



Herramientas de análisis automático para espectros estelares

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



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



Plan de Recuperación,
Transformación y Resiliencia



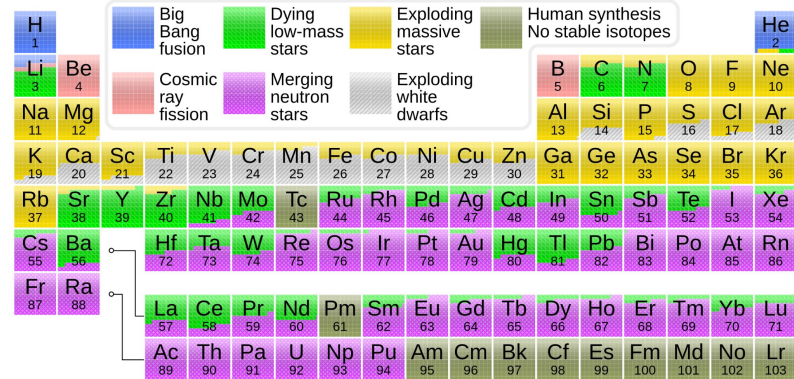
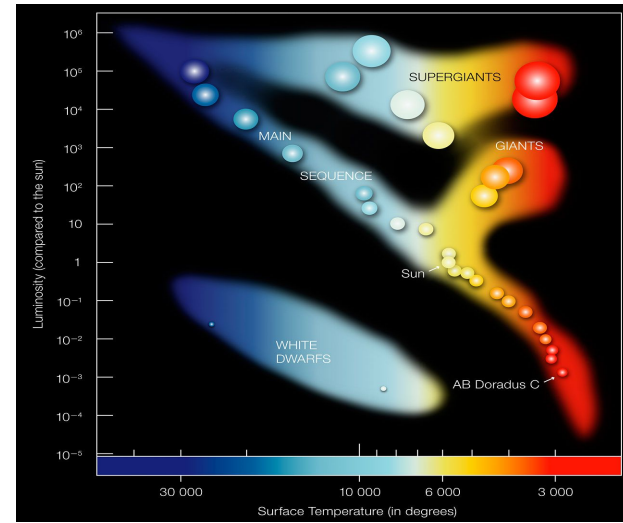
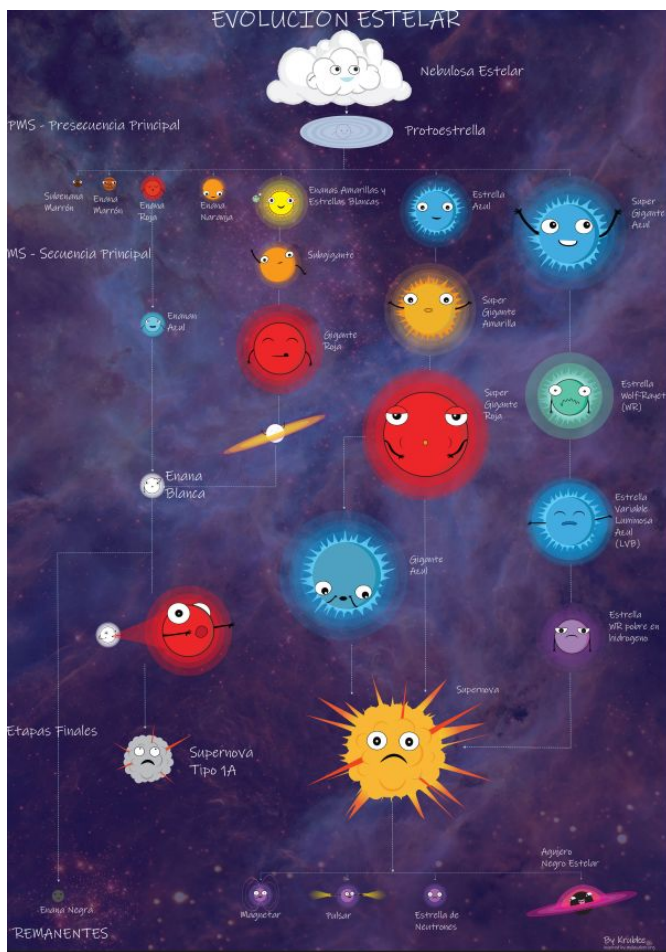
GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Treball

GVANEXT
Fondo Next Generation de la Comisión Europea

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





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 \Rightarrow **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** \Rightarrow generation of **high-energy sources**, gravitational wave event progenitors.



Effect on star formation

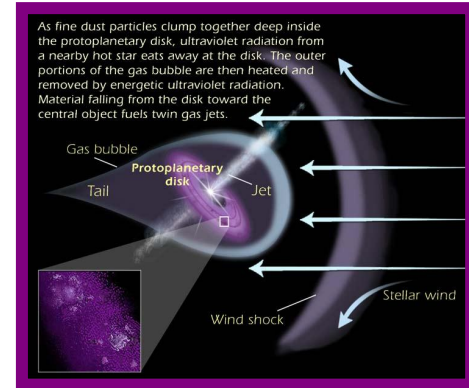
**Cloud destruction.
Radiation pressure
sweeping away
material.**



**High-mass
stars**



**Triggering of
new generations.**



LL Orionis, HST images



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



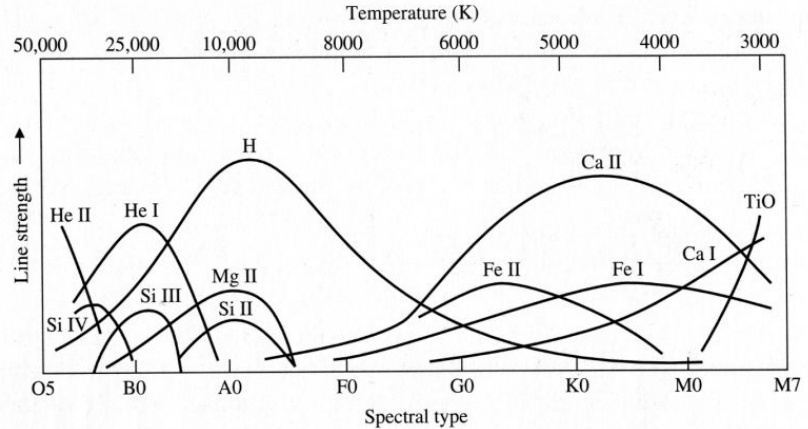
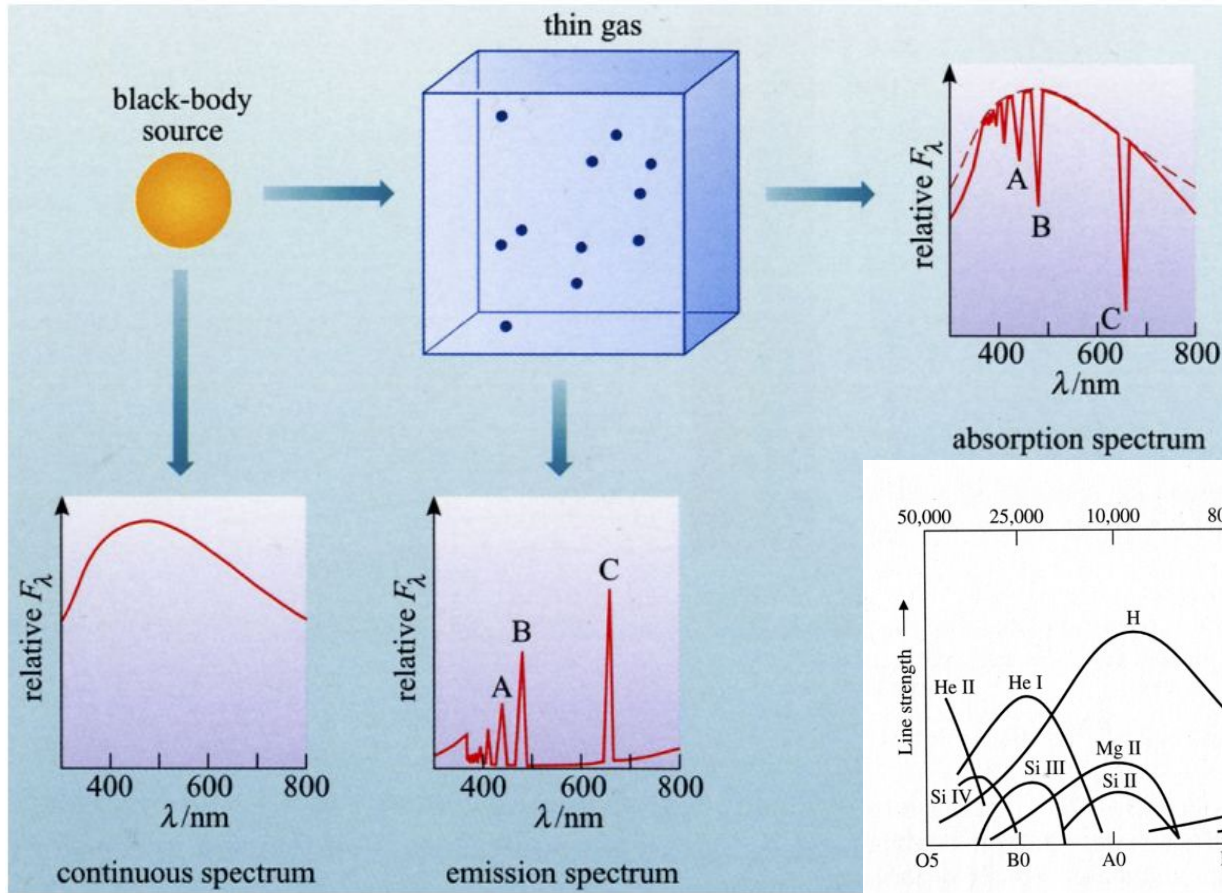
GOBIERNO
DE ESPAÑA
MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES

Plan de Recuperación,
Transformación y Resiliencia

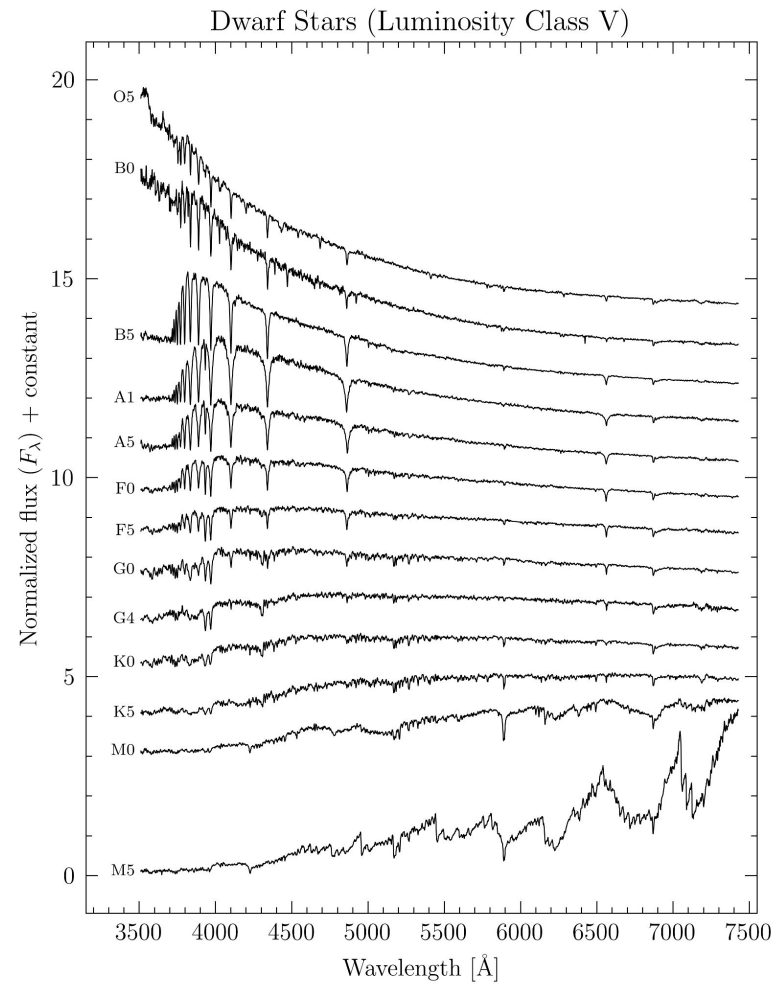
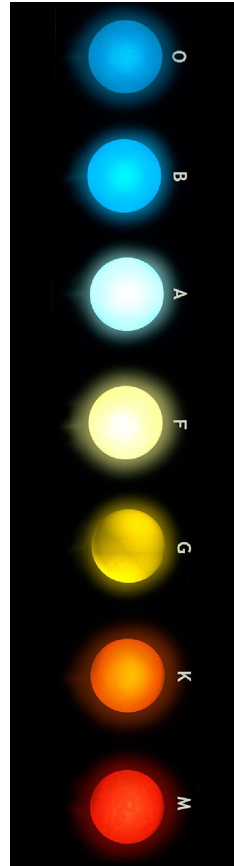
GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Treball

GVANEXT
Fondo Next Generation de la Comisión Europea

How to study them ?



Different stars produce different spectrum



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN
Y TURISMO

Plan de Recuperación,
Transformación y Resiliencia

GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Empreu

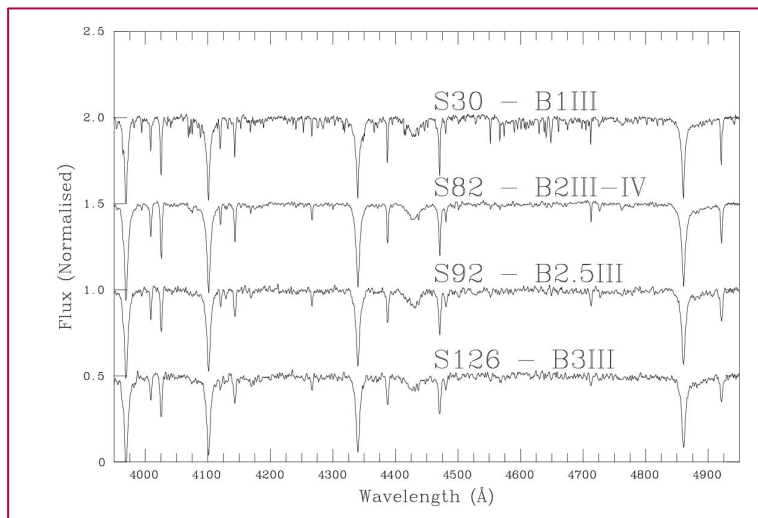
GVANEXT
Fondata Next Generation de la Conselleria Valenciana

Stellar parameters for OB stars

Spectral resolution $R \sim 10\,000$ is desirable, but $R \sim 5\,000$ with high S/N will do the job.

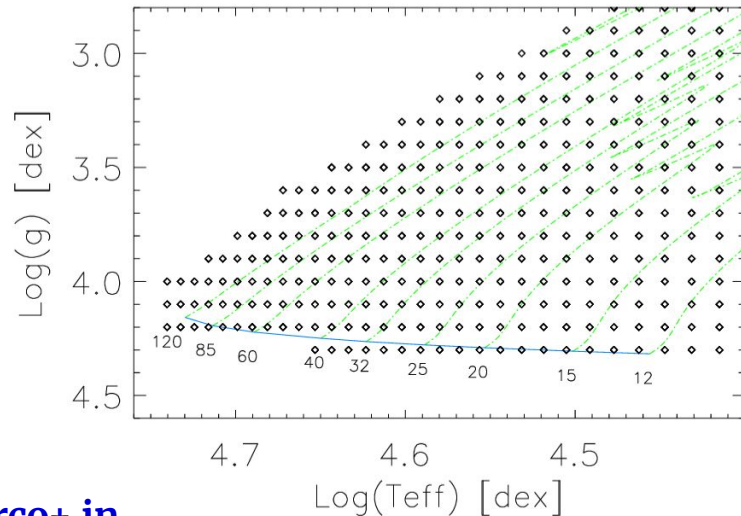


Analysis by N.
Castro (AIP,
Germany)



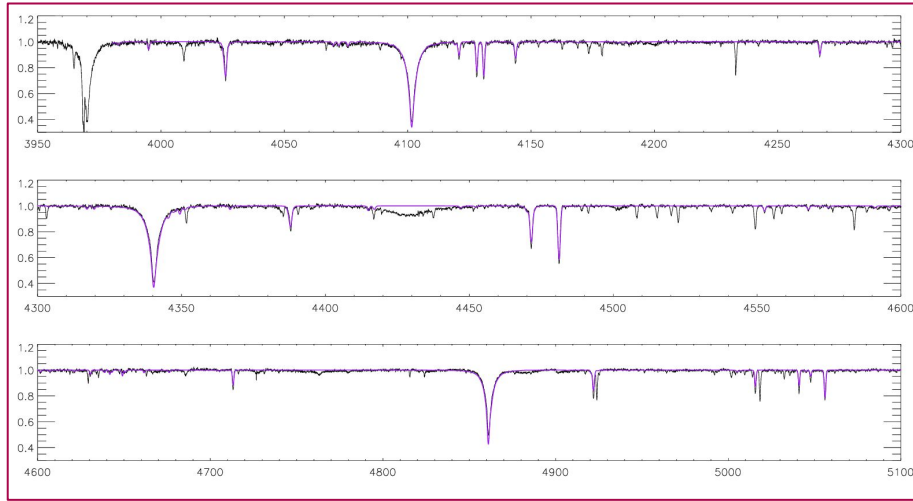
A sample of giants in NGC 663 **Marco+ in prep.**

GRID OF FASTWIND MODELS



Abundances for OB stars

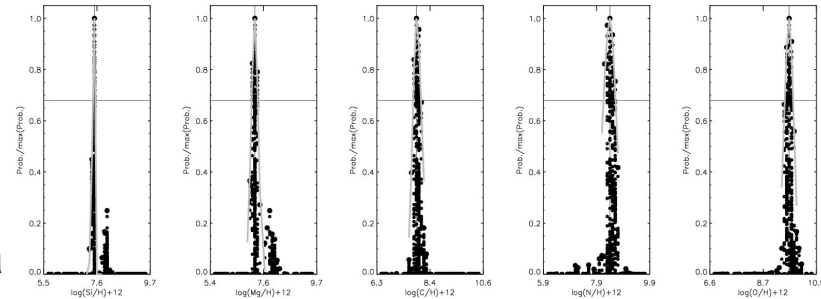
Spectral resolution $R > 10000$ is necessary with > 20000 highly desirable



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



Analysis by N.
Castro (AIP,
Germany)



The ASFAE's research projects acknowledge the financial support from the
MCU with funding from the European Union NextGenerationEU and
Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU

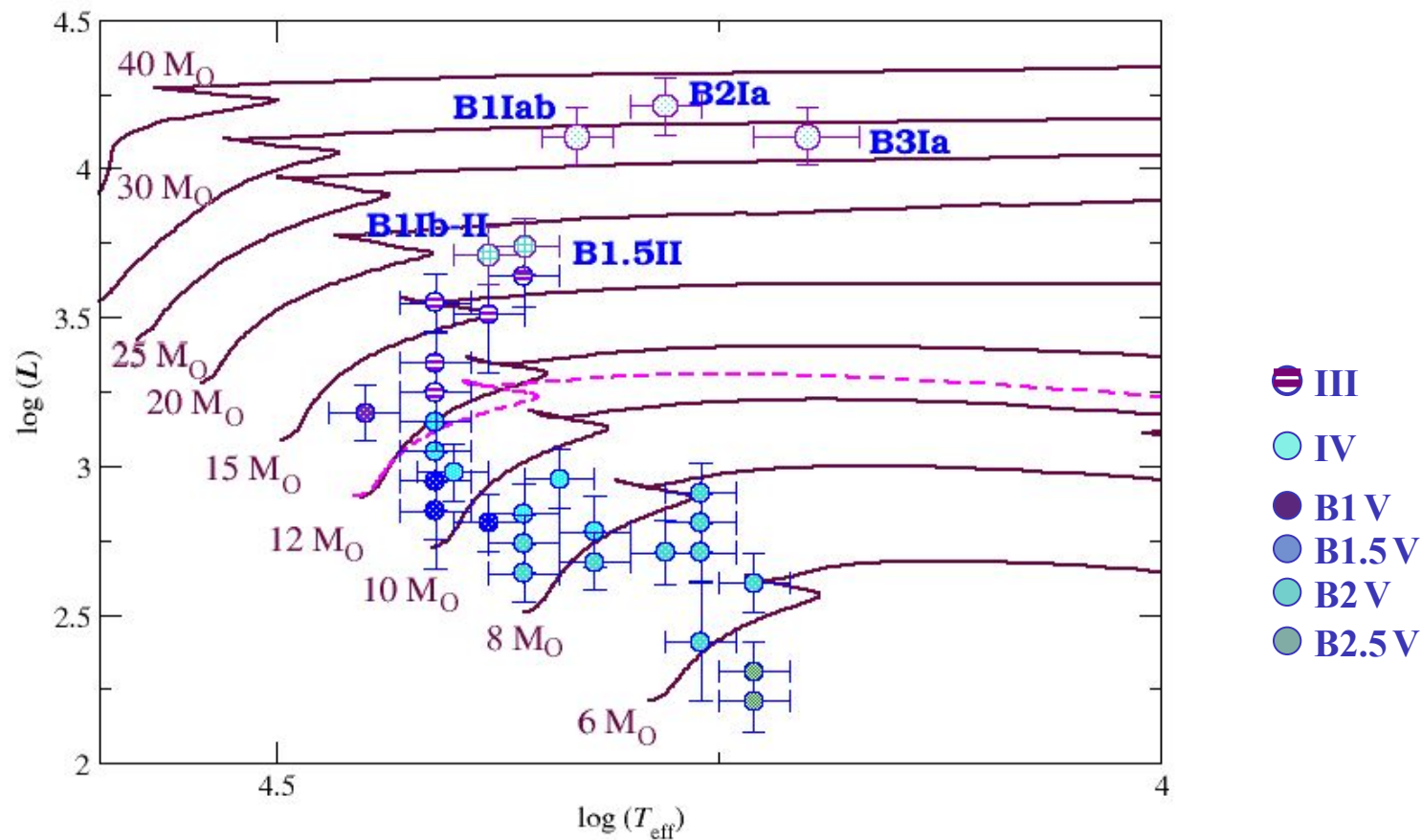


GOBIERNO
DE ESPAÑA
MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



GENERALITAT
VALENCIANA
Conselleria d'Educació,
Universitats i Innovació

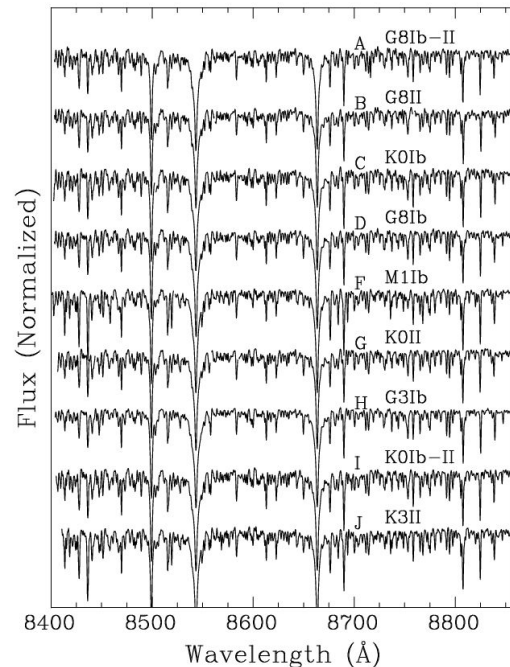
GVANEXT
Proyecto Next Generation de la Comisión Valenciana



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 ± 46	1.1 ± 0.11	-0.05 ± 0.06	40.6 ± 0.2	—
B	GSC 05121-00622	4256512843232515840	G8 II	4620 ± 51	1.42 ± 0.12	+0.01 ± 0.07	42.4 ± 0.2	40.1 ± 0.4
C	TYC 5121-819-1	4253508943153458048	K0 Ib	4639 ± 40	0.88 ± 0.11	+0.02 ± 0.06	39.8 ± 0.2	—
D	TYC 5121-218-1	4253508702635208832	G8 Ib	4640 ± 48	1.02 ± 0.11	-0.07 ± 0.06	41.1 ± 0.2	40.8 ± 0.5
E	CM Set	4253603501158148736	— ^a	5431 ± 36	1.03 ± 0.09	-0.15 ± 0.04	47.4 ± 0.3	—
F	TYC 5121-758-1	4253603501158148736	M1 Ib	3840 ± 20	0.33 ± 0.09	-0.10 ± 0.05	41.6 ± 0.2	—
G		4256511468842481408	K0 II	4725 ± 44	1.33 ± 0.09	+0.12 ± 0.05	41.5 ± 0.2	41.6 ± 0.4
H	TYC 5121-684-1	4253603501158148736	G3 Ib	5105 ± 27	0.72 ± 0.08	-0.07 ± 0.04	41.1 ± 0.2	41.8 ± 0.2
I	TYC 5125-1531-1	4253499219346450432	K0 Ib-II	4755 ± 22	0.91 ± 0.06	+0.08 ± 0.03	43.5 ± 0.6	42.1 ± 0.3
J		4253597556923196672	K3 II	4137 ± 40	0.65 ± 0.1	-0.06 ± 0.06	43.4 ± 0.2	—



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

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



The ASFAE's research projects acknowledge the financial support from the MCI with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por la Unión Europea
NextGenerationEU



GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y TURISMO

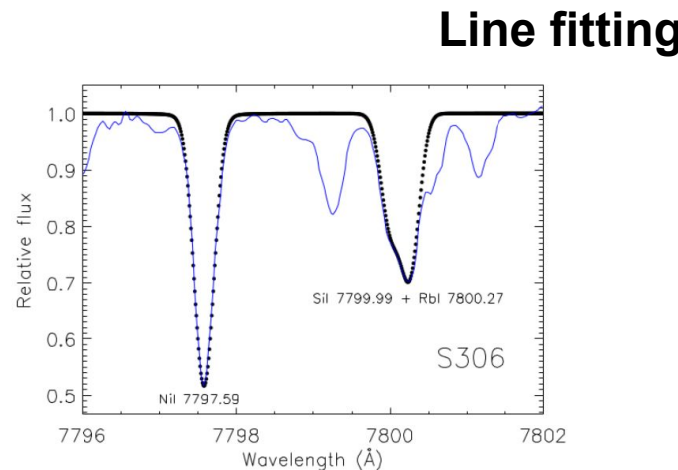
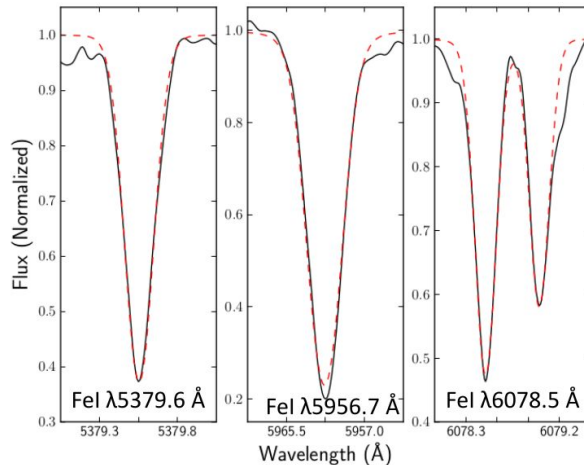


Abundances for cool supergiants

Spectral resolution $R > 20\,000$ is mandatory



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



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

Analysis with **SteParSyn**



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



GOBIERNO
DE ESPAÑA
MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



GENERALITAT
VALENCIANA
Conselleria d'Educació,
Universitats i Treball
GVANEXT
Fondo Next Generation de la Comisión Europea

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



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



GOBIERNO
DE ESPAÑA
MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



Plan de Recuperación,
Transformación y Resiliencia



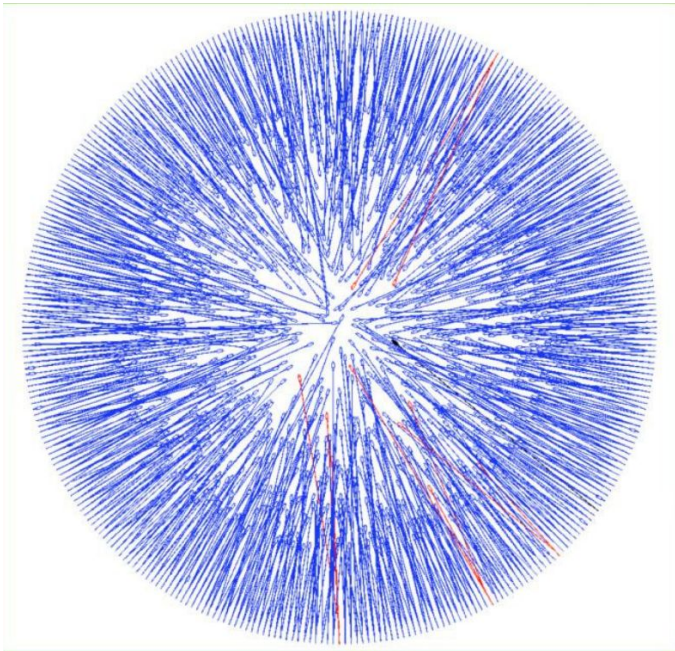
GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Enginyeria

GVANEXT
Fondo Next Generation de la Comisión Europea

- 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



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



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



Plan de Recuperación,
Transformación y Resiliencia



GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Empreu

GVANEXT
Fondo Next Generation de la Comisión Europea

Main surveys at $R \sim 5000$

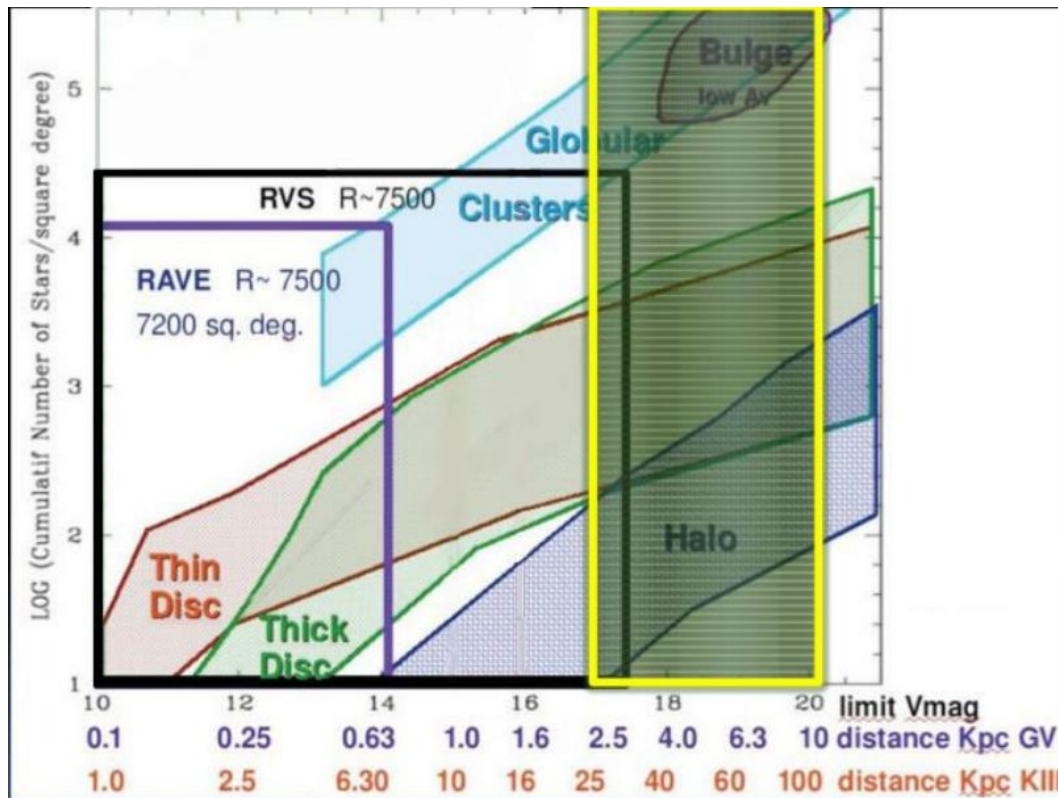


Image by Vanessa Hill (OCA)



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



GOBIERNO
DE ESPAÑA
MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



Plan de Recuperación,
Transformación y Resiliencia



GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Treball

GVANEXT
Fondo Next Generation de la Comisión Europea

High-resolution mode at $R \sim 20000$

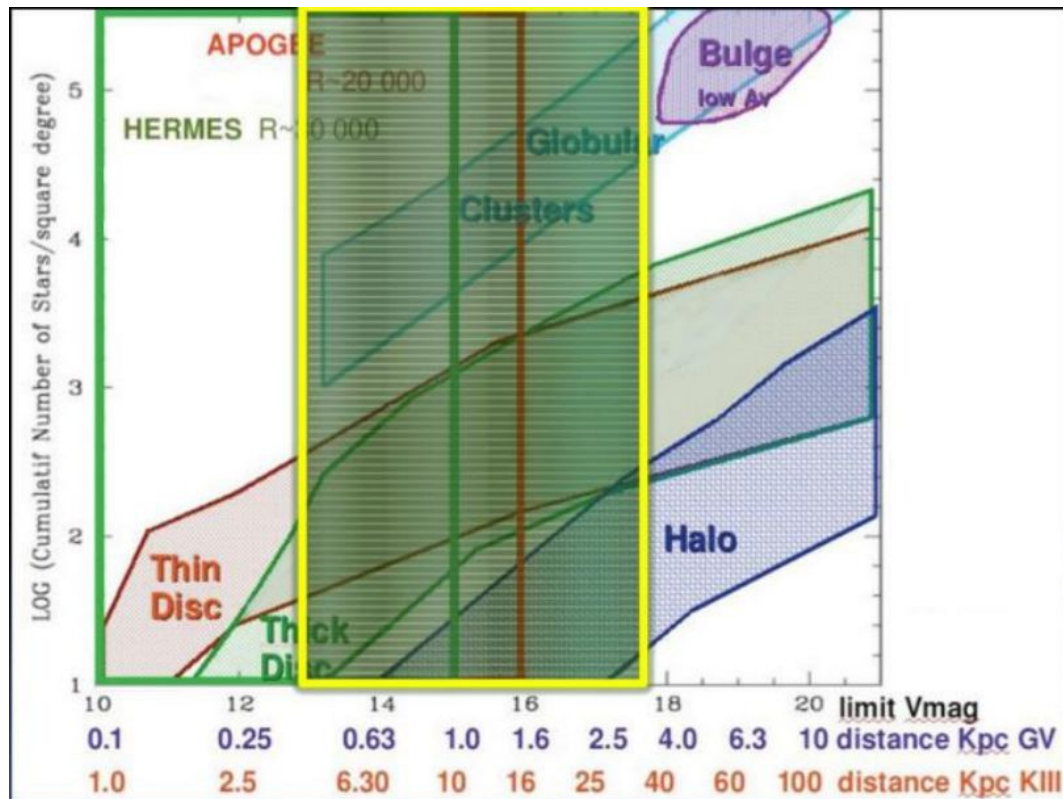


Image by Vanessa Hill (OCA)



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



Plan de Recuperación,
Transformación y Resiliencia



GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Treball

GVANEXT

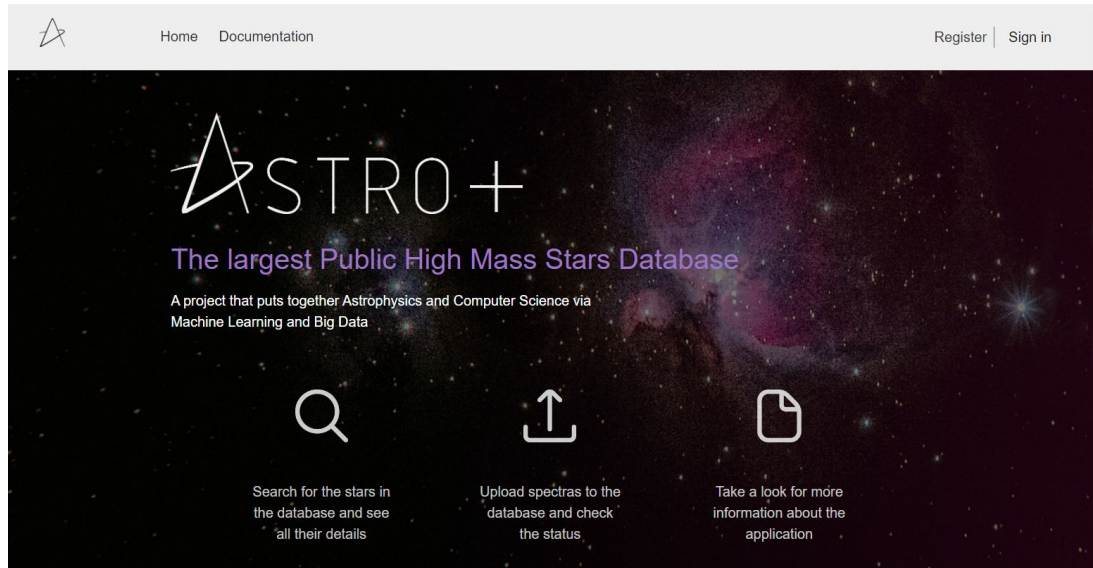
The Astro+ database (web/server)

<https://astroplus.ua.es>

PROMETEO/2019/041



P.I. Amparo Marco



- Gather spectra
- Unify
- Standardize
- Analysis tools



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

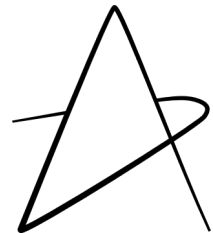


Financiado por
la Unión Europea
NextGenerationEU



Search for a spectrum

- ID
- Coordinates
- SQL Query



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

DEC

Cone

Search

Examples:
20 54 05.689 +37 01 17.38
10 12 45 3-45 17-50
15h17m-11d10m
15h17-89d15

Search

Identifier query Coordinate query **TAP query**

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

Query

Download available fields

Search

Examples: TEMP_EFF > 4500 AND TEMP_EFF > 5000



The ASFAE's research projects acknowledge the financial support from the MCI with funding from the European Union NextGenerationEU and Generalitat Valenciana.



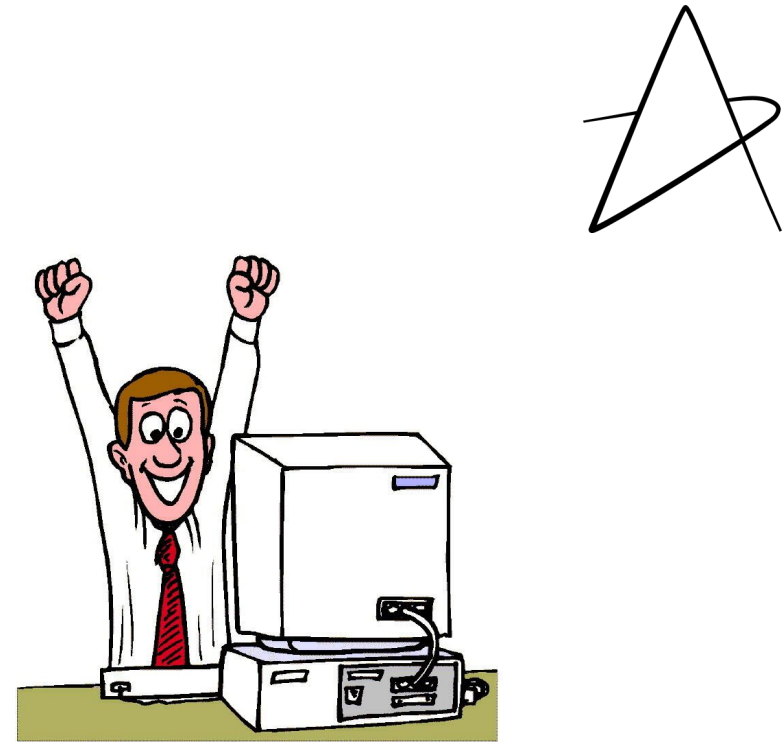
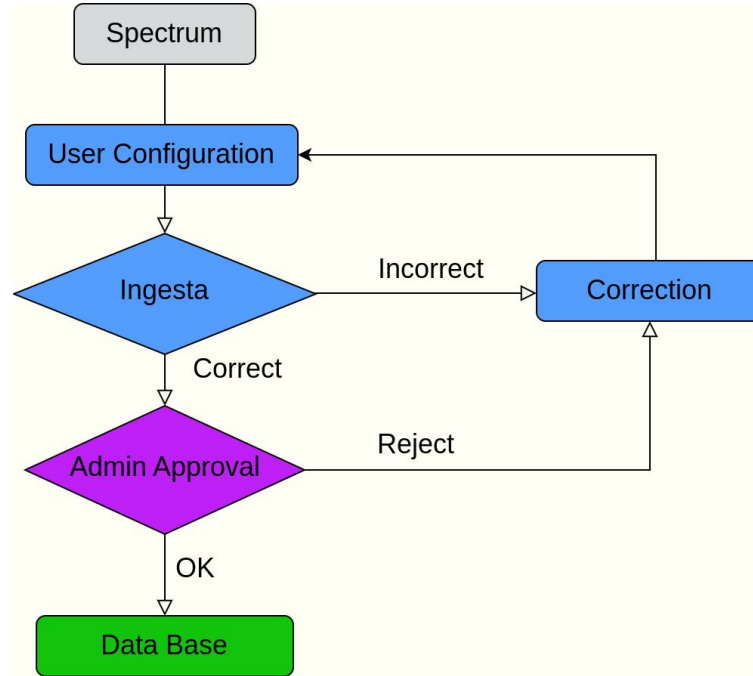
Financiado por
la Unión Europea
NextGenerationEU



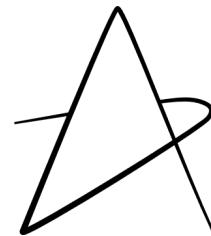
GOBIERNO
DE ESPAÑA
MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



GVANEXT
Fondo Next Generation de la Comisión Europea



Assign identification and catalogue data

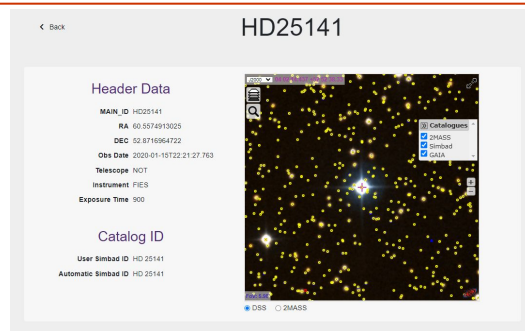


FITS

ASCII

APIs

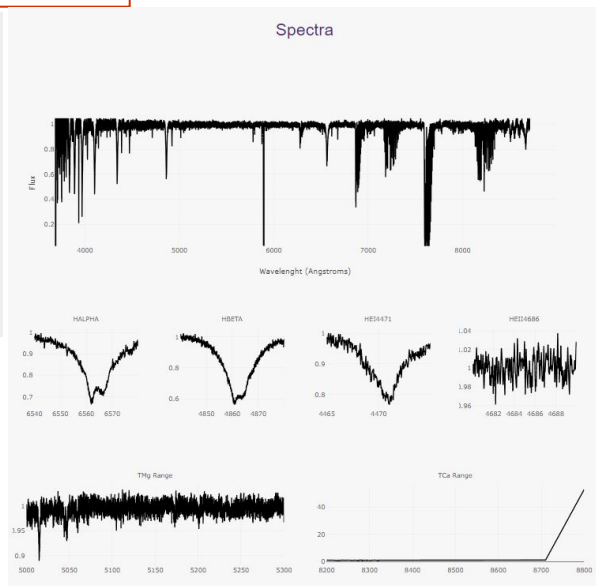
- SIMBAD
- 2MASS
- Gaia



MAIN_ID	RA	RA_PREC	DEC	DEC_PREC	COO_WAVELENGTH	COO_QUAL	COO_ERR_MNA	C
HD 25141	04 02 14.4378	14	+52 52 38.332	14	O	A	0.011300000362098217	0

source_id	ra	dec	name	parallax	pmra_error
25183919127285730	60.560157854220405	52.87728913629429	1.0265523195268724	0.8262462273058674	0.02316889783909321

designation	ra	dec	ph_qual	glat	glon	h_m	l_m	xdate	vr_m_opt	scan	rd_flg	pi
04021444+5252383	60.560174	52.877312	AAA	0.12	149.444	8.455	8.474	1999-10-13	8.91	105	112	91



The ASFAE's research projects acknowledge the financial support from the MCI with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES



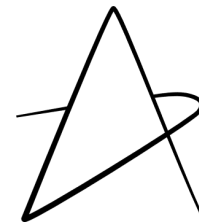
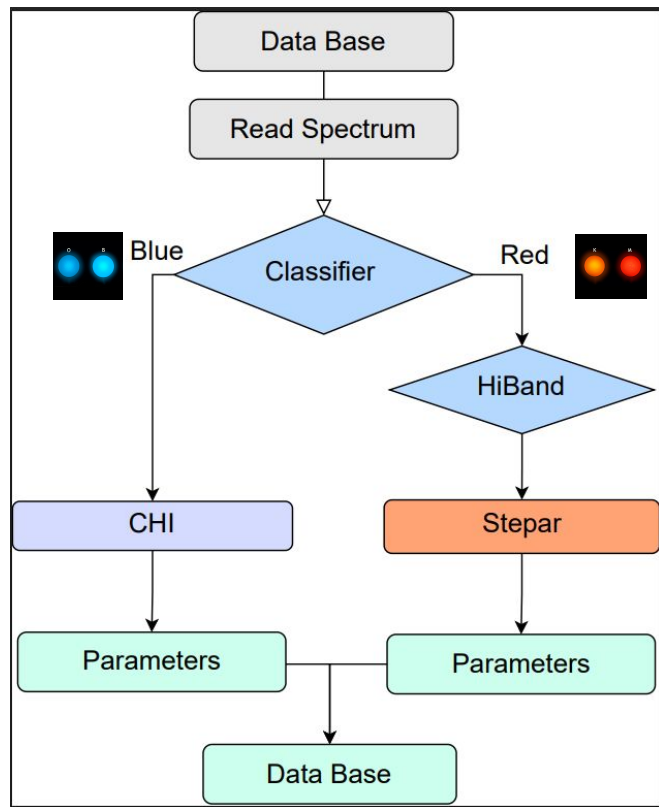
Plan de Recuperación,
Transformación y Resiliencia



GENERALITAT
VALENCIANA
Conselleria d'Educació,
Universitats i Innovació

GVANEXT
Fondo Next Generation de la Comisión Europea

Automatic Analysis tools



P.I. Ignacio Negueruela y Amparo Marco

HIAMAS , reference ASFAE/2022/017

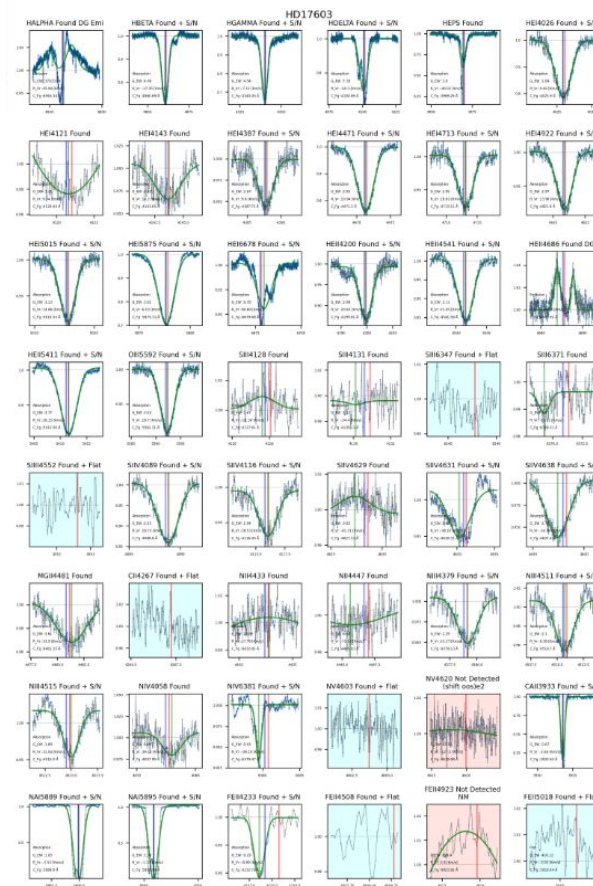


The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



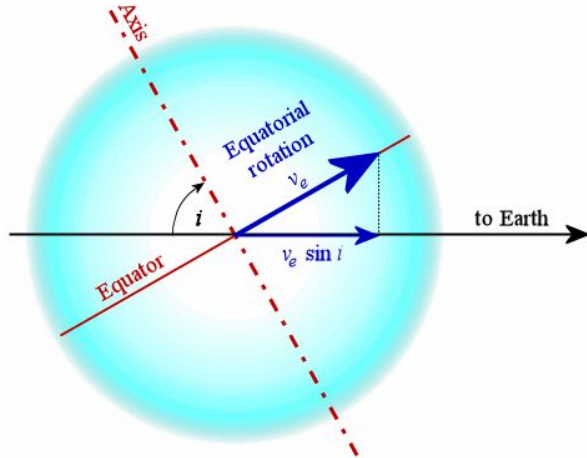
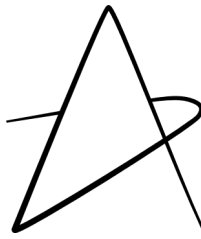
Financiado por
la Unión Europea
NextGenerationEU



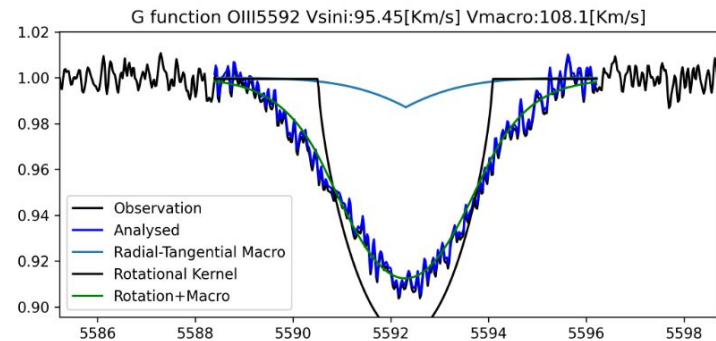
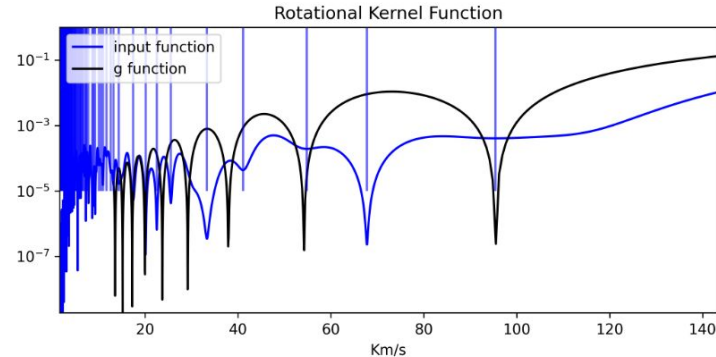


Line	λ	V_r	$V \sin i / \lambda$
H α	6562.80		
H β	4861.33	X	
H γ	4340.46	X	
H δ	4101.74	X	
H ϵ	3970.07	X	
He I 4026	4026.19	X	15
He I 4121	4120.82		
He I 4387	4387.93	X	
He I 4471	4471.47	X	9
He I 4713	4713.16	X	7
He I 4922	4921.93		14
He I 5015	5015.67	X	8
He I 5875	5875.62	X	10
He II 6678	6678.15		
He II 4200	4199.83		11
He II 4541	4541.59	X	13
He II 4686	4685.71		
He II 5411	5411.52	X	12
O III 5592	5592.37	X	1
Si II 4128	4128.07		
Si II 4131	4130.89		
Si II 6347	6347.11		
Si II 6371	6371.37	X	
Si III 4552	4552.62	X	2
Si IV 4089	4088.85		5
Si IV 4119	4116.10	X	6
Si IV 4626	4628.62		
Si IV 4631	4631.24		
Si IV 4638	4638.28		
Mg II 4481	4481.15	X	4
C II 4267	4267.24	X	3
N II 4433	4432.74		
N II 4447	4447.03		
N II 4379	4379.11	X	
N II 4511	4510.91	X	
N II 4515	4514.86	X	
N IV 4058	4057.76		
N IV 6381	6380.77		
N V 4603	4603.73		
N V 4620	4619.98		
Ca II 3934	3933.66		
Na I 5889	5889.95		
Na I 5895	5895.92		
Fe II 4233	4233.16		
Fe II 4508	4508.28		
Fe II 4549	4549.47		
Fe II 4923	4923.92		
Fe II 5018	5018.44		

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)



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



GOBIERNO
DE ESPAÑA
MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES

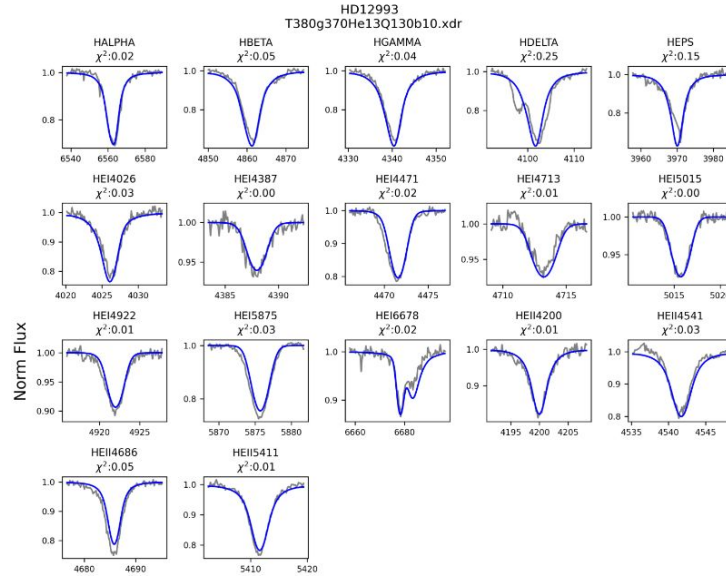
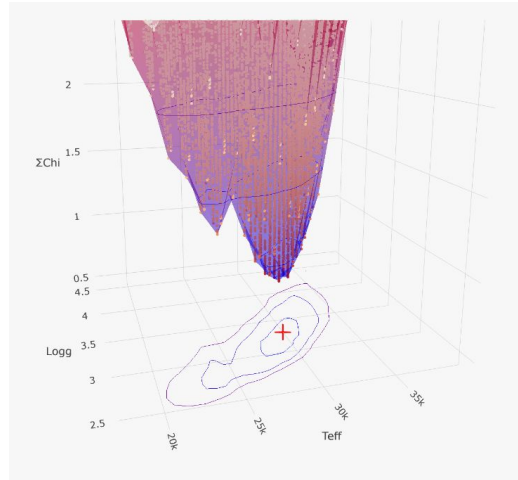
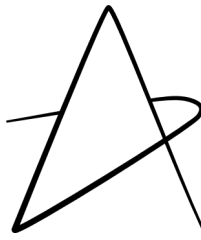
Plan de Recuperación,
Transformación y Resiliencia

GENERALITAT
VALENCIANA
Conselleria d'Educació,
Universitats i Innovació

GVANEXT
Fondo Next Generation de la Comisión Europea

HICHI

χ^2



Lambda Å



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



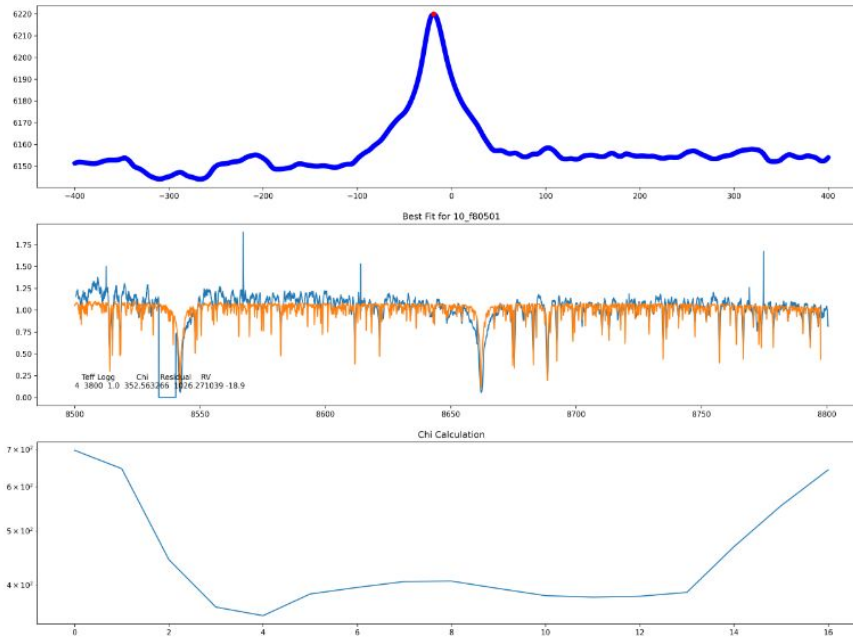
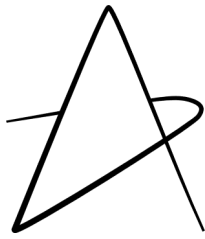
MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES

Plan de Recuperación,
Transformación y Resiliencia

GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Empreu

GVANEXT
Fondata Next Generation en la Comunitat Valenciana

HIBAND



TO → SteParSyn MCMC
Tabernero+ 2022



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU

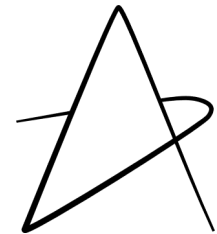


GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Plan de Recuperación, Transformación y Resiliencia



GENERALITAT VALENCIANA
Conselleria de Educació, Universitats i Empreu
GVANEXT
Fondata Next Generation de la Comunitat Valenciana

Quality control



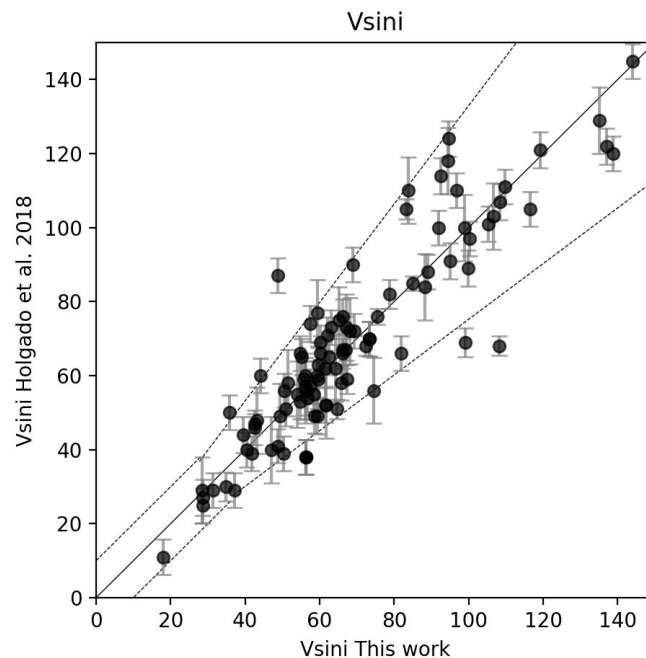
$v \sin i$ demination

102 Stars

The IACOB project

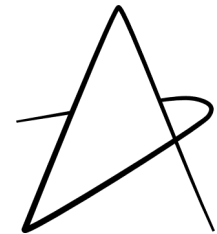
V. Spectroscopic parameters of the O-type stars in the modern grid of standards for spectral classification★

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



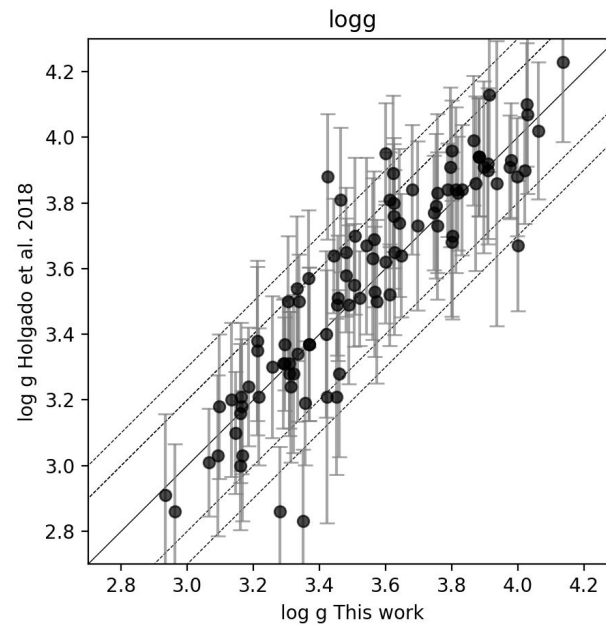
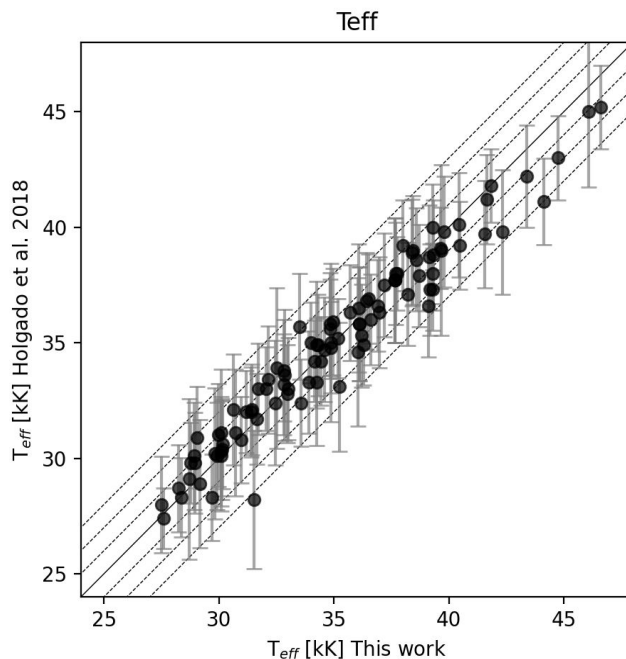
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Quality control



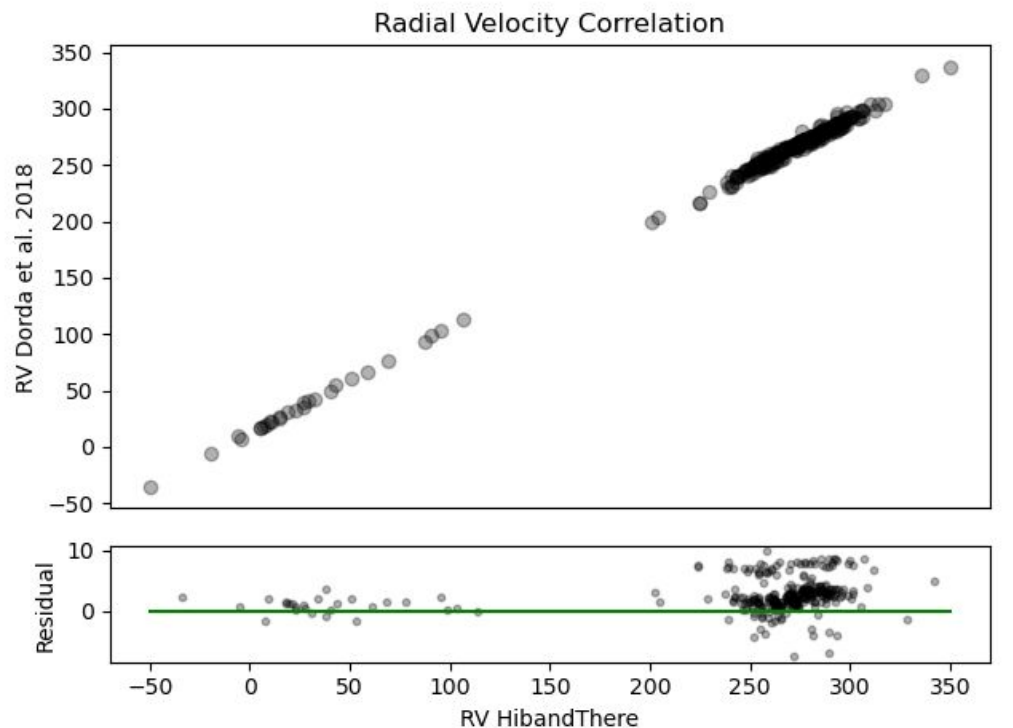
V2.0

Parameter determination

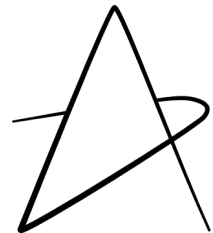


The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Quality control



Dispersion 7 km/s



TO → SteParSyn
Tabernero+ 2022



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



GOBIERNO
DE ESPAÑA
MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



Plan de Recuperación,
Transformación y Resiliencia



GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Treball

GVANEXT
Fondo Next Generation de la Comisión Europea

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)

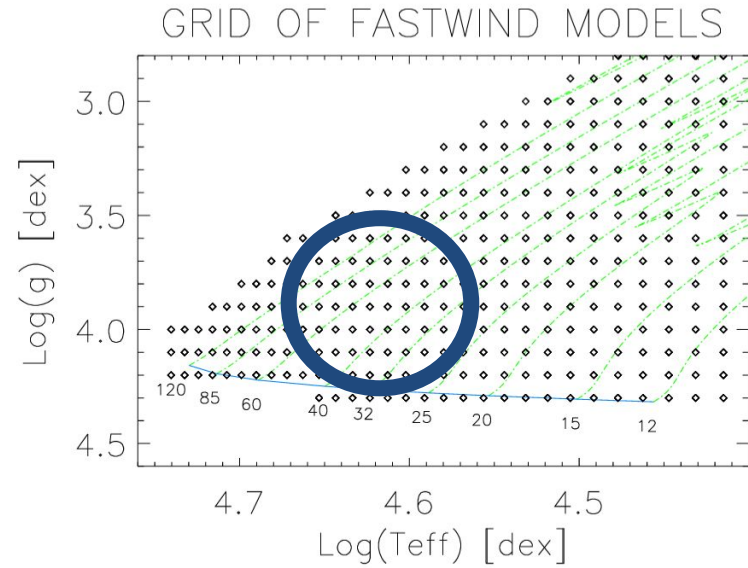
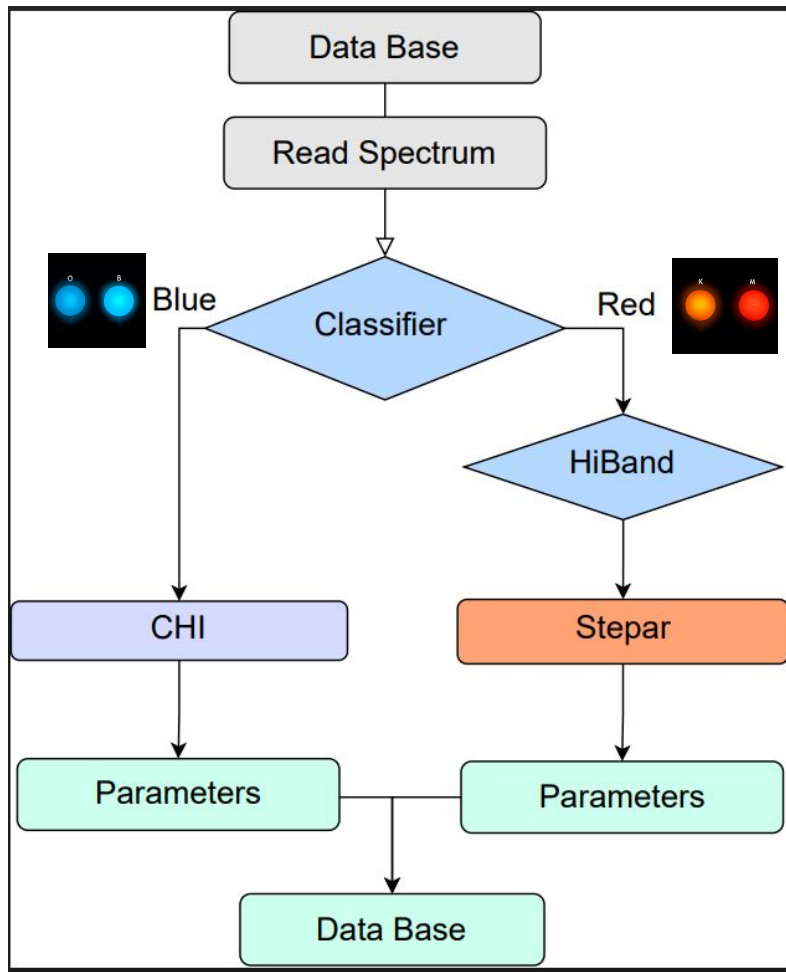


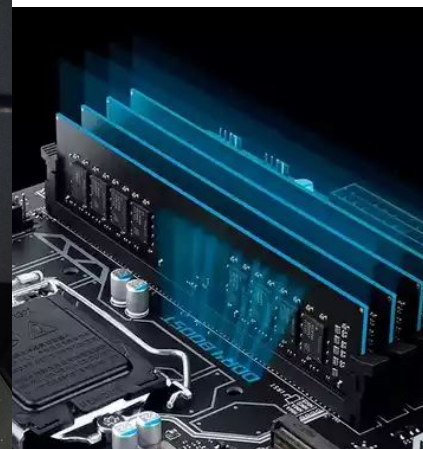
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU





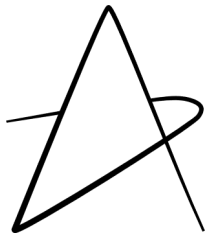


NVIDIA A10 X2



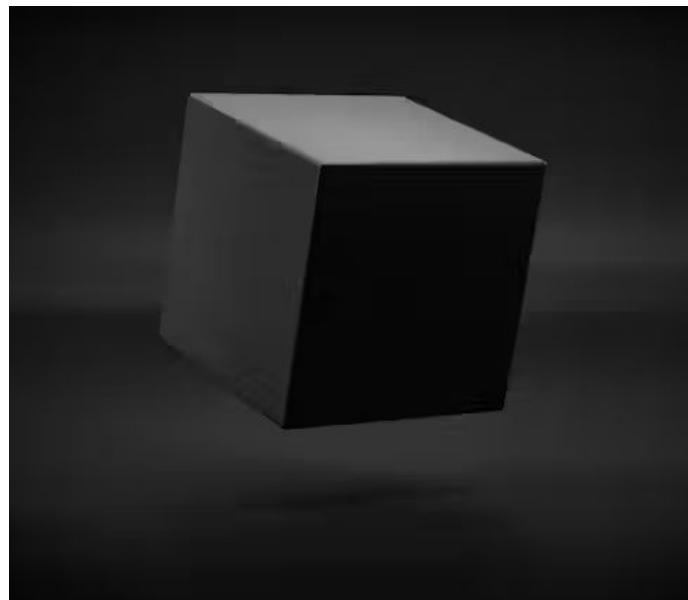
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.





- 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.





The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



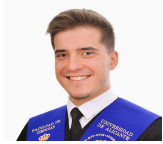
Plan de Recuperación,
Transformación y Resiliencia



GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Empreu

GVANEXT
Fondo Next Generation de la Comisión Europea

- TFG



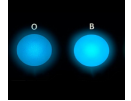
David

- 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)

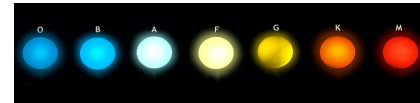


- TFM



Elias

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



Target/Coordinates
Gaia DR3 411183456779557376

Download

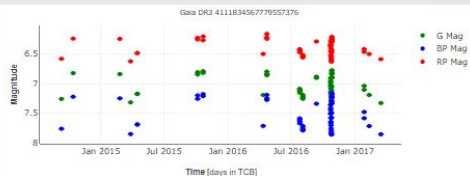
Gaia DR3 411183456779557376

Astrometry	Photometry	Spectroscopy	Astrophysical parameters
Description		Value	Unit
Equatorial ICRS (RA,DEC) at epoch 2016		256.5229102004, -26.5805651308	deg
Galactic (l, b) at epoch 2016		357.0803450631, 8.5731964881	deg
Parallax		1.1538 ± 0.0241	mas
RA proper motion		0.3896 ± 0.0256	mas yr ⁻¹
DEC proper motion		-0.2893 ± 0.0165	mas yr ⁻¹
Renormalised unit weight error		0.837	

Epoch Photometry

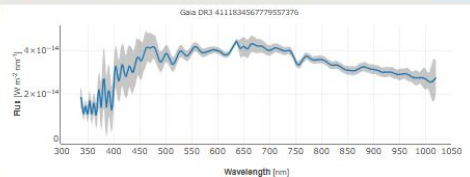
Show errors

Expand



BP/RP (XP) Spectrum

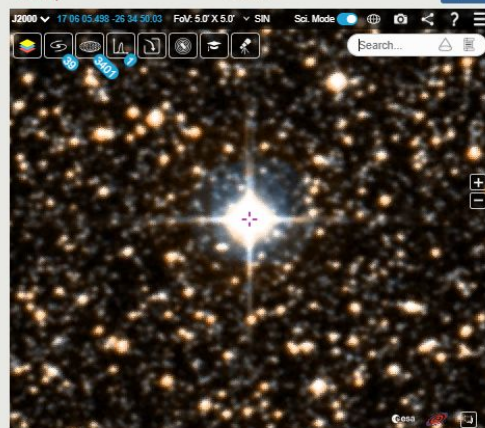
Expand



ESASky

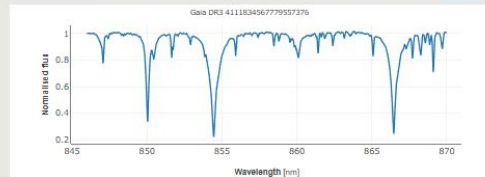
Set target

Expand



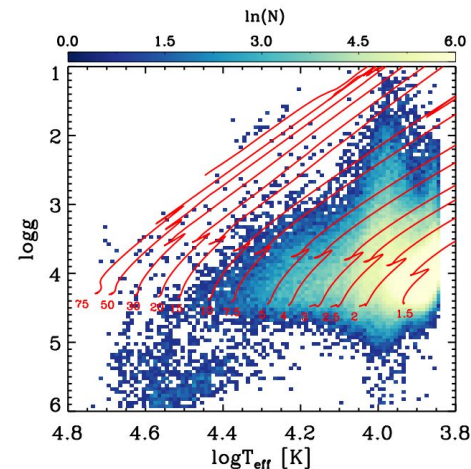
RVS Spectrum

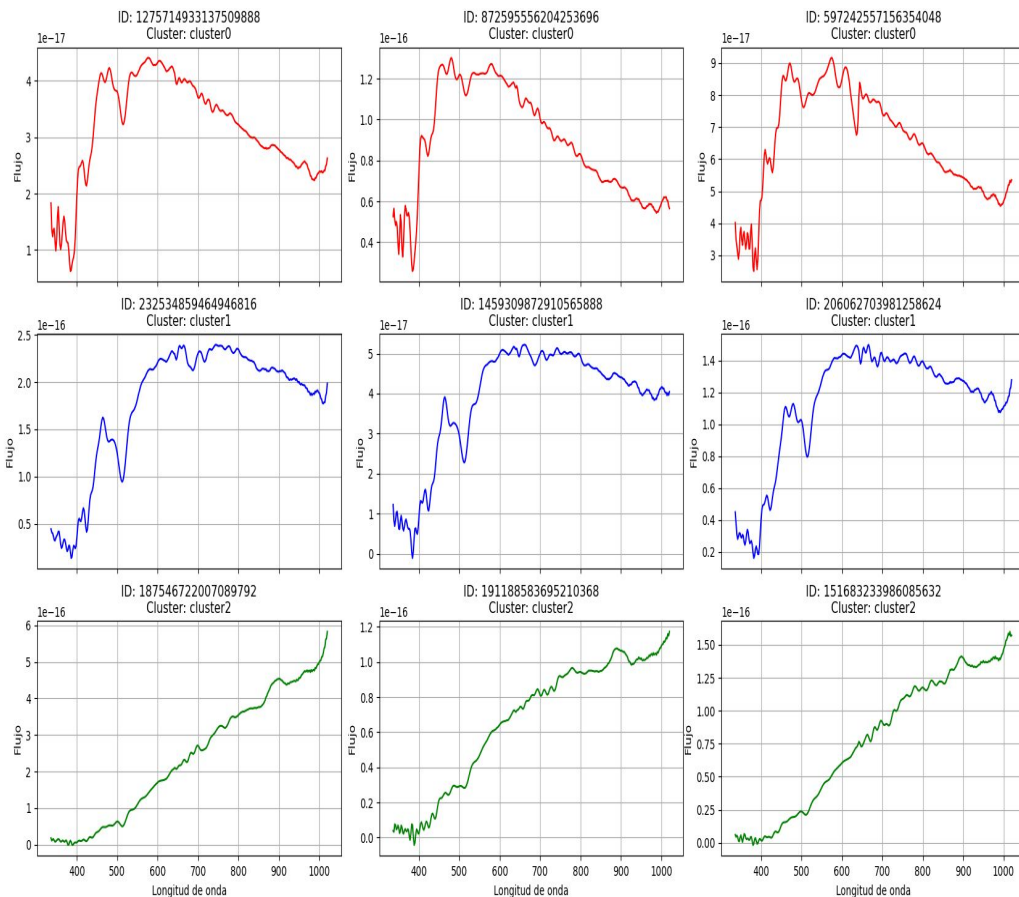
Expand



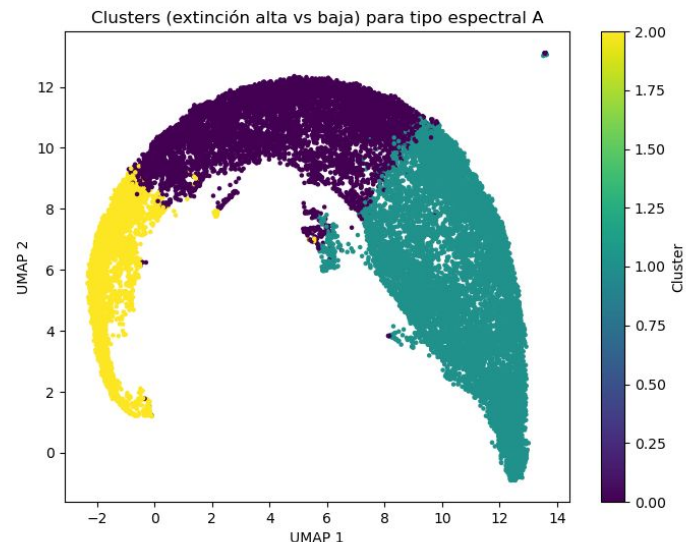
LAMOST

150000 spectra

Maosheng Xiang
2022



● PCA, K-MEANS & NN



The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.



Financiado por
la Unión Europea
NextGenerationEU



GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



Plan de Recuperación,
Transformación y Resiliencia

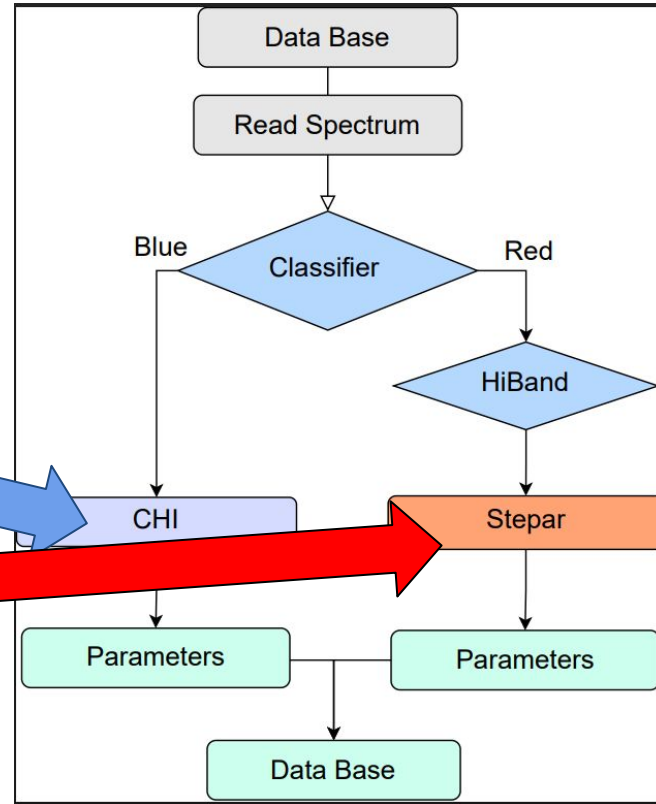
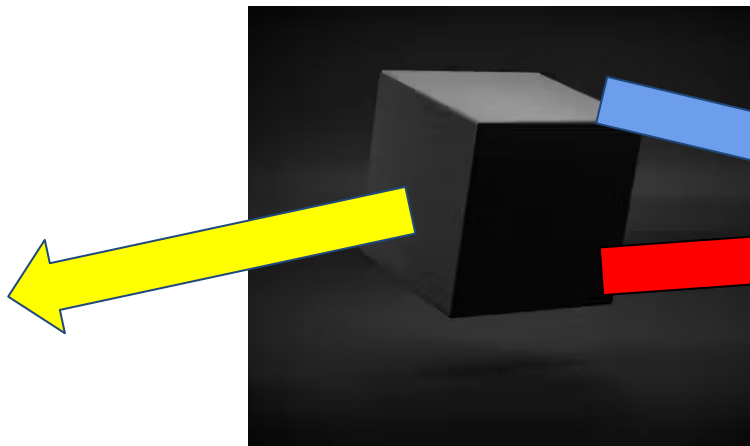


GENERALITAT
VALENCIANA
Conselleria de Educació,
Universitats i Treball

GVANEXT
Fondata Next Generation en la Conselleria Valenciana



Spectral type and level
of extinction





Herramientas de análisis automático para espectros estelares

Klaus Rübke

Centro de Estudios de Física del Cosmos de Aragón

Mayo 2025, Galactica