The IACOB project:

"Quantitative spectroscopic analyses"

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Outline of the talk

- Introduction: Massive OB type stars
- The IACOB project
  - Aims and working packages
  - WP1: The IACOB spectroscopic database
  - WP3: Quantitative spectroscopic analyses
- Synergies between IACOB and Gaia

Concerning OB-type stars

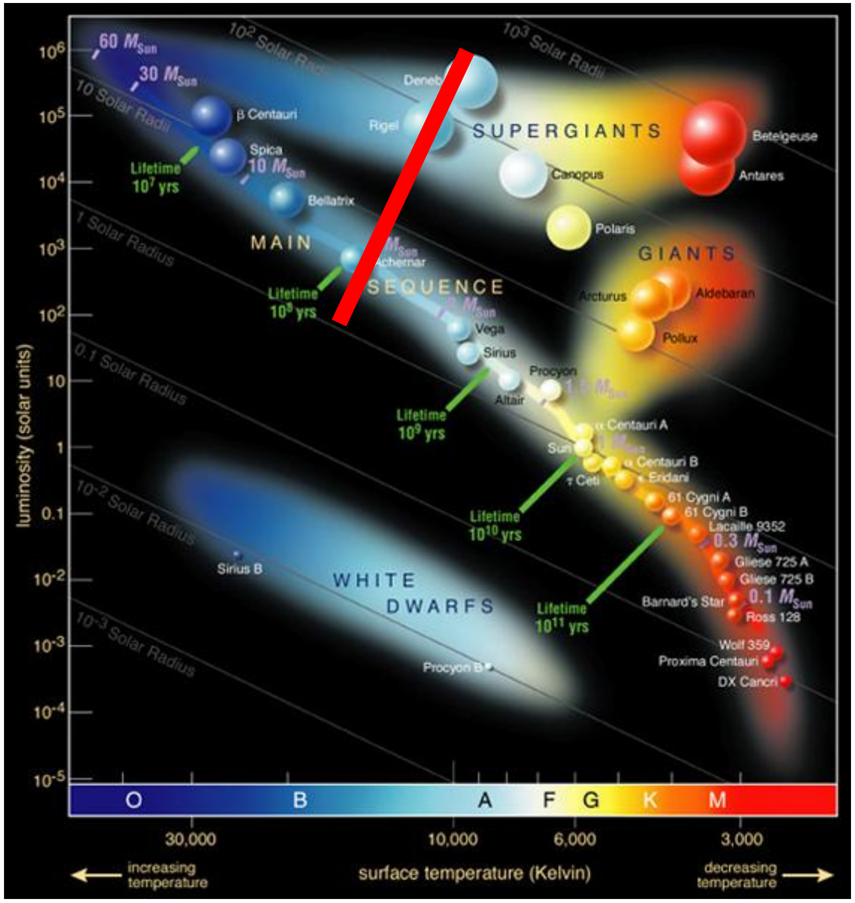
Master pieces in the formation and evolution of stellar clusters & associations

They are:

- Massive
- Hot
- Large
- Luminous
- Windy

- Few and complex

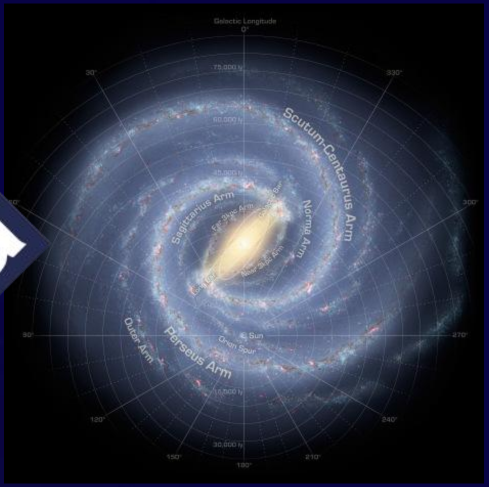
Every newly detected massive star is a treasure



- Intimatelly linked to the ISM
  (winds, SNII, HII regions)

- Associated to star-forming regions

The Gaia vision



Astrometry
ASTRO
a few – 300 μas

Photometry
BP: 320-660 nm
RP: 650-1000 nm

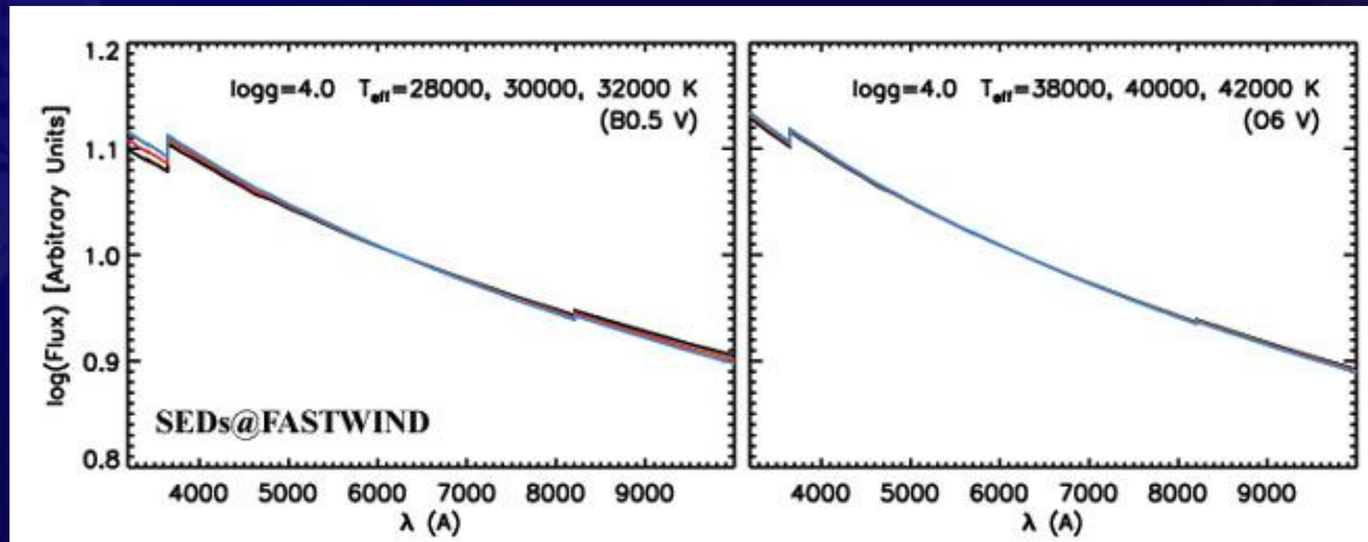
Spectroscopy
RVS
847-874 nm
R = 11500

The Gaia vision of Massive stars

Photometry

BP: 320-660 nm

RP: 650-1000 nm

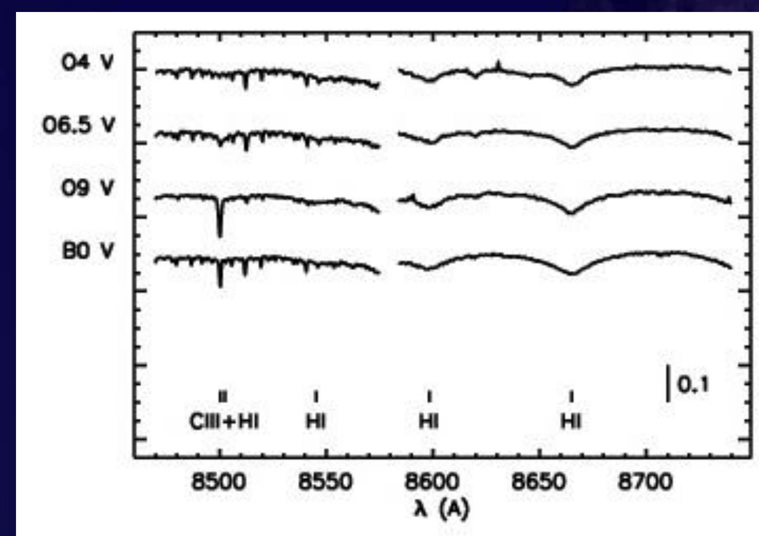


Spectroscopy

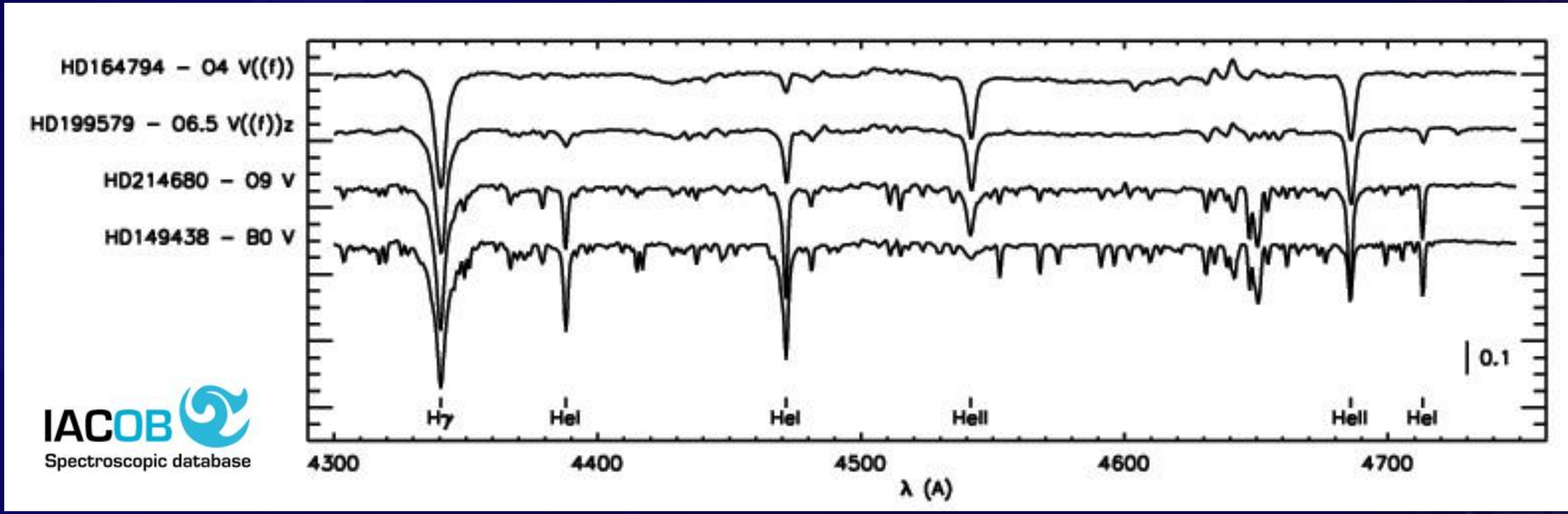
RVS

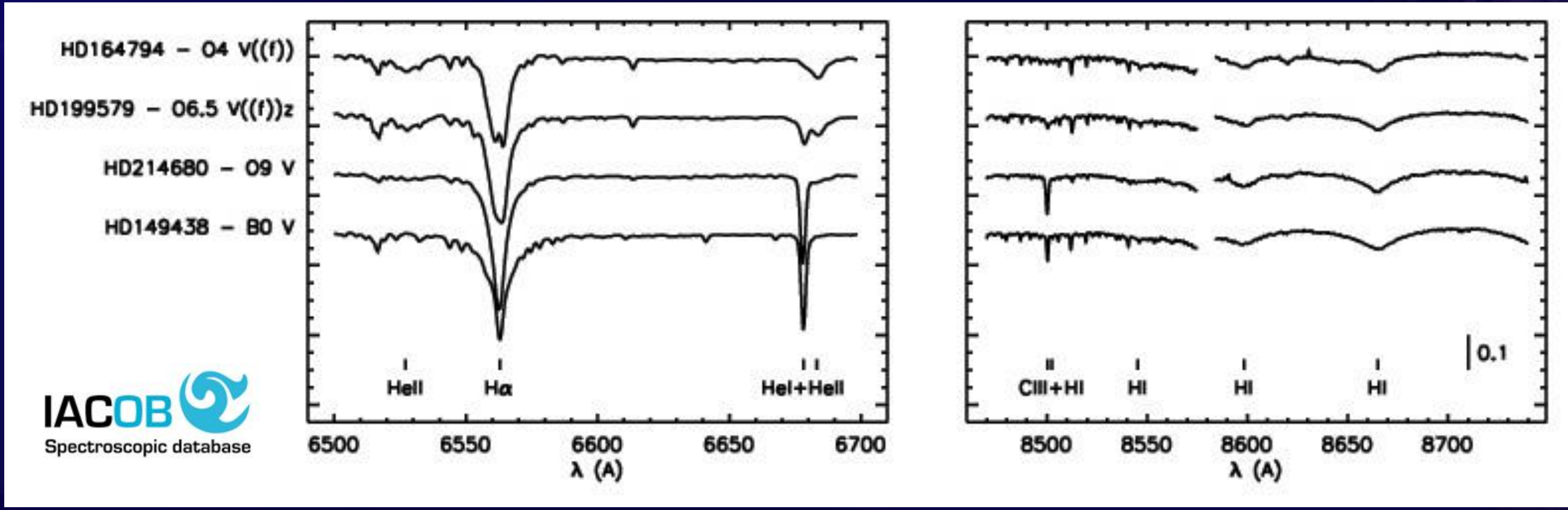
847-874 nm

R = 11500



Stellar parameters of Massive stars: Better to use optical spectra





On ground massive spectroscopic surveys of Massive stars

	GOSSS	OWN	IACOB	**NoMaDS**
Resolution	~2500	~40 000	46 000	**30 000**
Sp. range	3900-5100 Å	3700-6900 Å	3700-6900 Å	**3800-7300 Å**
Mag. limit	$B < 13$	$V < 8$	$V < 8$	$\boldsymbol{V < 13}$
S/N	~300	~200	~200	**~200**
δ	Full sky	$\delta < 12^o$	$\delta > -20^o$	$\boldsymbol{\delta > -12^o}$
# stars (current)	800	240	200	—
# stars (end 2012)	2400	240	200	**200**
Telescopes (in m)	OSN-1.5, CAHA-3.5 LCO-2.5, WHT-4.2	LCO-2.5, CASLEO-2.2, ESO-2.2	NOT-2.5	**HET**
Dates	2007-2013	2005-2013	2008-2013	**2011-2012**
P.I.	Maíz Apellániz	Barbá	Simón-Díaz	**Pellerin**

+ GOSC: Galactic O star catalogue
  (P.I: J. Maiz-Apellaniz)

+ Atlas of standards observed in the Gaia spectral range
  (P.I: I. Negueruela) MERCATOR-1.2

The IACOB project: aims and working packages

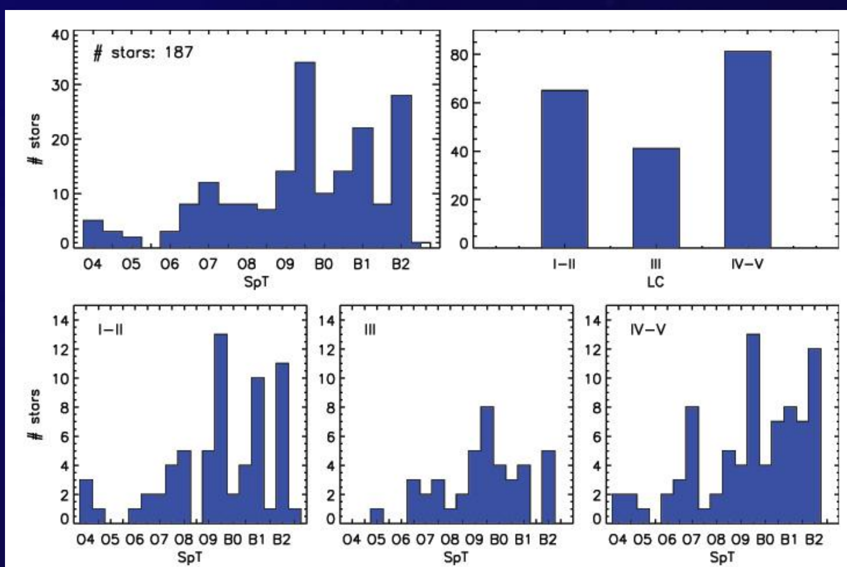
Objective: Step forward in our knowledge of Galactic Massive stars using a large, homogeneous, high-quality spectroscopic dataset and modern tools for the quantitative spectroscopic analysis of O and B-type stars

IACOB working packages:

- WP-1: The IACOB spectroscopic database
- WP-2: Line-broadening in OB stars (vsini, pulsations?)
- WP-3: Quantitative spectroscopic analyses (Teff, R, M, L, M_{dot} ...)
- WP-4: Abundances in OB-type stars
- WP-5: Massive binary/multiple systems
- WP-6: Massive stars and the ISM (IS lines/bands and ionizing fluxes)

WP1: The IACOB spectroscopic database

	Obs. run	Dates
Telescope: NOT2.56 m	08 A-D	2008/11/05-08
Instrument: FIES	09 A-D	2009/11/09-12
Fiber: med-res	10 A-C, D	2010/06/05-07, 22
Spectral range: 3800 - 7000 Å	10 D	2010/07/15
Resolution: 46000	10 F	2010/08/07
Sampling: 0.03 Å/pix	10 G	2010/08/24
Spectral type: O4-B2 (I-V)	10 H-J	2010/09/07-09
# stars: 187 # spectra: 968	10 K-L	2010/10/23-24
# O stars: 104 # B stars: 83	11 A-E	2011/01/11-15



IACOB Spectroscopic database

The largest homogeneous, multi-epoch, high-resolution, spectroscopic database of Northern Galactic O and early-B type stars compiled up-to-date

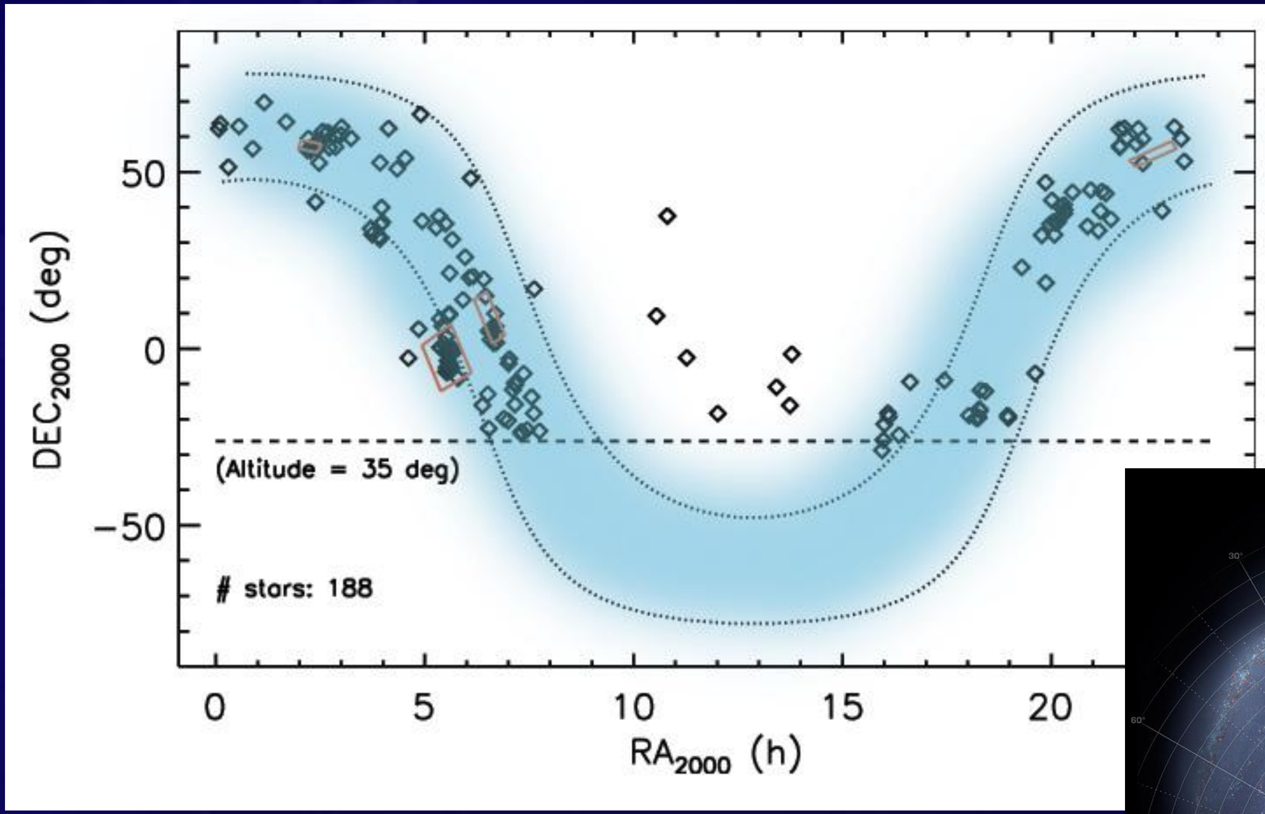
O stars: 104 (V< 8)

Based on the GOSC v2 (*Sota et al. 2008*)

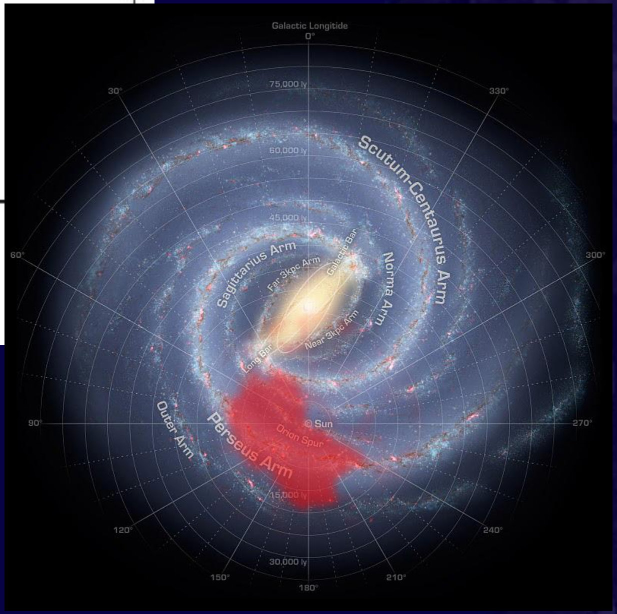
B stars: 83

- B-type stars in Ori OB1
- Investigation of the "macroturbulent" broadening in OB stars
- Still biased to B Sgs/Gs and narrow lined B dwarfs

WP1: The IACOB spectroscopic database



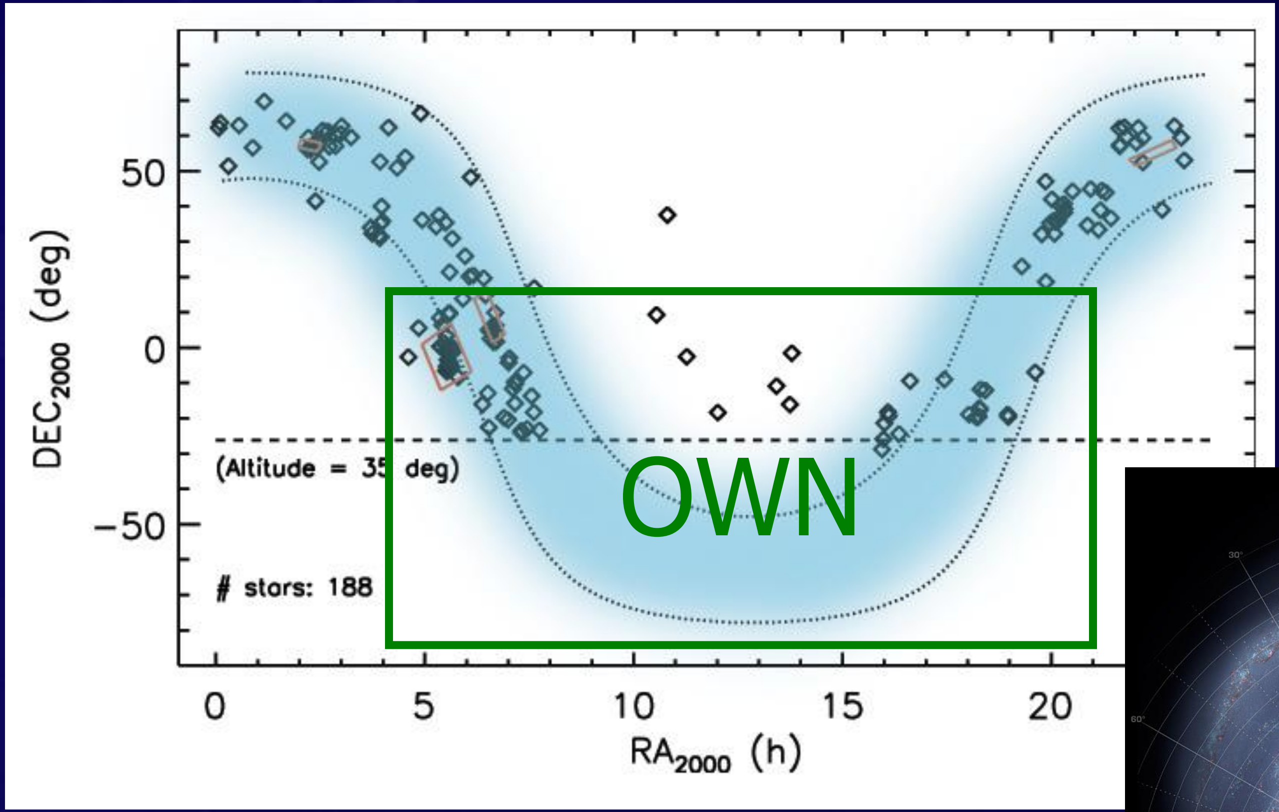
IACOB Spectroscopic database

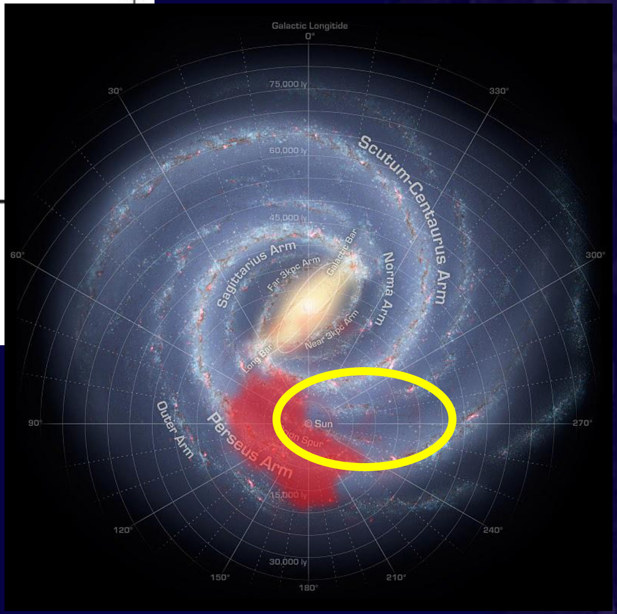


Observable from El Roque de los Muchachos
(La Palma, Spain)

WP1: The IACOB spectroscopic database

IACOB Spectroscopic database





Observable from El Roque de los Muchachos
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WP3: Quantitative spectroscopic analyses

Be careful when deriving T_{eff} using
PHOTOMETRY
in the case of O and B-type stars

→ Better use SPECTROSCOPY

- Good progress in the stellar atmosphere modelling of massive stars

(realistic stellar atmosphere codes, atomic models, enormous increasing in the efficiency of computers)

- Massive spectroscopic surveys of OB stars in the MW, the MCs and other more distant galaxies (M33, NGC55, IC1613 ...)

(Medium and large size telescopes + multiobject spectroscopy)

- Automatic tools for the quantitative analysis of large spectroscopic surveys of massive stars are more than welcome !!

WP3: Quantitative spectroscopic analyses

The IACOB-grid automatic tool

A

OBJECTIVE
FAST but
ACCURATE

way to perform quantitative spectroscopic analyses of large samples of OB type stars

+

PORTABLE
ADAPTABLE
EASY TO USE

WP3: Quantitative spectroscopic analyses

The IACOB-grid automatic tool

INPUT

- T_{eff}, log$g$, ε(He), β, ξ_t, & log$Q$ ranges
- Used HHe lines and weights
- v sin$i$, Θ_{RT} , v_∞ , M_v

FASTWIND subgrid

Synthetic, broadened HHe line-profiles

χ^2 distribution

Observed spectrum

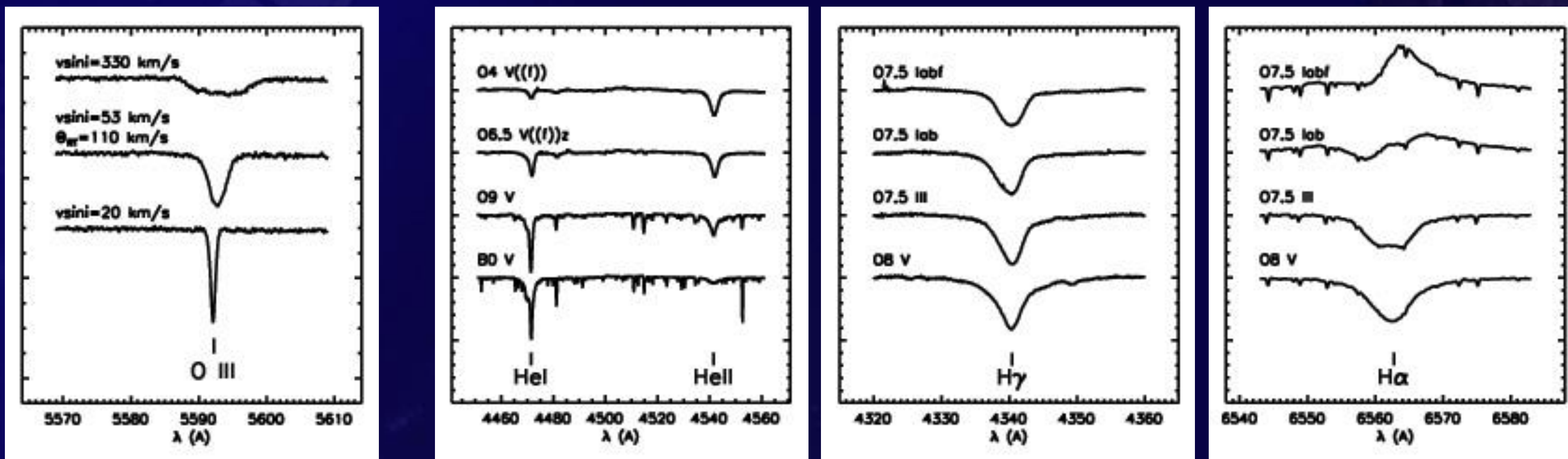
Clipped, v_{rad} corrected HHe profiles

OUTPUT

- χ^2 confidence level (p-value)
- Stellar and wind parameters determination
- Identification of degeneracies

WP3: Quantitative spectroscopic analyses

Diagnostic lines (O star case): HI, HeI-II



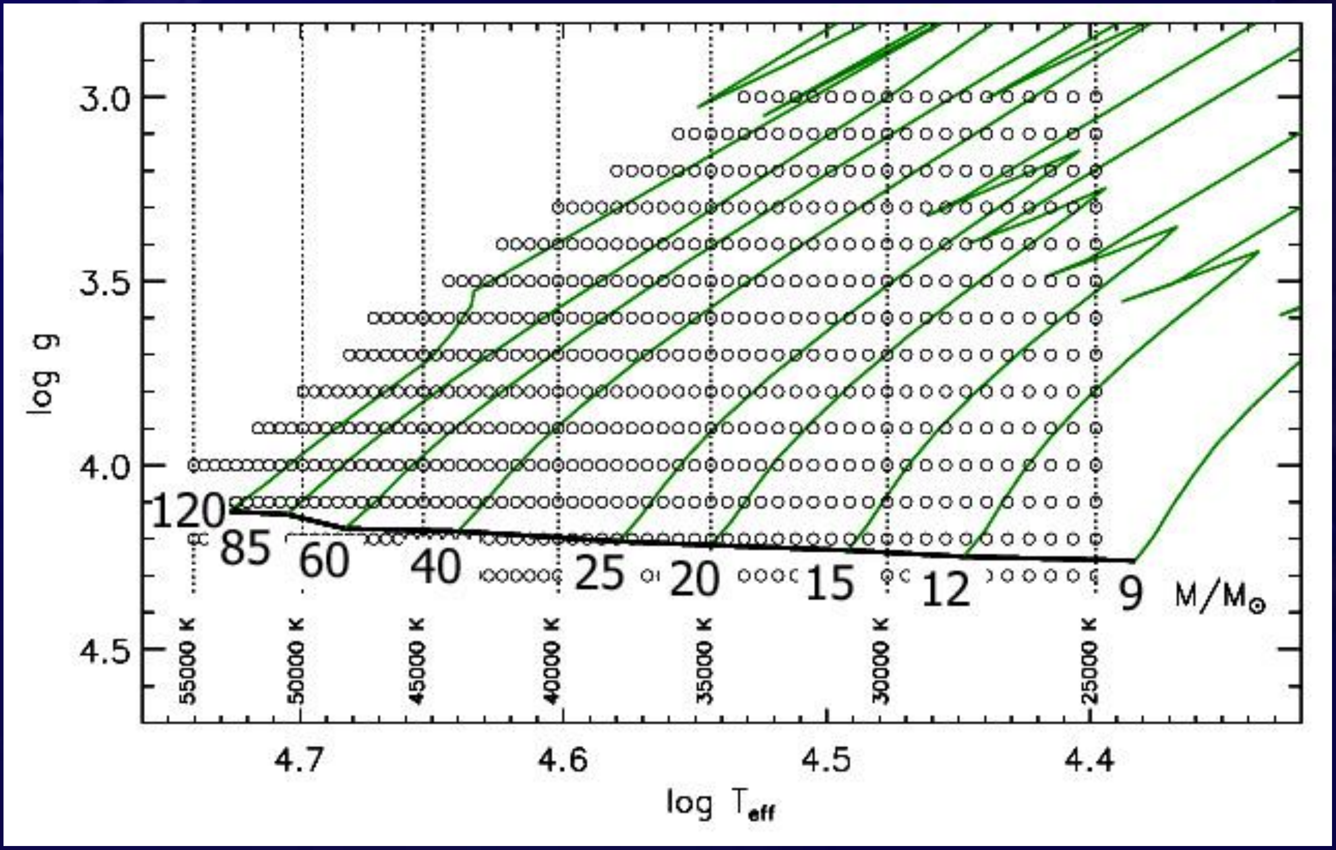
v sin*i*
+
extra-broadening

Stellar and wind parameters

T_{eff} ... log$g$ ... log$Q$ ... ζ_t ... ε(He)

WP3: Quantitative spectroscopic analyses

The FASTWIND O-grid (HHe)



FASTWIND: *Santolaya-Rey (1997), Puls et al. (2005)*

WP3: Quantitative spectroscopic analyses

The FASTWIND O-grid (HHe)

- Total #models / He : 29800
- Total #models / Z : 178800

[New He-plane: ~3 days]

FASTWIND OUTPUT → GRID-tool INPUT

+ Size optimization
+ Read-out time optimization
+ synthetic photometry

GRID-tool INPUT

IDL xdr-files:
- HHe line-profiles
- EWs
- OUT_TOT struct.
- Photometry

- Final size of the grid / Z : 300 Gb → 30 Gb !!
- IDL can restore the each xdr-file and compute the χ^2 in ~ 0.02 - 0.1 s

→ 80000 models in 30 min - 1 hour !!!

WP3: Quantitative spectroscopic analyses

Core of the IACOB-grid automatic tool: χ^2 computation

$$\chi^2\,(\text{line}) = \Sigma_{\lambda=1,N\lambda}\,[\,(F_{m,\lambda} - F_{o,\lambda}) / \sigma\,]^2 / N_\lambda$$

σ = 1/SNR *N_λ : Number of frequency points in the line*

$$\chi^2\,(\text{total}) = \Sigma_{i=1,NL}\, w_L\, \chi^2\,(\text{line}) / \Sigma_{i=1,NL}\, w_L$$

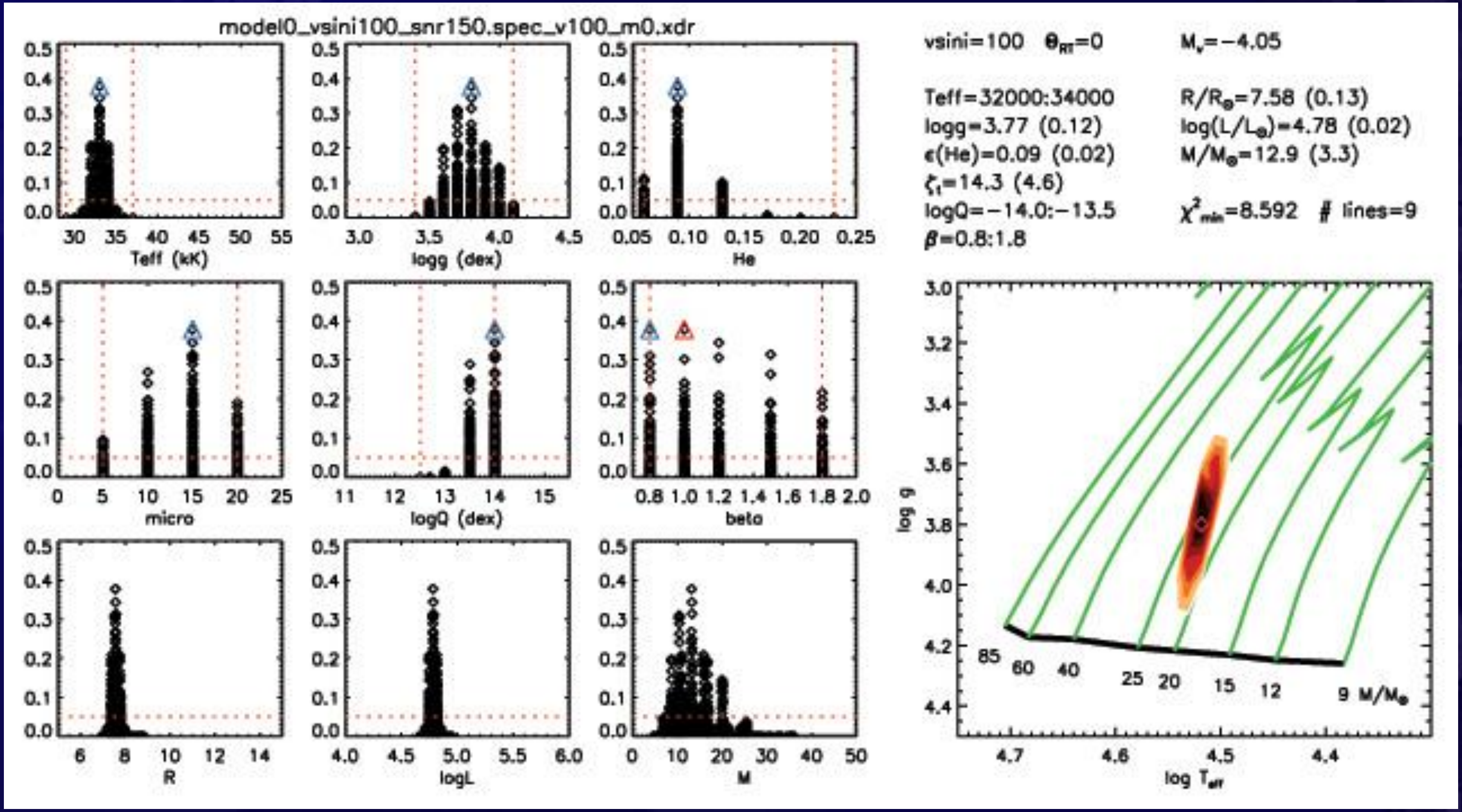
N_L = Number of lines *w_L: Weight of the line*

χ^2 distribution with N_L-1 degrees of freedom

The χ^2 values are translated into the corresponding p-values to better establish the significance level of the comparison

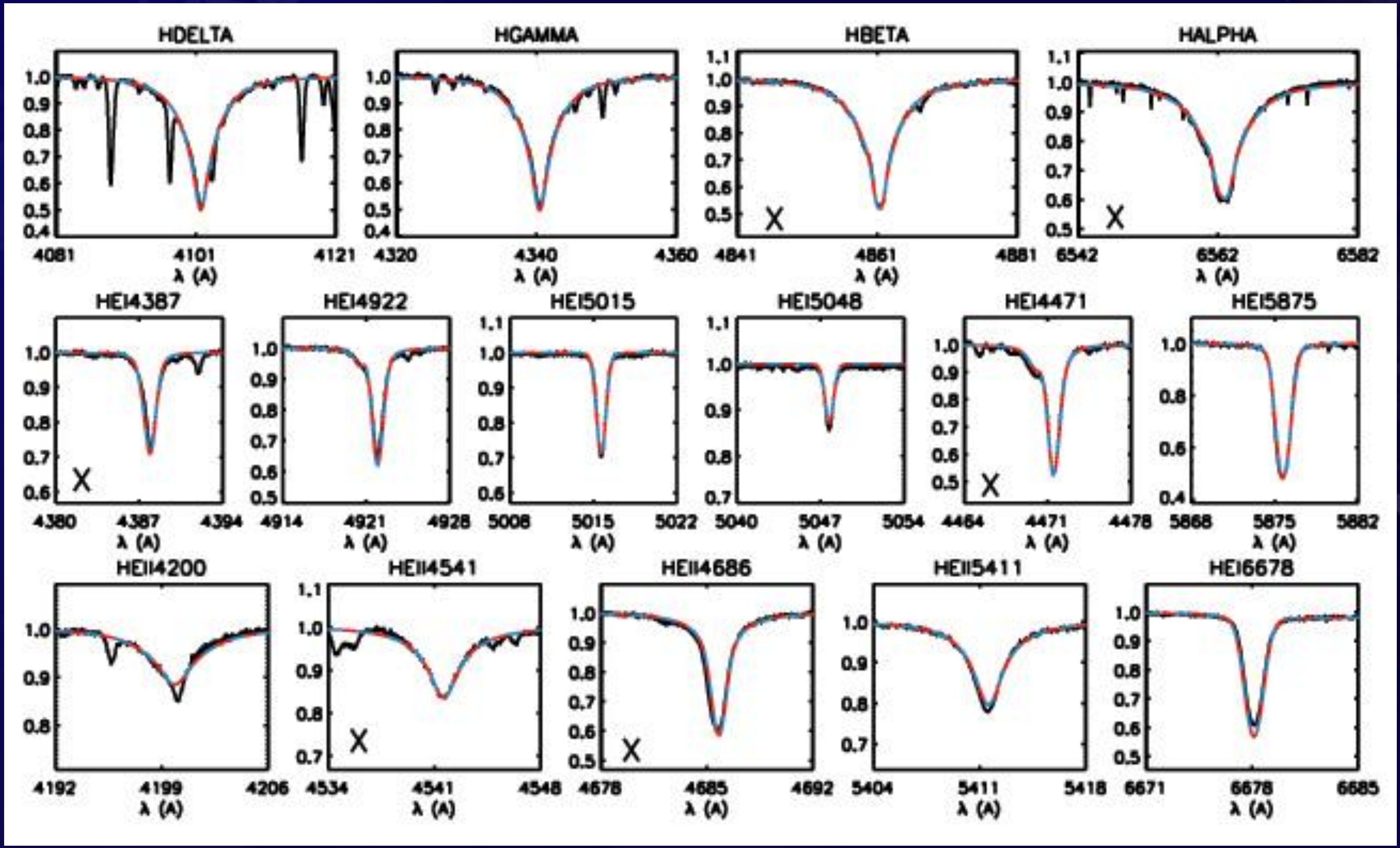
WP3: Quantitative spectroscopic analyses

Output of the IACOB-grid automatic tool (I)



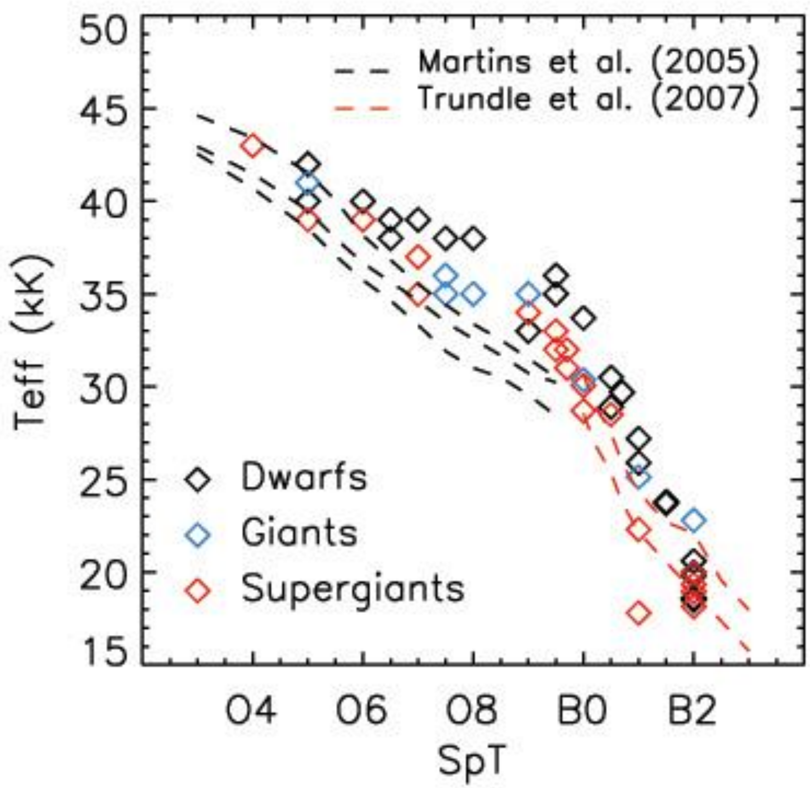
WP3: Quantitative spectroscopic analyses

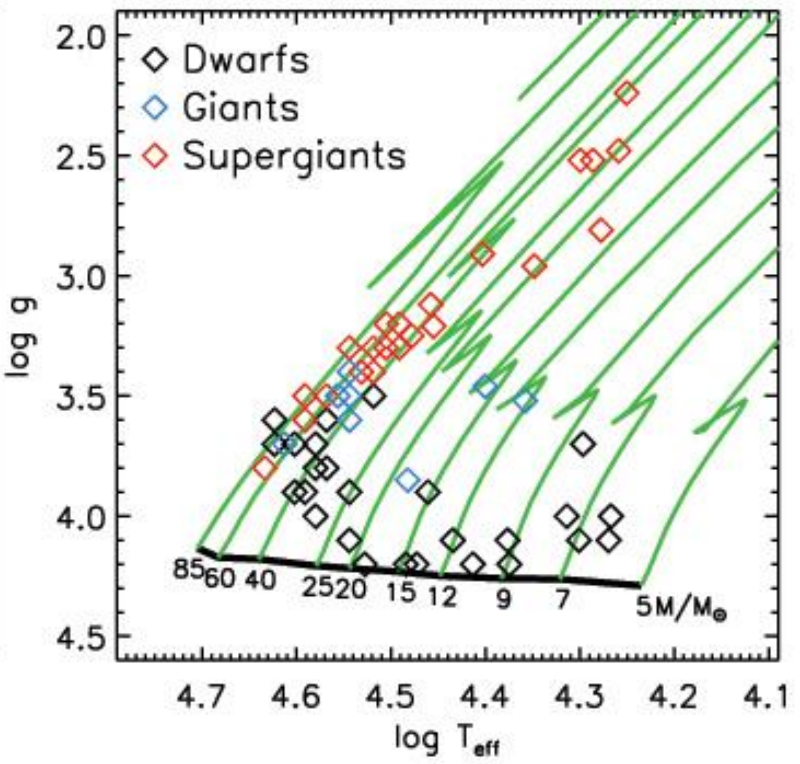
Output of the IACOB-grid automatic tool (II)



WP3: Quantitative spectroscopic analyses

Some first results from the IACOB project (on going work)

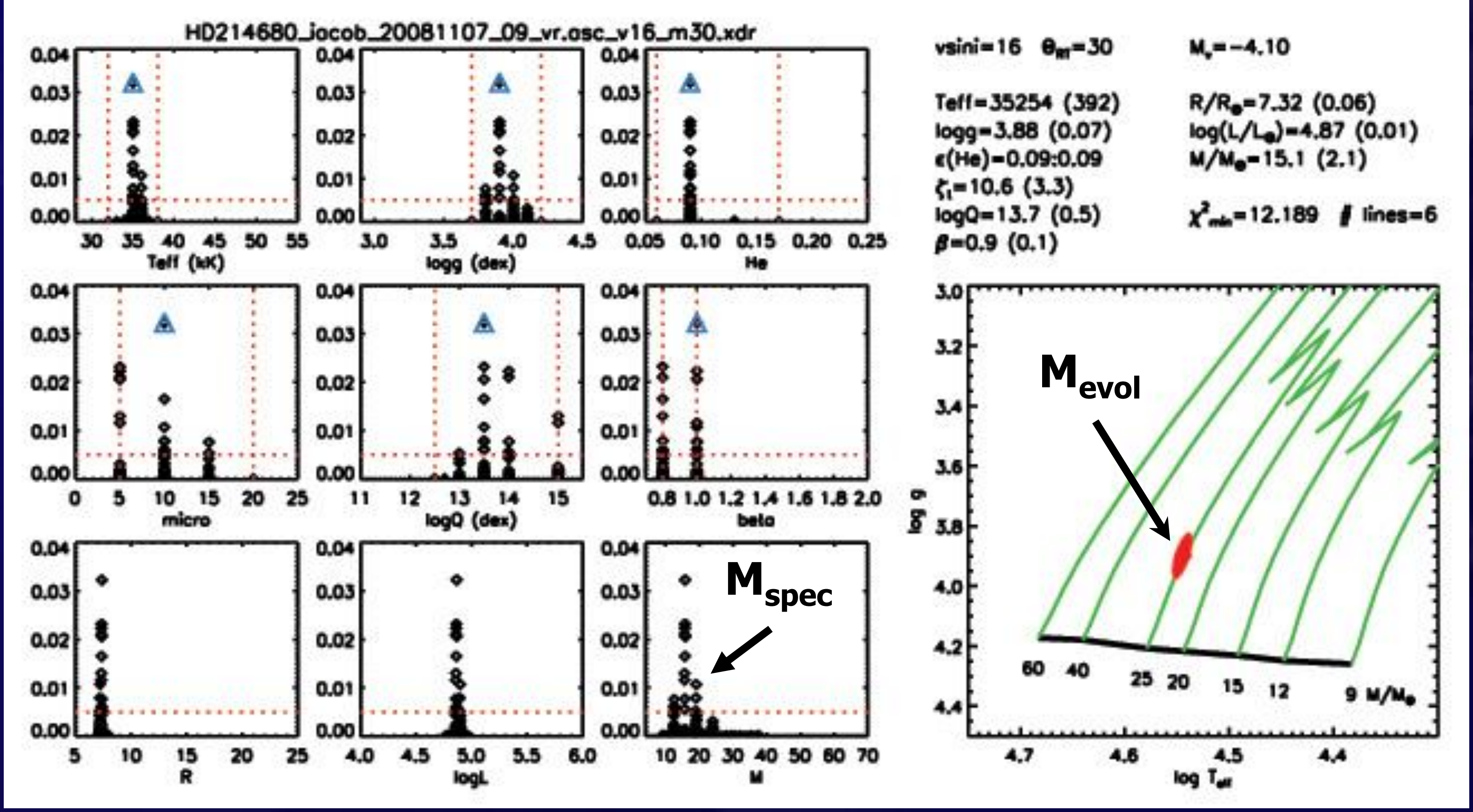




Synergies between IACOB and Gaia: a couple of examples

(I) IACOB needs accurate distances and photometry

Ex: HD214680 (10Lac, O9V)



Synergies between IACOB and Gaia: a couple of examples

(I) IACOB needs accurate distances and photometry

Ex: HD214680 (10Lac, O9V)

With the present accuracy in the distance to 10 Lac (d ≈ 580 pc)

$\Delta d/d \approx 15\,\% \rightarrow \Delta Mv \approx 0.3$

R/R_{sun} = 7.32 +/- 0.06 [+/- 1]
$\log L/L_{sun}$ = 4.87 +/- 0.01 [+/- 0.12]
M/M_{sun} = 15 +/- 2 [+/- 5]

$M_{evol} = 25\ M_{sun}$
Mass discrepancy
(Herrero et al. 1992)

Accuracy in T_{eff} & logg

Accuracy in distance !!!

We need more accurate distances

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+ Av !!!

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Accuracy in T_{eff} & logg

Accuracy in distance !!!

We need more accurate distances

Synergies between IACOB and Gaia: a couple of examples

(II) Interstellar extinction in the Galaxy

SEDs@FASTWIND ⟷ Gaia photometry

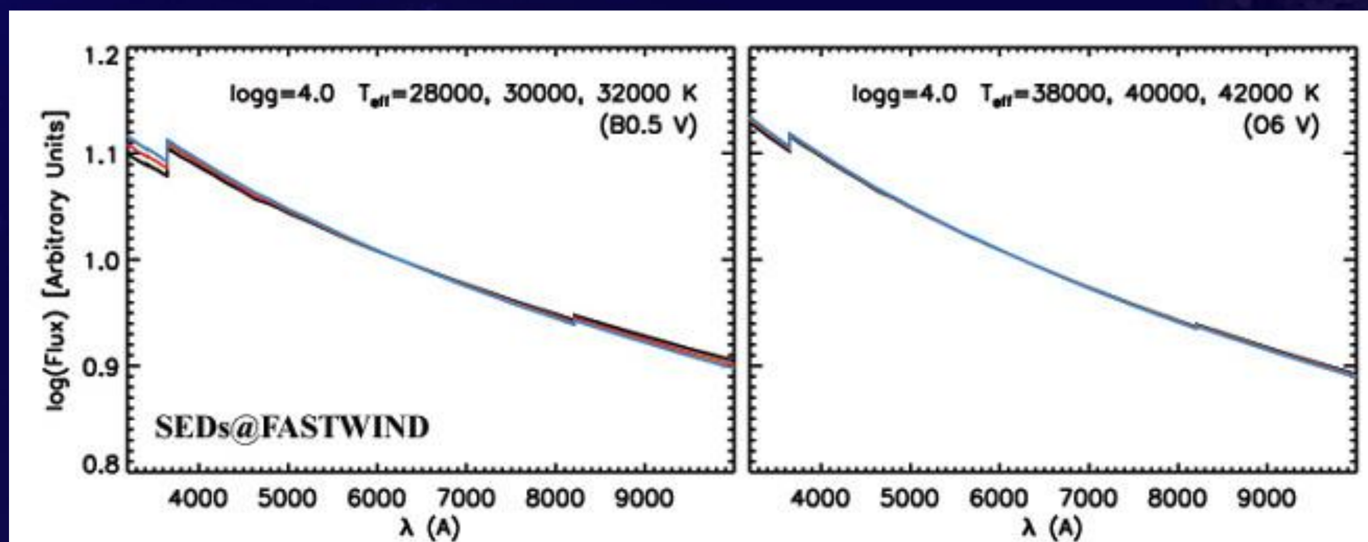
↓

Av, extinction law properties

Photometry

BP: 320-660 nm

RP: 650-1000 nm



Synergies between IACOB and Gaia

- Structure and dynamics of the Galaxy (+stellar clusters and associations)
- OB runaways
- Interstellar reddening
- The star formation history of the Galaxy
- IMFs *(the upper mass tail of the IMF)*
- Binaries and multiple stars
- Stellar astrophysics (Massive stars)
- Rotational velocities
- Atmospheric parameters (we need Gaia to better constraint R, L and M)
- Abundances (Galaxy gradient, solar neighb., individual clusters, stellar evolution)
- Stellar variability (pulsations in massive stars?)
- Brown dwarfs and planetary systems (e.g. σ Ori)

Highlights of the talk

Gaia will provide unique information about photometry, position, proper motions, radial velocities, and distances of millons of stars in our Galaxy.

In the case of massive OB stars, this information will be insuficient to determine the physical properties of the observed targets (T_{eff}, log$g$, Y(He) ...). The whole optical spectrum is better suited to this aim.

The IACOB project, using an automatic grid-based tool and modern optical, high-resolution spectroscopic databases, is performing quantitative spectroscopic analyses of about 150-200 Galactic O stars.

Future synergies IACOB Gaia will be necessary to extract the maximum possible information about Galactic Massive stars and other related topics from both projects (e.g. distances-masses, synthetic SEDs-extinction).

The IACOB project is ready

and

really looking forward

for

the Gaia revolution

Colabs.: A. Herrero, M. Garcia, N. Castro, J. Maiz-Apellaniz *(and the GOSSS team)*, J. Puls, N. Markova, I. Negueruela, J. Lorenzo, R. Barbá *(and the OWN team)*, N. Walborn