

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

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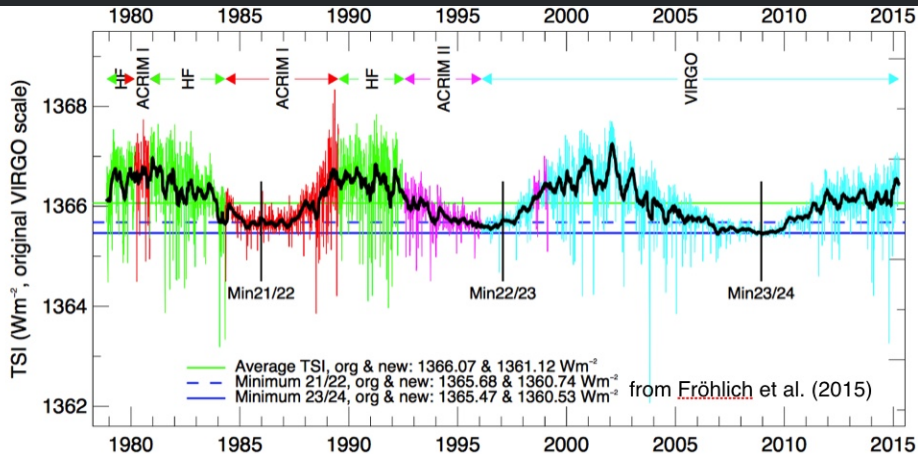
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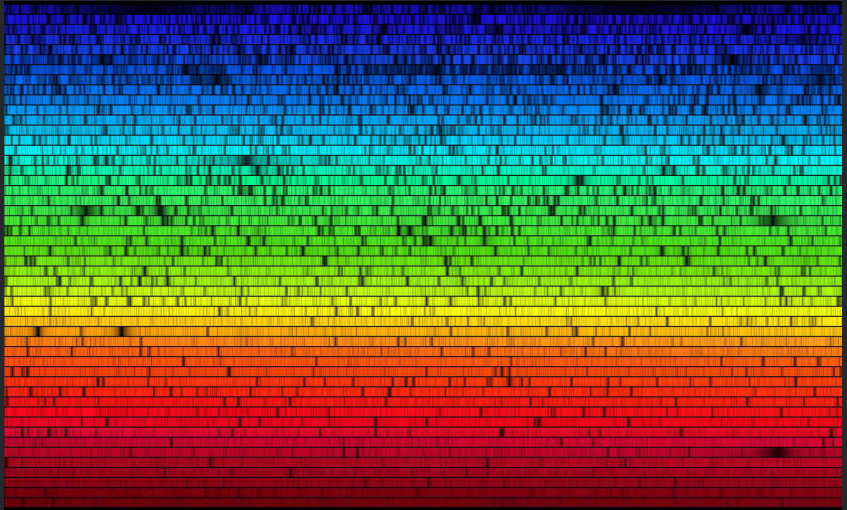
Total Solar Irradiance

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



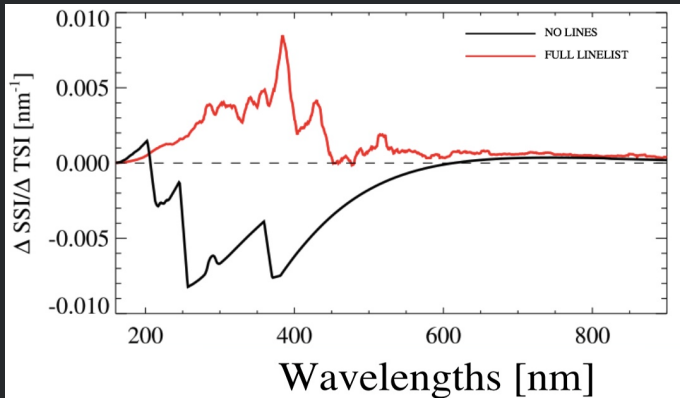
Spectra of the individual components

Solar spectra

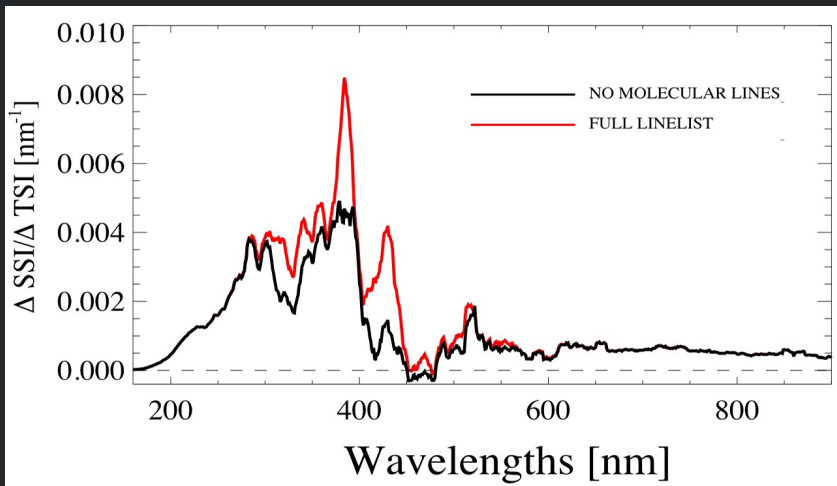


Importance of lines for variability

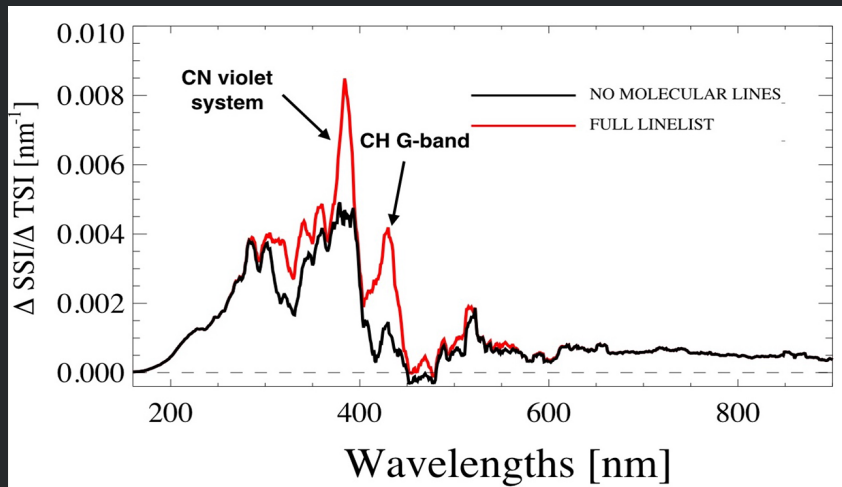
- TSI – Total Solar Irradiance, i.e. integrated over wavelengths
- SSI – Spectral Solar Irradiance, depends on wavelength
- Δ – difference between the solar minima and maxima



Importance of lines for variability

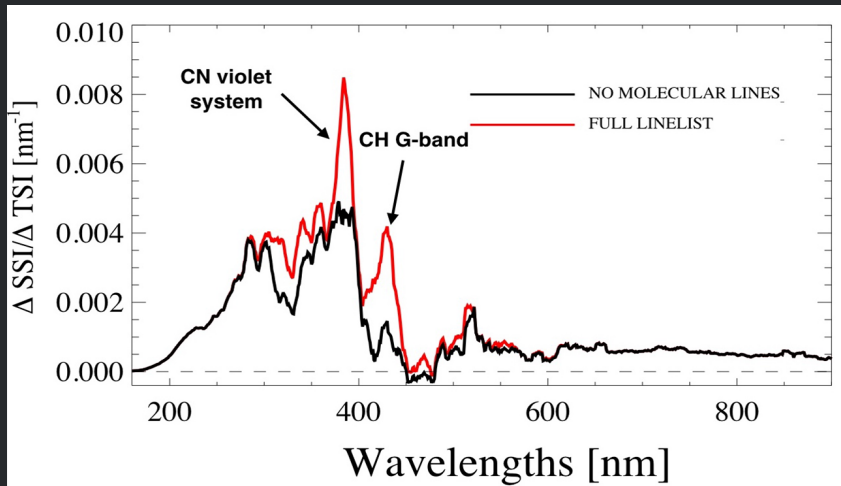


Importance of lines for variability



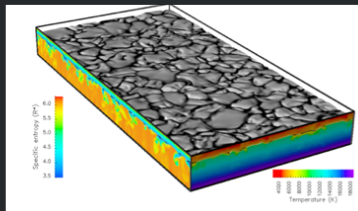
Importance of lines for variability

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



1.5D simulations

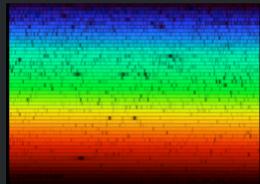
3D MHD simulations with MURaM



Structure of the magnetic features

+

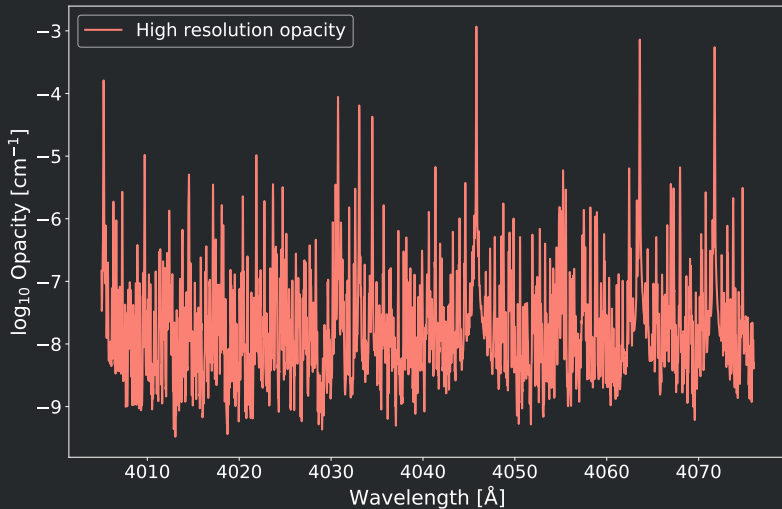
1.5D radiative transfer



Spectra of the magnetic features

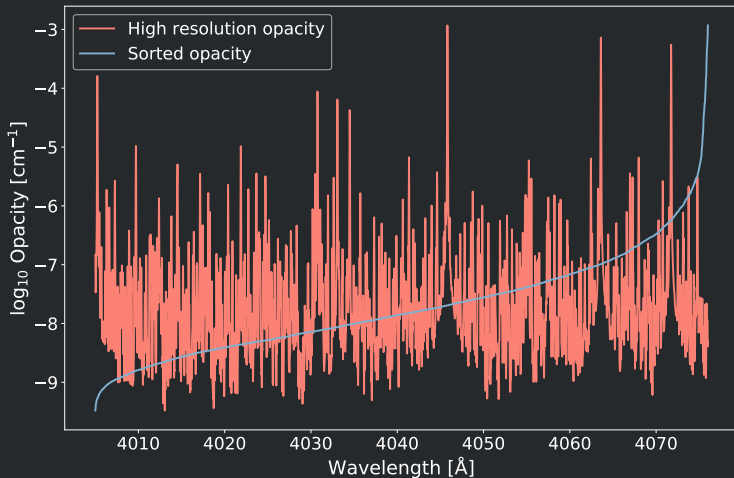
Generating ODFs

- Start with high resolution opacity



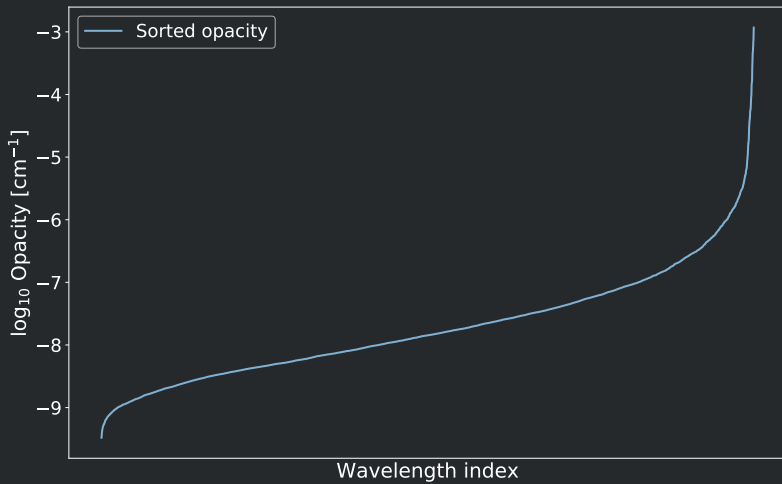
Generating ODFs

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



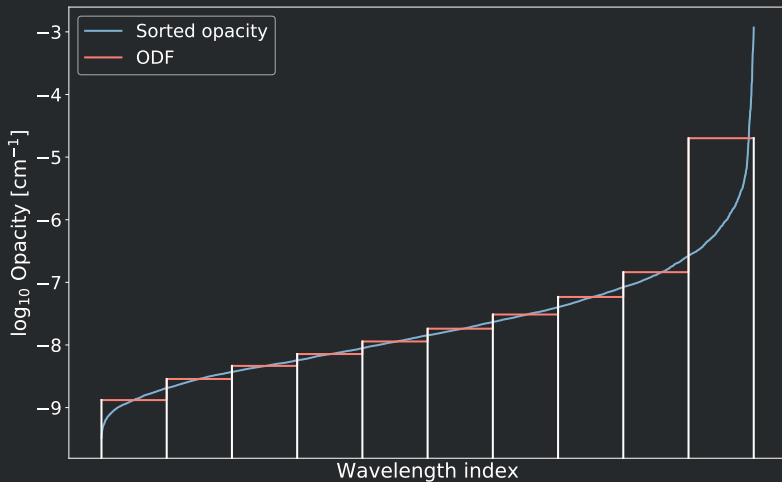
Generating ODFs

- All wavelength information within the bin is lost



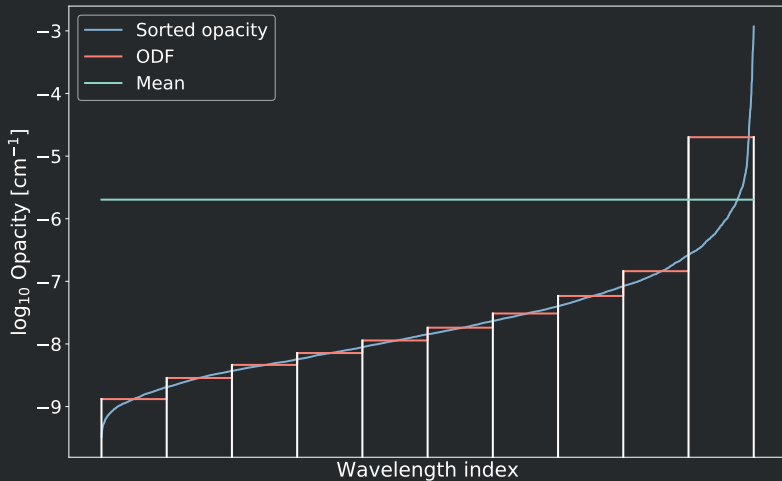
Generating ODFs - Example with 10 uniform sub bins

- Approximate the sorted opacity with a step-wise function



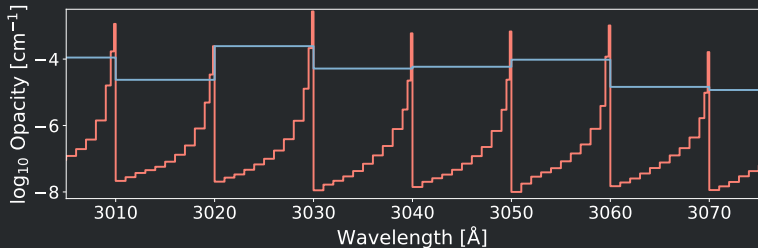
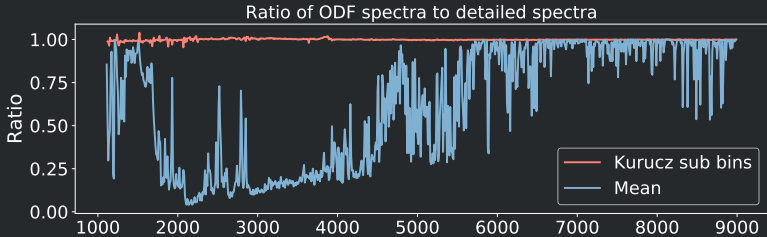
ODF generation process

- Mean is skewed by extreme values



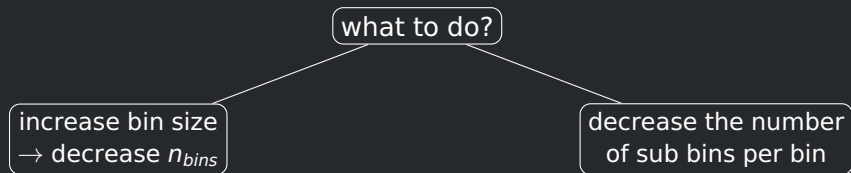
ODF performance analysis

- 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



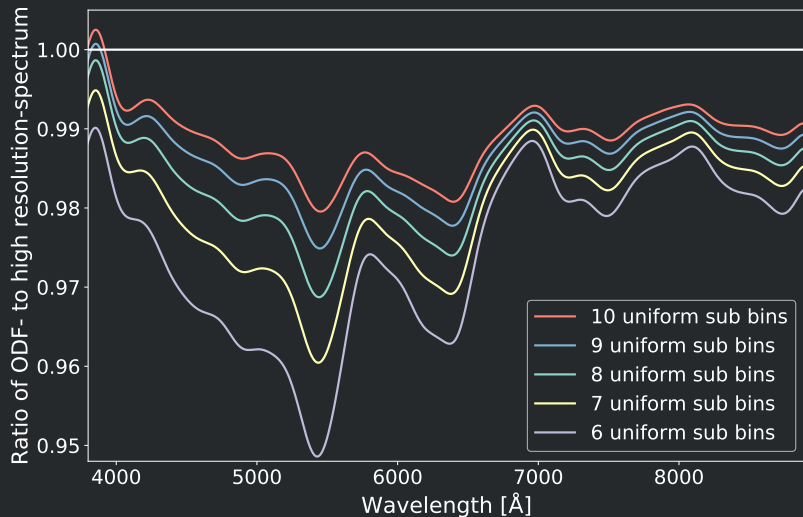
Possible solutions

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



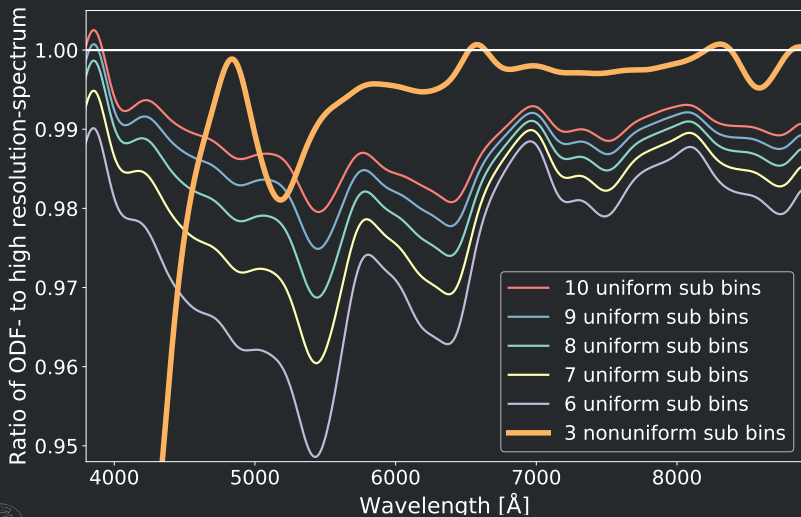
Analysis of different ODFs

- Uniform ODFs

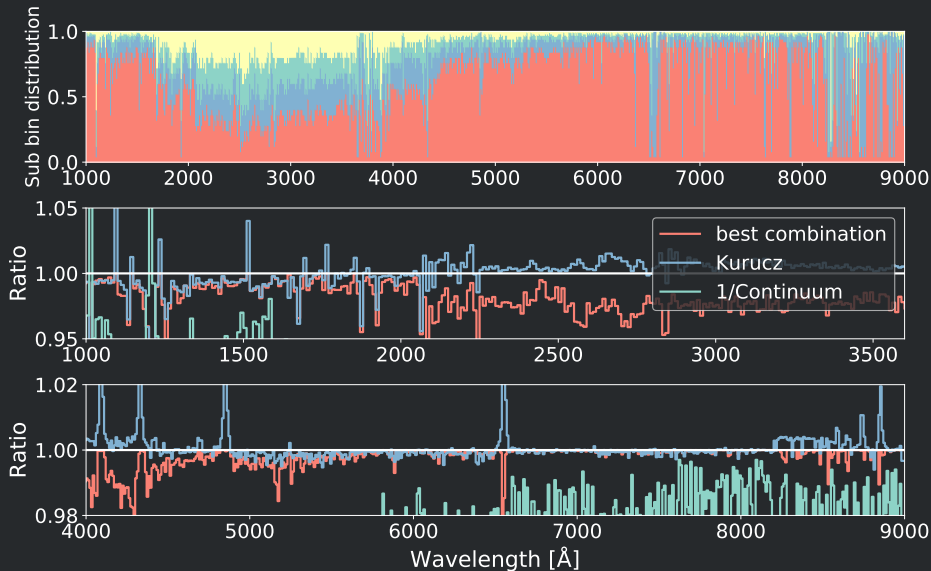


Analysis of different ODFs

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

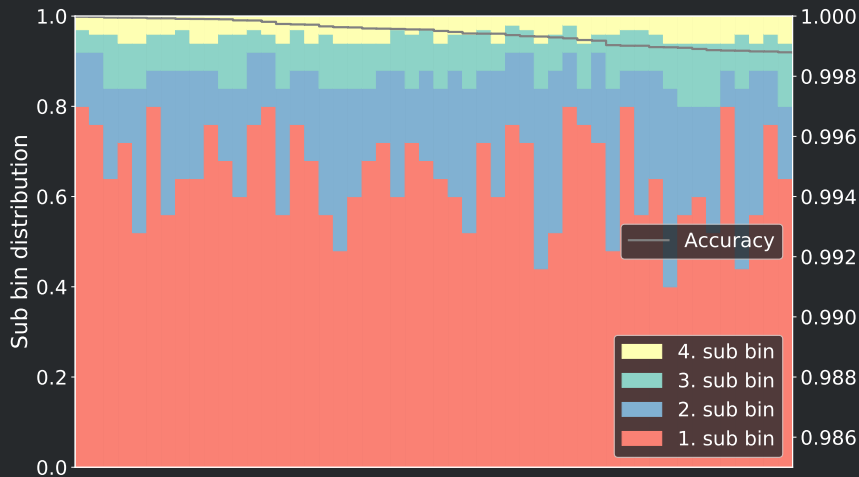


Best sub bin combinations using 4 sub bins



Best combination of 4 sub bins for Strömgren b

- Total line contribution $\sim 15\%$



Speedups in the case of Strömgren b

- Interval length: $\sim 400\text{\AA}$

High resolution: 80 points per $\text{\AA} \sim 32\,000$ points

ODF: 12 points per $10\text{\AA} \sim 480$ points
speedup 67 times

OODF: 3 points for the whole bin $\text{\AA} \sim 3$ 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!

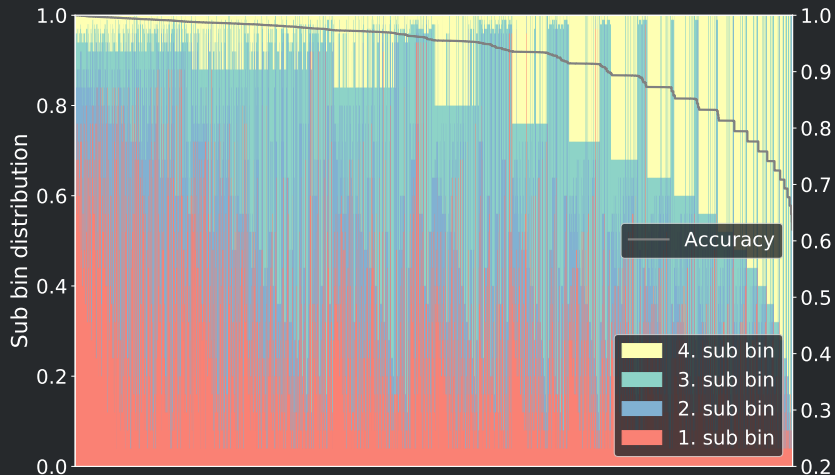


Conclusions

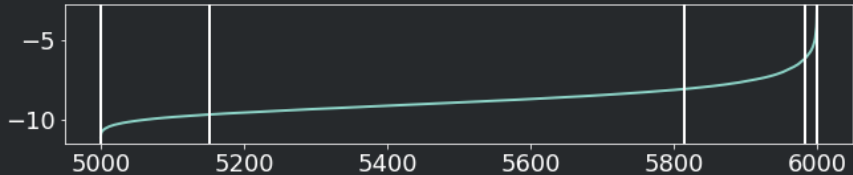
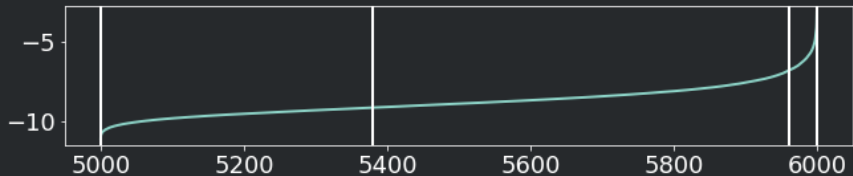
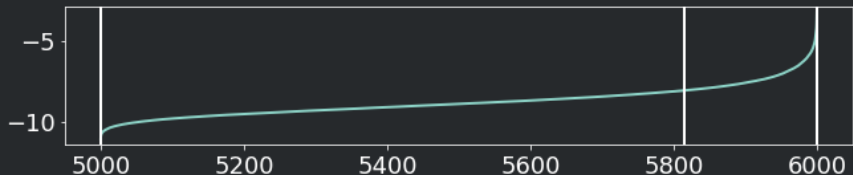
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Thank you for your attention!



Best combinations of 4 sub bins for Strömgren b 

Formula: value weighted by the derivative



Ascending vs descending sort

