OODF: Optimized Opacity Distribution Functions for a New Generation of Solar and Stellar Brightness Variability Models

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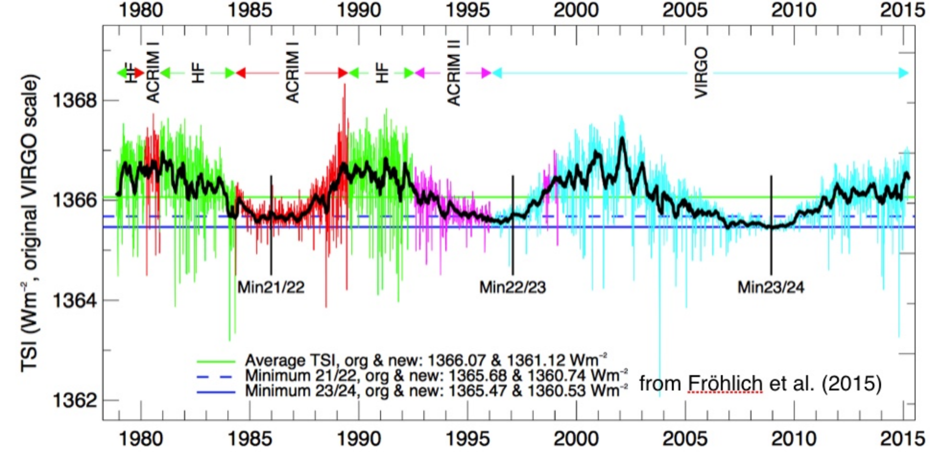
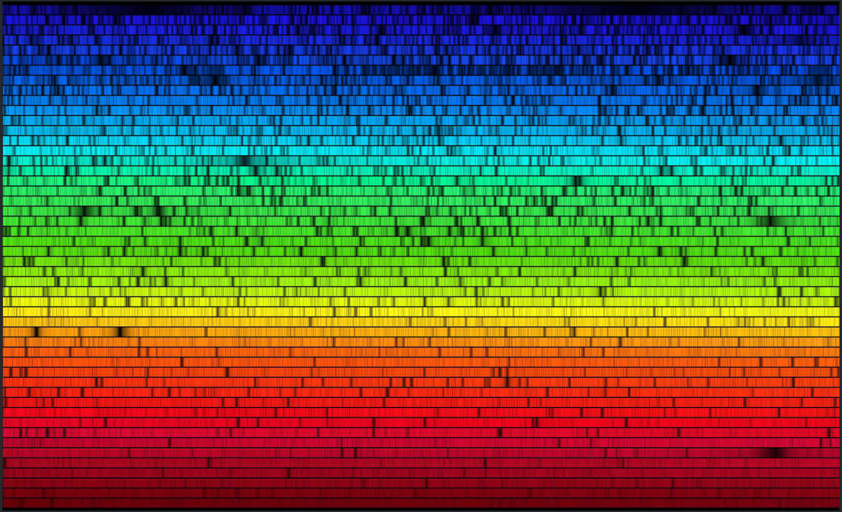
Total Solar Irradiance

- TSI – spectrally integrated solar radiative flux at 1 AU from the sun



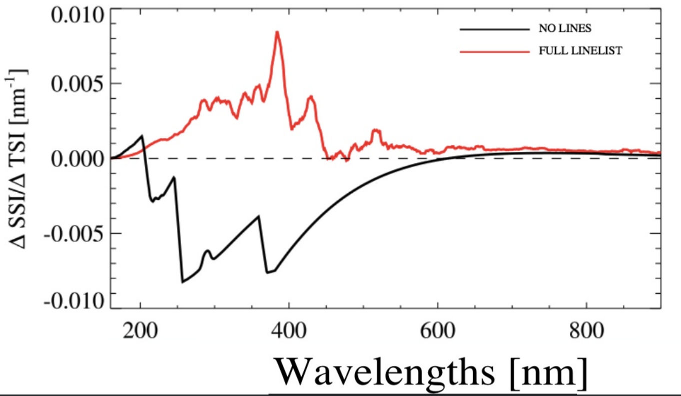
Spectra of the individual components

Solar spectra

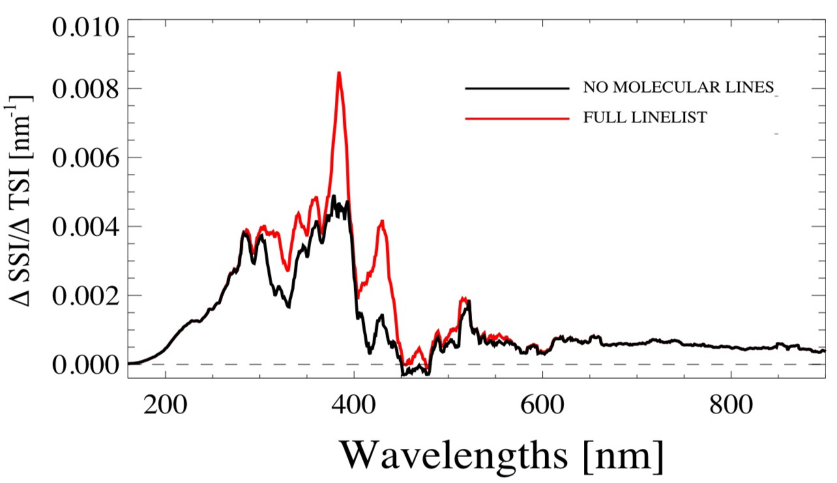


Importance of lines for variability

- TSI – Total Solar Irradiance, i.e. integrated over wavelengths
- SSI – Spectral Solar Irradiance, depends on wavelength
- △ – difference between the solar minima and maxima



Importance of lines for variability



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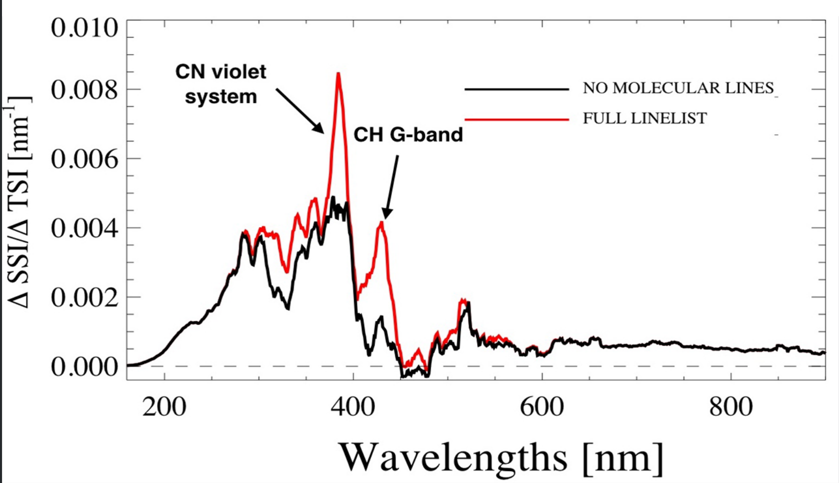
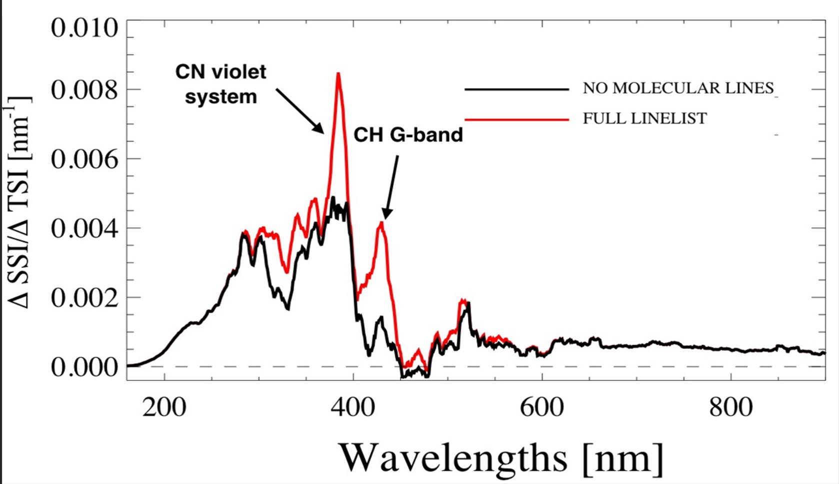


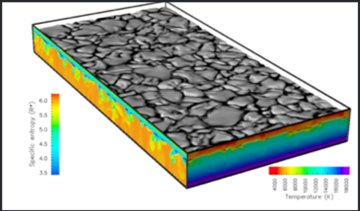
Importance of lines for variability

- 25% of the variability comes from molecular lines → accurate linelists are required



1.5D simulations

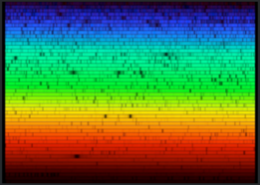
3D MHD simulations with MURaM



Structure of the magnetic features

+

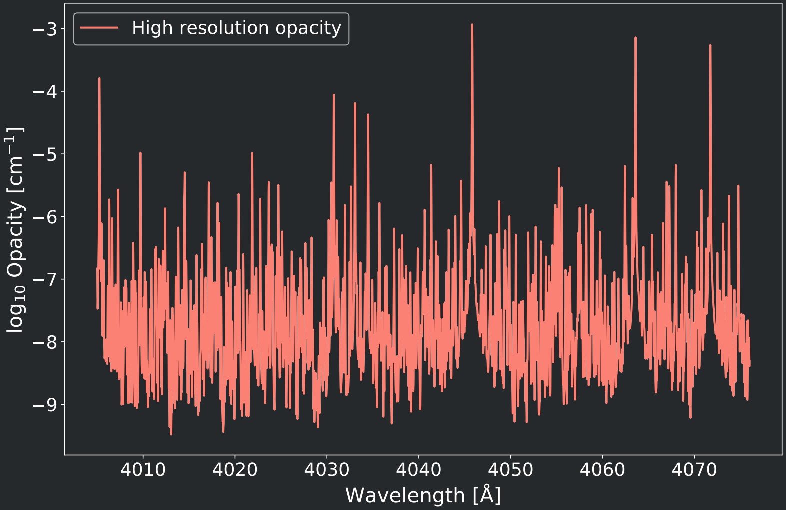
1.5D radiative transfer



Spectra of the magnetic features

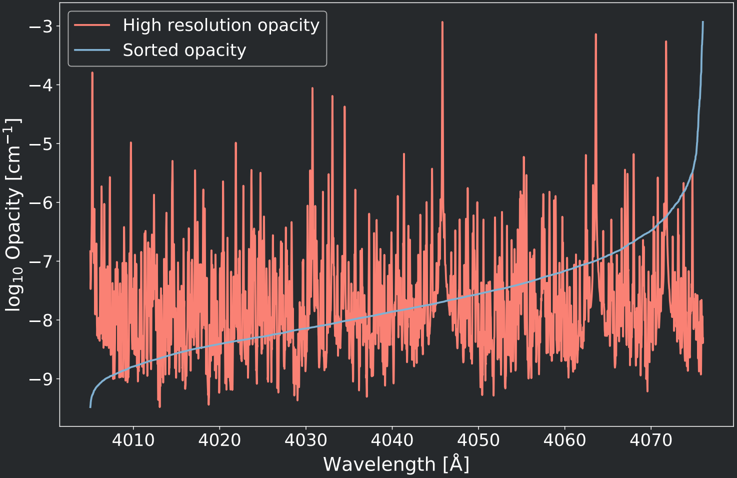
Generating ODFs

- Start with high resolution opacity



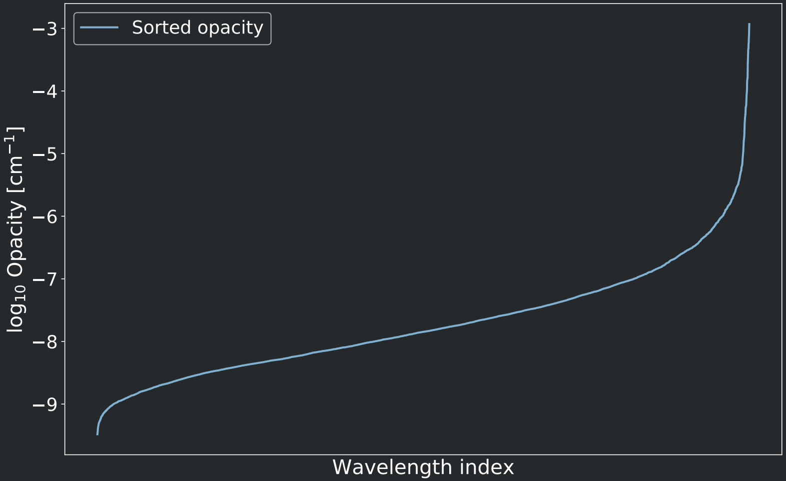
Generating ODFs

- Sort wavelength points by corresponding values of opacity; monotonically increasing opacity
- Integral is preserved by sorting



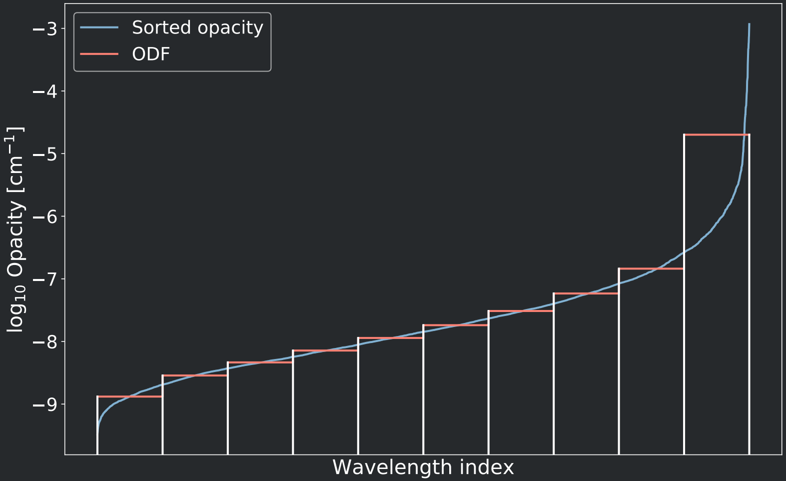
Generating ODFs

- All wavelength information within the bin is lost



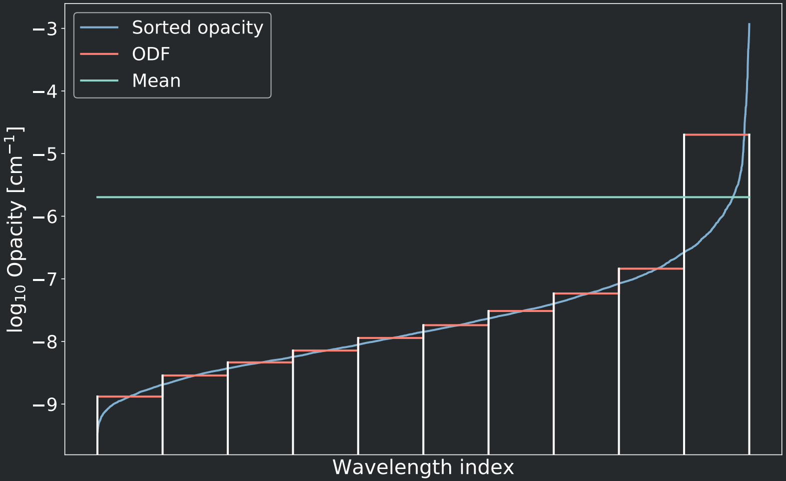
Generating ODFs - Example with 10 uniform sub bins

- Approximate the sorted opacity with a step-wise function



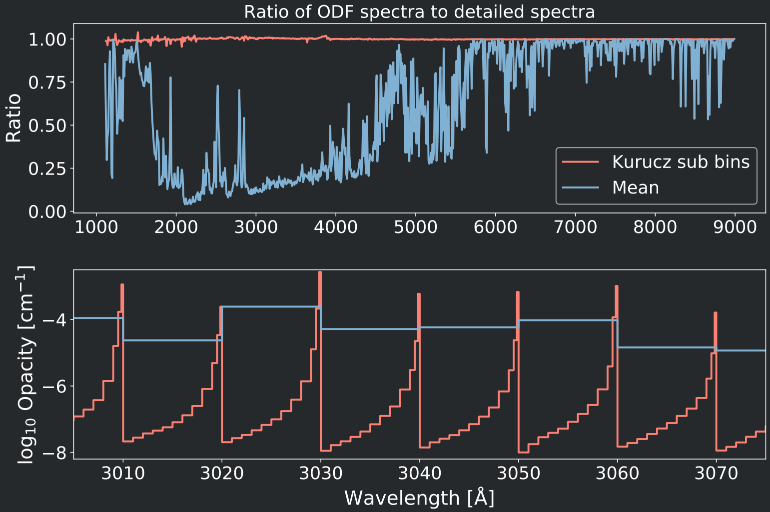
ODF generation process

- Mean is skewed by extreme values



ODF performance analysis

- Synthesize spectrum using ODFs from 1000-9000Å with 10Å bins
- Compare the fluxes from the ODF spectrum with the high resolution spectrum in the bins



Possible solutions

Number of calculations goes as: $n_{bins} \times n_{subbins}$

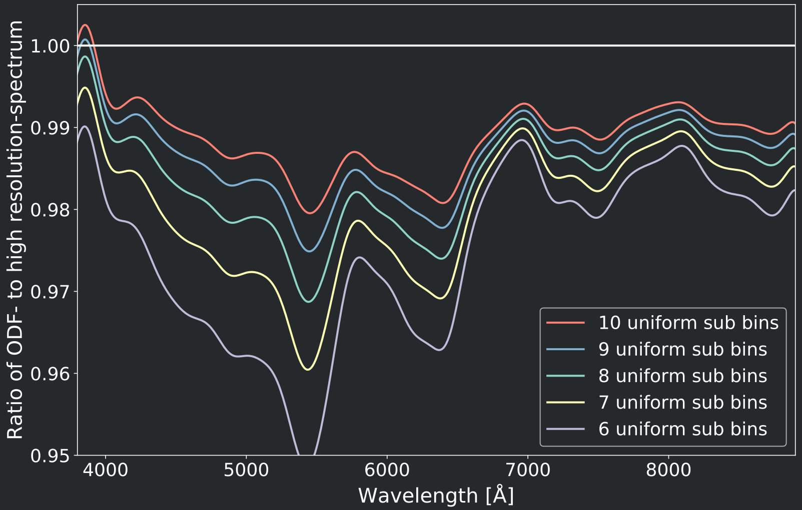
what to do?

increase bin size
$\rightarrow$ decrease n_{bins}

decrease the number
of sub bins per bin

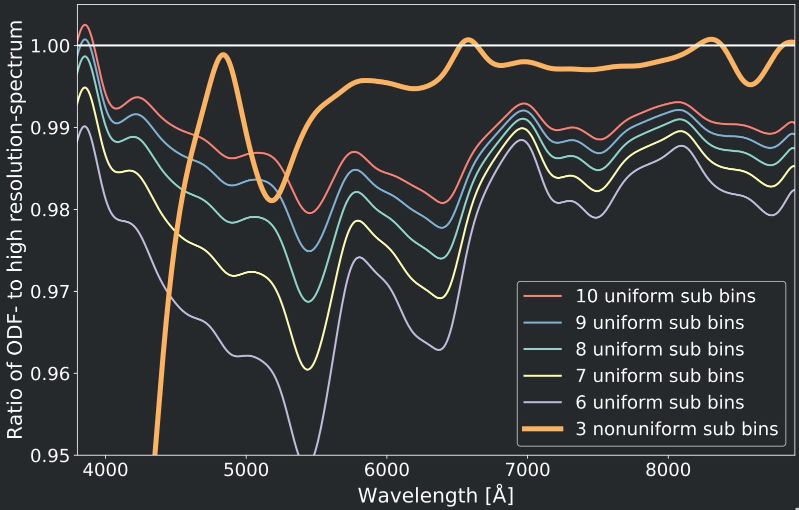
Analysis of different ODFs

- Uniform ODFs

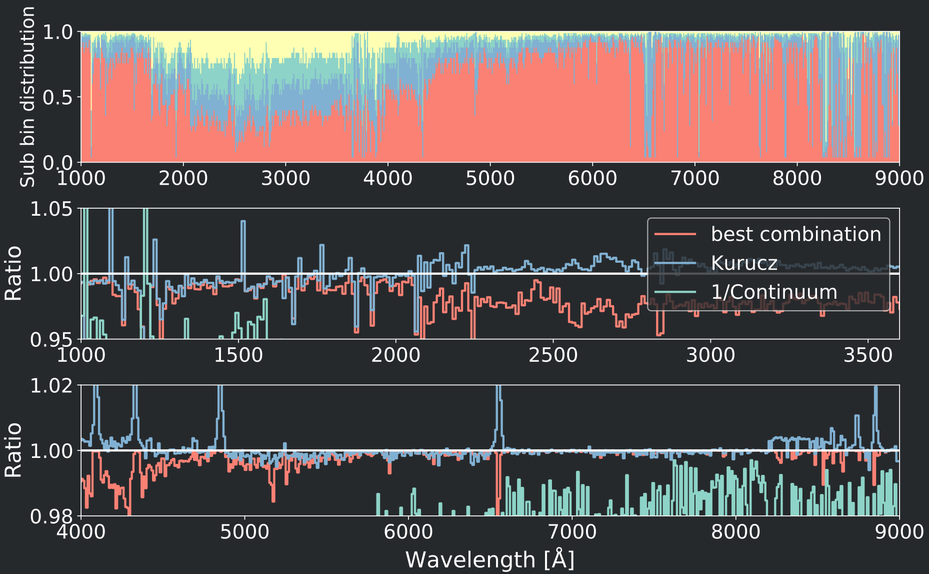


Analysis of different ODFs

- Nonuniform ODFs
- The last sub bin is crucial after 5000Å

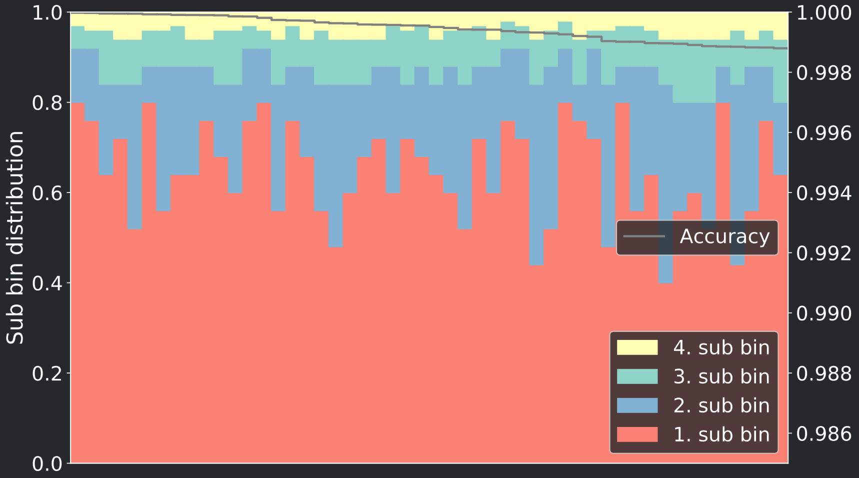


Best sub bin combinations using 4 sub bins



Best combination of 4 sub bins for Strömgren y

- Total line contribution ∼15%



Speedups in the case of Ströemgren *b*

- Interval length: $\sim$400Å

High resolution: 80 points per Å $\sim$ 32 000 points

ODF: 12 points per 10Å $\sim$ 480 points
speedup 67 times

OODF: 3 points for the whole binÅ $\sim$ 3 points
speedup $\sim$11 000 times

Conclusions

- We developed a novel method for fast spectral synthesis.
- Found optimal sub bins for different wavelength regimes.
- Can be tailored for different filters: Strömgren $b + y$, Kepler, PLATO and others.
- Significant speed up relative to standard methods by a factor of at least two orders of magnitude.

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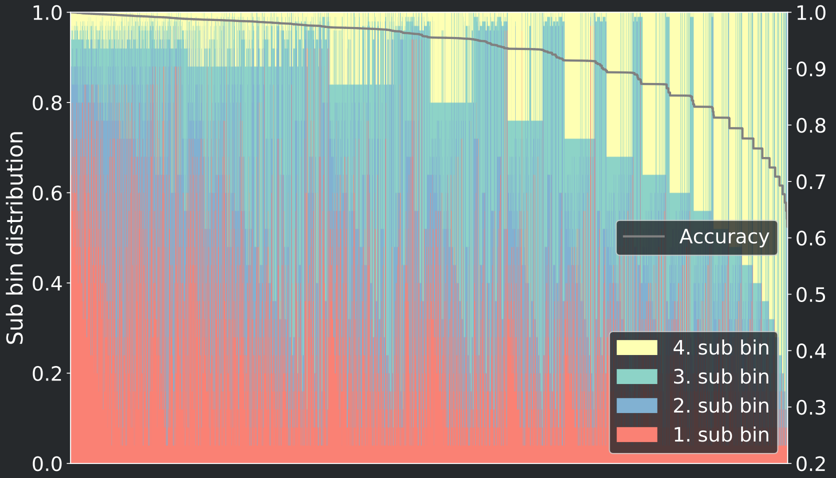
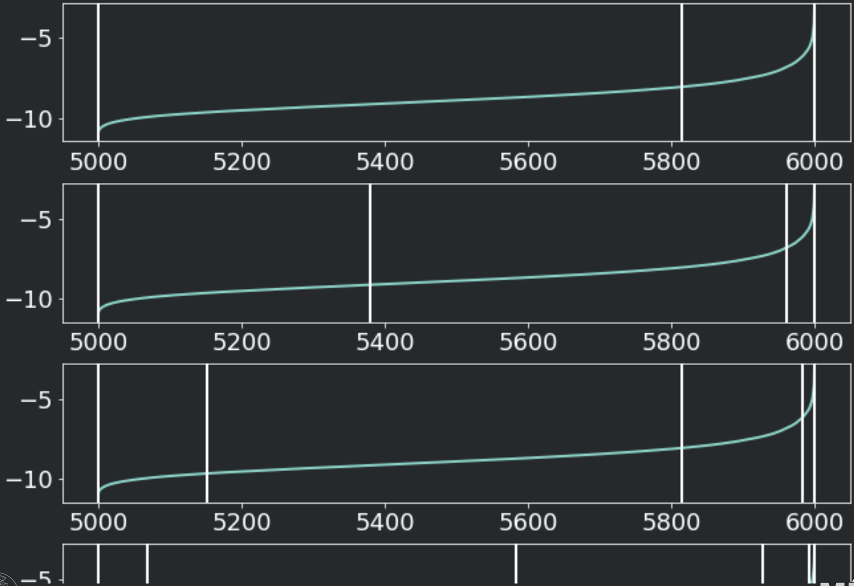
Thank you for your attention!

Best combinations of 4 sub bins for Strömgren *b*



Formula: value weighted by the derivative



Ascending vs descending sort