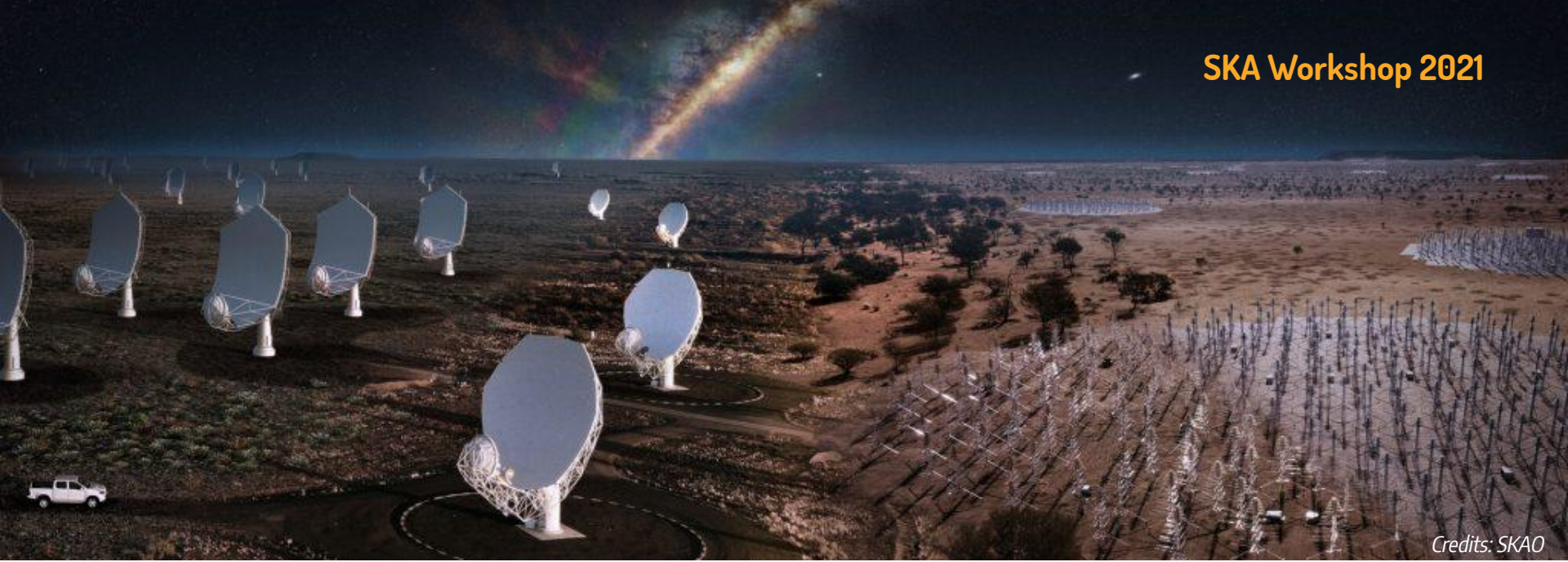


VISUALIZATION AND SOURCE ANALYSIS SERVICES FOR THE SRC

Simone Riggi
INAF-OACT

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

+ CIRASA, NEANIAS & ML4ASTRO collaborators

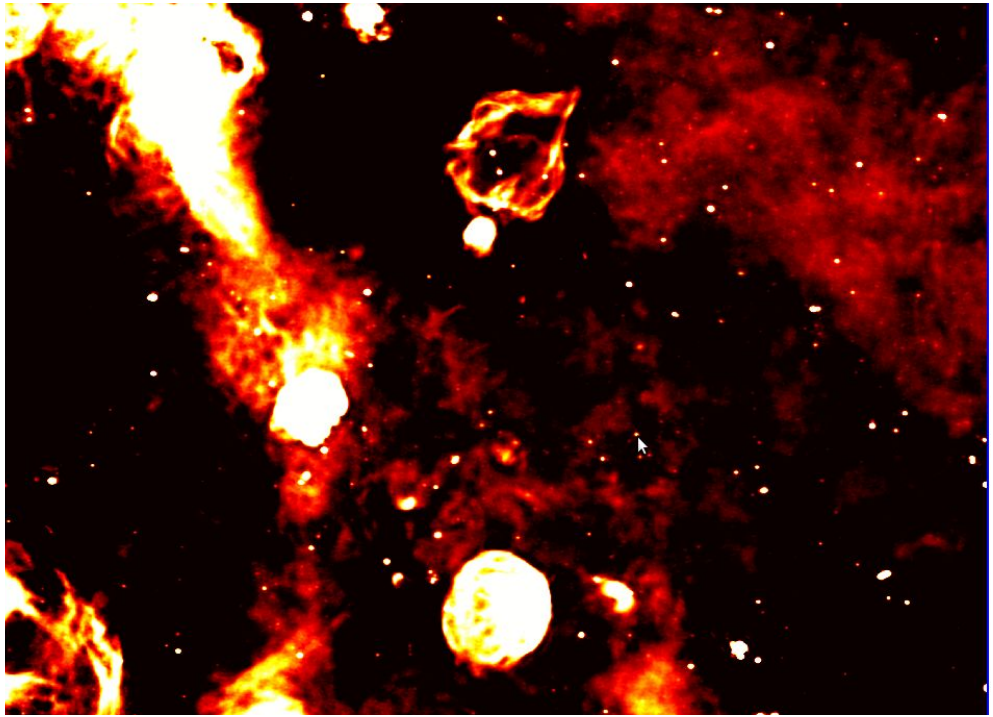
SRC SCIENCE USE CASES

- **SKAO & SKA Regional Centers (SRCs) responsible for *(see Possenti's presentation)*:**
  - **generation and lifecycle of Advanced Data Products (ADPs)** from Observatory or Project level data products (ODPs, PDPs)
  - **providing computing infrastructures and distributed services** to user community to deliver SKA science (following FAIR principles)

- **ADP generation and lifecycle**
  - joint responsibility of the science users and SRC Network
  - usually requiring interactive visualisation and comparison to other data
  - subjected to provenance and reproducibility policies
  - possibly complying with IVOA standards and accessed through VO services (TBD)

- **Several science cases being studied by the SRC WG3 & WG6 groups**
  - Our activities currently focusing on:
    - ✓ **SRC-WG3-TP2-USE-01:** Generation of Source Catalogues
    - ✓ **SRC-WG3-TP2-USE-04**: Postage Stamps & Stacked Postage Stamps

SCIENTIFIC DRIVERS



Patch of the Scorpio field observed with ASKAP @ 912 MHz

Galactic science mainly driving our technological developments

(see F. Cavallaro's talk)

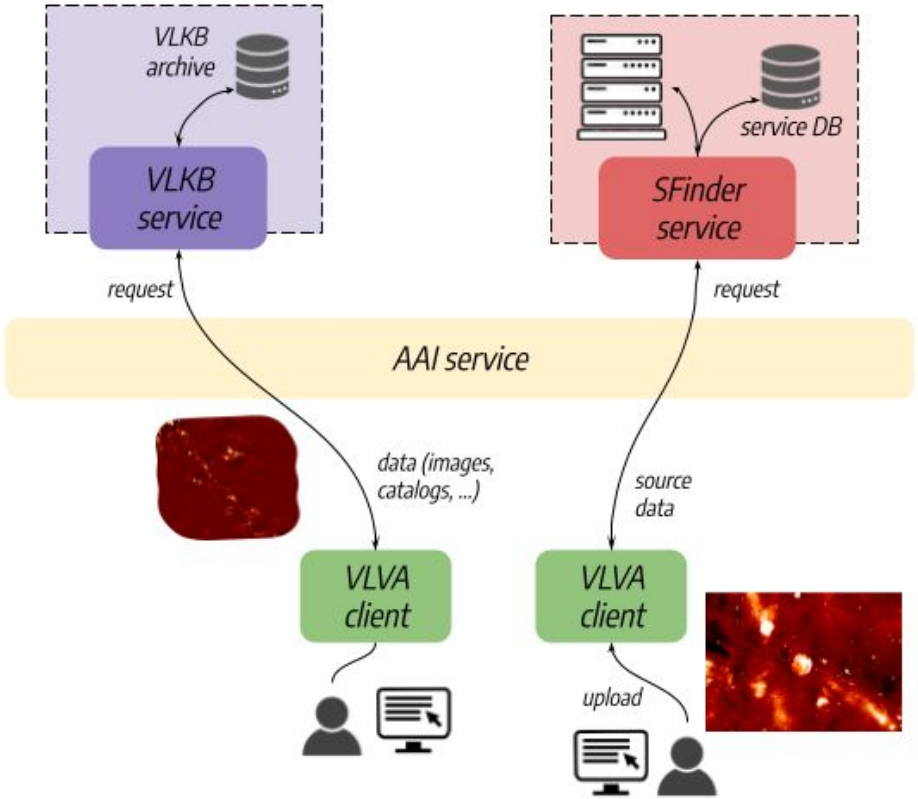
- **ASKAP EMU Survey**
  - Early Science observations of the SCORPIO field @ 912-1615 (2018-2019)
  - EMU pilot survey Phase 1 @ band 1 (2019)
  - EMU pilot survey Phase 2 @ band 1 (2021), including the SCORPIO field and other GP regions
- **MeerKAT Galactic Plane Survey**
  - Covering a large part of the GP @ 886 – 1678 MHz ($|b|<1.5°$, $2°<l<60°$, $252<l<358°$)
- **SKA Our Galaxy KSP**
  - Building on precursor experience, providing inputs to SKA WGs

⚠ | ADP GENERATION ISSUES

Limitations found when producing ADPs from SKA precursor data

- **Increased data product size (e.g. image, source density)**
  - Scalability issues in existing tools
  - Procured additional and dedicated resources for analysis and software development
- **Lack of tools to improve catalogue production automation and reproducibility**
  - Extended source extraction algorithms
  - Source classification (spurious vs real, galactic vs extragalactic, galactic classes) tools
  - Tools for unknown/anomaly detection, removal of duplicates,
- **Data visualization**
  - Starting to be challenging on local viewers
  - Limited source analysis functionalities in existing viewers
- **Knowledge gaps**
  - Astronomer community: best practises on computing, analysis automation and reproducibility
  - IT team: understanding of scientific use cases, science goal orientation

CIRASA PROJECT



CIRASA INAF PRIN TEC objectives

- Tackle selected SKA science cases from Galactic science perspective
- Speed-up the source cataloguing process for next-generation radio surveys
- Develop a visual analytic platform through integration of source finding, visualization, and knowledge base services
- Develop and integrate new ML source finders in the platform
- Add new interactive source visualization and analysis features
- Develop proto SKA Regional Center solutions, scalable to larger infrastructures

RELATED PROJECTS

NEANIAS

Horizon 2020
European Union Funding
for Research & Innovation

Novel EOSC services for Emerging Atmosphere, Underwater & Space Challenges

- Design innovative thematic services, following FAIR and Open Science principles
- Integrate services into the European Open Science Cloud (EOSC)
- Deliver services to end-user communities (Atmosphere, Underwater, Space)

ML4ASTRO Collaborations

- Development of ML techniques for astronomy
- MoU INAF-OACT-UniMalta: promoting scientific cooperation and mobility of researchers and PhD students
- Similar collaboration ongoing with the University of Catania and Milano Bicocca

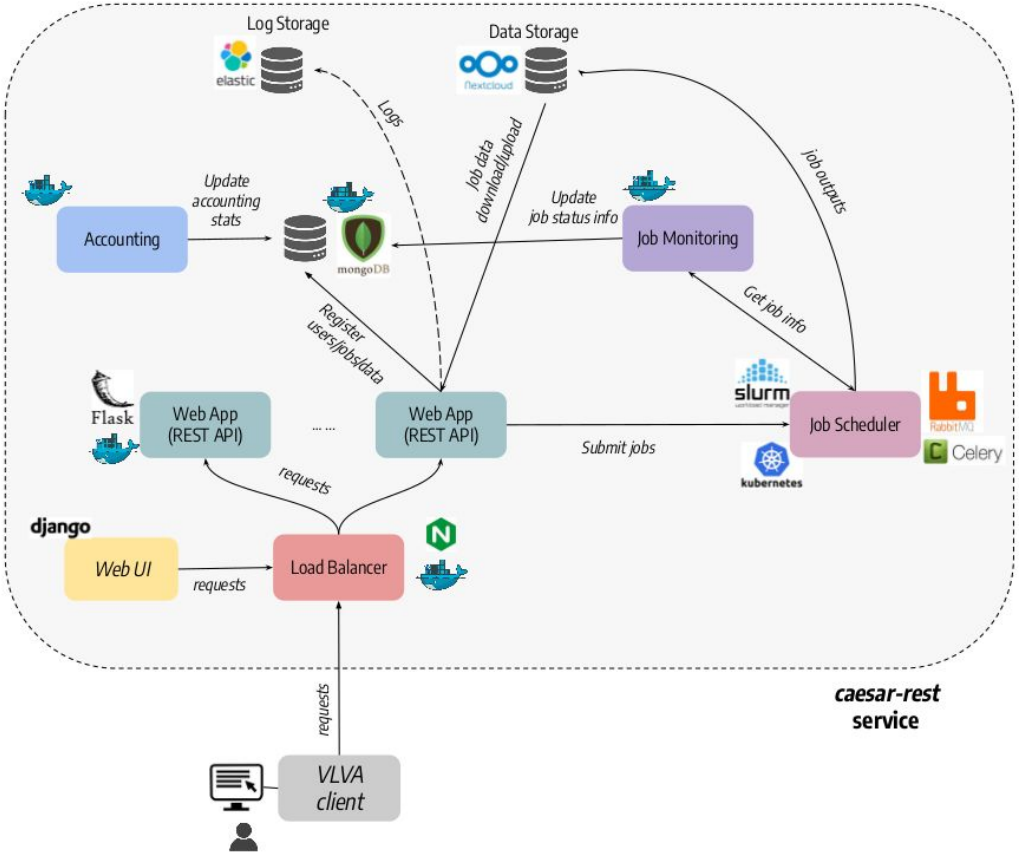
INAF ISTITUTO NAZIONALE DI ASTROFISICA

STVDIVM GENERALE SICILIAE 1434

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

L-Università ta' Malta
Institute of Space
Sciences & Astronomy

SFINDER SERVICES

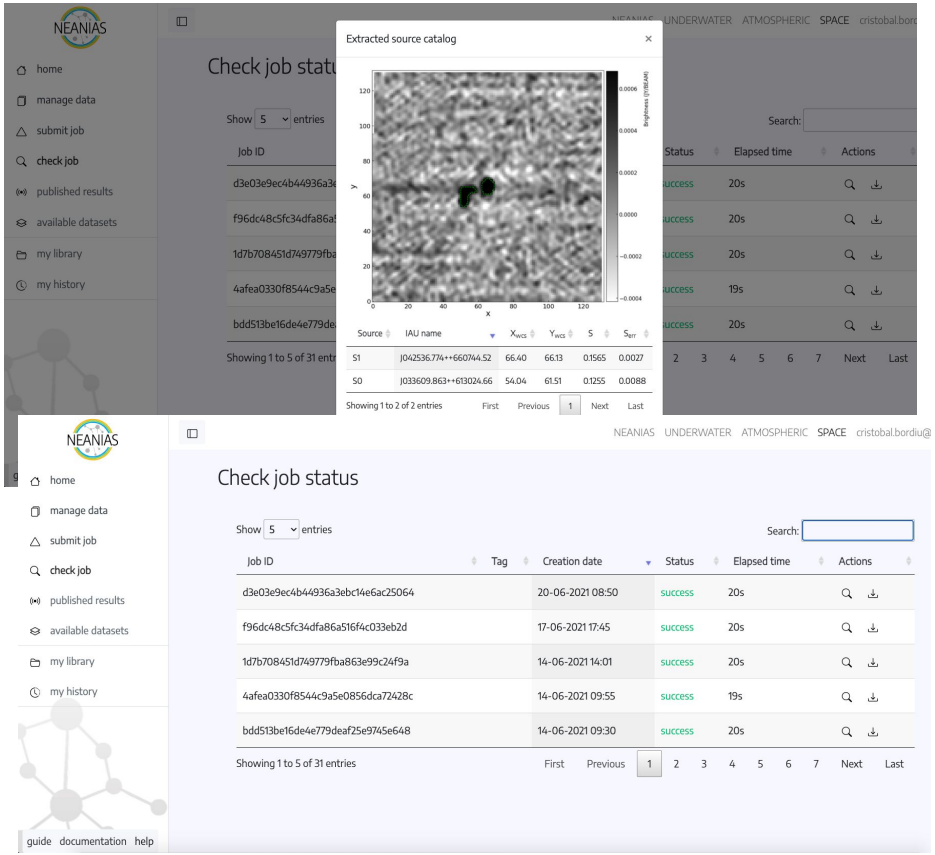


caesar-rest: *A REST-ful web service based on Flask framework for running CAESAR source finding jobs*

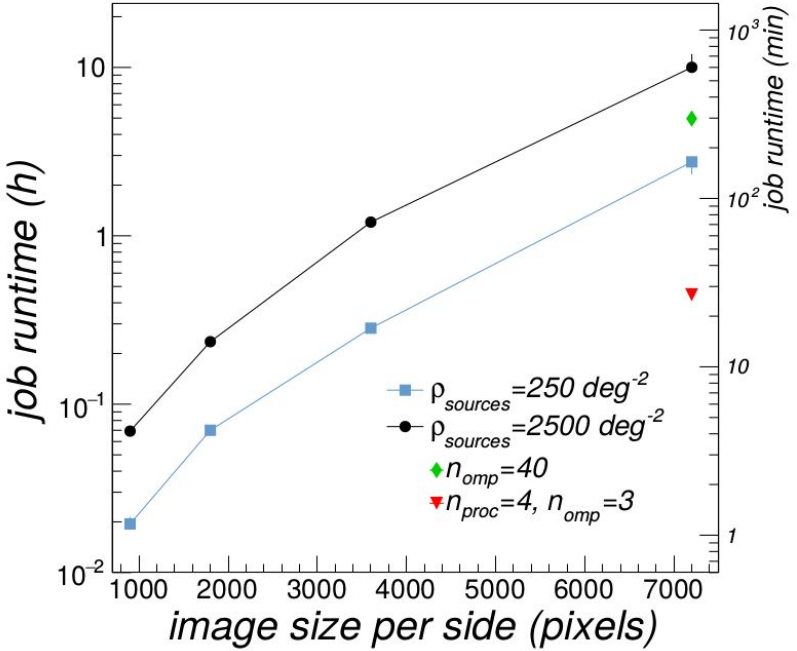
- Deployed and tested on GARR OpenStack Kubernetes cluster + CIRASA dedicated resources
- Multiple run strategies
  - Kubernetes Jobs (Docker)
  - Slurm Jobs (Singularity)
  - Celery async tasks
- Integrated with NEANIAS EOSC services (AAI, Logging, Accounting)
- Other source finders (ASGARD, CUTEX, Aegean) under integration
- Integration with ViaLactea visualization client ongoing

More details @ https://github.com/SKA-INAF/caesar-rest

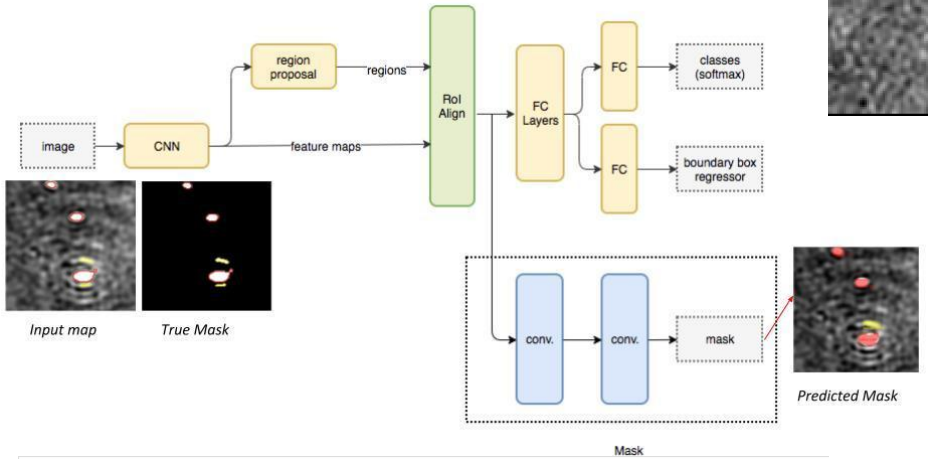
SFINDER SERVICES (contd)

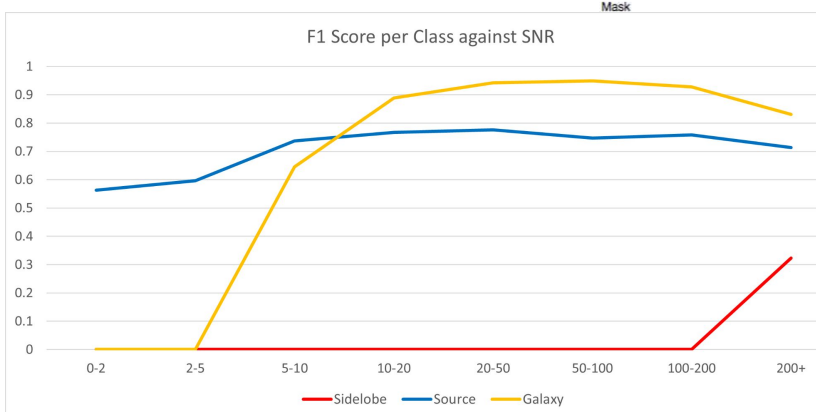


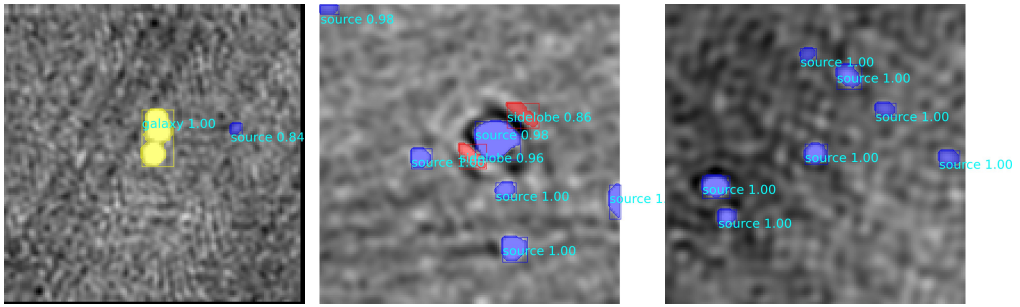
- Currently available on the EOSC marketplace, accessible from Django web UI
- Testing activities ongoing with ~30 users
- Searching for additional resources for larger scalability tests



ASGARD







Automated Source, Galaxy, and Artefact R-CNN Detector (ASGARD)

- Based on Mask R-CNN object detection framework
- Allowing detection of compact sources, sidelobes and extended radio galaxies
- Trained on ASKAP, RGZ FIRST, ATCA & MeerKAT data (galaxies, sidelobes, point-sources), ~15k images
- Used as Caesar classification step or as a new finder (detection + classification)
- MPI parallel version in alpha version
- Performance optimization studies ongoing

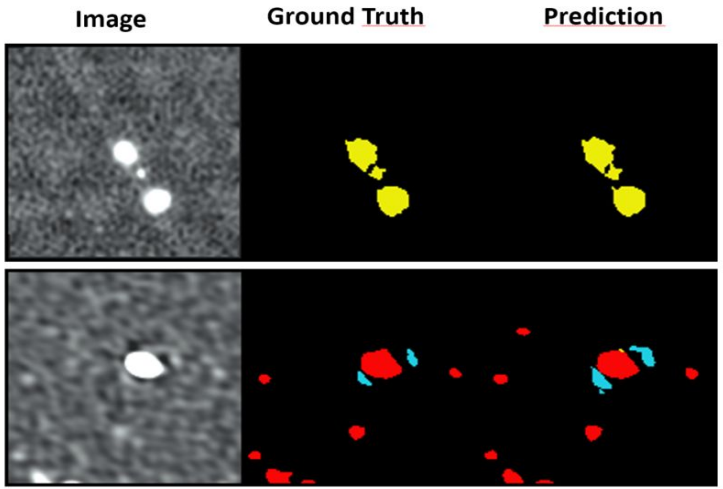
More details @ https://github.com/SKA-INAF/mrcnn

D. Magro & S. Riggi, PASA, 2021

NEW ML APPS

DE:TR

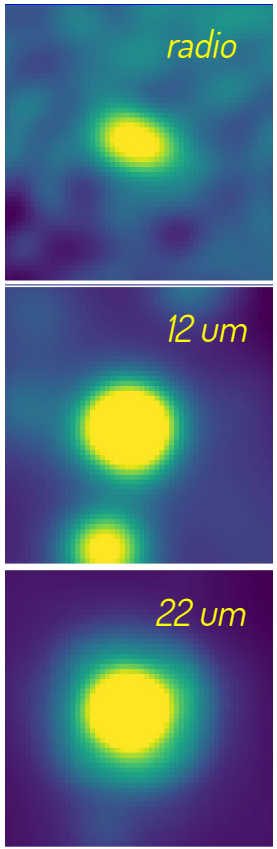
- Transformer model for object detection
- Removes the necessity for RPN, typical of R-CNN based models
- Heavier in terms of resources
- Preliminary results in images below



Semantic Segmentation with Tiramisu model

- Uses semantic segmentation, a different approach than object detection, to achieve the same goal of source detection
- Based on U-Net model
- Comparable results with ASGARD

SCUTOUT SERVICE



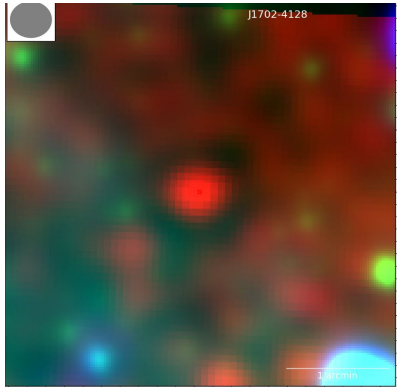
Source cutout service

- **Functionalities**
  - identify 2D survey data overlapping with a circle region and cutout on position
  - regridding outputs from multiple surveys to common WCS, resolution, map units
  - background subtraction
- **Technical details**
  - Mostly based on Montage
  - ~20 radio and infrared surveys available (~4 TB), no DB
- **Status**
  - Currently provided as a batch application for producing ML datasets
  - Service to be likely integrated in *caesar-rest*

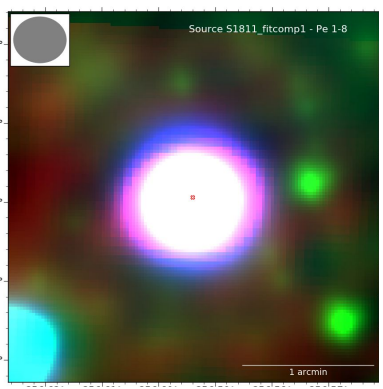
More details @ https://github.com/SKA-INAF/scutout

SCLASSIFIER SERVICE

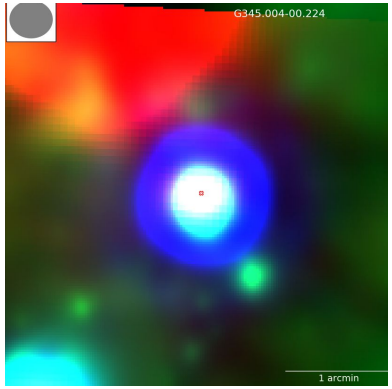
Known pulsar



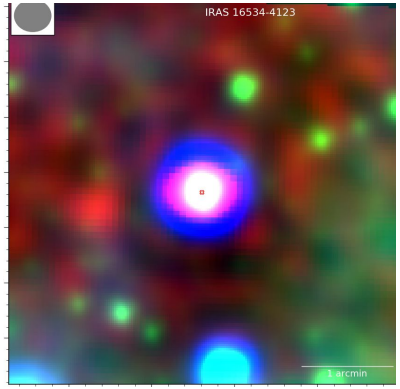
Known PN



Known HII region

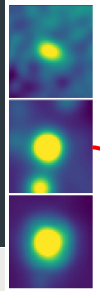


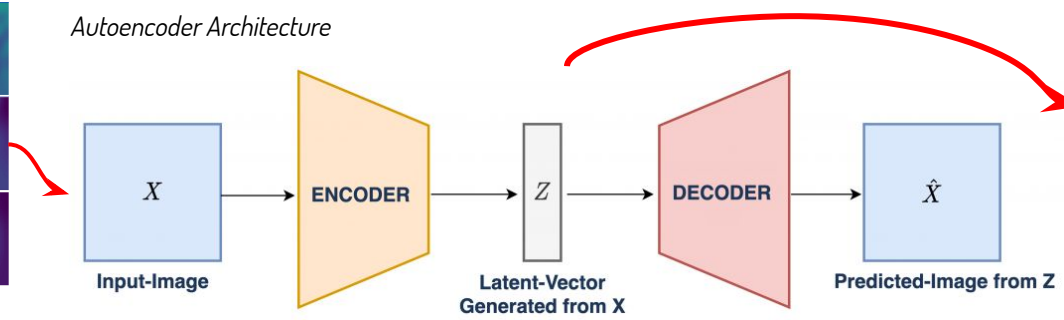
Known star

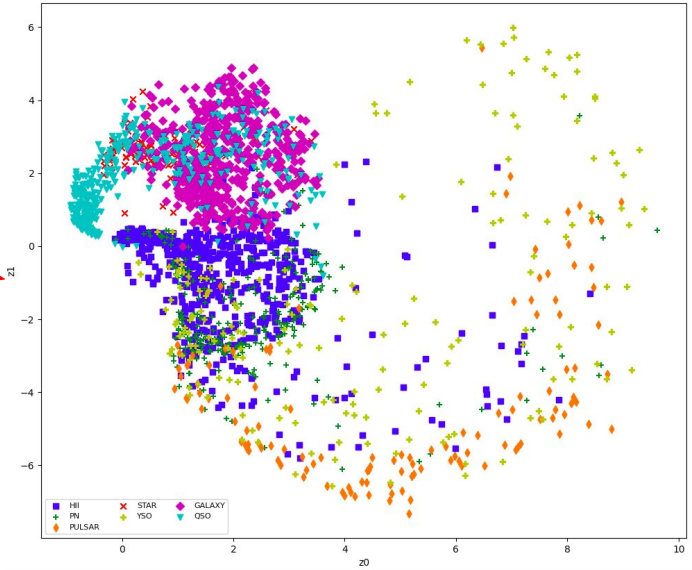


- **Goal: Developing classification/diagnostic tools using multiwavelength data:**
  - identify Galactic vs extragalactic objects, or discriminate individual Galactic classes
  - discover unexpected/anomalous objects, identifying the most similar known objects
- **Major issues**
  - Lack of homogeneous radio labelled datasets, possibly at multiple frequencies
  - Limited number of training data for some Galactic classes (~hundreds)
  - No catalogued extragalactic objects (e.g. RG, QSO) covering the GP, using extragalactic surveys
  - No full-sky coverage for some discriminant surveys (e.g. HiGAL @ 70 micron)

SCLASSIFIER SERVICE (contd)

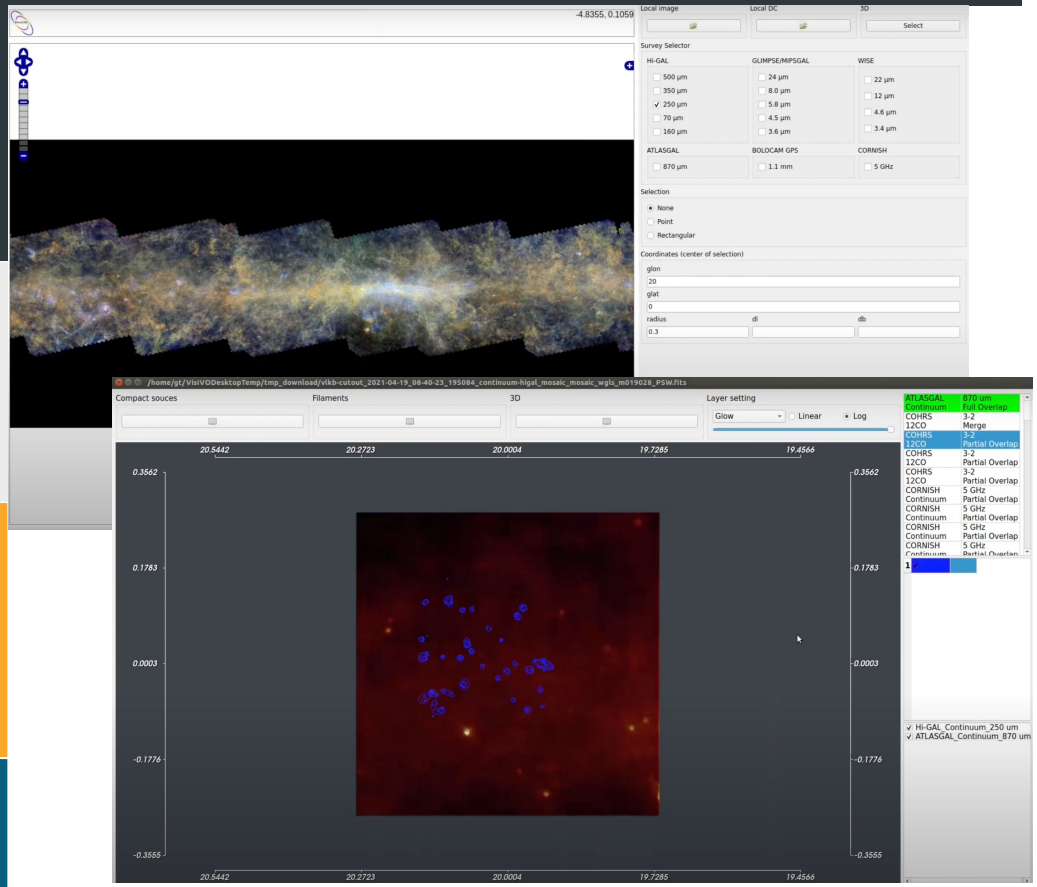






- **Dataset preparation ongoing**
  - MeerKAT GPS survey providing high-resolution data for a large portion of the GP, at multiple frequencies
  - Data cleaning requires a considerable effort
  - ~15 K objects (⅓ of the available data) currently available
- **Different unsupervised methods being considered**
  - First runs performed with different tools (autoencoders, UMAP) on a small (not fully cleaned) dataset
  - Some methods highly dependent on hyperparameters or network architecture
  - Tests to be repeated with improved dataset
- **UNIMIB collaborators developing a dedicated service (including different algorithms) for EOSC deployment**

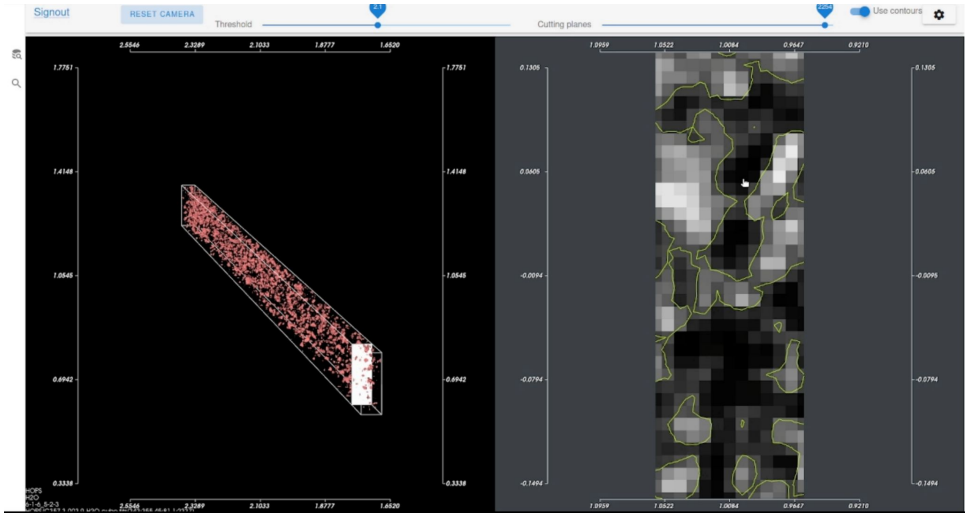
ViaLactea Visual Analytics



ViaLactea Visual Analytic (VLVA)

- Provides access to GP radio & infrared surveys 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.
- Open Source at GitHub: https://github.com/NEANIAS-Space/ViaLacteaVisualAnalytics
- See user manual at: https://vlva.readthedocs.io

ViaLactea Web

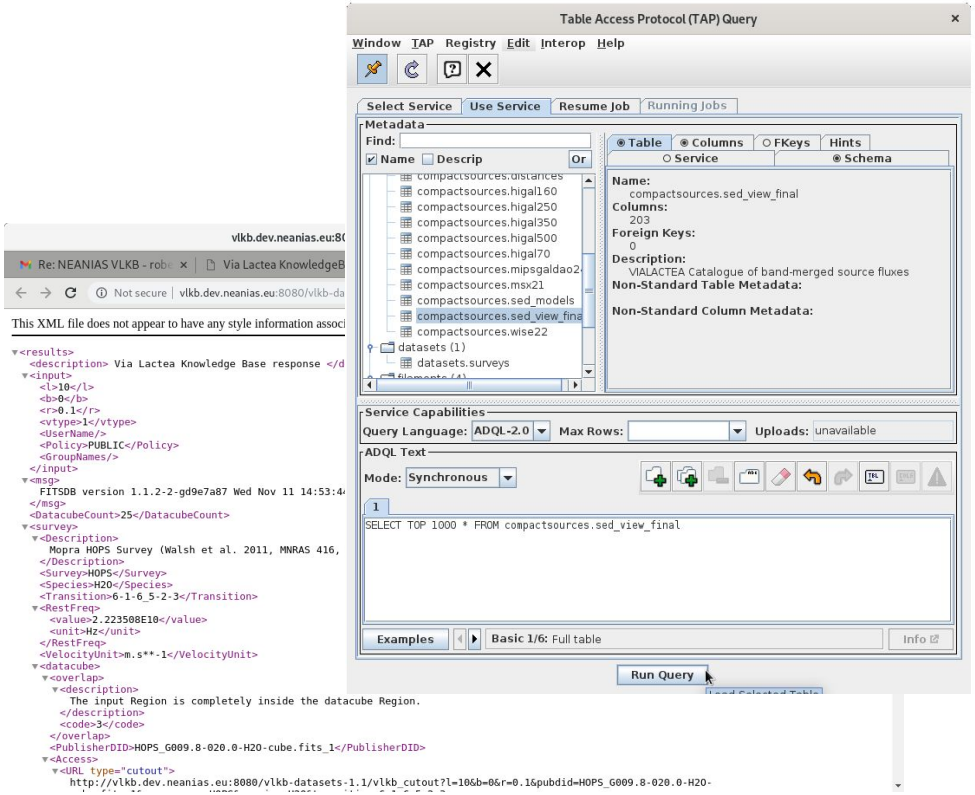


ViaLactea Web application (VLW)

- Work-in-progress simplified web version of the VISUAL ANALYTICS TOOL, developed in collaboration with University of Portsmouth (UK)
- Currently supporting only 3D velocity datacubes visualization
- 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

ViaLactea Knowledge Base



ViaLactea Knowledge Base (VLKB)

- 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

Summary

- **Technological solutions being developed to support SRC and precursor use cases**
  - CIRASA: development and integration of existing and new services for source analysis, visualization and knowledge base
  - NEANIAS: development, integration and deployment with external EOSC service and infrastructure

- **What we have done so far?**
  - Source finding services developed. integrated and deployed on EOSC
  - VLKB services integrated and deployed on EOSC, integrated with VLVA
  - New ML source finders and source cutout tools developed

- **What we are doing now?**
  - Integration of other existing applications (e.g. Aegean, CUTEX, SoFIA) in source finding service
  - Integration of source finding services with VLVA
  - Setting up of larger computing infrastructure (Kubernetes) for scalability tests
  - Dataset preparation for new source classifiers
  - Developing new features in source cutout application and service integration
  - Developing source visualization and tagging features in VLVA client

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+ the INAF-OACT radio & IT group