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

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Exemplary case of Strömgren $y$ filter

- Complex structure of spectrum due to lines
Complex structure of opacity

- Opacity varies by multiple orders of magnitude within 1Å
• Sort wavelength points by corresponding values of opacity

```
<table>
<thead>
<tr>
<th>Wavelength [Å]</th>
<th>log10 Opacity [cm⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
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<td>9</td>
<td>8</td>
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<tr>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>
```

Sorted opacity

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Approximating the sorted values

- Approximate opacity with a stepwise function
High resolution spectrum and ODF spectrum

- Use the stepwise opacity to calculate the flux

![Graph showing high resolution spectrum and ODF spectrum](image)

- 4 sub bins -> This two integrals differ by just 2%
High resolution spectrum and ODF spectrum

- Use the stepwise opacity to calculate the flux
- 4 sub bins -> This two integrals differ by just 2%
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

![Graph showing Sorted opacity vs Wavelength index](image-url)

- Sorted opacity
- Wavelength index
- Log$_{10}$ Opacity [cm$^{-1}$]
Generating ODFs - Example with 10 uniform sub bins

- Approximate the sorted opacity with a step-wise function

![Graph showing sorted opacity and ODF](image-url)
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
Analysis of different ODFs

- Uniform ODFs

![Graph showing the ratio of ODF to high resolution spectrum with different uniform sub bins.](image)
Analysis of different ODFs

- Nonuniform ODFs
- The last sub bin is crucial after 5000Å
Comparison of nonuniform sub bins

- Legend specifies sub bin sizes, starting with the first one
- Last sub bin is the same for all
Best sub bin combinations using 3 sub bins

- Sub bin distribution
- Sub bin distribution over Wavelength [Å]
- Ratio vs Wavelength [Å]

Legend:
- 3. sub bin
- 2. sub bin
- 1. sub bin
- Best combination
- Continuum only
- Kurucz
Best combinations of 3 sub bins for Strömgren $y$
Best combination of 3 sub bins for Strömgren $y$

Accuracy

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Speedups in the case of Ströemgren

- Interval length: $\sim 1000\text{Å}$

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

ODF: 12 points per 10Å $\sim 1200$ points
- speedup 67 times

OODF: 3 points per 1000Å $\sim 3$ points
- speedup 25 000 times
Conclusions

• An efficient procedure for radiative transfer is timely for new generation of solar and stellar variability models.

• We developed a novel method for fast spectral synthesis.

• 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!