Numerical tools for radiative transfer and the calculation of Solar Surface Velocity Fields

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Overview

MEDOC provides the scientific community with documented numerical tools dedicated to the interpretation of solar and stellar observations.
Two complementary families of numerical tools have been developed for the analysis and interpretation of past, current, and future solar and stellar observations from missions such as SoHO, Hinode, SDO, IRIS, and Solar Orbiter.

1. **Non-LTE Radiative Transfer Codes**
   1D and 2D numerical tools dedicated to the modelling of solar and stellar atmospheres, including prominences, filaments, chromospheres, coronal structures, cylindrical threads. Link : https://idoc.osups.universite-paris-saclay.fr/medoc/tools/radiative-transfer-codes/
2. **Coherent Structure Tracking (CST)**
   Codes dedicated to the computation of horizontal velocity fields at the solar surface using granules as tracers. Link : https://idoc.osups.universite-paris-saclay.fr/medoc/tools/cst-codes/

1. Non-LTE Radiative Transfer Codes

1D Models

H3CRD : 1D multilevel NLTE radiative transfer (H)

- Contact: Frédéric Paletou
- MALI and short-characteristics methods
- Semi-infinite solar atmosphere
- Designed for modern numerical implementations

PROM7: 1D prominence/filament model (H, Ca)

- Contacts: Nicolas Labrosse & Martine Chane-Yook
- Isothermal and isobaric atmosphere
- NLTE radiative transfer using the Feautrier method
- Continua and hydrogen/calcium spectral lines
- Partial Frequency Redistribution (PRD)
- Computes spectra emitted by prominences and filaments

PROM5: 1D prominence model with variable physical parameters (H)

- Contacts: Nicolas Labrosse & Martine Chane-Yook
- Similar to PROM7
- Physical quantities vary across the prominence
- Hydrogen continua and spectral lines

HYDR_NV / ATSTHS: 1D semi-infinite atmosphere (H, Mg, Ni, Na, Fe)

- Contacts: Nicolas Labrosse & Martine Chane-Yook
- NLTE radiative transfer in solar and stellar atmospheres
- Feautrier method with PRD
- Continua and multi-species spectral lines

PROMCOR: Optically thin coronal/prominence model

- Contacts: Eric Buchlin, Jean-Claude Vial & Martine Chane-Yook
- Derived from PROM5
- Thermodynamic parameters depend only on solar distance
- Valid for optically thin media

PRODOP: 1D prominence model including velocity fields (H, Ca, Mg, He)

- Contacts: Nicolas Labrosse & Martine Chane-Yook
- Extension of PROM7/PROM5
- Includes vertical velocity fields
- Computes H, Ca, Mg, and He spectra

1D results: Prominence Lyα profiles with velocity field

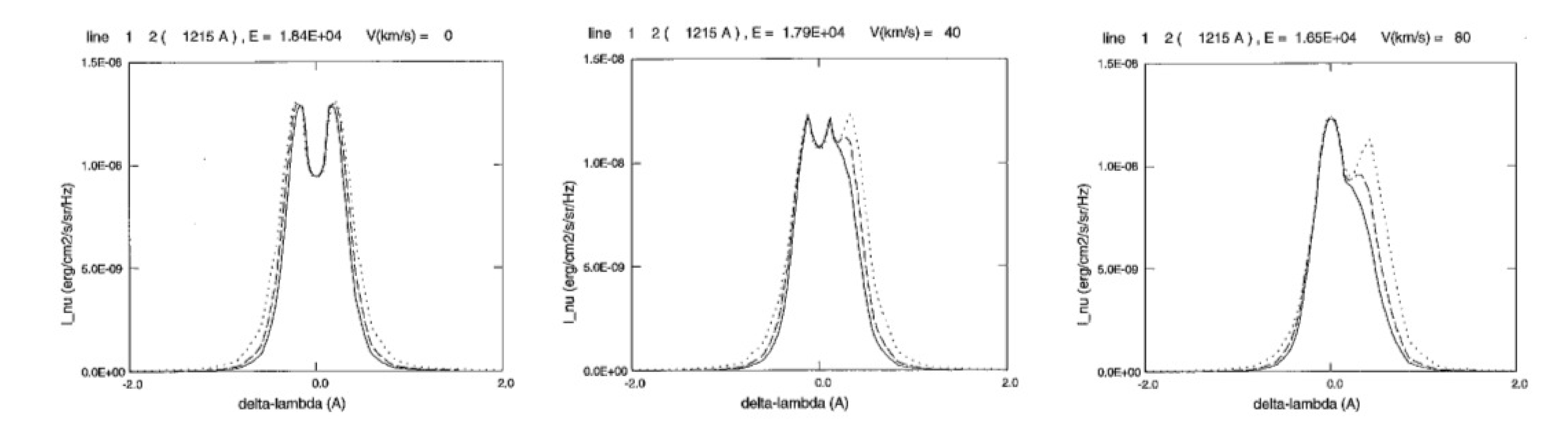

Figure 1:Left to right: V=0,40,80 km/s; 3 curves corresponding to emergent angles (0°,53°,78°)

2D Models

CYLA2DV: 2D cylindrical thread model with velocity fields (H)

- Contacts: Nicolas Labrosse & Martine Chane-Yook
- 2D NLTE radiative transfer
- Incident radiation and 3D velocity fields
- Complete Frequency Redistribution (CRD)
- Λ-iteration method with preconditioning (MALI)

C2D2E: 2D cylindrical thread model (H, He)

- Contacts: Nicolas Labrosse, Eric Buchlin & Martine Chane-Yook
- NLTE radiative transfer for hydrogen and helium
- Incident radiation with CRD treatment
- Λ-iteration method with preconditioning (MALI)

MALI & Gauss-Seidel Codes: Toulouse 2D prominence models (H, He)

- Contact: Frédéric Paletou
- Multilevel NLTE radiative transfer
- MALI and Gauss-Seidel iterative schemes
- Cartesian geometry for isolated structures

NLTE2D: Advanced 2D prominence/slab model (H)

- Contact: Frédéric Paletou
- MALI, Gauss-Seidel, SOR, and multigrid methods
- Short-characteristics formal solver
- Self-consistent electron density determination
- Explicit treatment of Lyman continuum radiation

Main features

- All codes written in Fortran and fully documented
- Flexible implementation of additional spectral lines

2. Coherent Structure Tracking (CST)

Solar Surface Velocity Measurements

The CST algorithm allows the determination of spherical velocity fields (V_r, V_ϕ, V_θ) from high to low spatial and temporal resolutions over the full Sun surface. Its applications are various: magnetic field diffusion (in quiet and active regions), detection of filament eruptions, solar rotation, meridian circulation, and links with solar wind production.

- Contacts: Thierry Roudier, Frédéric Paletou & Martine Chane-Yook
- Simplified data-processing workflow implemented with IDL and Fortran codes
- Input data: 4096 $\times$ 4096 HMI/SDO intensity images and Dopplergrams
- Temporal cadence: 45 s
- Automated HMI data retrieval from JSOC
- Spatial/temporal resolutions: 0.5 Mm – 30 min, 1.3 Mm – 15 min
- Granule deconvolution prior to velocity computation, producing 8192$\times$8192 images
- Documentation with detailed formulas for the implementation

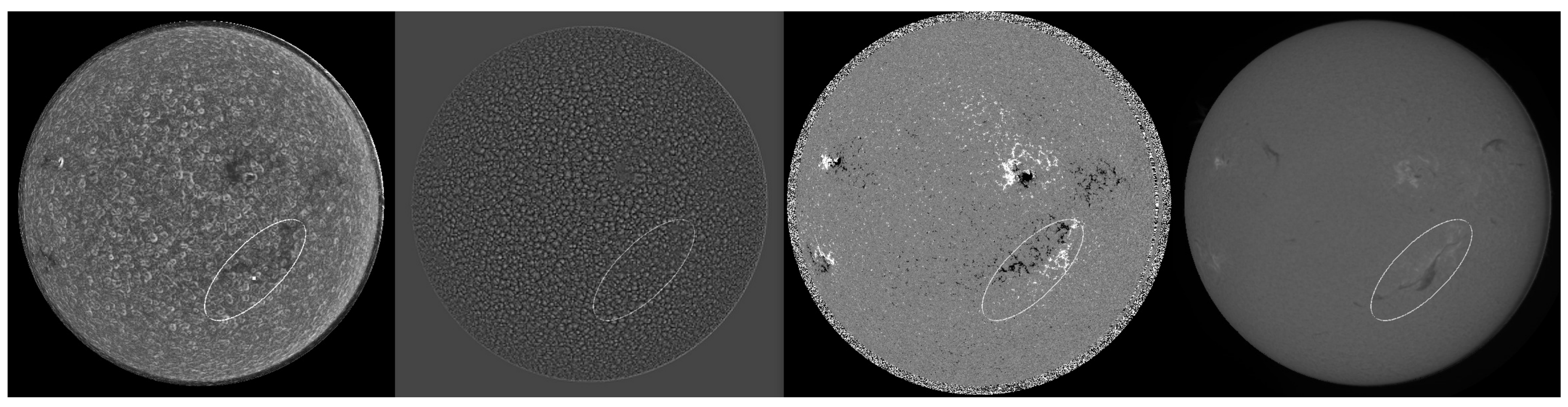

Figure 2:Full Sun observations on 26/01/2016, spatial resolution 2.5Mm. From left to right (at small scales): horizontal velocity module and divergence fields produced by CST codes, longitudinal magnetic field (HDMI/SDO), H_α image from GONG. Roudier et al. A&A 618, A43 (2018)

Share your code with the community ?

Have code to share ? Let's collaborate, get in touch !

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Acknowledgments: CNES for financial support