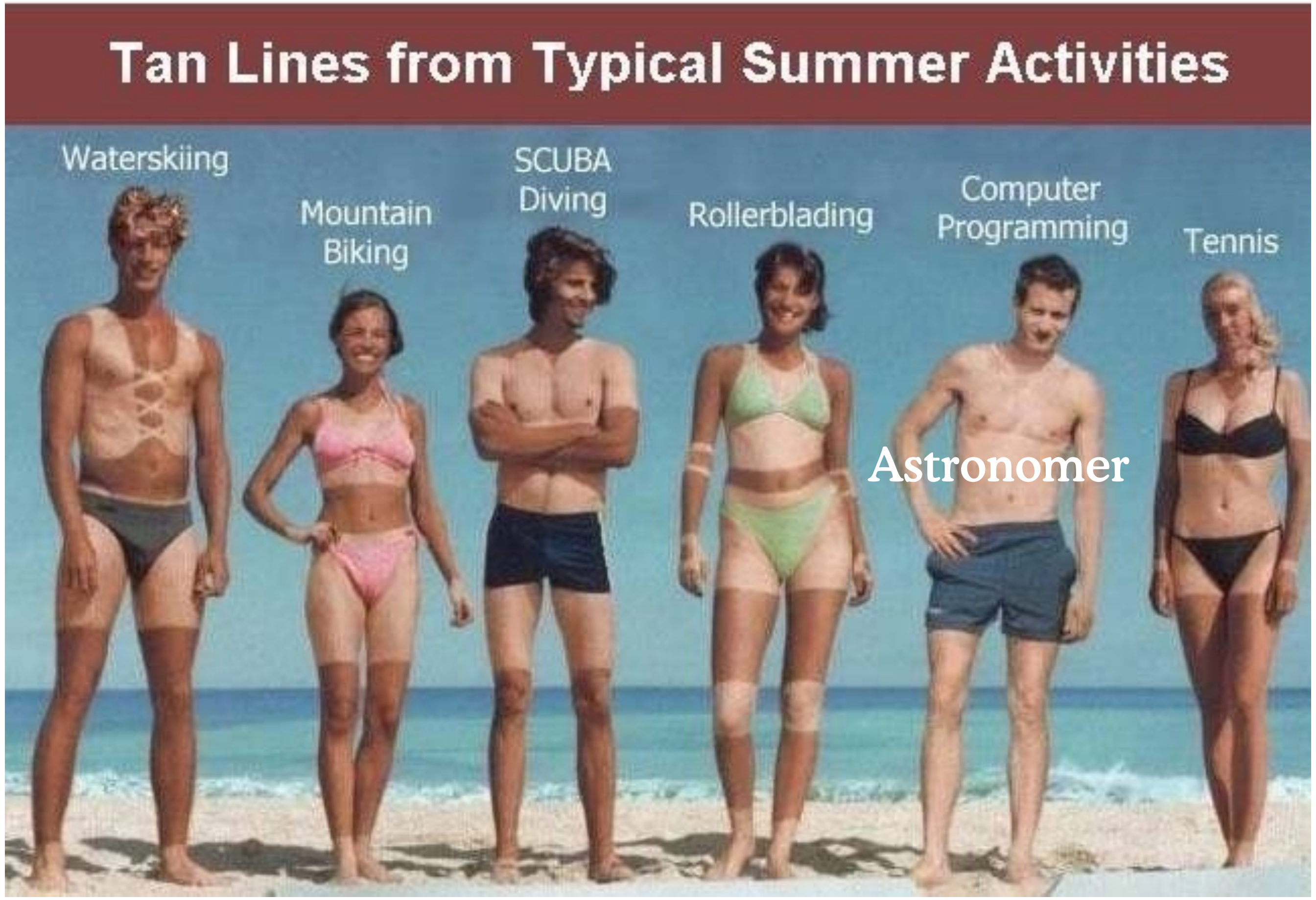
NOT, FIES & spectroscopy

Andreas Korn


Tan Lines from Typical Summer Activities
Waterskiing
Mountain Biking
SCUBA Diving
Rollerblading
Computer Programming
Tennis
Astronomer

This lecture

First half:

A quick introduction to the **N**ordic **O**ptical **T**elescope (NOT) at
Roque de las Muchachos, La Palma, The Canary Islands

and

dito for the **FI**ber-fed **E**chelle **S**pectrograph (FIES)

Second half:

An introduction on the normalizer (tool by Johannes Puschnig)

Roque de los Muchachos, La Palma

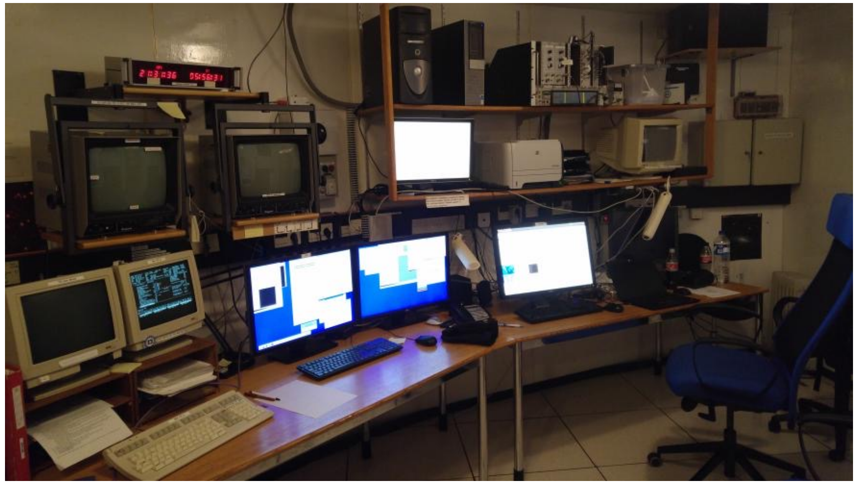
Largest and best observatory in Europe. Home of 15 operational telescopes, including the largest single-aperature optical telescope: the 10.4m **Gran Te**lescopio **Can**arias (GranTeCan).

(Site for the US TMT? Probably not.)

The Nordic Optical Telescope (NOT)

A 2.56m Nordic Optical Telescope (presently run by Arhus University, DK & University of Turku, FI) just below Roque de los Muchachos.
https://www.not.iac.es/

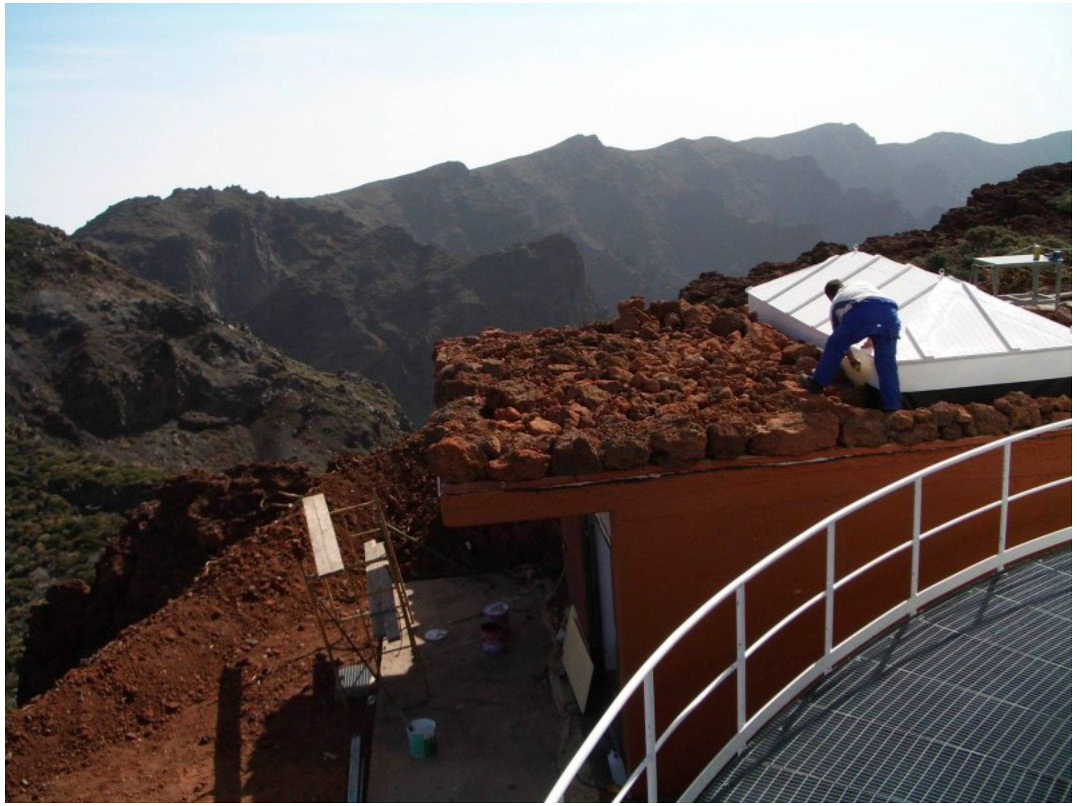
The telescope has been operated since 1989 and is known for its reliability.

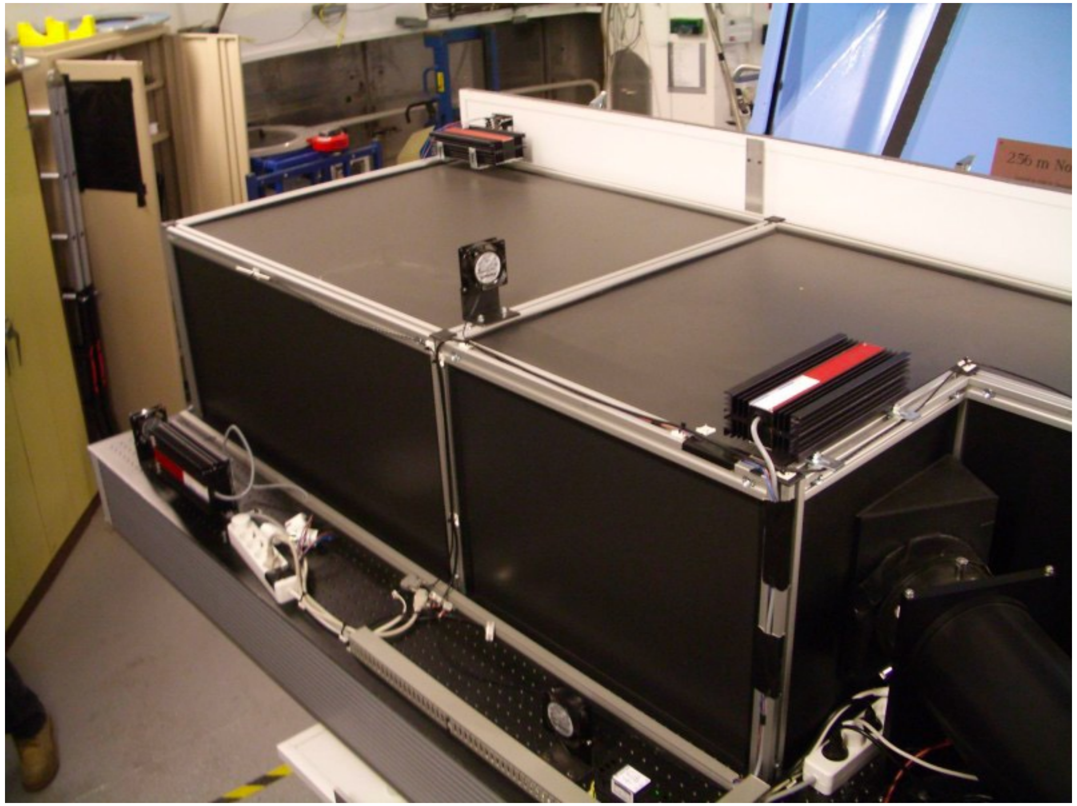


It has a modern spectrograph, FIES, which is the sole instrument we will use this week (except for ToOs/Tiina).

Parque Nacional de la Caldera de Taburiente


FIES is in a separate building…





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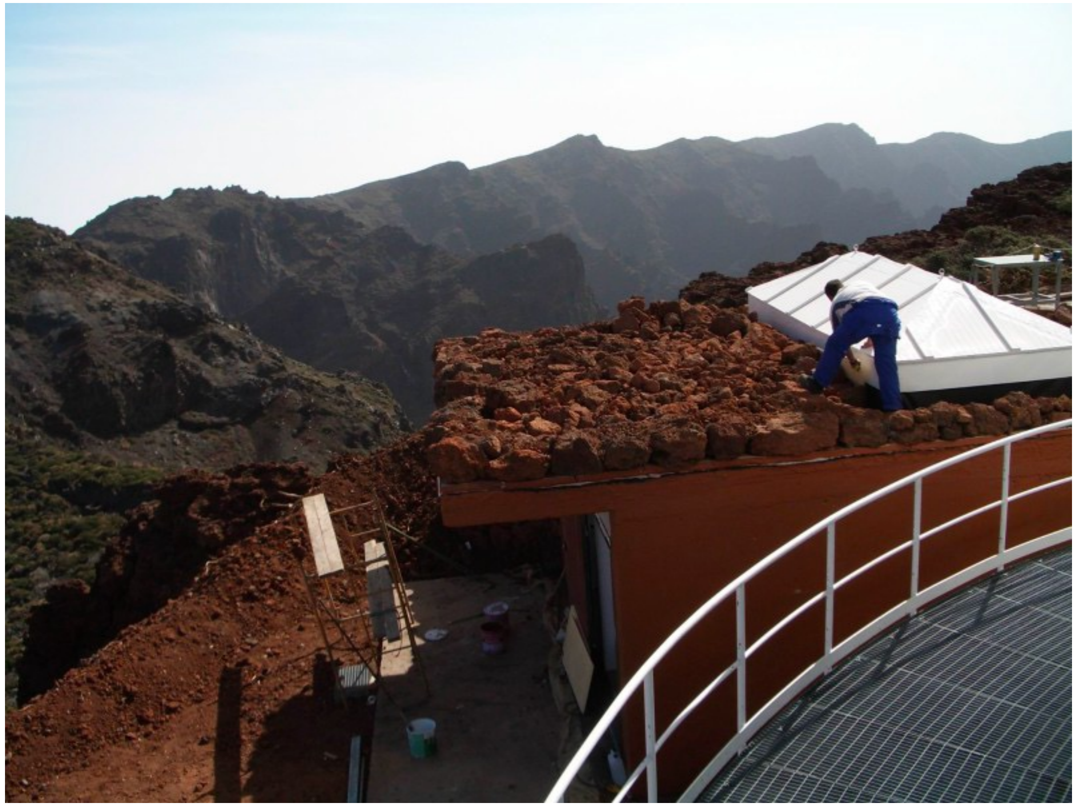
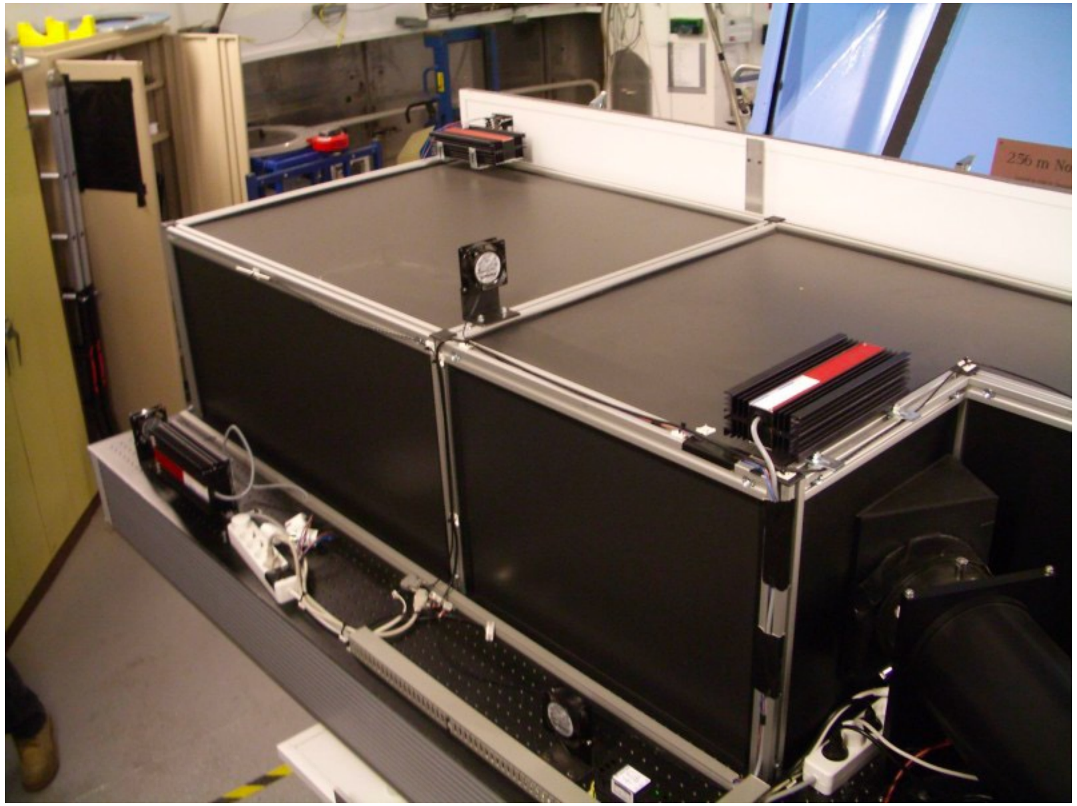
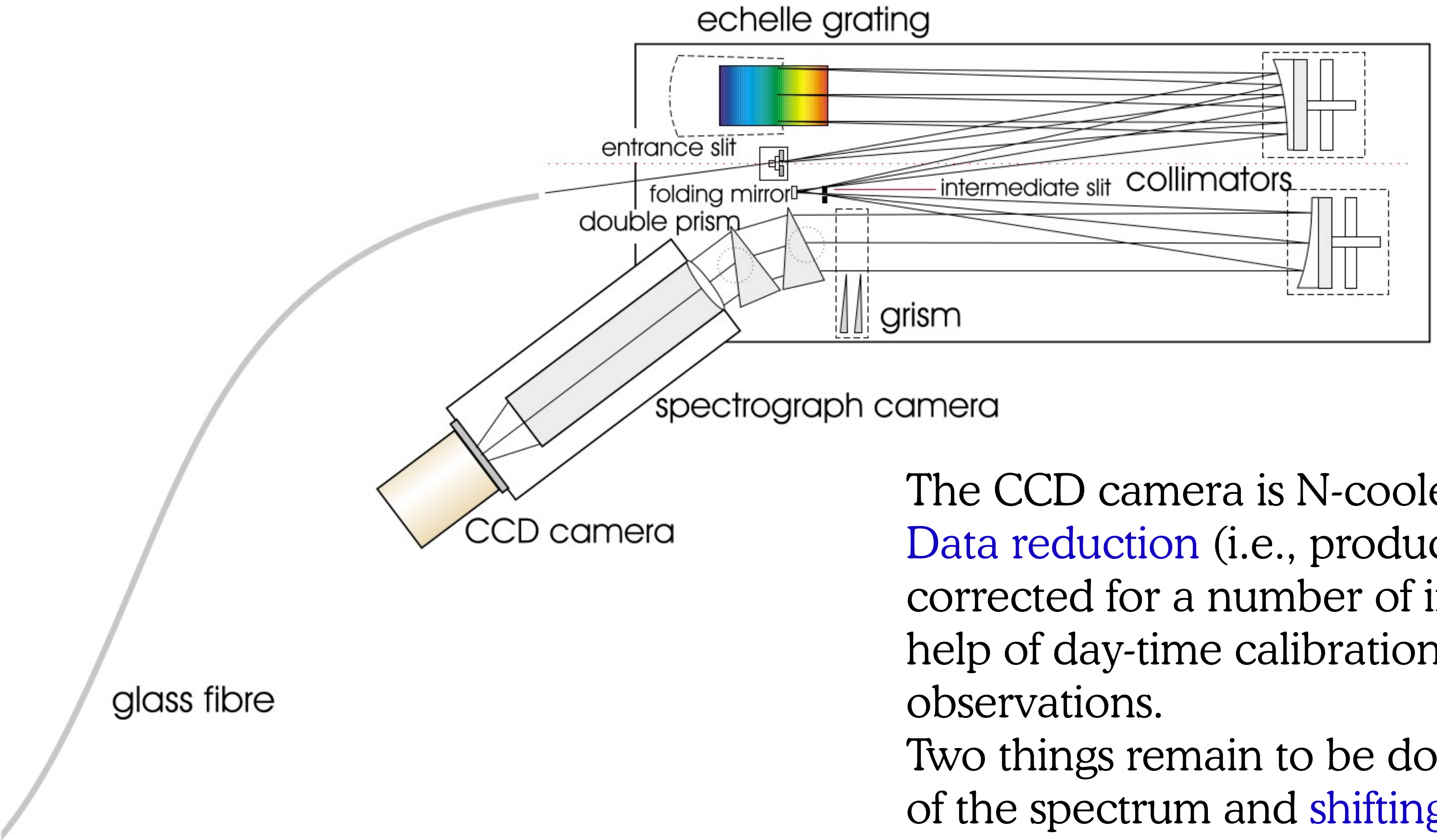




…for mechanical and thermal stability. Necessitates a fiber link.

Echelle spectrographs



The CCD camera is N-cooled to minimize dark current. Data reduction (i.e., producing one long spectrum corrected for a number of instrumental effects with the help of day-time calibration files) is done right after the observations.

Two things remain to be done: continuum normalization of the spectrum and shifting it to laboratory wavelength.

The FIber-fed Echelle Spectrograph (FIES)

FIES is a modern high-resolution fibre-fed echelle spectrograph. Light enters the spectrograph through a fibre with a 1.3 arcsec diameter on the sky. This means that if the seeing at the telescope is 1.3” (FWHM), roughly one third of the light gets lost.

The dispersive element is an echelle grating. Cross-dispersion is provided by a 48-degree prism. The spectral orders are recorded on a CCD. Data reduction is done on-the-fly, i.e. we receive a fits file with the reduced spectrum right after the observations.

FIES has several modes with different resolving powers. Since we are dealing with cool stars with intrinsically sharp lines, we go for the highest-R setting ($\lambda/\delta\lambda = 67{,}000$). Full optical coverage out to 7300 Å.

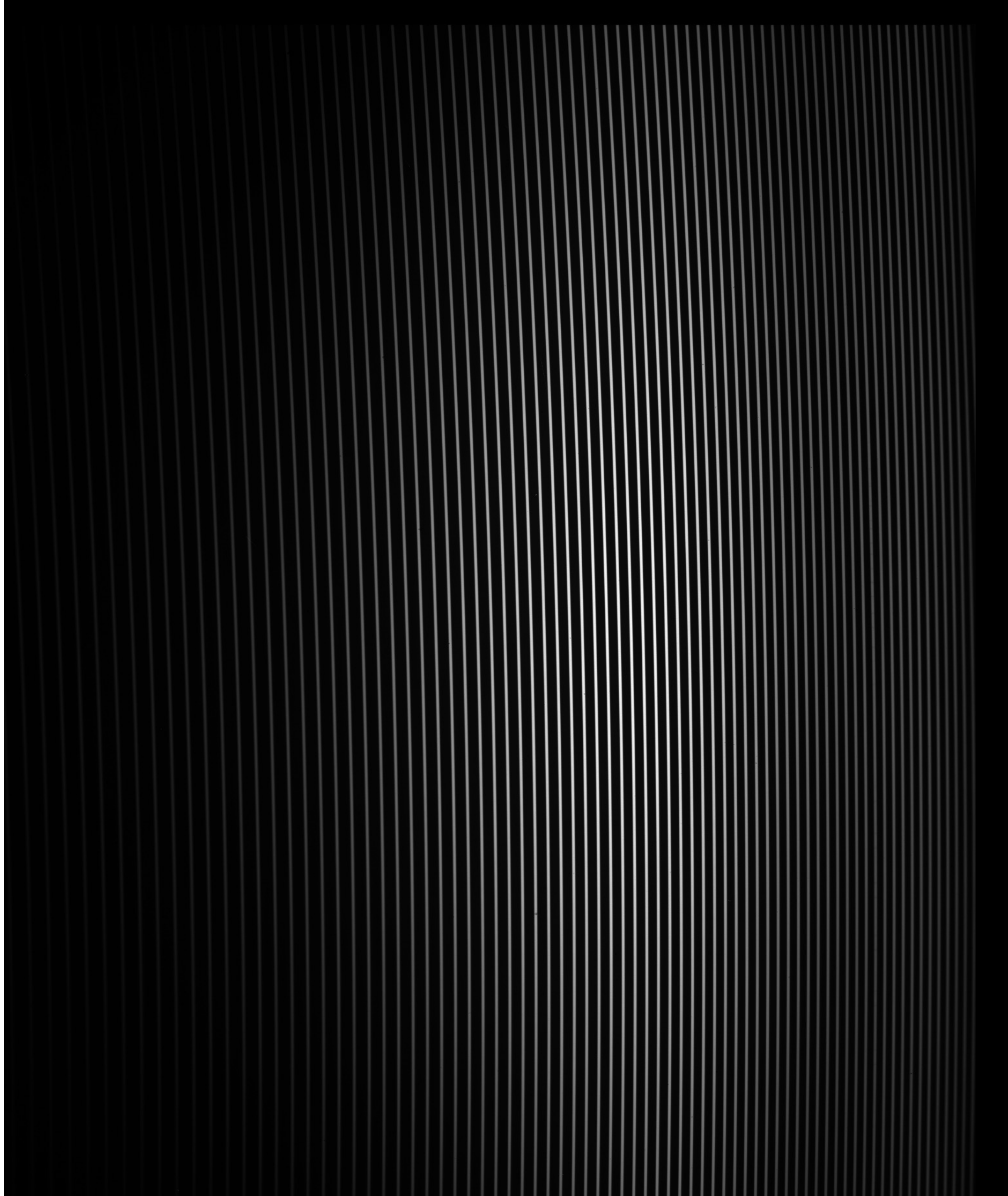
See http://www.not.iac.es/instruments/fies/ and

http://www.not.iac.es/instruments/fies/devel/telting2014FIES.pdf

A FIES echellogram

The cross-dispersion places the slightly curved spectral orders on the CCD. Each order contains a portion of the stellar spectrum, typically 100 Å.

There are numerous steps in the data reduction to produce a long spectrum, notably dark and bias correction, flat-fielding and wavelength calibration. Day-time frames are used for this.

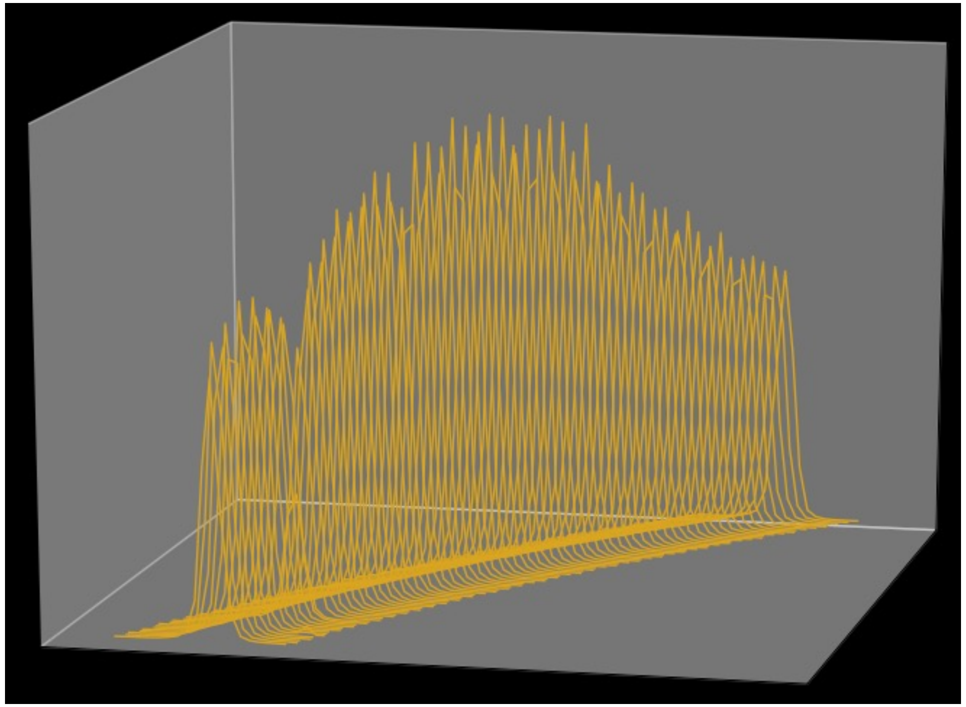


Night log 2025-07-21

FIIg210084	18:33		FIEStool flat	F4F4 HiRes	F4 HiRes HalogenThAr
FIIg210085	18:34		FIEStool flat	F4F4 HiRes	F4 HiRes HalogenThAr
FIIg210086	18:35		FIEStool flat	F4F4 HiRes	F4 HiRes HalogenThAr
FIIg210087	18:36		FIEStool bias	F4 HiRes	F4 HiRes HalogenThAr
FIIg210088	18:37		FIEStool bias	F4 HiRes	F4 HiRes HalogenThAr
FIIg210089	18:38		FIEStool bias	F4 HiRes	F4 HiRes HalogenThAr
FIIg210090	18:38		FIEStool bias	F4 HiRes	F4 HiRes HalogenThAr
FIIg210091	18:39		FIEStool bias	F4 HiRes	F4 HiRes HalogenThAr
FIIg210092	18:40		FIEStool bias	F4 HiRes	F4 HiRes HalogenThAr
FIIg210093	18:41		FIEStool bias	F4 HiRes	F4 HiRes HalogenThAr
FIIg210094	18:42		FIEStool dark	F4 HiRes	F4 HiRes HalogenThAr
FIIg210096	21:46	tyc1460-418-1	tyc1460-418-1	F3 MedRes	Parked3 ThAr
FIIg210097	22:44		test	F3 MedRes	Parked3 ThAr
FIIg210098	22:53	XZCyg	XZCyg	F4 HiRes	Parked4 ThAr
FIIg210099	23:19	WR142	WR142	F1 LowRes	Parked1 ThAr

Flat-fielding / blaze-function removal

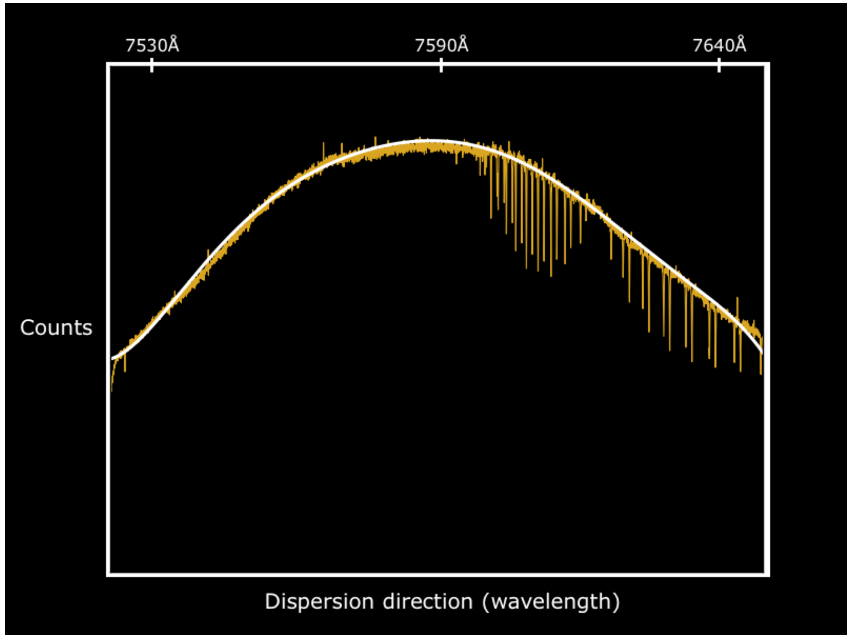
Every echelle order has an internal flux profile called the blaze. This is instrumental and has to be removed in order to put together the individual echelle orders into a long spectrum.

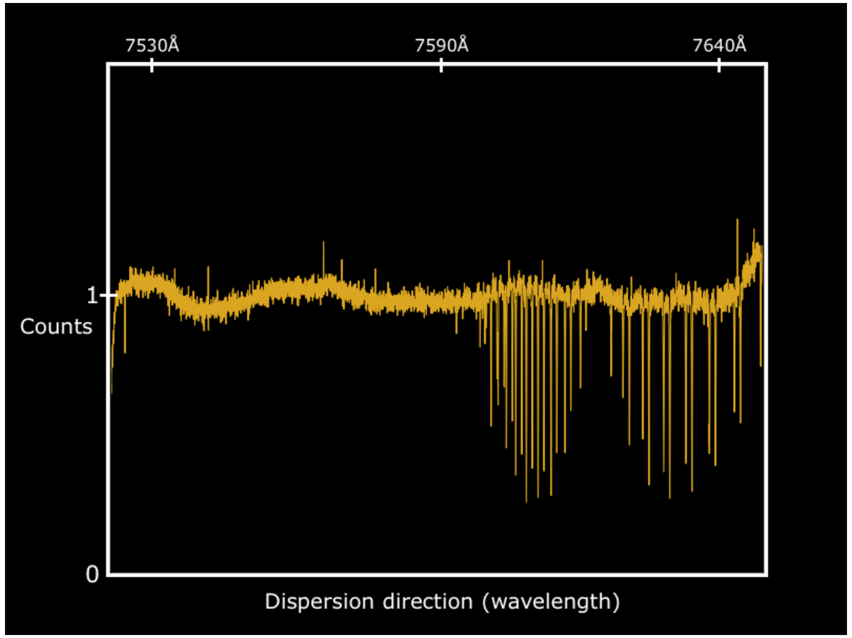


© https://www.theroncarmichael.com/echelle-spectra-reduction

Flat-fielding / blaze-function removal

To remove the blaze, we feed a featureless lamp spectrum through the spectrograph (one of the day-time calibration frames). By dividing the stellar spectrum by the flat-field spectrum (in 2D or in 1D), we get more or less a flat spectrum.





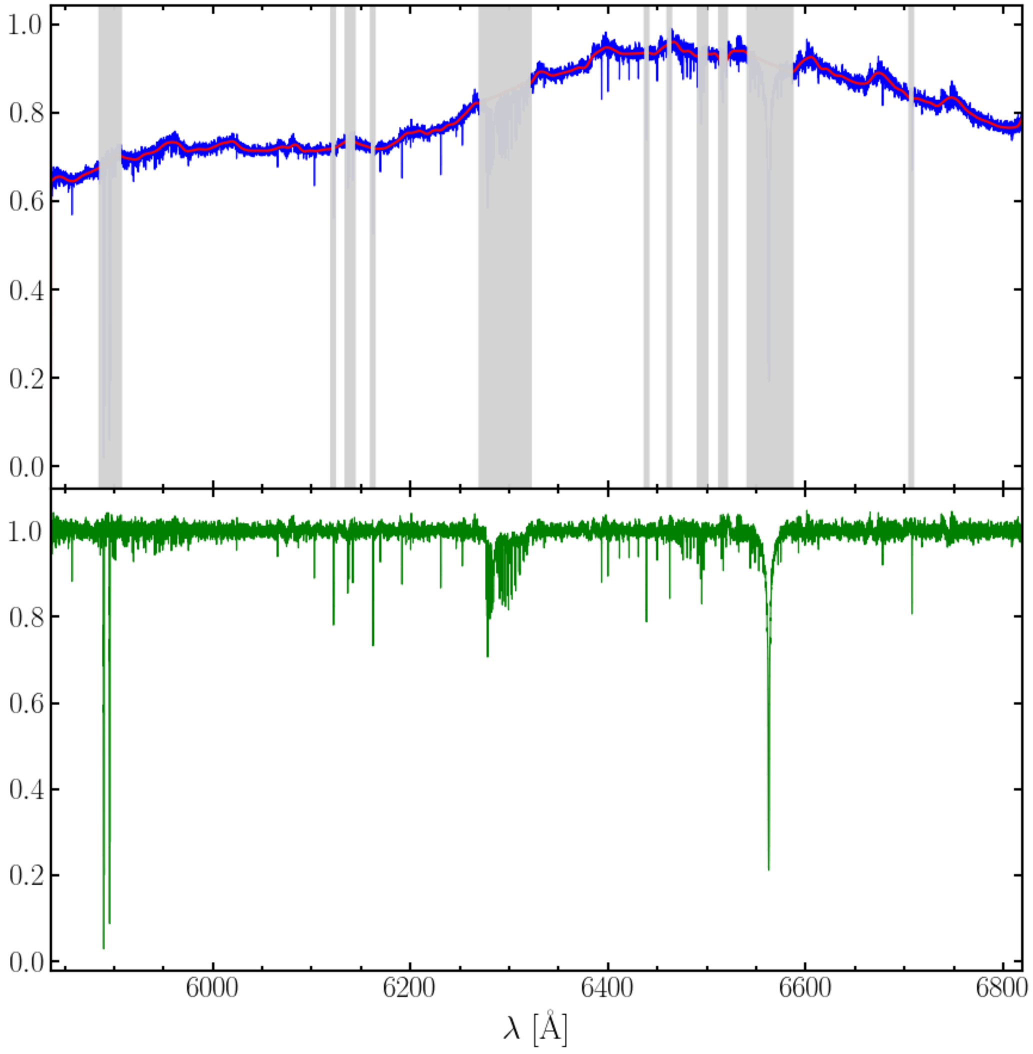
A small helper tool: JP's normalizer

We need to provide webSME will a normalized spectrum, i.e. continuum level = 1.

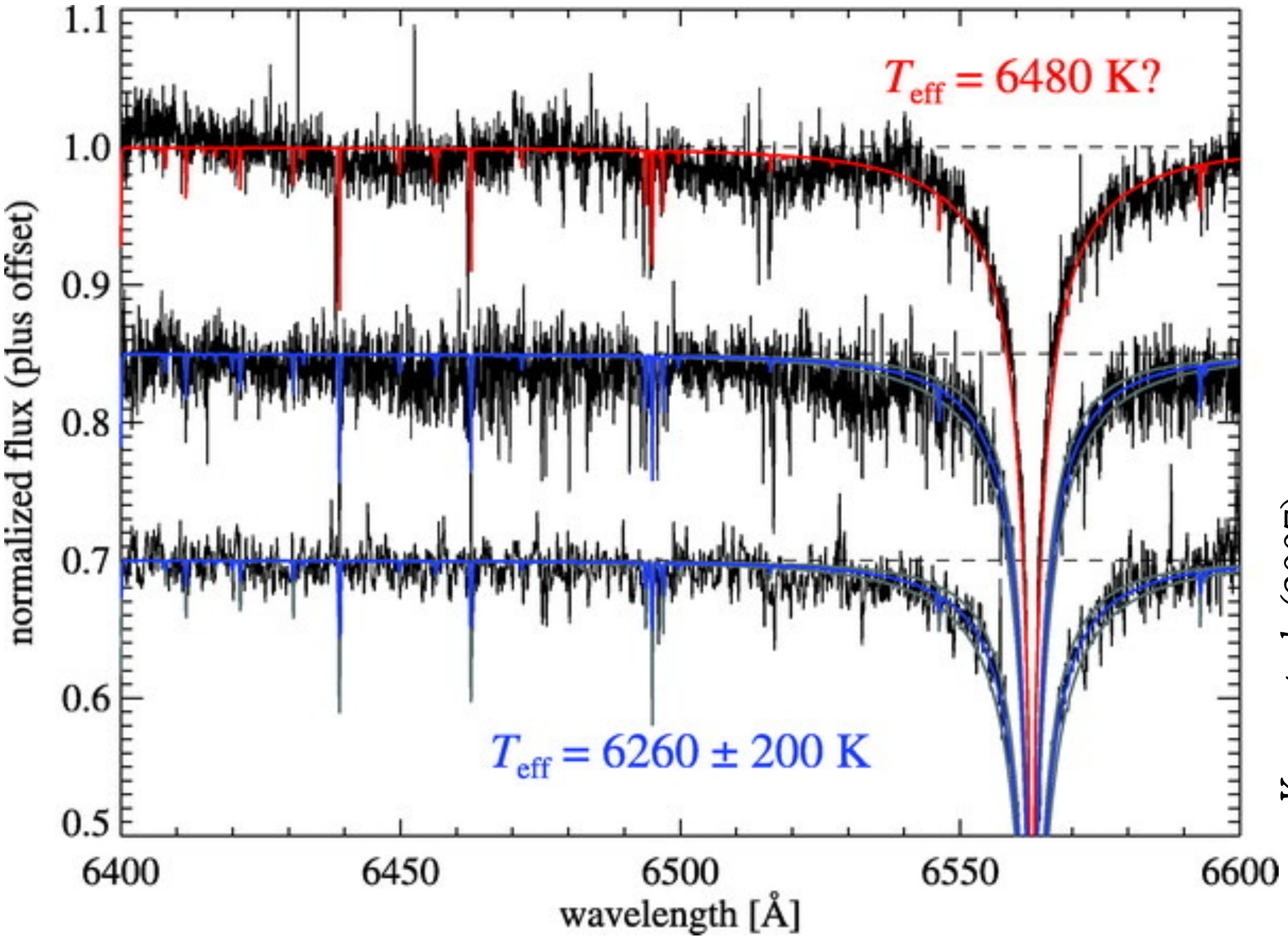
(Does not have to be perfect, as it will be refined by webSME.)

To this end, a normalization tool by ChETEC-INFRA postdoc Johannes Puschnig (UU) is provided: https://github.com/astrojohannes/normalizer

Download it and check it out!



Blaze removal matters!



Korn *et al.* (2007)

Let’s learn how to normalize spectra

Please open JP’s normalizer tool.

```
python run_normalizer.py --wave=6000,6800 5281_REDU_coadd_rebin.fits
```

Let’s get rid of some of the blaze-removal residuals, e.g., between the marked telluric bands (6310 – 6460 Å). So click on the hourglass and slice the spectrum (to only work on that part of it).

You can now play around with the different fitting routines, with or without identifying and masking lines. See github for some explanations.

Lastly, if there are enough lines, you can determine the momentary radial velocity (already applied here). Once you are happy, save the file.

Let's learn how to normalize spectra

You can now try to do the same with a solar spectrum (reflected moonlight observed during ChINOS1 in 2023).

FIGg260065_step011_merge.fits (school main page). $4800 < \lambda[\text{Å}] < 5300$.

This time the stellar-line density may be too high not to work with line masking. There are different modes for this. Play around with the options. Instructions on Github. You can always undo the masking.

Check the momentary radial velocity (works in the background, check the prompt and look for a new window opening). Should it be zero?

The analysis tool of the day: webSME

Evolution of "Spectroscopy Made Easy" (SME)

Original version published by Valenti & Piskunov (1996)

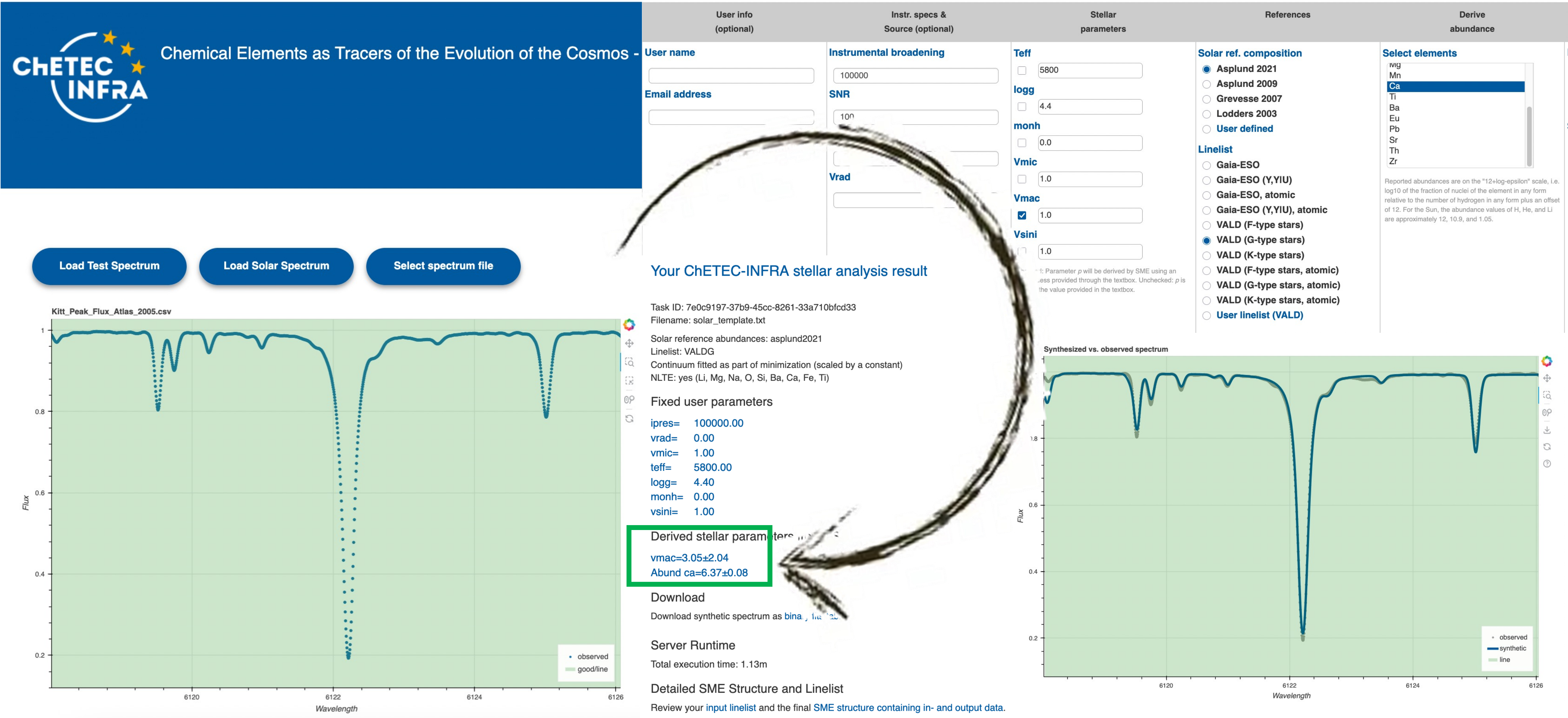
C++ and FORTRAN library complemented by IDL framework

Library has undergone significant development (Piskunov & Valenti 2017)

pySME: Wehrhahn *et al.* (2022) translated IDL part of code to python

webSME: based on pySME, with some cool updates (Puschnig *et al.*, in prep.)

From spectrum to stellar abundances



webSME: start small, iterate up

Complete atomic and molecular line lists (e.g. Gaia-ESO without any additional constraints) are huge, even for small wavelength intervals. Running 5 Å may take 15 minutes.

So start with a constrained line list: Gaia-ESO (Y,Y|U), atomic

The fastest way to see a spectral fit (e.g. to fix some parameters like Vmac) is to use the Forward modeling mode (toggle button at the top). Using this mode you can keep the number of fitting parameters for SME small which makes for a better convergence.