



Universitat d'Alacant
Universidad de Alicante



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GVA NEXT
Fondos Next Generation en la Comunitat Valenciana

Herramientas de análisis automático para espectros estelares



ASTROFÍSICA Y FÍSICA
DE ALTAS ENERGÍAS

Klaus Rübke

Centro de Estudios de Física del Cosmos de Aragón

Mayo 2025, Galactica

Outline

- The astrophysical context
- The WEAVE project
- The Astro+ database
- IA/ML development
- Future



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Plan de Recuperación,
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Definition of massive star

- Stars initiating Carbon burning ($\geq 8 M_{\odot}$).
- Stars ending up their lives in supernova explosions ($\geq 8.5^{+1}_{-1.5} M_{\odot}$ – **Smart+ 2009, MNRAS 395, 1409** – but closer to $10 M_{\odot}$ from theory – e.g. **Jones+ 2013, ApJ 772, 150**).
- Stars with self-initiating radiation-driven winds .
 - OB stars (O2-B2 V, O2-B9 I-III – **Reed 2009, AJ 125, 2531**)
 - Later type supergiants: the most luminous AFGK SGs, M-type SGs



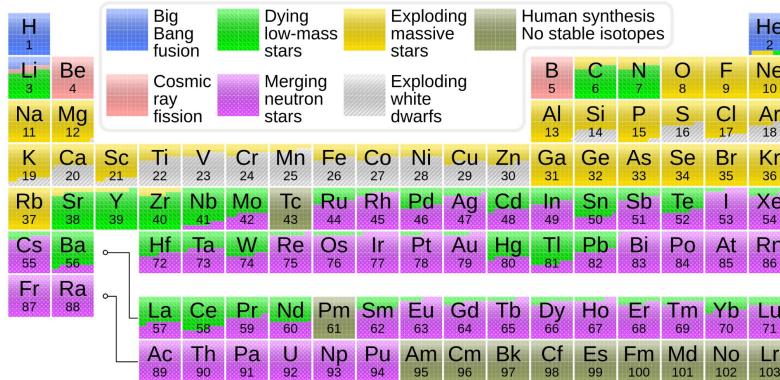
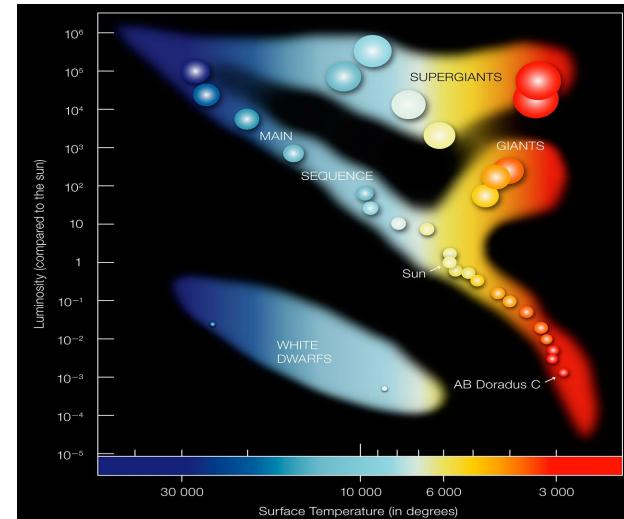
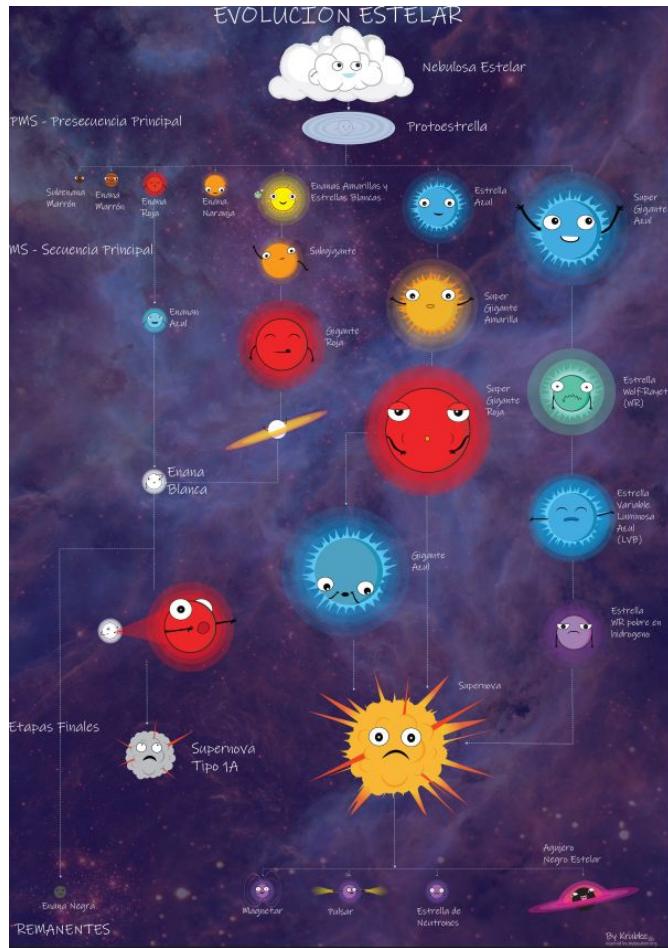
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Effects of massive stars on their environment

High-mass stars impact on the environment, via **stellar winds, UV radiation**, and, eventually, **supernova explosions**. Main effects are:

- **Ionisation** of neutral atoms (creation of H II regions) – in cosmology, reionisation
- Generation of shock waves within molecular clouds ⇒ **dispersion**, end of star formation.
- Destruction of accretion disks around lower-mass (proto-)stars

On the long term, they are the **progenitors of compact objects** ⇒ generation of **high-energy sources**, gravitational wave event progenitors.



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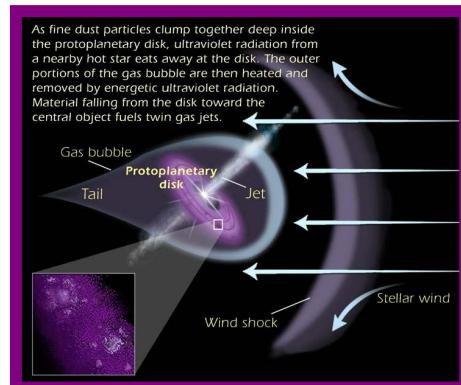
Effect on star formation

Cloud destruction.
Radiation pressure
sweeping away
material.



High-mass
stars

Triggering of
new generations.



LL Orionis, HST images



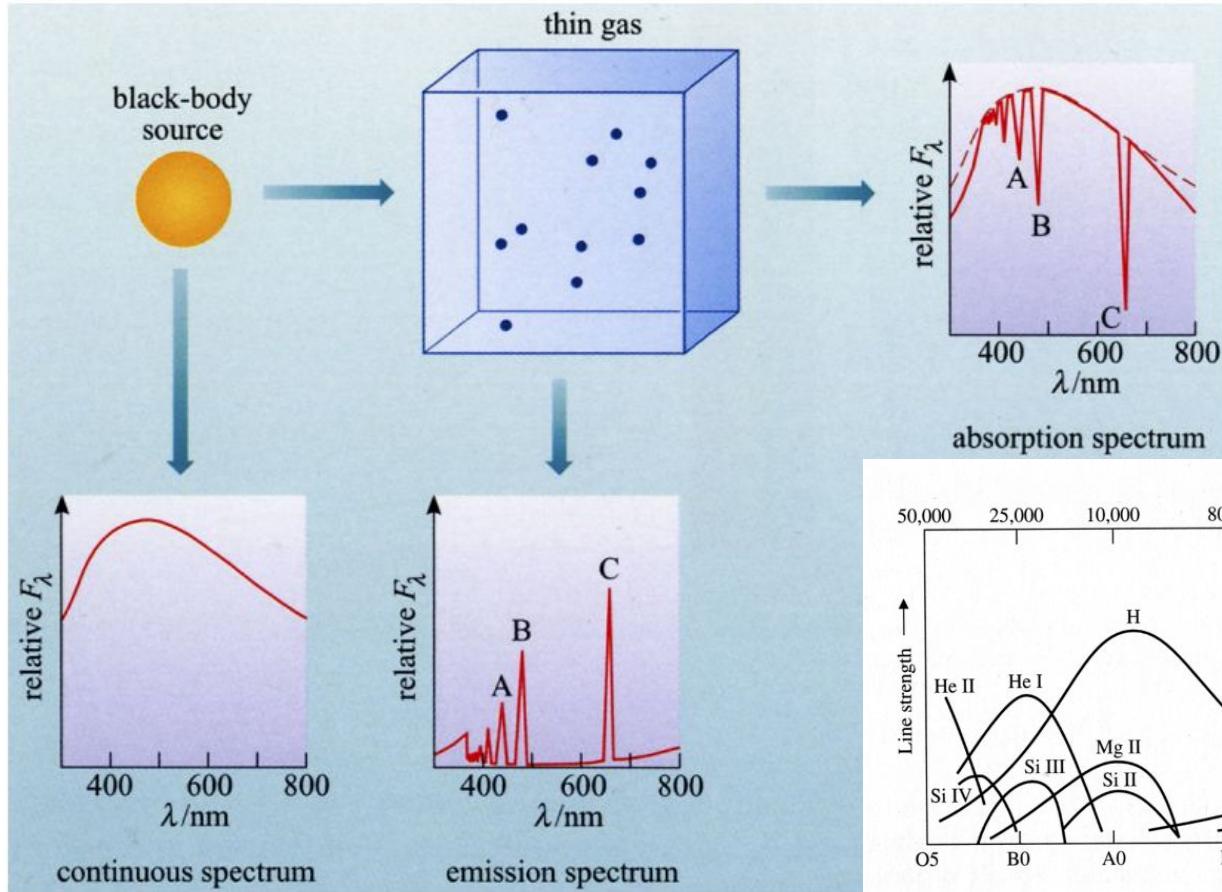
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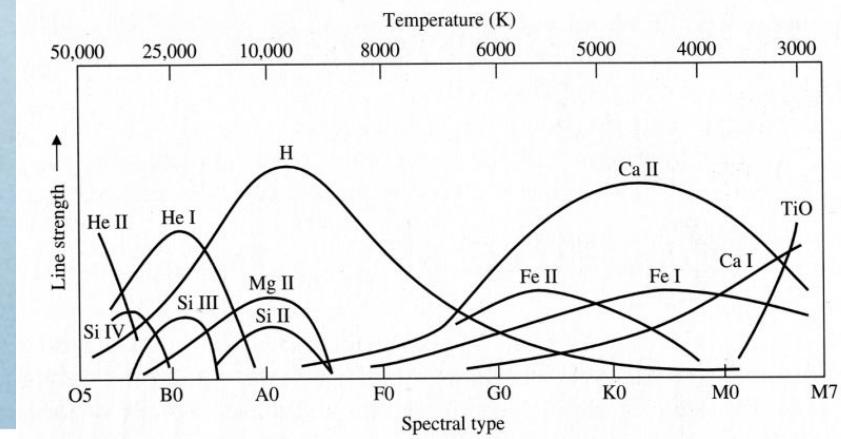
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How to study them ?



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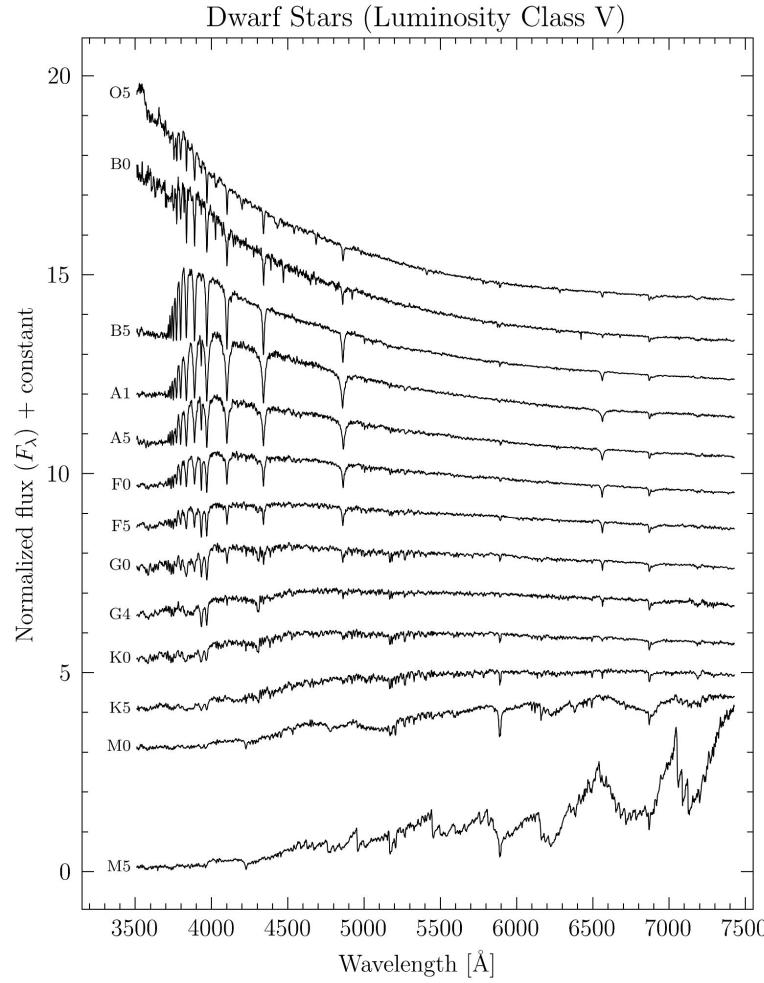
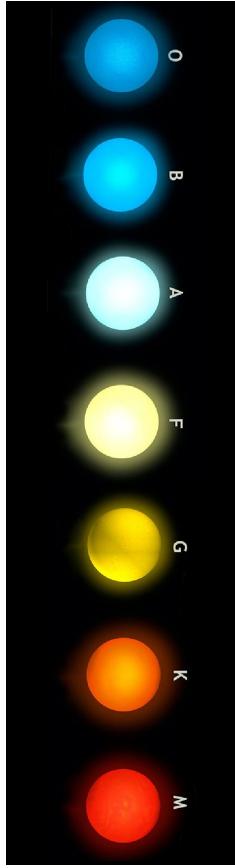


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Different stars produce different spectrum



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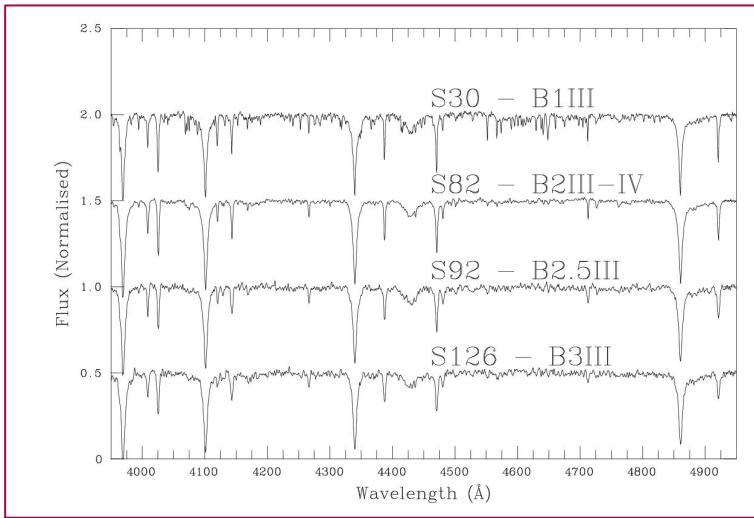
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Stellar parameters for OB stars

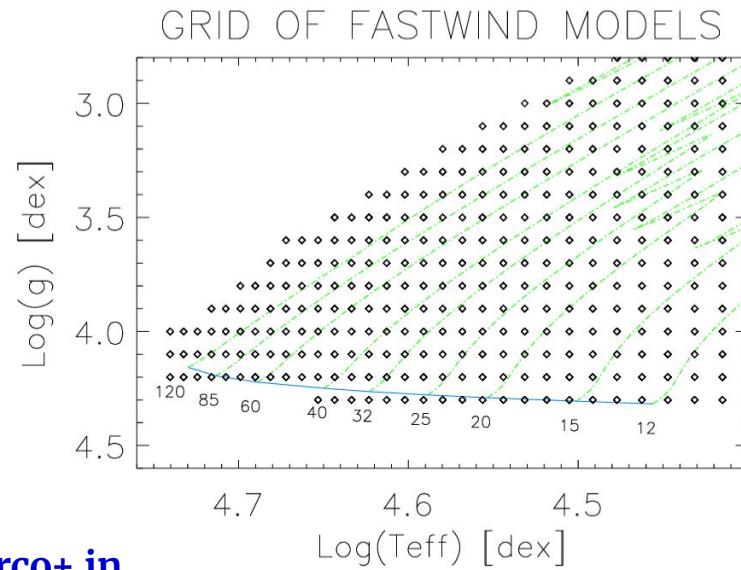
Spectral resolution $R \sim 10000$ is desirable, but $R \sim 5000$ with high S/N will do the job.



Analysis by N.
Castro (AIP,
Germany)



A sample of giants in NGC 663 [Marco+ in prep.](#)



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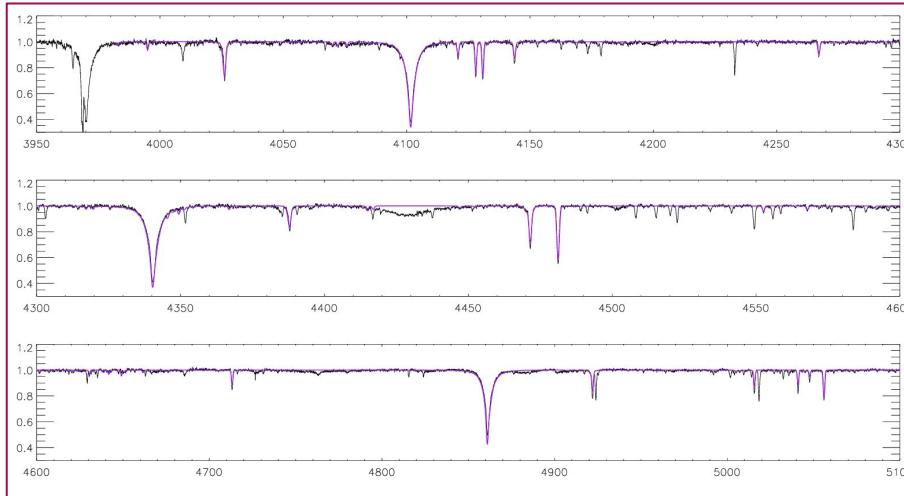


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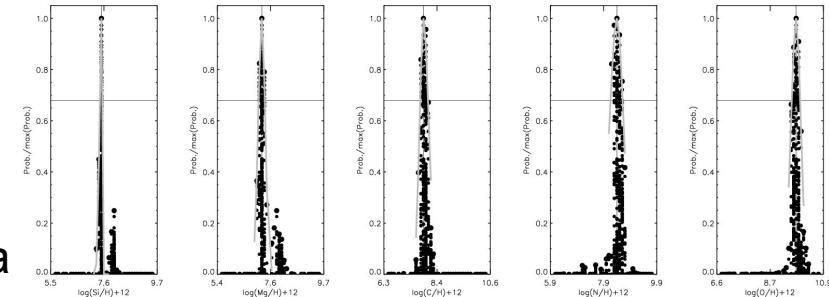
Fondo Next Generation en la Comunitat Valenciana

Abundances for OB stars

Spectral resolution $R > 10\,000$ is necessary with $> 20\,000$ highly desirable



Analysis by N.
Castro (AIP,
Germany)



Automatised abundance determination for a supergiant in NGC 663 **Marco+** submitted.



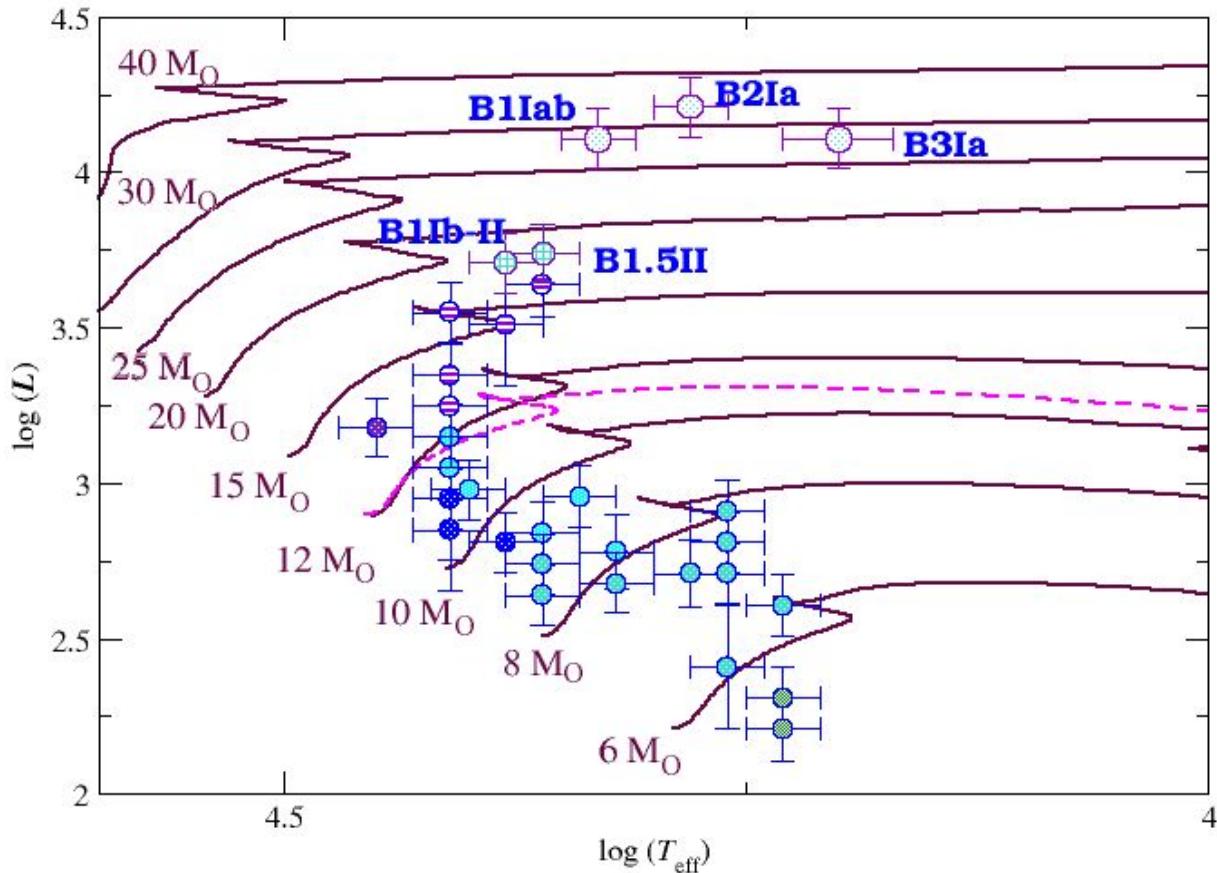
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- III
- IV
- B1 V
- B1.5 V
- B2 V
- B2.5 V



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Stellar parameters for cool supergiants

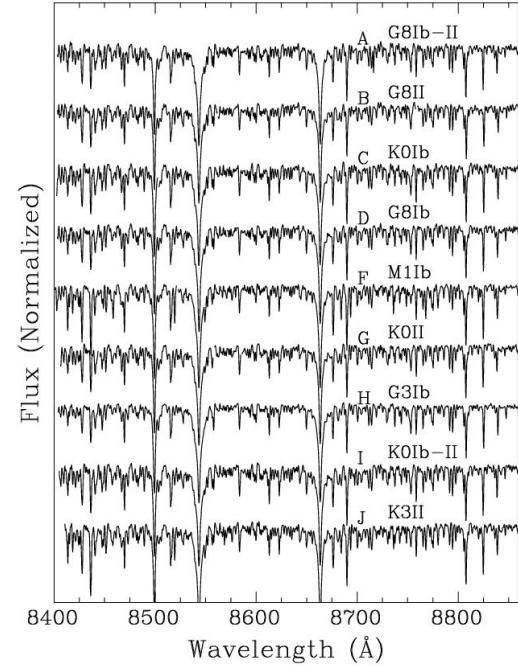
Spectral resolution $R \sim 10\,000$ is wanted,
although a bit less may do

Star	Other name	Gaia DR2	Spectral type	T_{eff} (K)	$\log g$	[M/H] (dex)	v_{hel} (km s $^{-1}$)	RV (Gaia) (km s $^{-1}$)
A	TYC 5121-543-1	4256511915482900608	G8 Ib-II	4693 \pm 46	1.1 \pm 0.11	-0.05 \pm 0.06	40.6 \pm 0.2	-
B	GSC 05121-00622	4256512843232515840	G8 II	4620 \pm 51	1.42 \pm 0.12	+0.01 \pm 0.07	42.4 \pm 0.2	40.1 \pm 0.4
C	TYC 5121-819-1	4253508943153458048	K0 Ib	4639 \pm 40	0.88 \pm 0.11	+0.02 \pm 0.06	39.8 \pm 0.2	-
D	TYC 5121-218-1	4253508702635208832	G8 Ib	4640 \pm 48	1.02 \pm 0.11	-0.07 \pm 0.06	41.1 \pm 0.2	40.8 \pm 0.5
E	CM Sct	4253603501158148736	- ^a	5431 \pm 36	1.03 \pm 0.09	-0.15 \pm 0.04	47.4 \pm 0.3	-
F	TYC 5121-758-1	4253603501158148736	M1 Ib	3840 \pm 20	0.33 \pm 0.09	-0.10 \pm 0.05	41.6 \pm 0.2	-
G		4256511468842481408	K0 II	4725 \pm 44	1.33 \pm 0.09	+0.12 \pm 0.05	41.5 \pm 0.2	41.6 \pm 0.4
H	TYC 5121-684-1	4253603501158148736	G3 Ib	5105 \pm 27	0.72 \pm 0.08	-0.07 \pm 0.04	41.1 \pm 0.2	41.8 \pm 0.2
I	TYC 5125-1531-1	4253499219346450432	K0 Ib-II	4755 \pm 22	0.91 \pm 0.06	+0.08 \pm 0.03	43.5 \pm 0.6	42.1 \pm 0.3
J		4253597556923196672	K3 II	4137 \pm 40	0.65 \pm 0.1	-0.06 \pm 0.06	43.4 \pm 0.2	-



Analysis by H. Tabernero
(UCM) with **SteParSyn**

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A sample of low-luminosity supergiants in
Valparaiso 1 Negueruela+21, **MNRAS 505**,
1618

Abundances for cool supergiants

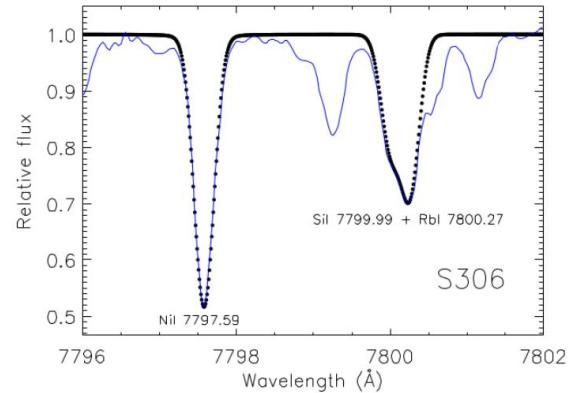
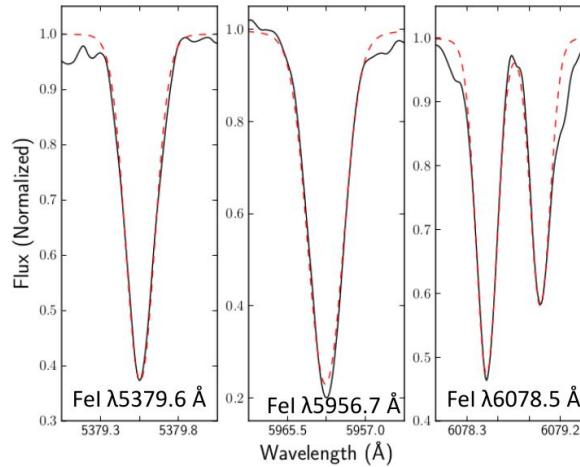
Spectral resolution $R > 20000$ is mandatory



Thesis of J. Alonso
Santiago
(now at INAF-Catania)



Analysis with **SteParSyn**



Low-luminosity supergiants in NGC 6067
Alonso Santiago+17, MNRAS 469, 1330



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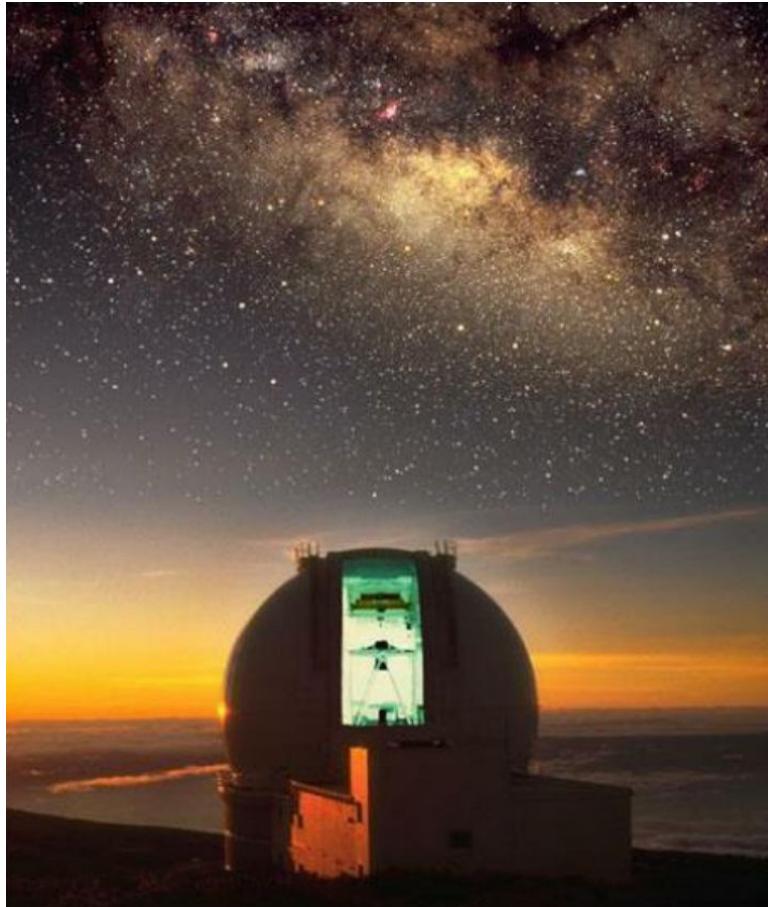
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The WEAVE project

- Next generation instrument for the 4.2 m WHT in La Palma
- Led by ING (Spain, UK; The Netherlands) with substantial backing from other European countries
- > 150 researchers involved in design and science teams



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- Multi-mode spectrograph with:
 - Multi-object
 - Large integral field
 - Several mini-IFU
- Two resolutions offered
- Operation mostly in survey mode, with several survey strands covering stellar astrophysics, galaxy evolution and cosmology
- Expected to be a major player, but already delayed by 6 years.
- LIFU is in operation with some survey observations done since summer
- MOS in comissioning



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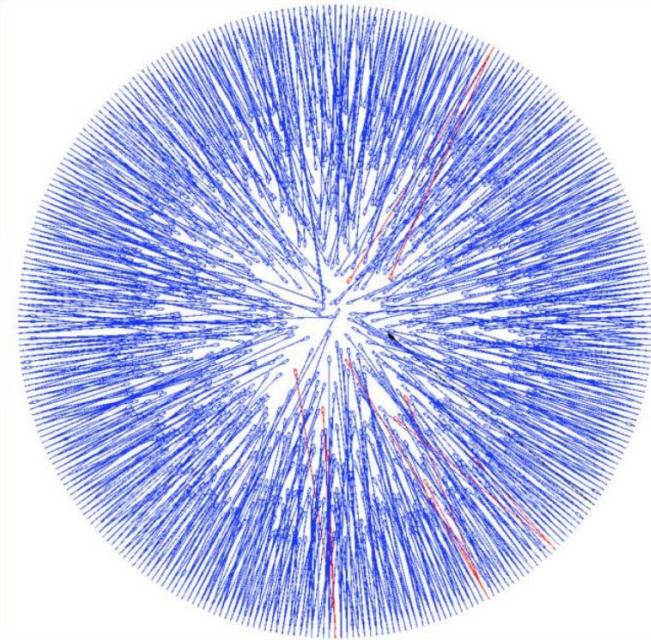
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More than 900 fibers can be allocated by the two robot positioners



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Main surveys at $R \sim 5000$

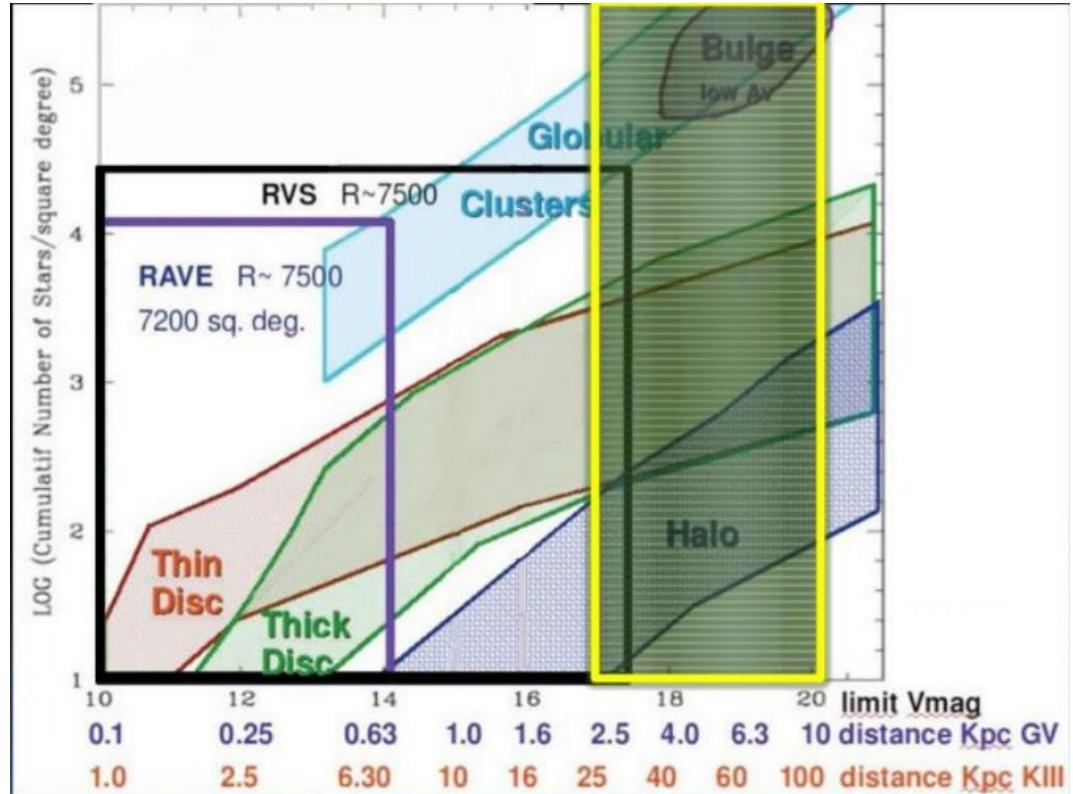


Image by Vanessa Hill (OCA)



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High-resolution mode at R \sim 20 000

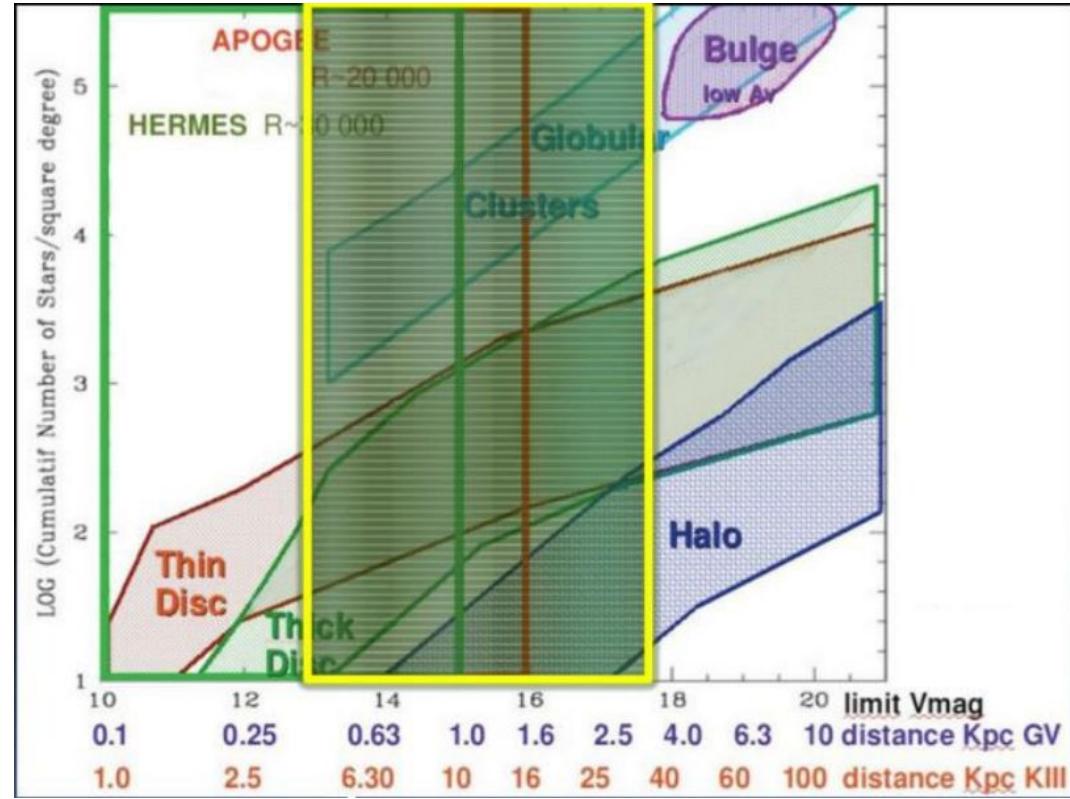


Image by Vanessa Hill (OCA)



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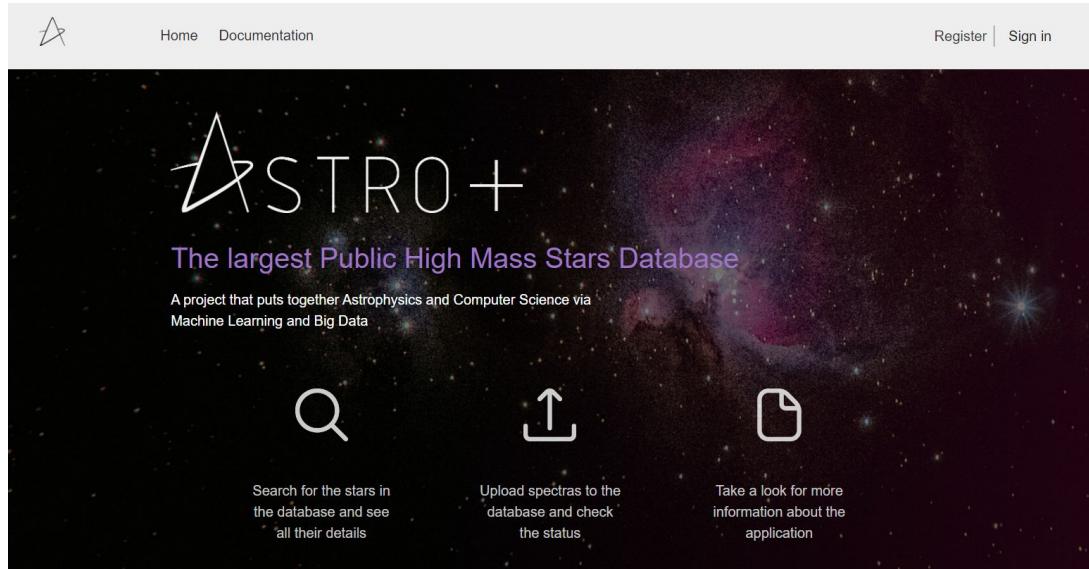
The Astro+ database (web/server)

<https://astroplus.ua.es>

PROMETEO/2019/041



P.I. Amparo Marco



- Gather spectra
- Unify
- Standardize
- Analysis tools

Search for a spectrum

Search

Identifier query

Coordinate query

TAP query

We use all the Simbad Identifiers

Identifier

Search

Examples: HD 15570, HIP 11837

Search

Identifier query

Coordinate query

TAP query

RA

Examples:

20 54 05.689 +37 01 17.38
10:12:45.3-45:17:50
15h17m-11d10m
15h17+89d15

DEC

Cone

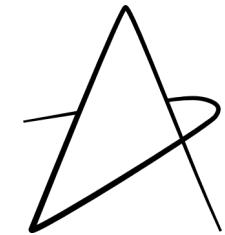
Search

Search

- ID

- Coordinates

- SQL Query



Search

Identifier query

Coordinate query

TAP query



This query is based on AI. Thus, it is not possible to search for data under analysis using this query.

Query

Download available fields

Examples: TEMP_EFF > 4500 AND TEMP_EFF > 5000



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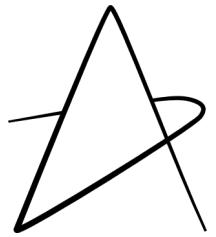
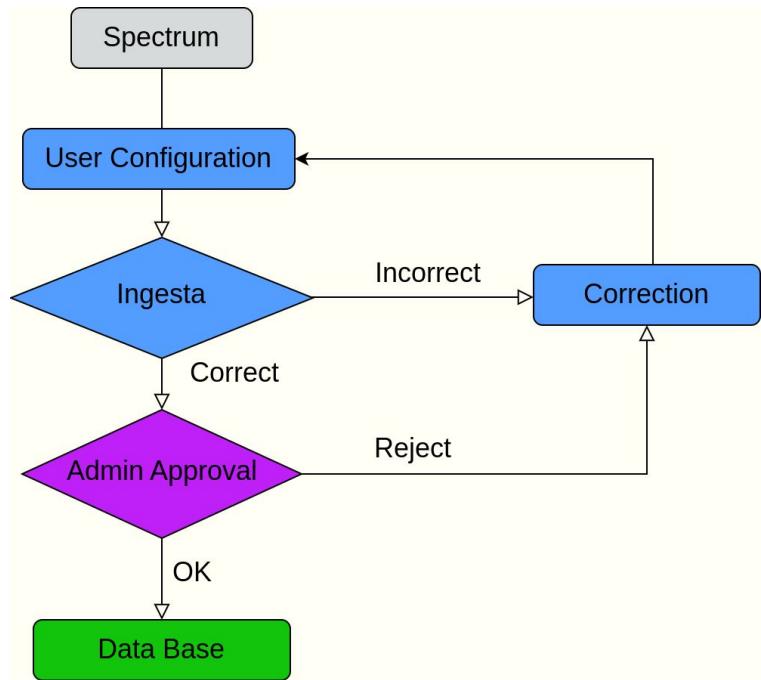
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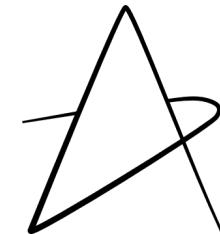
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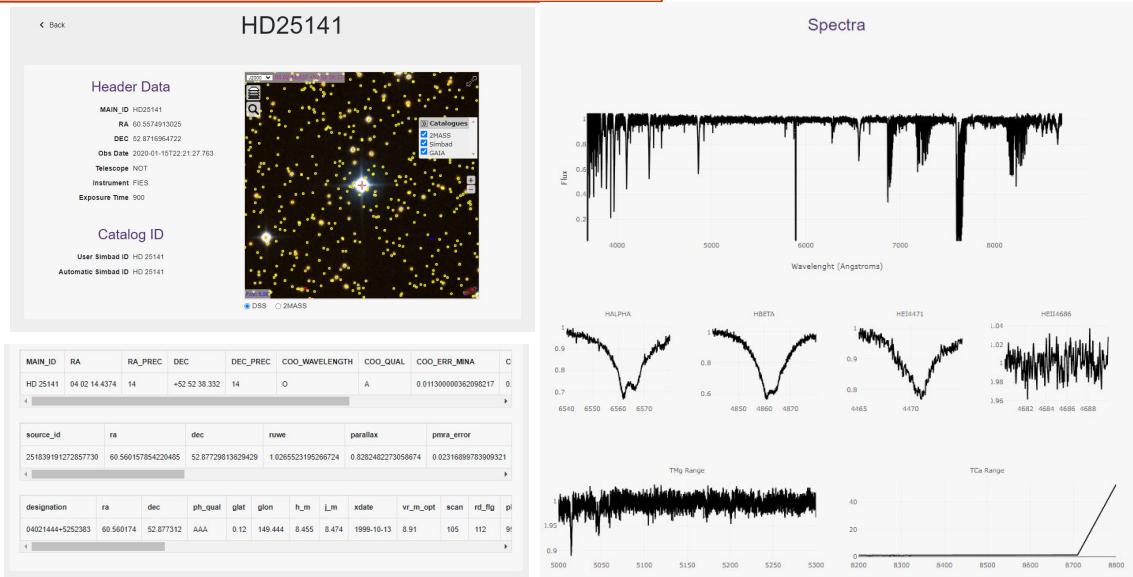
Assign identification and catalogue data



FITS
ASCII

APIs

- SIMBAD
- 2MASS
- Gaia



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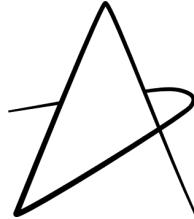
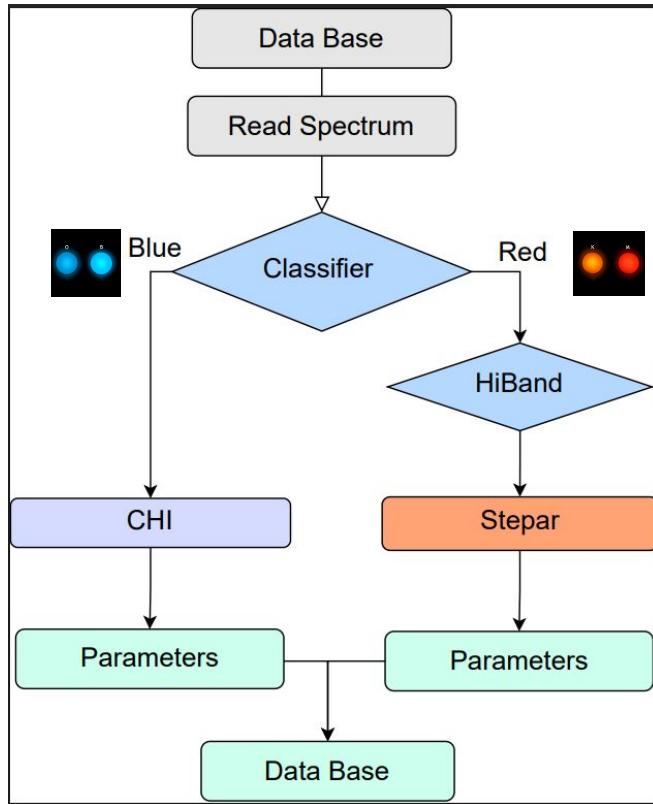


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Automatic Analysis tools



P.I. Ignacio Negueruela y Amparo Marco

HIAMAS , reference ASFAE/2022/017



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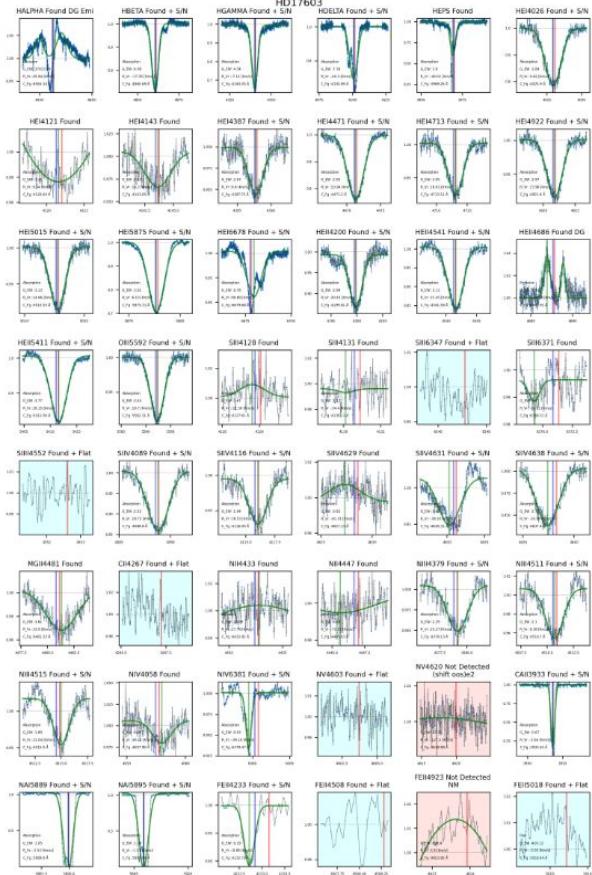
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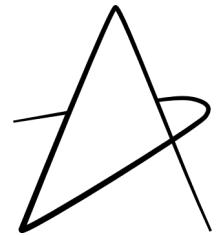
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HILINETHERE Fully Automatic Line detection and quantification



Line	Lambda	V_r	$V \sin i / \zeta$
H α	6562.80		
H β	4861.33	X	
H γ	4340.46	X	
H δ	4101.74	X	
H ϵ	3970.07	X	
He 1 4026	4026.19	X	15
He 1 4121	4120.82		
He 1 4387	4387.93	X	
He 1 4471	4471.47	X	9
He 1 4713	4713.16	X	7
He 1 4922	4921.93		14
He 1 5015	5015.67	X	8
He 1 5875	5875.62	X	10
He 1 6678	6678.15		
He 1 4200	4199.83		11
He 1 4541	4541.59	X	13
He 2 4686	4685.71		
He 2 5411	5411.52	X	12
O 1m 5592	5592.37	X	1
Si 1 4128	4128.07		
Si 1 4131	4130.89		
Si 1 6347	6347.11		
Si 1 6371	6371.37	X	
Si 1 4552	4552.62	X	2
Si 1 4089	4088.85		5
Si 1 4116	4116.10	X	6
Si 1 4629	4628.62		
Si 1 4631	4631.24		
Si 1 4638	4638.28		
Mg 1 4481	4481.15	X	4
Cu 1 4267	4267.24	X	3
Ni 1 4433	4432.74		
Ni 1 4447	4447.03		
Ni 1 4379	4379.11	X	
Ni 1 4511	4510.91	X	
Ni 1 4515	4514.86	X	
Ni 1 4058	4057.76		
Ni 1 6381	6380.77		
Ni 1 4603	4603.73		
Ni 1 4620	4619.98		
Ca 1 3934	3933.66		
Na 1 5889	5889.95		
Na 1 5895	5895.92		
Fe 1 4233	4233.16		
Fe 1 4508	4508.28		
Fe 1 4549	4549.47		
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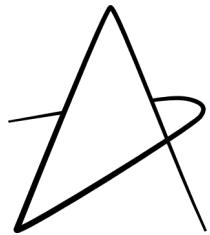
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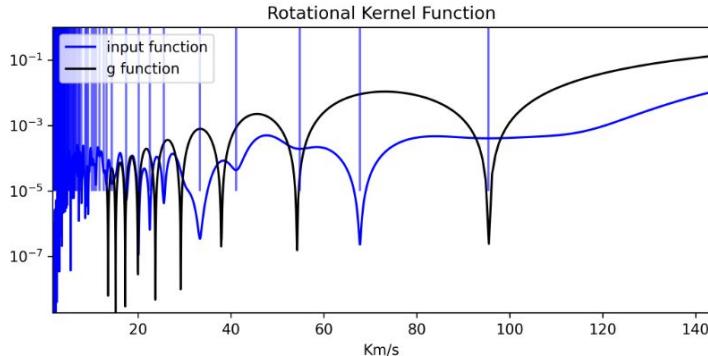
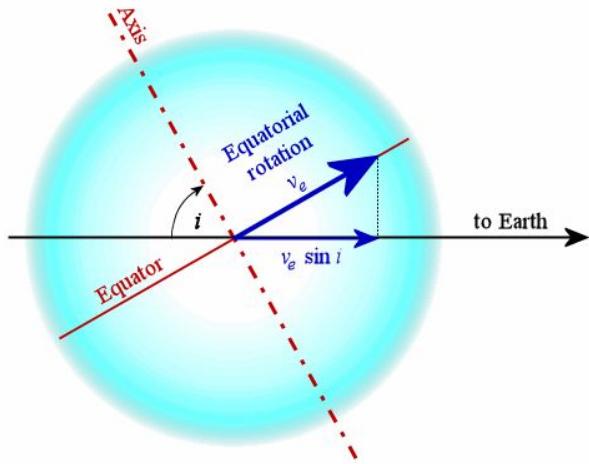
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HILINETHERE

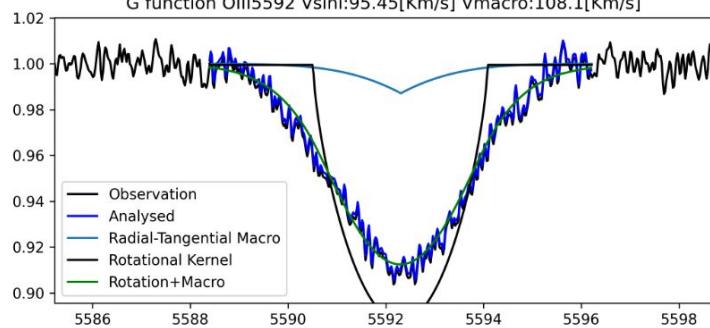


THE ROTATIONAL SPEEDS OF THE STARS.

J. A. Carroll, M.A., Ph.D., and L. J. Ingram, M.A.



Fourier-Bessel function Deeming et al. (1975)



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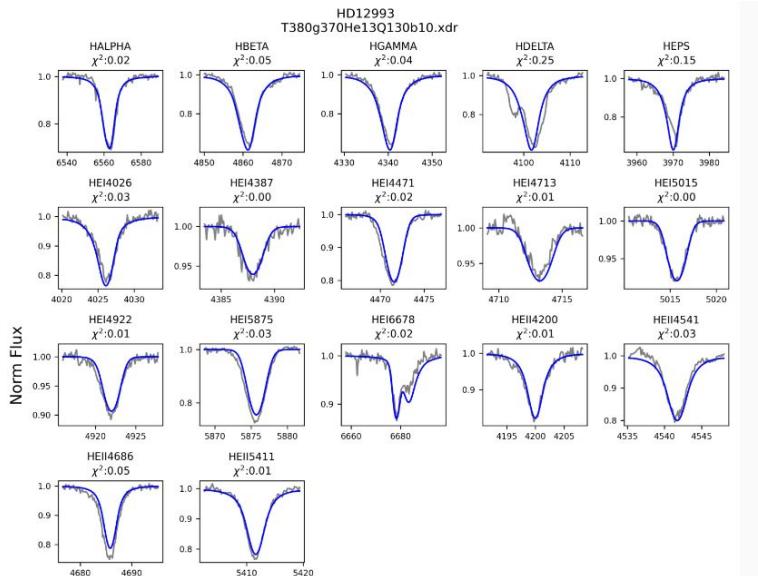
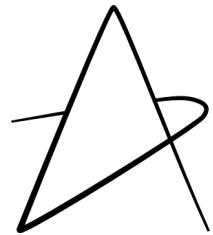
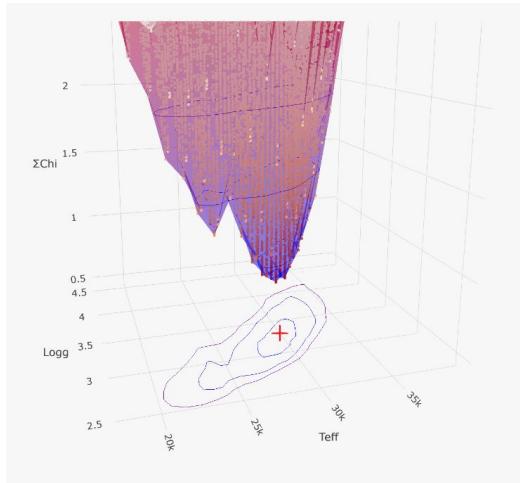


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HICHI

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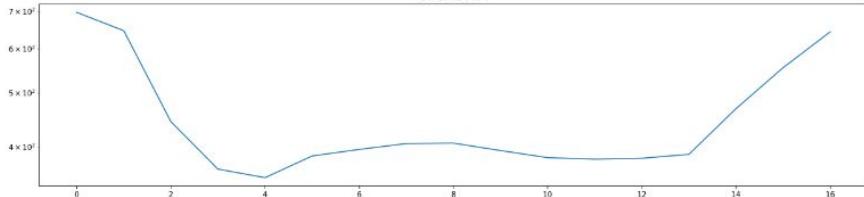
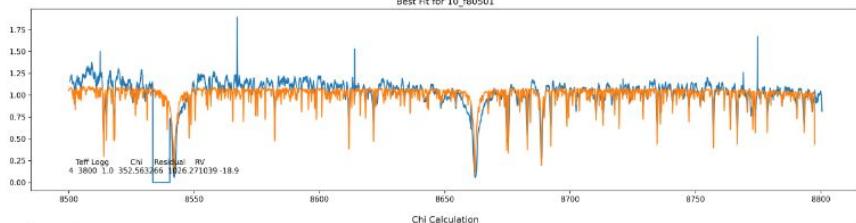
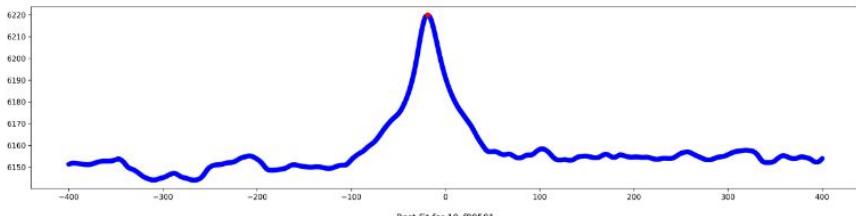
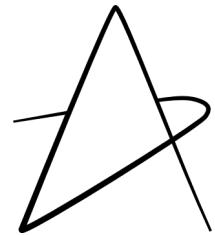


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HIBAND



TO → SteParSyn MCMC
Tabernerero+ 2022



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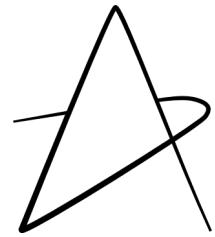


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Quality control



$v\sin i$ deminination

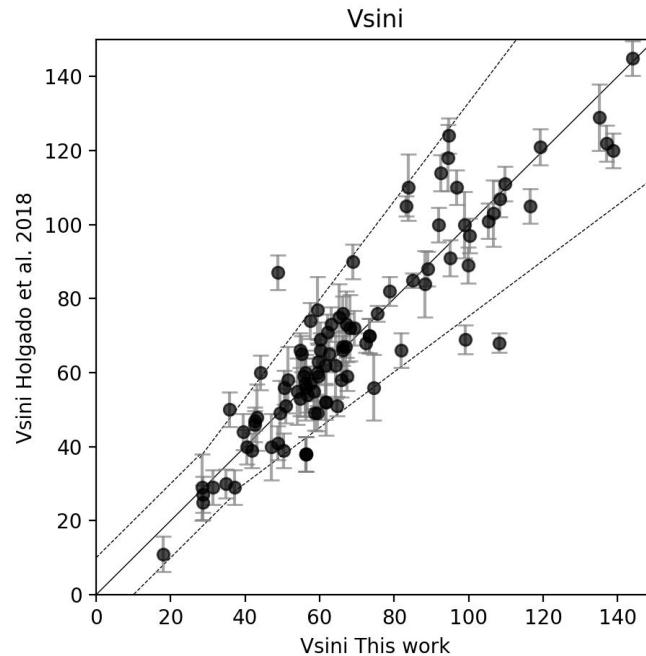


102 Stars

The IACOB project

V. Spectroscopic parameters of the O-type stars in the modern grid of standards for spectral classification*

G. Holgado^{1,2}, S. Simón-Díaz^{1,2}, R. H. Barbá³, J. Puls⁴, A. Herrero^{1,2}, N. Castro⁵, M. García⁶, J. Maíz Apellániz⁷, I. Negueruela⁸, and C. Sabín-Sanjulián³



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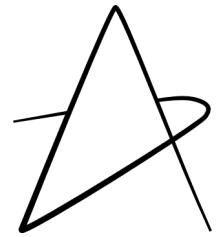
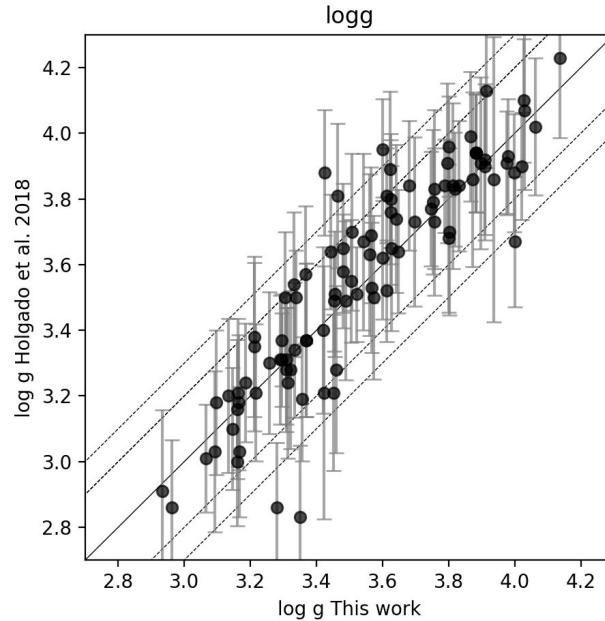
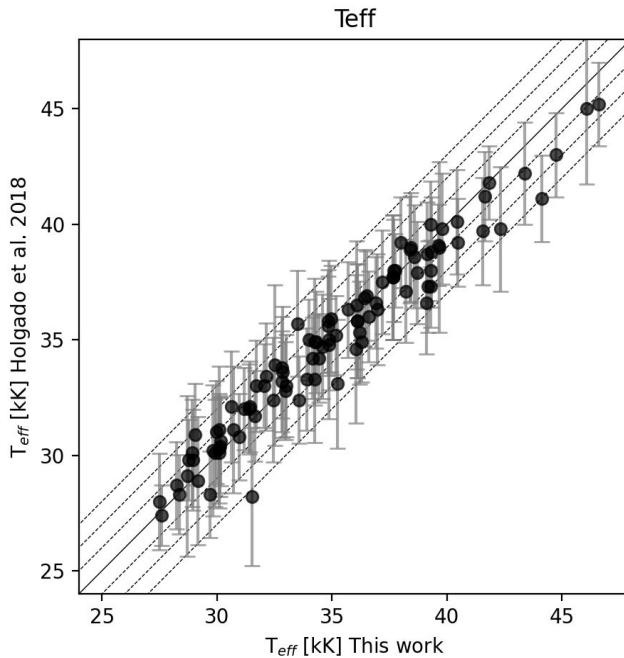
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V2.0

Parameter determination



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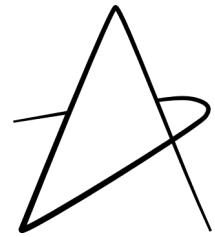
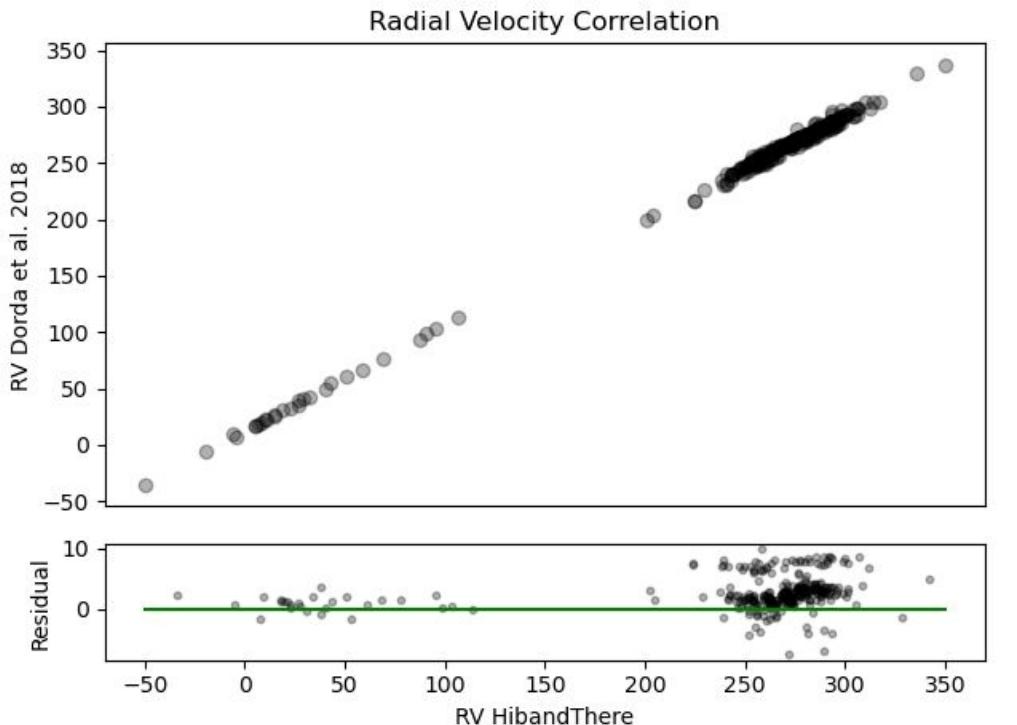


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Quality control



TO → SteParSyn

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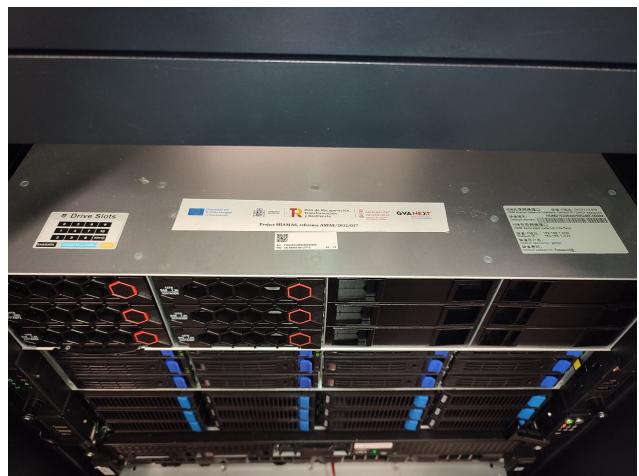
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Running time



Proceso	ANTES	AHORA
Classificador	1m35s	15s x 4
HiChi	1h20m	5m x 20
Stepar	1h30m	12m x 10



Rübke et al. (in prep)

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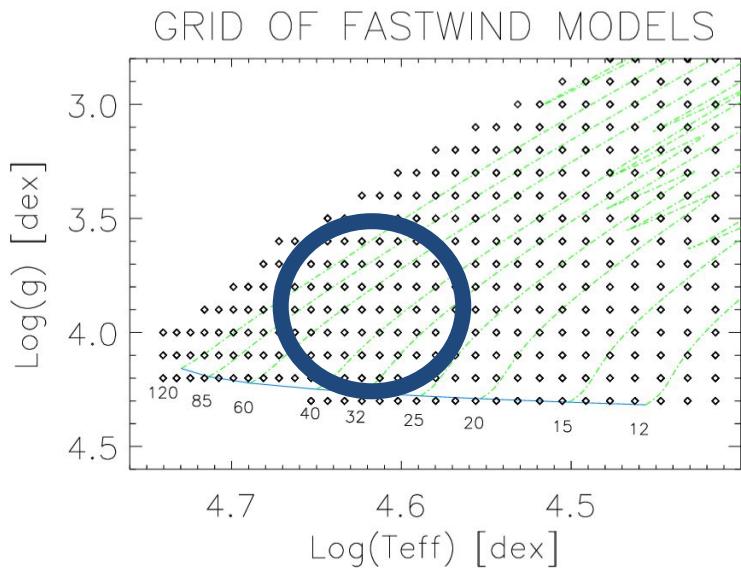
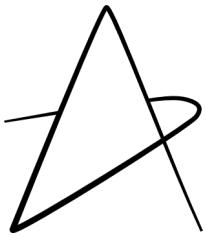
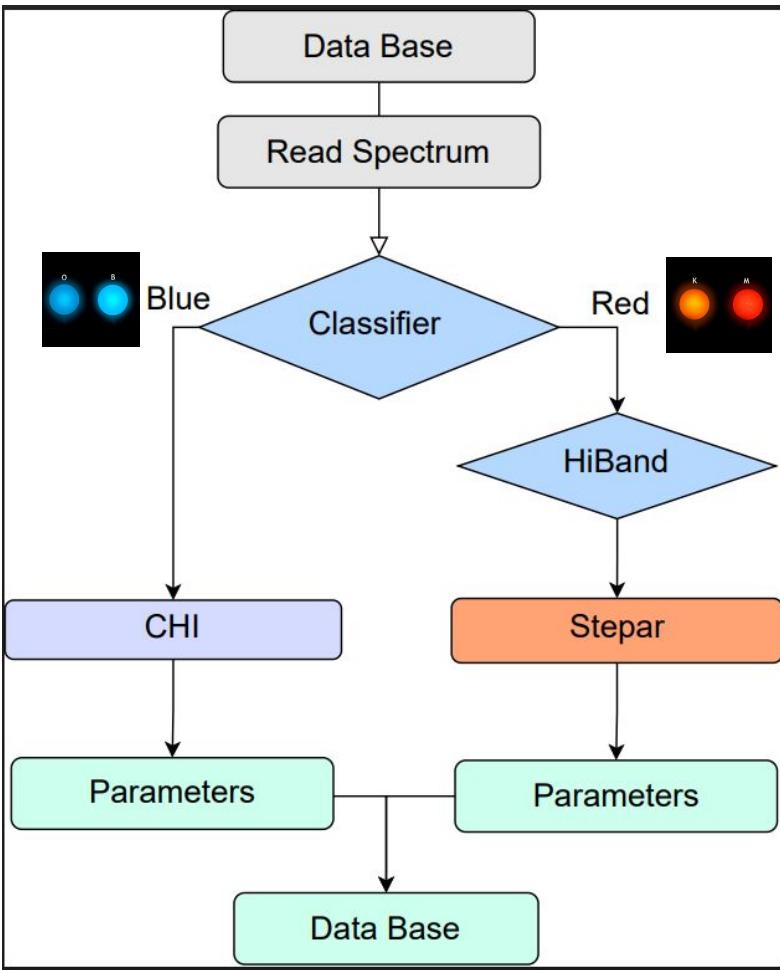


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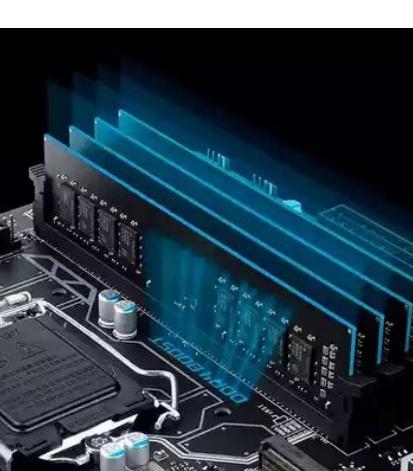
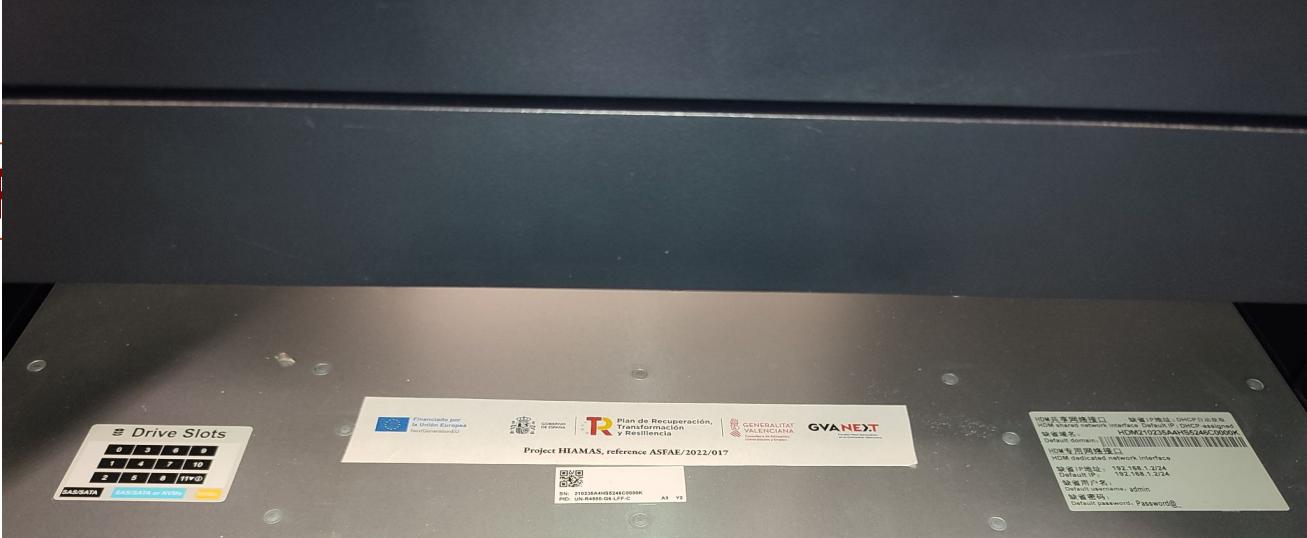
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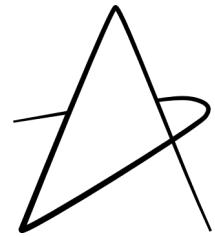
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NVIDIA A10 X2



- ML tool to determine parameters for the cool stars without having to resort to very time consuming MC simulations.
- Large numbers of spectra with parameter determination needed to train.
- ML tool that will consider $\sim 10^4$ WEAVE spectra of cool luminous stars and try unsupervised learning.



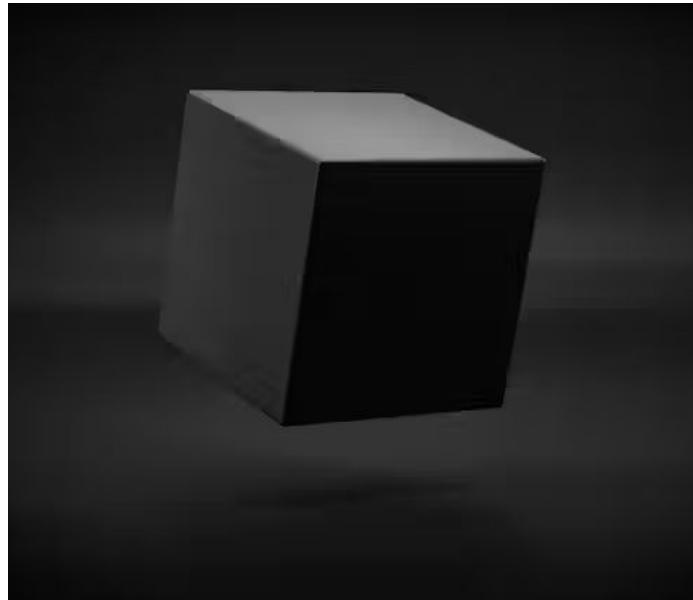
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- TFG



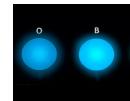
David

- TÍTULO: USO DE TÉCNICAS DE APRENDIZAJE AUTOMÁTICO (MACHINE LEARNING) SOBRE DATOS ESTELARES.



Ivan

- TÍTULO: TÉCNICAS DE DEEP LEARNING PARA DETECCIÓN DE BINARIEDAD EN ESTRELLAS. (En desarrollo)

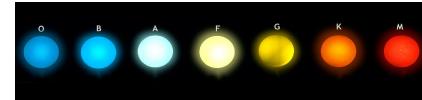


- TFM



Elias

- TÍTULO: BÚSQUEDA Y CARACTERIZACIÓN DE CÚMULOS ESTELARES EN LA GALAXIA MEDIANTE APRENDIZAJE AUTOMÁTICO. (En desarrollo)



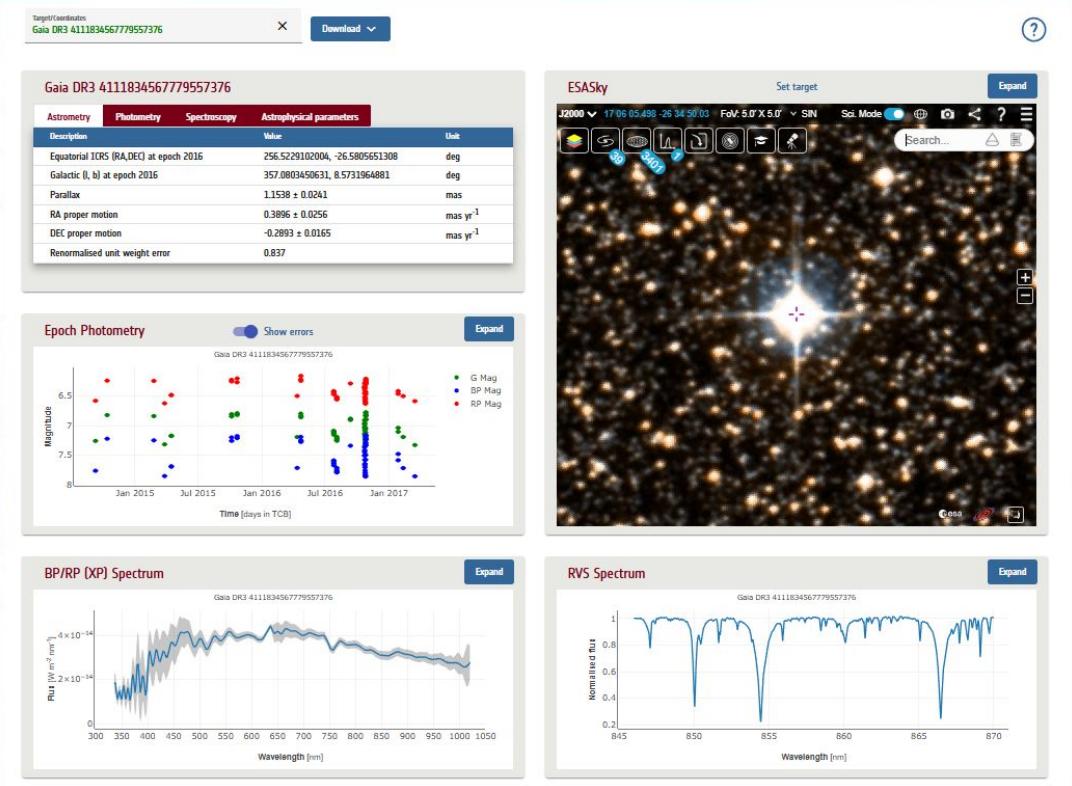
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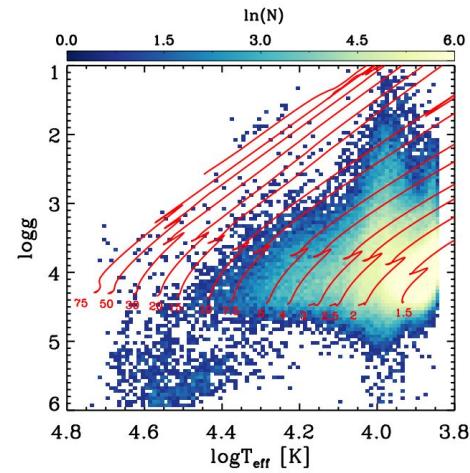
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LAMOST

150000 spectra



Maosheng Xiang
2022



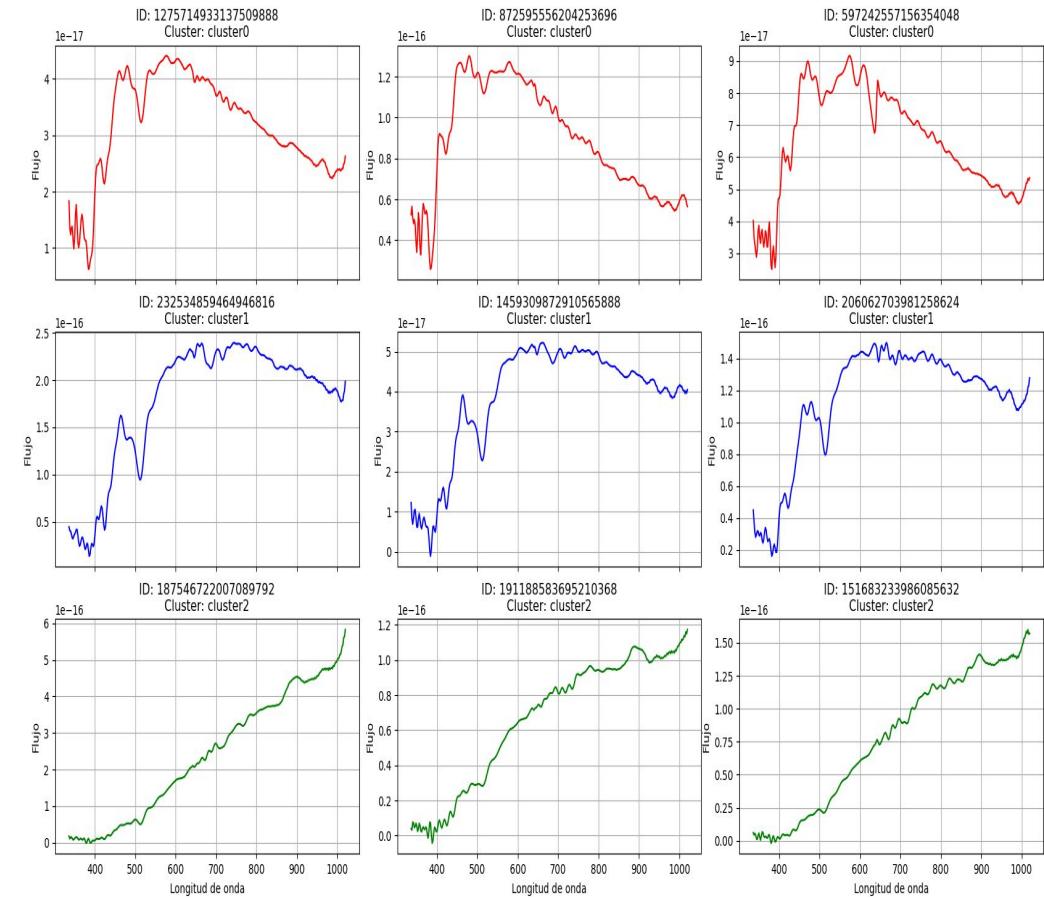
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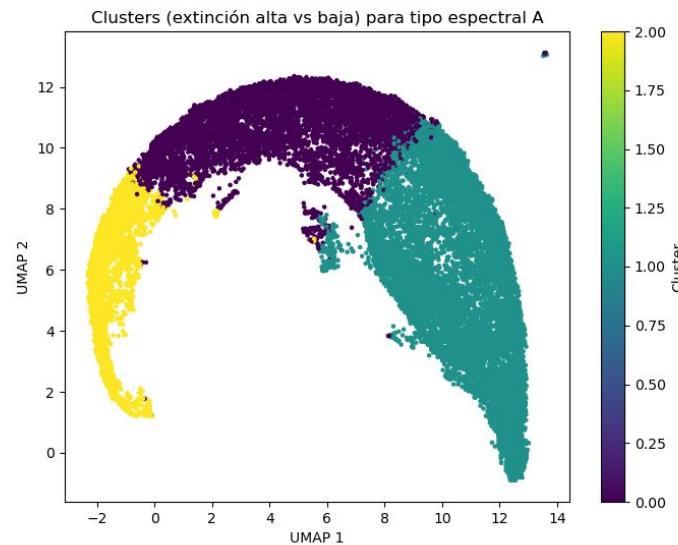
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- PCA, K-MEANS & NN



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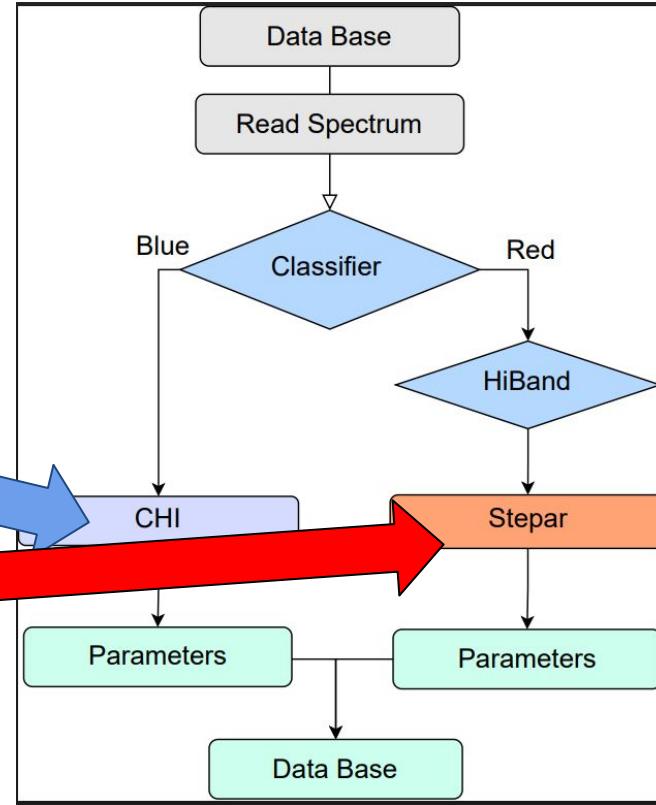
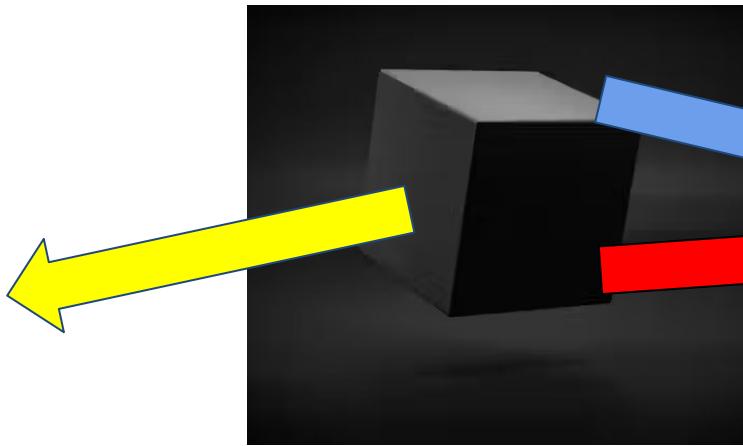
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Spectral type and level
of extinction



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Herramientas de análisis automático para espectros estelares



ASTROFÍSICA Y FÍSICA
DE ALTAS ENERGÍAS

Klaus Rübke

Centro de Estudios de Física del Cosmos de Aragón

Mayo 2025, Galactica