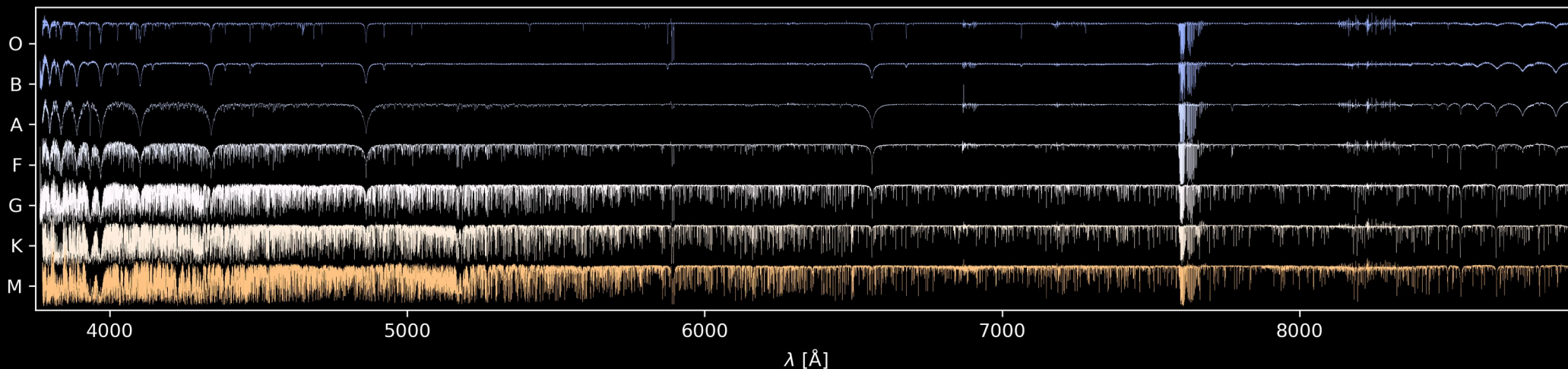


Melchiors: a new library of 2000 stars with high-spectral fidelity

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Submitted to A&A



www.royer.se/melchiors.html

Observed spectral libraries

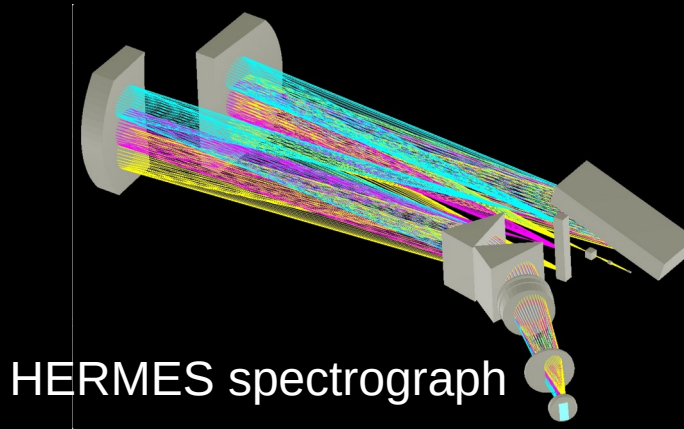
Library	N_*	N_{sp}	λ_{min}	λ_{max}	Resolution	Reference
Gunn & Strycker	175		313	1 080	200	Gunn & Stryker (1983)
Silva & Cornell	72		351	893	550	Silva & Cornell (1992)
James	83		350	750	800	James (2013)
Kitt-Peak	161		351	742	1 000	Jacoby et al. (1984)
Pickles	131		115	2 500	1 000	Pickles (1998)
NGSL	378		167	1 025	1 000	Gregg et al. (2006)
SDSS-MaStar	3 321	8 646	362	1 035	1 800	Yan et al. (2019)
STELIB	249		320	930	2 000	Le Borgne et al. (2003)
MILES	985		352	750	2 000	Falc3n-Barroso et al. (2011)
SDSS-BOSS	324		365	1 020	2 000	Kesseli et al. (2017)
Diaz et al.	106		790	910	2 300	Diaz et al. (1989)
MUSE library	35		480	930	3 000	Ivanov et al. (2019)
Indo-US	1 273		346	946	5 000	Valdes et al. (2004)
XSL	683	830	350	2 480	10 000	Gonneau et al. (2020); Verro et al. (2022)
ELODIE	1 388	1 962	390	680	42 000	Prugniel & Soubiran (2001, 2004); Prugniel et al. (2007)
FGKM library	404		499	641	60 000	Yee et al. (2017)
Gaia-FGK	34	71	300	1 020	80 000	Blanco-Cuaresma et al. (2014)
UVES-POP	394		304	1 040	80 000	Bagnulo et al. (2003)
MELCHORS	2 043	3 256	380	900	85 000	This work



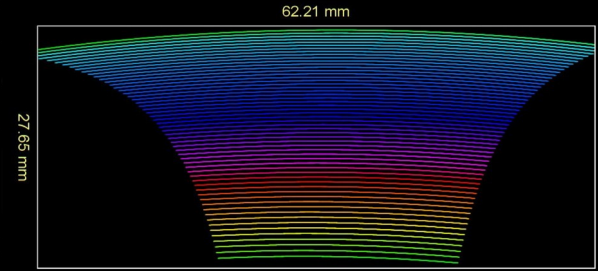
HERMES fibre-fed spectrograph at Mercator telescope in La Palma



Mercator telescope



HERMES spectrograph



Detector 2048 by 4608 pixels
with anti-reflective coating

The spectrograph characteristics (Raskin+ 2011):

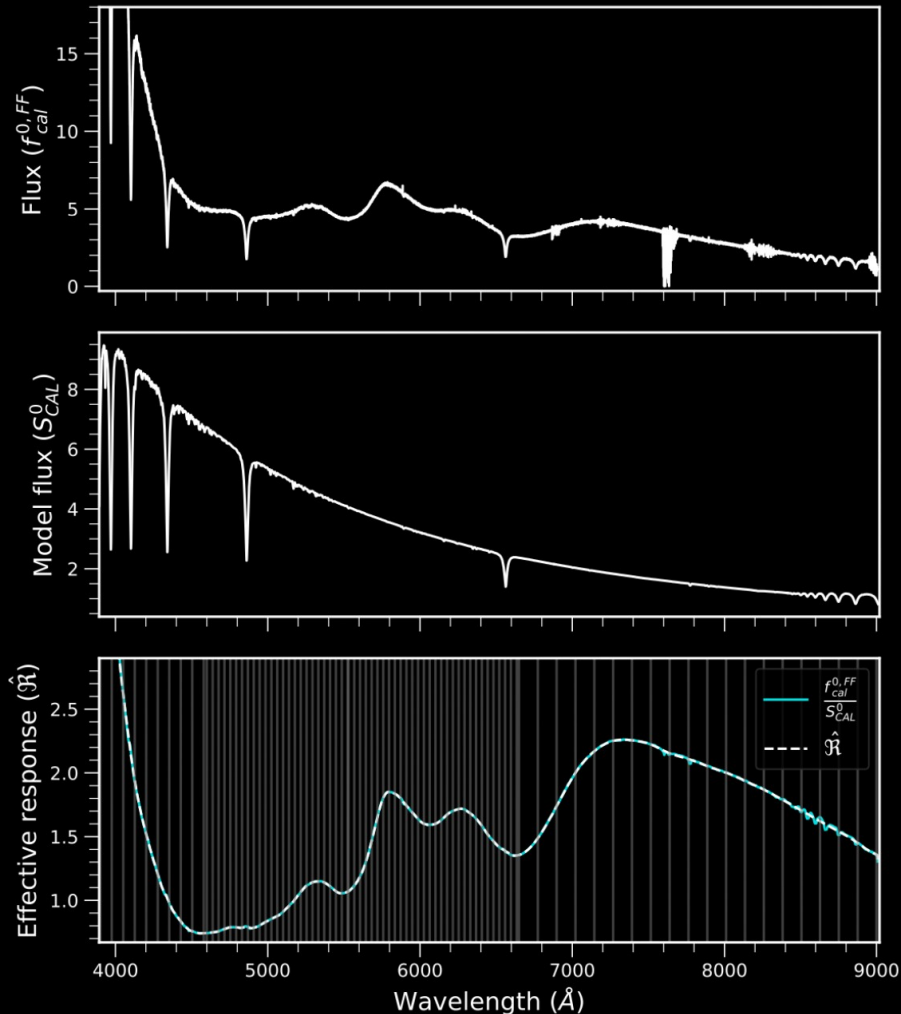
- Limiting visual magnitude ~ 12
- Wavelengths coverage from 3800 to 9000 Å
- Resolving power of 85000
- 2.5 arcsec octagonal fibre equipped with an image slicer
- optimised for high efficiency

Melchior's spectral library is the result of the filler program by Pierre Royer running from 2010 to 2020

The spectrograph reduction pipeline:

- bias correction
- background subtraction
- flat-field correction
- cosmic ray clipping
- spectral order merging
- wavelength calibration
- barycentric correction

Additional data reduction I: instrumental response correction



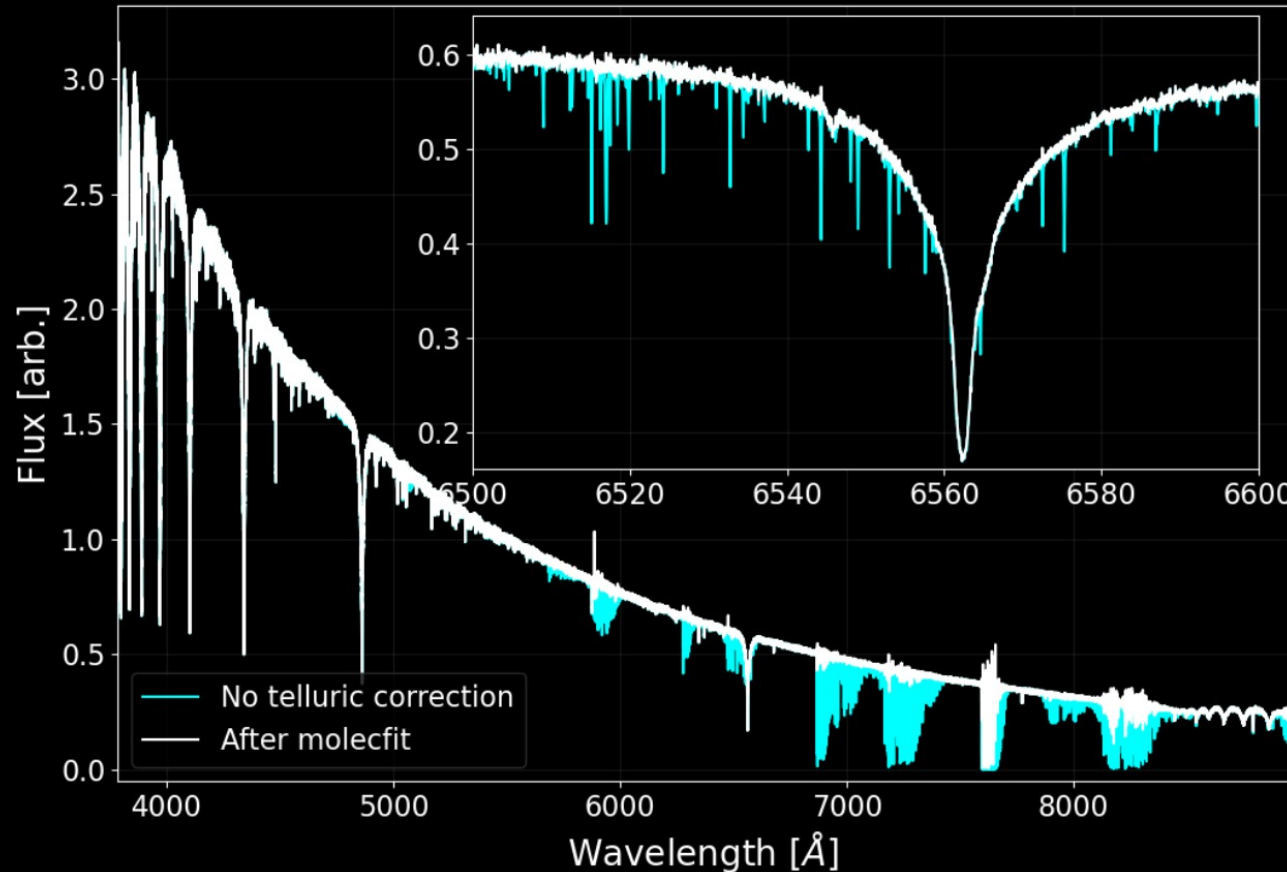
14 calibrators from 7000 to 15000 K are used.

- Calibrator observed spectrum (flat-field corrected and atmospheric extinction and telluric corrections)
- Calibrator model from GSSP (Tkachenko 2015)
- Instrumental response function
 - ratio of the observed/model
 - smooth version using median filter
 - Spline function using knot points

The density of knot points used to fit the spline is chosen locally depending on the complexity of the response.

Then all the spectra of a night are divided by the effective instrumental response function.

Additional data reduction II: atmospheric extinction and telluric corrections



Two corrections:

- Atmospheric extinction (continuous scattering) wavelength dependent
- Telluric absorptions (molecular absorption by H_2O , O_2 , etc.) Using Molecfit (Smette+ 2015, Kausch+2015)

Additional data reduction III: normalisation

The method is conceptually similar to a sigma-clipping process.

High-order polynomials are flexible enough on instrumental response corrected spectra

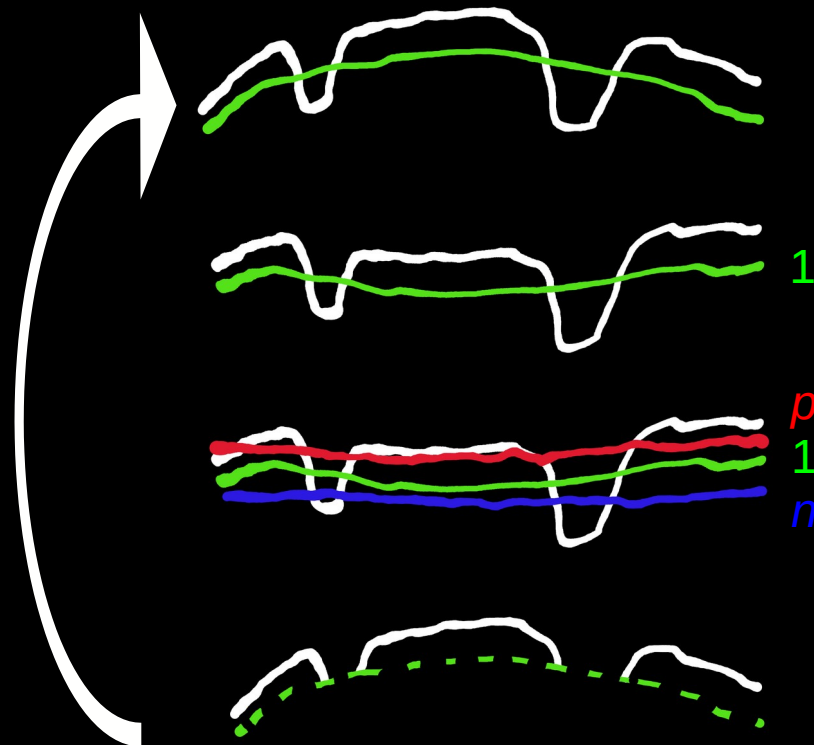
Brute force approach

For a given order (from 0 to 40):

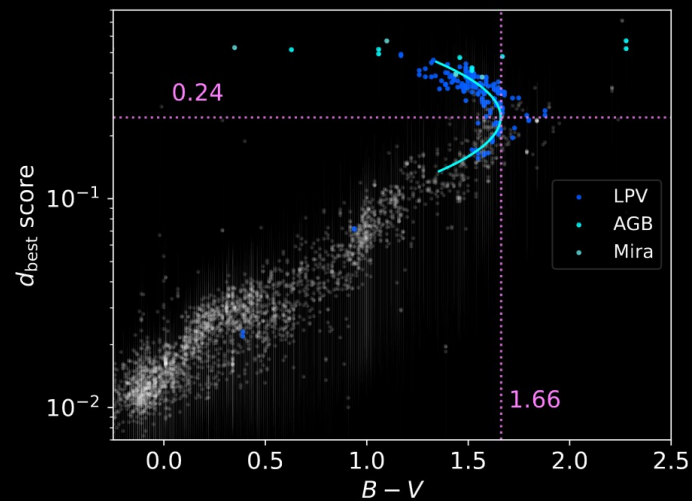
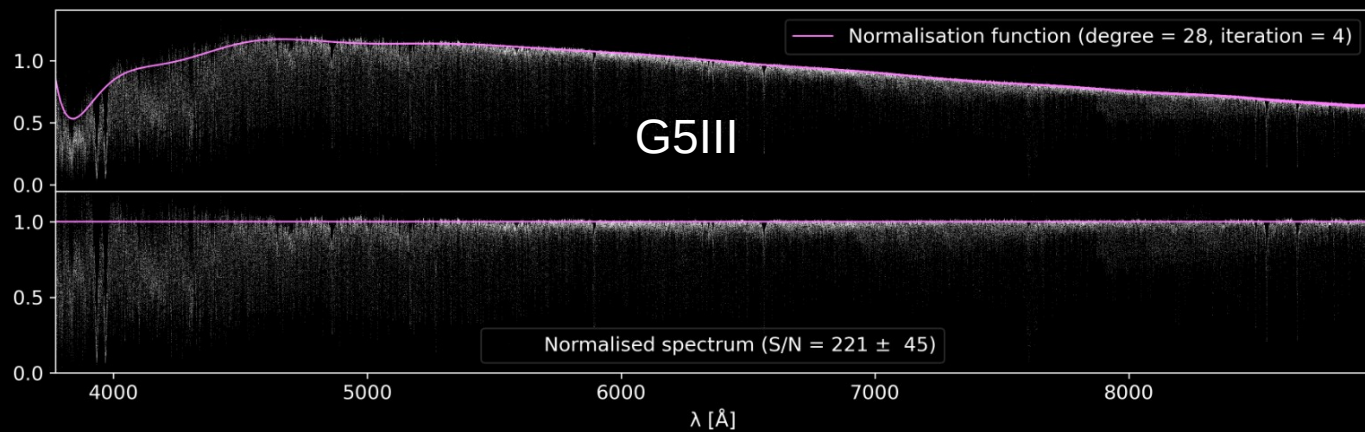
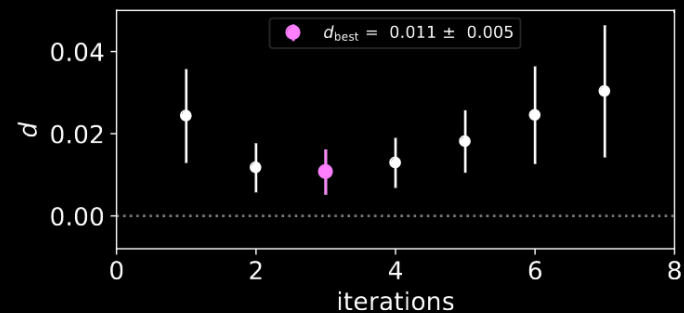
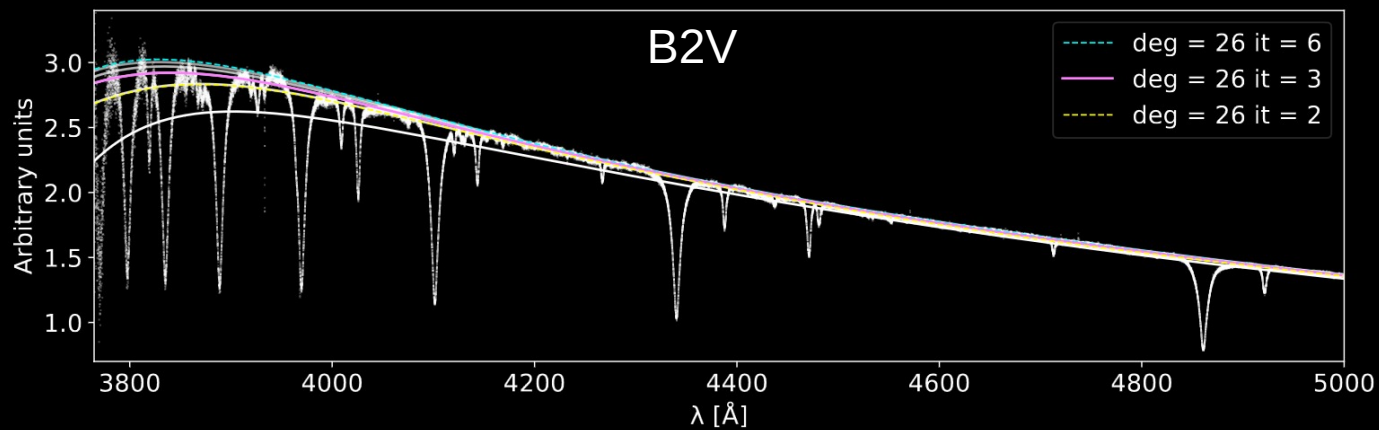
- fit a polynomial on flux densities
- Division of the spectrum by this polynomial
- Computation of the d score: $d = p - n$
 - p is the median of the flux densities above 1 (always ≥ 1)
 - n is the median of the flux densities below 1 (always ≤ 1)
- Remove of flux densities below the polynomial function

The best score d , d_{best} , is taken as the minimum score d , reflecting the best normalising function

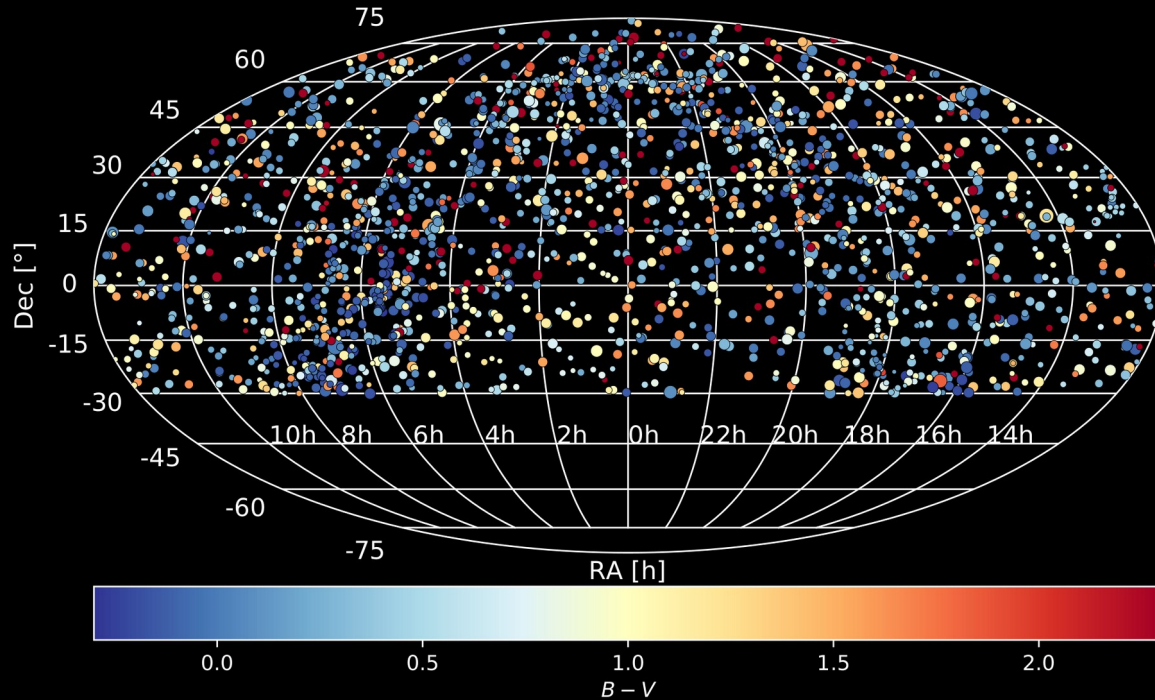
+ a minimum sampling density over the 5200 Å
(at least 1 sample per 10 Å)



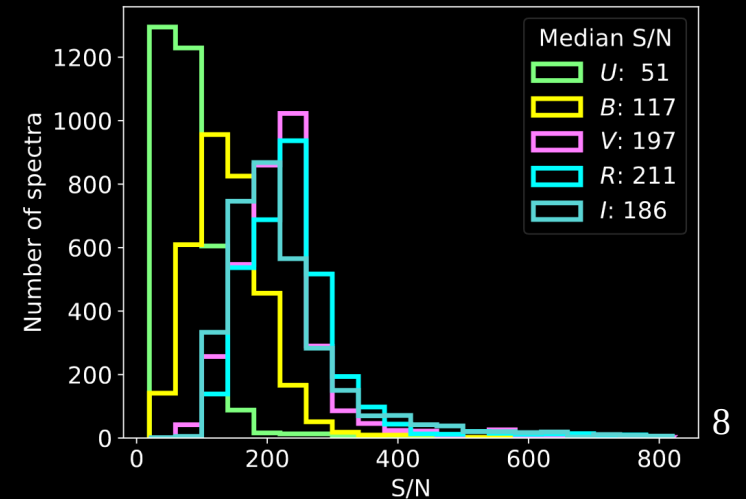
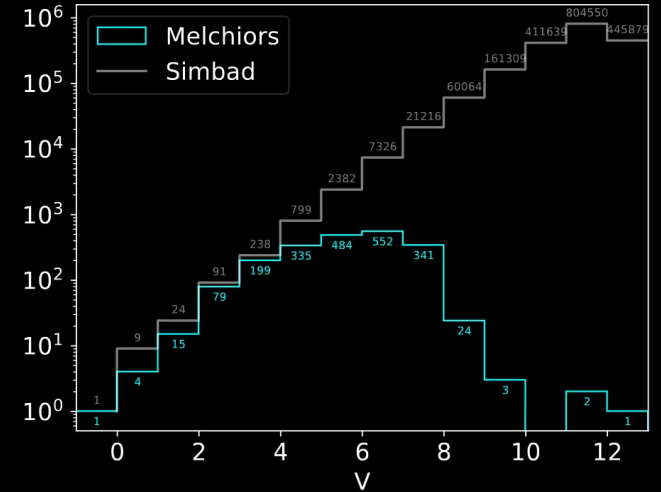
Additional data reduction III: normalisation



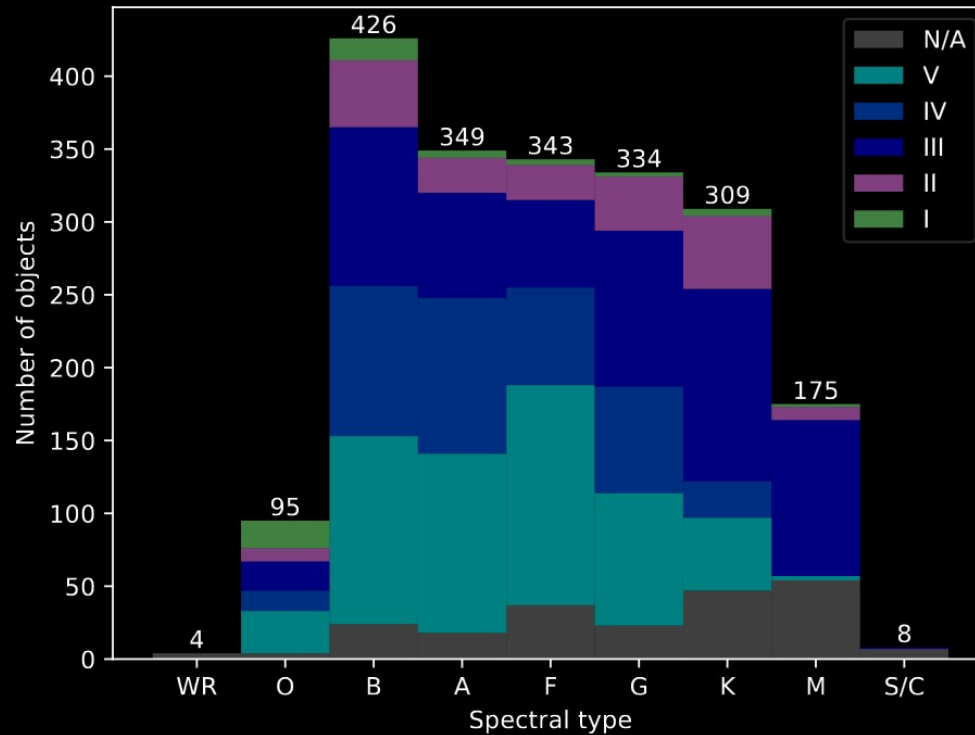
Library content: overview I



- 2042 stars with $\delta > -30^\circ$ and $V \leq 12$
- 80% complete for $V \leq 4$
- Median S/N ~ 200 in V band



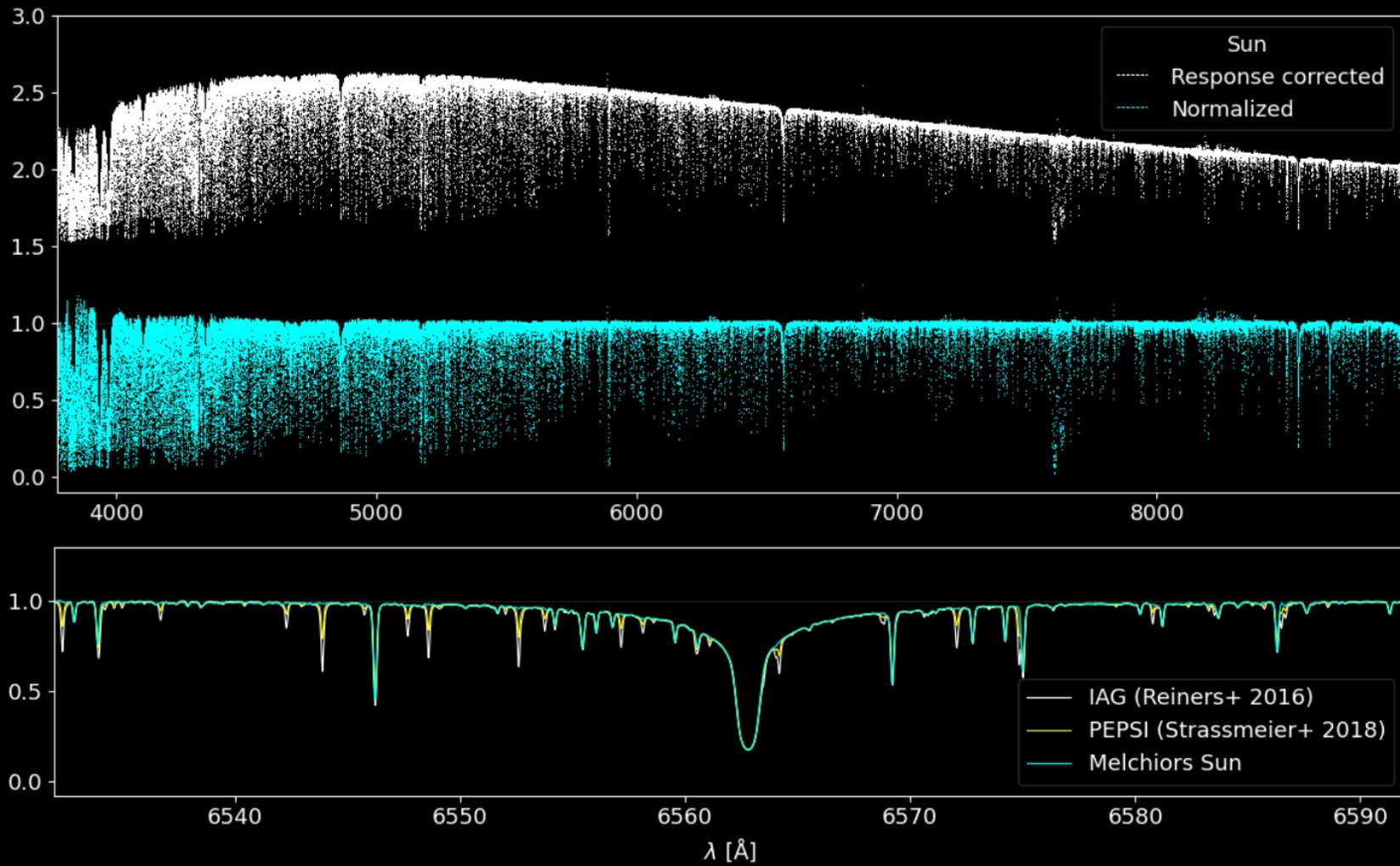
Library content: overview II



Melchioris include 3256 spectra for all spectral types and luminosity classes but biased toward:

- early spectral types
- high luminosity classes

Library content: the solar spectrum

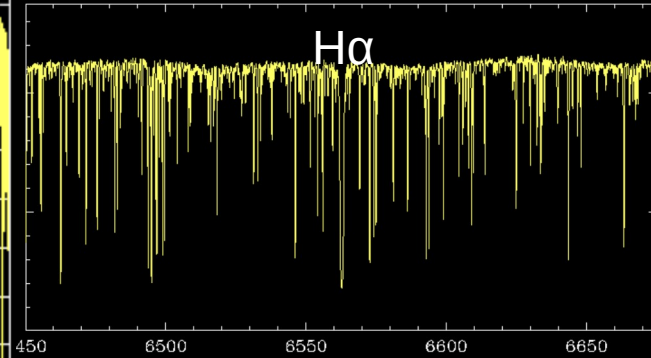
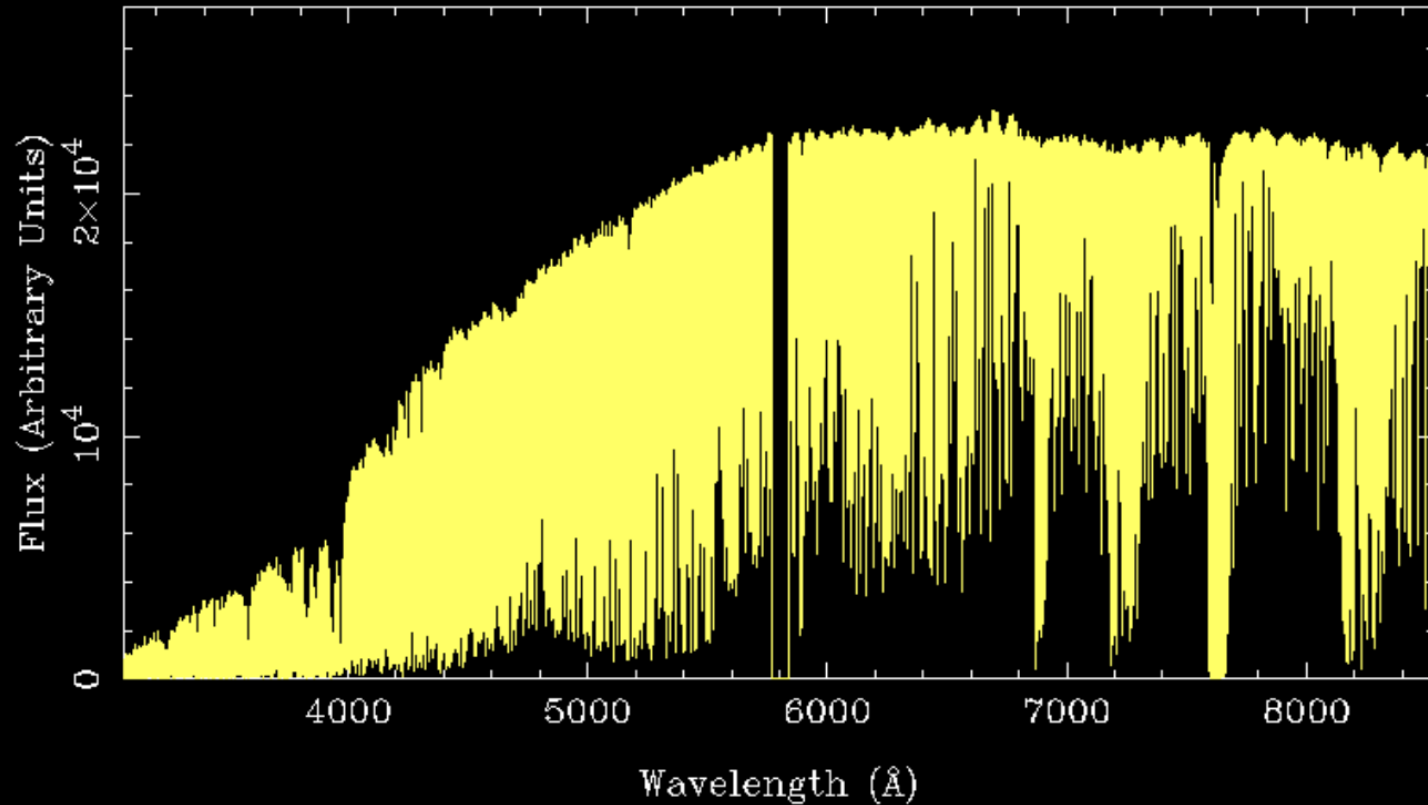


Comparison on Arcturus (K1.5III): UVES-POP

<https://www.eso.org/sci/observing/tools/uvespop/interface.html>

ARCTURUS

UVES PARANAL OBSERVATORY PROJECT
ESO PROGRAM 866.D-5066(A)

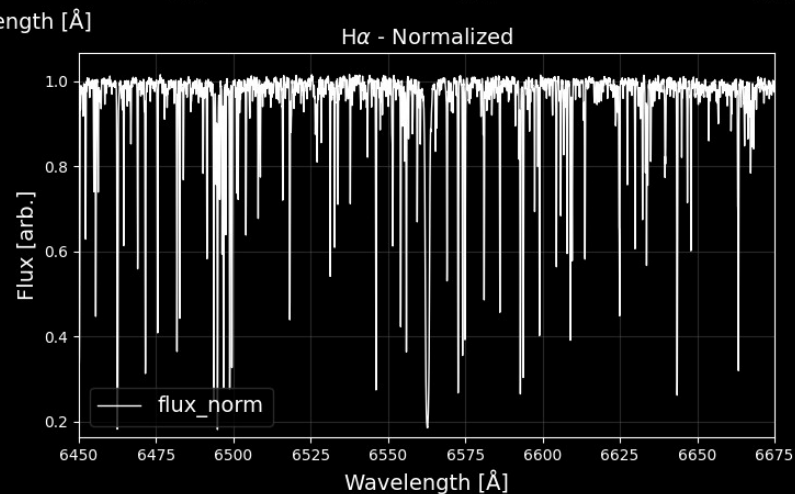
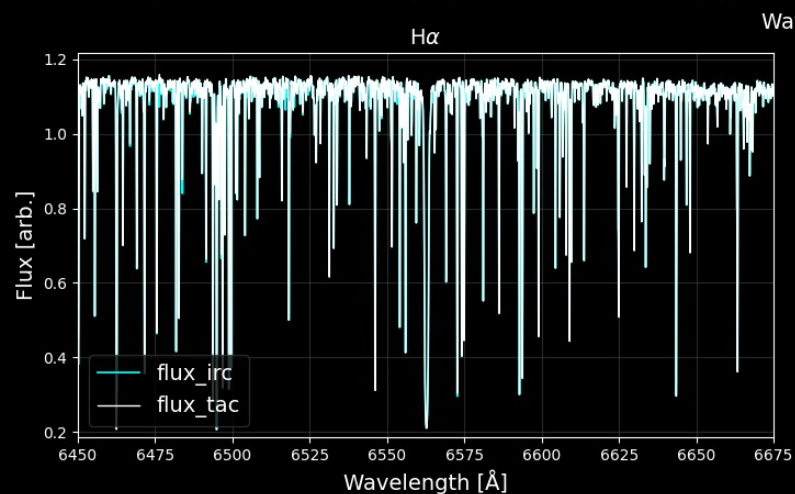
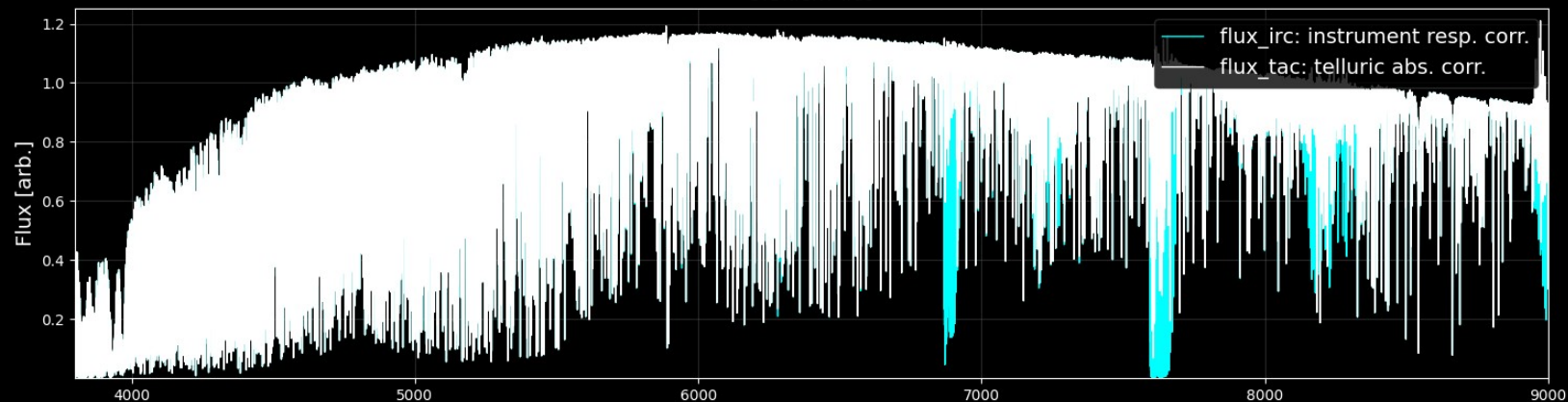


Comparison on Arcturus (K1.5III): Melchior's

https://www.royer.se/melchior/melchior_table.html

327245 -- NAME ARCTURUS -- K1.5IIIFe-0.5

STDNIGHT True

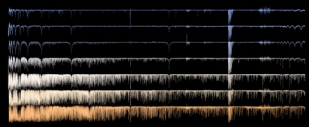


Summary

- **Melchiors**: new homogeneous and large observed spectral library of stars with $\delta > -30^\circ$
- 3256 spectra of 2043 stars (including the Sun) of all spectral types and luminosity classes
- Spectral range : [3800, 9000] Å, resolving power: 85000
- Median S/N ~ 200 in V band
- The sample is 80% complete for $V < 4$ and reaches $V \sim 12$
- Paper (**Royer, Merle et al. submitted**) under revision

but spectral library already available at: www.royer.se/melchiors.html

Melchiors



Introduction

Melchiors is a library of high resolution stellar spectra, covering a wide variety of spectral types, with high signal to noise ratios.

Spectral Resolution : 85000
Wavelength coverage : 390 - 895 nm
Spectral Range Coverage : 0 to 10
Number of spectra : 3256 (incl. Sun ref.)

The spectra were obtained with the Hermes spectrograph, installed on the Mercator telescope in the Roque de los Muchachos observatory on the island of La Palma, operated by the KU Leuven University.

Reference paper (un-reviewed draft) : [Royer et al. 2023](#)

Data Products

A. The spectra, presented in different flavors :

1. Raw i.e. 1D spectra obtained after processing with the Hermes pipeline
2. As 1., but corrected for the instrumental response of the instrument
3. As 2. but including a correction for the telluric absorption lines, with moleclet
4. As 3. but normalized

B. Calibration spectra, used to derive the instrumental responses, in raw format (same as A.1.)

C. Theoretical models of the calibration spectra

D. meta-data tables providing

1. the main information on the spectra and the corresponding target
2. the links between the spectra and their calibration counterpart
3. the cross-match of our targets with Gaia DR3.

E. Quick look pngs of all spectra, including zooms on H α

The format of all data products is detailed in the reference article.

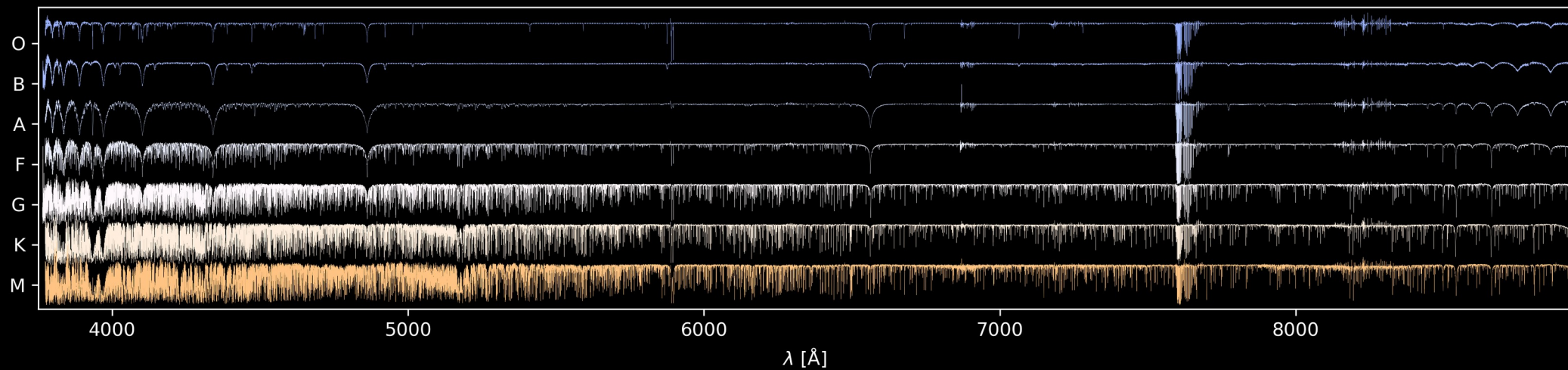
Browse, quick-look and downloads

Provision & Selection table

Bulk Downloads

Spectra Part I	Data product A, 19 Gb
Spectra Part II	Data product A, 19 Gb
Calibration Data	Data products B, C, D, E (11.7 Gb)

Backup – Melchior's spectral library



The Melchior's spectral library

- Access:
 - www.royer.se/melchior's.html
 - Will also be available at CDS
- Content:
 - The spectral library itself:
 - Wavelengths
 - Normalized flux densities
 - Telluric absorption and instrument response corrected flux densities
 - Raw flux densities (output of the HERMES pipeline)
 - The calibration spectra used to derive the instrumental response for every observing night
 - The models of the calibration stars
 - The meta-data information:
 - For the spectral library: observation + Simbad information
 - For the calibration spectra
 - Cross-match table with Gaia DR3

The Melchiors spectral library: the web interface

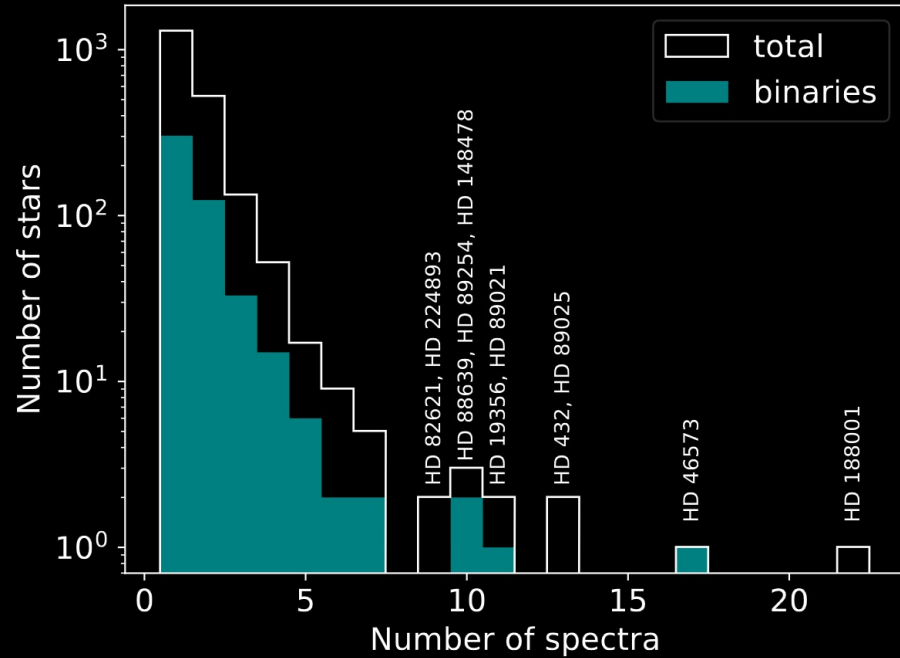
Melchiors

Information and bulk downloads: [see here](#)

Quick-look and individual downloads:

obsid/ quick look	TARGET ↕	starname ↕	V ↕	B-V ↕	stype ↕	ra ↕	dec ↕	airmass ↕	bsn ↕	vsn ↕	rsn ↕	Spectrum
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<div>Start <input type="text"/></div> <div>End <input type="text"/></div>	<input type="text"/>	
307233	HD 1404	NSV 118	4.52	0.05	A2V	00:18:19.70	36:47:06.79	1.261	172.5	209.3	185.5	307233.fits.gz
307234	HD 1404	NSV 118	4.52	0.05	A2V	00:18:19.70	36:47:06.79	1.277	234.7	284.5	252.2	307234.fits.gz
307238	HD 224893	HIP 124	5.57	0.4	A8II	00:01:37.00	61:13:22.12	1.553	209	317.2	307.5	307238.fits.gz
307337	HD 1843	HIP 1844	7.78	1.79	K7V	00:23:19.50	62:18:50.62	1.393	56.5	190.5	260.4	307337.fits.gz
307340	HD 15588	HIP 11622	6.77	0.19	A5/7III	02:29:55.40	-22:40:59.52	1.82	195.4	279	259.9	307340.fits.gz
307451	HD 224893	HIP 124	5.57	0.4	A8II	00:01:37.00	61:13:22.12	1.587	127.3	189.8	191.1	307451.fits.gz
307452	HD 224893	HIP 124	5.57	0.4	A8II	00:01:37.00	61:13:22.12	1.528	120.4	180	181.4	307452.fits.gz
307453	HD 123	V* V640 Cas	6.4	90	G3V+G8V	00:06:15.80	58:26:12.19	1.485	88.7	157.6	168.5	307453.fits.gz

Library content: overview II

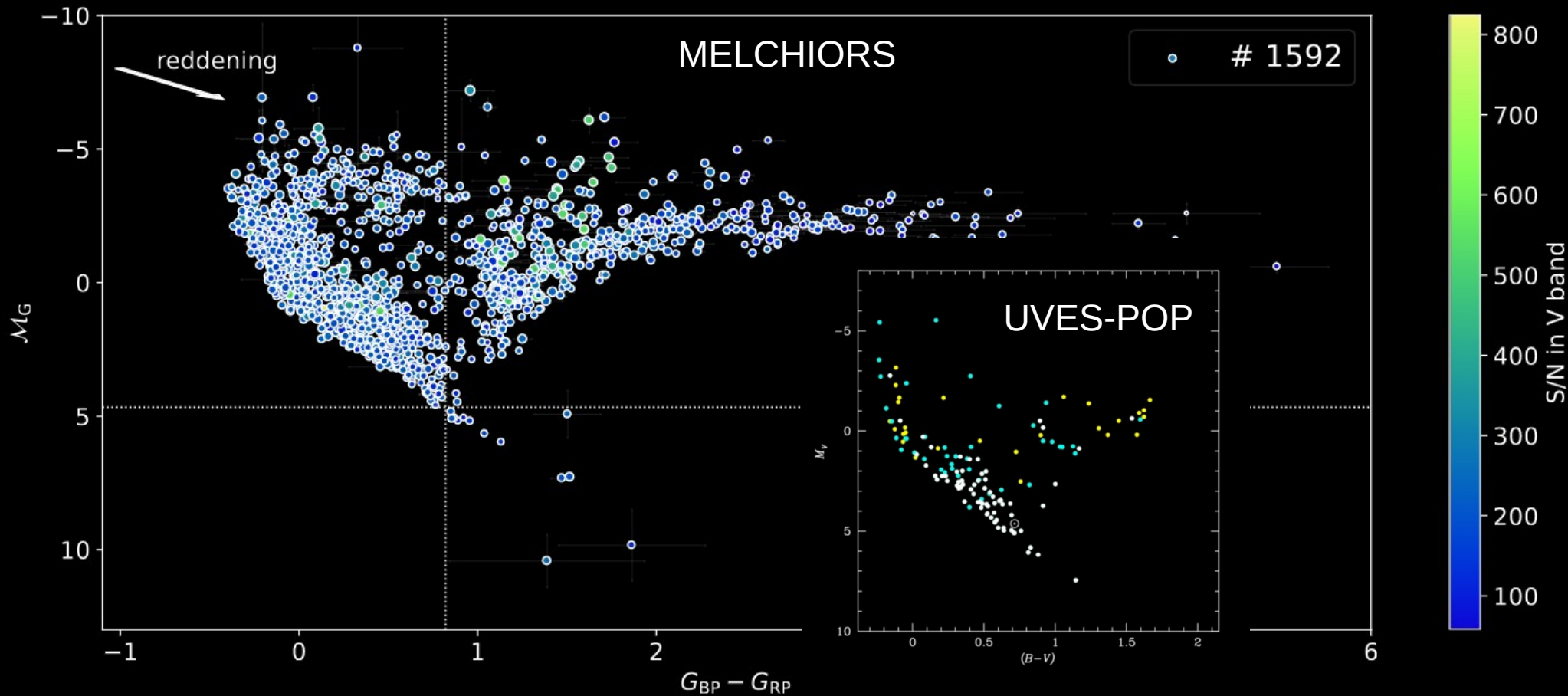


50% of stars have at least 2 spectra

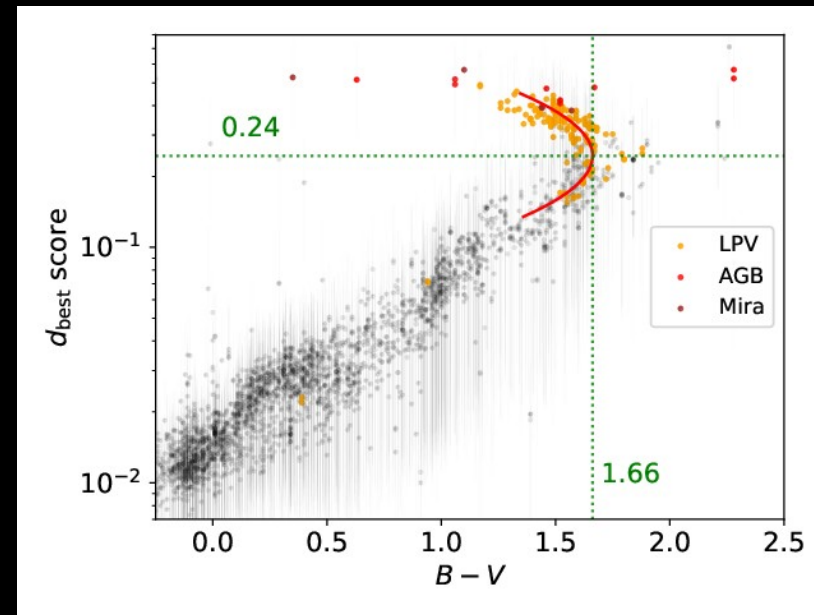
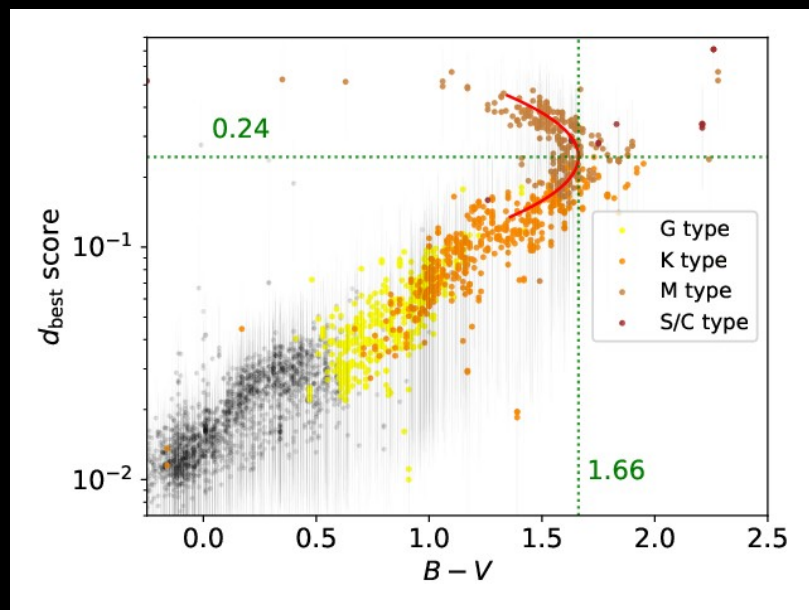
25% of stars are binaries



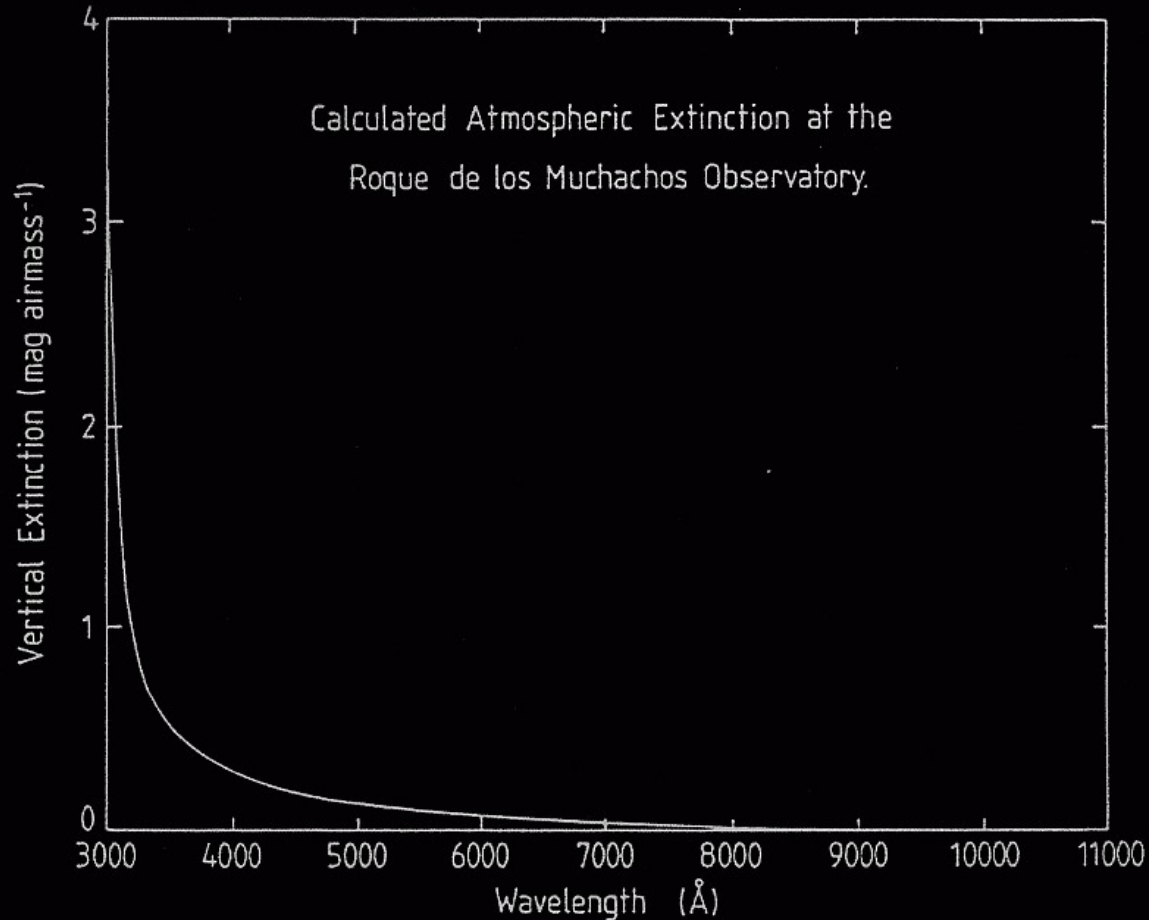
Library content: overview III



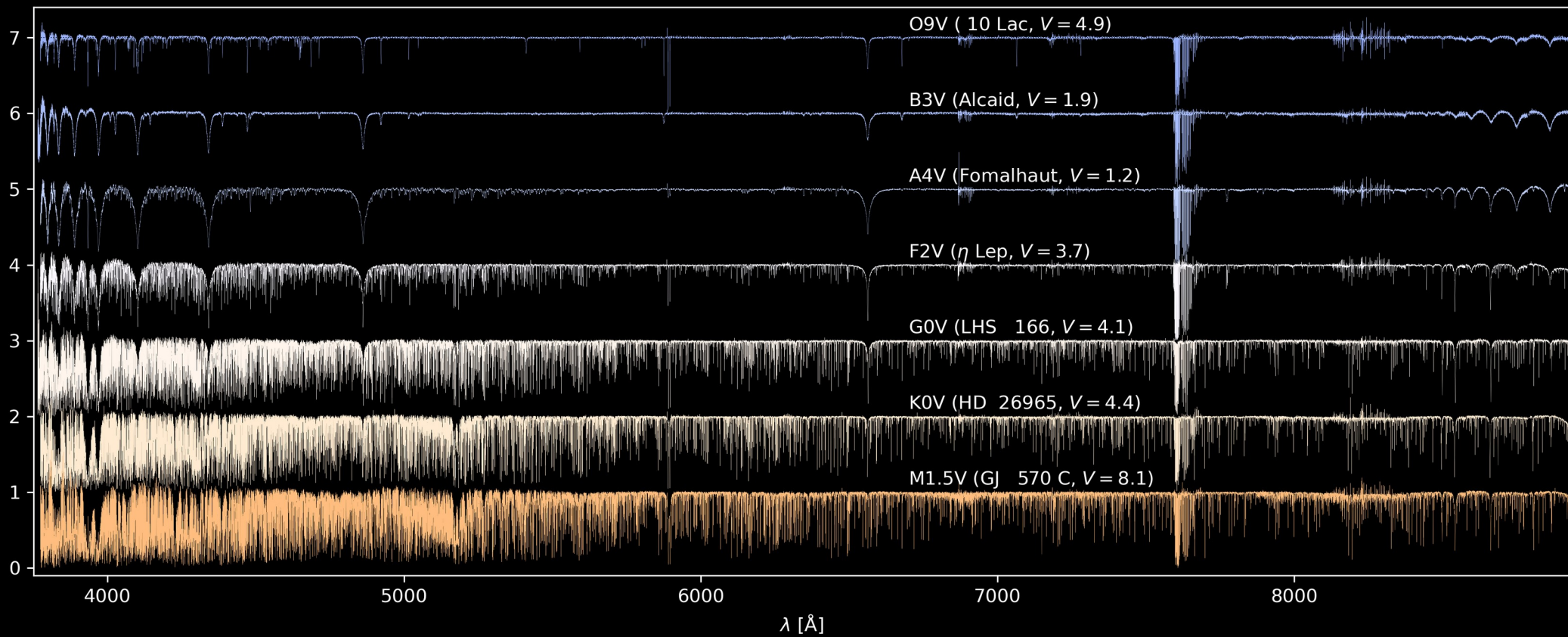
Best d score versus B-V



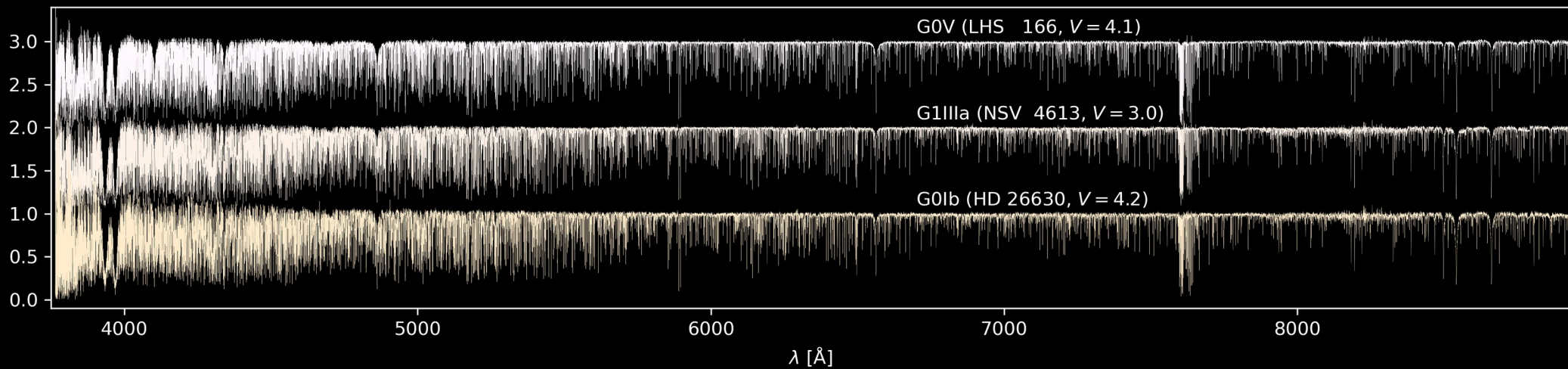
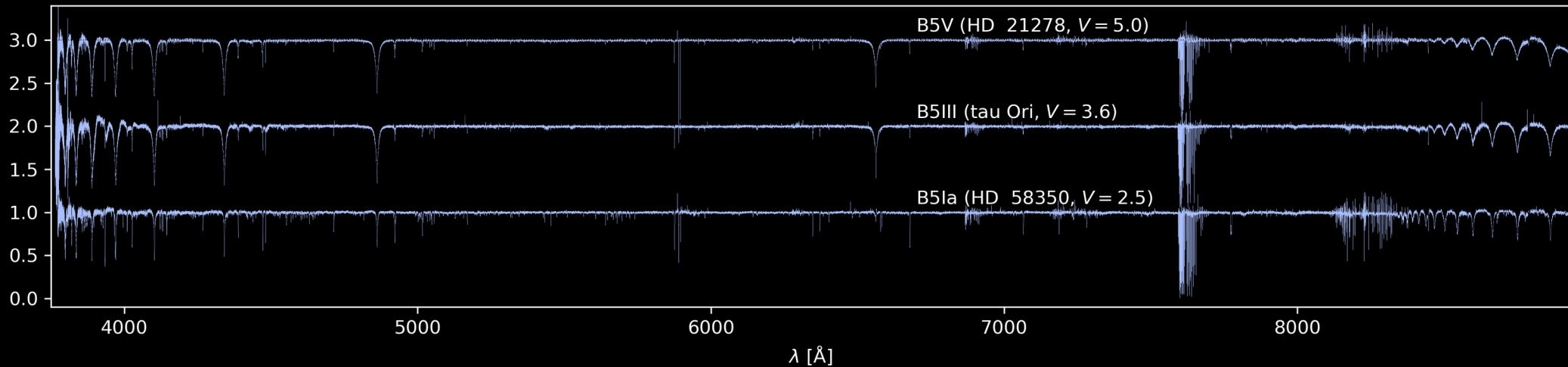
Theoretical atmospheric extinction on La Palma as a function of wavelength and airmass



Spectral type effects



Luminosity effects



Spectral types and luminosity classes of the Melchior's spectral library

	WR	O	B	A	F	G	K	M	S/C	Total
V	0	29	129	123	151	90	50	3	0	575
IV	0	14	103	107	67	73	25	0	0	389
III	0	20	109	72	60	107	132	107	1	608
II	0	9	46	24	24	37	50	9	0	199
I	0	19	15	5	4	3	5	2	0	53
N/A	4	4	24	18	37	23	47	54	7	218
Total	4	95	426	349	343	333	309	175	8	2042

Variability of the instrumental response function

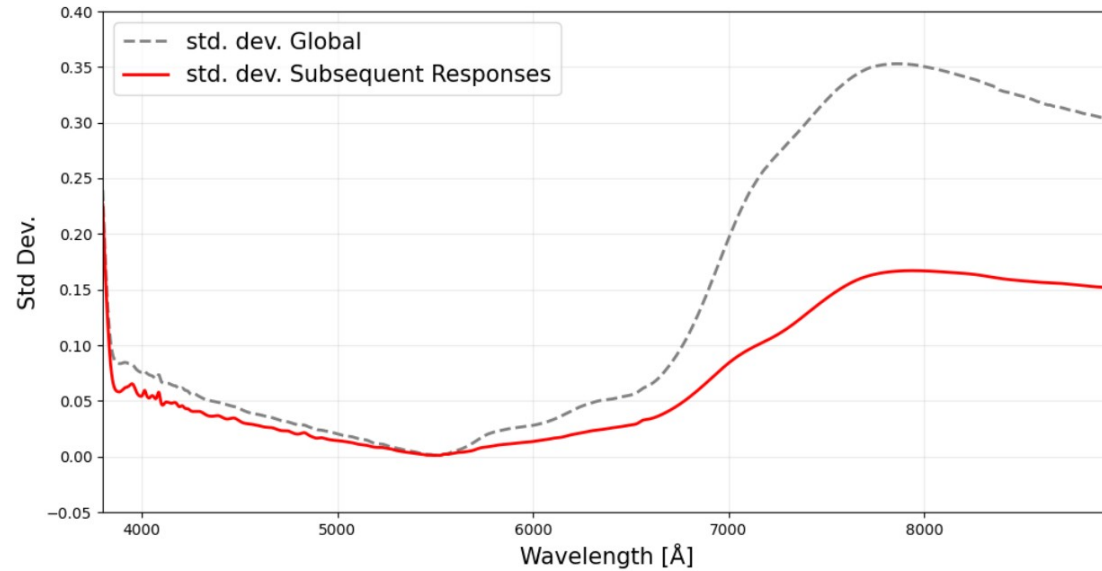


Fig. 5. Red: standard deviation of the ratio between subsequent responses derived for our programme indicative of the additional uncertainty on the low-frequency components of the continuum for the stars with `STDNIGHT=0`. grey: standard deviation computed over all responses, regardless of their acquisition time (see text for details).