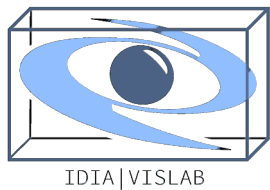
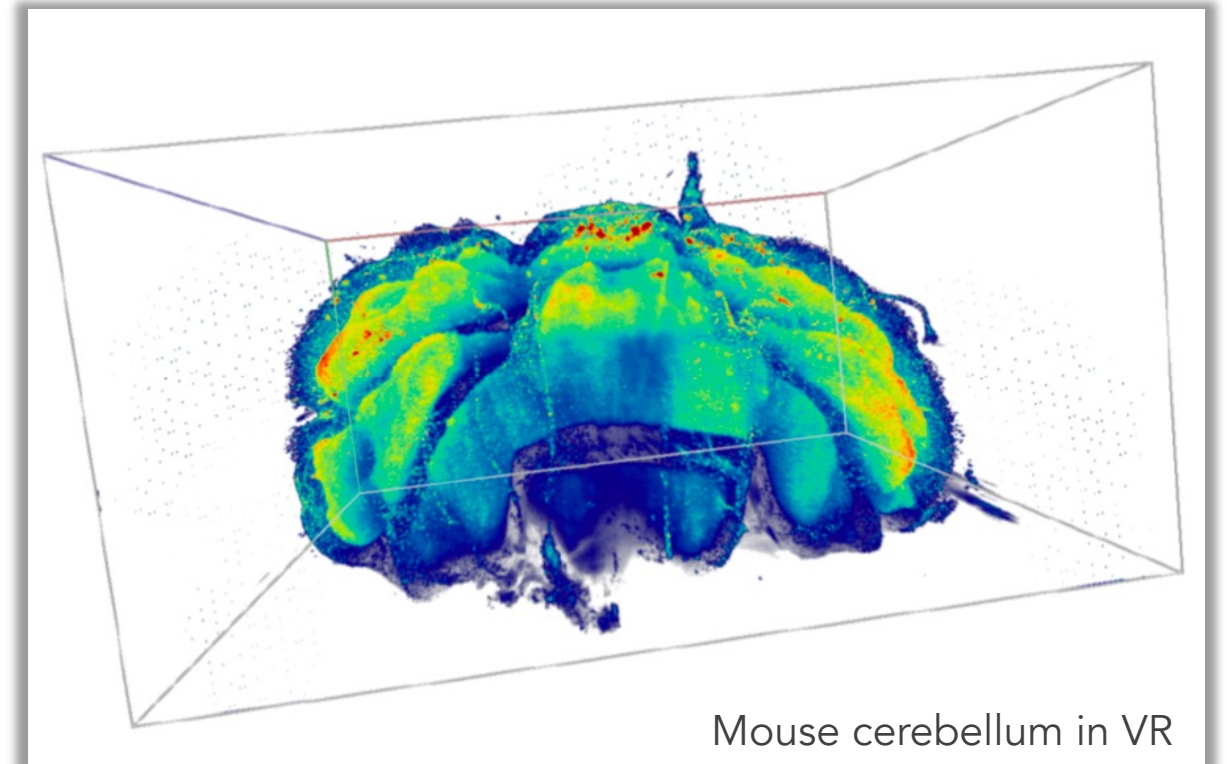
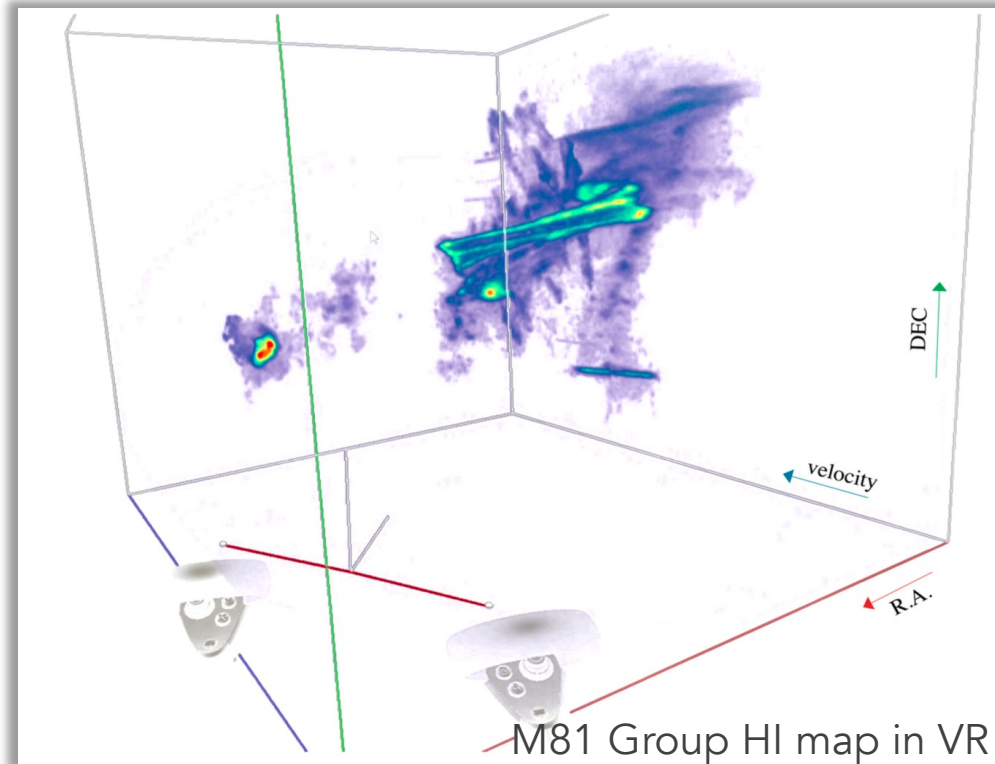


# Scientific Exploration of Spectral Cubes using Immersive Technology



Lucia Marchetti

T. H. Jarrett, Angus Comrie, A. Sivitilli, F. Vitello, R. A. Taylor, U. Becciani

[vislab.idia.ac.za](https://vislab.idia.ac.za)

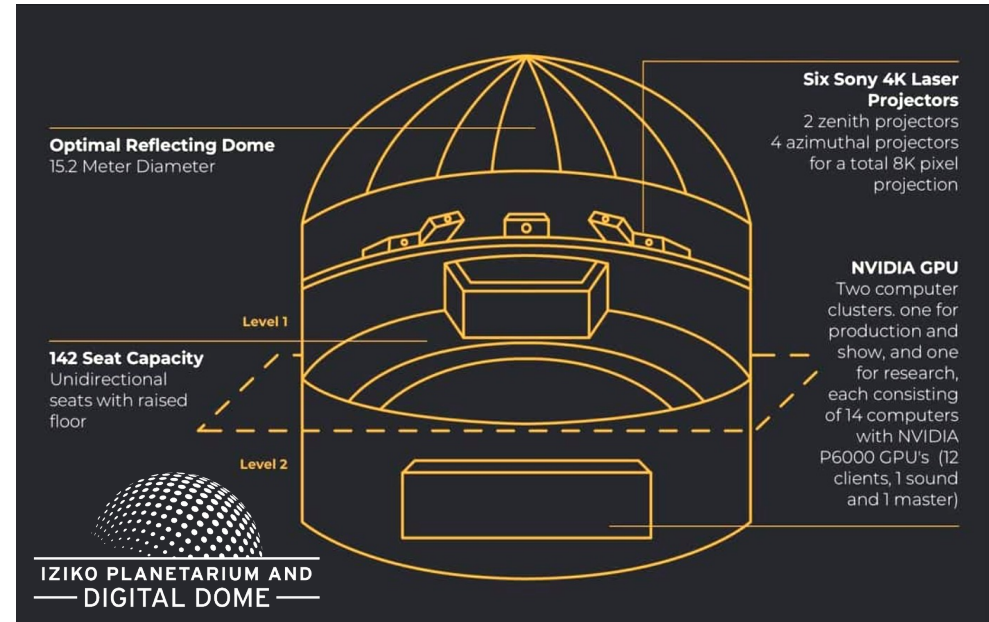
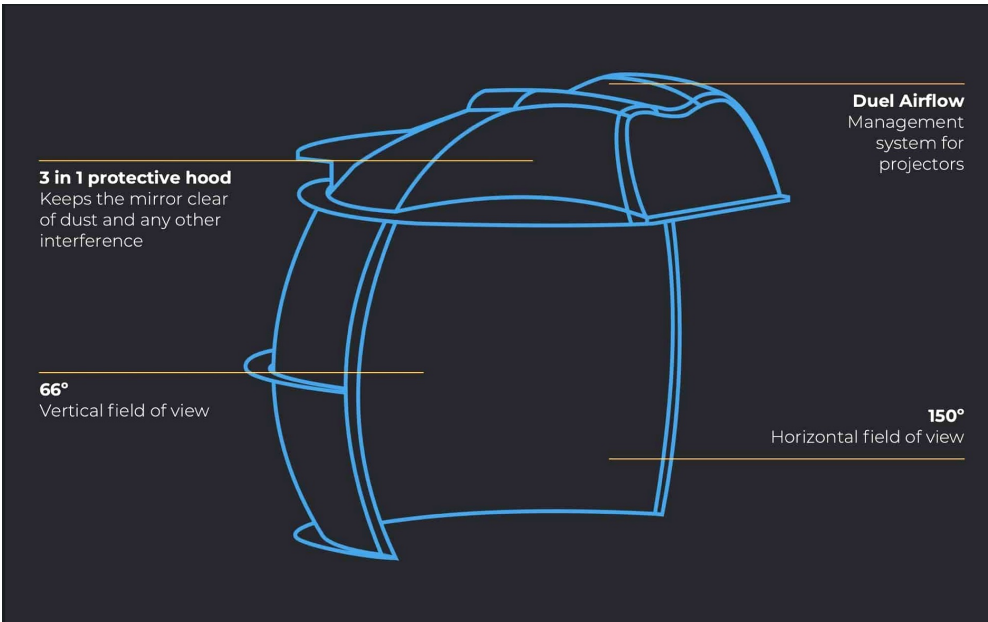
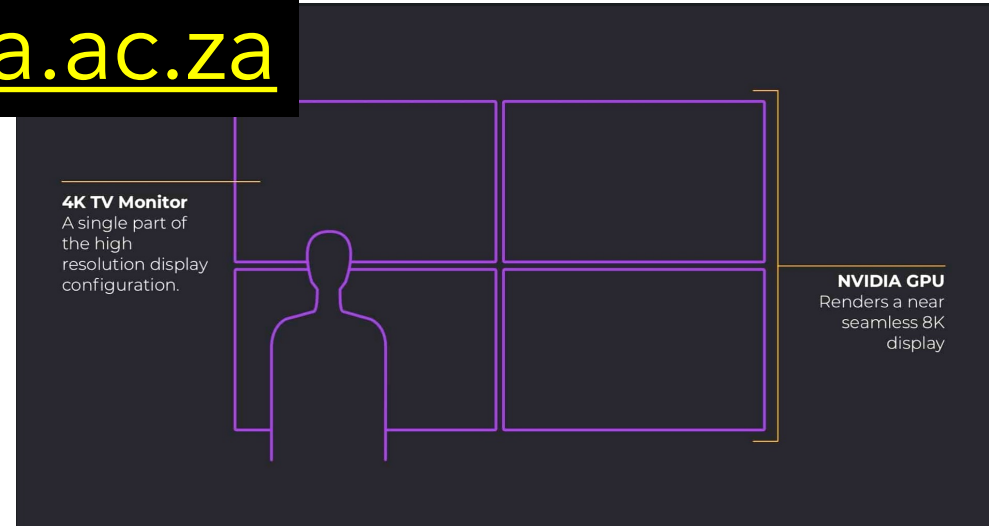
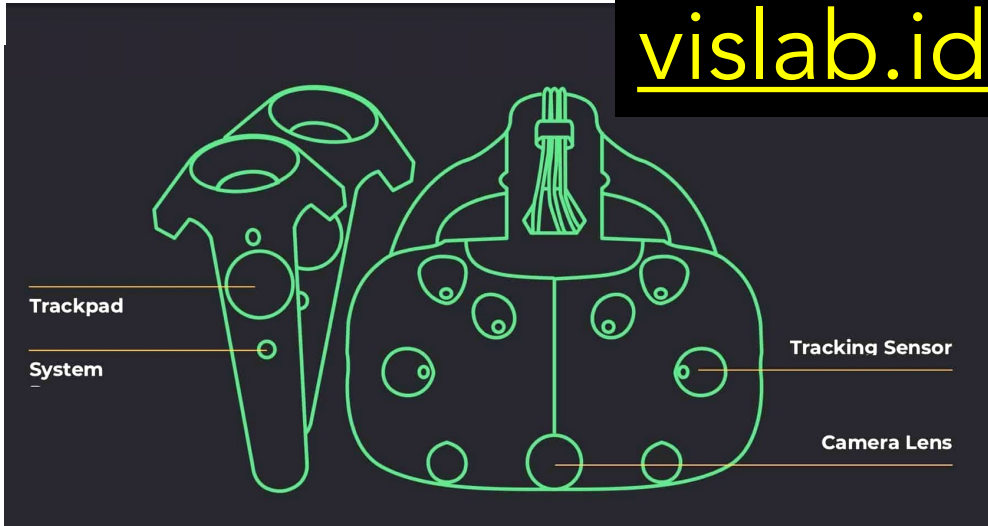
<https://idavie.readthedocs.io/>



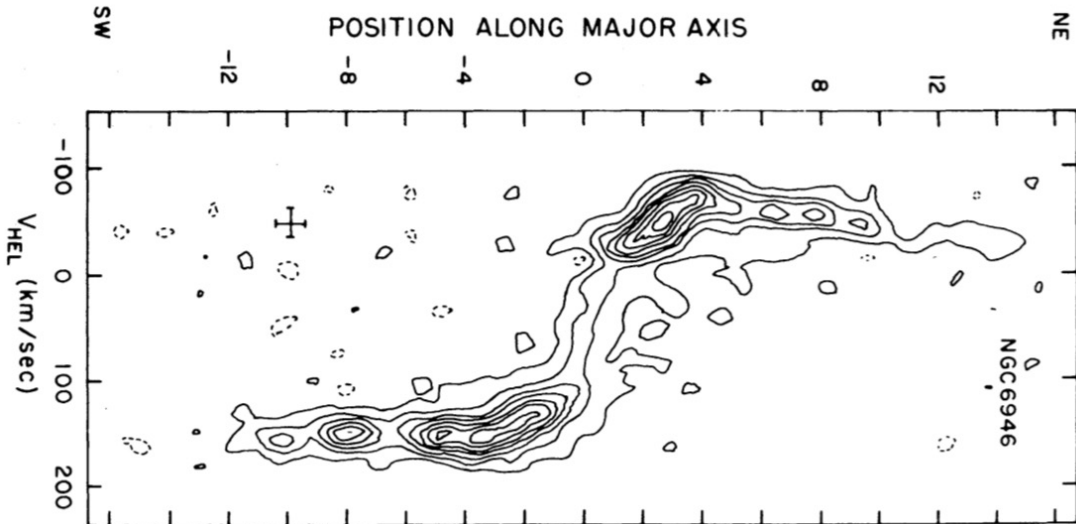
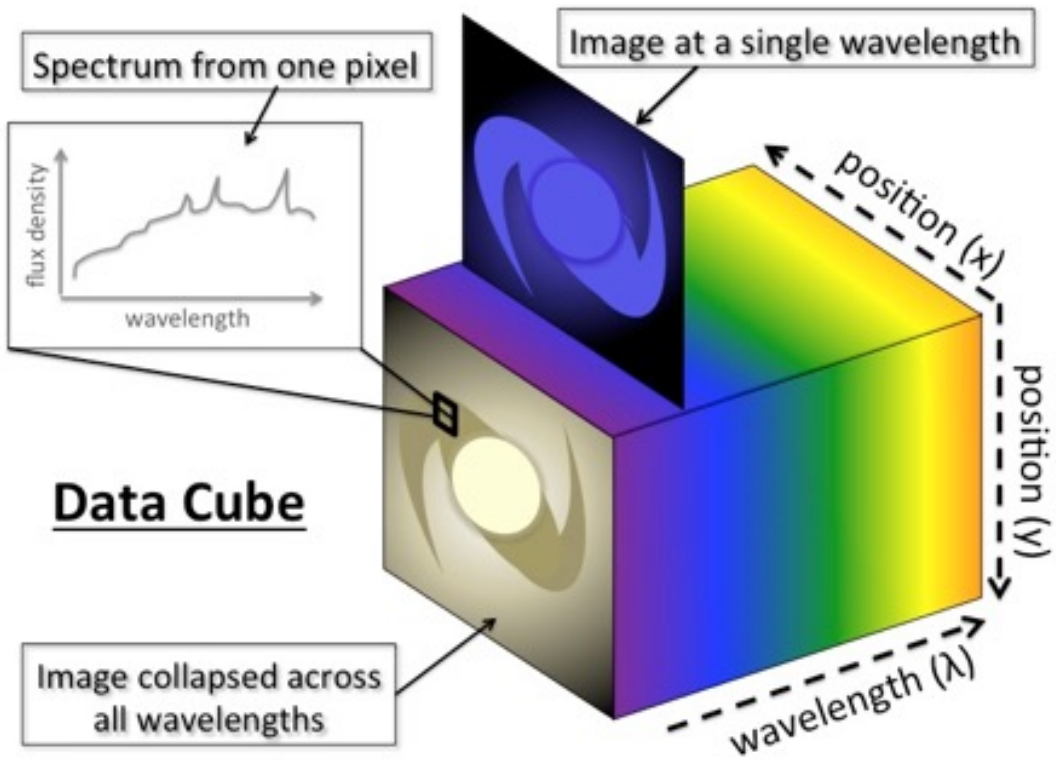
# The IDIA Visualisation Lab @ UCT

Conceived in Mid 2017 - Opened in January 2018

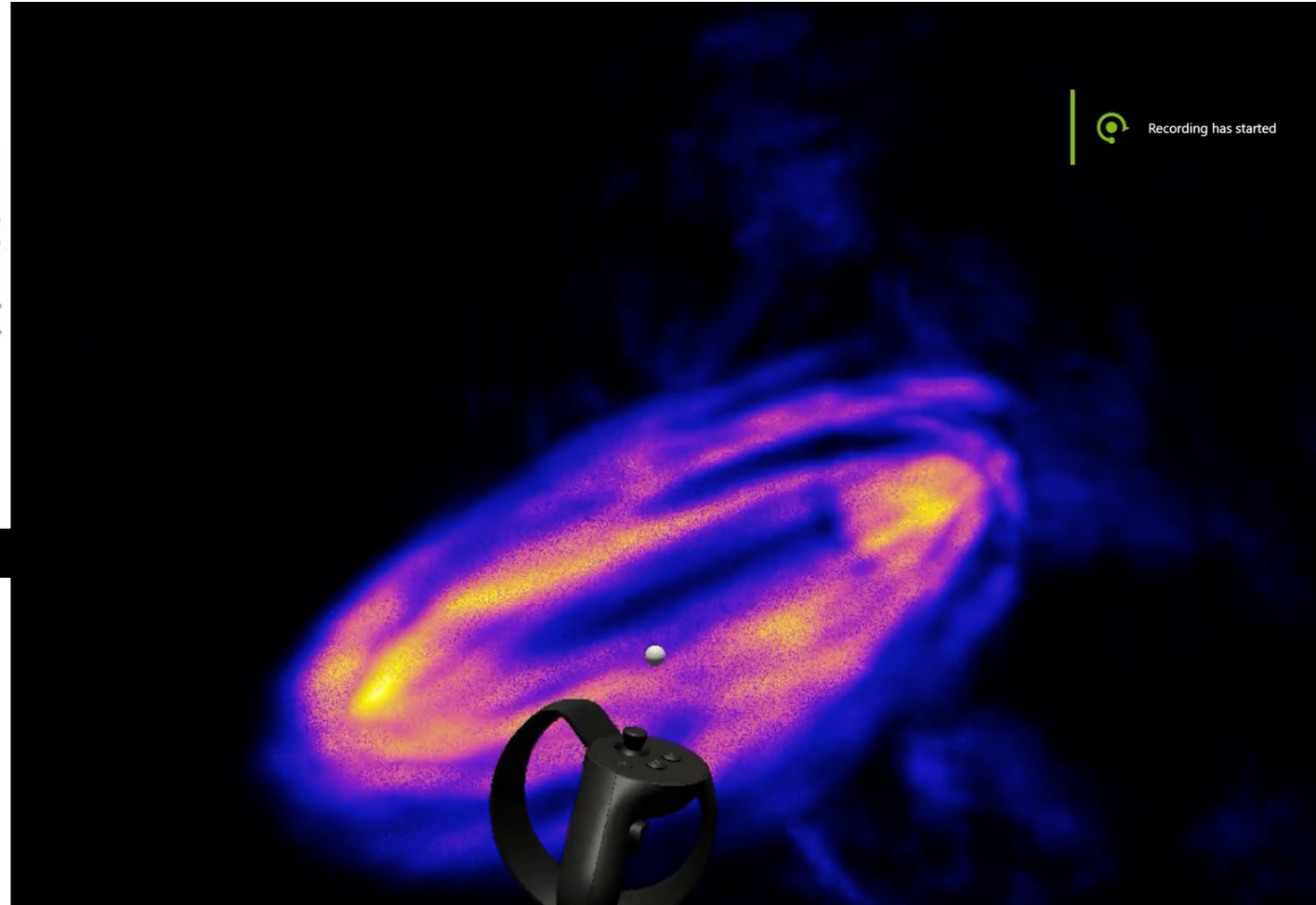
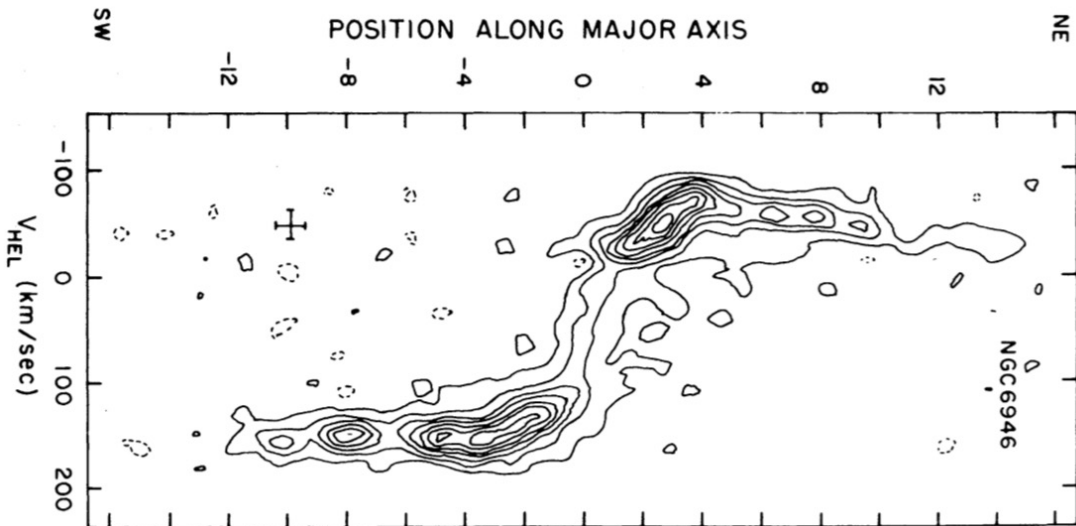
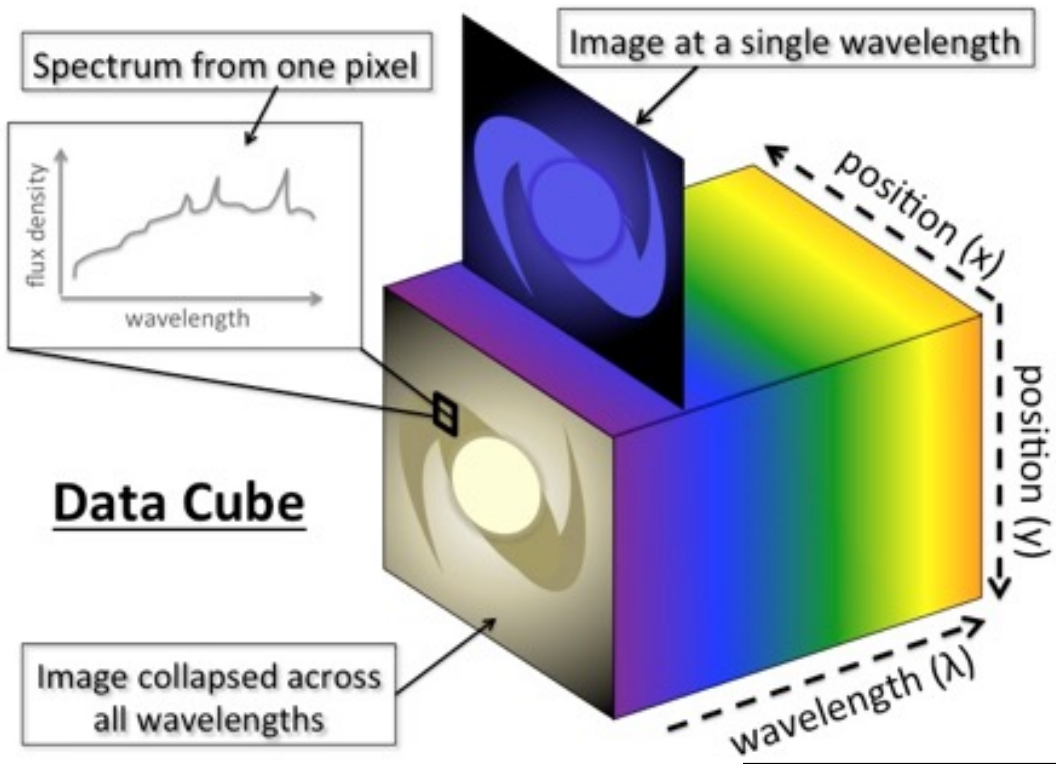
[vislab.idia.ac.za](http://vislab.idia.ac.za)



Why VR ?  
To move from this:



Why VR ?  
to this (and more)



iDaVIE

Carignan+ 1990; WRST velocity cube



# iDaVIE

## immersive Data Visualisation Interactive Explorer



### HOW?

- We need it to be cross-platform → Unity + SteamVR (but Unreal Engine was also tested)
  - Multiple headsets and operating systems compatible (on the long run..)
- CPU & GPU operations:
  - data ingest and re-sampling steps are carried out in core memory using C++ libraries
    - Multi-thread processing of reducing the cube size by scales of  $2^3$  increments (3 Gb → ~400 Mb).
    - the user can decide the scaling factor
  - interactive VR visualisation system employs the GPU and shader coding through Unity
    - Volume rendering through ray marching approach: "max" voxel (3D pixel) method
- We need it to be used by non-VR expert → user friendly GUI built *ad-hoc*
  - data interaction through menus, hand controllers and voice commands, with haptic feedback



# iDaVIE: requirements

(nothing too fancy)



➤ Minimum requirements:

CPU: Quad core AMD Ryzen or Intel i5

Memory: 16 GB

Disk: SSD highly recommended

GPU: NVIDIA 1060 / NVIDIA 1650 Super / AMD Radeon RX 5500 XT or higher

➤ Recommended requirements:

CPU: AMD Ryzen R7 or Intel i9

Memory: 32 GB

Disk: NVMe SSD

GPU: NVIDIA 2070 / AMD Radeon RX 5700 XT or higher

[MacBook option: MBP 16" with AMD Radeon Pro 5600M (running Windows 10 via bootcamp)]

# iDaVIE software suite

- iDaVIE-p : catalogue/particle rendering
  - Simulation visualization
  - 3D Large scale structure investigation
- iDaVIE-v : Volume rendering
  - Velocity (spectral) Cubes rendering
- iDaVIE-d : VR in the Dome



# iDaVIE software suite

- iDaVIE-p : catalogue/particle rendering
  - Simulation visualization
  - 3D Large scale structure investigation

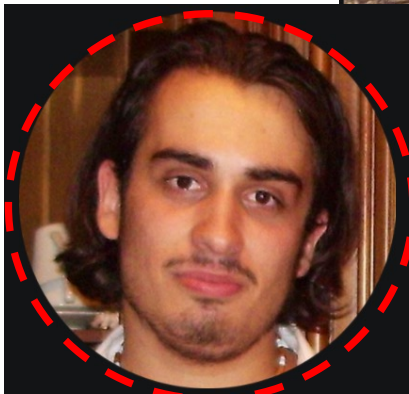
- iDaVIE-v : Volume rendering
  - Velocity (spectral) Cubes rendering

- iDaVIE-d : VR in the Dome





# Meet the team



# Desktop interface



**iDaVIE-v**

# Desktop interface

## Virtual Reality Data Analysis Tool

FILE

RENDERING

STATS

SOURCES

Image File:

filtered.fits

Browse

```
FILE          velocity
LSTART        1.66449996948E+02
LSTEP         6.59000015259E+00
LWIDTH        6.59000015259E+00
OBJECT        'afs_014 '
OBSERVER      'Serra '
HISTORY
ORIGIN        'SoFiA 1.3.1'
DATAMIN       -5.720216274261475
```

Mask File:

...

Browse

Axes

X:

1

Y:

2

Z:

3

Load



Scrive la tua query SQL in italiano



# Desktop interface

## Virtual Reality Data Analysis Tool

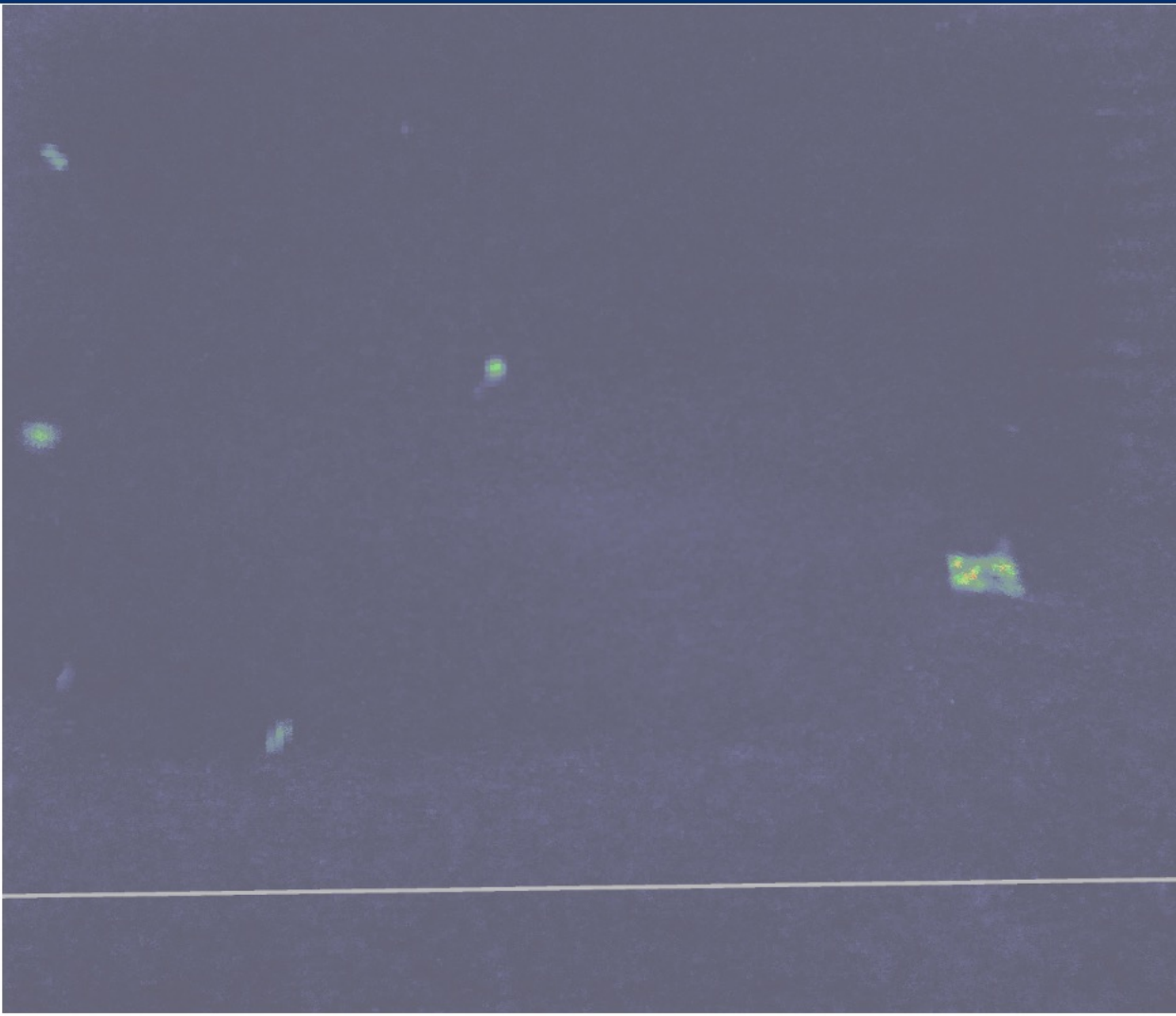
- FILE
- RENDERING
- STATS
- SOURCES

Sources File: NED\_fornax.xml

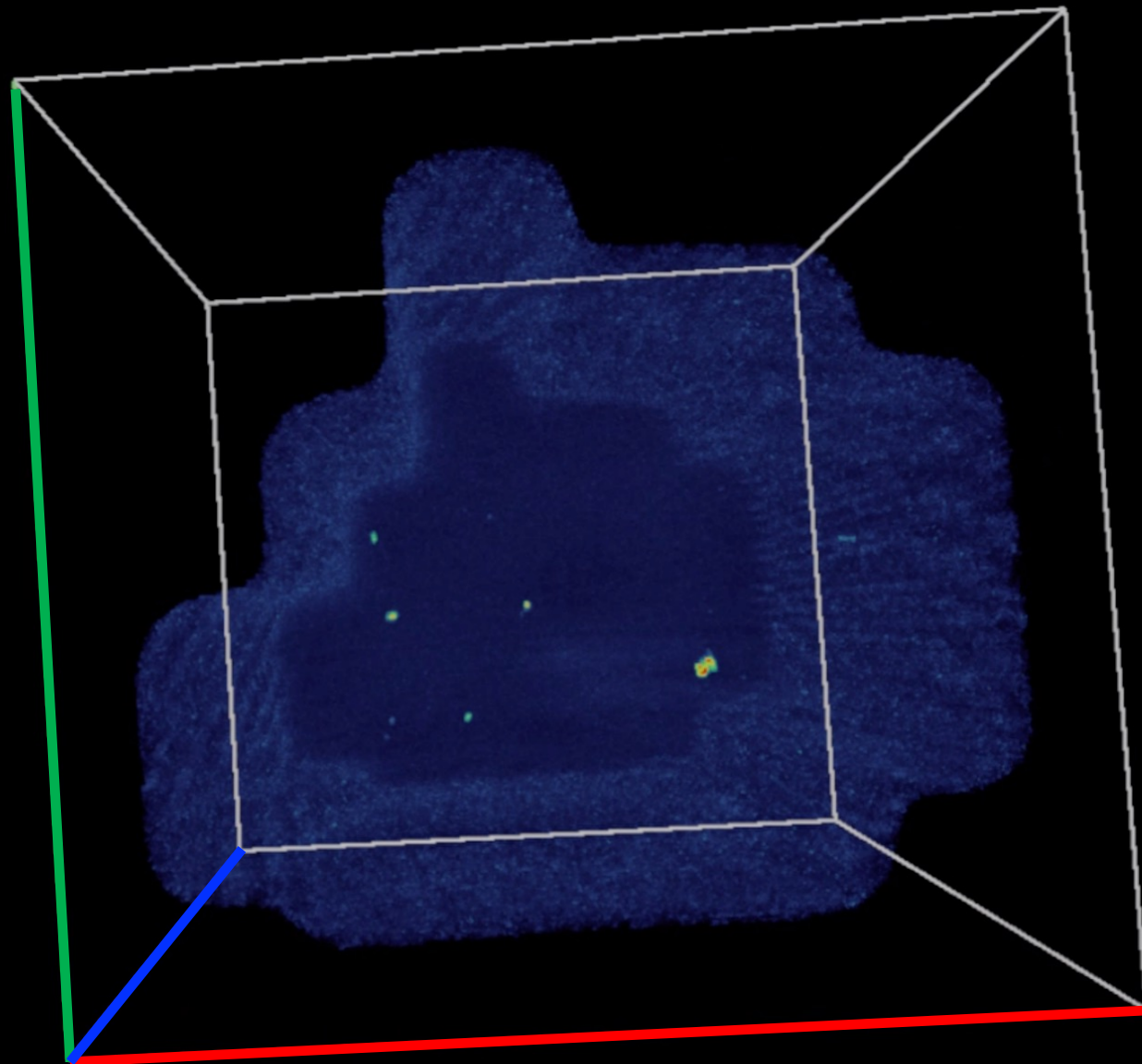
Mapping File: NED-galaxies.json

#	Name	Coord	Import?
0	ra	Ra	<input checked="" type="checkbox"/>
1	dec	Dec	<input checked="" type="checkbox"/>
2	z	Redshift	<input checked="" type="checkbox"/>
3	name	ID	<input checked="" type="checkbox"/>

Successfully loaded sources from:  
NED\_fornax.xml



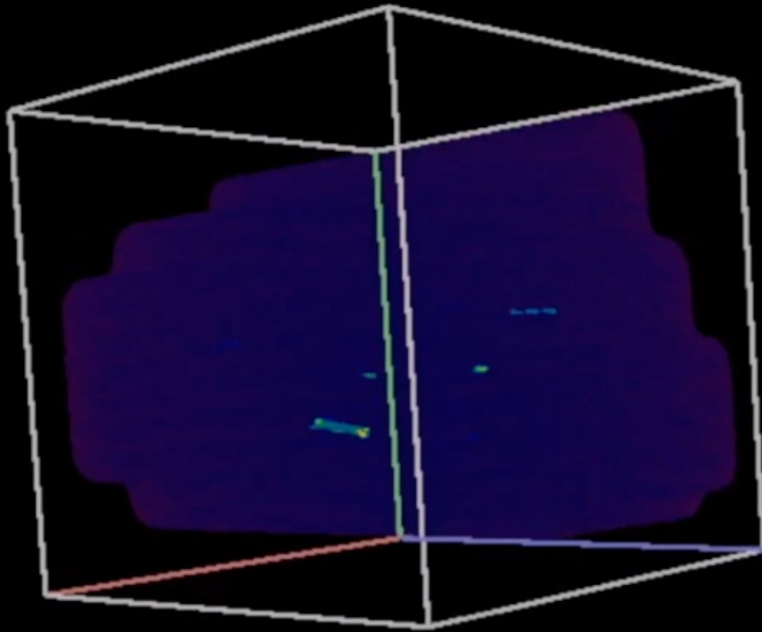
In VR



X, Y, Z → RA, Dec, Velocity

HI in the Fornax Cluster  
PI: Paolo Serra (INAF-CA)

In VR



### Main Menu

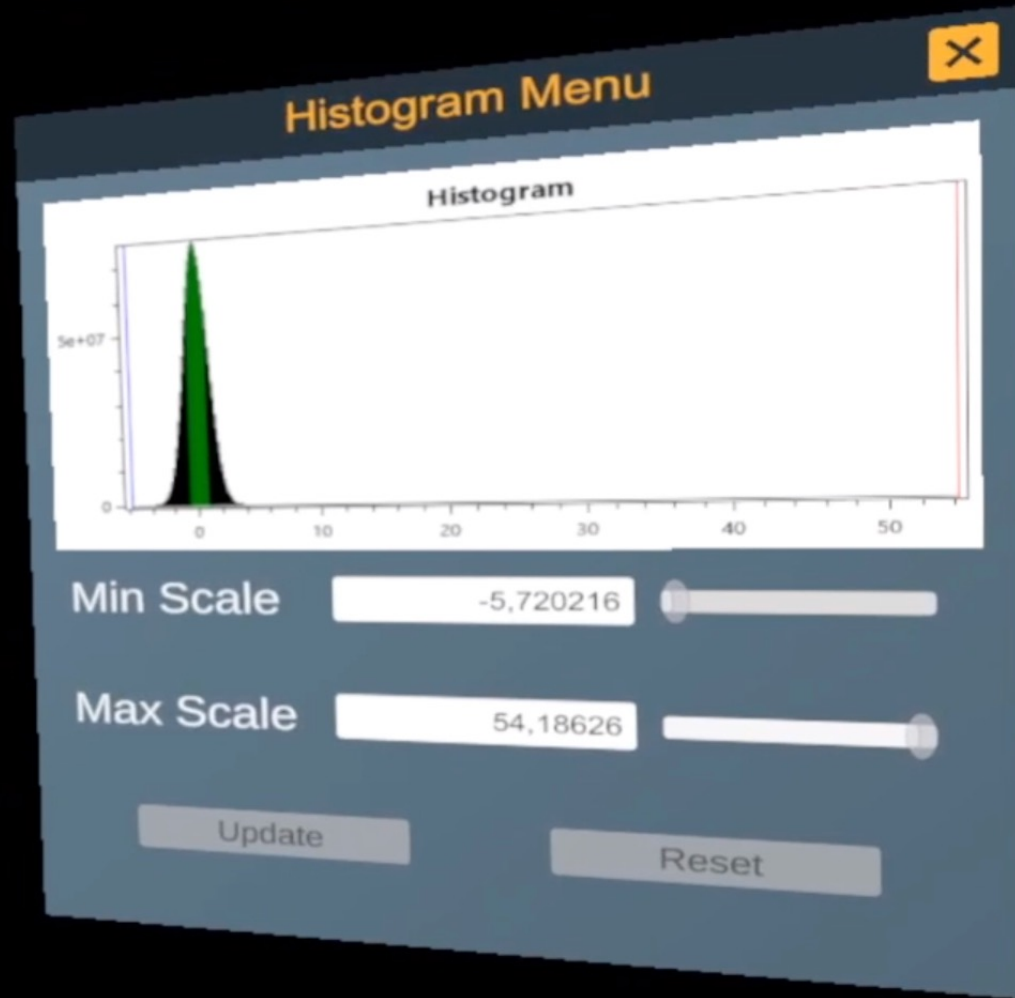
List Sofia | New List | Rendering | Options

ColorMap: NipySpectral

Threshold

Min	-5,720216
Max	54,18626

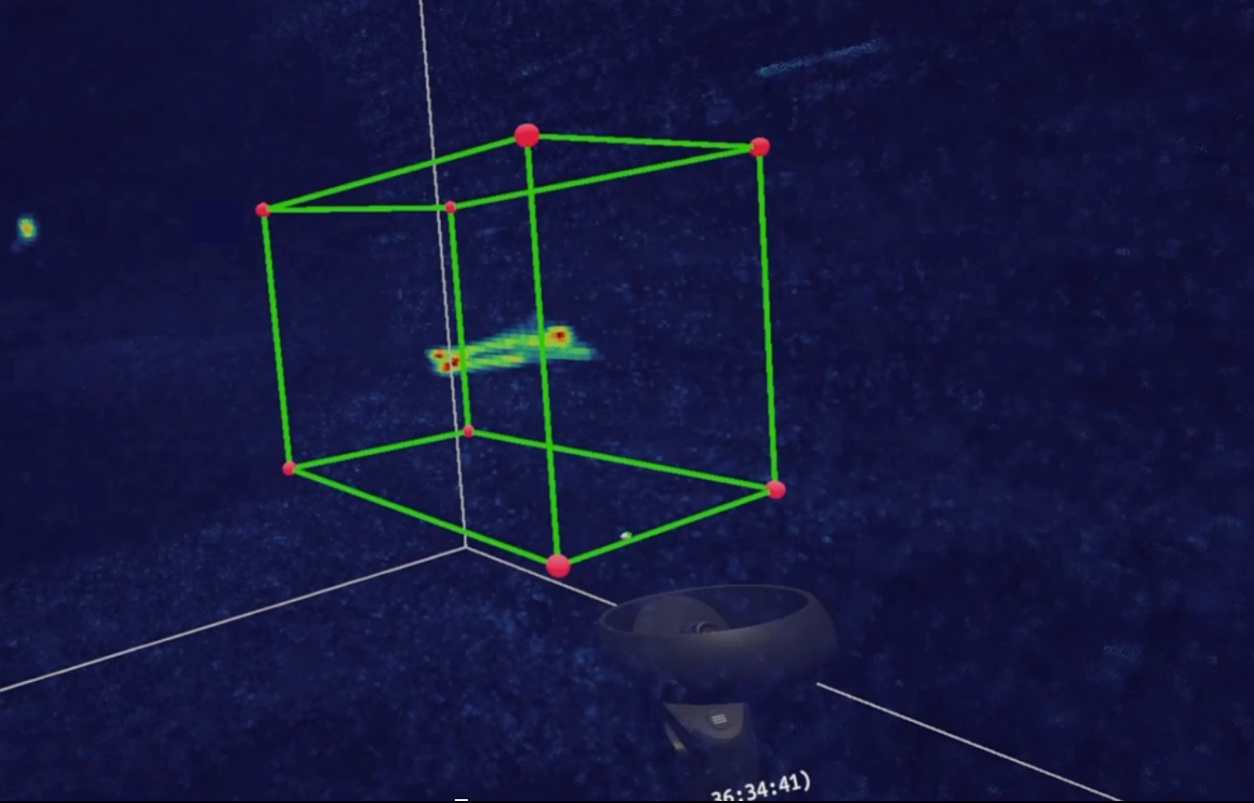
Navigation icons: back, forward, home, search, and a scroll indicator.



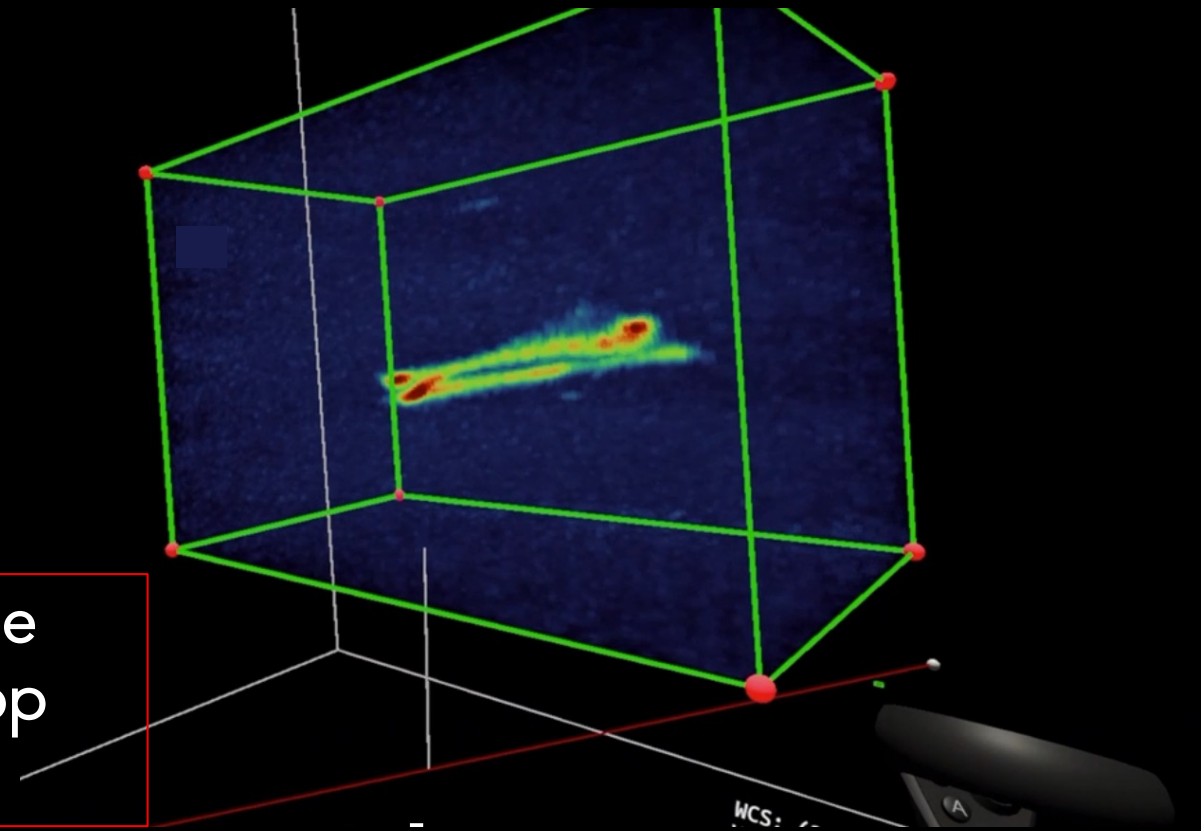
Menus & Voice command functions to better interrogate the data

Cursor information displayed  
to help with the exploration

WCS: (3:33:36.7, -36:08:55)  
VRAD: 1649.2 km/s  
Image: ( 757, 302, 226)  
Value: 0.004869323 JY/BEAM  
FREQ: 1.412592 GHz  
Source: 6

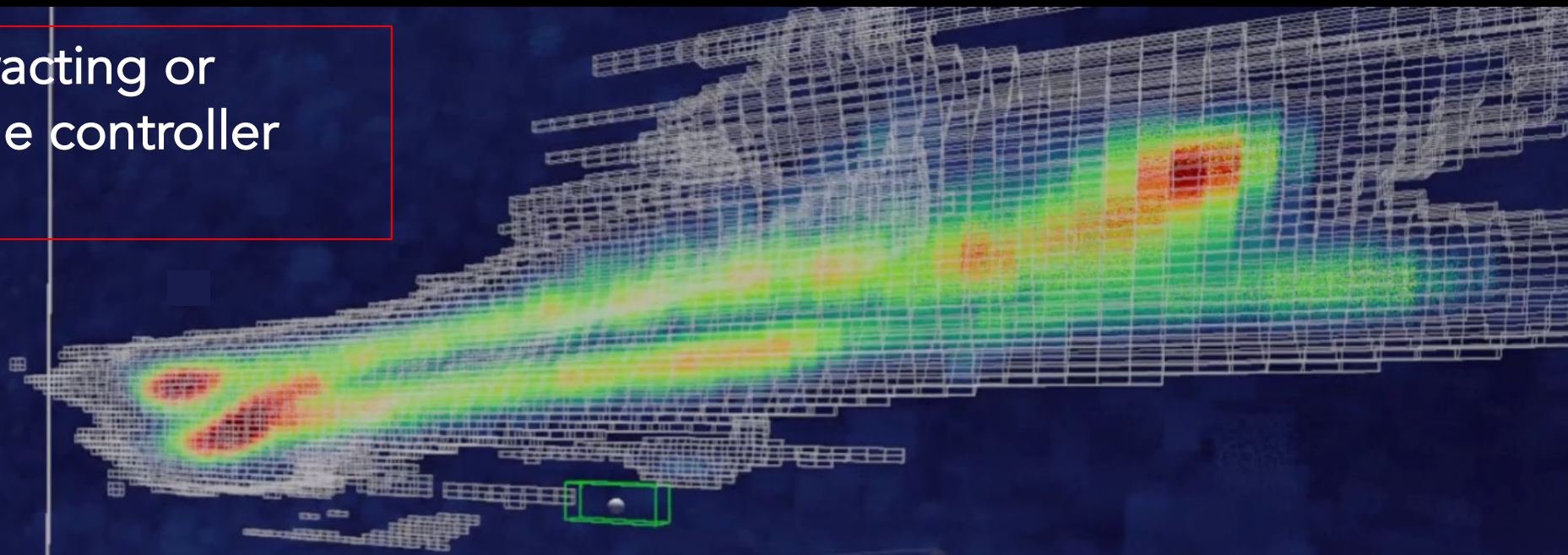


When a selection box is small enough to be displayed in full resolution the user can crop to that region to view it in full resolution





Edit the mask by subtracting or adding voxels using the controller and the "cursor"

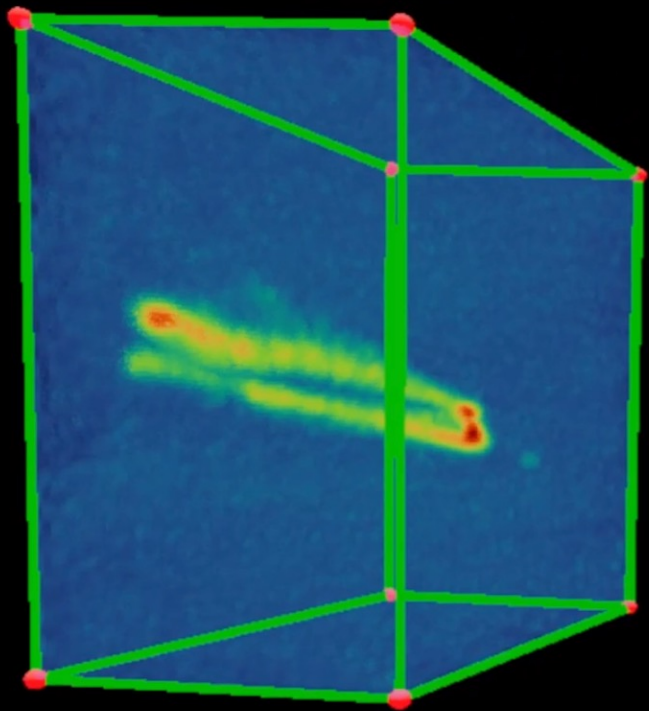


### Subtractive Paint Mode

Brush Size +    Brush Size -    Brush Size reset

Grid icon    Erase icon (+)    Erase icon (-)    Undo icon    Redo icon    Save icon    Exit icon

WCS: (3:33:18.2, -36:14:40)  
VRAD: 1616.25 km/s  
Image: ( 768, 284, 221)  
Value: 8.883233823 Jy/beam  
FREQ: 1.412748 GHz  
Source: 6



**Main Menu**

List Sofia   New List   Rendering   Options

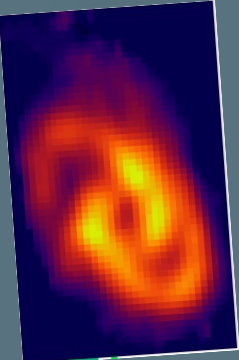
Primary Hand   ←   Right   →

Mom threshold steps   ←   0,00025   →

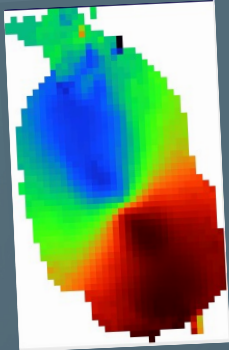
**Plots Window**

Moment Map   Histogram

Moment 0



Moment 1




Inclusion Type   ←   Threshold

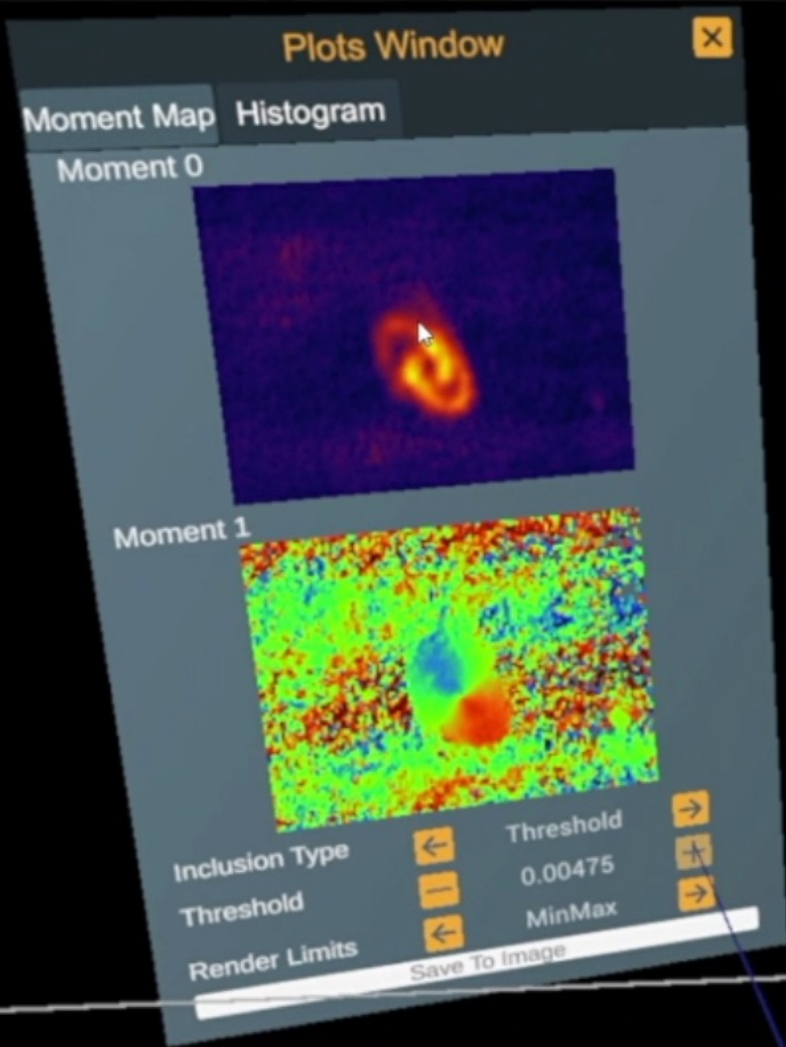
Threshold   -   0,0

Render Limits   ←   ZScale

Save To Image



Moment maps created and shown on the fly (for single sources or entire cube)



The **Main Menu** has four tabs: **List Sofia**, **New List**, **Rendering**, and **Options**. The **Options** tab is active, showing two settings: **Primary Hand** set to **Right** (with left and right arrow buttons) and **Mom threshold steps** set to **0.001** (with left and right arrow buttons and a pencil icon).

The **Keypad** displays the numerical value **0.001** and a **Confirm** button. The keypad layout includes digits 7, 8, 9, 4, 5, 6, 1, 2, 3, 0, a decimal point, and a less-than sign.

Moment maps threshold steps can be adjusted on the fly for better rendering also using a keypad

**Main Menu**

List Sofia   New List   Rendering   Options

15 [Zoom] [Home] [Eye]

Masked Source #29

16 [Zoom] [Home] [Eye]

Masked Source #30

17 [Zoom] [Home] [Eye]

Masked Source #31

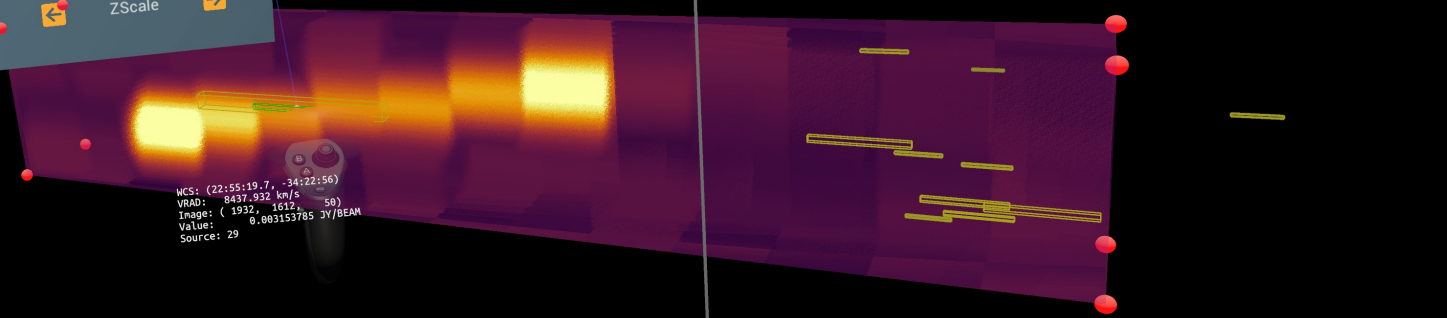
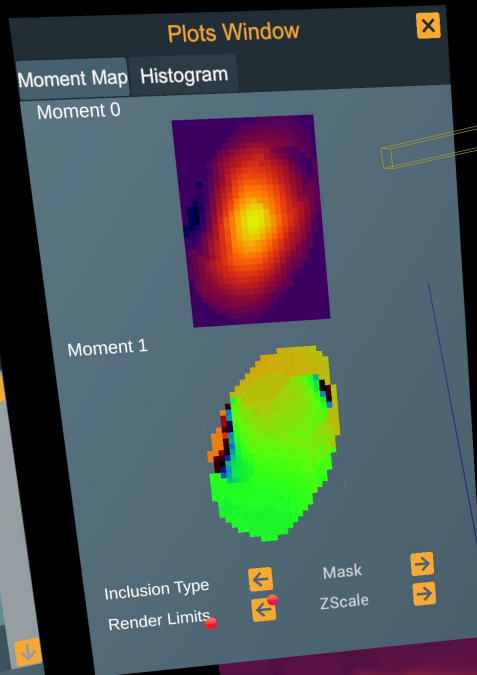
18 [Zoom] [Home] [Eye]

Masked Source #32

19 [Zoom] [Home] [Eye]

Mask Source Set

[Left] [Right] [Info] [Eye] [Refresh] [Save]



Ability to overplot catalogues on the data cube

**Main Menu**

List Sofia    New List    Rendering    Options

18			
03461375-3641467			
19			
03542842-3558017			
20			
03433706-3551107			
21			
03235400-3730449			

2mrs\_fornax.xml

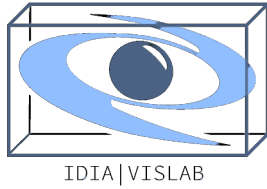
Navigation icons: back, forward, home, search, etc.

**Source Info**

Source # : 1  
RA: 56.2946805269548  
Dec: -35.582448745986  
VRAD: 802.385003881325  
Sum : 33.0472146971588  
Peak : 0.0837798118591309  
V Sys (Channel) : 96.496175041558  
W20 (Channel) : 14.7703845223585

MCS: (3:43:38.3, -35:51:01)  
VRAD: 1346.06 km/s  
Image: ( 392, 356, 180)  
Value: 0.002055136 JY/BEAM  
FREQ: 1.414028 GHz

Ability to "teleport" to a region/source of interest by scrolling through a catalog



# iDaVIE-v beta release



The iDaVIE-v system is designed and developed with user interaction foremost in mind.

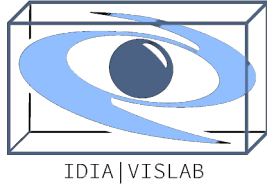
All most desired requirements have been implemented:

- downscaling to handle “big” data cube
- voice commands to do many operations
- the capability of working with input source catalogues ;
- overlay/modify source masks on the data cube voxels or “paint” a brand new one;
- editing in real-time source masks;
- derive in real time, sky and source statistics, moment maps and other analytics that may be derived from the data and masks.
- [NEW] select a region of interest and save as a sub-cube

Alpha testing completed: INAF-CT (Ugo Becciani, Fabio Vitello), INAF-CA (Paolo Serra), Kaptein Astronomical Institute, Groningen (Thjis Van Der Hulst)

**Beta release** (via Github) First released in March 2021 – **NEW release v.5 today!!!**

<https://idavie.readthedocs.io/>



# iDaVIE-v publications



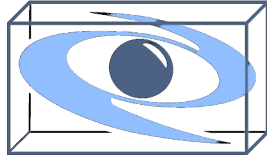
## Team publications:

- *iDaVIE-v: immersive Data Visualisation Interactive Explorer for volumetric rendering*  
Marchetti et al. 2020 (ADASS2020 proceeding) - <https://arxiv.org/pdf/2012.11553.pdf>
- *Exploring and Interrogating Astrophysical Data in Virtual Reality*  
Jarrett et al. 2021  
<https://www.sciencedirect.com/science/article/pii/S2213133721000561?via%3Dihub>

## Publication using iDaVIE-v:

- *MeerKAT view of pre-processing in the Fornax A group*  
Kleiner et al. 2021  
<https://www.aanda.org/articles/aa/pdf/2021/04/aa39898-20.pdf>
- Józsa, G. I. G. et al. 2021 (under submission to ApJ)





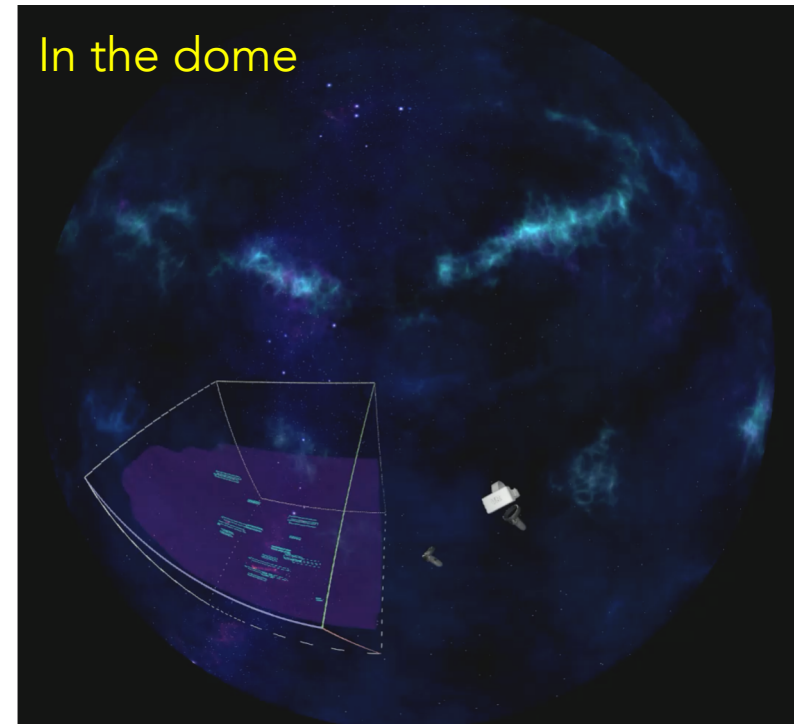
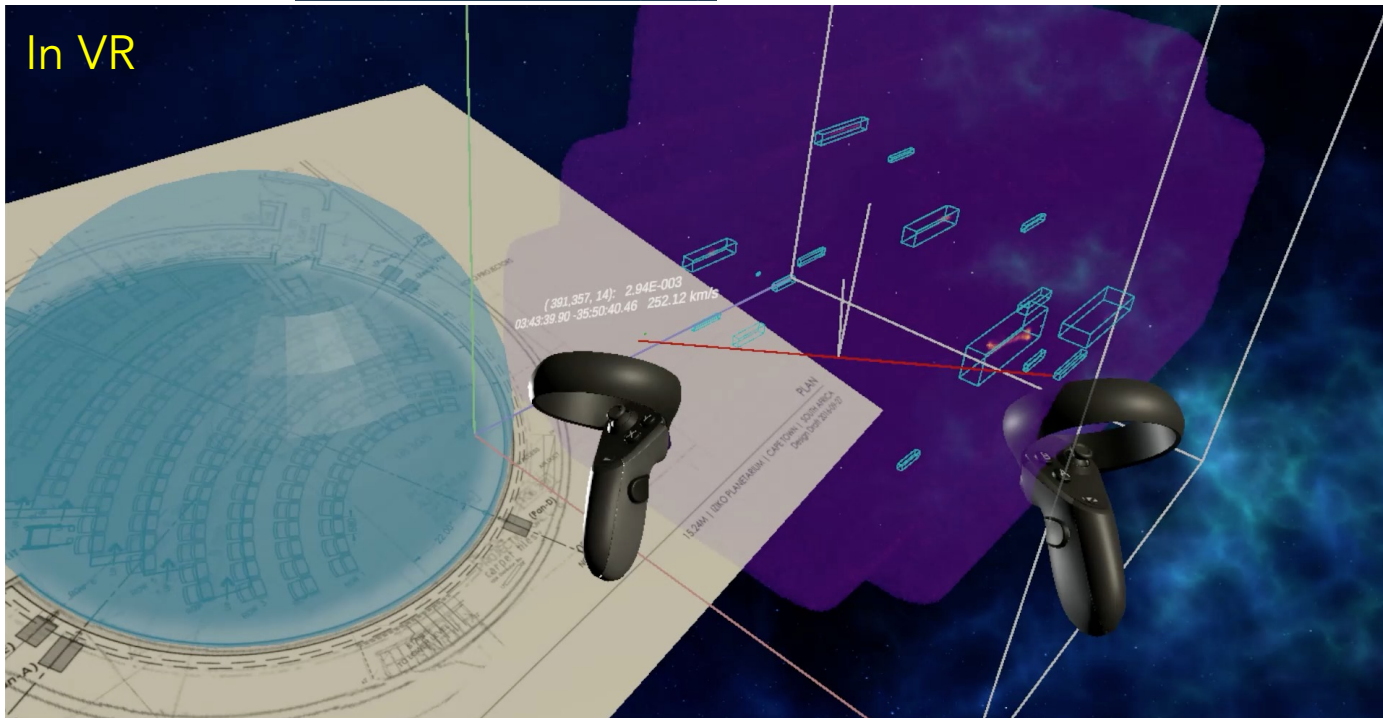
IDIA | VISLAB

# iDaVIE – what’s next?



## iDaVIE-p and iDaVIE-d development

International initiative bringing together Astronomy Data Providers and software developers to advance the state of the art of big data visualization



PoC : PhD student Alex Sivitilli (UCT)





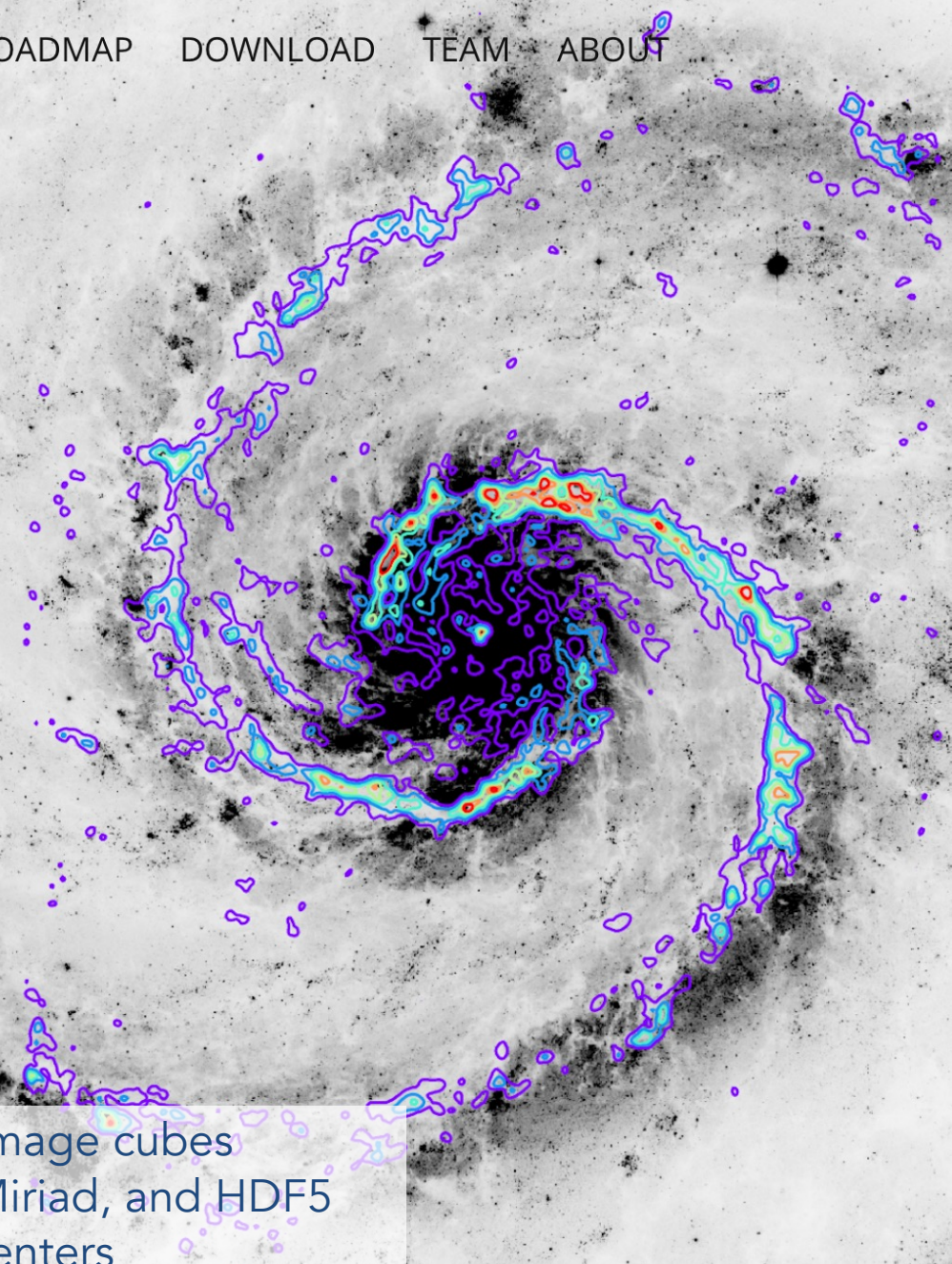
<https://cartavis.github.io>

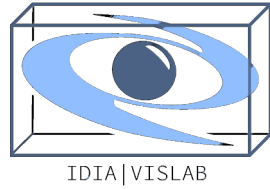
# CARTA

Cube Analysis and Rendering Tool for Astronomy, is a next generation image visualization and analysis tool designed for ALMA, VLA, and SKA pathfinders.

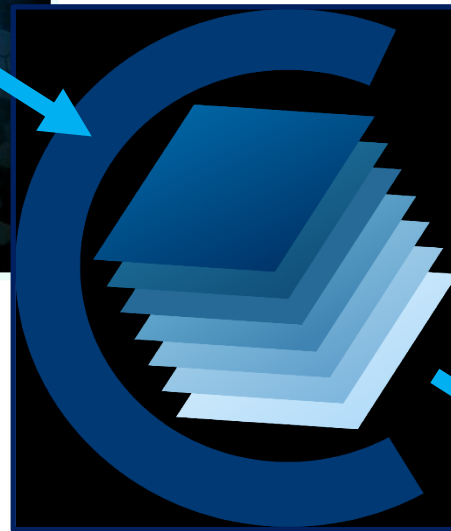
DOWNLOAD

- Cloud-based Visual analytic of remote large image cubes
- Supports many image formats: FITS, CASA, Miriad, and HDF5
- To be deployed at ALMA Regional Science Centers





# iDaVIE – what's next?



- iDaVIE-p and iDaVIE-d development
  - VR multi-player collaboration
  - cloud VR rendering

Thanks!

[vislab.idia.ac.za](http://vislab.idia.ac.za) <https://idavie.readthedocs.io/>

[lucia.marchetti@uct.ac.za](mailto:lucia.marchetti@uct.ac.za)