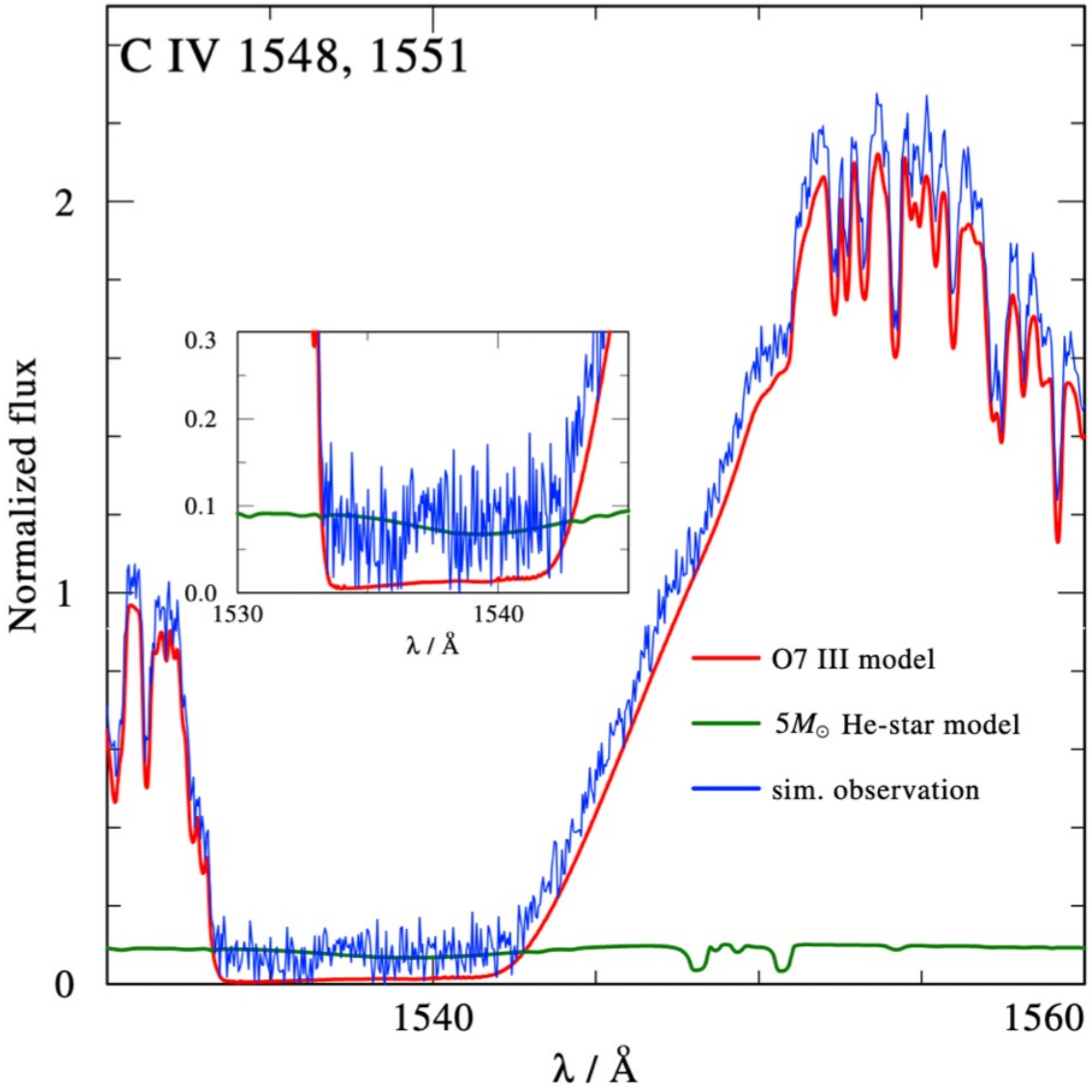
FUV spectroscopy as the final check: COS data on their way

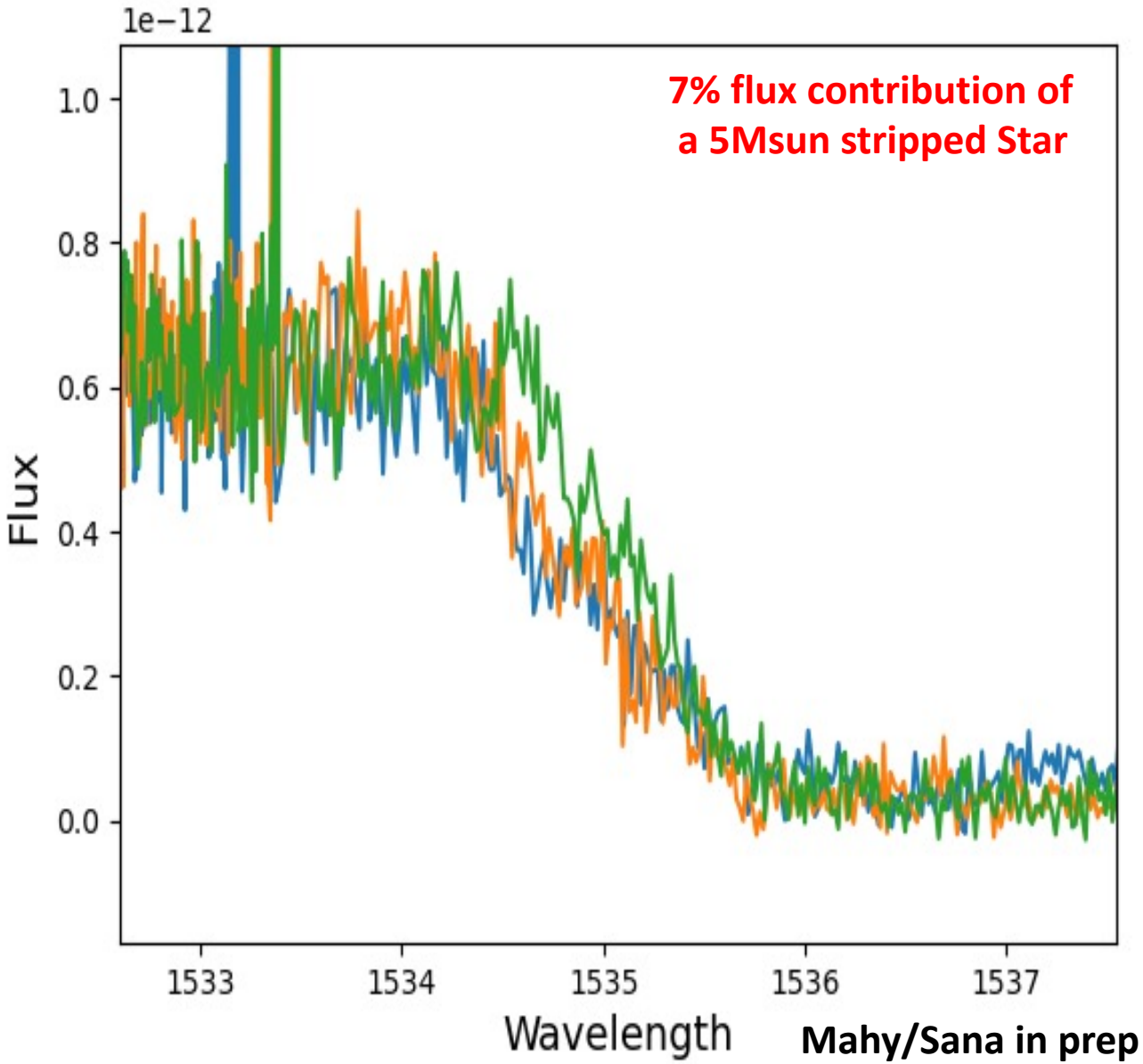


7% flux contribution of a 5Msun stripped Star

Mahy/Sana in prep

FUV spectroscopy as the final check: COS data on their way





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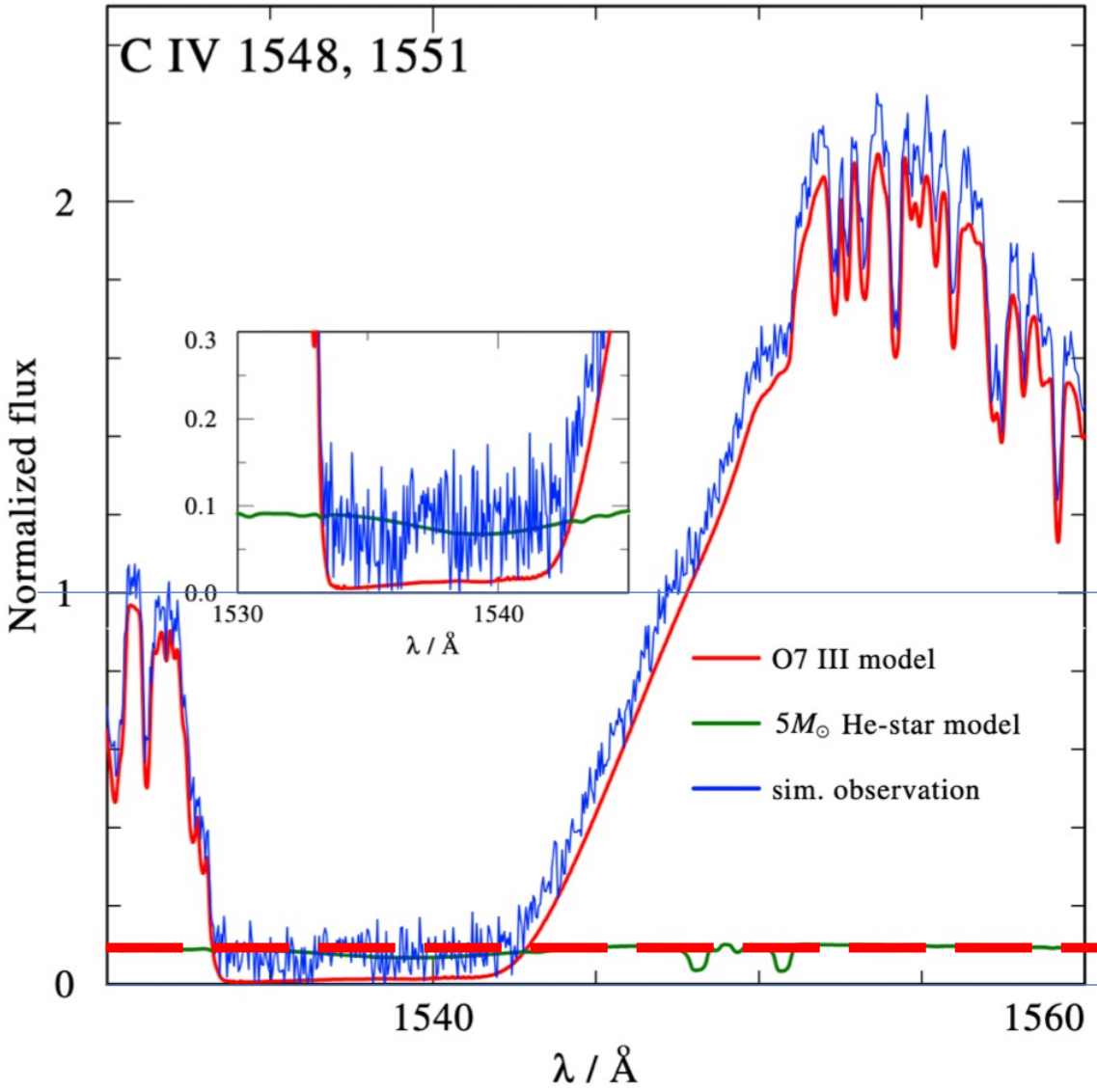
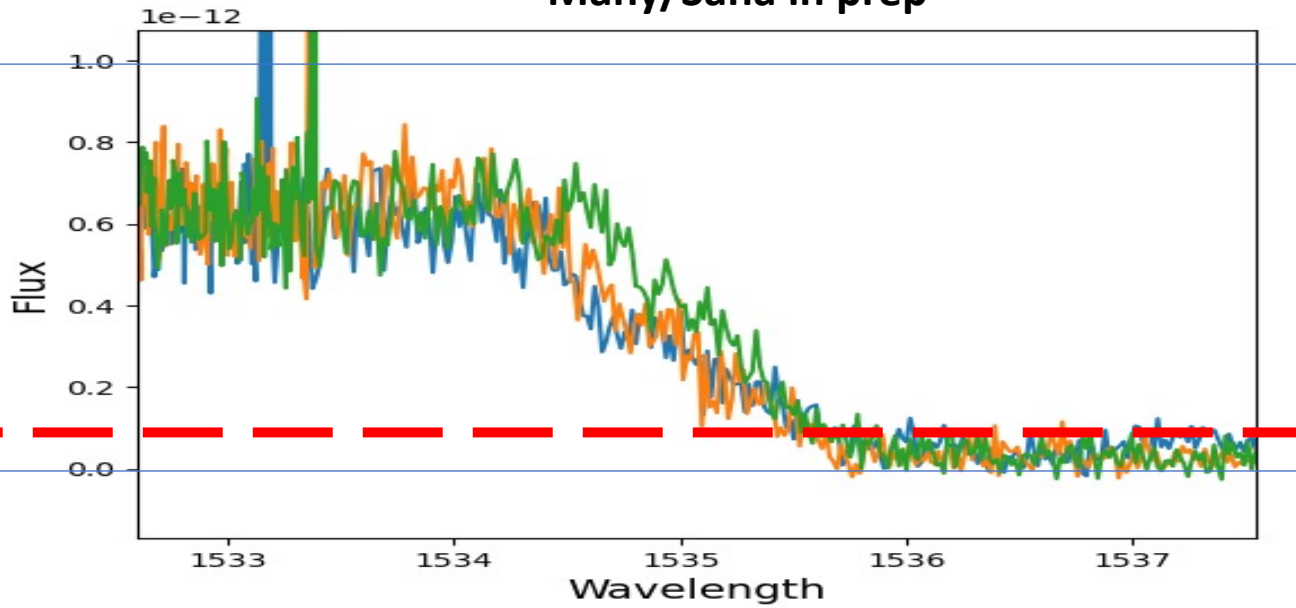
FUV spectroscopy as the final check: COS data on their way

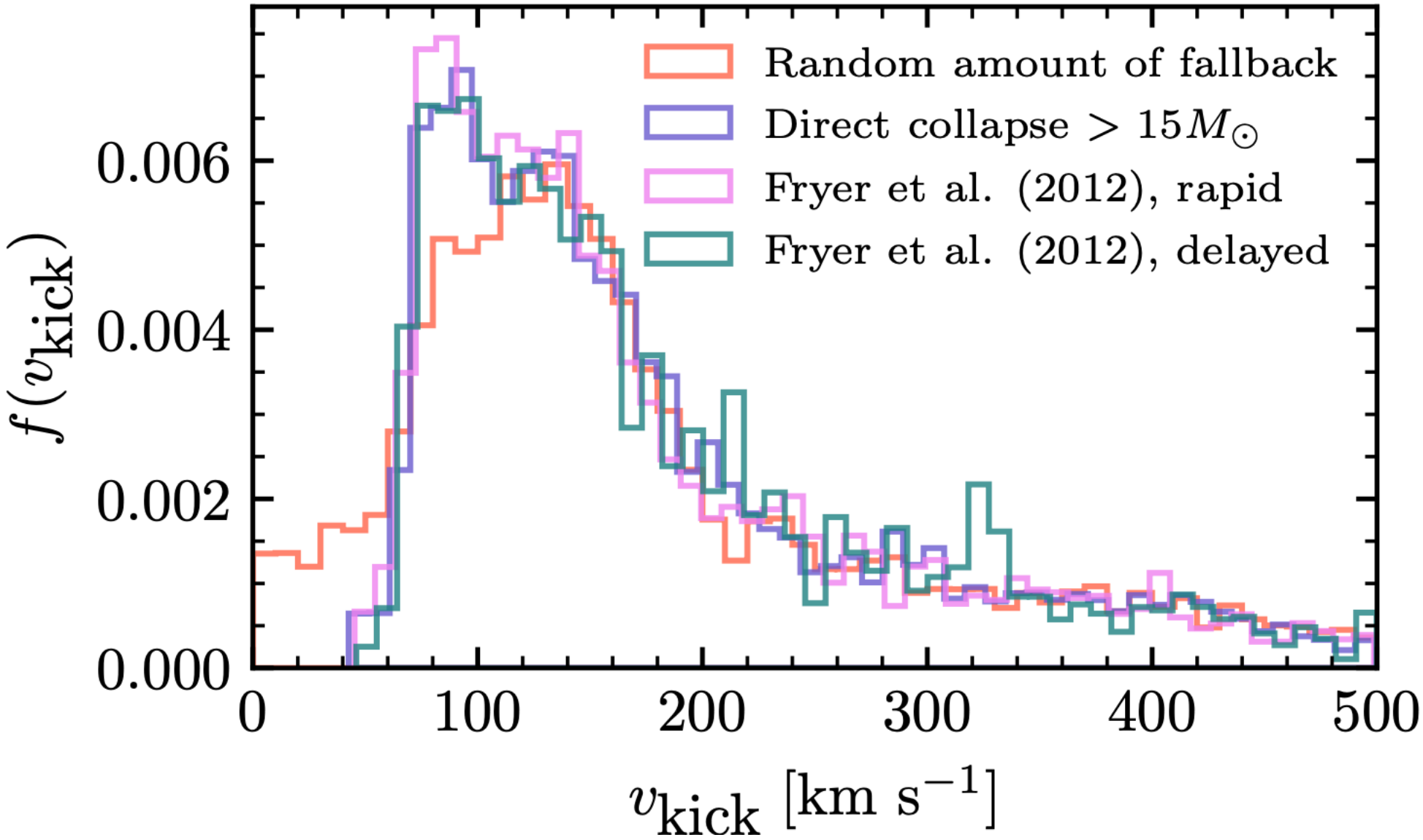


7% flux contribution of
a 5Msun stripped Star

Mahy/Sana in prep



Constraints on explosion physics



Marchant+ in prep

UVEX Magellanic Clouds Survey

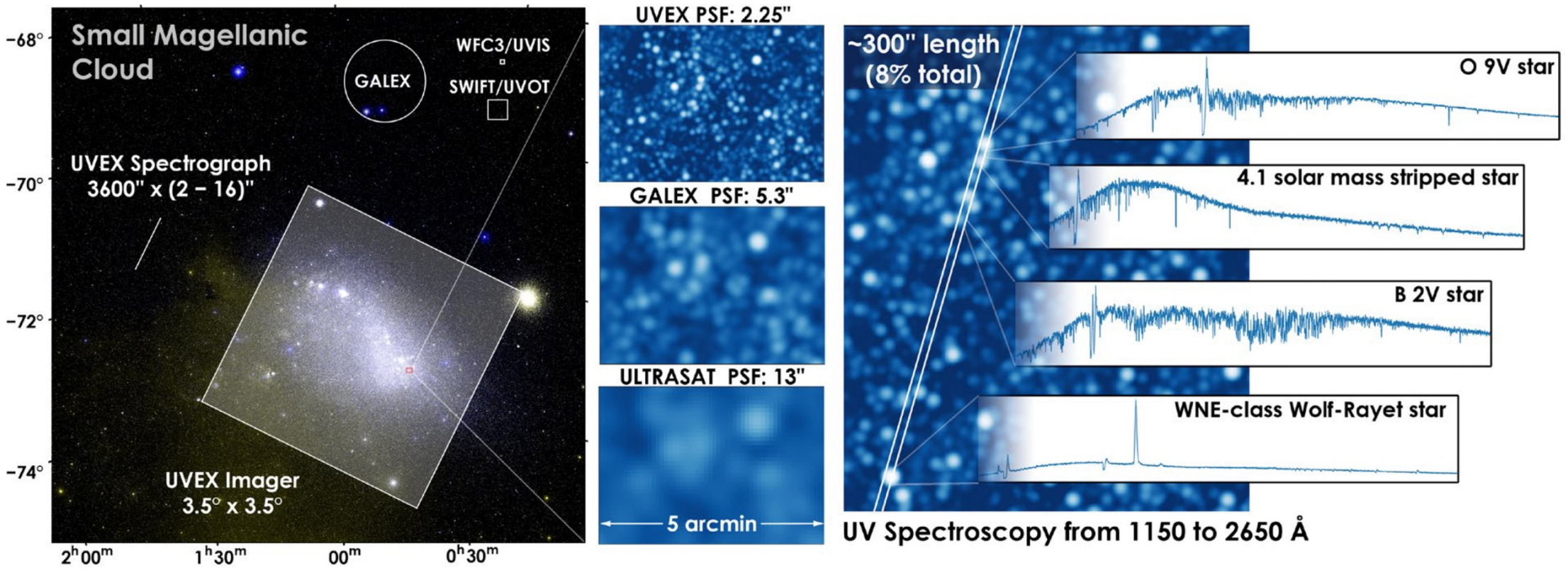
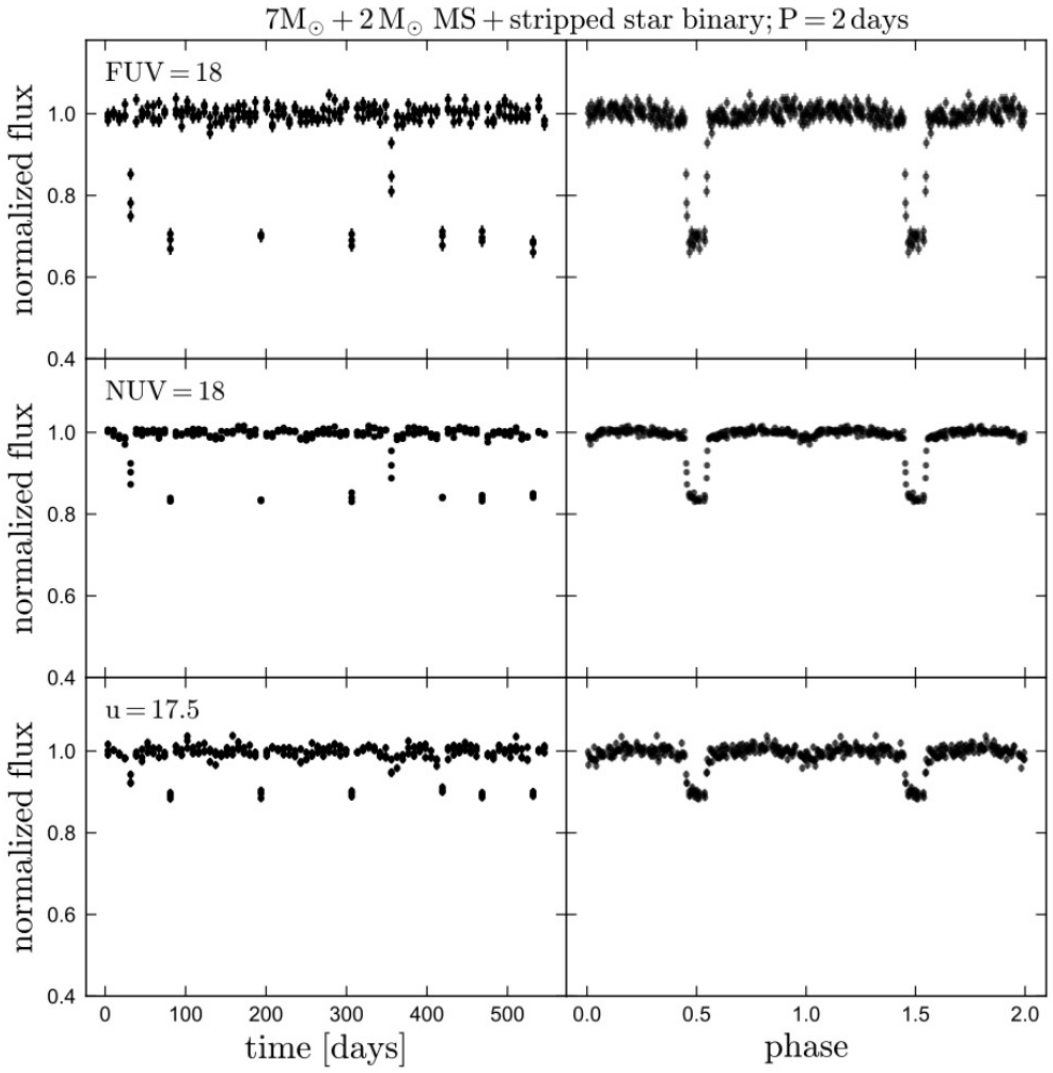
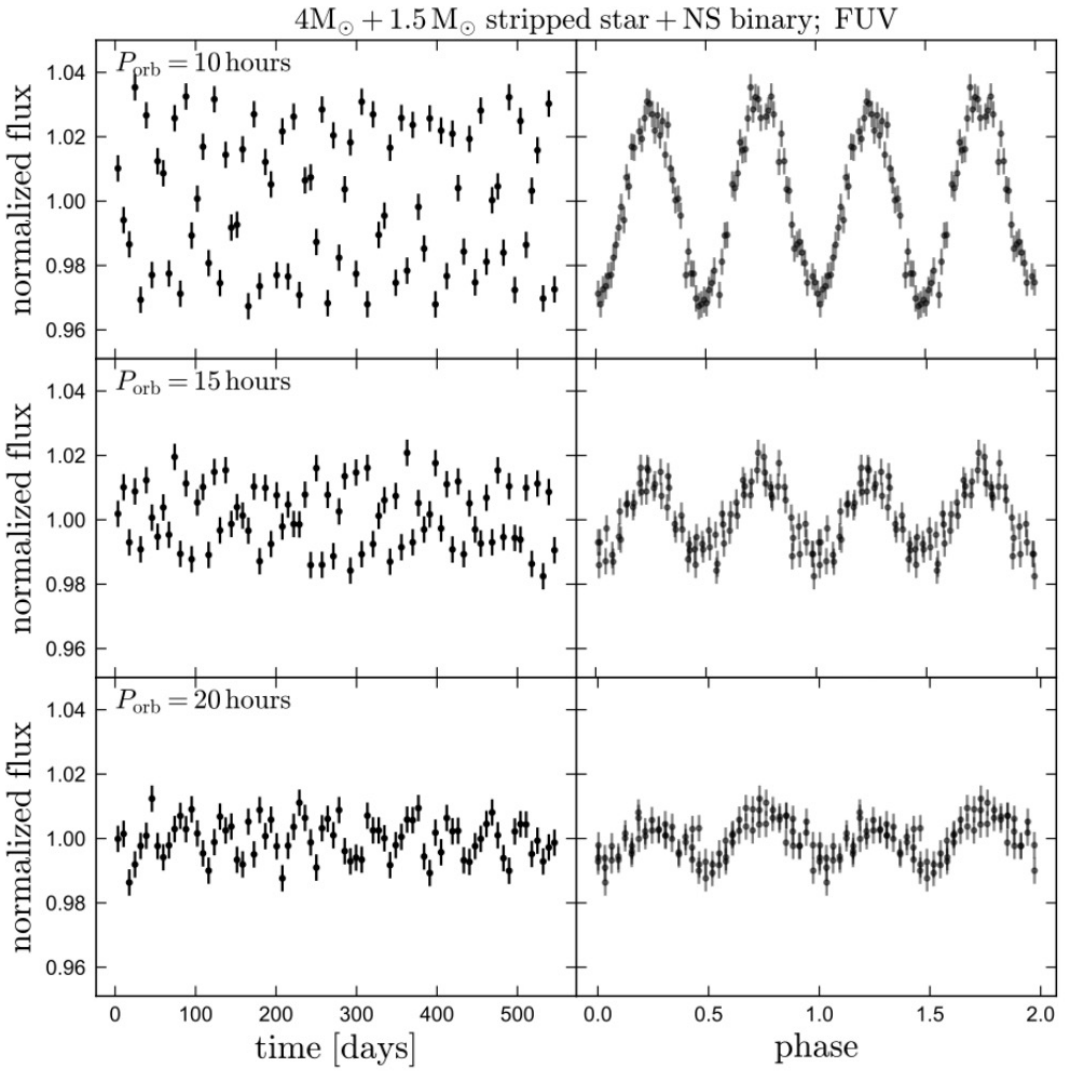


Fig. D-1. The UVEX 12 deg^2 FOV covers the SMC/LMC in 7 pointings, and the ~2.25" PSF resolves all but the densest star clusters. The UVEX slit spectrograph provides 2" - 16" widths for point and diffuse objects and <1Å resolution spectral data for every pointing for all sources that lie along its 1° length.

Census of short period (hot) binaries





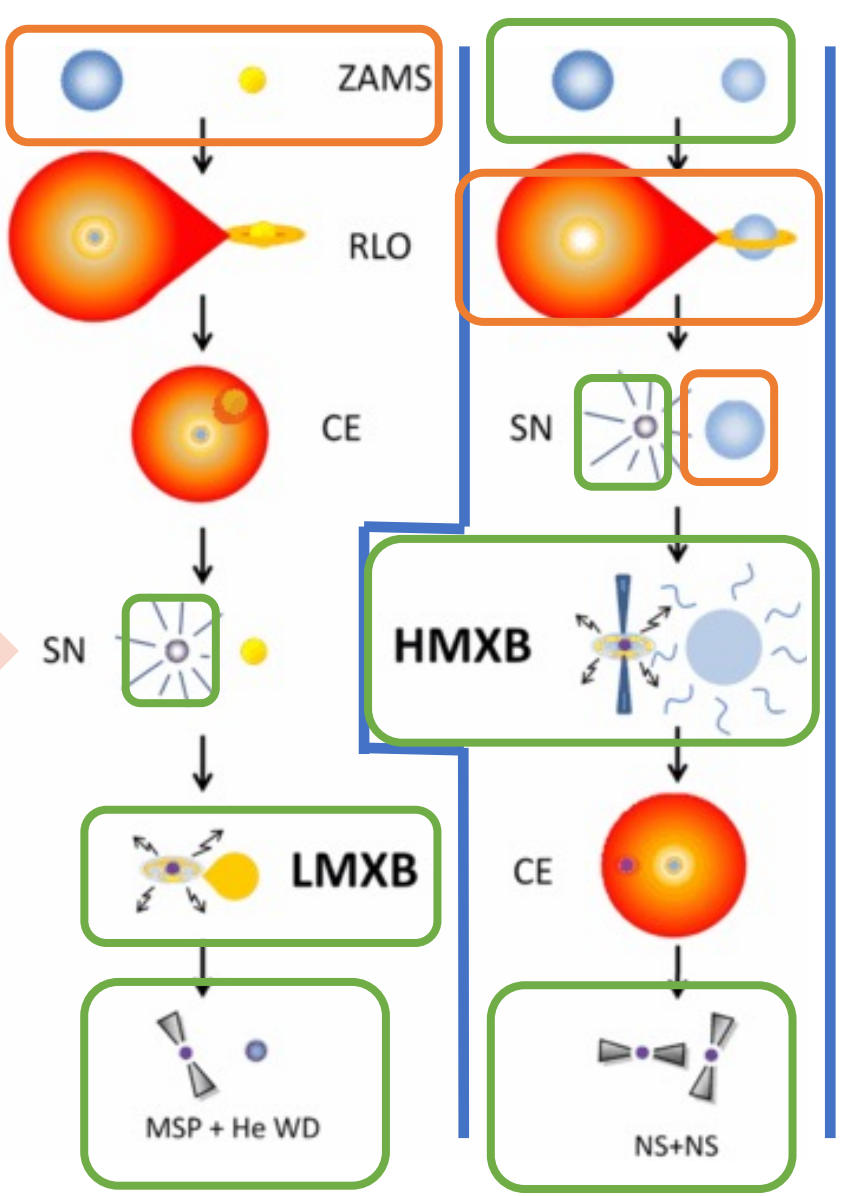
Systematic mapping crucuially missing

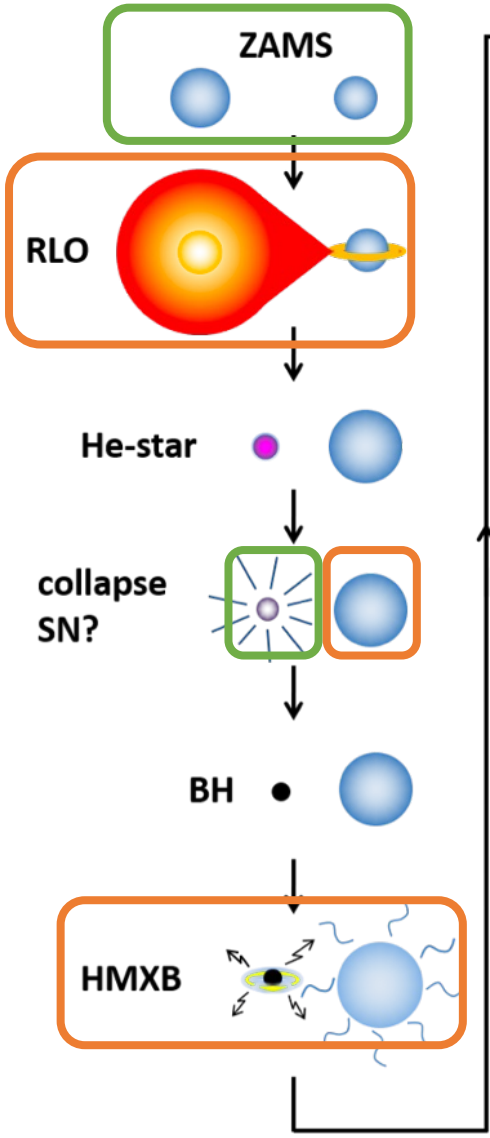
Observation Constraints

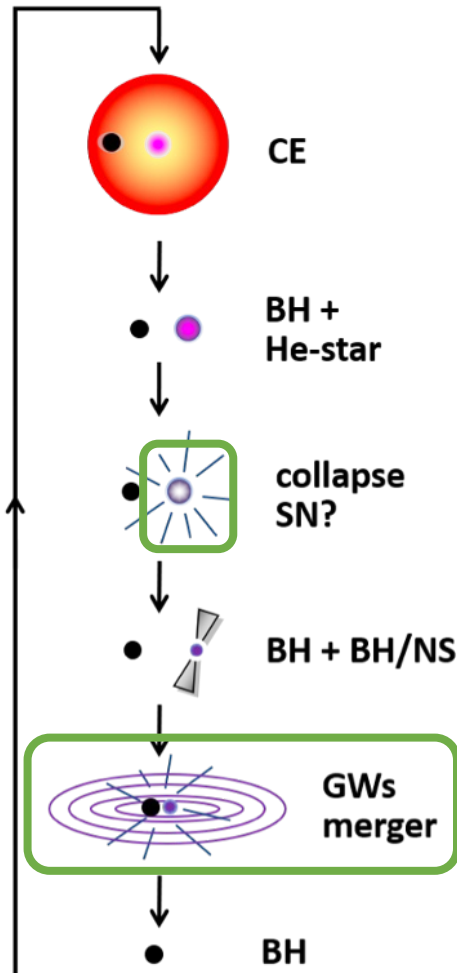
Large samples

Different metallicities

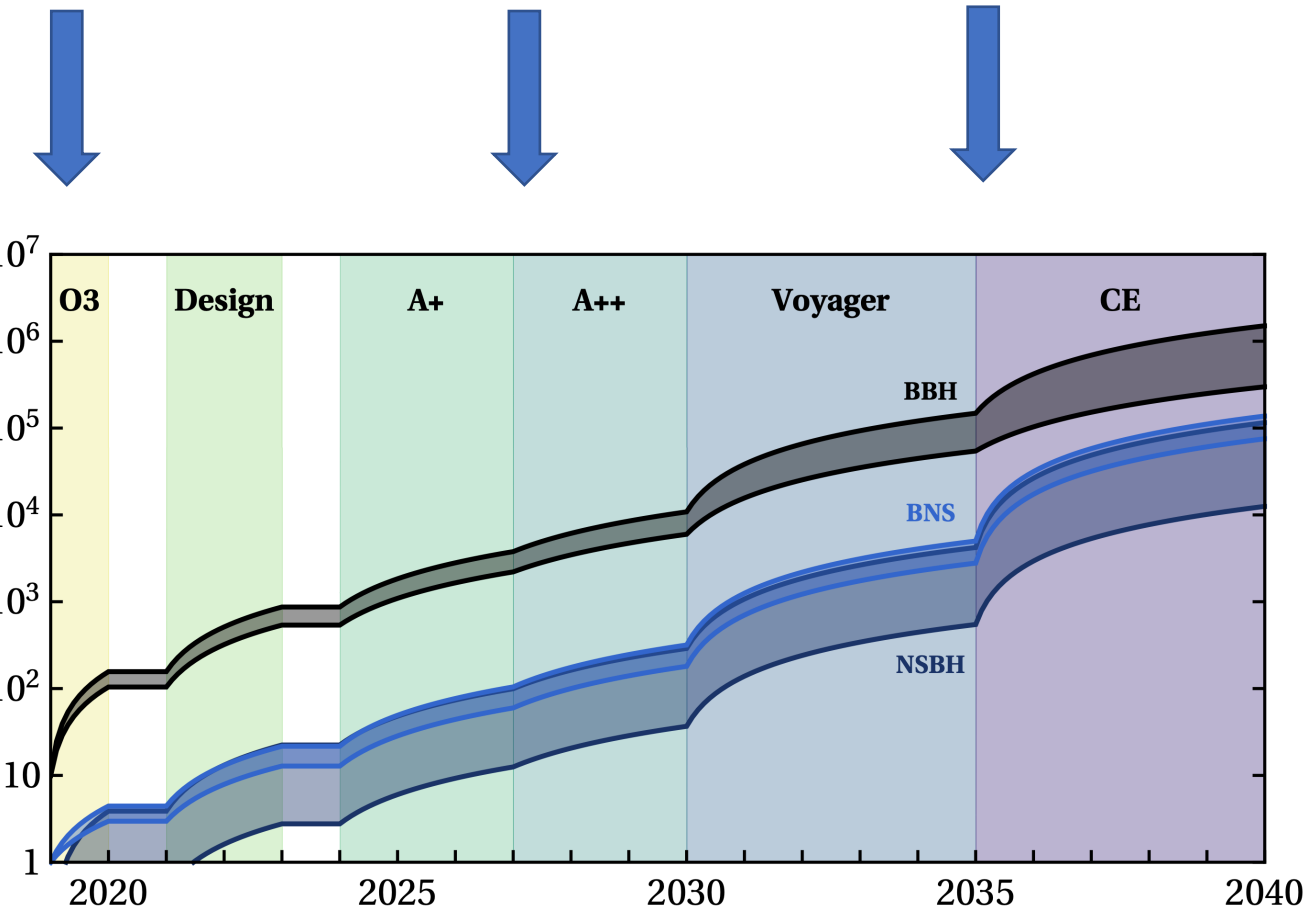
Pre & post interaction Phases







Systematic mapping crucuially missing



Observation Constraints

Large samples

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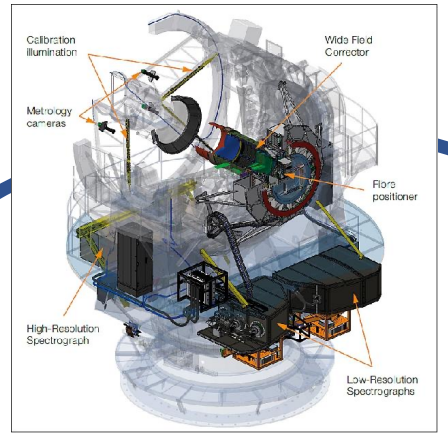
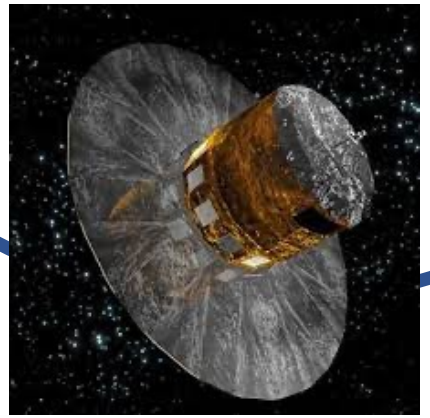
Treasury data set to unravel stellar (binary) physics in the GW and cosmological context



UVEX



FUV band: key temperature diagnostic
→ (Near) complete **census of hot stars**

Extinction law : absolutely critical for atmospheric analysis !

Multi-epochs:
(Near) complete **census of short-period (hot) binaries**

Metallicity dependance