

Portable workflows on interoperable infrastructures for astrophysics

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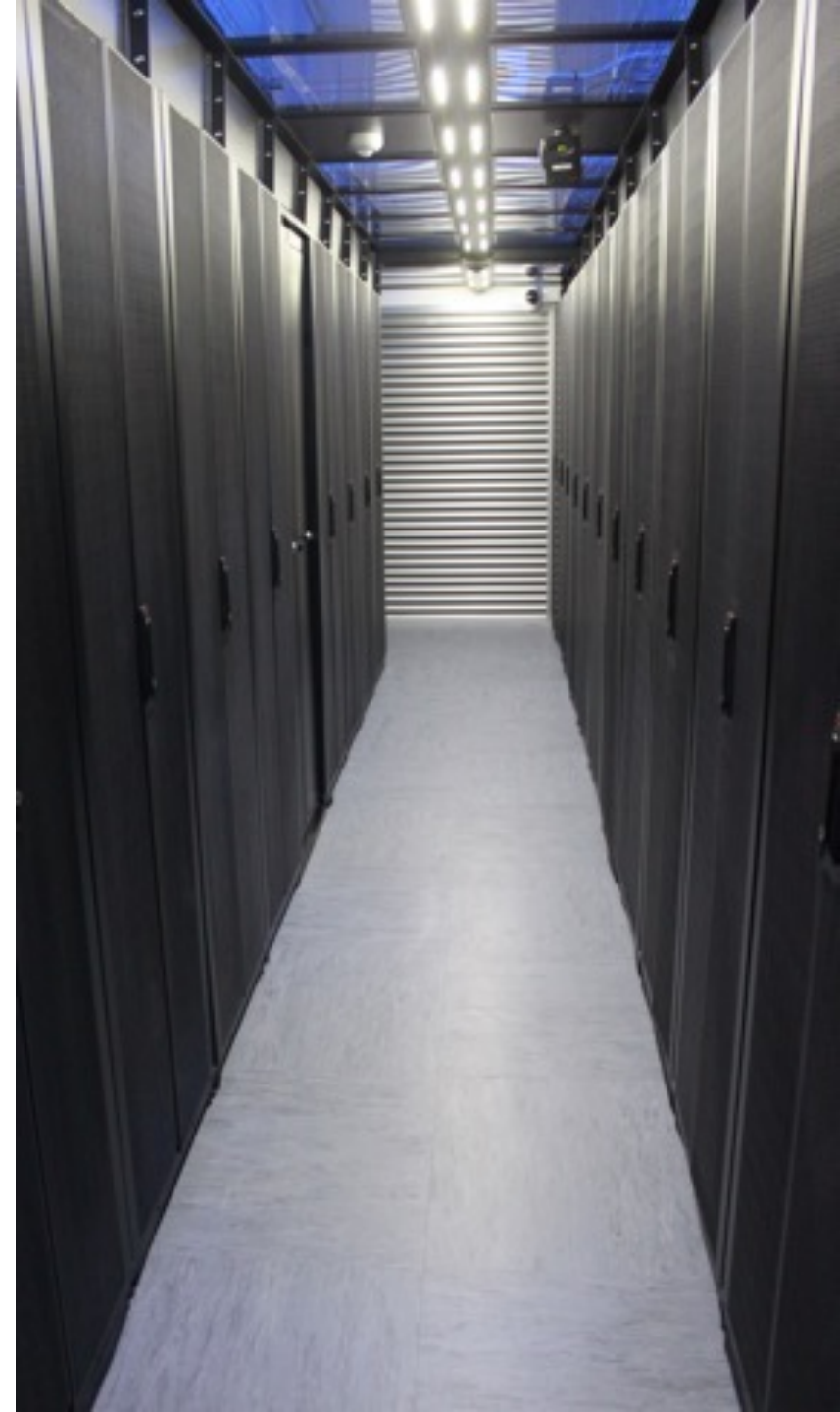
Acting Director IDIA

CTO Ilifu



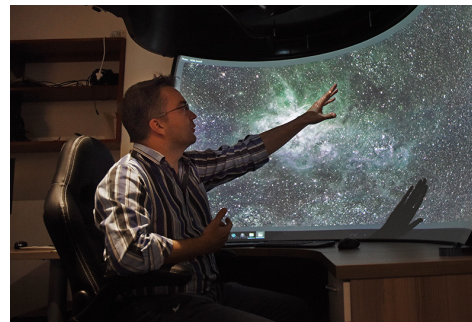
Talk Overview

- Astronomy in ZA
- Radio astronomy workflow
- The IDIA processing pipeline
- The CARTA visualization system
- Deploying specialized environments
- Future



ZA Astronomy

- MeerKAT – Radio telescope leading to the Square Kilometer Array (SKA) run by SARA0
- MeerLICHT – Optical telescope that tracks MeerKAT based at Sutherland
- SAAO runs many other optical telescopes at Sutherland
- IDIA/ilifu users primarily working with MeerKAT and MeerLICHT data





MeerKAT

Dishes	64
Dish Diameter	13.5 m
Total collecting area	9161 m²
Pairs of dishes	2016
Maximum baseline	8 km
Resolution	6" (robust = -0.5)
A_e / T_{sys} (per dish)	$\sim 6 \text{ m}^2 \text{ K}^{-1}$
Observing frequency	(1.7 over spec!)
Bandwidth	580 – 3500 MHz
Spectral Channels	856 MHz
	32,768



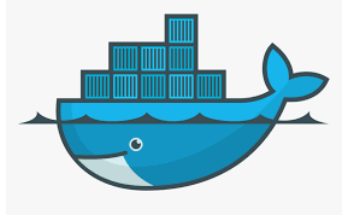


The path to the SKA

- A large number of technical challenges to overcome before being able to deliver SKA
 - Addressed in part by solving those related to its pathfinders, including MeerKAT that will form the centre of the SKA1-mid telescope
- The Inter-University Institute for Data-Intensive Astronomy (IDIA) focussed on the computational challenges
 - **IaaS cloud**
 - Data transfer
 - Software stack / containers
 - **Data processing (pipelines)**
 - **Visualisation**
 - Data quality



Why IaaS Cloud?



- Many users happy with generalized environments
 - Can be provided using VMs or bare metal deployment
- Users do want specific software stacks including specific versions
 - Can often now be provided by containers that run in the generalized environments
- Need for interactive web facing applications
 - VMs and/or Docker type containers and flexible network routing and proxying makes these easy to provide
- Some users want environments that they self manage for specialized applications
 - These final two points are simplified with IaaS cloud systems
 - IDIA runs an OpenStack IaaS system called ilifu



MeerKAT Large Survey Projects (LSPs)

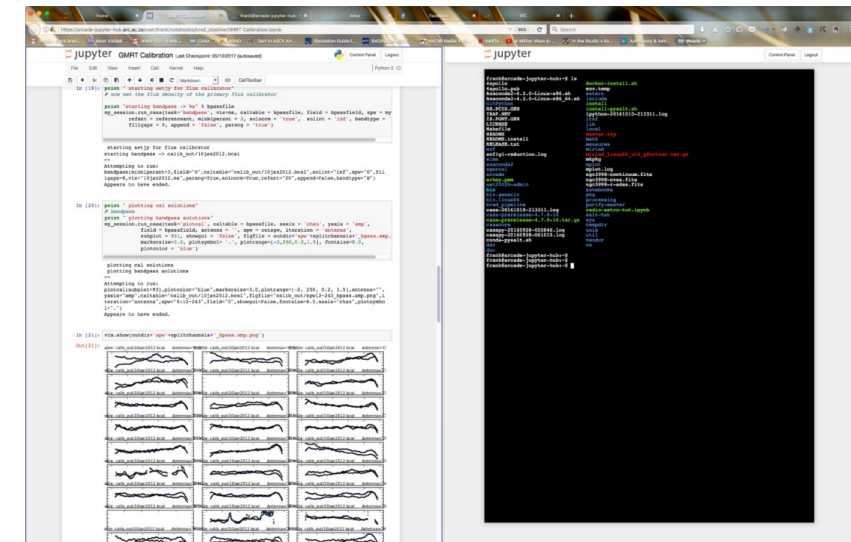
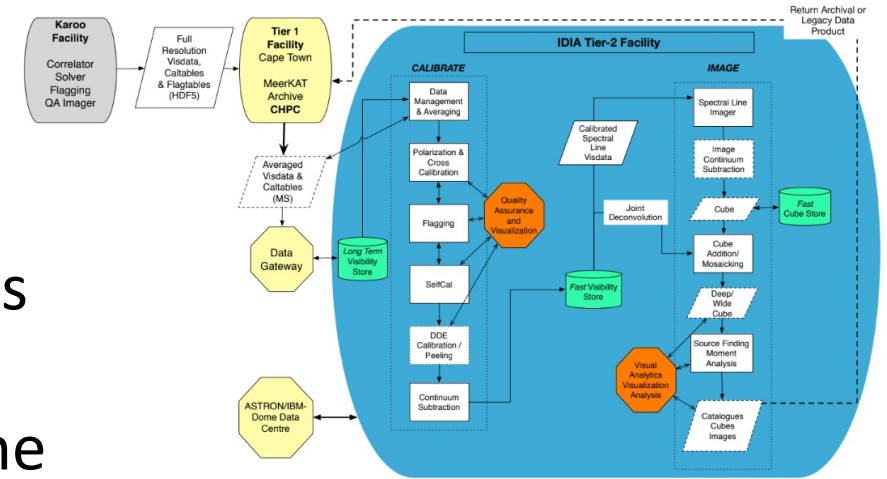
- Imaging
 - LADUMA (Deep neutral hydrogen)
 - MIGHTEE (Deep continuum imaging of the early universe)
 - Fornax (Deep HI Survey of the Fornax cluster)
 - MHONGOOSE (targeted nearby galaxies HI)
 - MeerKAT Absorption Line Survey (extragalactic HI absorption)
- Time domain
 - ThunderKAT (exotic phenomena, variables and transients)
 - TRAPUM (pulsar search)
 - Pulsar Timing (MeerTIME)

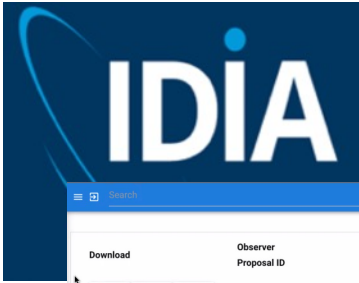
<http://public.ska.ac.za/meerkat/meerkat-large-survey-projects>



Radio Astronomer Workflow (simplified example)

- Data fetched from Observatory / Archive
- Pipeline software creates data cubes
- Data cubes examined using visual analytics tools
- Pipelines reparametrized, rerun, and cubes reexamined to expose “interesting” features (the science bit...)
- Camara ready images sliced from data cubes
 - Aim to have Pipeline available through EGI software distribution services
 - Also interested in having our visual analytics tool available



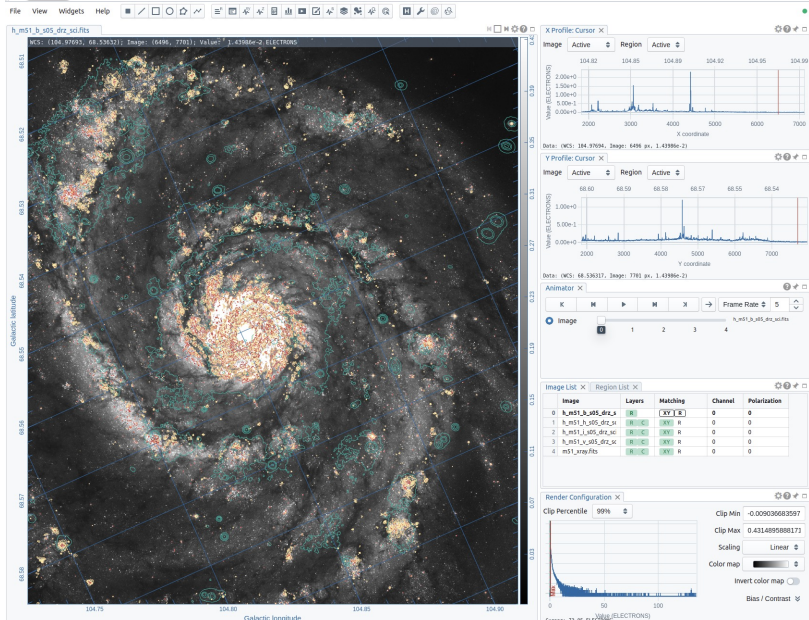


Tools deployed at ilifu

29277 matching observations

Download	Observer Proposal ID	Schedule Block Capture Block	Target/s	Description
	Operator CAL-20200106-OP-02	20220621-0005 1655796131	J1939-6342 PKS1934-638 PKS 1934-63	Delaycal 856 MHz to 1712 MHz Run at 2022-06-21 07:22:28 UTC
	Operator OPR-20190506-OP-05	20220621-0004 1655790890	J1939-6342 PKS1934-638 PKS 1934-63 J0408-6545	three calibrator imaging 856 MHz to 1712 MHz Run at 2022-06-21 05:55:33 UTC
	Operator OPR-20190506-OP-06	20220621-0003 1655790330	J1939-6342	pointing check on J1939-6342 856 MHz to 1712 MHz Run at 2022-06-21 05:46:17 UTC
	Operator CAL-20200106-OP-02	20220621-0001 1655789690	J1939-6342 PKS1934-638 PKS 1934-63	Delaycal 856 MHz to 1712 MHz Run at 2022-06-21 05:35:06 UTC
	Erwin de Blok SCI-20180516-EB-01	20210705-0046 1655769384	J1939-6342 1934-638 J0025-2602 0023-263	MHONGOOSE J0052-31 rising 1 1336.499999832362 MHz to 1443.499999832362 MHz Run at 2022-06-20 23:58:47 UTC
	Operator CAL-20200106-OP-02	20220620-0029 1655768921	J1939-6342 PKS1934-638 PKS 1934-63	Delaycal 1336.499999832362 MHz to 1443.499999832362 MHz Run at 2022-06-20 23:39:00 UTC
	Operator CAL-20200106-OP-02	20220620-0029 1655768316	J1939-6342 PKS1934-638 PKS 1934-63	Delaycal 856 MHz to 1712 MHz Run at 2022-06-20 23:38:47 UTC

The image shows two JupyterLab notebooks. The left notebook displays Python code for GMRT calibration, including sections for 'starting setup for flux calibration', 'pointing cal solutions', and 'flux calibration'. The right notebook shows the output of these scripts, which is a grid of 12 plots. Each plot represents a different frequency channel, showing the signal intensity across the field of view.



```
simmonds ~ ubuntu@test-deploy: -- ssh slurm.ilifu.ac.za -- 120x31
```

Welcome to the ilifu SLURM Cluster

Please familiarise yourself with the list of recommendations below.

DOs:

- * try run jobs using sbatch rather than interactive jobs
- * cleanup unused files when not needed
- * set `--time`, `--mem`, `--account` parameters when submitting jobs, accurate description of job parameters improves the performance of the SLURM scheduler

DO NOTs:

- * run software on the login-node
- * transfer large data on the login-node, use `transfer.ilifu.ac.za` (accessed via `ssh`) to do this
- * copy large files to `/users` directory
- * leave data in `/scratch` or `/scratch3` as this space is limited, after processing remove data that is not required and move files to your project directory

User documentation is available at <https://docs.ilifu.ac.za/>

For any queries or if you need help please contact the support team at support@ilifu.ac.za

Last login: Fri Apr 22 11:26:30 2022 from 129.285.185.89
simmonds@slurm-login:~\$

The image shows the Globus login interface. It includes a header with the Globus logo and navigation links. Below the header, there is a section titled 'Log in to use Globus Web App'. It prompts the user to use their existing organizational login, with a dropdown menu showing 'University of Cape Town'. There is a 'Continue' button. Below this, there is a section for 'Sign in with Google' and 'Sign in with ORCID ID'. At the bottom, there is a small footer with the text '© 2020-2022 University of Chicago, Argonne National Laboratory. Legal Privacy'.



IDIA MeerKAT pipeline (processMeerKAT.py)

- Brad Frank, Jordan Collier, Srikrishna Sekhar, Russ Taylor
 - v2 released Sept 2022, used by LSPs (LADUMA, MIGHTEE, more)
- Parallelised package for HPC processing
 - Deployed at IDIA on OpenStack system ilifu
- Similar approach to two-round CASA-based crosscal, **but**
 - Fast, necessary for 32k MeerKAT data (~12 TB raw per 8 hours)
 - Full Stokes polarisation calibration with output polarisation cubes
 - Adds our own automated (PyBDSF) selfcal masking algorithm + AWP
- Builds and submits pipeline jobs to resource managers
 - Input measurement set, build / run your config file, request resources
 - Optionally insert your own scripts, specify containers and MPI wrappers
- Goal: $T(\text{cal}) \sim T(\text{obs})$; result: $T(\text{crosscal}) \ll T(\text{obs})$



IDIA MeerKAT pipeline implementation

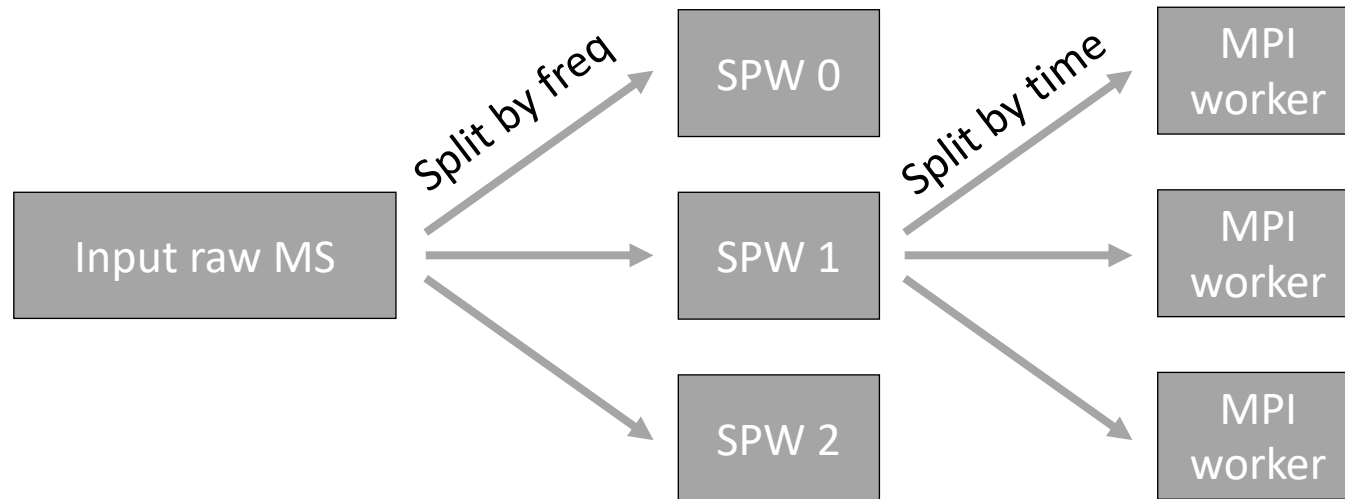
- Packaged as set of Python scripts
 - <https://github.com/idia-astro/pipelines/releases/tag/V2.0>
- These interact with singularity containers:
 - casa-6.5.0-modular.sif
 - Contains the modular CASA 6.5 install
 - kern7.simg
 - Contains the software packages provided by the Kern repository.
 - ASTRO-PY3.simg
 - Commonly used source finding packages.

These can be run on basic HPC systems that have singularity installed



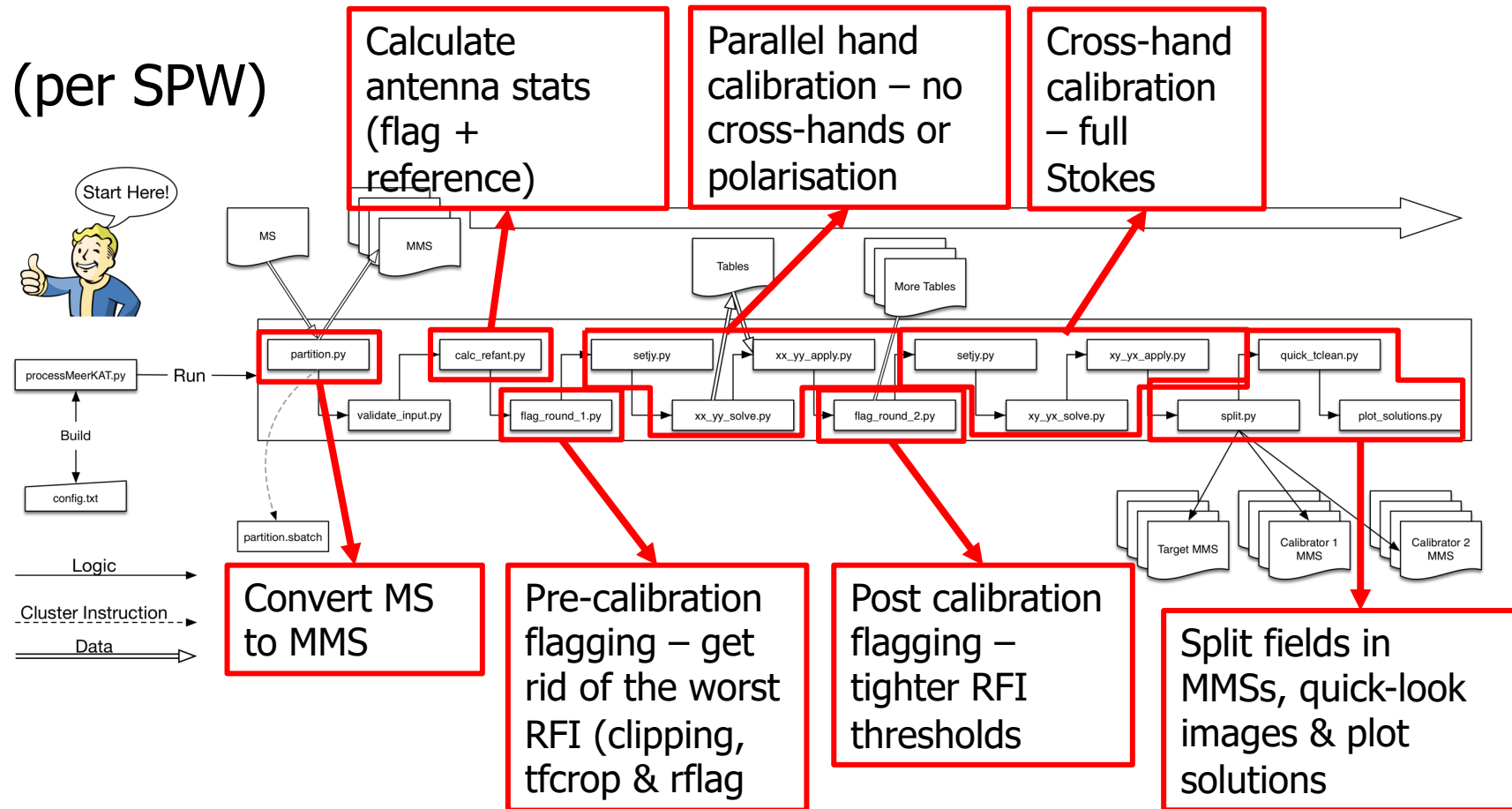
IDIA MeerKAT pipeline parallelism

- Two parallelism schemes across cluster
 - Partition in frequency (SPW): IDIA pipeline scheme
 - Partition in time (scan): CASA multi-measurement set (MMS)



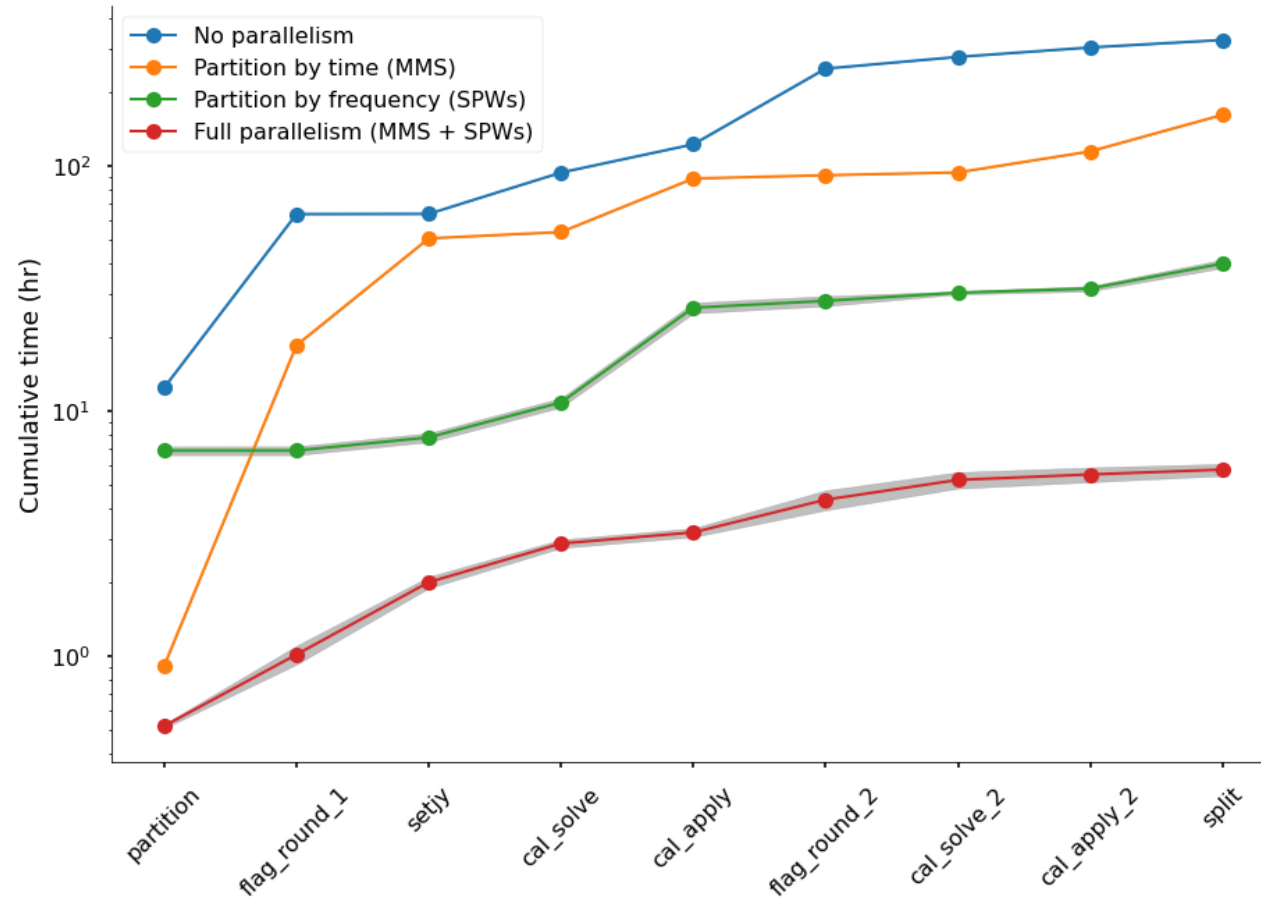


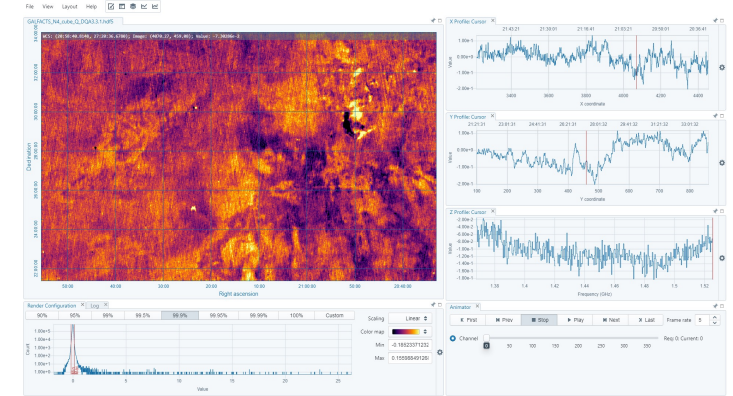
IDIA pipeline schematic





IDIA MeerKAT pipeline performance





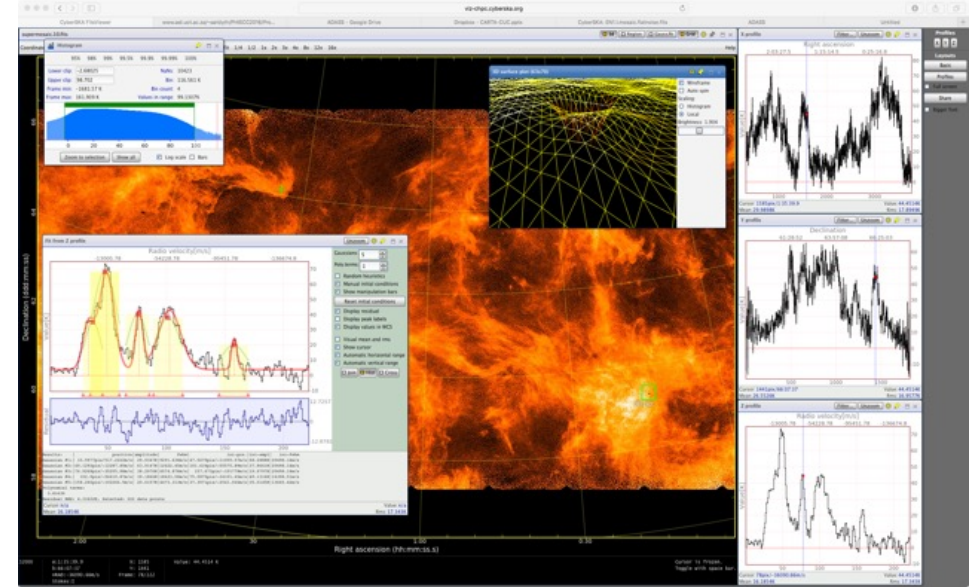
- Cube Analysis and Rendering Tool for Astronomy (CARTA)

- IDIA (South Africa) – NRAO (US) – ASIAA (Taiwan) – UofA (Canada)
- A remote visual analytic tool for large image cubes
- Performs latency hiding by doing large scale processing on remote servers / the Cloud, and interactive processing in a web client on the user's local computer
- Supports many image formats: FITS, CASA, Miriad, and HDF5
- v3.0 released August 2022, available here: <https://cartavis.org>
- Deployed at ALMA Regional Centres and servers around the world
- Being explored as a system to use at the SKA Regional Centres



CARTA Deployment

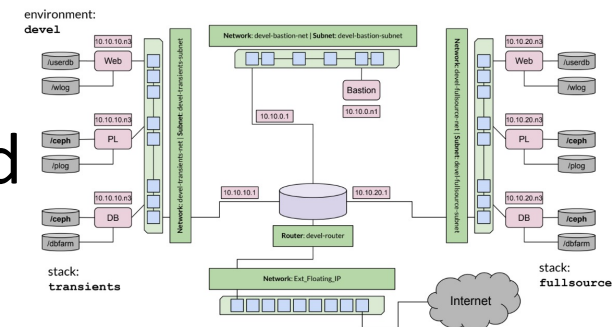
- CARTA can be run in several ways. The main types:
 - Site Deployment Mode (SDM)
 - User Deployment Mode (UDM)
- SDM is preferred for integrated web environments since it integrates well with tools such as Jupyter Hub and provides more interesting options for user collaboration
- Works fine on IaaS system such as OpenStack, since users have control of network services
 - Not clear how to setup correct reverse proxies without this on systems where users don't have root access
- SKA Regional Centre testing sites that don't have OpenStack are tending to use Docker / Kubernetes but these need root access
- This highlights that while software such as the IDIA pipeline code can be run on most clusters access to IaaS clouds makes deployment much easier for other software.





Specialized environment example

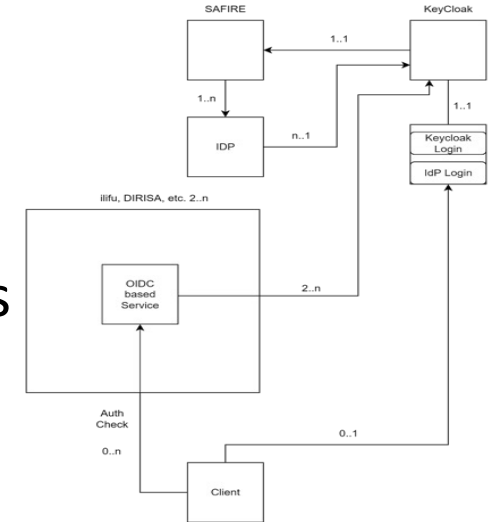
- Real-time processing for MeerLICHT performed in environment run by the research team
- Consists of VMs and virtualized networking components that run their workflows, with much image processing performed overnight
- Image data transferred from Sutherland to UCT/ilifu as it is captured by MeerLICHT
- Processing performed to search for transients
- Alerts issued and corresponding MeerKAT data examined





Cloud Federation

- Have federated ilifu with EGI cloud as part of EGI-ACE that simplifies gaining access to cloud resources
- Starting work with DIRISA on federating ZA systems
 - Start with making sure all web-based systems setup to use EduGain/SAFIRE federation
 - Then plan to add role-based authorization system
 - Experience gained withing with EGI key to this activity
- South African Open Science Cloud (SAOSC)
 - In planning with guidance from EOSC
 - Infrastructure plans include federation of software tools and repositories
- African Open Science Platform (AOSP)
 - About to start deploying systems.
- Global Open Science Cloud (GOSC)
 - Focusing on how to link regional OSC activities.





Summary + Future

- The OpenStack cluster hosted at UCT, has been in production since 2015 which supports large community of radio astronomy researchers
- Have much better understanding of requirements than when we started
- Have developed Pipeline and Visual Analytics system aimed at next generation radio telescopes
- Aim to work with EGI to simplify access to these tools on EGI resources as agreed to as part of the EGI-ACE project
- Working with EGI has provided us with access to best-in-class federation tools, and experience of operating systems using these
- Working with SKA Regional Centre planners on what tools should be supported at their sites
- Starting work with DIRISA to provide federation of South African services



ilifu