Unravelling post-binary evolutionary channels in Cygnus OB2 using WEAVE

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Hot Massive Stars

Massive stars are born with at least 8 $M_\odot$ and are associated with the **most powerful and luminous phenomena in the Universe** (e.g. SNR, GRB, GW) [1]. Along their rapid evolution, they play a crucial role in large-scale cosmic evolution: massive stars **significantly affect their surroundings** and host galaxies with mechanical and radiative feedback [2].

Important uncertainties and limits persist in our **understanding of these objects**. Recent efforts in the massive-star community have focused on understand their implications for the structure and evolution of

- wind structure and mass-loss rates
- rotation and internal mixing
- multiplicity fractions
- binary-interaction channels and mergers

WEAVE@WHT

WEAVE (WHT Enhanced Area Velocity Explorer) is the new multi-object spectrograph for the 4.2 m William Herschel Telescope (WHT) at the Observatorio del Roque de los Muchachos on La Palma (Canary Islands). Its MOS configuration allows us to take spectra of up to ~1000 targets over a 2° field of view.

The **SCIP HR Cygnus survey** [4] is an ambitious project for the study of hot massive stars using WEAVE. With this survey, the **Cygnus-X complex** will have **high-resolution spectroscopy** (R ~ 20000) in the optical range for thousand of OB-type stars. In addition, the survey design ensures that the Cygnus region is going to be observed at different times over 5 years to obtain **multi-epoch spectra** for the OB stars.

Massive Binary System Evolution

Because of their intense gravitational pull, massive stars are **often born in binary systems** [3]. This fact significantly influences the evolution of a massive star, that is heavily affected by the evolutionary and interactive processes of its companion.

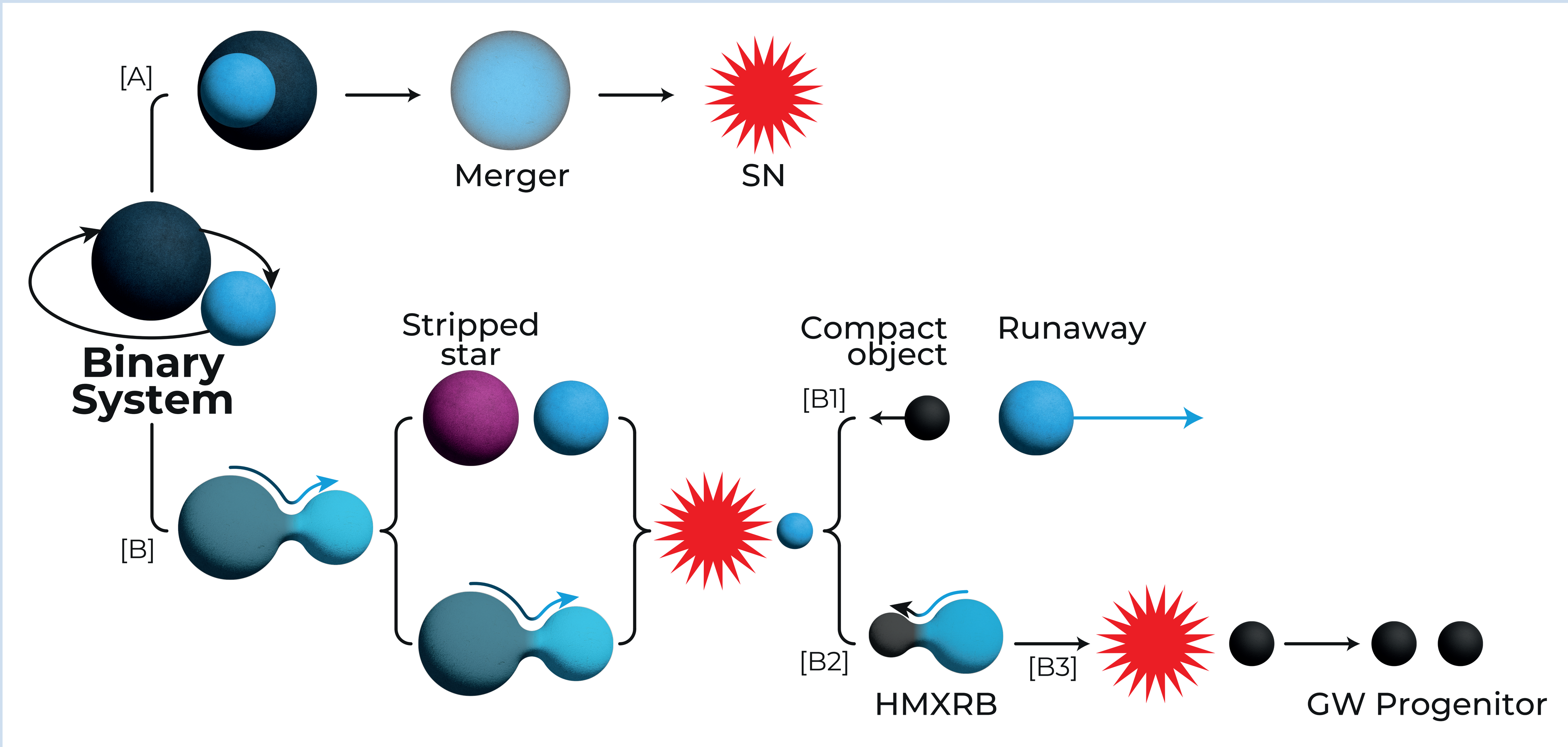

Fig 1. The different evolutionary paths a massive binary system may follow*.

As the massive binary system evolves, it can follow different evolutionary channels (see Fig. 1). The more massive star in the system will evolve more rapidly, eventually exploding as a supernova (SN); the result is a compact object such as a black hole (BH) or a neutron star (NS) [B]. In the process, a stripped star may form which is difficult to detect against the much more luminous original secondary.

+ The explosion may disrupt the system, causing the companion to be ejected at high velocity and then become a runaway star, moving across the sky with a relatively large proper motion [B1].
+ If the system is not disrupted, the companion will evolve near the compact remnant, which may accrete mass from the remaining star [B2]. This accreation process will form a high mass X-ray binary (HMXRB).

Regarding the companion, there exist two possible channels of evolution for this star:

- After some time, the companion star may be also stripped before exploding as a supernova [B3]. After the supernova event, the companion star leaves behind its own compact remnant. This results in the formation of a double compact system (BH+BH, BH+NS, or NS+NS), which can produce a gravitational wave event.
- Alternatively, before the more massive star explodes as a supernova, the two stars may get so close that they eventually merge [A]. This results in a more massive and apparently younger star, which then evolves as a single object.

Multi-epoch spectra for Cygnus OB2

Cygnus OB2, located in the Cygnus X region, is one of the **richest** areas of **massive star formation** in the Milky Way, and is the nearest to Earth (~ 1.7 kpc). Cygnus OB2 is a **key region** for studying

- the formation and evolution of massive stars,
- the dynamics of star clusters and
- the feedback processes that massive stars inject into their surroundings.

Fig 2. Composite image of Cygnus OB2**

With the SCIP HR Cygnus survey, Cygnus OB2 stars will have **high-resolution and multiepoch spectra**, opening up the possibility of a better understanding of the physics and life channels of the most massive stars [5]. In particular, a detailed spectroscopic **analysis of the merger and runaway populations** will

- indicate whether the **properties** of these stars and systems are **consistent** with the predictions of **theoretical models**,
- confirm or reject the **existence of a given evolutionary channel** in Cygnus OB2 and
- estimate the **relative frequency** with which **these channels** occur in nature.

References

[1] N. Langer. "Presupernova Evolution of Massive Single and Binary Stars". In: 50 (Sept. 2012), pp. 107–164. DOI: 10.1146/annurev-astro-081811-125534. arXiv: 1206.5443 [astro-ph.SR].

[2] Sam Geen et al. "A detailed study of feedback from a massive star". In: 448.4 (Apr. 2015), pp. 3248–3264. DOI: 10.1093/mnras/stv251. arXiv: 1412.0484 [astro-ph.GA].

[3] H. Sana et al. "Binary Interaction Dominates the Evolution of Massive Stars". In: *Science* 337.6093 (July 2012), p. 444. DOI: 10.1126/science.1223344. arXiv: 1207.6397 [astro-ph.SR].

[4] Shoko Jin et al. "The wide-field, multiplexed, spectroscopic facility WEAVE: Survey design, overview, and simulated implementation". In: 530.3 (May 2024), pp. 2688–2730. DOI: 10.1093/mnras/stad557. arXiv: 2212.03981 [astro-ph.IM].

[5] S. R. Berlanas et al. "New massive members of Cygnus OB2". In: 612, A50 (Apr. 2018), A50. DOI: 10.1051/0004-6361/201731856. arXiv: 1711.06945 [astro-ph.SR].

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Acknowledgements

We acknowledge funding from the Spanish Ministry of Science and Innovation (MICINN) through the Spanish State Research Agency through grants PID2021-122397NB-C21, and the Severo Ochoa Programme 2020–2023 (CEX2019-000920-S). SRB also acknowledges financial support from NextGeneration EU/PRTR and MIU (UNI/551/2021) through grant Margarita Salas-ULL.