The ESO WFI spectroscopic survey of Hα emission-line stars in the MW, LMC, SMC

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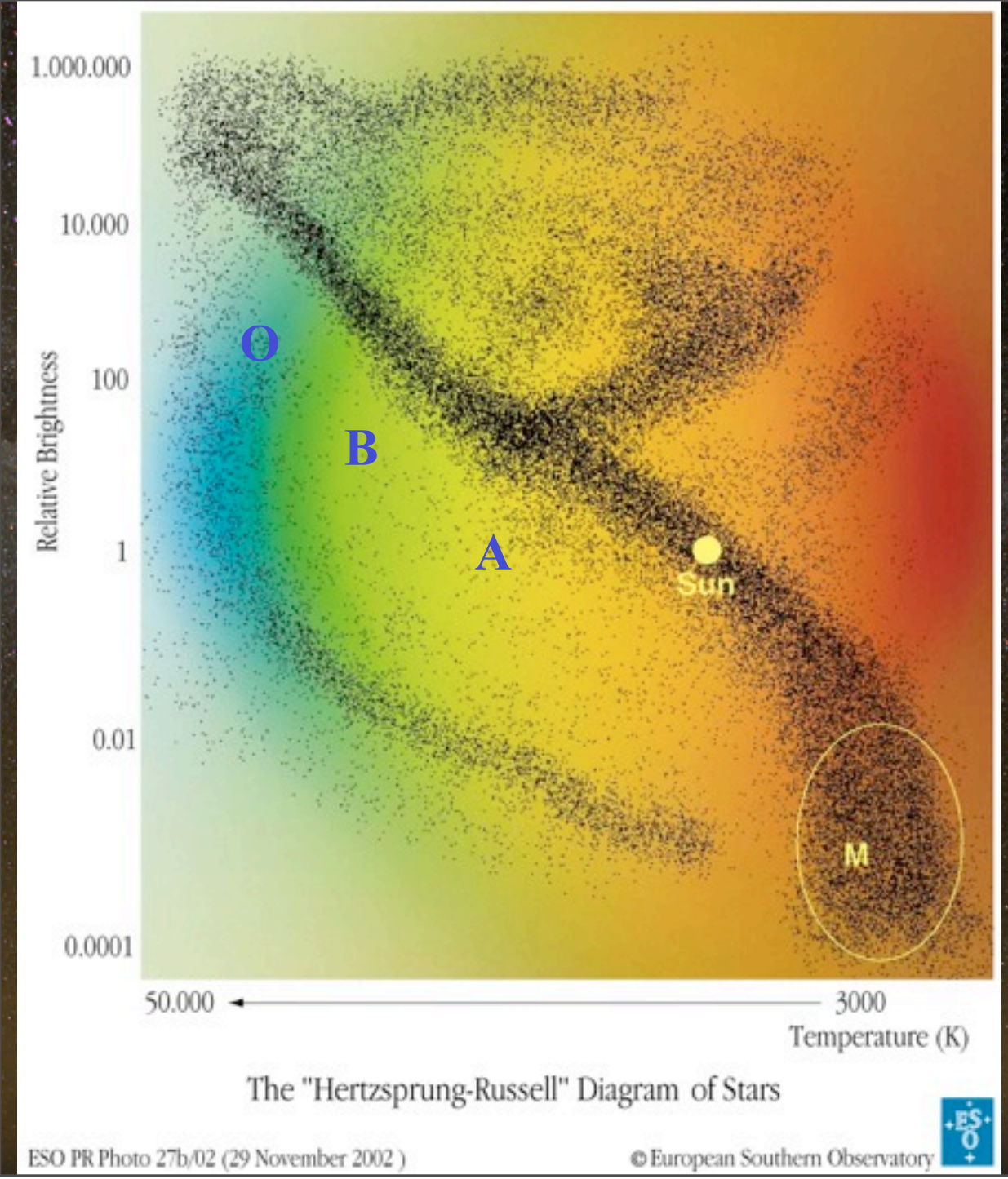
on behalf of

C. Martayan, D. Baade, J. Fabregat, G. Aguayo, H. Garrido, T. Rivinius, S. Stefl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Temperature (K)
The "Hertzsprung-Russell" Diagram of Stars
ESO PR Photo 27b/02 (29 November 2002)
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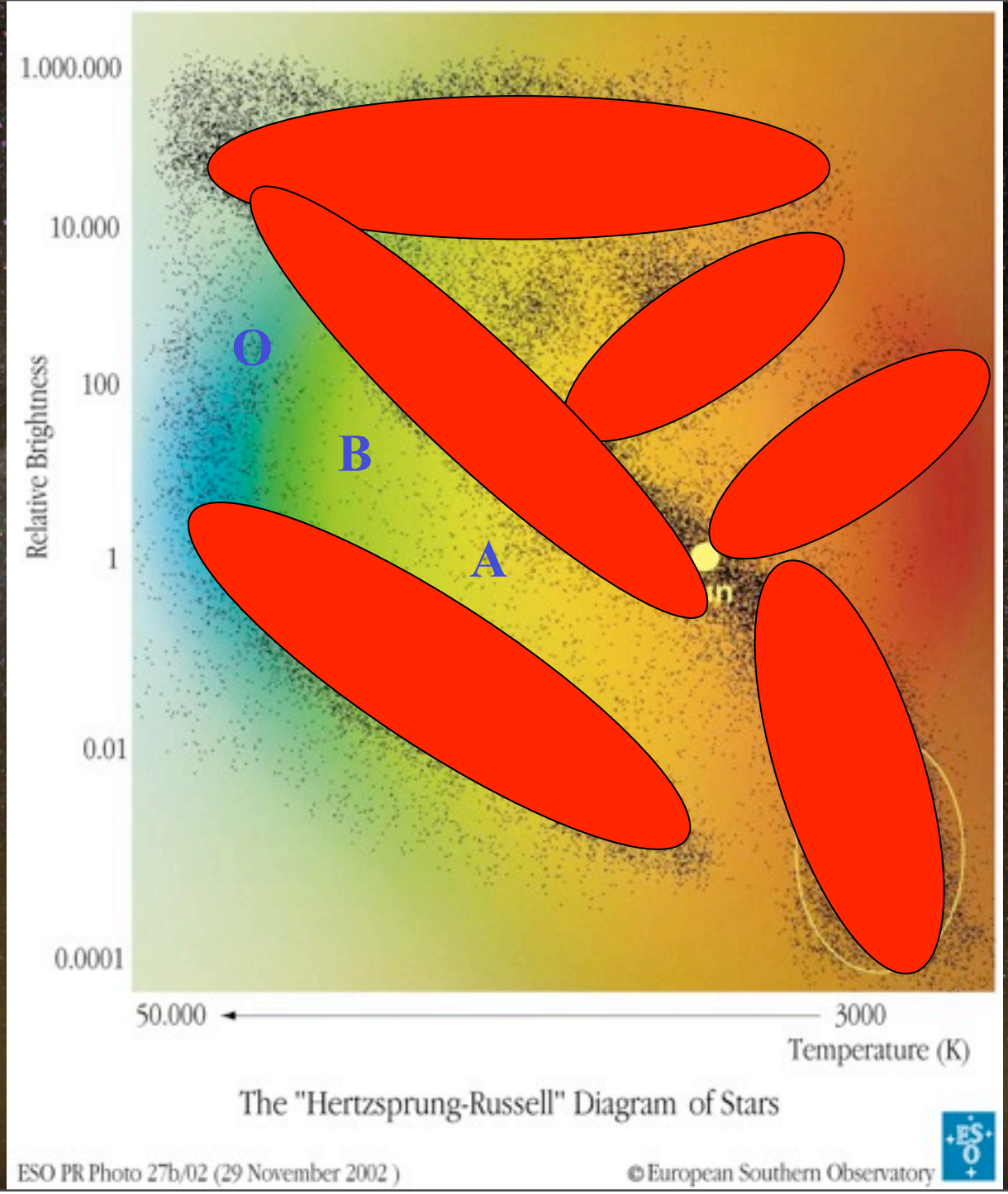


Emission line stars:

Evolved or young

Cool or hot:

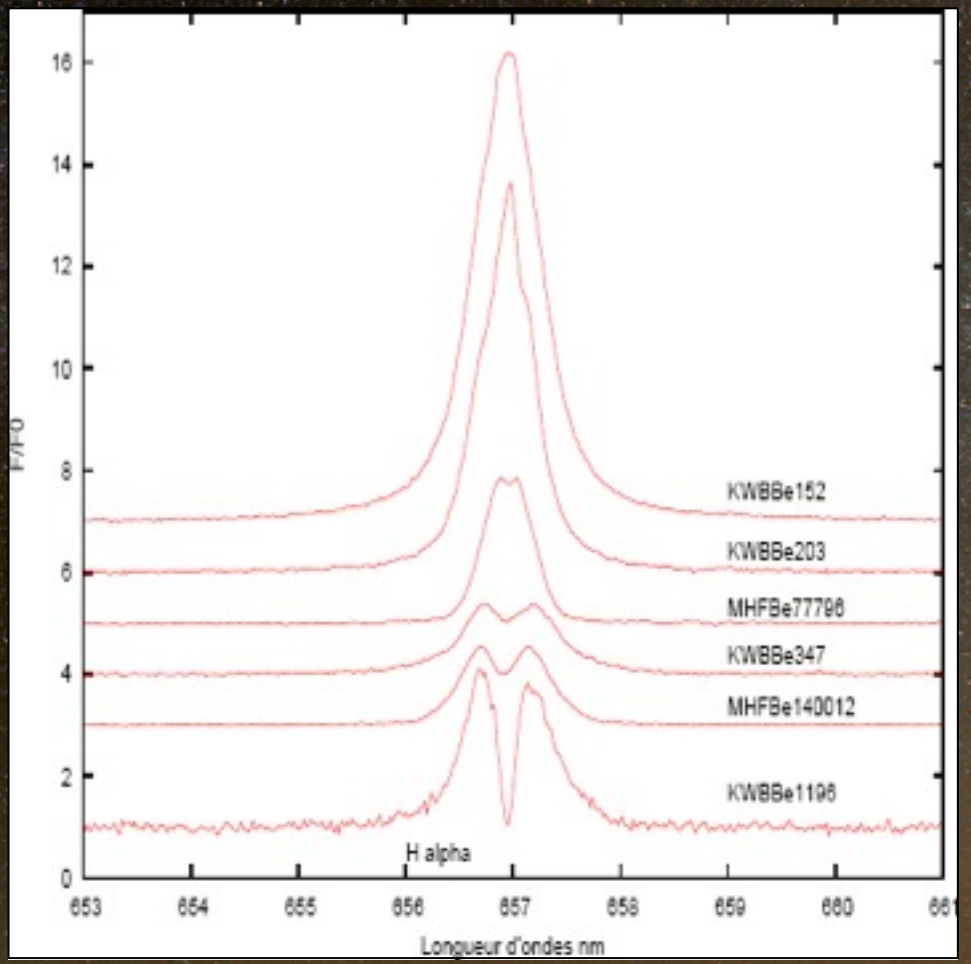
WR, LBV, Oe, Of, Be, Sge, PNe, HBe/Ae, B[e], HB[e], Mira e, TTauri, UV Ceti, Flare...

Introduction: ELS and Be stars

Secchi (1867): 1st Be star found: γ Cas

Classical Be stars:

- non supergiant OBA-type stars, have displayed, at least once, in their spectrum emission lines (Hα). (*Collins 1987*)
- Emission lines come from circumstellar disk *(Struve 1931)* formed by episodic matter ejections from the central star.
- **Links with:** the rotation (very fast rotators), the stellar evolution, the metallicity (Z), the density, the binarity…?



Rotational velocities, metallicity, and Be stars

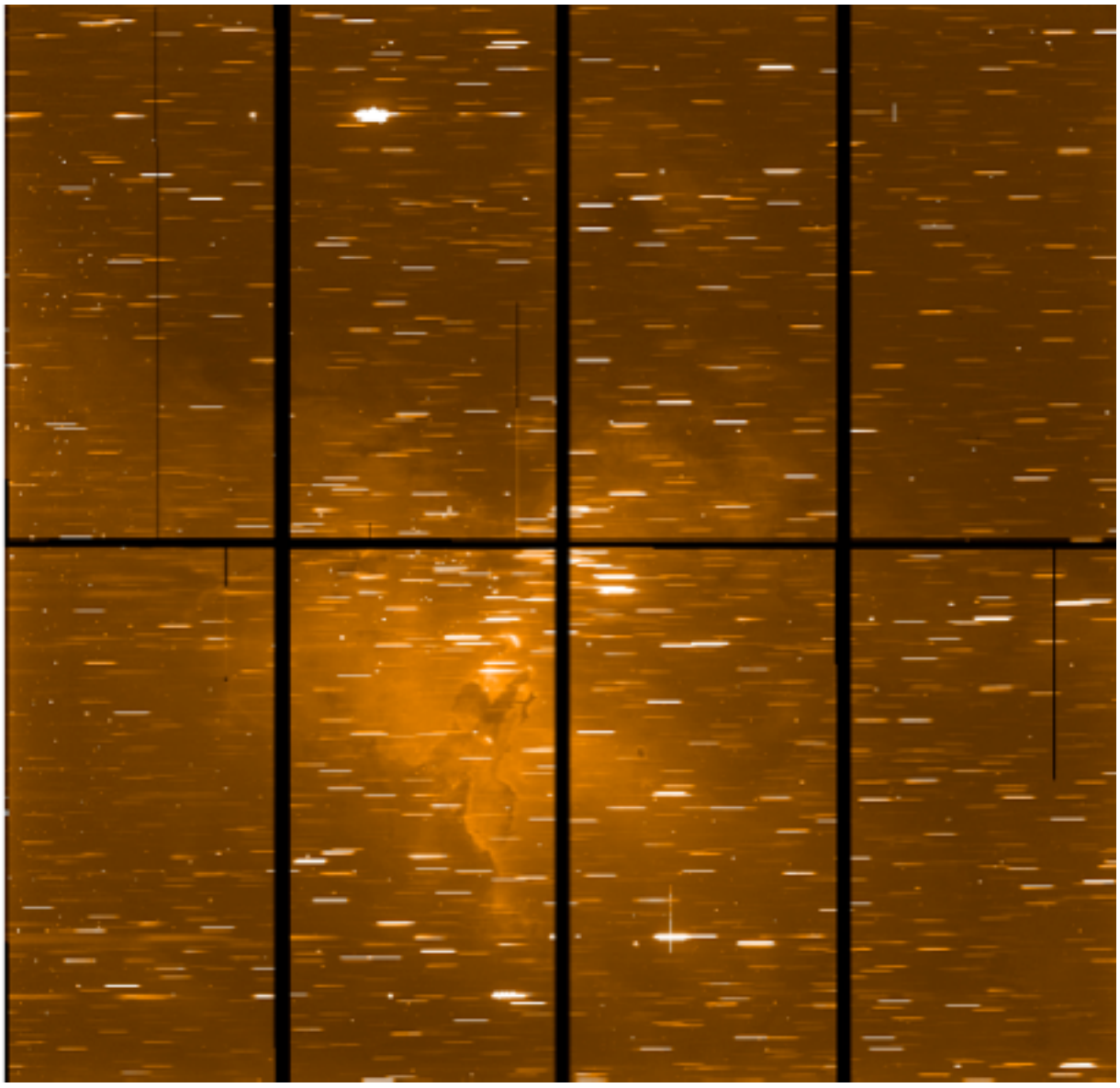
Theory	Observations, few references
Maeder & Meynet (2001): **at low metallicity** (LMC/SMC), **lower mass-loss** (stellar winds),	*Bouret et al. (2003)*, *Vink et al. (2007)*
⇒ **Lower angular momentum loss** ⇒ **higher rotational velocities**	*Keller (2004, 100 B* ✰ LMC), *Martayan et al. (2006, 2007:* 178 BBe ✰ LMC, 344 BBe ✰ SMC), *Smartt, Evans, et al. (2005-2008:* 241 OB✰ LMC, 244 ✰ OB SMC)
Maeder et al. (1999), Ekström et al. (2008): ⇒ more fast rotators at low Z? ⇒ **more Be stars at low Z (SMC)?**	Photometry: *Maeder et al. (1999*, 1 SMC Ocl, photometry), *Wisniewski et al. (2006, 2008,* 8 SMC Ocl, 5 LMC Ocl) Spectroscopy: *Martayan et al. (2006, 2007*, field)

The WFI Hα spectroscopic survey

- Needs to increase statistics: **more open clusters + constrain freedom degrees** (age, metallicity)
- Observations (PI: Baade, 25-26 Sep. 2002)
- 2.2m ESO La Silla Chile
- **ESO/Wide Field Imager** (8kx8k, 33'x34')
- **Slitless spectroscopic mode**
- **Grism** R~150
- **+ Hα filters** (MW broad bandpass: 200 nm, LMC/SMC reduced bandpass: 7 nm needed because the crowding)
- Exposure time ~200-600s
- **Not sensitive to the diffuse ambient nebulosity**
- **Not sensitive to weak emission**

  ⇒ lower estimates of ELS content.

WFI slitless in MW-NGC6611



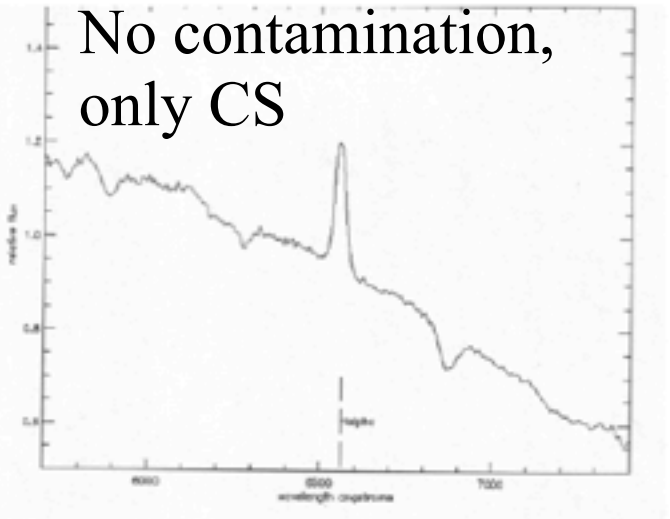
33’

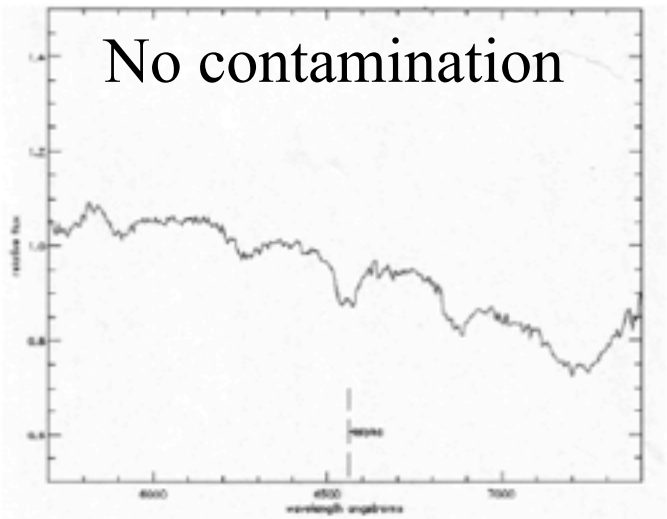
Not sensitive to diffuse nebulosity 34’

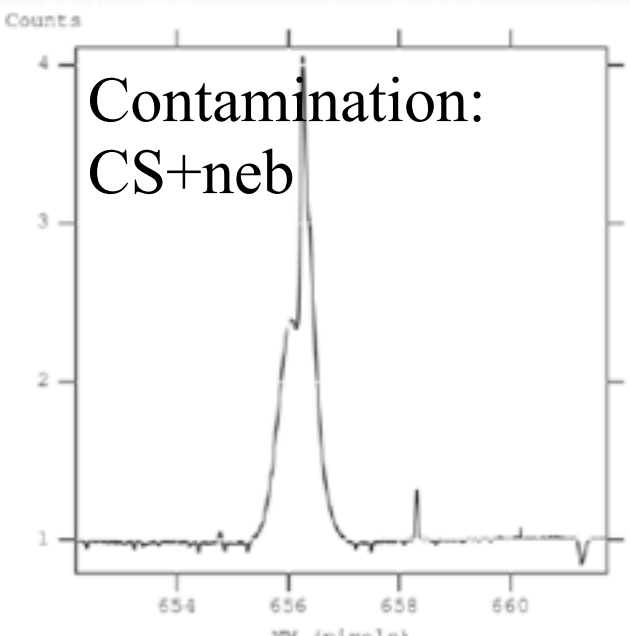
WFI slitless in MW-NGC6611

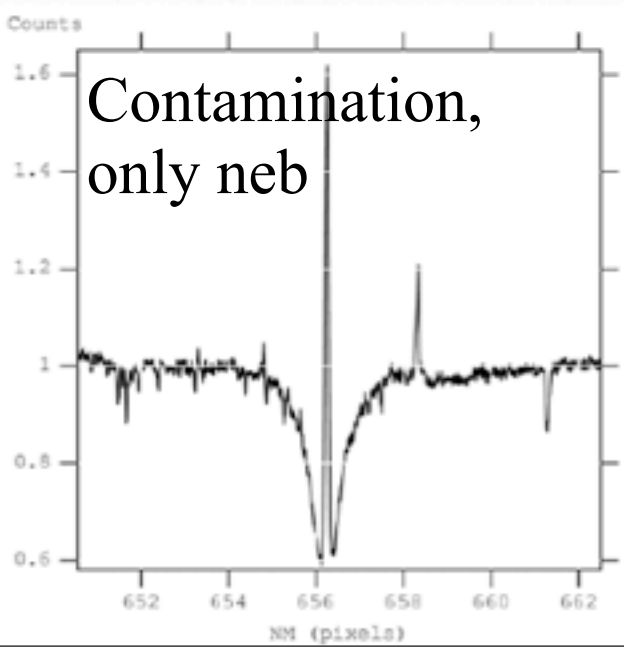
CS. + neb. emissions

Only neb. emissions









WFI slitless spectra

FLAMES spectra

WFI Hα spectro in the Magellanic Clouds

LMC:

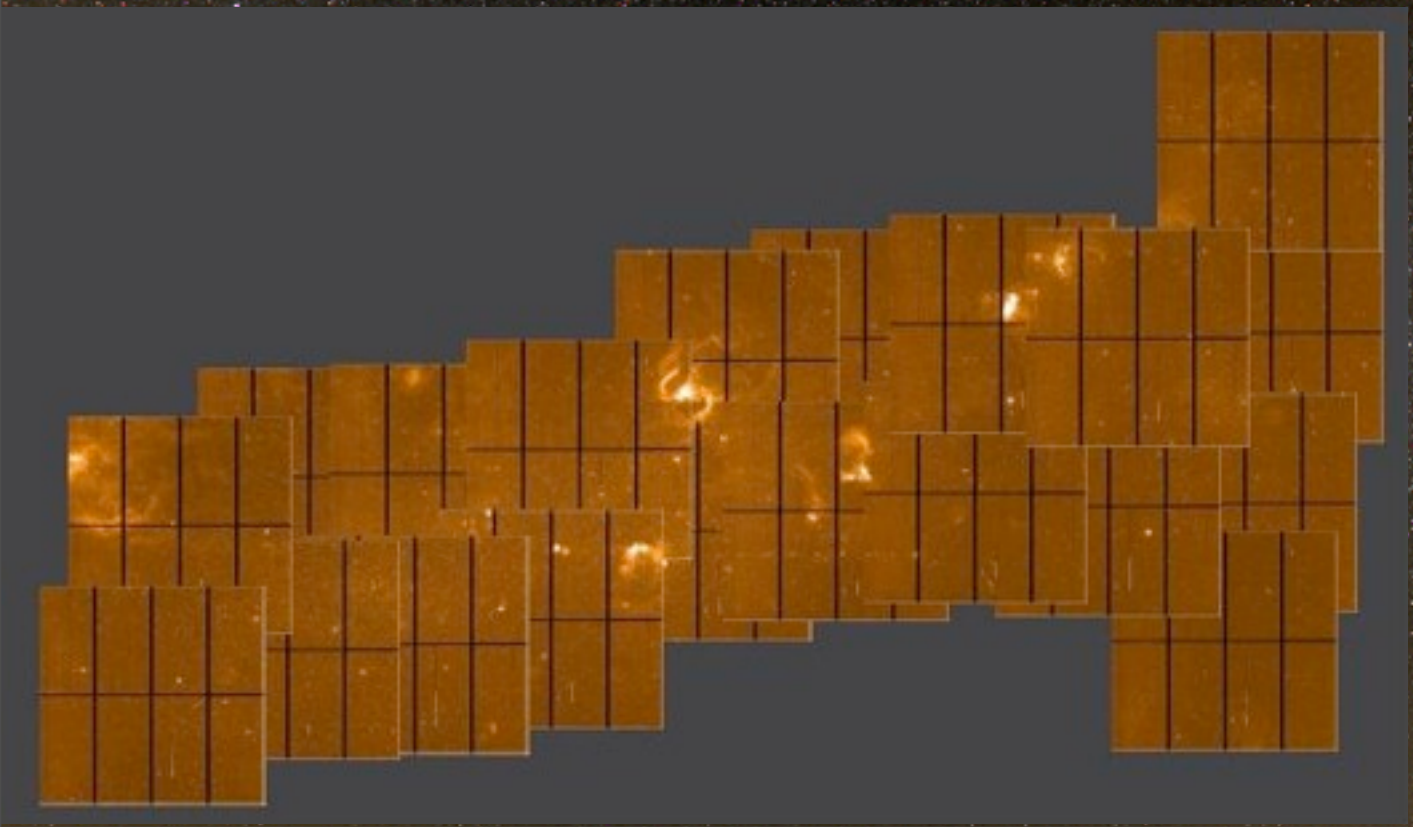
Central parts

20 images

~(4°)²

5 million spectra

WFI Hα spectro in the Magellanic Clouds



LMC:

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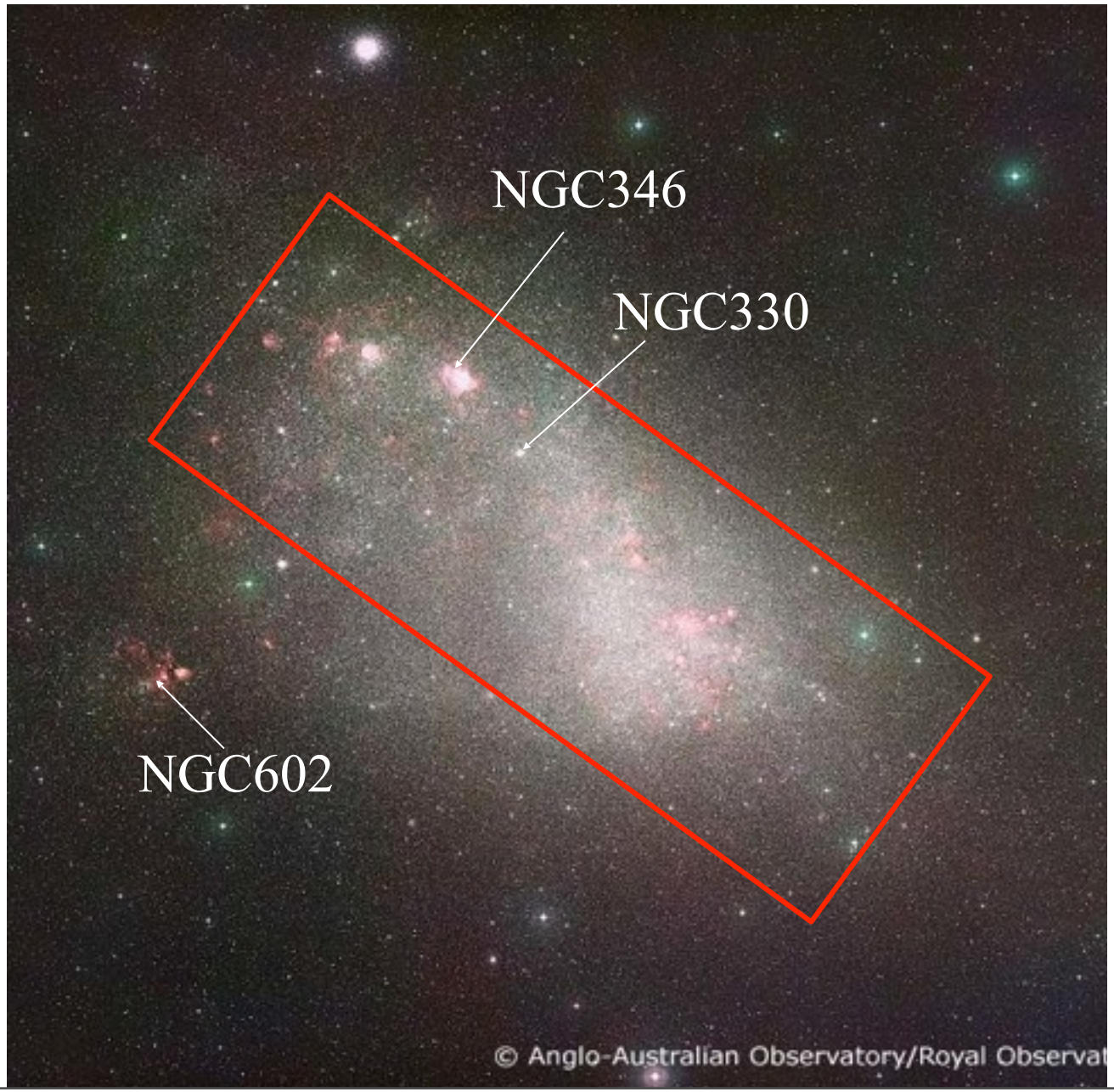


SMC:

Central parts

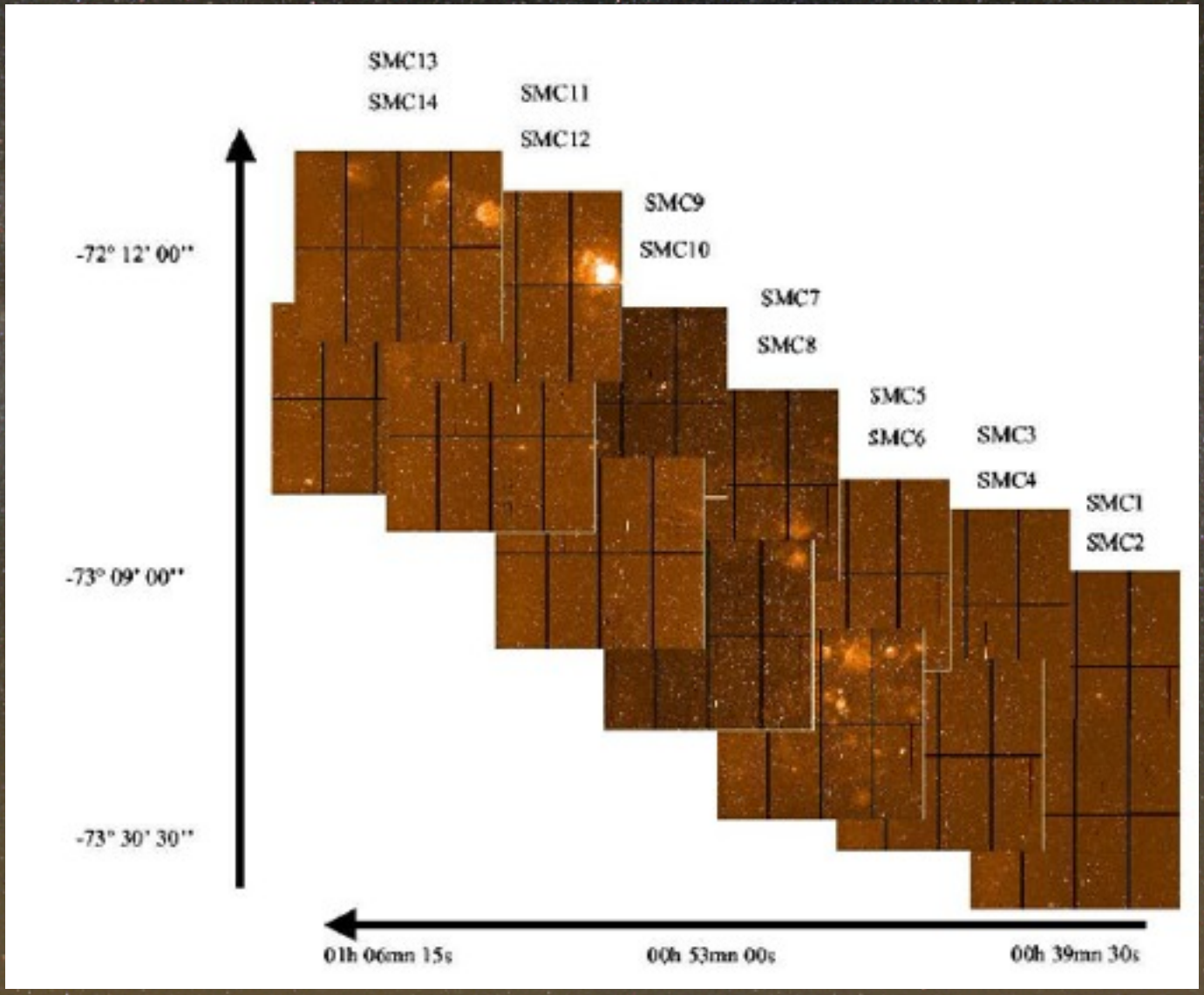
14 images

~(3°)²

3 million spectra

Martayan et al. 2010a

WFI H alpha spectro in the Magellanic Clouds



SMC:

Central parts

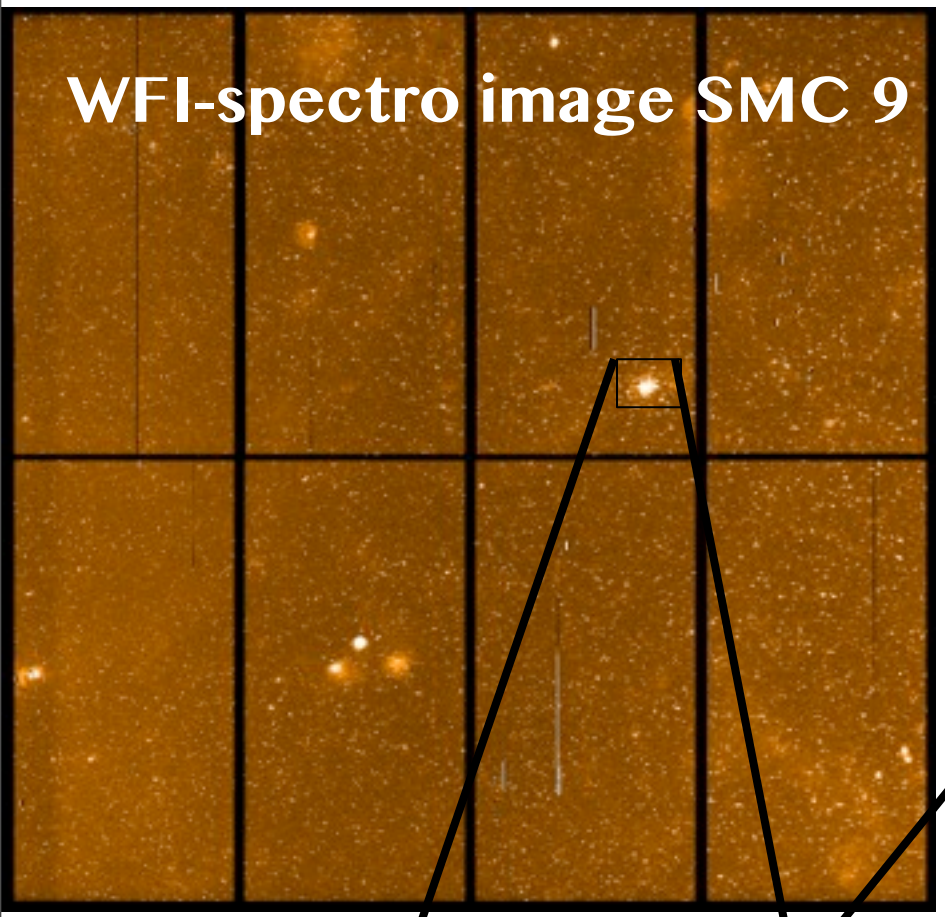
14 images

~$(3°)^2$

3 million spectra

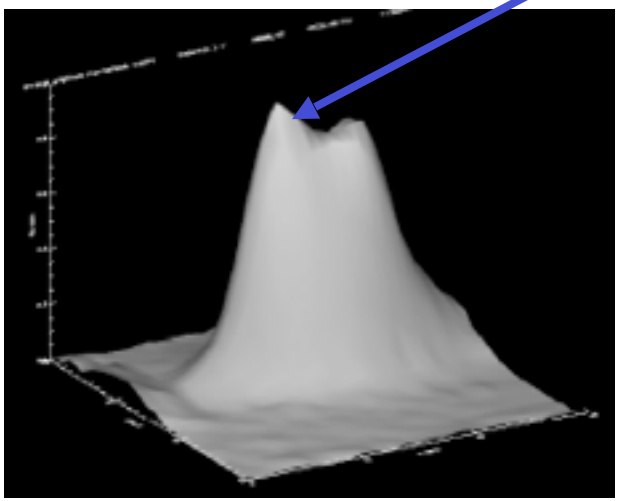
Martayan et al. 2010a

ALBUM code

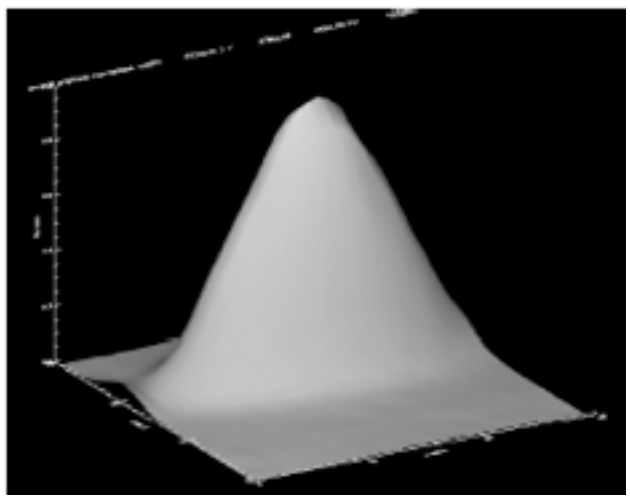


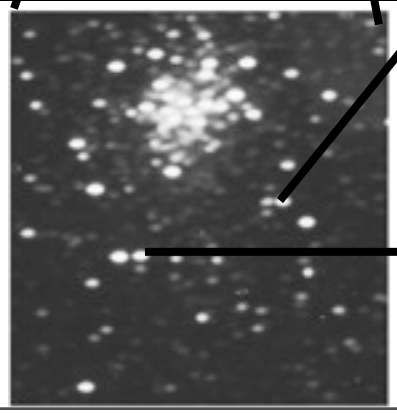
Hα

Source with emission



Source without emission





Open cluster

NGC330

ALBUM code

Martayan et al. 2006, ESO cal. workshop

Efficiencies WFI studies

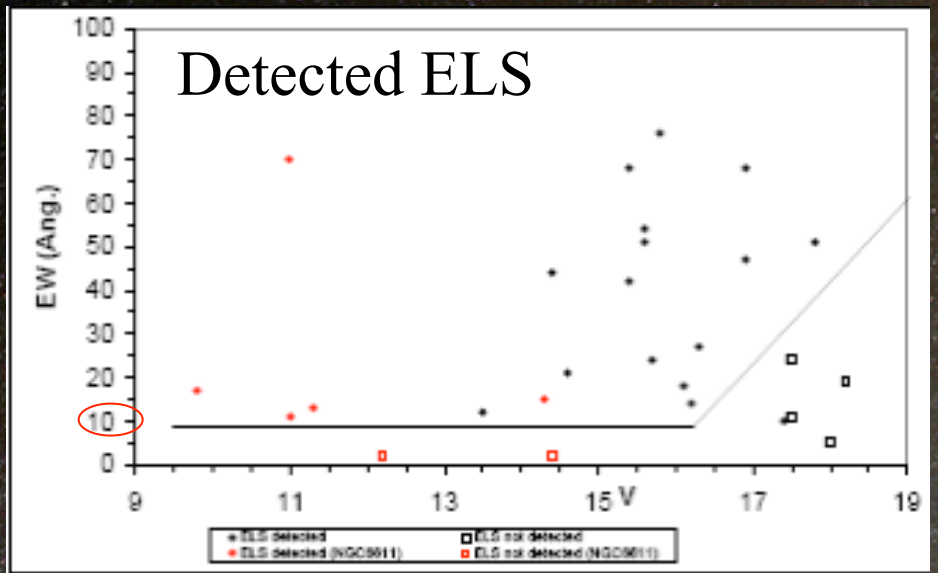
- **Extraction**: 50 to 85%

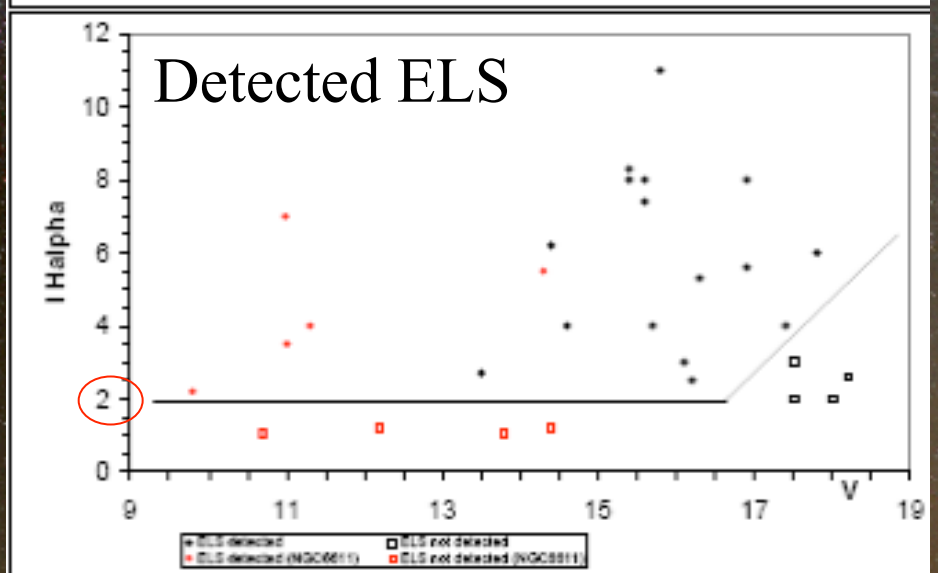
(SExtractor *Bertin & Arnouts 1996*)

- **Hα emission line detection** (ALBUM):
  - In EW
  - In Intensity

- Hα EWs, Hα I from

Martayan et al. (2007b, 2008a), Hummel et al. (1999, 2001)





Martayan et al. 2013

Classification

ALBUM

List of stars (ELS or not)

~10000 spectra

Astrom software

(~0.5")

(Wallace & Gray 2003)

List with astrometry

Cross-match with OGLE-75% (Udalski et al. 1998)

List with OGLE photometry BVI

E[B-V] + clusters age (Pietrzynski & Udalski 1999)

Corrected photometry

Distance modulus (Udalski 2000)

Absolute photometry

Lang (2001) calibration

"spectral types" Classification 4300 stars, 84 SMC clusters

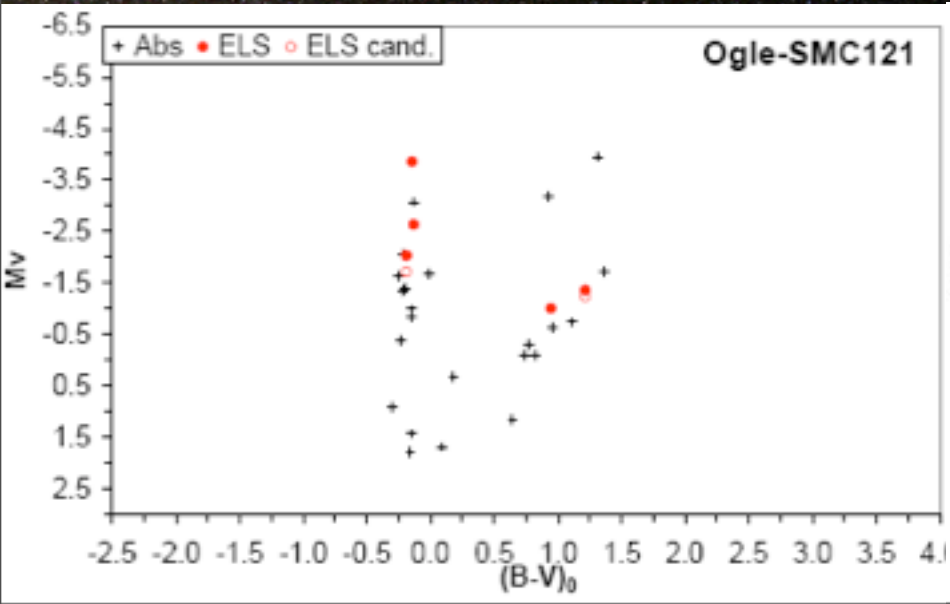
Comparison SMC, MW of Be stars in Oopen clusters

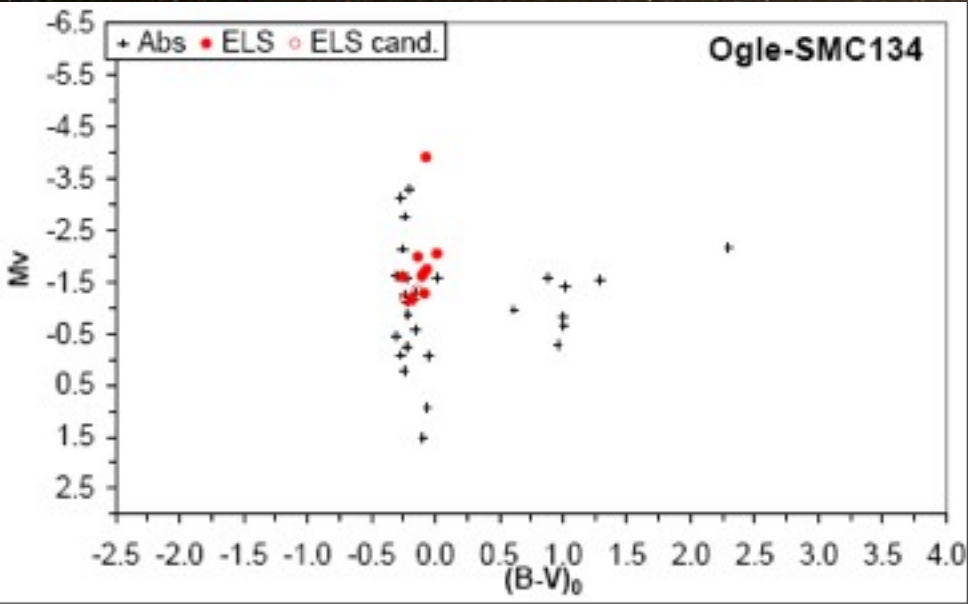
MW: *McSwain & Gies (2005)*

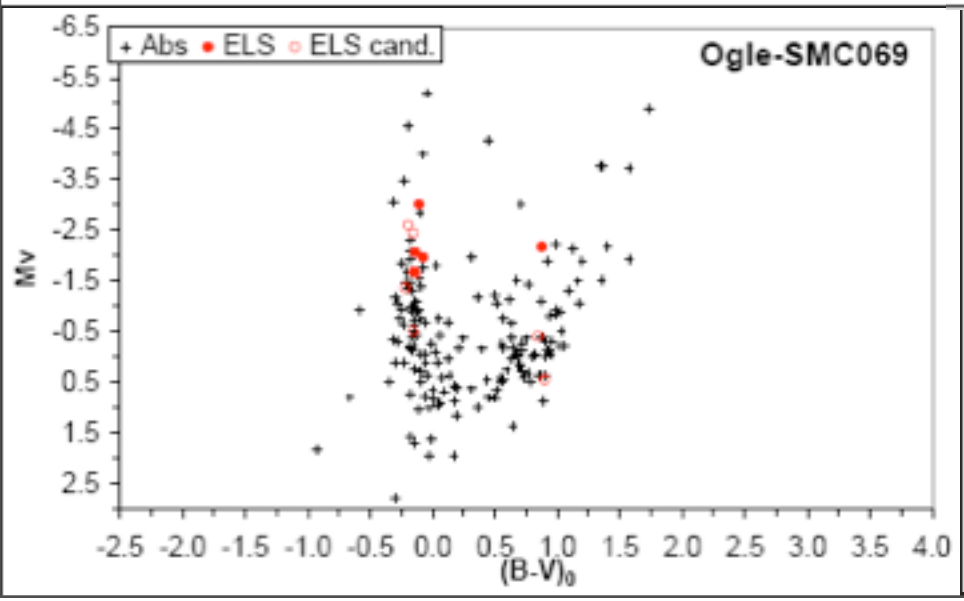
Statistics of Be stars vs Z, spectral type, density, age, evolution: *Martayan et al. 2010a*

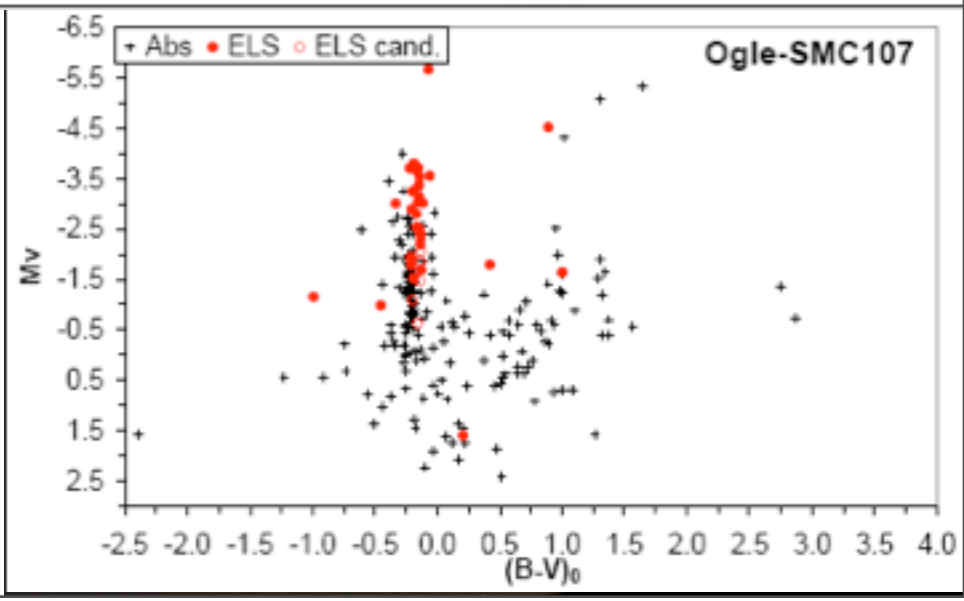
HR CMDs: individual several examples

Martayan et al. 2010a

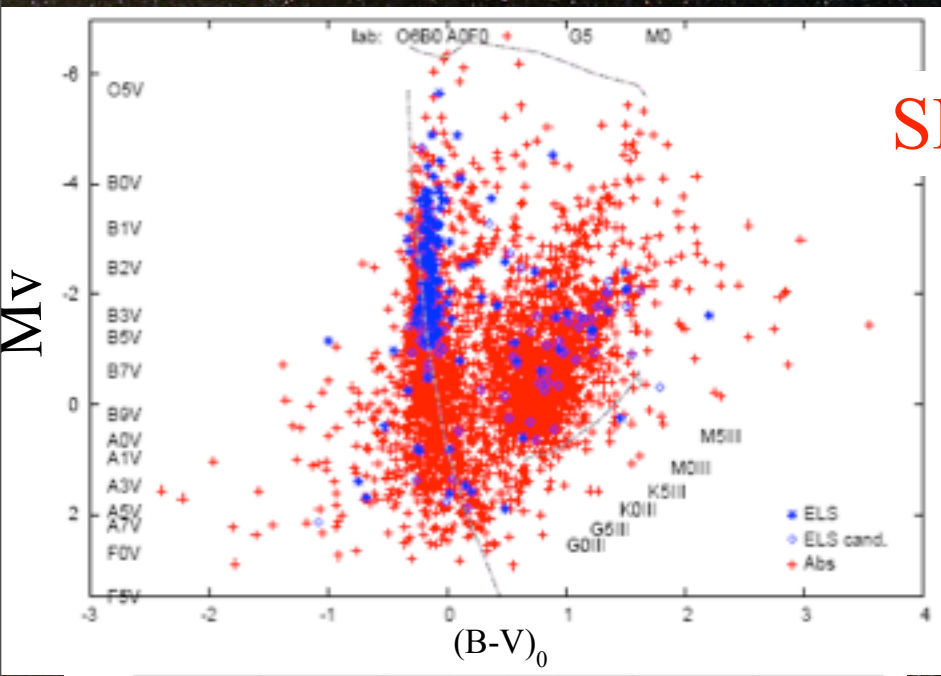


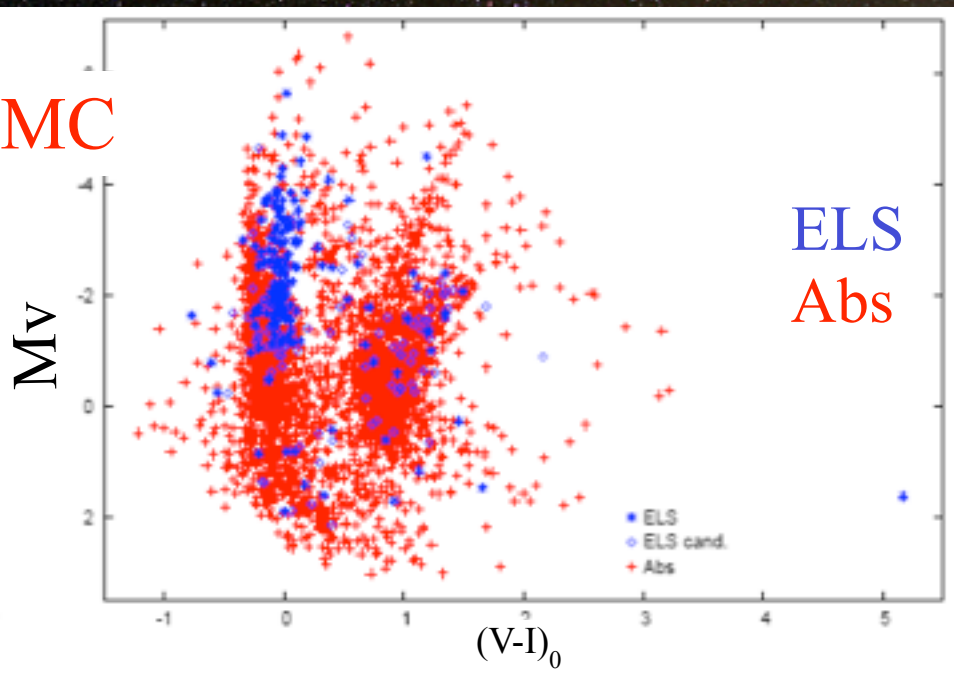


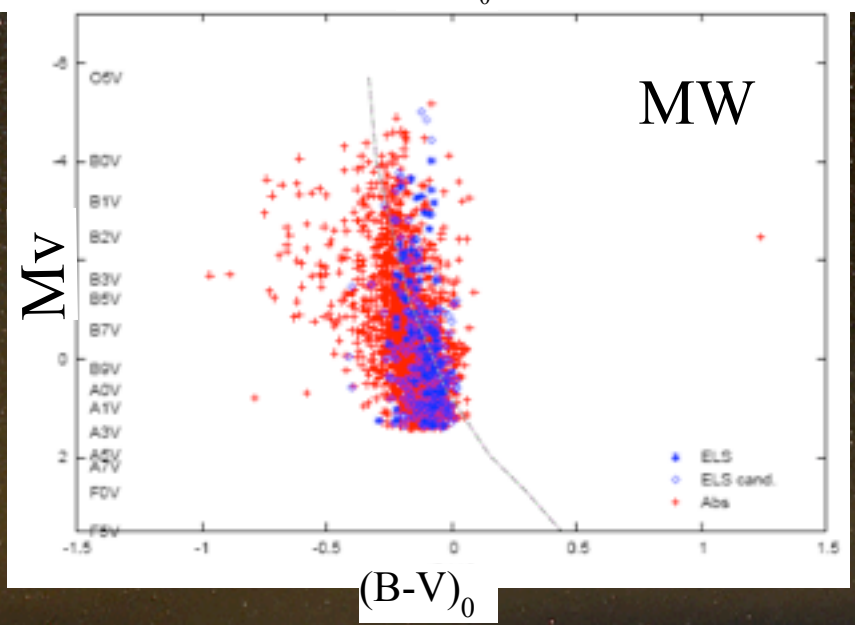




HR CMDs: global







SMC: $Mv,(B-V)_0$; $Mv,(V-I)_0$

MW: $Mv,(B-V)_0$ from data of McSwain & Gies (2005)

Same range of ages, we group the stars to avoid the variability between open clusters.

Ratios of Early Be stars: SMC vs. MW

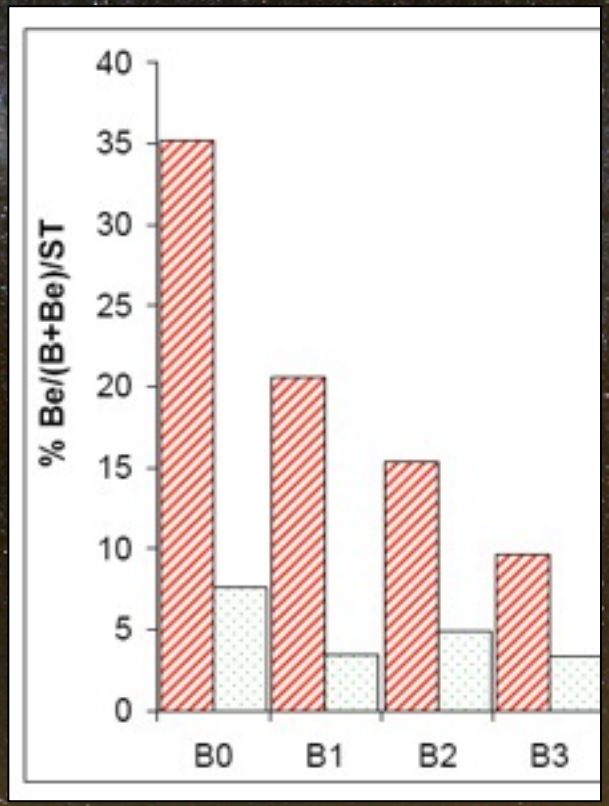
SMC: *Martayan et al. (2010a)*

MW: *McSwain & Gies (2005)*

Ratios of definite Be stars to all B-type stars by spectral type categories:

B0e/(B0e+B0), B1e/(B1e+B1), etc.

	SMC	MW
N OCl	**84**	**54**
N Be stars	163	168
N B stars	1384	1761
N total stars	4437	20322



3 to 5 more Be stars in the SMC than in the MW, ditto for Oe stars.

Confirmation and **quantification** of the trend seen by *Maeder et al. (1999)* and *Wisniewski et al. (2006, 2008)*.

Samples not complete for types later than B3

Martayan et al. 2010a

Preliminary results in LMC, see poster by G. Aguayo

Same procedure than in the SMC

~90 LMC open clusters, 2950 stars

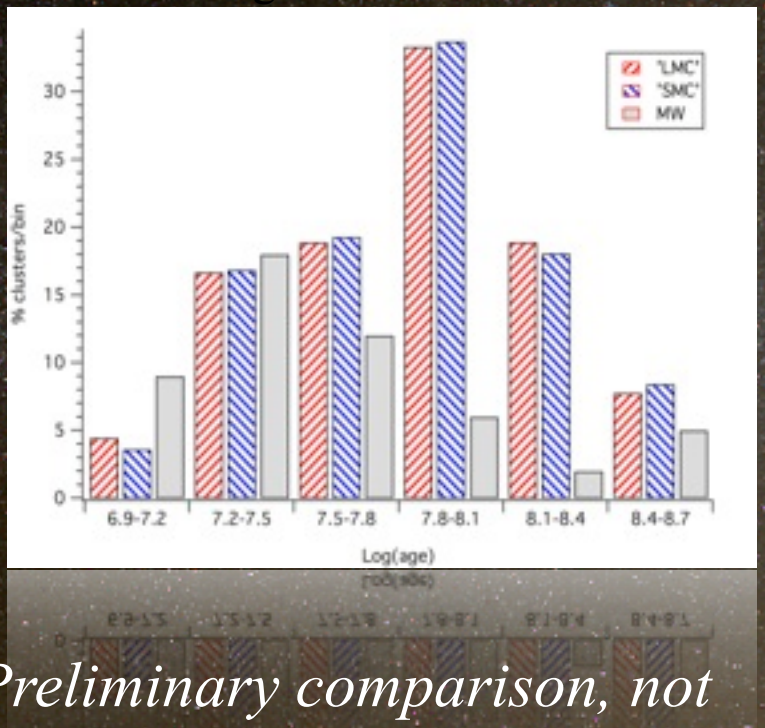
Age distribution chosen to be the same than in the SMC study

66 ELS + 244 ELS?, classification ongoing

Be to B stars ratio ongoing determination

Aguayo et al., in prep.

Age distribution



Preliminary comparison, not conclusive yet:

% "Be max" LMC: 2.24%

% Be SMC: 2.46%, MW: 0.26%

Preliminary results in LMC, star formation region of NGC1850
see poster by G. Aguayo

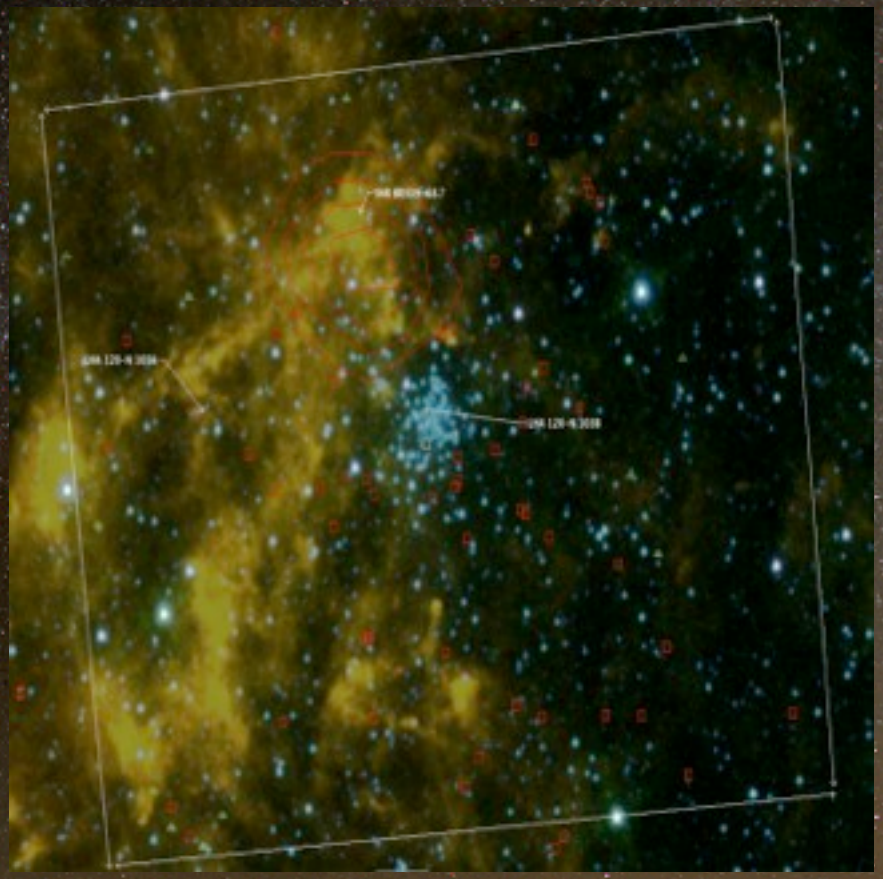
WFI slitless spectra => ELS (all types)

photometry + lightcurves combination

⇒ Classification: PMS, Be, Giants

⇒ Spatial distribution of ELS: function of mass/evolution

- segregation
- ELS = tracers of star formation



Garrido, Aguayo et al. 2013, in prep.

Summary

- Combination Wide Field + slitless => 8 million of spectra in 1 night = powerful for statistics + catalogues + no contamination by diffuse nebulosity
- More Be to B stars in the SMC (low Z) than in the MW (high Z)

- Ongoing work in the LMC open clusters
- SMC field treatment: 4.5% => 477 ELS, expected ~11000 ELS (PMS, MS, post MS)

Questions/more results

- Please have a look at *Martayan et al. A&A 2008, 489,459* and *2010,509,A11*
- And also later this year at *Garrido, Aguayo et al. and Aguayo et al.*
- Send questions to cmartayan@eso.org
- Many thanks to Gustavo Aguayo (master student) for presenting this talk while I have to attend an ESO astronomers/engineers observatory meeting (my apologizes).