

Yellow Supergiants:

Unlocking the Mysteries of Post-RSG Evolution

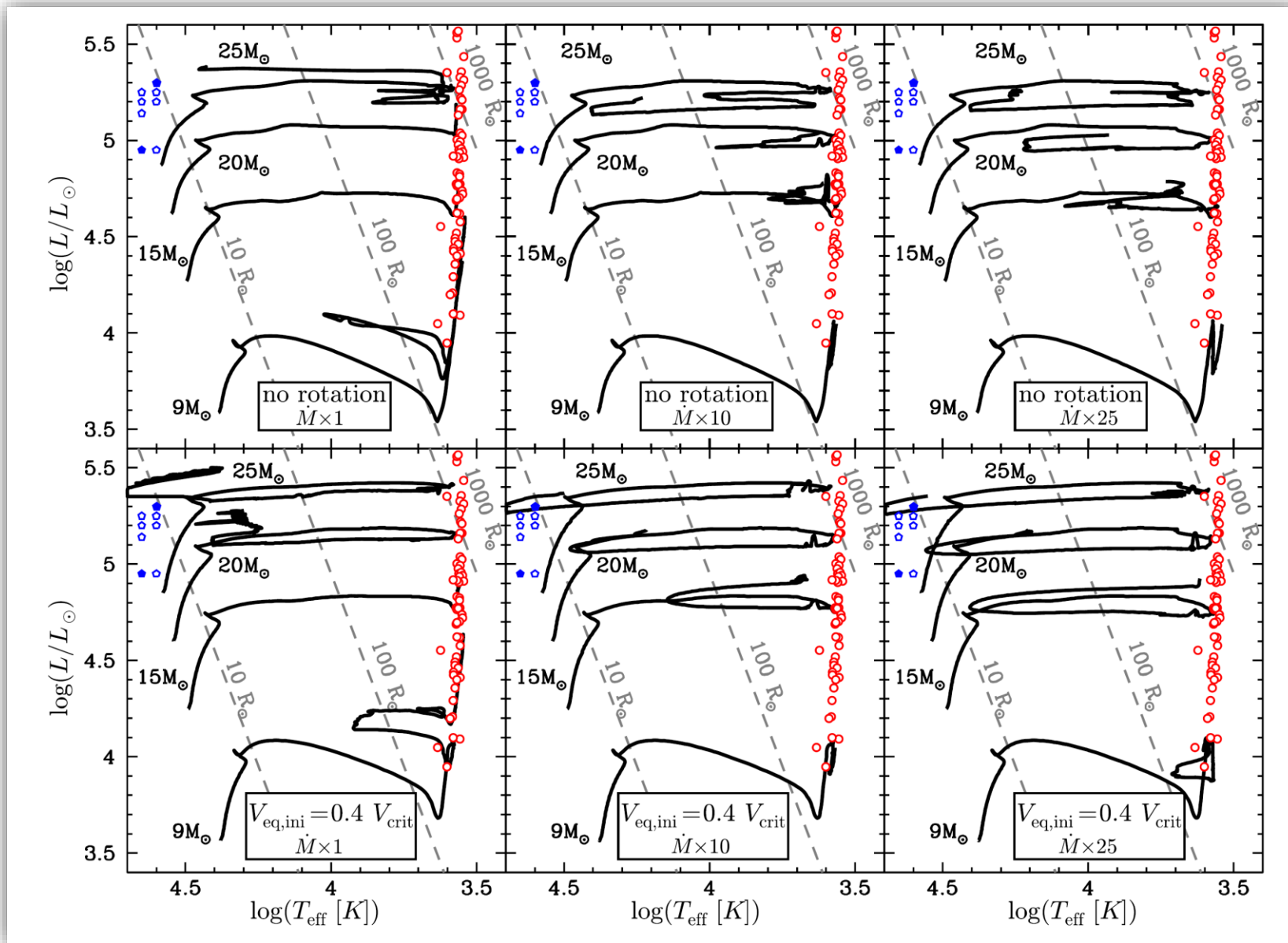
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Motivation

- What is the terminal state for evolved RSGs ($> 20 M_{\odot}$)?
- What can YSGs tell us about stellar evolution?
- How can we identify post-RSG YSGs?

- Warm supergiants: excellent laboratory for testing theory



Meynet et al. 2015

Goals

- Identify evidence of post-RSG evolution in M31/M33
 - signatures of mass-loss in SEDs and spectra
- Estimate statistics of supergiant populations
 - post-RSG or post-MS YSGs
 - RSGs with or without circumstellar dust

Background

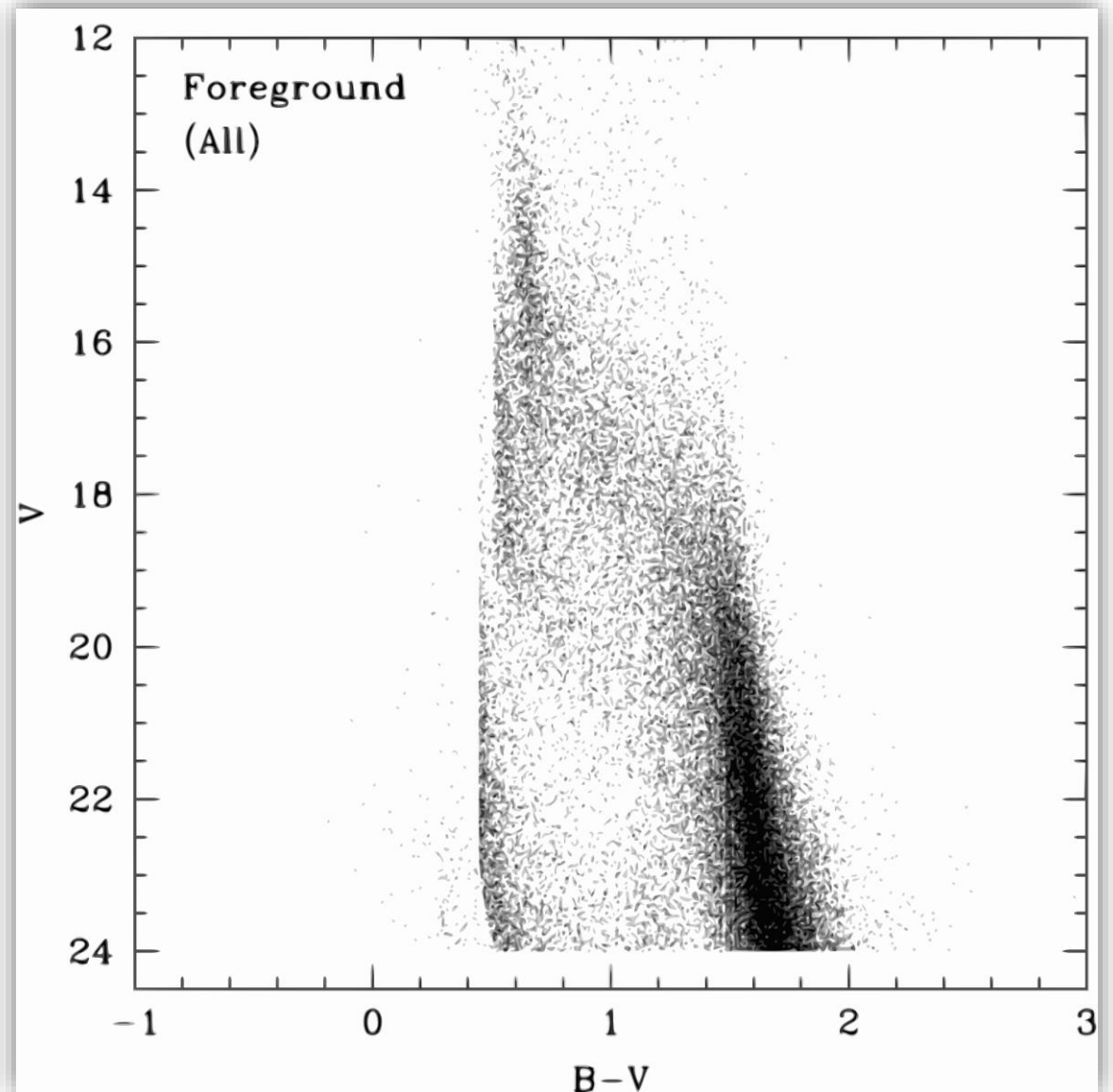
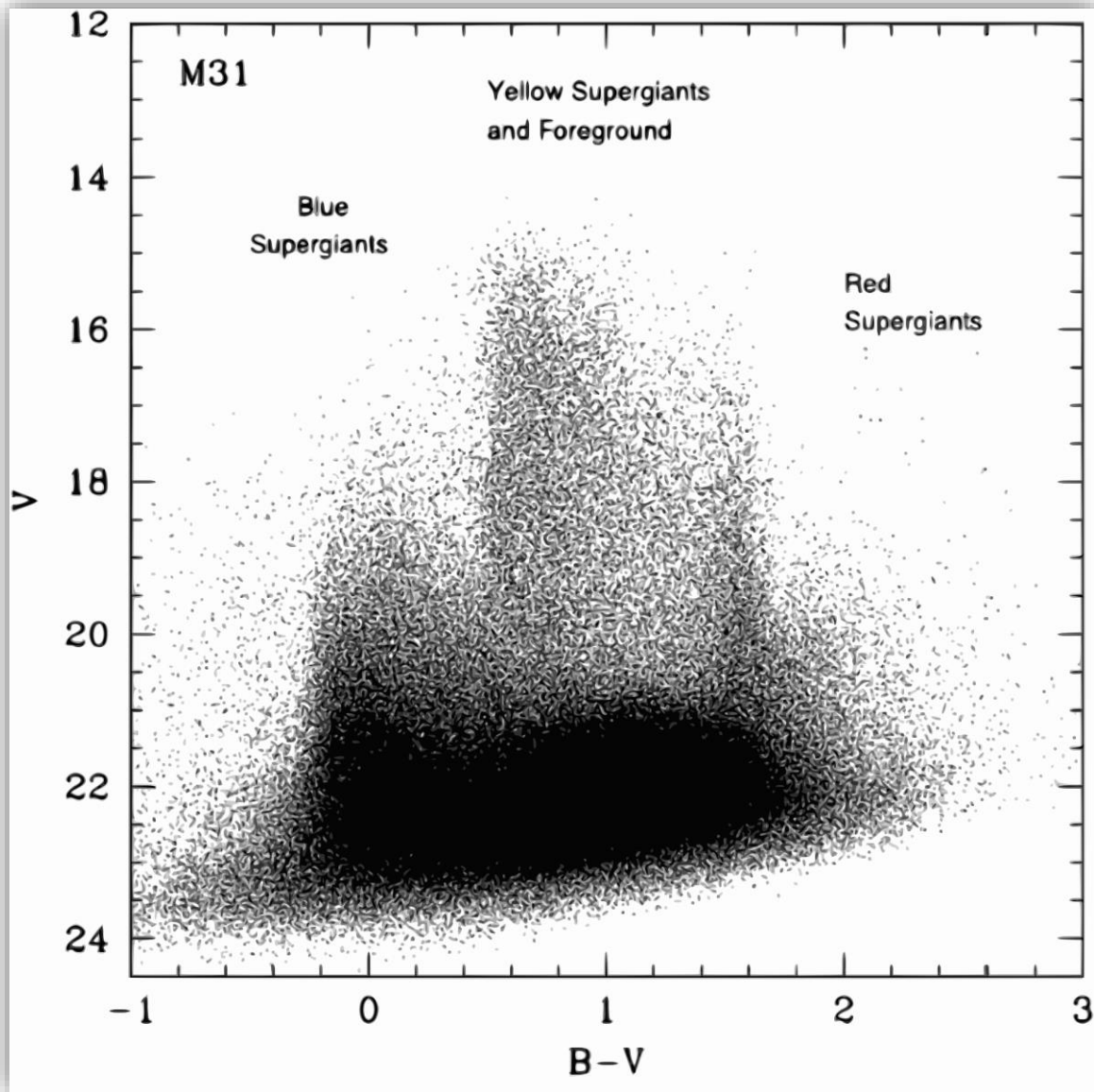
- Census of supergiants in the local universe
 - M31 red (Massey et al. 2009) and yellow (Drout et al. 2009)
 - M33 red and yellow (Drout et al. 2012)
 - **Radial velocity and O I $\lambda 7774$ triplet strength criteria**
- Observational challenges:
 - Foreground contamination
 - Extinction correction

Data

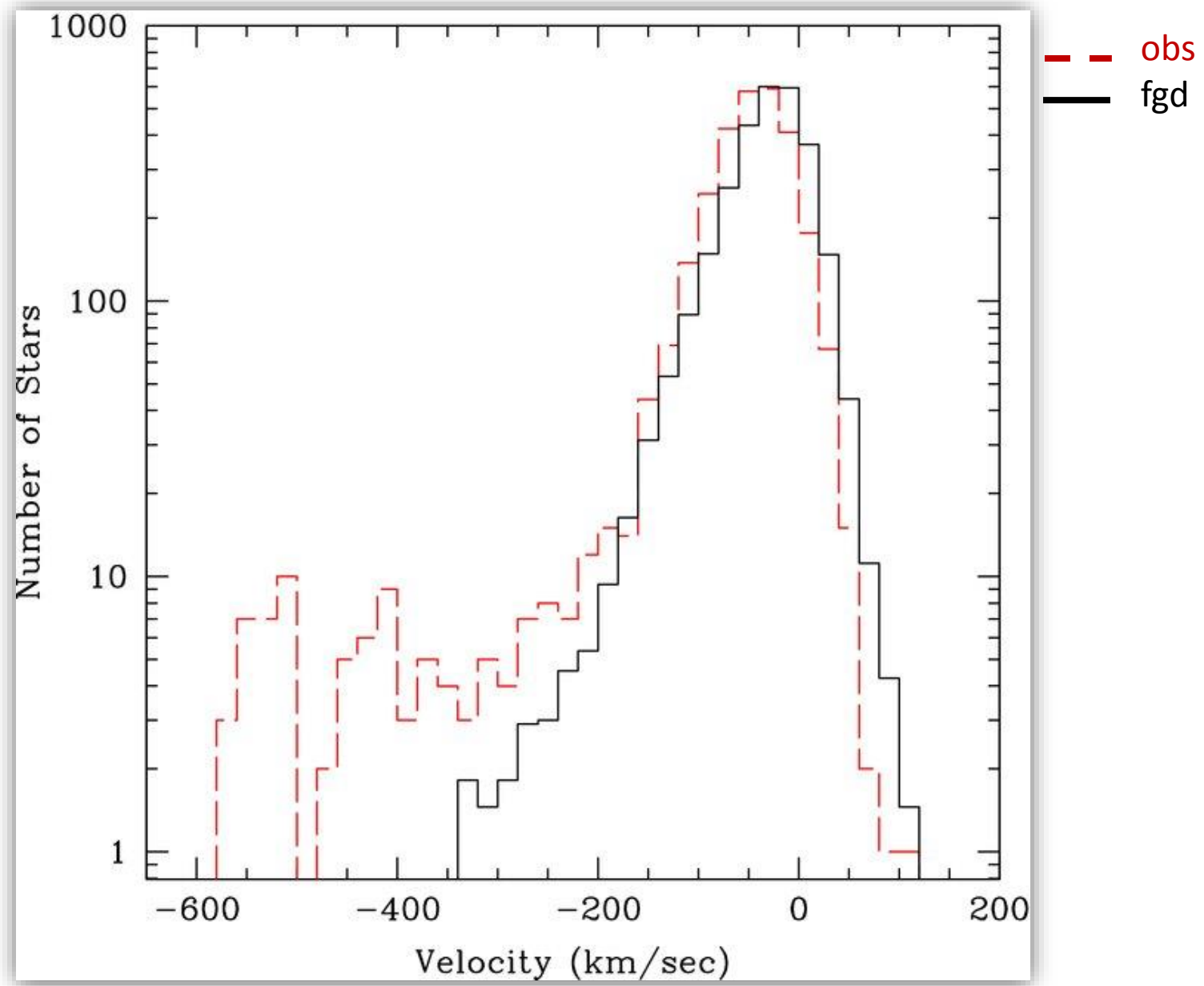
- YSG/RSG Target Selection
 - Massey & Drout candidate sources
 - Humphreys et al. (2013/2014)
confirmed super/hypergiants

Galaxy	YSG Spectra	YSG Photometry	RSG Photometry
M31	108	127	444
M33	119	179	204

- Observations
 - MMT Hectospec, Oct 2013, Nov 2014
 - Fiber-fed MOS, 300 fibers, 1.5" on sky
 - ~3600 – 8000 Å @ 0.54 Å/pixel resolution
 - Total exptime: 90 min red, 120 min blue
 - Multi-band photometry
 - Optical to mid-IR catalogs



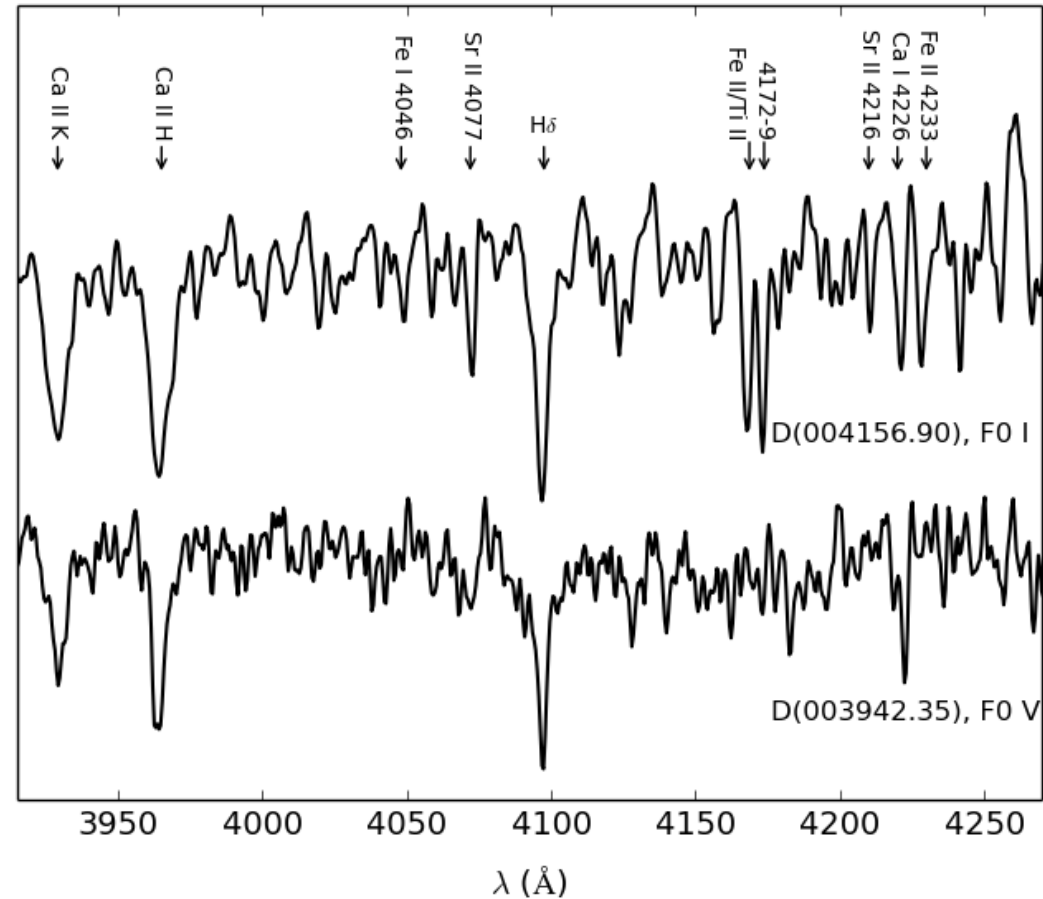
Drout et al. 2009



Drout et al. 2009

YSG Classification

- YSG spectra
 - spectral types
 - luminosity classification
- Supergiant luminosity criteria
 - Ti II/Fe II blends $\lambda\lambda 4172-9, \lambda\lambda 4395-4400$
 - Sr II $\lambda\lambda 4706, 4216$
 - O I $\lambda 7774$ triplet
- G-dwarf criteria
 - G-band, CH absorption @ $\lambda 4300$
 - Mg I triplet $\lambda\lambda 5167, 72, 83$

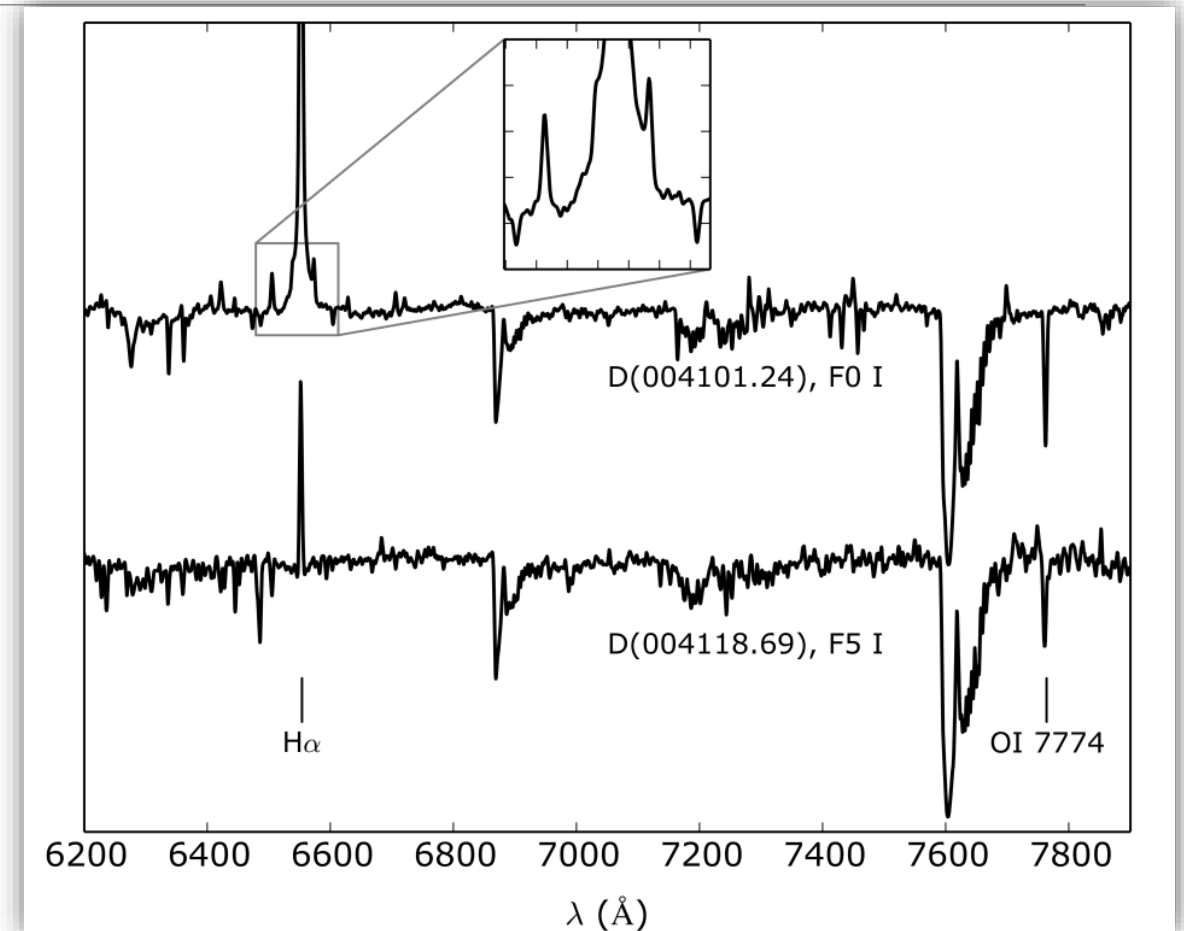


Evidence for Mass Loss

- Spectroscopic evidence
 - P Cygni profiles
 - broad H α wings
 - [Ca II] and Ca II triplet emission

Galaxy	YSGs w/ mass loss	YSGs confirmed	% w/ mass loss
M31	12	67	18%
M33	15	72	21%

* Work in progress. Numbers subject to change before publication.



YSG Population

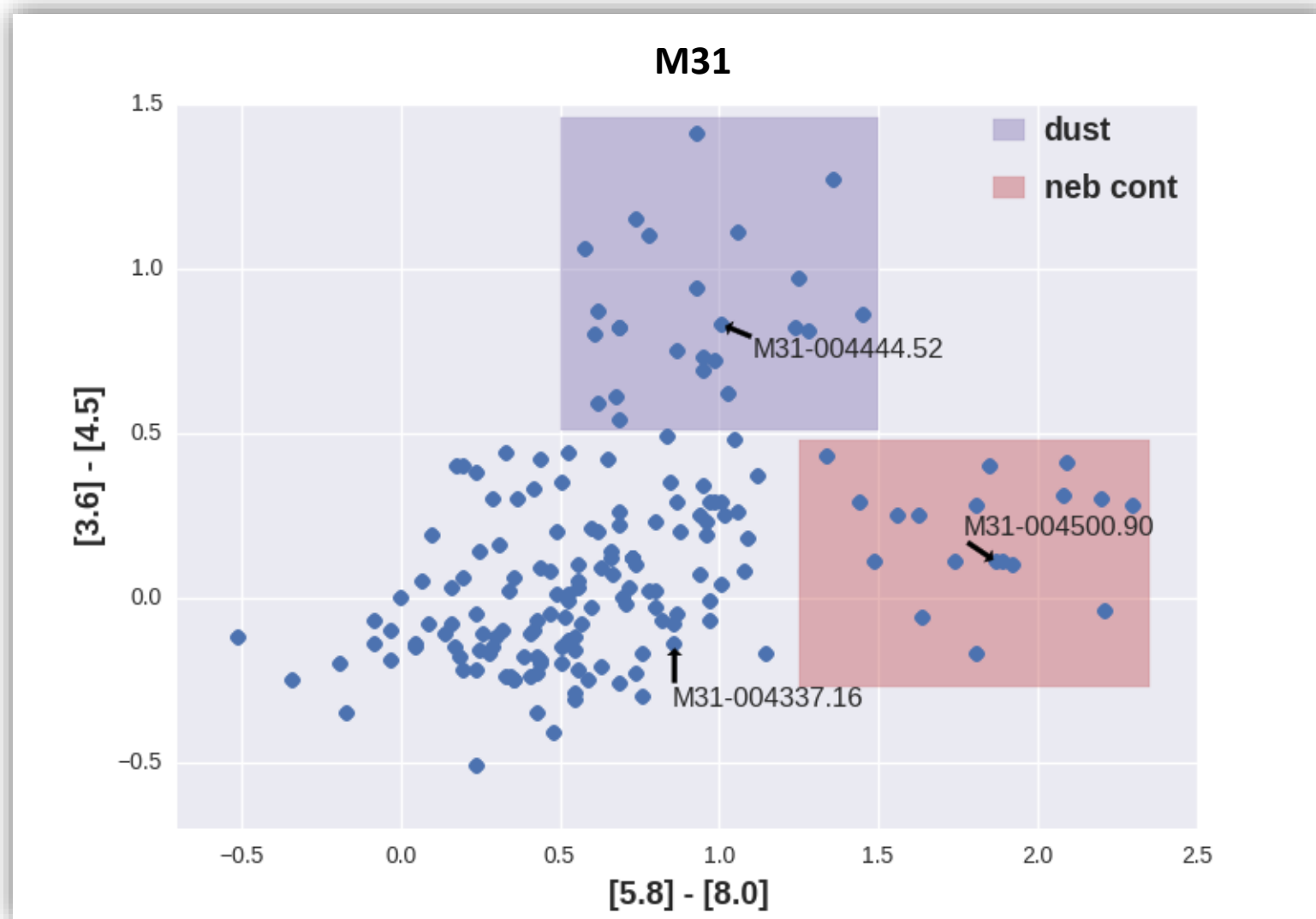
- Statistics from the Massey/Drout samples:

Galaxy	Obs / Total	SGs / Dwarfs	% fgd
M31	98 / 120	60 / 38	32%
M33	82 / 135	64 / 18	13%

- Drout et al. 2012 catalog of M33 less contaminated by fgd dwarfs
- Accurate spectral/luminosity classifications necessary for assembling clean catalog of YSGs

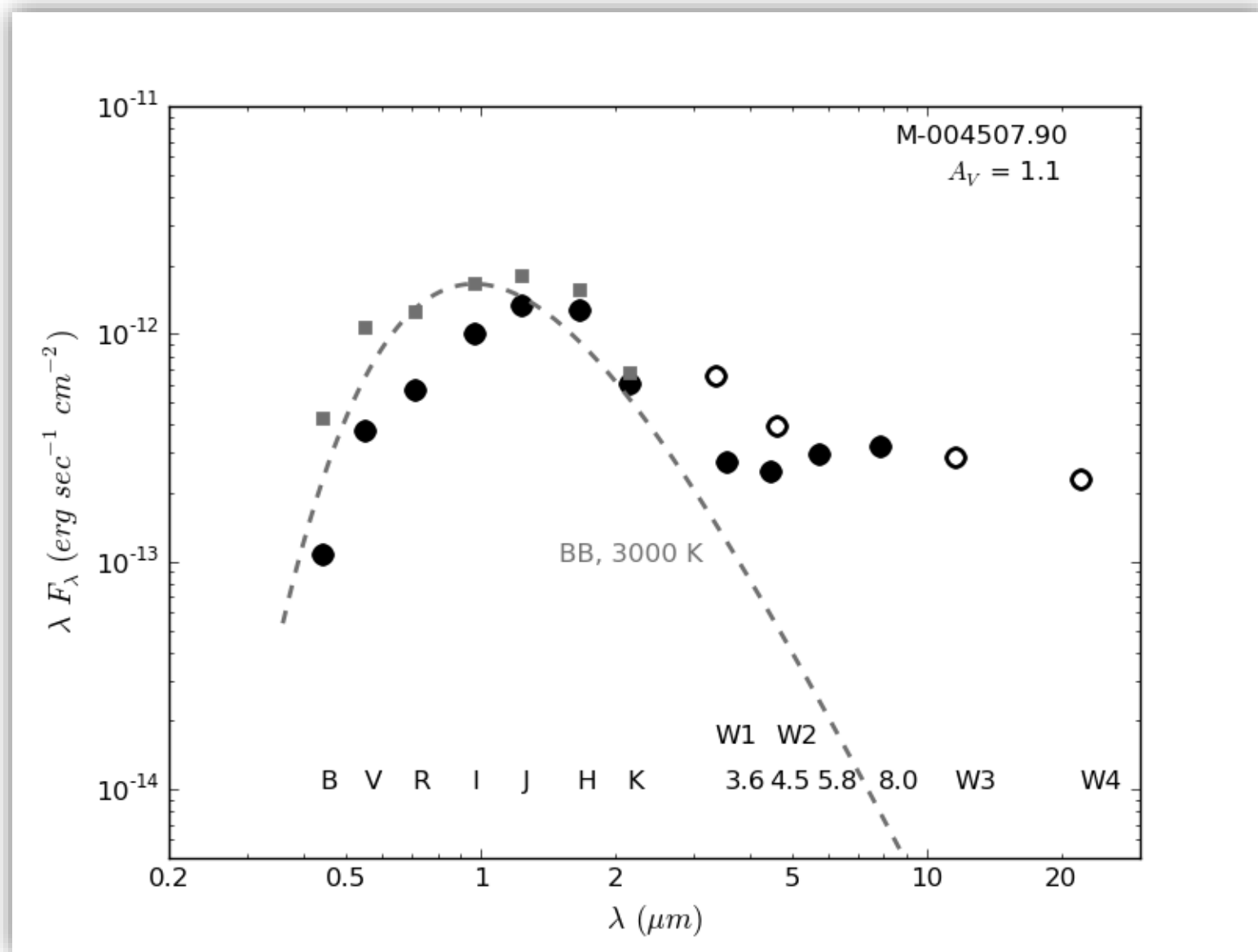
Spectral Energy Distributions

- Multi-band Photometry
 - *UBVRI* from LGGs (Massey et al. 2007)
 - *JHK* from 2MASS (Skrutskie et al. 2006)
 - *3.6, 4.5, 5.8, 8 μm* from Spitzer/IRAC
(M31: Mould et al. 2008, M33: McQuinn et al. 2007)
 - *3.4, 4.6, 12, 22 μm* from WISE (Wright et al. 2010)



YSG & RSG Photometry

- near- to mid-IR: circumstellar dust ejecta
- Requires analysis of extinction-corrected photometry
 - Calculate A_V in three ways:
 1. Intrinsic color (if spectral type is known)
 2. Nearby O- to B-type stars (Q-method)
 3. HI 21-cm maps $\longrightarrow N_H \longrightarrow A_V$



YSG & RSG Photometry

- Supergiants with evidence of circumstellar dust in SEDs:

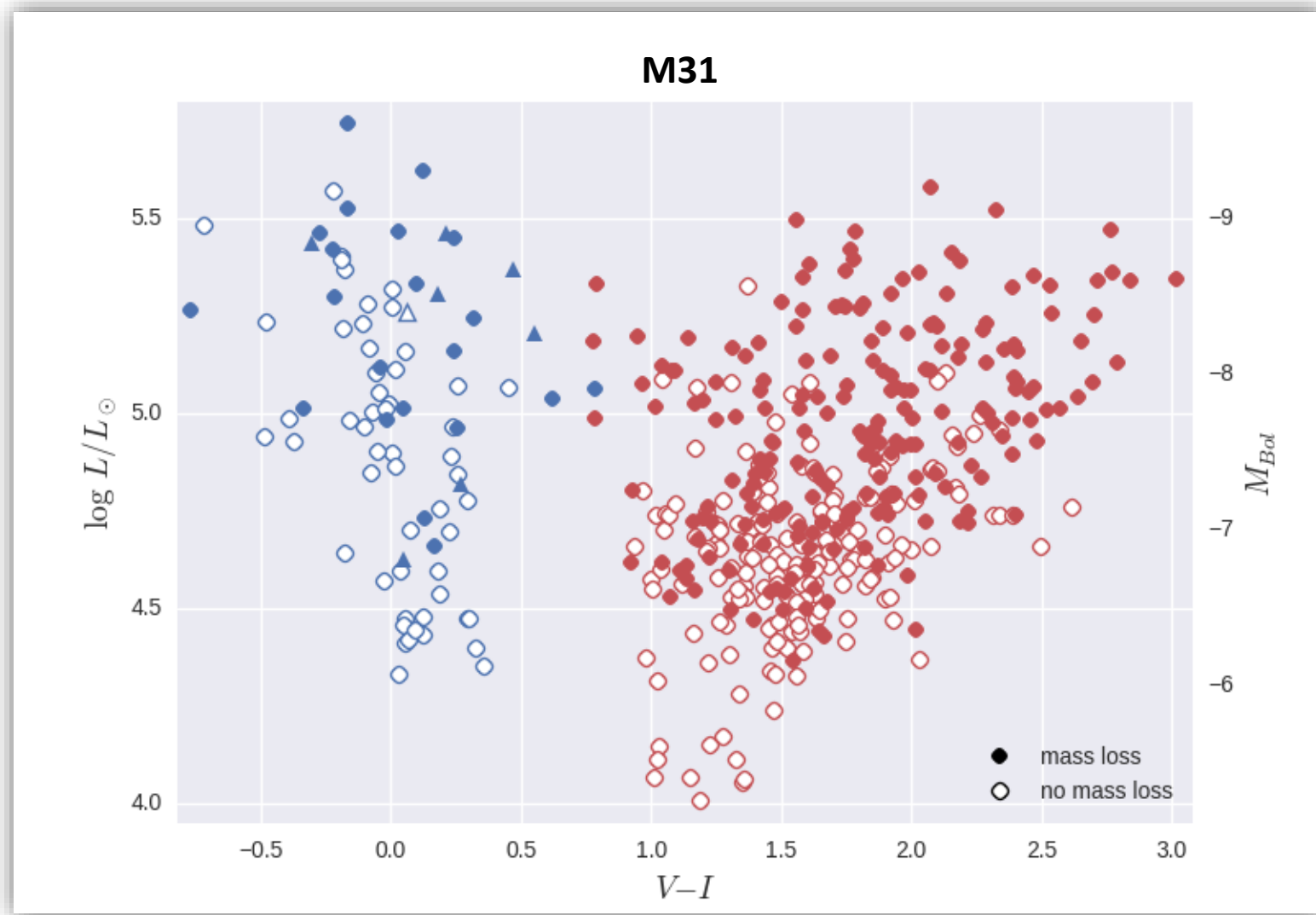
Galaxy		Dust	Neb Cont	Total Obs	% Dust
M31	yellow	25	6	93	27%
	red	231	110	444	52%
M33	yellow	19	36	145	13%
	red	126	45	204	62%

* Work in progress. Numbers subject to change before publication.

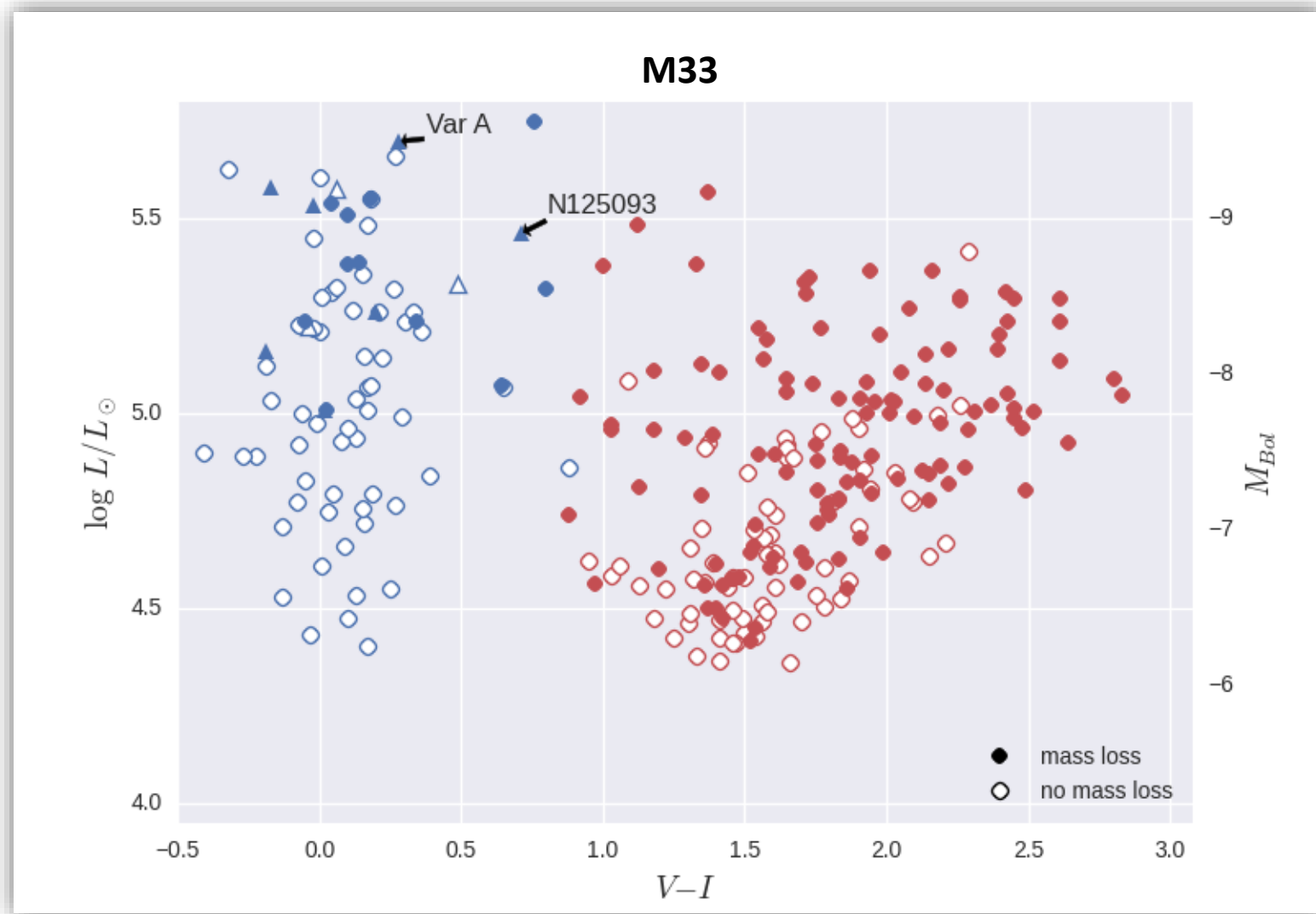
Summary

- Of the observed **YSG** candidates, we identify:
 - **35 | 30** post-RSG candidates in **M31 | M33** (**38% | 21%** of candidate YSGs)

- Of the observed **RSG** candidates, we identify:
 - **231 | 126** RSGs with circumstellar dust in **M31 | M33** (**52% | 62%** of candidate RSGs)



* Work in progress. Derived bolometric luminosities subject to change before publication.



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Conclusions

- We identified **35 | 30 post-RSG candidates** in **M31 | M33**
 - these post-RSG stars represent **38% | 21%** of candidate YSGs
 - * Work in progress. Numbers subject to change before publication.
- **> 50% of RSGs** show evidence for circumstellar dust
- Current/Future work:
 - measure mass-loss rates from spectra/mid-IR photometry
 - more YSG spectra from M31 in Fall 2015
 - search for dust-obscured supergiants with infrared spectrograph, **IRMOS**

