

# Reducing data from SALSA in MATLAB – SalsaSpectrum

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## Abstract

This document describes the use of the SalsaSpectrum MATLAB class, designed to assist when analysing data from the SALSA Onsala radio telescope.

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# 1 Introduction

The SALSA Onsala telescope is a 2.3 m in diameter antenna located at Onsala space observatory outside Gothenburg. The telescopes are designed to detect the faint radiation from cold hydrogen gas in our galaxy, the Milky way. The hydrogen gas emits radiation at a wavelength of 21 cm (or a frequency of 1420.4 MHz). This signal can be detected by the microwave receiver connected to the telescope. The observed spectrum can be exported into a FITS-file, which is the currently most used type of file for astronomical images and spectra. The fits file has two parts: (1) a *header* which includes information about the data such as the velocity resolution, central frequency and many others, and (2) the data itself.

Having completed the observations, the observer may want to process the data further in order to more accurately deduce the kinematics, as well as the amount of hydrogen gas in the Milky Way. There are currently two main options when analysing data from SALSA, summarized here:

- **Salsa-J**: a software package that is used to reduce spectral data from the SALSA telescopes, but can also be used as a simple image editor and processor. A spectral module with functionality to reduce SALSA data is available. The main advantage of SalsaJ is its easy-to-use point-and-click interface. The main disadvantage is that reducing many spectra can be tedious. SalsaJ can be downloaded at the SALSA website. SalsaJ was developed for the European Hands-On Universe (EU-HOU) project, an education project aimed to provide interesting exercises in the field of astronomy for high school students.
- **SalsaSpectrum** is a data reduction environment written in the popular mathematical software MATLAB - aimed for reduction of data from SALSA Onsala, developed by Daniel Dahlin.

There has previously not existed any published MATLAB code to handle data from SALSA (although several students have written their own code over the years). This effort to write a Matlab class that reads, reduces and analyzes data from SALSA was made to provide such a code for use with MATLAB. The class, named **SalsaSpectrum** can be freely used, changed and improved by anyone interested in the project. This document describes the use of the **SalsaSpectrum** class at its current state.

## 2 The SalsaSpectrum class

The code is implemented as a MATLAB class. A fits-file from the SALSA telescopes is read into memory as an object of the **SalsaSpectrum** class. The user can then perform different operations on the spectrum object, such as fitting a baseline, plot the spectrum, calculate the noise level and fit a number of gaussians to the spectrum. All results can be printed to screen and the commands used to reduce the data can be placed in a MATLAB m-file for repeated use. It is also possible to write more complex scripts and reduce many spectra at the same time.

The different capabilities of the **SalsaSpectrum** class will now be presented.

### 2.1 Installation

The code used for the reduction environment is contained within one MATLAB m-file which includes the class definitions and functions. No installation of the code is therefore needed. Move the m-file to the directory where you do your work. MATLAB will then automatically find and use the **SalsaSpectrum** class.

If you want to use the class from many locations, you can store the m-file in a central directory, and use the matlab `addpath` command to add that location to the matlab path.

```
addpath /path/to/directory/with/SalsaSpectrum/class/files
```

## 2.2 Read a spectrum

The class constructor method `SalsaSpectrum` is used to read a spectrum from a fits-file and place it into the `SalsaSpectrum` object `spec`

```
>> spec = SalsaSpectrum('Example/sample_data.fits')
```

If everything goes well the following information will be printed

```
>> spec

spec =

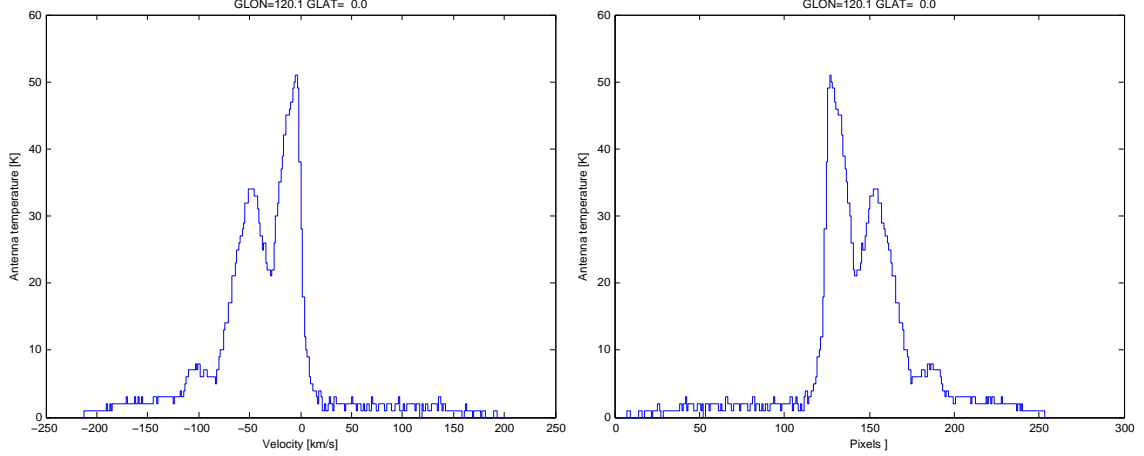
SalsaSpectrum handle

Properties:
         c: 299792458
      HIfreq: 1.4204e+09
      fittype: 0
    fileName: 'Example/sample_data.fits'
         freq: [1x256 double]
         vel: [1x256 double]
        index: [1x256 double]
         info: [1x1 struct]
         data: [1x256 double]
    baseLine: []
   baseWindow: []
baseWindowParVel: []
baseWindowParInd: []
baseWindowParFreq: []
         rms: []
      gaussFit: []
   gaussConfInt: []
      gaussPar: []
   gaussParVel: []
   gaussParFreq: []
      gaussErr: []
   gaussErrVel: []
   gaussErrFreq: []
gaussIntegrated: []
    residuals: []
        labVel: []
        labSig: []
```

Several properties of the object have already been added. Arrays containing the data, info (the header), and frequency, velocity and index have been created, as well as constants (the speed of light and the frequency of the HI line). Other properties are not yet calculated. The functions that calculate and fill the empty variables are discussed in the following sections.

## 2.3 Plot a spectrum

It is easy to plot a spectrum. The MATLAB class system allows two types of calls to the plot function. A `SalsaSpectrum` object `spec` may be plotted either by using `spec.plot()` or `plot(spec)`. Using these commands on a SALSA spectrum results in the first graph shown in figure 1.



**Figure 1:** Salsa spectra as a function of velocity and channel index (“pixel”).

The `plot` is an overloaded function, i.e. it has the same name as the normal plot command but some extra features that makes the plot more useful. A few such thing are apparent when looking at the spectrum. The `SalsaSpectrum` class has made the decision to display the spectrum as a function of velocity, which is the most useful representation when working with a radioastronomical spectrum. Labels are present for both axes. It is also possible to display the spectrum as a function of frequency or channel index, by sending either `'freq'` or `'pix'` to `plot`. An example of a spectrum plotted in pixel scale is also shown in figure 1.

## 2.4 Fit and subtract a baseline

In radioastronomical jargon, the “baseline” is the part of the spectrum where no line emission is present. Spectra from SALSA are produced by so-called *frequency switching* which principally removes any continuum signal that is present. However, the switching technique is not perfect and sometimes a spectrum either is offset from the zero-level, or has a small slope or parabola from one end to the other. On such occasions it is customary to fit a baseline to the spectrum. These principles are most easily understood when seeing an example.

Fitting a baseline with `SalsaSpectrum` consists of finding the spectral coordinates of the parts of the spectrum with no signal. The end coordinates of that range are called *spectral windows*. There are currently two ways of defining the spectral windows:

1. *Manual method*: define spectral windows on the command line. Useful in scripts.
2. *Interactive method*: define spectral windows using the mouse.

The two methods are described below in more detail.

### 2.4.1 Manual method

In the spectrum showed in Fig. 1 there is no signal between velocities  $+50 \text{ km s}^{-1}$  and  $+200 \text{ km s}^{-1}$ , or between,  $-200 \text{ km s}^{-1}$  and  $-150 \text{ km s}^{-1}$ . The `fitBaseline` command fits a polynomial to the

data in the baseline windows. In the following example, a polynomial of order  $n = 2$  (a parabola) is fitted to the data in the spectral windows between  $[-200 \text{ km s}^{-1} \leq v \leq -150 \text{ km s}^{-1}]$  and  $[50 \text{ km s}^{-1} \leq v \leq 200 \text{ km s}^{-1}]$ .

```
>> spec.fitBaseline([-200 -150 50 200], 'vel', 2)
```

let us now take a look at the spectrum object again.

```
>> spec
```

```
spec =
```

```
SalsaSpectrum with properties:
```

```

        c: 299792458
      HIfreq: 1.4204e+09
    fitttype: 0
  fileName: 'Example/sample_data.fits'
      freq: [1x256 double]
      vel: [1x256 double]
     index: [1x256 double]
      info: [1x1 struct]
      data: [1x256 double]
   baseLine: [1x256 double]
  baseWindow: [1x123 double]
baseWindowParVel: [-200.0828 -150.6162 50.5477 200.5962]
baseWindowParInd: [246 216 94 3]
baseWindowParFreq: [1.4214e+09 1.4211e+09 1.4202e+09 1.4195e+09]
        rms: 0.7815
    gaussFit: []
  gaussConfInt: []
    gaussPar: []
  gaussParVel: []
  gaussParFreq: []
    gaussErr: []
  gaussErrVel: []
  gaussErrFreq: []
gaussIntegrated: []
    residuals: []
      labVel: []
     labSig: []

```

The object has now been filled with more information related to the baseline fit. The coefficients of the fitted polynomial, as well as the actual polynomial as well the indices for the baseline windows in all units have been added. Finally, the task has calculated the rms value of the data in the baseline windows.

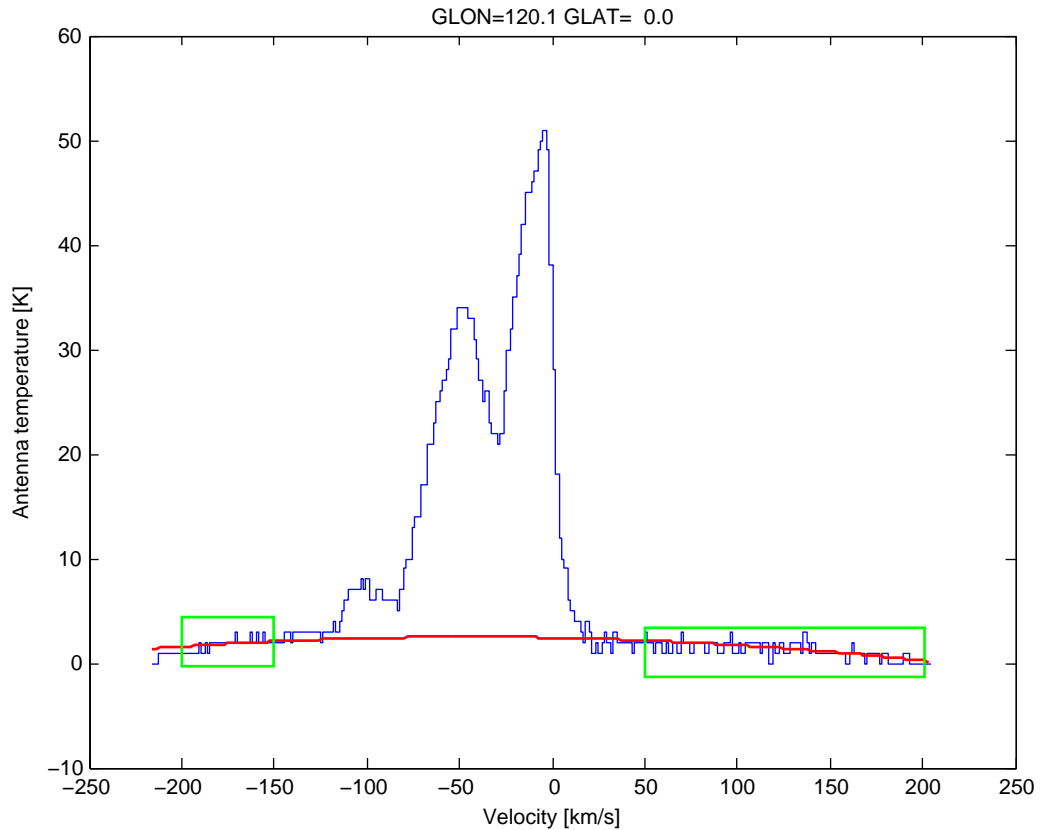
To show the fitted baseline, use the command `showBaseline`.

```
>> spec.showBaseline()
```

which produces Fig. 2.

At this point, if you are satisfied with the baseline fit, you can subtract the baseline from the spectrum with the function `subtractBaseline`.

```
>> spec.subtractBaseline()
```



**Figure 2:** Fitting a baseline. The `showBaseline` command produces this graph showing the fitted baseline as well as the baseline windows used for the fit.

In case you are not satisfied with the fit and want to change some parameters, just redo the fit with new baseline windows or change the order of the polynomial (as a rule-of-thumb, use `order`  $\leq 3$  for good results). The new fit overwrites the previous one. Once you are satisfied with the fit, use `subtractBaseline` to subtract the baseline. A baseline-subtracted spectrum is shown in Fig. 3.

It is not possible to subtract a baseline twice.

## 2.4.2 Interactive fit

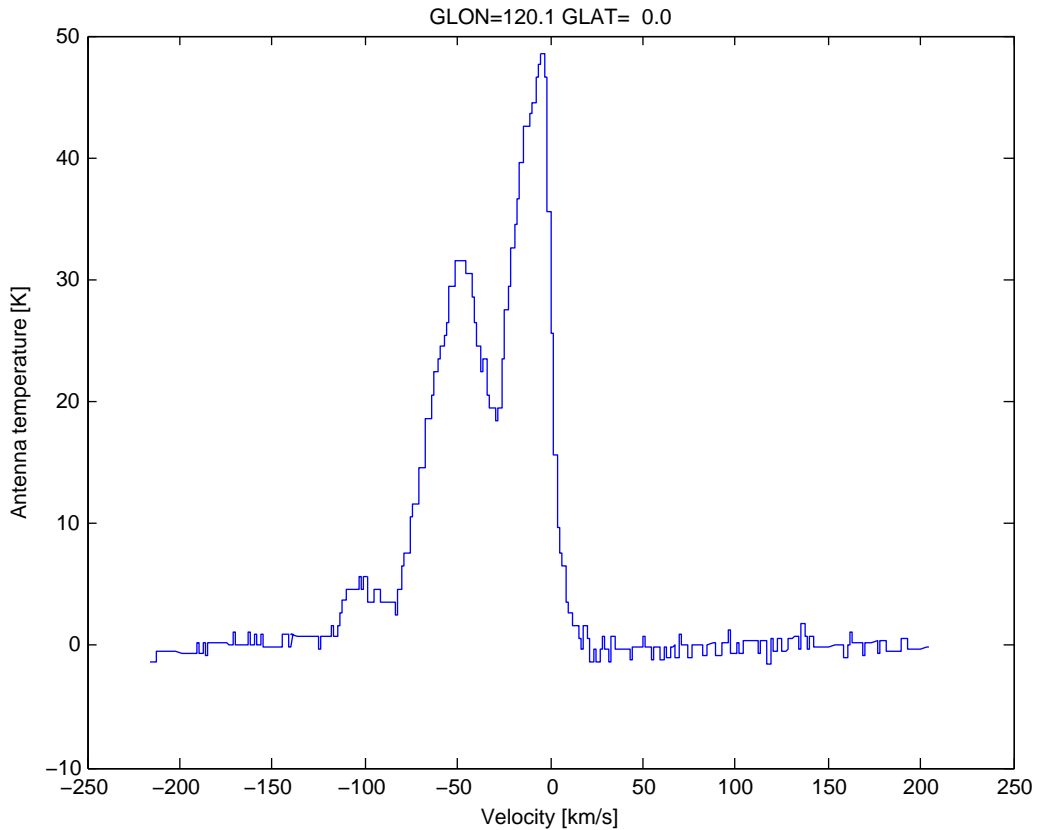
If you prefer to use the mouse to mark the baseline windows, you can try the interactive method. Invoke the function `fitBaseline` without arguments

```
>> spec.fitBaseline()
```

The following text is shown in the command window:

```
Mark each baseline window by clicking twice, on each side of the window.
You can mark several windows but it is important that you only
click an even number of times.
Press return when you are finished.
```

The baseline windows are then defined by marking the left and rightmost channel of each window with the mouse. A crosshair appears when the function is invoked. Left-click with the mouse to start defining the baseline windows. Between pairs of points the color changes, making it easier



**Figure 3:** A baseline-subtracted spectrum plotted using `spec.plot()`.

to see which pair a point belongs to. When finished, press enter. After that, focus is given back to the command window where you are asked to give the polynomial order.

```
Input polynomial order: 2
```

After that the same fitting routine is used as in the manual method.

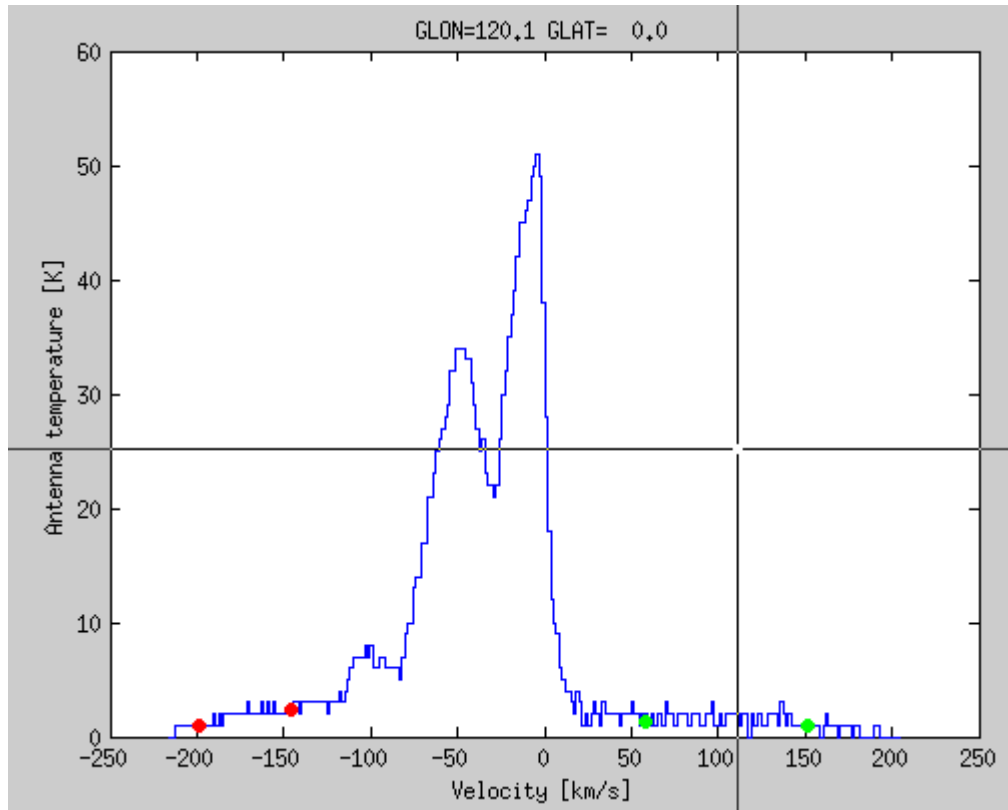
## 2.5 Fit gaussians to the spectrum

The `fitGaussians` function fits up to five Gaussian functions to the spectrum. There are (from version 1.7 of the code) three ways of fitting gaussians to a spectrum:

1. *Manual method*: supply starting guesses for the peak value, central velocity and velocity width of each gaussian function to be fitted.
2. *Blind fit*: allow the software to find peaks and fit Gaussians to them. This works well when the spectral lines are separated, but is not as good when fitting to blended lines.
3. *Interactive fit*: mark peaks in the spectrum with the mouse and use those as starting guesses for the Gaussian fit.

### 2.5.1 Manual method

Starting guesses are entered in velocity units. The spectrum plotted in Figures 1, 2 and 3 appears to consist of three peaks at velocities about  $-5$ ,  $-50$  and  $-100$   $\text{km s}^{-1}$ , with intensities 50, 30



**Figure 4:** Screenshot from interactive baseline fitting

and 5. Assuming an initial width of  $10 \text{ km s}^{-1}$  for each peak, the starting guesses for fitting three gaussian profiles using the `fitGaussians` function would then be

```
>> spec.fitGaussians([50 -5 10 30 -50 10 5 -100 10])
Fitting 3 Gaussians.
Use plot() to see the fitted Gaussians.
```

When the fit is completed, the spectrum object `spec` has been extended with further parameters.

```
>> spec

spec =

SalsaSpectrum with properties:

    c: 299792458
   HIfreq: 1.4204e+09
  fittype: 0
  fileName: 'Example/sample_data.fits'
    freq: [1x256 double]
    vel: [1x256 double]
   index: [1x256 double]
    info: [1x1 struct]
    data: [1x256 double]
  baseLine: [1x256 double]
 baseWindow: [1x90 double]
baseWindowParVel: [-198.4339 -145.6696 58.7921 151.1297]
```



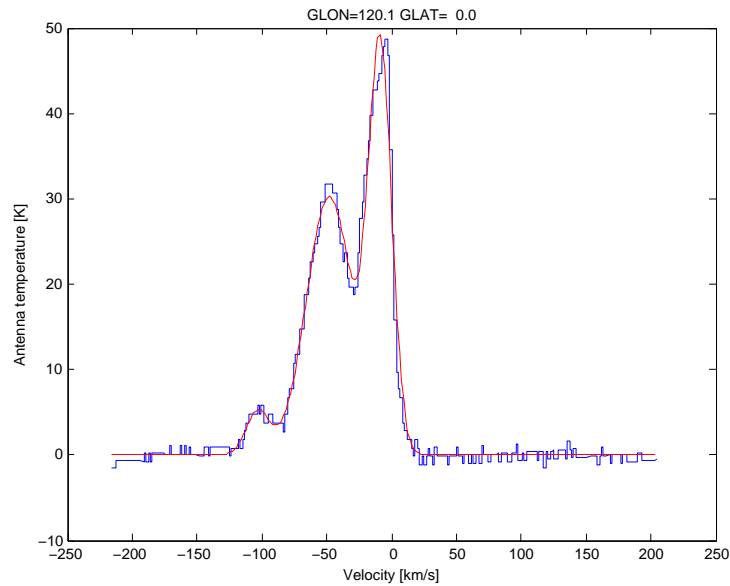
```

baseWindowParInd: [245 213 89 33]
baseWindowParFreq: [1.4213e+09 1.4211e+09 1.4201e+09 1.4197e+09]
rms: 0.5712
gaussFit: [1x256 double]
gaussConfInt: [1x512 double]
gaussPar: [1x9 double]
gaussParVel: [1x9 double]
gaussParFreq: [1x9 double]
gaussErr: [1x9 double]
gaussErrVel: [1x9 double]
gaussErrFreq: [1x9 double]
gaussIntegrated: [1.0471e+03 1.3346e+03 113.9120]
residuals: [1x256 double]
labVel: []
labSig: []

```

The parameters `gaussFit`, `gaussPar`, `gaussParVel` and `gaussParFreq` are now non-empty. `gaussFit` is an array with the best-fit sum of gaussians. The three other parameters hold the best-fit values for the peak, central value and width of the gaussians.

The guesses should be quite close in order for the fit to be good. When the fit is done the `spec.plot` command is used to show the fitted gaussian functions.



**Figure 5:** Plot of a spectrum with three fitted gaussians overlaid.

## 2.5.2 Automatic method

The automatic method will search for peaks in the spectrum. It will then fit Gaussians with the peaks as starting guesses for amplitude, velocity center and width. To use the automatic method, call the `fitGaussians` function without arguments.

```
>> spec.fitGaussians()
```

An example of this fitting method is shown in Figure 6. First the automatic fit is applied, and three gaussians are found. However, there is room for improvement at the negative velocities, so

two extra gaussians are manually added using the following syntax.

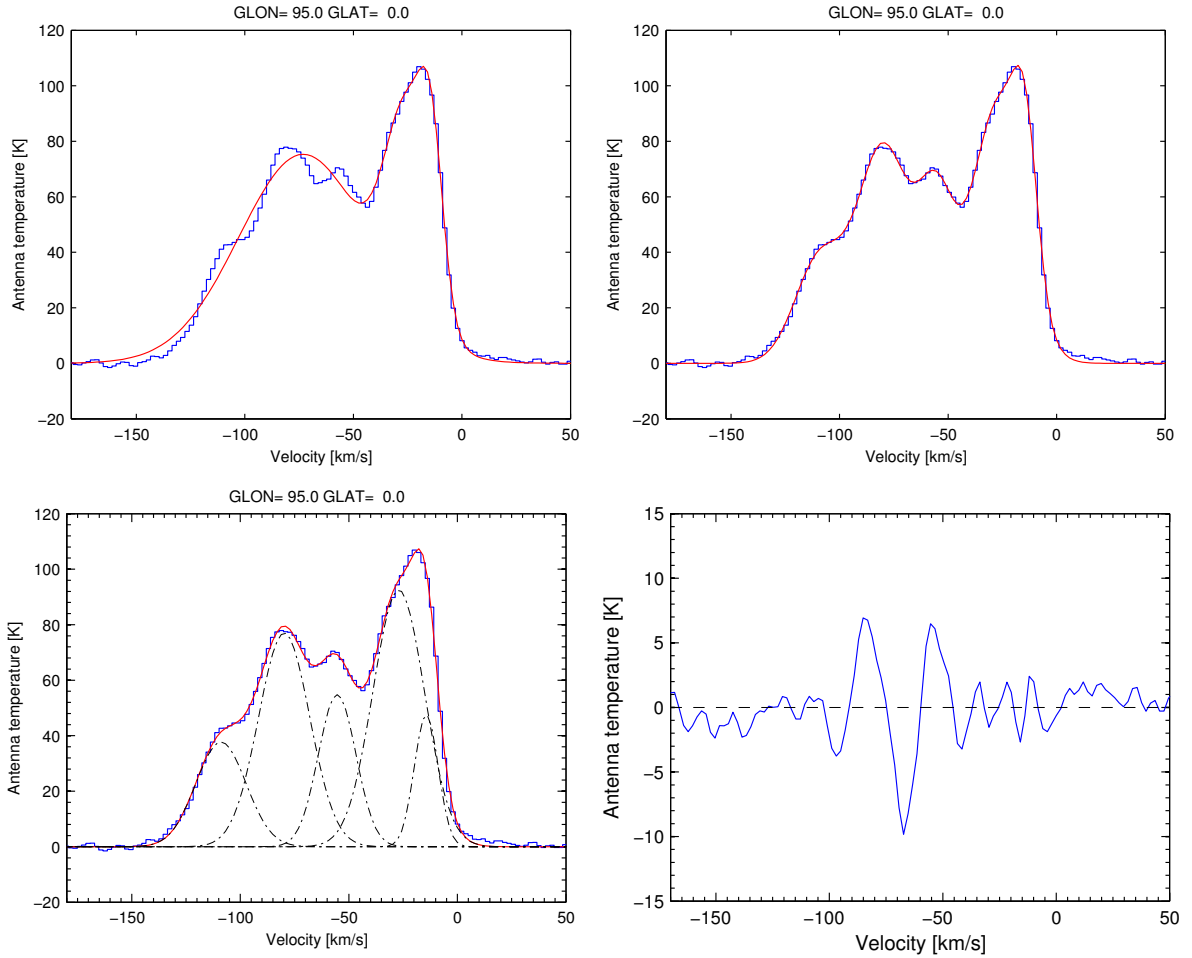
```
>> spec.fitGaussians([guesses], 'dummy')
```

“Dummy” could be number or string. This refits the previous gaussians together with the new which can improve the total fit to the spectrum. The parameter **guesses** has the exact same format as in the manual fitting method, i.e. [*Gauss peak 1, Gauss center 1, Gauss width 1, Gauss peak 2 ...*].

It is also possible to show the individual gaussians in a fit overlaid on the spectrum. Call the `plot` function with the following syntax.

```
>> spec.plot('vel','individual')
```

where `'freq'` or `'pix'` could also be used.



**Figure 6:** Zoom-in on fit to blended spectrum. *Top left:* blind fit. The algorithm cannot distinguish between the blended peaks between  $-120$  and  $-50$  km s $^{-1}$ . *Top right:* refining the blind fit by adding two additional gaussians. *Bottom left:* same as top right, but also showing the individual gaussian functions. *Bottom right:* residuals  $data - Gaussian\ fit$  shown with the `showResiduals` function.

### 2.5.3 Interactive method

From version 1.7 of `SalsaSpectrum`, an interactive Gaussian fit is included. It is designed as a wrapper around the `fitGaussians` function, and it is called without arguments.

```
>> spec.fitGaussiansInteractive()
```

When this function is invoked, the user can mark peaks in the displayed spectrum with the mouse. Press the enter key when you are finished marking the peaks. The data will then be sent to `fitGaussians` which performs the actual fitting. An example is shown in figure 7.

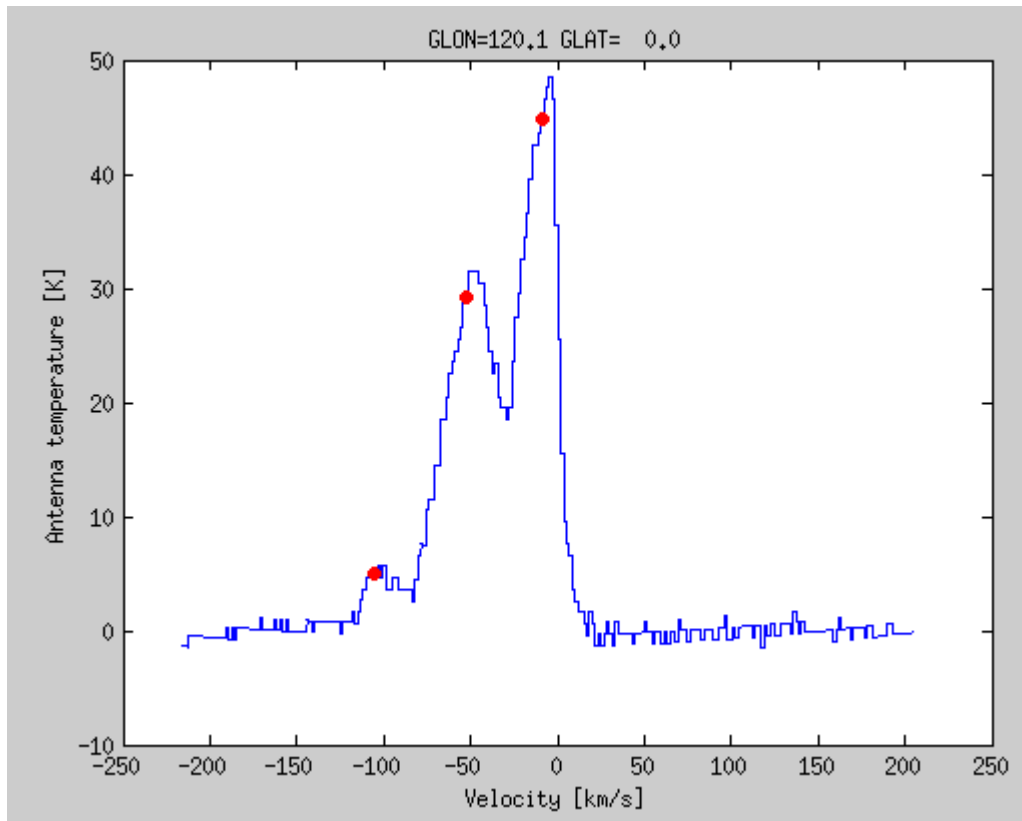


Figure 7: Screenshot from interactive Gaussian fitting.

### 2.5.4 Extracting fit parameters

After performing the gaussian fit, all fit parameters are available within the `SalsaSpectrum` object. Of most interest to users is probably the peak intensity of each Gaussian, their central velocity and width. The integrated intensity of each gaussian is also calculated.

Using the fit to the spectrum presented in figure 6 above, the central velocities of the five gaussians are extracted with the commands:

```
>> spec.gaussParVel(1:3:end) % peak of each gaussian
    47.6    92.5    77.0    54.8    37.7
>> spec.gaussParVel(2:3:end) % central velocity of each gaussian
   -14.4   -27.0  -79.8  -55.4 -108.9
>> spec.gaussParVel(3:3:end) % width (1sigma) of each gaussian
     5.5     11.9     11.8      8.7     11.5
```

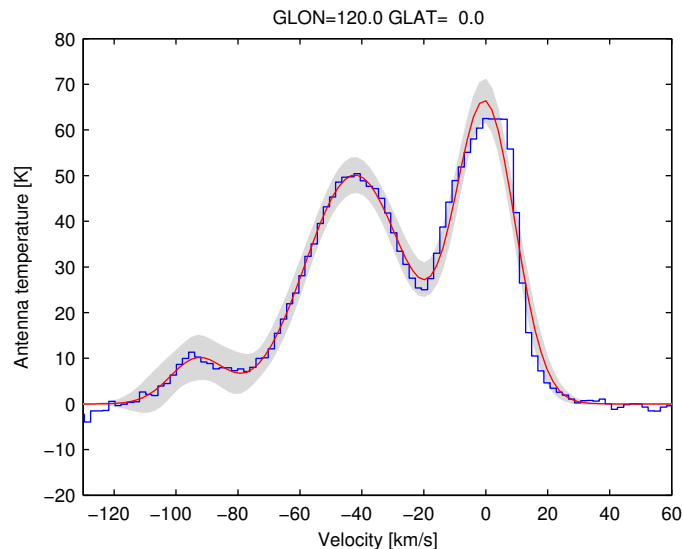
and the integrated intensity:

```
spec.gaussIntegrated
```

Uncertainties on the parameter values are calculated, and stored in the `gaussErr`, `gaussErrVel` and `gaussErrFreq` properties of the `SalsaSpectrum` object, when Gaussians have been fitted. Finally, a 68% confidence interval on the total sum of Gaussians is calculated, and saved in the property `gaussConfInt`. To visualize the confidence interval, use the `showConfInt` function.

```
>> spec.showConfInt()
```

which for the spectrum and Gaussian fit displayed in Figure 5, produces the plot shown in Figure 8.



**Figure 8:** Spectrum with Gaussian fit and confidence intervals overlaid.

## 2.6 Saving your work

A reduced spectrum can be saved so that the fitted baseline and gaussians can be brought back later, without having to redo the reduction. The built-in MATLAB functions `save` and `load` can be used to save and load a spectrum. To save the spectrum stored in the object `spec1` to the MATLAB `.mat` file `spec1.mat`, simply type:

```
>> save spec1.mat spec1
```

This command places the `.mat` file `spec1.mat` in the current directory. To read the file and bring back the `SalsaSpectrum` object, type

```
>> load spec1.mat
```

Note that to load a spectrum from a `mat`-file, the `SalsaSpectrum` class must either be stored in the working directory, or added to the MATLAB path.

## 2.7 Getting help

Most of the functionality of `SalsaSpectrum` is described in this manual. Online help is available in MATLAB for several of the functions, using the `help` syntax. Type `help functionName`. An example for the `fitBaseline` function follows.

```
>> help fitBaseline
--- help for SalsaSpectrum/fitBaseline ---

fit a polynomial to the spectrum baseline. Define the
baseline using a set of windows in the following way:

[ x11 x12 x21 x22 x31 x32 ... ]

as the first parameter passed to the function.

check that the baseline vector consists of an even
number of values.

supply the baseline windows in units of

1. indices      ['pix']
2. velocity     ['vel']
3. frequency    ['freq']

by sending the string as a second argument. If you do not
give any units, it is assumed that you have given indices.

By default, this routine fits a first order polynomial
to the chosen spectral windows. If you want another
polynomial order, supply it as the third parameter.

spec.fitBaseline([-200 -150 40 200], 'vel',2)

will fit a second order polynomial between velocities -200
to -150 and 40 to 200
```

### 3 Cookbook

How was the spectrum presented in figure 6 reduced? Here are the steps summarized. This data reduction is sufficient for most spectra.

```
% read the spectrum
spec=SalsaSpectrum('../SalsaFits/obs20060314/00031c.fits');
% fit a baseline
spec.fitBaseline([-220 -150 30 220], 'vel',3)
% subtract the baseline
spec.subtractBaseline()
% perform blind gaussian fit
spec.fitGaussians()
% refine the blind gaussian fit
spec.fitGaussians([30 -55 6 30 -110 5], 'dummy')
% read the LAB spectrum
spec.readLab
% plot everything
spec.plot; spec.showLab
```

## 4 Additional functions

There is further functionality in the `SalsaSpectrum` class which are intended for more advanced users. They are listed here.

### 4.1 Download data from the LAB survey

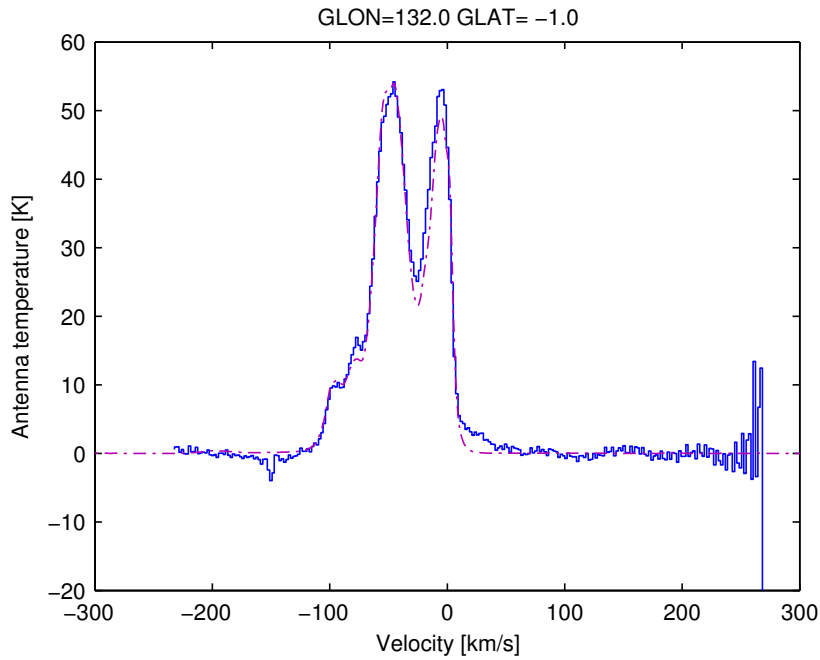
The LAB survey is a compilation of three major HI surveys performed with telescopes in the Netherlands, Argentina and Australia. It covers the entire sky and has a resolution of 30 arcminutes. It can be useful to compare the observed spectra taken with SALSA with those from the LAB survey.

LAB spectra can be viewed and downloaded at <http://www.astro.uni-bonn.de/hisurvey/profile/>. The high-resolution spectra can also be convolved to the resolution of the SALSA telescopes ( $\sim 5.4^\circ$  FWHM). The LAB data are available for download as ascii-files.

`SalsaSpectrum` includes functionality so that the user can automatically download and display a spectrum from LAB. The function (`readLab`) downloads a spectrum at the coordinates of the current spectrum. This function can be called for any `SalsaSpectrum` object.

```
>> spec.readLab
```

To reduce the use of the LAB server, the function also checks if the appropriate data has already been downloaded. In figure 9 a spectrum from SALSA toward the calibration region S7 ( $l = 132^\circ$ ,  $b = -1^\circ$ ) is compared to the LAB spectrum.



**Figure 9:** SALSA spectrum taken toward S7 compared with the LAB spectrum, convolved to  $5.4^\circ$  resolution.

The spectra from LAB are presented in the brightness temperature scale. The absolute calibration of data from SALSA is still uncertain. There may therefore be differences between the LAB and SALSA spectra due to calibration.

*Reference to the LAB survey:* Kalberla, P.M.W., Burton, W.B., Hartmann, Dap, Arnal, E.M., Bajaja, E., Morras, R., & Pöppel, W.G.L. (2005), A&A, 440, 775

## 4.2 Reduce several spectra

The `SalsaSpectrum` class is easily extensible to allow reduction of large sets of spectra from SALSA. If several fits files from SALSA are stored in a directory, the following code will read them and store them in the MATLAB cell array `spec`. It also fits baselines with different baseline windows depending on which

```
direc = '/home/daniel/SalsaSpectra/SalsaFits/mwscan_1201210/'
files = dir([direc,'*.fits']);

for i = 1:length(files)

    fname = [direc,files(i).name];
    spec{i} = SalsaSpectrum(fname);

    longspec(i) = spec{i}.getKeyword('CRVAL2');
    l = longspec(i);

    if (l>0 & l<40)
        spec{i}.fitBaseline([-240 -205 -140 -100 120 220],'vel',3);
    elseif (l>=40 & l<90)
        spec{i}.fitBaseline([-230 -200 -150 -110 100 220],'vel',3);
    elseif (l>=90 & l<180)
        spec{i}.fitBaseline([-230 -190 -130 -110 50 220],'vel',3);
    elseif l>=180
        spec{i}.fitBaseline([-230 -180 -120 -40 60 220],'vel',3);
    end

    spec{i}.showBaseline()
    spec{i}.subtractBaseline()
    spec{i}.fitGaussians()
    spec{i}.plot()

end % end loop over spectra
```

## 5 List of functions and properties

### 5.1 List of properties

```
properties (Constant)
    c = 2.99792458e8;           % speed of light
    HIfreq = 1.42040575177e9; % HI frequency in Hz
end

properties (GetAccess = 'private', SetAccess = 'private')
    baseSubtracted
    coordType
    gaussiansFitted
end

properties (GetAccess = 'public', SetAccess = 'private')
    % public read access, but private write access.
    fileName
end

properties
    freq           % frequency array
    vel            % velocity array
    index          % spectrum index array
    info           % fitsinfo
    data           % data spectrum
    baseLine       % fitted polynomial baseline
    baseWindow     % all indices of the baseline windows
    baseWindowParVel % velocity values of start-end baseline window
    baseWindowParInd % index values -"-
    baseWindowParFreq % frequency values -"-
    rms            % rms value calculated in the baseline windows
    gaussFit       % fitted gaussian functions
    gaussConfInt   % 68% confidence interval on the gaussian fit
    gaussPar       % parameters of gaussians
    gaussParVel    % -"- in velocity units
    gaussParFreq   % -"- in frequency units
    gaussErr       % 1 sigma errors on gaussians
    gaussErrVel    % -"- in velocity units
    gaussErrFreq   % -"- in frequency units
    gaussIntegrated % integrated intensity in K km/s
    residuals      % residuals data - gauss fit
    labVel         % velocity axis of LAB spectrum
    labSig         % data of LAB spectrum
end % properties
```

### 5.2 List of functions

A complete list of the functions within the `SalsaSpectrum` class follows, along with the information in each functions's help file.

#### **SalsaSpectrum**



Class to initialize and do operations on spectra from the Salsa Onsala telescopes and the Qradio software. Create a spectrum object using the syntax

```
spec = SalsaSpectrum('filename.fits');  
  
which then can be displayed and analyzed.
```

This software comes with no warranty. It has been thoroughly tested, but there may still be bugs. It can be downloaded on the SALSA onsala Web site at [brage.oso.chalmers.se](http://brage.oso.chalmers.se) , under "Salsa data in \textsc{Matlab}".

A manual describing how the class can be used is posted at together with this matlab class at <http://brage.oso.chalmers.se/salsa/?q=node/142>

## **plot**

```
HANDLE = PLOT(obj,varargin)
```

Plot a spectrum. The default syntax

```
spec.plot()
```

By default the velocity scale is used. Other options are 'pix' for indices and 'freq' for frequency.

```
spec.plot('freq')
```

If you have fitted Gaussians, they will also be displayed.

If a second 'dummy' argument is supplied, and gaussians have been fitted, the individual Gaussians will be shown.

```
spec.plot('vel', 'dummy')
```

## **showResiduals**

```
SHOWRESIDUALS(obj)
```

Plot the residuals; the difference between the data and the Gaussian model.

## **showIndividual**

```
HANDLE = SHOWINDIVIDUAL(obj,varargin)
```

plots the individual gaussian functions fitted to the spectrum. Can only be called after fitGaussians has ben used.

### **shiftVel**

```
SHIFTVEL(obj,deltav)
```

Shift the velocity scale by a value. To shift the scale 20 km/s toward positive velocities, use

```
spec.shiftVel(-20)
```

### **scale**

```
SCALE(obj,scalefac)
```

Scale the spectrum and fitted Gaussians by a factor, by multiplication. To scale a spectrum down by 20 percent, use the command

```
spec.scale(8/10)
```

### **fitBaseline**

```
FITBASELINE(obj,varargin)
```

fit a polynomial to the spectrum baseline. Define the baseline using a set of windows in the following way:

```
[ x11 x12 x21 x22 x31 x32 ... ]
```

as the first parameter passed to the function.

The baseline vector should consist of an even number of values. If not, the function gives an error.

The baseline windows are supplied in units of

1. indices        ['pix']
2. velocity      ['vel']
3. frequency     ['freq']

Send the string (e.g. 'vel') as a second argument. The index unit is default.

By default, this routine fits a first order polynomial to the chosen spectral windows. Supply another polynomial order as an argument

```
spec.fitBaseline([-200 -150 40 200], 'vel', 2)
```

This command will fit a second order polynomial between velocities -200 to -150 and 40 to 200

## **getIndices**

help function for the fitBaseline function

## **showBaseline**

```
SHOWBASELINE(obj)
```

Show the fitted baseline overlaid on the spectrum, as well as boxes indicating the baseline windows.

```
spec.showBaseline()
```

This function does not subtract the baseline. Use the subtractBaseline function to do that.

## **subtractBaseline**

```
SUBTRACTBASELINE(obj)
```

Subtract the fitted baseline from the data.

## **fitGaussians**

```
FITGAUSSIANS(obj,varargin)
```

Fit a number of gaussians to the spectrum. Supply guess values of height, central value and width of each gaussian, in units of velocity.

```
spec.fitGaussians([60 0 8 30 -55 10])
```

If you don't supply any guess, the function will search for peaks in the spectrum and use those as starting guesses for the fit. If the fit is not good, you can redo it with a new guess.

If you want to add gaussians to a fit, call this function again with guesses for the new gaussian, and send a second dummy argument, like

```
spec.fitGaussians([60 -10 10], 'dummy')
```

which will add an extra gaussian of peak 60 K, central velocity -10 km/s and velocity width 10 km/s to the fit.

## **getRms**

```
GETRMS(obj)
```

calculate and display the rms of the data contained in the baseline windows.

## **showBaselineWindows**

```
SHOWBASELINEWINDOWS(obj)
```

Plot a graphical representation of the chosen baseline windows.

## **getKeyword**

GETKEYWORD(OBJ, KEY) returns the value of KEY from the fits header OBJ.INFO.

This function was kindly provided by Magnus Sand n and Eskil Varenius.

## **showLab**

## **readLab**

```
READLAB(obj)
```

download data from the LAB survey at  
<http://www.astro.uni-bonn.de/hisurvey/profile/index.php>

convolved to Salsa's angular resolution

## **clipSpectrum**

```
BACK = CLIPSPECTRUM(obj,window)
```

NOTE: EXPERIMENTAL, USE AT YOUR OWN RISK.

given the indices in the window parameter, this function "clips" (removes) the indicated spectral channels from the data. Several spectral windows can be specified. Only the 'pixel' spectral unit can be used.

```
spec.clipSpectrum([1 10 230 250])
```

would clip all channels between channels 1 and 10 (1 2 3 4 5 6 etc) and between channels 230 and 250.

## **despike**

`DESPIKE(obj, varargin)`

NOTE: EXPERIMENTAL, USE AT YOUR OWN RISK.

experimental function to remove 'spikes' in the data. Works well for the spike at the edge of the spectrum, works sometimes also for strong RFI in the spectrum.

## **smoothSpectrum**

`SMOOTHSPECTRUM(obj, varargin)`

Smooth a spectrum to a lower spectral resolution. To lower the resolution by a factor of 2, supply the command

`spec.smoothSpectrum(2)`

# **6 Changelog**

Change log for this document. Code changes are described in the code.

### *version 1.91*

- 2014-12-27: Uploaded this document to the SALSA github repository to track future changes. Also replaced some figures using data from the new software defined radio receiver system, and did some minor text changes.

### *version 1.9*

- 2014-12-26: Small changes to the text.

### *version 1.8*

- Rewrote the `readLab` function so that it now also works on Windows machines.

### *version 1.7*

- Added information about interactive fitting of baselines and Gaussians

### *Version 1.6*

- added documentation for all functions

- tidied up the document

#### *Version 1.3*

- Major reorganisation of the text
- added figures and examples

#### *Version 1*

- Initial documentation

## **7 Conclusions and outlook**

This document is a brief manual in the use of the `SalsaSpectrum` MATLAB class. The manual is intended to reflect the methods available in the MATLAB class. However, it is possible that this documentation will lag the code itself. My hope is that the code will be useful for some people interested in reducing data from SALSA.

Göteborg, March 11, 2013

*Daniel Dahlin*