



Conference

ESCAPE to the Future | 25-26 October 2022

Royal Belgian Institute of Natural Sciences | Brussels, Belgium

25 October 2022, 14:25 - 15:20

ESCAPE ESAP - Common standards to access and use data with a science platform toolkit



John Swinbank
ASTRON



Matthias Fueßling
CTAO



James Collinson
SKAO



Aard Keimpema
JIVE





ESCAPE to the Future

25-26 October 2022
Brussels, Belgium

Work Package 5

ESAP: A Science Analysis Platform Toolkit

John Swinbank — swinbank@astron.nl — WP5 Coordinator
On behalf of the WP5 team



ESAP in the ESCAPE Cluster

ESCAPE OSSR

Catalogue & Repository of resources

- Datasets
- Software & services
- Tutorials
- Training
- Publications

ESCAPE VO Virtual Observatory

Astronomy Data centres

VO Registry

VO Registry
Analysis Tools
VO Services

ESCAPE ESAP Science Platforms

Workflows, notebooks, deployment platforms, packaging


RI-Specific Science Platforms

ESCAPE CS Citizen Science




ESCAPE DIOS Data Lake

FAIR data management
Content discovery and delivery



HPC



HTC

Grid clusters, etc

Private/public clouds

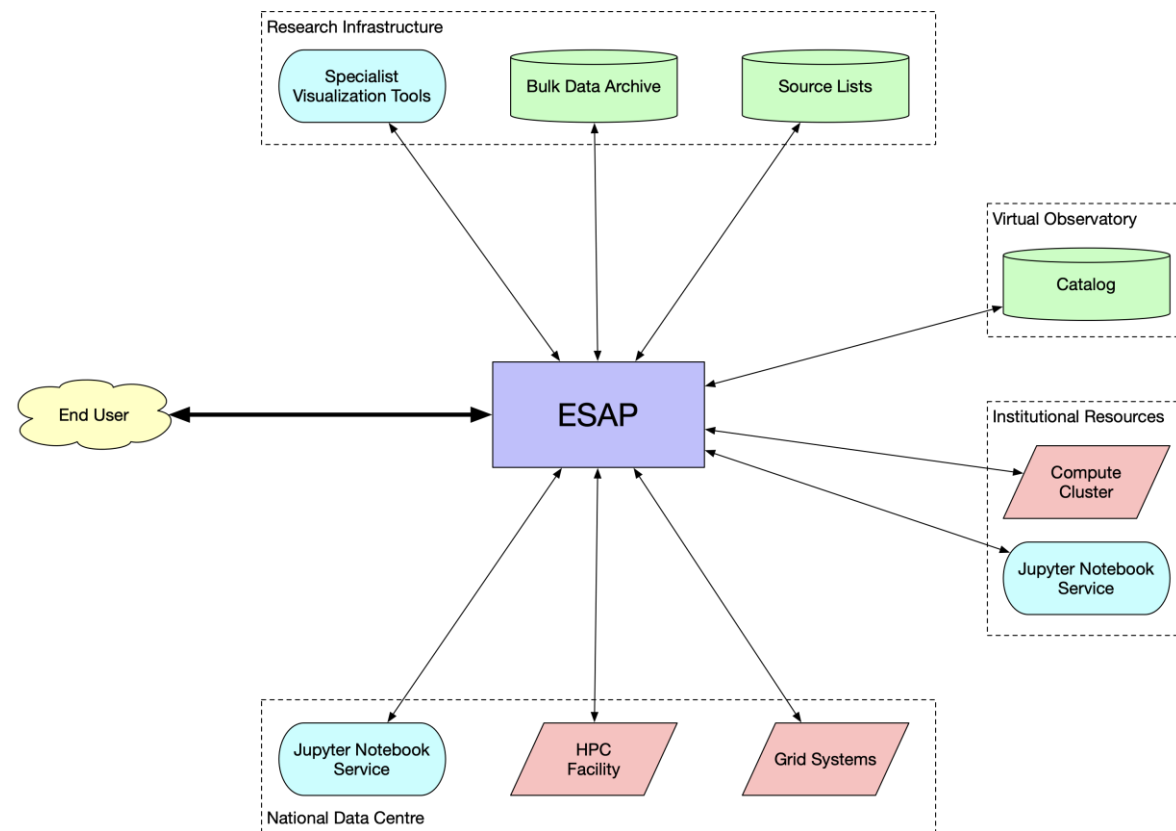
Commercial clouds

GÉANT



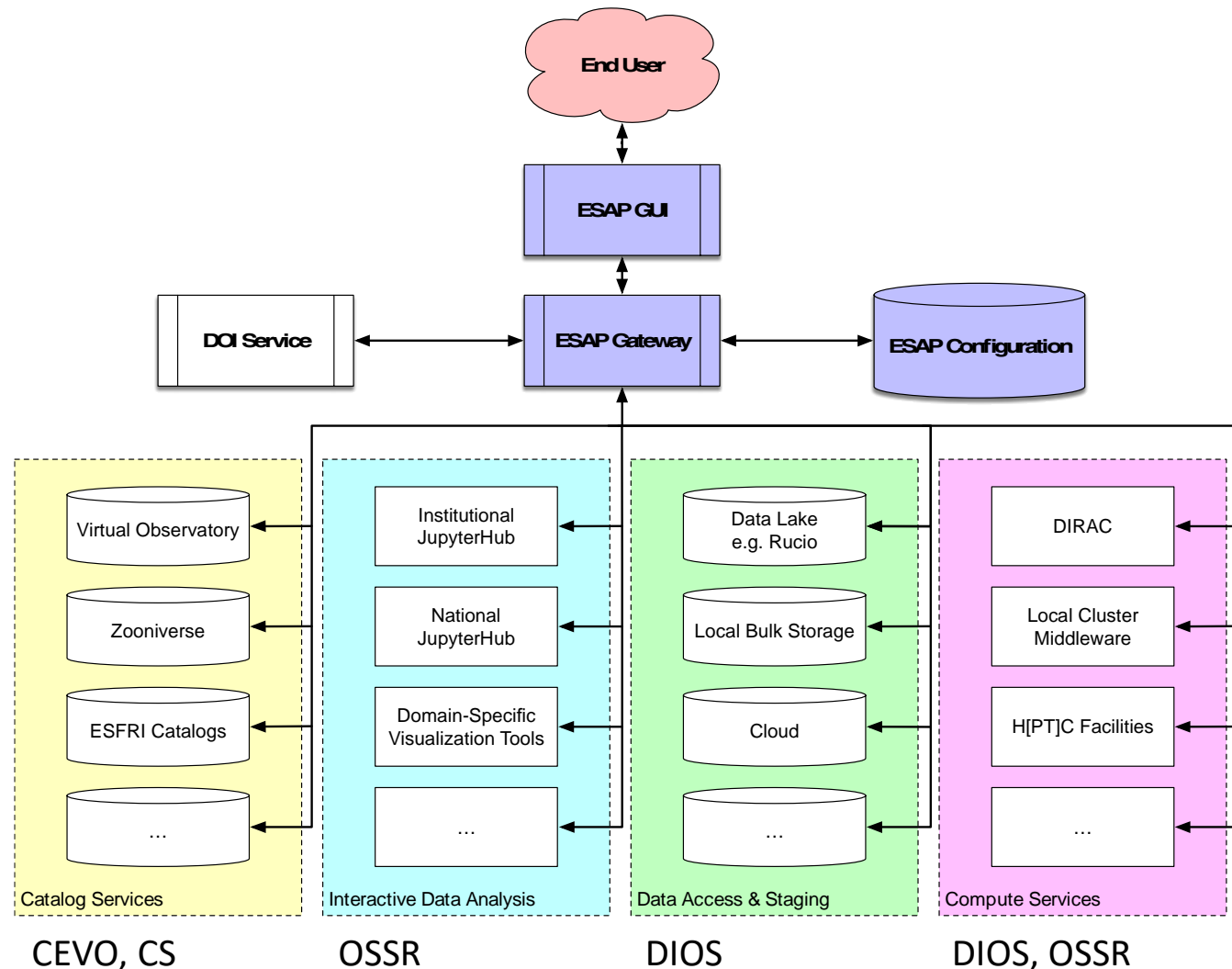
The Twin Missions of Work Package 5

- Development of **ESAP**, the ESFRI Science Analysis Platform
 - A *toolkit* for building platforms through which users can discover and interact with the data products, software tools, workflows, and services that are made available through ESCAPE and from elsewhere.
- Preparing ESFRI services, data products, and tools for integration with ESAP and their subsequent use within ESCAPE and across EOSC

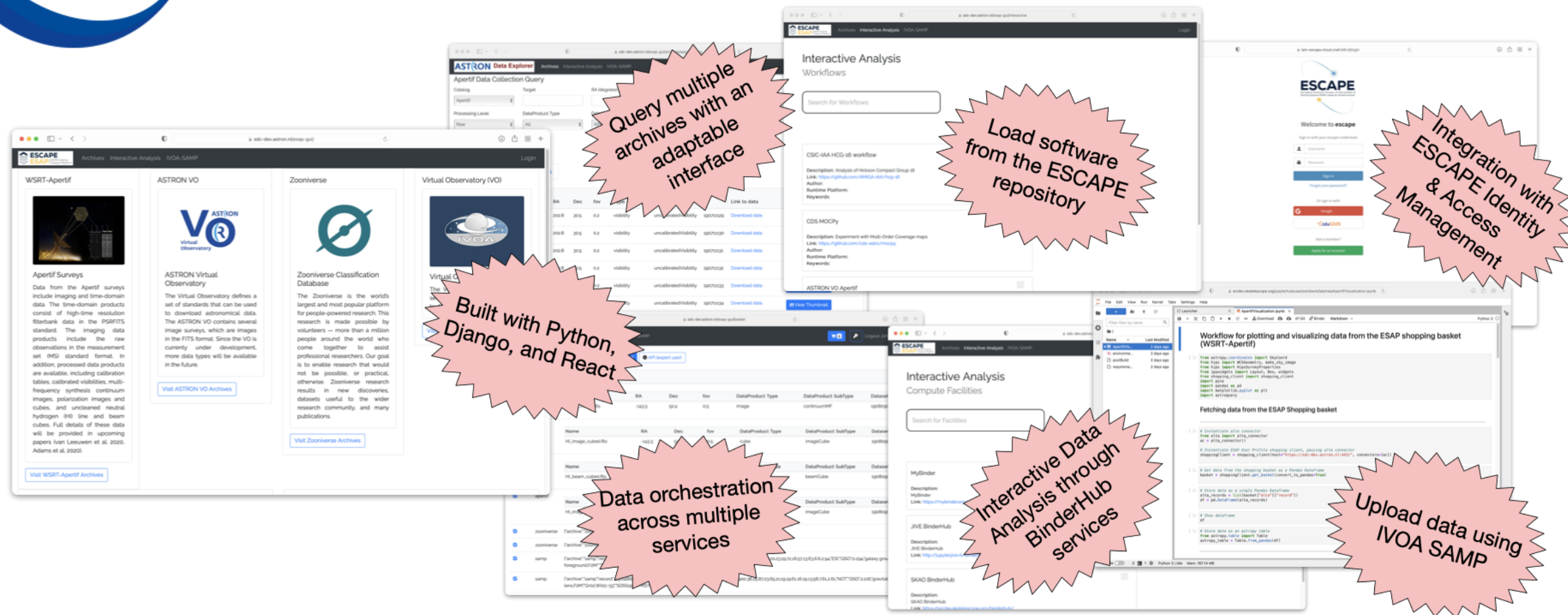


Goals and structure of ESAP

- ESAP provides the *focal point* for integrating diverse services from a range of providers.
- Two major components: GUI and Gateway.
- Focal point of a range of pluggable, independent services.
- Flexible, robust, extensible.
- A toolkit; deployable and customizable to meet the needs of different research infrastructures.



ESAP Capabilities



Query multiple archives with an adaptable interface

Load software from the ESCAPE repository

Integration with ESCAPE Identity & Access Management

Built with Python, Django, and React

Data orchestration across multiple services

Interactive Data Analysis through BinderHub services

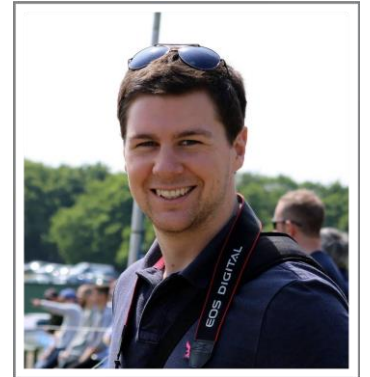
Upload data using IVOA SAMP

Special Guest Stars



Mathias Füßling
CTAO

Cherenkov Telescope Array Observatory: Experiences with ESAP



James Collinson
SKAO

SKA Regional Centres and ESAP



Aard Keimpema
JIV-ERIC

The EVN Archive Portal: Bringing science to the data using JupyterHub



ESCAPE to the Future
25-26 October 2022
Brussels, Belgium

Cherenkov Telescope Array Observatory (CTAO): the experiences with ESAP

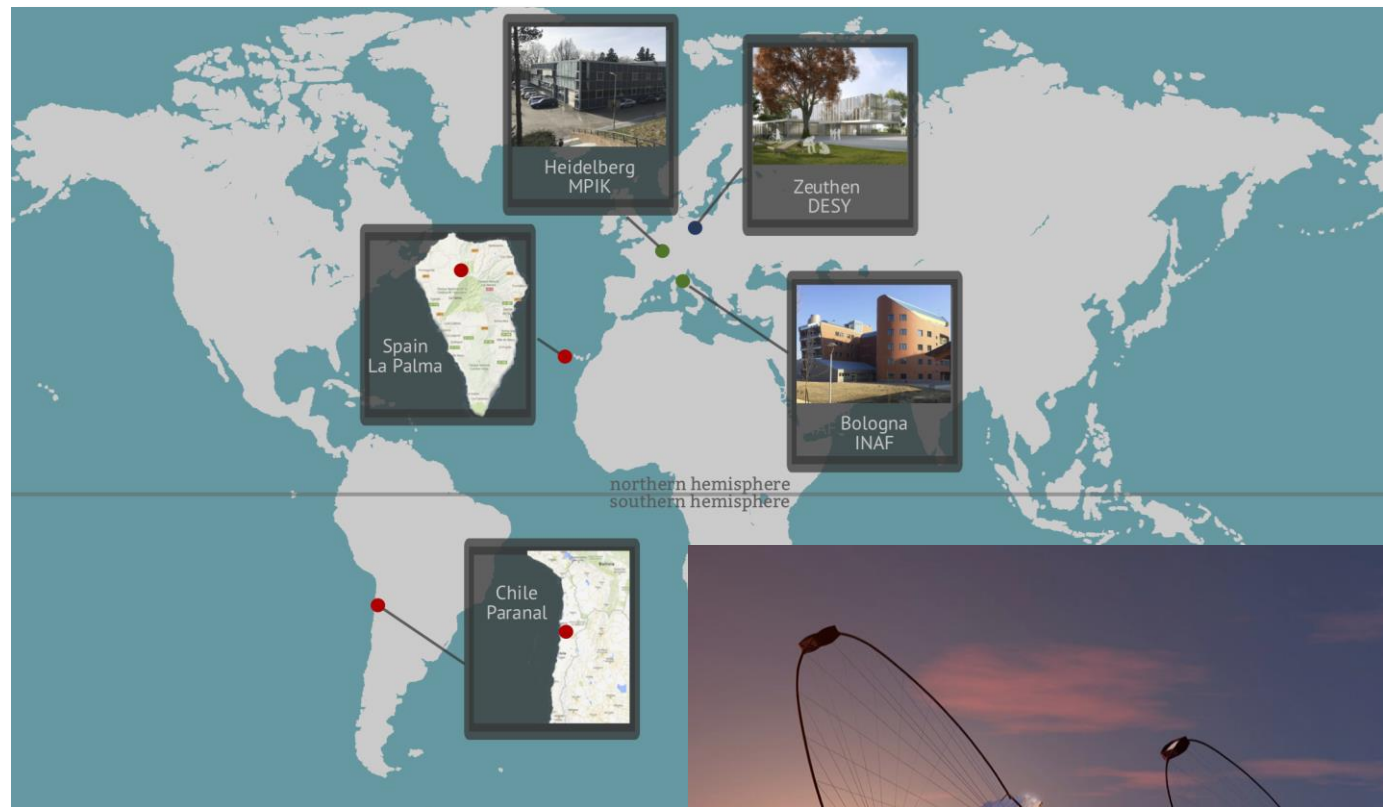
Matthias Fülling, Gareth Hughes (CTAO)



Cherenkov Telescope Array Observatory

The first ground-based gamma-ray **observatory**

- CTAO provides to the User Community:
 - a science portal for access to products and services
 - High-quality data and science tools
- ESAP offers to the ESFRIs:
 - main building blocks to build platforms tailored for specific purposes
 - ability to explore workflows:
 - CTAO users executing a science analysis (finding data, workflow, software)
 - UIs for CTAO staff to do data management tasks (batch processing)
 - Science data challenge (interactive processing)

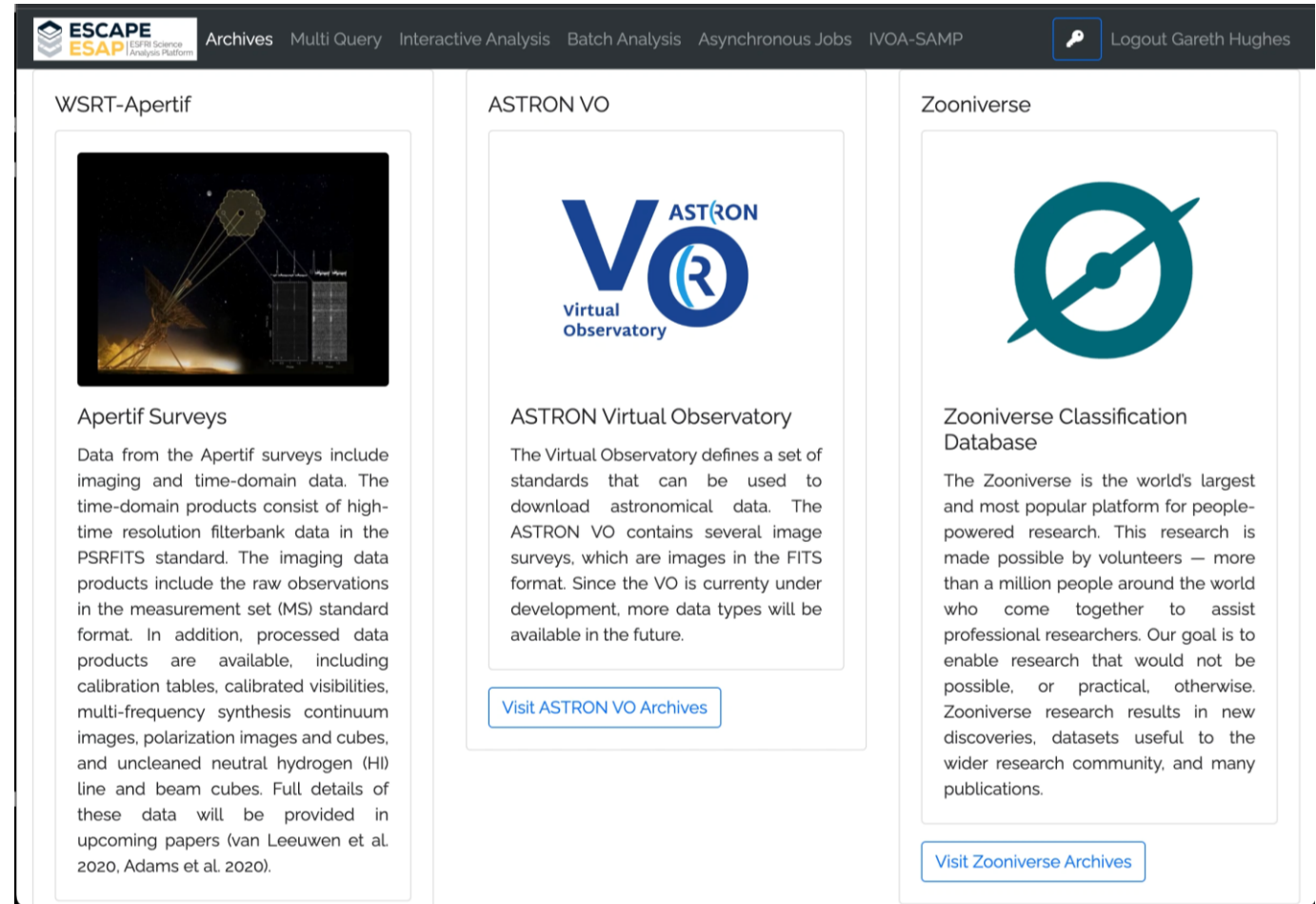


<https://www.cta-observatory.org/>



Modularity: Adding Services

- The ability to easily **add services** to a platform makes it versatile
 - The ESAP makes it simple to add an archive or service to the platform
- If a service has a REST API then it can be connected and queried through the ESAP
- Enables cross collaboration and linking of data and workflows
- A simple example of this is using the [eOSSR](#) python library developed in WP3/OSSR
 - We can now query the [Zenodo](#) archive to look for anything linked to ESCAPE and CTAO
 - For example, the CTAO Instrument response functions

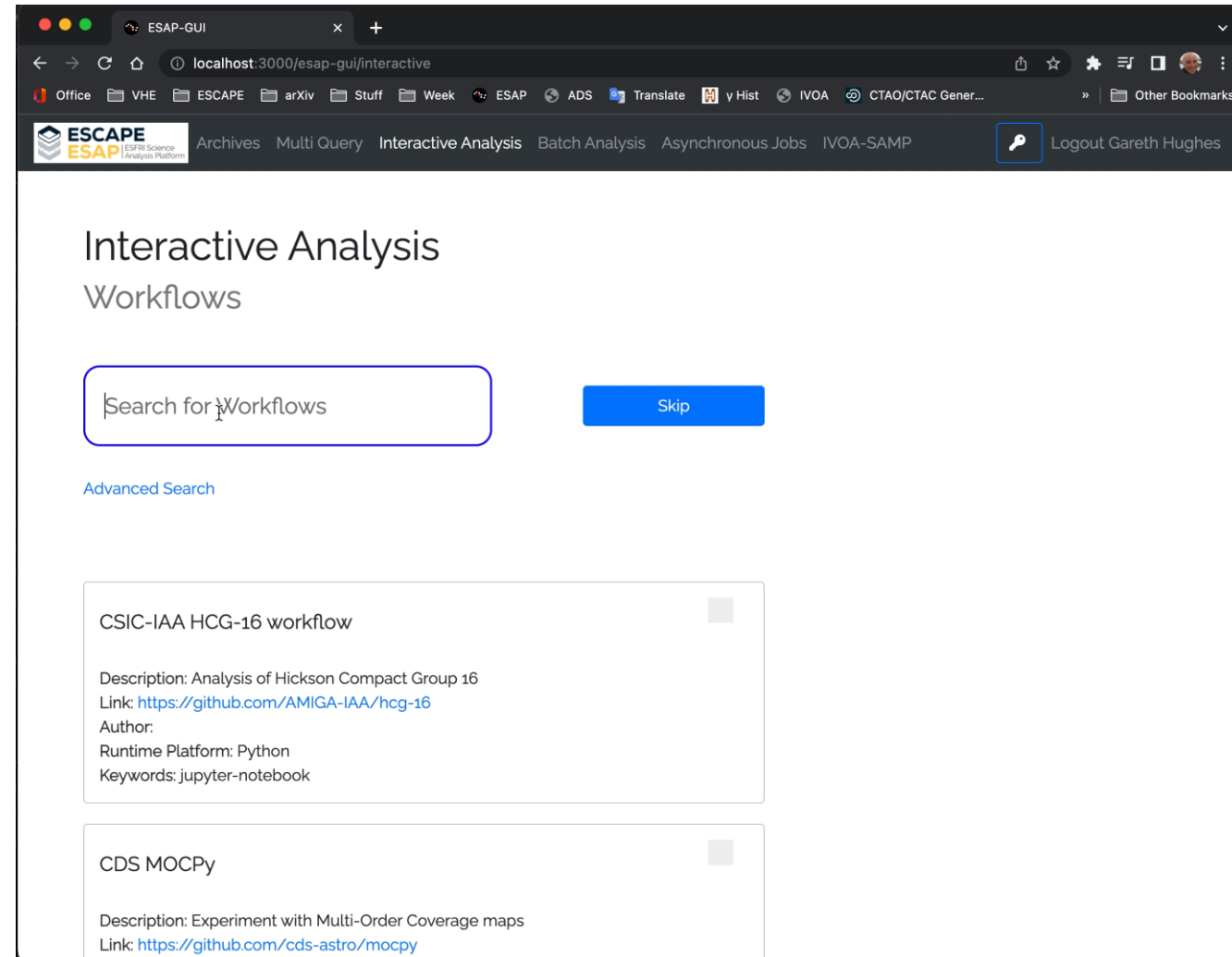


The screenshot shows the ESCAPE ESAP Analysis Platform interface. The top navigation bar includes links for Archives, Multi Query, Interactive Analysis, Batch Analysis, Asynchronous Jobs, IVOA-SAMP, and a Logout button for Gareth Hughes. The main content area displays three service cards:

- WSRT-Apertif**: Features an image of a radio telescope. Below it, the text reads: "Apertif Surveys. Data from the Apertif surveys include imaging and time-domain data. The time-domain products consist of high-time resolution filterbank data in the PSRFITS standard. The imaging data products include the raw observations in the measurement set (MS) standard format. In addition, processed data products are available, including calibration tables, calibrated visibilities, multi-frequency synthesis continuum images, polarization images and cubes, and uncleaned neutral hydrogen (HI) line and beam cubes. Full details of these data will be provided in upcoming papers (van Leeuwen et al. 2020, Adams et al. 2020)." A button labeled "Visit ASTRON VO Archives" is at the bottom.
- ASTRON VO**: Features the ASTRON Virtual Observatory logo. Below it, the text reads: "ASTRON Virtual Observatory. The Virtual Observatory defines a set of standards that can be used to download astronomical data. The ASTRON VO contains several image surveys, which are images in the FITS format. Since the VO is currently under development, more data types will be available in the future." A button labeled "Visit ASTRON VO Archives" is at the bottom.
- Zooniverse**: Features the Zooniverse logo. Below it, the text reads: "Zooniverse Classification Database. The Zooniverse is the world's largest and most popular platform for people-powered research. This research is made possible by volunteers — more than a million people around the world who come together to assist professional researchers. Our goal is to enable research that would not be possible, or practical, otherwise. Zooniverse research results in new discoveries, datasets useful to the wider research community, and many publications." A button labeled "Visit Zooniverse Archives" is at the bottom.

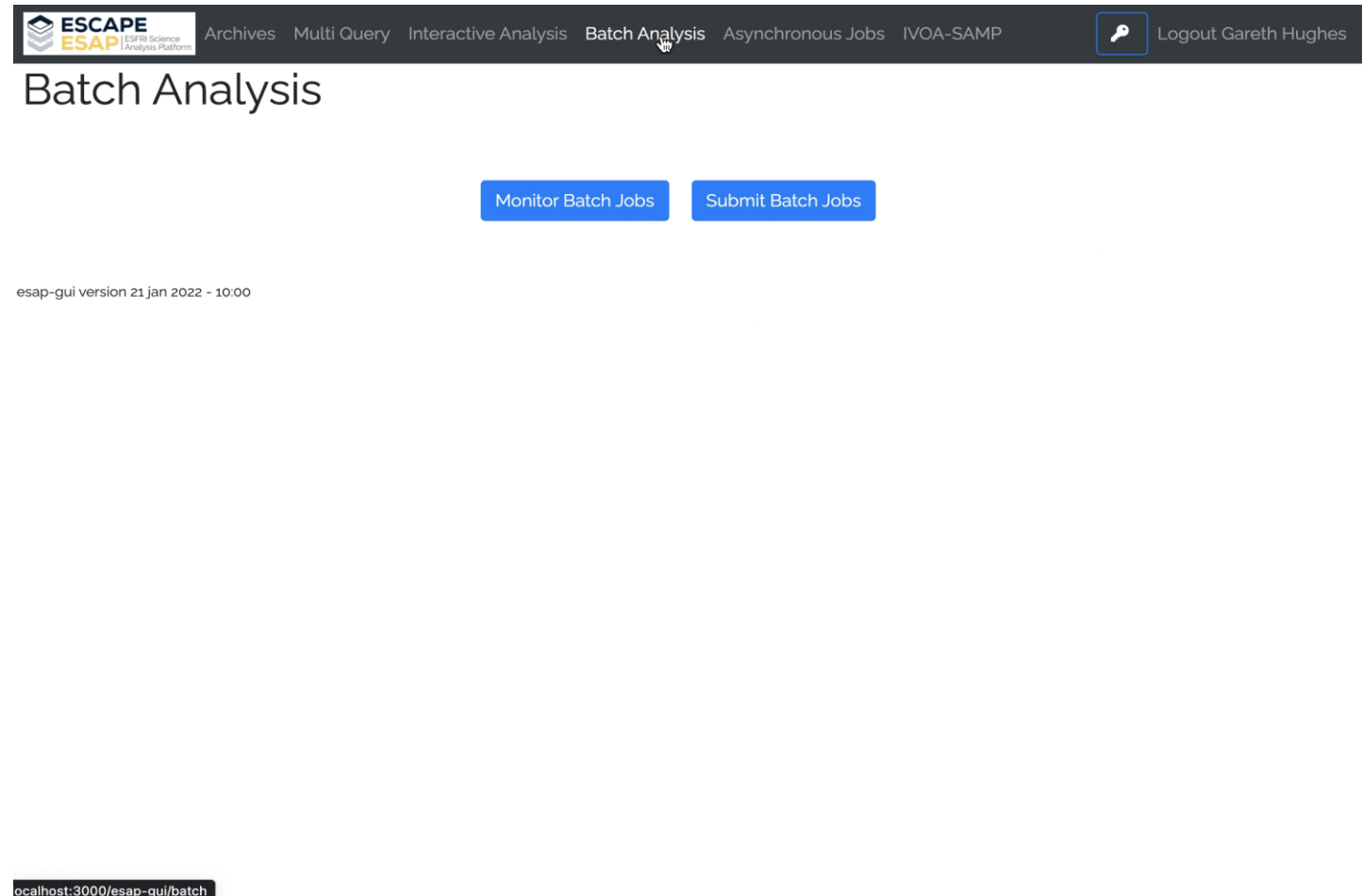
ESAP and Analysis Workflows: a tool for CTAO Users and Staff

- ESAP facilitates the connection of software, data and interactive analysis
- The CTAO Science Portal needs to offer data and services to its users and staff
 - This will allow users to interact with data
 - It can also help foster cross collaboration and joint analysis
 - Could be used to support observatory staff
- Both [Gammapy](#) and [AGNpy](#) were onboarded to the OSSR/WP3
 - Gammapy: open-source Python package for gamma-ray astrometry and will form the basis of the CTAO science analysis tools
 - AGNpy: software package developed by high-energy astrophysicists to compute of the photon spectra produced Active Galactic Nuclei
 - The workflow shown uses both Gammapy and AGNpy to fit the Spectral Energy Distribution of the BL Lacertae blasar



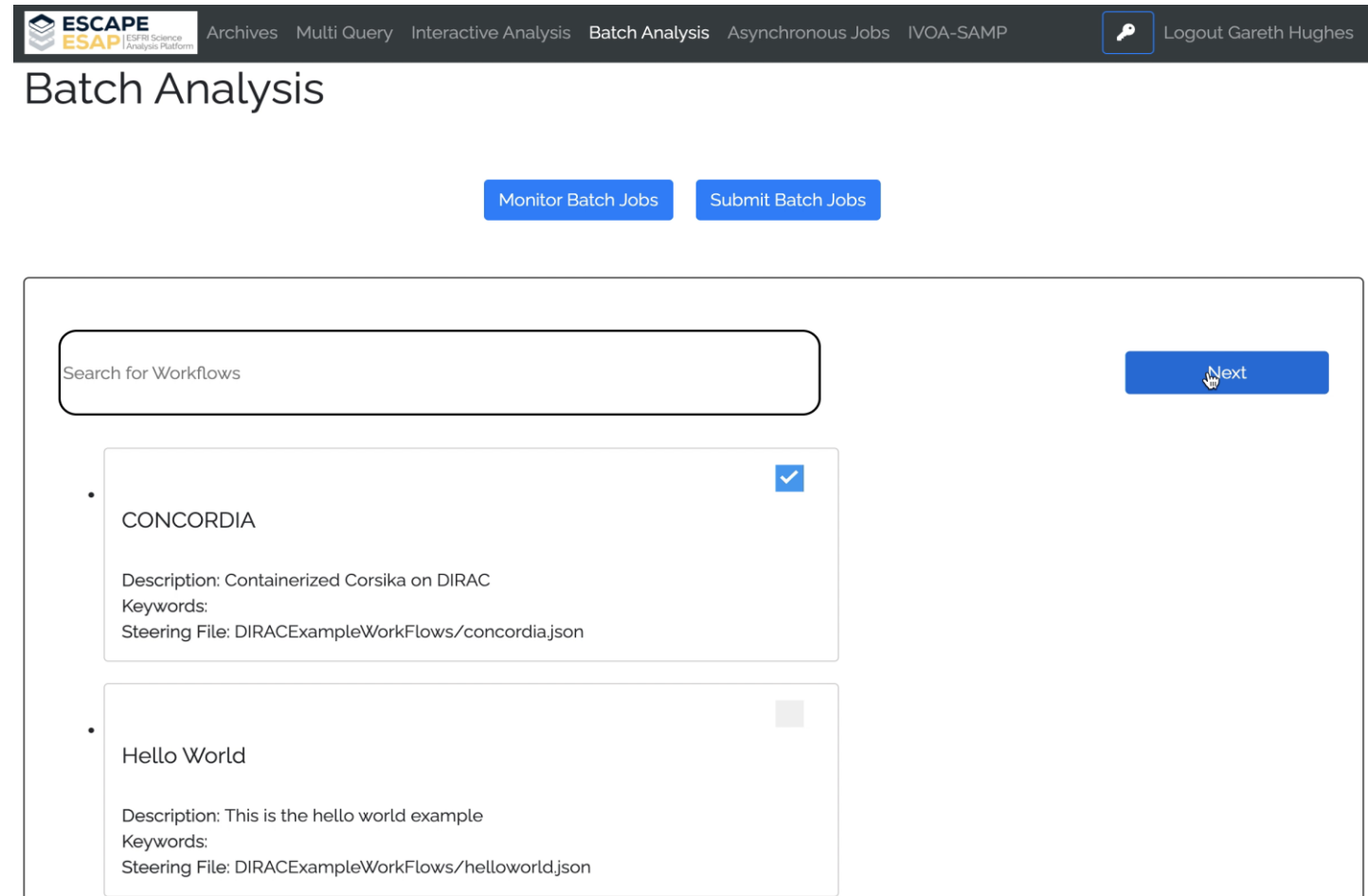
ESAP and Batch Processing

- CTAO needs to internally manage data processing at PByte-scale:
 - Service task of the Observatory
 - Automated batch processing needed
 - Data could be spread across multiple data centers
 - CTAO staff would be able to launch data management tasks
- A batch API and asynchronous worker component was developed to connect the ESAP to CTADIRAC
 - CTAO uses DIRAC as its workload management software
- Given the correct setup jobs can be launched



ESAP and Batch Processing

- Groups with access to a DIRAC system should be able to easily customize an ESAP to launch and monitor batch jobs
- Workflow:
 - A user can define a steering file
 - work ongoing with IVOA and CEVO to define standards
 - This tells the ESAP where to find a containerized version of your program
 - From there you can modify the parameters and submit the job
 - The jobs submitted can then be monitored via the Async worker or a custom Batch component
- Example
 - Links to WP3/OSSR CONCORDIA group
 - Potential links to ongoing and future work in WP2/DIOS
- In the future DIRAC will move to tokens making this process significantly easier

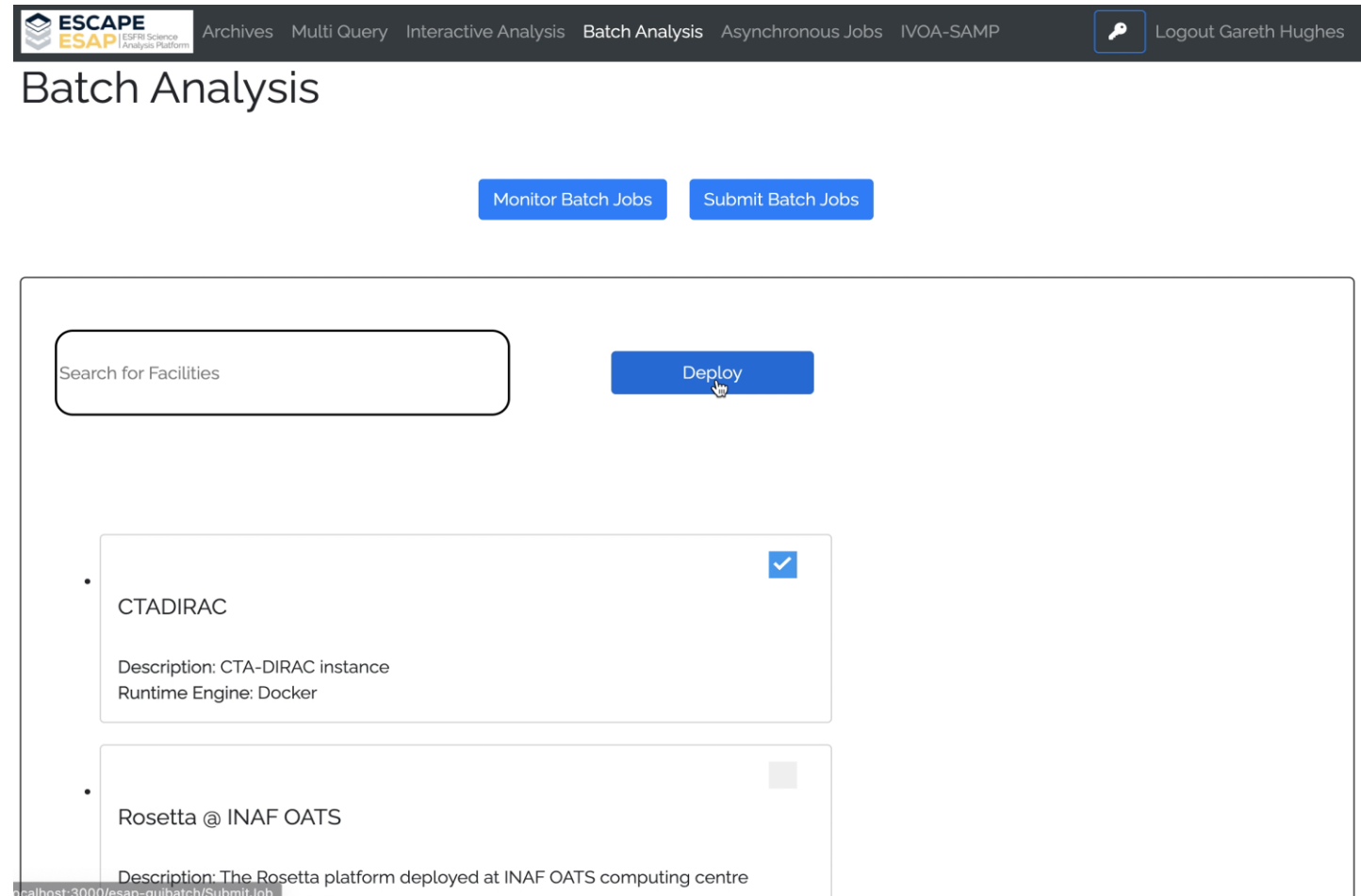


The screenshot shows the ESAP Batch Analysis interface. At the top, there is a navigation bar with links: Archives, Multi Query, Interactive Analysis, Batch Analysis (highlighted), Asynchronous Jobs, and IVOA-SAMP. A user profile 'Logout Gareth Hughes' is visible on the right. Below the navigation bar, the title 'Batch Analysis' is displayed. Two buttons, 'Monitor Batch Jobs' and 'Submit Batch Jobs', are present. The main content area features a search bar labeled 'Search for Workflows' and a 'Next' button. Below the search bar, two workflow entries are listed:

- CONCORDIA** (checked): Description: Containerized Corsika on DIRAC, Keywords: , Steering File: DIRACExampleWorkFlows/concordia.json
- Hello World** (unchecked): Description: This is the hello world example, Keywords: , Steering File: DIRACExampleWorkFlows/helloworld.json

ESAP and Batch Processing

- Groups with access to a DIRAC system should be able to easily customize an ESAP to launch and monitor batch jobs
- Workflow:
 - A user can define a steering file
 - work ongoing with IVOA and CEVO to define standards
 - This tells the ESAP where to find a containerized version of your program
 - From there you can modify the parameters and submit the job
 - The jobs submitted can then be monitored via the Async worker or a custom Batch component
- Example
 - Links to WP3/OSSR CONCORDIA group
 - Potential links to ongoing and future work in WP2/DIOS
- In the future DIRAC will move to tokens making this process significantly easier




The screenshot shows the ESCAPE ESAP Batch Analysis interface. At the top, there is a navigation bar with links: Archives, Multi Query, Interactive Analysis, Batch Analysis, Asynchronous Jobs, and IVOA-SAMP. A user profile for Gareth Hughes is visible in the top right corner. Below the navigation bar, the main heading is "Batch Analysis". There are two buttons: "Monitor Batch Jobs" and "Submit Batch Jobs". Below these buttons is a search bar labeled "Search for Facilities" and a "Deploy" button. A list of facilities is displayed below the search bar:

- CTADIRAC (checked)
 - Description: CTA-DIRAC instance
 - Runtime Engine: Docker
- Rosetta @ INAF OATS
 - Description: The Rosetta platform deployed at INAF OATS computing centre


At the bottom left of the interface, there is a URL: localhost:3000/esap-quickbatch/SubmitJob.

ESAP and Batch Processing

- Groups with access to a DIRAC system should be able to easily customize an ESAP to launch and monitor batch jobs
- Workflow:
 - A user can define a steering file
 - work ongoing with IVOA and CEVO to define standards
 - This tells the ESAP where to find a containerized version of your program
 - From there you can modify the parameters and submit the job
 - The jobs submitted can then be monitored via the Async worker or a custom Batch component
- Example
 - Links to WP3/OSSR CONCORDIA group
 - Potential links to ongoing and future work in WP2/DIOS
- In the future DIRAC will move to tokens making this process significantly easier



[Archives](#)
[Multi Query](#)
[Interactive Analysis](#)
[Batch Analysis](#)
[Asynchronous Jobs](#)
[IVOA-SAMP](#)

 Logout Gareth Hughes

Batch Analysis Submission

ESAP CONCORDIA

This workflow is the example

singularity_image	<input type="text" value="http://doublehi5.com/"/>
output_file_name	<input type="text" value="output.tar"/>
cputime	<input type="text" value="500"/>
job_name	<input type="text" value="ESAPTEST"/>
group_name	<input type="text" value="ESAPTEST_GROUP"/>
dirac_path	<input type="text" value="/vo.cta.in2p3.fr/user/g"/>
dirac_SE	<input type="text" value="CC-IN2P3-USER"/>
argument1	<input type="text" value="1"/>
argument2	<input type="text" value="22"/>
argument3	<input type="text" value="3"/>


Job Number: 33

Status: PENDING

Select RUN to submit the job with the above parameters or ABORT to cancel.

ESAP and Batch Processing

- Groups with access to a DIRAC system should be able to easily customize an ESAP to launch and monitor batch jobs
- Workflow:
 - A user can define a steering file
 - work ongoing with IVOA and CEVO to define standards
 - This tells the ESAP where to find a containerized version of your program
 - From there you can modify the parameters and submit the job
 - The jobs submitted can then be monitored via the Async worker or a custom Batch component
- Example
 - Links to WP3/OSSR CONCORDIA group
 - Potential links to ongoing and future work in WP2/DIOS
- In the future DIRAC will move to tokens making this process significantly easier


Archives
Multi Query
Interactive Analysis
Batch Analysis
Asynchronous Jobs
IVOA-SAMP

Logout Gareth Hughes

Jobs: 33
Page: 1

REFRESH

Run ID	Phase	Creation date	Parameters	Results	Action
batch	COMPLETED	6 Oct 2022, 15:40 UTC	11 parameters i	1 results i	<div>ARCHIVE</div>
batch	COMPLETED	6 Oct 2022, 15:39 UTC	2 parameters i	1 results i	<div>ARCHIVE</div>
batch	COMPLETED	6 Oct 2022, 15:39 UTC	11 parameters i	1 results i	<div>ARCHIVE</div>
batch	COMPLETED	6 Oct 2022, 15:38 UTC	2 parameters i	1 results i	<div>ARCHIVE</div>
batch	COMPLETED	6 Oct 2022, 15:38 UTC	2 parameters i	1 results i	<div>ARCHIVE</div>
batch	COMPLETED	6 Oct 2022, 15:37 UTC	2 parameters i	1 results i	<div>ARCHIVE</div>
batch	COMPLETED	6 Oct 2022, 15:17 UTC	2 parameters i	1 results i	<div>ARCHIVE</div>
batch	COMPLETED	6 Oct 2022, 15:16 UTC	2 parameters i	1 results i	<div>ARCHIVE</div>
batch	COMPLETED	6 Oct 2022, 15:15 UTC	2 parameters i	1 results i	<div>ARCHIVE</div>
batch	COMPLETED	6 Oct 2022, 15:14 UTC	2 parameters i	1 results i	<div>ARCHIVE</div>

Create a new Job

Run ID

key: "jobid",

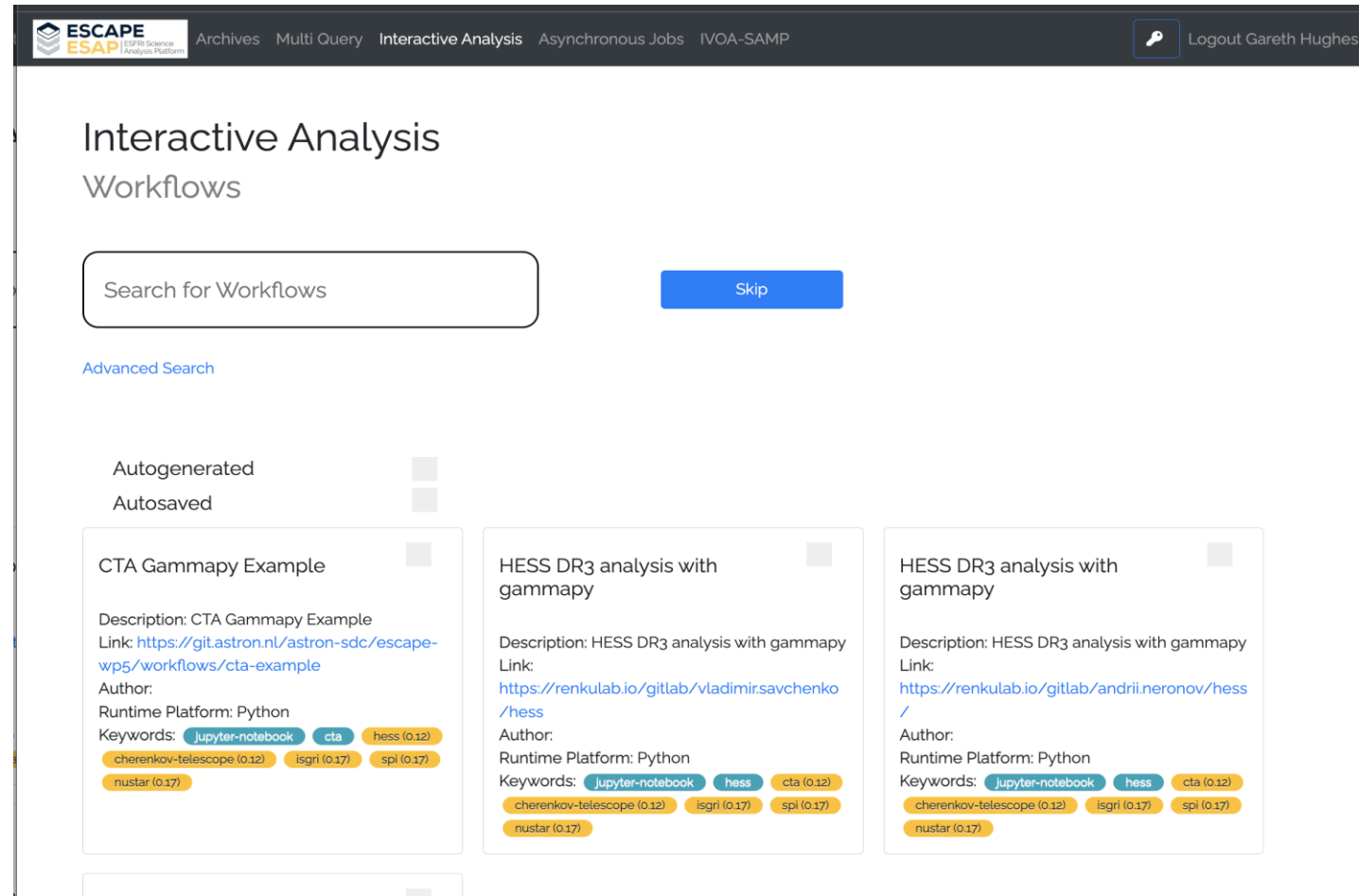
value: "19458006",

size: null,

mimeType: null

Exploring the ESAP for potential use in a Science Data Challenge

- Science Data Challenge a way to engage with CTAO users
- V. Savchenko has deployed a version of ESAP using Kubernetes on one of the future CTAO Data Centers (CSCS)
 - With the aim to investigating how it might be used for a CTAO data challenge
- They found it could be **easily customized**
 - github based login
 - addition of workflows
 - advanced search options and use of metadata
- A mybinder instance has also been added and made available to the platform
 - This work is being fed back into WP5/ESAP
- Challenge: For a Data Challenge the workflows would need to be **persistent**

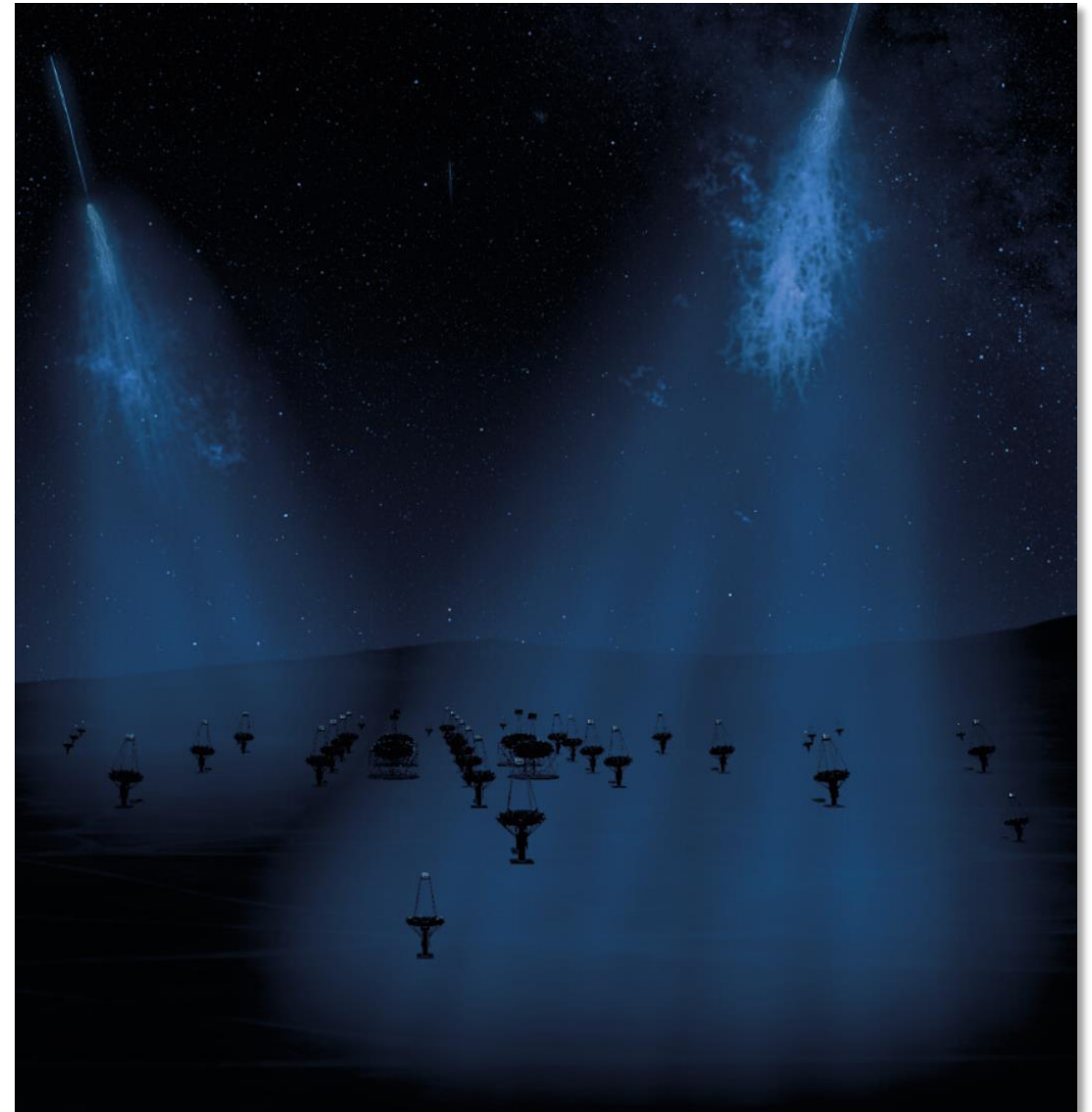


The screenshot shows the ESAP Interactive Analysis Workflows interface. At the top, there's a navigation bar with links: Archives, Multi Query, Interactive Analysis, Asynchronous Jobs, and IVOA-SAMP. A user is logged in as Gareth Hughes. The main heading is 'Interactive Analysis Workflows'. Below this is a search bar labeled 'Search for Workflows' and a 'Skip' button. There's also a link for 'Advanced Search'. The page displays a list of workflows under 'Autogenerated' and 'Autosaved' sections. Three workflows are visible:

- CTA Gammapy Example**: Description: CTA Gammapy Example. Link: <https://git.astron.nl/astron-sdc/escape-wp5/workflows/cta-example>. Author: [redacted]. Runtime Platform: Python. Keywords: jupyter-notebook, cta, hess (0.12), cherenkov-telescope (0.12), isgri (0.17), spi (0.17), nustar (0.17).
- HESS DR3 analysis with gammapy**: Description: HESS DR3 analysis with gammapy. Link: <https://renkulab.io/gitlab/vladimir.savchenko/hess>. Author: [redacted]. Runtime Platform: Python. Keywords: jupyter-notebook, hess, cta (0.12), cherenkov-telescope (0.12), isgri (0.17), spi (0.17), nustar (0.17).
- HESS DR3 analysis with gammapy**: Description: HESS DR3 analysis with gammapy. Link: <https://renkulab.io/gitlab/andrii.neronov/hess/>. Author: [redacted]. Runtime Platform: Python. Keywords: jupyter-notebook, hess, cta (0.12), cherenkov-telescope (0.12), isgri (0.17), spi (0.17), nustar (0.17).

Conclusions

- CTAO has **contributed** workflows and functionality to the ESAP
- The ESAP provides an **excellent toolbox** from which one can build and tailor a Science Platform
- CTAO has been able to identify key **technologies** and ideas which it will further investigate in the future
- CSCS colleagues have been able to **deploy** their own version of the ESAP and **customize** it, to investigate possible use for a Science Data Challenge
- We look forward to further work together on these topics in future collaborations



Thank You

● ESAP work package for their active support and engagement

- John Swinbank
- Klaas Kliffen
- Nico Vermaas
- Stelios Voutsinas
- Hugh Dickinson
- Zheng Mayer
- James Collinson
- Yan Grange

● CTAO

- Federico Ferrini
- Jose-Luis Contreras
- Nuria Alvarez Crespo
- Jordi Delgado
- Catherine Boisson
- Mathieu Servillat

● CSCS Team

- Volodymyr Savchenko
- Andrii Neronov
- Victor Holanda

ESCAPE to the Future
25-26 October 2022
Brussels, Belgium

SKA Regional Centres and ESAP

Dr James Collinson
Operations Data Scientist

SKAO



- SKA Regional Centres (**SRCs**)
 - Capabilities to meet challenges of **SKAO data**
 - High level architectural vision
- ESCAPE prototyping activities
 - **Science platform** and **data lake** for SKAO use cases
 - **Bringing compute to the data**
- ESCAPE's legacy within the SKAO
 - Current SRC Network **prototyping** activities
 - **Other benefits**: collaborators, cloud techs, best practices

The SKAO Project

SKA MID

Karoo, South Africa

197 dishes

0.35 - 15 GHz

65K frequency channels



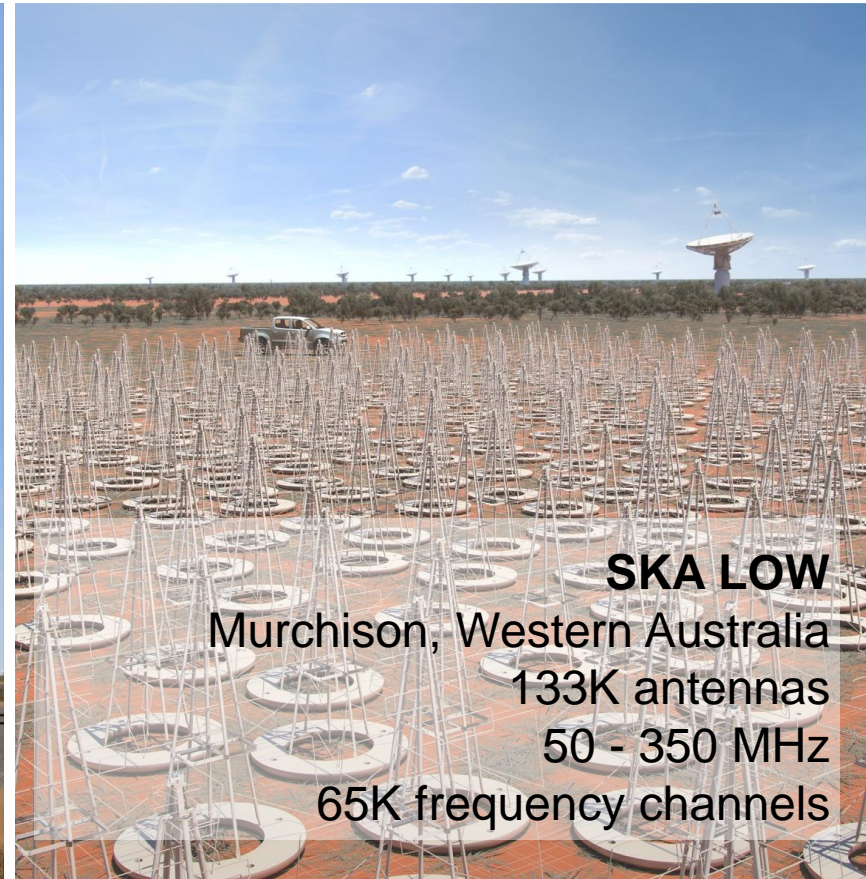
SKA LOW

Murchison, Western Australia

133K antennas

50 - 350 MHz

65K frequency channels



Test systems already taking data. Main science programmes from ~2028/9. 50 year lifetime.

SKA Regional Centres: SKAO data processing stages

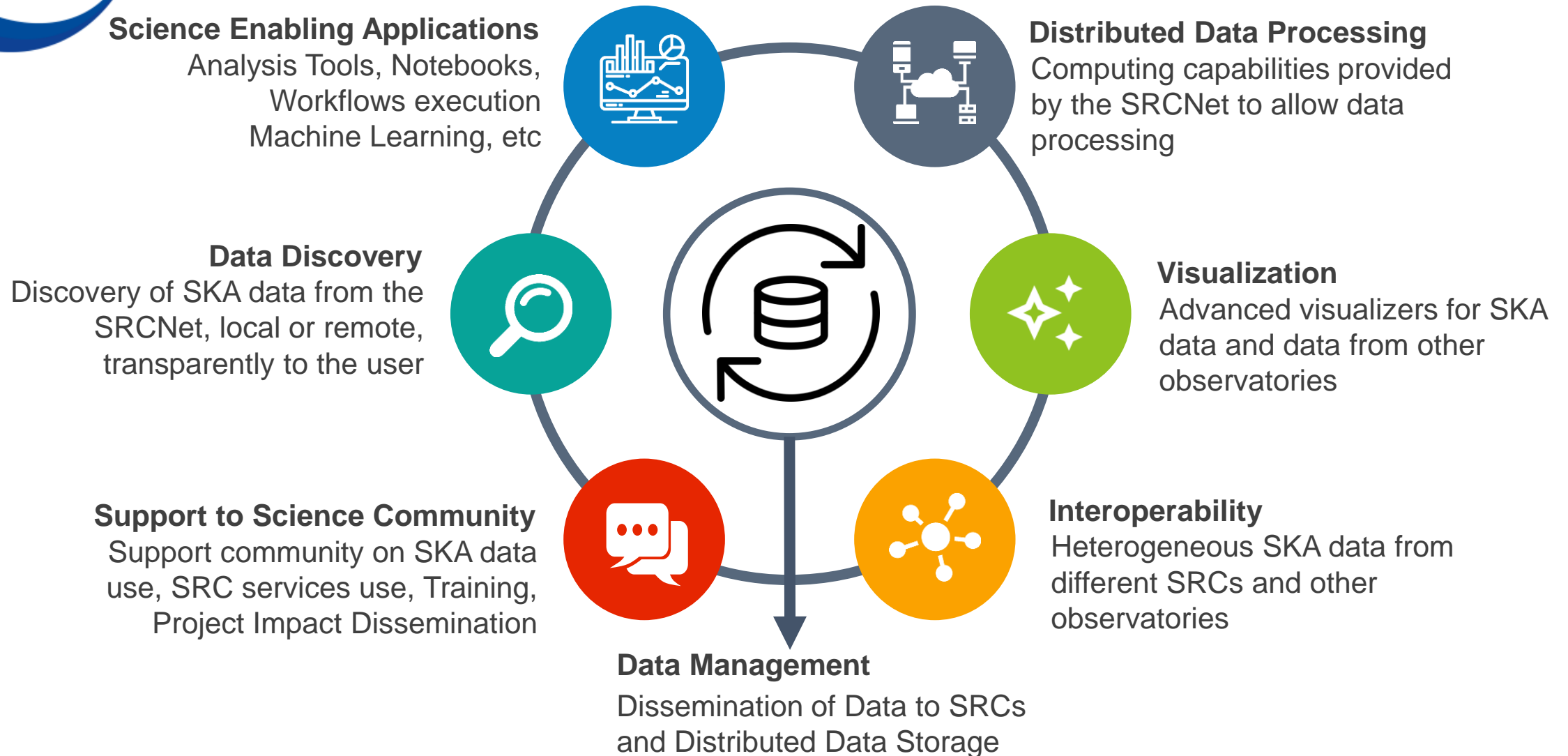


* Data rates approximate

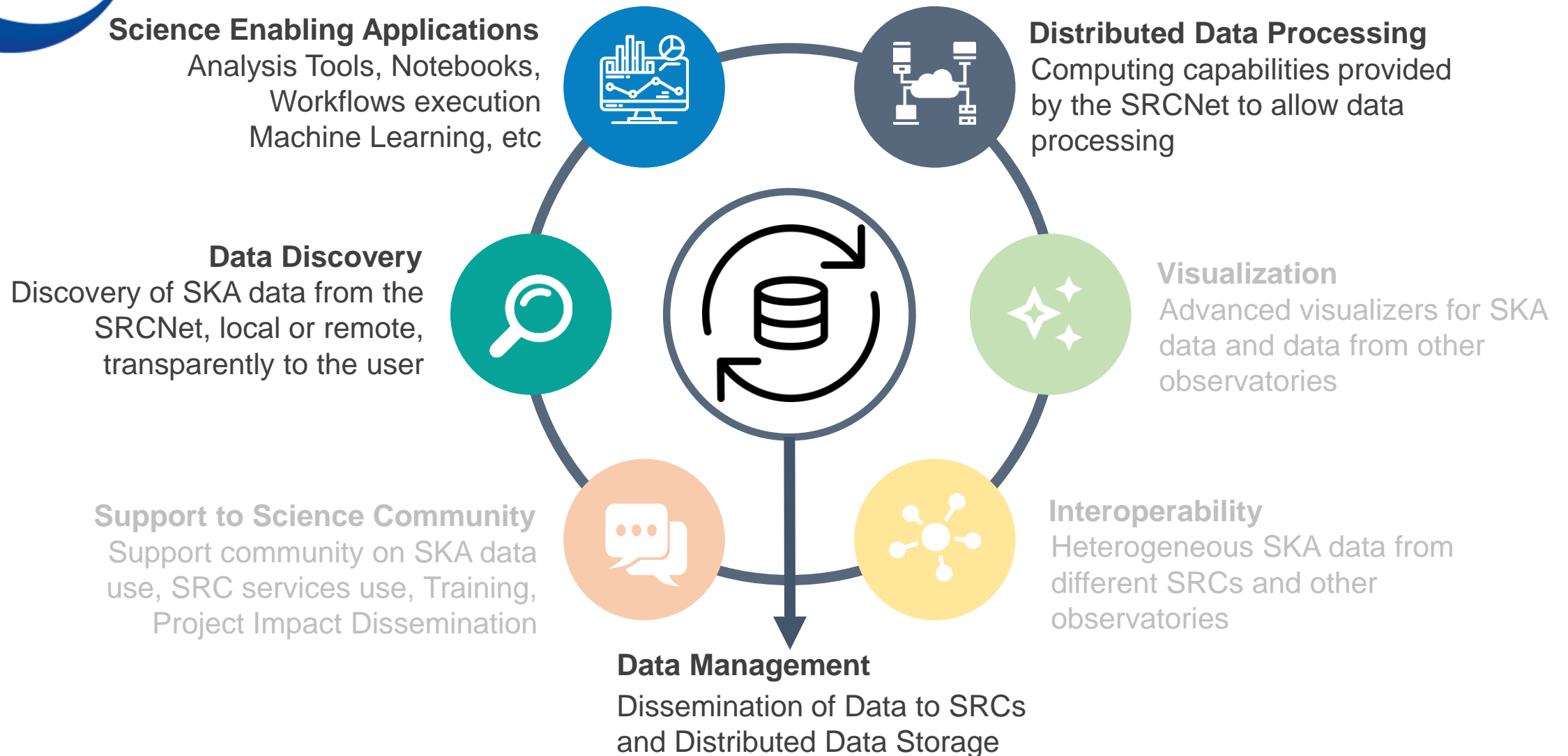
The SRC Vision

"To ensure that **scientists can access **SKA data products** and use them to make **discoveries**"**

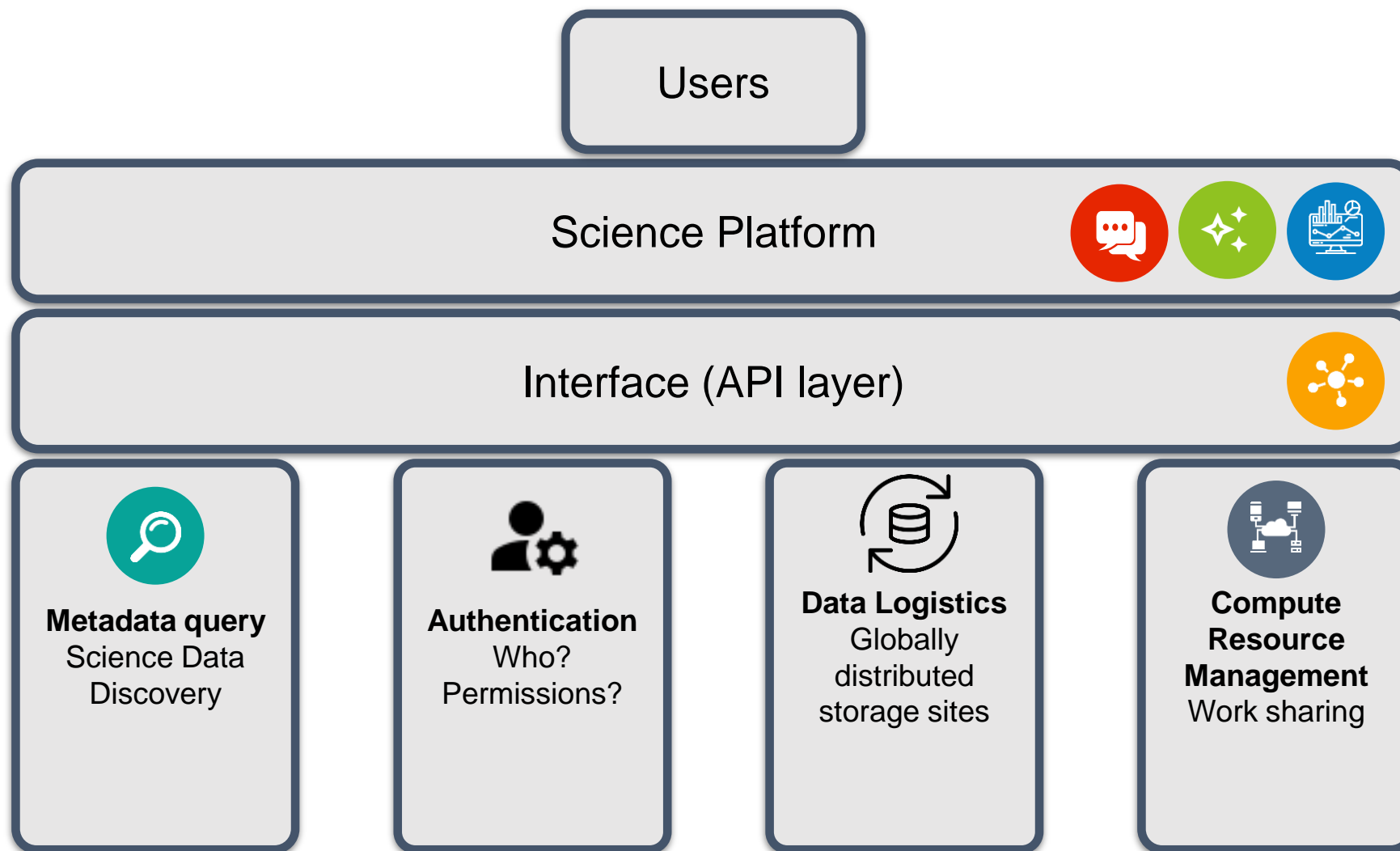
SKA Regional Centre Capabilities



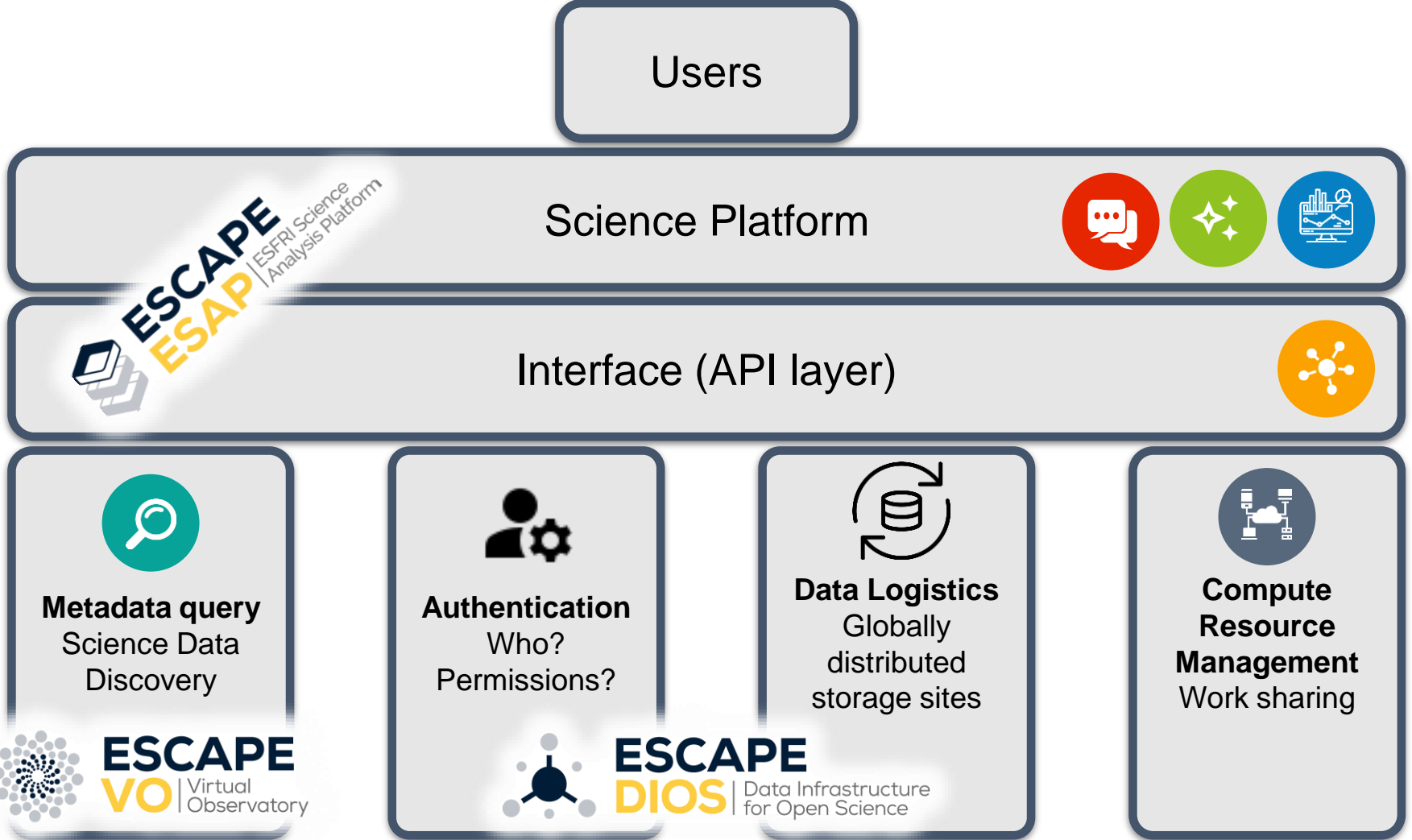
SKA Regional Centre Capabilities



SRC Logical View

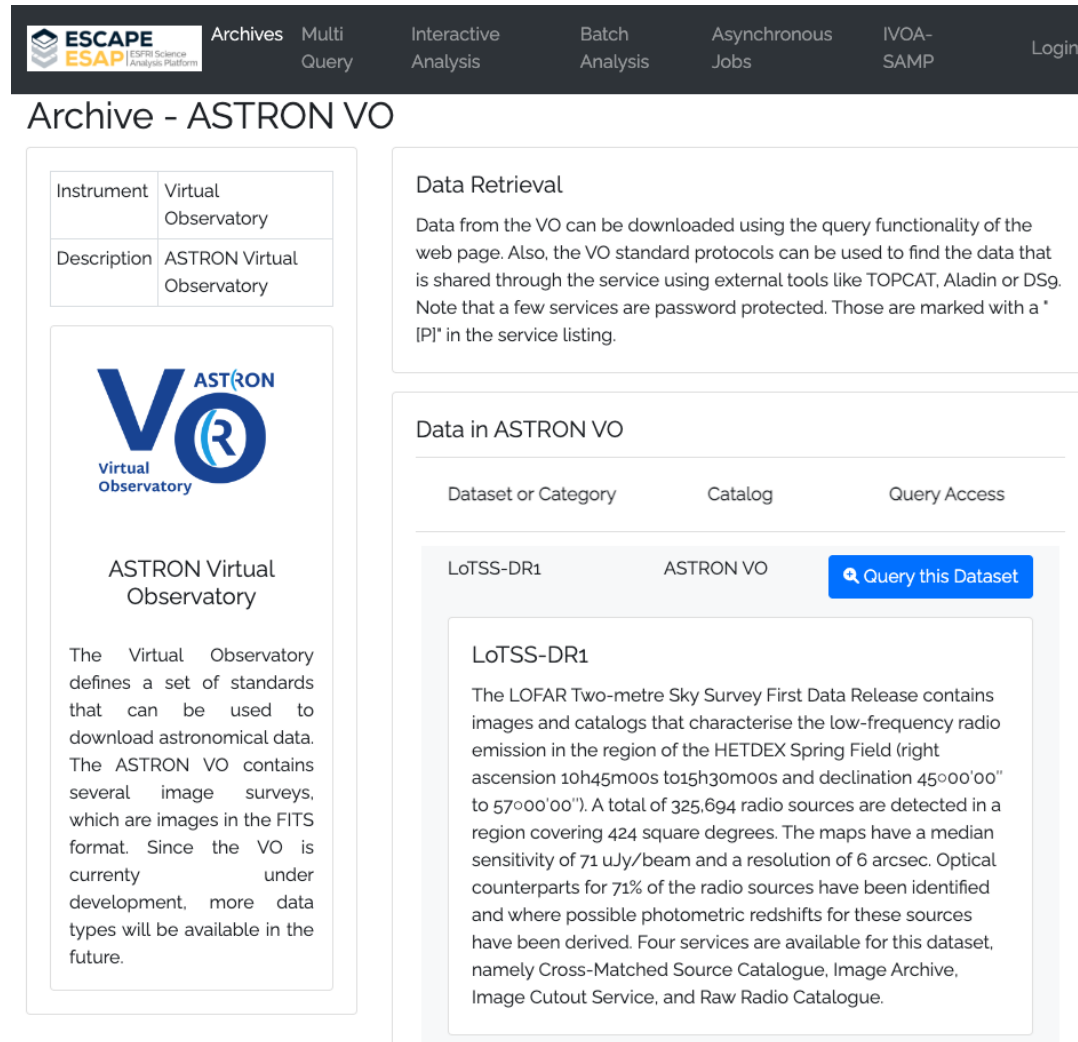


SRC Logical View



ESCAPE prototyping - SKAO

- Precursor data archives in ESAP (thanks to ASTRON folks!)
- Helps inform decisions on **archive structure**



The screenshot shows the ESCAPE ESAP Science Analysis Platform interface. The top navigation bar includes links for Archives, Multi Query, Interactive Analysis, Batch Analysis, Asynchronous Jobs, IVOA-SAMP, and Login. The main content area is titled "Archive - ASTRON VO".

On the left, there is a table with the following content:

Instrument	Virtual Observatory
Description	ASTRON Virtual Observatory

Below the table is the ASTRON Virtual Observatory logo, which consists of a large "V" and a circular "R" with "ASTRON" above and "Virtual Observatory" below.

Under the logo, the text reads: "ASTRON Virtual Observatory".

The main text block describes the Virtual Observatory: "The Virtual Observatory defines a set of standards that can be used to download astronomical data. The ASTRON VO contains several image surveys, which are images in the FITS format. Since the VO is currently under development, more data types will be available in the future."

On the right, the "Data Retrieval" section states: "Data from the VO can be downloaded using the query functionality of the web page. Also, the VO standard protocols can be used to find the data that is shared through the service using external tools like TOPCAT, Aladin or DS9. Note that a few services are password protected. Those are marked with a '*' [PI] in the service listing."

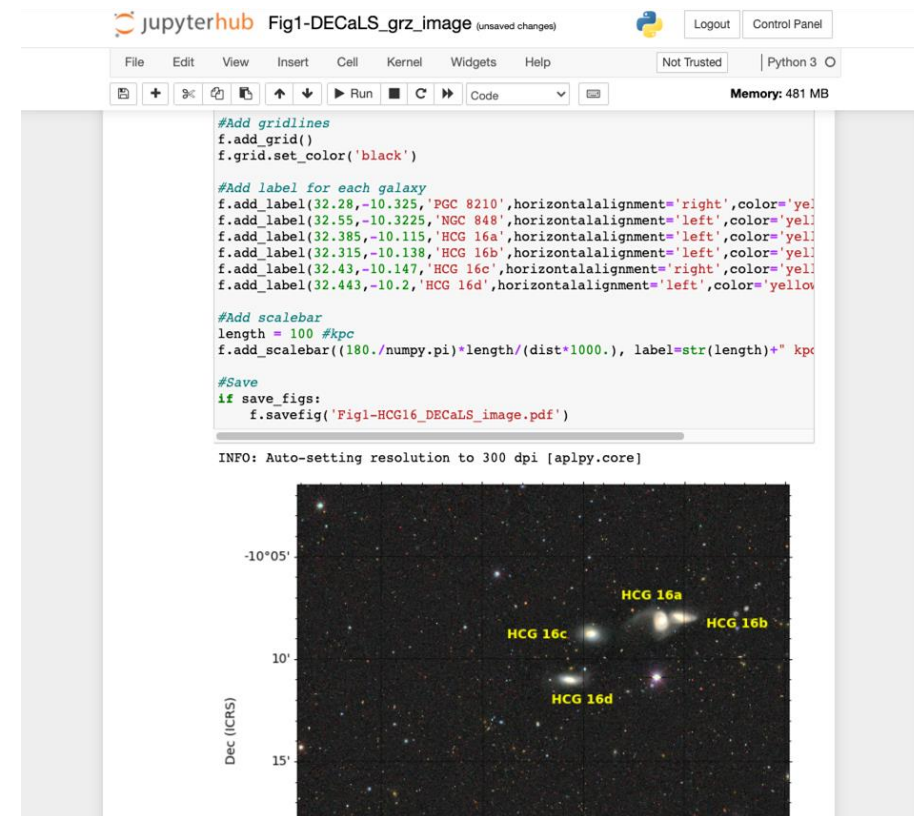
Below this, the "Data in ASTRON VO" section features a table with columns: "Dataset or Category", "Catalog", and "Query Access".

Dataset or Category	Catalog	Query Access
LoTSS-DR1	ASTRON VO	Query this Dataset

Below the table, the "LoTSS-DR1" section provides a detailed description: "The LOFAR Two-metre Sky Survey First Data Release contains images and catalogs that characterise the low-frequency radio emission in the region of the HETDEX Spring Field (right ascension 10h45m00s to 15h30m00s and declination 45°00'00" to 57°00'00"). A total of 325,694 radio sources are detected in a region covering 424 square degrees. The maps have a median sensitivity of 71 uJy/beam and a resolution of 6 arcsec. Optical counterparts for 71% of the radio sources have been identified and where possible photometric redshifts for these sources have been derived. Four services are available for this dataset, namely Cross-Matched Source Catalogue, Image Archive, Image Cutout Service, and Raw Radio Catalogue."

- JupyterHub on STFC Cloud
- Augmentations for SKA
 - Indigo IAM authentication
 - Persistent storage volumes
 - Binder service to dynamically build environments
 - Dask Gateway (WIP) – provision ephemeral compute clusters on demand

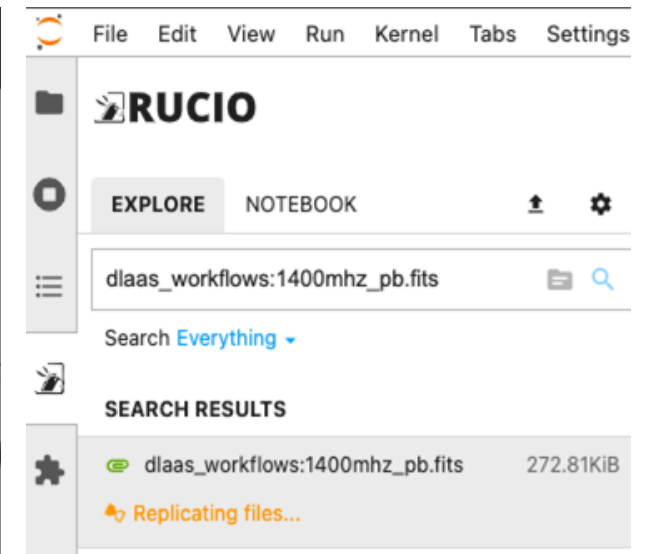
Turn a Git repo into a collection of interactive notebooks



ESCAPE prototyping - SKAO

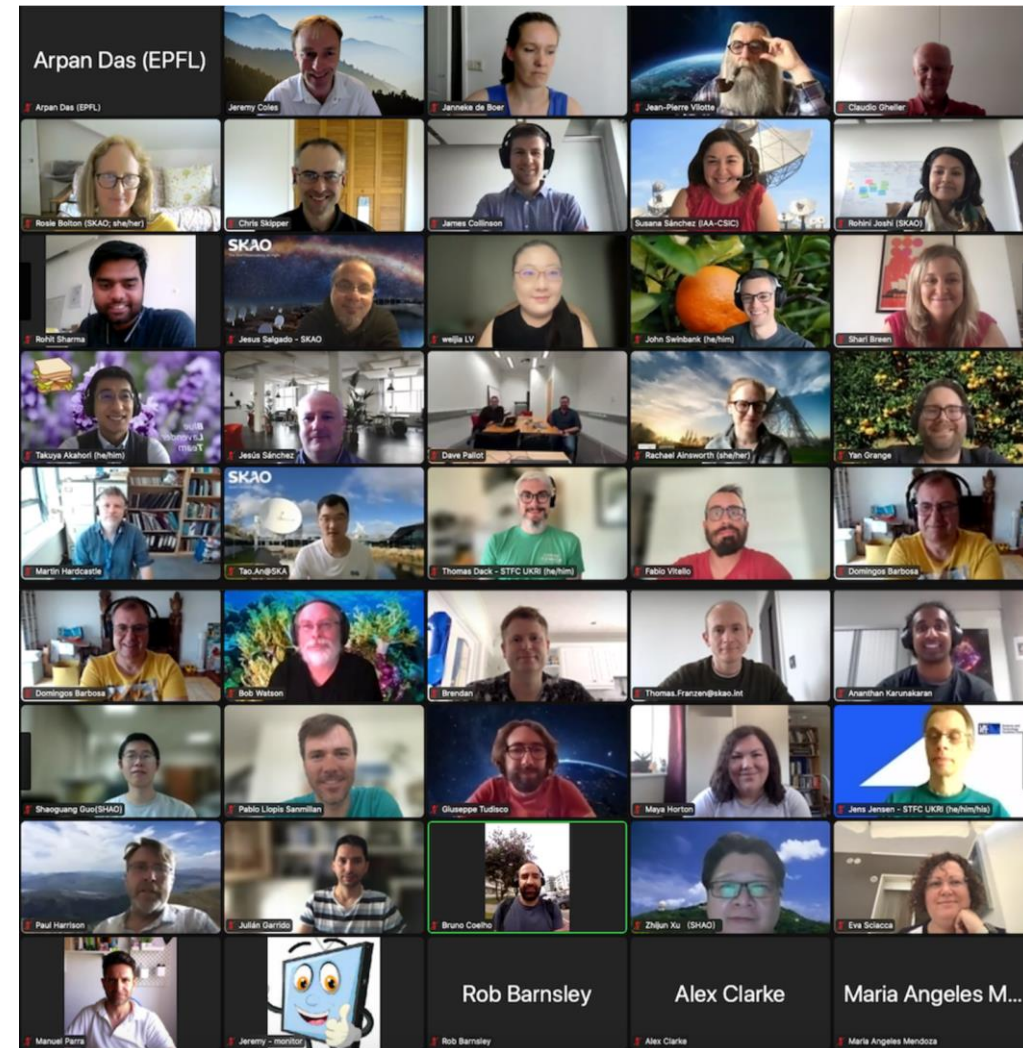
- SKAO **Rucio** instance
- RSEs at SKAO sites
- Full mesh **automated functional tests**
- Integrated with JupyterHub prototype - '**datalake as a service**'

Transfer success site matrix						
Src\Dst	SPSRC_STORM	JPSRC_STORM	IMPERIAL	CNAF	AUSSRC_STORM	STFC_STORM
STFC_STORM	100%	100%	100%	100%	100%	NO DATA
SPSRC_STORM	NO DATA	100%	100%	100%	100%	100%
JPSRC_STORM	100%	NO DATA	100%	100%	100%	100%
IMPERIAL	100%	100%	NO DATA	100%	61%	100%
CNAF	100%	100%	100%	NO DATA	100%	100%
AUSSRC_STORM	100%	100%	100%	100%	NO DATA	100%

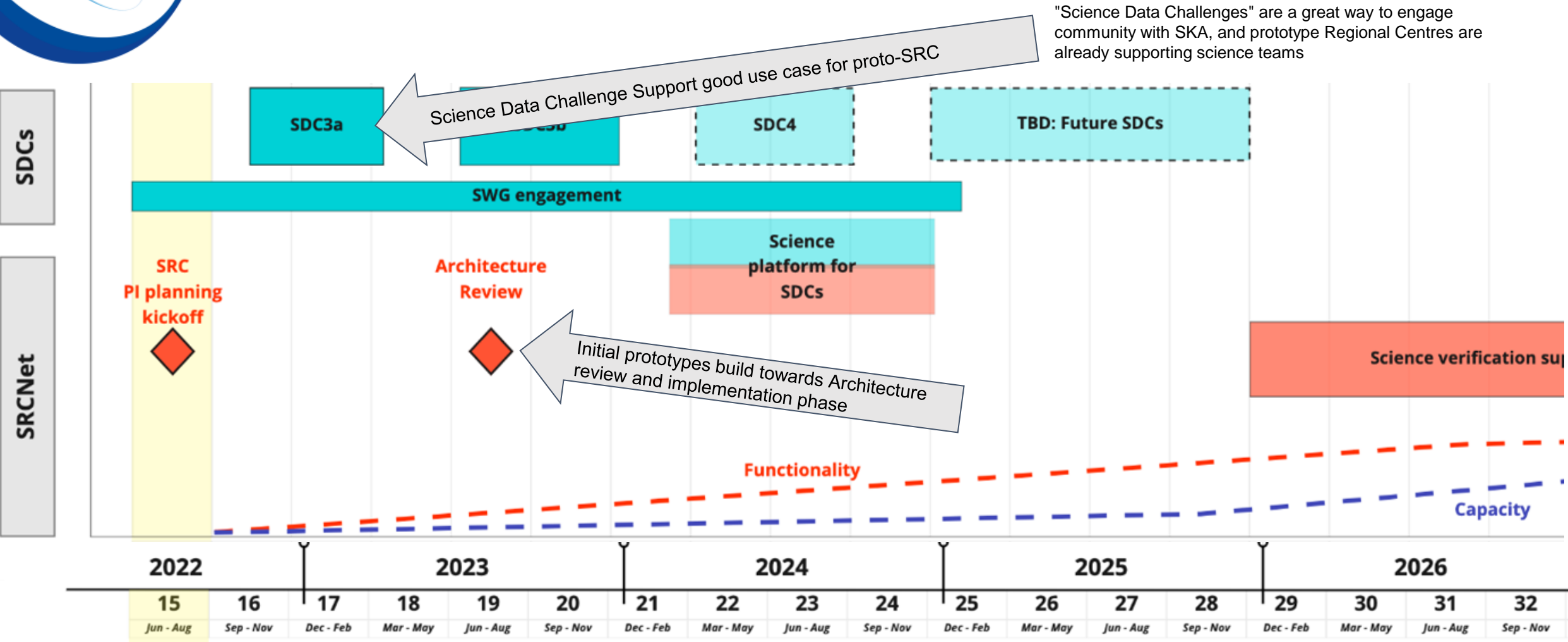


SRC Network Prototyping - 2022 onwards

- Global team of development teams
- 12 countries plus SKAO
- ~1000 dev days every 3 months, set to grow
- ESCAPE candidates further assessed include **Rucio**, **ESAP**, **Indigo IAM**
- ESCAPE collaborations will continue!



SRC Network Prototyping - 2022 onwards



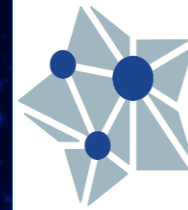
Other Benefits of ESCAPE

- **Collaborations** - experts in range of fields
 - A number of ESCAPE members are now involved in **SRC prototyping** (**ASTRON, IAA**)
 - Will continue to work with the contacts we have made (collaboration agreements with e.g. **CERN/CTAO**)
- **Service operations experience**
 - Data lake ops
 - **Kubernetes** deployments
 - Automated integration testing

The background of the slide is a deep blue space filled with numerous small, bright white stars. In the center, there is a large, semi-circular structure resembling a particle detector or a telescope, composed of many blue, rectangular segments arranged in a ring. The structure has a complex, layered appearance with many small protrusions and recesses.

Thanks to all our collaborators!

ESCAPE to the Future
25-26 October 2022
Brussels, Belgium



JIVE

Joint Institute for VLBI
ERIC

The EVN Archive Portal

Bringing the science to the data using JupyterHub

Aard Keimpema

keimpema@jive.eu



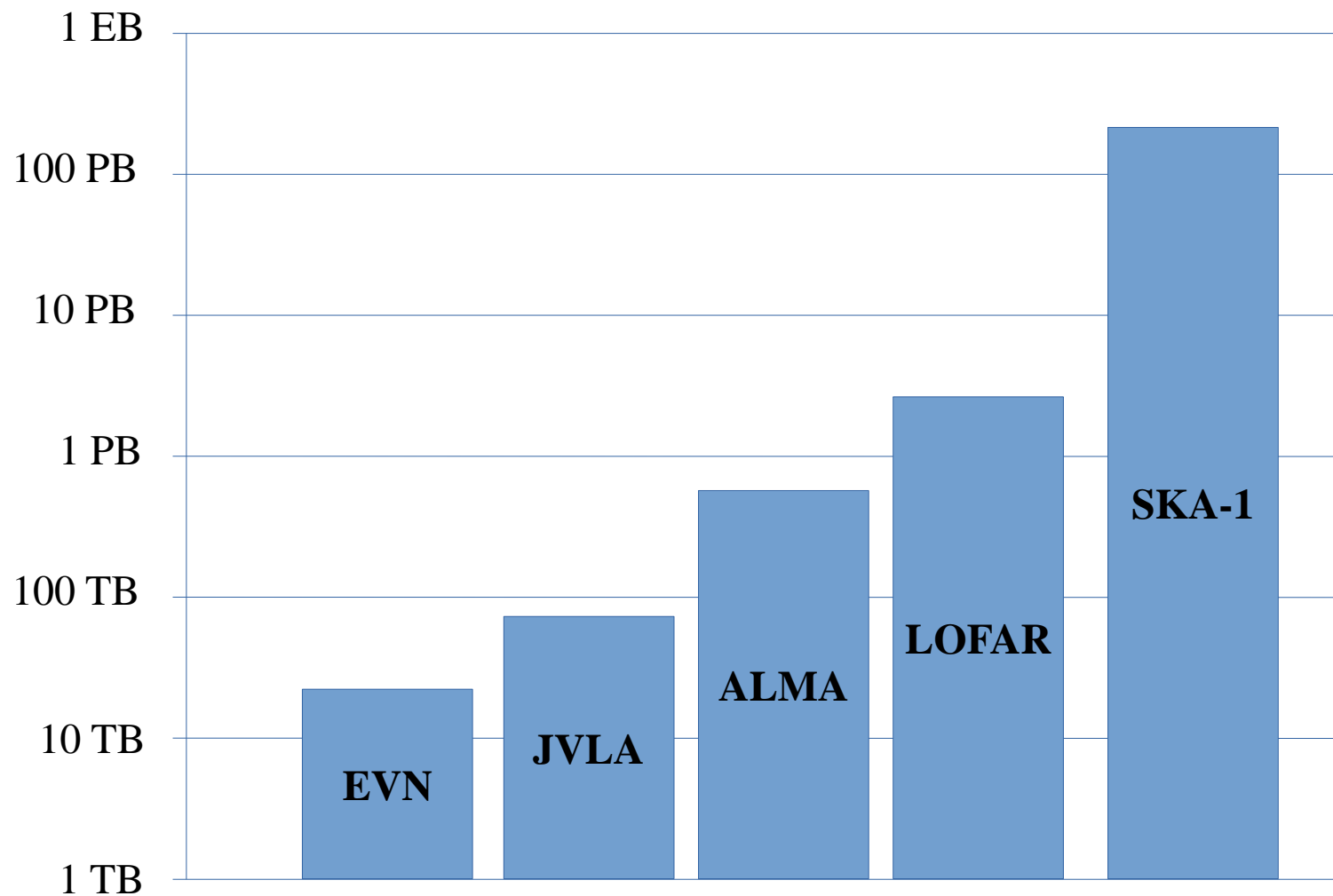
JIVE and the EVN

- JIVE is located in the Netherlands
- Technical operations and user support for the European VLBI Network
- The EVN is an *Open Skies* facility
- All EVN data is public after 1 year



The European VLBI Network

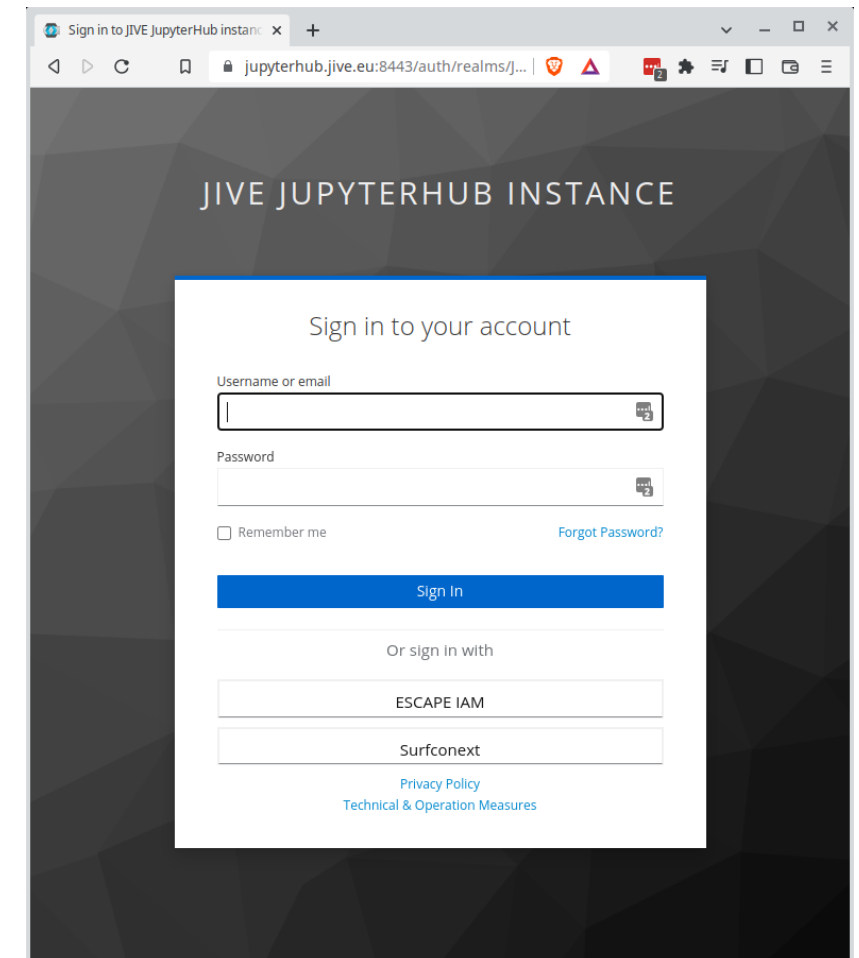
Yearly data volumes (archived data)



Remote interactive pipelines

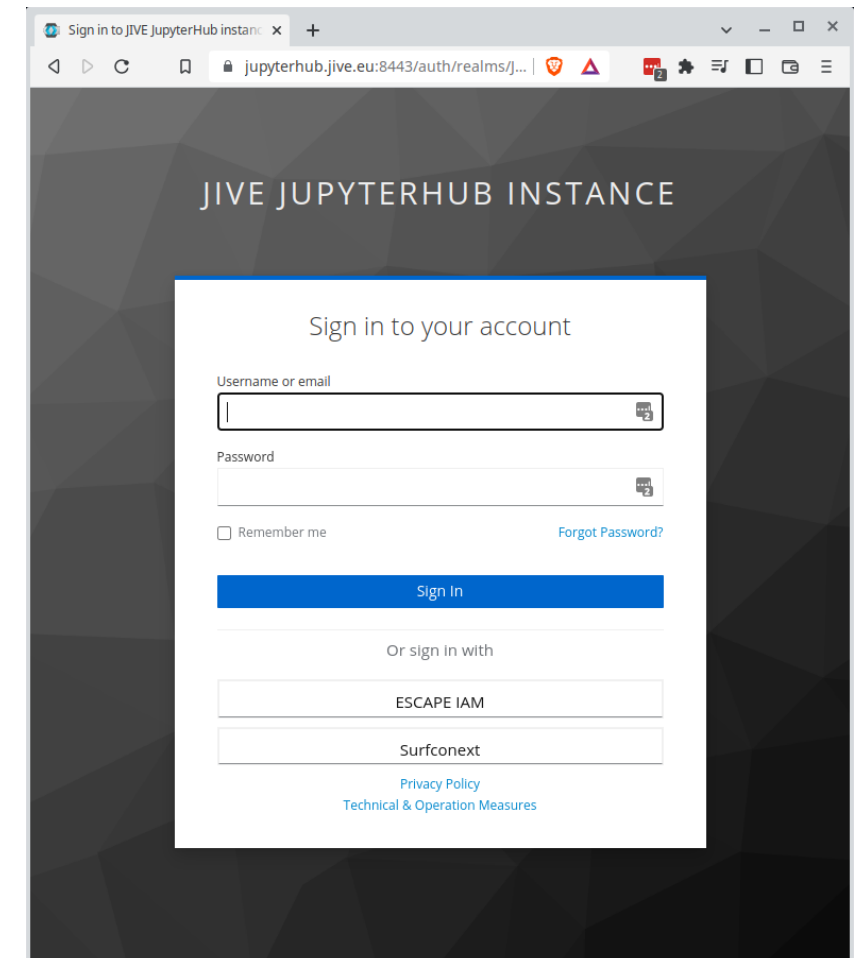
- Data should be processed close to where it is archived
- Solutions should accommodate both automated pipelines and interactive data processing
- Main advantages of using Jupyter for remote interactive pipelines:
 - **User friendly**: Notebooks are easy and intuitive to use; all results are embedded in a single document
 - **Interactivity is optional**: Notebooks can optionally be run as a non-interactive pipeline for batch processing
 - **Accountability**: Data reduction process is self-documenting and fully repeatable

- JupyterHub instance hosted at JIVE
- Open service: All interested users can make a free account and process any observation from the EVN archive
- Builds on the results from WP3 and WP4
- Allow federated logins: ESCAPE IAM, SurfCONEXT; Applying for eduGAIN access
- Integrated with the ESAP using BinderHub



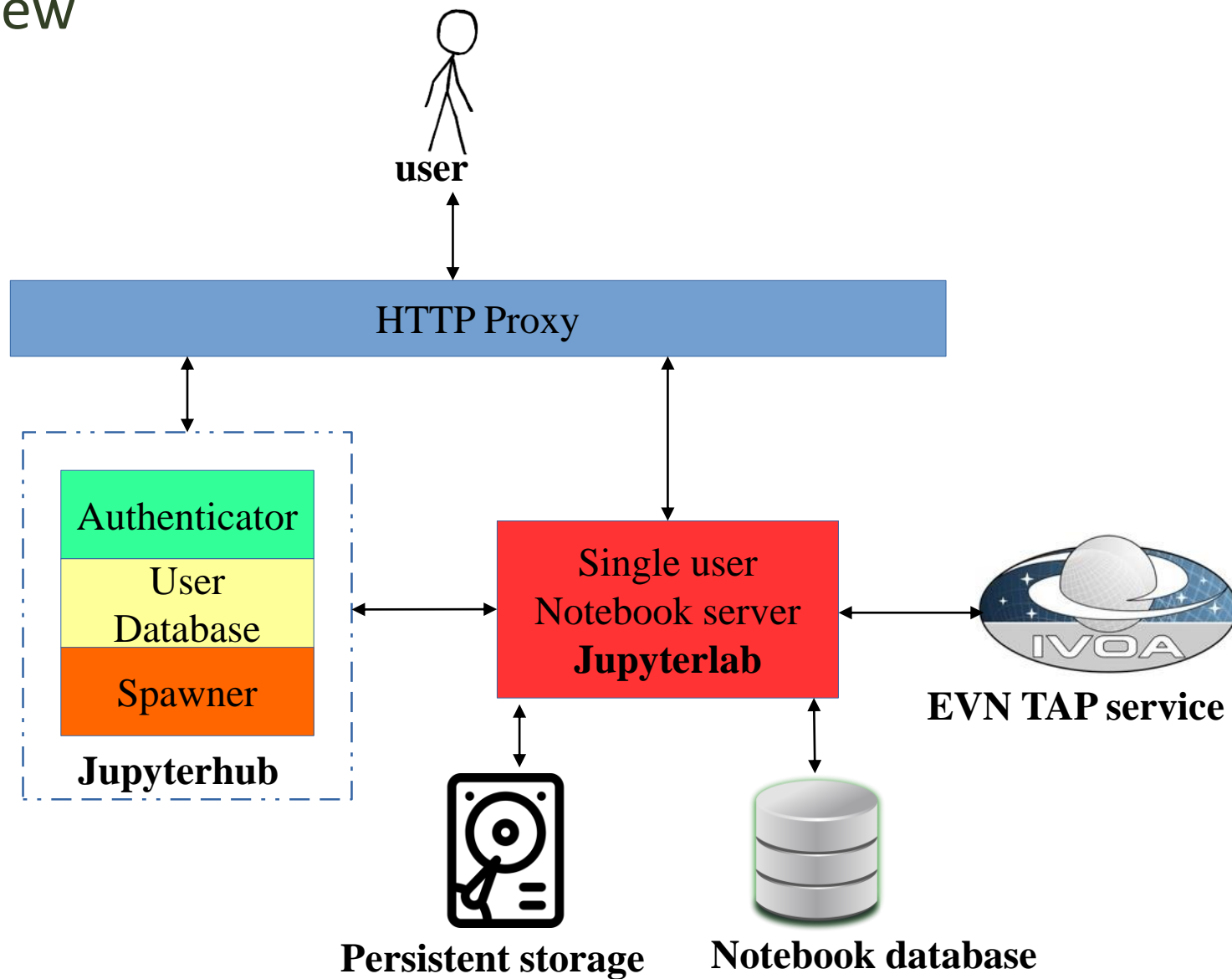
<https://jupyterhub.jive.eu>

- Data on the EVN archive is
 - **Findable:** Through VO and web interface
 - **Accessible:** EVN data is public after one year and is accessible through the VO or web interface.
 - **Interoperable:** Only open source programs and open data formats are used (FITS, Measurement Set)
 - **Reusable:** Data comes with all relevant metadata and there are no restrictions on use
- Users can submit their notebooks back to the EVN archive allowing other researchers to reproduce their results

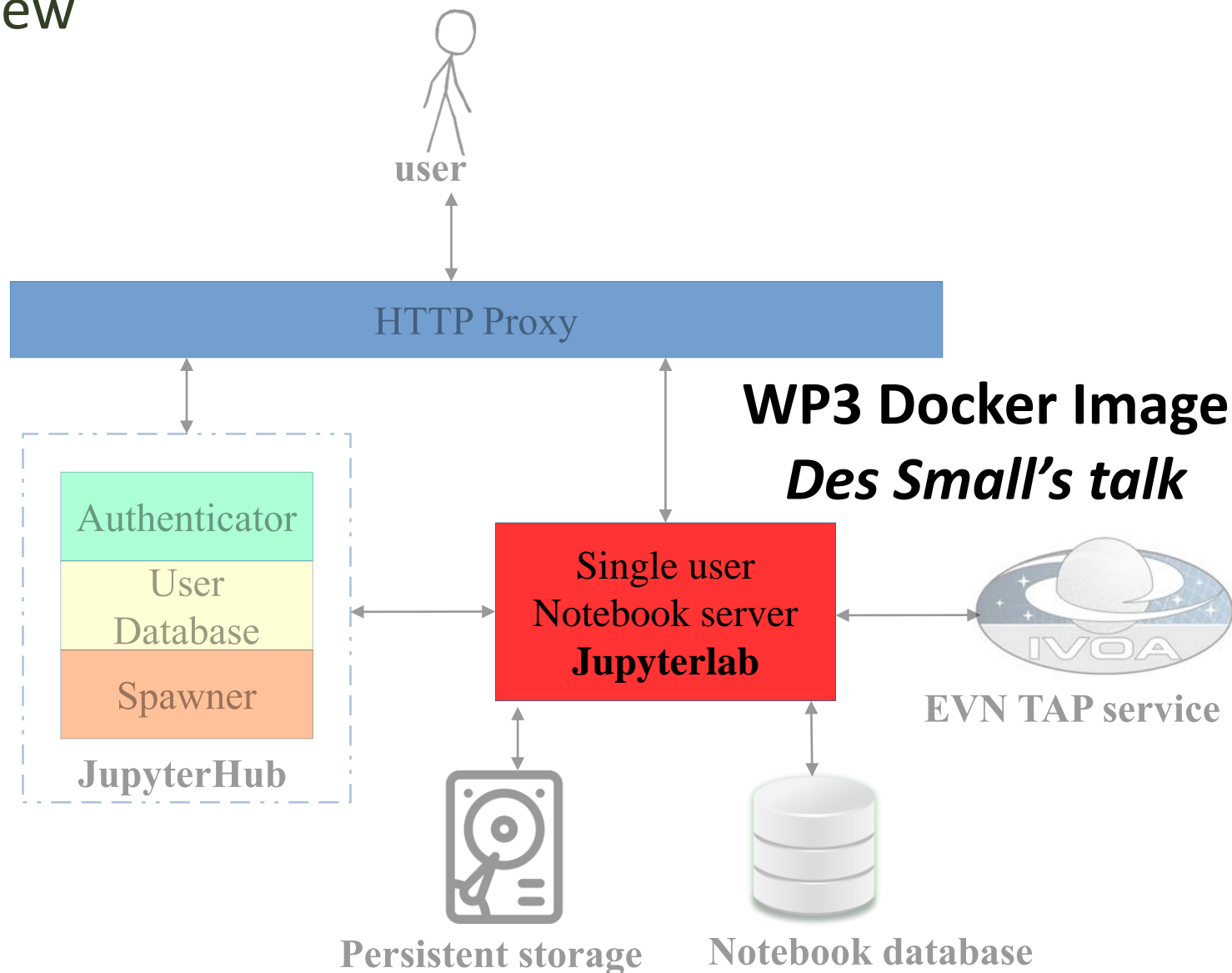


<https://jupyterhub.jive.eu>

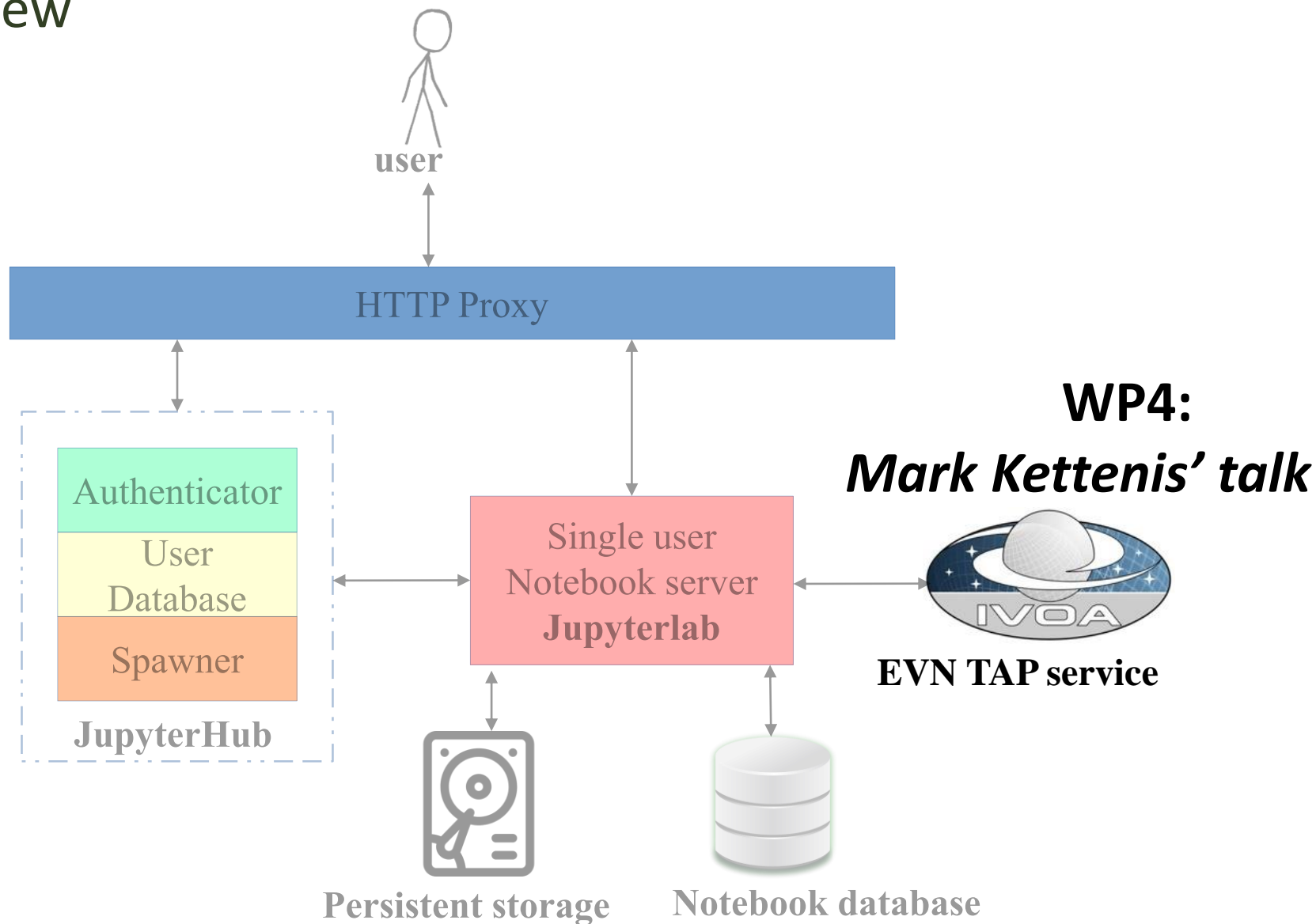
Overview



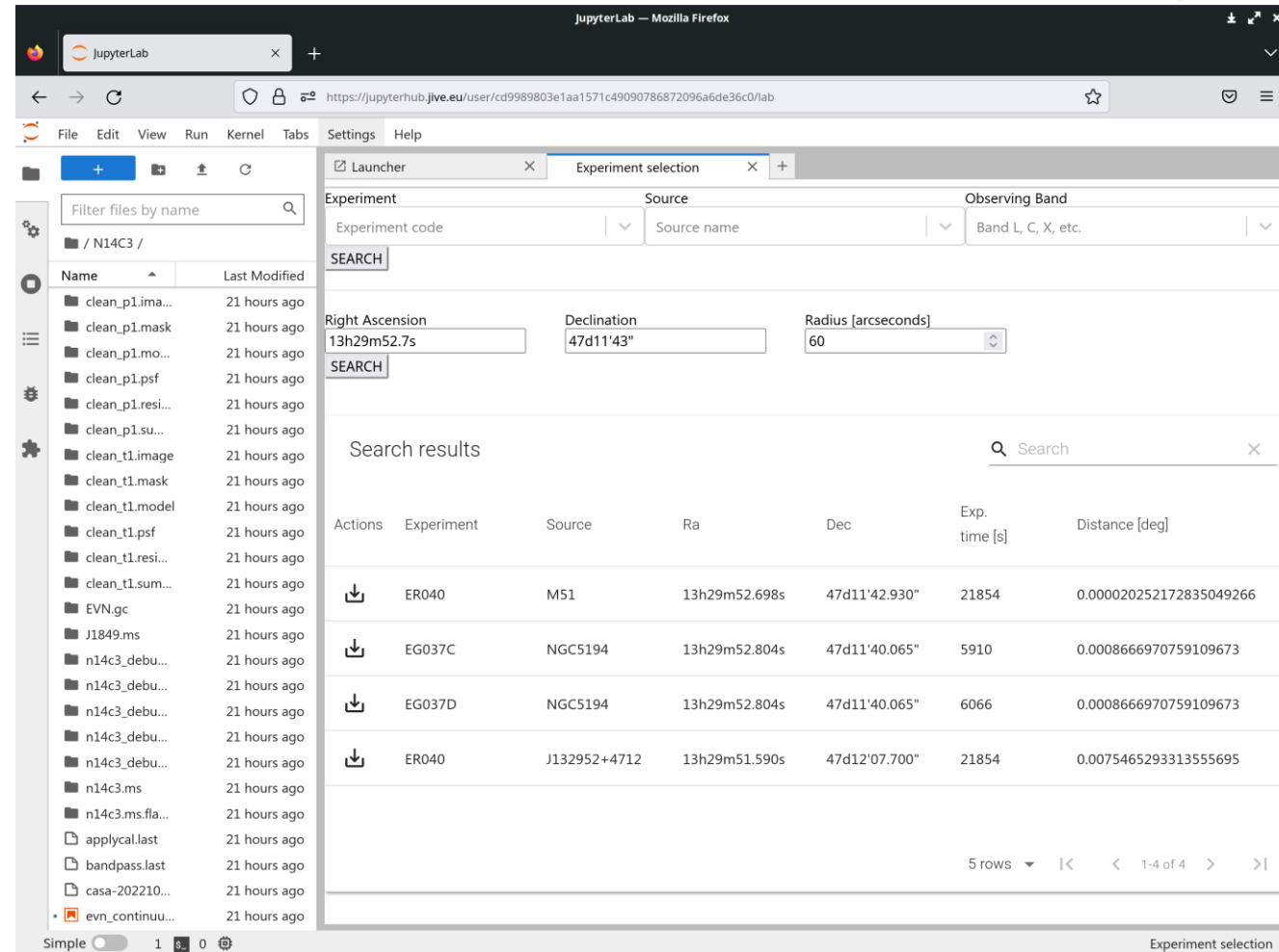
Overview



Overview



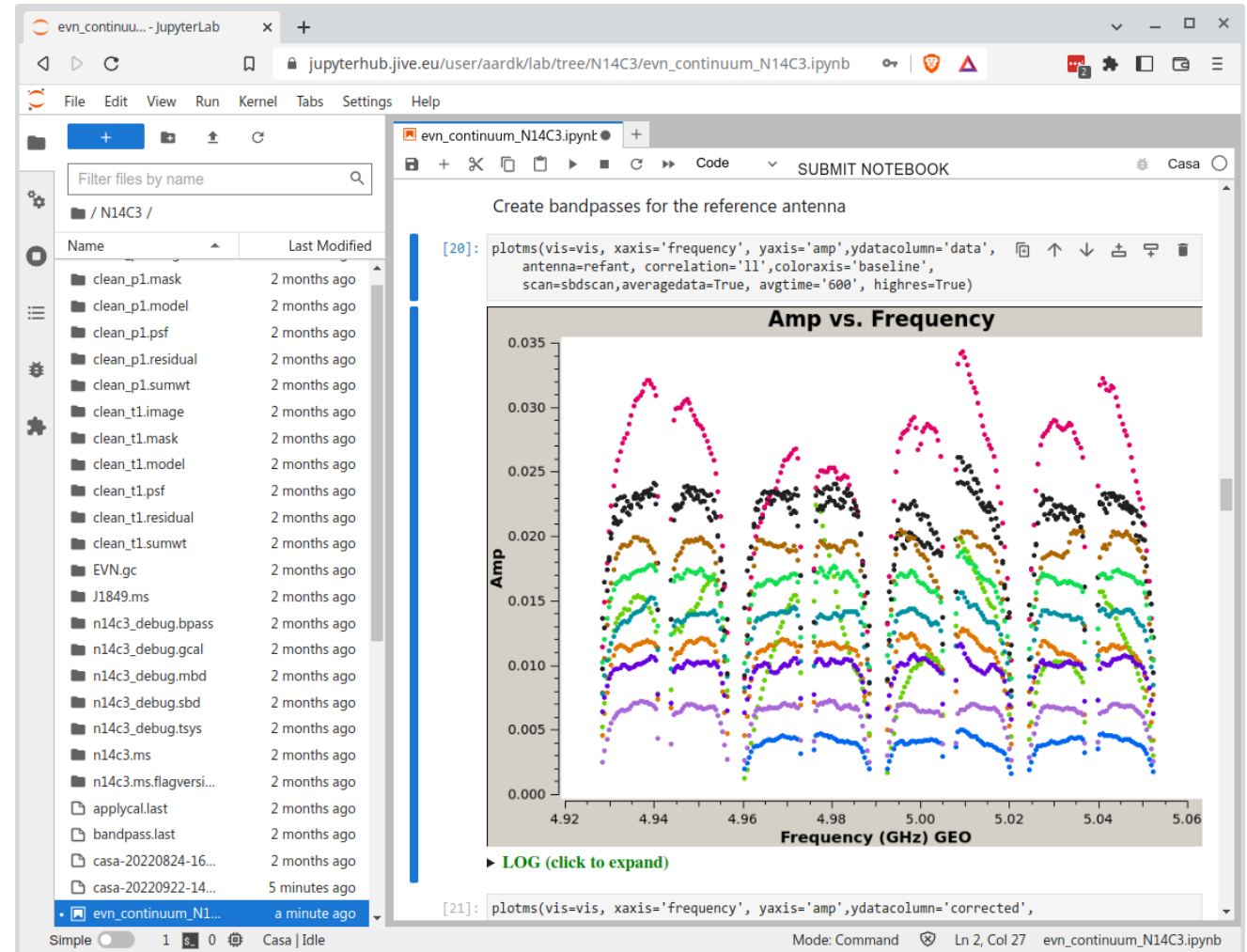
- Data discovery is through a JupyterLab plugin developed at JIVE
- The plugin executes queries using the EVN VO service
- The EVN VO contains the metadata pertaining to all public EVN observations
- Each search result has a Jupyter notebook associated with it



Actions	Experiment	Source	Ra	Dec	Exp. time [s]	Distance [deg]
	ER040	M51	13h29m52.698s	47d11'42.930"	21854	0.000020252172835049266
	EG037C	NGC5194	13h29m52.804s	47d11'40.065"	5910	0.0008666970759109673
	EG037D	NGC5194	13h29m52.804s	47d11'40.065"	6066	0.0008666970759109673
	ER040	J132952+4712	13h29m51.590s	47d12'07.700"	21854	0.0075465293313555695

Cone search on the EVN archive

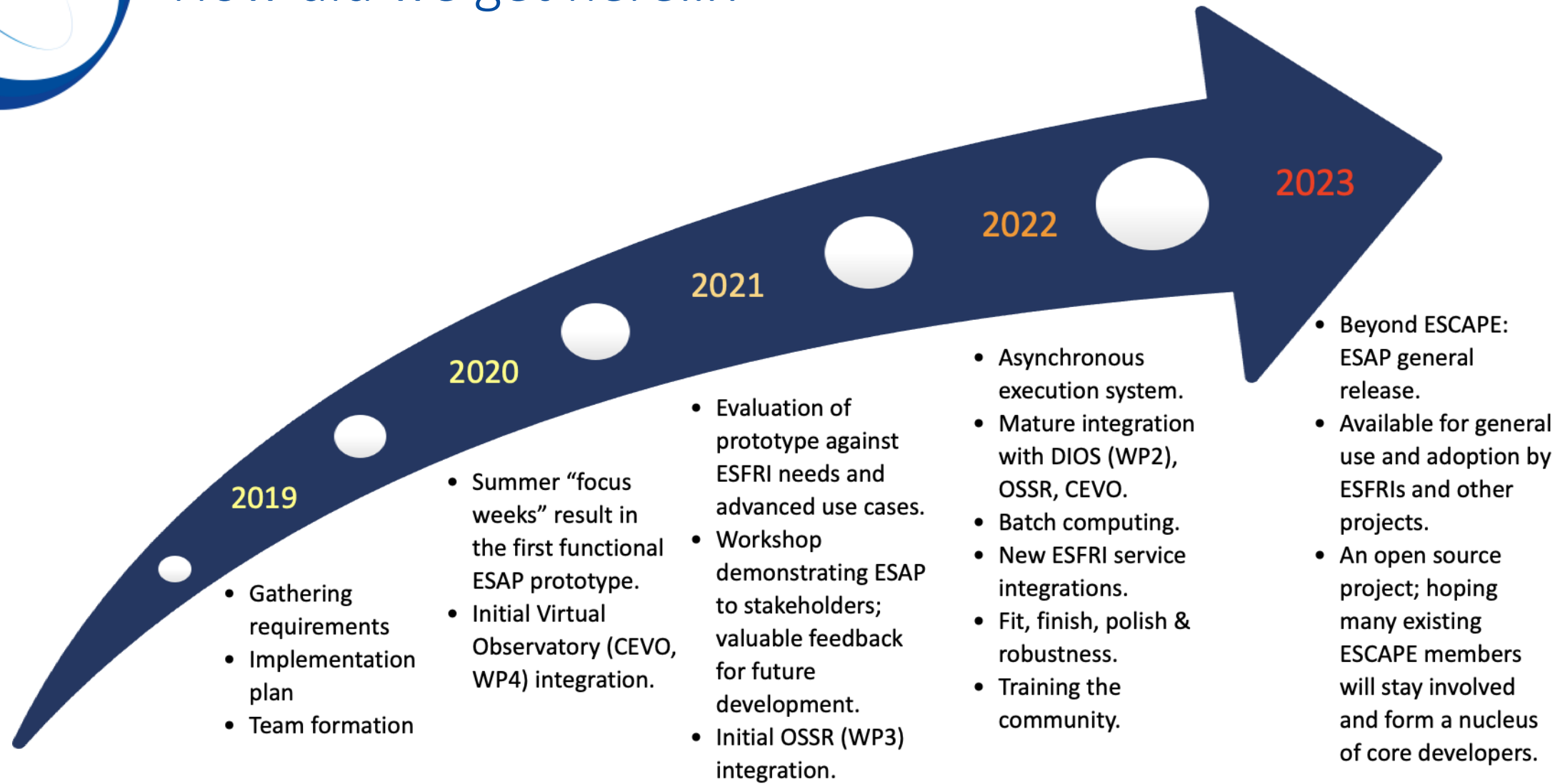
- Astronomical data processing is based on the widely used CASA software
- The Docker image contains
 - CASA 6.5.1
 - WP3: The Jupyter-CASA kernel
 - WP3: CASA VLBI tools
 - EVN data discovery JupyterLab plugin
 - A collection of widely used radio astronomy packages



Thank you for your attention!

<https://jupyterhub.jive.eu>

How did we get here...?



The ESAP Open Source Future

● *Technical Improvements*

- Improved support for provenance and persistent identifiers.
- Data sharing and collaborative workflows.
- Persistent development environments.
- Rich semantics for describing the relationships between data products, and between data products and compute/analysis software.

● *Sustainability*

- Build out complete, ESFRI-focused virtual research environments using ESAP.
- The ESAP open source core provides ongoing development and maintenance.

● *Common Standards*

- A federated network of science platforms.
- [IVOA Execution Planner](#) as a first step.