FASMA tutorial

February 19, 2020

1 The configuration file

To use FASMA, configure the `config.cfg` which is in YAML format. The configuration file contains all the input parameters necessary for FASMA set by the user. Because this format is whitespace sensitive, you can check if the format is correct here: http://www.yamllint.com/ . This file must be in the folder where FASMA runs. There are various configuration combinations depending on what the user wants. A mandatory requirement is the line list and the interval file, where the whole path needs to be inserted. **The option Number 2 is recommended for the parameter determination.**

1. This is the simplest option for FASMA where a synthetic spectrum is created. The rest options are set to default.

```
#
star:
  linelist: /home/FASMA_synthesis/FASMA/rawLinelist/linelist.lst
  intervals_file: /home/FASMA_synthesis/FASMA/rawLinelist/intervals.lst
```

   The default line list is in the `rawLinelist` folder already provided within FASMA.

2. For a given line list select your options, e.g.:

```
#linelist options
star:
  linelist: /home/FASMA_synthesis/FASMA/rawLinelist/linelist.lst
  intervals_file: /home/FASMA_synthesis/FASMA/rawLinelist/intervals.lst
  fix_vmac: true
  fix_vt: true
  minimize: true
  refine: true
  observations: /home/FASMA_synthesis/FASMA/spectra/Sun_HARPS.fits
  resolution: 115000
  plot: true
```

   This example indicates that for the observed spectrum `Sun_HARPS.fits` with resolution 115000, FASMA will start the minimization process starting from solar values, keeping the parameters vmac and vt fixed and using the refine option (see below). This option was used to derive parameters in Tsantaki et al. (2018). The spectral regions for the synthesis are difined in the intervals.lst file with the option intervals_file. The final spectrum will be plotted. For the not listed options, FASMA uses the default ones. **The complete paths of the line list, spectrum, and intervals file should be given.** FASMA already includes the line list (`linelist.lst`), the interval file (`intervals.lst`) and a HARPS spectrum of the Sun (`Sun_HARPS.fits`)

3. For a given line list and a set of initial values, create a synthetic spectrum, save the output in the results folder and plot it.

```
#linelist options
star:
  teff: 5777
  logg: 4.44
  vmac: 3.21
  vsini: 1.9
  vt: 1.0
  linelist: /home/FASMA_synthesis/FASMA/rawLinelist/elements.lst
  intervals_file: /home/FASMA_synthesis/FASMA/rawLinelist/intervals_elements.lst.lst
  resolution: 115000
  plot: true
  save: true
```

4. This option will deliver chemical abundances of any of the provided elements ('Na', 'Mg', 'Al', 'Si', 'Ca', 'Sc', 'Ti', 'V', 'Cr', 'Mn', 'Ni'), in this case for Ti. Note that for this option the line list and intervals are different than for the stellar parameters. The options 'minimize' and 'elements' contradict each other.

```
#linelist options
star:
  teff: 5777
  logg: 4.44
  vmac: 3.21
  vsini: 1.9
  vt: 1.0
  element: 'Ti'
  linelist: /home/FASMA_synthesis/FASMA/rawLinelist/linelist.lst
  intervals_file: /home/FASMA_synthesis/FASMA/rawLinelist/intervals.lst
  observations: /home/FASMA_synthesis/FASMA/spectra/Sun_HARPS.fits
  resolution: 115000
  plot: true
  save: true
```

1.1 Default options

The default options of FASMA can be changed in the configuration file `config.cfg`.

1. `model:  marcs`

   The model atmospheres included in FASMA are: apogee_kurucz, and marcs.

2. `MOOGv:  2019`

   The version of MOOG currently is 2019 but can easily updated to newer versions. This is relevant only if the output files change for future updates of MOOG.

3. `save:  False`

   If save = True, the output synthetic spectrum is saved in the folder `results`. The output is saved in a .spec format and is read with the astropy.io fits module.

4.
```
teff:       False
logg:       False
feh:        False
vt:         False
vmac:       False
vsini:      False
```

   If any of these options is set, then they are fixed in the minimization process.

5.
```
plot:       False
plot_res:   False
```

   These are plotting options of the synthetic/observed spectra (plot) and of their residuals in case of minimization (plot_res).

6.
```
damping:    1
```

   The damping option of MOOG to deal with the van der Waals broadening. The acceptable values are: 0, 1, 2.

7.
```
step_wave:  0.01
step_flux:  3.0
```

   The wavelength step for the synthetic spectrum to be created and the flux limit to consider opacity distributions from the neighboring lines measured in Å. These are the same options of MOOG.

8.
```
minimize:   False
```

   If minimize appears in the options, the minimization process will start to find the best-fit parameters for the observed spectrum, therefore observations must be included in the options.

9.
```
refine:     False
```

   The refine option performs corrections on the derived parameters after the minimization for a more detailed analysis. After a first run, a second minimization starts with optimized microturbulence and macroturbulence values according to the parameters of the first run.

10.
```
observations: False
```

    The name of the spectrum is given here. The full path of the spectrum should be given.

11.
```
intervals_file:  intervals.lst
```

    This is the file which contains the intervals of the synthesis. FASMA already has specific intervals which correspond to the given line list. This file should be inside the `rawLinelist` folder. The complete path should be given.

12.
```
snr:        None
```

    The signal-to-noise (SNR) values of the observed spectra can be given by the user (optional). They are used in the normalization process. Otherwise the SNR is calculated by the PyAstronomy function within FASMA.

13. `resolution:  None`

    The resolution of the synthetic spectrum or the resolution of the observed spectrum. This value is necessary when minimization is on.

14. `limb:  0.6`

    The limb darkening coefficient for the vsini calculations. It is set fixed to 0.6 but can have different values depending on luminosity class.

15. `element:  False`

    This option will start the minimization process to derive the chemical abundance of a specific element. The element has to be set from this list: Na, Mg, Al, Si, Ca, Sc, Ti, V, Cr, Mn, Ni. In this case the line list and intervals are different than the standard derivation of the stellar parameters. They are also included in FASMA, elements.lst and `intervals_elements.lst`, respectively in the `rawLinelist` folder. For the derivation of the chemical abundance the minimize option should be False.

2 Run FASMA

There are different ways to run FASMA. FASMA is installed as a python module.

To run the batch version, the `config.cfg` file has to configured and then simply run:

```
fasma
```

If your configuration file is called something else (recommended for different projects), then run:

```
fasma myConf.cfg
```

The module can be imported in scripts to be run automatic for large lists of stars. To run the function to derive the stellar parameters:

```
python
>>> from FASMA import FASMA
>>> opt = {'minimize':True, 'observations':'Sun_HARPS.fits'} # Define the options here
>>> driver = FASMA(**opt)
>>> result = driver.result()
```

3 Input/Output files

This is a summary of the input files in the `rawLinelist` folder already provided by FASMA:

- `linelist.lst` – line list for the derivation of stellar parameters
- `intervals.lst` – the intervals where synthesis takes place. The line data are included in the above file.
- `elements.lst` – the line list the calculation of the chemical abundances
- `intervals_elements.lst` – the lines of the specific elements where the intervals are calculated

An example of the spectrum of the Sun with the HARPS spectrograph is provided at the `spectra` folder.
This is a summary of the output files:

- `synthresults.dat` – the final stellar parameters of the minimization process
- `synthresults_elements.dat` – the final chemical abundances of the minimization process
- `out.atm` – the interpolated stellar atmospheres
- `linelist.lst` – the line list in the format readable by MOOG
- `batch.par` – the configuration file of MOOG created by FASMA (see options in the `config.cfg` file)
- `result.out` – main parameters of the synthetic spectrum generated by MOOG
- `summary.out` – the synthetic spectrum generated by MOOG