Evidence for episodic mass loss in red supergiants from the ASSESS project

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What is the ASSESS project?

The ERC-funded ASSESS project (2018-2024) aims to determine the role of episodic mass loss in the evolution of the most massive stars, by conducting the first extensive, multi-wavelength survey of ~1000 evolved massive stars in the nearby Universe using FORS2/VLT and OSIRIS/GTC. We obtained 763 spectra in WLM, NGC 55, NGC 247, NGC 253, NGC 300, NGC 1313, NGC 3109, Sextans A, M83 and NGC 7793, which span span a range of metallicities Z = 0.06–1.6 $Z_\odot$. ASSESS has produced **the largest catalog of evolved massive stars (185 stars) and in particular of red supergiants (129 stars) in nearby galaxies at low *Z* beyond the Local Group**[1]. The brightest and reddest of these are candidates for episodic mass loss.

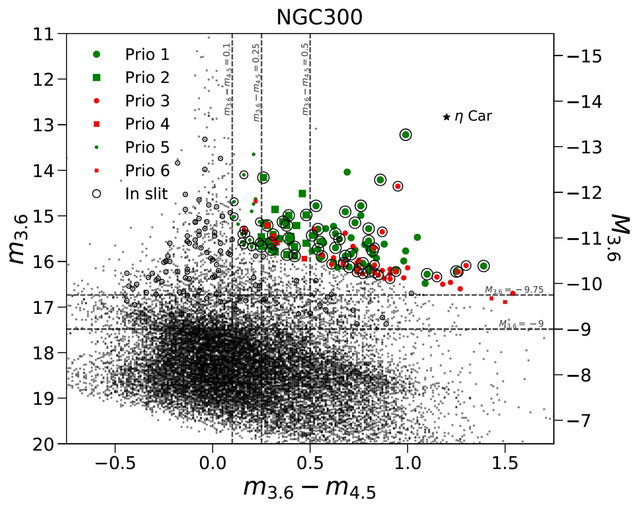

Fig. 1: Target selection criteria in NGC 300 used for selecting dusty, evolved massive stars for spectroscopy with VLT/FORS2.

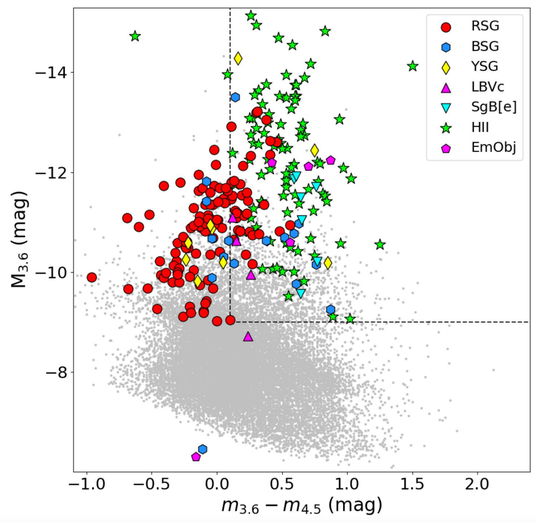

Fig. 2: Mid-IR CMD of all classified objects. Sources within the box defined by the dashed lines have IR excess due to dust.

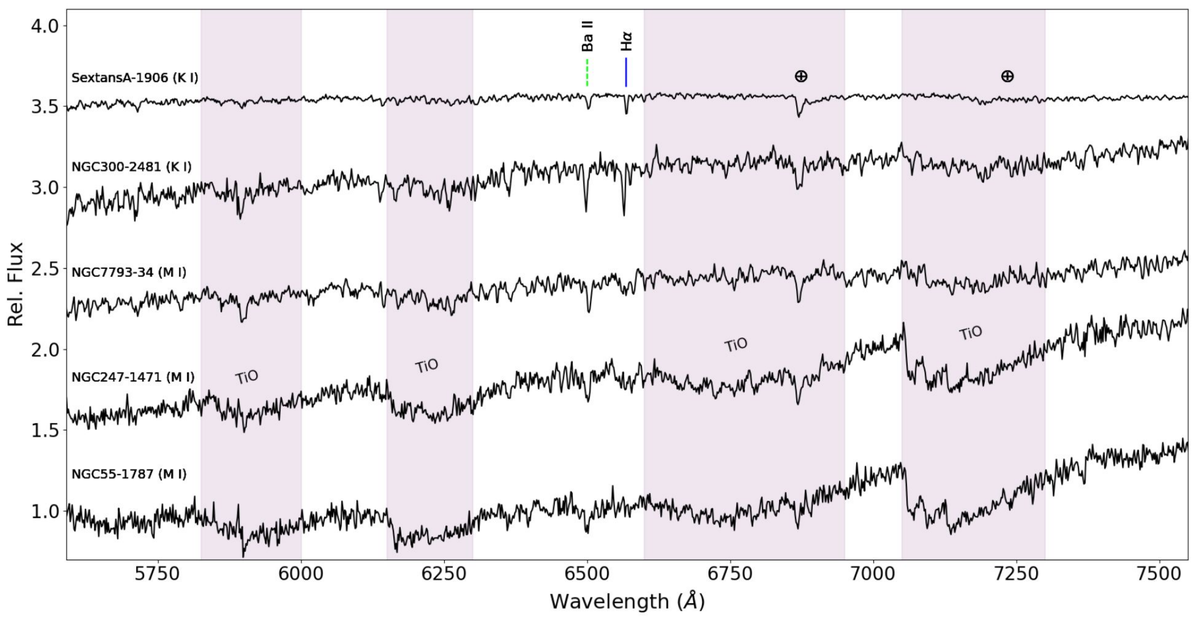

Fig. 3: VLT/FORS2 example spectra of classified RSGs from ASSESS. The increasing TiO strengths indicate a spectral type sequence from early to later types.

Galaxy Name	Class.	RSG	BSG	YSG	LBVc	sgB[e]	Em. Obj.	H II[b]	Clusters	Other Stars[c]	C-stars	Galaxies[d]	Fgd
WLM	19	-	-	-	-	1	1	-	-	5	7	1	4
NGC 55	85	42	4	1	2	1	-	15	1	12	-	3	4
NGC 247	49 (3)	16	3 (2)	2 (1)	1	1	1	10	2	5	-	4	4
NGC 253	63 (1)	12	- (1)	1	-	1	2	24	11	9	-	-	3
NGC 300	105 (5)	46	7 (2)	1 (2)	-	2	2	10	3	8	1 (1)	8	17
NGC 1313	15 (2)	1	1 (2)	-	-	-	-	5	3	-	-	-	5
NGC 3109	15	1	-	1	1	-	-	1	-	-	-	2	9
Sextans A	15 (2)	1	2 (2)	-	-	-	1	-	-	10	1	-	-
M83	46	1	-	-	-	-	-	28	5	1	-	-	11
NGC 7793	28 (1)	9	1	- (1)	-	1	1	6	2	1	-	3	4
Total	**440 (14)**	**129**	**18 (9)**	**6 (4)**	**4**	**7**	**8**	**99**	**27**	**51**	**9 (1)**	**21**	**61**

Table 1: Distribution of classified sources from ASSESS per galaxy and per spectral type. The large sample of RSGs is presented below.

What can we learn about dusty RSGs?

We model the optical spectra of our red supergiants with MARCS models[2] to measure stellar properties from their optical spectra, such as the effective temperature, extinction, and radial velocity[3]. By fitting the spectral energy distribution, **we obtained the stellar luminosity and radius for 97 RSGs, finding ~ 50% with log(L/L$_\odot$) ≥ 5 and six RSGs with R ≥ 1400 R$_\odot$**. We also find a correlation between the stellar luminosity and mid-IR excess of 33 dusty, variable sources. Three of these dusty RSGs have luminosities exceeding the observed upper luminosity limit and are expected to be progenitors of core-collapse supernovae. We speculate that three other hot, dusty RSGs (10% of the K-type sample) may have experienced a recent mass ejection and indicate them as candidate Levesque-Massey variables. The frequency of dusty RSGs (26% of the sample), i.e. those that show evidence for recent episodic mass loss events, is expected to be related to the frequency of Type II supernovae with pre-existing CSM, such as the recent example of SN 2023ixf[4].

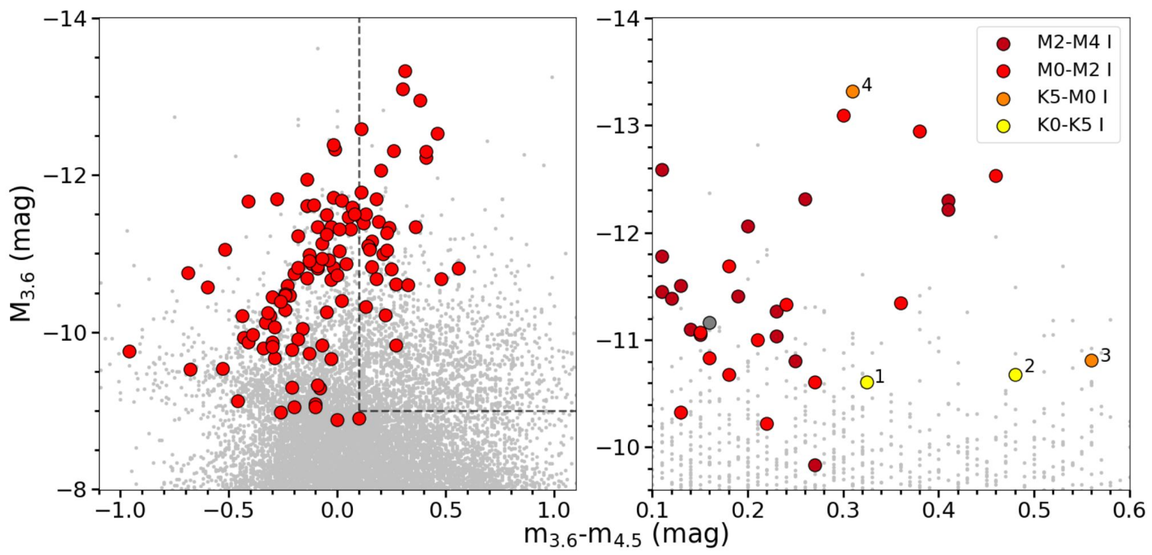

Fig. 4: *Left:* Color-magnitude diagram showing the infrared properties of 129 RSGs. *Right*: CMD of dusty (33) RSGs. The K-type RSGs have an unexplained IR excess!

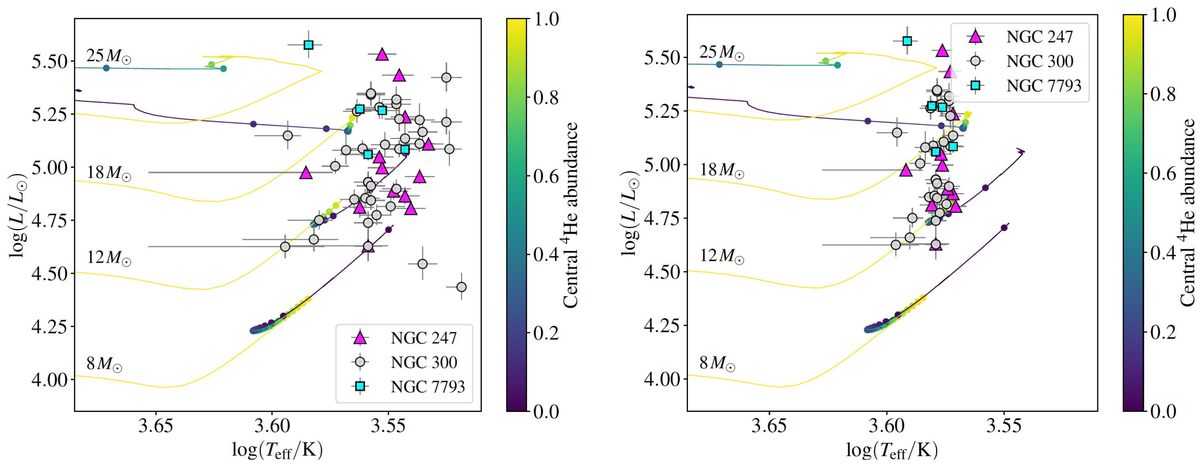

Fig. 5. *Left*: RSGs in NGC 247, NGC 300 and NGC 7793 compared to POSYDON evolutionary tracks, with *T*eff from the TiO bands. *Right*: Same as *Left*, but with *T*eff derived using the scaling relation from [3]. The scaled temperatures are in agreement with the tracks.

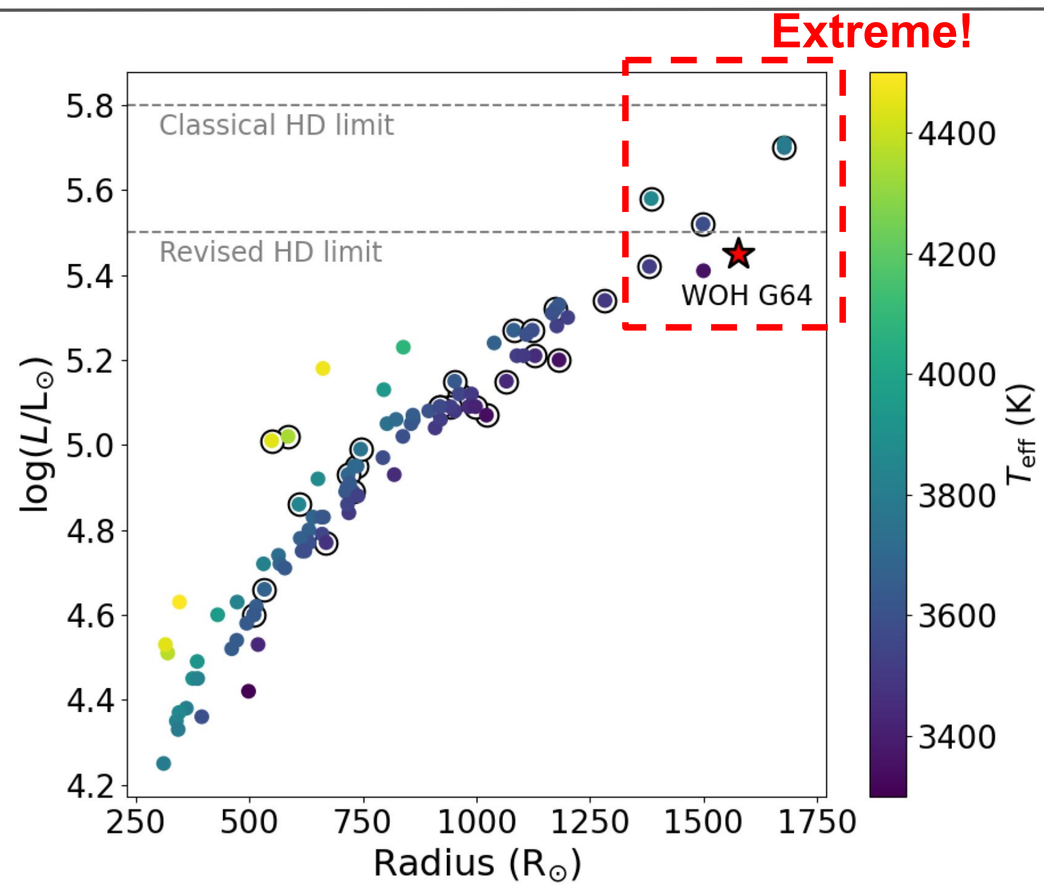

Fig. 6: Luminosity-radius diagram showing four extreme RSGs. Three of these sources show infrared excess. These sources may be analogs of WOH G64, the most extremely mass losing RSG in the LMC and therefore may hold clues on episodic mass loss in RSGs!

ASSESS project:

- investigates the role of episodic mass loss at various Z
- obtained 763 spectra of massive, dusty candidates
- published largest catalog of evolved massive stars beyond Local Group (185 stars)
- identified 130 RSG (117 new discoveries)

Red supergiant sample:

- physical parameters were derived for 127 RSGs
- 50% of these are extreme RSG with log(L/L$_\odot$) ≥ 5
- 26% of the sample show evidence for dust
- 3 potential candidates for recent episodic mass loss

References:
[1] Bonanos et al., A&A, in press (arXiv:2312.04626)
[2] Gustafsson et al. 2008, A&A, 486, 951
[3] de Wit et al., A&A, in press (arXiv:2402.12442)
[4] Soraisam et al. 2023, ApJ, 957, 64

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