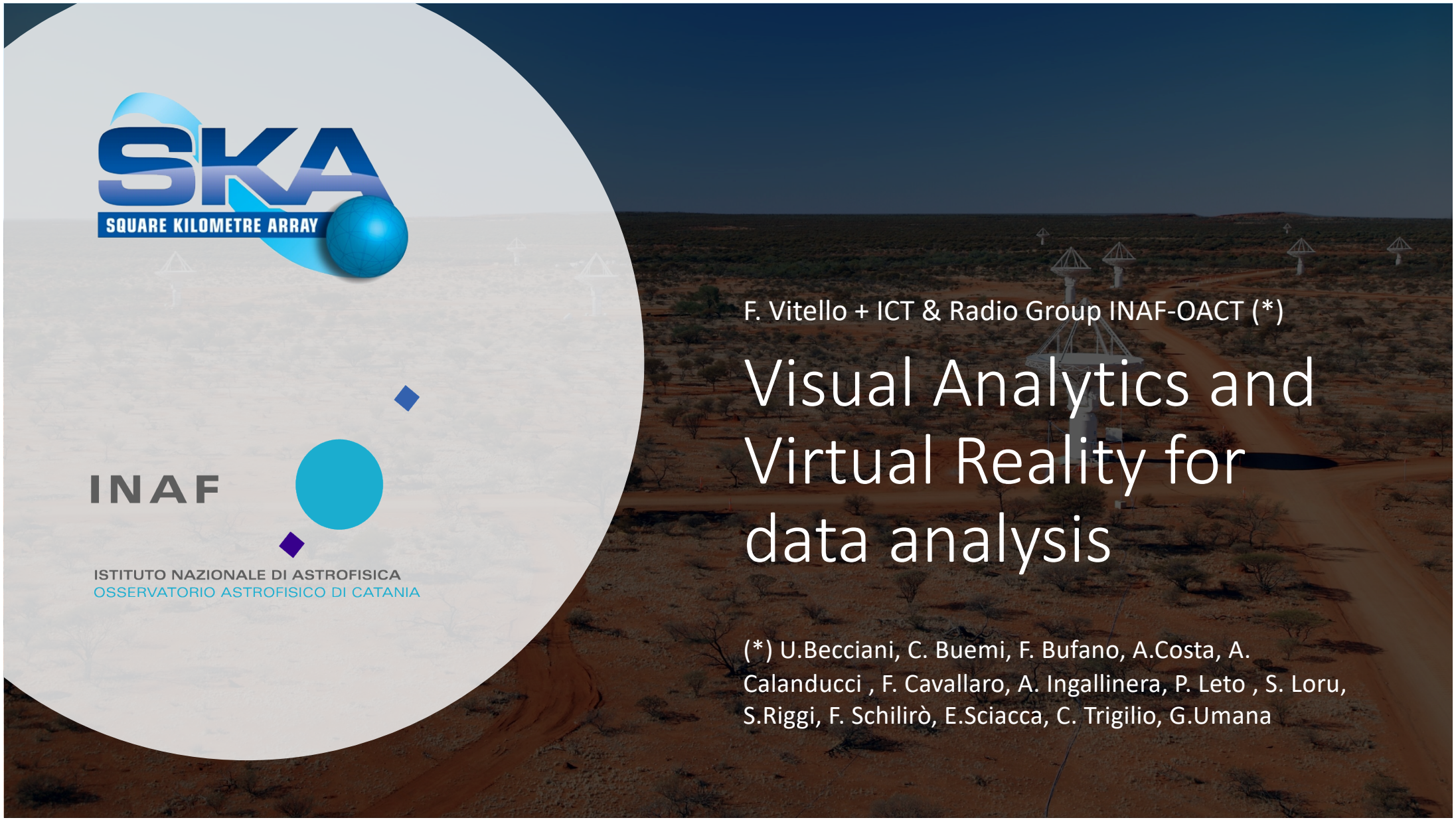


F. Vitello + ICT & Radio Group INAF-OACT (*)

Visual Analytics and Virtual Reality for data analysis

(*) U.Becciani, C. Buemi, F. Bufano, A.Costa, A. Calanducci , F. Cavallaro, A. Ingallinera, P. Leto , S. Loru, S.Riggi, F. Schilirò, E.Sciacca, C. Trigilio, G.Umana

Data Visualization in Astrophysics

Data visualization is a fundamental, enabling technology for knowledge discovery.

The broader field of astrophysics visualization encompasses topics such as optical and radio imaging, presentation of simulation results, multi-dimensional exploration of catalogues, and public outreach visuals.

Aspects of visualization are utilized in the various stages of astronomical research - from the planning stage, through the observing process or running of a simulation, quality control, qualitative knowledge discovery and quantitative analysis.

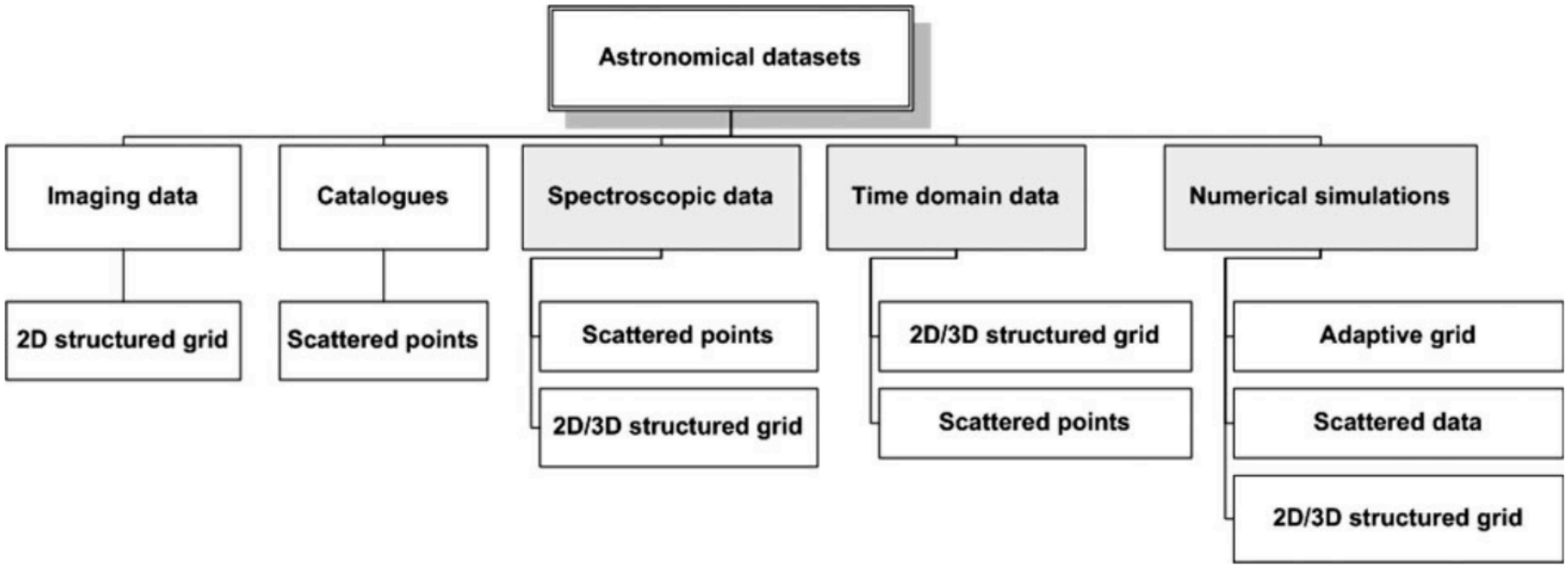
Indeed, much of astronomy deals with the process of making and displaying 2D images, 3D cubes or graphs which are suitable for publication in books, journals, conference presentations and in education.

Visualization in Astrophysics

The nature of data has an impact on the choice of visualization technique, and hence software.

- **Imaging data**: two-dimensional within a narrow wavelength range at a particular epoch.
- **Catalogues**: secondary parameters determined from processing of image data (coordinates, fluxes, sizes, etc.).
- **Spectroscopic data and associated products**: this includes one-dimensional spectra and 3D spectral data cubes, data on distances obtained from redshifts, chemical composition of sources, etc.
- **Studies in the time domain**: including observations of moving objects, variable and transient sources which require multiple observations at different epochs, and synoptic surveys.
- **Numerical simulations from theory**: which can include properties such as spatial position, velocity, mass, density, temperature, and particle type. These properties may also be presented with an explicit time dependence through the use of 'snapshot' outputs.

Visualization in Astrophysics

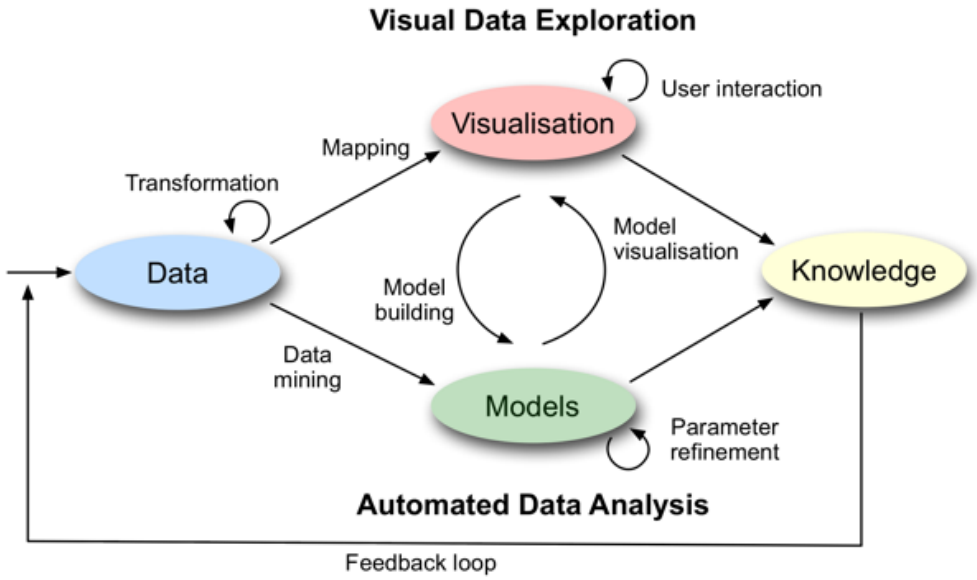


Credits: Hassan, Amr, and Christopher J. Fluke. "Scientific visualization in astronomy: Towards the petascale astronomy era." *Publications of the Astronomical Society of Australia* 28.2 (2011): 150-170.

Visual Analytics

- Visual analytics combines **automated analysis techniques** with **interactive visualisations** for an effective understanding, reasoning and decision making on the basis of very large and complex datasets.

- The Visual Analytics Process is characterized through interaction between data, visualizations, models about the data, and the users in order to discover knowledge.



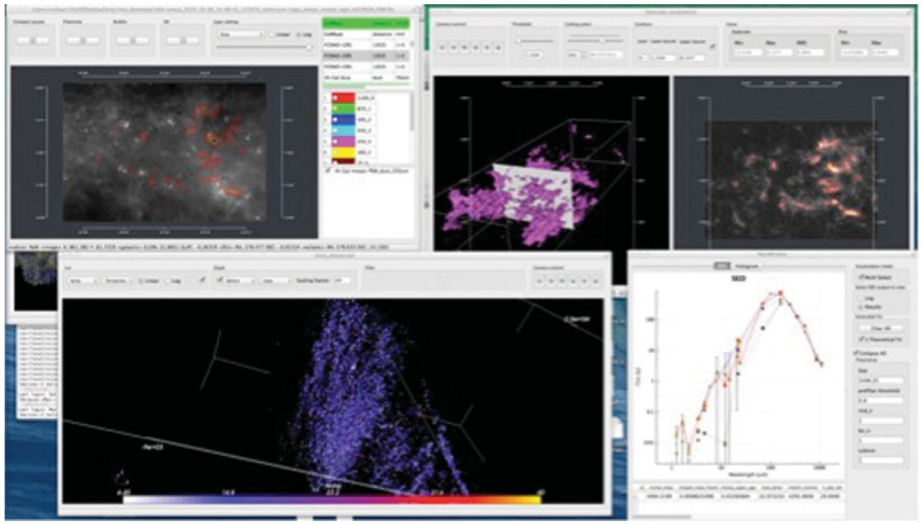
VIALACTEA Visual Analytic Client

Ref: Vitello et al (2018) doi: 10.1088/1538-3873/aac5d2
http://vialactea.iaps.inaf.it/vialactea/eng/index.php

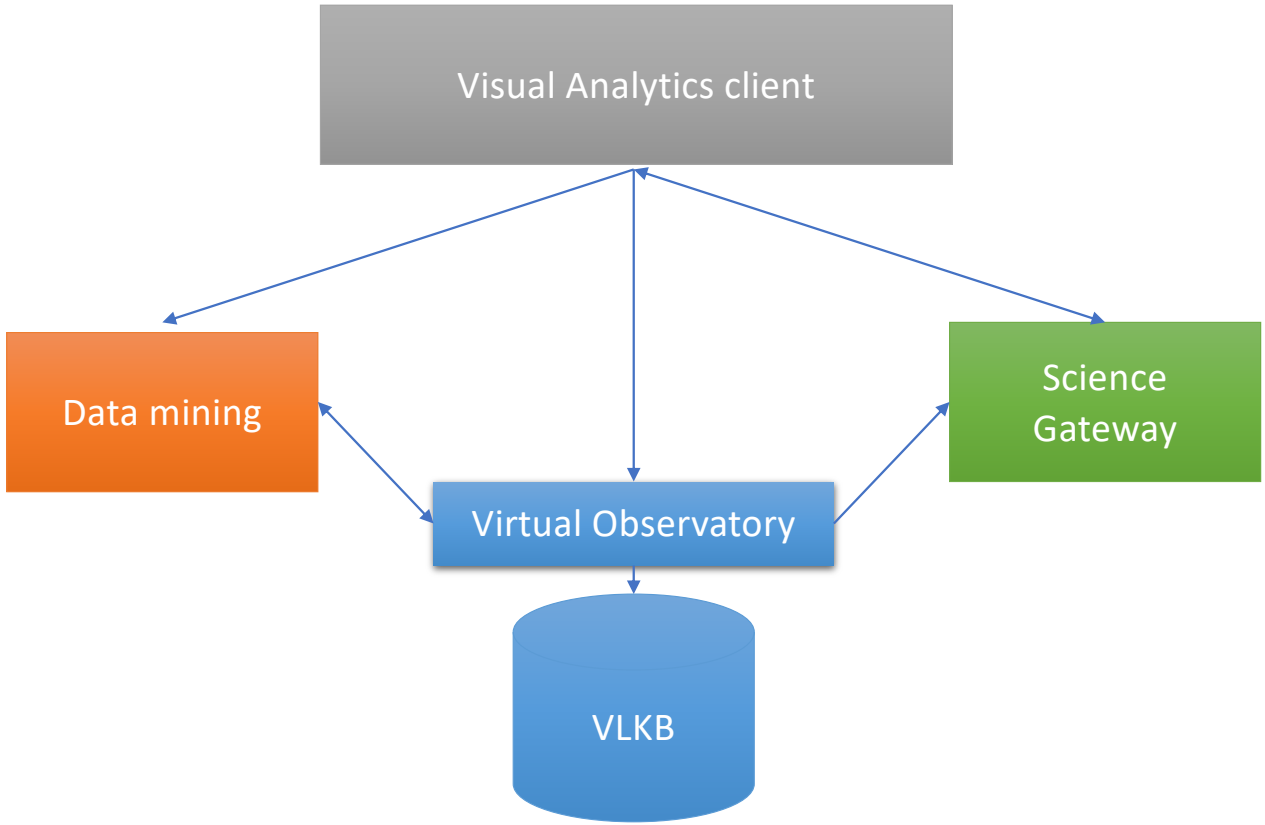
The development of the tool has been started within the VIALACTEA project, founded by the 7th Framework Programme of the European Union.

Visual analytics environment allows to easily conduct research activities for multidimensional data and information visualization. It provides real-time data interaction to carry out complex tasks for multi-criteria data/metadata queries on subsamples selection and further analysis.

Visual analytics combine **data mining** algorithms and **advanced analysis techniques** with highly **interactive visual interfaces** offering scientists the opportunity for in-depth understanding of **massive, noisy, and high-dimensional data**.

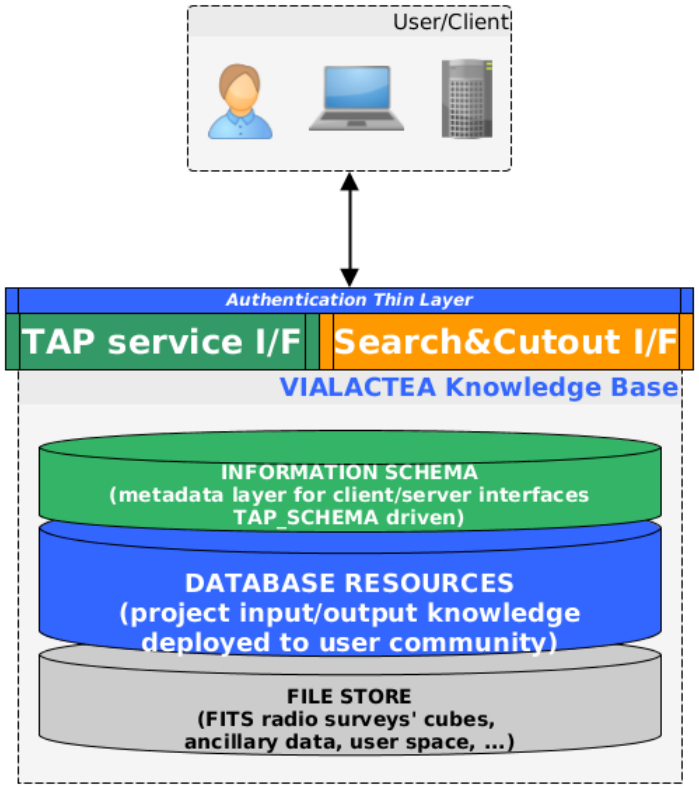


VIALACTEA Tools and Infrastructures

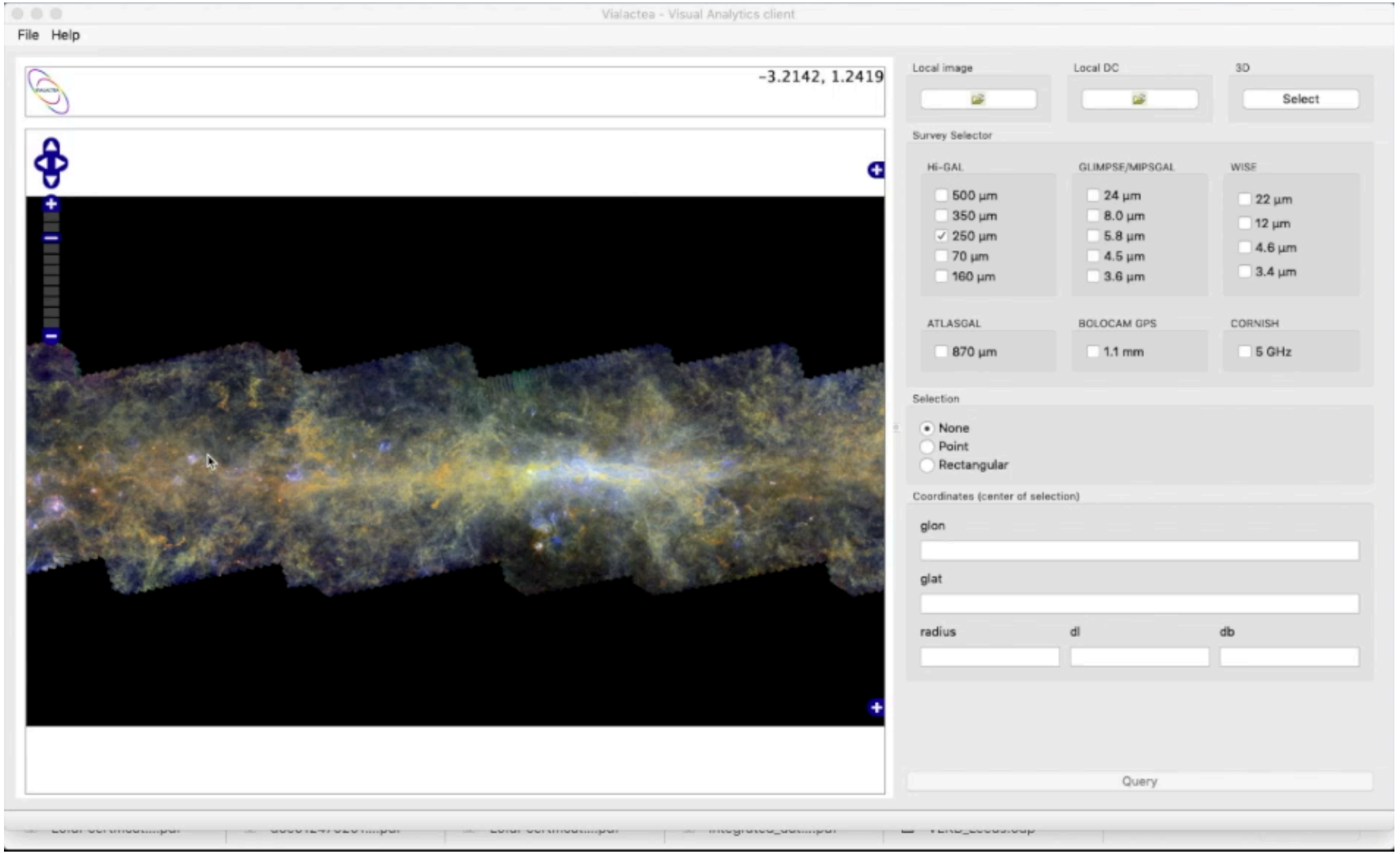


VIALACTEA Knowledge Base (VLKB)

Ref: Molinaro et al (2016) doi: 10.1117/12.2231674



- Filaments, bubble
- Compact Sources catalogues
- SED models
- Cubes & image survey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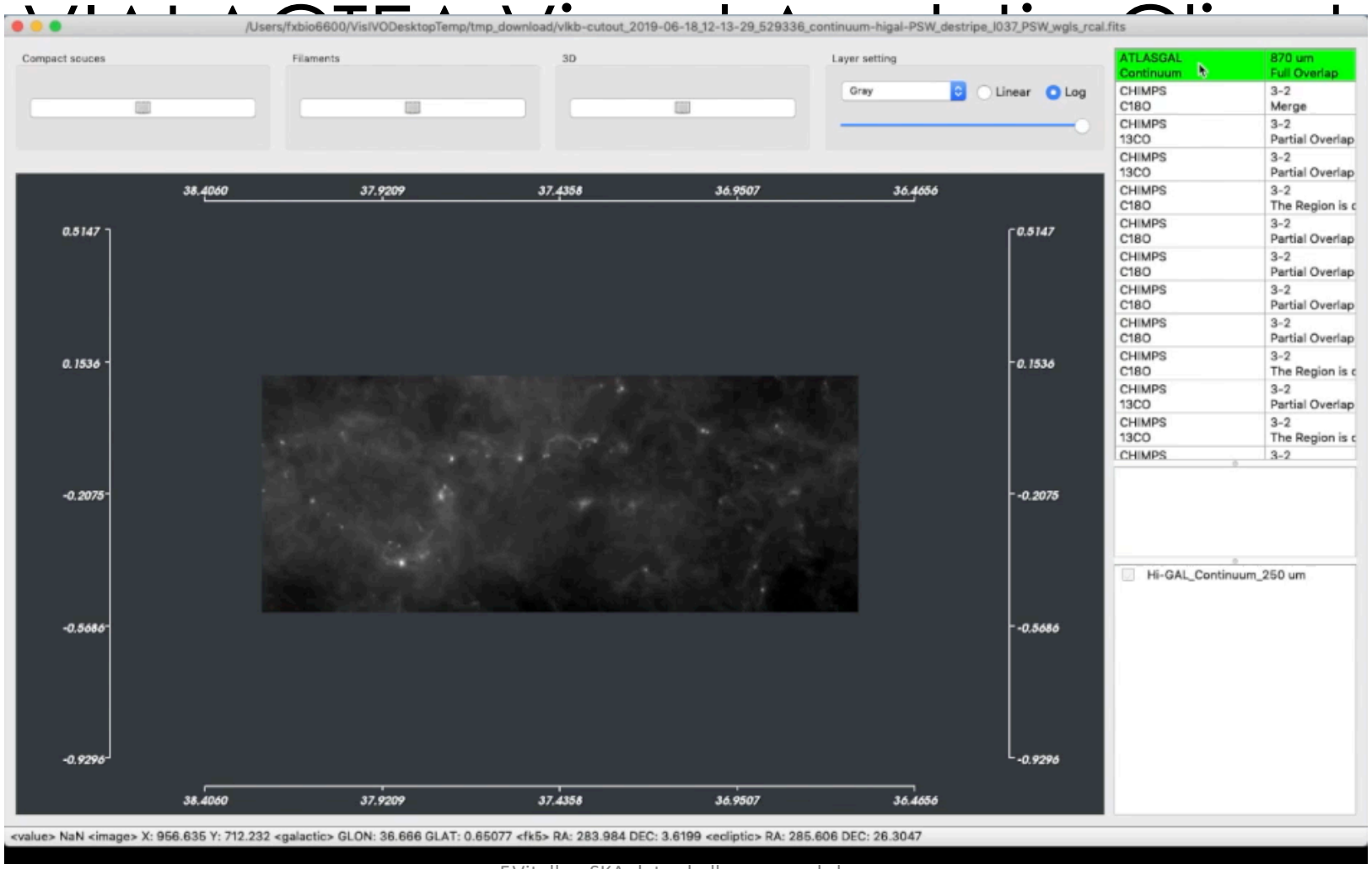
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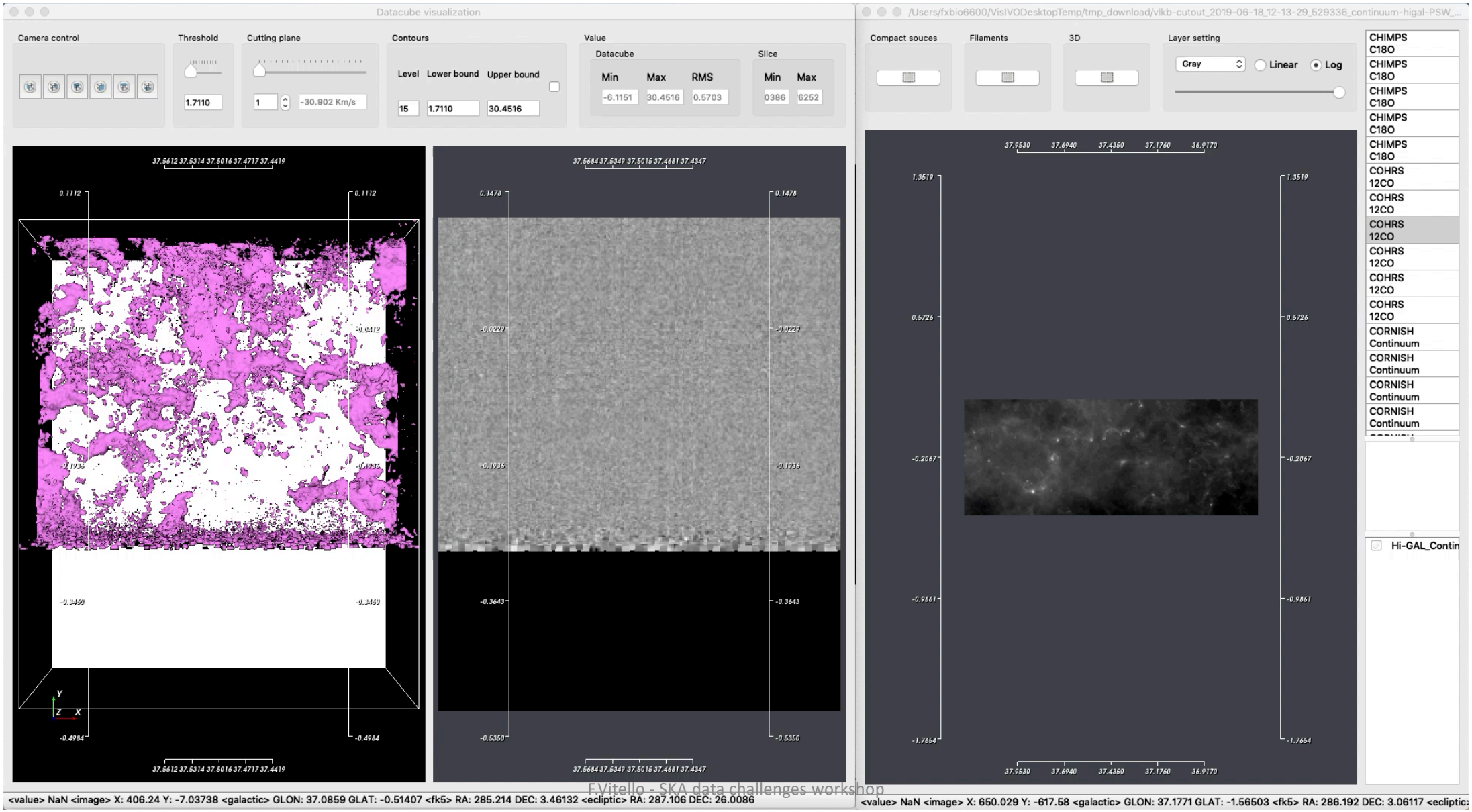
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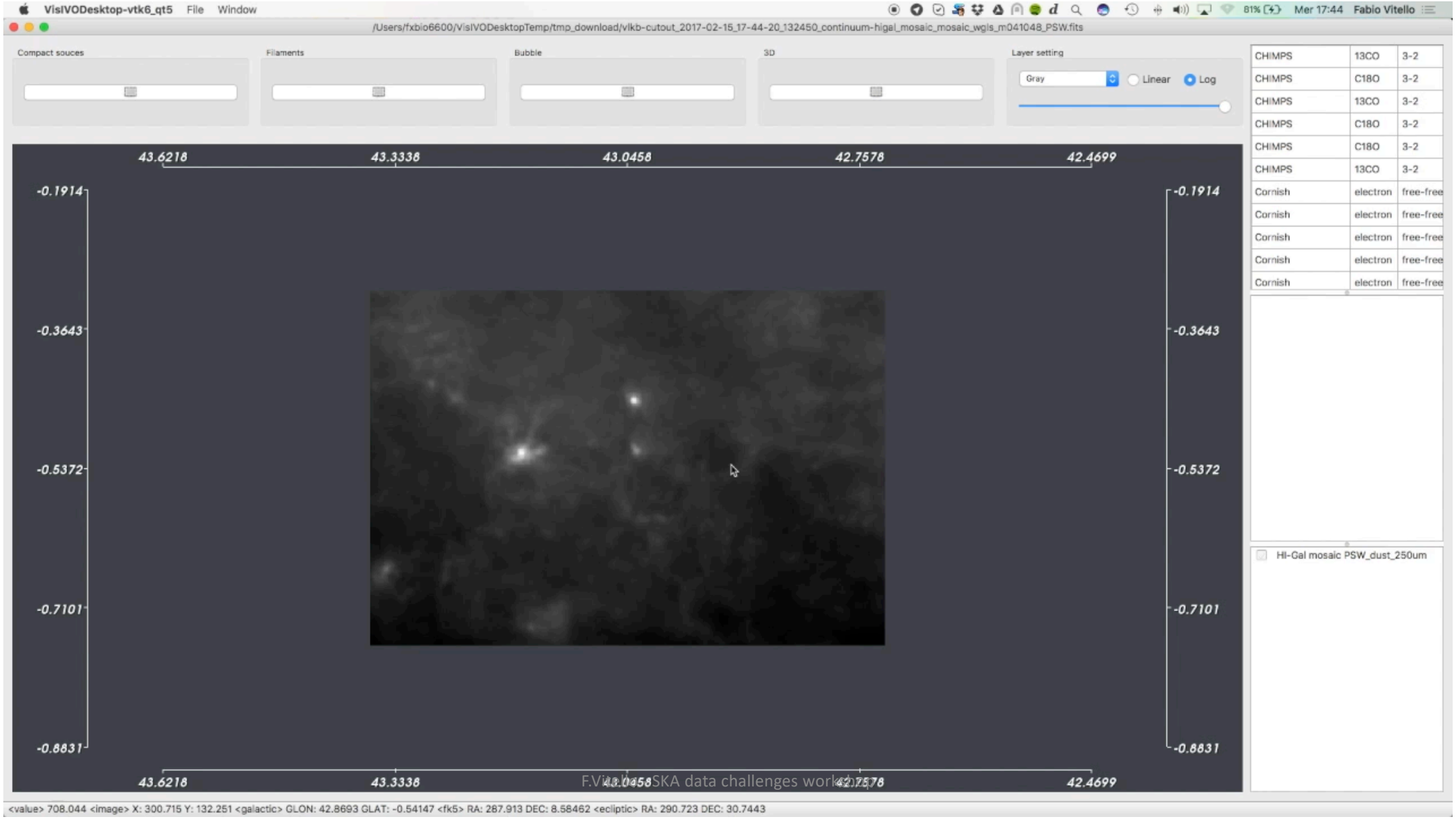
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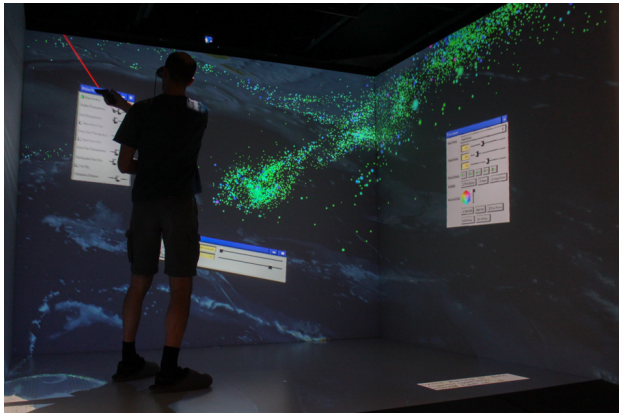
Advanced technique for 3D visualization

The use of advanced technique for presentation of, and interaction with, three-dimensional datasets is worthy of consideration.

These may include:

- tiled or multidisplay walls
- immersive Cave Automatic Virtual Environment
- Virtual Reality devices



Virtual Reality

Immersive VR - the user is completely isolated from the external environment and is transported in the virtual reality thanks to a complex set of accessories e.g. professional viewers such as the Oculus Rift;

Non immersive VR - the environment has less emotional impact on the subject. The user has a limited degree of interaction with the environment. Often the smartphone inserted in a special box is used as screen

Virtual Reality Data Analysis tool for Source Identification in HI cubes from SKA precursors

A MoU between IDIA and "ICT-VR-Lab & MeerKAT Fornax Survey teams" was signed in September 2019.

- The purpose of this project is to share expertise towards the first public release of a **user driven** virtual reality (VR) tool to enable **MeerKAT HI data cube exploration and source identification**. This project builds upon an existing Radio data cube analysis VR code set developed by IDIA as part of its long term plan in VR research to support Big Data Visualisation and Analysis on the development pathway to the SKA.
- This project is also supported by the **Bilateral Program Italy-South Africa** managed by joint Research Scheme Project (Progetto di Grande Rilevanza) between the Ministero degli Affari Esteri e della Cooperazione Internazionale (MAECI) and the National Research Foundation "RADIO SKY 2020 - Fostering cooperation between Italy and South Africa through radio astronomy".
- Will impact MeerKAT large projects (LADUMA, MHONGOOSE, Fornax) and researchers of the MeerKAT community interested in HI science features.

Ref. https://www.media.inaf.it/2019/09/04/ska-vr-inaf-idia/

Virtual Reality Data Analysis tool for Source Identification in HI cubes from SKA precursors

Scientific objectives:

- Navigate inside HI datacubes to explore the 3D distribution and morphology of HI detections, and compare that to the distribution of galaxies from optical spectroscopic catalogues.
- Validate the result of automated source finding. This would require that both datacube and the result of the source finding (typically a mask) are displayed in the VR environment, such that a user can check whether some real emission was missed, or some detections are not real.

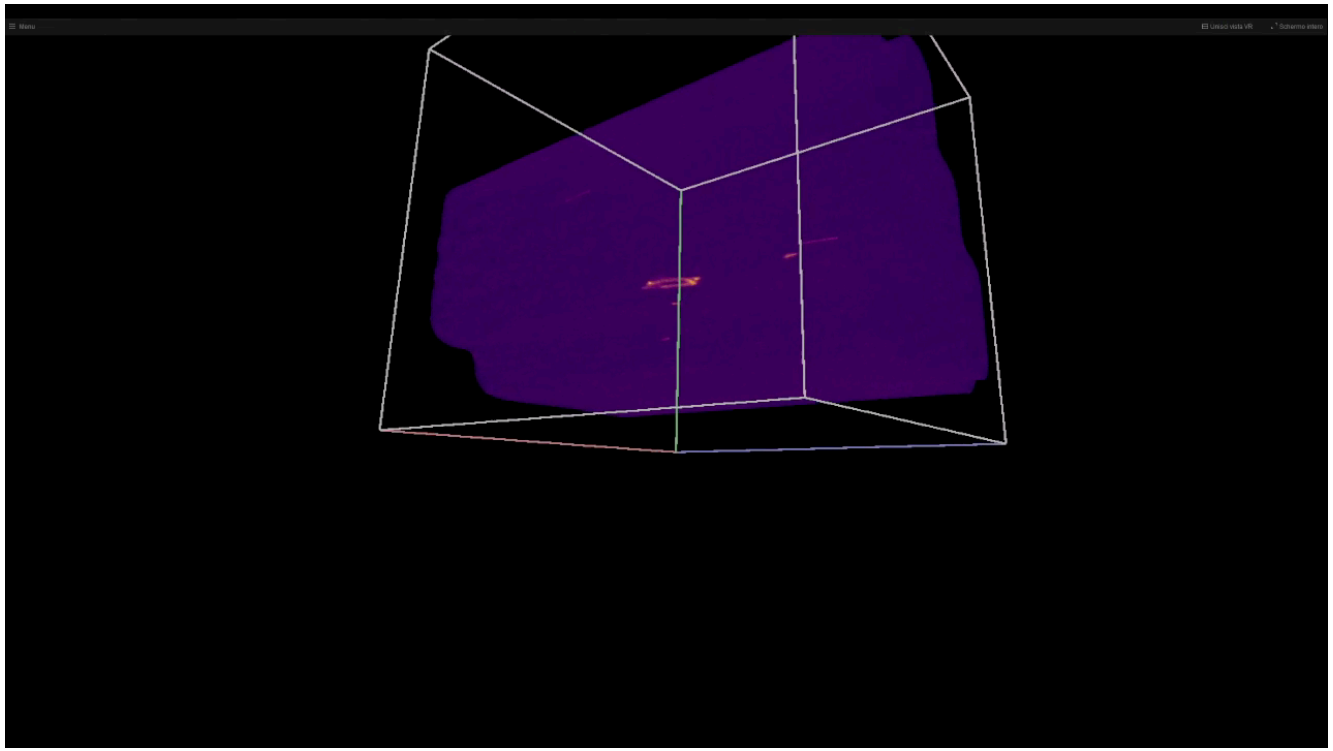
SoFiA

Ref: Serra et al (2015) doi: 10.1093/mnras/stv079

SoFiA, the Source Finding Application, is a new **HI source finding pipeline** intended to find and parametrise galaxies in HI data cubes.

- Flexible software application for the detection and parameterization of sources in 3D spectral-line datasets;
- Search for line emission on multiple scales to detect 3D sources;
- Estimate the reliability of individual detections;
- Look for signal in arbitrarily large data cubes using a catalogue of 3D coordinates as a prior;
- Provide a wide range of source parameters and output products which facilitate further analysis by the user.

VR Tools for HI data cube exploration



- Render the entire big data cube, at degraded resolution, and render a desired (selected by the user) smaller fraction of the data cube at the original resolution;
- Interact with the data through a pop-up User friendly Menu in the VR environment (e.g. select region, zoom-in, zoom-out, write notes, overlay contour, browse catalogues, etc..);
- Import SOFIA output in the VR environment, including source lists and mask;
- Modify/annotate the SOFIA output while in the VR environment;
- Export an "amended" version of the SOFIA output from the VR session that will then be used as input for an extra source extraction run with SOFIA.

Ongoing activities

- Porting the Visual Analytic application to the **European Open Science Cloud** (EOSC) within the H2020 **NEANIAS project** toward a FAIR (Findable Accessible Interoperable Reproducible) management of data/images/analysis and relative metadata.
- Integration of novel source finders, such as **CAESAR** (see S. Riggi's presentation) within the visual analytic application.
- Enabling the Virtual Reality application with the Virtual Observatory standards toward enhancing **interoperability** with VO compliant tools.
- Explore **novel techniques for rendering** larger-than-memory datacubes exploiting HTC and GPUs.

That's all folks!

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http://visivo.oact.inaf.it