Inference of log(gf) values for atomic lines in NUV spectral range

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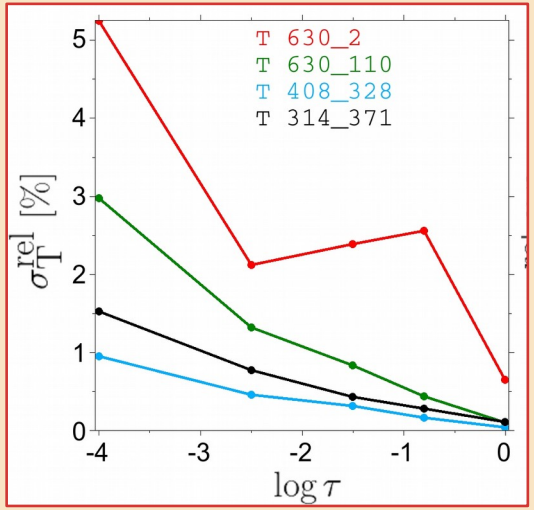
NUV many-line inversion

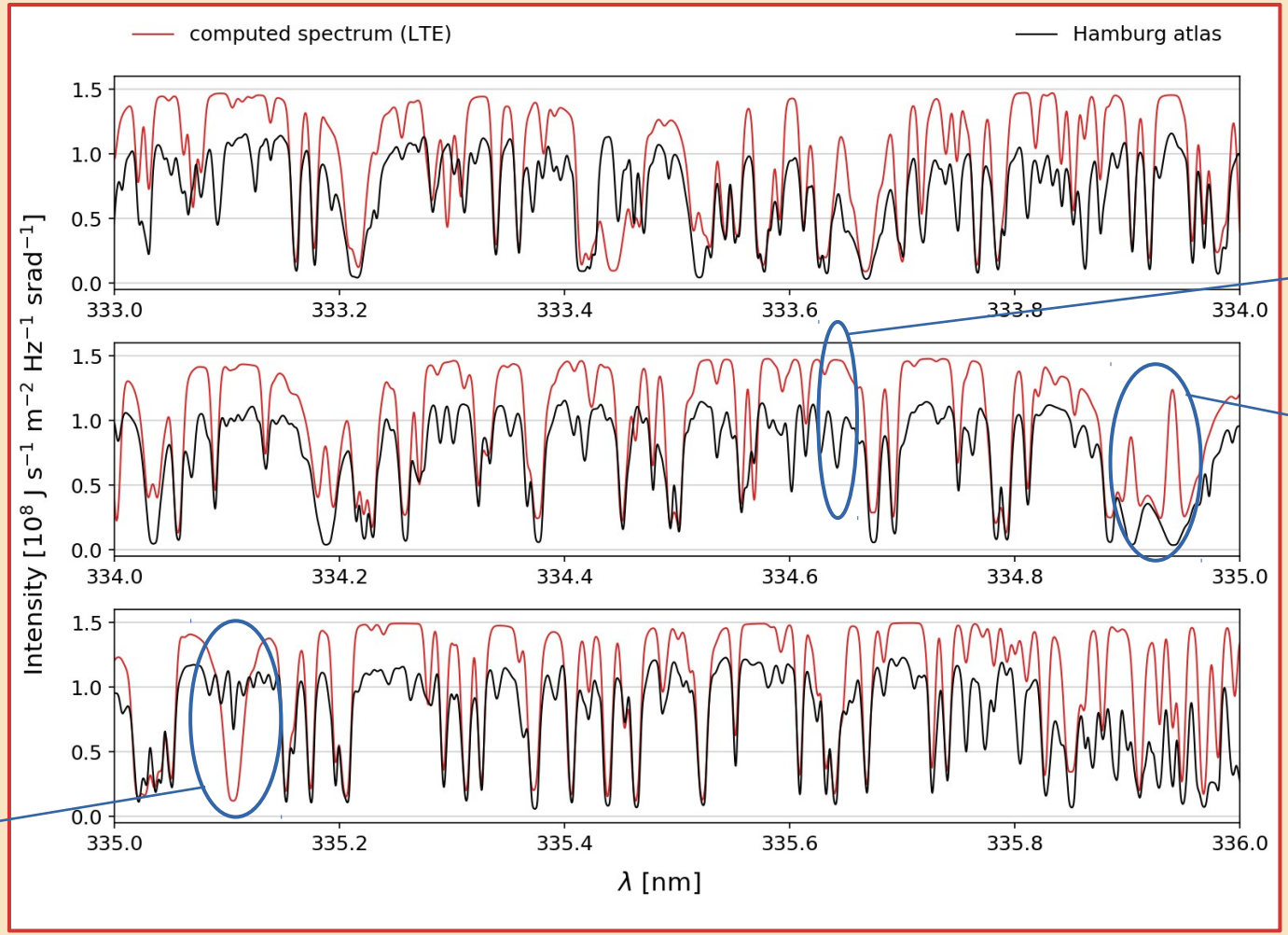
- Preparation for analysis of upcoming SUSI/SUNRISE observations in NUV (310-410 nm).
- Many-line inversion retrieve better height stratification of physical parameters (Riethmüller & Solanki 2019).
- NUV range offers greater height coverage than VIS/IR part of spectrum with higher density of lines and strong polarization signals.



Riethmüller & Solanki (2019)

Challenges of the NUV spectral region

overall poorly determined continuum



missing line

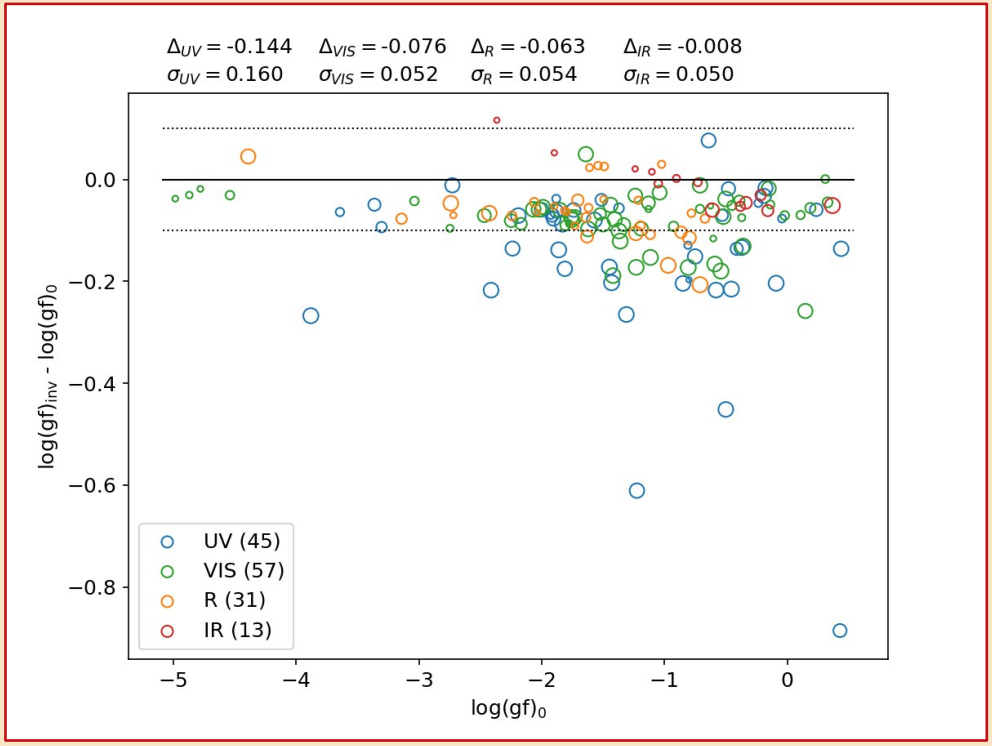
NLTE lines

poor log(gf)

Standard method

UV @ 314 nm VIS @ 408 nm
R @ 630 nm IR @ 1560 nm

- Comparison of synthetic spectrum from mean solar atmosphere model with mean observed spectrum.
- Problem: need to have precise atmospheric model. Any deviations leads to a shift or large scatter in inferred values.
- Example: using FAL C atmosphere in an ideal conditions (no observational effects) to fit mean spectra from MURaM cube.
- Inversion parameters:
  - micro- and macro-velocity
  - log(gf) and rest wavelength for a sample of lines in each spectral region



circle size correspond to line depth

Global inversion algorithm

- In global approach we minimize χ^2 from all pixels in FoV:

$$\chi^2(\mathbf{p}) = \frac{1}{N_{\mathrm{dof}}} \sum_{a=1}^{N_{\mathrm{atm}}} \sum_{i=1}^{N} \frac{w_i^2}{\sigma_i^2} \cdot (\mathbf{O}_{i,a} - \mathbf{S}(\mathbf{p})_{i,a})^2$$

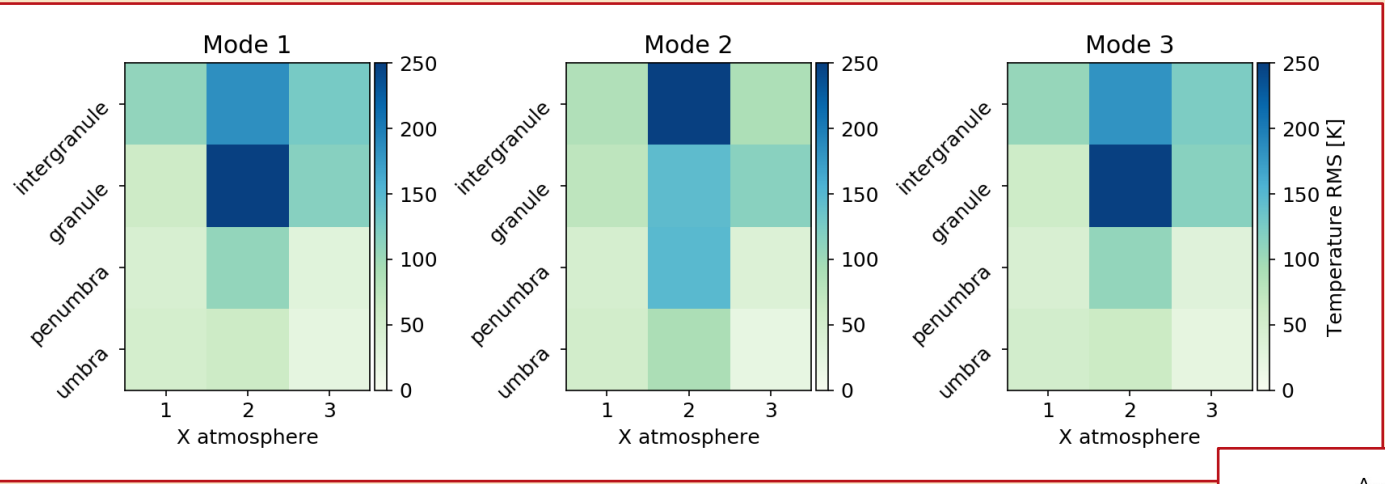
- We use Levenberg-Marquardt minimization routine. Response function of atomic parameter is non-zero in every pixel, while atmospheric parameters have non-zero values only for their respective pixel.
- Single value atomic parameter must satisfy simultaneously many different spectra emerging from a large number of solar atmospheres!

- We disrupt block diagonal form of Hessian matrix and couple the information for atomic parameters while having pixel-by-pixel inversion of atmospheric parameters.
- Three modes of inversion:

	atmospheric parameters	atomic parameters
Mode 1	pixel-by-pixel	/
Mode 2	pixel-by-pixel	pixel-by-pixel
Mode 3 (global)	pixel-by-pixel	global

Mode 2 inversion proposed by Trelles Arjona+21

Example: U + PU + G + IG atmospheres

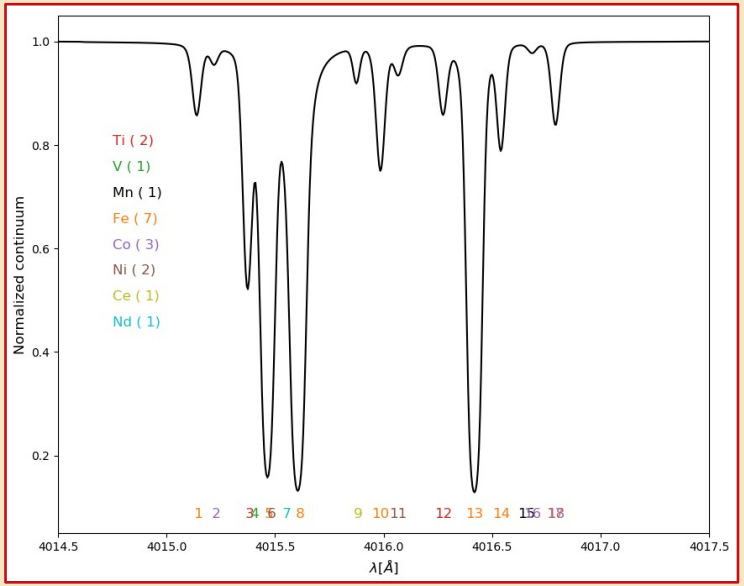


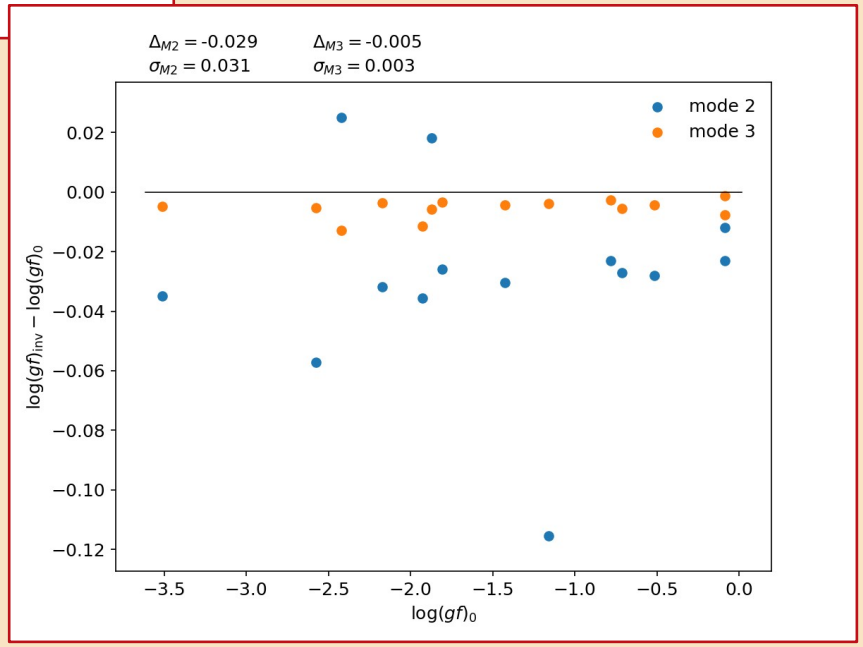
	atmospheric parameters	atomic parameters
Mode 1	pixel-by-pixel	/
Mode 2	pixel-by-pixel	pixel-by-pixel
Mode 3 (global)	pixel-by-pixel	global

sample of 18 lines @ 401.6 nm

Inversion:
- temperature in 4 nodes
- log(gf)
- rest wavelength

14 lines have free parameters





Outlook

- Through global inversion we are reducing the number of free parameters and enable better inference of global parameters along with pixel-by-pixel inversion of local parameters.
- Real-life application: invert observations @ 401 nm from SST.
- Inverting spectra from different atmospheric features ensure better inversion results. Find the minimum number of necessary atmospheres for good parameter inference.
- Necessity for NUV region: identify unknown line (abundance, log(gf), lower energy level, …) to account for missing lines.
- Incorporate and opacity fudge (OF) inference (important for NUV). Derive temperature dependence of OF coefficients.

opacity fudge (OF) correction in NUV add opacity in continuum and gives better match of LTE synthetic spectrum to observed Hamburg atlas spectrum.