HiPS3D frequency discovery tutorial

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- Version française : https://aladin.cds.unistra.fr/java/TutoHiPS3D.pdf
- English version: https://aladin.cds.unistra.fr/java/TutoHiPS3Den.pdf

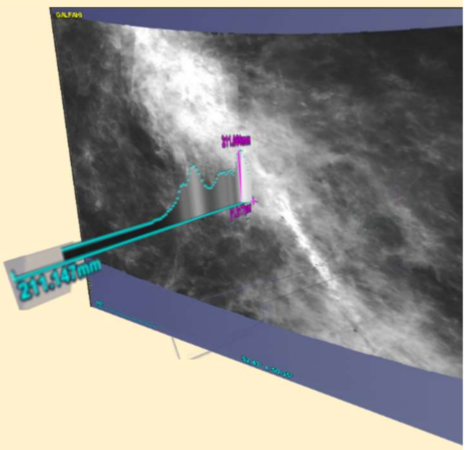
The aim of this tutorial is to introduce you to the possibilities offered by the new HiPS3Ds implemented by CDS over the last few weeks, which can be manipulated with the latest prototype version of Aladin Desktop.

Please note that this is an R&D version, and therefore not a final prototype (still bugs, functions that don't work yet, or not like before). So please do not use this version for anything other than this tutorial (and certainly not distribute it without informing the recipient).

First of all, what is a HiPS3D?

A HiPS3D is a generalization of HiPS that allows you to walk around in a "cubic" mosaic of observations. Instruments like MUSE, ASKAP or SKA produce data cubes, not images. HiPS3D takes this third dimension into account, allowing you to pan and zoom both spatially (as with conventional HiPS) and in frequency (a new feature).

Note that extension to "temporal" cubes is planned (Rubin observations, for example).



If you don't have the time or the inclination to do this tutorial, you can just watch this video => https://aladin.cds.unistra.fr/java/HiPS3D-apr25.mp4

More videos are available at the end of this tutorial.

Once you've finished this tutorial, please don't hesitate to send us feedback (cds-question@astro.unistra.fr) with your suggestions, reviews and encouragement, as this will be very useful to us. Thanks for your time.

Here we go with the tutorial, which should take you no more than 10 minutes... but more if you enjoy it!

Requirements

All you need is the "good" proto version of Aladin Desktop (at least **v12.626**). => https://aladin.cds.unistra.fr/java/AladinProto.jar

For those who have already performed this tutorial, a number of improvements have been made in response to your initial feedback. They mainly involve the representation of the spectrogram, the RGB colour display and the use of links to the original cubes. The latest additions appear in brown in this document.

It doesn't really matter how powerful your machine is. The quality of your network will enhance your experience. A basic Internet connection should be enough (see the last section of this document).

Start-up

You start Aladin as usual (perhaps just check that it's the right version via the Help -> About... menu).

Direct loading ...

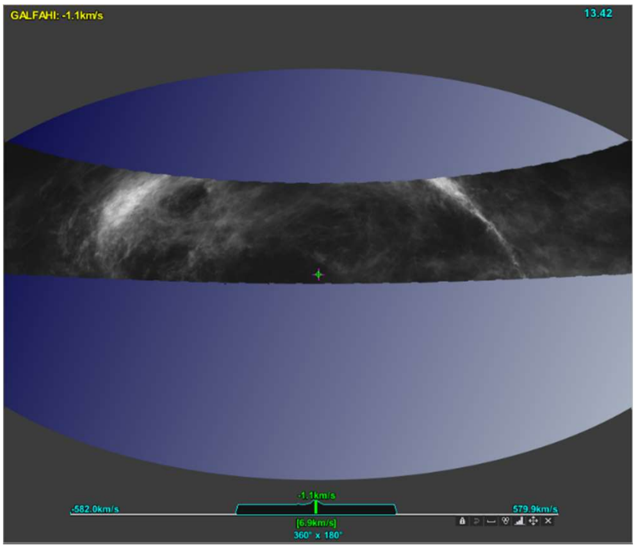
You are going to load the HiPS3D **GalfaHI** which is available on our HiPS server. The most direct method is to "load" this URL via the "command" field.
=> https://alasky.cds.unistra.fr/GALFAHI/GALFAHI-Narrow-DR2-3D

... Or indirect loading

If you'd like to extend your experience to include other HiPS3D, you can also upload a list of them, which will be added temporarily to the Aladin resource tree. To do this, just replace the URL in the previous step with the one below, then click on the GalfaHI HiPS.

=> https://aladin.cds.unistra.fr/java/HipsList3D.txt

In addition to having a wider choice, you'll benefit from a local cache for an experience more in line with normal operation (if you do this tutorial again). Note that some of these HiPS3D are not freely available. You'll need to be located at Strasbourg Observatory (or VPN) to access them. For GalfaHI and MUSE, don't worry, they'll work wherever you are.



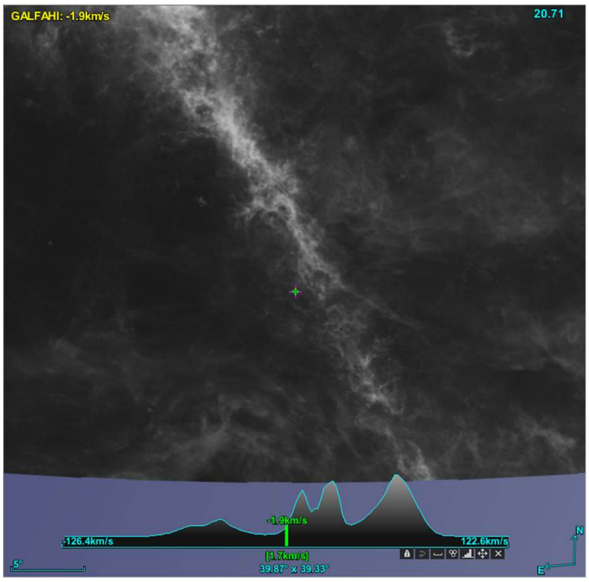
After a few seconds, you should get this. The central band is the mosaic of the 225 cubes of the GalfaHI survey for its central velocity channel. The small graphic below this band represents the "**spectrogram**" extracted from the GalfaHI survey in the center of the view (marked by a small circle - often coinciding with the crosshairs). This spectrogram is displayed here in "velocity". This spectrogram is currently very flat. This is quite normal, as there isn't much vraiation in this particular area.

The HiPS3D of this GalfaHI survey was generated with a new Hipsgen code (proto just like Aladin Desktop). This HiPS is currently distributed as a collection of HiPS tiles which now have a "frequency thickness". Like the classic HiPS, this collection of tiles is available in 2 complete sets, one "full dynamic" in the form of cubic FITS tiles, the other "preview[1]. (See the end of the IVOA

[1] In JPEG or PNG in "mosaic" mode.

Interop presentation in Malta (slide 17 and following) for further explanations.
-> https://wiki.ivoa.net/internal/IVOA/InterOpNov2024Apps/HiPS_generation_news.pdf

Spatial zoom and pan



To pan the spatial view, there's nothing new compared to previous versions of Aladin: a simple click & drag and you're done. The same principle applies to zooming: your mouse wheel is your friend. The mosaic image displayed always corresponds to the frequency channel at start-up.

On the other hand, the "spectrogram" will automatically update according to the new extraction position (the little circle in the center of the view). If you pan the view to put this circle on a bright area, you'll immediately see that the "spectrogram" is no longer flat at all.

To check whether all the tiles required for spatial and spectral display have been delivered, check the status light to the right of the plane in the Aladin stack from time to time. If it's flashing, it's not finished. If it turns green, you've also reached maximum resolution.

Spectral zoom and pan

Panning within the spectrogram is a new Aladin function. It uses the same logic as for spatial navigation: a click & drag to the side, but only if your mouse is over the spectrogram (the shaded area below the spectrum). The magenta bar in the middle of the spectrogram indicates the value of the current channel corresponding to the spatial mosaic. The channel's spectral width is displayed in square brackets. Moving the spectrogram will update the spatial view according to the newly selected channel. Note that you can also click directly on a channel in the spectrogram to shift it to the corresponding frequency.

Zoom and Coverages

The spatial field of view - or "spatial coverage" - is limited by the size of the view on the screen. The more you zoom in, the better the resolution, but for a smaller field of view. In fact, this method seems self-evident when it comes to spatial zooming. The "spectral coverage" of the spectrogram follows exactly the same logic. The more you zoom in, the better the resolution, but for a smaller visible spectral range. A complete view of the spectrum and a complete view of the spatial survey therefore require maximum zooming out.

Spatial zoom and frequency zoom are linked. When we zoom in spatially, we also zoom in frequency-wise (and vice versa). It's an implementation choice that simplifies the user's operations, and avoids the need to pre-calculate all the HiPS3D tile alternatives - a time-consuming and volume-consuming process)[2].

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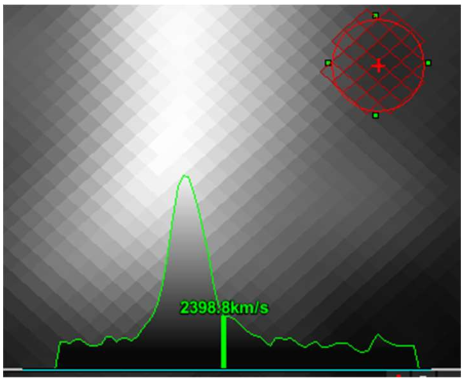
[2] It remains to be seen whether this will enable you to "walk" around HiPS3D efficiently enough, or whether you'll need to consider other pre-calculated resolutions (perhaps for other uses of HiPS3D).

Alternative sliders

The zoom factor and frequency channel selection can also be controlled via the “zoom” and “cube” sliders respectively, which appear below the Aladin stack. If the “cube” slider is not visible, it must be activated via the user preferences (menu Edit -> User preferences -> Control sliders). Please note that, unlike the “spectrogram”, the “cube” slider always covers the entire spectral range of the plane (which means that moving it can be very/too fast, and may skip channels).

Help, I'm lost!

If, during your spatial and/or spectral displacements, nothing is displayed, you are lost at a position (spatial and/or spectral) where no observations have been made. To return to the original position of the survey, simply double-click on the plan name in the Aladin stack.

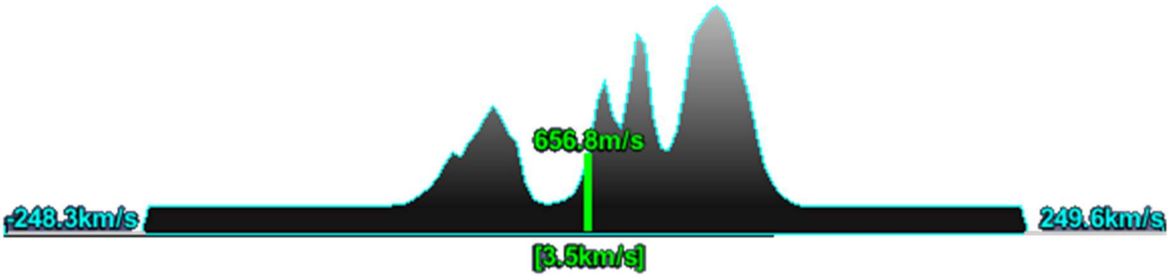


Spectrogram measurement area

The portion of the spectrum visualized in the spectrogram is generated by averaging the pixel values within the “extraction target” for all available channels. This “target” is represented by a small cross, surrounded by a circle. When the mouse hovers over this target, the “handles” that appear allow you to modify its radius. As explained in detail below, by default, the “target” is located at the center of the current view - it is displayed in green, but can be “moved” to a specific position by a click-&-drag, in which case it appears in red.

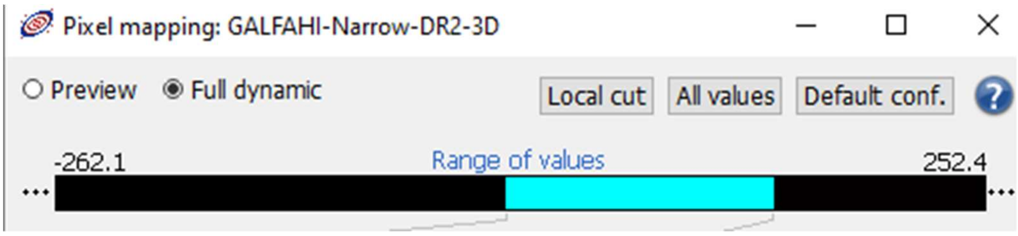
Dynamics and color of the spectrogram

As you can see, the spectrogram is a representation of the spectrum over a given interval at a given resolution.

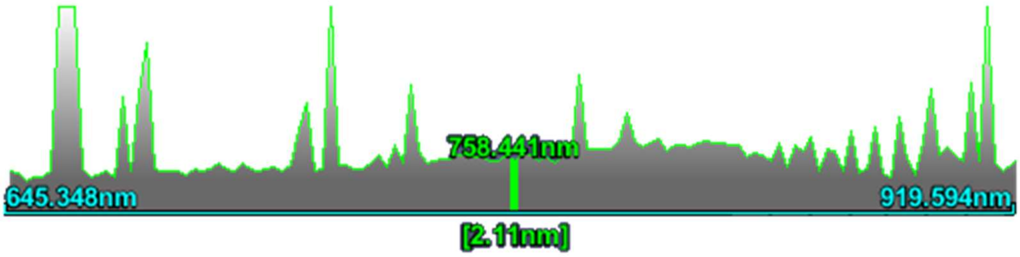


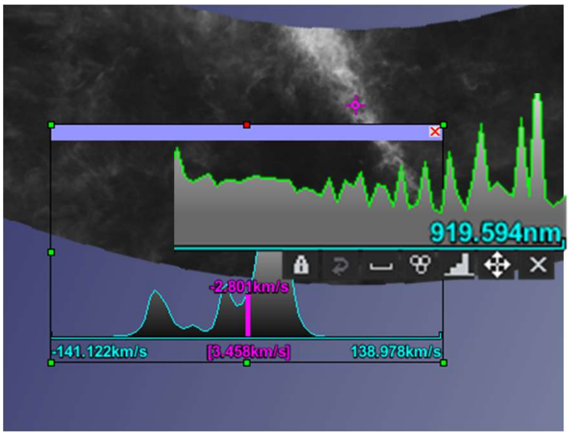
The flux value for a channel is represented by a bar whose width is fixed, and its height is a function of the flux value minus the minimum value for the visible portion of the spectrum. In practical terms, it's the relative variations that are highlighted rather than the absolute amplitude (which is easier to show than to describe). The spectrogram's color gradient uses the same color table and transfer function as the display of pixel values in the spatial view.

Pixel dynamics adjustment (“Pixel” control box) will act simultaneously on both spatial and spectral display. This feature is particularly interesting when coupled with a HiPS display in “Full dynamic” mode, rather than in “Preview” mode. In this way, local saturation in space and/or frequency can be avoided.



The top of the graph is drawn as a poly-line to make emission or absorption lines more visible. An example of a MUSE HiPS spectrogram is shown below.





Spectrogram control

The spectrogram has its own "toolbar", displayed on the right below the graph axis. These little "buttons" give you access to control functions, on the extraction target, display units, visualization modes and finally the layout of the spectrogram in the view.

Extraction target lock

As explained above, by default, the spectral values displayed in the spectrogram are extracted from the view's central position. This location is represented by a small green cross doubled by a circle. This is the "extraction target". Clicking on the "padlock" icon will lock this target at the current location. It will now be displayed in red. Moving the view will no longer modify the contents of the spectrogram, unless the lock is removed by clicking on the "padlock" icon again.

When the target is locked, it is still possible to change its position using the mouse: click-&-drag the "extraction target" to the new location.

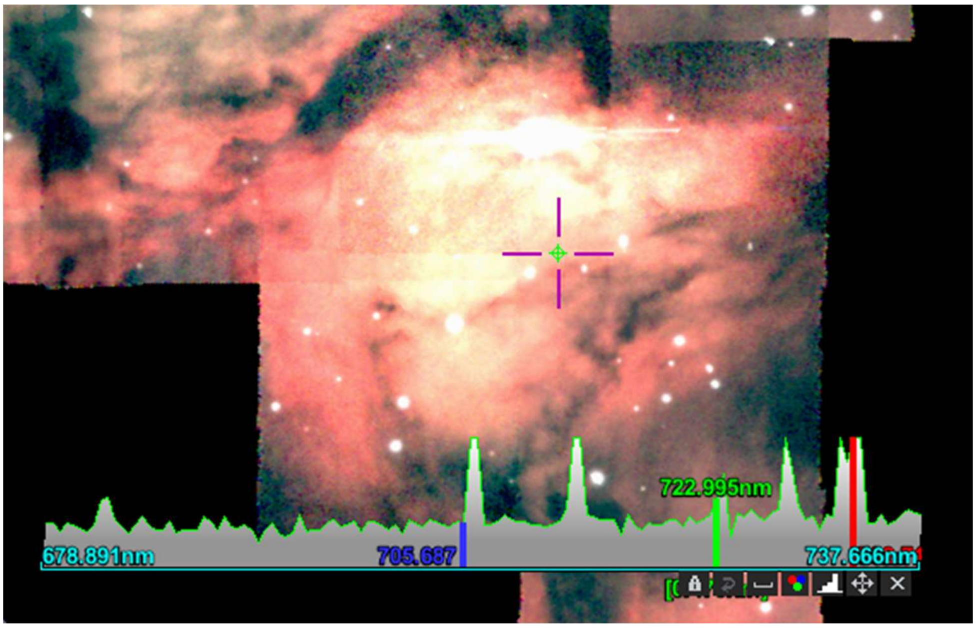
Finally, if the extraction target is locked, it is possible that it will no longer be visible in the current field of view. To easily return to it, simply click on the second icon "Return to target".

Spectrogram units

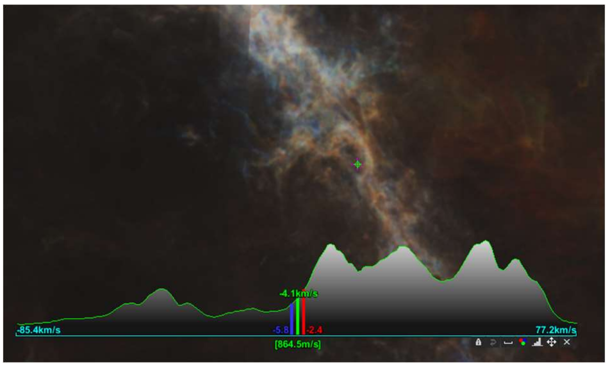
A frequency HiPS3D always stores the 3rd dimension in frequencies. However, the spectrogram is displayed in the most appropriate units: in wavelengths for high frequencies, and otherwise in frequencies directly. On the other hand, if the HiPS3D has been generated from "velocity" cubes, the spectrogram will be displayed in velocity units (km/s or m/s). This default choice can be changed using the 3rd button.

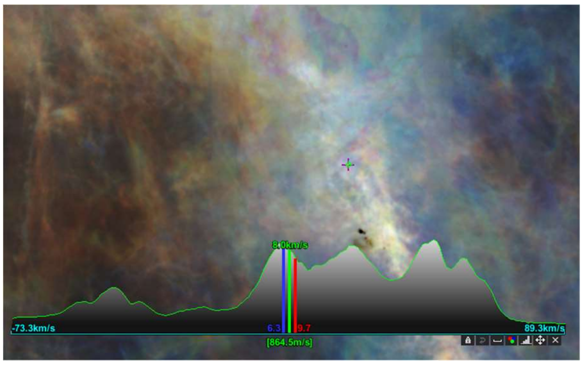
RGB color display

By default, a HiPS3D displays the spatial rendering of a single channel, the one marked by the green bar. Activating the 4th button on the “toolbar” will enable 3 channels to be displayed simultaneously, generating a color composition based on the channels designated by the red, green and blue bars. The color display can be used to highlight one or more specific lines, as illustrated below. These 3 bars can be moved independently with a simple mouse-click&-drag to position them in the right places.



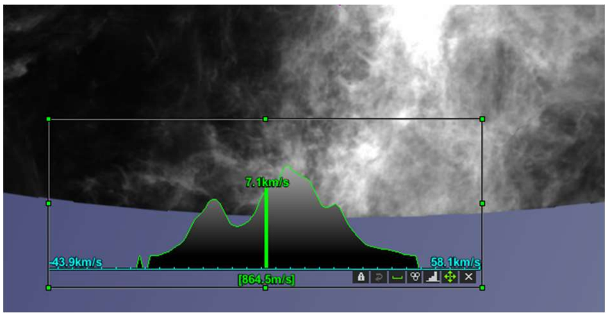
The color display can also be used to highlight variations in the cube step by step. In this case, the red and blue channels are positioned on either side of the green channel, so that variations from the current channel are visible (pressing the SHIFT key will force symmetry). To modify the current channel, it's best to click & drag on the spectrogram itself (shaded area), rather than moving each color bar one by one. In this way, you can preserve the distances between each channel. The dynamic visual effect is stunning (difficult to illustrate in a tutorial - try it, you'll see!).





Lines or bars

If you wish to display the spectrogram not as “polylines” but as “bars”, simply activate the 5th button.



Position, size, folding

By default, the spectrogram is displayed at the bottom of the Aladin window, superimposed on the spatial view, across the entire width. This can be cumbersome. You can move the spectrogram, or even change its proportions, by clicking on the penultimate button, then acting on the handles that appear at the 4 corners and on the edges.

You can even temporarily “fold” the spectrogram by clicking on the last cross icon. The spectrogram is then replaced by a small button, which must be activated to display the spectrogram again.

Mouse flying over

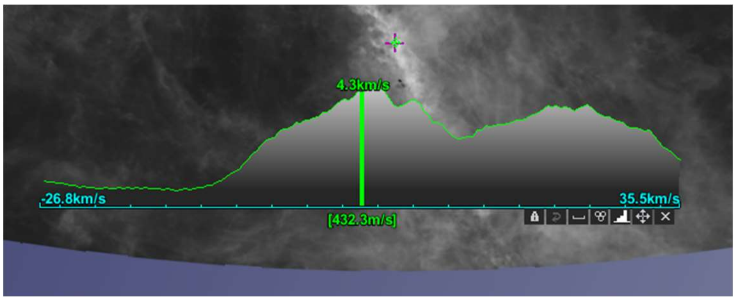
As before, flying over the spatial view displays the celestial coordinates under the mouse in the “command” field above the view. Similarly, flying over the spectrogram displays the corresponding spectrogram value in the same command box.

In “Full dynamic” display mode (via the ‘pixels’ control box or via the “hdr” button below the view), hovering will also display the pixel value under the mouse in the top right-hand corner, both on the spatial view and on the spectrogram (in fact, it's not done yet).

Zooms desynchronization

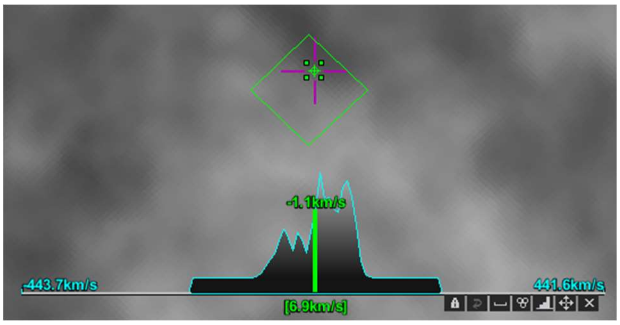
New for experts.

It was mentioned earlier that a HiPS3D, although hierarchically multi-resolution, does not provide all combinations of spatial versus frequency resolution. However, this choice does not exclude the possibility of desynchronizing spatial and frequency zoom. Thus, it is possible to “over-zoom” the spectrogram compared to the spatial zoom, in order to visualize more details of the spectrum while retaining a sufficiently broad spatial view. And, on the contrary, you can “sub-zoom” the spectrogram to display greater coverage while retaining the same spatial field of view. To do this, use the mouse wheel in the usual way, but after moving the cursor on the spectrogram content or on its axis.



Please note that this desynchronization of spatial and frequency zooms does not “invent” the missing resolutions. To highlight this, an “over-zoom” of the spectrogram will reveal small graduations on the frequency axis representing the spatial channels available at the current spatial resolution. In other words, the spatial view will not change between two graduations, unless you also zoom in spatially.

Conversely, a “sub-zoom” in the spectrogram corresponds to a lower-resolution extraction area. The more the spectrum is degraded in relation to the spatial view, the wider this area will be. This area can be visualized as a green diamond that appears when the mouse is hovering over the extraction point. The spectrogram will not change regardless of the position of the extraction target in this diamond.



If this remains obscure, try it and you'll see (or not)..

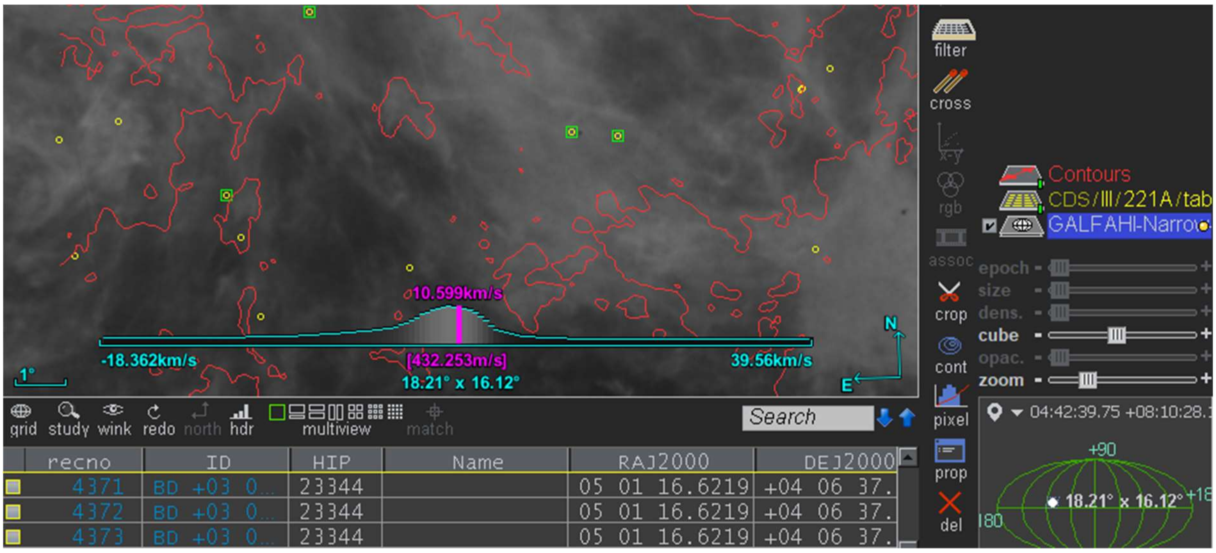
Script command

As well as entering spatial coordinates in the “command” field modify the spatial center position, you can also enter a frequency, or alternatively a wavelength, to set the spectrogram to the corresponding channel. For example, entering “**211.09mm**” will automatically set the spectrogram to the corresponding channel.

Note that it is also possible to enter a speed (in m/s or km/s) if the HiPS3D displayed is supplied with a reference frequency.

Catalog and graphics overload

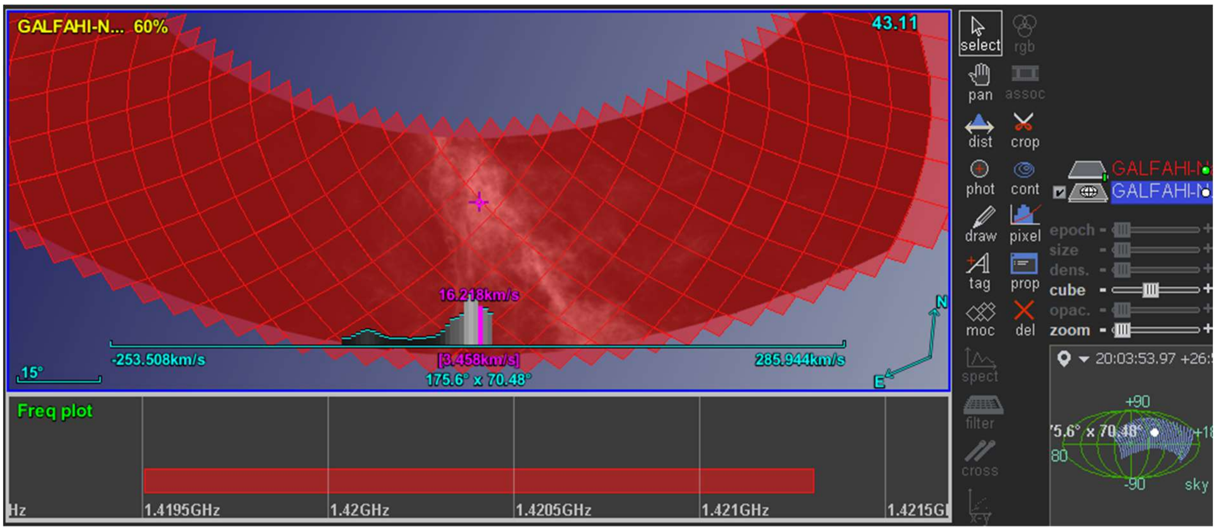
Currently, graphic overlays (loading a catalog, FoV, MOC, contours, etc.) only concern the spatial view. It would be conceivable to do the same thing in the spectral view, for example, to overload the spectrogram with the position of the most common spectral lines, to be able to insert graphic markers, spectral distance measurements, etc).



Frequency and space-frequency MOC

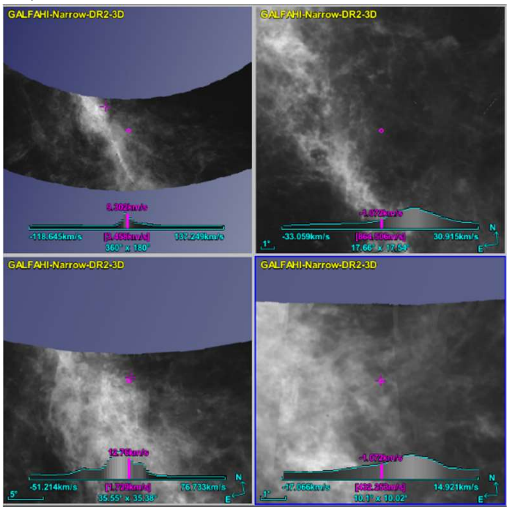
As with conventional HiPS, the HiPS3D in this survey is supplied with a “MOC” describing its coverage. As this is a frequency HiPS3D, the associated MOC is in fact a SFMOC, i.e. a space-frequency MOC. It's new, but already presented at an IVOA Interop 18 months ago
-> https://wiki.ivoa.net/internal/IVOA/InterOpMay2023Apps/FMOC_IVOA_Bologne_Fernique.pdf

The display and manipulation of such a MOC is still being implemented, but you can already visualize what it might look like by using the “Coverage -> Load the MOC of the current survey” menu. The display follows the same logic as for temporal or spatio-temporal MOCs, i.e. 2 coupled views, one showing the spatial component and the other the frequency component. As with temporal MOC, this frequency view/plot is also used to display any “plots” whose abscissa can be expressed in frequencies.



Multi-views

Aladin Desktop's multi-view mode allows you to compare several edge-to-edge surveys. The HiPS3D display preserves this functionality by enabling simultaneous display of the same HiPS3D, or several HiPS3D in different views, at different spatial and/or spectral positions.



Using the same logic as in the original interface, frequency synchronization is obtained by using the SHIFT key to select the chosen channel in one of the spectrograms.

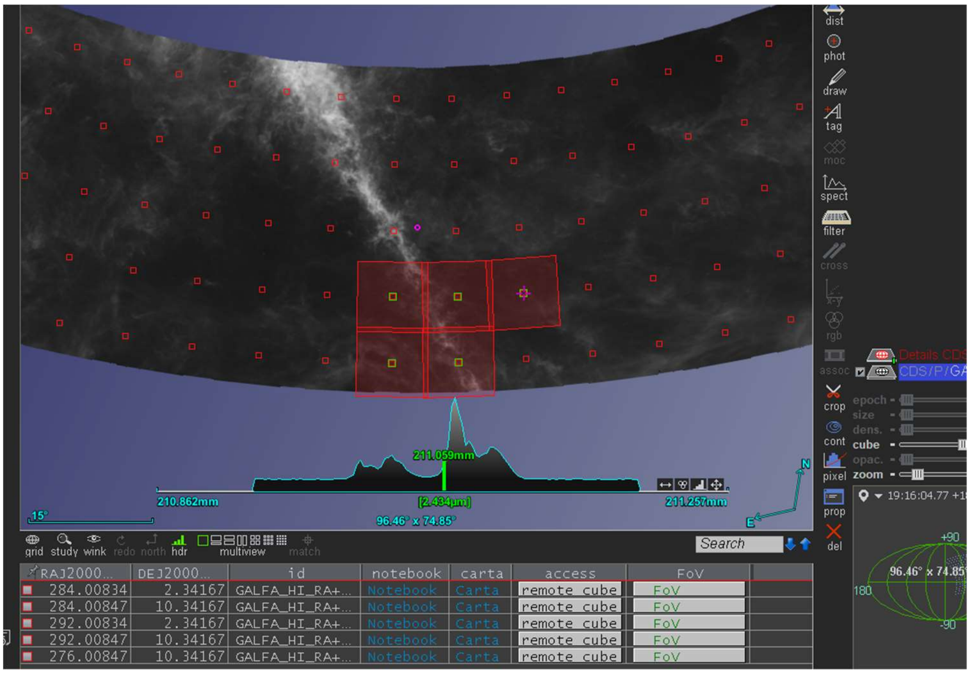
On the other hand, the “match” button does not provide “frequency” synchronization, only spatial synchronization (whether this would be a good idea in practice, and/or whether a second button is needed).

Access to "progenitors"

As with the classic HiPS, you can also access information on the original cubes, i.e. the HiPS3D “progenitors”.

Clicking on the “Progenitors” button will load the catalog of original cubes, and you will then be able to access information on each cube by selecting the corresponding marker. The information and links available have been defined when the HiPS was generated, and can concern any of the values taken from the FITS headers of the original cubes (e.g. DATE_OBS, TELESCOP, INSTRUME, OBSFREQ, etc.). In the case of this HiPS3D GalfaHI, you'll find the name of the original file, a link to download it directly into Aladin (be patient, it's already a few hundred MB), to display its spatial field of view, or to instantiate a Jupyter notebook in your Web browser, which will run on the site where the cube in question is located.

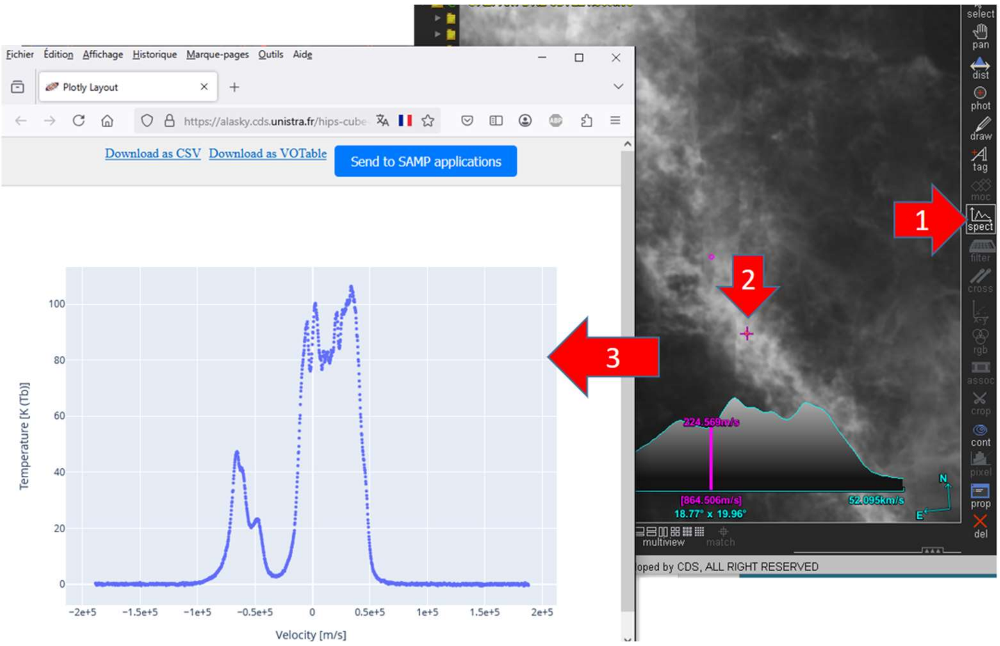
We can also imagine instantiating a remote session of the CARTA cube viewer, which will run at the cube's location.



Full-resolution spectrum extraction

The spectrogram is a handy tool for moving around the survey, but it's no substitute for a conventional spectrum, which takes into account the entire spectral coverage at optimum resolution. For this reason, it is preferable to generate it not on the client side, but directly on the HiPS server, which has access to all HiPS tiles without having to download them. The CDS (thanks Thomas Boch) has developed a prototype of such a service, which you can now test via the Aladin Desktop “spect” tool (1), or directly via its URL[3]. Once you've clicked on a position (2), Aladin will make a remote request to this spectrum extraction service, and the result will be displayed in your browser (3) in the absence of specialized spectrum processing software. Via the “Send to SAMP applications” button, you can, for example, send this spectrum to the CASSIS tool or any other SAMP-compatible software.

[3] Public soon…



A few figures to finish (already a little old)

The HiPS3D you are exploring was generated from 225 cubes of 512x512 x2048 channels in 16-bit integer pixel coding. Generating the FITS tiles (size 256x256x16) took 1h30 on the hips-calculator1 computing machine. The HiPS3D was calculated using the Hipsgen 12.500 code, with a slight spatial oversampling (HiPS order 4 (pixel ang.res orig:1' hips:51.53" x1.16) and a small frequency undersampling (HiPS frequential order 22 (freq res orig:871.9zHz hips:1aHz x0.85). The final size of HiPS3D, including hierarchy, is 250GB (compared with the 225GB of the original cubes - or the classic cubic HiPS already available for the same survey of 475GB (without multi-scale frequency resampling)).

A second set of tiles was generated in compressed mode using the APNG (Animated PNG) format. Computation time was 5mn for a final size of 9GB.

At startup, to view the entire GalfaHI at the lowest HiPS resolution, Aladin needs to load 12 order 0 tiles for the spatial view, and 3 additional tiles for the spectral view. In compressed mode this represents 4MB, and in "Fits" mode 36MB. Each new position/zoom will require roughly the same amount of data to be loaded (network or local cache). These values do not depend on the size of the survey, only on the size of the client's display window (the advantage of HiPS).

GALFAHI cubes

Cube	GB	# of files	Time
Original size	225,00	225	
HiPS classical cube FITS	475	944106	???
HiPS classical cube PNG	15,00	944106	???
Hips3D FITS trim	250,00	70416	01:30:00
Hips3D APNG	9,00	70416	00:04:45

Additional illustrative videos

Below you'll find links to videos demonstrating other cubic surveys.

- LGLBSHI – overview and zoom M31: http://aladin.cds.unistra.fr/java/HiPS3D-LGLBSHI.mp4

- DHIGLS RVB compositio: http://aladin.cds.unistra.fr/java/DHIGLS-HiPS3D-RGB.mp4
- DHIGLS multiviews : http://aladin.cds.unistra.fr/java/DHIGLS-HiPS3D_multiview.mp4
- ALMA M83 : http://aladin.cds.unistra.fr/java/Alma-M83-test1.mp4
- ALMA M83 - 3 bands: http://aladin.cds.unistra.fr/java/HiPS3D-ALMA-M83.mp4

And finally ... you can now try to build your own HiPS3D

Some of you may have wanted to test HiPS3D visualization on your own cubic data. This is now possible, although the method described below is still subject to change, and the HiPS3Ds produced may not be compatible with future versions of AladinProto. So, this is just for testing purposes, without any guarantee.

The Hipsgen code that enables HiPS3D generation shares the same packaging as Aladin Desktop. This means you already have everything you need to generate a HiPS3D. All you have to do is execute the following command in a console:

> **java –Xmx2G –jar AladinProto.jar –hipsgen –hips3D –trim in=YourCube.fits out=YourHips3D id=AUTH/C/xxx INDEX TILES PNG**

where:

- YourCube.fits - is a cube (or a directory containing a list of cubes) in FITS format, with spatial and frequency calibration supported by AladinProto;
- YourHips3D - is a directory name in which the HiPS3D product will be stored;
- AUTH/C/xxxx - is an ID of your choice;
- INDEX TILES PNG : are the 3 Hipsgen actions to generate a HIPS3D with FITS tiles and PNG tiles;
- -hips3D –trim - are two parameters specific to the generation of a HiPS3D;
- -Xmx2G – specifies that 2GB of RAM will be reserved for computation.

You'll probably need the Hipsgen documentation available at https://aladin.cds.unistra.fr/hips/HipsgenManual.pdf to adjust the various parameters you may need (resolution control, overlays, etc.). But this manual does not yet describe 3D extensions Two new options you may find useful are “orderFreq=nn”, to specify a frequency resolution different from that determined automatically, and “restFreq=xxx”, which lets you specify the rest frequency in Hz if your cubes are given in velocity, and the rest frequency of the observed line has not been specified in the original cubes.

If all goes well, the generation process will produce a HiPS3D in the target directory. Simply drag and drop this directory into the AladinProto interface to visualize the result. Please note that the HiPS3D generation code is still under development. If you encounter any difficulties (unsupported calibration, poor adjustment of pixel dynamics, non-optimal management of CPU and RAM resources, crashes, etc.), please let us know, without any obligation on CDS's part to help you quickly.