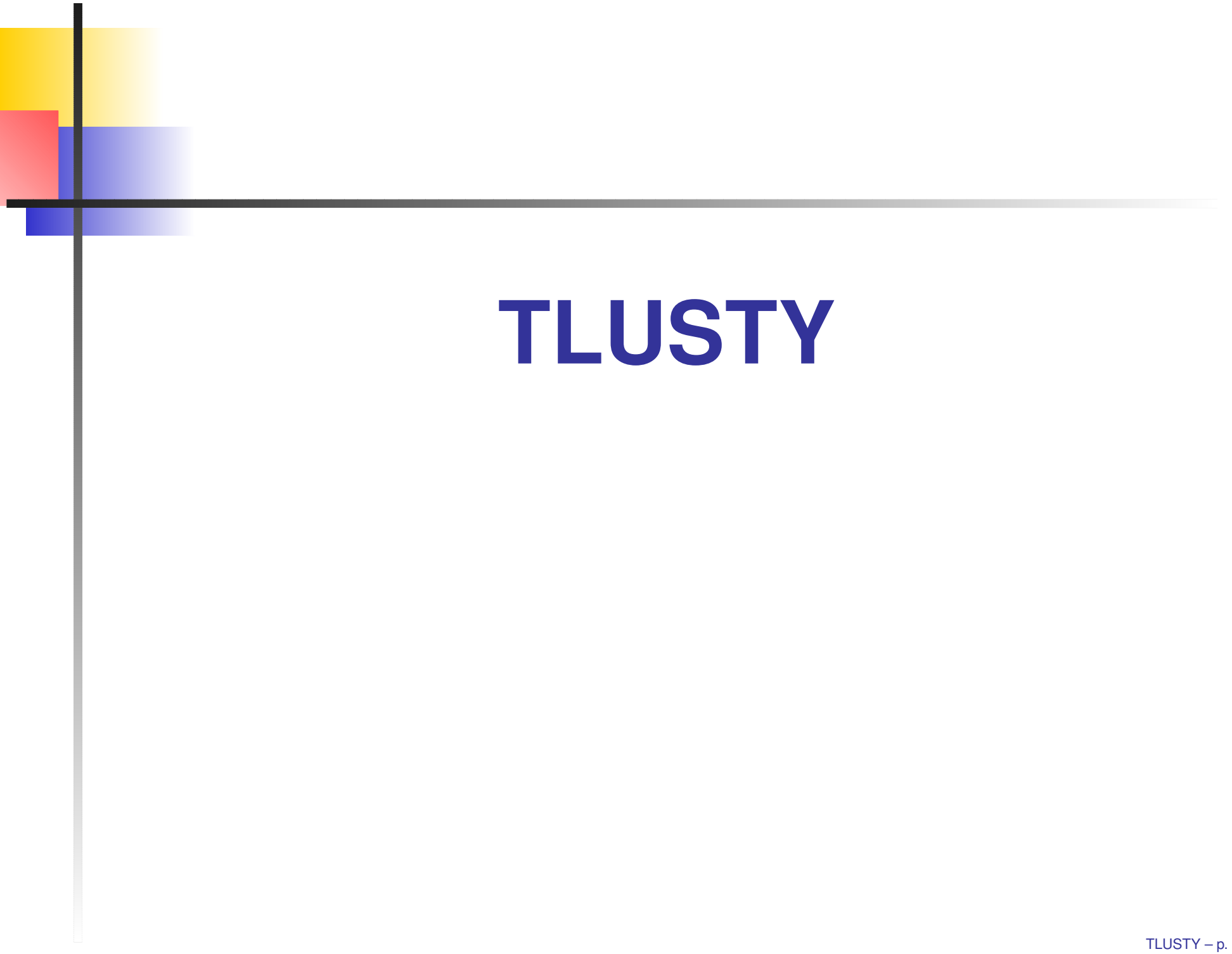

TLUSTY

TLUSTY

- calculation of plane-parallel model stellar atmospheres ($T_{\rm eff} \gtrsim 10\,000$ K) and disk models
- radiative and hydrostatic equilibrium
- assumption of LTE or NLTE
- input for the SYNSPEC code

Hubeny, I. 1988, Comp. Phys. Commun., 52, 103
Lanz T., Hubeny I., 2003, ApJS, 146, 417
Lanz T., Hubeny I., 2007, ApJS, 169, 83
http://www.physics.muni.cz/~krticka/tlusty200.tgz

Model equations

- radiative transfer equation

$$\mu \frac{\partial}{\partial z} I(z,\mu,\nu) = \eta(z,\nu) - \chi(z,\nu) I(z,\mu,\nu)$$

Model equations

- radiative transfer equation
- equations for the level occupation numbers
  - LTE: Saha and Boltzmann equations

$$\frac{N_j}{N_{j+1}} = n_{\rm e} \frac{U_j(T)}{U_{j+1}(T)} \frac{1}{2} \left(\frac{h^2}{2\pi m_{\rm e} kT} \right)^{3/2} \exp\left(\frac{\chi_{I,j}}{kT} \right)$$

$$\frac{n_{ij}}{N_j} = \frac{g_{ij}}{U_j(T)} \exp\left(-\frac{\chi_{ij}}{kT} \right)$$

Model equations

- radiative transfer equation
- equations for the level occupation numbers
  - LTE: Saha and Boltzmann equations
  - NLTE: kinetic equations (statistical equilibrium equations)

$$\sum_{j\neq i} n_j P_{ji} - n_i \sum_{j\neq i} P_{ij} = 0$$

Model equations

- radiative transfer equation
- equations for the level occupation numbers
  - LTE: Saha and Boltzmann equations
  - NLTE: kinetic equations (statistical equilibrium equations)
- hydrostatic equilibrium equation

$$\frac{\mathrm{d}p}{\mathrm{d}m} = g - g_{\mathrm{rad}}$$

Model equations

- radiative transfer equation
- equations for the level occupation numbers
  - LTE: Saha and Boltzmann equations
  - NLTE: kinetic equations (statistical equilibrium equations)
- hydrostatic equilibrium equation
- radiative equilibrium equation

$$\int_0^\infty (\chi_\nu J_\nu - \eta_\nu)\,\mathrm{d}\nu = 0$$

$$F = \text{const.}$$

TLUSTY code files

http://nova.astro.umd.edu/

- tlusty200.f code
- BASICS.FOR some important settings (dimensions of variables)
- ODFPAR.FOR opacity parameters
- ALIPAR.FOR, ATOMIC.FOR, IMPLIC.FOR, MODELQ.FOR, ARRAY1.FOR, ITERAT.FOR

compilation:
ifort [-O3 -mcmodel=medium] tlusty200.f

Input files

http://nova.astro.umd.edu/

- file 1: atmosphere (no file) / disc ("1")
- file 5: main file, model description
- files of individual ions
- nonstandard settings
- file 8: input model atmosphere, output from the previous run (if necessary)

File 5 (fort.5)

```
 10000. 4.0
 T  F                    ! LTE,  LTGRAY
'a10g4.nasta'            ! name of file contai
*
* frequencies
*
 100
*
* data for atoms
*
 30                      ! NATOMS
* mode abn modpf
  2   0.        0          ! H
```

File 5 (fort.5)

```
*
*iat iz nlevs ilast ilvlin nonstd typion
*
 1   0    9   0   0   0   ' H 1' 'data/h1.dat'
 1   1    1   1   0   0 ' H 2' ' '
 2   0   14   0   0   0   'He 1' 'data/he1.dat
 2   1   14   0   0   0   'He 2' 'data/he2.dat
 2   2    1   1   0   0   'He 3' ' '
 6   0   26   0   0   0   ' C 1' 'data/c1f.dat
 6   1   14   0   0   0   ' C 2' 'data/c2.dat'
 6   2    1   1   0   0   ' C 3' ' '
```

Model ion files

for each ion:

- levels
- photoionization cross-sections (even in LTE!)
- line transitions (even in LTE!)
- additional files for iron group elements

very important files

Nonstandard settings

```
NLAMBD=3,ITEK=4,XGRAD=0.,
NITER=91,ND=50,VTB=2.,
ICOLHN=1,ITLAS=0,
POPZER=1.D-30,POPZR2=1.D-30,
TAUFIR=1d-6
```

Example run

file `T1`:

```
MOD=$1
cp $MOD.8 fort.8
rm fort.9
~/tlusty/ahvez/tlusty200 <$MOD.5 >$MOD.6
cp fort.7 $MOD.7
cp fort.9 $MOD.9
cp fort.69 $MOD.69
cp fort.13 $MOD.13
```

run: `T1 300_1`, input files: `300_1.5, 300_1.8`

Output files

- file 6: basic model description
- file 7: output model atmosphere
- (file 8: input model)
- file 9: convergence log
- file 13: output file

CGS!

File 6 (fort.6)

- general model output
- tables with input data
- error messages
- information about convergence
- human readable model atmosphere

File 7 (fort.7)

- output model atmosphere
- output for additional calculations (fort.8)
- 1st line: number of depth points and variables
- next lines: column densities [g cm^{-2}]
- for each depth point: T [K], $n_{\rm e}$ [cm^{-3}], occupation numbers [cm^{-3}]

File 9 (fort.9)

- relative change of variables in each depth point during individual iterations

File 13 (fort.13)

- emergent flux
- dependence of H_ν [erg s^{-1} cm^{-2} Hz^{-1}] on frequency ν [s^{-1}]

Computational strategy

calculation from scratch:

1. LTE model, variables TAUFIR, TAULAS, and TAUDIV most important for the gray model, typically purely H-He model
2. inclusion of additional atoms (consecutively)
3. NLTE model

in some cases it is possible to calculate NLTE model directly from previous older NLTE model

Grids of calculated models

- starting models for further calculations
- sufficient for some purposes

OSTAR2002, BSTAR2006
http://nova.astro.umd.edu/

Additional model atmospheres

- CMFGEN (Hillier): source code and model grid
http://kookaburra.phyast.pitt.edu/hillier/web/CMFGEN.htm
- ATLAS (Kurucz): source codes and grids
http://wwwuser.oats.inaf.it/castelli/
- 3D model atmospheres (cool stars)
http://www.stagger-stars.net