Testing the evolution theory of massive binary systems

Laurent Mahy – KU Leuven

Collaborators: H. Sana – F. Martins – G. Rauw – M. Abdul-Masih – L. A. Almeida – N. Langer – K. Sen – T. Shenar – A. de Koter – S. E. de Mink – C. J. Evans – A. F. J. Moffat – S. Simon-Diaz – F. R. N. Schneider – R. Barbá – J. S. Clark – M. Fabry – P. Crowther – G. Gräfener – D. J. Lennon – F. Tramper, – J. S. Vink

Abstract: Massive stars are often found to be in pairs. This configuration is both a blessing and a curse. From it, we can estimate their exact properties such as their masses but the interactions that result during their life considerably affect the way that the stars evolve. To understand how the stars evolve when they are in pair and what are the effects of these interactions on the stellar properties, we undertook a large study of more than 60 massive binaries at Galactic and LMC metallicities using spectral disentangling[1,2], atmosphere modelling[3] and light curve fitting to determine their stellar parameters, and surface abundances. This unique dataset is the largest sample of binaries composed of at least one O-type star to be studied in such a homogeneous way. It allows us to give strong observational constraints to test theoretical binary evolutionary tracks, to probe rotational and tidal mixings and mass transfer episodes.

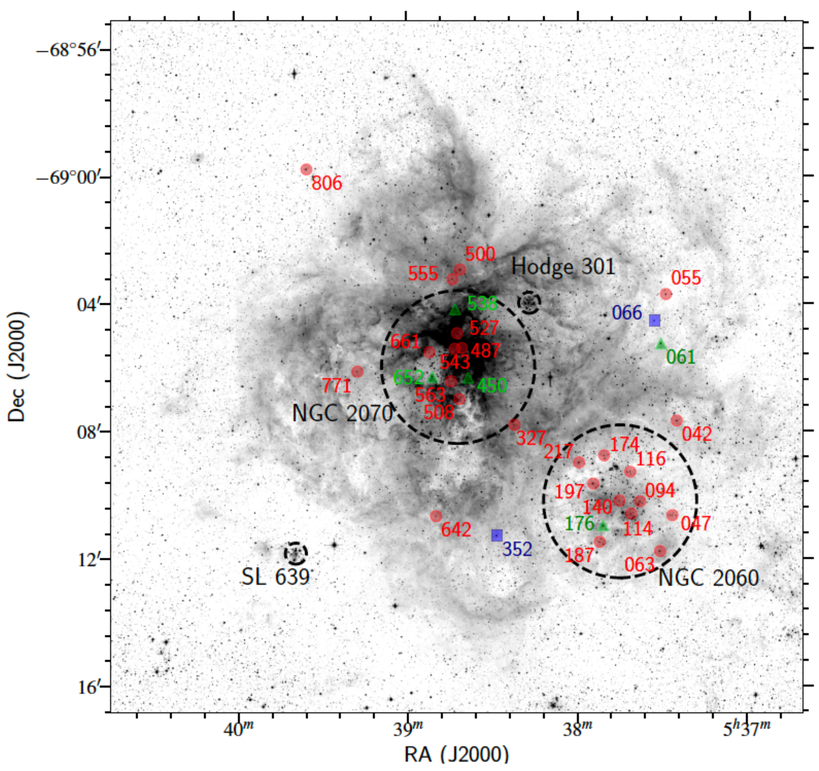

Fig 1: Location of the 31 SB2 massive systems in the Tarantula nebula. Red circles indicate the detached systems, the green triangles the semidetached systems and the blue squares the contact systems.

Science Goals:

- Probing the effects of the metallicity on the mass and angular momentum transfers
- Constraining the effects of the tides on the stellar physical properties
- Investigating the mass transfer efficiency, the internal mixing, core mass and overshooting

Results published in Mahy et al. (2020a,b)

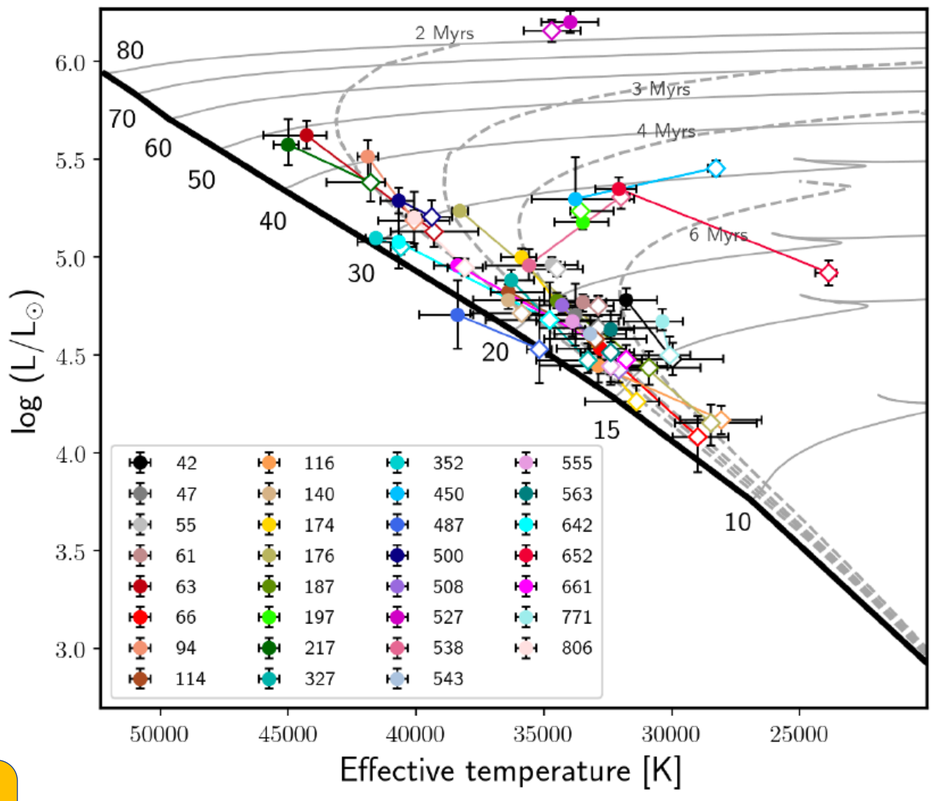

Fig. 2: Hertzsprung-Russell diagram. Tracks and isochrones are from Brott et al. (2011), computed with an initial rotational velocity of 150 km s^{-1}. Filled (open) circles (diamonds) refer to the primary (secondary) of each binary system.

Detached binary systems

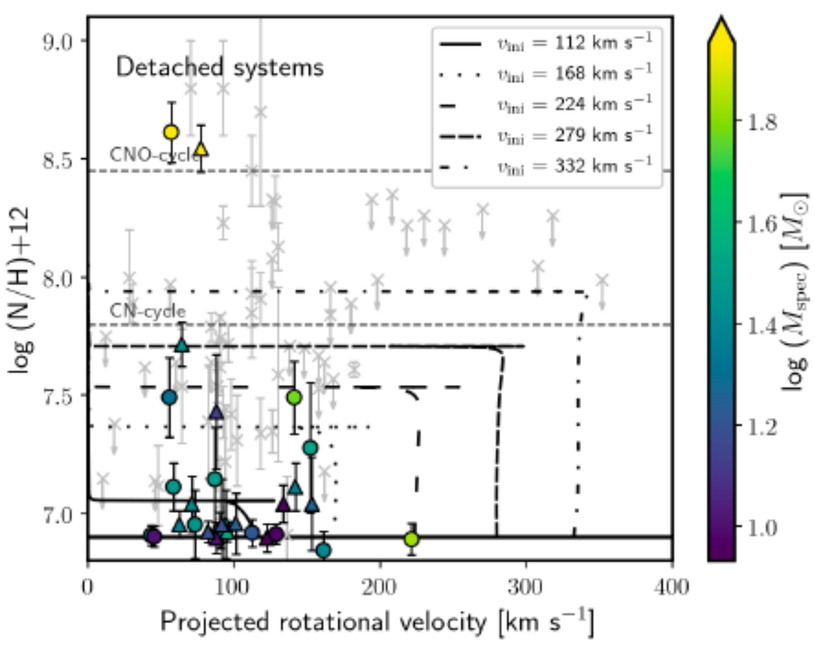

Fig.3: Projected rotational velocity vs. the nitrogen content of the stars in detached systems. The circles represent the primaries, the triangles the secondaries. In grey is plotted the population of single giant and supergiant O-type stars in the 30 Dor[4]. Tracks are from Brott et al. (2011); they correspond to an initial mass of 25 $M_\odot$. The colour-bar represents the spectroscopic masses of the components.

1. Evolution of massive main-sequence stars in long-period detached binary systems is not affected by the presence of the companion and they represent ideal objects to probe single-star evolution
2. The effects of the tides are more limited on the nitrogen content of the detached components

Algol systems:

Mass accretion onto stars can have two outcomes:

1. Only little mass is accreted because the accretor rapidly spins-up which then prevents further mass accretion.
2. Much more mass (if not all) is accreted because there is a way to get rid of angular momentum such that the accretor never reaches critical rotation.

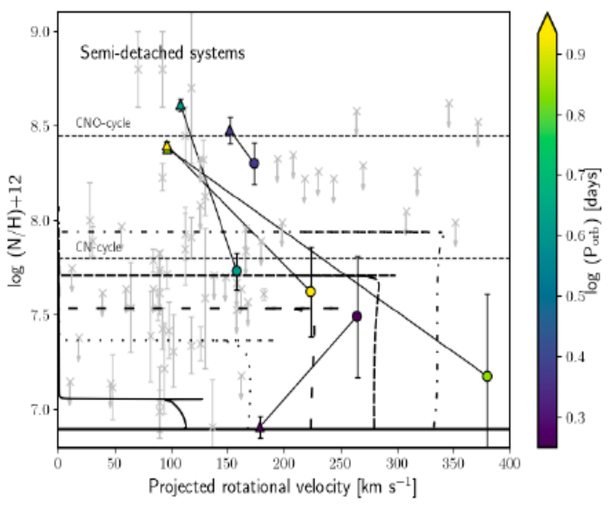

Fig.4: Projected rotational velocity vs. nitrogen content of the stars in semi-detached configuration. Circles and triangles represent the primary and secondary component, respectively. Tracks are from Brott et al. (2011) and correspond to an initial mass of 25 $M_\odot$. The colour-bar represents the orbital period of the systems.

Future project: The Milky Way

~25 eclipsing binary systems and ~10 long-period interferometric binary systems in the Galaxy are currently analysed (Mahy et al. in prep.)

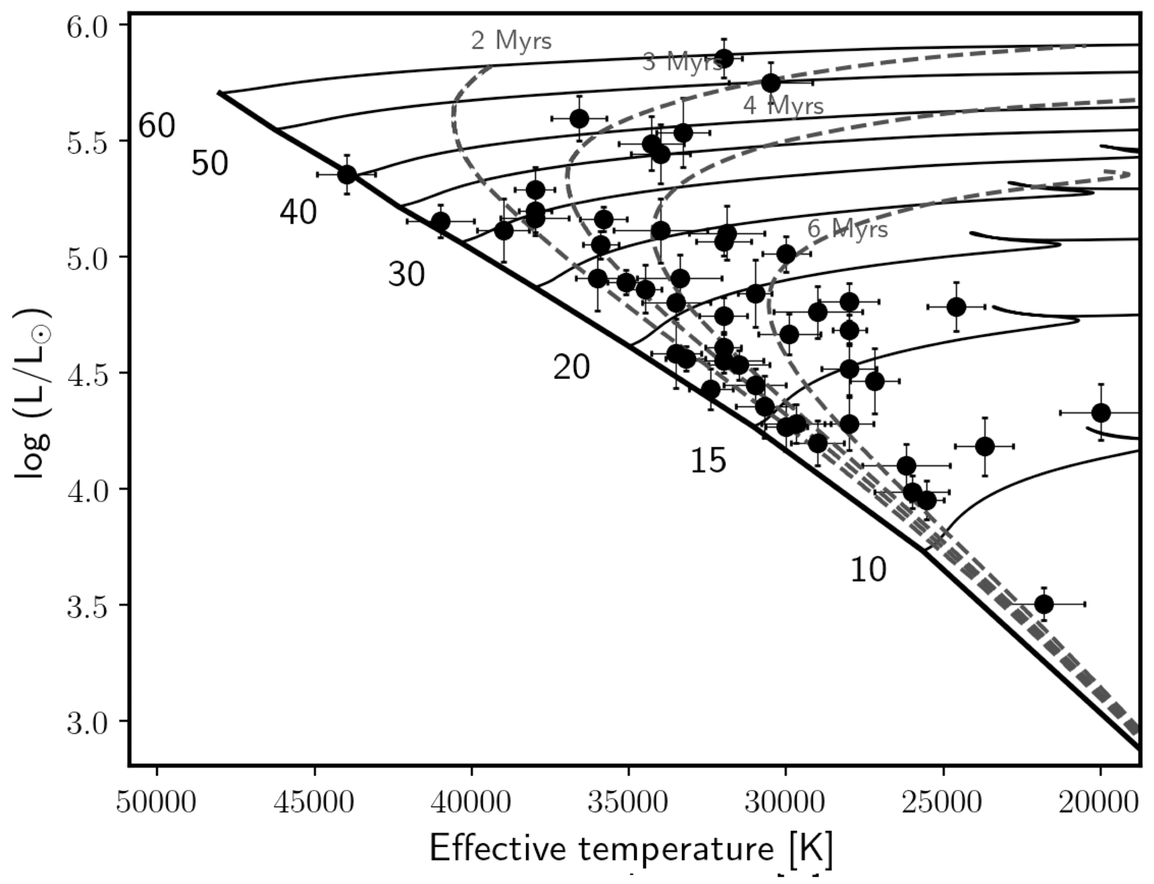

Fig. 5: Hertzsprung-Russell diagram. Tracks and isochrones are from Brott et al. (2011), computed with an initial rotational velocity of 150 km s^{-1}. Filled (open) circles (diamonds) refer to the primary (secondary) of each binary system.

The evolution of these systems will be simulated using MESA[6] to probe the efficiency of mass and angular momentum transfers (Sen et al. in prep.)

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References:

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[4] Grin, N. J., Ramírez-Agudelo, O. H., de Koter, A., et al. 2017, A&A, 600, A82
[5] Brott, I., de Mink, S. E., Cantiello, M., et al. 2011, A&A, 530, A115
[6] Paxton, B., P. Marchant et al. 2015, ApJS220, 15, 15