A fast all-in-one code for synthesising stellar spectra based on ATLAS9

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A bit technical but I will show some CLVs in the end :)

Stellar Photometric data

Ground-based data (Strömgren b and y, Ca II index)

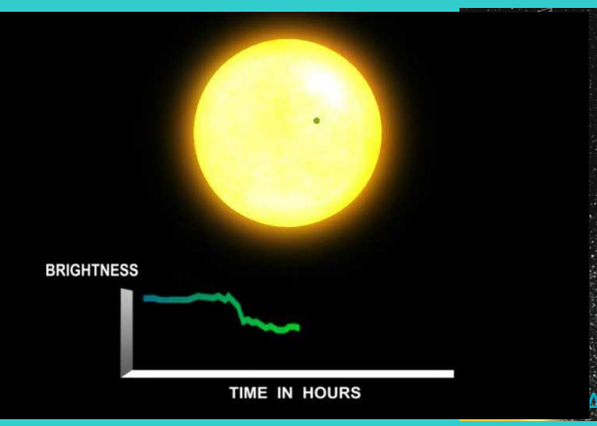
21-inch refractor at the Lowell Observatory

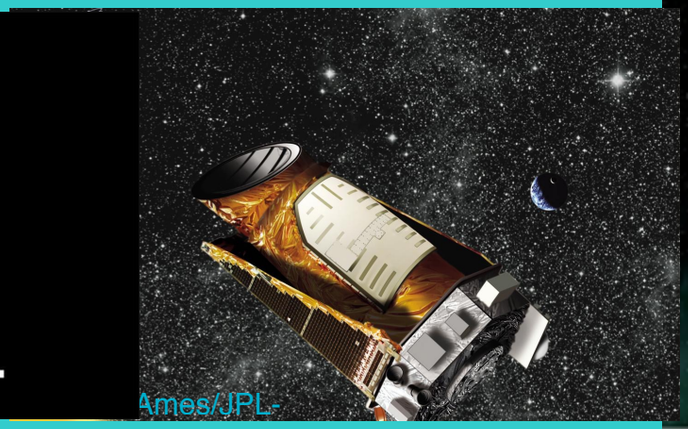
Automatic Photoelectric Telescopes at the Fairborn Observatory

~10^2 stars; ~10-20 years

LSST (2021)

Spaceborne data (broadband photometry)





Kepler

CoRoT

~10^5 stars; ~100 days

TESS (2018)

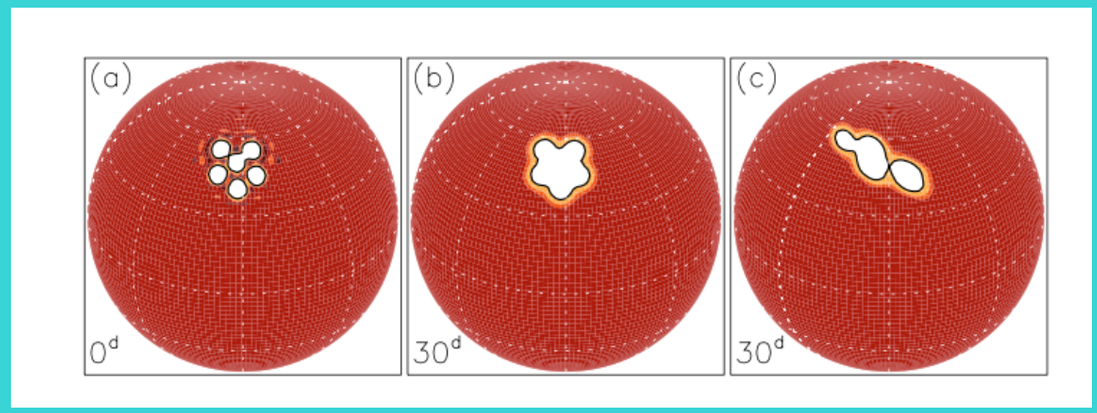
CHEOPS (2019)

PLATO (2026)

Tools

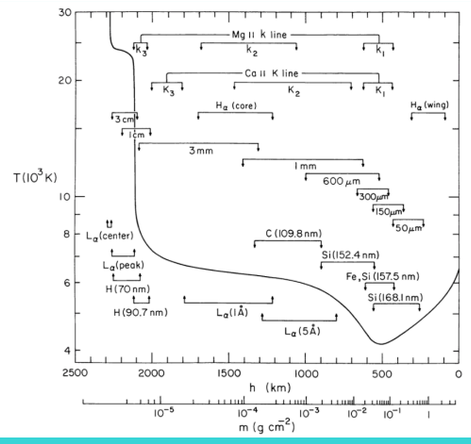
Extrapolation from the Sun

evolution of magnetic field on stellar surface



1D semi-empirical models

effect of magnetic field on stellar atmosphere



3D MHD simulations

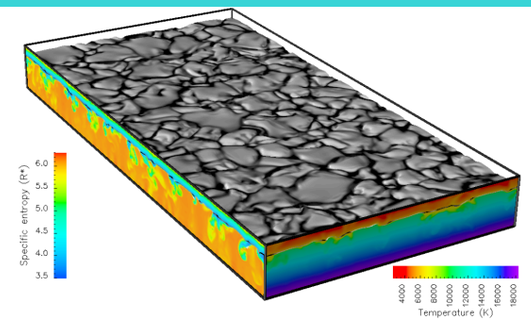
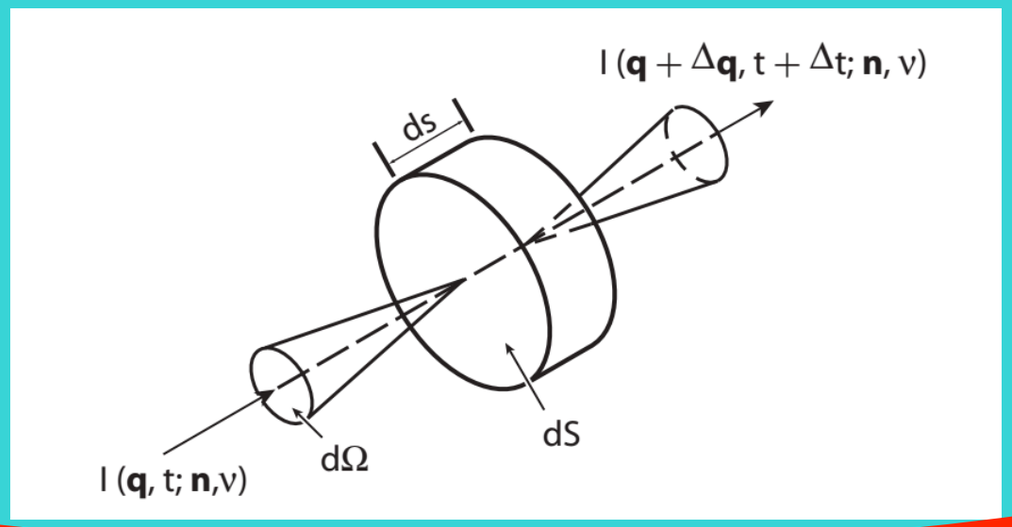
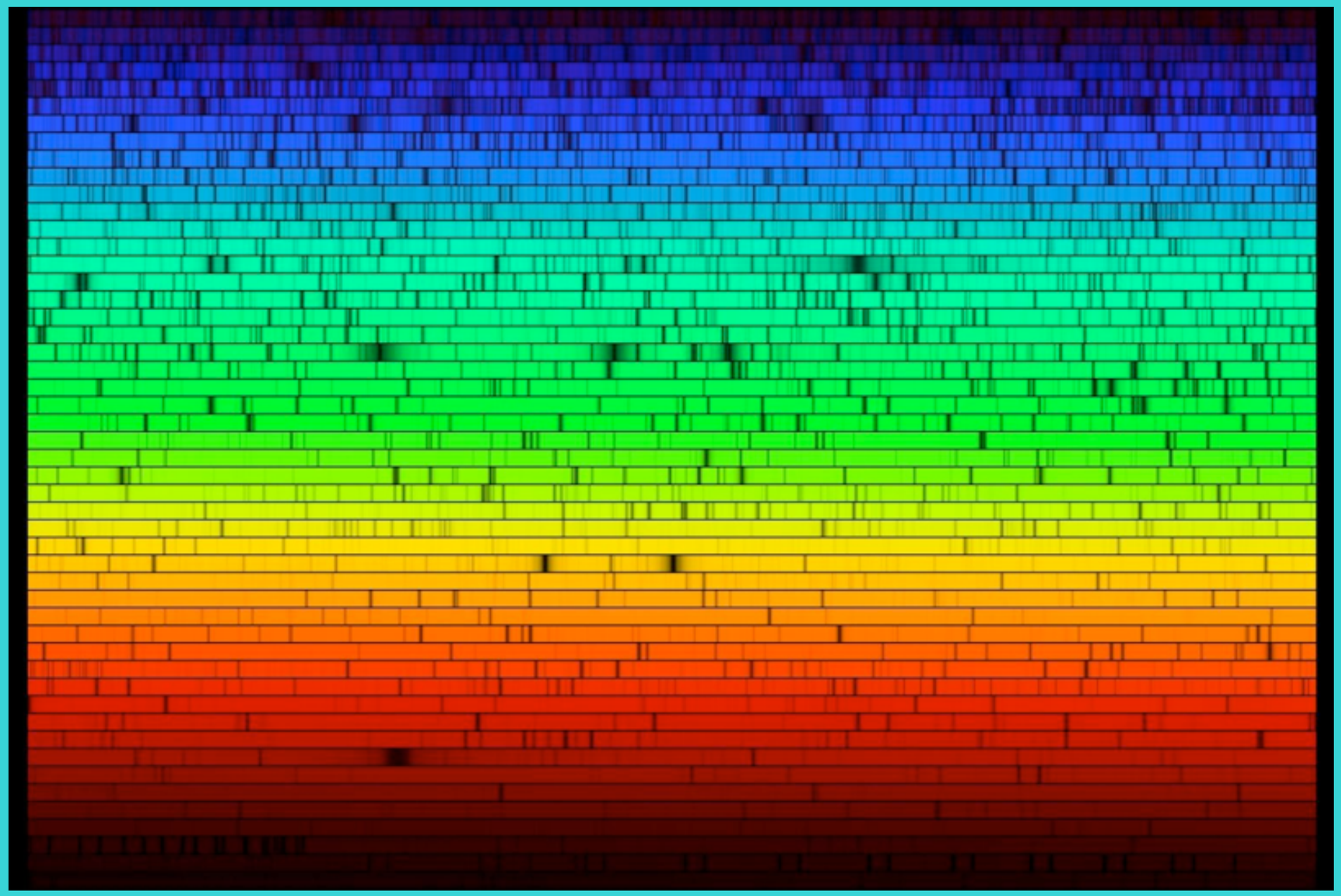


Figure 3.1: A snapshot of the 3D model of the upper convection zone and the photosphere. The gray surface shows the $\tau_{\rm Ross} = 1$ level. The grey scale on this surface shows the vertical velocity of the material at that level (dark is downflowing and light is upflowing). The vertical slice on the right side of the domain shows the temperature stratification. The vertical slice on the left side shows the specific entropy distribution.

Radiative transfer codes

calculation of the emergent spectra



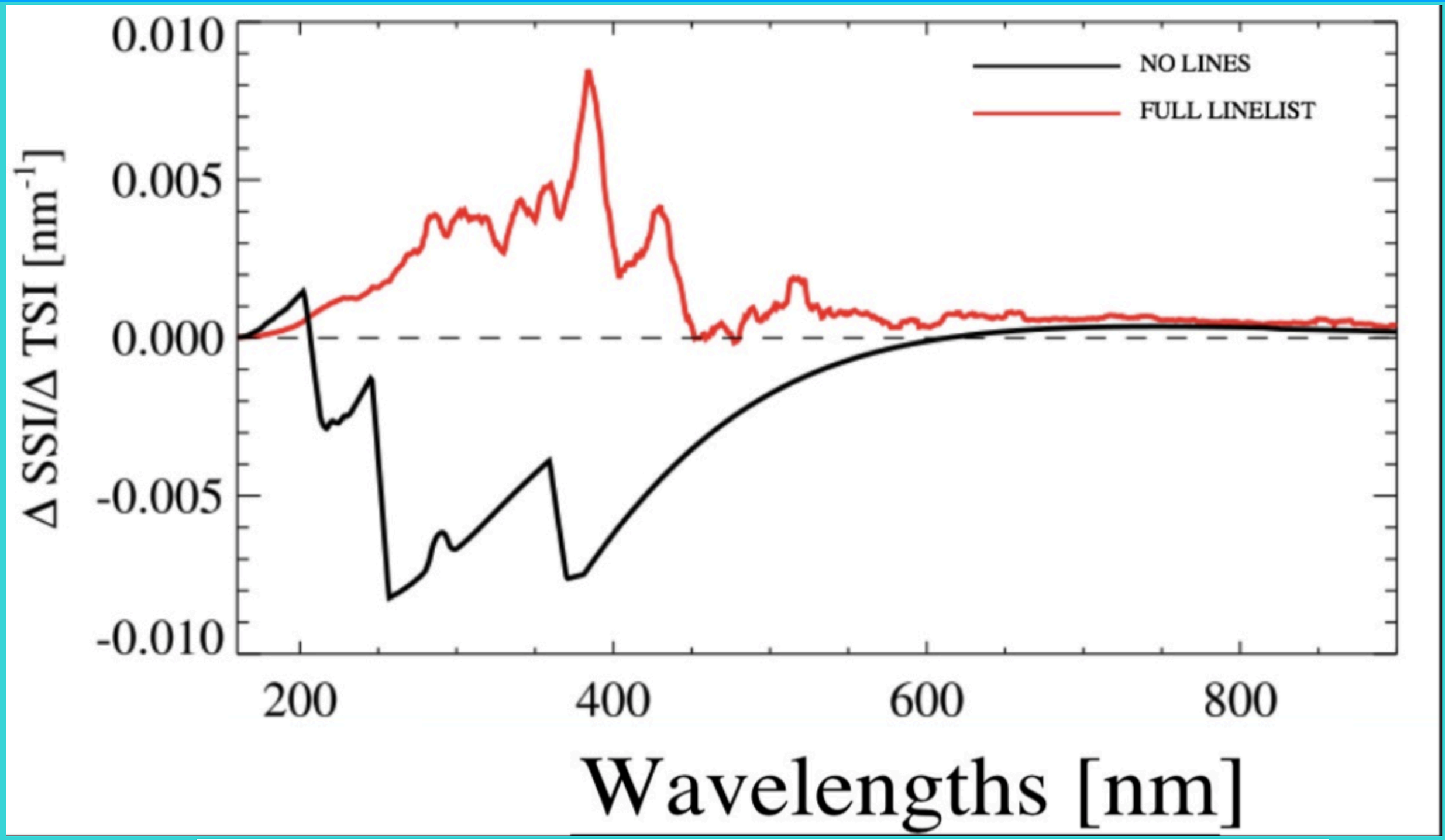


Deviations from the Local Thermodynamical Equilibrium

Small effect longwards 350-400 nm

Millions of Fraunhofer lines

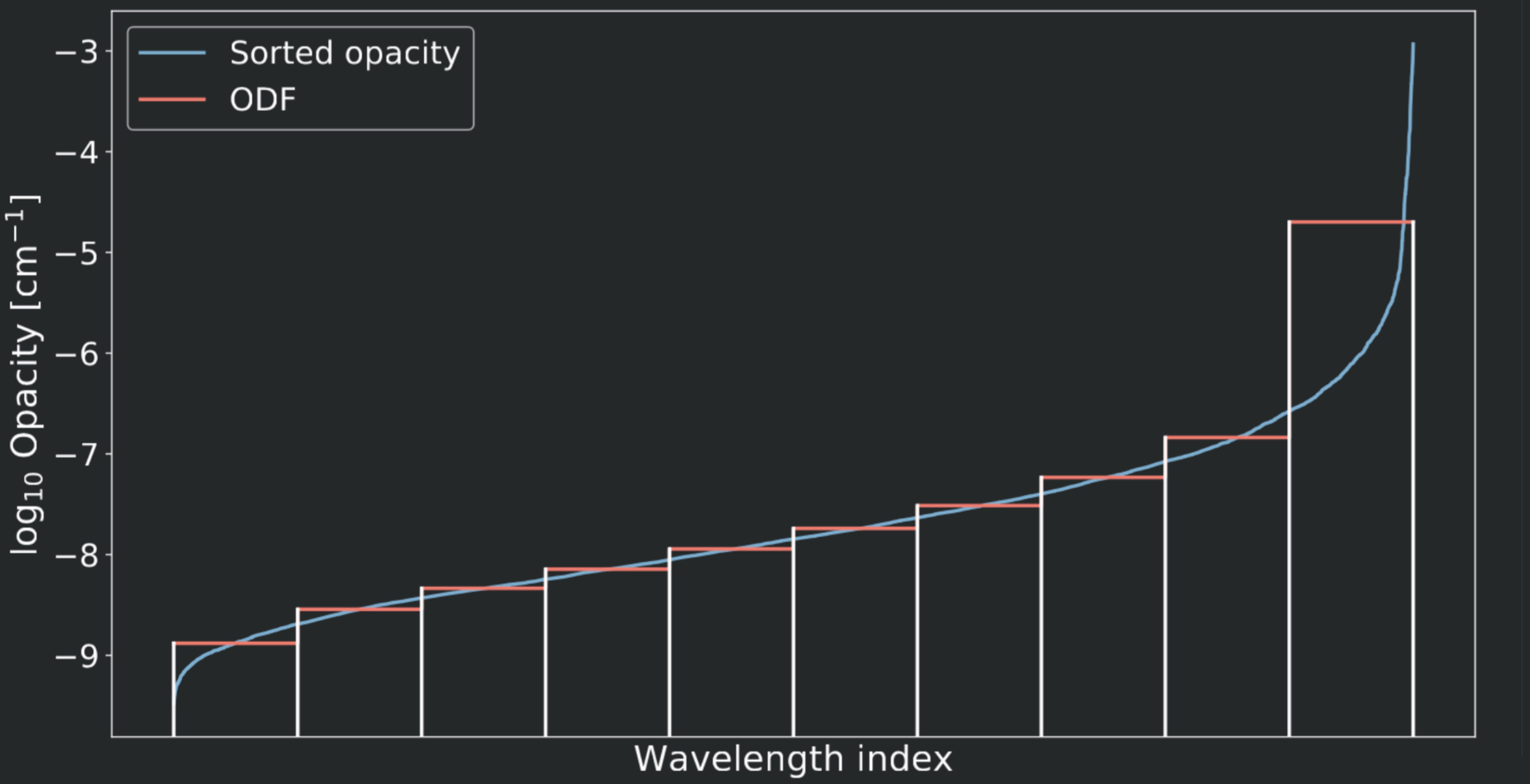
Contribution of spectral lines to solar brightness variability



The increase of the TSI at maximum of the activity cycle compared with minimum is directly attributed to the variability in spectral lines

ATLAS9: LTE, 1D, Opacity Distribution Functions (ODFs)

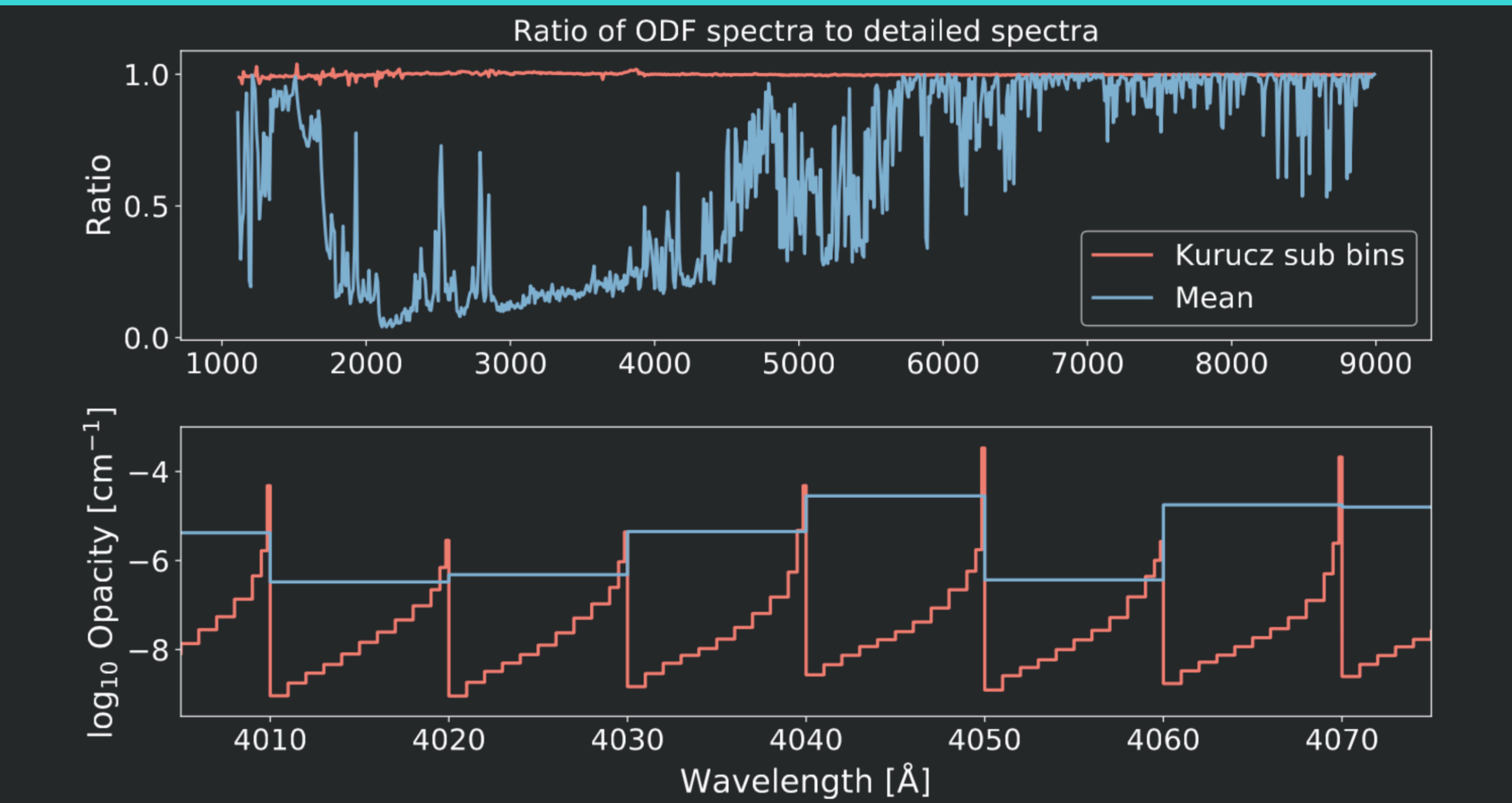
Opacity distribution functions



How to choose bins and sub-bins?

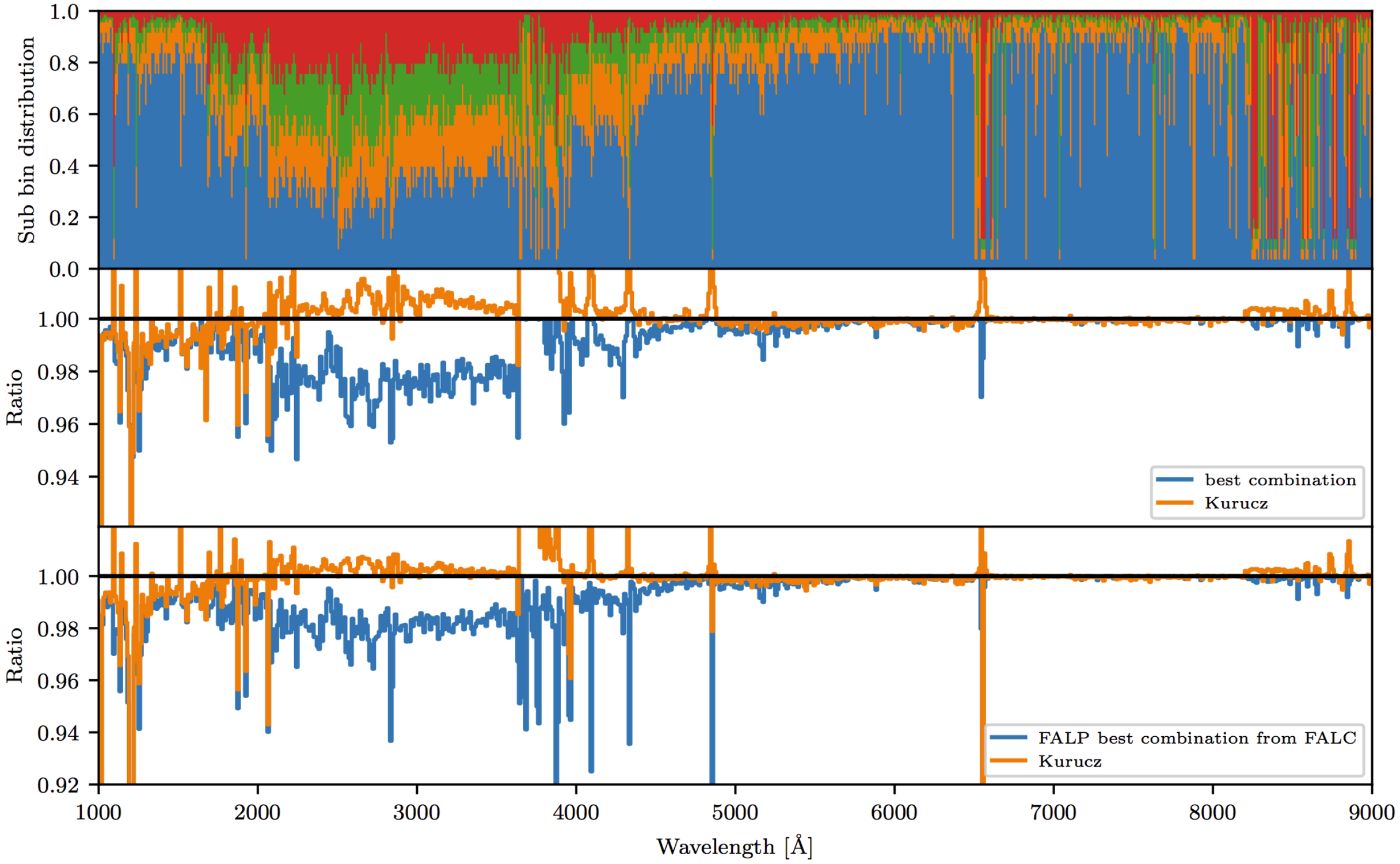
Fine vs. coarse binning

NESSY high-resolution calculations vs. ODFs calculations



1 nm bins

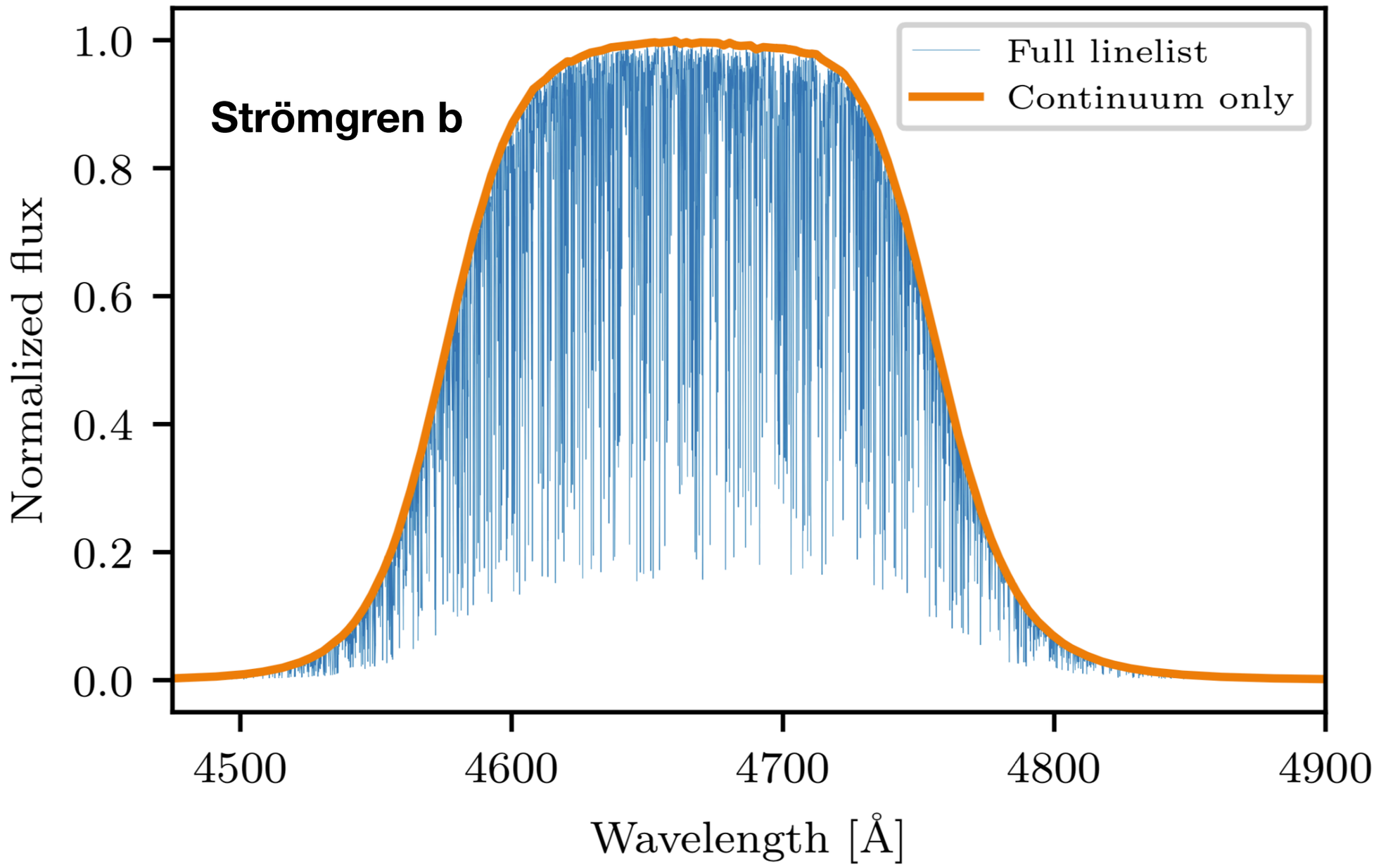
Optimal configuration of sub-bins



1 nm bins

Filter ODFs

Total line contribution ~15%



High resolution calculations: 100 points per Å: 40000 points

Kurucz's ODFs: 12 points per 10 Å: 480 points **speedup 80 times**

0.05%

Optimised ODFs: 3 points per entire filter **speedup 13000 times**

Implementation to ATLAS9

Initial procedure to calculate emergent spectra using DFSYNTHE and ATLAS9

1. Generating opacity distribution functions (ODFs)
2. Calculating atmosphere model in radiative equilibrium
3. Obtaining emergent spectra

A pretty efficient tool for the 1.5D calculations based on 3D MHD cubes (useful e.g. for limb calculations)

Teff, log g, Fe/H+abundances → Spectrum and CLVs

a couple of minutes

-one executable three options (or all in one go)
-choose frequency grid
-high-resolution calculation

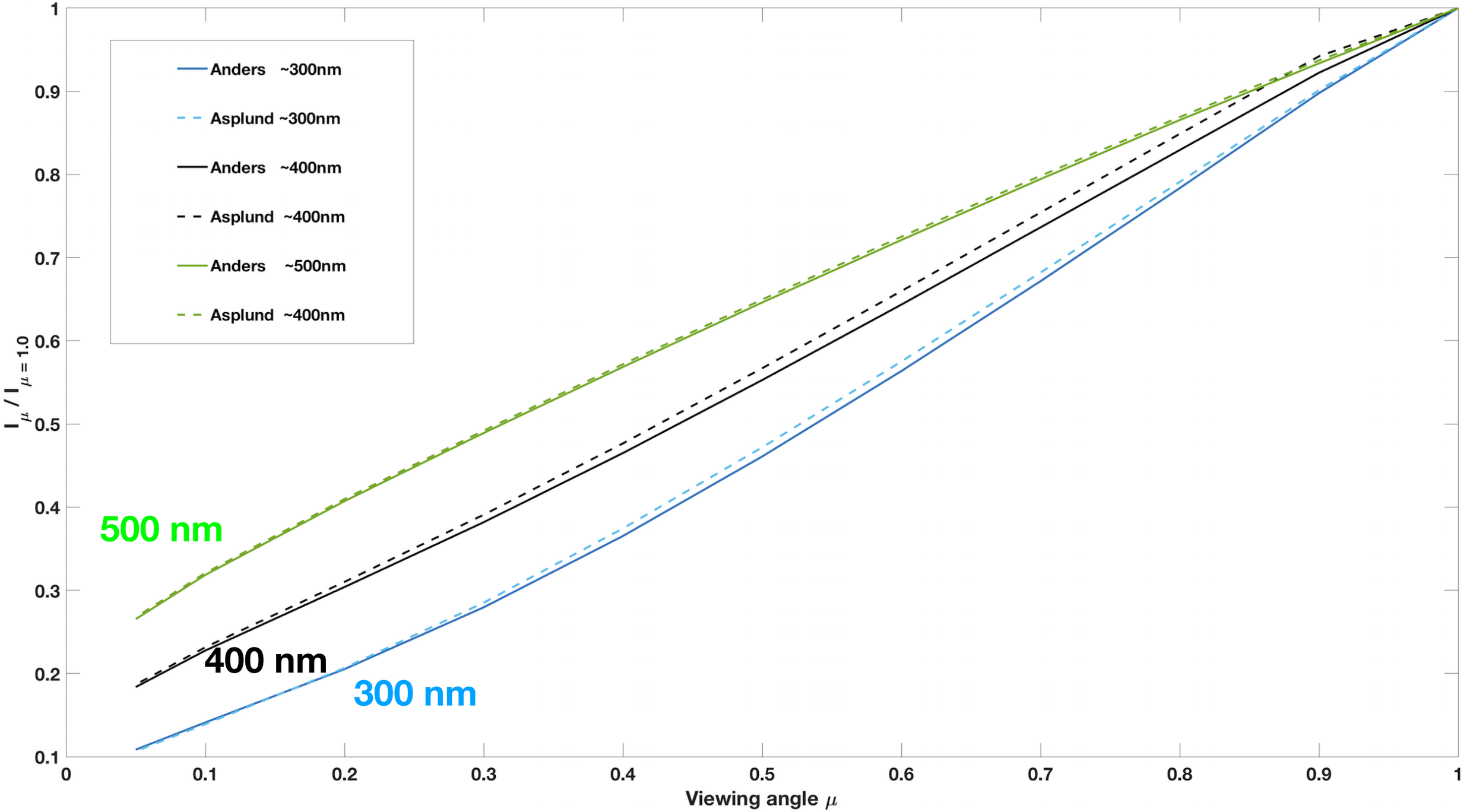
Optimised ODFs (OODF).

-large speed ups

-Filters can be taken into account
- Plato, Kepler, Tess, Strömgren

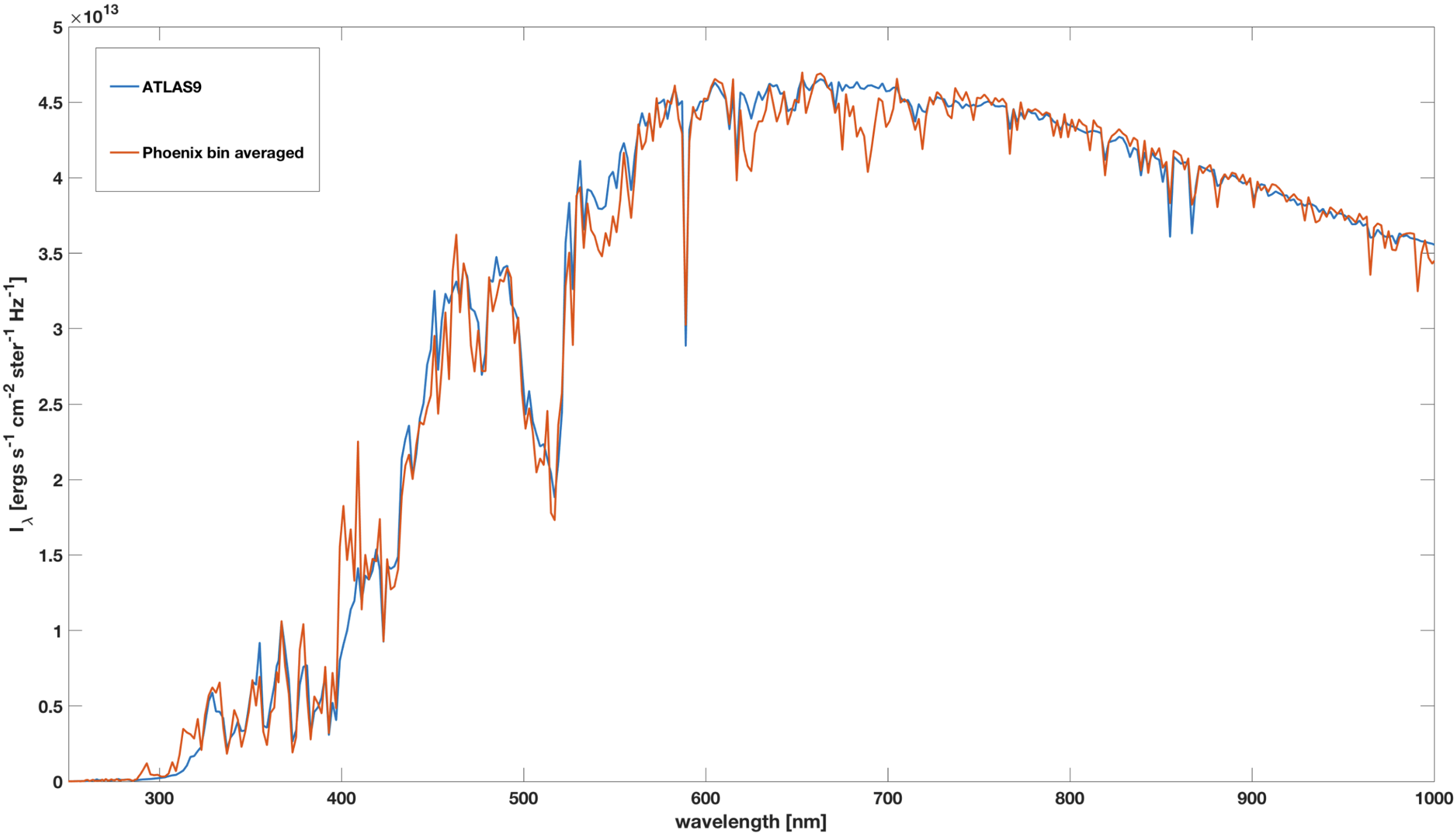
-line lists can be changed
-VALD III

Effect of abundances on CLVs

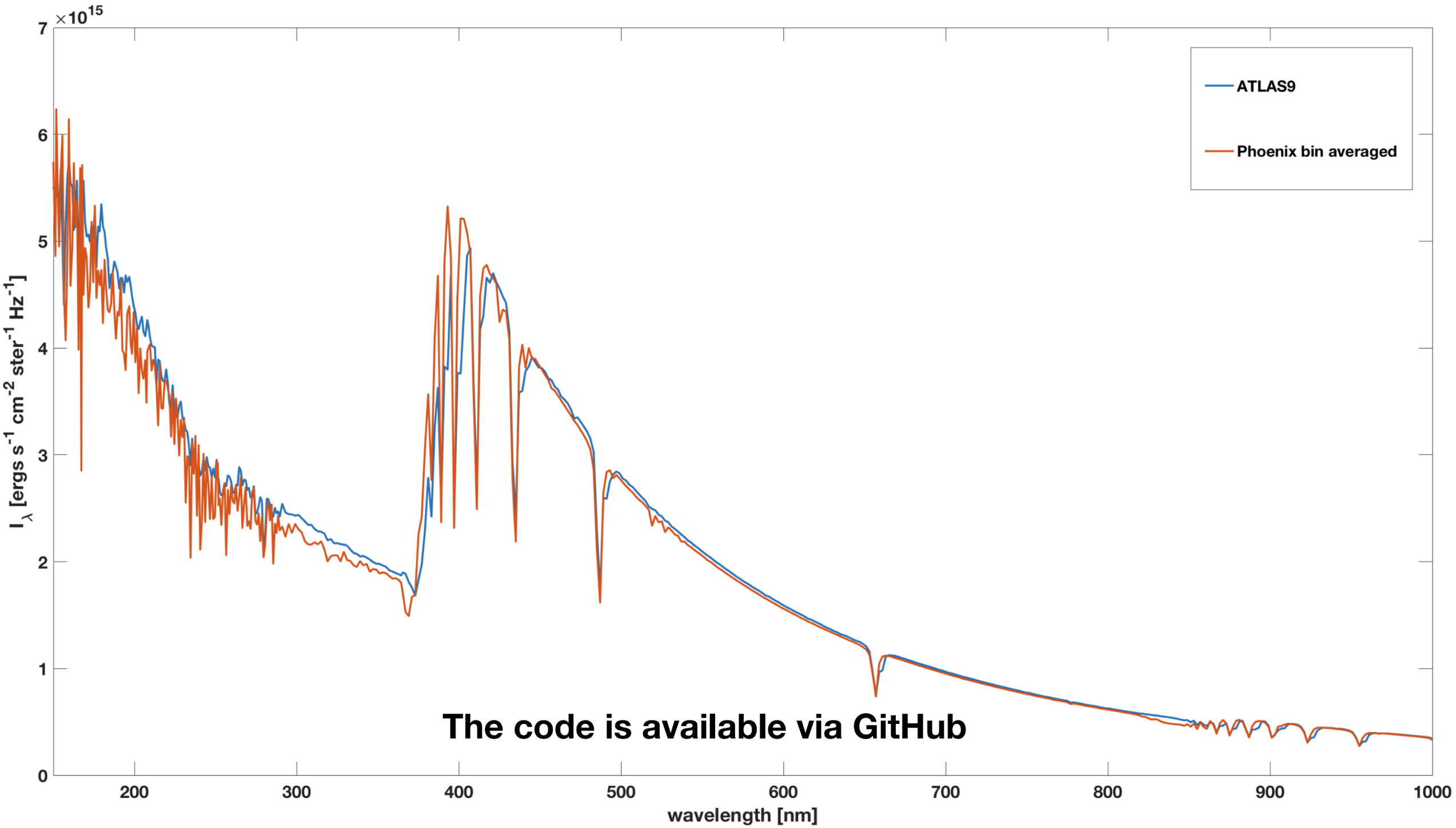


PLATO filter. 30 frequencies instead of roughly 3000 (Kurucz ODFs) with equal accuracy

K-star: 4000 K, Fe/H=-0.5, log g=4.0



A-star: 6500 K, Fe/H=-0.5, log g=4.0

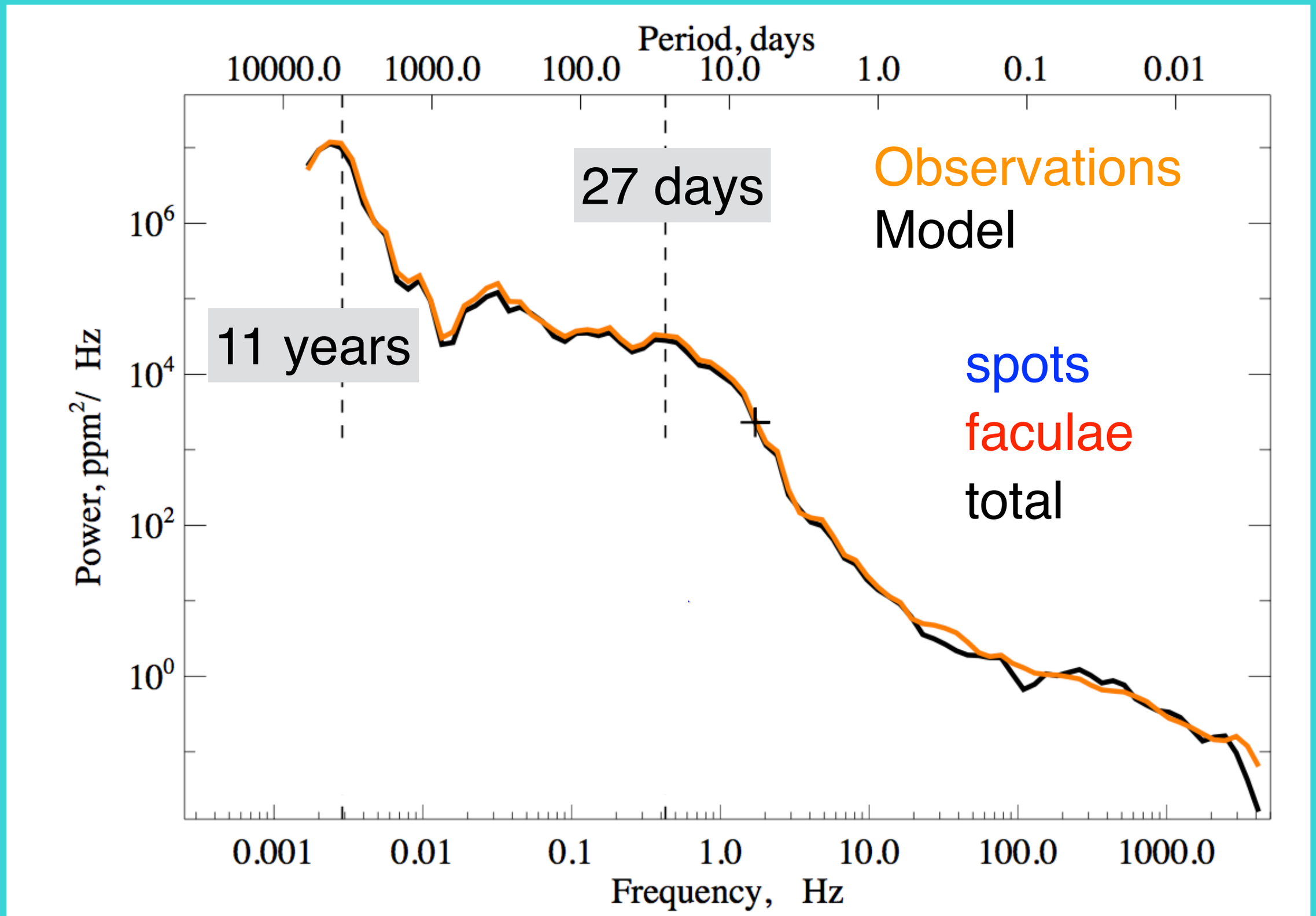


The code is available via GitHub

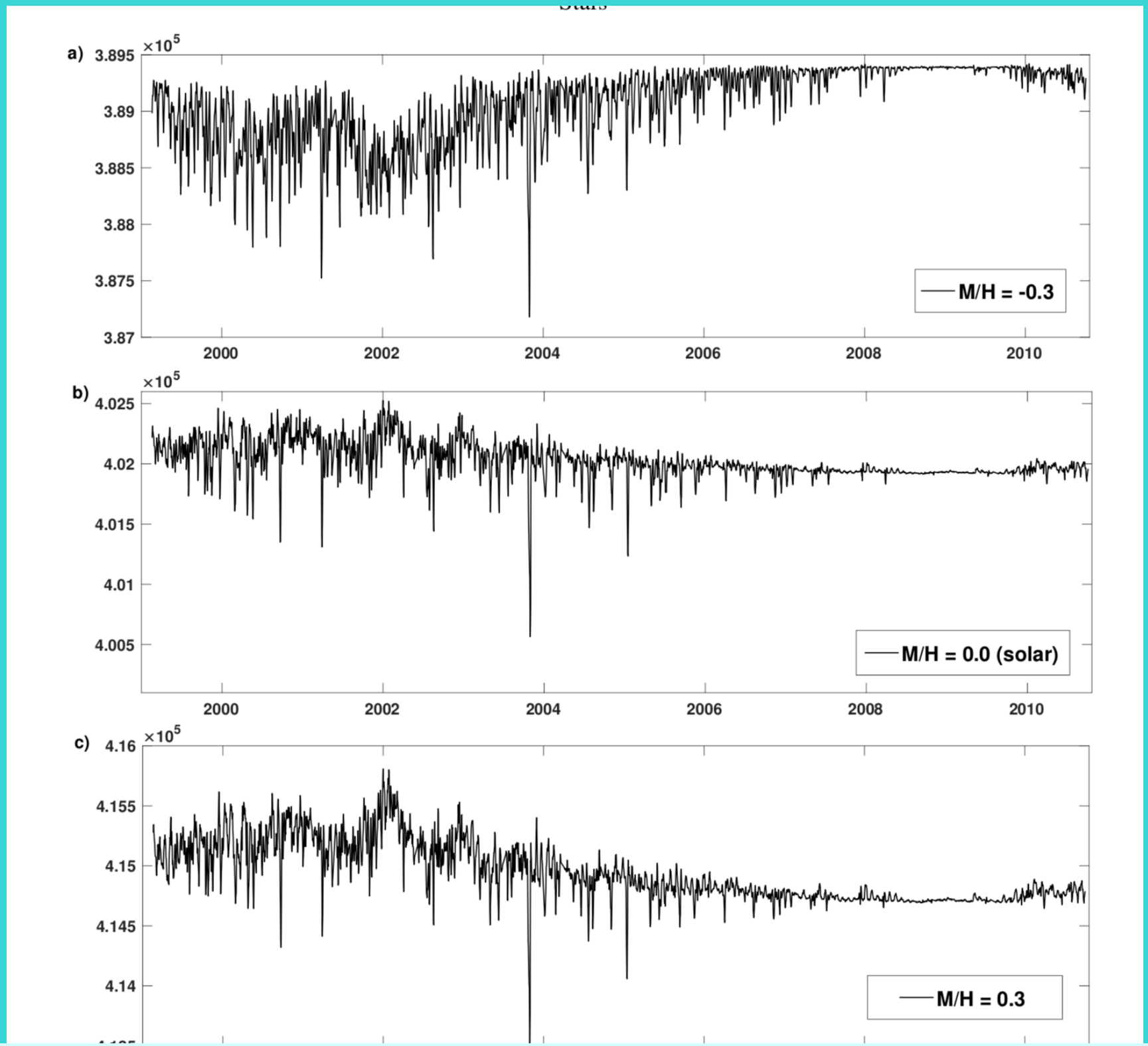
Power spectrum of solar brightness variations

Surface magnetic field (SATIRE)

Granulation (MURaM)



Effect of M/H on brightness variations



THANK YOU!