Research of Massive Star Clusters by NIR Narrow-band Imaging Observations

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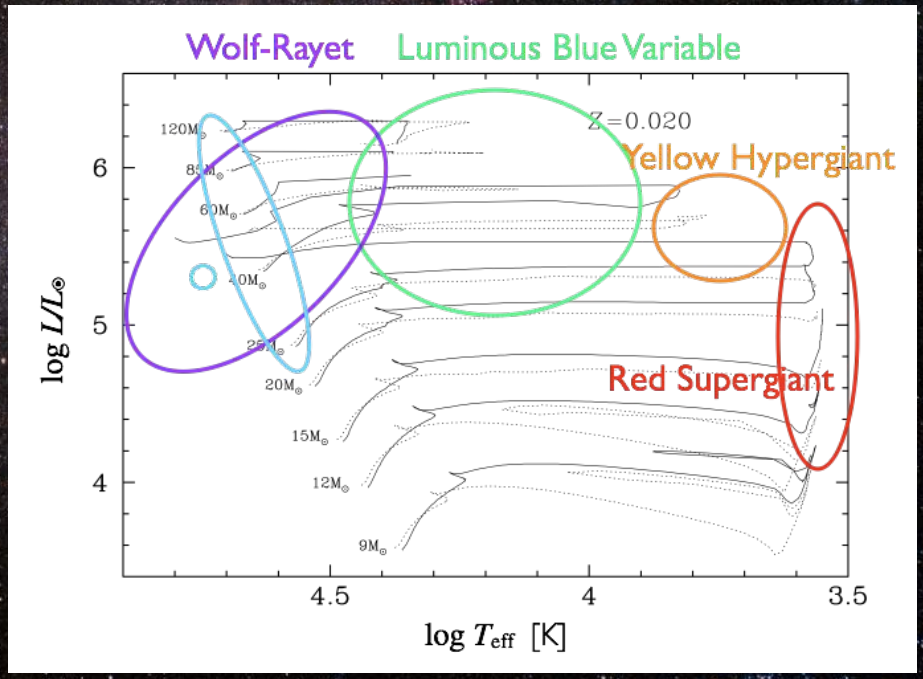
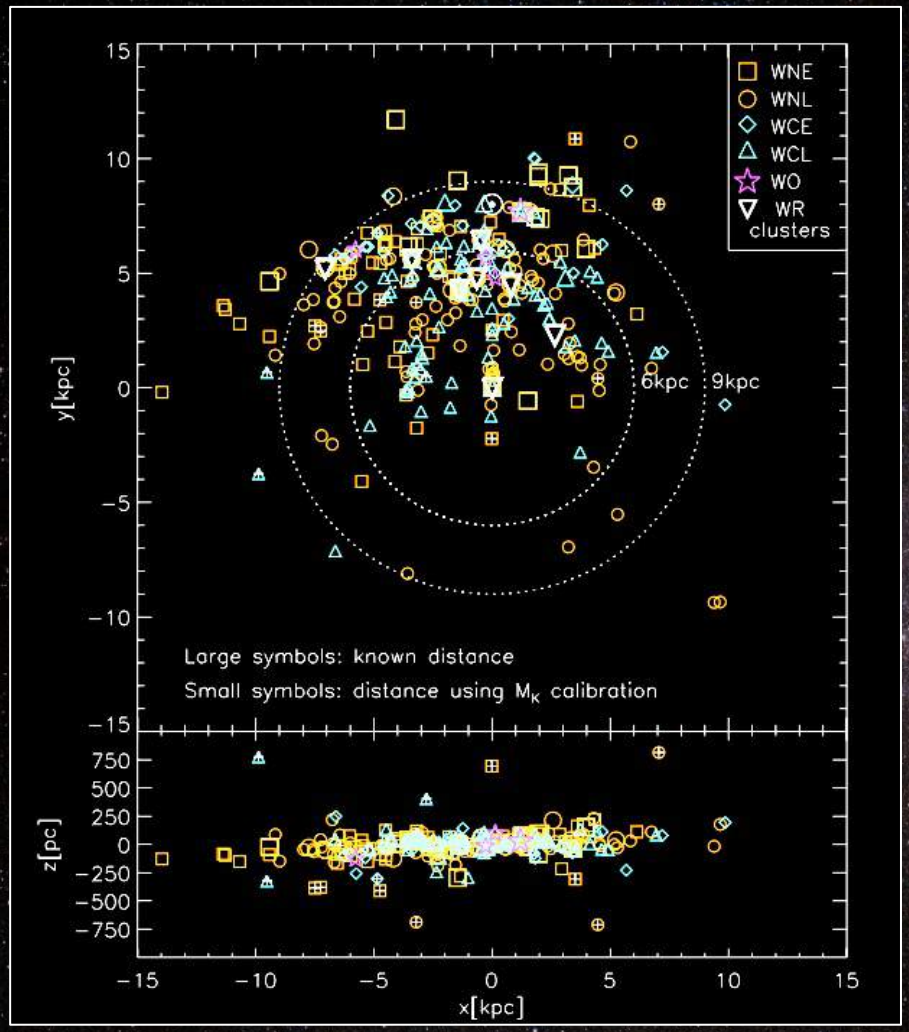
Objectives

Massive Stars
- WR, LBV, YHG, RSG, OB* .....
- supply huge energy and dust toward interstellar field
- have great influence over evolution of galaxies
  (starformation efficiency, chemical evolution , etc…)
- have many mysteries about its life (Where? How? Number? MF? etc…)

ex; WR star
- Progenitors of SNs
- number of observed WR is ~10-30% than that of simulation (@MW).



Distribution of WR stars in Our Galaxy



Rosslowe & Crowther 2015

$$N_{WR}(R) = N_{0,WR} \exp\{-(R - R_0)/\alpha_{WR}\}$$

Number density of WR

Radial distribution

R : Distance from GC

R_0 : Distance from GC to the Sun

Total number of WR within Galaxy …

$$\Sigma_{WR}(<R) = \int_0^R N_{WR}(R')\, 2\pi R' dR'$$

$$\Sigma_{WR}(<R) \simeq 6200\ \{1-(1+R/1.66)\exp(-R/1.66)\}$$

for $N_{0,WR} = 2.87\ kpc^{-2}$, $\alpha_{WR} = 1.66\ kpc$

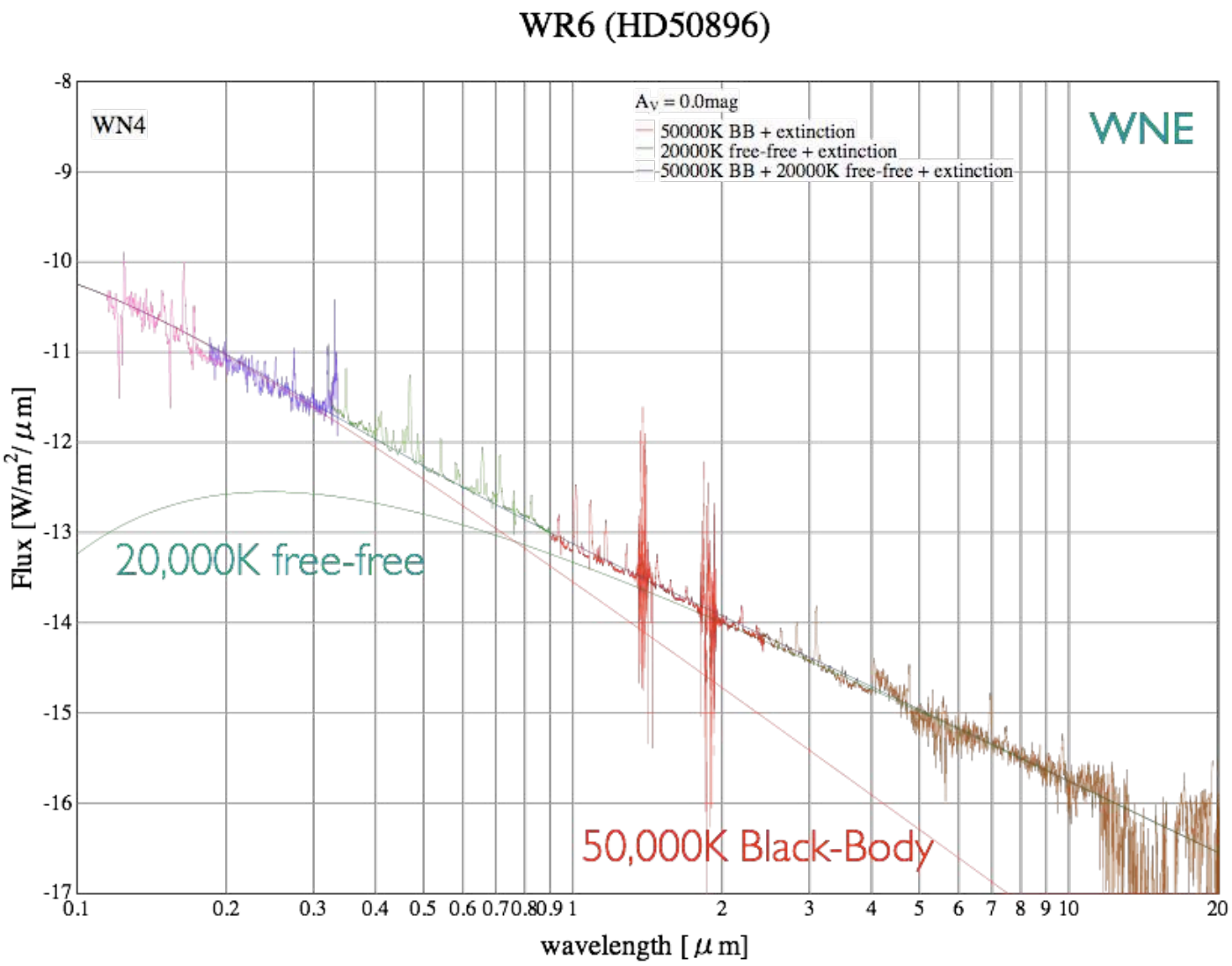
$$\Sigma_{WR}(<R) \simeq 2500\ \{1-(1+R/2.24)\exp(-R/2.24)\}$$

for $N_{0,WR} = 2.20\ kpc^{-2}$, $\alpha_{WR} = 2.24\ kpc$

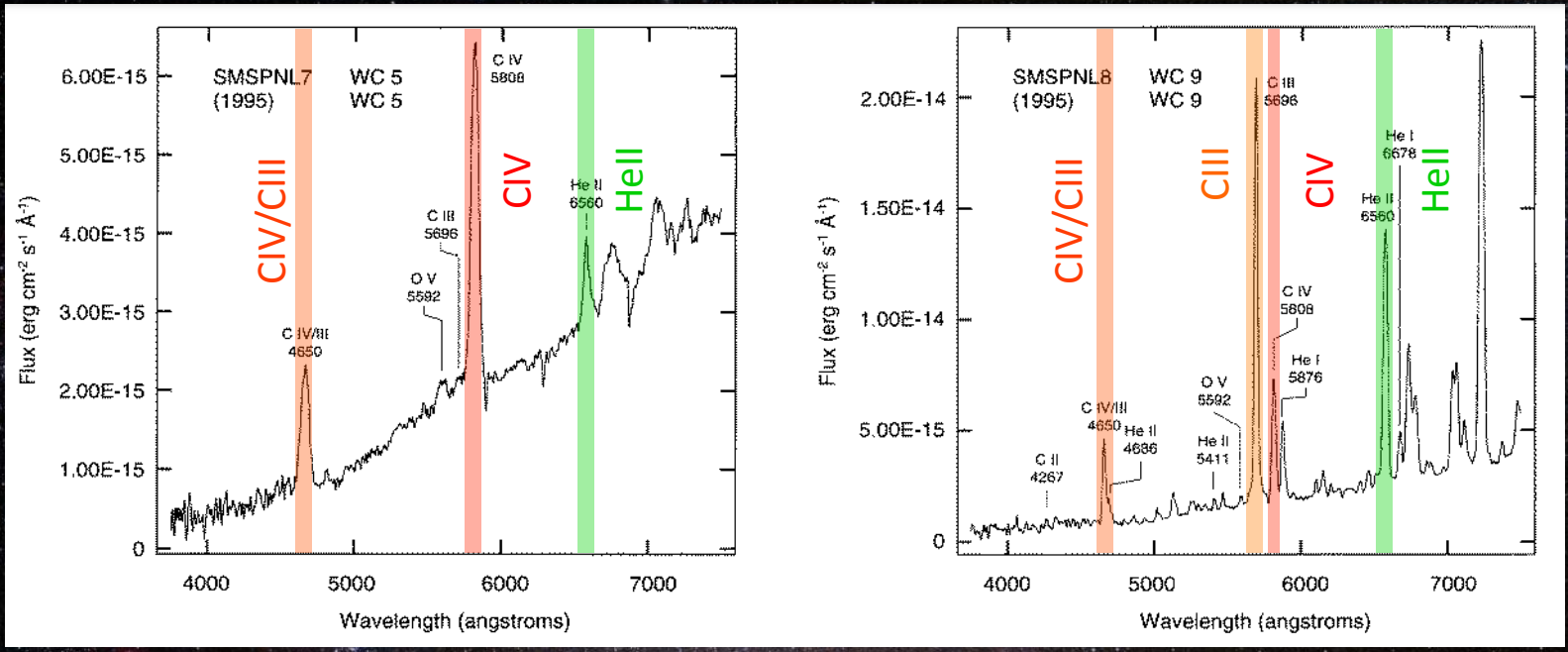
Current catalogue : **642**

http://pacrowther.staff.shaff.shef.ac.uk/Wrcat/

Sample spectrum of WN/WR (wide range)

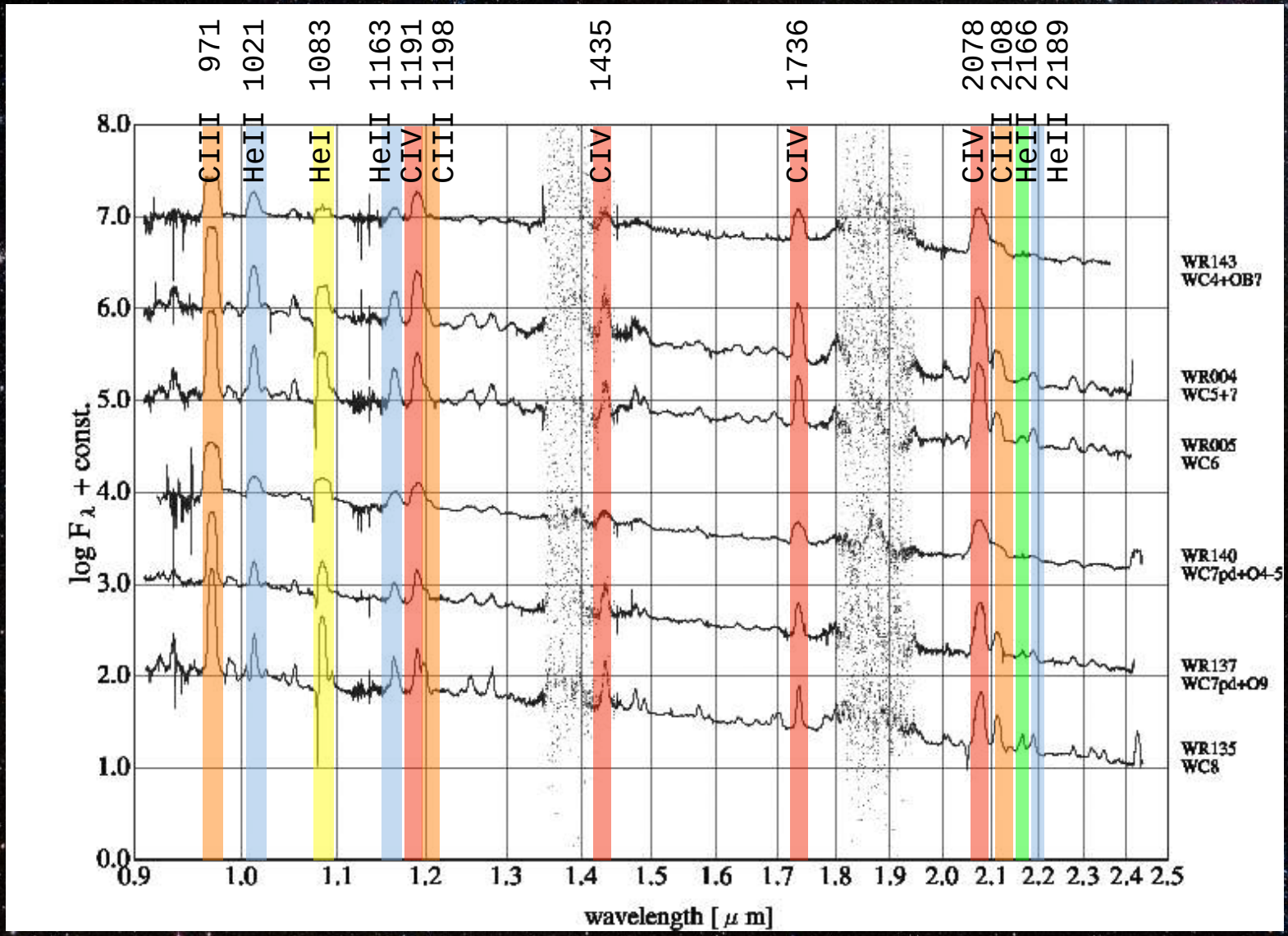


Sample spectrum of WN/WR (optical)



Sample spectrum of WN/WR (NIR)

Nishimaki et al. 2006



Objectives and method

Strong against extinction : **Infrared** →Imaging

Spectrum of massive stars : **Narrow-band filter** →Spectroscopy

❖ Productions and Outcome

▶2-color diagram（[N207/Ks] vs [N187/Ks]）

- Classification of Species of cluster
- Detection of known objects
- Picking-up of Unknown objects
- Extinction
- (Extremely) Red objects

▶Ks magnitude vs N187 excess

- Classification of sub-class of WNs
- Environment / physical conditions and evolution of cluster

Observation

Telescope

miniTAO 1m (the University of Tokyo Atacama Observatory, Chile)

- 5640m Altitude → Paa 1.875um

Instrument

ANIR (Atacama Near-Infrared Camera)

- HAWAII array (1024 x 1024), 0.3”/pix → 5’x5’ FOV
- **Ks**, **N187**(Paa, HeII), **N207**(CIV)

Observed Area

- Galactic Center Regions (Arches, Quintuplet, SgrA*)
- Westerlund 1
- LMC/30Doradus
- SMC/N66

Filter system

N187 filter

- Wavelength : λ center = 1.875 μm, Δλ = 0.008 μm
- detection lines : Paα , He II [n=8-6, n=6-5]
- target objects : WN / WRs, LBV

N207 filter

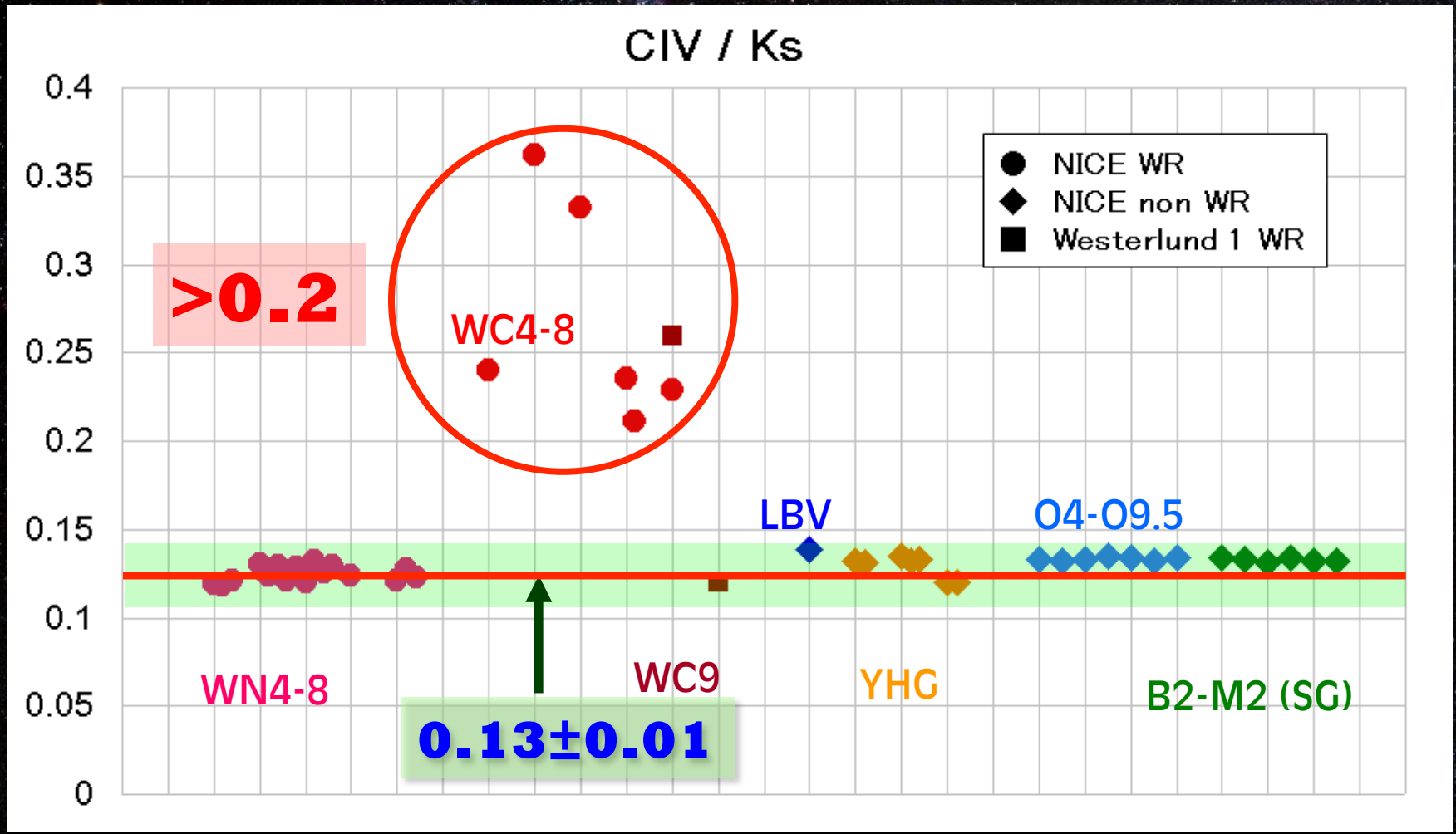
- Wavelength : λ center = 2.074 μm, Δλ = 0.041 μm
- detection lines : CIV 2.07 μm
- target objects : WC / WRs

Ks filter

- Wavelength : λ center = 2.149 μm, Δλ = 0.322 μm
- spectrum : continuum（line off filter）
- target objects : All

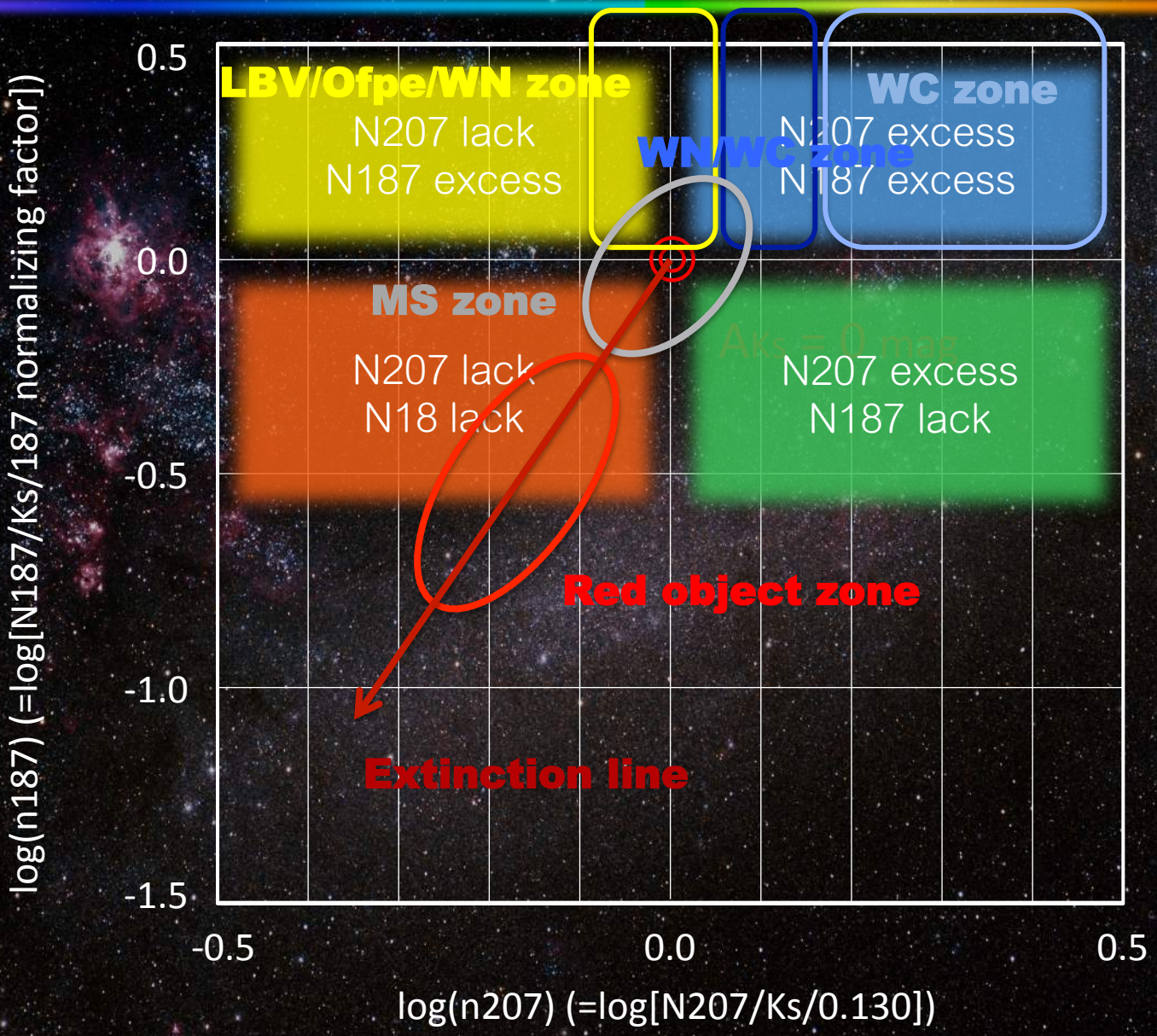
N207/Ks ratio

❖[N207/Ks] ratio calculated from observed spectra by NICE

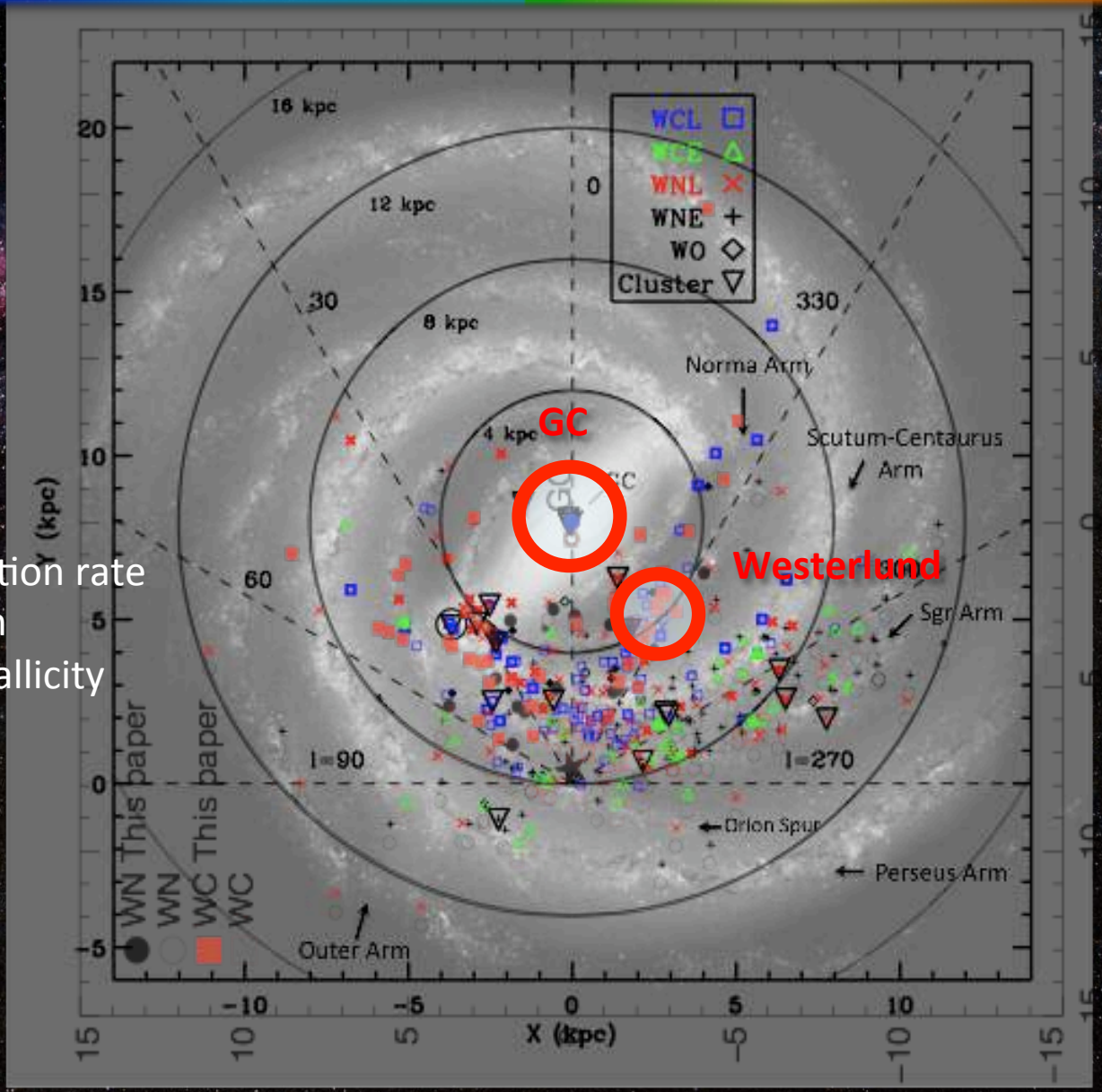


Type / sub-class

Color-color diagram



Observed Areas



- High starformation rate
- High extiinction
- High / low metallicity

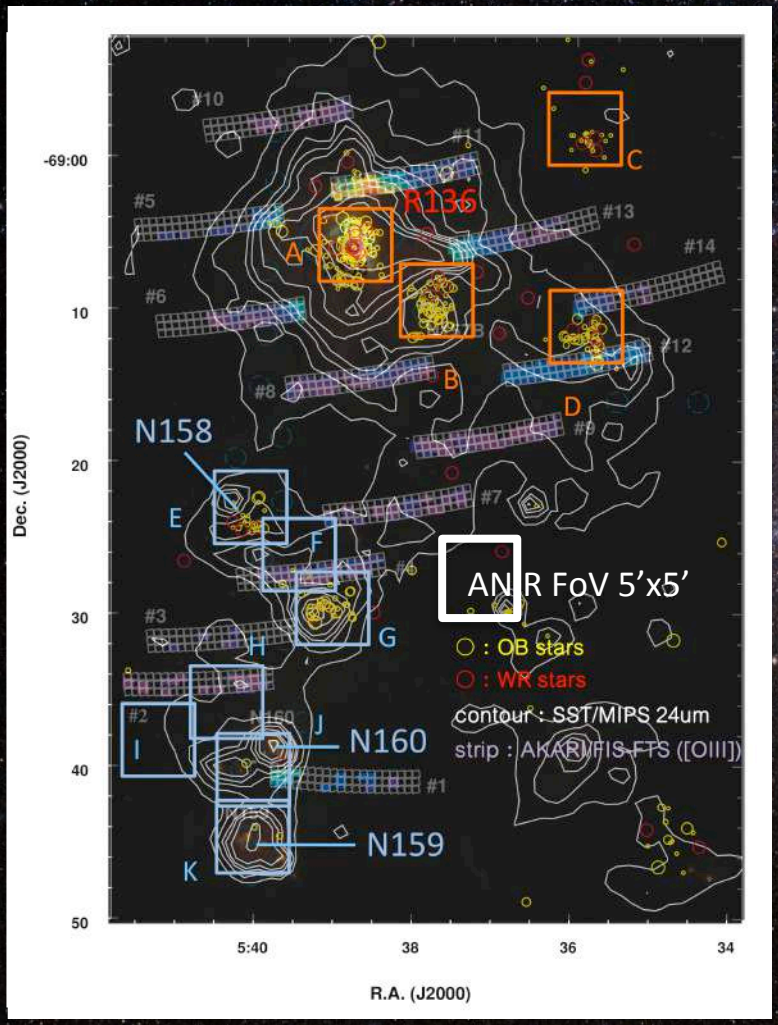
LCM/SMC

Shara et al. 2011

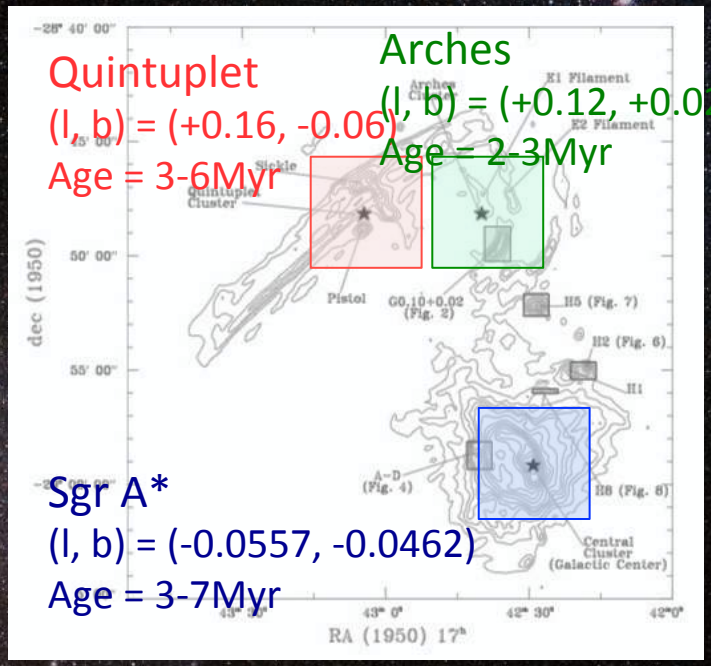
Mauerhan, Van Dyk, & Morris 2011

Observed Areas

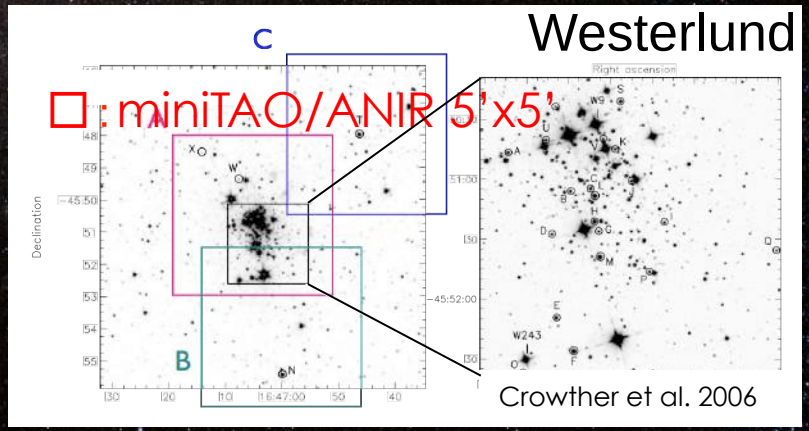
LMC



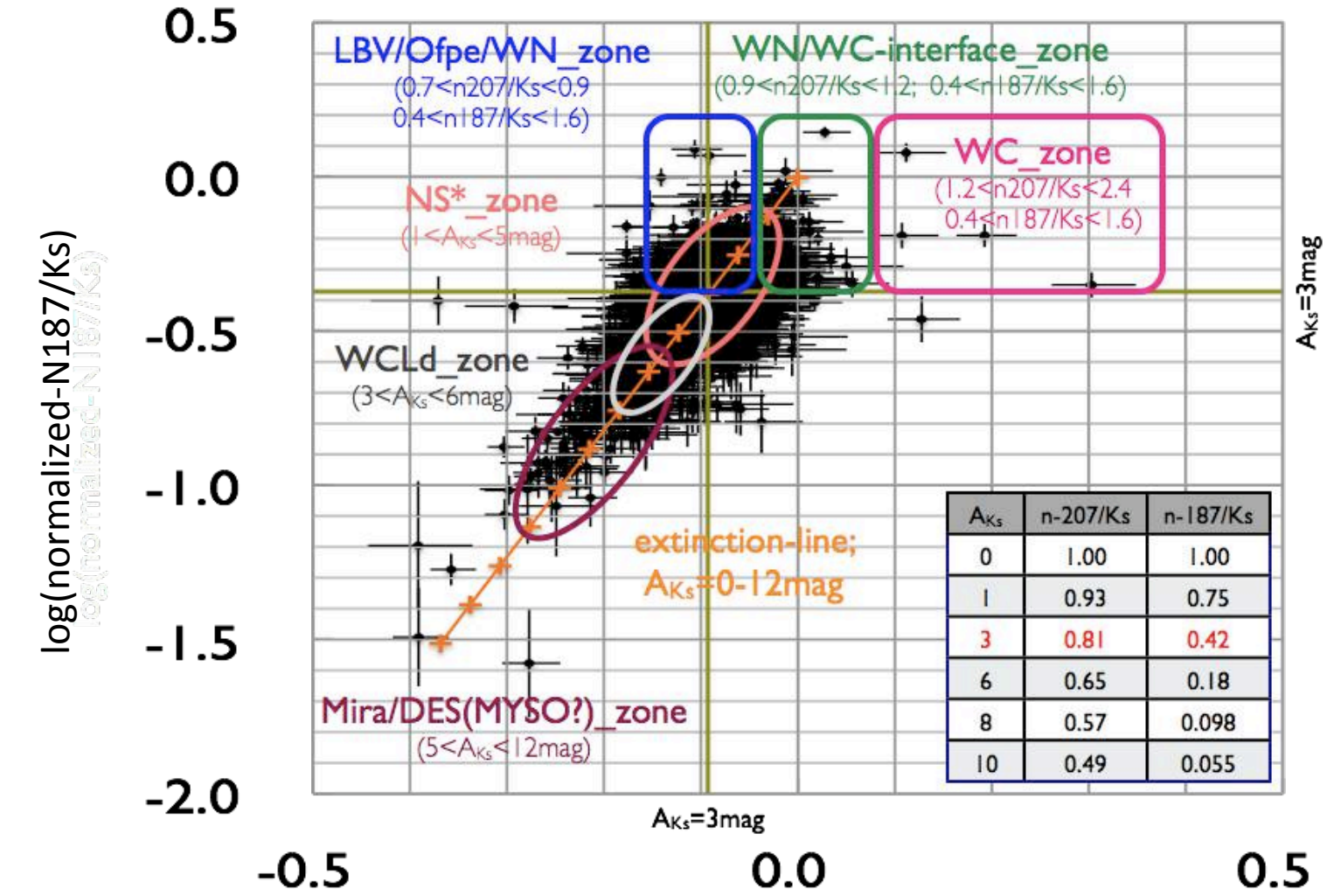
Galactic Center



Westerlund



Galactic Center Regions A_K=3mag

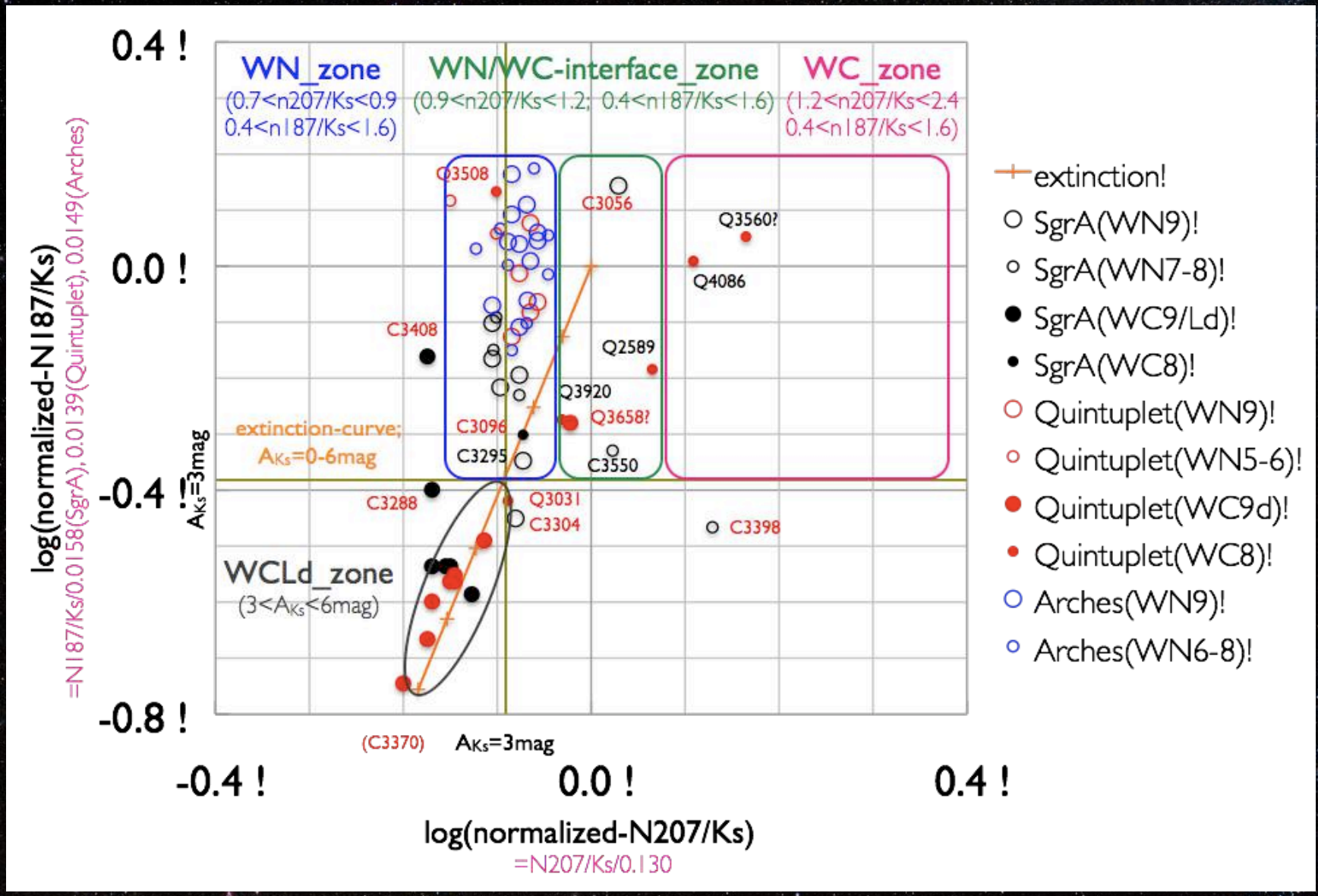


A_{Ks}	n-207/Ks	n-187/Ks
0	1.00	1.00
1	0.93	0.75
3	0.81	0.42
6	0.65	0.18
8	0.57	0.098
10	0.49	0.055

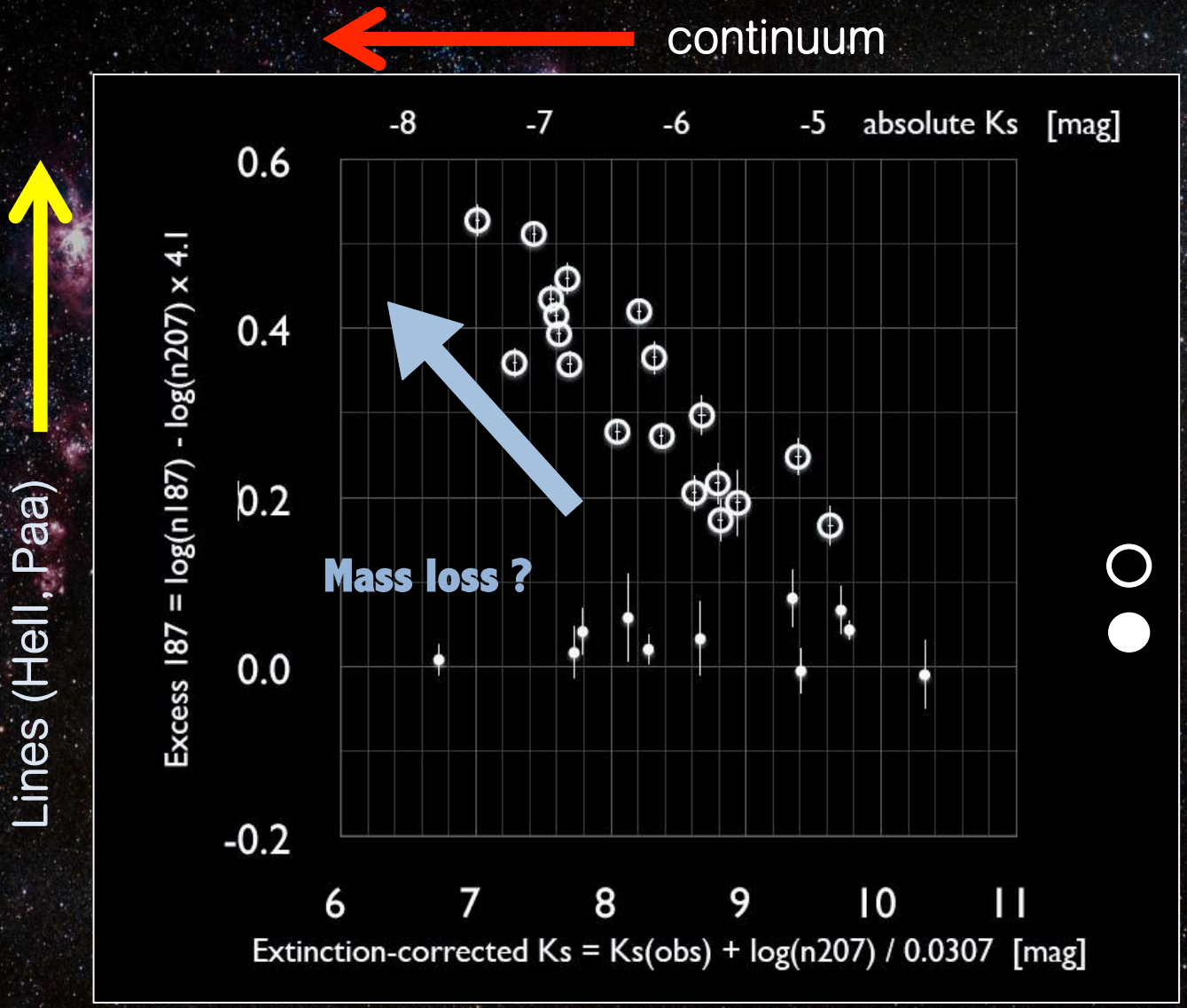
NS*: normal stars including RG/RSG

extinction line; $n207/Ks = 10^{(-0.0307 A_{Ks})}$, $n187/Ks = 10^{(-0.126 A_{Ks})}$

Galactic Center Regions

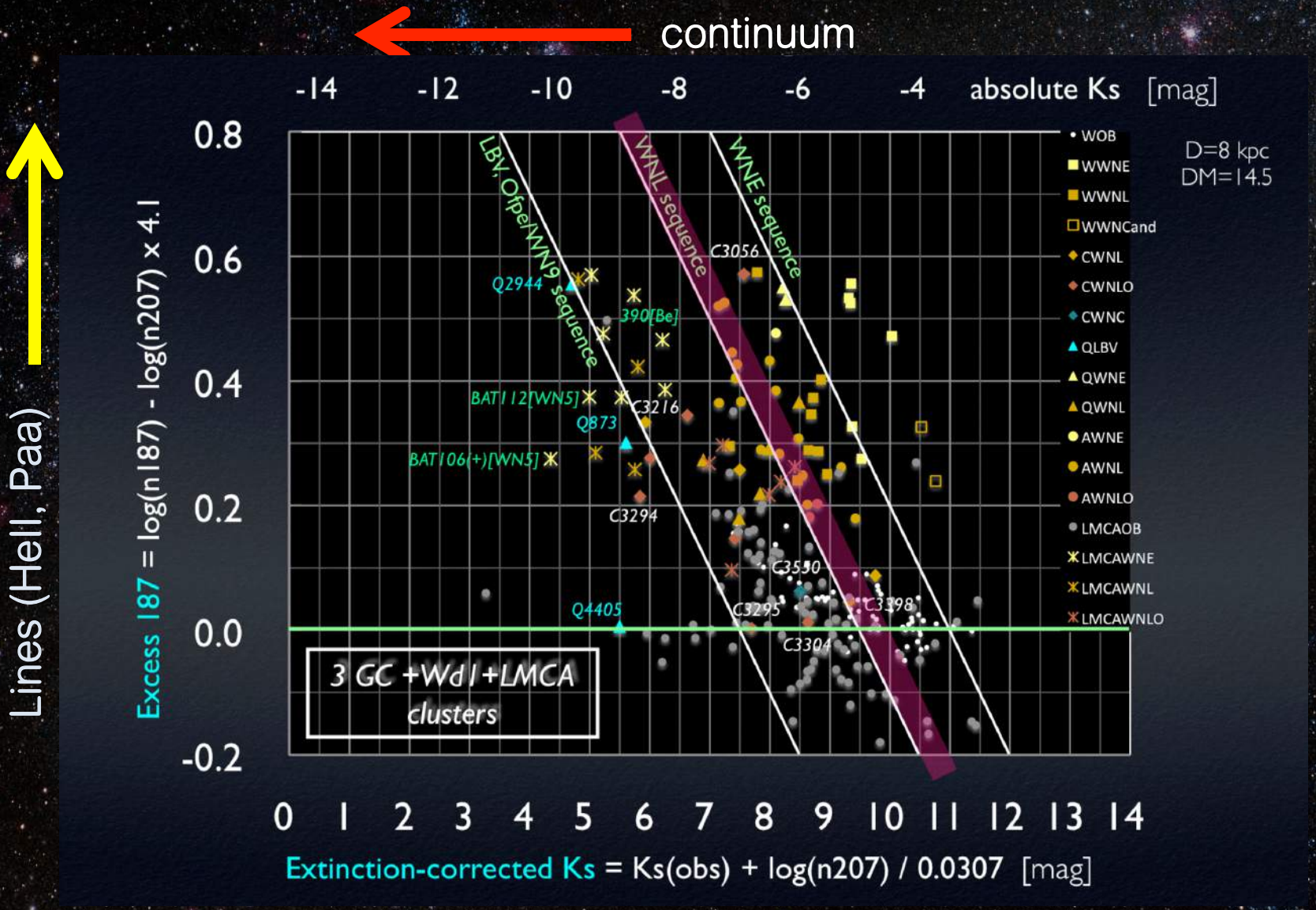


Color-187 excess diagram

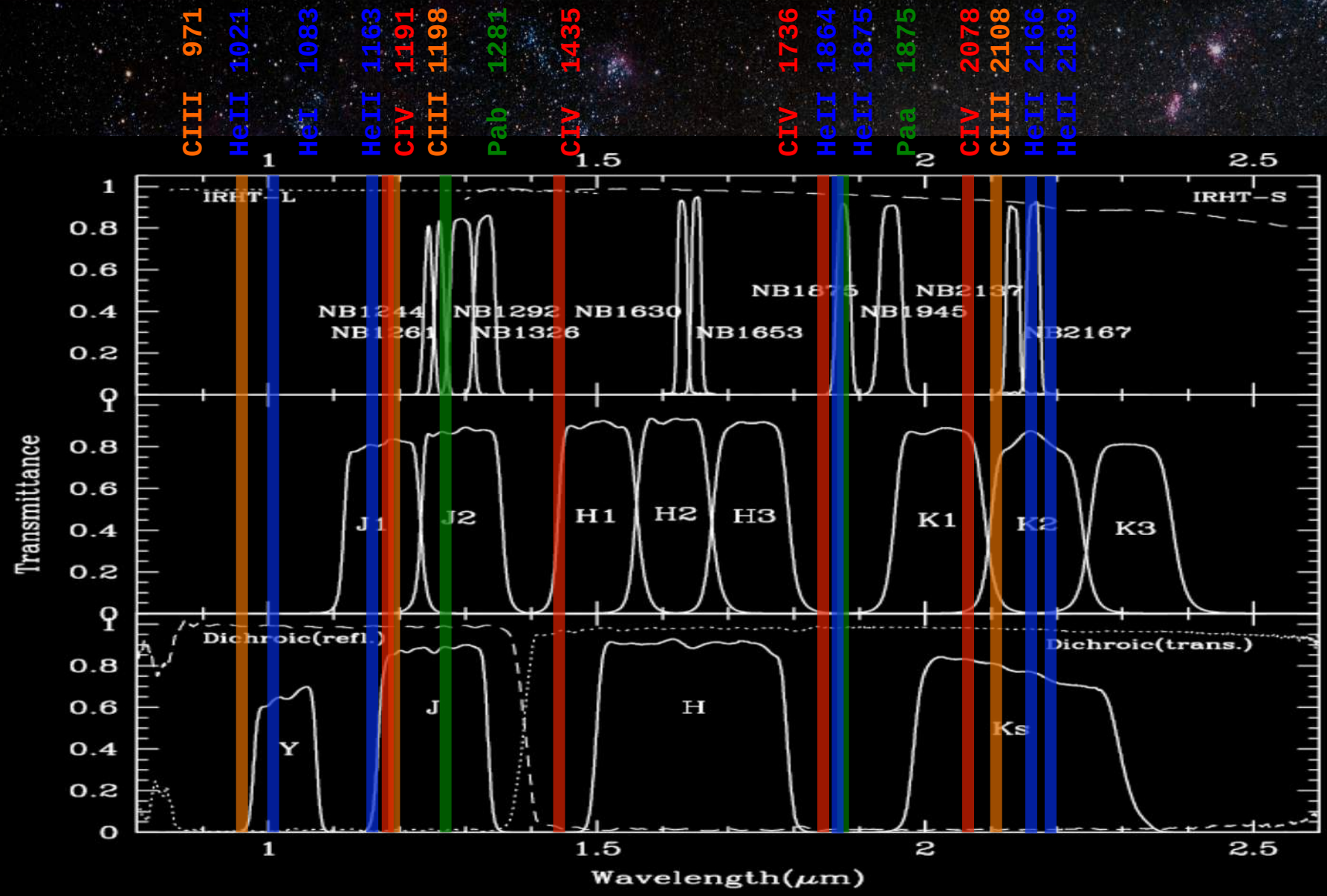


Tanaka et al. in prep.

Color-187 excess diagram



Observations with SWIMS



Observations with SWIMS

❖ Imaging

Lines	Target	NB / MB / WB
Pab 1281	WN, LBV	NB1292 / J2 / J
HeII 1864	WN, LBV	
HeII 1875	WN, LBV	NB1875 / - / -
Paa 1875	WN, LBV	
CIV 2078	WC	- / K1 / Ks
HeII 2166	WN, LBV	NB2167 / K2 / KS
HeII 2189	WN, LBV	- / K2 / KS

Pick-up emission objects

Estimation of extinction

Classification of type of stars

❖ Spectroscopy

- with MOSU
- multi objects spectra in star cluster
- for identification of type / subclass of massive stars

❖ Advantage & Merit of observation for MSC with SWIMS

- imaging → spectroscopy
- high spatial resolution : resolve crowded sources
- short exposure time : small atmospheric fluctuation

Summary

- We built up new filter system using narrow & broad band filters N187, N207, Ks.
- Almost known WR stars which seems to be progenitors of SNs are confirmed. New candidates are also detected.
- Type of massive stars can be distinguished by color-color diagram [N207/Ks] vs [N187/Ks]
- We can reveal the nature of massive star clusters by our research.
- This research will be continued by SWIMS and may be the Legacy program on starformation.

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