

# Interactions between Massive Stars and the Interstellar Medium

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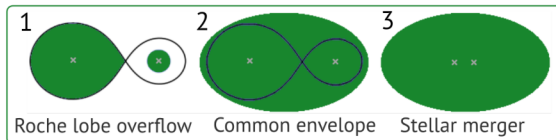
## Abstract

We visually inspect four samples of massive stars in WISE 22  $\mu\text{m}$  data in the search for associations with extended IR emission. We report associations with such nebulae in  $\sim 7\%$  of all OBA stars in the Bright Star Catalogue (BSC), with a steep decline towards later spectral types. Besides well-known bow shocks with their typical sickle-like shape, we find other morphologies like round or elliptical nebulae. We propose that at least some of them are the remnants of non-conservative mass transfer that took place in previous close binary interactions.

## Motivation

\*  $\sim 70\%$  of massive stars interact with a binary companion during some time of their evolution [Sana et al. 2012]

\* possible interaction channels [Podsiadlowski 2001]:



\* the mechanism leading to the nearly critical rotation of classical Be stars remains unknown [Rivinius et al. 2013]

\* one of the main theories: spin-up due to mass transfer in binary interactions (channel 1 & 3) [de Mink et al. 2009]

## Methods

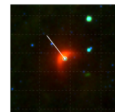
\* input samples:  $\sim 3800$  OBA stars in the BSC,  $\sim 200$  Be stars in the BSC,  $\sim 70$  BeXRBs, 6 Be+sdOs

\* visual inspection of the surroundings of all stars in WISE data at 22  $\mu\text{m}$

\* classification in four morphological groups:

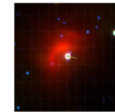
### aligned bow shocks:

- sickle-like
- $\alpha < 20^\circ$
- offset to star



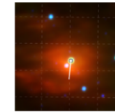
### not aligned bow shocks:

- sickle-like
- $\alpha > 20^\circ$
- offset to star



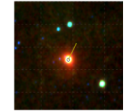
### no bow shocks:

- circular / elliptical
- no offset

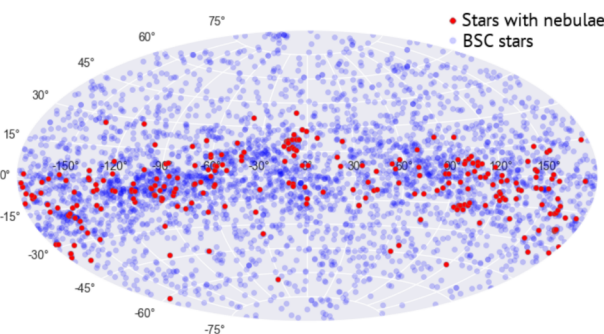


### others:

- low resolution
- background contamination



## Results



\* 28% | 13% | 0.4% of all O | B | A stars are associated with IR nebulae in WISE data at 22  $\mu\text{m}$

\* associations detected at all Galactic latitudes  
 $\Rightarrow$  no chance coincidence with fore- or background ISM

\* different physics for different morphologies:

- bow shocks (aligned or not aligned)  
 $\Rightarrow$  interaction between stellar wind and ISM
- circular / elliptical / diffuse nebulae  
 $\Rightarrow$  remnants of previous binary interactions ?

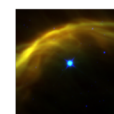
\* five confirmations with BeXRBs and Be+sdOs

	shape	$\alpha$	offset	$N_{\text{neb}}$	$f_{\text{neb}}$
aligned bow shocks	sickle - like	$\leq 20^\circ$	yes	32	12 %
not aligned bow shocks	sickle - like	$\geq 20^\circ$	yes	55	22 %
no bow shocks	round / elliptical	-	no	53	21 %
others	ambiguous	-	-	115	45 %

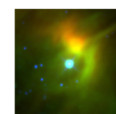
## Discussion

- \* binary interactions can lead to non-conservative mass-transfer which means that material is lost from the system
- \* depending on the interaction, the matter lost from the system may be sufficient to create a dusty circumstellar nebula visible in the IR
- \* detection rates are lower limits because of finite lifetimes of nebulae

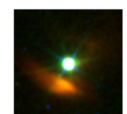
prominent examples:



$\zeta$  Oph  
O9.2IVnn  
V = 2.56



$\tau$  Sco  
B02.V  
V = 2.81



48 Lib  
B8Ia/lab  
V = 4.87