Presentation for *Seminar on Astrophysics*

SDSS-V LVM: Detectability of Wolf-Rayet stars and their He II ionizing flux in low-metallicity environments
I. The weak-lined, early-type WN3 stars in the SMC

González-Torà et al. 2025, arXiv: 2509.04569

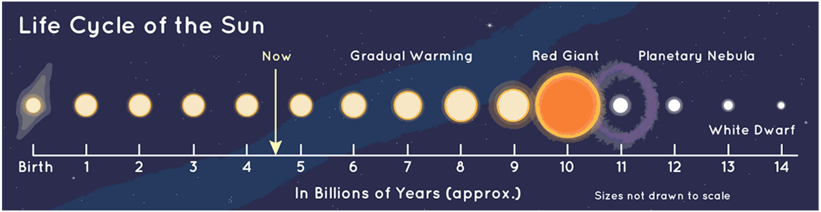
Laksh Gupta

Supervisor: **Dr. Abel Schootemeijer** (AIfA, University of Bonn)

8th December 2025

Sun as a Star

A few more billions of years until our Sun runs out of fuel.



Lifecycle of our Sun. Credits: NASA Science Space Place/JPL.

Massive Stars

- $M_{\text{initial}} > 8M_{\odot}$.
- $T_{\text{effective}} \gtrsim 10$ kK.
- Radiation from these stars peaks in UV and is strong enough to ionize the surrounding interstellar medium— H I ($\lambda < 912$Å), He I ($\lambda < 504$Å), **He II** ($\lambda < 228$Å).
- Hence, one expects to see these emission features from the spectra of massive stars.

$Q_{\text{He II}}$ is defined as the ionizing flux of He II.

Do all massive stars contribute equally to $Q_{\text{He II}}$?

No. Only stars with

1. hot temperatures,
2. thin stellar winds, and
3. strong dependence on metallicity (low).

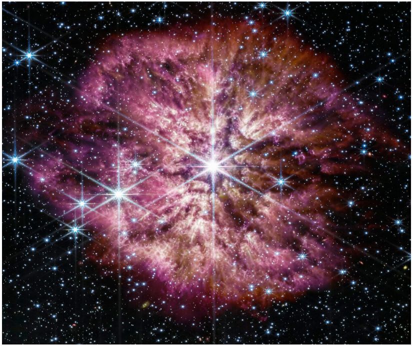
contribute to $Q_{\text{He II}}$.

Hence, massive stars with thin winds in low-metallicity environments contribute to $Q_{\text{He II}}$.

Six such stars are present in Milky Way's satelite galaxy **Small Magellanic Clouds**. All six of them are **Wolf-Rayet Stars**.

Wolf-Rayet Stars

- First discovered by C. J. E. Wolf and G. Rayet while working at the Paris Observatory in 1867.
- Hot ($T_{\text{effective}} \gtrsim 25$ kK) and Massive ($M_* \gtrsim 25 M_\odot$).

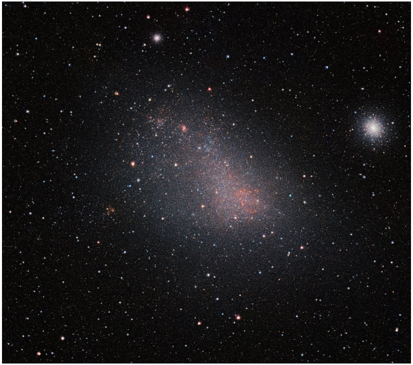


WR 124 is a Wolf-Rayet star in Sagittarius. Credits: Yves Grosdidier, Anthony Moffat, and NASA.

Small Magellanic Cloud (SMC)

- **Nearby** galaxy which hosts a **significant population** of resolvable **hot**, **massive** stars and is metal poor[a].
- 12 WRs are known in SMC, this study deals with 6 of them.

[a] $\approx 0.2 Z_{\odot}$.



SMC in infrared wavelength. Credits: ESO/VISTA VMC.

WRs contribute to the ionizing flux of He II ($Q_{\text{He II}}$)

Massive stars with thin winds in low-metallicity environments contribute to $Q_{\text{He II}}$ - **theoretical prediction**.

$\Downarrow$

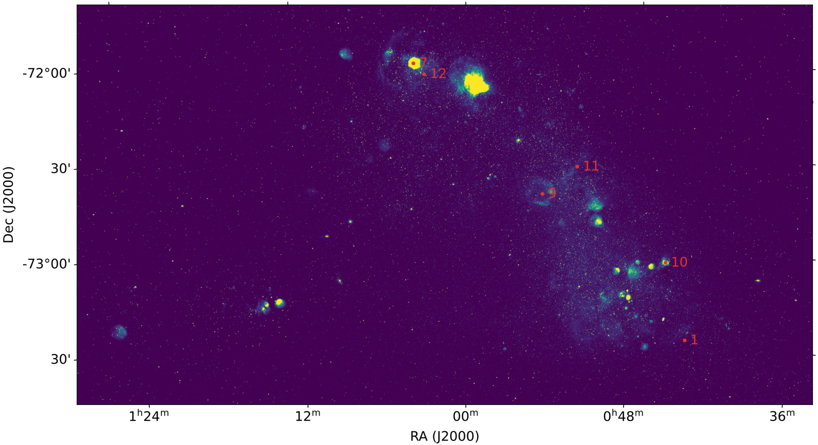
Observations **do not match this prediction**, i.e., the integrated light spectra[a] of low-metallicity galaxies[b] does not show the feature associated to $Q_{\text{He II}}$.

This study **explains this discrepancy**.

---

[a] ILS.

[b] typically star-forming



The six WR stars analyzed in this study.

Observations

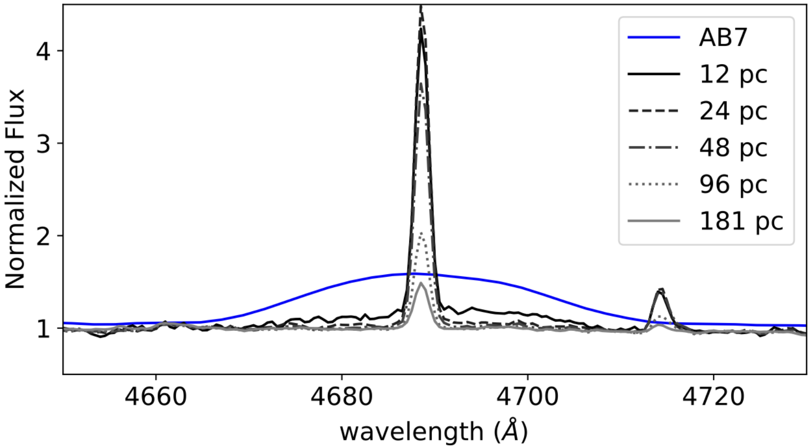
- Data from Local Volume Mapper (LVM) was used in this study.
- Integrated spectra from apertures with 40″, 80″, 160″, 320″, and 600″ diameter.
- For stellar spectra - optical slit spectroscopy (He II 4686Å) was used.

The Local Volume Instrument on Robot Ridge at Las Campanas. Credits: SDSS

What ways did the authors analyze the spectra?

1. Obtain WR star number count from the spectra.
2. Compared $Q_{\text{He II}}$ values from theoretical predictions to observations.

Analysis - Part I

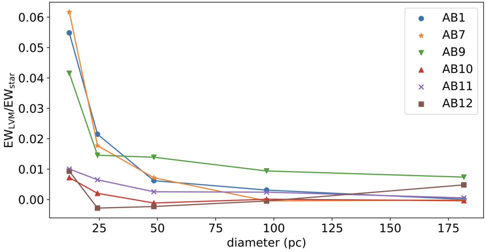


Normalized stellar flux in blue. Black curve for the 40'' aperture, lighter gray for wider apertures.

Normalization dilutes the feature!

Analysis - Part I

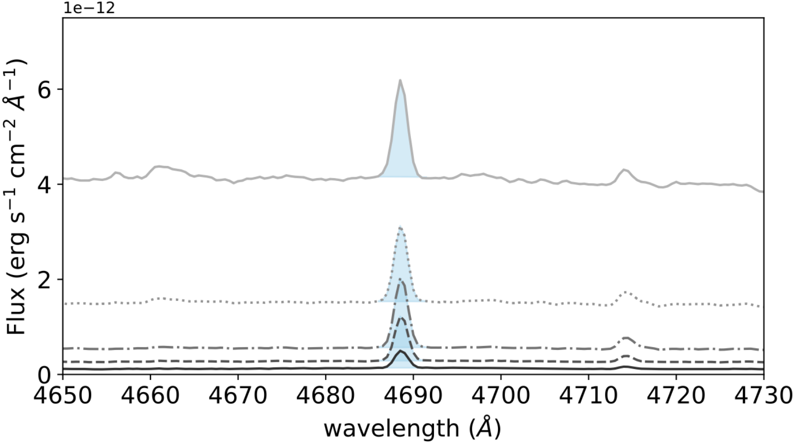
- The integrated light spectra (ILS) of a star-forming region will show WR features— **WR bump**.
- Strength of WR bumps is a method to estimate the number of WRs in an unresolved region or galaxy (Crowther et al. 2023).



y-axis: "observed number of stars", x-axis: aperture size.

Result 1: The broad emission of any SMC WN3 star is completely diluted (i.e., undetectable) if the flux is integrated over a region with a diameter $>$ 24 pc.

Analysis - Part II



Calibrated flux for the nebular region. Black curve for 40" aperture, lighter gray for wider apertures. Light blue regions selected of the HeII that contribute to the nebular component.

Analysis - Part II

- Since, $Q_{\text{He II}} \propto L_{\text{He II}}$, we have $Q_{\text{He II}}$ or more precisely, $Q_{\text{He II}}^{\text{Observed}}$.
- For theoretical $Q_{\text{He II}}$, PoWR was used. They gave $Q_{\text{He II}}^{\text{Theoretical}}$.
- On comparing, $Q_{\text{He II}}^{\text{Observed}} < Q_{\text{He II}}^{\text{Theoretical}}$.

Result 2: This means that a significant number of ionizing photons from the WN3 targets escape from the immediate environment.

Takeways

- **Result 1**: The broad emission of any SMC WN3 star is completely diluted (i.e., undetectable) if the flux is integrated over a region with a diameter > 24 pc.
- **Result 2**: A significant number of ionizing photons from the WN3 targets escape from the immediate environment.

WN stars with comparably thin winds are easy to "hide", even when they are significantly away from larger clusters, despite their strong contribution of He II ionizing photons. This **solves** the posed discrepancy.

How do these results affect current science?

- Stellar-evolution and population-synthesis models that include WR stars must be updated with this new insight.
- Caution when interpreting the lack of WR bumps as meaning "no WR stars" in star-forming galaxies.

Thank you.
I thank Dr. Abel Schootemeijer for guiding me in understanding this work better.

Scan to download this presentation