J-band spectroscopy of mass losing red supergiants in low metallicity galaxies

HELLENIC REPUBLIC
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European Research Council
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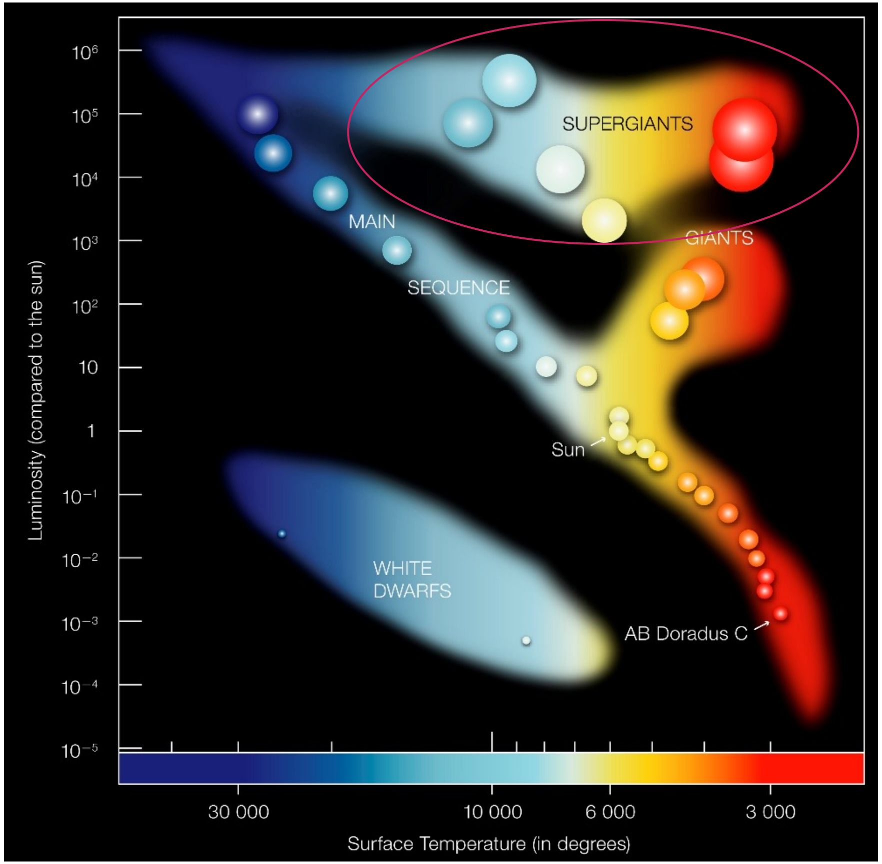
Introduction



- Massive stars: M_{ZAMS} > 8 M_{sun} (supernovae threshold)
- It is estimated that ~70 % will exchange mass with their companion
- They have winds that change their evolution
- Their radiation, winds and supernovae ejecta enrich the ISM, driving the evolution of the Universe

Episodic mass loss: significant mass loss event on a short timescale (**not** necessarily eruptive), physical mechanism not yet understood, not included in evolutionary models

The ASSESS project

- PI: Dr. Alceste Bonanos
- Objective: Determine the role of episodic mass loss in the evolution of massive stars
- Funded by the European Research Council (ERC) *under the EU's Horizon 2020 research and innovation program (Grant agreement No. 772086).*
- Recent Publications: Maravelias et al. 2023, Bonanos et al. 2024, Antoniadis et al. 2024, de Wit et al. 2024
- Upcoming: Munoz-Sanchez et al. → Next talk
- In preparation: de Wit et al. , Zapartas et al. , Munoz-Sanchez et al. , Antoniadis et al. and Christodoulou et al. → This talk

Analysis of 127 RSGs found in Bonanos et al. 2024

Catalog of 185 dusty evolved massive stars in 10 southern galaxies

Mass loss rate relation based on 2000 RSGs in the LMC

Discovery of 7 sgB[e] + 4 LBVc at low Z

Implementation of RSG winds at SMC metallicity

Catalog of dusty evolved massive stars in 5 northern galaxies

Dependence of RSG mass loss rate with Z

Motivation

- TiO bands of the optical spectra of red supergiants (RSGs) used to estimate T_{eff} but they form high in the atmosphere, so T_{eff} underestimated.
- Fitting atomic lines in the J-band using NLTE MARCS models (Bergemann et al. 2012, 2015, 2017) will provide improved T_{eff}, leading to a more robust estimate of mass-loss.
- Calibrate the temperature scale for RSG at low metallicity.
- Obtain robust physical parameters and mass-loss estimates for the rest of our sample (consisting of **~130** RSGs in total), for which IR spectroscopy is not feasible.

EMIR data

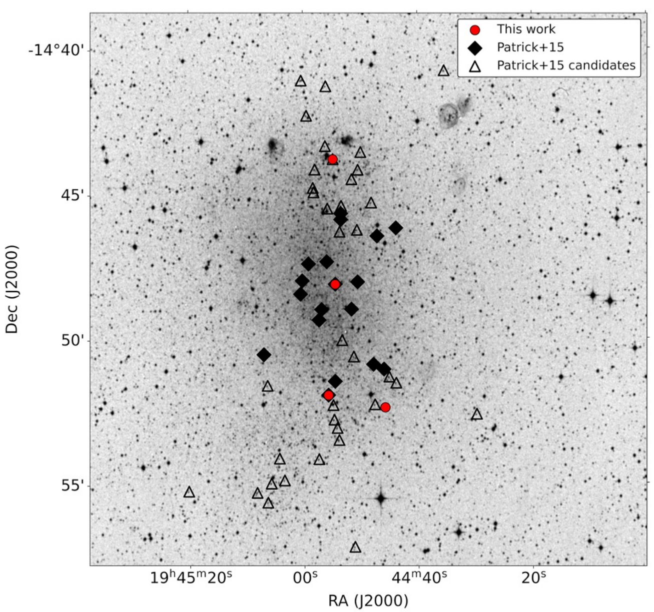
PI: David Garcia Alvarez (92-GTC77/22B)

- **Aim:** Obtain accurate physical parameters for **dusty** RSGs.
- **Concept:** Obtain medium resolution NIR spectra (**R**~3200 for **J band**) and model them using **NLTE MARCS** models.
- Follow up observations of **13 RSG**, found in our OSIRIS sample (**9** in **NGC 6822** and **3** in **IC 10**) + 1 target in **WLM** from Britavskiy et al. 2019) in the **NIR** using **EMIR** at GTC (long slit mode) .
- Observations from September to December 2022

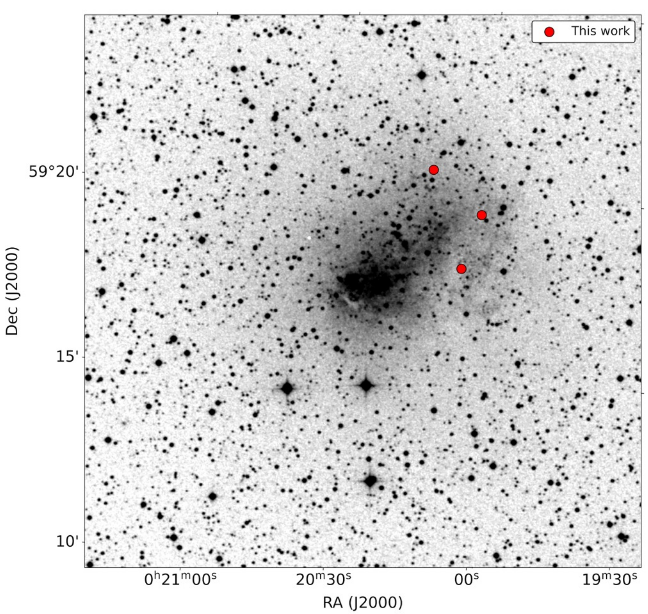
Targets

10 / 13 targets were observed, 8 were usable

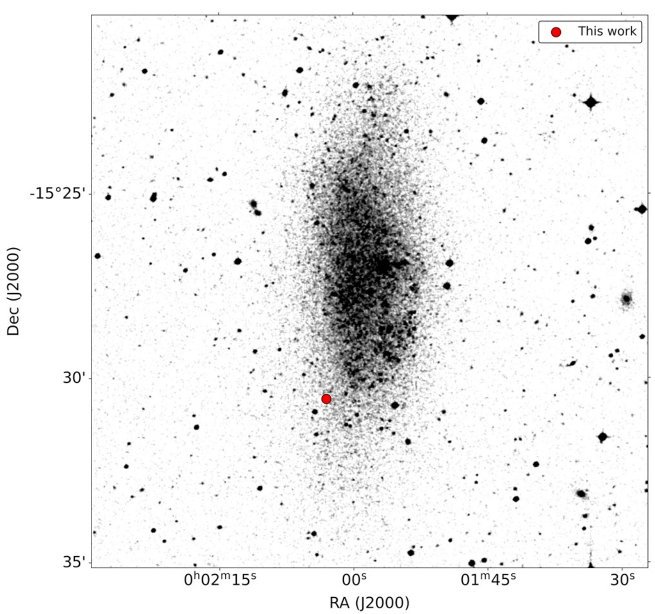
NGC 6822



IC 10



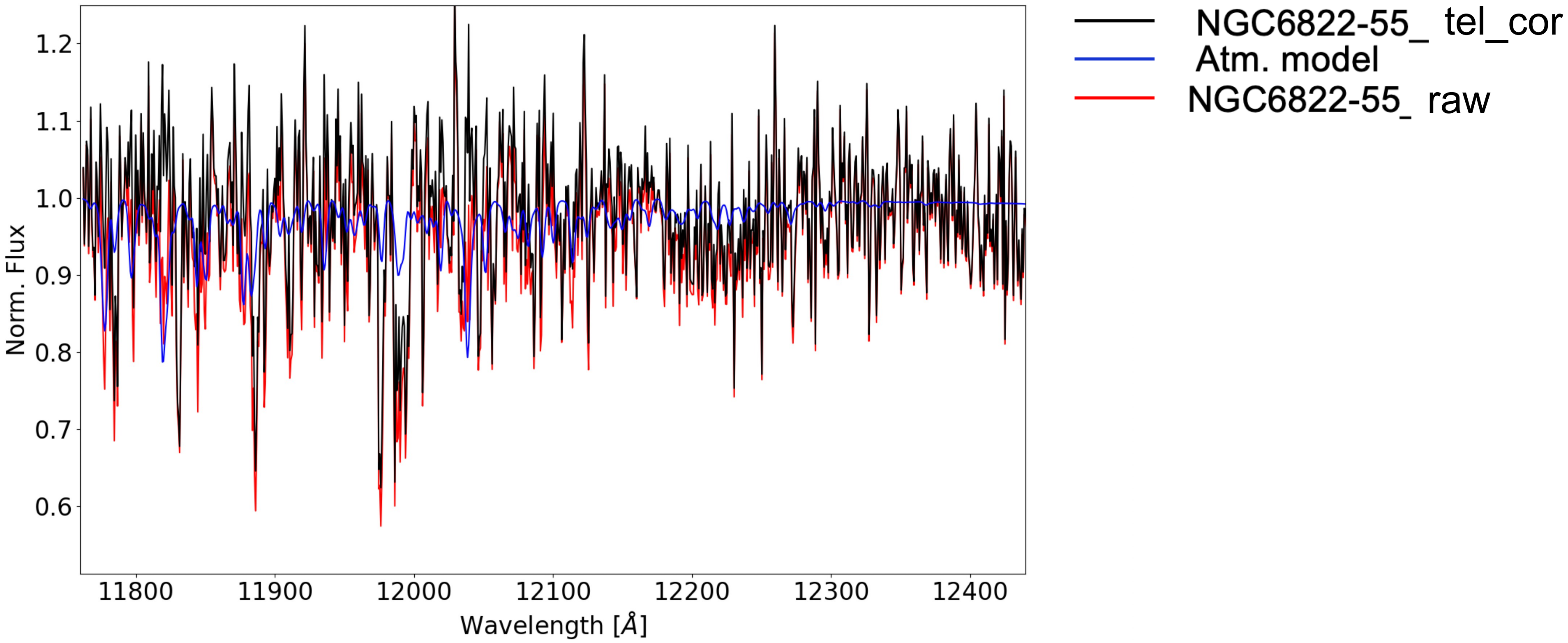
WLM



Status

- Data Reduction **complete** using the EMIR pipeline
- Telluric correction **completed** using Molecfit (Smette et al. 2015, Kausch et al. 2015)
- **Finalizing** NLTE MARCS modeling
- Proposal (2023B) to observe more RSG with EMIR in lower metallicities **accepted** on a shared risk basis. No data obtained.

Telluric correction



Modelling Methodology

- We have constructed a grid consisting of ~14,000 models and we fit for six parameters T_{eff}, log g, [Fe/H], ξ, RV and Amplitude.

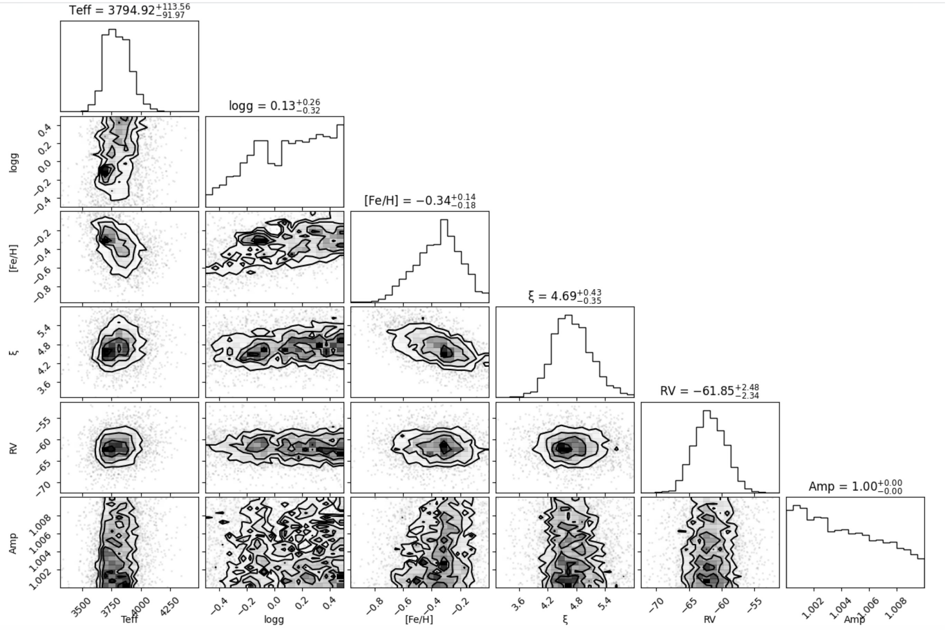
- The range in the parameters used span:
    - 3300 ≤ T_{eff} ≤ 4500 K with a step of 100K,
    - -0.5 ≤ log g ≤ 0.5 with a step of 0.1,
    - -1.0 ≤ [Fe/H] ≤ 0.0 with a step of 0.1,
    - 2.0 ≤ ξ ≤ 6.0 with a step of 0.5

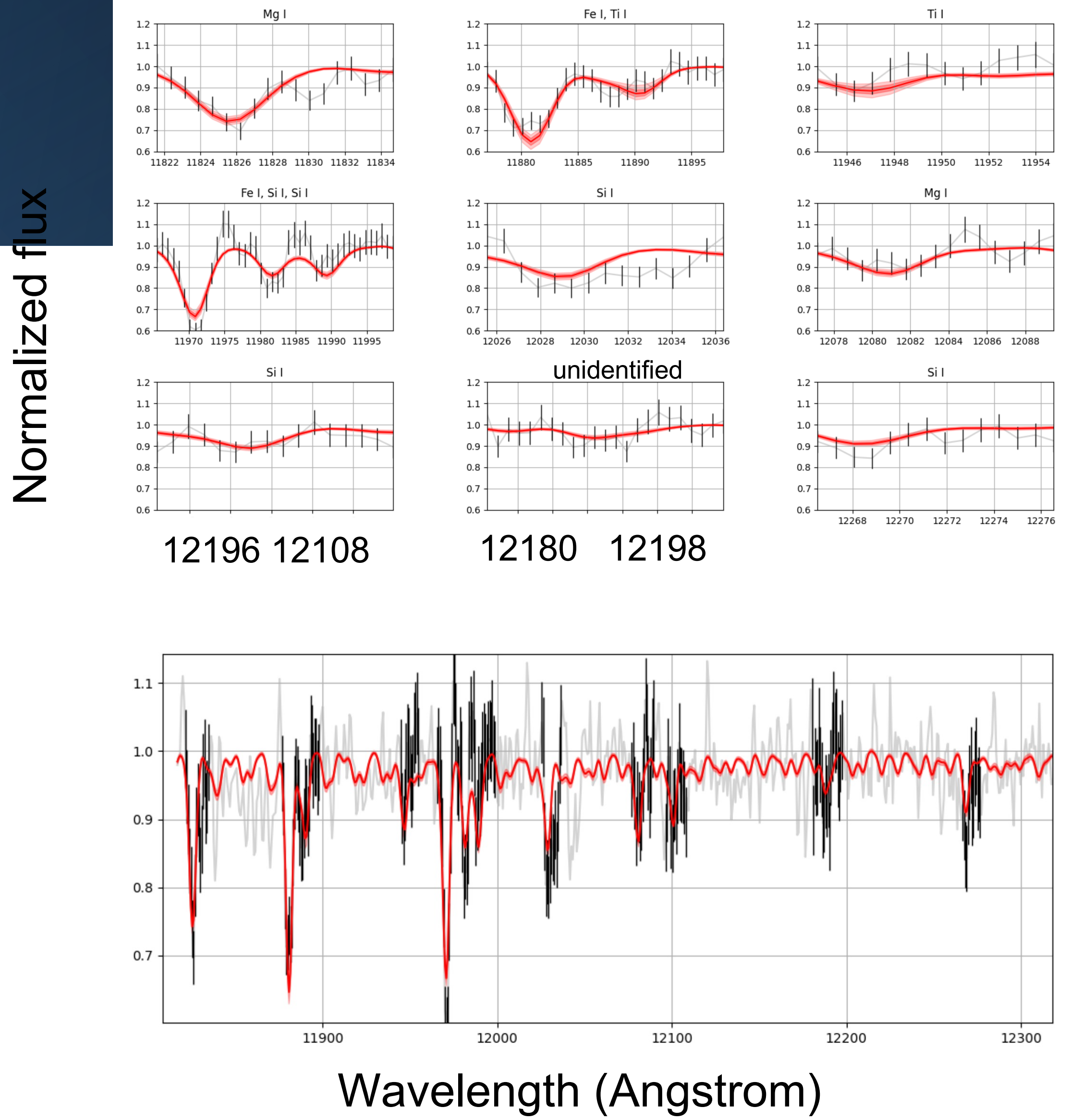
- Range of the RV depends on the location of the target within the host galaxy and range of Amplitude depends on the correction to the normalization needed per spectrum.

- We select spectral windows around the crucial spectral diagnostics.

- We use Ultranest (Buchner et al. 2021) to obtain a relation between physical properties.

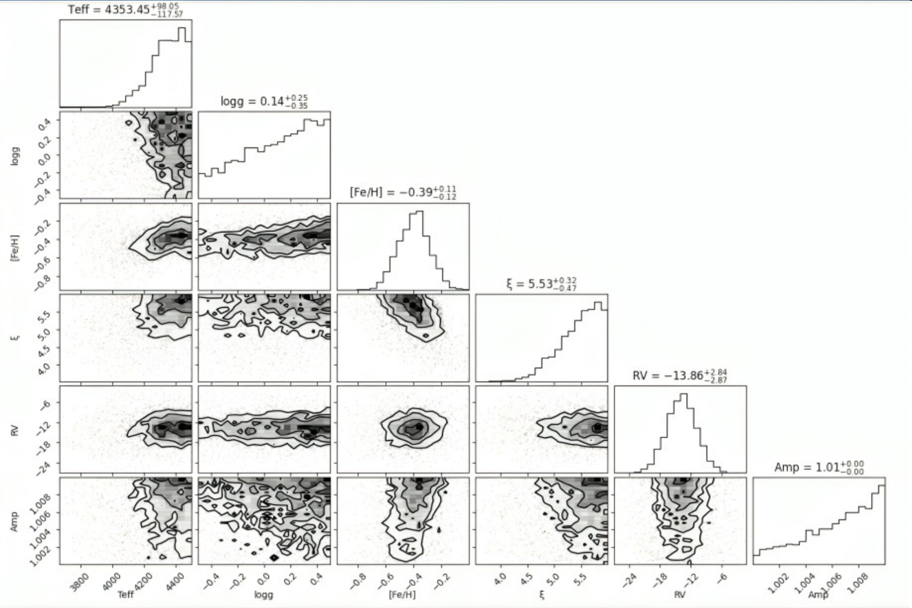
NGC6822-103

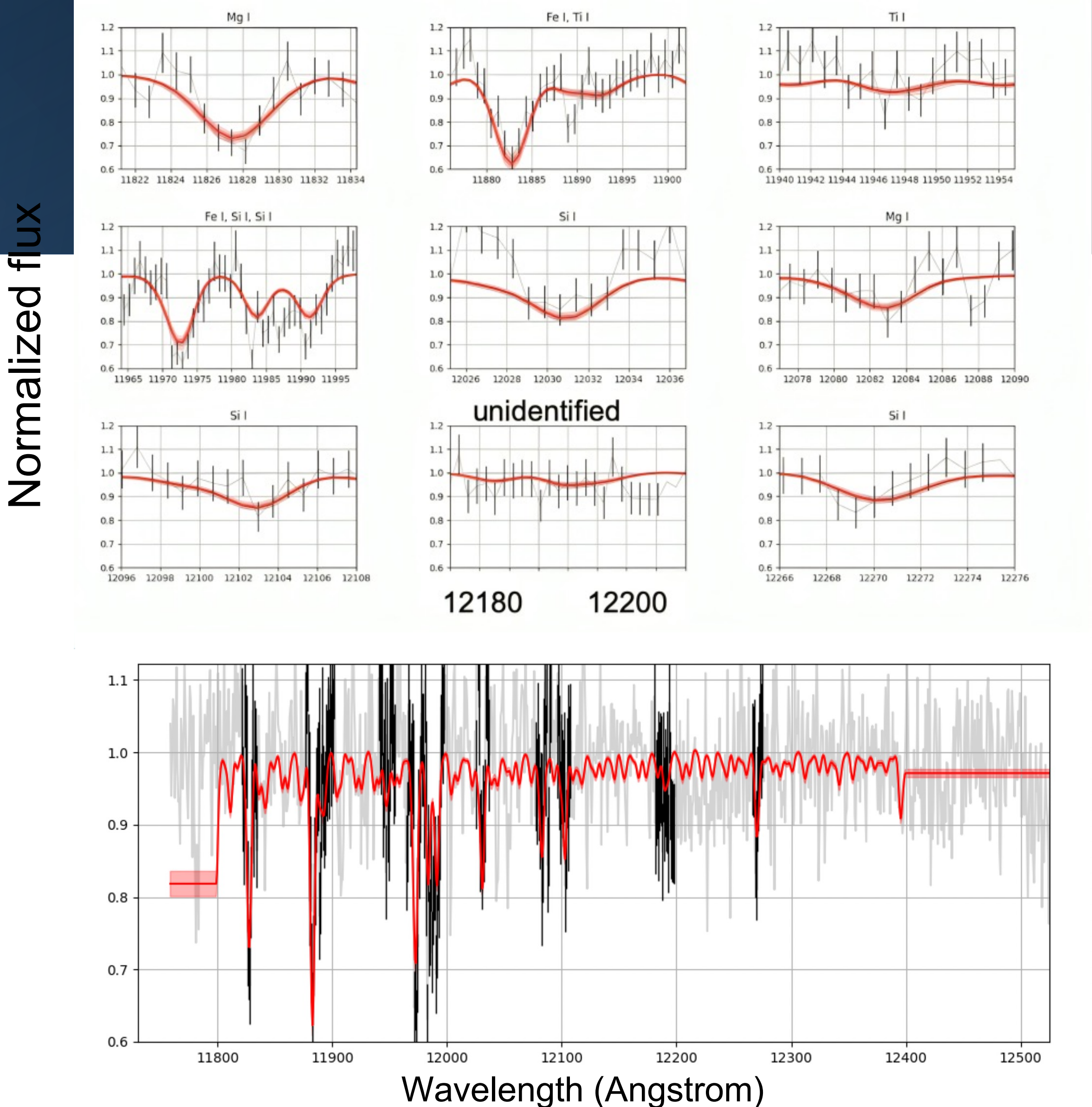




Christodoulou et al. in prep.

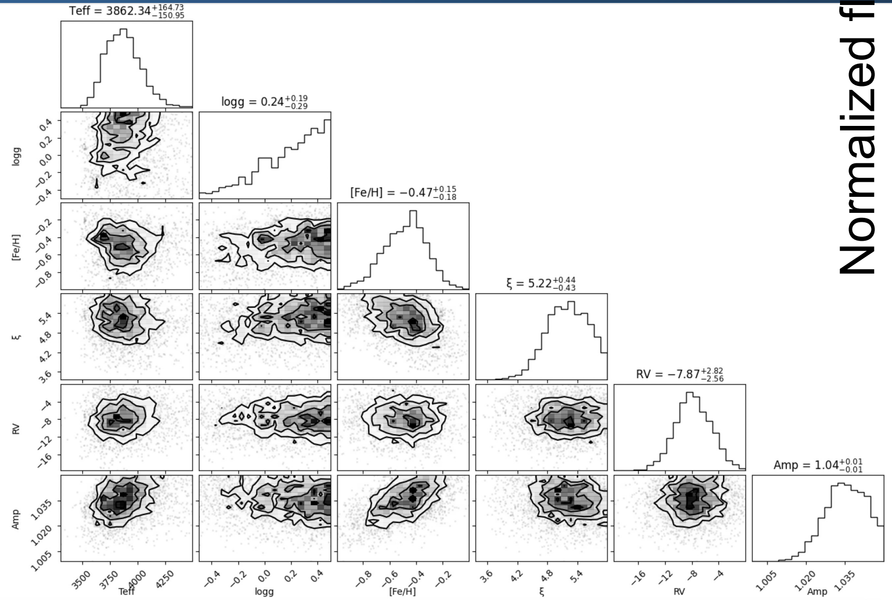
NGC6822-55

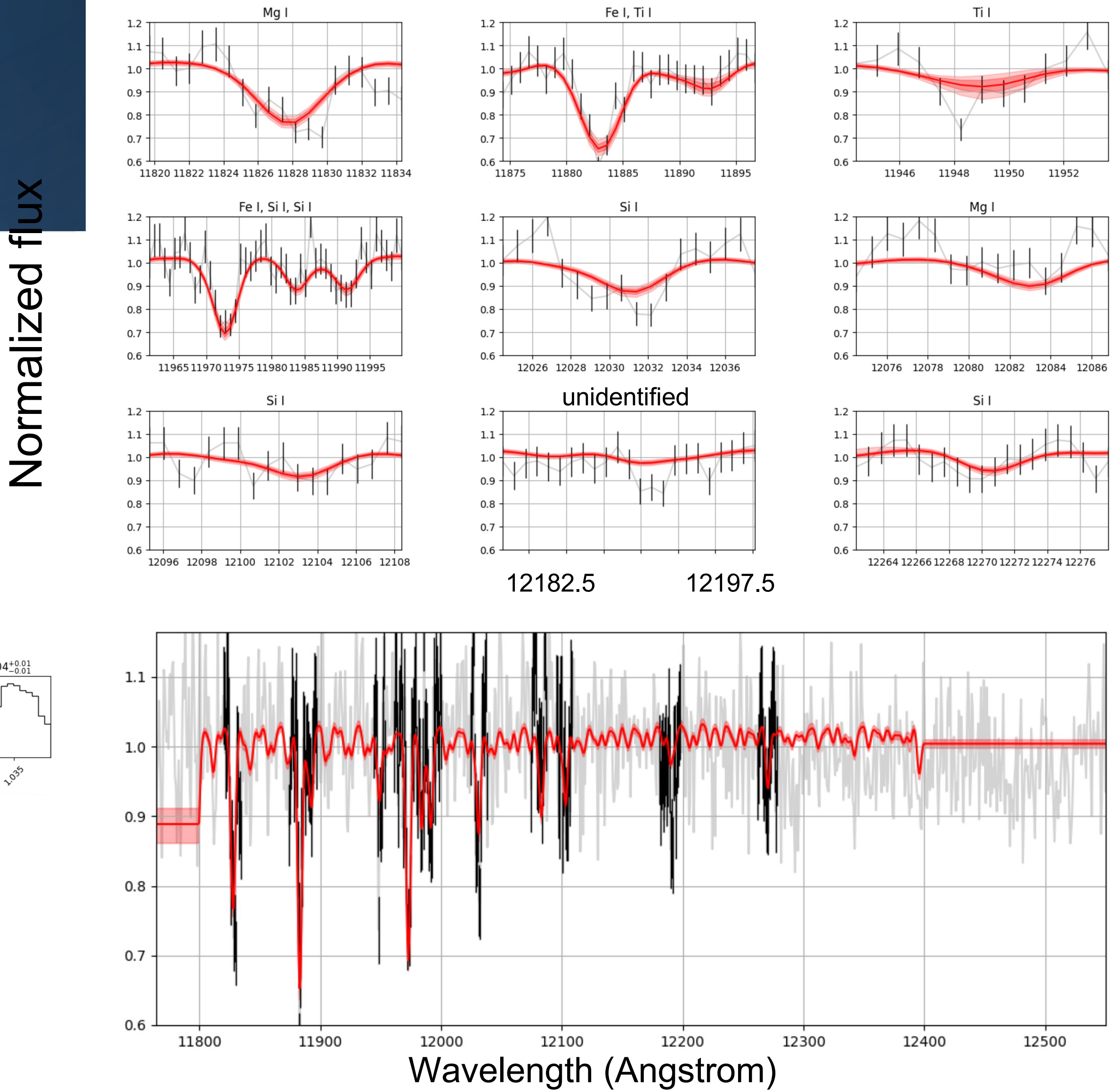




Christodoulou et al. in prep.

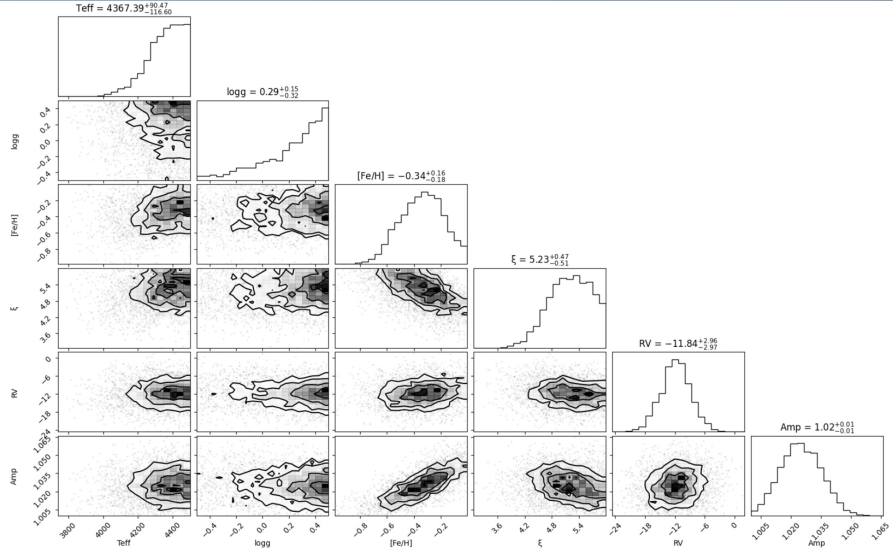
NGC6822-70

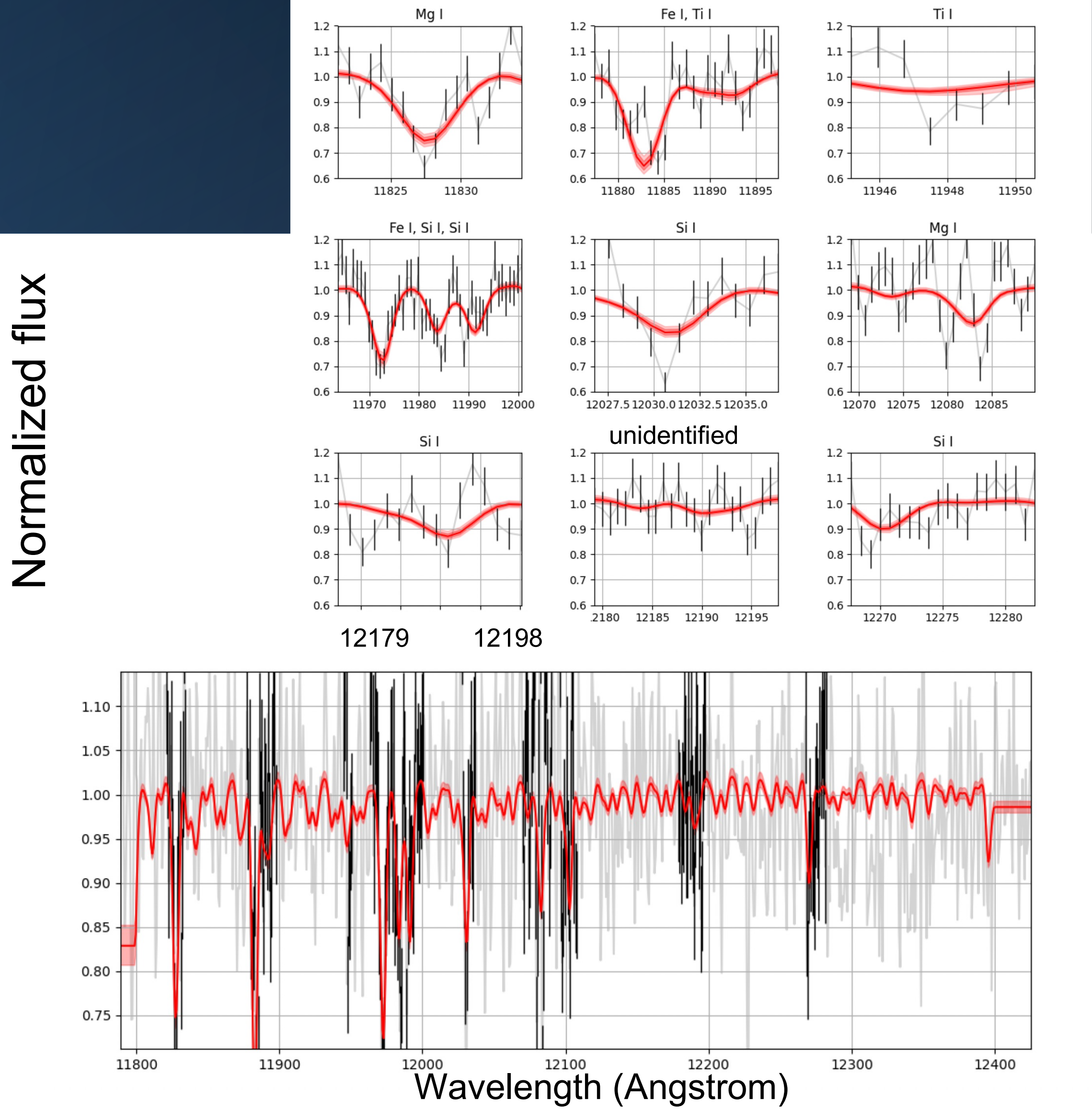




Christodoulou et al. in prep.

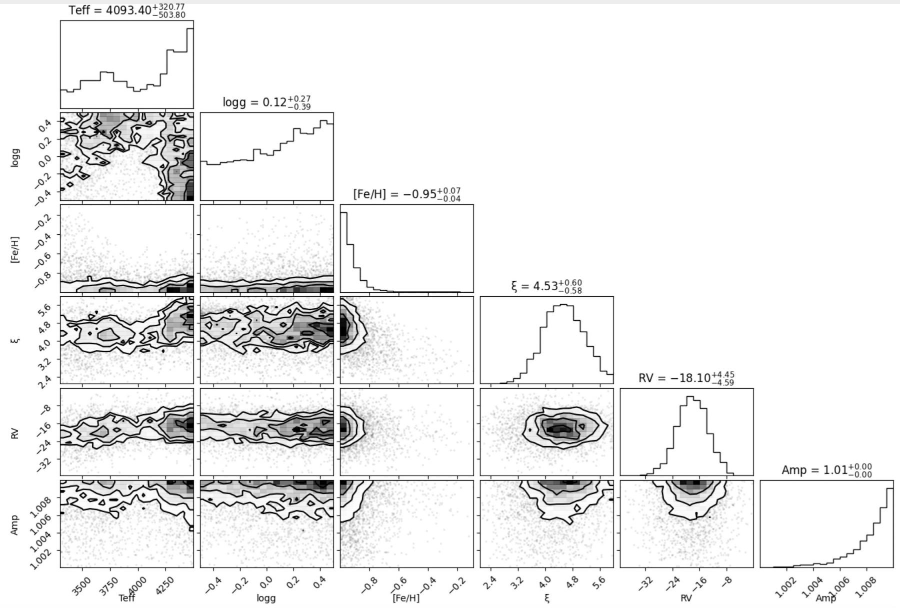
NGC6822-175

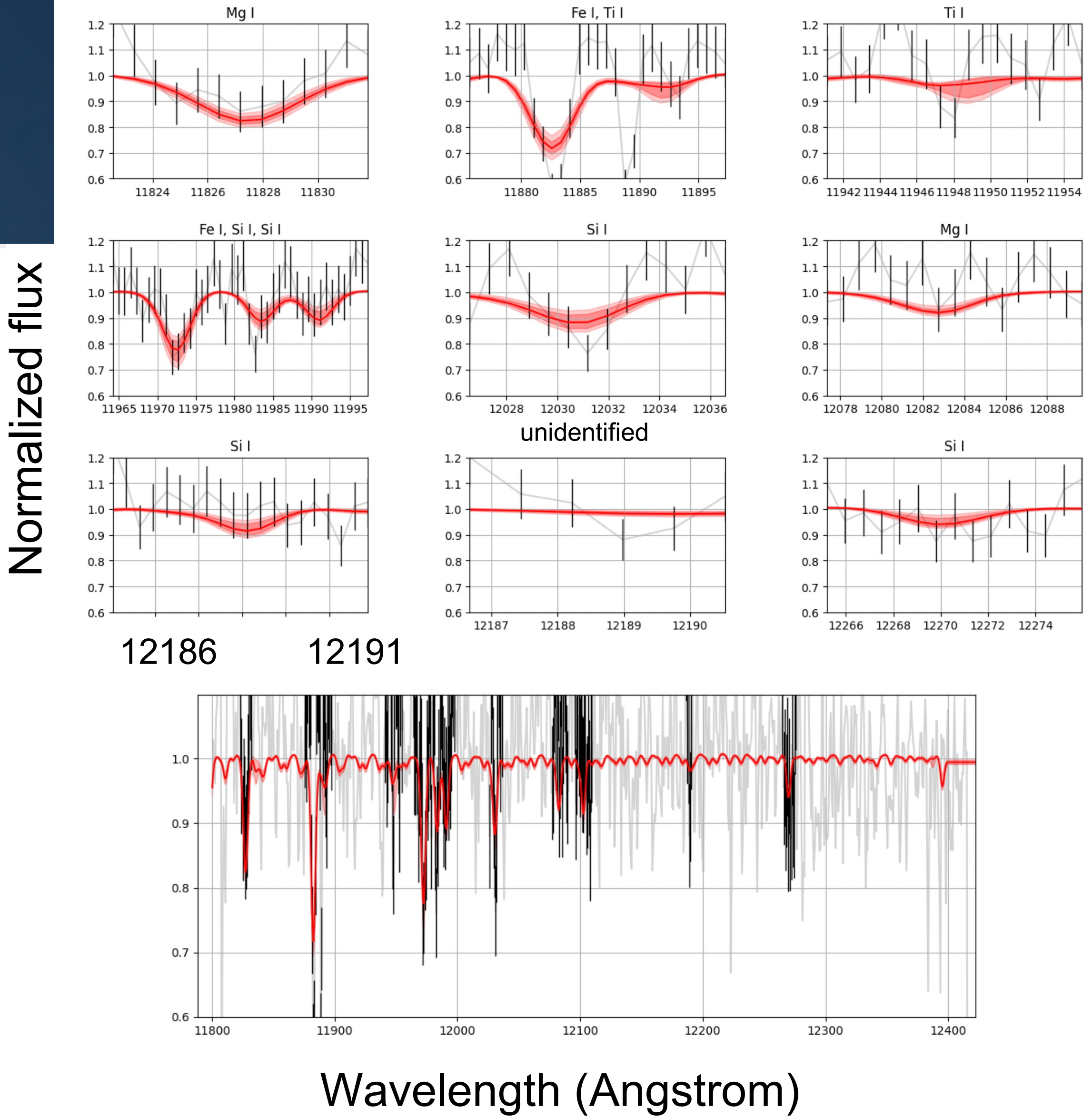




Christodoulou et al. in prep.

WLM 14





Christodoulou et al. in prep.

Summary table

Targets in common with Patrick et al. 2015 (J-band spectra) and Levesque & Massey 2012 (optical spectra)

Object	S/N	Sp. Type	T_{eff} (K)	log g	[Fe/H]	ξ (km s^{-1})	RV (km s^{-1})
NGC6822-103	17	M0.5 I	3794.92	0.13	-0.34	4.69	-61.89
NGC6822-55	13	K7 I	4353.45	0.14	-0.39	5.53	-13.86
NGC6822-70	15	M2 I	3862.34	0.24	-0.47	5.22	-7.87
NGC6822-175	13	M3 I	4367.39	0.29	-0.34	5.23	-11.84
IC10-50206	5						
IC10-26929	2	M5 I					
IC10-26089	6	K4 I					
WLM 14	10	K4-5 I	4093.40	0.12	-0.95	4.53	-18.10

Spectral variability study

Christodoulou et al. in prep.

Future work

- Analyze the three IC10 targets (hopefully we will get something out of them)
- Finalize modelling strategy
- Construct light curves
- SED fitting to calculate physical parameters (e.g. L)
- Implement scaling relations derived from de Wit et al. 2024 to test our results
- Analysis of KMOS J-band spectra of RSG in M83

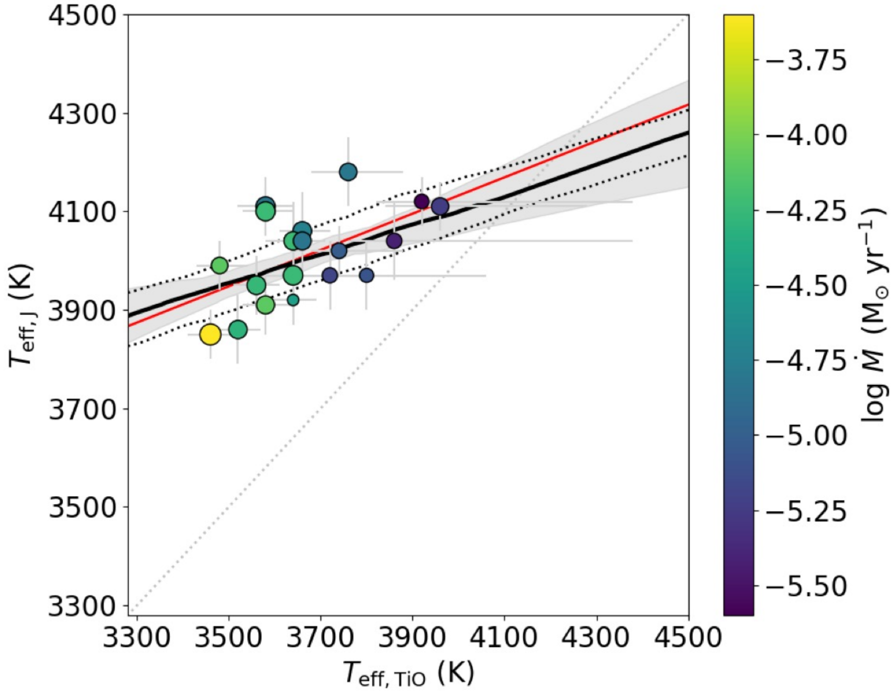


Figure from de Wit et al. 2024

Summary

- We analyzed follow up observations of securely classified RSG in low metallicity galaxies

- We corrected for the telluric features using Molecfit on EMIR observations for the first time

- We devised a new modelling method using Ultranest

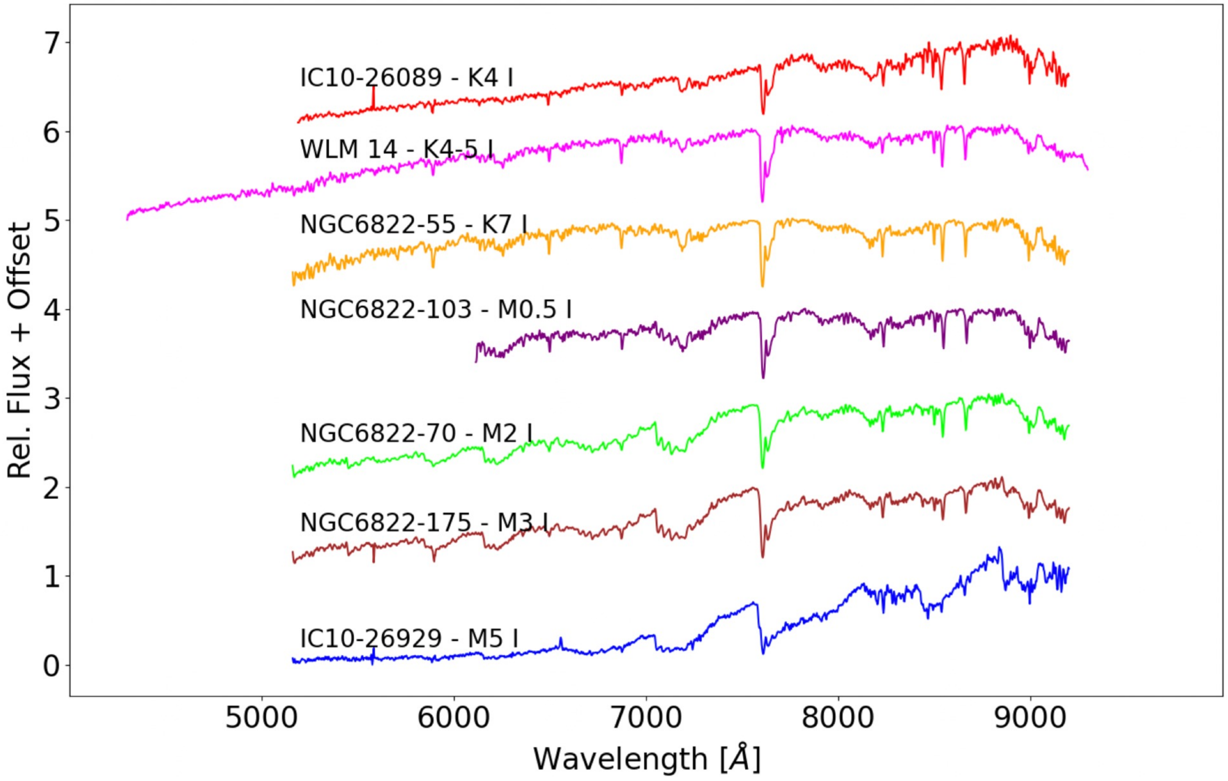
- We presented results of our spectral modelling

- We discussed future work

Thank you for your attention!

Back up slides

Optical spectra



Scaling relations

https://arxiv.org/abs/2402.12442

Investigating episodic mass loss in evolved massive stars:

II. Physical properties of red supergiants at subsolar metallicity★

S. de Wit[1,2], A.Z. Bonanos[1], K. Antoniadis[1,2], E. Zapartas[3,1], A. Ruiz[1], N. Britavskiy[4,5], E. Christodoulou[1,2], K. De[6], G. Maravelias[1,3], G. Munoz-Sanchez[1,2], and A. Tsopela[7]

The scattered data points and their uncertainties are taken from Davies et al. (2013, 2015). The thick black line indicates the best-fit scaling relation, the gray shaded band shows the combination of slopes and offsets acceptable within a 1σ uncertainty and the black dotted lines indicate the scatter on the best-fit relation. In red, we show a simple linear fit to the data when one excludes the effect of asymmetric uncertainties. We show a 1:1 relation for comparison. The color bar indicates the mass-loss rates obtained with DUSTY. The sizes of the markers increase proportionally to metallicity.