[W60] B90: a mass-losing luminous RSG in the LMC interacting with the CSM

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Motivation

[W60] B90 is **one** of the **largest**, $R \approx 1200 R_{sun}$, **most luminous**, $\log(L/L_{sun})=5.32 \pm 0.01$, and **mass-losing,** $\log(\dot{M})= -5.35$, **red supergiants** (RSG) in the **Large Magellanic Cloud** (LMC) *[1][2]*.

Its location in the Hertzsprung-Russell diagram **close to the observational RSG luminosity limit**, $\log(L/L_{sun})=5.50$ *[3]*, places it within the "**RSG problem".** [W60] B90 presents a unique opportunity to understand better supernova progenitors and episodic mass-loss in low metallicity environments.

Our discovery of a bar-like nebular structure at 1 pc, reminiscent of the bar around Betelgeuse, raised the **question** of whether [W60] B90 is the **4th RSG with a bow shock** and **1st extragalactic** case **(*Fig. 1*)**.

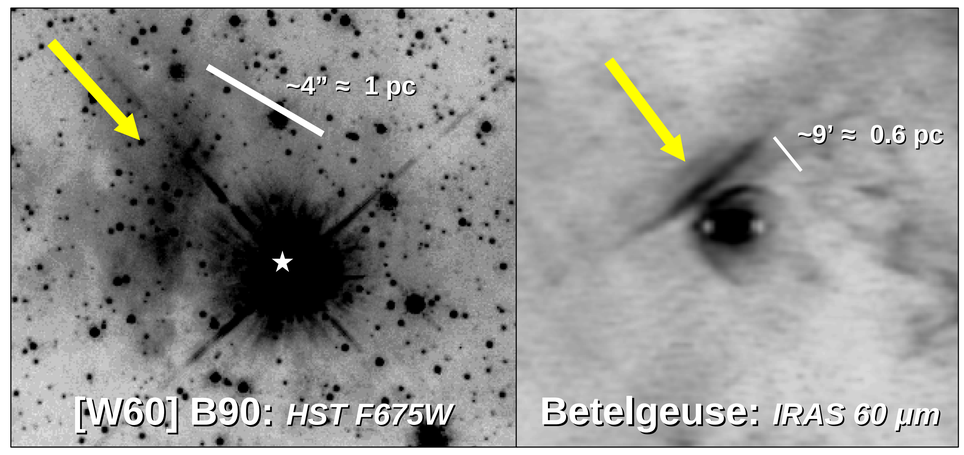
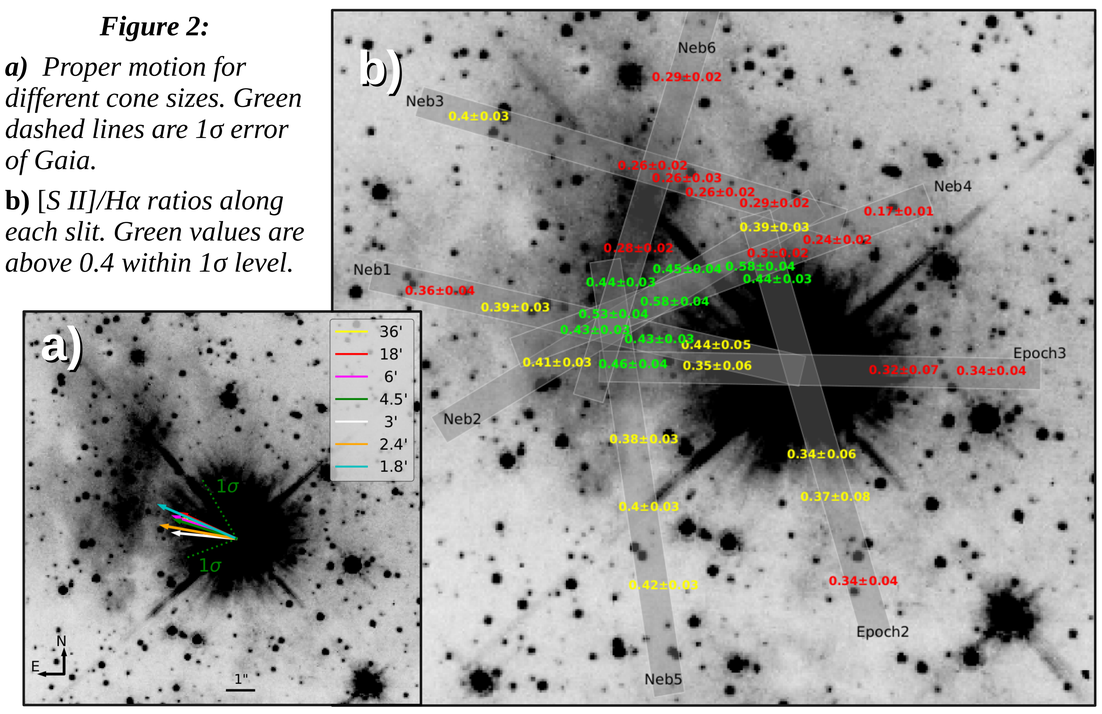


Figure 1: *Comparison of the bar in [W60] B90 with the Betelgeuse case*

Figure 2:

a) *Proper motion for different cone sizes. Green dashed lines are 1σ error of Gaia.*

b) [*S II]/Hα ratios along each slit. Green values are above 0.4 within 1σ level.*



Evidence of shocked material

To prove the interaction between [W60] B90 and the bar, we compiled *Gaia* DR3's proper motion of the stars inside a cone centered on our RSG, cleaned the foreground contamination *[4]*, computed a LMC local proper motion, and subtracted this value to [W60] B90's proper motion to obtain its peculiar velocity. We conclude that **[W60] B90 is moving towards the bar** independently of the parameters used and consistently with 1σ error from *Gaia* (***Fig. 2a***).

The intensity ratio of [S II]/Hα is historically used to detect shocked material when it surpasses the critical value of 0.4. We investigated the circumstellar material around our RSG obtaining long-slit spectroscopy with MagE, 6.5-m Baade telescope (Las Campanas, Chile).

Finally, we report **ratios higher than [S II]/Hα > 0.4 between the bar and the star** (***Fig. 2b)*** and in **agreement with the proper motion,** suggesting that the **shocked material is result of the interaction** of the star with the ISM**.** However, further investigation is needed in order to resolve the bow shock.

[W60] B90 variability and dimming events

Archival photometry spanning the last 30 years revealed **three dimming events** with ***ΔV*~1 mag**, **a rise time of ~400 days** and a **recurrence of ~11.8 years (*Fig. 3*)**. We attributed the **delay in the recovery** to the **size of the atmosphere**, as [W60] B90 is more extended than Betelgeuse *[5,6]* and the adjustment within the atmosphere needs additional time to manifest. We reinforce this argument by reporting similarities in the timescale between [W60] B90 with those of μ Cep *[7]* and the hypergiant RW Cep *[8]*.

[W60] B90: 1210 R_{sun} **μ Cep: 1259 R_{sun}**
Betelgeuse: 700-1000 R_{sun} **RW Cep: 900-1760 R_{sun}**

TiO bands from the optical

	Spectral type	ATLAS *o* (mag)	$T_{eff,TiO}$ (K)	$E(B-V)$ (mag)	A_V (mag)	χ^2
Epoch1	M3 I	–	3550±40	1.00±0.15	3.41±0.51	13.0
Epoch2	M4 I	12.6±0.1	3460^{+20}_{-30}	1.10±0.10	3.75±0.34	193.7
Epoch3	M3 I	12.3±0.1	3550^{+40}_{-30}	$1.35^{+0.10}_{-0.05}$	$4.60^{+0.34}_{-0.17}$	47.9
Epoch4	M3 I	11.8±0.1	3610^{+60}_{-50}	$1.25^{+0.10}_{-0.05}$	$4.26^{+0.34}_{-0.17}$	26.9

Table 1: *Physical parameters of [W60] B90 obtained from optical spectroscopy*

Figure 3: *Comparison of the three dimming events with Betelgeuse, μ Cep and RW Cep.*

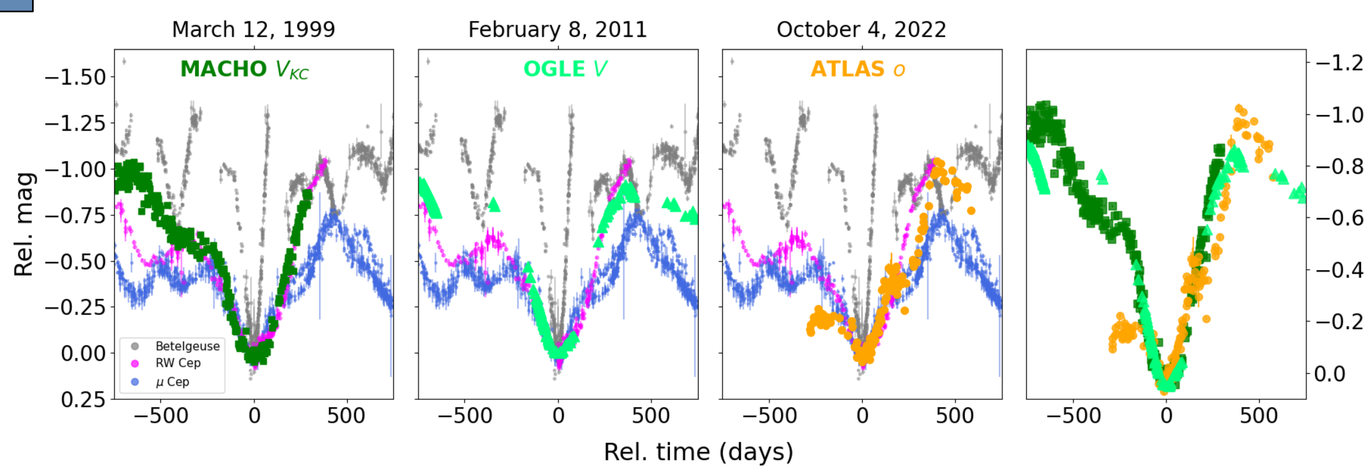
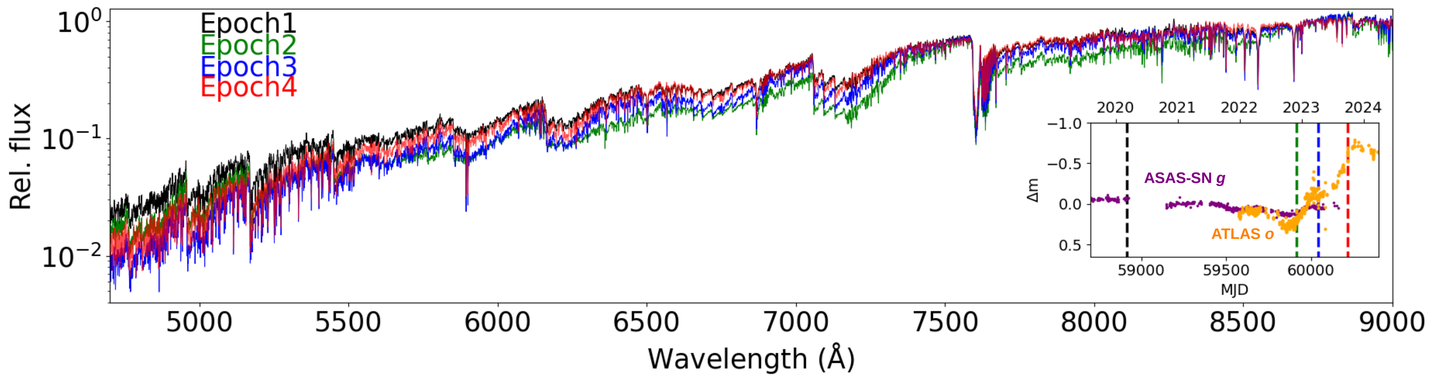


Figure 4: *Optical multi-epoch spectroscopy of [W60] B90. The last dimming event is shown in the subplot.*



Multi-epoch spectroscopy with MagE of [W60] B90 **during the last dimming** (Epochs2-4, ***Fig. 4***) revealed **similar** conditions **as** in the **Great Dimming of Betelgeuse** *[9]*: evolution of the atmospheric properties**,** a correlation between T_{eff}-ATLAS *o*, and an enhancement of the *Av* after the minimum. We used the MARCS *[10]* models to derive the properties of [W60] B90 (*Table 1*).

Take away points

- [W60] B90 is moving towards the bar
- [S II]/Hα > 0.4 between the star and the bar, where the bow shock is expected
- Dimming with a 11.8 years recurrence
- Time scale of the dimming depends on the radius
- Spectroscopy on the last dimming revealed similar properties as in The Great Dimming of Betelgeuse
- **[W60] B90 is undergoing episodic mass-loss**

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