spectacle Documentation

Release 0.4

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Jul 19, 2019

CONTENTS

Spectacle is an automated model generator for producing models that represent spectral data. It features the ability to reduce spectral data to its absorption components, fit features and continua, as well as allow for statistical analysis of spectral regions.

This package can also be used to generate analytical spectra from detailed characteristics, find potential line features, and simultaneously fit sets of absorption/emission lines.

Part I

Quick example

Include some setup imports for plotting and unit support.

```
>>> from astropy import units as u
>>> import numpy as np
>>> from matplotlib import pyplot as plt
>>> from astropy.visualization import quantity_support
>>> quantity_support()  # for getting units on the axes below  # doctest: +IGNORE_OUTPUT
```

Import the spectral model and profile model.

```
>>> from spectacle.modeling import Spectral1D, OpticalDepth1D
```

Create some HI lines to add to the spectral model. **Note** that all column densities are given in $\log 1/\mathrm{cm}^2$.

```
>>> line = OpticalDepth1D("HI1216", v_doppler=50 * u.km/u.s, column_density=14)
>>> line2 = OpticalDepth1D("HI1216", delta_v=100 * u.km/u.s)
```

Create the multi-component spectral model, defining a rest wavelength and explicitly defining some redshift value.

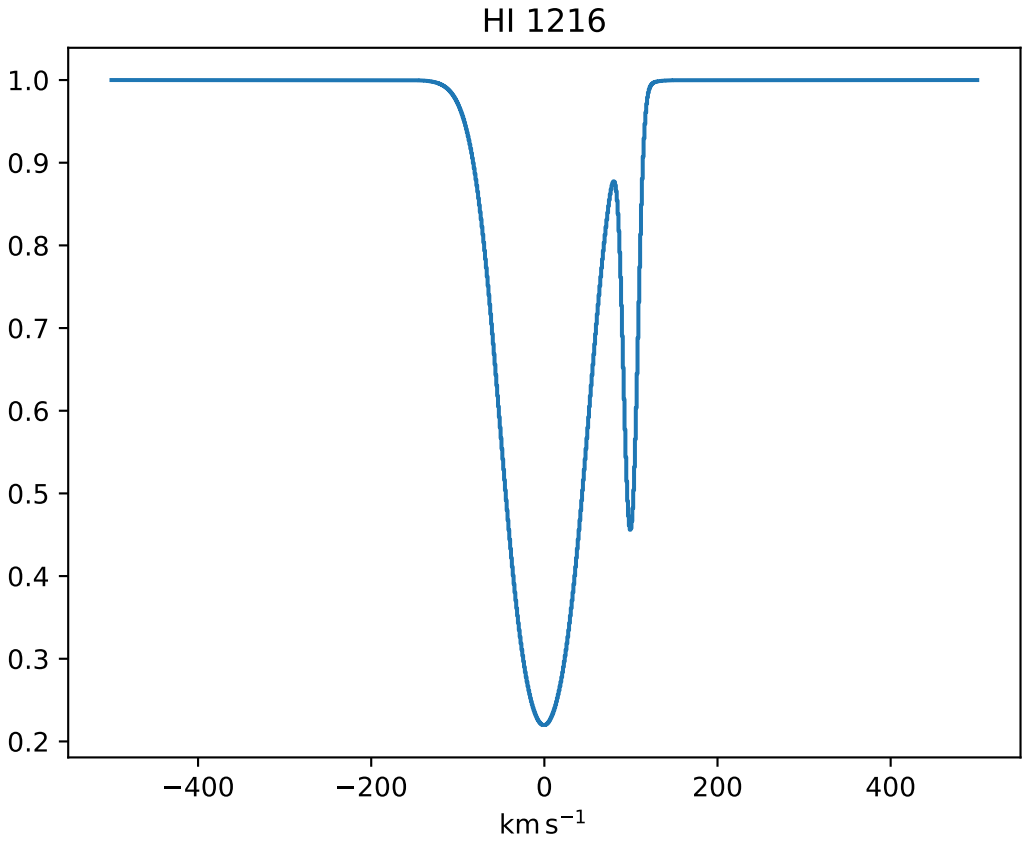
```
>>> spec_mod = Spectral1D([line, line2], continuum=1, z=0, output='flux')
```

Generate spectral data from the model.

```
>>> x = np.linspace(-500, 500, 1000) * u.Unit('km/s')
>>> y = spec_mod(x)
```

Plot the result.

```
>>> f, ax = plt.subplots()  # doctest: +IGNORE_OUTPUT
>>> ax.set_title("HI 1216")  # doctest: +IGNORE_OUTPUT
>>> ax.step(x, y)  # doctest: +IGNORE_OUTPUT
```


HI 1216
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
−400
−200
0
200
400
km s^{-1}

Part II

Using Spectacle

CHAPTER

ONE

INSTALLATION

1.1 Dependencies

The packages needed to run Spectacle should be installed automatically when the user installs the package. These dependencies include

- astropy>=3.1
- specutils>=0.4
- emcee > 3.0

1.2 Stable release

To install Spectacle, run this command in your terminal:

```
$ pip install spectacle
```

This is the preferred method to install Spectacle, as it will always install the most recent stable release.

If you don't have pip installed, this Python installation guide can guide you through the process.

1.3 From sources

The sources for Spectacle can be downloaded from the Github repo.

You can either clone the public repository:

```
$ git clone git://github.com/MISTY-pipeline/spectacle
```

Or download the tarball:

```
$ curl  -OL https://github.com/MISTY-pipeline/spectacle/tarball/master
```

Once you have a copy of the source, you can install it with:

```
$ python setup.py install
```

CHAPTER

TWO

CONTRIBUTING

Contributions are welcome, and they are greatly appreciated! Every little bit helps, and credit will always be given.

You can contribute in many ways:

2.1 Types of Contributions

2.1.1 Report Bugs

Report bugs at https://github.com/MISTY-pipeline/spectacle/issues.

If you are reporting a bug, please include:

- Your operating system name and version.
- Any details about your local setup that might be helpful in troubleshooting.
- Detailed steps to reproduce the bug.

2.1.2 Fix Bugs

Look through the GitHub issues for bugs. Anything tagged with "bug" and "help wanted" is open to whoever wants to implement it.

2.1.3 Implement Features

Look through the GitHub issues for features. Anything tagged with "enhancement" and "help wanted" is open to whoever wants to implement it.

2.1.4 Write Documentation

Spectacle could always use more documentation, whether as part of the official Spectacle docs, in docstrings, or even on the web in blog posts, articles, and such.

2.1.5 Submit Feedback

The best way to send feedback is to file an issue at https://github.com/MISTY-pipeline/spectacle/issues.

If you are proposing a feature:

- Explain in detail how it would work.
- Keep the scope as narrow as possible, to make it easier to implement.
- Remember that this is a volunteer-driven project, and that contributions are welcome :)

2.2 Get Started!

Ready to contribute? Here's how to set up `spectacle` for local development.

1. Fork the `spectacle` repo on GitHub.
2. Clone your fork locally:

```
$ git clone git@github.com:your_name_here/spectacle.git
```

3. Install your local copy into a virtualenv. Assuming you have Anaconda installed, this is how you set up your fork for local development:

```
$ conda create -n spectacle_env python=3
$ conda activate spectacle_env
$ cd spectacle/
$ python setup.py develop

Alternatively, if you have virtualenvwrapper installed::

$ mkvirtualenv spectacle
$ cd spectacle/
$ python setup.py develop
```

4. Create a branch for local development:

```
$ git checkout -b name-of-your-bugfix-or-feature
```

   Now you can make your changes locally.

5. When you're done making changes, check that your changes pass flake8 and the tests, including testing other Python versions with tox:

```
$ flake8 spectacle tests
$ python setup.py test or py.test
$ tox
```

   To get flake8 and tox, just pip install them into your virtualenv.

6. Commit your changes and push your branch to GitHub:

```
$ git add .
$ git commit -m "Your detailed description of your changes."
$ git push origin name-of-your-bugfix-or-feature
```

7. Submit a pull request through the GitHub website.

2.3 Pull Request Guidelines

Before you submit a pull request, check that it meets these guidelines:

1. The pull request should include tests.
2. If the pull request adds functionality, the docs should be updated. Put your new functionality into a function with a docstring, and add the feature to the list in README.rst.
3. The pull request should work for Python 2.6, 2.7, 3.3, 3.4 and 3.5, and for PyPy. Check https://travis-ci.org/MISTY-pipeline/spectacle/pull_requests and make sure that the tests pass for all supported Python versions.

2.4 Tips

To run a subset of tests:

```
$ py.test tests.test_spectacle
```

CHAPTER

THREE

GETTING STARTED

Spectacle is designed to facilitate the creation of complex spectral models. It is built on the Astropy modeling module. It can create representations of spectral data in wavelength, frequency, or velocity space, with any number of line components. These models can then be fit to data for use in individual ion reduction, or characterization of spectra as a whole.

3.1 Creating a spectral model

The primary class is the `Spectral1D`. This serves as the central object through which the user will design their model, and so exposes many parameters to the user.

`Spectral1D` models are initialized with several descriptive properties:

Attribute	Description
`z`	This is the redshift of the spectrum. It can either be a single numerical value, or an array describing the redshift at each e.g. velocity bin. Note if the user provides an array, the length of the redshift array must match the length of the dispersion array used as input to the model. *Default: 0*
`rest_wavelength`	The wavelength at which transformations from wavelength space to velocity space will be performed. *Default: 0 Angstrom*
`output`	Describes the type of data the spectrum model will produce. This can be one of `flux`, `flux_decrement`, or `optical_depth`. *Default: 'flux'*
`continuum`	An `FittableModel1D` or single numeric value representing the continuum for the spectral model. *Default: 0*
`lsf`	The line spread function to be applied to the model. Users can provided an `LSFModel`, a `Kernel1D`, or a string indicating either `cos` for the COS LSF, or `guassian` for a Gaussian LSF. In the latter case, the user should provide key word arguments as parameters for the Gaussian profile.
`lines`	The set of lines to be added to the spectrum. This information is passed to the `OpticalDepth1D` initializer. This can either be a single `OpticalDepth1D` instance, a list of `OpticalDepth1D` instances; a single string representing the name of an ion (e.g. "HI1216"), a list of such strings; a single `Quantity` value representing the rest wavelength of an ion, or a list of such values.

The `Spectral1D` does not require that any lines be provided initially. In that case, it will just generate data only considering the continuum and other properties.

3.2 Providing lines to the initializer

As mentioned in the table above, lines can be added by passing a set of `OpticalDepth1D` instances, ion name strings, or rest wavelength `Quantity` objects to the initializer.

Using a set of `OpticalDepth1D` instances:

```
line = OpticalDepth1D("HI1216", v_doppler=50 * u.km/u.s, column_density=14)
line2 = OpticalDepth1D("HI1216", delta_v=100 * u.km/u.s)
spec_mod = Spectral1D([line, line2])
```

Using ion name strings:

```
spec_mod = Spectral1D(["HI1216", "OVI1032"])
```

Using rest wavelength `Quantity` objects:

```
spec_mod = Spectral1D([1216 * u.Angstrom, 1032 * u.Angstrom])
```

3.3 Adding lines after model creation

Likewise, the user can add a line to an already made spectral model by using the `with_line()` method, and provide to it information accepted by the `OpticalDepth1D` class

```
>>> from spectacle import Spectral1D
>>> import astropy.units as u
>>> spec_mod = Spectral1D([1216 * u.AA])
>>> spec_mod = spec_mod.with_line("HI1216", v_doppler=50 * u.km/u.s, column_density=14)
>>> print(spec_mod)
Model: Spectral1D
Inputs: ('x',)
Outputs: ('y',)
Model set size: 1
Parameters:
    amplitude_0 z_1 lambda_0_2 f_value_2   gamma_2   v_doppler_2 column_density_2 delta_v_2 delta_
↪lambda_2 lambda_0_3 f_value_3   gamma_3   v_doppler_3 column_density_3 delta_v_3 delta_lambda_3 z_5
                     Angstrom                              km / s                        km / s     Angstrom␣
↪    Angstrom                            km / s                       km / s     Angstrom
    ----------- --- ---------- --------- ----------- ----------- ---------------- --------- ------------
↪-- ---------- --------- ----------- ----------- ---------------- --------- -------------- ---
            0.0 0.0  1215.6701    0.4164 626500000.0        10.0             13.0       0.0           ␣
↪0.0  1215.6701    0.4164 626500000.0        50.0             14.0       0.0            0.0 0.0
```

CHAPTER

FOUR

MODELING

The purpose of Spectacle is to provide a descriptive model of spectral data, where each absorption or emission feature is characterized by an informative Voigt profile. To that end, there are several ways in which users can generate this model to more perfectly match their data, or the data they wish to create.

4.1 Defining output data

Support for three different types of output data exists: `flux`, `flux_decrement`, and `optical_depth`. This indicates the type of data that will be outputted when the model is run. Output type can be specified upon creation of a `spectacle.modeling.Spectral1D` object:

```
spec_mod = Spectral1D("HI1216", output='optical_depth')
```

Spectacle internally deals in optical depth space, and optical depth information is transformed into flux as a step in the compound model.

For flux transformations:

$$f(y) = np.exp(-y) - 1$$

And for flux decrement transformations:

$$f(y) = 1 - np.exp(-y) - 1$$

All output types use the continuum information when depositing absorption or emission data into the dispersion bins. Likewise, `flux` and `flux_decrement` will generate results that may be saturated.

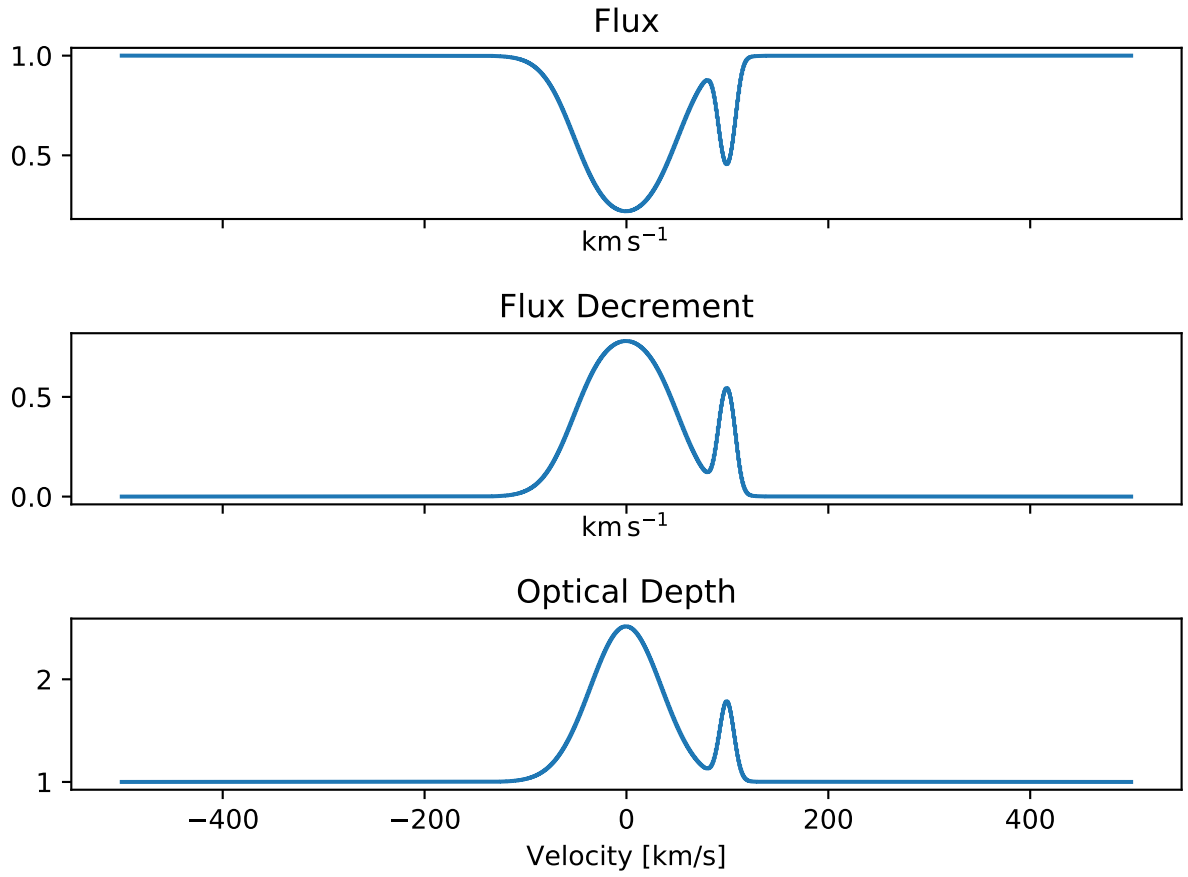
```
>>> from astropy import units as u
>>> import numpy as np
>>> from matplotlib import pyplot as plt
>>> from spectacle.modeling import Spectral1D, OpticalDepth1D
```

```
>>> line = OpticalDepth1D("HI1216", v_doppler=50 * u.km/u.s, column_density=14)
>>> line2 = OpticalDepth1D("HI1216", delta_v=100 * u.km/u.s)
```

```
>>> spec_mod = Spectral1D([line, line2], continuum=1, output='flux')
>>> x = np.linspace(-500, 500, 1000) * u.Unit('km/s')
```

```
>>> flux = spec_mod(x)
>>> flux_dec = spec_mod.as_flux_decrement(x)
>>> tau = spec_mod.as_optical_depth(x)
```

```
>>> f, (ax1, ax2, ax3) = plt.subplots(3, 1, sharex=True)
>>> ax1.set_title("Flux") # doctest: +IGNORE_OUTPUT
>>> ax1.step(x, flux) # doctest: +IGNORE_OUTPUT
>>> ax2.set_title("Flux Decrement") # doctest: +IGNORE_OUTPUT
>>> ax2.step(x, flux_dec) # doctest: +IGNORE_OUTPUT
>>> ax3.set_title("Optical Depth") # doctest: +IGNORE_OUTPUT
>>> ax3.step(x, tau) # doctest: +IGNORE_OUTPUT
>>> ax3.set_xlabel('Velocity [km/s]') # doctest: +IGNORE_OUTPUT
>>> f.tight_layout()
```



4.2 Applying line spread functions

LSFs can be added to the `Spectral1D` model to generate data that more appropriately matches what one might expect from an instrument like, e.g., HST COS

```
>>> from astropy import units as u
>>> import numpy as np
>>> from matplotlib import pyplot as plt
>>> from spectacle.modeling import Spectral1D, OpticalDepth1D
```

```
>>> line1 = OpticalDepth1D("HI1216", v_doppler=500 * u.km/u.s, column_density=14)
>>> line2 = OpticalDepth1D("OVI1032", v_doppler=500 * u.km/u.s, column_density=15)
```

LSFs can either be applied directly during spectrum model creation:

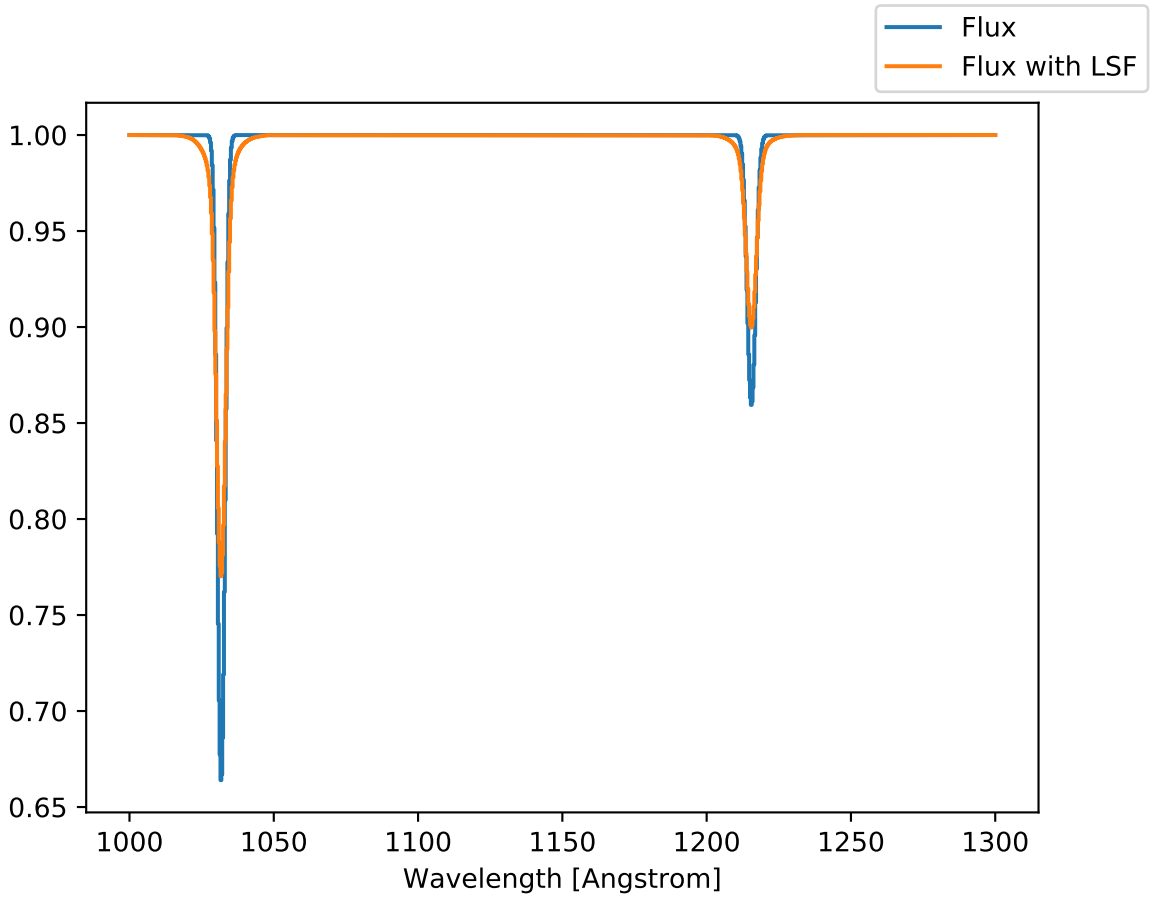
```
>>> spec_mod_with_lsf = Spectral1D([line1, line2], continuum=1, lsf='cos', output='flux')
```

or they can be applied after the fact:

```
>>> spec_mod = Spectral1D([line1, line2], continuum=1, output='flux')
>>> spec_mod_with_lsf = spec_mod.with_lsf('cos')
```

```
>>> x = np.linspace(1000, 1300, 1000) * u.Unit('Angstrom')
```

```
>>> f, ax = plt.subplots()
>>> ax.step(x, spec_mod(x), label="Flux") # doctest: +IGNORE_OUTPUT
>>> ax.step(x, spec_mod_with_lsf(x), label="Flux with LSF") # doctest: +IGNORE_OUTPUT
>>> ax.set_xlabel("Wavelength [Angstrom]")  # doctest: +IGNORE_OUTPUT
>>> f.legend(loc=0)  # doctest: +IGNORE_OUTPUT
```



4.2.1 Supplying custom LSF kernels

Spectacle provides two built-in LSF kernels: the HST COS kernel, and a Gaussian kernel. Both can be applied by simply passing in a string, and in the latter case, also supplying an additional `stddev` keyword argument:

```
.. code-block:: python
```

spec_mod = Spectral1D("HI1216", continuum=1, lsf='cos') spec_mod = Spectral1D("HI1216", continuum=1, lsf='gaussian', stddev=15)

Users may also supply their own kernels, or any Astropy 1D kernel. The only restriction is that kernels must be a subclass of either `LSFModel`, or `Kernel1D`.

```
from astropy.convolution import Box1DKernel
kernel = Box1DKernel(width=10)

spec_mod_with_lsf = Spectral1D([line1, line2], continuum=1, lsf=kernel, output='flux')
```

4.3 Converting dispersions

Spectacle supports dispersions in either wavelength space or velocity space, and will implicitly deal with conversions internally as necessary. Conversion to velocity space is calculated using the relativistic doppler equation

$$V = c\frac{f_0^2 - f^2}{f_0^2 + f^2},$$
$$f(V) = f_0\frac{\left(1 - (V/c)^2\right)^{1/2}}{(1 + V/c)}.$$

This of course makes the assumption that observed redshift is due to relativistic effects along the light of sight. At higher redshifts, however, the predominant source of observed redshift is due to the cosmological expansion of space, and not the source's velocity with respect to the observer.

It is possible to set the approximation used in wavelength/frequency to velocity conversions for Spectacle. Aside from the default relativistic calculation, users can choose the "optical definition"

$$V = c\frac{f_0 - f}{f}$$
$$f(V) = f_0(1 + V/c)^{-1}$$

or the "radio definition"

$$V = c\frac{f_0 - f}{f_0}$$
$$f(V) = f_0(1 - V/c).$$

This can be done upon instantiation of the `Spectral1D` model:

```
spec_mod = Spectral1D("HI1216", continuum=1, z=0, velocity_convention='optical')
```

The `velocity_convention` keyword supports one of either `relativisitic`, `optical`, or `radio` to indiciate the definition to be used in internal conversions.

4.4 Implementing redshift

When creating a `Spectral1D` model, the user can provide a redshift at which the output spectrum will deposit the lines by including a `z` parameter.

Note: When *fitting*, including the z parameter indicates the redshift of the *input* dispersion. Spectacle will de-redshift the data input using this value before performing any fits. Also, the provided continuum is *not* included in redshifting.

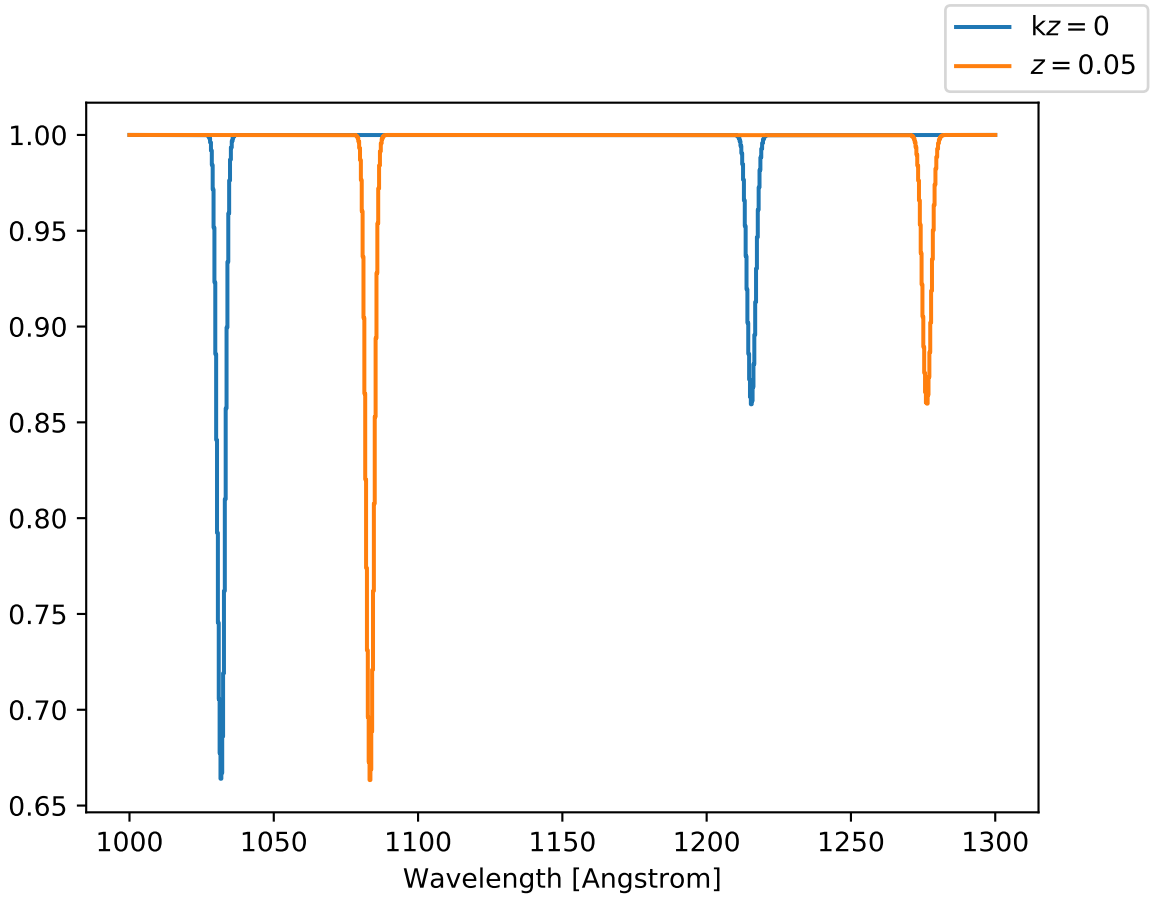
```
>>> from astropy import units as u
>>> import numpy as np
>>> from matplotlib import pyplot as plt
>>> from spectacle.modeling import Spectral1D, OpticalDepth1D
```

```
>>> line1 = OpticalDepth1D("HI1216", v_doppler=500 * u.km/u.s, column_density=14)
>>> line2 = OpticalDepth1D("OVI1032", v_doppler=500 * u.km/u.s, column_density=15)
```

```
>>> spec_mod = Spectral1D([line1, line2], continuum=1, z=0, output='flux')
>>> spec_mod_with_z = Spectral1D([line1, line2], continuum=1, z=0.05, output='flux')
```

```
>>> x = np.linspace(1000, 1300, 1000) * u.Unit('Angstrom')
```

```
>>> f, ax = plt.subplots()  # doctest: +SKIP
>>> ax.step(x, spec_mod(x), label="k$z=0$") # doctest: +SKIP
>>> ax.step(x, spec_mod_with_z(x), label="$z=0.05$")  # doctest: +SKIP
>>> ax.set_xlabel("Wavelength [Angstrom]")  # doctest: +SKIP
>>> f.legend(loc=0)  # doctest: +SKIP
```

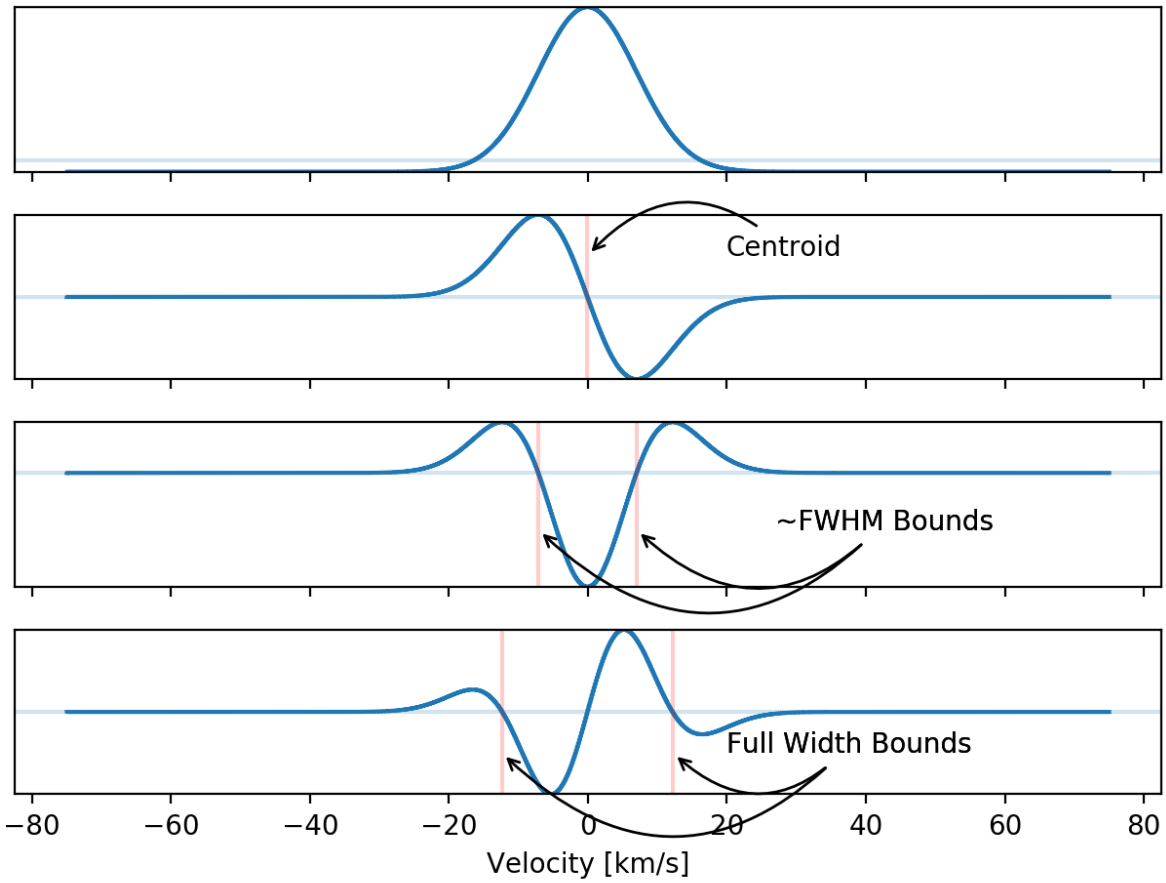


CHAPTER

FIVE

LINE FINDING

Spectacle has automated line-finding and characterization, including support for blended features. The line finder uses a series of convolutions to indicate where the slope of the spectrum changes, and uses these positions to characterize the shape of the absorption or emission lines. Such characterization includes finding the centroid, the width of the line, and the whether or not lines are buried within the region of another.



The line finder will return a generated spectral model from the found lines.

5.1 Auto-generate spectral model

The inputs to the `LineFinder` class help dictate the behavior of the finding routine and what lines the finder will consider when it believes it has found a feature.

The user may note that the line finder takes many of the same parameters accepted when creating a `Spectral1D` model explicitly. This is because these parameter are based onto the internal initialization of the spectral model. The accepted line finder arguments are summarized in the table below.

Argument	Description
ions	The subset of ion information to use when parsing potential profiles in the spectral data.
continuum	A `FittableModel1D` or single numeric value,representing the continuum for the spectral model. *Default: 0*
defaults	A dictionary describing the default arguments passed to internal `OpticalDepth1D` profiles.
auto_fit	Whether the line finder should attempt to automatically fit the resulting spectral model to the provided data.
velocity_convention	The velocity convention used in internal conversions between wavelength/frequency and velocity space.
output	Describes the type of data the spectrum model will produce. This can be one of `flux`, `flux_decrement`, or `optical_depth`. *Default: 'flux'*

The `ions` argument allows the user to select a subset of the entire ion table for the line finder to use when attempting to parse a particular profile. If no ions are provided, the entire ion table will be searched to find the ion whose λ_0 most closely aligns with the detected centroid.

Note: Currently, when running the line finder in velocity space, only one ion definition is supported at a time. This is because there is no way to disambiguate the kinematics of multiple ions simultaneously in velocity space.

As an example of the line finder functionality, let us define two lines within a set of "fake" data.

```
line1 = OpticalDepth1D("HI1216", v_doppler=20 * u.km/u.s, column_density=16)
line2 = OpticalDepth1D("OVI1032", v_doppler=60 * u.km/u.s, column_density=14)

spec_mod = Spectral1D([line1, line2], continuum=1, output='optical_depth')
```

We will describe the lines in wavelength space to disambiguate their emission profiles without considering kinematics.

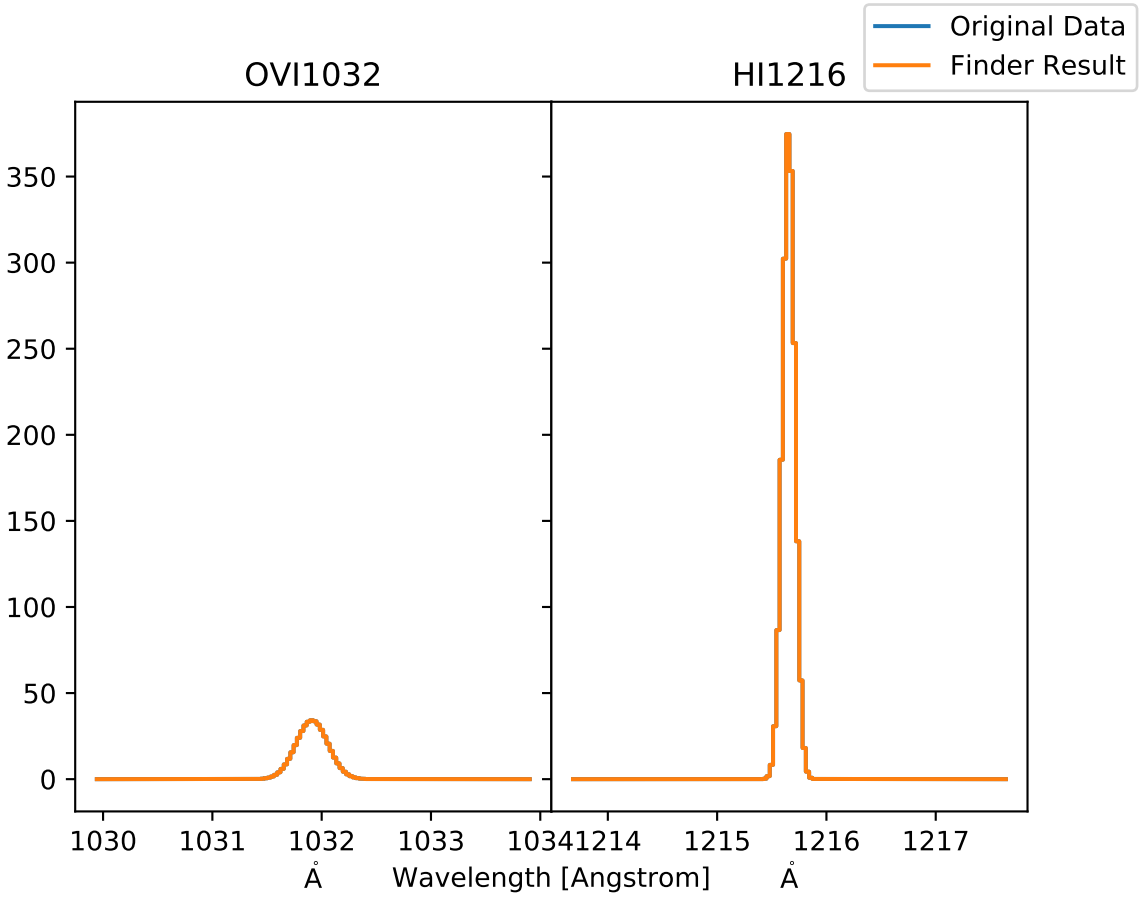
```
x = np.linspace(1000, 1300, 1000) * u.Unit('Angstrom')
y = spec_mod(x)
```

Now we tell the line finder that there are two possible lines that any feature it comes across could be. Doing so means that any `OpticalDepth1D` profiles generated will be given the correct attributes (e.g. `f_value`, `gamma`, etc.) when the line finder attempts to lookup the ion in the ion table.

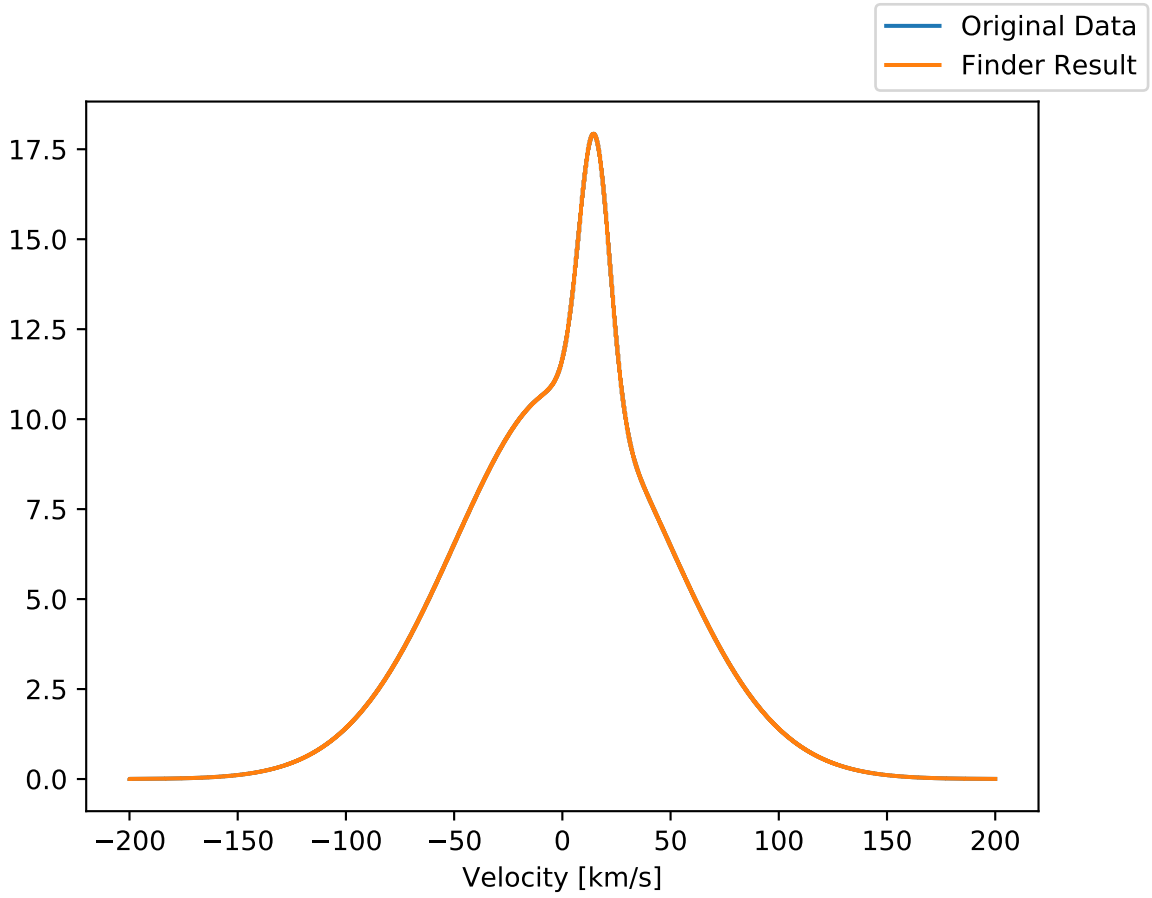
```
line_finder = LineFinder1D(ions=["HI1216", "OVI1032"], continuum=0, output='optical_depth')
finder_spec_mod = line_finder(x, y)
```

5.1.1 Dealing with buried lines

The line finder will implicitly deal with buried lines by considering the results of the series of convolutions and looking for characteristics that might indicate that the peak of a line is buried within the region of another profile.


Original Data
Finder Result
OVI1032
HI1216
350
300
250
200
150
100
50
0
1030
1031
1032
1033
1034
1214
1215
1216
1217
Å
Wavelength [Angstrom]
Å

The basic premise for determining the possibility of a buried line is to compare the bounds of the second differencing convolution with that of the third. A buried line is one which, in both cases, share the same found centroid, but two different sets of region bounds.



5.2 Defining default parameters

The line finder class can accept a `defaults` dictionary whose values will be applied when new `OpticalDepth1D` profiles are initialized. This is an easy way, for example, to manually set global parameter bounds information that would otherwise be up to Spectacle to determine.

```
defaults_dict = {
    'v_doppler': {
        'bounds': (-10, 10),
        'fixed': False
    },
    'column_density' = {
        'bounds': (13, 18)
    }
}

line_finder = LineFinder1D(ions=["HI1216"], defaults=defaults_dict, continuum=0, output='optical_depth')
```

5.3 Searching for ion subsets

As mentioned above, the line finder attempts to retrieve information about a potential profile by looking up the detected centroid in the ion table and selecting the nearest match. (A more extensive overview of the line registry can be found in the *line registry docs*). The user can provide a subset of ions that will help to narrow the possible options available to the line finder by passing in a list of ion names or λ_0 values. The default ion list is provided by Morton (2003).

Subsets behave by limiting the entire table of ions in the registry to some specified list:

```
>>> from spectacle.registries.lines import line_registry
>>> print(line_registry)

<LineRegistry length=329>
  name      wave    osc_str     gamma
          Angstrom
  str9    float64   float64    float64
-------- --------- --------- ------------
  HI1216 1215.6701    0.4164  626500000.0
  HI1026 1025.7223   0.07912  189700000.0
   HI973  972.5368     0.029   81270000.0
   HI950  949.7431   0.01394   42040000.0
   HI938  937.8035  0.007799   24500000.0
   HI931  930.7483  0.004814   12360000.0
   HI926  926.2257  0.003183    8255000.0
     ...       ...       ...          ...
NiII1317  1317.217   0.07786  420500000.0
CuII1368 1367.9509     0.179  623000000.0
CuII1359  1358.773    0.3803  720000000.0
ZnII2063  2062.664     0.256  386000000.0
ZnII2026  2026.136     0.489  407000000.0
GeII1602 1602.4863    0.1436  990600000.0
GaII1414  1414.402       1.8 1970000000.0

>>> subset = line_registry.subset(["HI1216", "NiII1468", "ZnII2026", "CoII1425"])
>>> print(subset)

<LineRegistry length=4>
  name      wave   osc_str    gamma
          Angstrom
  str9    float64  float64   float64
-------- --------- ------- -----------
CoII1425 1424.7866  0.0109  35800000.0
  HI1216 1215.6701  0.4164 626500000.0
NiII1468  1467.756  0.0099  23000000.0
ZnII2026  2026.136   0.489 407000000.0
```

Passing in a list to the `spectacle.fitting.LineFinder1D` will internally do this for the user

```
line_finder = LineFinder1D(ions=["HI1216", "NiII1468", "ZnII2026", "CoII1425"], continuum=0, output=
↪'optical_depth')
```

Warning: Only a single ion can be defined for the line finder if the user provides the dispersion in velocity space. This is because the line finder cannot disambiguate ions based on their kinematics.

CHAPTER

SIX

FITTING

The core `Spectral1D` behaves exactly like an Astropy model and can be used with any of the supported non-linear Astropy fitters, as well as some not included in the Astropy library.

Spectacle provides a default Levenberg–Marquardt fitter in the `CurveFitter` class.

```
>>> from spectacle.fitting import CurveFitter
>>> from spectacle.modeling import Spectral1D, OpticalDepth1D
>>> import astropy.units as u
>>> from matplotlib import pyplot as plt
>>> import numpy as np
```

Generate some fake data to fit to:

```
>>> line1 = OpticalDepth1D("HI1216", v_doppler=10 * u.km/u.s, column_density=14)
>>> spec_mod = Spectral1D(line1, continuum=1)
>>> x = np.linspace(-200, 200, 1000) * u.Unit('km/s')
>>> y = spec_mod(x) + (np.random.sample(1000) - 0.5) * 0.01
```

Instantiate the fitter and fit the model to the data:

```
>>> fitter = CurveFitter()
>>> fit_spec_mod = fitter(spec_mod, x, y)
```

Users can see the results of the fitted spectrum by printing the returned model object

```
>>> print(fit_spec_mod)  # doctest: +SKIP
Model: Spectral1D
Inputs: ('x',)
Outputs: ('y',)
Model set size: 1
Parameters:
    amplitude_0 z_1 lambda_0_2 f_value_2   gamma_2      v_doppler_2      column_density_2      delta_v_
↪2          delta_lambda_2    z_4
                   Angstrom                                km / s                                km / s␣
↪             Angstrom
    ----------- --- ---------- --------- ----------- ------------------ ------------------ -------------
↪----- -------------------- ---
            1.0 0.0  1215.6701    0.4164 626500000.0 10.010182187404824 13.998761432240995 1.
↪0052009119192702 -0.004063271434522016 0.0
```

Plot the results:

```
>>> f, ax = plt.subplots()  # doctest: +SKIP
>>> ax.step(x, y, label="Data")  # doctest: +SKIP
```

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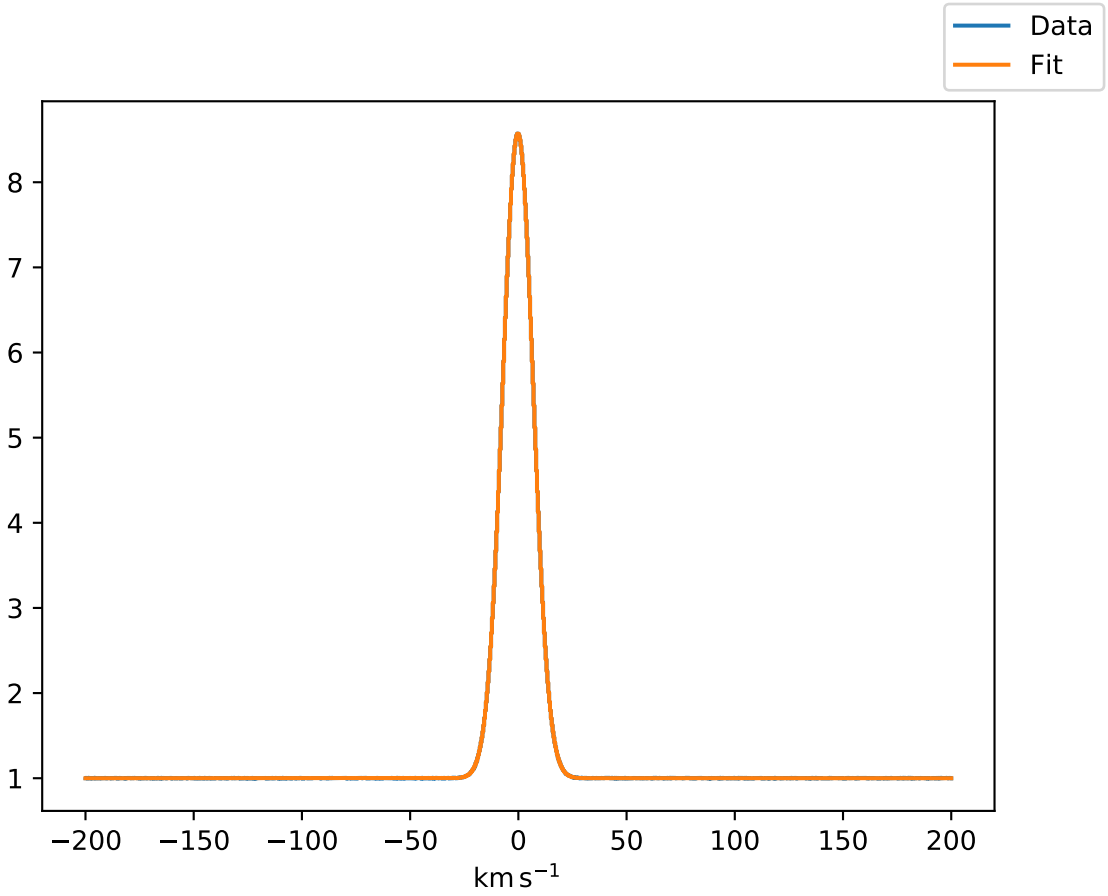
(continued from previous page)

```
>>> ax.step(x, fit_spec_mod(x), label="Fit")  # doctest: +SKIP
>>> f.legend()  # doctest: +SKIP
```



On both the `CurveFitter` class and the `EmceeFitter` class described below, parameter uncertainties can be accessed through the `uncertainties` property of the instantiated fitter after the fitting routine has run.

```
>>> fitter.uncertainties
    <QTable length=9>
      name               value                 uncert          unit
     str16              float64               float64         object
--------------- --------------------- -------------------- --------
            z_0                   0.0                  0.0     None
     lambda_0_1               1215.6701                 0.0 Angstrom
       f_value_1                  0.4164                 0.0     None
         gamma_1             626500000.0                 0.0     None
     v_doppler_1     10.000013757295898  0.000957197044912263   km / s
column_density_1     14.000043173540684 3.589807779429899e-05     None
       delta_v_1 0.00011598087488537782 0.0006777042342563724   km / s
  delta_lambda_1                   0.0                  0.0 Angstrom
     amplitude_2                   1.0                  0.0     None
```

6.1 Using the MCMC fitter

Spectacle provides Bayesian fitting through the emcee package. This is implemented in the `EmceeFitter` class. The usage is similar above, but extra arguments can be provided to control the number of walkers and the number of iterations.

```
from spectacle.fitting import EmceeFitter
...

fitter = EmceeFitter()
fit_spec_mod = fitter(spec_mod, x, y, , nwalkers=250, steps=100, nprocs=8)
```

The fitted parameter results are given as the value at the 50th quantile of the distribution of walkers. The uncertainties on the values can be obtained through the `uncertainties` property on the `fitter` instance, and provide the 16th quantile and 80th quantile for the lower and upper bounds on the value, respectively.

Note: The MCMC fitter is a work in progress. Its results are dependent on how long the fitter runs and how many walkers are provided.

6.2 Custom fitters with the line finder

The `LineFinder1D` class can also be passed a fitter instance if the user wishes to use a specific type. If no explicit fitting class is passed, the default `CurveFitter` is used. Fitter-specific arguments can be passed into the `fitter_args` keyword as well.

```
line_finder = LineFinder1D(ions=["HI1216", "OVI1032"], continuum=0,
                           output='optical_depth', fitter=LevMarLSQFitter(),
                           fitter_args={'maxiter': 1000})
```

More information on using the line finder can be found in the *line finding documentation*.

CHAPTER

SEVEN

REGISTRIES

Spectacle uses an internal database of ions in order to look up relevant atomic line information (specifically, oscillator strength, gamma values, and rest-frame wavelength). Spectacle provides an extensive default ion registry taken from Morton 2003. However, it is possible for users to provide their own registries.

Spectacle searches the line registry for an atomic transition with the closest rest-frame wavelength to the line in question. Alternatively, users can provide a specific set of lines with associated atomic information for Spectacle to use.

```
>>> from spectacle.registries import line_registry
>>> import astropy.units as u
```

Users can query the registry by passing in the restframe wavelength, λ_0, information for an ion

```
>>> from spectacle.registries import line_registry
>>> line_registry.with_lambda(1216 * u.AA)
<Row index=0>
 name     wave   osc_str    gamma
        Angstrom
 str9   float64  float64   float64
------ --------- ------- -----------
HI1216 1215.6701  0.4164 626500000.0
```

Alternatively users can pass ion names in their queries. Spectacle will attempt to find the closets alpha-numerical match using an internal auto-correct:

```
>>> from spectacle.registries import line_registry
>>> line_registry.with_name("HI1215")
spectacle [INFO    ]: Found line with name 'HI1216' from given name 'HI1215'.
<Row index=0>
 name     wave   osc_str    gamma
        Angstrom
 str9   float64  float64   float64
------ --------- ------- -----------
HI1216 1215.6701  0.4164 626500000.0
```

The default ion registry can be seen in its entirety here.

7.1 Adding your own ion registry

Users can provide their own registries to replace the internal default ion database used by Spectacle. The caveat is that the file must be an ECSV file with four columns: `name`, `wave`, `osc_str`, `gamma`. The user's file can then be loaded by importing and the `spectacle.registries.LineRegistry` and declaring the `line_registry` variable

```
>>> from spectacle.registries import LineRegistry
>>> line_registry = LineRegistry.read("/path/to/ion_file.ecsv")
```

CHAPTER

EIGHT

ANALYSIS

Spectacle comes with several statistics on the line profiles of models. These can be accessed via the `line_stats()` method on the spectrum object, and will display basic parameter information such as the centroid, column density, doppler velocity, etc. of each line in the spectrum.

Three additional statistics are added to this table as well: the equivalent width (`ew`), the velocity delta covering 90% of the flux value (`dv90`), and the full width half maximum (`fwhm`) of the feature.

```
>>> spec_mod.line_stats(x)

<QTable length=2>
  name     wave    col_dens  v_dop  delta_v delta_lambda          ew                dv90               fwhm
         Angstrom            km / s  km / s   Angstrom         Angstrom            km / s            Angstrom
bytes10  float64   float64  float64 float64   float64          float64            float64            float64
------- --------- -------- ------- ------- ------------ ------------------ ------------------ ---------- -----------
 HI1216 1215.6701     13.0     7.0     0.0          0.0 0.05040091274475814  15.21521521521521 0.04870914429488948
 HI1216 1215.6701     13.0    12.0    30.0          0.0 0.08632151159859157 26.426426426426445 0.08119004034051613
```

The `dv90` statistic is calculated following the "Velocity Interval Test" formulation defined in Prochaska & Wolf (1997). In this case, the optical depth of the profile is calculated in velocity space, and 5% of the total is trimmed from each side, leaving the velocity width encompassing the central 90%.

8.1 Arbitrary line region statistics

It is also possible to perform statistical operations over arbitrary absorption or emission line regions. Regions are defined as contiguous portions of the profile beyond some threshold.

```
>>> from spectacle.modeling import Spectral1D, OpticalDepth1D
>>> import astropy.units as u
>>> from matplotlib import pyplot as plt
>>> import numpy as np
>>> from astropy.visualization import quantity_support
>>> quantity_support()  # doctest: +IGNORE_OUTPUT
```

We'll go ahead and compose a spectrum in velocity space of two HI line profiles, with one offset by $30 \frac{km}{s}$.

```
>>> line1 = OpticalDepth1D(lambda_0=1216 * u.AA, v_doppler=7 * u.km/u.s, column_density=13, delta_v=0 *␣
↪u.km/u.s)
>>> line2 = OpticalDepth1D("HI1216", delta_v=30 * u.km/u.s,  v_doppler=12 * u.km/u.s, column_density=13)
```

```
>>> spec_mod = Spectral1D([line1, line2], continuum=1, output='flux')
```

```
>>> x = np.linspace(-200, 200, 1000) * u.km / u.s
>>> y = spec_mod(x)
```

Now, print the statistics on this absorption region.

```
>>> region_stats = spec_mod.region_stats(x, rest_wavelength=1216 * u.AA, abs_tol=0.05)
>>> print(region_stats)   # doctest: +IGNORE_OUTPUT
    region_start        region_end     rest_wavelength          ew                dv90              ␣
↪fwhm
       km / s             km / s           Angstrom          Angstrom            km / s           ␣
↪Angstrom
------------------- ------------------ --------------- ------------------ ----------------- -----------
↪---------
-12.612612612612594 48.648648648648674          1216.0 0.12297380252108686 46.44644644644646 0.
↪056842794376279926
```

Plot to show the found bounds of the contiguous absorption region.

```
>>> f, ax = plt.subplots()  # doctest: +IGNORE_OUTPUT
>>> ax.axhline(0.95, linestyle='--', color='k', alpha=0.5)  # doctest: +IGNORE_OUTPUT
>>> for row in region_stats:
...     ax.axvline(row['region_start'].value, color='r', alpha=0.5)  # doctest: +IGNORE_OUTPUT
...     ax.axvline(row['region_end'].value, color='r', alpha=0.5)  # doctest: +IGNORE_OUTPUT
>>> ax.step(x, y)  # doctest: +IGNORE_OUTPUT
```

8.2 Re-sampling dispersion grids

Spectacle provides a means of doing flux-conversing re-sampling by generating a re-sampling matrix based on an input spectral dispersion grid and a desired output grid.

```
>>> from spectacle.modeling import Spectral1D, OpticalDepth1D
>>> from spectacle.analysis import Resample
>>> import astropy.units as u
>>> from matplotlib import pyplot as plt
>>> import numpy as np
>>> from astropy.visualization import quantity_support
>>> quantity_support()  # doctest: +IGNORE_OUTPUT
```

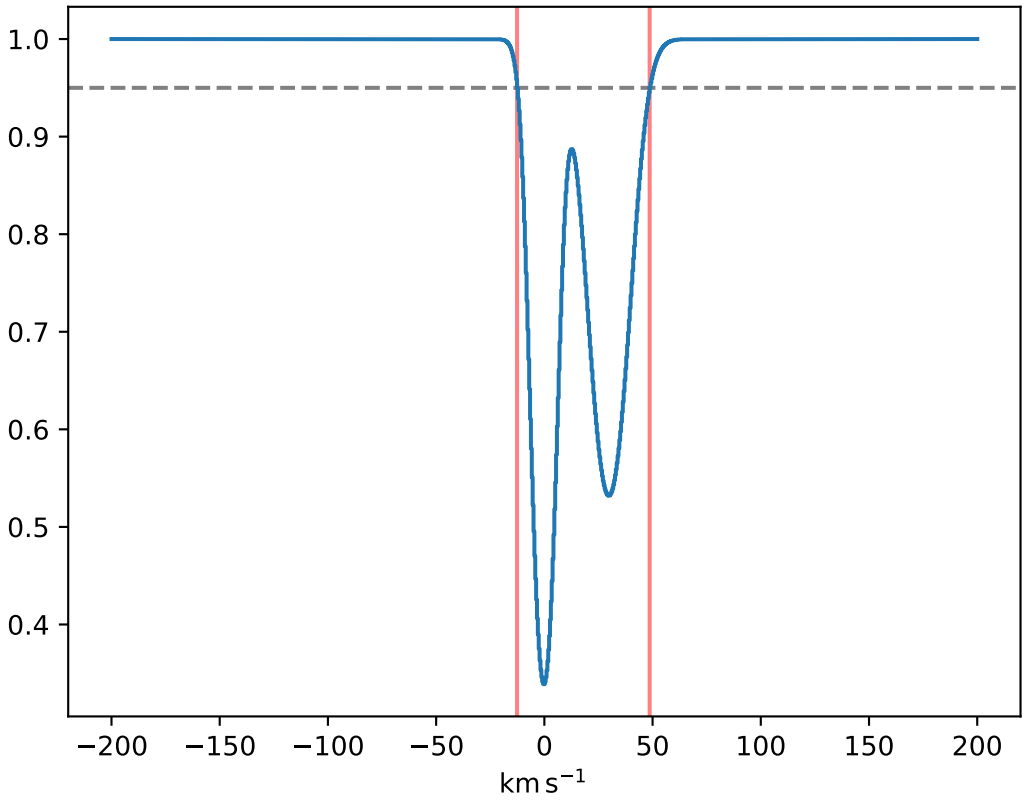
Create a basic spectral model.

```
>>> line1 = OpticalDepth1D("HI1216")
>>> spec_mod = Spectral1D(line1)
```

Define our original, highly-sampled dispersion grid.

```
>>> vel = np.linspace(-50, 50, 1000) * u.km / u.s
>>> tau = spec_mod(vel)
```

Define a new, lower-sampled dispersion grid we want to re-sample to.


1.0
0.9
0.8
0.7
0.6
0.5
0.4
−200
−150
−100
−50
0
50
100
150
200
km s^{-1}

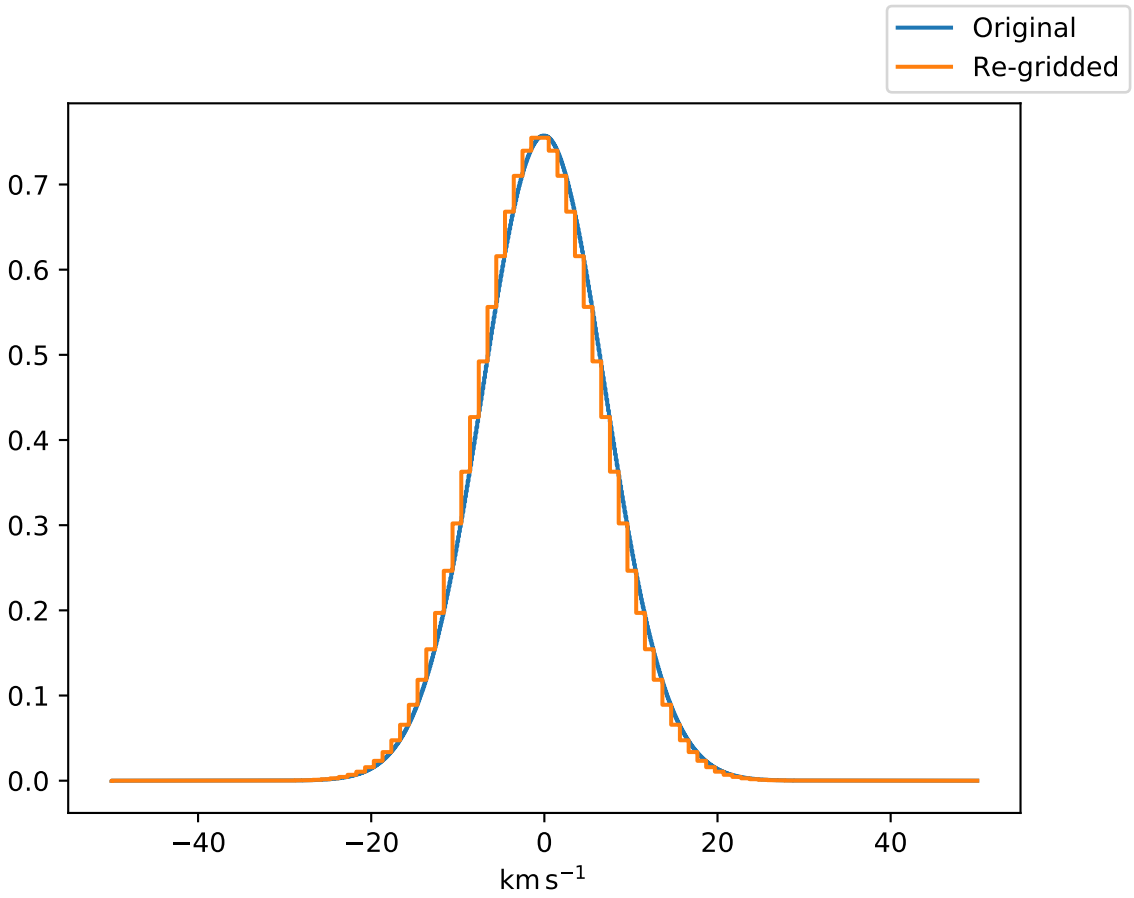
```
>>> new_vel = np.linspace(-50, 50, 100) * u.km / u.s
```

Generate the resampling matrix and apply it to the original data.

```
>>> resample = Resample(new_vel)
>>> new_tau = resample(vel, tau)
```

Plot the results.

```
>>> f, ax = plt.subplots()  # doctest: +IGNORE_OUTPUT
>>> ax.step(vel, tau, label="Original")  # doctest: +IGNORE_OUTPUT
>>> ax.step(new_vel, new_tau, label="Re-gridded")  # doctest: +IGNORE_OUTPUT
>>> f.legend()  # doctest: +IGNORE_OUTPUT
```



Part III

API

CHAPTER

NINE

API

9.1 Modeling

9.2 spectacle.modeling Package

9.2.1 Classes

OpticalDepth1D([name, line_list])	Implements a Voigt profile astropy model.
Spectral1D(*args, **kwargs)	Base representation of a compound model containing a variable number of OpticalDepth1D line model features.

OpticalDepth1D

class spectacle.modeling.**OpticalDepth1D**(*name=None*, *line_list=None*, **args*, ***kwargs*)

Bases: astropy.modeling.Fittable1DModel

Implements a Voigt profile astropy model. This model generates optical depth profiles for absorption features.

Parameters

lambda_0
[float] Central wavelength in Angstroms.

f_value
[float] Absorption line oscillator strength.

gamma
[float] Absorption line gamma value.

v_doppler
[float] Doppler b-parameter in km/s.

column_density
[float] Column density in cm^-2.

delta_v
[float] Velocity offset from lambda_0 in km/s. Default: None (no shift).

delta_lambda
[float] Wavelength offset in Angstrom. Default: None (no shift).

lambda_bins
[array-like] Wavelength array for line deposition in Angstroms. If None, one will created using n_lambda and dlambda. Default: None.

n_lambda
[int] Size of lambda bins to create if lambda_bins is None. Default: 12000.

dlambda
[float] Lambda bin width in Angstroms if lambda_bins is None. Default: 0.01.

Returns

tau_phi
[array-like] An array of optical depth values.

Attributes Summary

column_density	
delta_lambda	
delta_v	
f_value	
gamma	
input_units	This property is used to indicate what units or sets of units the evaluate method expects, and returns a dictionary mapping inputs to units (or None if any units are accepted).
inputs	
lambda_0	
outputs	
param_names	
v_doppler	

Methods Summary

__call__(self, x[, model_set_axis, ...])	Evaluate this model using the given input(s) and the parameter values that were specified when the model was instantiated.
evaluate(self, x, lambda_0, f_value, gamma, ...)	Evaluate the model on some input variables.
fit_deriv(x, x_0, b, gamma, f)	
full_width_half_max(self, x)	
voigt(a, u)	

Attributes Documentation

column_density

delta_lambda

delta_v

f_value

gamma

input_units
This property is used to indicate what units or sets of units the evaluate method expects, and returns a dictionary mapping inputs to units (or None if any units are accepted).

Model sub-classes can also use function annotations in evaluate to indicate valid input units, in which case this property should not be overridden since it will return the input units based on the annotations.

inputs = ('x',)

lambda_0

outputs = ('y',)

param_names = ('lambda_0', 'f_value', 'gamma', 'v_doppler', 'column_density', 'delta_v', 'delta_lambda')

v_doppler

Methods Documentation

__call__(*self*, *x*, *model_set_axis=None*, *with_bounding_box=False*, *fill_value=nan*, *equivalencies=None*)
Evaluate this model using the given input(s) and the parameter values that were specified when the model was instantiated.

evaluate(*self*, *x*, *lambda_0*, *f_value*, *gamma*, *v_doppler*, *column_density*, *delta_v*, *delta_lambda*)
Evaluate the model on some input variables.

static fit_deriv(*x*, *x_0*, *b*, *gamma*, *f*)

full_width_half_max(*self*, *x*)

static voigt(*a*, *u*)

Spectral1D

class spectacle.modeling.**Spectral1D**(**args*, ***kwargs*)
Bases: astropy.modeling.Fittable1DModel

Base representation of a compound model containing a variable number of OpticalDepth1D line model features.

Parameters

lines
[str, OpticalDepth1D, list] The line information used to compose the spectral model. This

can be either a string, in which case the line information is retrieve from the ion registry; an instance of `OpticalDepth1D`; or a list of either of the previous two types.

continuum
[`Fittable1DModel`, optional] An astropy model representing the continuum of the spectrum. If not provided, a `Const1D` model is used.

z
[float, optional] The redshift applied to the spectral model. Default = 0.

lsf
[`LSFModel`, `Kernel1D`, str, optional] The line spread function applied to the spectral model. It can be a pre-defined kernel model, or a convolution kernel, or a string referencing the built-in Hubble COS lsf, or a Gaussian lsf. Optional keyword arguments can be passed through.

Attributes Summary

as_flux	New spectral model that produces flux output.
as_flux_decrement	New spectral model that produces flux decrement output.
as_optical_depth	New spectral model that produces optical depth output.
continuum	
input_units	This property is used to indicate what units or sets of units the evaluate method expects, and returns a dictionary mapping inputs to units (or None if any units are accepted).
input_units_allow_dimensionless	Allow dimensionless input (and corresponding output).
input_units_equivalencies	
inputs	
is_single_ion	Whether this spectrum represents a collection of single ions or a collection of multiple different ions.
lines	The collection of profiles representing the absorption or emission lines in the spectrum model.
lsf_kernel	
output_type	The data output of this spectral model.
outputs	
redshift	The redshift at which the data given to.
rest_wavelength	
velocity_convention	

Methods Summary

__call__(self, x, *args, **kwargs)	Override the default call function to handle fixed parameters based on the unit of the provided dispersion.
evaluate(self, x, *args, **kwargs)	Evaluate the model on some input variables.
line_stats(self, x)	Calculate statistics over individual line profiles.
region_stats(self, x, rest_wavelength[, ...])	Calculate statistics over arbitrary line regions given some tolerance from the continuum.

Continued on next page

Table 5 – continued from previous page

rejection_criteria(self, x, y[, auto_fit])	Implementation of the Akaike Information Criteria with Correction (AICC) (Akaike 1974; Liddle 2007; King et al.
with_continuum(self, continuum)	New spectral model defined with a different continuum.
with_line(self, *args[, reset])	Add a new line to the spectral model.
with_lines(self, lines[, reset])	Create a new spectral model with the added lines.
with_lsf(self[, kernel])	New spectral model with a line spread function.
with_redshift(self, value)	Generate a new spectral model with the given redshift.

Attributes Documentation

as_flux
New spectral model that produces flux output.

as_flux_decrement
New spectral model that produces flux decrement output.

as_optical_depth
New spectral model that produces optical depth output.

continuum

input_units
This property is used to indicate what units or sets of units the evaluate method expects, and returns a dictionary mapping inputs to units (or None if any units are accepted).

Model sub-classes can also use function annotations in evaluate to indicate valid input units, in which case this property should not be overridden since it will return the input units based on the annotations.

input_units_allow_dimensionless
Allow dimensionless input (and corresponding output). If this is True, input values to evaluate will gain the units specified in input_units. If this is a dictionary then it should map input name to a bool to allow dimensionless numbers for that input. Only has an effect if input_units is defined.

input_units_equivalencies

inputs = ('x',)

is_single_ion
Whether this spectrum represents a collection of single ions or a collection of multiple different ions.

Returns

: bool
Is the spectrum composed of a collection of single ions.

lines
The collection of profiles representing the absorption or emission lines in the spectrum model.

Returns

: list
A list of Voigt1D models.

lsf_kernel

output_type
The data output of this spectral model. It could one of 'flux', 'flux_decrement', or 'optical_depth'.

Returns

: str
The output type of the model.

outputs = ('y',)

redshift
The redshift at which the data given to.

Returns

: float
The redshift value.

rest_wavelength

velocity_convention

Methods Documentation

__call__(*self*, *x*, **args*, ***kwargs*)
Override the default call function to handle fixed parameters based on the unit of the provided dispersion.

Notes

The initial call to this method from fitter will provide unit information on the dispersion. Subsequent calls do not. It is assumed that subsequent calls provide dispersion as km/s.

evaluate(*self*, *x*, **args*, ***kwargs*)
Evaluate the model on some input variables.

line_stats(*self*, *x*)
Calculate statistics over individual line profiles.

Parameters

x
[Quantity] The input dispersion in either wavelength/frequency or velocity space.

Returns

tab
[QTable] A table detailing the calculated statistics.

region_stats(*self*, *x*, *rest_wavelength*, *rel_tol=0.01*, *abs_tol=1e-05*)
Calculate statistics over arbitrary line regions given some tolerance from the continuum.

Parameters

x
[Quantity] The input dispersion in either wavelength/frequency or velocity space.

rest_wavelength
[Quantity] The rest frame wavelength used in conversions between wavelength/ frequency and velocity space.

rel_tol
[float] The relative tolerance parameter.

abs_tol
[float] The absolute tolerance parameter.

Returns

tab
[QTable] A table detailing the calculated statistics.

rejection_criteria(*self*, *x*, *y*, *auto_fit=True*)
Implementation of the Akaike Information Criteria with Correction (AICC) (Akaike 1974; Liddle 2007; King et al. 2011). Used to determine whether lines can be safely removed from the compound model without loss of information.

Parameters

x
[Quantity] The dispersion data.

y
[array-like] The expected flux or tau data.

auto_fit
[bool] Whether the model fit should be re-evaluated for every removed line.

Returns

final_model
[Spectral1D] The new spectral model with the least complexity.

with_continuum(*self*, *continuum*)
New spectral model defined with a different continuum.

with_line(*self*, **args*, *reset=False*, ***kwargs*)
Add a new line to the spectral model.

Returns

: Spectral1D
The new spectral model.

with_lines(*self*, *lines*, *reset=False*)
Create a new spectral model with the added lines.

Parameters

lines
[list] List of `OpticalDepth1D` line objects.

Returns

: `Spectral1D`
The new spectral model.

with_lsf(*self*, *kernel=None*, ***kwargs*)
New spectral model with a line spread function.

with_redshift(*self*, *value*)
Generate a new spectral model with the given redshift.

9.3 Fitting

9.4 spectacle.fitting Package

9.4.1 Classes

`CurveFitter`()
`EmceeFitter`()
`LineFinder1D`([ions, continuum, defaults, z, ...])

CurveFitter

class spectacle.fitting.**CurveFitter**
Bases: `astropy.modeling.fitting.LevMarLSQFitter`

Attributes Summary

`uncertainties`

Methods Summary

`__call__`(self, *args[, method])	Fit data to this model.

Attributes Documentation

uncertainties

Methods Documentation

__call__(*self*, **args*, *method='curve'*, ***kwargs*)
Fit data to this model.

Parameters

model
[FittableModel] model to fit to x, y, z

x
[array] input coordinates

y
[array] input coordinates

z
[array (optional)] input coordinates

weights
[array (optional)] Weights for fitting. For data with Gaussian uncertainties, the weights should be 1/sigma.

maxiter
[int] maximum number of iterations

acc
[float] Relative error desired in the approximate solution

epsilon
[float] A suitable step length for the forward-difference approximation of the Jacobian (if model.fjac=None). If epsfcn is less than the machine precision, it is assumed that the relative errors in the functions are of the order of the machine precision.

estimate_jacobian
[bool] If False (default) and if the model has a fit_deriv method, it will be used. Otherwise the Jacobian will be estimated. If True, the Jacobian will be estimated in any case.

equivalencies
[list or None, optional and keyword-only argument] List of *additional* equivalencies that are should be applied in case x, y and/or z have units. Default is None.

Returns

model_copy
[FittableModel] a copy of the input model with parameters set by the fitter

EmceeFitter

class spectacle.fitting.**EmceeFitter**
Bases: object

Attributes Summary

errors
uncertainties

Methods Summary

__call__(self, model, x, y[, yerr, ...])	Call self as a function.

Attributes Documentation

errors

uncertainties

Methods Documentation

__call__(*self*, *model*, *x*, *y*, *yerr=None*, *nwalkers=500*, *steps=200*, *nprocs=1*)
Call self as a function.

LineFinder1D

class spectacle.fitting.**LineFinder1D**(*ions=None*, *continuum=None*, *defaults=None*, *z=None*, *auto_fit=True*, *velocity_convention='relativistic'*, *output='flux'*, *fitter=None*, *with_rejection=False*, *fitter_args=None*, **args*, ***kwargs*)
Bases: astropy.modeling.Fittable2DModel

Attributes Summary

fitter	
input_units_allow_dimensionless	Allow dimensionless input (and corresponding output).
inputs	
min_distance	
model_result	
outputs	
param_names	
threshold	

Methods Summary

__call__(self, x, *args[, auto_fit])	Evaluate this model using the given input(s) and the parameter values that were specified when the model was instantiated.
evaluate(self, x, y, threshold, ...)	Evaluate the model on some input variables.

Attributes Documentation

fitter

input_units_allow_dimensionless
Allow dimensionless input (and corresponding output). If this is True, input values to evaluate will gain

the units specified in input_units. If this is a dictionary then it should map input name to a bool to allow dimensionless numbers for that input. Only has an effect if input_units is defined.

inputs = ('x', 'y')

min_distance

model_result

outputs = ('y',)

param_names = ('threshold', 'min_distance')

threshold

Methods Documentation

__call__(*self*, *x*, **args*, *auto_fit=None*, ***kwargs*)
Evaluate this model using the given input(s) and the parameter values that were specified when the model was instantiated.

evaluate(*self*, *x*, *y*, *threshold*, *min_distance*, **args*, ***kwargs*)
Evaluate the model on some input variables.

9.5 Analysis

9.6 spectacle.analysis Package

9.6.1 Functions

delta_v_90(x, y)	Calculate the dispersion that encompasses the central 90 percent of the apparant optical depth.
equivalent_width(x, y[, continuum])	
full_width_half_max(x, y)	Use a univariate spline to fit the line feature, taking its roots as representative of the full width at half maximum.

delta_v_90

spectacle.analysis.**delta_v_90**(*x*, *y*)
Calculate the dispersion that encompasses the central 90 percent of the apparant optical depth. Follows the formulation defined in Prochaska & Wolf (1997).

Parameters

x
[Quantity] The dispersion axis. Can be either wavelength or velocity space.

y
[array-like] Flux or optical depth array. Note that the calculation assumes that the data is optical depth. If providing flux, it will be converted to apparant optical depth.

equivalent_width

spectacle.analysis.**equivalent_width**(*x*, *y*, *continuum=None*)

full_width_half_max

spectacle.analysis.**full_width_half_max**(*x*, *y*)
Use a univariate spline to fit the line feature, taking its roots as representative of the full width at half maximum.

Parameters

x
[astropy.units.Quantity] The dispersion array.

y
[np.ndarray] The data array.

Returns

float
The full width at half maximum.

9.6.2 Classes

Resample(new_dispersion)	Resample model which can be used with compound model objects.

Resample

class spectacle.analysis.**Resample**(*new_dispersion*)
Bases: object

Resample model which can be used with compound model objects.

Methods Summary

__call__(self, x, y)	Call self as a function.

Methods Documentation

__call__(*self*, *x*, *y*)
Call self as a function.

9.7 Registries

9.8 spectacle.registries Package

9.8.1 Classes

LineRegistry(*args, **kwargs)

LineRegistry

class spectacle.registries.**LineRegistry**(**args*, ***kwargs*)

Bases: astropy.table.QTable

Methods Summary

correct(self, name)
load(self, path)
load_default(self)
subset(self, ions)
with_lambda(self, lambda_0)
with_name(self, name)

Methods Documentation

correct(*self*, *name*)

load(*self*, *path*)

load_default(*self*)

subset(*self*, *ions*)

with_lambda(*self*, *lambda_0*)

with_name(*self*, *name*)

Part IV

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