The IACOB project:

"Synergies for the Gaia era"

Sergio Simon-Diaz
Instituto de Astrofisica de Canarias

Spanish ICTS contributions to ESA's Gaia mission

Madrid, 2012 March 21st

The IACOB project:

"an example of how the Spanish ICTS can efficiently contribute to ESA's Gaia mission"

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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
  - The IACOB survey and other related on-going surveys
  - WP3: Quantitative spectroscopic analyses
- Synergies between IACOB and Gaia

OB-type stars in the MW

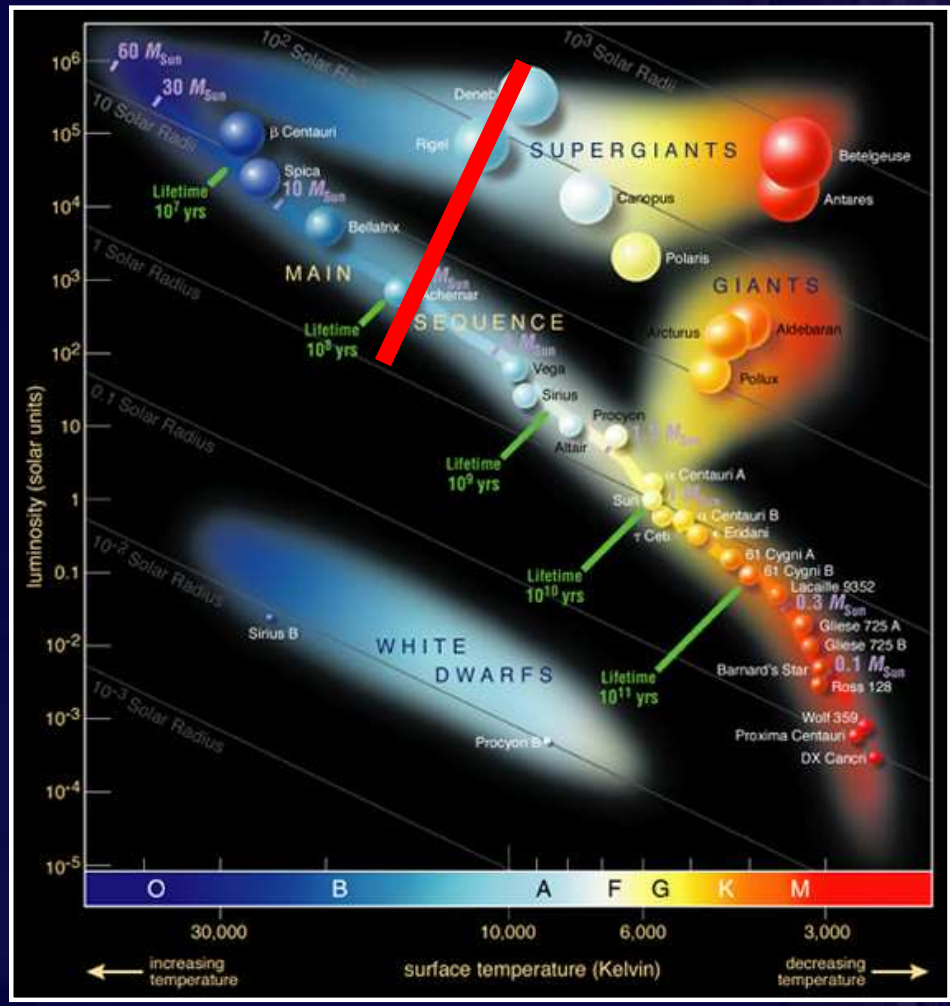
They are:

- 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

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



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)

The IACOB spectroscopic survey *(PI. S. Simón-Díaz)*

IACOB Spectroscopic database

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

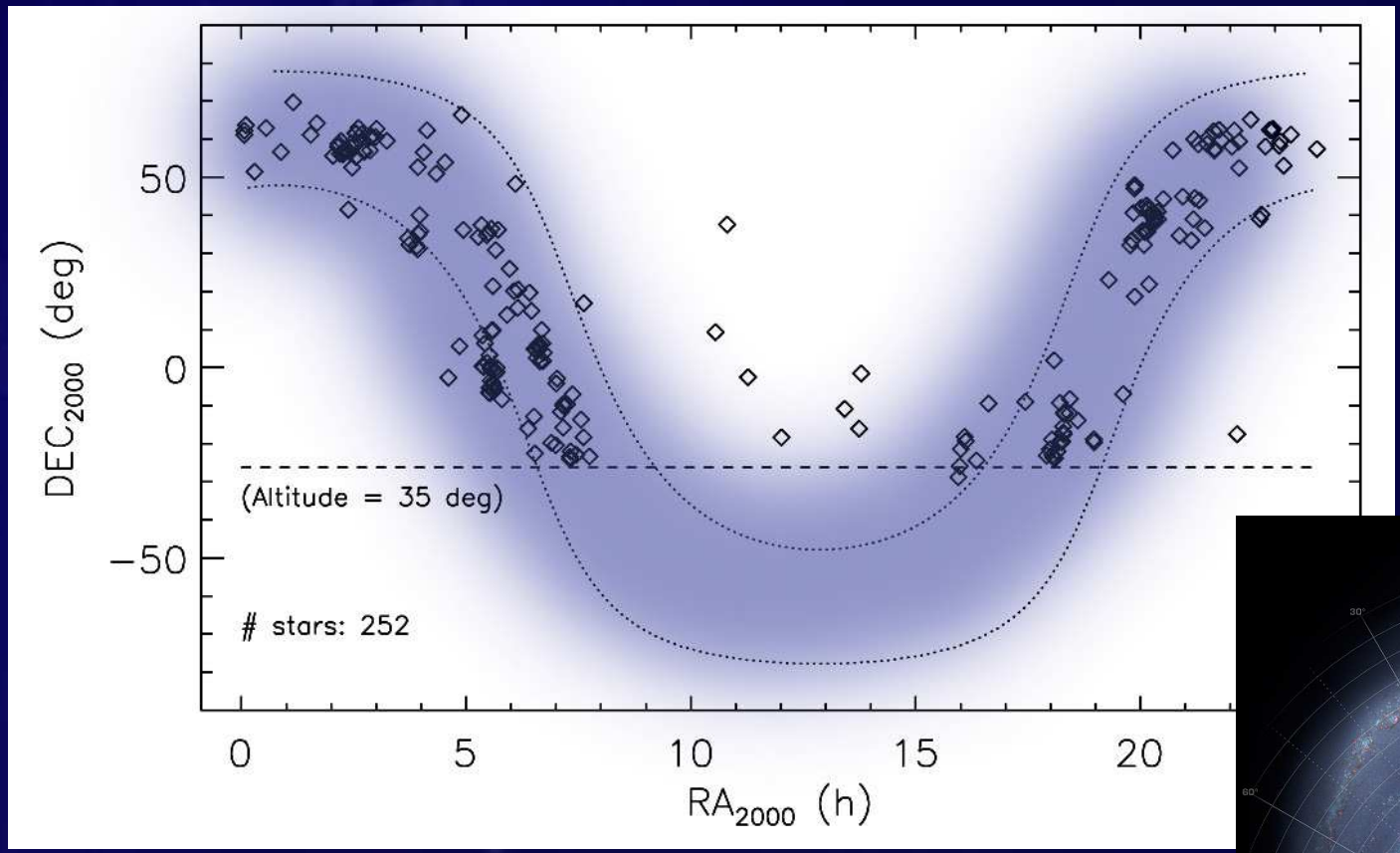
37 observing nights with NOT

~ 300 hours
2008 – 2011

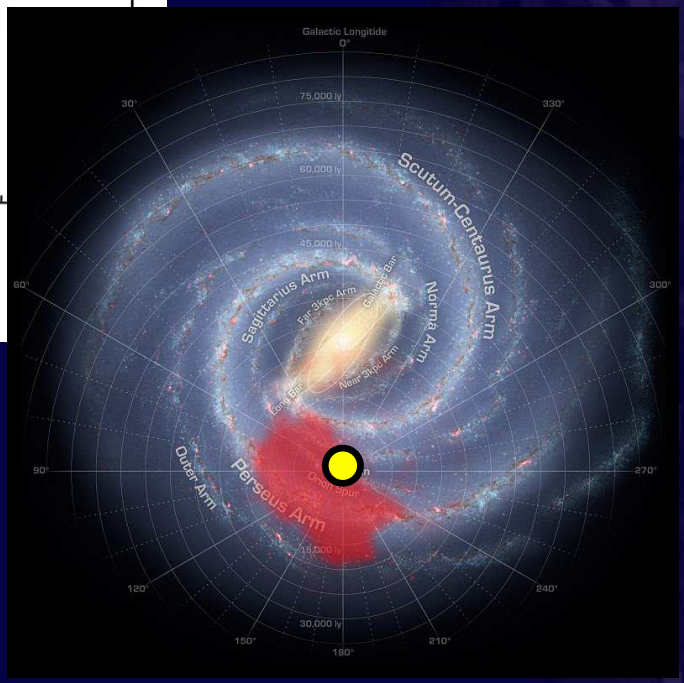
V < 9
δ > -25 deg

Instrumental configuration	*Observing runs and dates*	
Telescope: NOT2.56 m	08 A-D	2008/11/05-08
Instrument: FIES	09 A-D	2009/11/09-12
Fiber: med-res / low-res	10 A-C, D	2010/06/05-07, 22
Spect. range: 3800 - 7000 Å	10 E	2010/07/15
Resol. power: 46000 / 23000	10 F,G	2010/08/07,24
Sampling: 0.03 Å/pix	10 H-J	2010/09/07-09
SpT & LC coverage	10 K-L	2010/10/23-24
O4-B2 (I-V)	11 A-E	2011/01/11-15
Some statistics	11 F,G	2011/02/11,20
# stars: 250	11 H	2011/03/27
# spectra: 1255	11 I	2011/04/08
# O stars: 153	11 J-K	2011/08/28-29
# B stars: 97	11 L-Q	2011/09/07-12

The IACOB spectroscopic survey *(PI. S. Simón-Díaz)*



IACOB Spectroscopic database



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

The IACOB survey in the context of other on-going related surveys

Gaia *(ESA)*

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

On-ground spectroscopic surveys

	Northern hemisphere				South. hem.
High-res	**NoMaDS** *(Pellerin)* O stars Multi-epoch V<13 Survey	**CAFÉ-BEANS** *(Negueruela)* O stars Multi-epoch V<8 Binaries	**IACOB-sweG** *(Negueruela)* OB-type stars + Gaia range V<8 Standards	**IACOB** *(Simón-Díaz)* OB-type stars Multi-epoch V<8 Survey	**OWN** *(Barbá)* O+WR stars Multi-epoch V < 8 Survey
					ESO-Gaia
Low-res	**GOSSS** *(Maíz Apellániz)* Galactic O star spectroscopic survey (aims at being complete up to B< 13) Multi-epoch				

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The IACOB survey in the context of other on-going related surveys

R ~ 2500

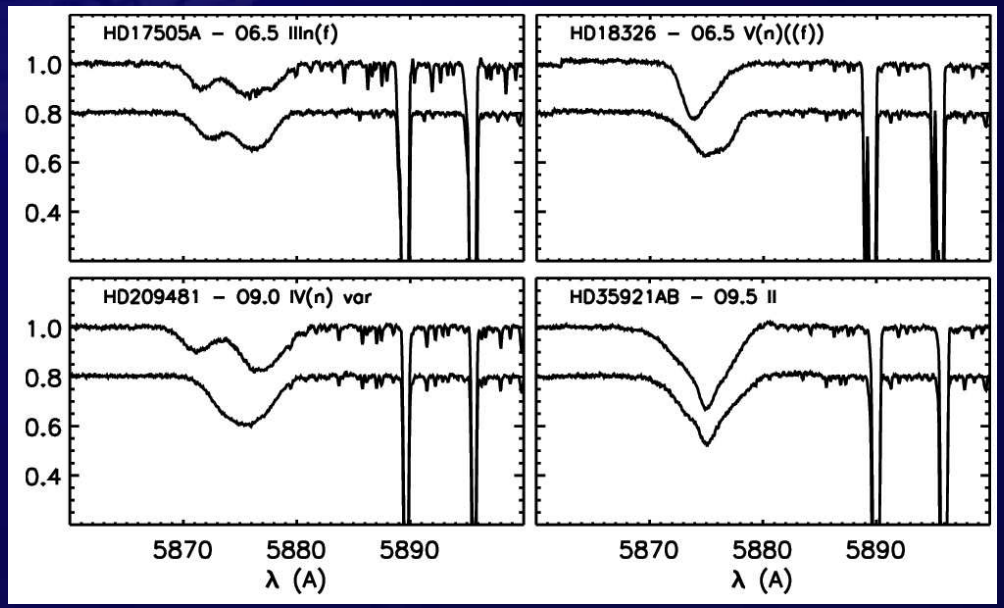
The Galactic O-Star Spectroscopic Survey *(GOSSS, P.I. J. Maíz Apellániz)* is doing an impressive work:

- The most complete census of Galactic O stars up-to-date
- Spectral classification revisited
  (better and homogeneous observations)
- Atlas of Galactic O stars at R=2500
- Identification of massive binaries
  (complemented with lucky-image surveys)
- Study of DIBs and correlation with interstellar extinction

see Sota et al. (2011)

The IACOB survey in the context of other on-going related surveys

But *multi-epoch, higher-resolution spectra* are crucial to obtain quantitative information about the stars themselves (and unveil some spectroscopic features hidden at lower resolution)



Important to be aware of
binaries
in the quantitative analyses

+ accurate abundance determinations (C, N, O, Si, Mg, Fe, Ne)
+ studies of rotational and macroturbulent broadenings
+ line-profile variations (LPVs) -> wind variability, pulsations, magnetic fields

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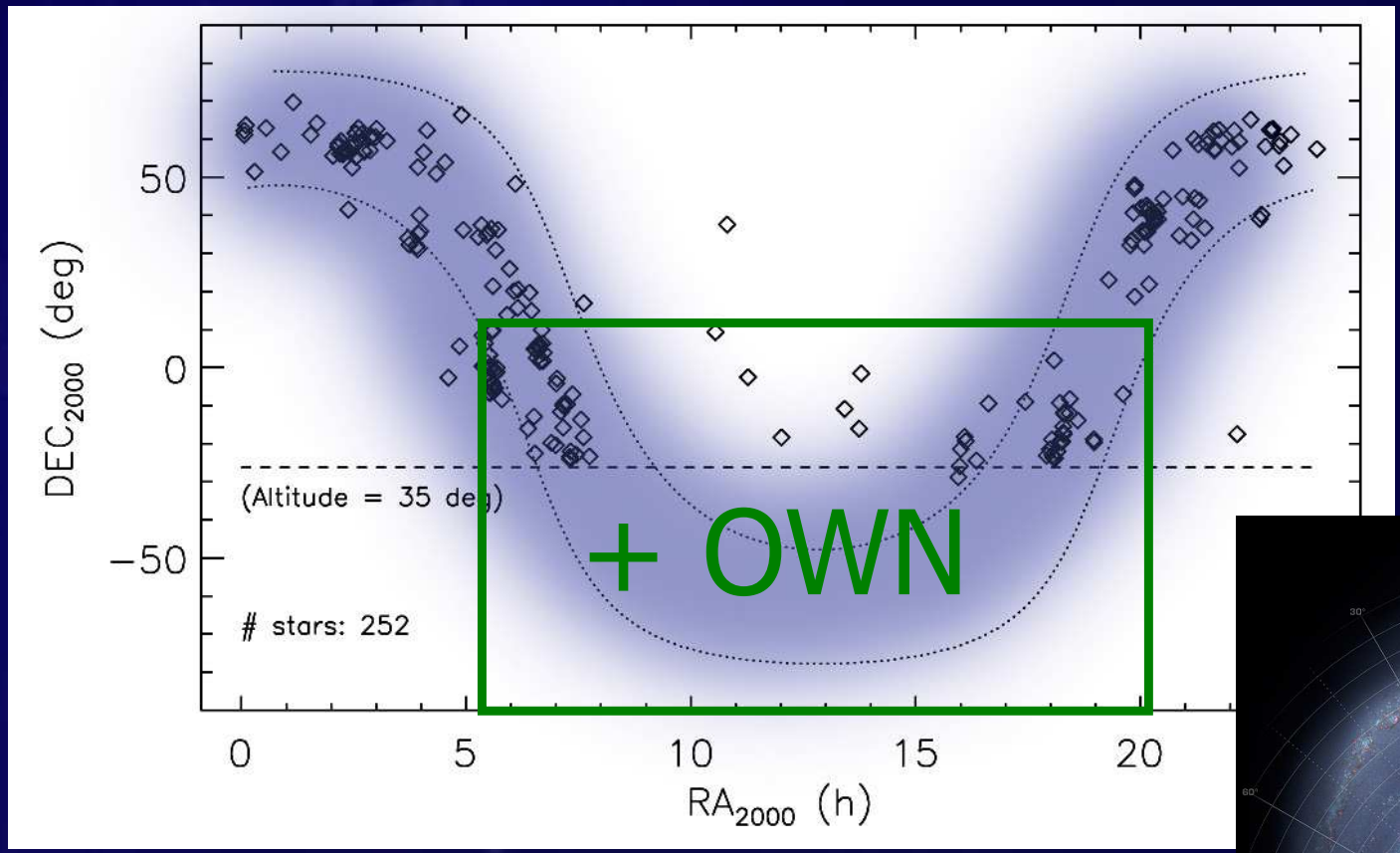
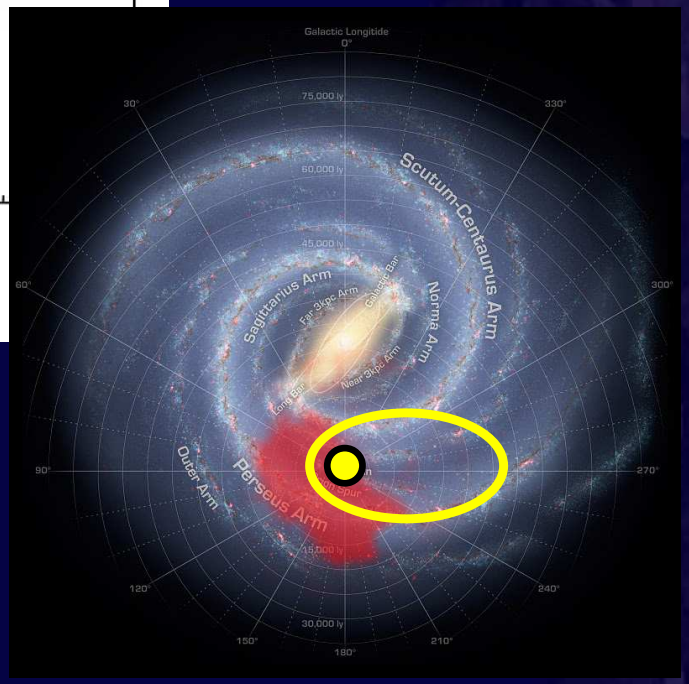
IACOB & other high-resolution spectroscopic surveys



IACOB Spectroscopic database



+ NoMaDS: Northern massive DIM stars

+ CAFÉ-BEANS: massive binaries from CAHA

IACOB & other high-resolution spectroscopic surveys

+ IACOB-sweG *(PI. I. Negueruela)*

Grid of (~ 100) standars with

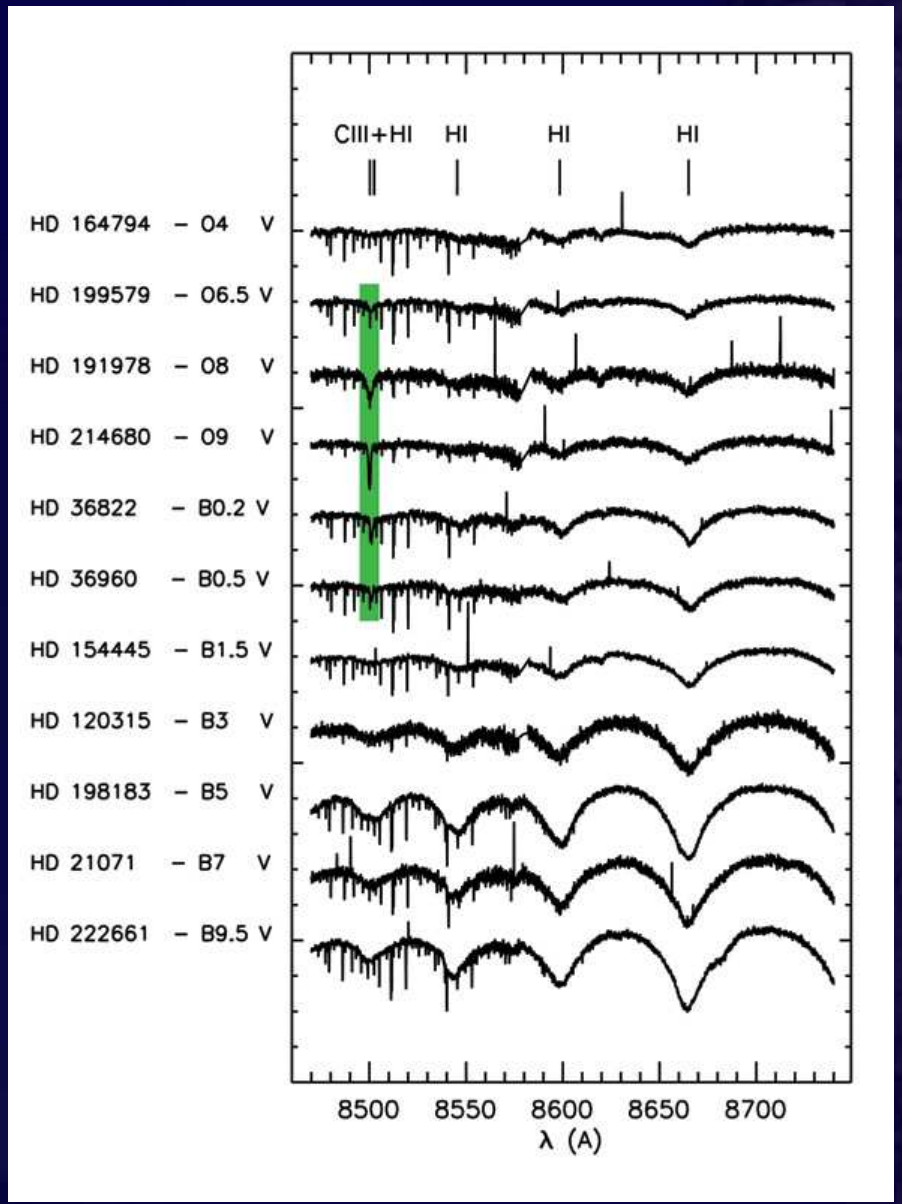
SpT: O4 – B9

LC: V, IV, III, II, Ib, Iab, Ia

observed with HERMES@MERCATOR

R = 85000 (3700 – 9000 A)

see also *Negueruela et al. (2010)*



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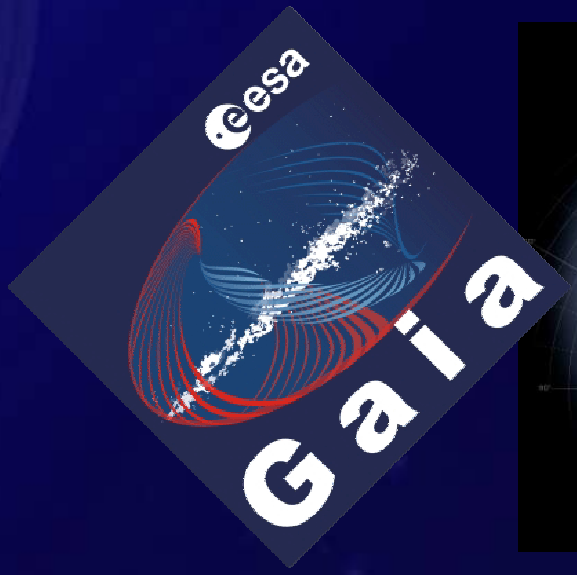
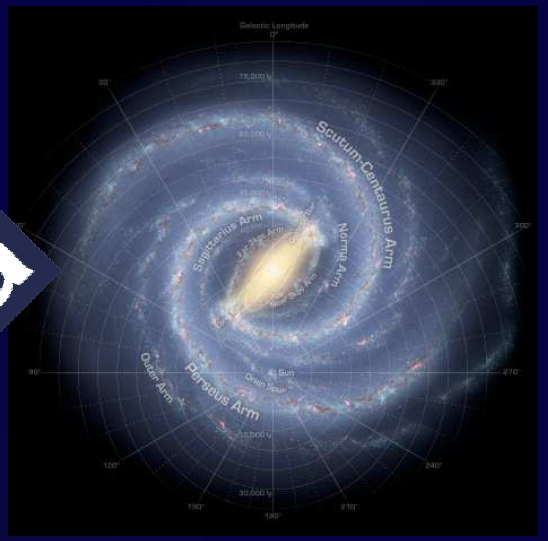
The Gaia vision of Massive stars



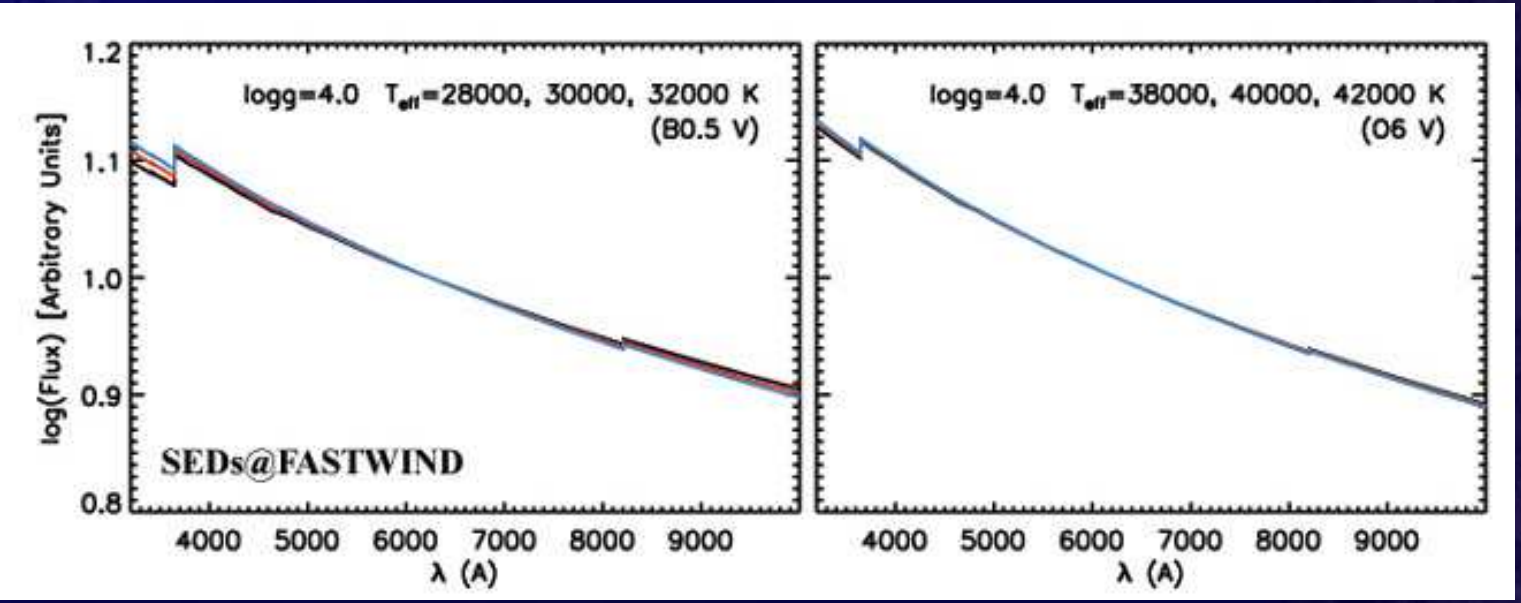


Gaia will provide unique information about photometry, position, proper motions, radial velocities, and distances of millons of stars in our Galaxy.

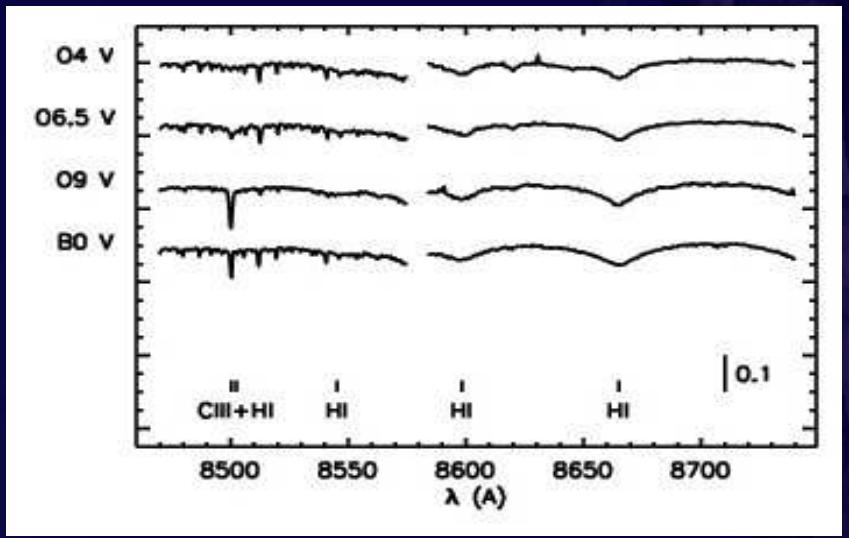
Astrometry	Photometry	Spectroscopy
ASTRO	BP: 320-660 nm	RVS
a few – 300 μas	RP: 650-1000 nm	847-874 nm
		R = 11500

The Gaia vision of Massive stars

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

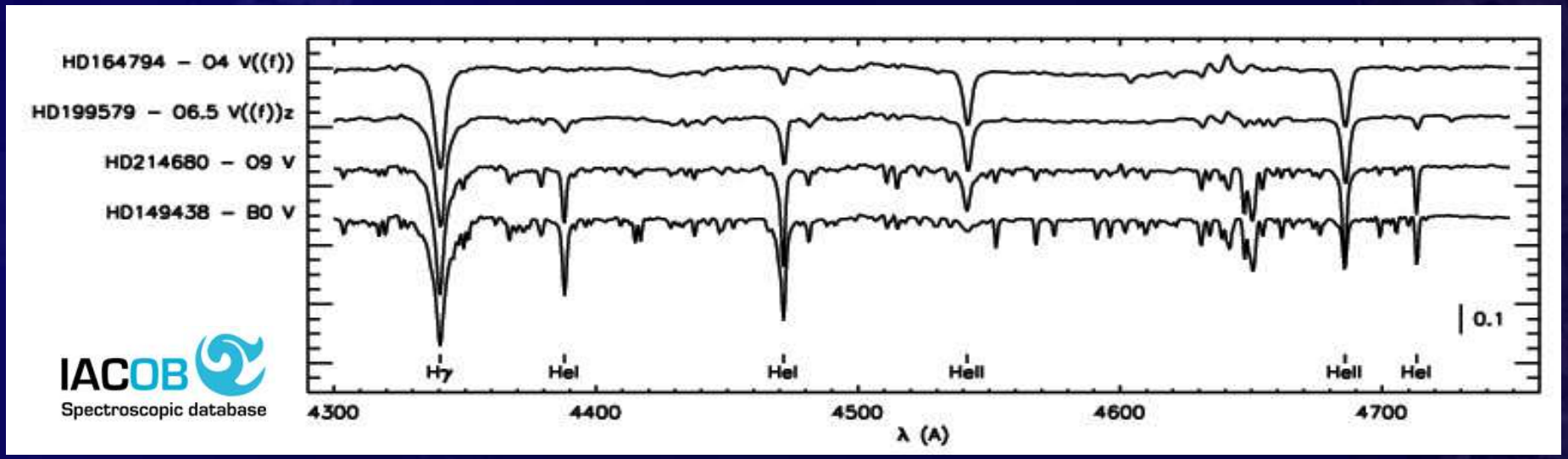


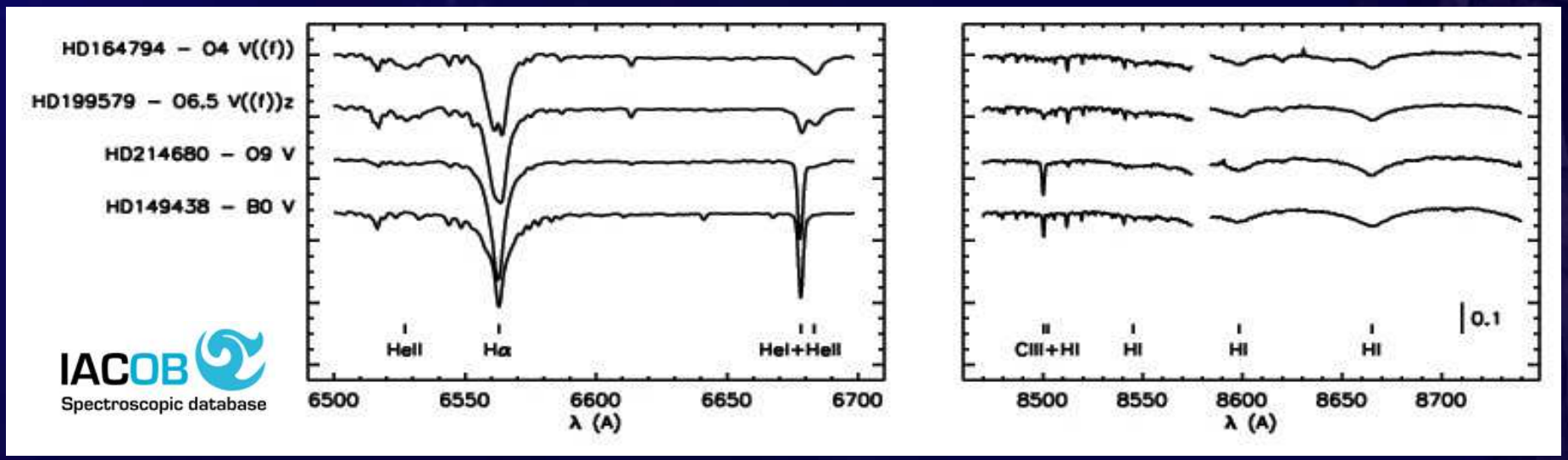
Spectroscopy
RVS
847-874 nm
R = 11500



Stellar+wind parameters & abundances of massive stars:

*** Better use optical spectra ***





Stellar+wind parameters & abundances of massive stars:

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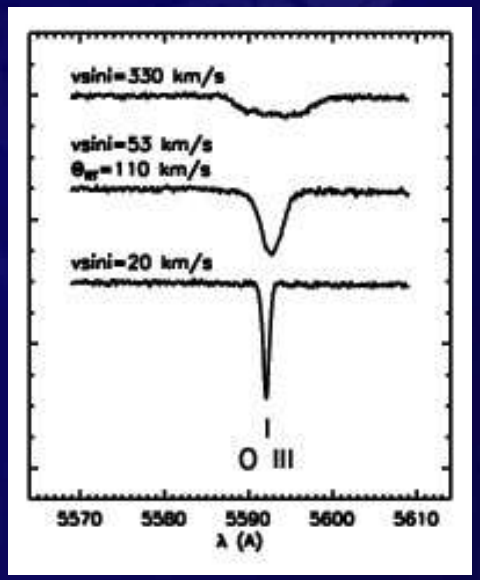
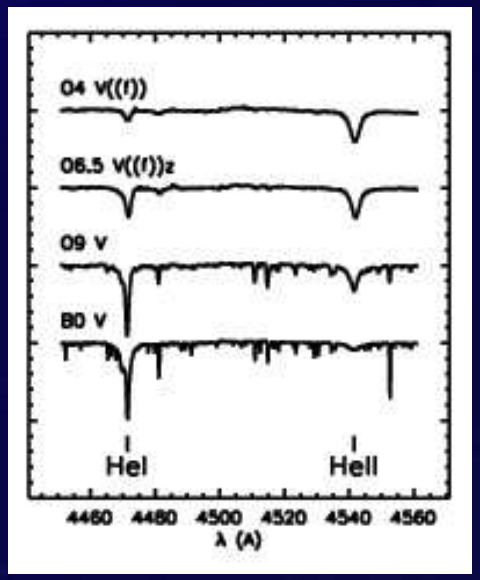
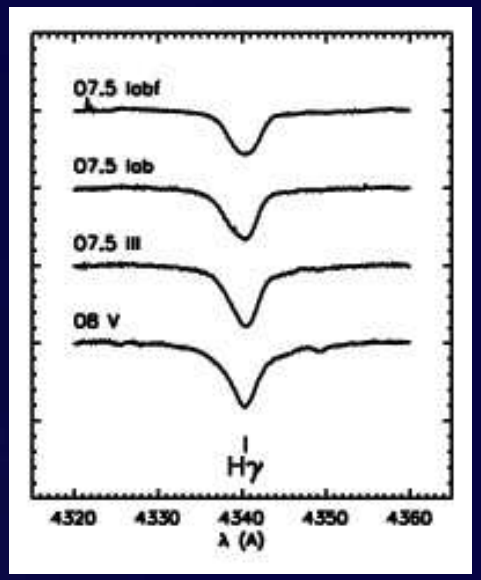
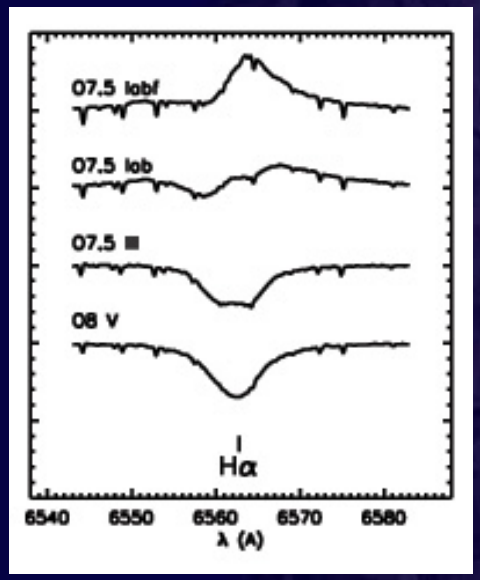
An example of the variation of some diagnostic lines (O star case):









v sin*i*
+
extra-broadening

Stellar and wind parameters

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

The IACOB project: Quantitative spectroscopic analyses

One of the main goals of the IACOB project is to end up with
the most complete database of stellar and wind parameters *
of Galactic OB-type stars
determined in a homogeneous way.

** (Teff, logg, R, logL, M, M_{dot})*

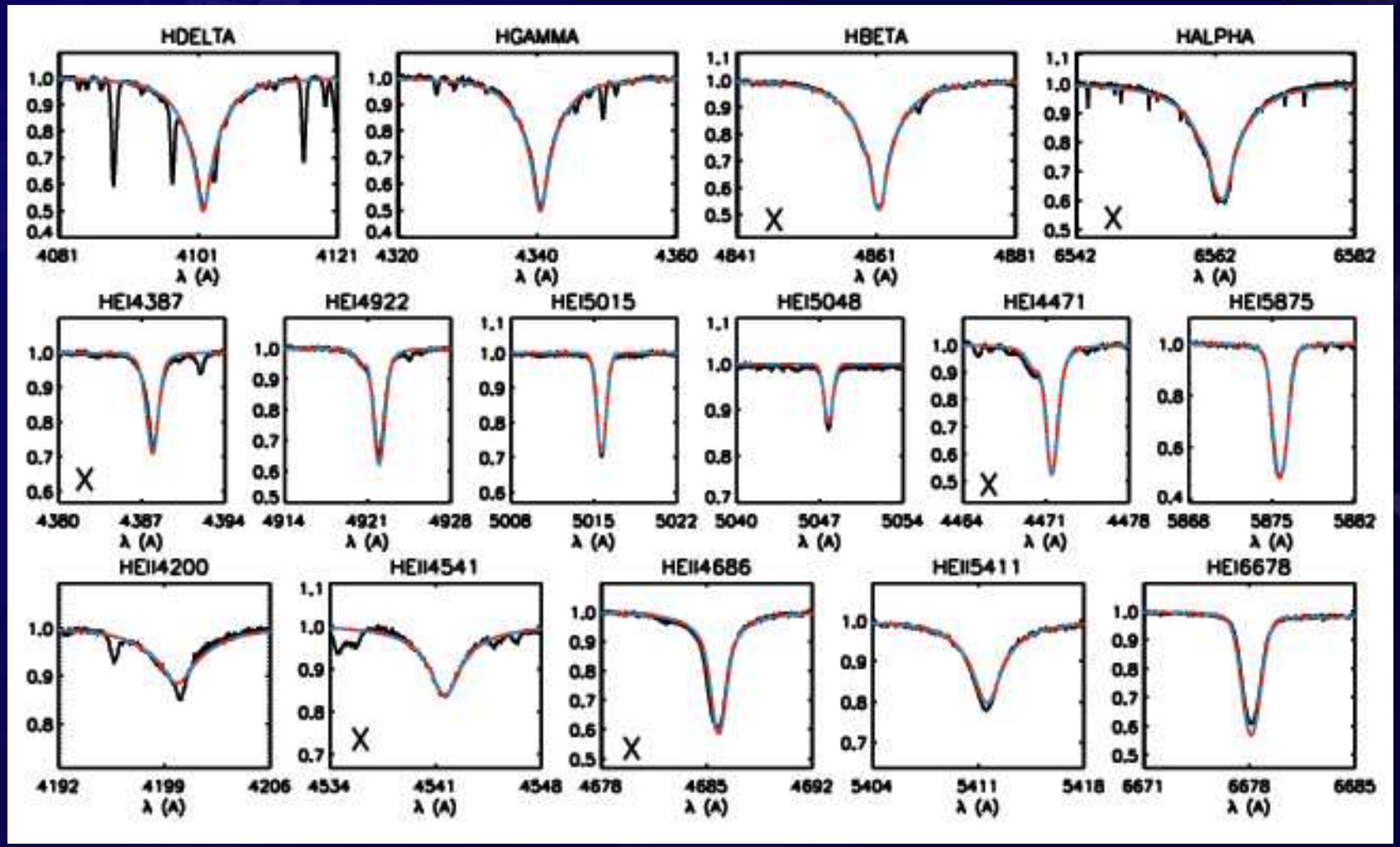
Tools:

1) The IACOB spectroscopic database (+ other high resolution surveys)
2) The FASTWIND stellar atmosphere code *(Puls et al. 2005)*
3) The IACOB-GBAT tool *(Simón-Díaz et al. 2011)* : A objective, fast but accurate way to perform quantitative spectroscopic analyses of large samples of OB-type stars

+ Information provided by Gaia will be of great importance

The IACOB project: Quantitative spectroscopic analyses

An example: 10 Lac (O9 V)



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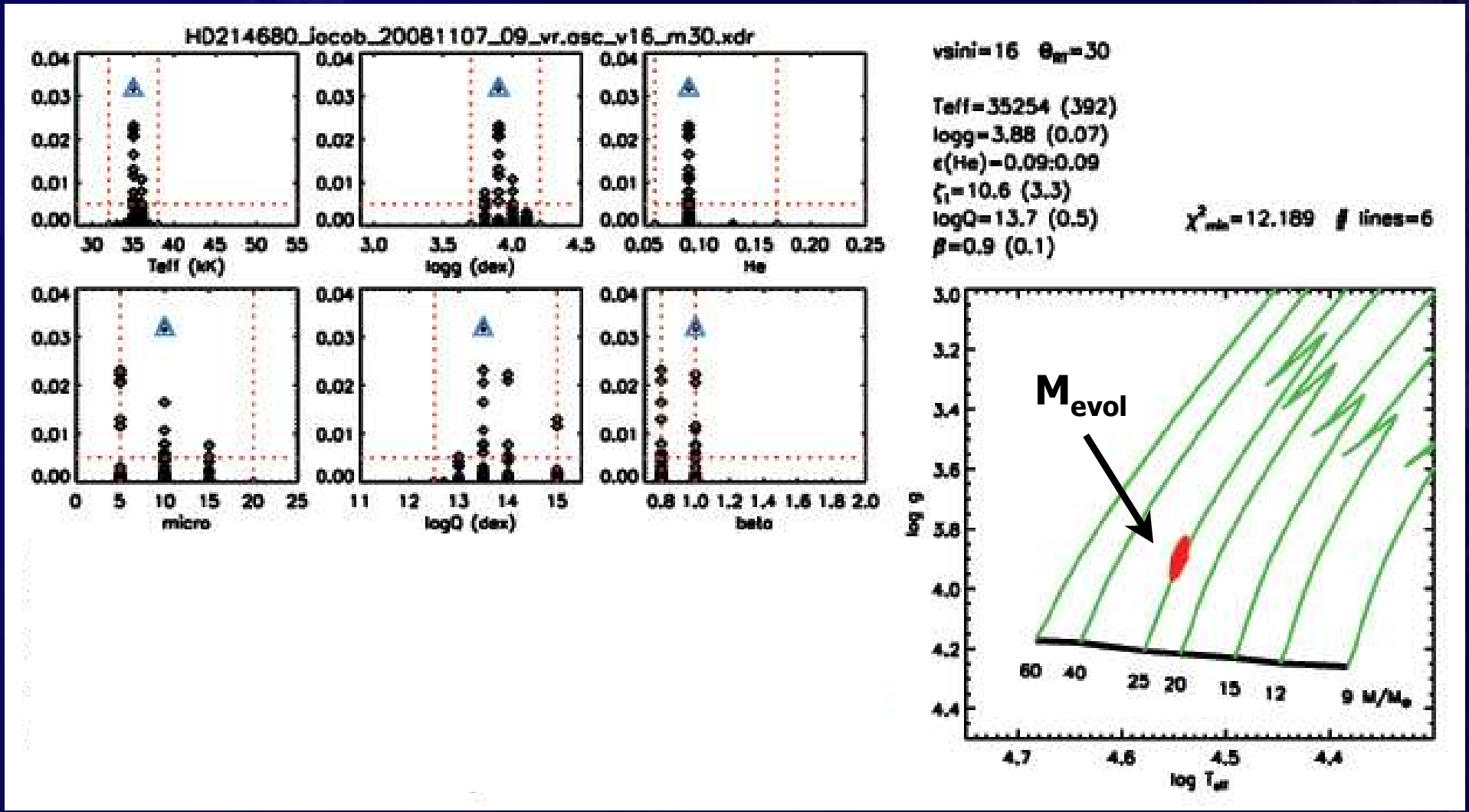
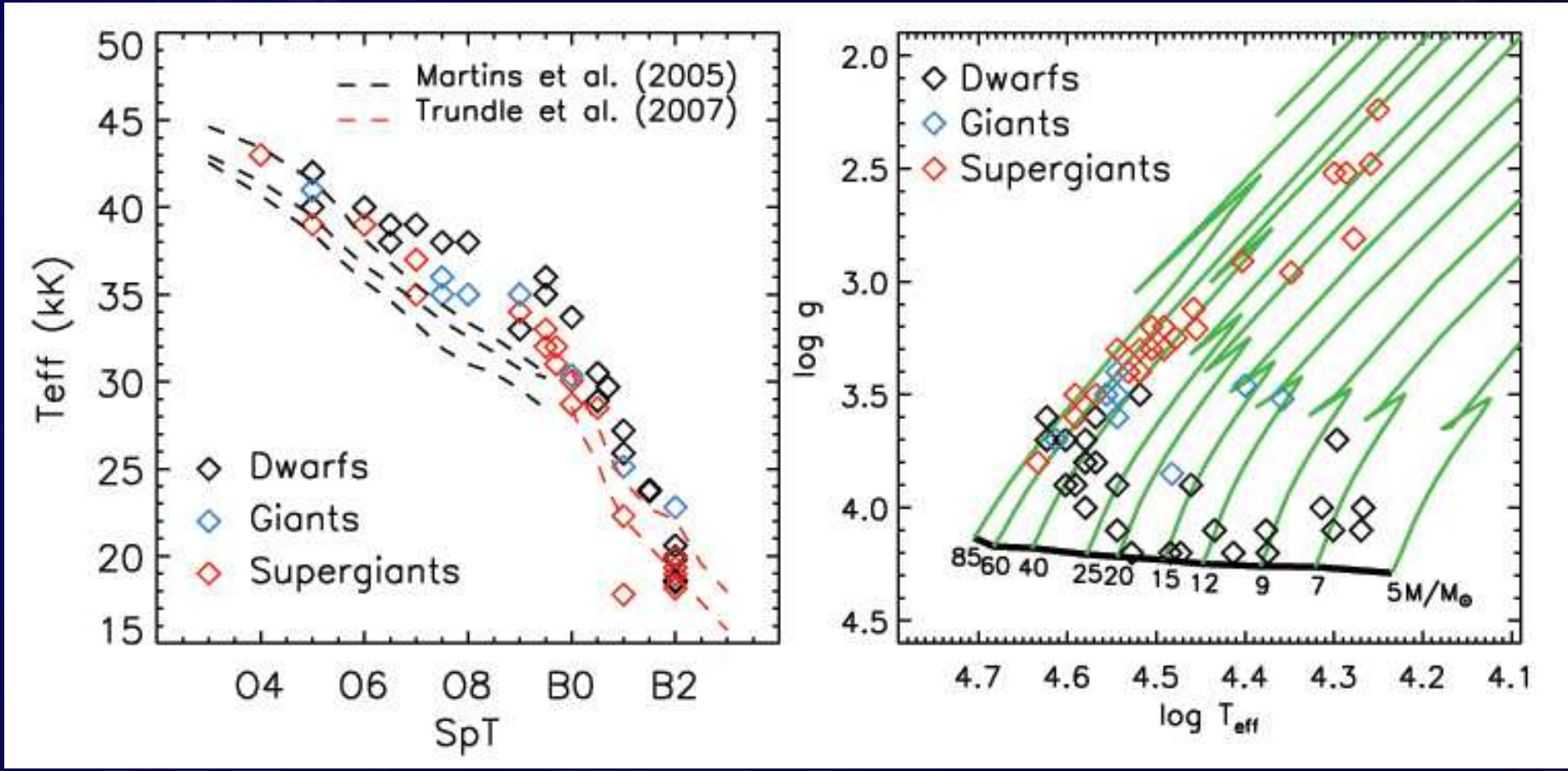


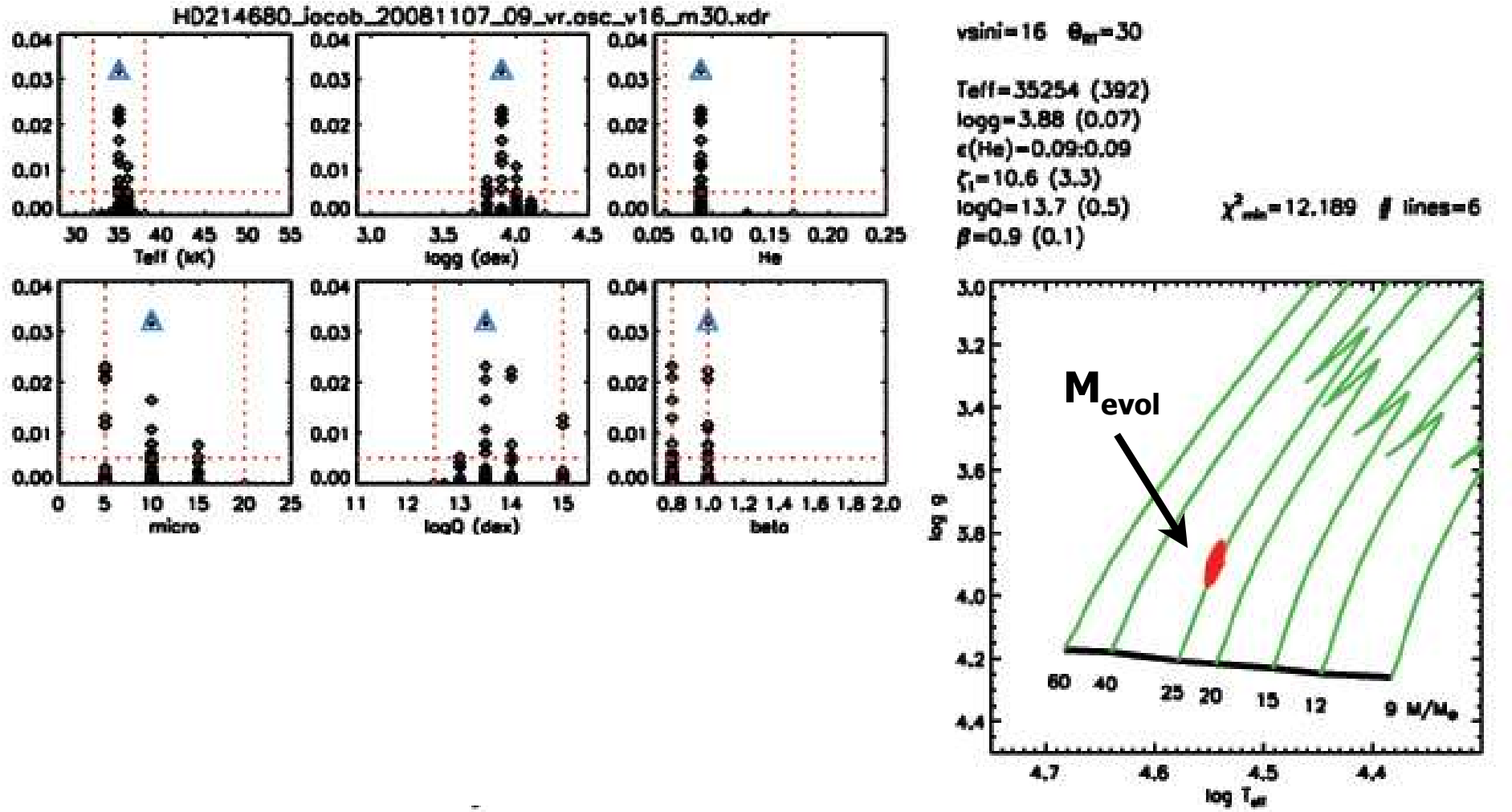
The IACOB project: Quantitative spectroscopic analyses

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



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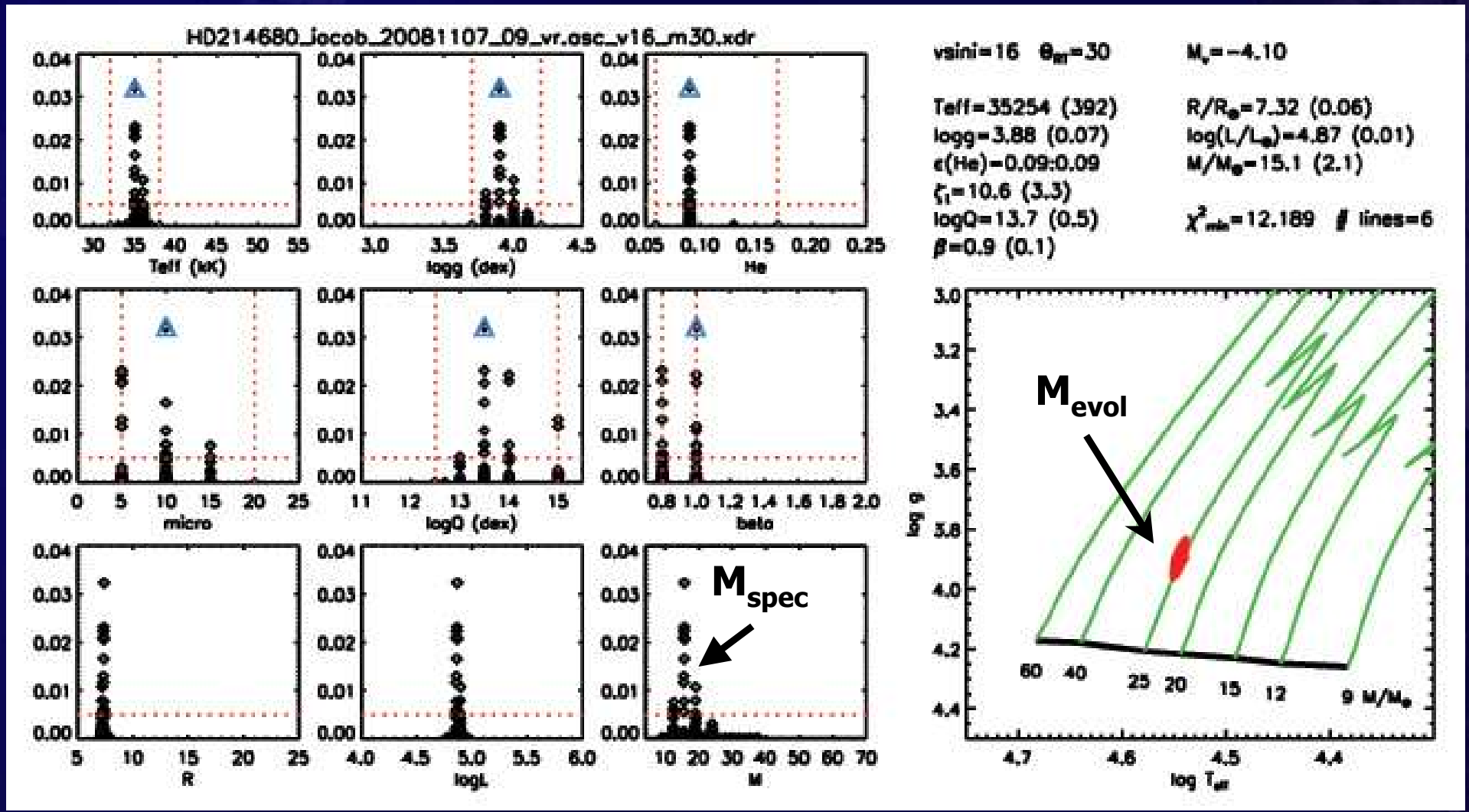

Synergies between IACOB and Gaia: a couple of examples

(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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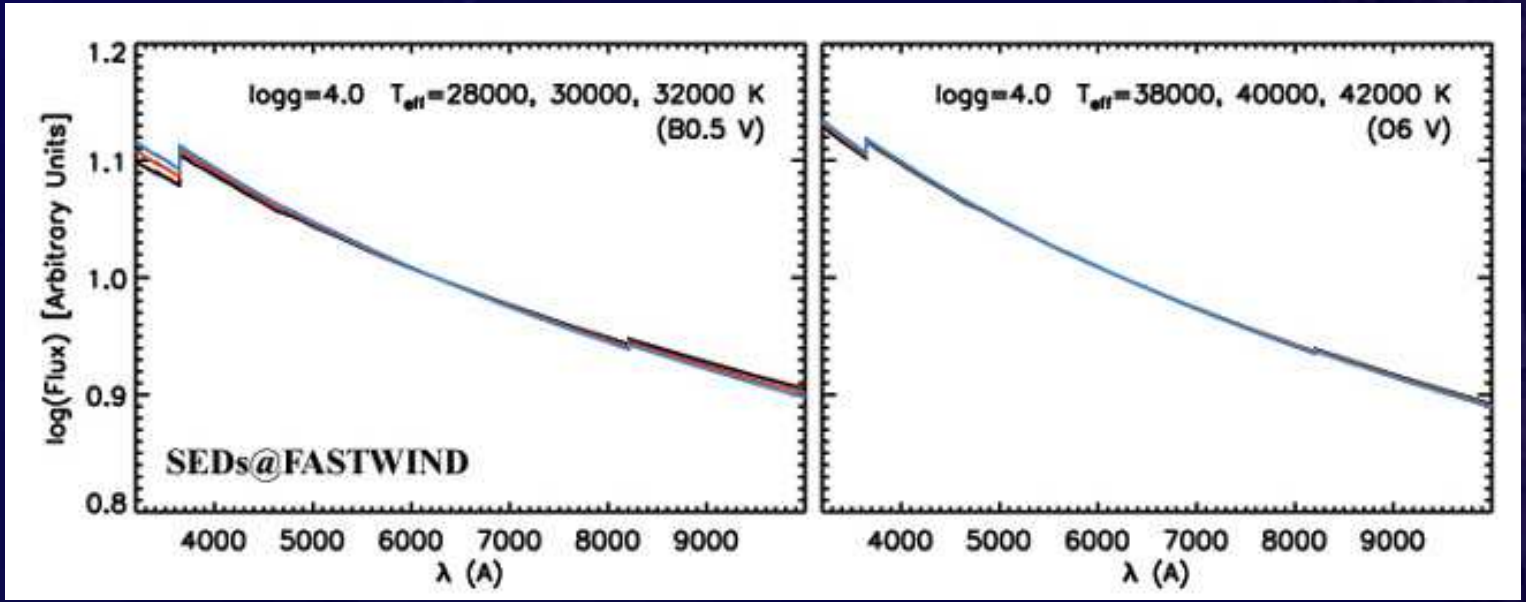
Synergies between IACOB and Gaia: a couple of examples

(II) Interstellar extinction in the Galaxy

SEDs@FASTWIND ⟷ Gaia photometry

Av, extinction law properties

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



Highlights of the talk

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, Gaia observations 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:

An example of how the Spanish ICTS can efficiently contribute to ESA's Gaia mission

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

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)

On ground massive spectroscopic surveys of Massive stars

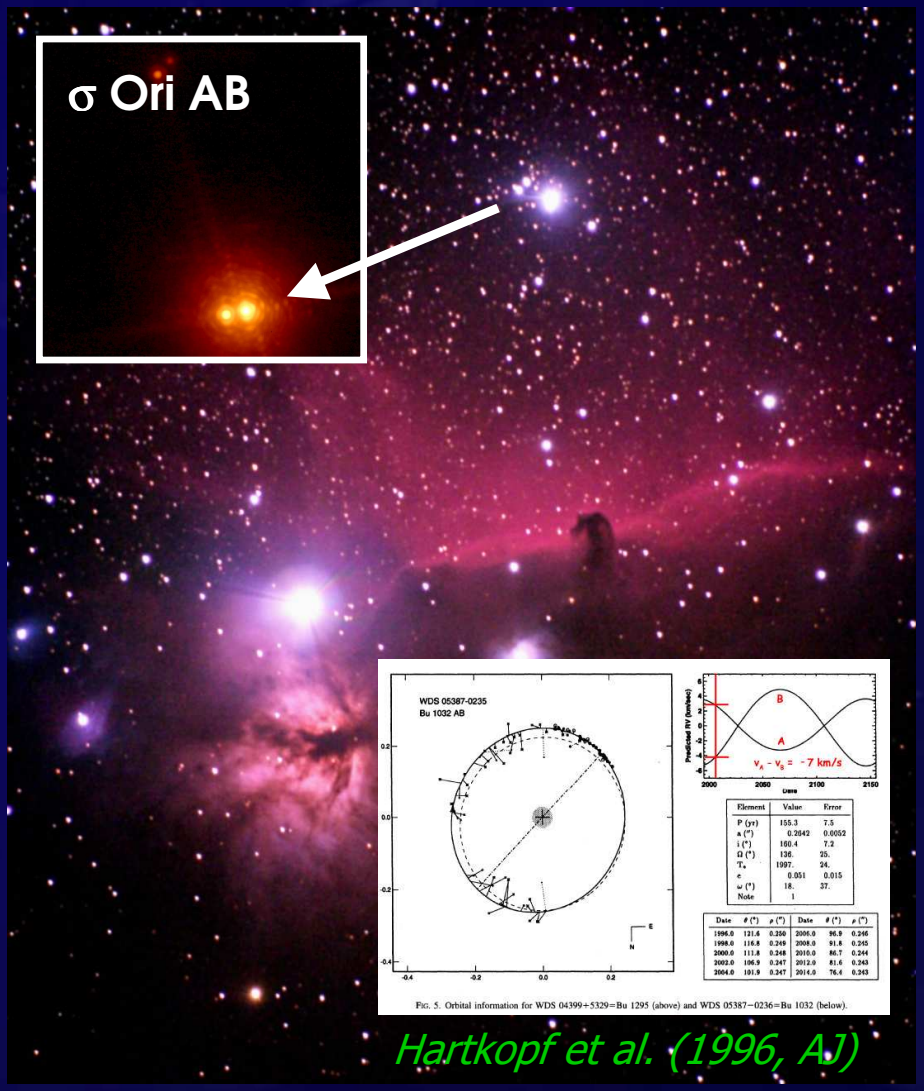
	GOSSS	OWN	IACOB	**NoMaDS**
Resolution	~2500	~40 000	46 000	**30 000**
Sp. range	3900-5100 Å	3700-6900 Å	3700-6900 Å	**3800-7300 Å**
Mag. limit	$B < 13$	$V < 8$	$V < 8$	**$V < 13$**
S/N	~300	~200	~200	**~200**
δ	Full sky	$\delta < 12^{\circ}$	$\delta > -20^{\circ}$	**$\delta > -12^{\circ}$**
# stars (current)	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)

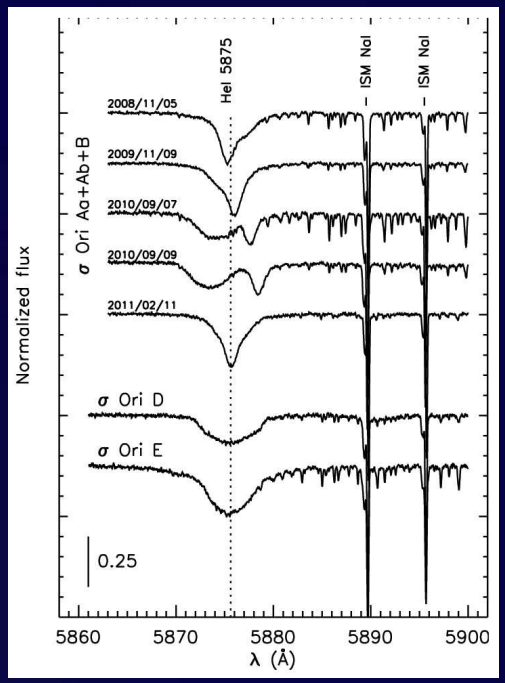
+ Atlas of standards observed in the Gaia spectral range
  (P.I: I. Negueruela) MERCATOR-1.2

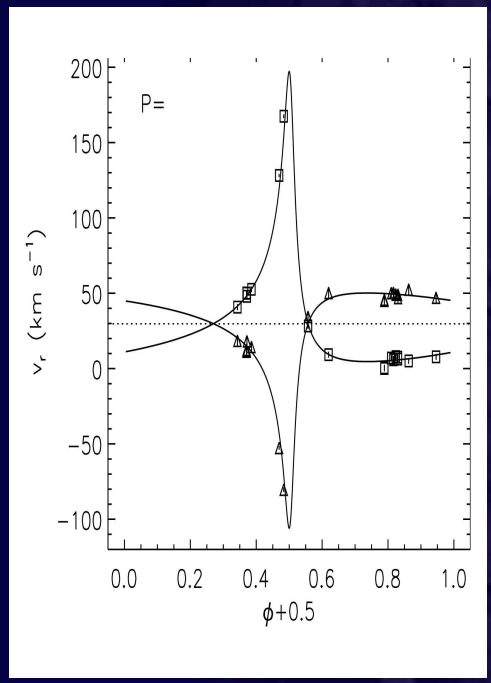
The importance of high-resolution, multi-epoch spectroscopy

The "binary" system σ Ori AB



Hartkopf et al. (1996, AJ)





Simón-Díaz, Cabelleroi & Lorenzo (2011)

P_{astrom} = 155 a

P_{spect} = 144 d

Circular
Δvr ≈ a few km/s
$M_A + M_B$ = 43 M_{sun} @385 pc

Highly excentric
Δvr ≈ 300 km/s
M_{Aa}/M_{Ab} ≈ 1.2 M_{sun}