Analysis and visualization tools in INAF

Fabio Vitello

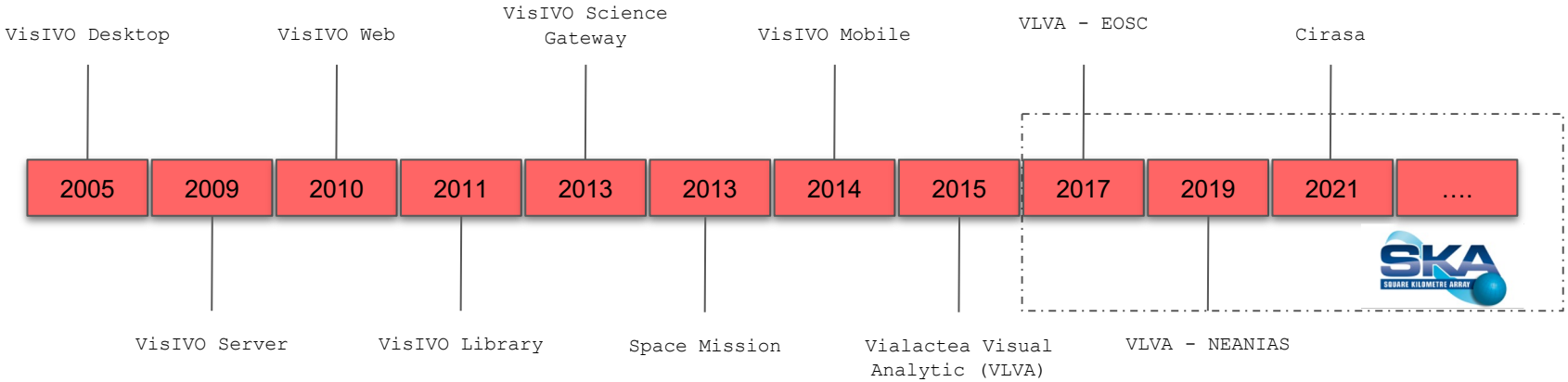
VisIVO

NEANIAS

CIRASA

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

VisIVO Suite: History

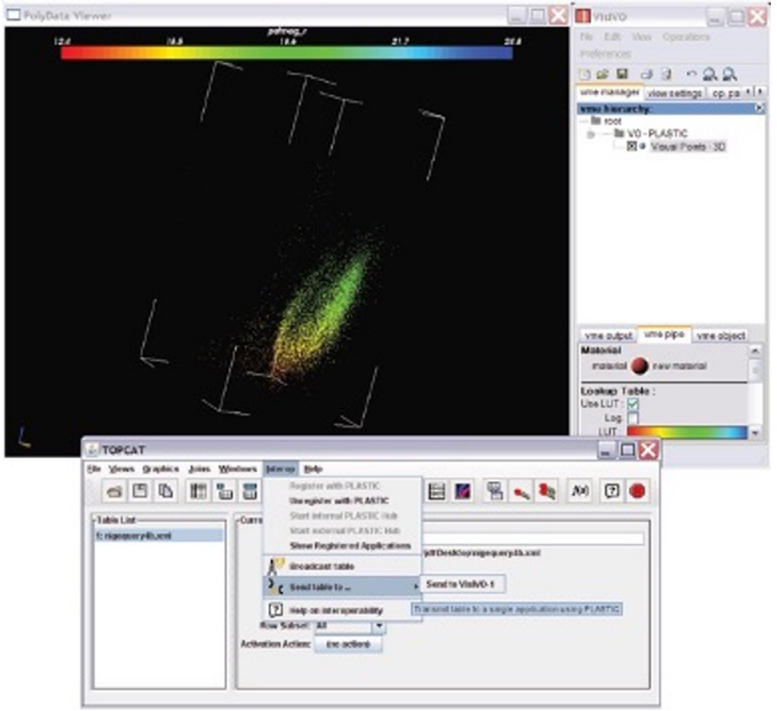


VisIVO Desktop

VisIVO Desktop was our **first experience** of a Visualisation and Data Analysis Tool developed as a collaboration between the Italian National Institute for Astrophysics - Astrophysical Observatory of Catania and CINECA.

Supports **different kinds of file formats**: VOTables, FITS, HDF5, ASCII, raw binaries, GADGET, etc.

The capabilities of VisIVO were extendable through an application **interoperability** protocol called PLASTIC (Platform for Astronomy Tool Interconnection) to leverage the abilities of different desktop applications in a seamless way.

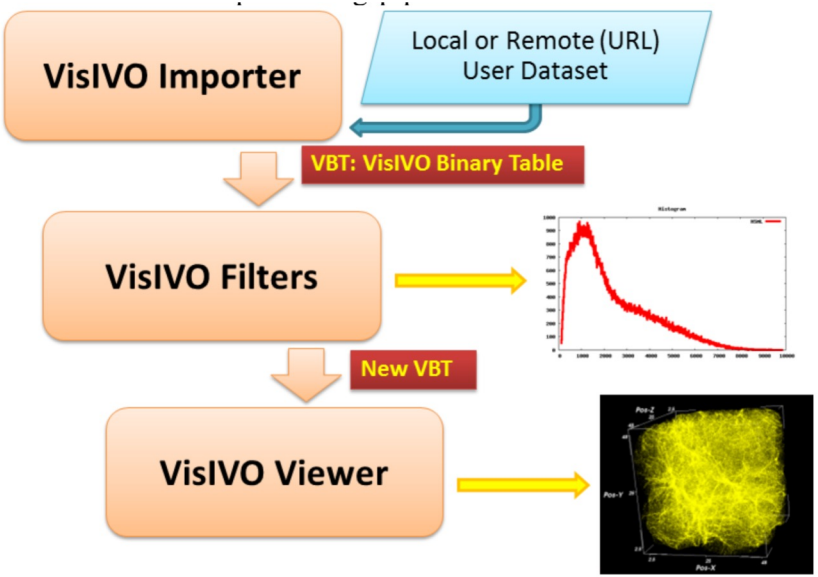


VisIVO Server

VisIVO Server is an **open source** collection of visualization modules for **fast rendering** of 3D views of astrophysical datasets.

VisIVO Server is built upon the VisIVO Desktop functionality and supporting Unix platforms.

The defining characteristic of VisIVO Server compared to VisIVO Desktop is support for very **large-scale datasets**; no fixed limits (in principle) are imposed for visualization.



VisIVO Library

The VisIVO Library is an API written in **C++**

Allows a job running on HPC system to produce a set of **images or movies** directly using VisIVO with its internal data arrays without the need to produce intermediate files.

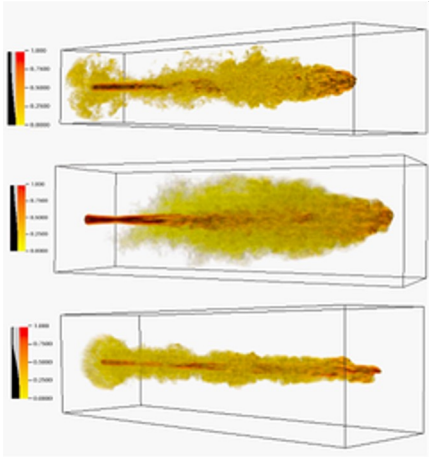
This is particularly important when running on DCIs and running large simulations, where the user wants to have a **quick look to the results** during the data production phase.

```
#include "visivo.h"
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#include <time.h>


#define NB 16777
#define NVOL 262144

int main(int argc, char*argv[])
{
int errorCode;

char filename[256];

//**********************************
//**********************************
//********************************** VisIVOImporter
VisIVOImporter envVI1;

errorCode=VI_Init(&envVI1);
errorCode=VI_SetAtt(&envVI1,VI_SET_FFORMAT,"ascii");
errorCode=VI_SetAtt(&envVI1,VI_SET_FILEPATH,"mrvbt16.ascii");
errorCode=VI_SetAtt(&envVI1,VI_SET_OUTFILEVBT,"mrvbt16.bin");

VI_Import(&envVI1);
//**********************
//**********************
//********************** VisIVOFilter
VisIVOFilter envVF1;

char operation[256];
strcpy(operation,"pointproperty");

errorCode=VF_Init(&envVF1);
errorCode=VF_SetAtt(&envVF1,VF_SET_OPERATION,operation);
errorCode=VF_SetAtt(&envVF1,VF_SET_FILEVBT,"mrvbt16.bin");
errorCode=VF_SetAtt(&envVF1,VF_SET_RESOLUTION,"32 32 32");
errorCode=VF_SetAtt(&envVF1,VF_SET_POINTCOLUMNS,"X Y Z");
errorCode=VF_SetAtt(&envVF1,VF_SET_APPEND,"");
errorCode=VF_SetAtt(&envVF1, VF_SET_OUTCOL,"density");
```

VisIVO Server @ Pluto

Creating a visualization environment for **Pluto Code** (http://plutocode.ph.unito.it)

PLUTO is a freely-distributed software for the **numerical solution** of mixed hyperbolic/parabolic **systems of partial differential equations** (conservation laws) targeting high Mach number flows in astrophysical fluid dynamics. The code is designed with a modular and flexible structure whereby different numerical algorithms can be separately combined to solve systems of conservation laws using the finite volume or finite difference approach based on Godunov-type schemes.



credits:
http://plutocode.ph.unito.it/

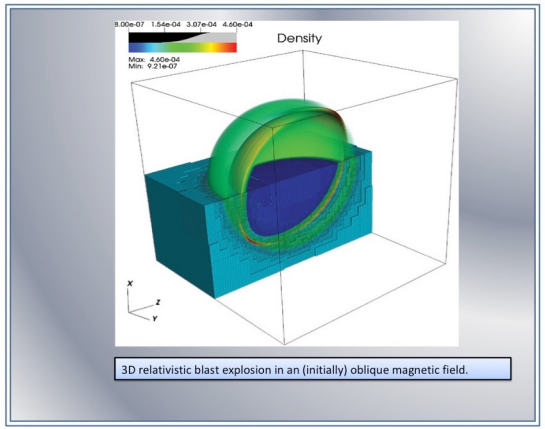
VisIVO Server @ Pluto

Creating **readers** to import static grid produced by pluto into VisIVO Server:

- **VTK** format file format using structured or rectilinear grids (serial/parallel);
- **HDF5 double-precision** (8 byte) HDF5 data (serial/parallel);
- **HDF5 single-precision** (4 byte) HDF5 data (serial/parallel);

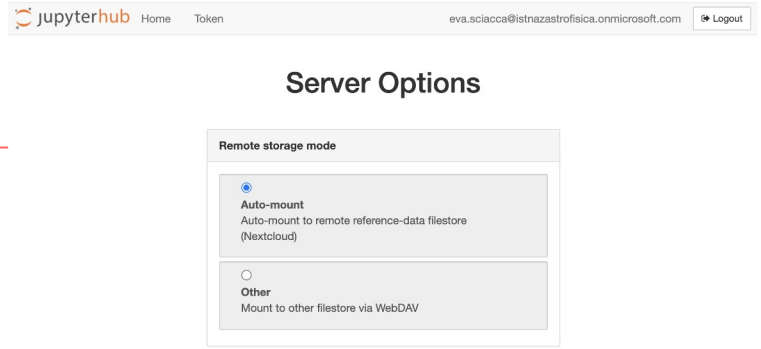
Support for **Adaptive Mesh Refinement** (AMR)

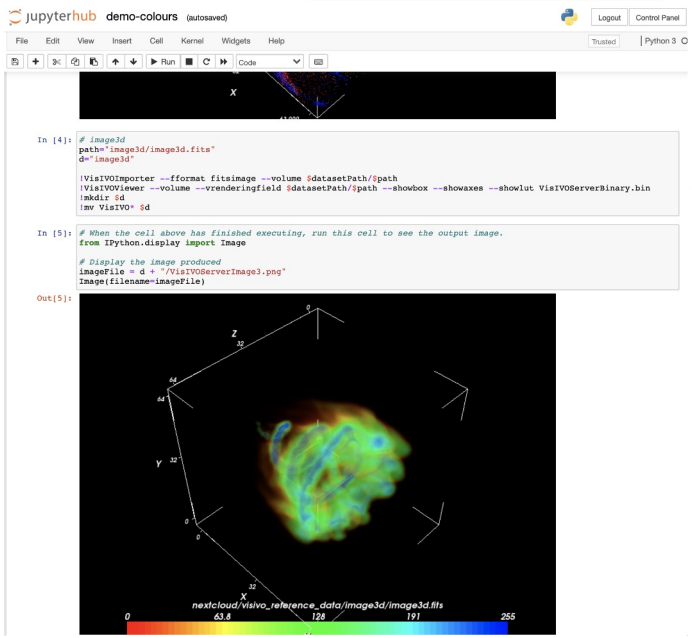
Python Wrapper for VisIVO Library



credits: http://plutocode.ph.unito.it/

Visualization Gateway





- Fully based on **JupyterHub** framework and including **VisIVO Server** and **Splotch** as two visualization environments.
- Integrated **Data Sharing Service** with auto-mount containing demo data (read-only).
- Fully containerized running on the **GARR Kubernetes Cluster**

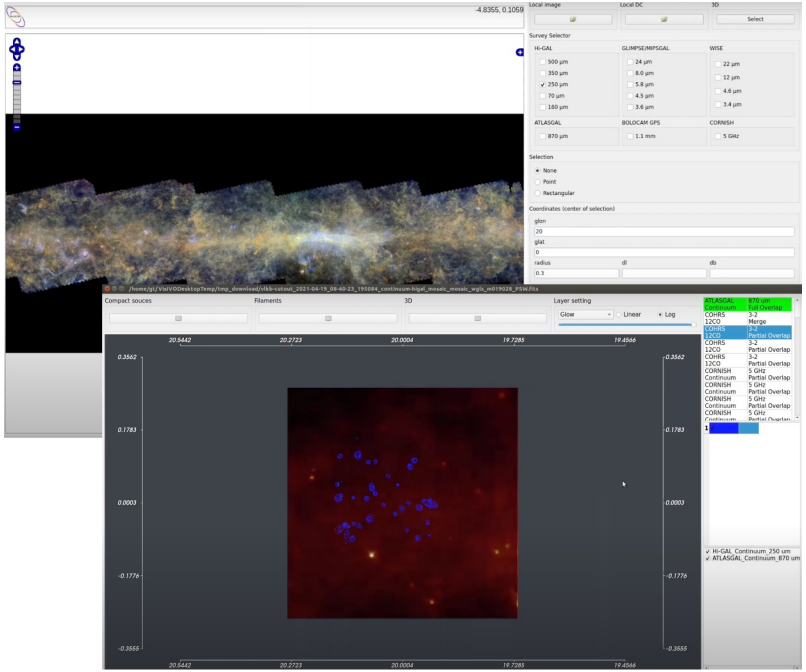
More details @ E. Sciacca et al
Journal of Grid Computing

Next Talk: M. Raciti «The advantages of Notebooks running the cloud»
https://www.youtube.com/watch?v=lZUkdXAAyzU

VLVA: Vialactea Visual Analytic

3D visual analytics systems

- Provides access to **radio & infrared surveys** of the Galactic Plane archived in the Knowledge Base (VLKB)
- Supporting **visualization** of **2D images** and **3D velocity datacubes** (vol. renderings, slices), loaded locally or from VLKB
- Enabling **visualization** of **compact sources** and **filaments** from VLKB
- Currently **being integrated** with source **finding services**
- Available as **desktop application** for Mac OS and Ubuntu and also as **Docker container**.



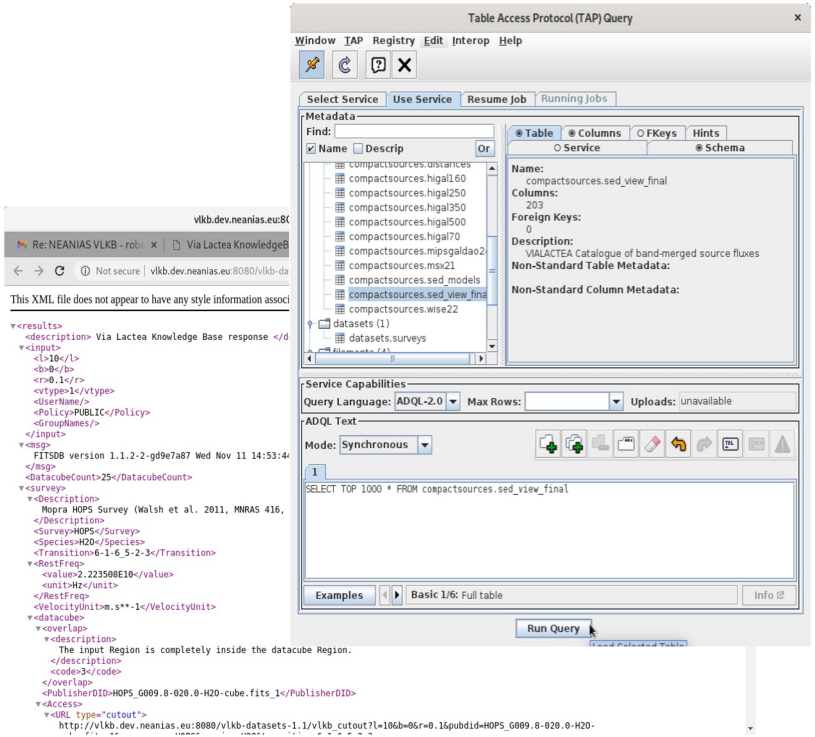
More details @ Vitello, F., et al. *PASP* (2018)

https://github.com/NEANIAS-Space/ViaLacteaVisualAnalytics

https://vlva.readthedocs.io/en/latest/

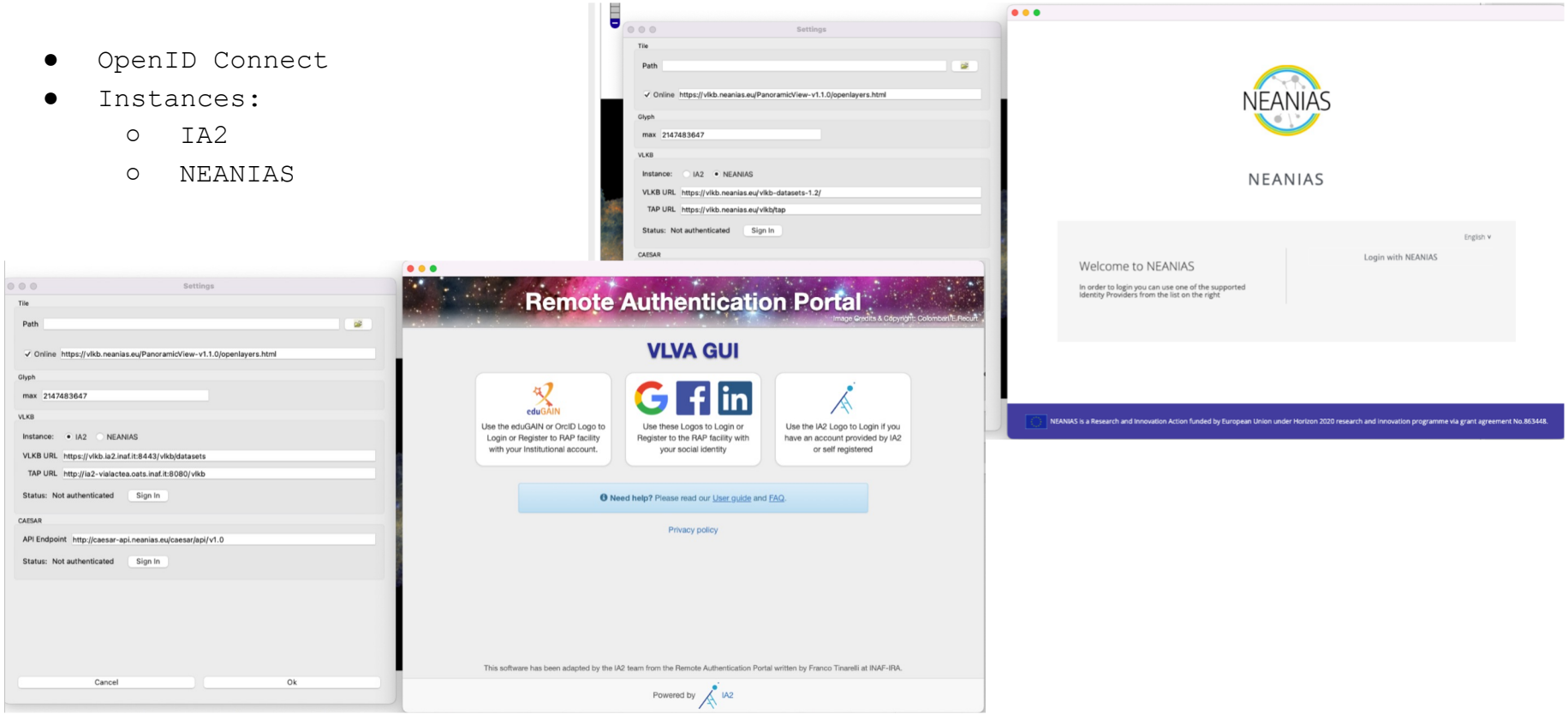
VLKB: Vialactea Knowledge Base

- Provides discovery services and access to **data collections** and **catalogues** of the galactic plane, initially made available by the EU FP7 VIALACTEA Project.
- Accessible through a **Virtual Observatory** enabled infrastructure (by the TAP protocol).
- Data access available through REST-API services: search, cutout and merge.
- Also provides information about compact sources, filament structures and numerical SED models
- Fully exploited by ViaLactea Visual Analytic client tools (desktop and web).
- Secured under Authentication and Authorization Infrastructure (**AAI**)
- Handles user privacy **roles** regarding access to specific surveys.



VLVA: AAI and VLKB Instances

- OpenID Connect
- Instances:
  - IA2
  - NEANIAS

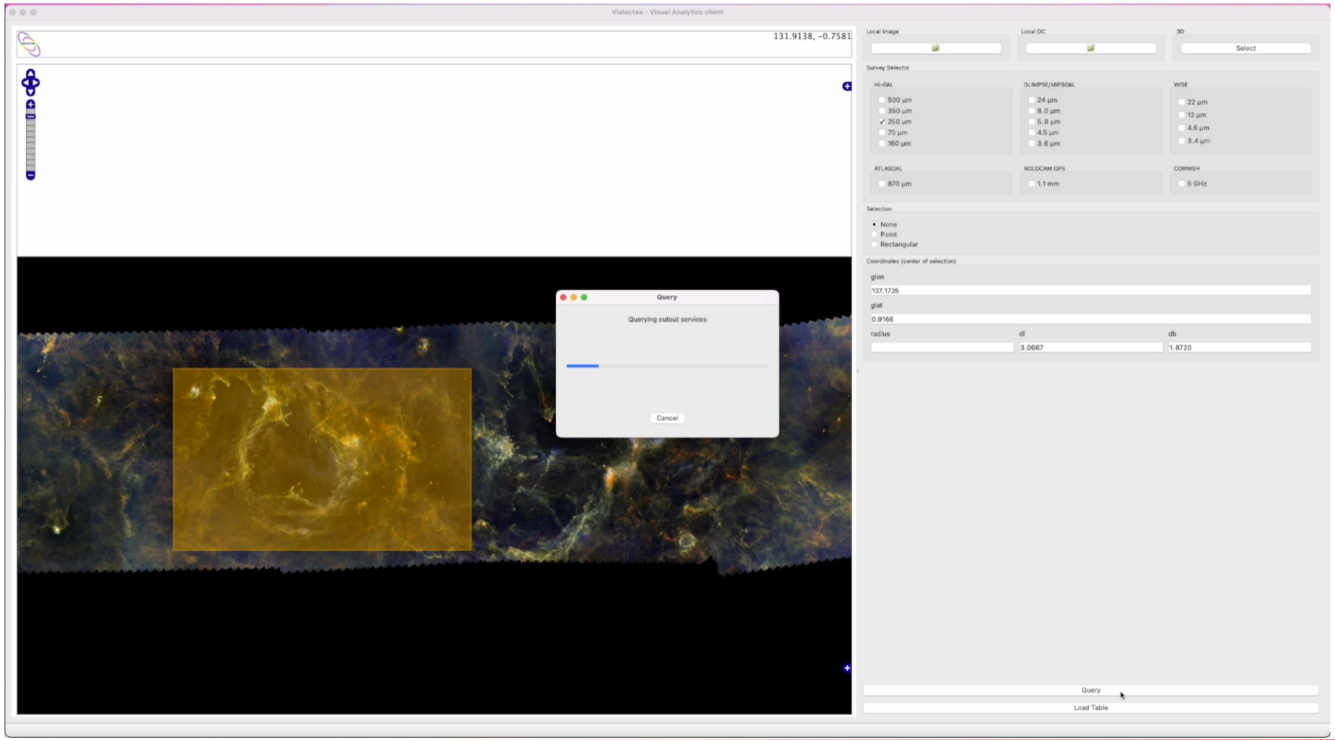


https://youtu.be/Y52N2r3IY4I

VLVA: Interactive view of the GP

Interactive view of the galactic plane (longitude from -180° to +180° and latitude from -2° to 2°).

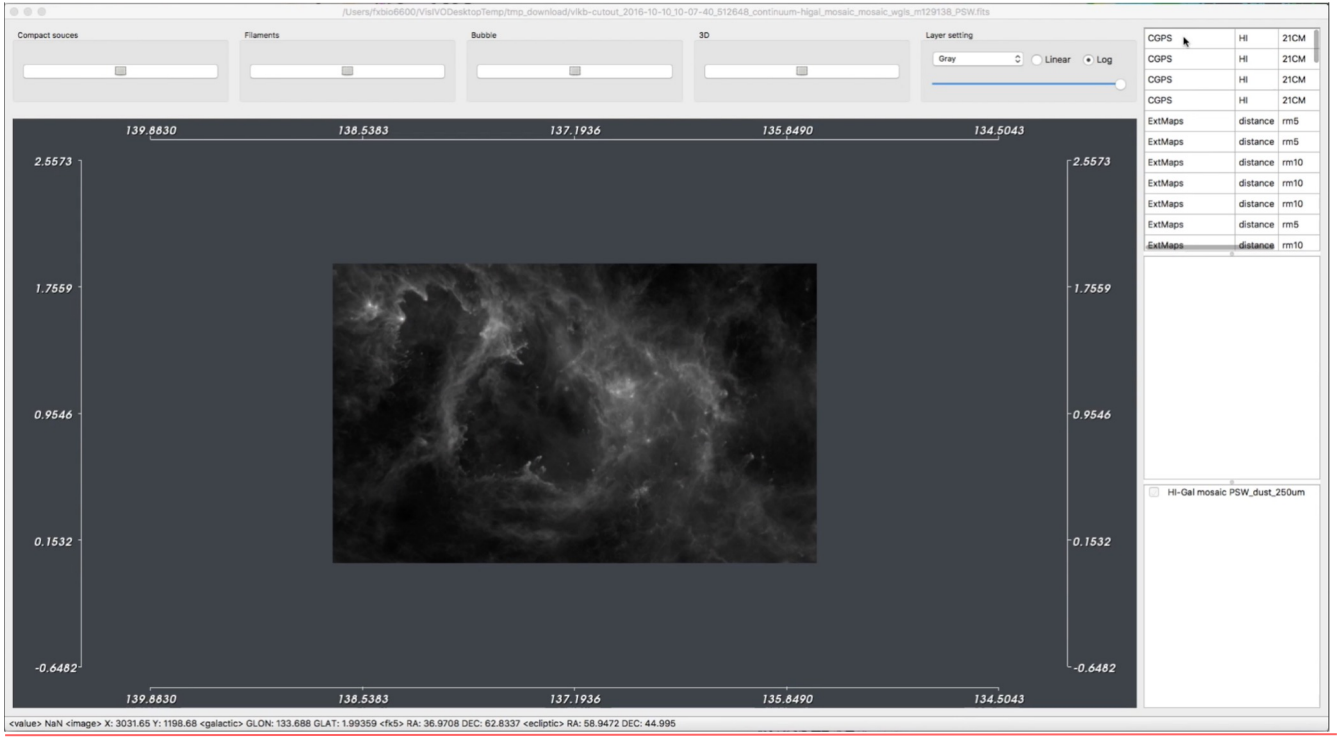
This view can be used to perform a **visual selection of the region of interest.**



https://youtu.be/BfIFQGnVPFM

VLVA: 2D Visualization

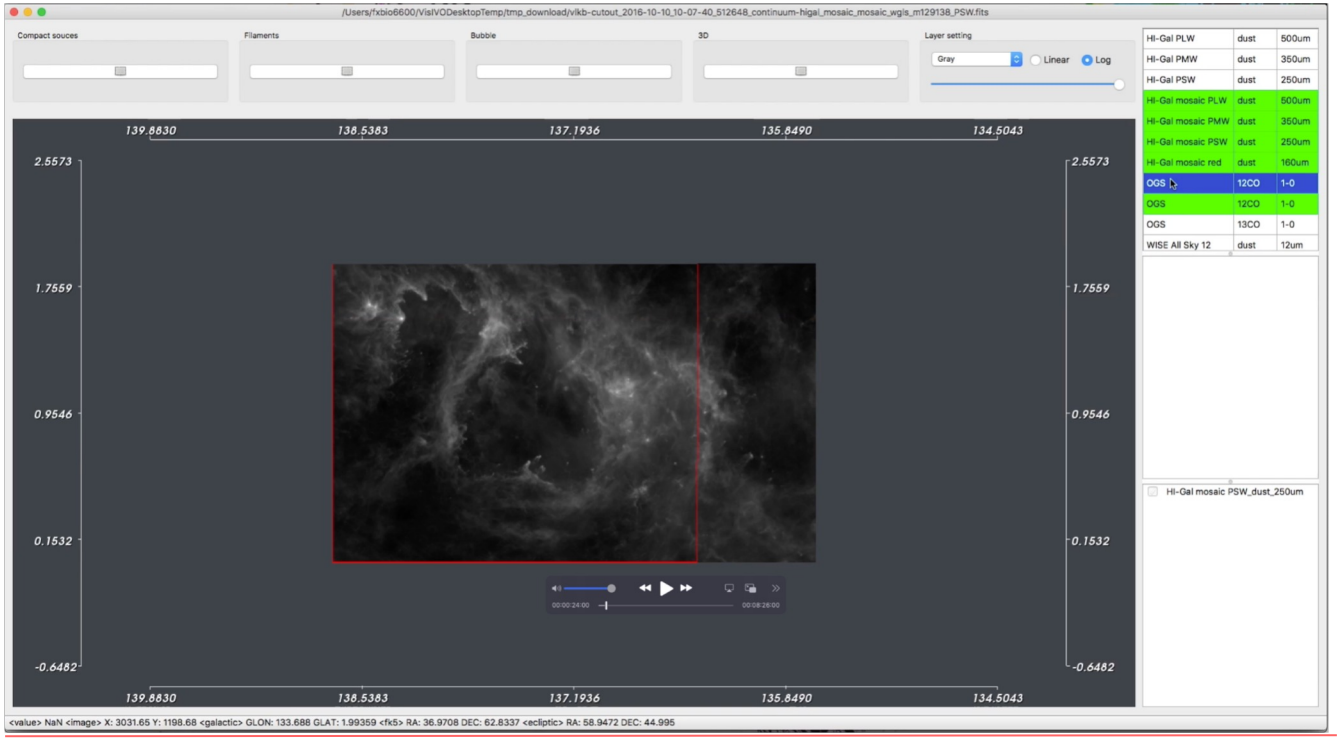
Once the selected region has been downloaded or locally loaded, the **2D visualization** window is shown.



https://youtu.be/BfIFQGnVPFM

VLVA: VLKB Data overview

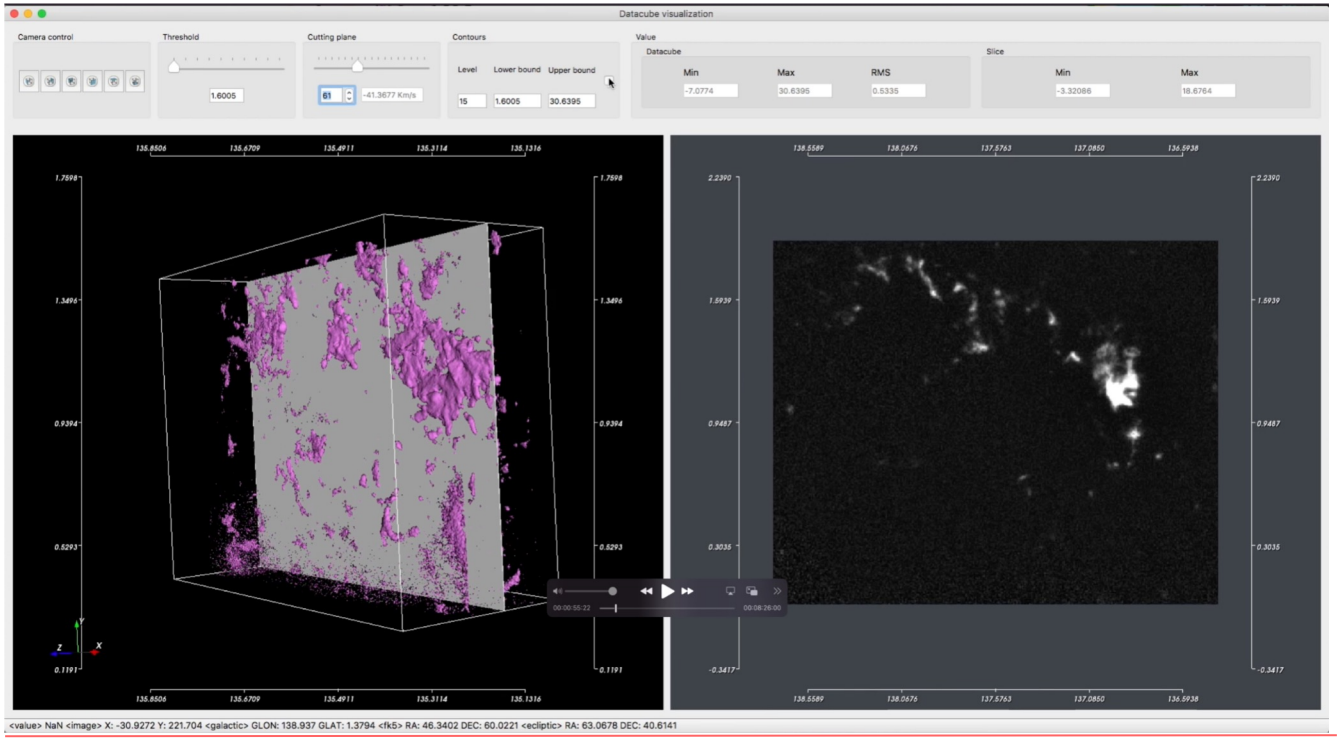
Clicking on the VLKB inventory a **footprint** of the selected item is shown



https://youtu.be/BfIFQGnVPFM

VLVA: Datacube Visualization

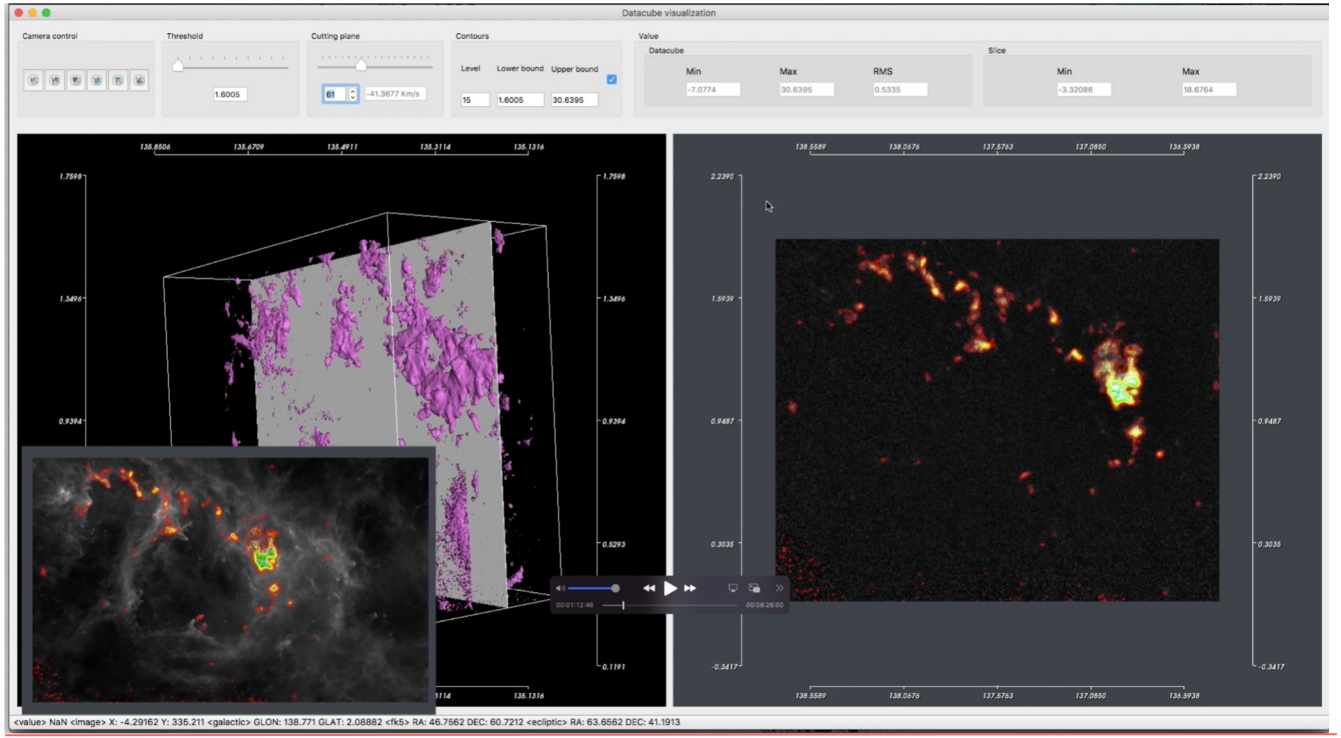
The **3D rendering of the datacube** is show on the left panel. The right panel shows the selected **slice** of the velocity datacube.



https://youtu.be/BfIFQGnVPFM

VLVA: Datacube Visualization - isocontours

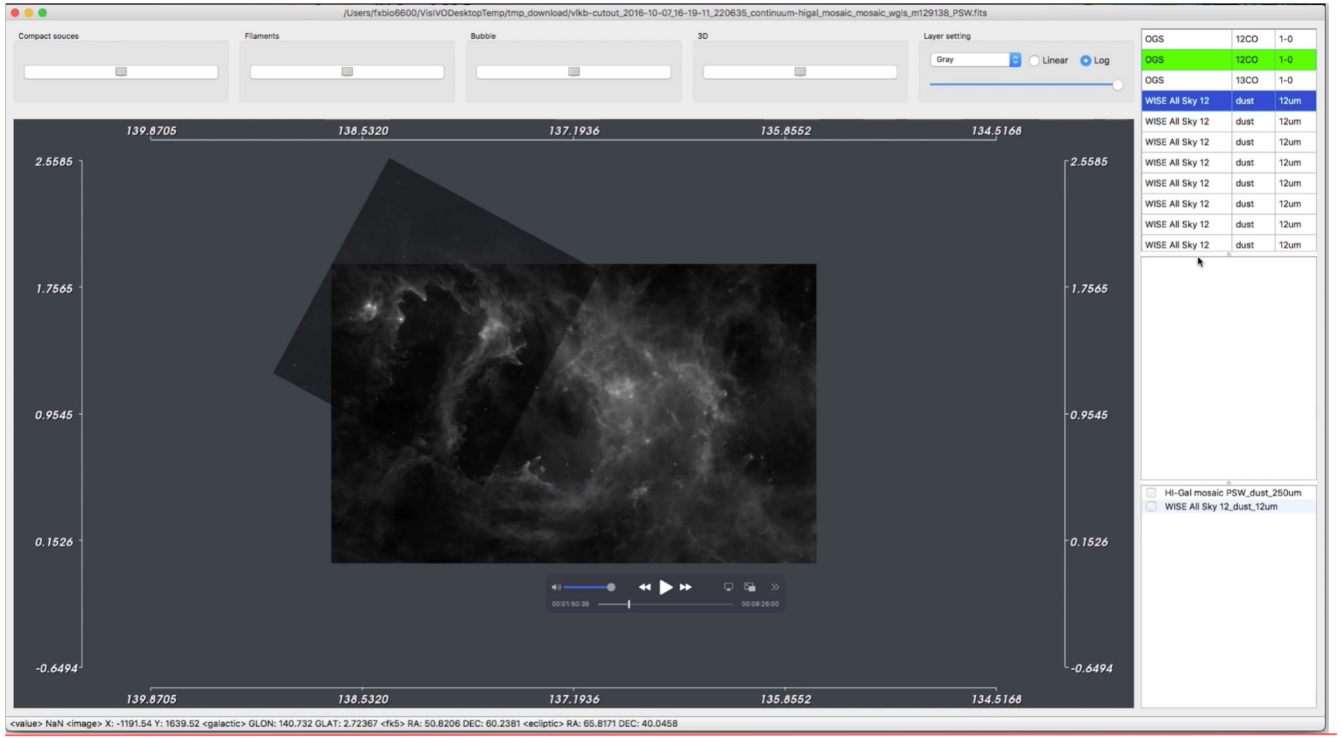
If the Contours checkbox is enabled, the **isocontours** are displayed on t**op of the selected slice**. The contours are also r**eported on the 2D map image.**



https://youtu.be/BfIFQGnVPFM

VLVA: Vialactea Visual Analytic

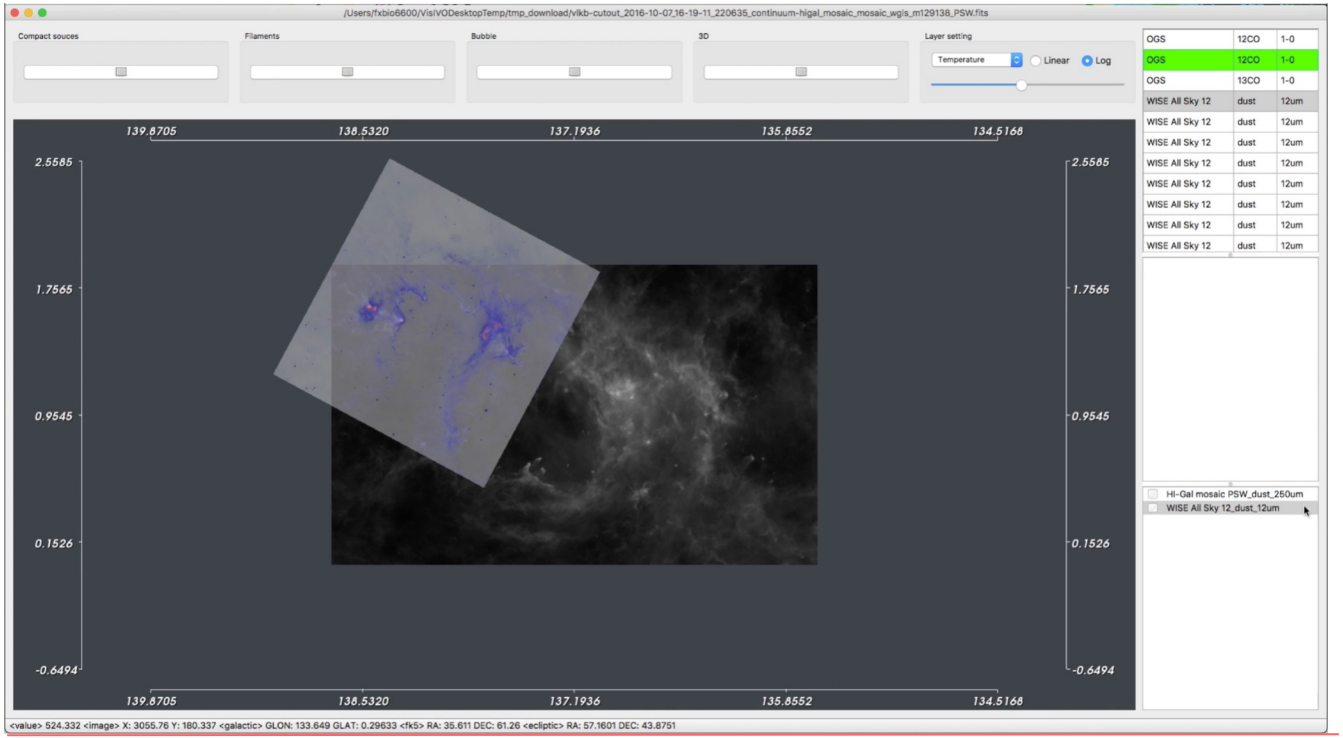
New layers are aligned (position, scaling pixel size, rotation) to the “base image” using the information contained in their header.



https://youtu.be/BfIFQGnVPFM

VLVA: 2D layers

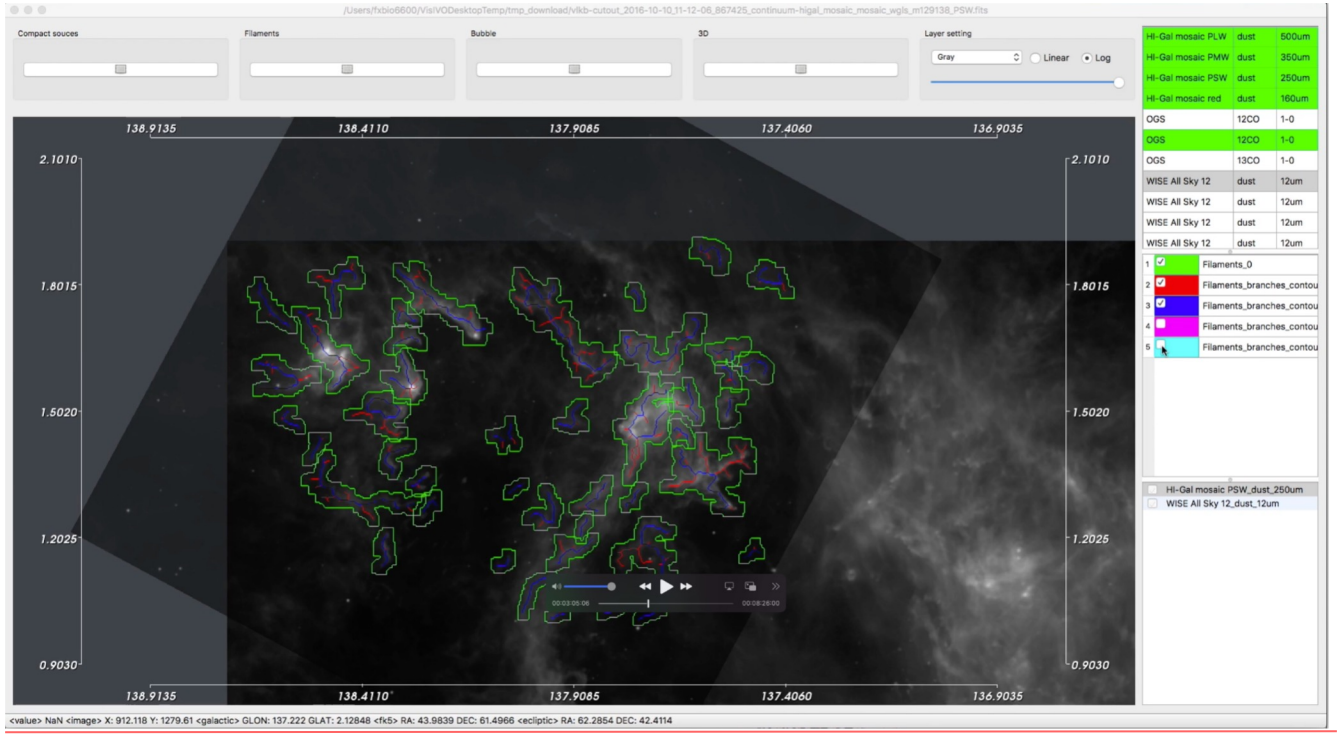
By default, a grey color palette is used to visualize the image. The **color palette** can be changed using a predefined one embedded in the tool, selecting whether to use **linear** or **logarithmic scale**.



https://youtu.be/BfIFQGnVPFM

VLVA: Filament structures visualization

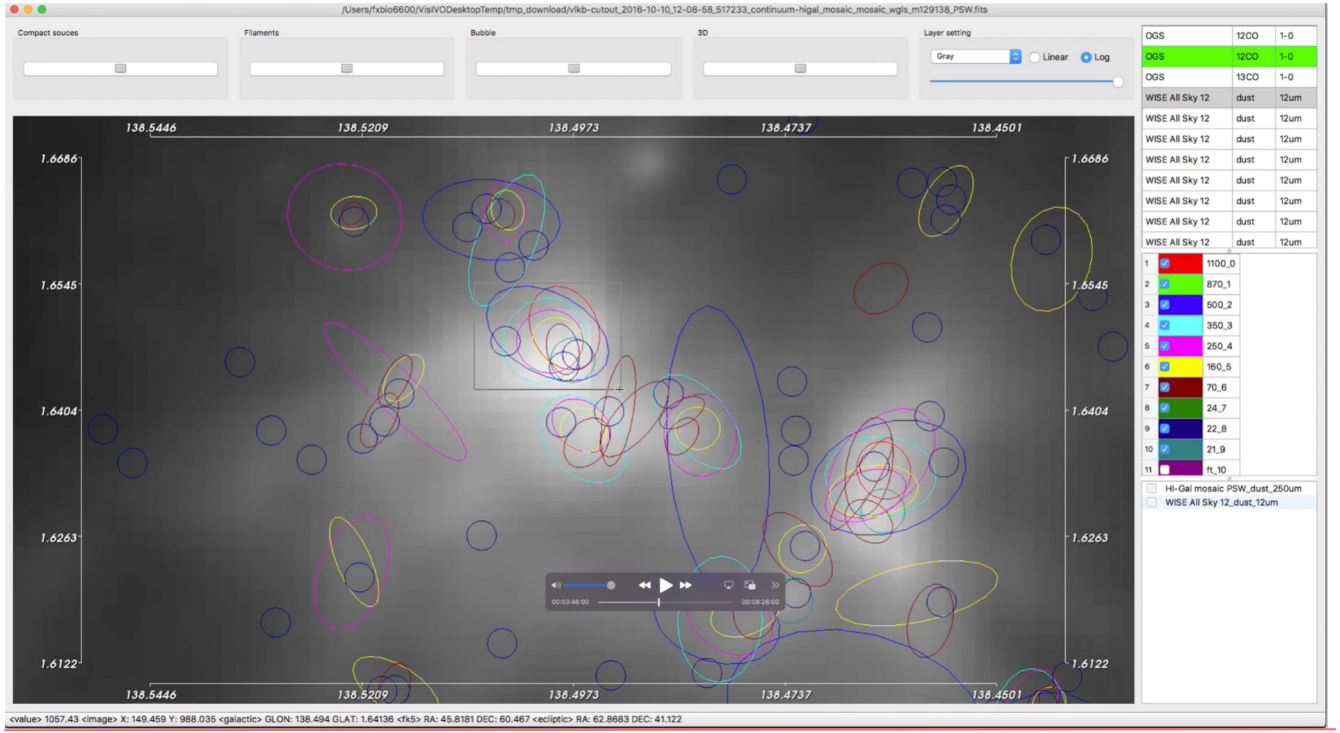
Filament structures can be visualized by selecting the Filaments button on top of the window and making a rectangular selection. The filaments are displayed with **contour** and **spine** on top of the image



https://youtu.be/BfIFQGnVPFM

VLVA: Compact sources visualization

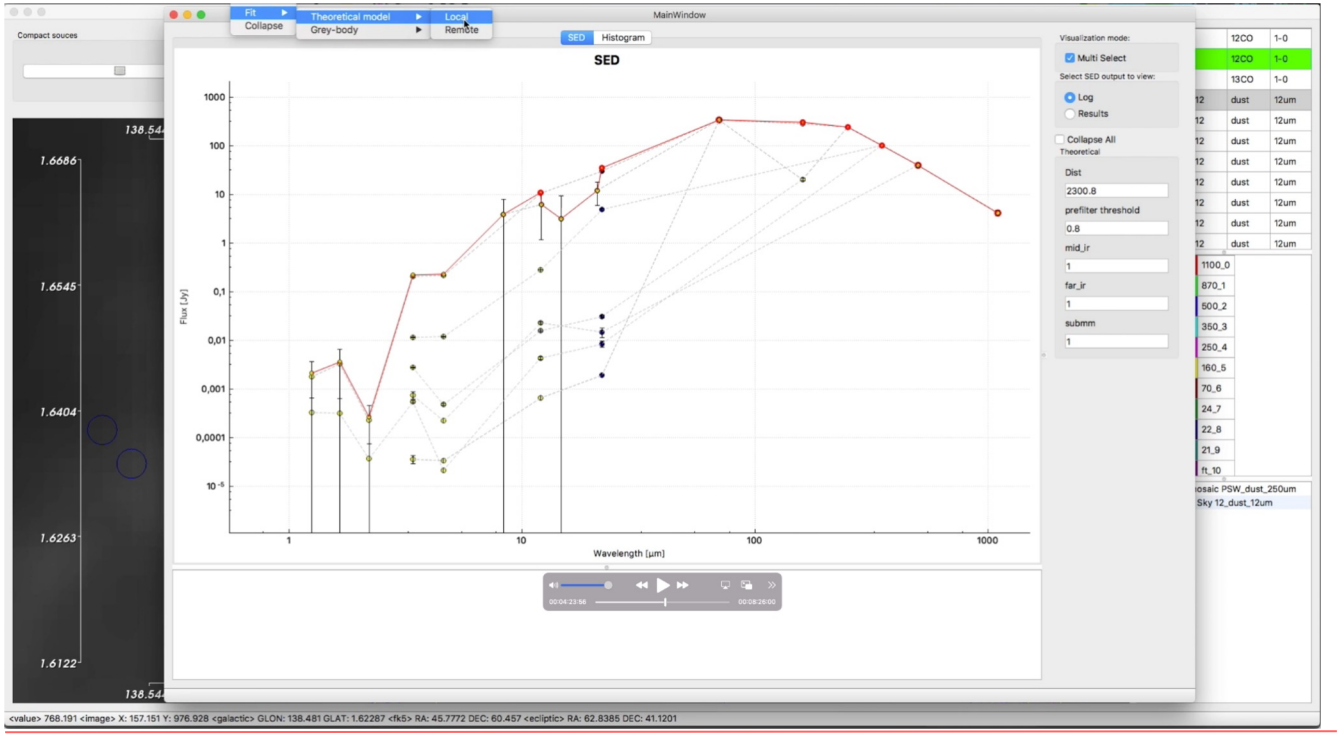
VLVA allows to visualize **compact sources** overlapped to the fits image. The compact sources are shown in different colors on the image depending on the relative wavelength.



https://youtu.be/BfIFQGnVPFM

VLVA: SED Analysis

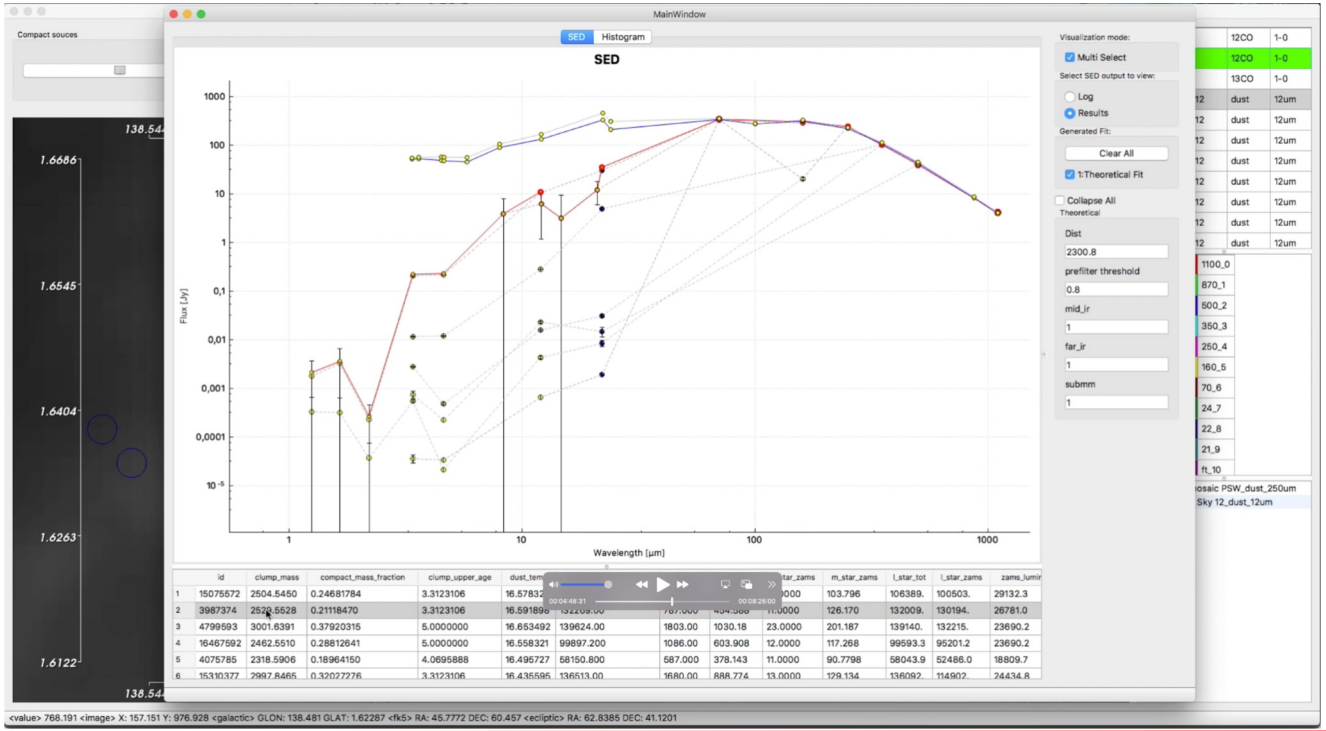
VLVA integrates a **SED Analyis tool**. There are three different kinds of fitting operations available, one for the fit with the t**heoretical models** and two for the **analytical fit**



https://youtu.be/BfIFQGnVPFM

VLVA: SED Analysis

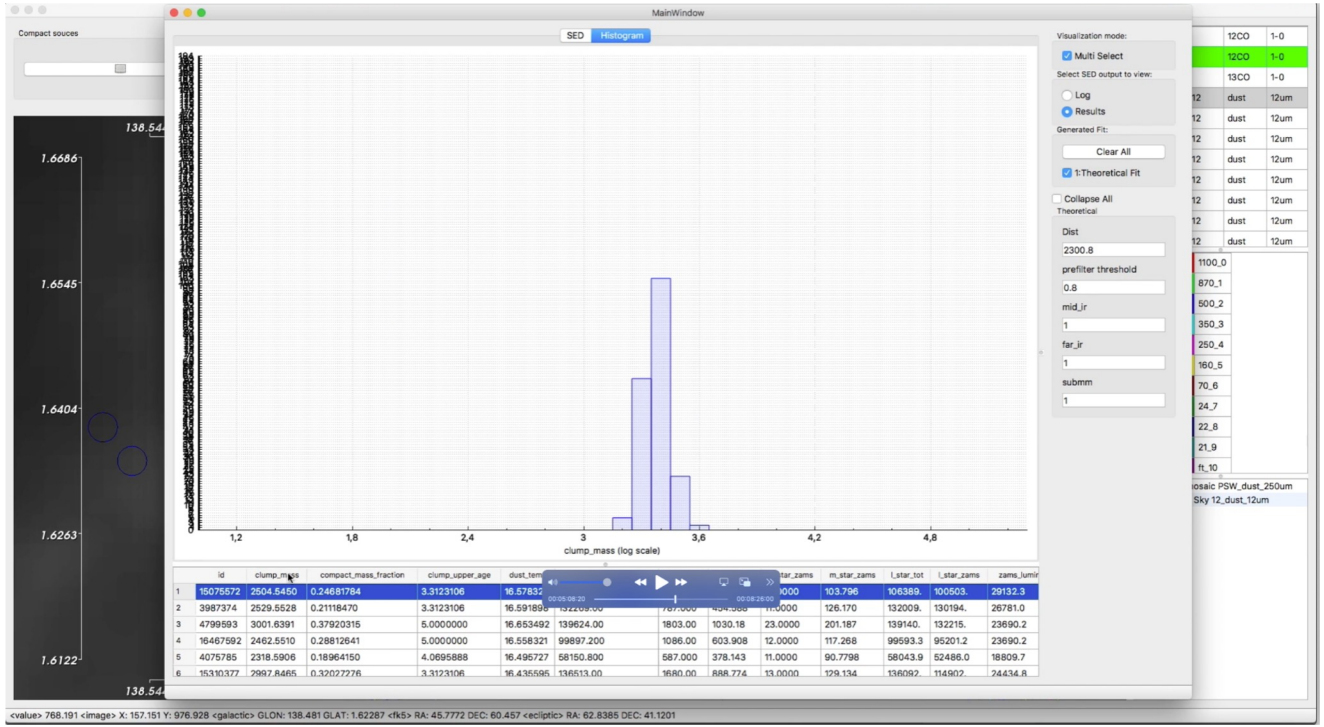
Fitting operations are performed in a transparent way for the user **locally** using integrated python routines or **remotely**.



https://youtu.be/BfIFQGnVPFM

VLVA: SED Analysis

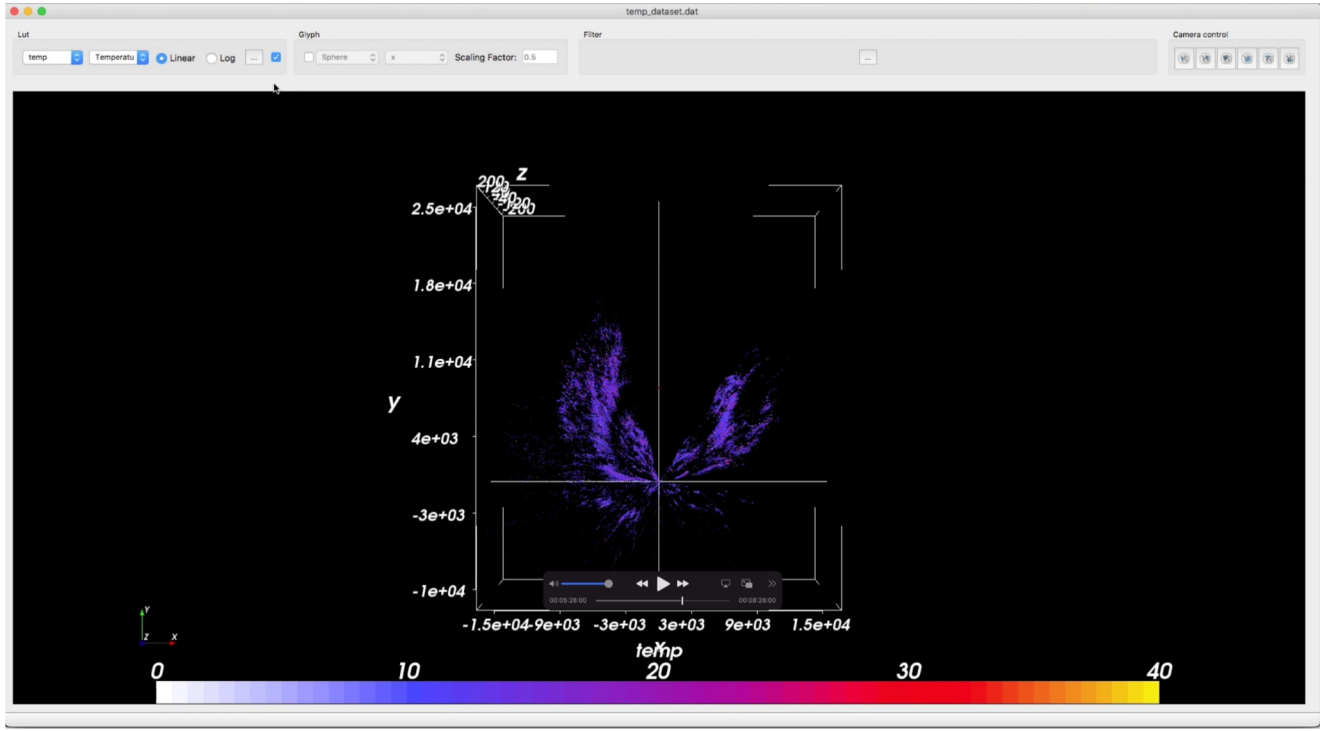
Fitting operations are performed in a transparent way for the user **locally** using integrated python routines or **remotely**.



https://youtu.be/BfIFQGnVPFM

VLVA: 3D visualization

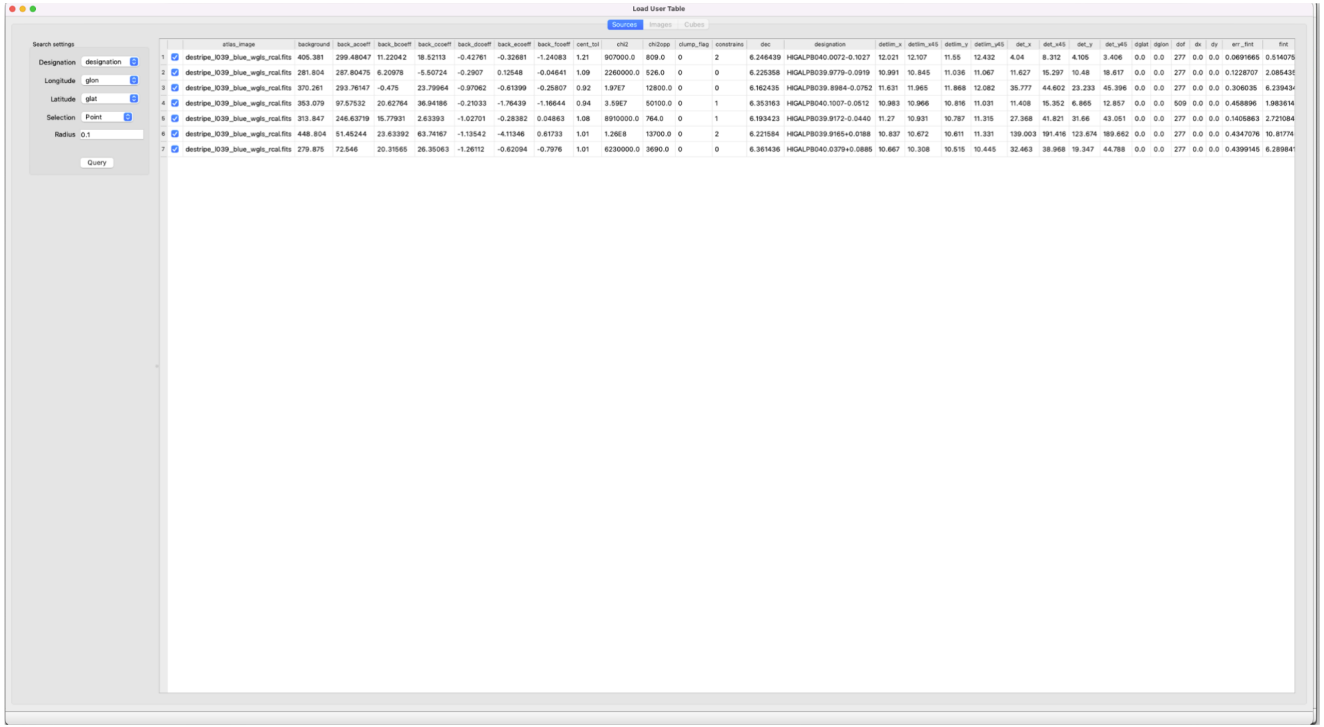
VLVA allows to explore a **3D visualization** of compact source **distributions** on the galactic plane



https://youtu.be/BfIFQGnVPFM

VLVA: Local catalogs

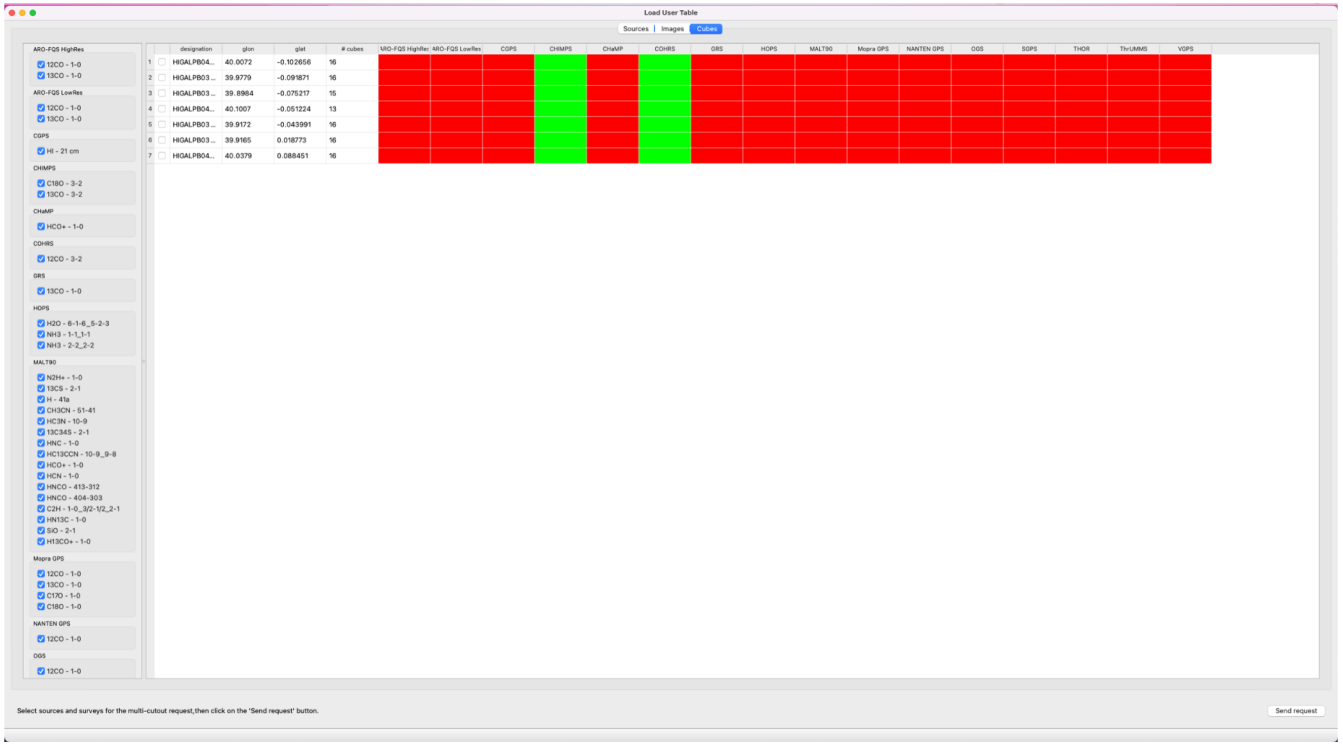
VLVA has recently been extended with support for **loading local catalogs**



https://youtu.be/BfIFQGnVPFM

VLVA: Local catalogs

When a local catalog is loaded, an **overview** of the **images** and **cubes** stored in the VLKB covering the region of the catalog is shown



https://youtu.be/BfIFQGnVPFM

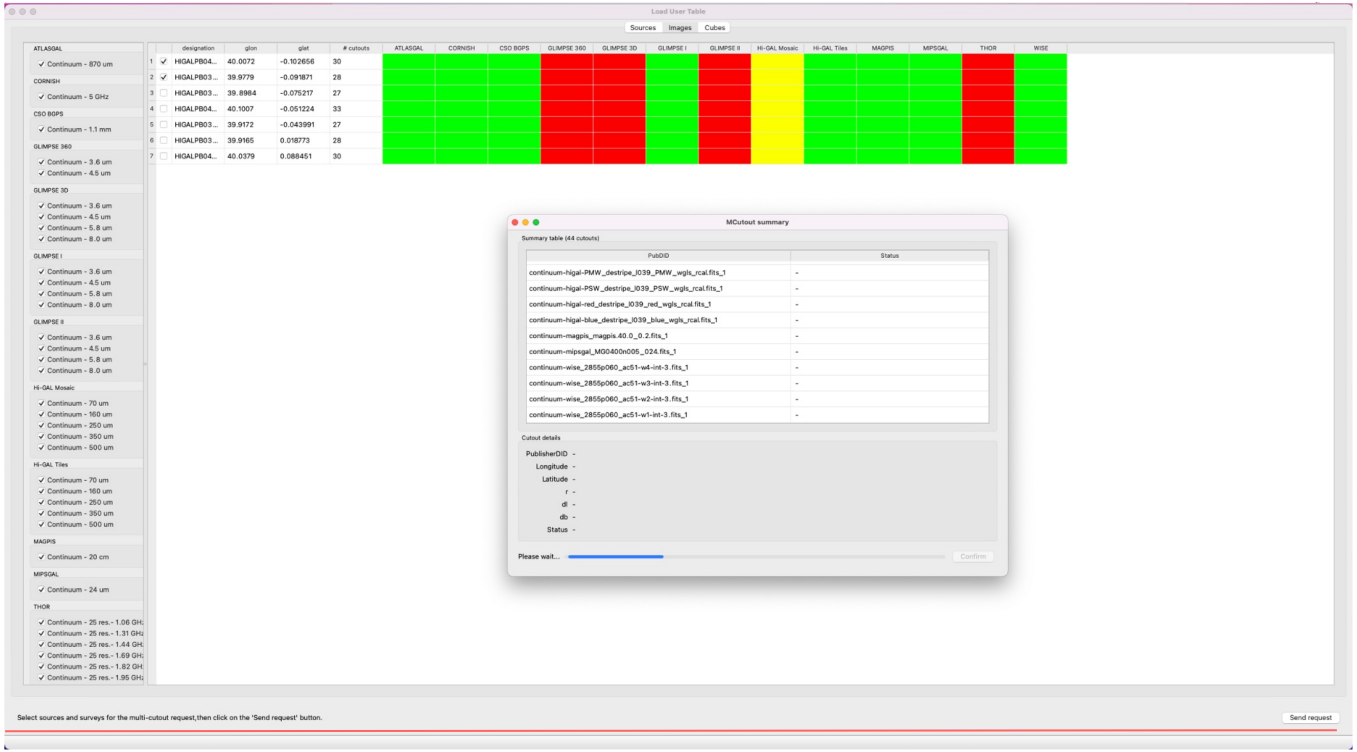
VLVA: Local catalogs

When a local catalog is loaded, an **overview** of the **images** and **cubes** stored in the VLKB covering the region of the catalog is shown

https://youtu.be/BfIFQGnVPFM

VLVA: VLVA: Local catalogs

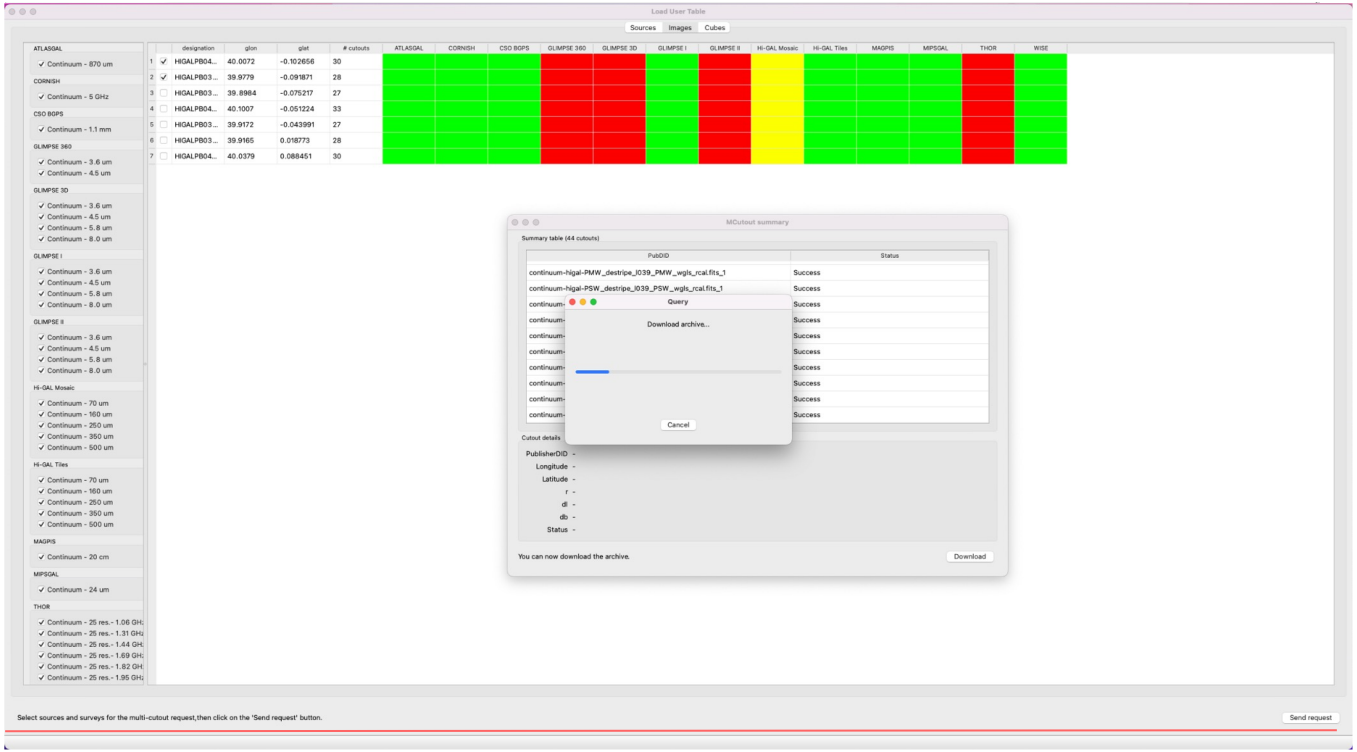
User can easily **select** and **download** all the datasets that cover the region of sources loaded from local catalog



https://youtu.be/BfIFQGnVPFM

VLVA: Local catalogs

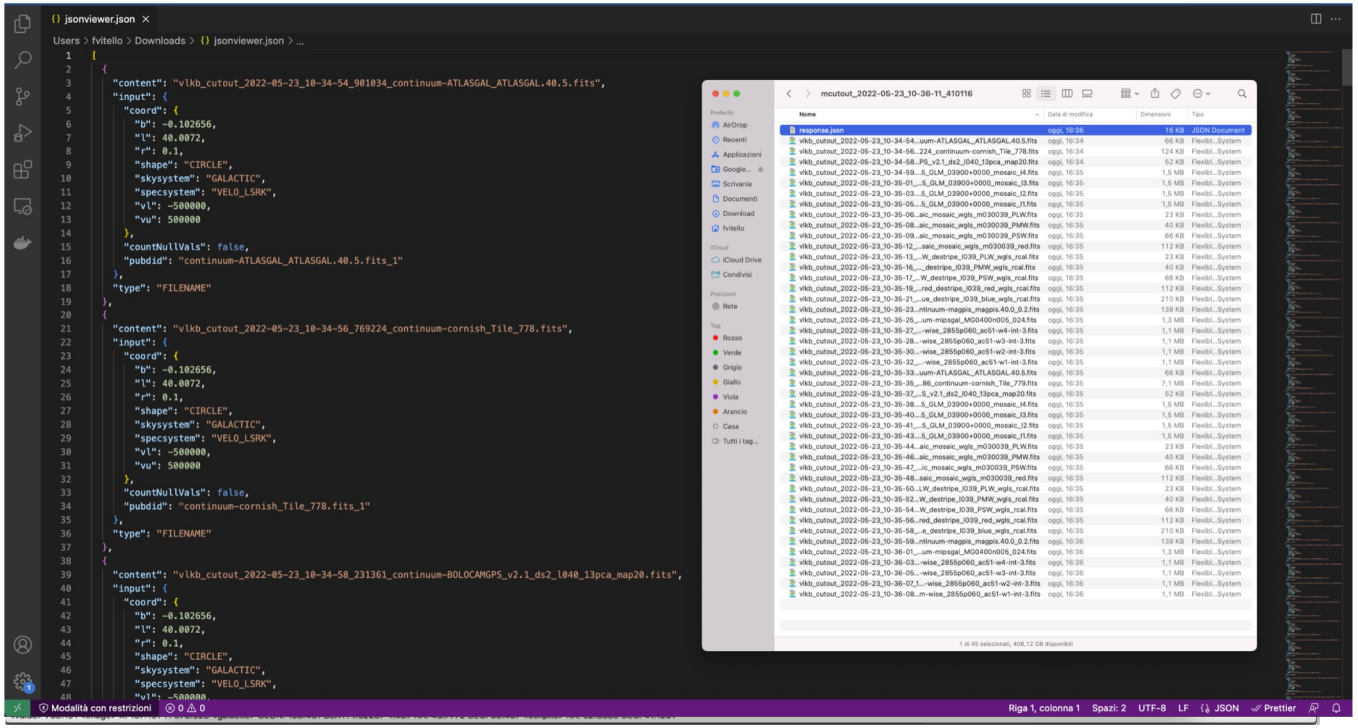
User can easily **select** and **download** all the datasets that cover the region of sources loaded from local catalog



https://youtu.be/BfIFQGnVPFM

VLVA: Local catalogs

The downloaded **archive contains all the fits file (images and datacubes)** plus a **metadata** file that can be used to load the dataset into VLVA

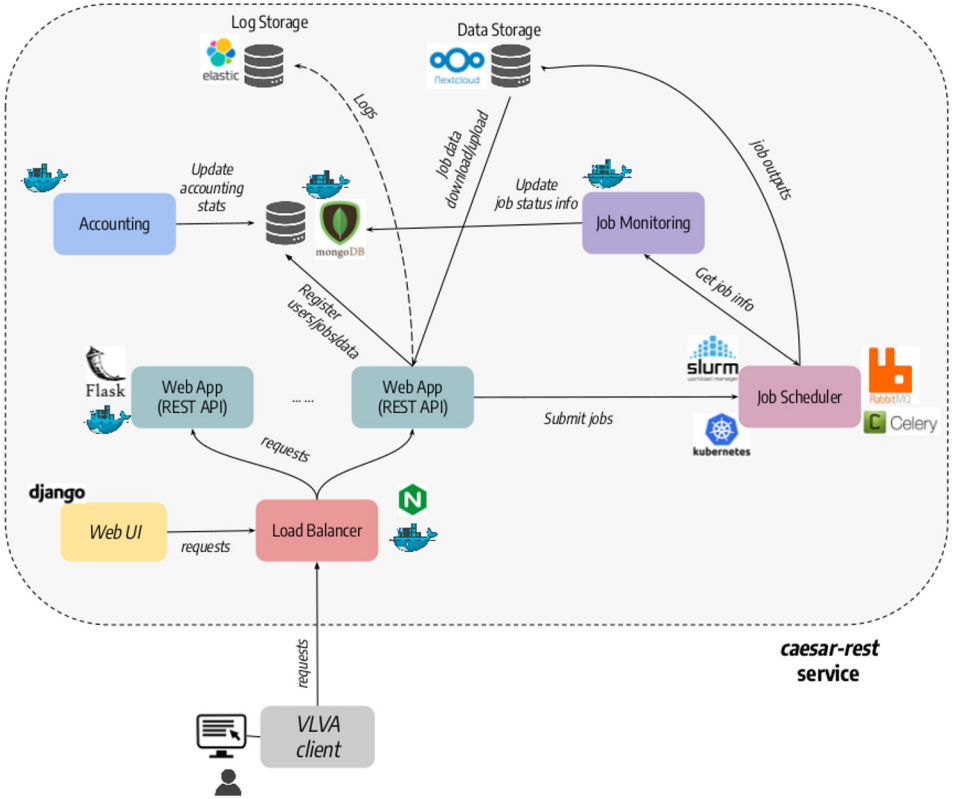


https://youtu.be/BfIFQGnVPFM

SFinder service - Source Finding

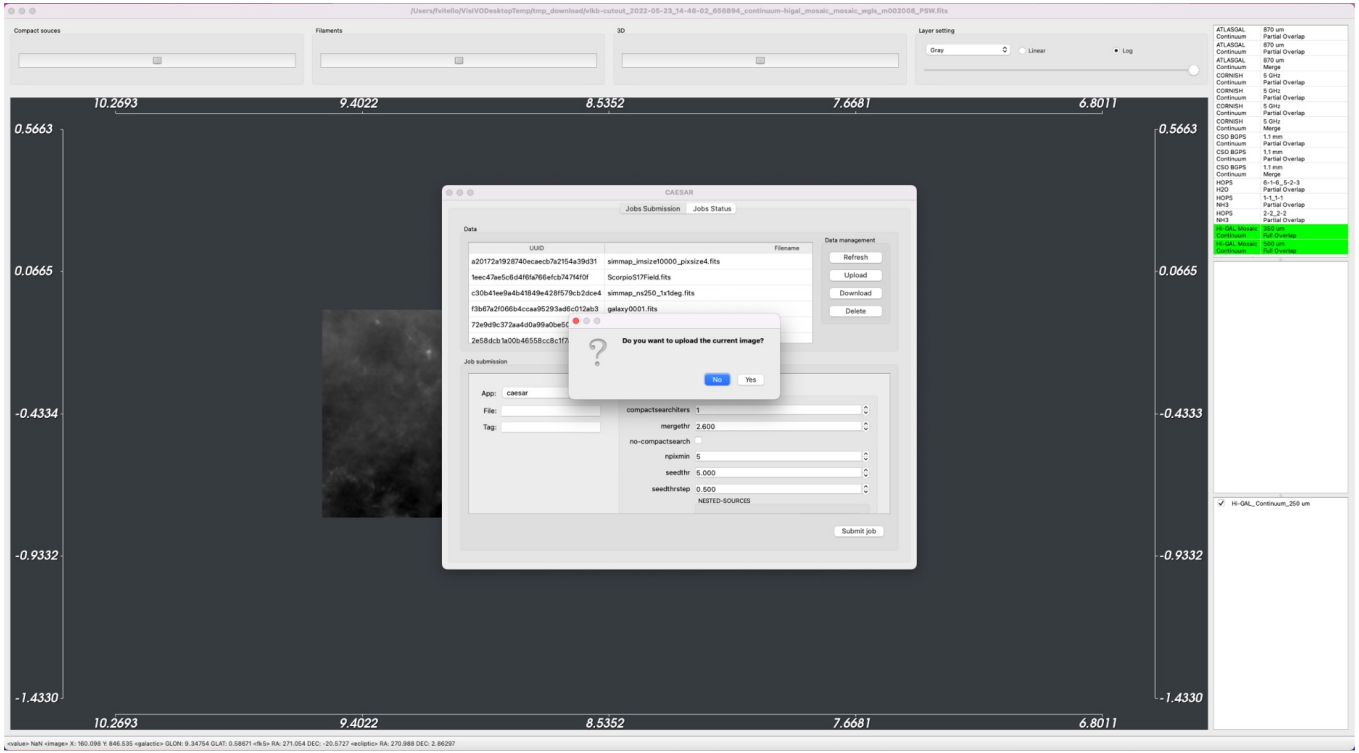
- A REST-ful web service based on Flask framework for running **CAESAR source finding** jobs
- Deployed and tested on **GARR OpenStack Kubernetes** cluster + CIRASA dedicated resources
- Multiple run strategies
  - Kubernetes Jobs (Docker)
  - Slurm Jobs (Singularity)
  - Celery async tasks
- Integrated with NEANIAS EOSC services (AAI, Logging, Accounting)
- Other source finders (ASGARD, CUTEX, Aegean) under integration
- Integrated with ViaLactea visualization

More details @ Riggi, S., et al. (2021) *Astronomy and Computing*
https://github.com/SKA-INAF/caesar-rest



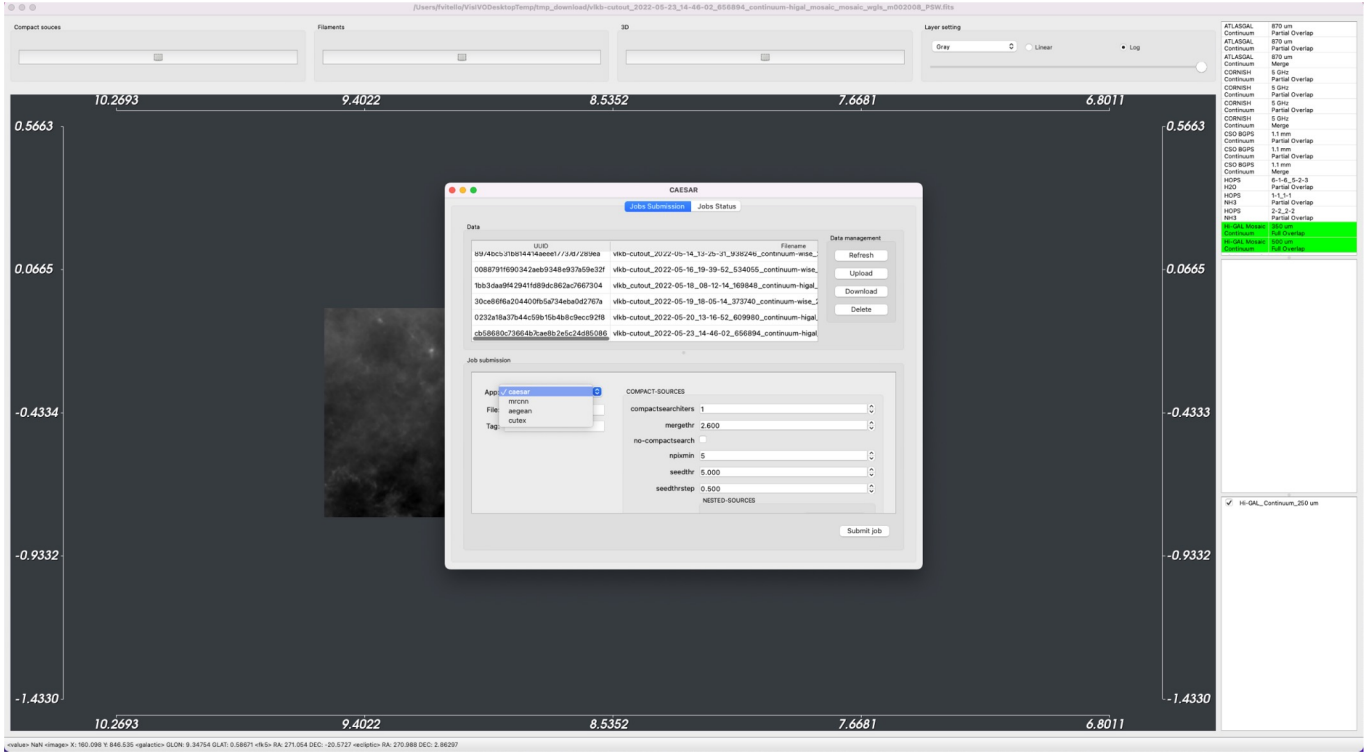
VLVA: SFinder integration

Upload the visualised image to the SFinder service



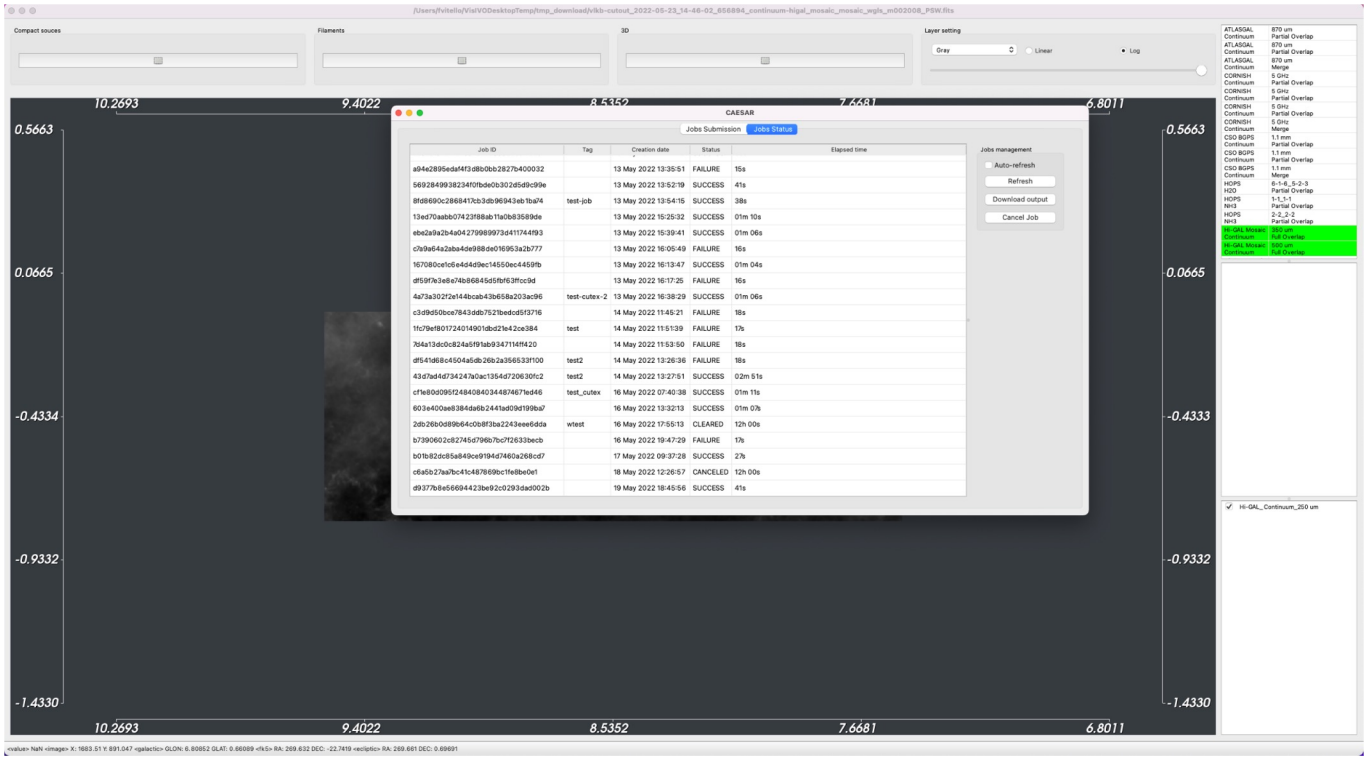
VLVA: SFinder integration

Configuring the job, selecting the source finder to run



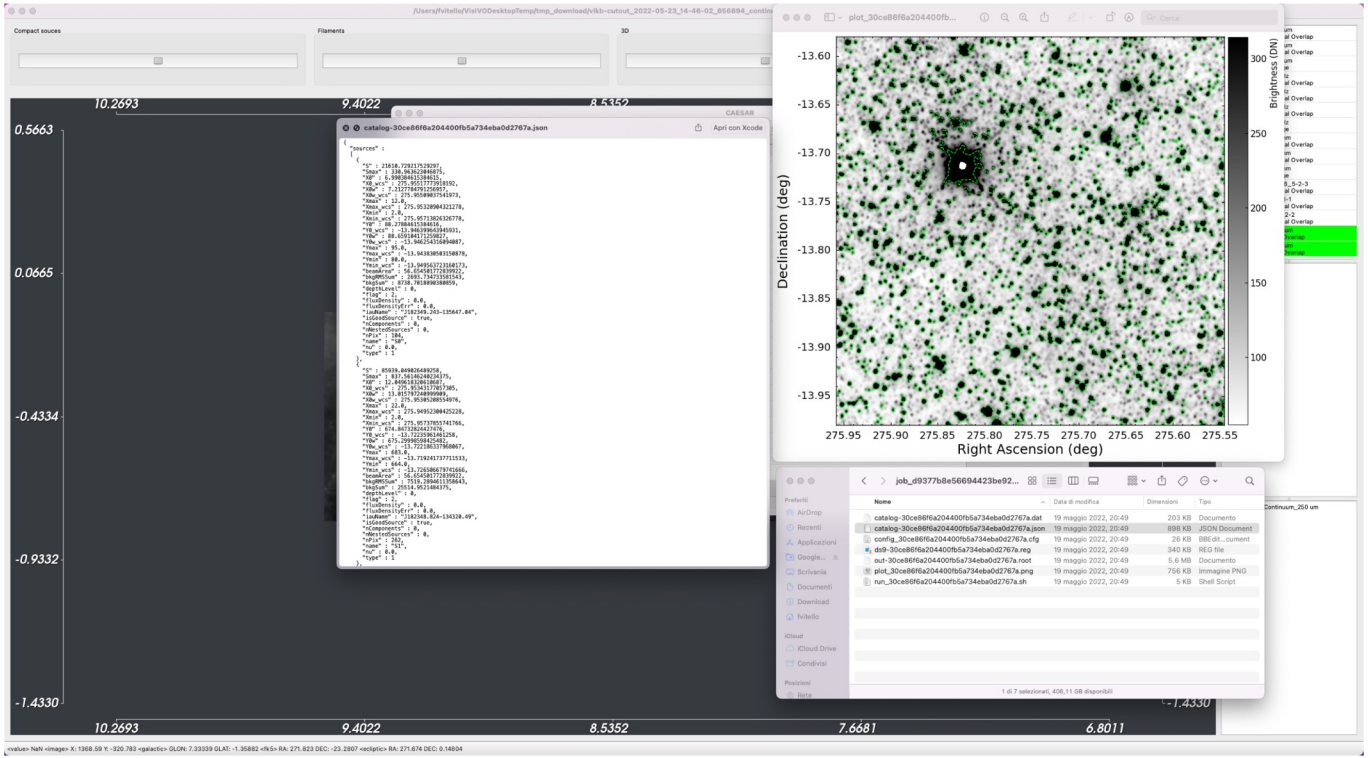
VLVA: SFinder integration

Monitoring the job, and download the output



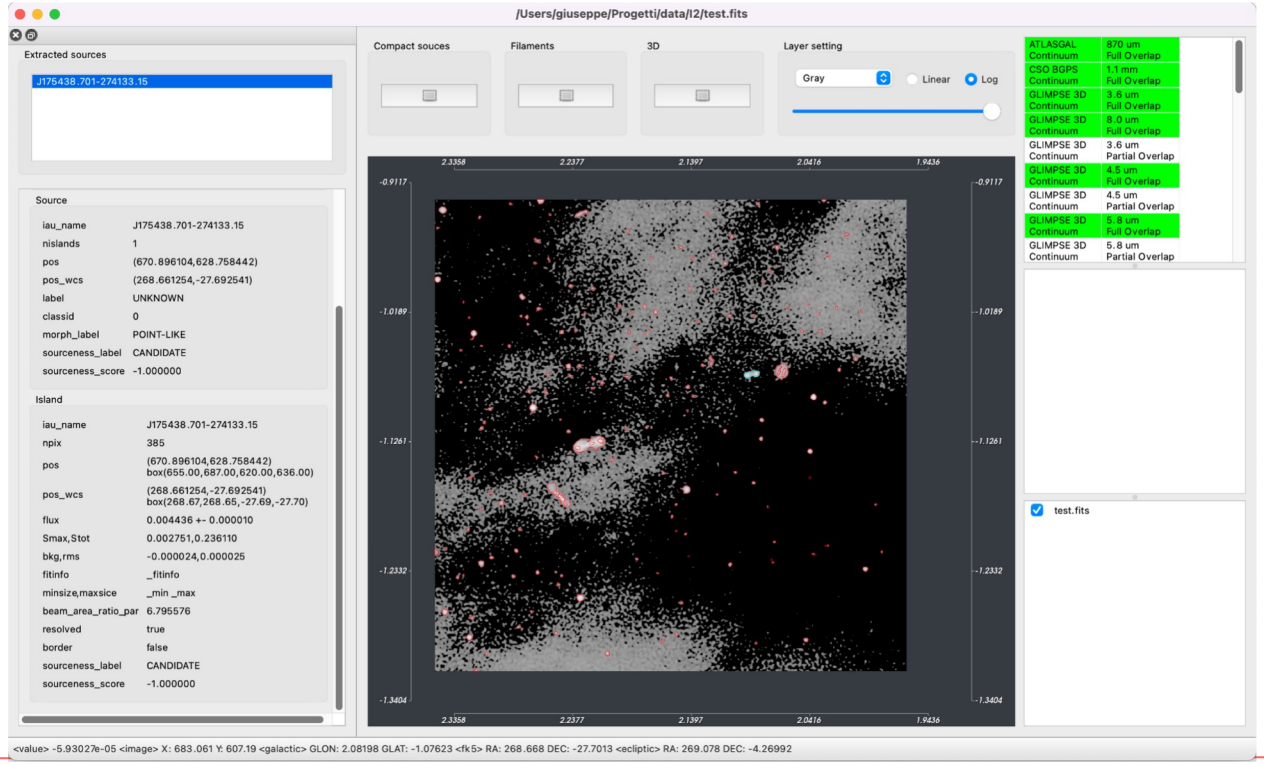
VLVA: SFinder integration

Outputs includes a PNG of extracted sources and region file (DS9 and JSON format)



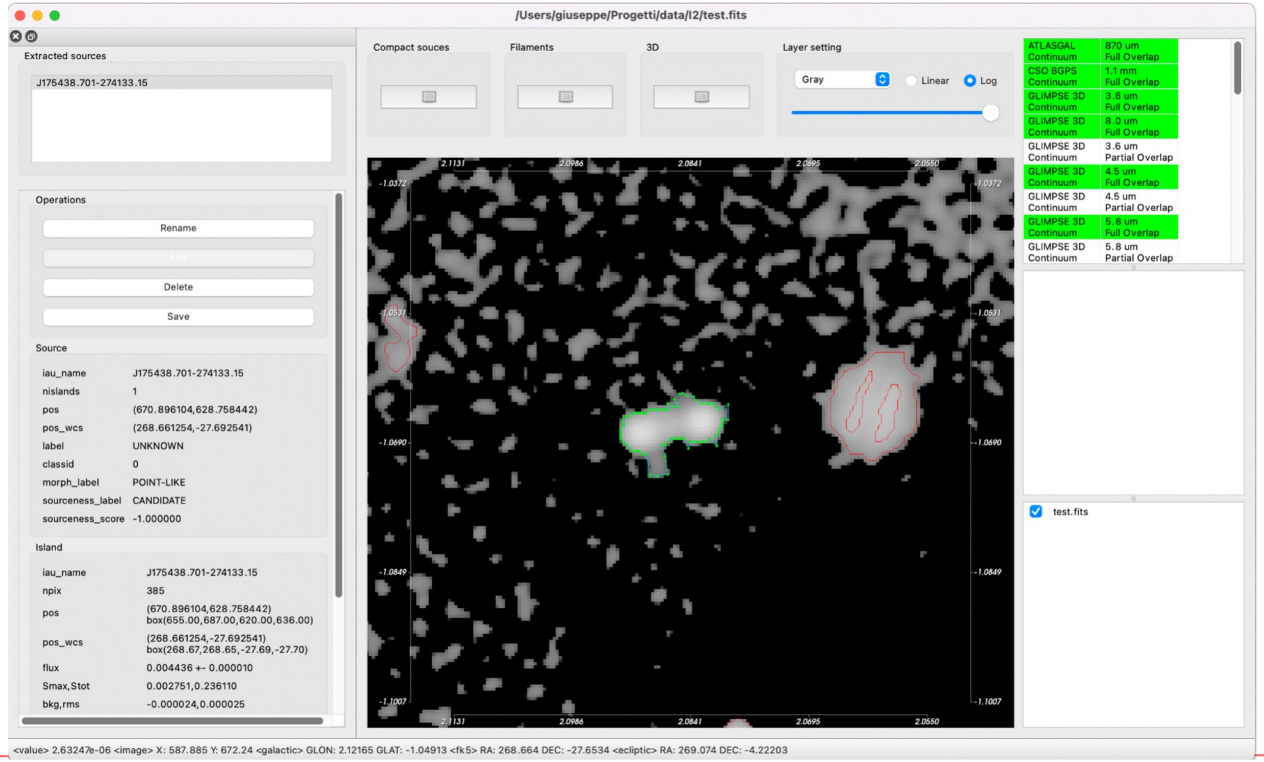
VLVA: extracted sources refinement

Analysis of source finder results with VLVA application



VLVA: extracted sources refinement

Refinement of extracted source



Prototype 4 - SKA Regional Centres

Visualization of SKA data with high volume of users and high amount of data

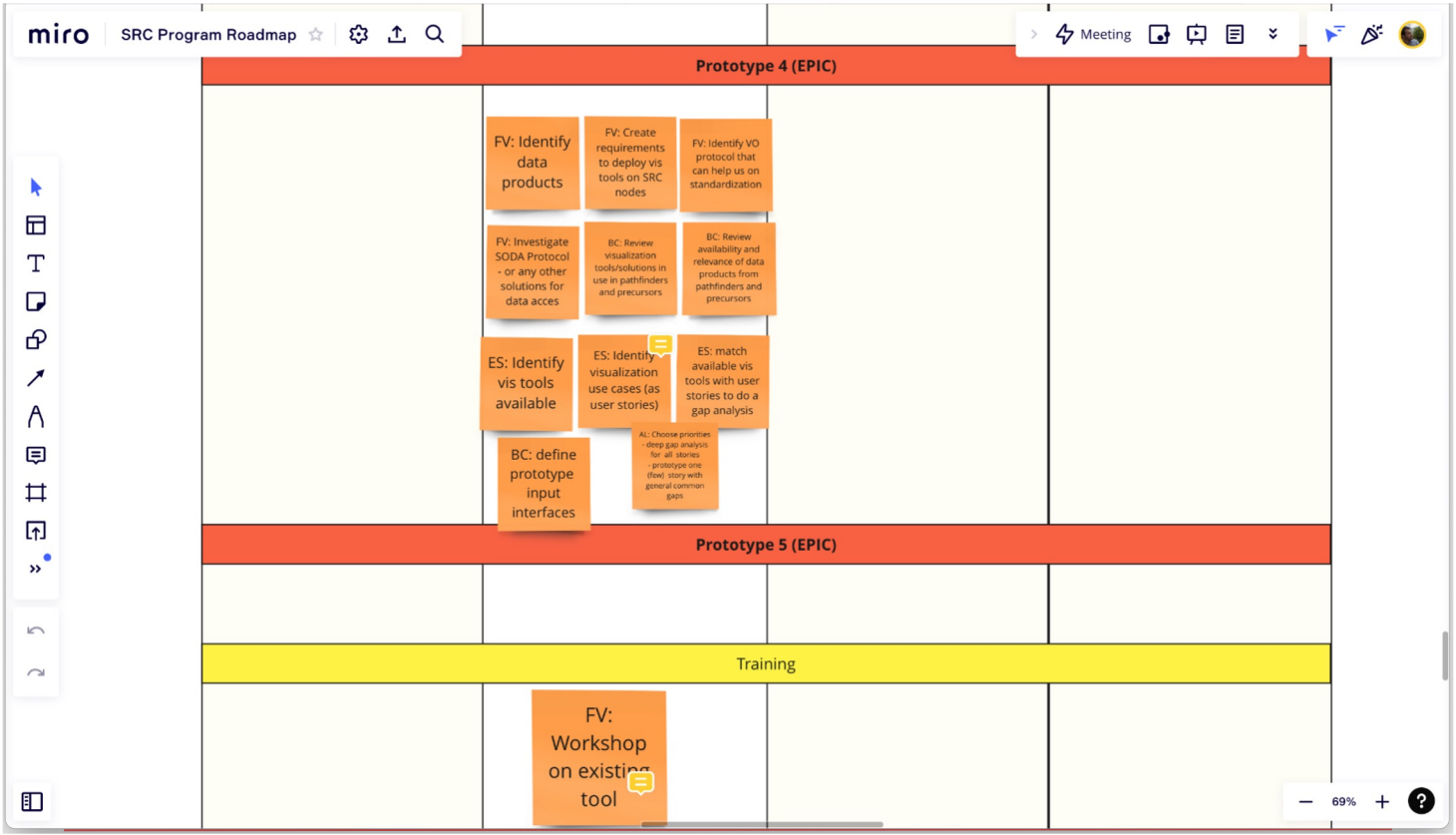
Team Orange

Italy SRC:

- Fabio Vitello (product owner) 0.5 FTE
- Giuseppe Tudisco (scrum master) 0.8 FTE
- Eva Sciacca 0.3 FTE
- Andrea Lorenzani 0.3 FTE
- Matteo Canzari 0.2 FTE
- Franco Tinarelli 0.2 FTE
- Claudio Gheller 0.2 FTE
- Alessandra Zanichelli 0.1 FTE
- Vincenzo Galluzzi 0.1 FTE

		FTE	SRC
Scrum Master	@Tudisco, Giuseppe	80%	IT
Product Owner	@Vitello, Fabio	50%	IT
Team Members	@Sciacca, Eva	30%	IT
	@Lorenzani, Andrea	30%	IT
	@Tinarelli, Franco	20%	IT
	@Gheller, Claudio	20 %	IT
	@Das, Arpan	40%	SWI
Observers	@Xu, Zhijun		China
	@Zanichelli, Alessandra	10%	IT
	@Galluzzi, Vincenzo	10%	IT
	@Kirkham, Kechil		SA
	@Pandey, Vishambhar Nath	10%	FR
	@Allen, Mark	5%	FR
	@Boch, Thomas	5 %	FR
	@Fernique, Pierre	5 %	FR
	@Bonnarel, Francois	5 %	FR
	@Salome, Philippe	10 %	FR
	@Cecconi, Baptiste	10 %	FR
	@Loh, Alan	10 %	FR
	@Vilotte, Jean-Pierre		FR
	@Moreau, Nicolas	10 %	FR
	@Yaye-Awa, Ba	10 %	FR
	@Salgado, Jesus		SKAO

Prototype 4 - SKA Regional Centres



Remote Visualization

Rendering close to the datasets

Scale Up resources

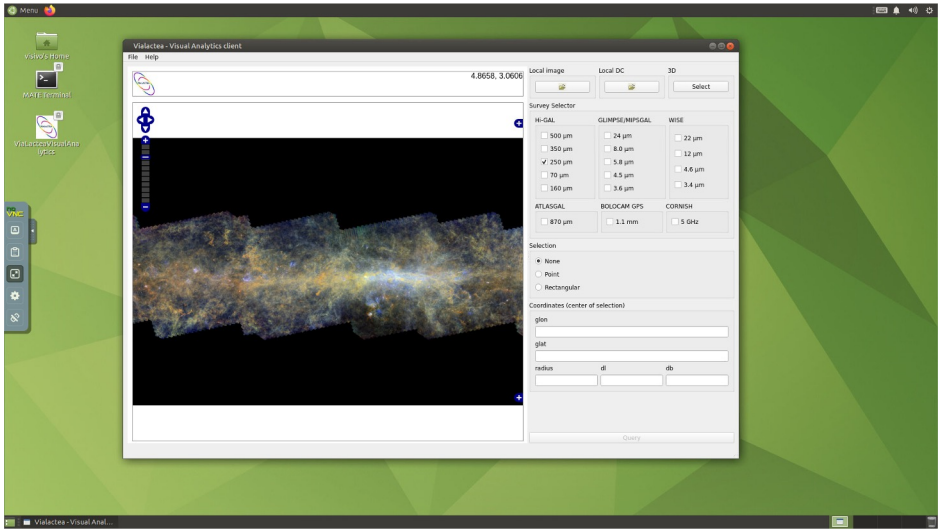
Prototypes:

- Docker + noVNC
- Remote Rendering + web interface
- Remote Rendering + Desktop interface

VLVA@Docker

- Run VLVA in a docker container
- Accessible through VNC via web browser
- Based on NVIDIA Container Toolkit

PROS: Easier to develop
CONS: Vertical Scalability

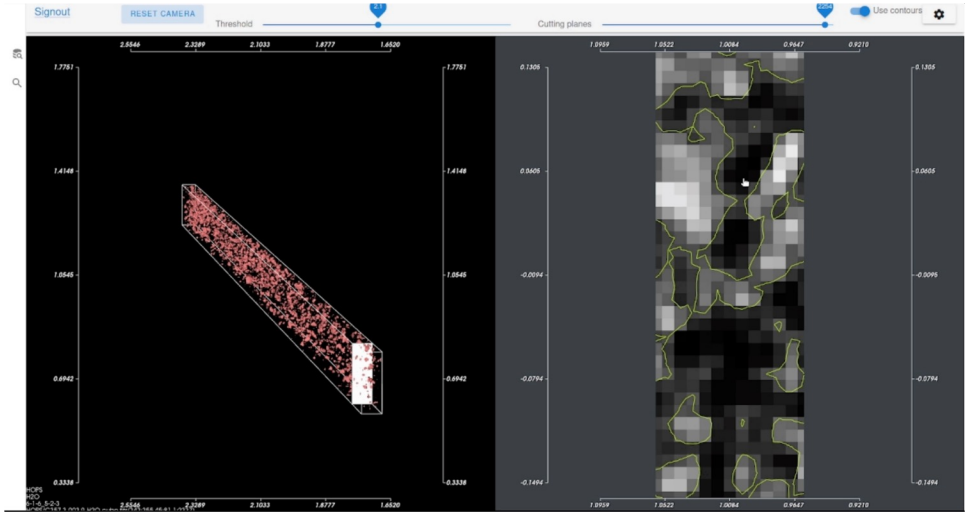


https://vlva.readthedocs.io/en/latest/install.html#docker-container

Vialactea Web - VLW

https://youtu.be/F6Q4xiMbHqg

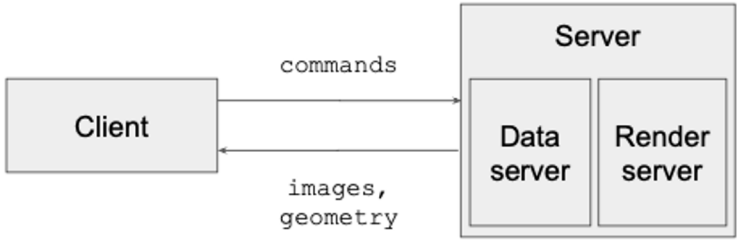
- Work-in-progress simplified web version of the VISUAL ANALYTICS TOOL, developed in collaboration with University of Portsmouth (UK)
- Multi-user support within web environment
- Provides efficient offscreen visualisation (GPU and CPU rendering) on remote server

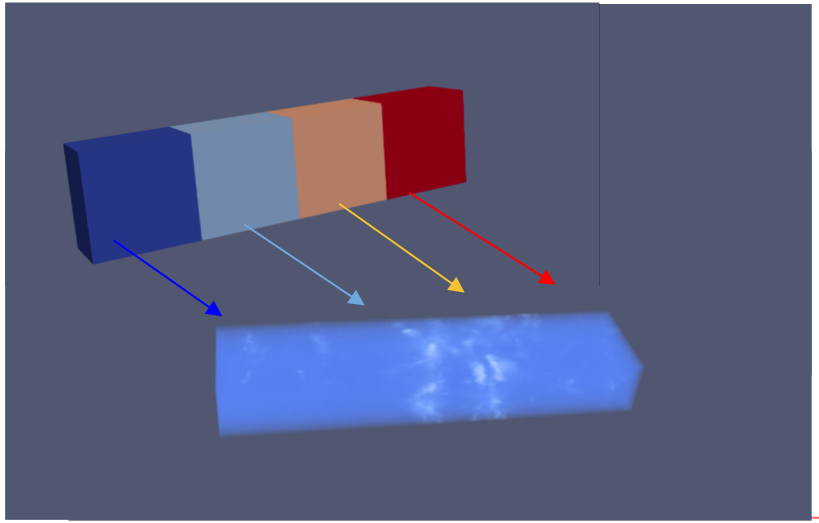


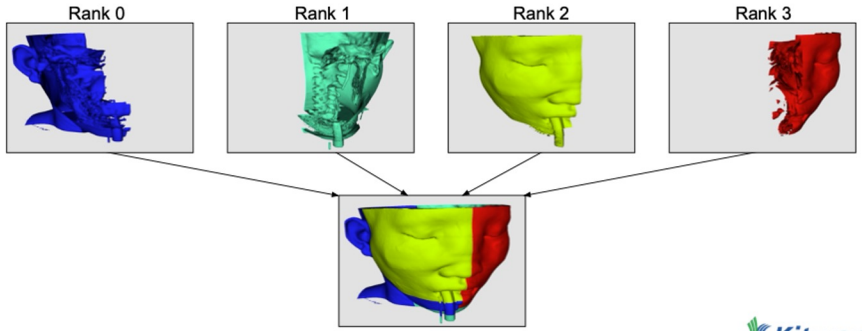
- Web browser solution with desktop/mobile/tablet support that is flexible for future functional extension
- Working on full containerization for optimized deployment on cloud and distributed infrastructures

Remote Rendering + Desktop interface

- Based on Kitware Paraview
- Vertical and Horizontal Scalability
- Data Parallel Pipelines
  - MPI Based readers



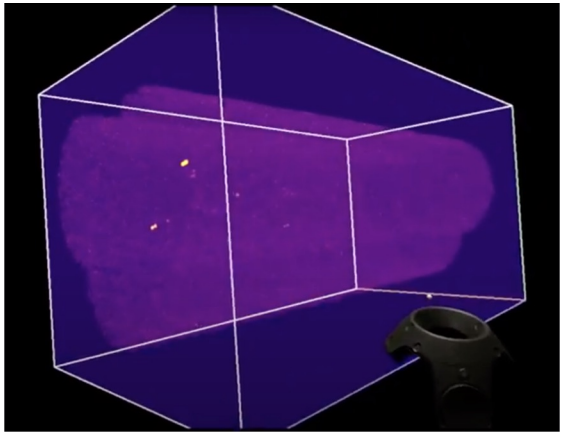




Kitware

iDaVIE: immersive Data Visualisation Interactive Explorer

iDaVIE is a VR software allows **data cube investigation** from an immersive perspective with several operations on the data such as **source identifications**, **mask visualization** and **mask editing** on the fly.



Involved Persons:

- **IDIA teams**: Prof. Tom Jarrett (PI) and Prof. Russ Taylor (Co-PI), both directors of the IDIA Viz Lab, Dr. Lucia Marchetti (Project Scientist and Project Manager) , Dr. Angus Comrie (Lead Developer), Alexander Sivitilli (Developer), Prof. Mattia Vaccari (Italy-South Africa Bilateral Program representative);
- **ICT-VR-Lab and MeerKAT Fornax Survey teams**: Dr. Ugo Becciani (Co-PI), Dr. Fabio Vitello (lead the design and development of the user interface), Dr. Paolo Serra (Co-Project Scientist, HI expert and HI Community Representative)

Webinar

https://forms.gle/iWkjcBHwQ3VTc1iY9

Thank you

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