Non-LTE radiative transfer codes (1D and 2D) in solar structures

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Introduction

- For more than 30 years, numerical codes for Non-LTE radiative transfer have been developed at IAS. They are dedicated to various solar structures (prominences, filaments, chromospheres, ...) and different geometries are considered : 1D, 2D cylindrical. Radiative transfer is computed both for continua and for lines belonging to various atomic systems (H, He, Mg, Ca, Fe, Ni) and velocity fields are also included.
- These codes have already been extensively used for **SOHO**, and more recently for **AIA/SDO** images and **IRIS** spectra. Modern versions of these codes will be soon available, in preparation of future missions.
- On **MEDOC** website, codes, documents and test cases can be found : **http://medoc.ias.u-psud.fr/, "TOOLS", "RADIATIVE TRANSFER CODES"**

Theoretical models

Atomic line intensities and profiles are used to diagnose solar structures. To compute radiative transfer inside these lines, it is necessary ([1], [2], [3], [4]) to :

1. **have** a good atomic model corresponding to the different atoms and ions responsible of line formation, as well as plasma parameters (electron density and temperature), external radiation field, ... Statistical equilibrium equations of atomic levels are solved including all available atomic data.
2. **solve** radiative transfer equation coupled to statistical equilibrium. It is done iteratively using hydrogen level populations obtained without radiation field as starting values. The computation of minor elements is performed after the electron density is determined from H (and He) ionization equilibrium.
3. **describe** the considered solar structures. Different geometries can be used : 1D, 2D, ...

1D slab and 2D cylinder geometries

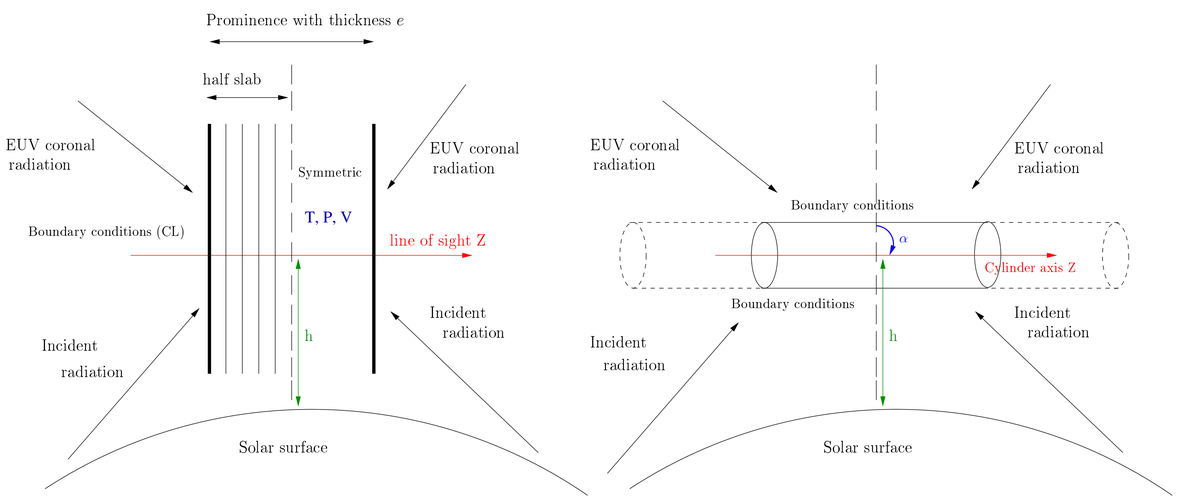

Figure 1: 1D geometry (LHS), 2D cylinder geometry (RHS)

Codes description

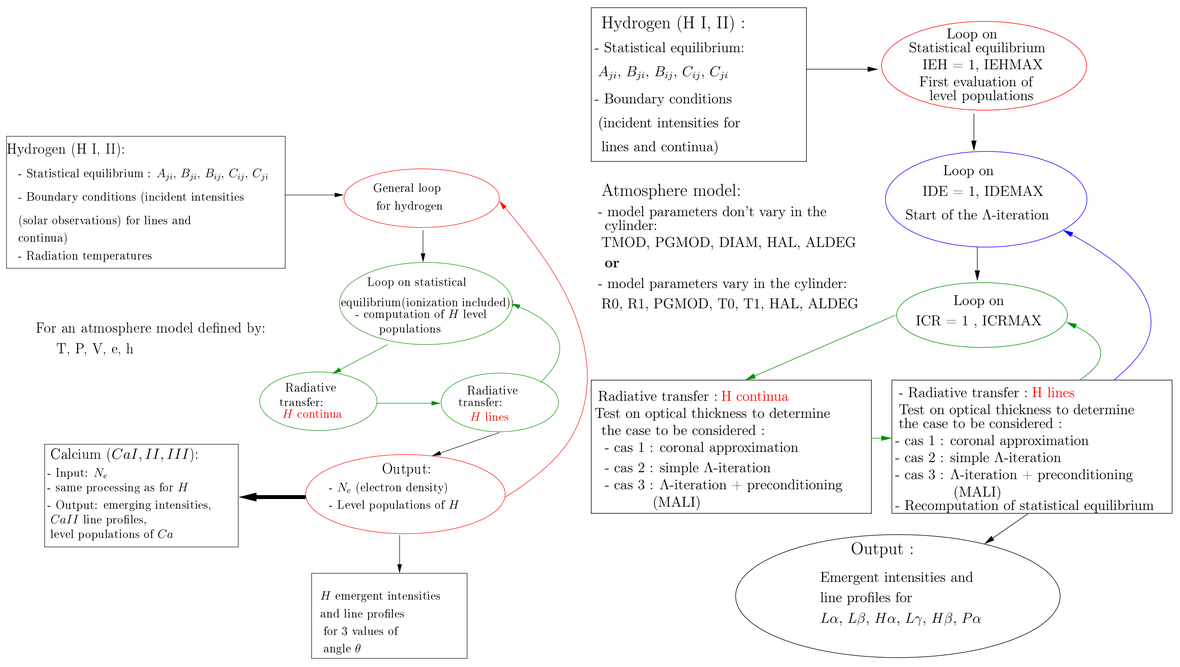

Figure 2: Algorithms: 1D (PROM7, on left) and 2D (CYMA2DV, on right)

Results 1D: Prominence Lyα profiles with velocity field

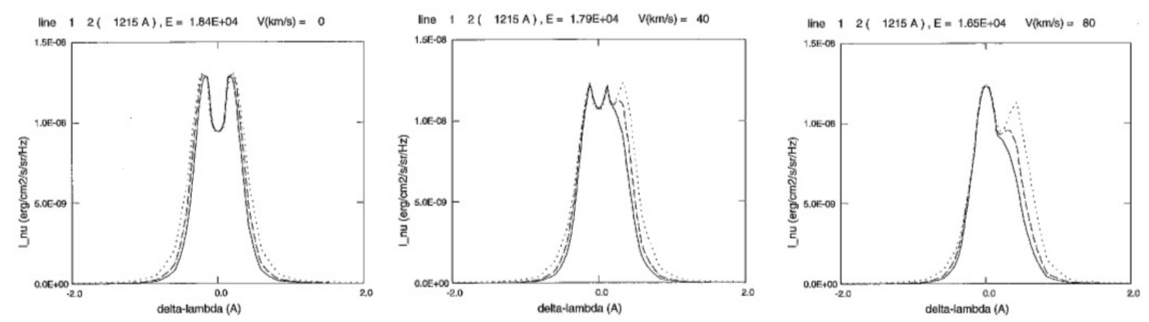

Figure 3: Left to right: V=0,40,80; 3 curves corresponding to emergent angles (0°,53°,78°)

Results 2D: Lyβ profiles with velocity field (30 km/s)

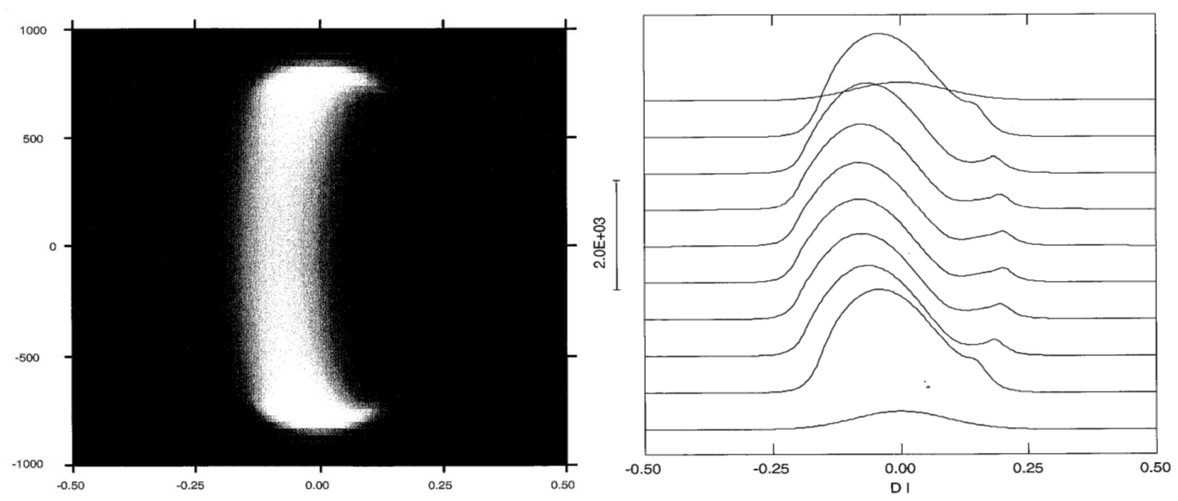

Figure 4: Left: variation of the intensity profile at the bottom of the loop. Right: profiles at some positions across the loop

Summary of available codes at MEDOC website

- PROM5 (1D): prominence, model with varying physical properties across the prominence (H)
- PROM7 (1D): prominence/filament, isobaric-isothermal atmosphere model (H, Ca)
- HYDR_NV/ATSTHS (1D): **semi-infinite atmosphere** (H, Mg, Ni, Na, Fe)
- PROMV (1D): prominence, velocity field (H, Ca, Mg, He)
- CYMA2DV (2D): cylinder, velocity field (H)
- C2D2E (2D): cylinder (H, He)
- IRAP codes (2D)
- Prospective: graphic interface, codes improvement, 3D (?), ...

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