AIPS Memo 124 Revised

Further Exploration of Image Cubes in AIPS

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Abstract

AIPS has powerful tasks to fit models to the spectral axis of image cubes. Tasks like `XGAUS` and `RMFIT` are easier to run if the user is already familiar with the general structure of the data cube. Task `TVSPC` was written to explore data cubes with emphasis on plots of spectra. Now a new task `TVIEW` has been written to explore data cubes with displays of position-velocity transpositions of the data cube. This task provides an additional exploration tool within the AIPS environment, rather than requiring users to export their cubes to one or more of the many excellent visualization tools now available. `TVIEW` offers the option of rotating the image in the celestial axes so that the position-velocity curves may be viewed along axes pertinent to the source, *e.g.*, the major axis. [1]

1 Introduction

AIPS has a suite of tasks designed to fit models to the spectral axis of image cubes. Gaussians may be fit in emission or absorption, Zeeman splitting may then be fit, and, in polarization, rotation measures may be fit. These tasks, along with display and modeling tasks, are described in an AIPS Memo[2] which includes descriptions of the mathematics, the input adverbs, and the flow of each program. Similar tasks geared for use with absorption-line spectral cubes have appeared and `AGAUS` and `ZAMAN` are described in an AIPS Memo[3]. `TVSPC` is an interactive data exploration task which assists users to become familiar with the spectral content of their data cubes. It is described in yet another AIPS Memo[4]

One can use the above tasks without being familiar with the contents of the image cubes. However, users who are familiar with the contents of their data cubes will find the modeling tasks simpler to use. `TVSPC` emphasizes spectra at individual pixels on the celestial axes. A full understanding of the data cube however requires examining the cube on planes with one spectral and one celestial axis (the so-called "position-velocity" display). There are two such transpositions of the data cube in addition to the one having two celestial axes on each plane.

2 Image cube exploration: `TVIEW`

A new task, called `TVIEW`, has now appeared in the `31DEC18` version of AIPS. It presumes that the user has a "spectral" image cube in any transposition which has 2 celestial and one spectral axes as the first 3 axes. Optionally, the user may also have a second "reference" image, only one plane of which will be displayed. It is assumed that the two celestial axes are the first two axes of this image. The reference image can be any image that is meaningful to the study of the data cube and is not required to be on a coordinate system

[1] The color red has been used for changes made to this memo in April 2025 while blue is for changes in October 2019.

[2] Greisen, E.W. 2015, AIPS Memo 118 revised, "Modeling Spectral Cubes in AIPS," March 2017.

[3] Greisen, E.W. 2017, AIPS Memo 122, "Modeling Absorption-line Cubes in AIPS," March 2017.

[4] Greisen, E.W. 2016, AIPS Memo 120, "Exploring Image Cubes in AIPS," revised October 2019.

identical to the data cube. An obvious example of a reference image would be the zero-moment image (integral under the line) as shown in the figures in this Memo. Other possibilities would be a continuum or rotation measure image. In 31DEC25, TVIEW will offer the choice to display the reference image (if specified) or the spectrum at the celestial pixel selected for the two position-spectral displays. Menu options now allow the user to switch between the two displays. The new pseudo-coloring scheme named OFMCOLOR was also added.

2.1 Inputs

The usual INNAME *et al.* adverbs define the three-dimensional image cube to be displayed in grey-scale on the AIPS TV. Adverbs BLC and TRC may be used to limit the extent of the cube that is displayed. The usual IN2NAME *et al.* adverbs, if not blank, define the two-dimensional reference image. Adverbs TBLC and TTRC select the portion of this image to appear on the TV including the plane if IN2NAME points at an image cube. If IN2NAME is left blank, the upper left portion of the screen will be used to display spectra. If it is not blank, the upper left portion of the screen will begin by displaying the reference image. A menu option will allow the user to switch to the spectrum display and back again. TVCHAN selects the TV channel used for the gray-scale display. PIXRANGE selects the reference image intensity range while FUNCTYPE selects the transfer function used to load all images to the TV. The image intensity range for the reference image (or the spectra) and, separately, for the cube may be changed while running the task as well. CBPLOT controls the plotting of a Clean beam on position-position images when labeling is enabled. The REWEIGHT adverb controls the accuracy and blanking parameters of the interpolation used when rotating the images. The larger REWEIGHT(1), the greater the accuracy and the greater the computation time. With the 952 x 538 data cube with 108 spectral planes used in the figures of this memo, a rotation with REWEIGHT(1) = 1 required 7 seconds while REWEIGHT(1) = 4, the upper limit required 37 seconds. There are no other adverbs.

2.2 Execution: the image

When TVIEW begins it reads the reference image, if any, into dynamic memory and then reads the image cube into 3 different dynamic memory segments, one for each transposition. The reference image is then displayed in the upper left quadrant of the TV screen. If there is no reference image, then the spectrum at the celestial position used for the S-Y-X and S-X-Y displays is shown. The X-Y-S cube (X is usually right ascension, Y declination, and S frequency or velocity) is displayed in the lower left quadrant using the central spectral plane. The S-X-Y cube is displayed in the upper right quadrant and the S-Y-X cube is displayed in the lower right quadrant. Each image is made as large as the available TV real estate will allow. If the image is small, pixels will be interpolated. If it is large, only every n^{th} pixel will be displayed. In the spatial displays (two left images), the X and Y increments are kept the same. In the other displays, the S increment and the X and Y increments are allowed to differ. Every time the images are loaded, information on the increments of windows is given in the message window. The pixel number along the third axis of the displayed image plane is shown at the upper right of the corresponding image along with the appropriate coordinate, usually right ascension and declination.

The following menu appears in yellow at the left of the screen whenever you need to select some operation. (Graphics colors mentioned in this Memo assume that the user has not changed the default colors of the XAS graphics planes.) When the TV cursor is moved to an option, the color of the option changes to purple. To select the option, press buttons A, B, or C; button D will cause a brief explanation of the option to appear in the command input window.

The gray-scale image(s) are displayed with a black-and-white enhancement function followed by pseudo coloring, all with familiar functions. TVTRANSF is an interactive alteration of the black-and-white enhancement in which the TV cursor x position controls the intercept and the y position controls the slope of a linear transfer function. Buttons A and B turn a plot of this function on and off, button C changes the sign of the slope, and button D exits. OFF TRANS resets the transfer function. TVPSEUDO is an interactive pseudo coloring. Button A selects triangles in the three colors with the cursor x position controlling the position separating the lowest color from the highest, the cursor y position controls the "gamma" correction affecting the intensity of the colors, and repeated hits of button A cycling between all 6 possible color orders. Button B selects circles in hue at maximum saturation and intensity, with the cursor x position controlling the number of circles and the cursor y position controlling the starting hue. Button C selects color contours with the cursor x position controlling the image intensity at which contours begin, the cursor y position sets the range of image intensities over which the contours extend, and repeated hits of button C select between five different contour designs. Button D exits, returning to read the next operation from the menu. `TVPHLAME` implements a flame-like pseudo-coloring ranging initially from red through orange and yellow to white. The cursor x position controls the intensity at which the color transitions take place, the y position controls the gamma correction and repeated hits of buttons A or B will cycle between the 6 color sequences possible. Buttons C and D return you to the main menu. `OFMCOLOR` allows you to choose any one of 10 "output function memory" tables attached to each of buttons A, B, and C, 30 in all. Having selected a color scale, it may be adjusted with the horizontal position of the cursor. `OFF PSEUDO` turns off all coloring.

`OFF TRANS`	Initialize black-and-white transfer function
`OFF PSEUDO`	Turn of any pseudo-coloring
`TVTRANSF`	Adjust black-and-white transfer function
`TVPSEUDO`	Color contours of a variety of types
`TVPHLAME`	Flame-like pseudo-coloring
`OFMCOLOR`	Many color tables available
`LABEL IMAGES?`	Cycle through image labeling options
`CURVALUE`	Display intensity and pixel under the cursor
`SET CUBE RANGE`	Enter cube images intensity display range
`SET REF RANGE`	Enter reference image intensity display range
`SET SPEC RANGE`	Enter spectrum plot intensity display range
`SPECTRA`	Display spectra in upper left
`REFERENCE`	Display reference image in upper left
`ROAM`	Select planes to display in the cube images
`SET WINDOW`	Select a sub-image for more detailed viewing
`RESET WINDOW`	Return to viewing full image
`ROTATE`	Enter angle to rotate all images
`TV ROTATE`	Interactively set angle to rotate all images
`RELOAD IMAGES`	Reread the images from disk undoing any rotation
reference image	
`EXIT`	Exit `TVIEW`

The `LABEL IMAGES?` option has three states: labels off, labels on the gray-scale image(s), and labels on the image(s) with a full coordinate grid. Successive selection of this option cycles through the three states. The `CURVALUE` option lets you display the pixel numbers and intensity under the cursor when the cursor is placed in any of the grey-scale images. The `SET REF RANGE` option lets you set the intensity range displayed for the reference image. If spectra are being displayed, this option is replaced with `SET SPEC RANGE` which allows you to set the spectrum plot intensity range. When the reference image (if any) is again displayed, this option returns. `TVIEW` will prompt you with a message indicating the image intensity range. Enter two numbers in the command input window. If the first is less than the second, the two numbers define the desired display range. If the two numbers are the same, or the first is larger, then the display reverts to the full image intensity range. The `SET CUBE RANGE` is similar but applies to the three displays of the cube image.

`SET WINDOW` is used to select a section of the reference image or the cube images to be blown up for more detailed examination. You must first move the TV cursor to the image which you wish to examine more closely and hit any button. Then it behaves like verb `TVWINDOW` and begins by setting the lower-left corner. Hit buttons A or B to switch to setting the upper right corner. Buttons A and B switch between the corners thereafter. Buttons C and D exit with the window set. At this point, TVIEW reloads the affected image(s) with the selected corners, maximizing the size of the image on the TV while keeping the X and Y pixel increments the same (in the reference and X-Y-S images only). A window in the reference image affects only that image. A window in the other three displays will affect the appropriate axes in all displays. Thus, a window in the X-Y-S display will affect the vertical axes in the S-X-Y and S-Y-X displays. A window in the S-X-Y display will affect the horizontal axis of the X-Y-S display and the S-Y-X display and a window in the S-Y-X display will affect the vertical axis in the X-Y-S display and the horizontal axis in the S-X-Y display. All planes in each of the cube transpositions remain available for display without regard for the selected windows.

RESET WINDOW requires you to position the cursor in the desired gray-scale display and press any button. Then the window in that image will be reset to the initial corners (BLC and TRC of the cube and TBLC and TRC of the reference image). Note that the reset window parameters affect the images as described above for SET WINDOW.

2.3 Execution: examining the cube

The ROAM option allows you to choose which planes of the cubes are displayed. Position the cursor in one of the image windows and move it around. Two of the displayed windows will change. If you are in either of the left-hand (reference X-Y and X-Y-S) windows, the two right-hand windows will change as you select the Y and X planes. If you are in the top right window (S-X-Y), then the two lower windows will change as you select S and X planes. If you are in the lower right window, the top right and lower left windows will change as you select S and Y planes. The plane number will appear at the top right of each window along with an approximate coordinate for that plane. The spectral coordinate is assumed linear and the celestial coordinate in X is computed at the reference pixel in Y and vice versa. Since the celestial coordinates are non-linear projections, these only approximate the correct coordinate especially if there is rotation. If there is no reference image or the spectrum plot has been selected, that plot will change to that appropriate to the X and Y pixels selected.

The user may wish to examine the cube after some rotation in the celestial coordinates. The example shown in the next section includes a rotation to make the galaxy major axis horizontal. Doing this removes some of the projection affects in the apparent rotation curve. There are two options to perform this rotation. In the simple ROTATE option, the user is prompted to enter an angle in the command input window. Units are degrees clockwise. In the interactive TV ROTATE option, the reference image is shown using the full screen. If there is no reference image, the current plane of the X-Y-S image is shown. A short green line is overlaid. Move one end of the line to the end of a the desired slice and hit button A, B, or C. Then move the other end of the slice to the desired point. Buttons A, B, and C switch ends of the slice. Hit button D to determine the angle subtended by the slice which will be used to rotate the images. Note that the rotation requires an interpolation operation which is controlled by the REWEIGHT adverb (see above). After the rotation has been computed, the altered images are displayed.

Note that pixels in the rotated image that do not occur in the previous images must be blanked. Each subsequent rotation will increase the number of blanked pixels. To start over with the initial, unrotated images, select the RELOAD IMAGES option.

2.4 Examples

The image used to illustrate TVIEW is an HI spectral line cube of NGC 6503. The reference gray-scale image chosen is a moment-zero image giving a wide-angle view of the total HI in the galaxy. It covers a larger spatial area than the cube which also has different spatial pixel size and other different coordinate parameters. In one of the figures, the moment one image is shown giving a wide-angle view of the predominant velocity of the HI. An analysis of these data has been published.[5]

Figure 1 illustrates, in the upper portion, the screen at the start of the program. The reference image is at the top left, the X-Y-S image central plane is at the lower left, the S-X-Y central plane is at the upper right, and the S-Y-X central plane is at the lower right. The lower portion of the Figure shows the screen after a `LABEL IMAGES?`, a `SET WINDOW` in the reference image, and a `ROAM` in which the cursor was only placed in the lower right image.

Figure 2 also illustrates the `TV ROTATE` option. The upper portion shows the interactive setting of the desired rotation angle and the lower portion shows the images after the rotation. The second invocation of `LABEL IMAGES?` has been invoked and `TVPSEUDO` has been used to label fully and to color the lower portion.

Figure 3 illustrates the screen when the spectral display has been selected (or there is no reference image). It also illustrates use of sub-images, display of the Clean beam, use of rotation, and pseudo-coloring.

[5] Greisen, E. W., Spekkens, K., van Moorsel, G. A. 2009, "Aperture Synthesis Observations of the Nearby Spiral NGC 6503: Modeling the Thin and Thick Disks", AJ, 137, 4718-4733.

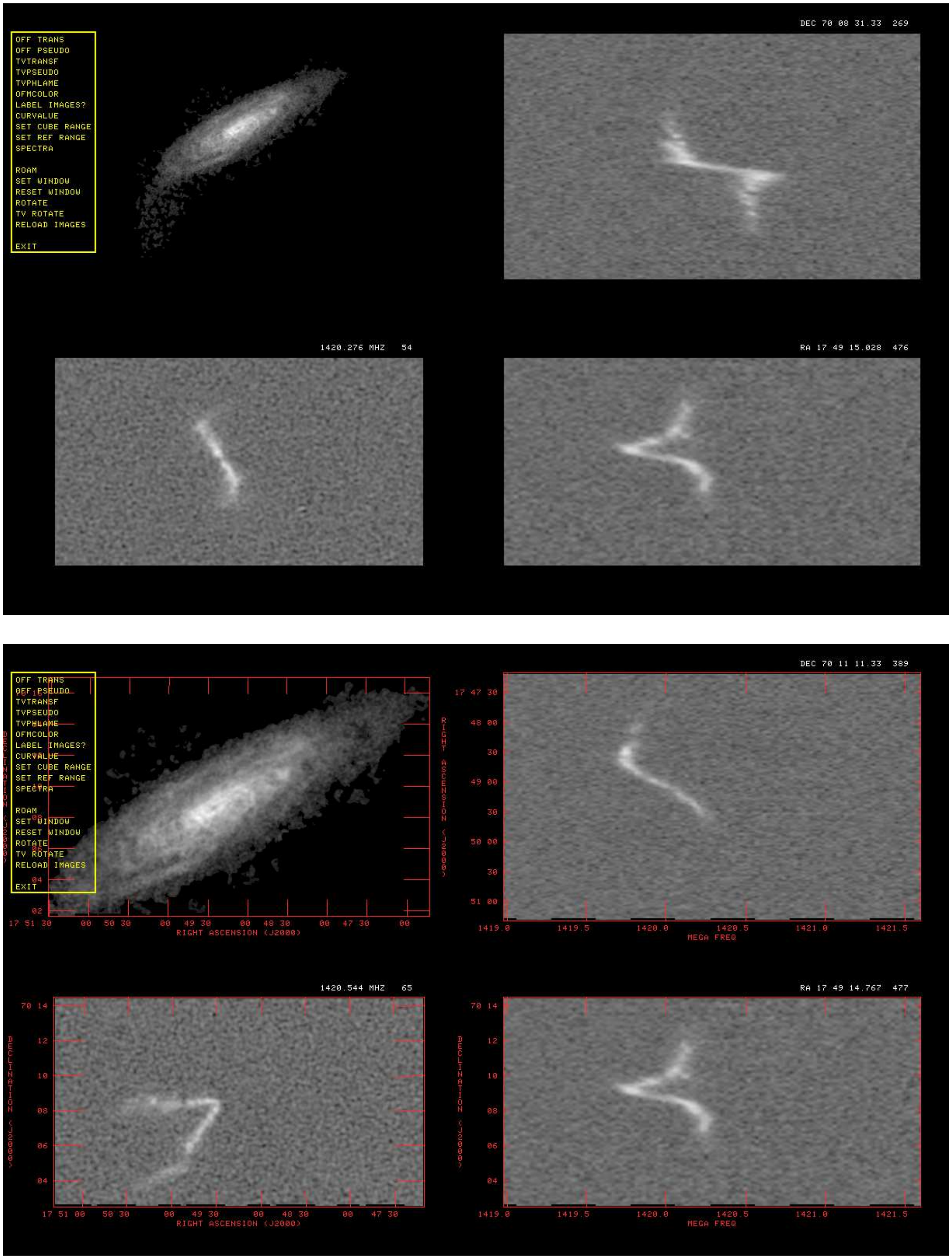


Figure 1: HI moment-zero reference image with image cube in 3 transpositions. Top: initial view, all at central planes. Bottom: images labeled, reference image has been sub-imaged, Y and S planes have been changed by `ROAM` in lower right image. Clean beam is not plotted (`CBPLOT = 0.`)

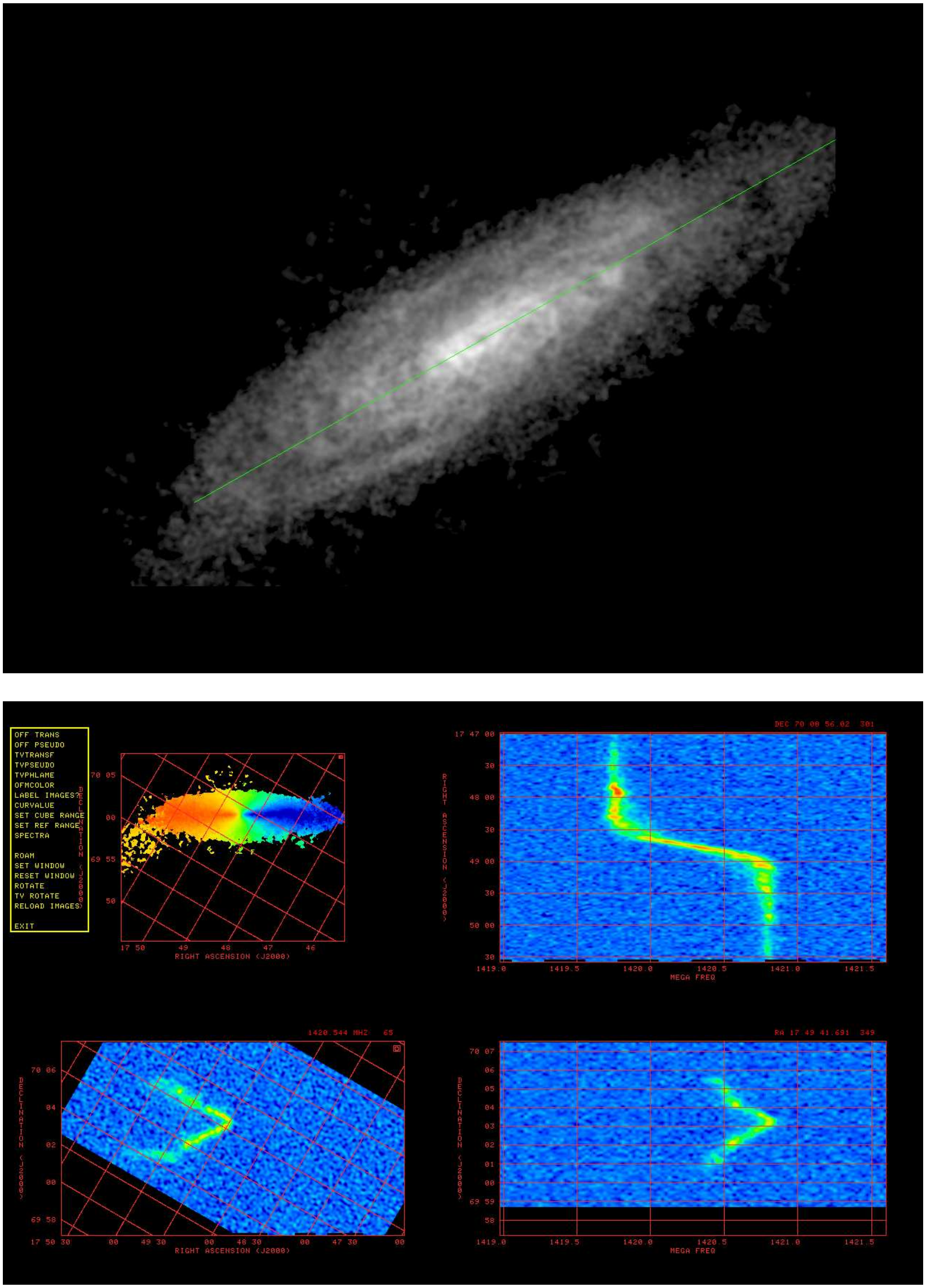
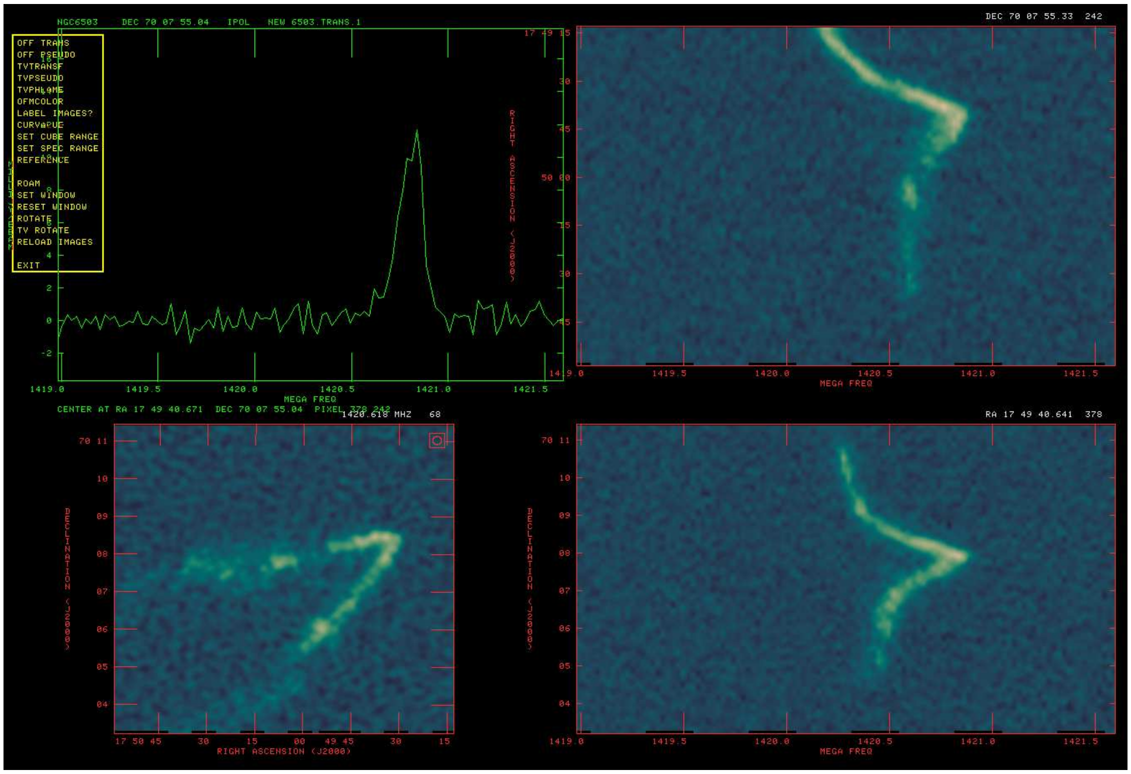


Figure 2: Top: HI moment-zero reference image with slice to set rotation angle. Bottom: moment one image and image in 3 transpositions after rotation. The CBPLOT=3 Clean beam is visible and a TVPSEUDO coloring has been selected.



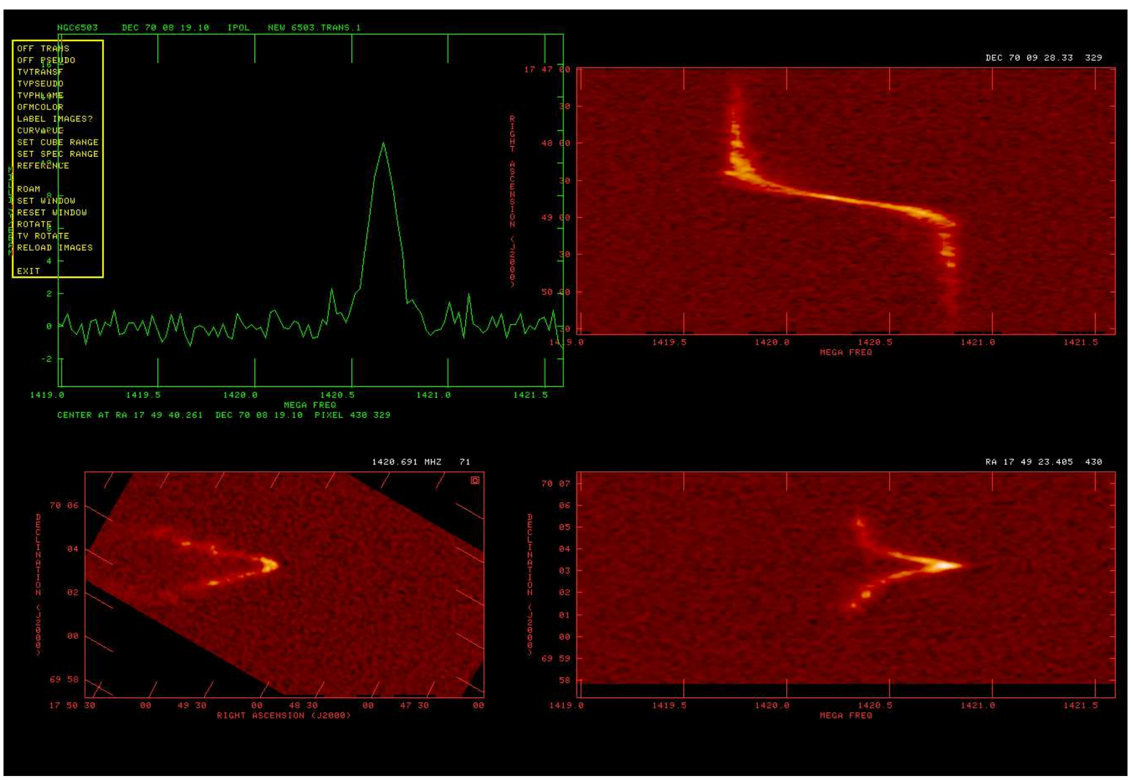


Figure 3: Top: display with spectral plot selected. The X-Y-S image has been sub-imaged to make the `CBPLOT=3` Clean beam more visible. An `OFMCOLOR` has been selected. Bottom: image in 3 transpositions after a `RESET WINDOW` and a rotation with the corresponding spectrum and a `TVPHLAME` pseudo-coloring.