European Organisation
for Astronomical
Research in the
Southern Hemisphere

VERY LARGE TELESCOPE

3D Visualization Tool Manual

VLT-MAN-ESO-19500-5651

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Prepared:	Martin Kümmel (editor)	25 July 2012	
	Name	Date	Signature
Approved:	Pascal Ballester	7/9/2012	
	Name	Date	Signature
Released:	Luca Pasquini	10/9/2012	
	Name	Date	Signature

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1 List of acronyms

CASA	Common Astronomy Software Applications
ESO	European Organisation for Astronomical Research in the Southern Hemisphere
VLT	Very Large Telescope
MUSE	Multi Unit Spectroscopic Explorer
SINFONI	Spectrograph for INtegral Field Observations in the Near Infrared
FITS	Flexible Image Transport System
IR	Infrared
NaN	Not a Number (IEEE floating-point standard representing an undefined or unrepresentable value)
WCS	World Coordinate System
pixel	pixel (or picture element)
spaxel	SPAtial piXture Elemen

2 Preamble

The 3D visualization tool has been implemented as part of the CASA viewer, which itself is part of the CASA software. From the users point of view the terms “3D visualization tool” and “CASA viewer” cannot be distinguished and should be seen as synonyms.

This manual concentrates on how to use the CASA viewer for the visualization of optical/near infrared data cubes (i.e. two spatial plus one spectral axis) taken with ESO/VLT instruments such as MUSE or SINFONI. Complementary to the manual, the 3D Visualization Tool Cookbook (VLT-MAN-ESO-19500-5652; available at www.eso.org) offers an example oriented introduction to the main features of the CASA viewer. Radio specific functionality is largely omitted in the manual here but described in the CASA documentation (see below). The requirements for the 3D visualization tool are given in VLT-SPE-ESO-19500-5003 and were partially implemented in the CASA viewer.

In addition to the functionality described here, CASA offers a much larger functionality and data reduction capability, which is described in the CASA User Reference & Cookbook (`http://casa.nrao.edu/ref_cookbook.shtml`).

This 3D Visualization Tool Manual was developed from the CASA User Reference & Cookbook, kindly provided by J. Ott (project scientist).

3 Obtaining and Installing CASA

The ESO 3D visualization tool was developed as part of CASA and the CASA viewer (see Section 2). Hence the installation of the 3D visualization tool requires or is identical to the installation of the CASA software.

3.1 Releases

CASA is released twice per year in spring (around May) and fall (around October). In between these major releases there are releases of 'stable' versions of CASA. The features described in this manual are included in a CASA special release for ESO that has been published in July 2012. However these features will also be included in the next major CASA release 3.5.0, which is projected for October 2012.

3.2 Obtaining CASA

CASA is available for the following operating systems:

- Linux
  - RedHat 5.5 (32-bit & 64-bit)
  - Fedora 14 (64-bit)
  - Ubuntu 10.10 (64-bit)
- Mac OS
  - Mac OS 10.6 (Snow Leopard)
  - Mac OS 10.7 (Lion)

The latest and previous releases can be downloaded from our CASA home page: `http://casa.nrao.edu/casa_obtaining.shtml` [1].

[1] The CASA special release for the ESO 3D viewer is available for download at `https://svn.cv.nrao.edu/casa/linux_distro/eso/` (Linux) and `https://svn.cv.nrao.edu/casa/osx_distro/eso/` (MAC OS)

3.3 Installation On Linux

To install CASA for Linux, we have packaged up a binary distribution of CASA which is available as a downloadable tar file. We believe this binary distribution works with most Linux distributions.

3.3.1 Installation

You do not have to have root or sudo permission, you can easily install CASA, delete it, move it, and it works for many versions of Linux. The one caveat is that CASA on Linux currently will not run if the Security-Enhanced Linux option of the linux operating system is set to enforcing. For the non-root install to work. SElinux must be set to disabled or permissive (in /etc/selinux/config) or you must run (as root):

```
setsebool -P allow_execheap=1
```

Otherwise, you will encounter errors like:

```
casapy: error while loading shared libraries: /opt/casa/casapy-20.0.5653-001/lib/liblapack.so.3.1.1: c
```

The non-root installation is thought to work on a wide variety of linux platforms, see Sect. 3.2 for the latest supported OSs. The non-root install may work on other platforms not listed.

3.3.2 Download & Unpack

You can download the distribution tar file from

http://casa.nrao.edu/casa_obtaining.shtml

This directory will contain two tar files one will be the 32-bit version of CASA and the other will be the 64-bit version of CASA. The file name of the 64-bit version ends with -64b.tar.gz. After downloading the appropriate tar file, untar it with

```
tar -zxf casapy-*.tar.gz
```

This will extract a directory with the same basename as the tar file. Change to that directory and add it to your path with, for example,

```
PATH=‘pwd‘:\$PATH.
```

After that, you should be able to start the CASA viewer by running

```
casaviewer
```

and the CASA python shell with

```
casapy
```

3.4 Installation on Mac OS

CASA for Macintosh is distributed as self-contained Macintosh application. For installation purposes, this means that you can install CASA by simply dragging the application to your hard disk. It should be as easy as copying a file.

1. Download the CASA disk image for your OS version from our download site `http://casa.nrao.edu/casa_obtaining.shtml`
2. Open the disk image file (if your browser does not do so automatically).
3. Drag the CASA application to the Applications folder of your hard disk.
4. Eject the CASA disk image.
5. Double-click the CASA application to run it for the first time. This ensures everything is properly updated if you had installed a previous version.

You may need to unload the dbus before the copy will work

```
launchctl remove org.freedesktop.dbus-session
launchctl remove org.freedesktop.dbus-system
```

The CASA distribution is 64bit only and will not work on older mac intel machines The first time you launch the CASA application, it will prompt you to set up an alias to the casapy command. You will be taken through the process of creating several casapy symbolic links, it is advisable to do so as this will allow you to run casapy from a terminal window by typing casapy. Additionally, the viewer (casaviewer), table browser (casabrowser), plotms (casaplotms), and buildmytasks will also be available via the command line. Creating the symbolic links will require that you have administrator privileges.

3.5 User Support

If you experience an unexpected behavior of the 3D Visualization Tool, please send a report to the ESO User Support Department using the email address:

`usd-help@eso.org`

In the email, please specify:

- the CASA version you are using;
- the version of your operating system;
- the exact sequence of actions that were performed before the problem occurred;
- what were the precise symptoms and the possible error message(s);
- whether the problem is repeatable.

4 Visualization With The CASA Viewer

This chapter describes how to display data with the casaviewer either as a stand-alone or through the viewer task within casapy. The images that are used in this Section are available for download at: https://svn.cv.nrao.edu/svn/casa-data/trunk/regression/viewertest/.

4.1 Starting the viewer

casaviewer is the name of the stand-alone viewer application that is available with a CASA installation. From the operating system prompt, the following command starts up the CASA viewer:

```
casaviewer &
```

The name of the image to be opened can be given as the first parameter:

```
casaviewer image_filename &
```

Alternative to opening the CASA viewer as a standalone application, it also can be opened from within CASA with the task viewer. Details can be found in the CASA User Reference & Cookbook (http://casa.nrao.edu/ref_cookbook.shtml).

The CASA viewer stores user preferences in a file $HOME/.casa/viewer/rc, which is generated when starting the viewer the first time. Upgrading to a new CASA version might result into inconsistencies concerning the preferences. Such problems can be solved by removing (or renaming) the preference file, which is then re-created the next time the CASA viewer is started.

4.2 Displaying FITS images

Besides FITS images the CASA viewer can also display images in the CASA image format.

When loading an image, an intensive check of the FITS header keywords is performed. The warning or error messages from this process are sent to the terminal and provide feedback if a particular image cannot be loaded into the CASA viewer.

When starting the CASA viewer from the command line, individual extensions in a FITS file are addressed via the extension name and the extension version:

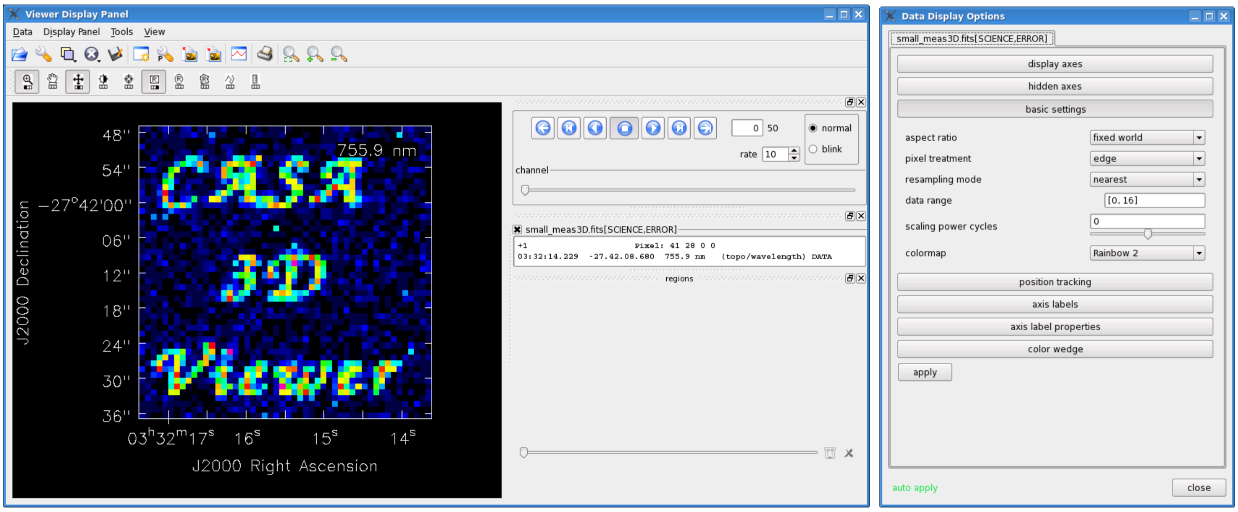

Figure 4.1: The **Viewer Display Panel** (left) and **Data Display Options** (right) panels that appear when the `viewer` is called with the image cube from `small_meas_3D.fits`. The initial display is of the first channel of the cube.

```
casaviewer myimage.fits[1] &

casaviewer myimage.fits[science] &

casaviewer myimage.fits[science,2] &

casaviewer myimage.fits[science,error] &
```

The first line opens the first extension of the image `myimage.fits`, the second line the extension with the extension name `science` and the third the extension named `science` with the extension version number `2` (the commands shown above may require additional backslashes \ to save the special characters `[`, `]`, `' '` in the terminal shell). In the last line, the term `[science,error]` loads both the extension `science` as the data layer and the extension `error` as the error layer into the CASA viewer.

Note: *In CASA, data can be masked, such that the corresponding data points are not being used in data analysis operations. Concerning FITS images, data points with the value* `NaN` *(Not a Number; IEEE floating-point standard representing an undefined or unrepresentable value) are interpreted as masked. In the operations done in the profiler (spectral extraction and image/spectral analysis, see Sect. 4.5), masked data points are neglected.*

4.3 The `viewer` GUI

The CASA `viewer` application consists of a number of graphical user interface (GUI) windows that respond to mouse and keyboard input. Here we describe the **Viewer Display Panel** (§ 4.3.1) and the windows for loading and exporting images (**Load Data** window (§ 4.3.4) and **Save Data** window in § 4.3.5). Several other windows are context-specific and are described in the sections on viewing images (§ 4.4) and the spectral profiler (§ 4.5).

4.3.1 The Viewer Display Panel

The Viewer Display Panel is the window that actually displays the image. This is shown in the left panels of Figures 4.1.

At the top of the Viewer Display Panel are the menus:

- **Data**
  - `Open` — choose a data file to load and display
  - `Register` — select/de-select the (previously-loaded) data file(s) which should display right now (menu expands to the right showing all loaded data)
  - `Close` — close (unload) selected data file (menu expands to the right)
  - `Adjust` — open the Data Display Options ('Adjust') panel
  - `Save as...` — save/export data to a file
  - `Print` — print the displayed image
  - `Save Panel State` — to a 'restore' file (xml format)
  - `Restore Panel State` — from a restore file
  - `Preference` — change the display preferences (on MacOSX in the menu `casaviewer`)
  - `Close Panel` — close the Viewer Display Panel (will exit if this is the last display panel open)
  - `Quit Viewer` — close all display panels and exit (on MacOSX in the menu `casaviewer`)
- **Display Panel**
  - `New Panel` — create another Viewer Display Panel (cleared)
  - `Panel Options` — open the Display Panel's options window
  - `Save Panel State`
  - `Restore Panel State`
  - `Print` — print displayed image
  - `Close Panel` — close the Viewer Display Panel (will exit if this is the last display panel open)
- **Tools**
  - `Spectral Profile` — plot frequency/velocity profile of point or region of image

Figure 4.2: The display panel's **Main Toolbar** appears directly below the menus and contains 'shortcut' buttons for most of the frequently-used menu items.

- **View**
  - `Main Toolbar` — show/hide top row of icons
  - `Mouse Toolbar` — show/hide second row of mouse-button action selection icons
  - `Animator` — show/hide tape-deck control panel
  - `Position Tracking` — show/hide bottom position tracking report box
  - `regions` — show/hide region box

Below this is the **Main Toolbar** (Figure 4.2), the top row of icons for fast access to some of these menu items:

- **folder** — show the Load Data panel
- **spanner/wrench** — show the Data Display Options ('Adjust') panel
- **panels** — show the menu of loaded data
- **delete** — closes/unloads selected data
- **save data** — save/export data to a file
- **new panel** — open a new panel
- **panel spanner/wrench** — show the Display Panel's options window
- **save panel** – save panel state to a 'restore' file
- **restore panel** – restore panel state from a restore file
- **profile panel** – open the spectral profiler
- **print** — print data
- **magnifier box** — zoom out all the way
- **magnifier plus** — zoom in (by a factor of 2)
- **magnifier minus** — zoom out (by a factor of 2)

Below this are the ten **Mouse Tool** buttons (Figure 4.3). These allow assignment of *each* of the three mouse buttons to a different operation on the display area. Clicking a mouse tool icon will [re-]assign **the mouse button that was clicked** to that tool. The icons show which mouse button is currently assigned to which tool.

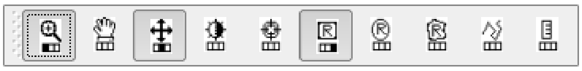

Figure 4.3: The **'Mouse Tool' Bar** allows you to assign separate mouse buttons to tools you control with the mouse within the image display area. Initially, zooming, color adjustment, and rectangular regions are assigned to the left, middle and right mouse buttons, respectively.

The 'escape' key can be used to cancel any mouse tool operation that was begun but not completed, and to erase any tool showing in the display area.

- **Zooming (magnifying glass icon):** To zoom into a selected area, press the Zoom tool's mouse button (the **left** button by default) on one corner of the desired rectangle and drag to the desired opposite corner. Once the button is released, the zoom rectangle can still be moved or resized by dragging. To complete the zoom, double-click inside the selected rectangle (double-clicking *outside* it will zoom *out* instead).
- **Panning (hand icon):** Press the tool's mouse button on a point you wish to move, drag it to the position where you want it moved, and release. *Note: The arrow keys, Page Up, Page Down, Home and End keys can also be used to scroll through your data any time you are zoomed in. (Click on the main display area first, to be sure the keyboard is 'focused' there).*
- **Stretch-shift colormap fiddling (crossed arrows):** This is usually the handiest color adjustment; it is assigned to the **middle** mouse button by default.
- **Brightness-contrast colormap fiddling (light/dark sun)**
- **Positioning (bombsight):** This tool can place a 'crosshair' marker on the display to select a point region. It is used to select a spaxel whose spectrum is displayed in the spectral profiler (see § 4.5) Click on the desired position with the tool's mouse button to place the crosshair; once placed you can drag it to other locations. Double-click is not needed for this tool. See § 4.3.3 for more detail and § 4.6 on how to manage regions.
- **Rectangle, Ellipse and Polygon region drawing:** The rectangle region tool is assigned to the **right** mouse button by default. As with the zoom tool, a rectangle region is generated by dragging with the assigned mouse button; the selection is confirmed by double-clicking within the rectangle. An ellipse region is created by dragging with the assigned mouse button. In addition to the elliptical region, also its surrounding rectangle is shown on the display. The selection is confirmed by double-clicking within the ellipse. Polygon regions are created by clicking the assigned mouse button at the desired vertices, clicking the final location twice to finish. Once created, a polygon can be moved by dragging from inside, or reshaped by dragging the handles at the vertices. Double-click inside to confirm region selection. See § 4.3.3 for the uses of this tool and § 4.6 on how to manage regions.
- **Polyline drawing:** A polyline can be created by selecting this tool. It is manipulated similarly to the polygon region tool: create segments by clicking at the desired positions and then double-click to finish the line. [Uses for this tool are still to be implemented].

- **Distance tool:** After selecting the distance tool by assigning any mouse button to it, distances on the image can conveniently be measured by dragging the mouse with the assigned button pressed. The tool measures the distances along the world coordinate axes and along the hypotenuse. If the units in both axes are [*deg*], the distances are displayed in [*arcsec*].

The main **Display Area** lies below the toolbars.

On the right side of the display area is the **Animator** panel. The most prominent feature is the "tape deck" which provides movement between image planes along a selected third dimension of an image cube. This set of buttons is only enabled when a registered image reports that it has more than one plane along its 'Z axis'. In the most common case, the animator selects the spectral axis. From left to right, the tape deck controls allow the user to:

- **rewind** to the start of the sequence (i.e., the first plane)
- **step backwards** by one plane
- **play backwards**, or repetitively step backwards
- **stop** any current play
- **play forward**, or repetitively step forward
- **step forward** by one plane
- **fast forward** to the end of the sequence

To the right of the tape deck is an editable text box indicating the current frame (channel) number and a label showing the total number of frames. Below that is a box for controlling the (nominal) animation speed. To the right is a 'normal/blink' toggle.

'Blink' mode is useful when more than one raster image is registered. In that mode, the tape-deck controls *which image* is displayed at the moment rather than the particular image plane (set that in 'Normal' mode first). The registered images must cover the same portion of the sky and use the same coordinate projection. Details on registered and opened images are given in § 4.3.4.1. At the bottom of the animator panel is a slider to interactively speed-browse through the channels of an image.

Note: *In 'normal' mode, it is advisable to have only ONE raster image registered at a time, to avoid confusion. Unregister (or close) the others).*

Underneath the Animator Panel is the **Position Tracking** panel. As the mouse moves over the main display, this panel shows information such as flux density, position (e.g. RA and Dec) and spectral value for the point currently under the cursor. Each registered image displays its own tracking information. Tracking can be 'frozen' (and unfrozen again) with the space bar. (Click on the main display area first, to be sure the keyboard is 'focused' there).

Note: *In CASA, a dot (*`.`*) is used as a delimiter for the number groups in the declination values, e.g.* `+30.00.06.156`.

The Animator or Tracking panels can be hidden or detached (and later re-attached) by using the boxes at upper right of the panels; this is useful for increasing the size of the display area. (Use the

'View' menu to show a hidden panel again). The individual tracking areas (one for each registered image) can be hidden using the checkbox at upper left of each area.

4.3.2 Saving and Restoring Display Panel State

It is straightforward to save a display panel's current state (what data is on display along with data and panel settings). Select 'Save Display Panel State to File' (seventh icon from left in Figure 4.2) and confirm the filename. It is strongly advisable (but not required) to retain the file's '.rstr' extension.

Press 'Restore Display Panel State from File' (the button to the right of 'Save Display Panel State to File') to choose a previously-created restore file. You can also select restore files from the 'Load Data' window.

It is possible to restore images or multiple layers such as contour-over-raster. You can also the save the panel state with no data loaded, to restore preferred initial settings such as overall panel size. Animation and zoom state should likewise restore themselves.

Restore is fairly forgiving about data location, and will find files located:

- in the original location recorded in the restore file
- in the current working directory (where you started the viewer)
- in the restore file's directory
- in the original location relative to the restore file

This means that restore files will generally work if moved together with data files. The process is less forgiving if you save the display of an LEL (image) expression, however; the files must be in the locations specified in the original LEL expression. If a data file is **not** found, restore will attempt to proceed but results will vary.

Restore files are in ascii (xml) format, and some obvious manual edits are possible. However, these files are longer and more complex than you might imagine. Use caution, and back up restore files you want to preserve. If you make a mistake, the viewer may not recognize the file as a restore file; other unexpected results could also occur. It is usually easier and safer to make changes on the display panel and then save the restore file again.

4.3.3 Region Selection and Positioning

You can draw regions or select positions on the display with the mouse, once you have selected the appropriate tool(s) on the `Mouse Toolbar` (see above).

The `Rectangle Region` drawing tool currently works for the following:

- Region statistics reporting for images,
- Region spectral profiles for images, via the `Spectral Profile` menu,

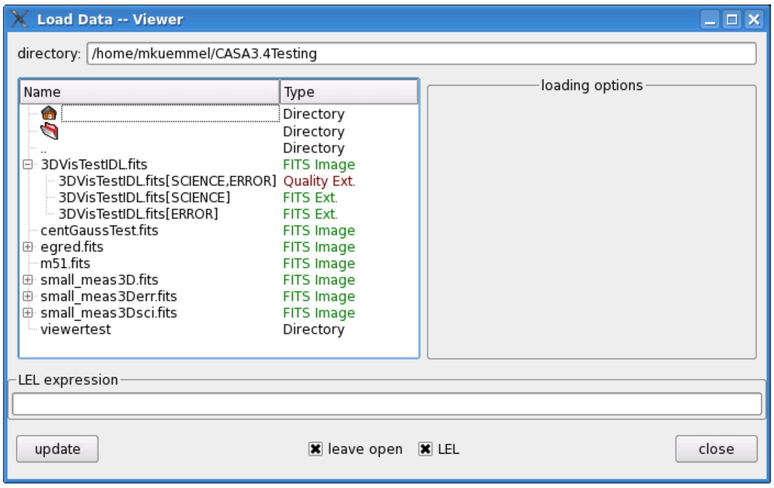

Figure 4.4: The **Load Data - Viewer** panel that appears if you open the `viewer` without any `infile` specified, or if you use the `Data:Open` menu or Open icon. You can see all available files in the current directory that could be loaded into the viewer.

- Creating and Saving an image region for various types of analysis (§ 4.6)

The `Polygon Region` drawing has the same uses.

The `Positioning` crosshair tool works for the last two of the above.

The `Spectral Profile` display (see § 4.5), when active, updates on *each change* of the rectangle, polygon, or crosshair. Flagging with the crosshair also responds to single click or drag.

Region statistics are printed in the terminal window (not the logger) by double-clicking the completed region. The statistics are also displayed in the region dock (§ 4.6).

Here is an example of region statistics from the viewer:

```
    Frequency Spectral_Value         Quality BrightnessUnit          Npts
 3.96603e+14Hz         755.9nm          DATA                           90
          Sum            Mean             Rms        Std dev       Minimum
  8.401877e+01    9.335419e-01   1.273830e+00   8.715402e-01  0.000000e+00
       Maximum
  4.000000e+00
```

Note that even for optical images the spectral value is first given in frequency, followed by the value in the display units (`[nm]` in the example above).

4.3.4 The Load Data Panel

You can use the **Load Data - Viewer** GUI to interactively choose images to load into the viewer. An example of this panel is shown in Figure 4.4. This panel is accessed through the `Data:Open` menu or the Open icon of the **Viewer Display Panel** (see Fig. 4.2). It also appears if you open the `viewer` without any `infile` specified. In addition to the home and the root directories the load data panel shows the files that could be loaded into the viewer (images and restore files) and the sub-directories of the current directory. FITS images with several extensions are show with a `+`-sign (grey arrow on MacOSX) that can be expanded. In the expanded view, the FITS extensions of an image are shown with their extension name and extension version (if available) as type `‘‘FITS ext.’’`.

The document VLT-SPE-ESO-19500-5667 describes a way of storing science data and its pixel-by-pixel error in separate extensions of a FITS file. In the load data panel, such a pair of data-error extensions have the type `Quality Ext.` and are shown with their combined extension names (see Fig. 4.4). Loading a Quality Extension into the viewer means loading both, the data and the error values. In the spectral profiler the error values are used to e.g. overplot the data values (see § 4.5).

Selecting a file on disk in the `Load Data` panel will provide options for how to display the data. Images can be displayed as (see § 4.4 for details):

1. raster image (useful for optical/near IR data),
2. contour map (useful for optical/near IR data),
3. vector map,
4. marker map.

4.3.4.1 Registered vs. Open Datasets

When you ’load’ data as described above, it is first *opened*, and then *registered* on all existing `Display Panels`. The distinction is subtle. An ’open’ dataset has been prepared in memory from disk; it may be registered (enabled for drawing) on one `Display Panel` and not on another. All open datasets will have a tab in the `Data Options` window, whether currently registered or not. On the other hand, only those datasets registered on a particular panel will show in its `Tracking` area.

At present, it is useful to have more than one image registered on a panel *only* if you are displaying a contour image over a raster image (§ 4.4.3) or ’blinking’ between images (see **Animator** in § 4.3.1). (In future we also hope to provide transparent overlay of raster images).

It is the user’s responsibility – and highly advisable – to unregister (or close) datasets that are no longer in use, using the `Register` or `Close` toolbutton or menu.

If you close a dataset, you must reload it from disk as described above to see it again. If you unregister a dataset, it is set to draw immediately when you re-register it, with its options as you have previously set them. In general, close unneeded datasets but unregister those you’ll be working with again.

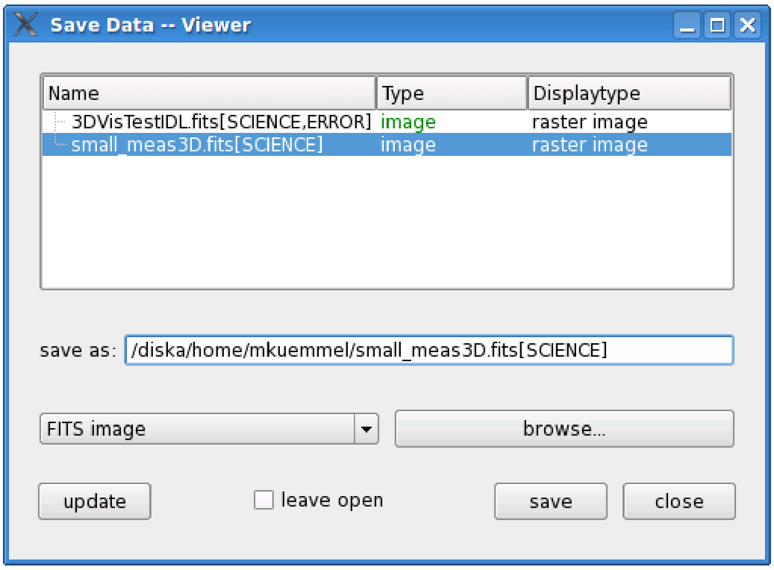

Figure 4.5: The **Save Data - Viewer** panel that appears when pressing the 'save data' icon in the **Main Toolbar** (Figure 4.2).

4.3.5 The Save Data Panel

The user can use the **Save Data - Viewer** GUI to export images from the viewer to a file. The panel is shown Figure 4.5. This panel is opened with the `Data:Save as` menu or pressing the 'Save Data' icon in the **Main Toolbar** (Figure 4.2). The upper part lists all images that can be exported to disk. To save an image to a file, the user can either enter the new filename in the box labeled 'save to:' followed by the save-button (alternatively the 'Enter'-key), or press 'browse...' and specify a filename via a standard filebrowser GUI.

Independent on the original format, images can be exported in both, FITS format and CASA image format.

4.4 Viewing Images

There are several options for viewing an image. These are seen at the right of the **Load Data - Viewer** panel described in § 4.3.4 and shown in Figure 4.6 after selecting an image. They are:

- `raster image` — a greyscale or color image,
- `contour map` — contours of intensity as a line plot,
- `vector map` — vectors (as in polarization) as a line plot,
- `marker map` — a line plot with symbols to mark positions.

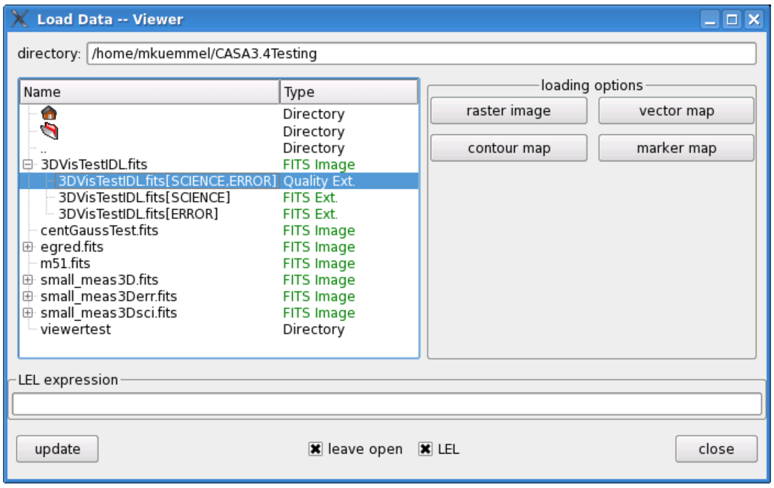

Figure 4.6: The **Load Data - Viewer** panel as it appears if you select an image. You can see all options are available to load the image as a `raster image`, `contour map`, `vector map`, or `marker map`. In this example, clicking on the `raster image` button would bring up the displays shown in Figure 4.1.

The `raster image` is the default image display, and is what you get if you invoke the `viewer` from `casapy` with an image file name. In this case, you will need to use the `Open` menu to bring up the **Load Data** panel to choose a different display.

4.4.1 Viewing a raster map

A raster map of an image is the normal mode to display an image. Here the pixel intensities are shown in a two-dimensional cross-section of gridded data with colors selected from a finite set of (normally) smooth and continuous colors, i.e., a colormap.

Starting the `casaviewer` with an image as a raster map will look something like the example in Figure 4.1.

You will see the GUI which consists of two main windows, entitled "Viewer Display Panel" and "Load Data". In the "Load Data" panel, you will see all of the viewable files in the current working directory along with their type. After selecting a file, you are presented with the available display types (raster, contour, vector, marker) for these data. Clicking on the button `raster image` will create a display Fig. 4.1.

The data display can be adjusted by the user as needed. This is done through the **Data Display Options** panel. This window appears when you choose the `Data:Adjust` menu or use the spanner/wrench icon from the **Main Toolbar**.

The **Data Display Options** window is shown in the right panel of Figure 4.1. It consists of a tab for each image or MS loaded, under which are a cascading series of expandable categories. For an image, these are:

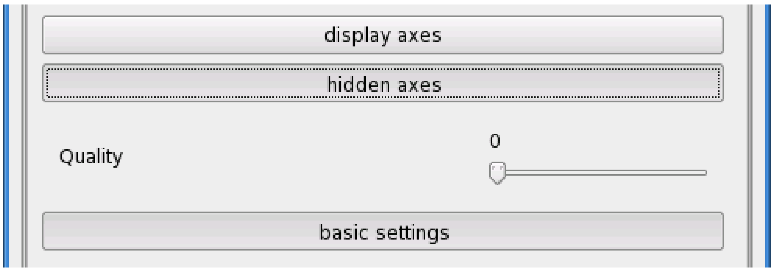

Figure 4.7: The `hidden axis` category of the **Data Display Options** panel as it appears if you load data and error values stored in two image extensions. The data and error values are mapped to an axis called quality axis, and moving the slider to the left and right displays the data and error values, respectively.

- **display axes**
- **hidden axes**
- **basic settings**
- **position tracking**
- **axis labels**
- **axis label properties**
- **color wedge**

The **basic settings** category is expanded by default. To expand a category to show its options, click on it with the left mouse button.

4.4.1.1 Raster image — display axes

In this category the physical axes (i.e. Right Ascension, Declination, Velocity, Stokes) to be displayed can be selected and assigned to the x, y, and z axes of the display.

4.4.1.2 Raster image — hidden axes

Since the viewer can only show three axes of an image (in x- y- and z-axis of the display), images with more than three axes need a selection mechanism for the axes that cannot fully be displayed. This selection mechanism is in the `hidden axes` drop-down. For each additional axis a slider allows to select the plane displayed. Such hidden axes could be the "quality axis" if data and error values are loaded. Figure 4.7 shows the slider for a quality axis. The Slider to the left (0) displays the data values and the slider to the right shows the error values.

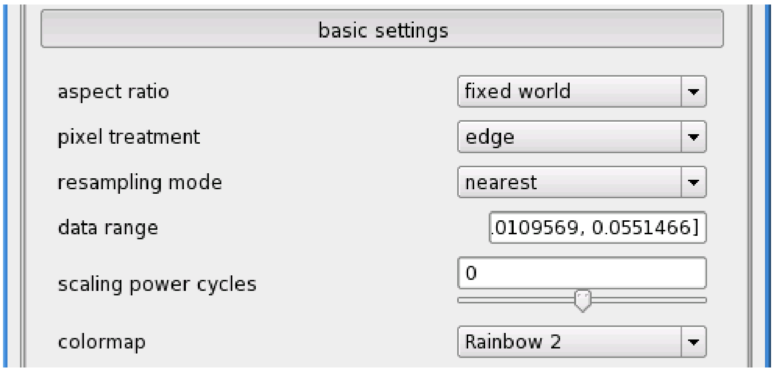

Figure 4.8: The `basic settings` category of the **Data Display Options** panel as it appears if you load the image as a `raster image`. This is a zoom-in for the data displayed in Figure 4.1.

4.4.1.3 Raster image — basic settings

This roll-up is open by default. It has some commonly-used parameters that alter the way the image is displayed; three of these affect the colors used. An example of this part of the panel is shown in Figure 4.8.

The options available are:

- `basic settings: aspect ratio`

  This option controls the horizontal-vertical size ratio of data pixels on screen. `fixed world` (the default) means that the aspect ratio of the pixels is set according to the coordinate system of the image (i.e., true to the projected sky). `fixed lattice` means that data pixels will always be square on the screen. Selecting `flexible` allows the map to stretch independently in each direction to fill as much of the display area as possible.

- `basic settings: pixel treatment`

  This option controls the precise alignment of the edge of the current 'zoom window' with the data lattice. `edge` (the default) means that whole data pixels are always drawn, even on the edges of the display. For most purposes, `edge` is recommended. `center` means that data pixels on the edge of the display are drawn only from their centers inwards. (Note that a data pixel's center is considered its 'definitive' position, and corresponds to a whole number in 'data pixel' or 'lattice' coordinates).

- `basic settings: resampling mode`

  This setting controls how the data are resampled to the resolution of the screen. `nearest` (the default) means that screen pixels are colored according to the intensity of the nearest data point, so that each data pixel is shown in a single color. `bilinear` applies a bilinear interpolation between data pixels to produce smoother looking images when data pixels are large on the screen. `bicubic` applies an even higher-order (and somewhat slower) interpolation.

- `basic settings: data range`

  You can use the entry box provided to set the minimum and maximum data values mapped to the available range of colors as a list `[min, max]`. For very high dynamic range images, you will probably want to enter a `max` less than the data maximum in order to see detail in lower brightness-level pixels. The next setting also helps very much with high dynamic range data.

- `basic settings: scaling power cycles`

  This option allows logarithmic scaling of data values to colormap cells.

  The color for a data value is determined as follows: first, the value is clipped to lie within the data range specified above, then mapped to an index into the available colors, as described in the next paragraph. The color corresponding to this index is determined finally by the current colormap and its 'fiddling' (shift/slope) and brightness/contrast settings (see **Mouse Toolbar**, above). Adding a **color wedge** to your image can help clarify the effect of the various color controls.

  The `scaling power cycles` option controls the mapping of clipped data values to colormap indices. Set to zero (the default), a straight linear relation is used. For negative scaling values, a logarithmic mapping assigns a larger fraction of the available colors to lower data values (this is usually what you want). Setting `dataMin` to something around the noise level is often useful/appropriate in conjunction with a negative 'power cycles' setting.

  For positive values, an larger fraction of the colormap is used for the high data values[1].

  See Figure 4.9 for sample curves.

- `basic settings: colormap`

  You can select from a variety of colormaps here. `Hot Metal`, `Rainbow` and `Greyscale` colormaps are the ones most commonly used.

4.4.1.4 Raster image — position tracking

Contains settings for the position tracking box (Sect. 4.3.1), e.g. the units of the spectral values .

4.4.1.5 Raster image — axis labels

Settings for axis labelling in the main viewer, e.g. to add a title or give dedicated axis labels. These setting might be especially relevant when generating publication-ready plots.

[1] The actual functions are computed as follows:
For negative scaling values (say $-p$), the data is scaled linearly from the range (`dataMin` – `dataMax`) to the range ($1 - 10^p$). Then the program takes the log (base 10) of that value (arriving at a number from 0 to p) and scales that linearly to the number of available colors. Thus the data is treated as if it had p decades of range, with an equal number of colors assigned to each decade.
For positive scaling values, the inverse (exponential) functions are used. If p is the (positive) value chosen, the data value is scaled linearly to lie between 0 and p, and is raised to the power of 10, yielding a value in the range ($1 - 10^p$). Finally, that value is scaled linearly to the number of available colors.

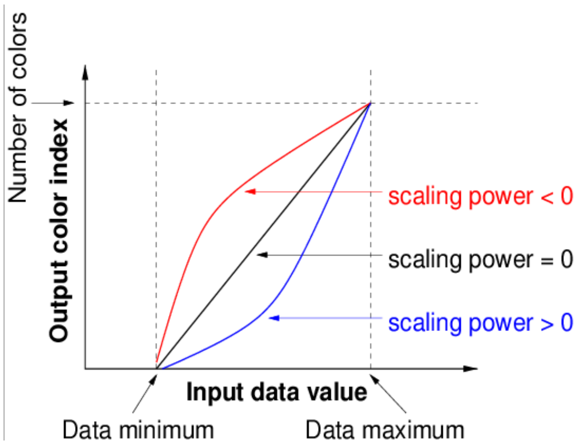

Figure 4.9: Example curves for `scaling power cycles`.

4.4.1.6 Raster image — axis label properties

Many settings in this section address the layout of the axis labels, such as the label color and the font size, which are important when generating dedicated plots, e.g. for publications.

Other settings control the units shown in the main viewer (see Figure 4.10)

- `axis label properties: world or pixel coordinates`

  Showing the x- and y-axis of the main viewer either in world or pixel coordinates.

- `axis label properties: direction reference`

  The reference system for the directional coordinate. Possible choices are `J2000`, `B1950`, `GALACTIC`, `ECLIPTIC` and `SUPERGAL` independent on the reference system associated to the image coordinates.

- `axis label properties: spectral reference`

  The reference system for the spectral coordinate.

- `axis label properties: spectral unit`

  The unit for the spectral coordinate. Available are many units in the frequency, velocity (optical and radio [2]), wavelength and air wavelength domain. Selecting a velocity unit is only reasonable if a rest frequency is given in the setting `axis label properties: rest frequency or wavelength`, either with user input or via the image metadata.

- `axis label properties: movie axis label type`

[2]There are two velocity definitions in use in radio astronomy. The "radio" definition, used in Galactic radio astronomy is $v_r = \frac{\nu_0 - \nu}{\nu_0} c$. The "optical" definition, used throughout extragalactic astronomy is $v_o = \frac{\nu_0 - \nu}{\nu} c = \frac{\lambda - \lambda_0}{\lambda_0} c = zc$. Neither optical, nor radio velocities represent physical quantities; they are merely approximations of the full relativistic expressions for small velocities ($< 1000\,\mathrm{km\,s^{-1}}$)

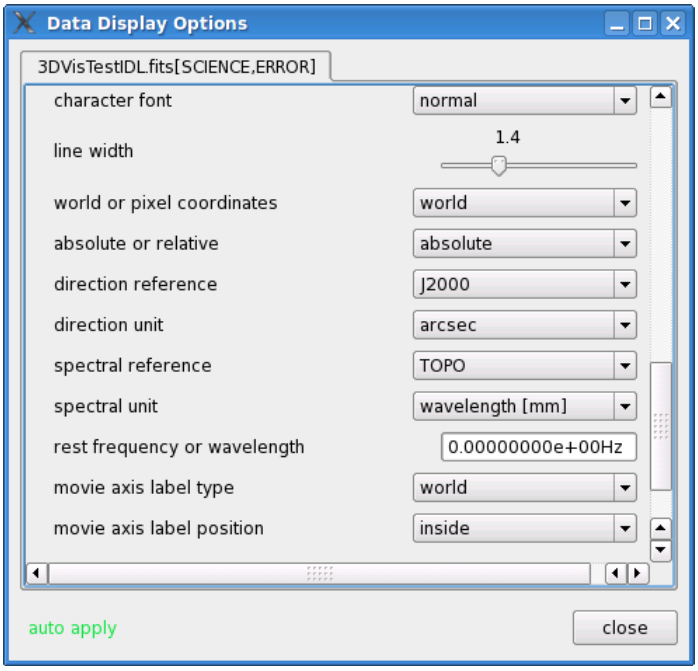

Figure 4.10: Selected settings from the `axis label properties` category of the **Data Display Options** panel. These options control the units on all displayed axes.

Showing the z-axis (or movie-axis) of the main viewer either in world or pixel coordinates.

- `axis label properties: movie axis label position`

  The position of the movie axis label. Available are four positions inside and four positions outside of the pixel image.

4.4.1.7 Raster image — color wedge

Settings to add a color wedge in the main display.

4.4.2 Viewing a contour map

Viewing a contour image is similar to the process above. A contour map shows lines of equal data value (e.g., flux density) for the selected plane of gridded data (Figure 4.11). Contour maps are particularly useful for overlaying on raster images so that two different measurements of the same part of the sky can be shown simultaneously (§ 4.4.3).

Several `basic settings` options control the contour levels used. The contours themselves are specified by a list in the box `Relative Contour Levels`. These are defined relative to the two other parameters, the `Base Contour Level` (which sets what 0 in the relative contour list corresponds

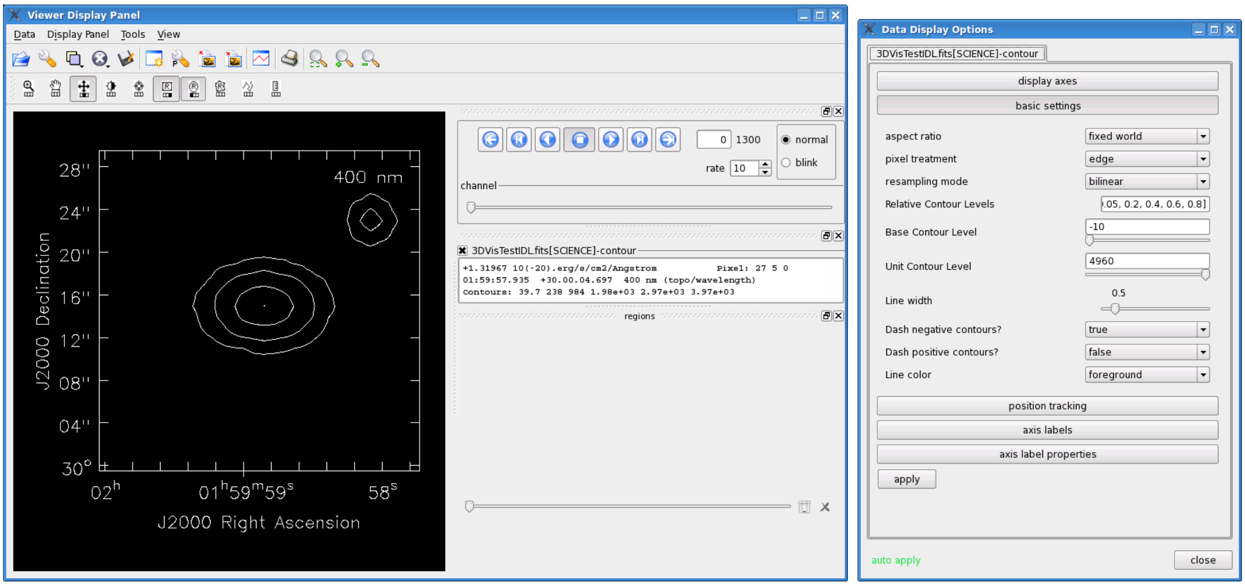

Figure 4.11: The **Viewer Display Panel** (left) and **Data Display Options** panel (right) after choosing `contour map` from the **Load Data** panel. The image shown is for channel 500 of the cube `3DVisTestIDL.fits`, selected using the **Animator** tape deck. Note the different options in the open `basic settings` category of the **Data Display Options** panel (as compared to `raster image` in Figure 4.1).

to in the image), and the `Unit Contour Level` (which sets what 1 in the relative contour list corresponds to in the image). Note that negative contours are usually dashed.

For example, it is relatively straightforward to set fractional contours (e.g. "percent levels"), e.g.:

```
Relative Contour Levels = [0.01, 0.05, 0.2, 0.4, 0.6, 0.8]
Base Contour Level = -10.0
Unit Contour Level = <image max>
```

This maps the maximum to 1 and thus the contours are fractions of the peak.

Another example shows how to set absolute values so that the contours are given in image units:

```
Relative Contour Levels = [10, 100, 1000, 1900]
Base Contour Level = 0.0
Unit Contour Level = 1.0
```

Here we have contours at 10, 100, 1000 and 1900.

We can also set contours in multiples of the image rms ("sigma"):

```
Relative Contour Levels = [-3,3,5,10,15,20]
Base Contour Level = 0.0
Unit Contour Level = <image rms>
```

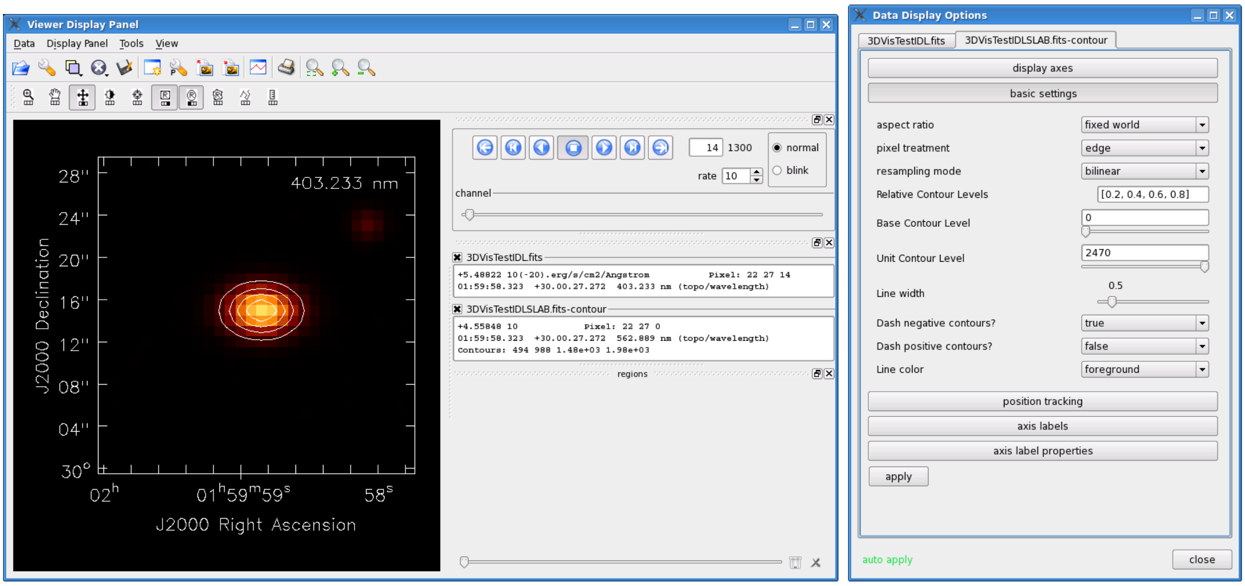

Figure 4.12: The **Viewer Display Panel** (left) and **Data Display Options** panel (right) after overlaying a `Contour Map` on a `Raster Image`. The tab for the contour plot is open in the **Data Display Options** panel.

Here we have first contours at negative and positive 3-sigma. You can get the image rms using the `imstat` task or using the Viewer statistics tool on a region of the image (§ 4.3.3).

4.4.3 Overlay contours on a raster map

Contours of either a second data set or the same data set can be used for comparison or to enhance visualization of the data. The Data Options Panel will have multiple tabs which allow adjusting each overlay individually (Note tabs along the top). **Beware:** it's easy to forget which tab is active! Also note that `axis labeling` is controlled by the *first-registered* image overlay that has labeling turned on (whether raster or contour), so make label adjustments within that tab.

To add a Contour overlay, open the **Load Data** panel (Use the **Data** menu or click on the folder icon), select the data set and click on `contour map`. See Figure 4.12 for an example.

4.5 Spectral Profile Plotting

From the **Main Toolbar** (see Fig. 4.2), the `Spectral Profile` plotting tool can be selected. This creates a new **Spectral Profile** window containing an x-y plot of the intensity versus spectral axis. The displayed spectrum is extracted in region marked with the **Point**, **Rectangle**, **Ellipse** or **Polygon Region** tool in the **Viewer Display Panel**. The spectrum shown in the **Spectral**

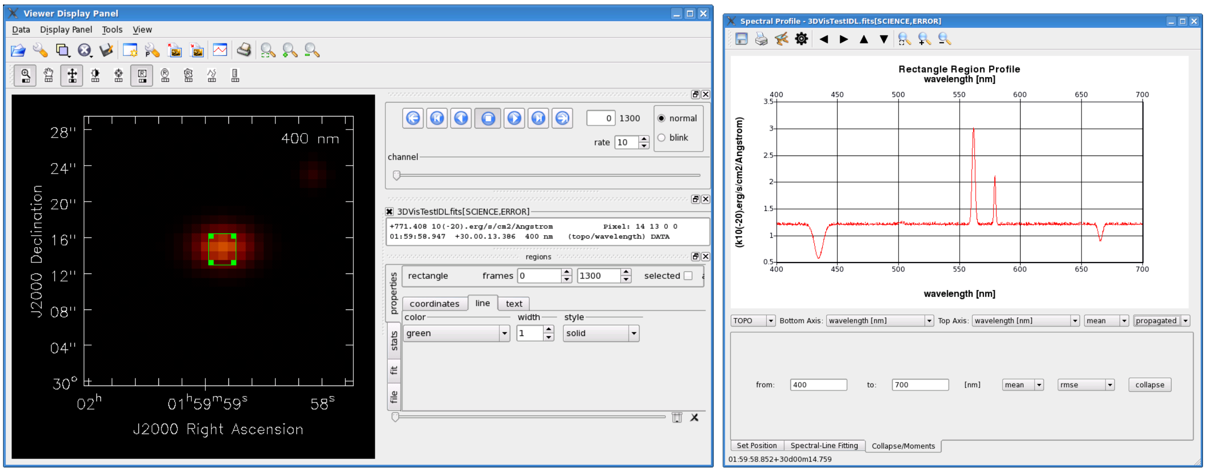

Figure 4.13: The **Spectral Profile** panel (right) that appears when pressing the button **Open the Spectrum Profiler** in the **Main Toolbar** and then use the tools to select a region in the image, such as the rectangular region on the left panel. The profile changes to track movements of the region if moved by dragging with the mouse.

Profile window (right panel in Figure 4.13) is automatically updated if the corresponding region is dragged across the image in the **Viewer Display Panel** (right panel in Fig. 4.13).

4.5.1 Toolbar

The toolbar of the **Spectral Profile** (Figure 4.14) contains action icons to (from left to right):

- **save data** - export the current profile to a FITS or ASCII file;
- **print** - print the main window;
- **save panel** - save the panel as an image (PNG, JPG, PDF, ...);
- **preferences** - set plot preferences;
- **move left** - 'move' the x-boundaries of the spectrum plot to the left;
- **move right** - 'move' the x-boundaries of the spectrum plot to the right;
- **move up** - 'move' the y-boundaries of the spectrum plot up;
- **move down** - 'move' the y-boundaries of the spectrum plot down;
- **zoom reset** - reset the zoom;
- **zoom in** - zoom in;
- **zoom out** - zoom out;

Figure 4.15 shows the panel with the plot preferences. Several settings can be switched on/off:

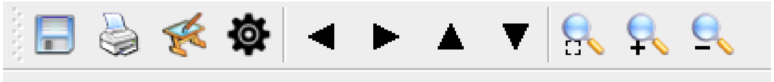

Figure 4.14: The toolbar of the **Spectral Profile** contains a couple of action icons to save data or manipulate the displayed xy-range.

- **x Auto Scale:** adjust the x-boundaries dynamically;
- **y Auto Scale:** adjust the y-boundaries dynamically;
- **Show Grid:** connect the tickmarks with lines;
- **Overlay:** extract and plot the spectra of all cubes registered in the viewer;
- **Top Axis:** show units on the top axis.

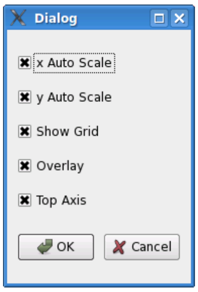

Figure 4.15: The plot preferences panel

4.5.2 Main window

The main window shows the spectrum extracted from the image. The unit of the spectral axis can be selected between frequency, wavelength and velocity units. Velocity units are only available if a rest frequency is defined (see Sect. 4.4.1.6). The user can choose between the different combine types `mean`, `median` and `sum` in a combo box. The spectra are scaled in the y-axis to avoid numbers that are long and difficult to decipher. The scaling is expressed in prefix letter to the y-axis unit ($m = 10^{-3}$, $k = 10^3$, $M = 10^6$, . . . ; see e.g. Fig. 4.16).

Besides the spectral values also the error bars can be plotted. There are two different ways to derive error values, which are set in a combo box. If the region used for the extraction has two dimensions (rectangle, ellipse and polygon), for each spectral channel the root-mean squared error can be computed and used as error (error type `rmse` in the combo box). If both, the data values and the pixel-by-pixel error values had been loaded into the viewer as a `Quality Extension` (see Sect. 4.3.4), these error values are used for the error bars (error type `propagated` in the combo box). For a point-region, the error values are directly plotted as error bars, for rectangle, ellipse

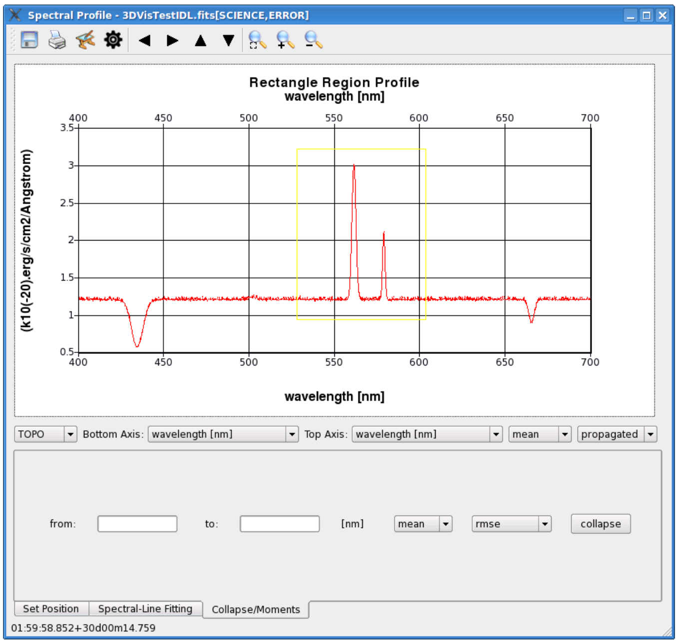

Figure 4.16: With `dragging the left mouse button` over the main window the user can interactively modify the plot boundaries in x and y and thus zoom in or out the profile (yellow box in left panel).

and polygon the pixel errors are, at each wavelength, propagated to determine a single error value which overplot the data value.

The main window is sensitive to the following combination input from keyboard and mouse (Figure 4.18):

- **zoom:** When `pressing and dragging the left mouse button`, a yellow box is drawn onto the panel. After releasing the mouse button, the xy-range is zoomed to the values of the yellow box (see Figure 4.16). The sensitive area includes the regions outside the current plotting boundaries, thus it is also possible to zoom out.

- **spectral range selection:** When `pressing and dragging left mouse button with shift-key`, a gray box marks a spectral range in the plot, as shown in Figure 4.17. The start and end values are written into the `from:` and `to:` box of the **collapse/moments** and **linefit** tab. This allows an interactive selection of the spectral range used in the collapse/moments or linefit operation;

- **spectral channel selection:** When pressing the `ctrl-key`, a gray line is drawn at the current position of the mouse in the spectral profile window (Fig. 4.18). After `pressing the left mouse button`, the image in the **Viewer Display Panel** displays in the z-axis the spectral channel marked with the gray line.

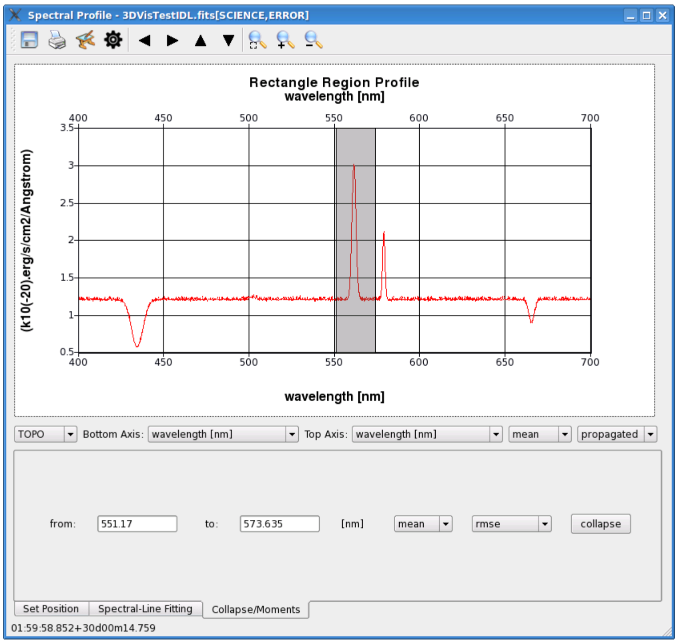

Figure 4.17: Pressing the `shift-key` while `dragging the left mouse button` marks a spectral range with a gray area (middle panel) and provides start and end values for the tabs `collapse/moments` and `linefit`.

4.5.3 Spectral/Image analysis

The two tabs labeled `Collapse/Moments` and `Spectral-Line Fitting` in the lower part of the **Spectral Profile** panel offer simple image analysis tools to the user (see Figs. 4.17 and 4.19).

In `Collapse/Moments` the user can collapse the image along the spectral axis between the start and end values provided in the corresponding boxes. Various collapse types (`mean`, `median` and `sum`) are offered, and the error is computed via error propagation from the pixel errors `propagated` or by computing the root-mean squared error (`rmse`). The collapsed image is displayed in the **Viewer Display Panel**.

In `Spectral-Line Fitting` the user can fit a function to the spectrum profile (Figure 4.19). A Gaussian plus a polynomial of up to first (linear) order can be selected for the fit function in two combo boxes. If error bars are displayed in the spectral profiler, they are used in the fitting as weights. The main results of the fit are shown in the status bar of the **Spectral Profile**. A detailed summary of the fit is sent to the standard output (either the casapy window or the window where the viewer was started).

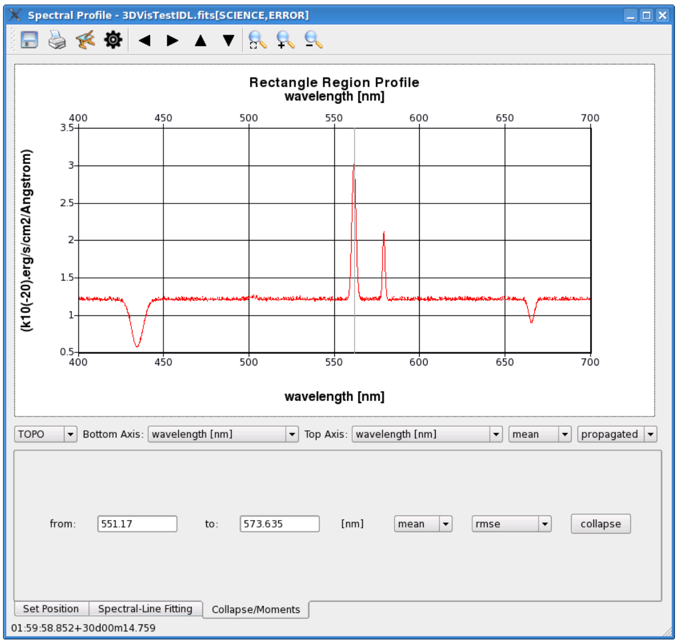

Figure 4.18: With the `ctrl-key` pressed, a gray line marks the cursor position. Clicking the `left mouse button` displays the corresponding spectral channel in the **Viewer Display Panel**.

4.5.4 Set Position

The third tab labeled `Set Position` in the lower part of the **Spectral Profile** panel offers a non-interactive way of extracting spectra from the 3D cube loaded in the main viewer. The coordinates (absolute and pixel) of point and rectangular region are inserted into the GUI elements. When pressing the button **Apply**, the spectrum is extracted and displayed in the main window of the profiler. The operation does not create a corresponding region in the region panel of the main viewer.

4.6 Managing Regions and Annotations

CASA regions are following the CASA 'crtf' standard as described in the CASA User Reference & Cookbook. CASA regions can be used in all applications, including `clean` and image analysis tasks of CASA . In addition, a leading 'ann' to each region definition indicates that it is for visual overlay purposes only. On a side note: apart from the regions mentioned here, CASA supports image masks, i.e. images that contain only 0 and 1 (or 0 and non-0). In some images, masks are stored in a True/False Boolean format.

Alert: Whereas the region format is supported by all the data processing tasks, the `viewer` implementation is still limited to rectangles, ellipses, and some markers. We expect the full imple-

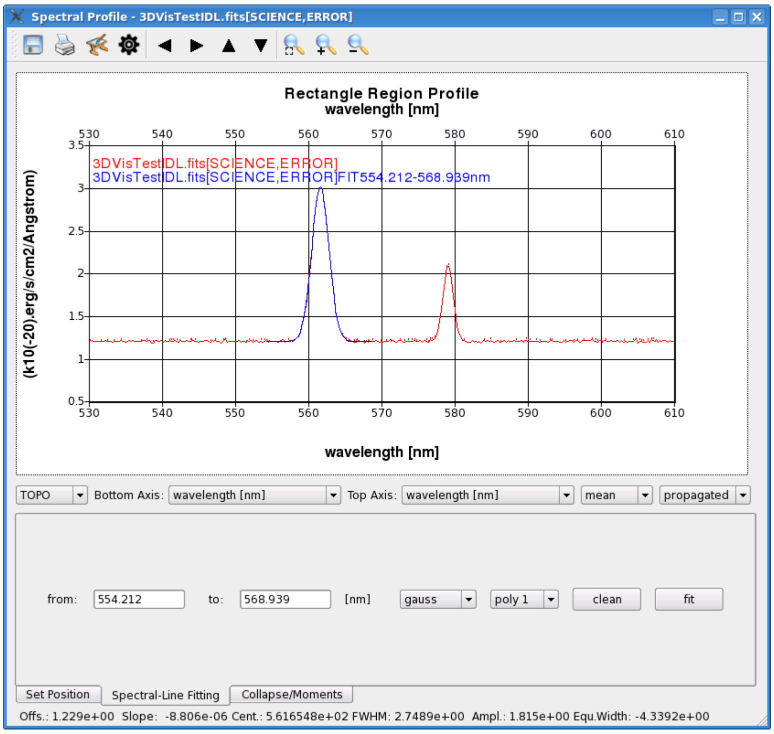

Figure 4.19: A Gaussian fit (blue line) to the spectral profile (red line). The status line at the bottom of the panel contains the main fit results, all details are printed to standard output.

mentation to be available in a future CASA release.

Regions can be created with the buttons marked as 'R' in the mouse tool bar (§ 4.3.1, § 4.3.3). The viewer currently supports rectangles, ellipses, polygons, and the point (crosshair). As usual, a mouse button can be assigned to each button as indicated by the small black square in each button (marking the left, middle, or right mouse button § 4.3.1, § 4.3.3). An example is shown in Fig. 4.21.

Regions can be selected by SHIFT+click, de-selected by pressing SHIFT+click again, and removed by hitting the ESC button.

Once regions are selected, they will feature little, skeletal squares in the corners of their boundary boxes. This distinguishes them from a zoom box (magnifier glass § 4.3.1), where the corners are solid.

Regions can be moved by dragging with the mouse button and if more than one region is selected, all selected regions move together.

To load, unload, modify, and to display the value statistics of each region, the Region Panel can be loaded via the 'View'→'region' drop-down menu. As all other panels, the region panel can be docked to different portions of the viewer and it can also be detached. If it is dismissed (the cross in the upper right corner), it can be retrieved by the `'View'` menu.

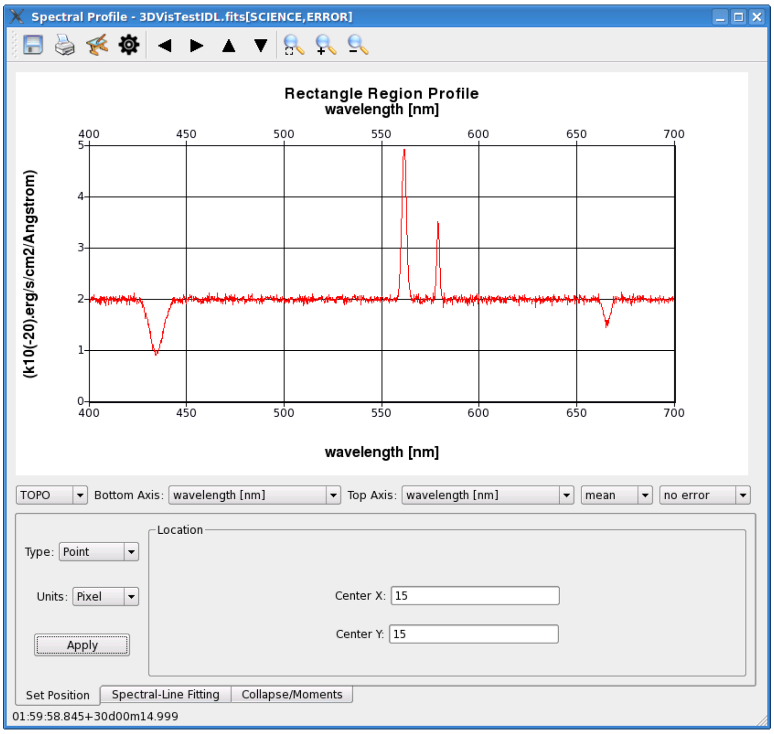

Figure 4.20: Extracting a spectrum with the `Set Position` tab. The pixel coordinates of the point region ($(x, y) = (15, 15)$) is specified in the GUI elements.

The three basic windows of the region panel are shown in Fig. 4.22.

4.6.1 Region Panel: properties

The properties tab can be used to adjust the the size, center, and coordinate frame of the region (`'coordinates'` selection at the top). The inputs can be in different units, and those implemented in the viewer are commonly used sub-sets of the options listed in the CASA User Reference & Cookbook. At the top of the panel, one can specify the channel range over which the region shall be defined. The `'selection'` check box is an alternative way to the `SHIFT+click` to select a region. The `'annotation'` checkbox will place the `'ann'` string in front of the region ascii output – annotation regions are not be used for processing in, e.g. data analysis tasks.

The second horizontal tab `'line'` brings up a panel to change the color, line width, and line style (solid, dotted, dashed) of the selected region.

The third panel, `'text'`, can be used to assign a string to the region which can be controlled in position (the little dial at the bottom, and the two right hand boxes), as well as text font, style, and color.

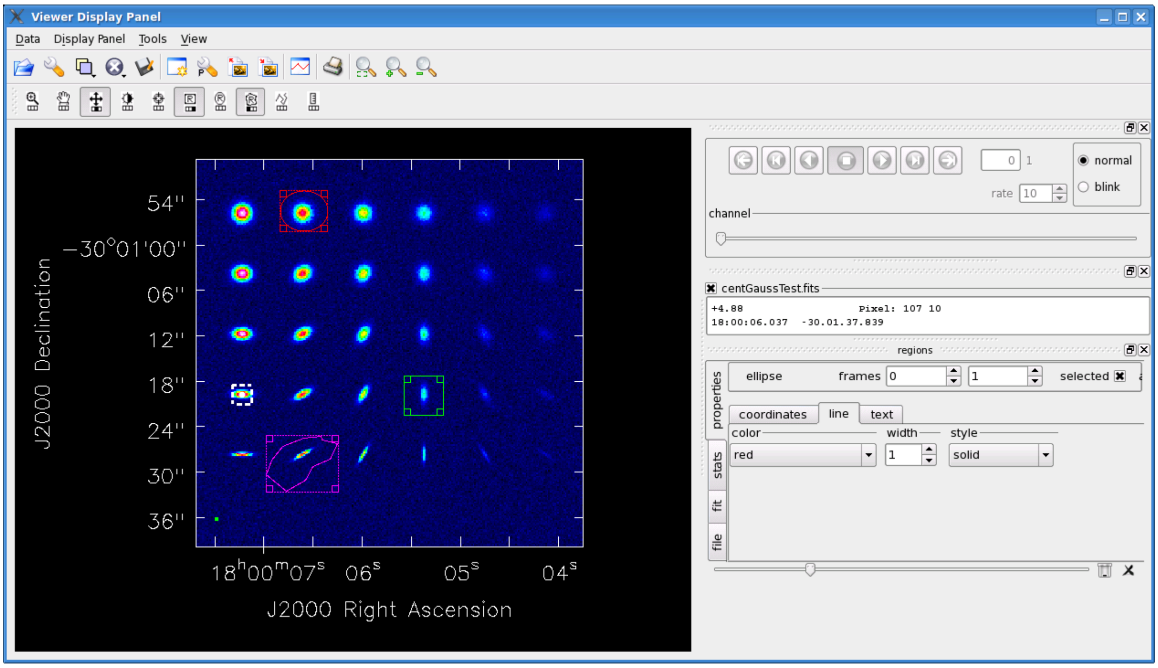

Figure 4.21: Image regions created with the region tools of the viewer. The region panel is shown to the right.

4.6.2 Region Panel: stats

The second vertical tab, 'stats', displays the statistics of each region. When more than a single region is drawn, one can select them one by one and the region panel updates image information and value statistics for each region. The informational section contains the frequency, velocity, stokes and brightness unit of the image. The beam area is also calculated from the header information of the image. The statistical properties of the pixels within in the region comprises the number of pixels (Npts), the Sum, Mean, RMS, Minimum, and Maximum of the pixel values, as well as the image flux integrated over the region. All values are updated on the fly when the region is dragged across the image.

Note that double-clicking the region will output the statistics to the terminal as explained above. This is an easy way to copy and paste the statistical data to a program outside of CASA for further use.

4.6.3 Region Panel: fit

The third tab 'fit' is used for fitting 2D Gaussians to the pixels values enclosed in the rectangle, ellipse or polygon region. Figure 4.23 illustrates the Gaussian fitting. Pressing the button `gaussfit` executes the fit with the option of taking into account a constant sky level in the box `sky component`. The fitting results are written to the terminal and to the region panel (both in

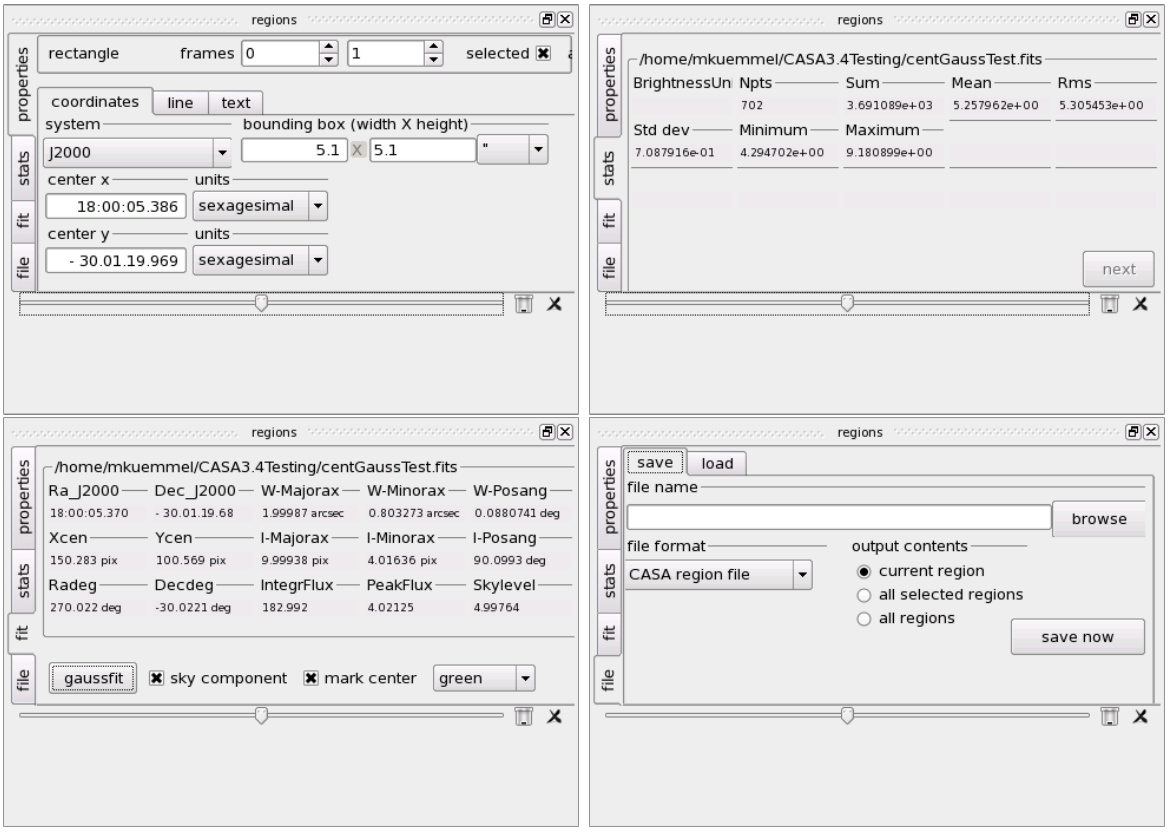

Figure 4.22: The four vertical tabs of the region panel: `properties`, `stats`, `fit`, and `file`.

pixel and world coordinates). The center coordinates and the position angle can be overlayed in the main image (left side of Fig. 4.23) using a color chosen by the user.

If a region is modified or moved, or a different layer in z is shown, the fitted values are no longer valid. As a consequence the overlay of the center and position angle is removed and the fit results in the panel are shown with a dark background.

4.6.4 Region Panel: file

The fourth tab 'file' is used for loading and saving regions from and to disk (select the appropriate the action at the top). To save to ascii file, one can specify the file format, where the default is a CASA region file (saved with a *.crtf suffix, see the CASA User Reference & Cookbook).It is also possible to load and save DS9 regions, but remember that the DS9 format does not offer the full flexibility and cannot capture stokes and spectral axes. DS9 regions will only be usable as annotations in the viewer, they cannot be used for data processing in other CASA tasks.

When saving regions, one can also specify whether to save only the current region, all regions that were selected with SHIFT+click, or all regions that are visible on the screen.

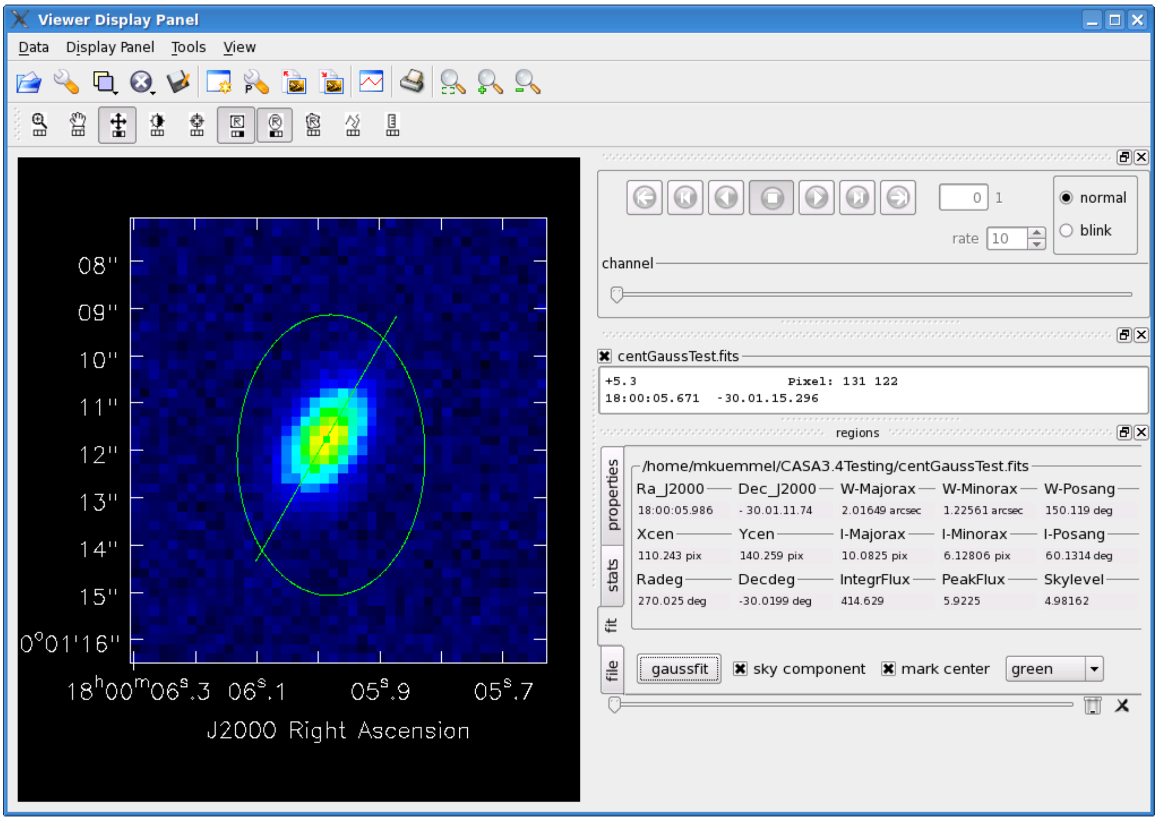

Figure 4.23: 2D Gaussian fitting in regions. The fit results are written to the terminal, shown in the region panel and overlaid in the image (left).

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