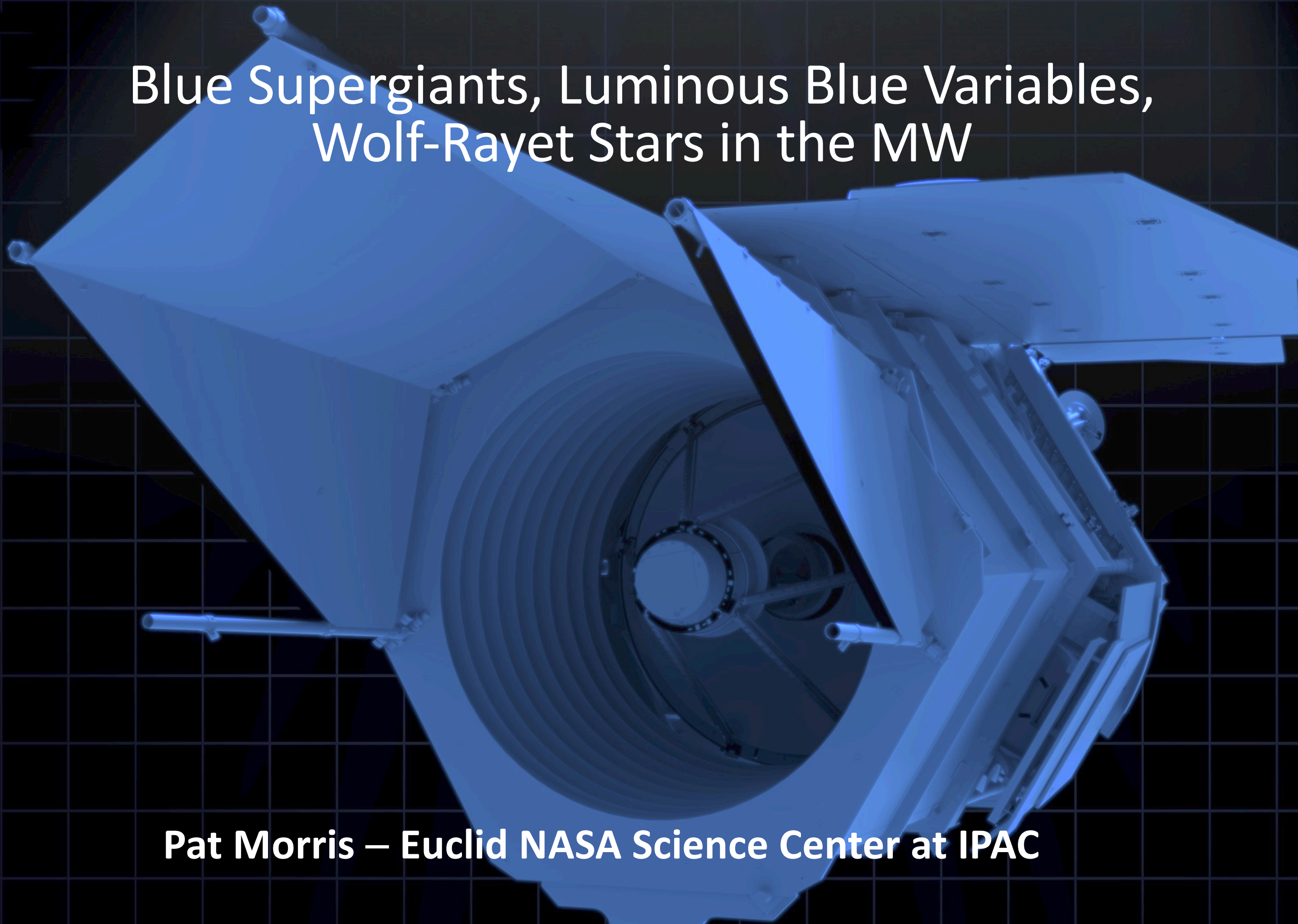
# Roman's Potential Impact on the Census of Evolved Massive Stars in Transition

## Blue Supergiants, Luminous Blue Variables, Wolf-Rayet Stars in the MW



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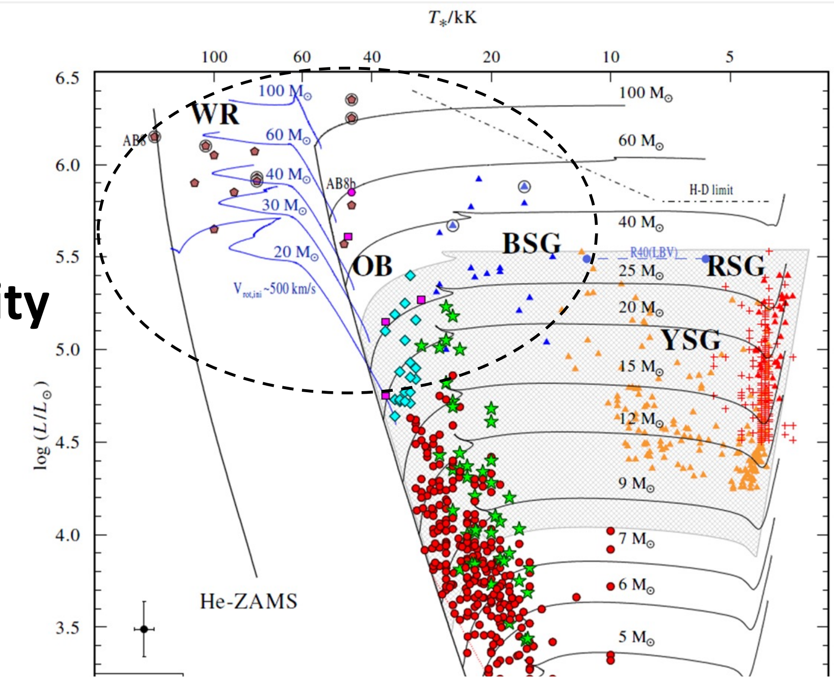
# A (too?) Rare Population

Post-MS phases are <u>brief</u>: ~300 MW WRs cataloged. Predicted lifetimes depend on **mass-loss rates, rotation, metallicity, binarity -- tested by <u>population statistics</u>.**

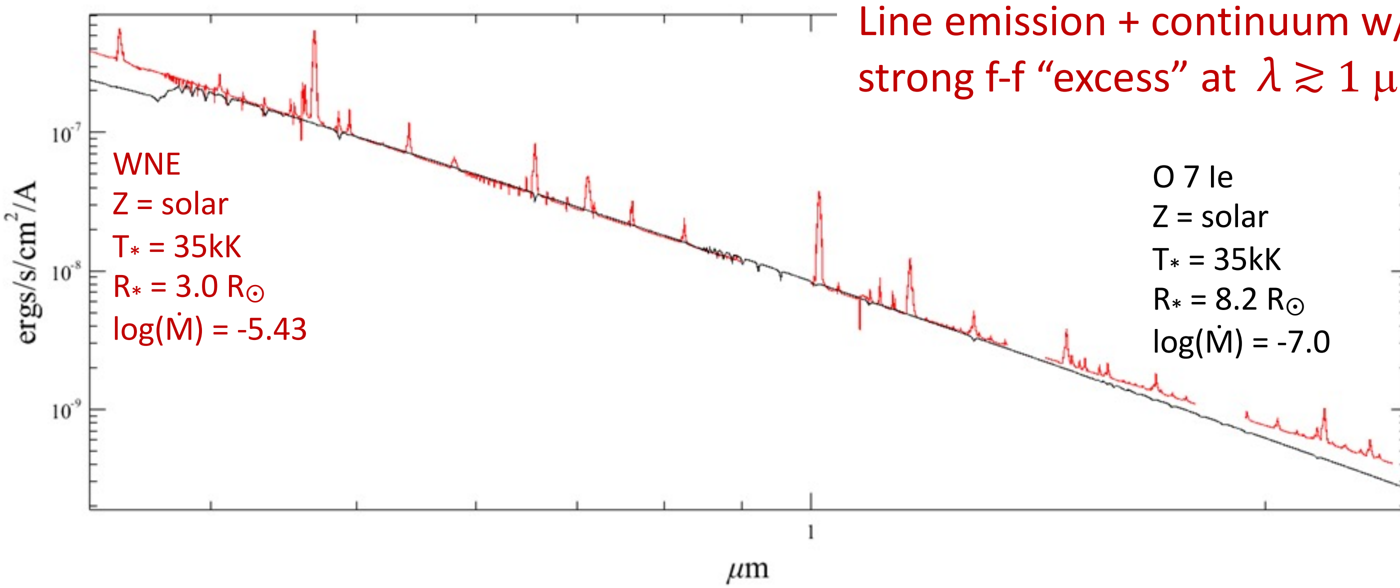
***The known population of WRs and LBVs is short of model predictions by ~5-10x.***




Ramachandran+ 2019

“Models” = Geneva tracks (Meynet & Maeder 2005;

Radiation pressure in stars M(init) $\gtrsim$ 25 $M_\odot$ transitioning to H/He shell and He/C/O/Si core burning drive dense metal-rich stellar winds.

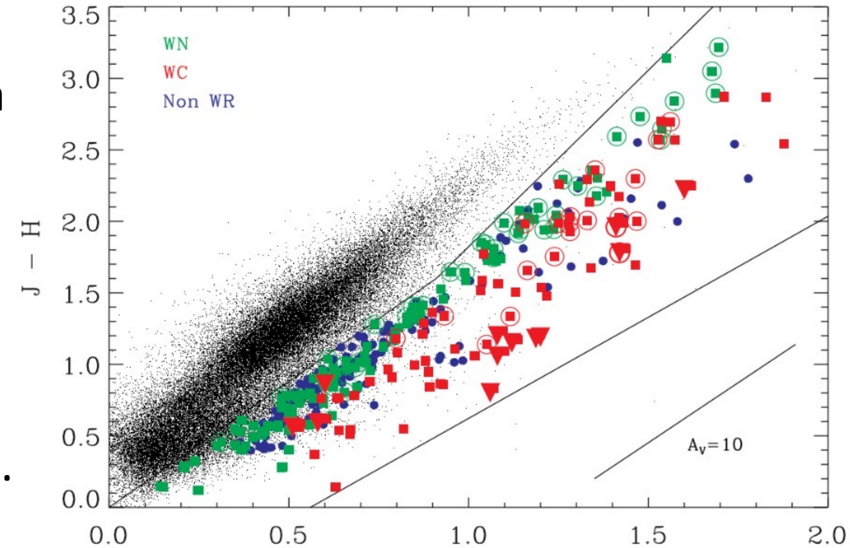



Line emission + continuum w/ strong f-f “excess” at $\lambda \gtrsim 1\ \mu\mathrm{m}$.

# Predictions are Census-Limited

- Color-mag diagnostics + optical/NIR spectra → ~125 newly ID'd WRs since 2007.

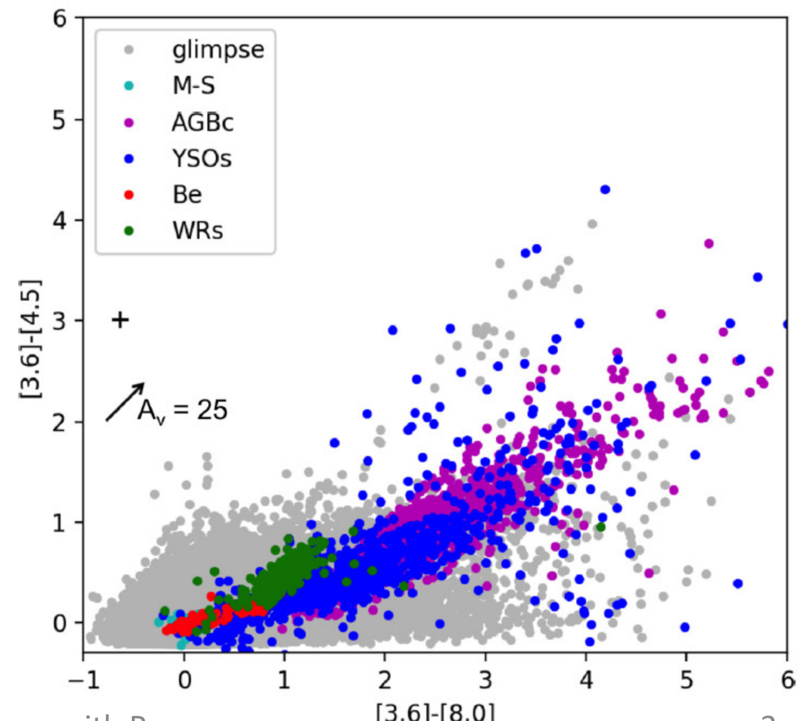
- **<u>Broad-band NIR/MIR approach</u> @ IPAC:** Hadfield+ 2007; Mauerhan+ 2009, 2011; Morello+ 2018.
- **<u>Narrow filter em. lines</u>:** Shara+ 2009, 2012.




Mauerhan+ 2011

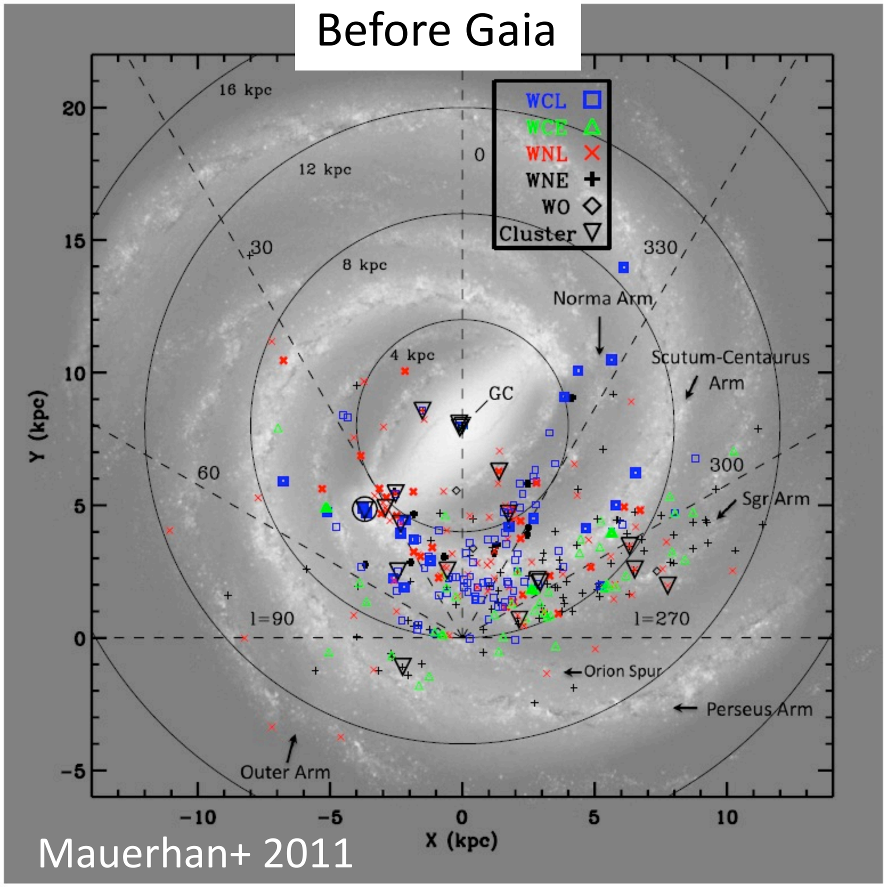
**2MASS colors are not unique, produces many 1000s of candidate WRs.**

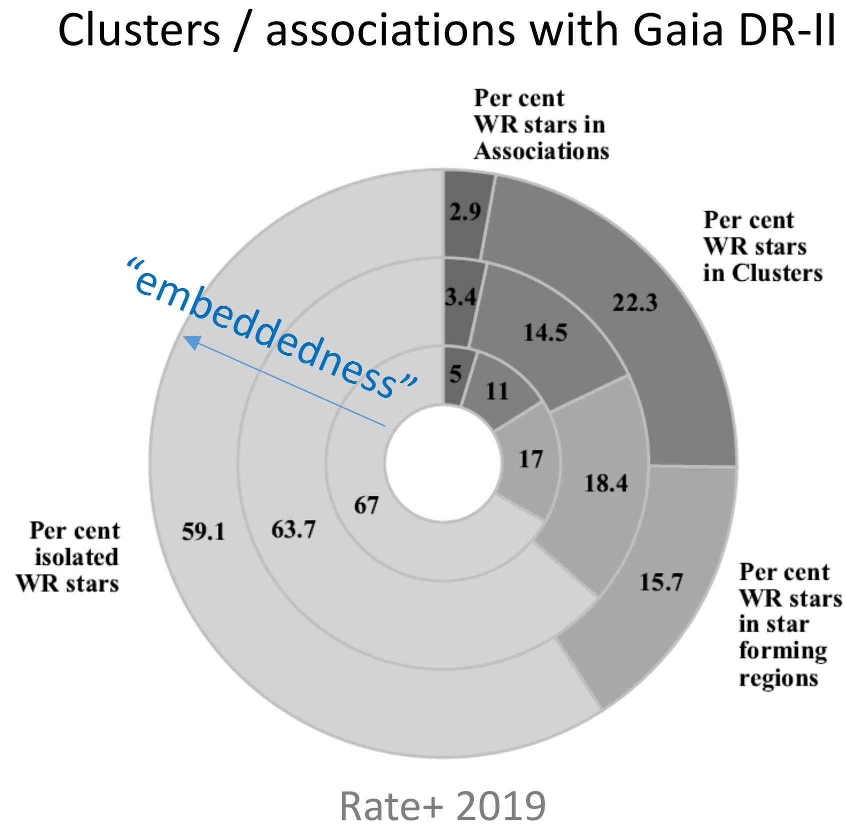
Adding Spitzer/GLIMPSE to sample stronger f-f emission and additional broad lines helps… but gets into trouble with dusty red objects.




Morello+ 2018

# Why completeness matter – most WRs isolated?



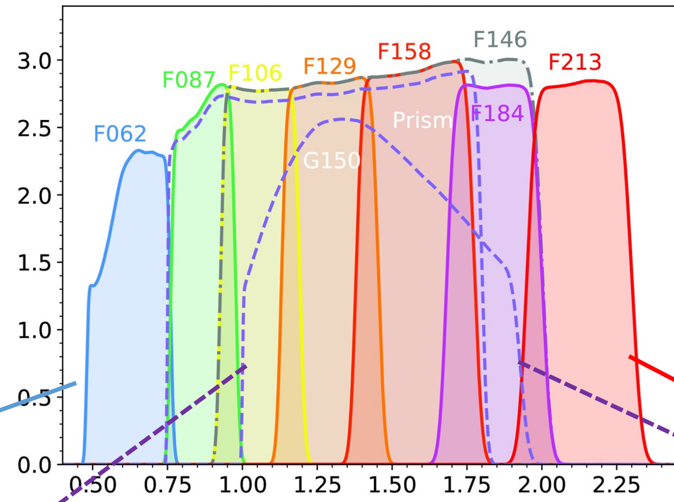




Formation environment has been assumed to be in massive SFRs (Lada & Lada 2003). OB progenitors believed to be restricted to rich, dense clusters with masses in excess of $10^3\,M_\odot$ (Weidner+ 2010), favorable to formation via competitive accretion or mergers → significant tension with observations! Implications on SNe & BH distributions.

# Stellar types and wind parameters with Roman filters

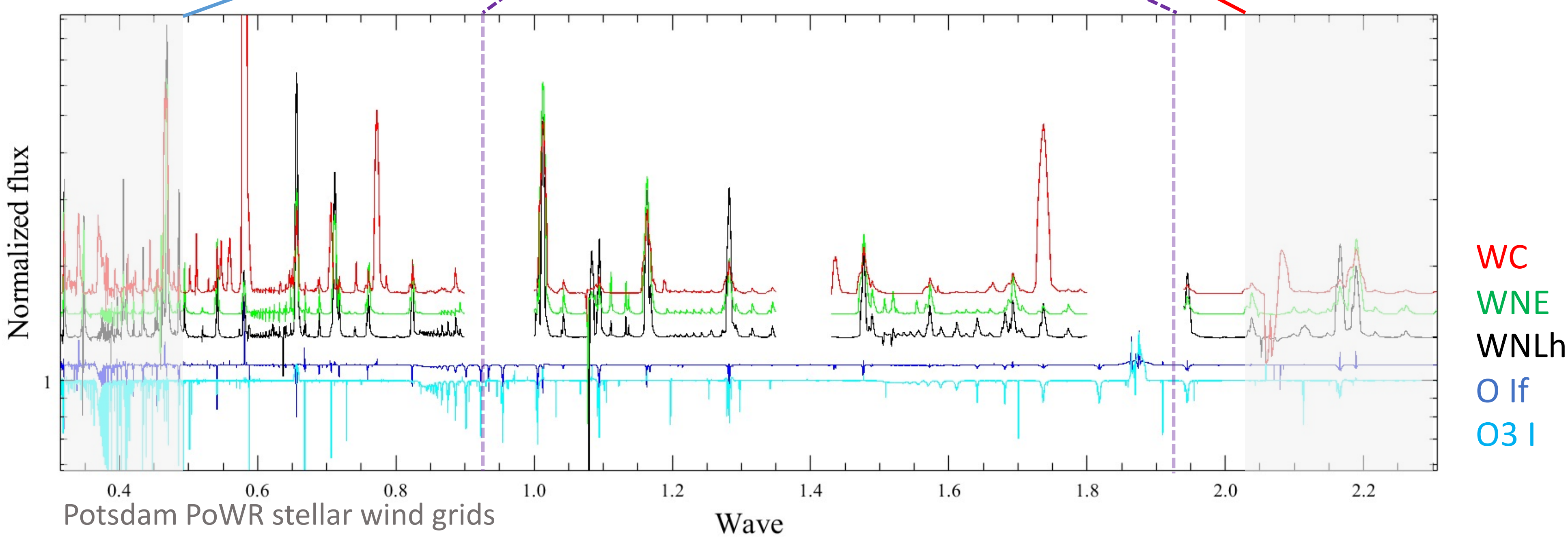
Candidate BSGs, LBVc, WRs with color-color & color-mag diagrams.

(F062 – F213) is *most* sensitive to $T_*$




**Spectroscopic fitting →**
**T*, R*, mass loss rates**

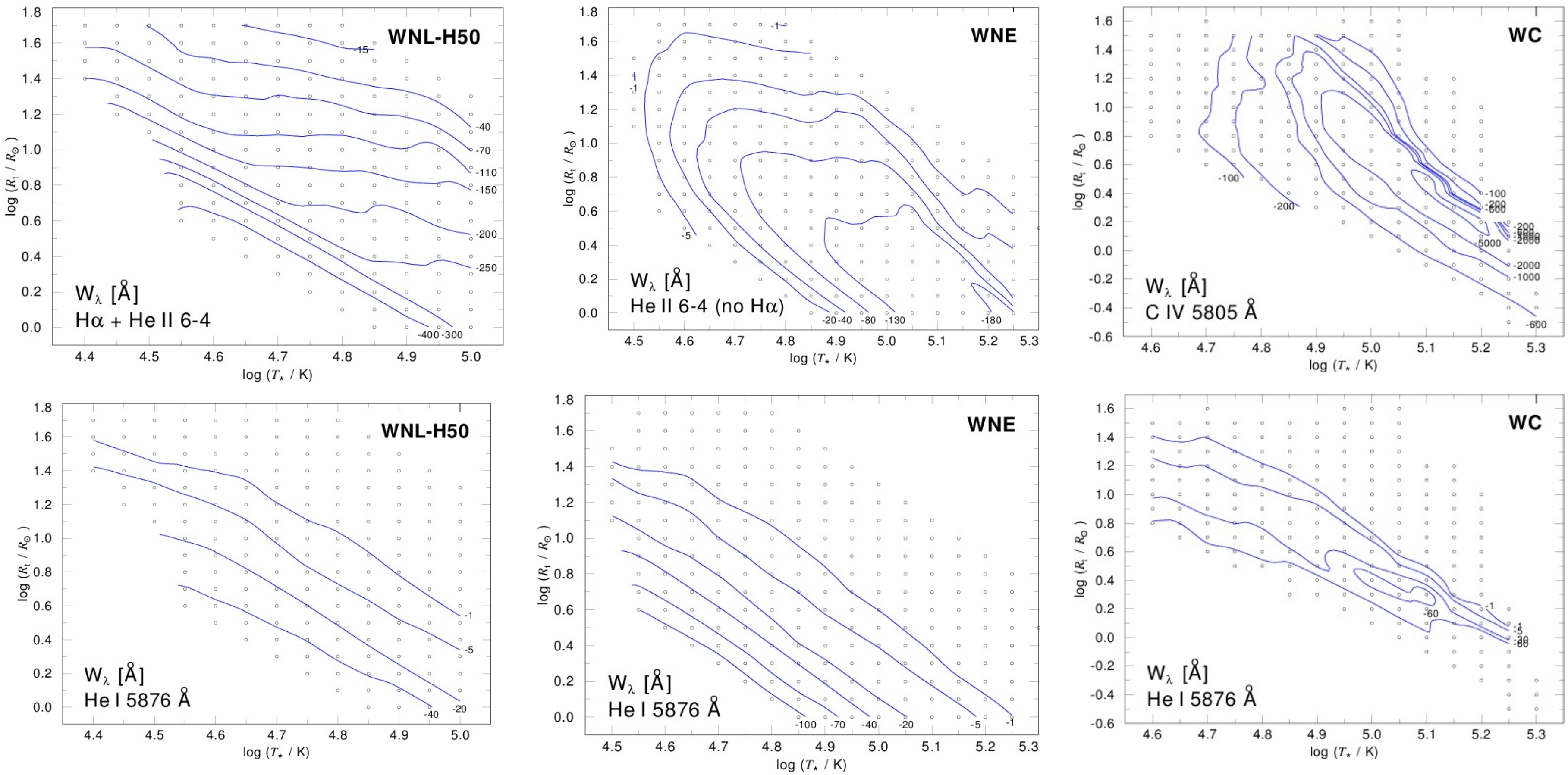
Grism needed to measure EWs of OB/LBVs; most WR lines are resolved with prism




Potsdam PoWR stellar wind grids
Gräfener+ 2012, Sand+ 2015, Hainich+ 2019

# EW fitting for stellar parameters

Potsdam PoWR stellar wind grids
Gräfener+ 2012, Sand+ 2015, Hainich+ 2019




EWs from multiple lines → unique $T_*$, $R_t$

"Transformed radius" $R_t = R_* \, [(v_\infty \,/\, 2500 \text{ km/s})] / [\dot{M} \sqrt{D} \,/\, 10^{-4} M_\odot/\text{yr}])^{2/3}$

**Wind performance $\eta = \dot{M} v_\infty / L/c$ = mechanical/radiative momentum**

**$\eta < 1$ → Single-photon scattering wind. $\eta > 1$ (WRs, LBVs) → optically dense wind.**

# Finding the “V”s in LBVs

- LBVs are known by their **transient eruptions** (e.g. P Cyg, η Car), $\boldsymbol{\Delta m_V}$ **~ 2.5 mag,** $\boldsymbol{\Delta T_{eff}}$ ***~ few to 10s of kK*.**
    - Light curves + spectra establish SN or “SN imposter”.
    - Brightness, $T_{\mathrm{eff}}$ excursions last several weeks or months, **then(?) fade into quiescence** (e.g., P Cyg, AG Car) before WR phase or direct SN (e.g. SN2009ip).

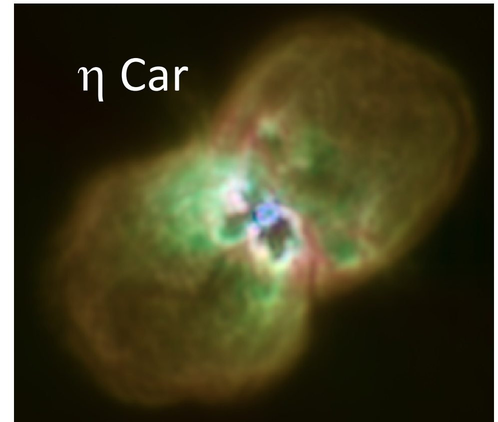
- LBV numbers are short of predictions by 80-90%.

- Important questions on distribution, formation environment, role of multiplicity and mergers in eruptions.

- Variability can be periodic (η Car) or aperiodic (S Dor).

- **Roman can reveal new candidate LBVs via “micro-activity” as indicator of recent or imminent passage into / out of this phase.**

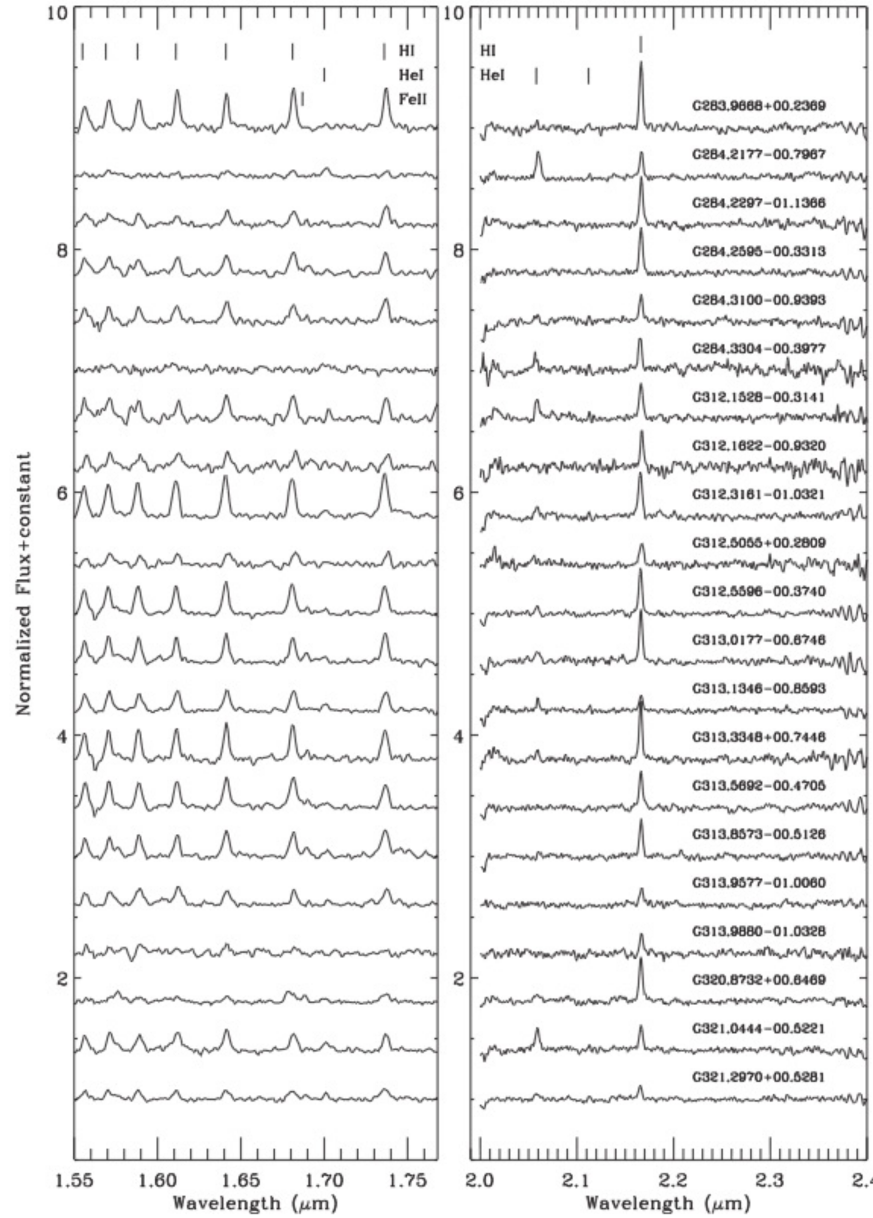
  1-2% variability on few days timescales of LMC LBV HD 269582 with TESS (Dorn-Wallenstein+ 2019).





# Finding the “V”s in LBVs

Mauerhan+ 2011

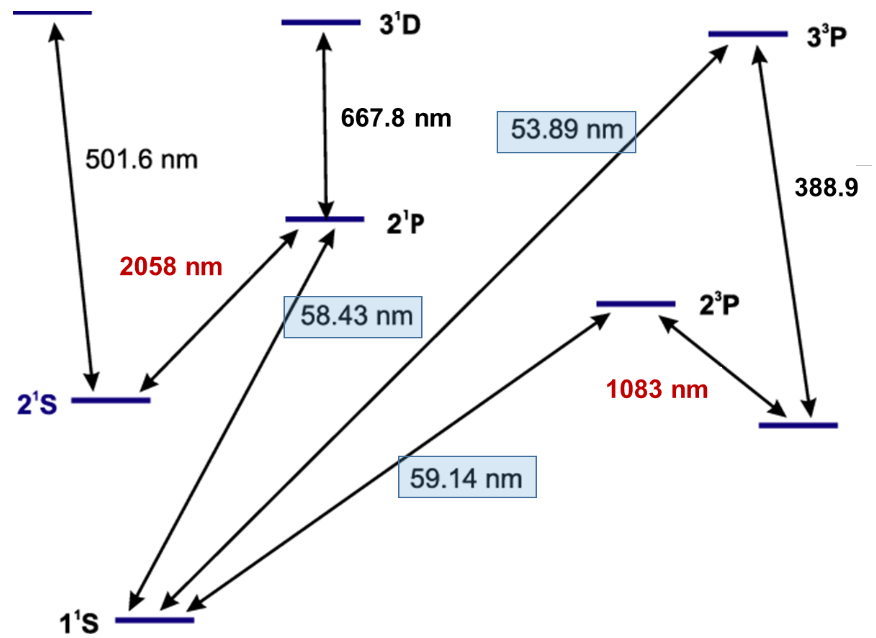


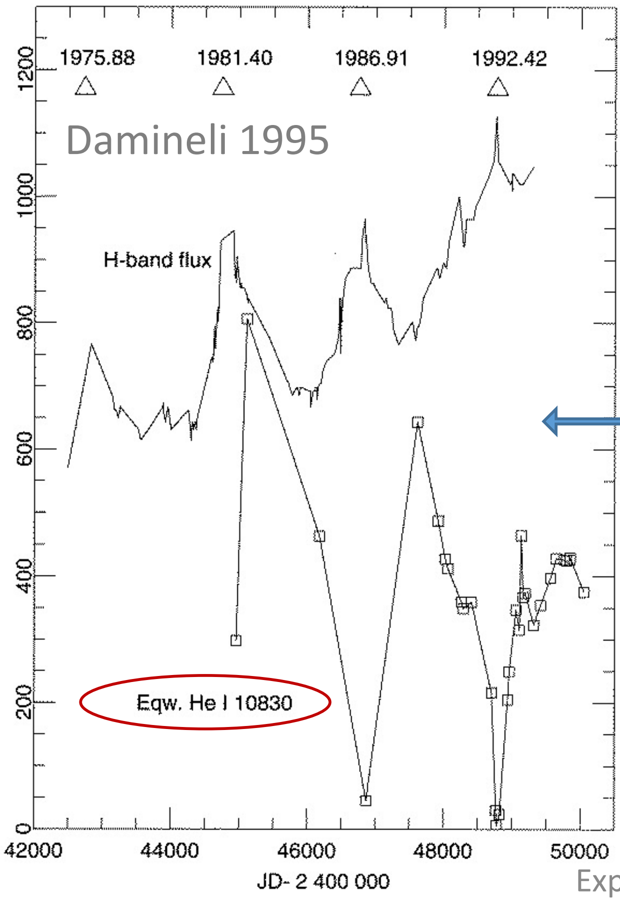

- **NIR spectra of most known LBVs in quiescence resemble early-type Be stars →** Few dozen of single-visit candidate “LBVc”.
- **Returning to known LBVc with WFI will quickly reveal which have varied in brightness and $T_{eff}$ below eruption energies (at constant $L_{Bol}$).**
- Wind efficiency parameter η > 1 identifies the sgBe stars most LBV-like.
- Certain lines are ideal to follow in such stars for revealing micro-variability characteristic of LBVs.

# Finding the "V"s in LBVs

He I lines, **esp 1.083 μm**, v. sensitive to variations in the UV radiation field deep in hot star atmospheres.

Needs high $\dot{M}$, wind density to see it in emission (Conti & Howarth 2002).



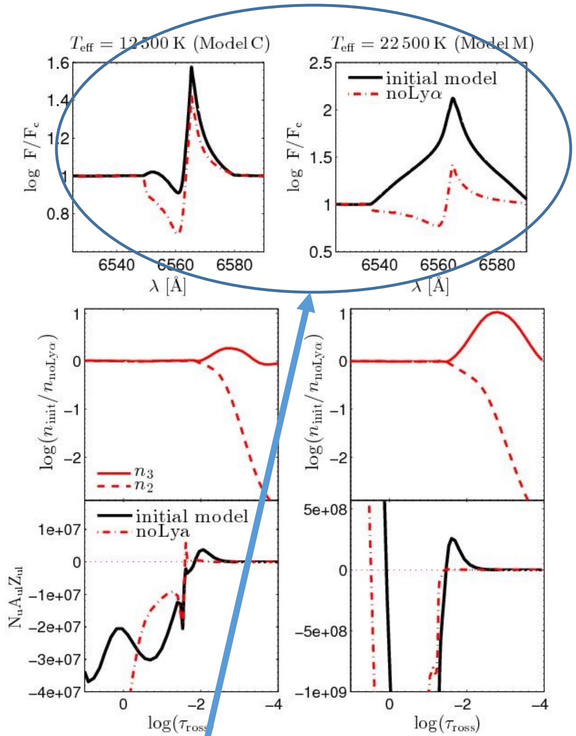

Great examples are HDE 316285 (LBVc, extreme P Cyg star) and η Car by UV field attenuation.

Shorter periods (days) expected where LBV mass loss is driven by pulsations, following Abolmasov (2011)

$$t_{dyn} \approx 0.6 \left( \frac{R_*}{10^{12}\mathrm{cm}} \right)^{3/2} \left( \frac{M_*}{100\mathrm{M}_\odot} \right)^{-1/2} \mathrm{d}$$

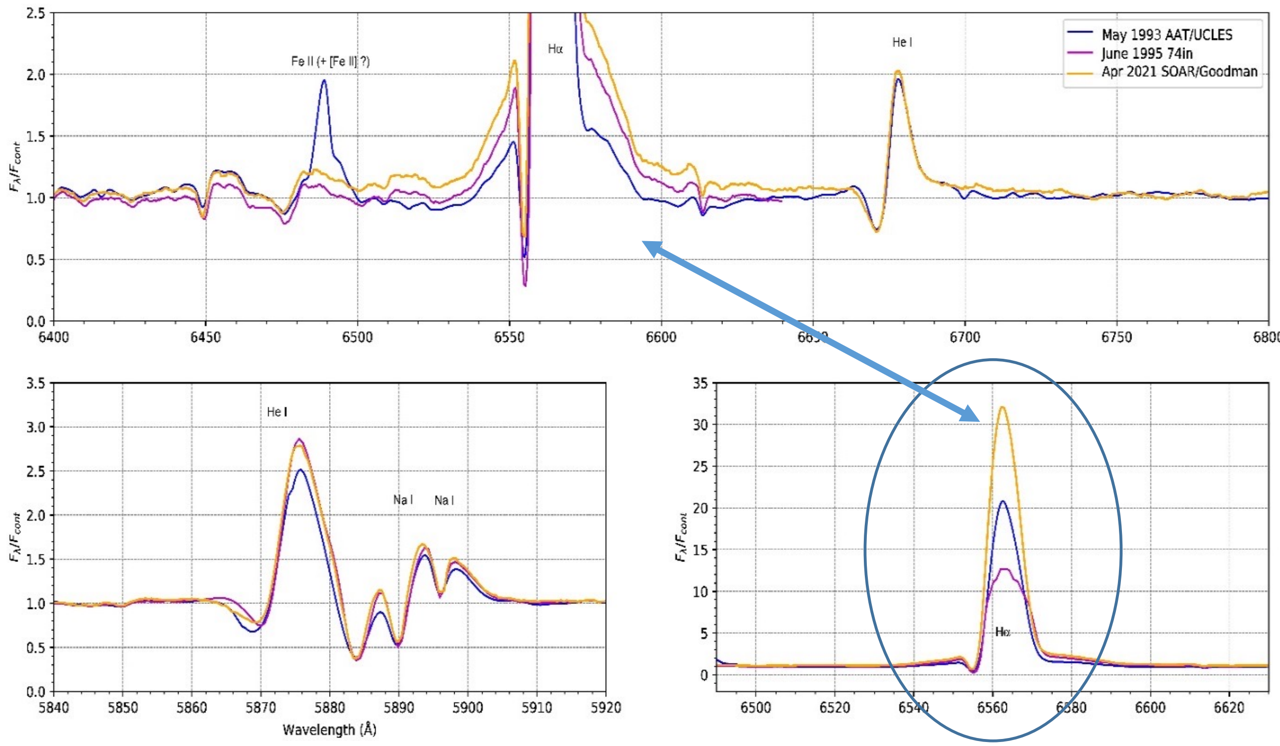
(w/ attenuations by CSM material.)

# Hα behavior in sgBe stars




Petrov+ 2014

η Car "sibling" sgBe (LBVc) HDE 316285




Hα emission in sgBe stars sensitive to Lyman continuum, increasing with $T_{eff}$.

**Objects like HD 316285 w/ high wind performances show broad Hα + e-scattering wings (clumping). Variability at the levels seen in 'extreme' sgBe stars (e.g., Clarke+ 2012) should be easy to detect with the WFI prism.**

# Summary

- A WFI YJHK imaging (colors + HST angular resolution) plus grism/prism spectra will reveal evolved massive stars with immediate impact.
  - Population completeness, distribution.
  - Spectral types, bulk stellar and wind parameters
  - WR/O, WR/RSG, WN/WC statistics test lifetime predictions (and multiplicity frequency; E. Levesque 11/15/21 talk).

- H and He I lines sensitive to UV field and mass-loss variations can establish variability activity (days to weeks) at the level of quiescent LBVs for sgBe's selected for high wind efficiency.
  → narrows the LBV look-alike candidate to actual candidates.

- **Synergy with Rubin-LSST and Euclid (later mission) potential for variable stars with multi-epoch photometry.**
  - Merged pt source photometry and periods/amplitudes for pulsating variable stars from Rubin recommended (Guy+ 2022)

☹ He I 2.058 μm, $H_2$ 2.112 μm lines