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

Miha Cernetic, Alexander I. Shapiro, Veronika Witzke, Natalia A. Krivova, Sami K. Solanki, Rinat V. Tagoirov

Max Planck Institute for Solar System Research
SOLVe group
✉cernetic@mps.mpg.de

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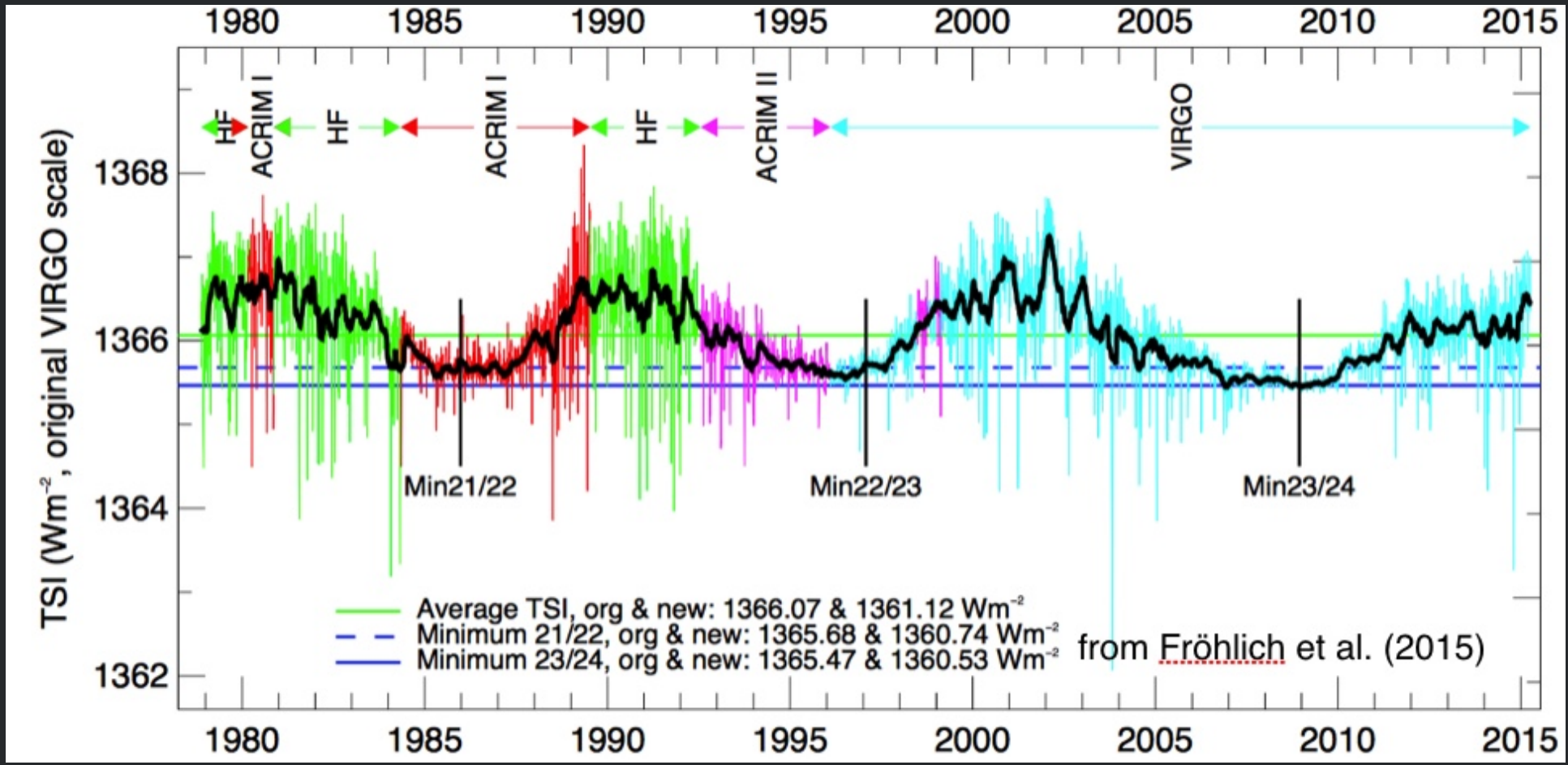
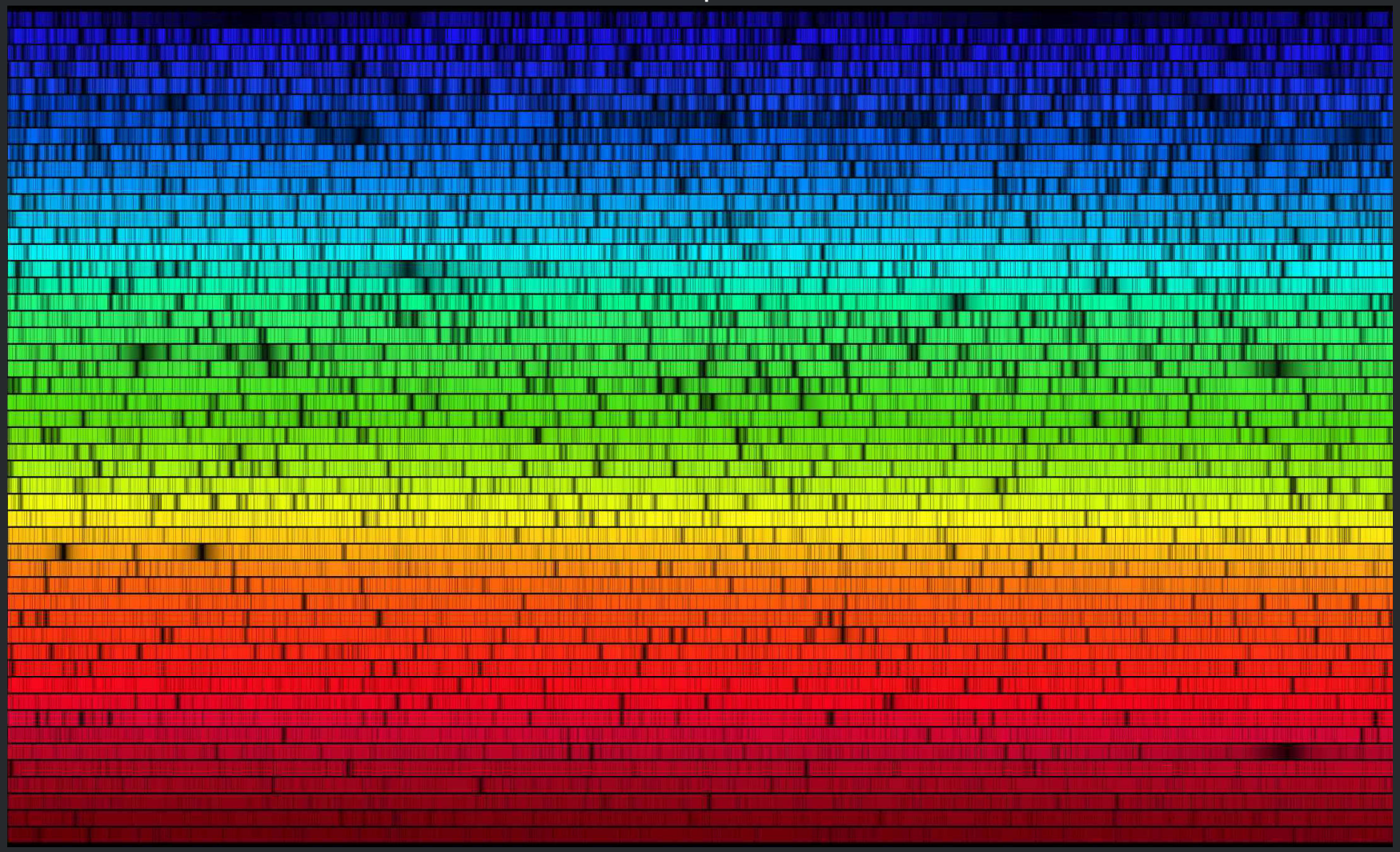
Total Solar Irradiance

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



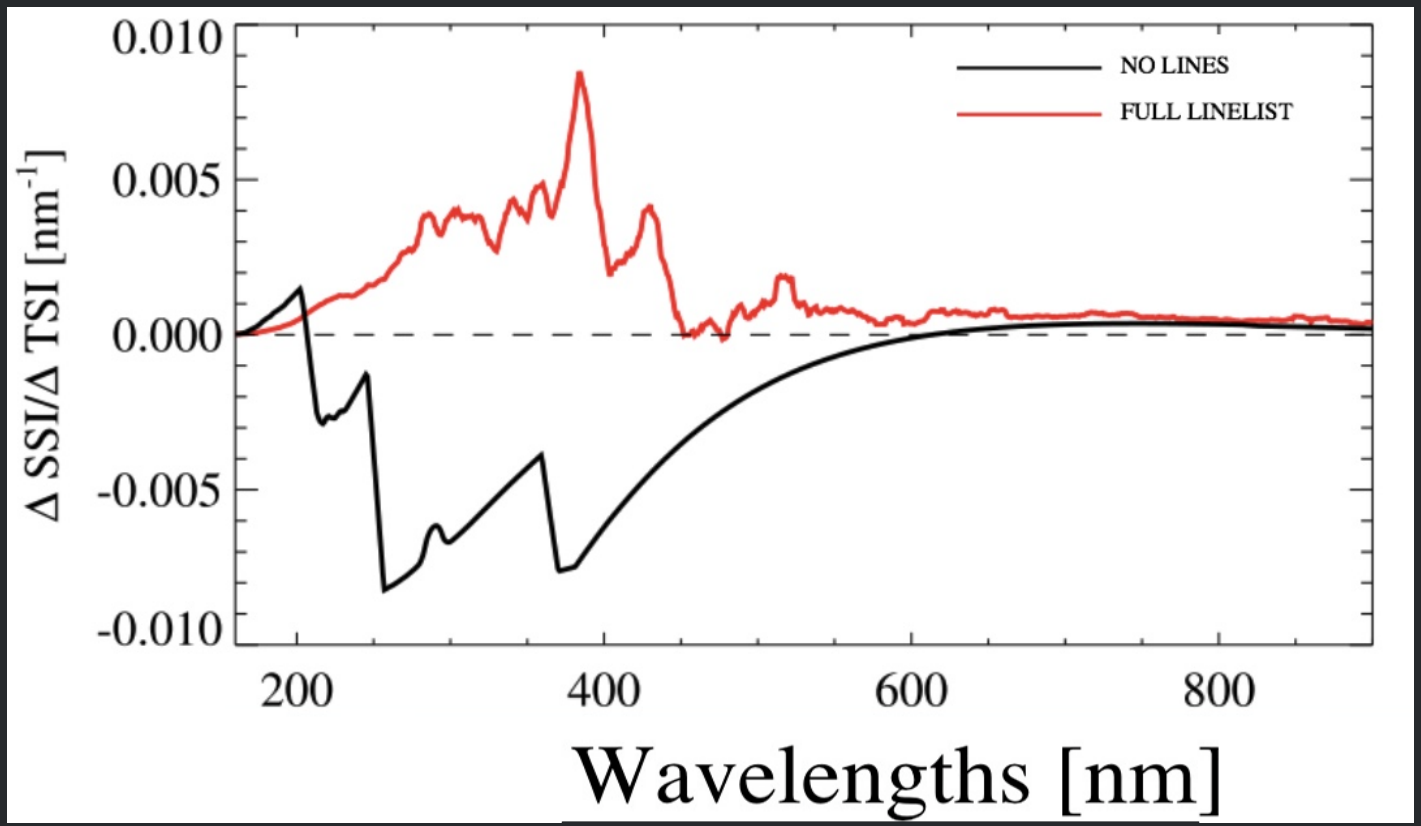
Spectra of the individual components

Solar spectra

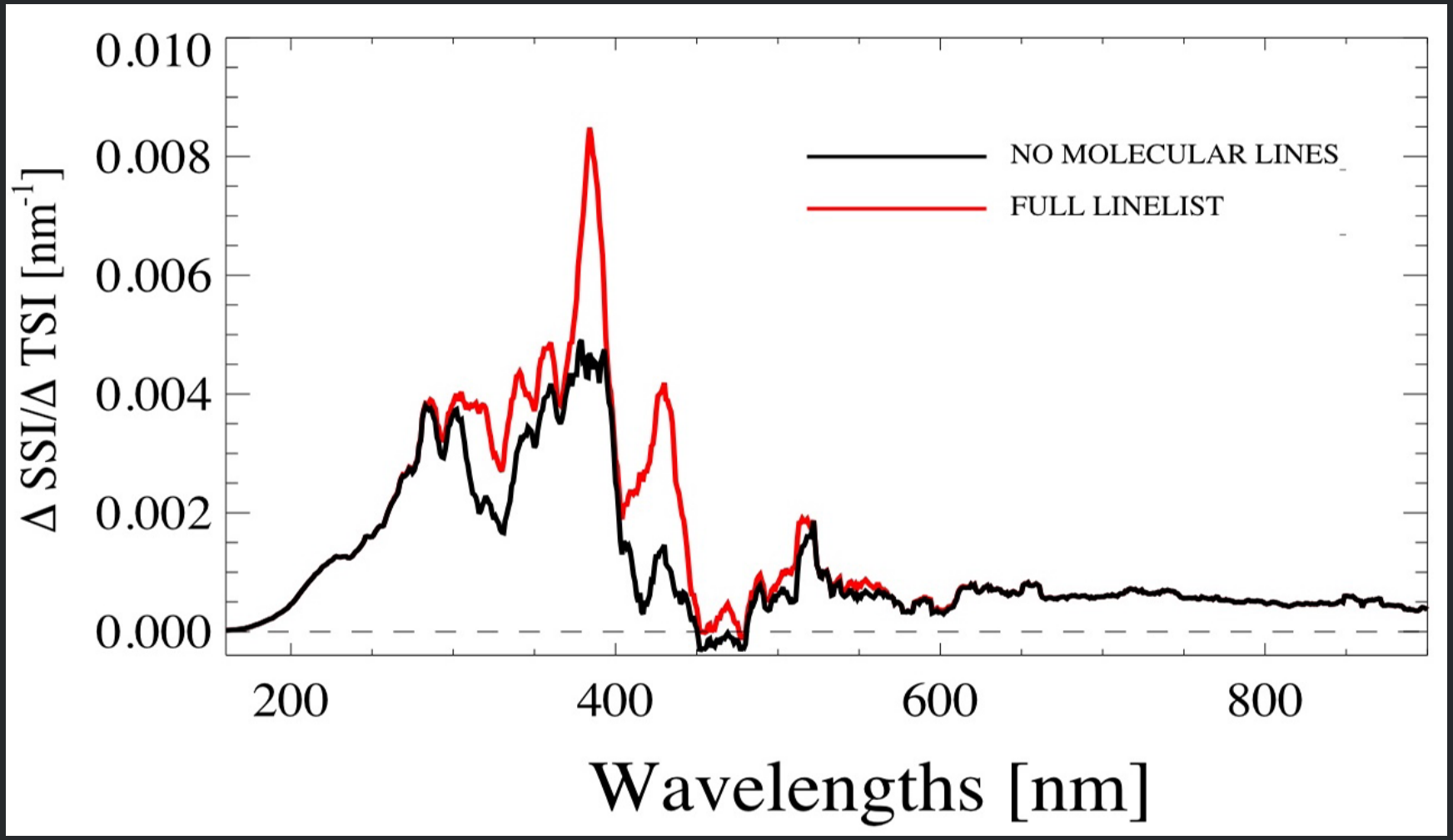


Importance of lines for variability

- 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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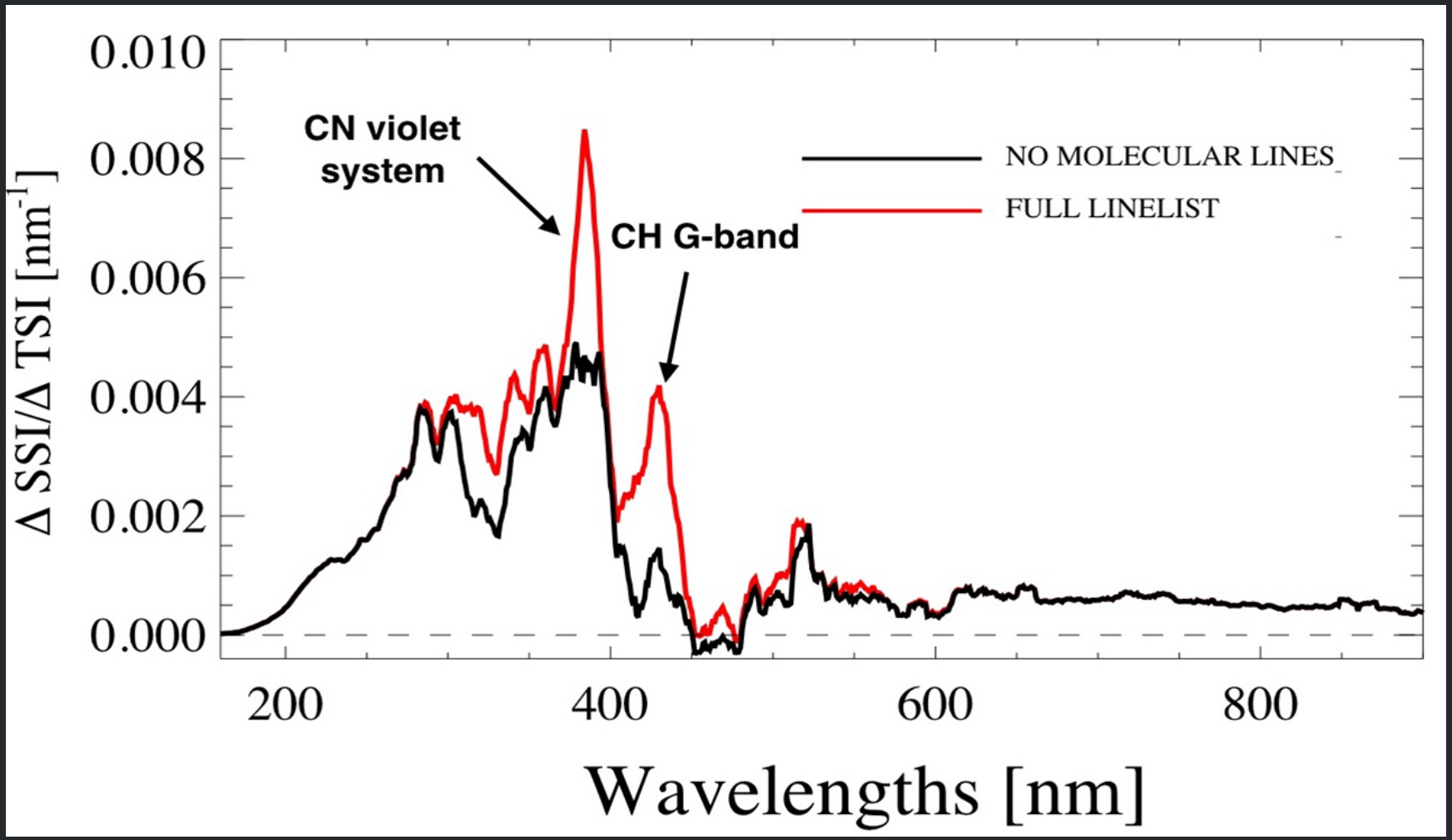
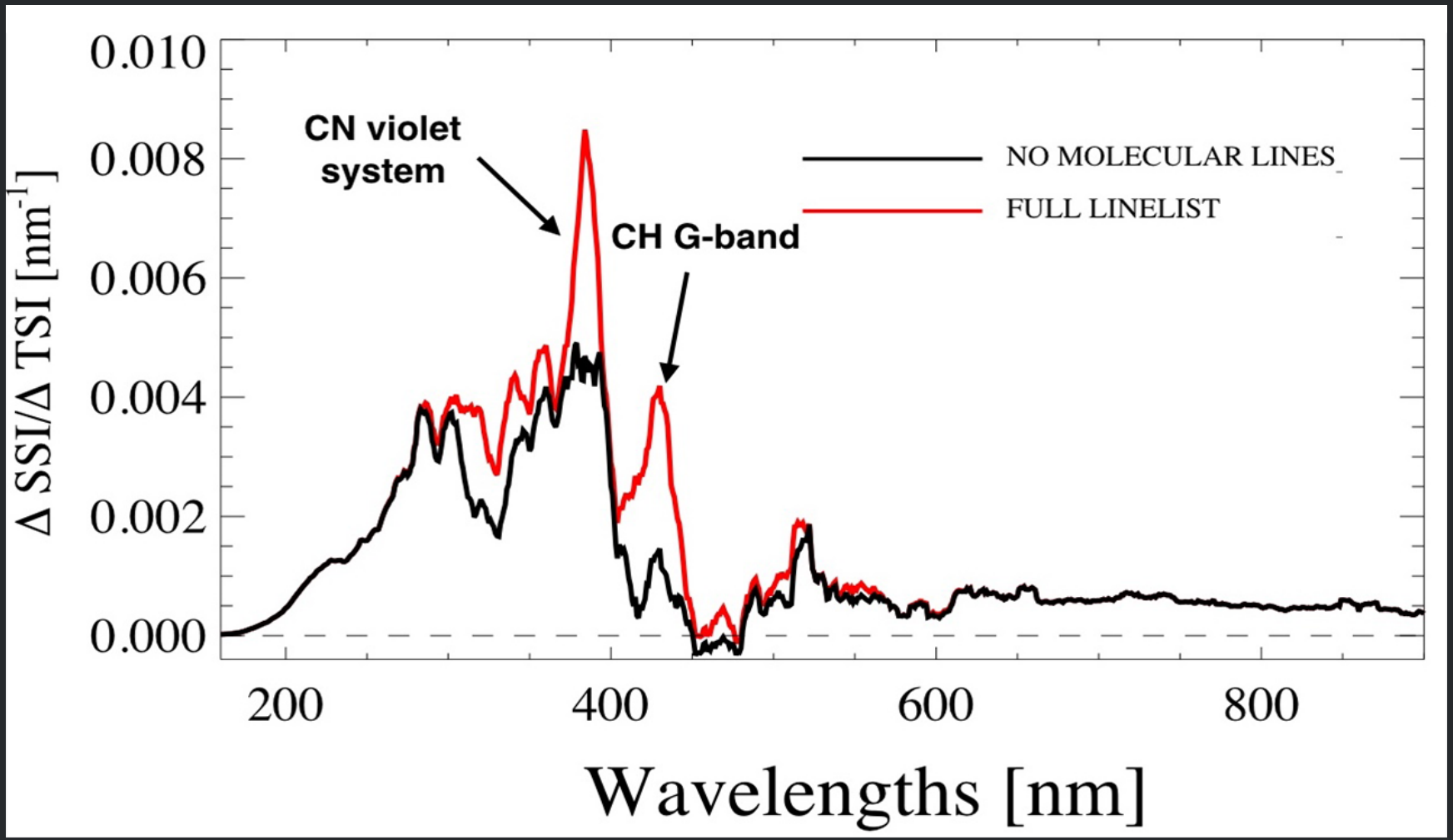


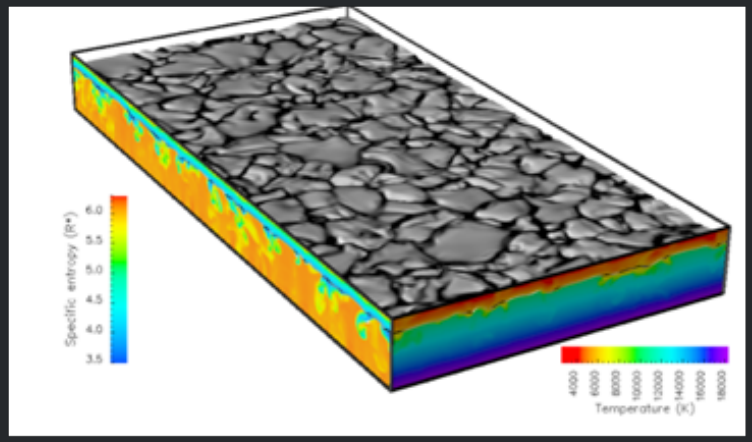
Importance of lines for variability

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



1.5D simulations

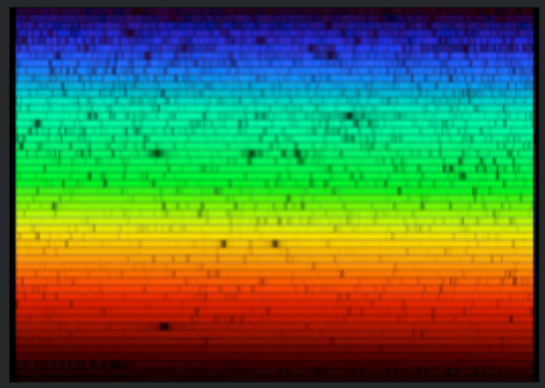
3D MHD simulations with MURaM



Structure of the magnetic features

+

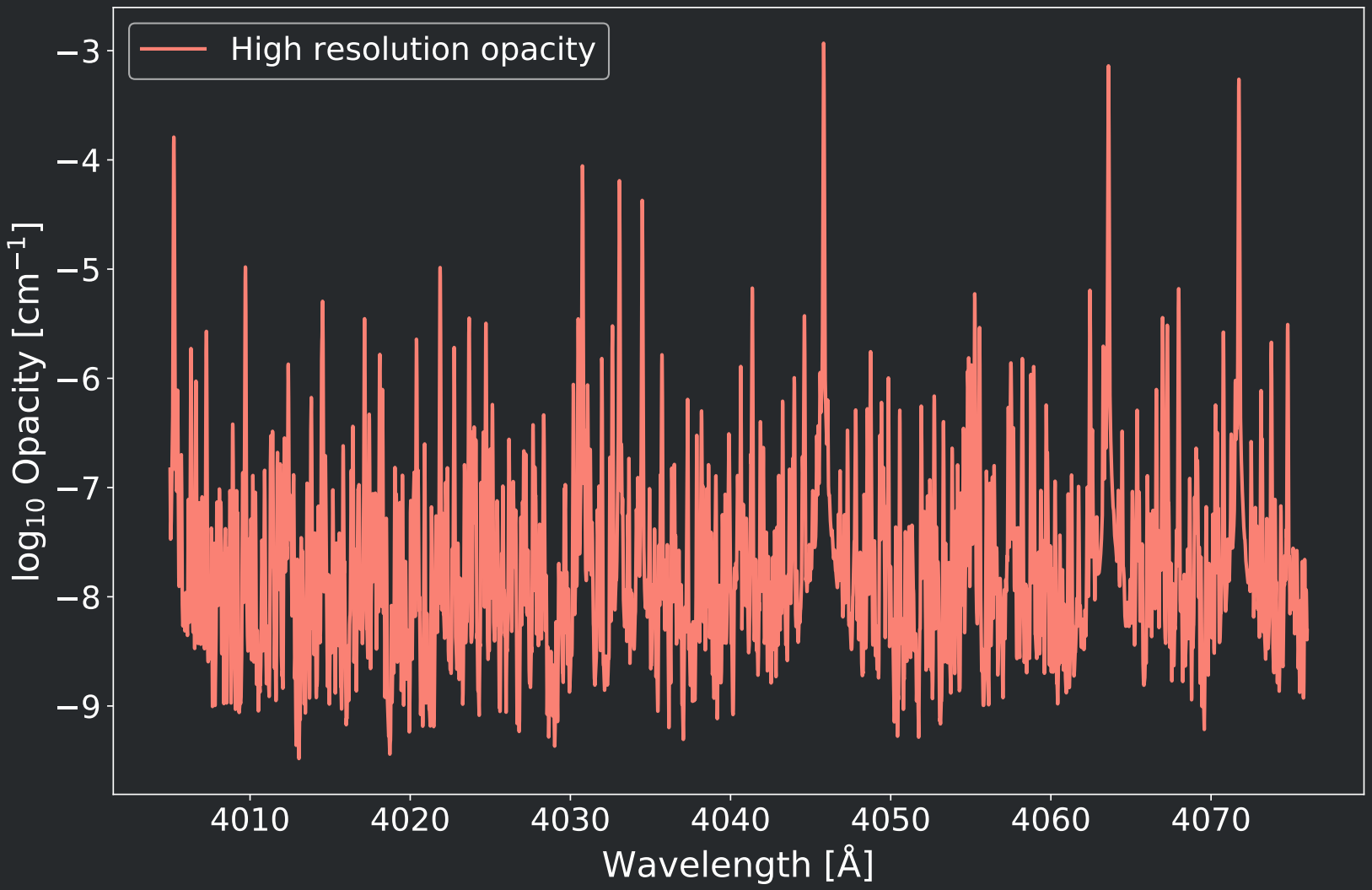
1.5D radiative transfer



Spectra of the magnetic features

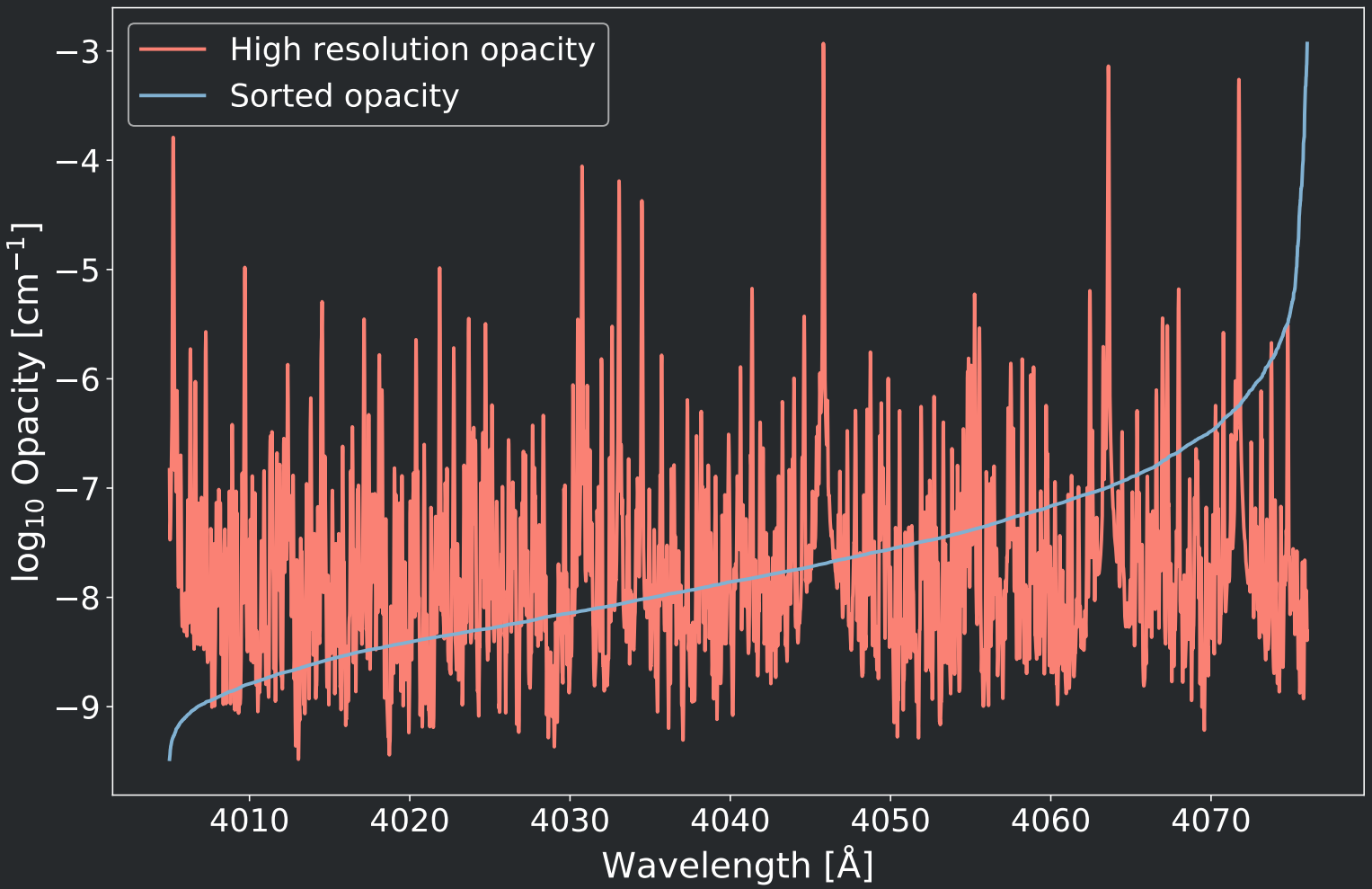
Generating ODFs

- Start with high resolution opacity



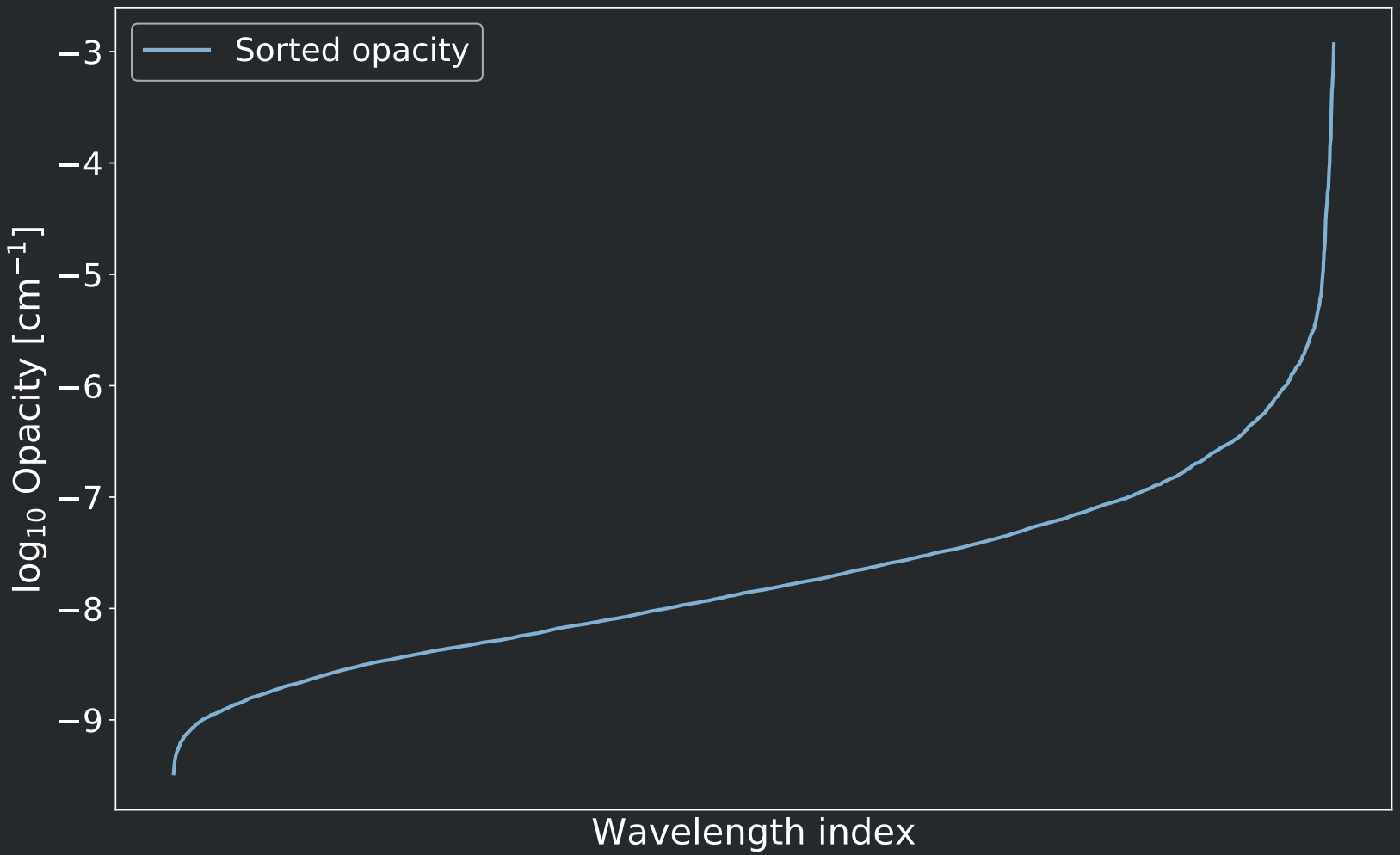
Generating ODFs

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



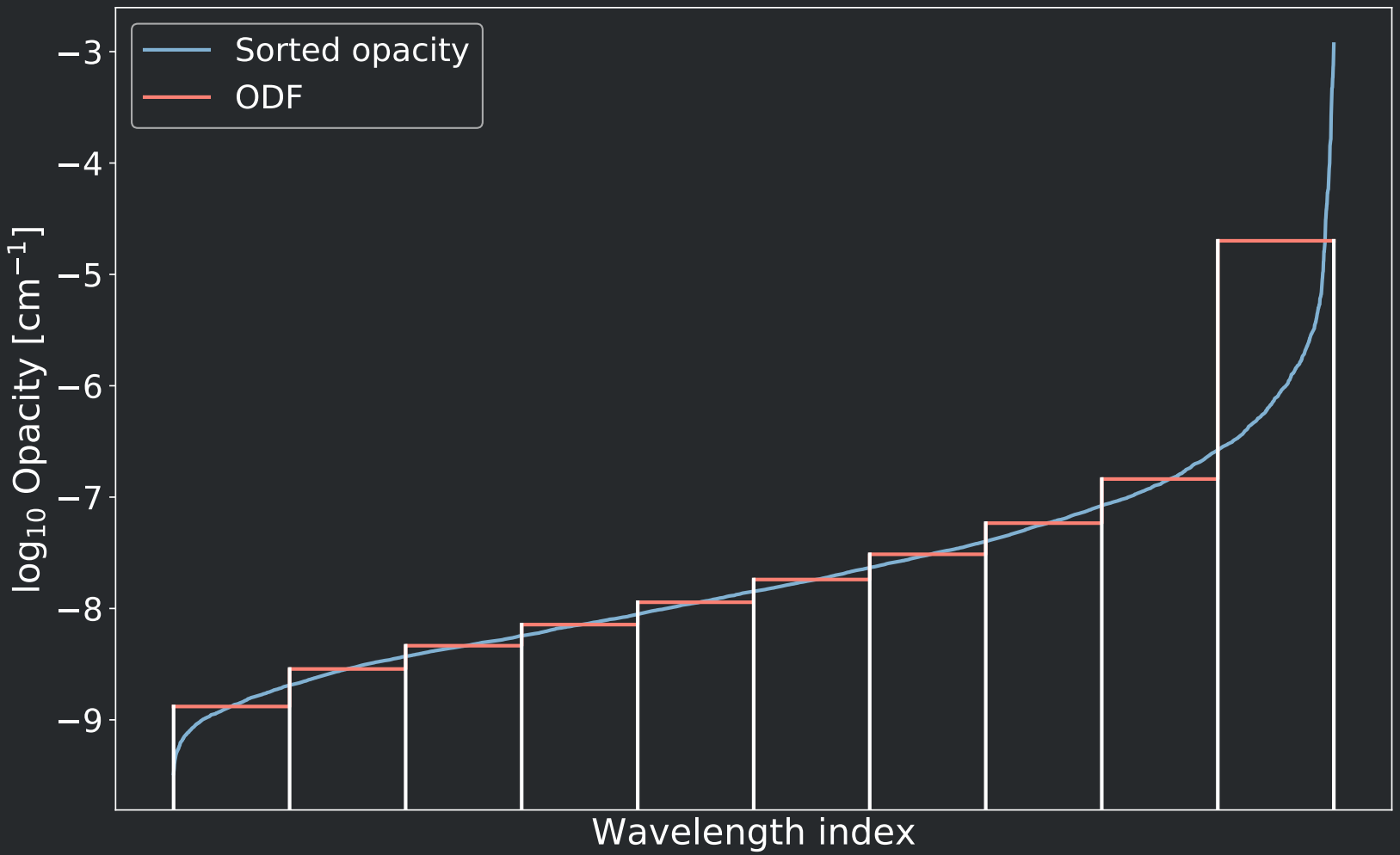
Generating ODFs

- All wavelength information within the bin is lost



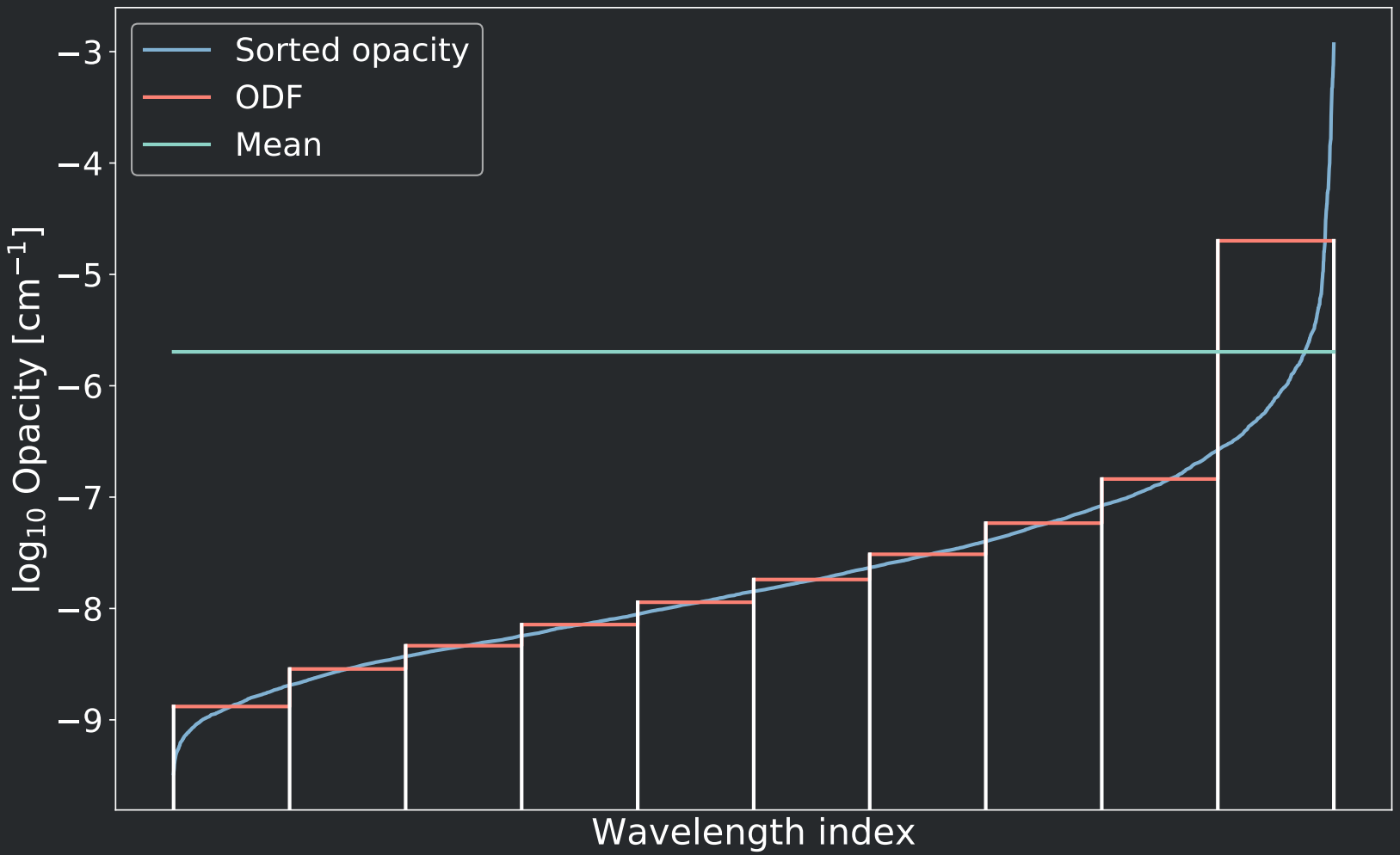
Generating ODFs - Example with 10 uniform sub bins

- Approximate the sorted opacity with a step-wise function



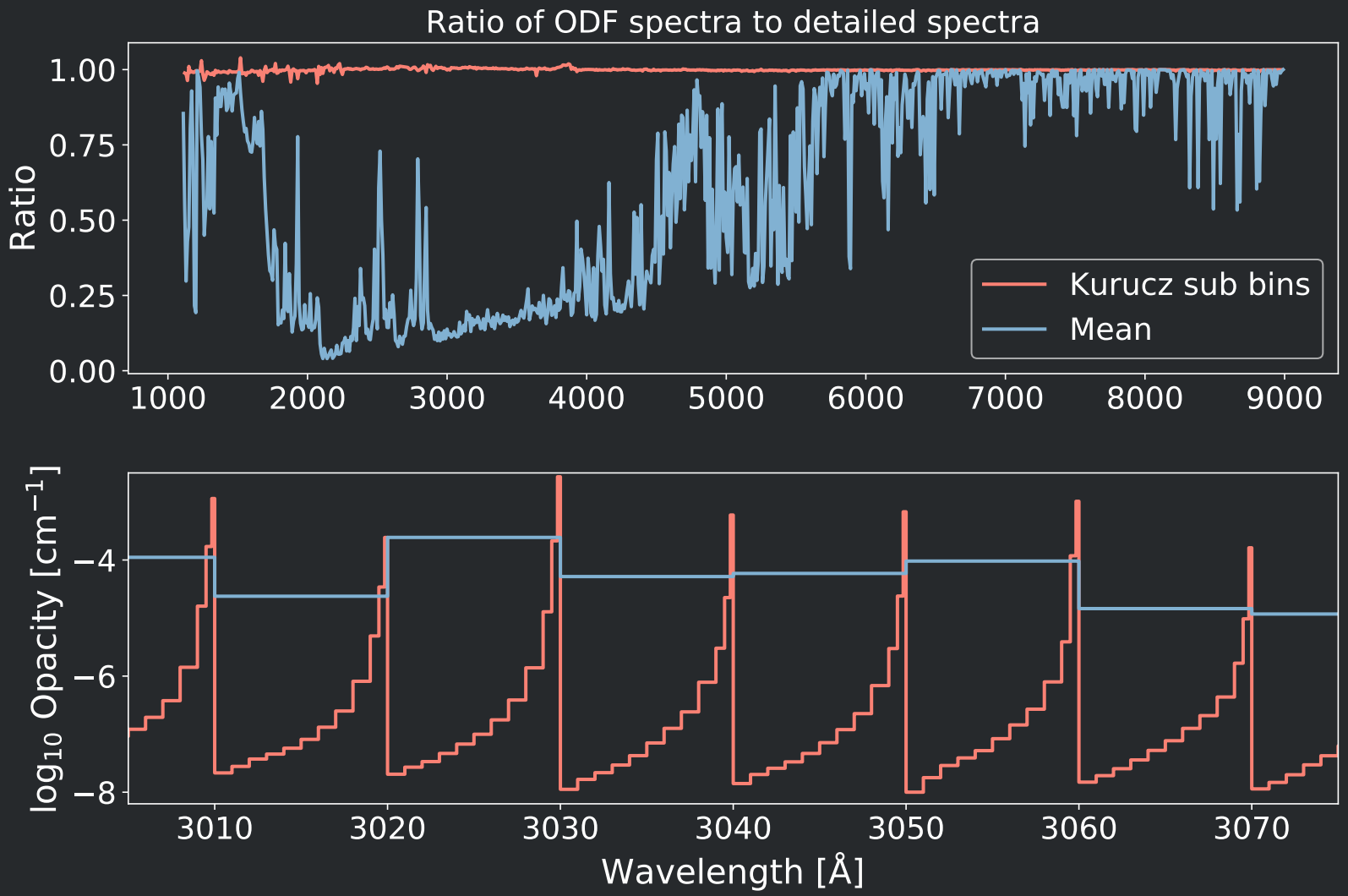
ODF generation process

- Mean is skewed by extreme values



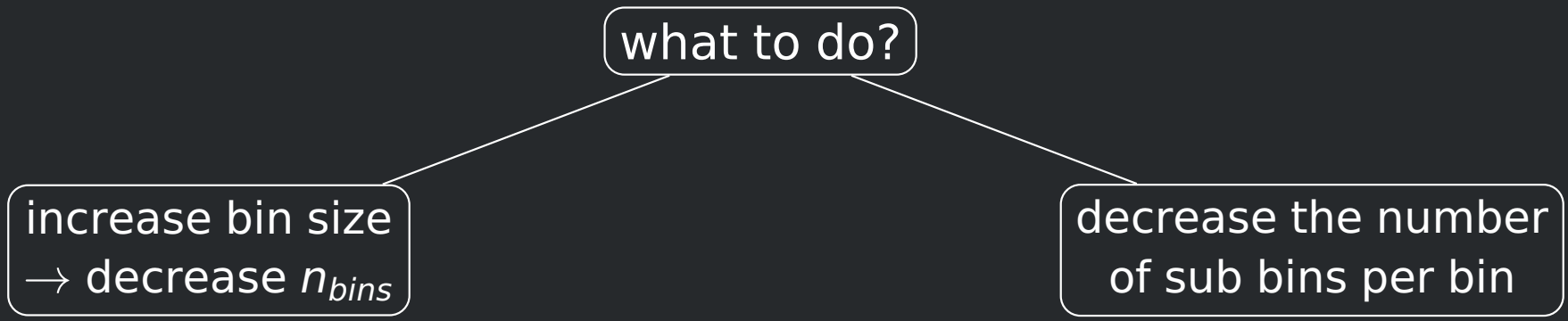
ODF performance analysis

- 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



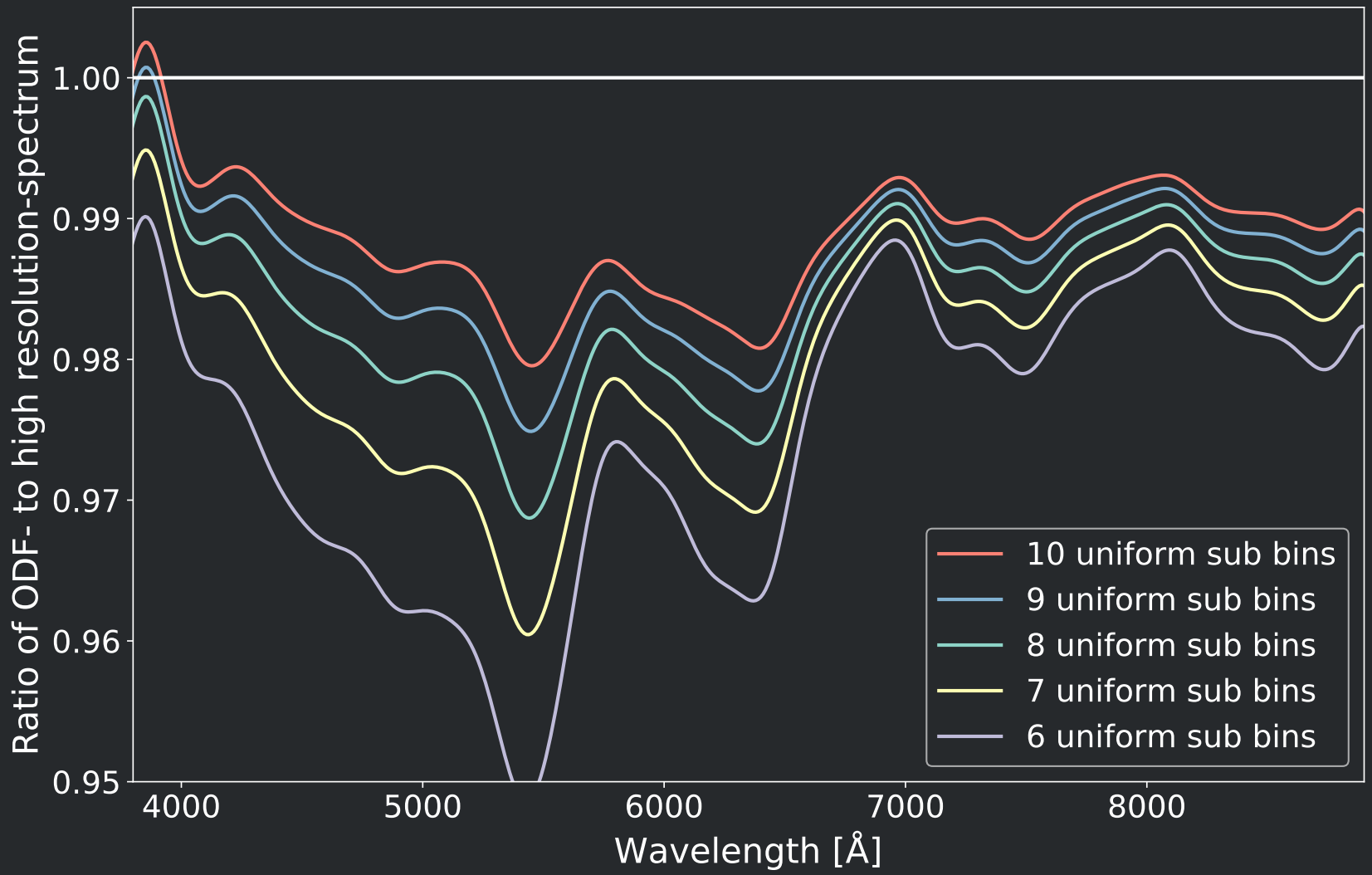
Possible solutions

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



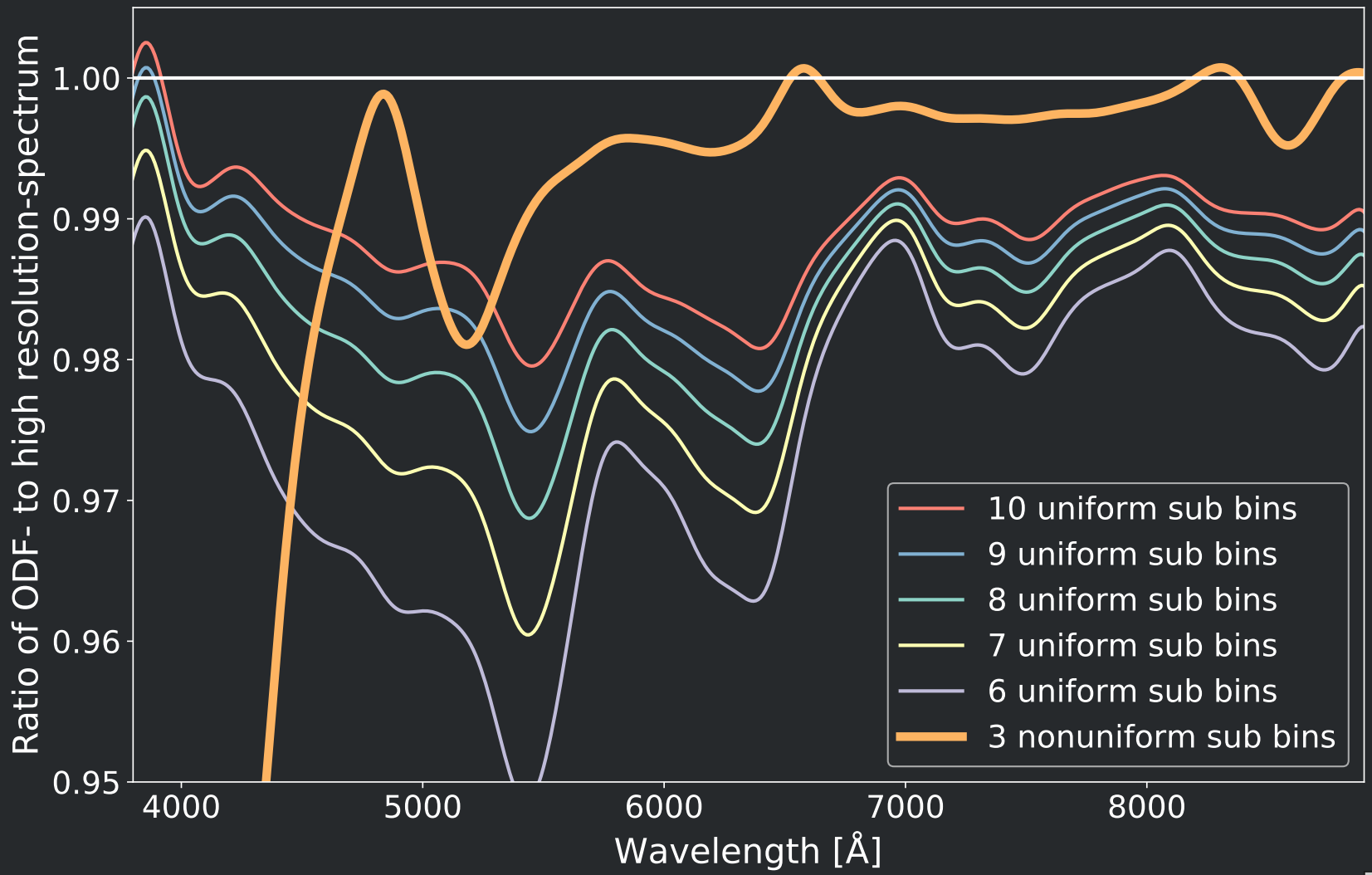
Analysis of different ODFs

- Uniform ODFs

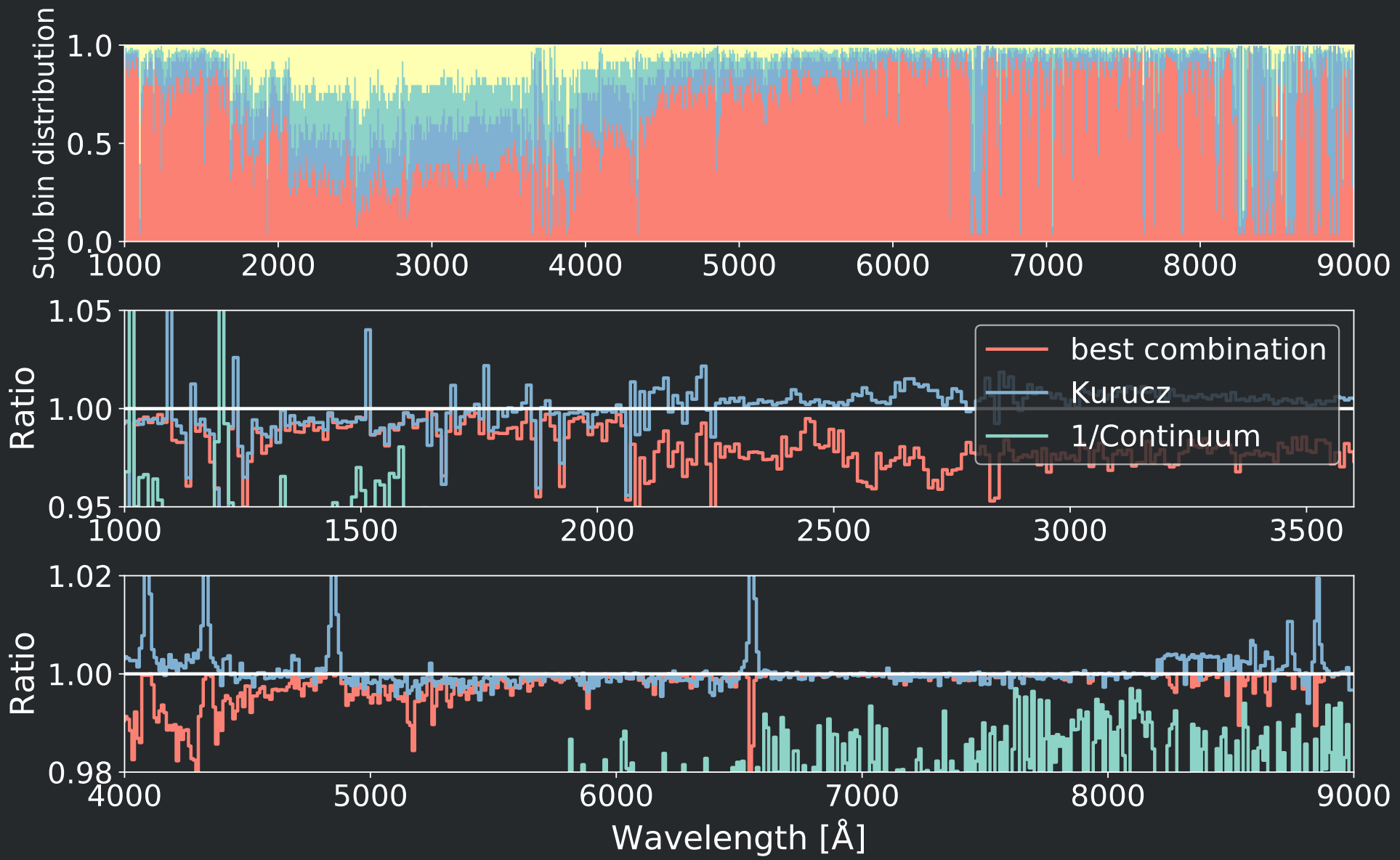


Analysis of different ODFs

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

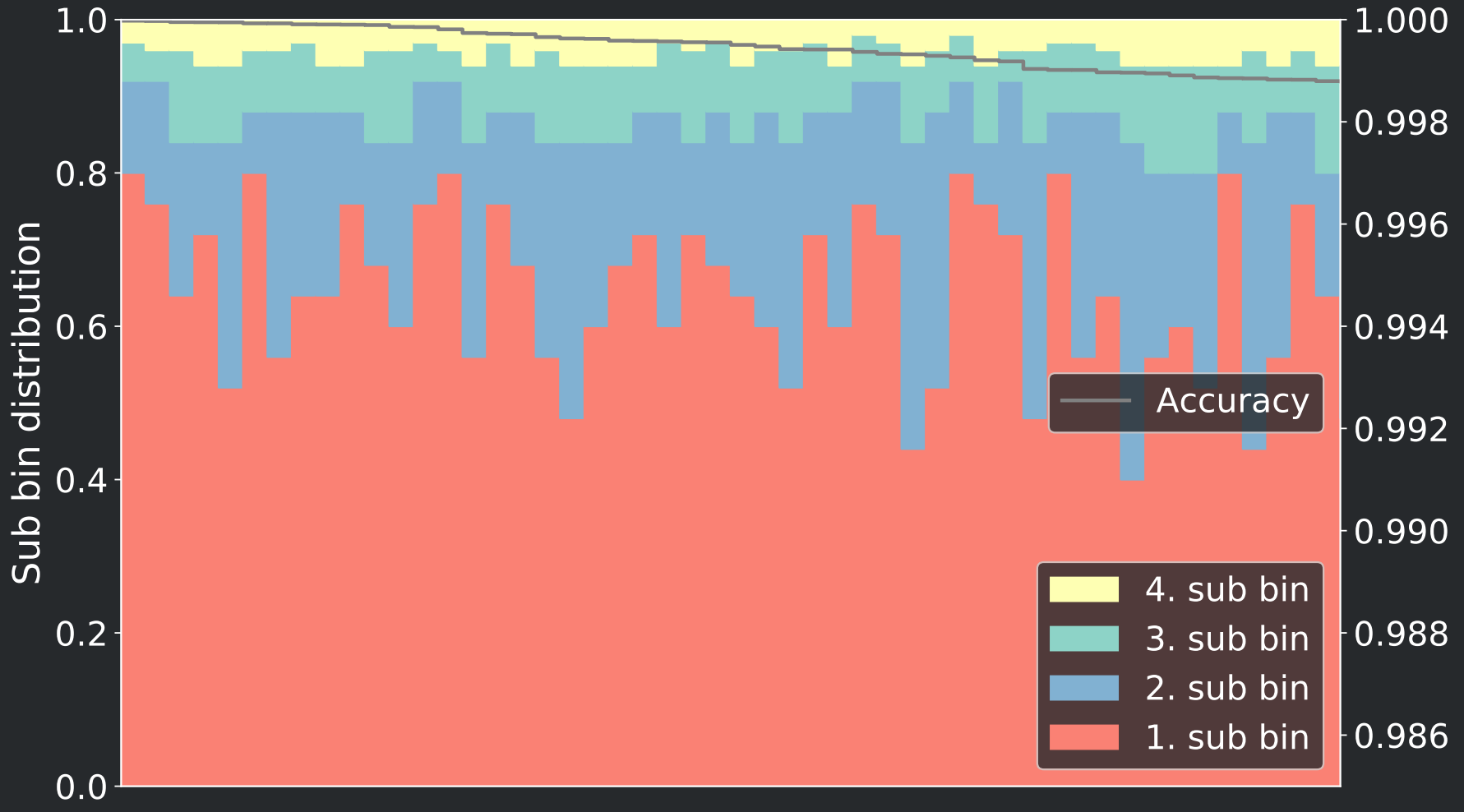


Best sub bin combinations using 4 sub bins



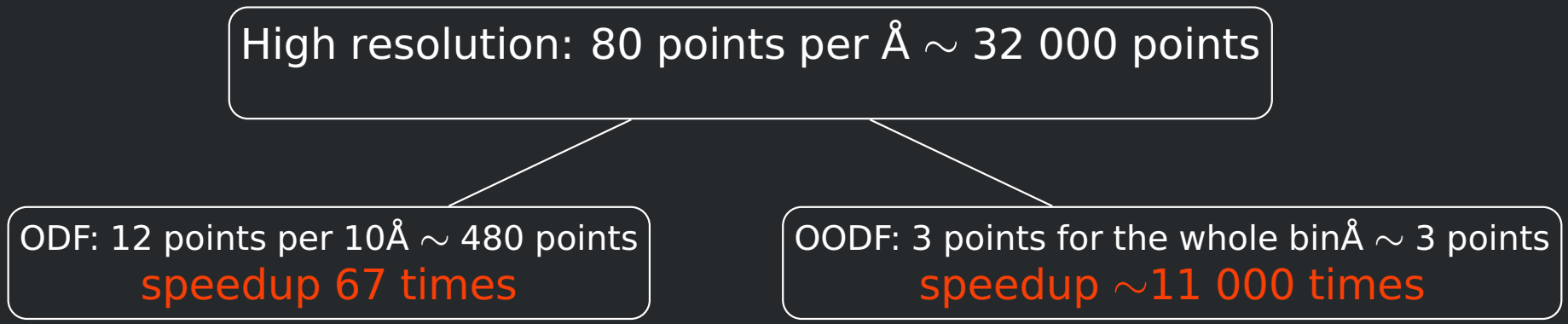
Best combination of 4 sub bins for Strömgren b

- Total line contribution ∼15%



Speedups in the case of Ströemgren *b*

- Interval length: ∼400Å



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.

MPS

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Thank you for your attention!

MPS

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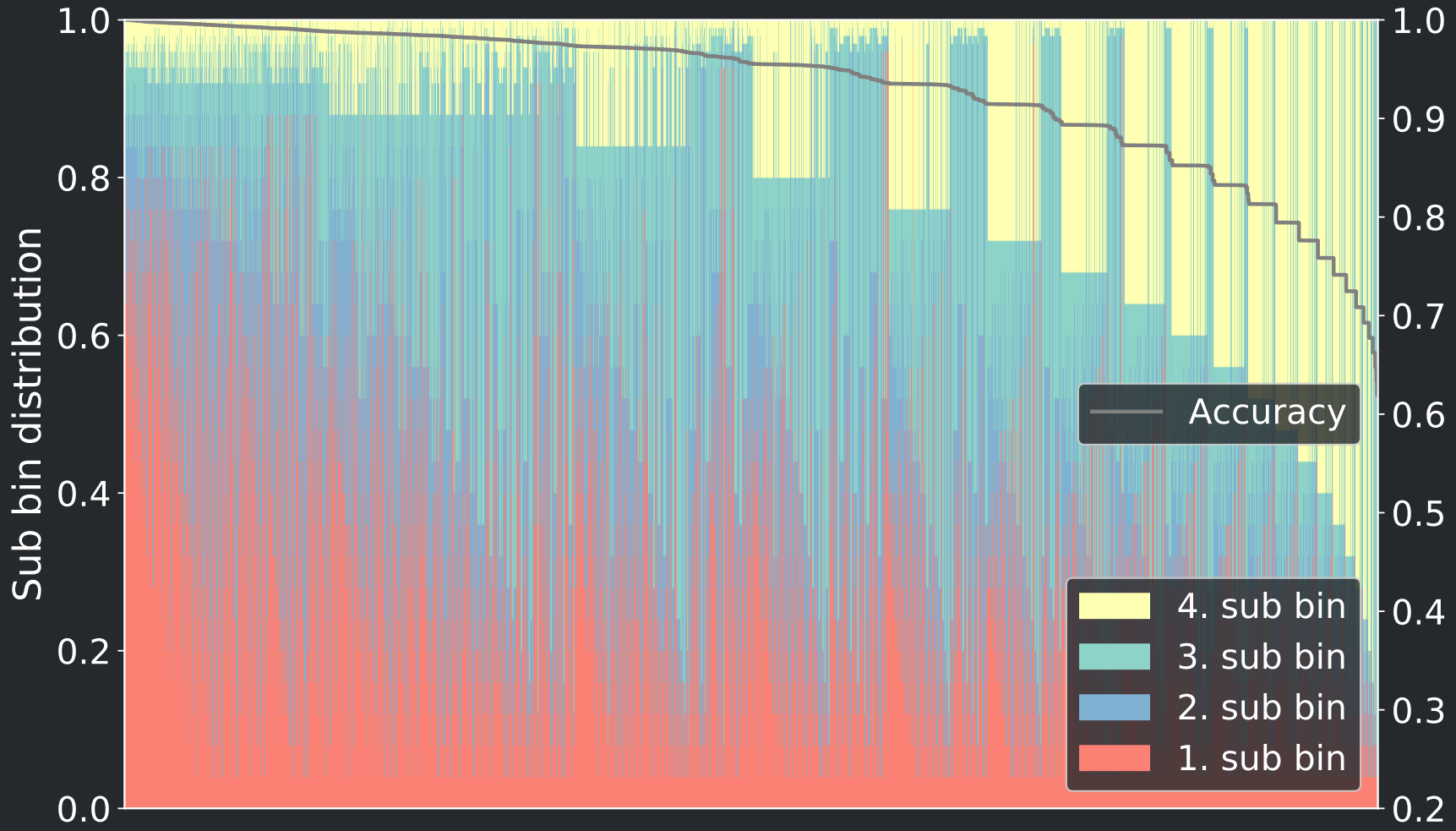
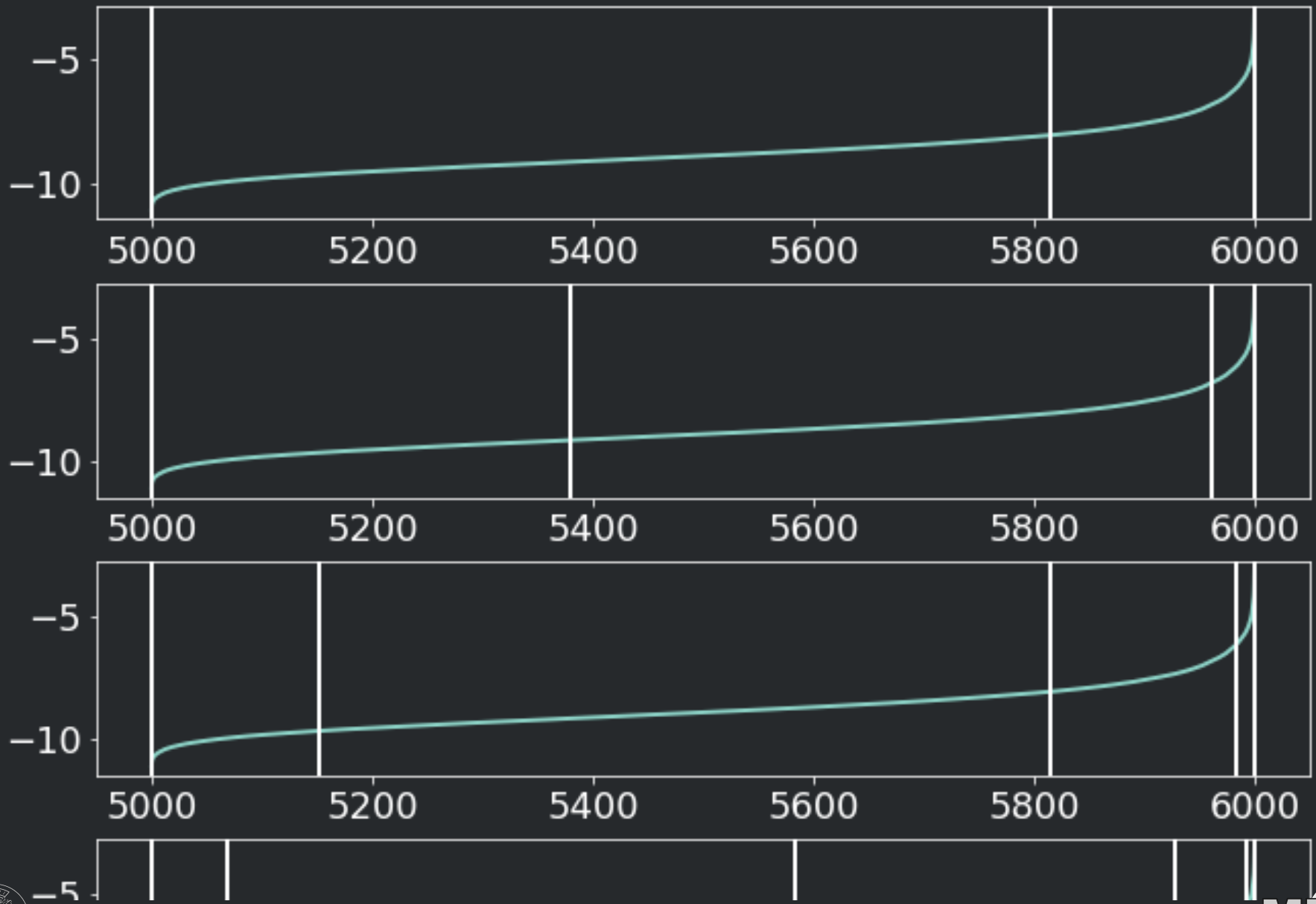
Best combinations of 4 sub bins for Strömgren *b*



Formula: value weighted by the derivative



Ascending vs descending sort